MOTOROLA
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ASTRO® Digital Spectra® and Digital Spectra Plus
UHF/VHF/800 MHz Mobile Radios
Detailed Service Manual

Foreword

This manual provides sufficient information to enable qualified service technicians to troubleshoot and repair ASTRO® Digital Spectra® and ASTRO Digital Spectra Plus mobile radios (models W3, W4, W5, W7, and W9) to the component level. For the most part, the information in this manual pertains to both ASTRO Digital Spectra and ASTRO Digital Spectra Plus radios. Exceptions are clearly noted where they occur.

For details on radio operation or basic troubleshooting, refer to the applicable manuals available separately. A list of related publications is provided in the section, “Related Publications,” on page xiv.

Product Safety and RF Exposure Compliance

Caution	**Before using this product, read the operating instructions for safe usage contained in the Product Safety and RF Exposure booklet enclosed with your radio.**

ATTENTION!

This radio is restricted to occupational use only to satisfy FCC RF energy exposure requirements. Before using this product, read the RF energy awareness information and operating instructions in the Product Safety and RF Exposure booklet enclosed with your radio (Motorola Publication part number 68P81095C99) to ensure compliance with RF energy exposure limits.

Manual Revisions

Changes which occur after this manual is printed are described in FMRs (Florida Manual Revisions). These FMRs provide complete replacement pages for all added, changed, and deleted items, including pertinent parts list data, schematics, and component layout diagrams.

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Related Publications

ASTRO Digital Spectra and Digital Spectra Plus Model W3 User's Guide 68P81090C61
ASTRO Digital Spectra and Digital Spectra Plus Models W4, W5, W7, and W9 User's Guide ... 68P81090C62
ASTRO Digital Spectra Hand-Held Control Head User's Guide (Model W3) 68P81073C25
ASTRO Digital Spectra (Model W4, W5, W7, and W9) User's Guide 68P81074C80
ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual 68P81076C20
ASTRO Digital Spectra Mobile Radios Dual Control Head Radio System Service Manual 68P81091C78
ASTRO Spectra and Digital Spectra FM Two-Way Mobile Radios Installation Manual 68P81070C85
ASTRO Spectra Motorcycle Radios Supplemental Installation Manual 68P80103W01
KVL 3000 User's Manual 68P81131E16
Spectra VHF VCO Section Detailed Service Manual Supplement 68P81074C48
Spectra High-Power Power Amplifier Detailed Service Manual Supplement 68P81077C25
Spectra Systems 9000 Control Unit Detailed Service Manual Supplement 68P81077C30
Spectra A5 and A7 Control Head Instruction Manual 68P81109C33
Spectra A4 Control Head Instruction Manual 68P81109C34

Commercial Warranty

Limited Warranty

MOTOROLA COMMUNICATION PRODUCTS

I. What This Warranty Covers And For How Long

MOTOROLA INC. (“MOTOROLA”) warrants the MOTOROLA manufactured Communication Products listed below (“Product”) against defects in material and workmanship under normal use and service for a period of time from the date of purchase as scheduled below:

ASTRO Digital Spectra and Digital Spectra Plus Units	One (1) Year
Product Accessories	One (1) Year

Motorola, at its option, will at no charge either repair the Product (with new or reconditioned parts), replace it (with a new or reconditioned Product), or refund the purchase price of the Product during the warranty period provided it is returned in accordance with the terms of this warranty. Replaced parts or boards are warranted for the balance of the original applicable warranty period. All replaced parts of Product shall become the property of MOTOROLA.

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II. General Provisions

This warranty sets forth the full extent of MOTOROLA'S responsibilities regarding the Product. Repair, replacement or refund of the purchase price, at MOTOROLA's option, is the exclusive remedy. THIS WARRANTY IS GIVEN IN LIEU OF ALL OTHER EXPRESS WARRANTIES. IMPLIED WARRANTIES, INCLUDING WITHOUT LIMITATION, IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED TO THE DURATION OF THIS LIMITED WARRANTY. IN NO EVENT SHALL MOTOROLA BE LIABLE FOR DAMAGES IN EXCESS OF THE PURCHASE PRICE OF THE PRODUCT, FOR ANY LOSS OF USE, LOSS OF TIME, INCONVENIENCE, COMMERCIAL LOSS, LOST PROFITS OR SAVINGS OR OTHER INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE SUCH PRODUCT, TO THE FULL EXTENT SUCH MAY BE DISCLAIMED BY LAW.

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This warranty gives specific legal rights, and there may be other rights which may vary from state to state.

IV. How To Get Warranty Service

You must provide proof of purchase (bearing the date of purchase and Product item serial number) in order to receive warranty service and, also, deliver or send the Product item, transportation and insurance prepaid, to an authorized warranty service location. Warranty service will be provided by Motorola through one of its authorized warranty service locations. If you first contact the company which sold you the Product, it can facilitate your obtaining warranty service. You can also call Motorola at 1-888-567-7347 US/Canada.

V. What This Warranty Does Not Cover

A. Defects or damage resulting from use of the Product in other than its normal and customary manner.

B. Defects or damage from misuse, accident, water, or neglect.

C. Defects or damage from improper testing, operation, maintenance, installation, alteration, modification, or adjustment.

D. Breakage or damage to antennas unless caused directly by defects in material workmanship.

E. A Product subjected to unauthorized Product modifications, disassemblies or repairs (including, without limitation, the addition to the Product of non-Motorola supplied equipment) which adversely affect performance of the Product or interfere with Motorola's normal warranty inspection and testing of the Product to verify any warranty claim.

F. Product which has had the serial number removed or made illegible.

G. Rechargeable batteries if:

H. any of the seals on the battery enclosure of cells are broken or show evidence of tampering.

I. the damage or defect is caused by charging or using the battery in equipment or service other than the Product for which it is specified.

J. Freight costs to the repair depot.

K. A Product which, due to illegal or unauthorized alteration of the software/firmware in the Product, does not function in accordance with MOTOROLA's published specifications or the FCC type acceptance labeling in effect for the Product at the time the Product was initially distributed from MOTOROLA.

L. Scratches or other cosmetic damage to Product surfaces that does not affect the operation of the Product.

M. Normal and customary wear and tear.

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B. that MOTOROLA will have sole control of the defense of such suit and all negotiations for its settlement or compromise; and

C. should the Product or parts become, or in MOTOROLA's opinion be likely to become, the subject of a claim of infringement of a United States patent, that such purchaser will permit MOTOROLA, at its option and expense, either to procure for such purchaser the right to continue using the Product or parts or to replace or modify the same so that it becomes noninfringing or to grant such purchaser a credit for the Product or parts as depreciated and accept its return. The depreciation will be an equal amount per year over the lifetime of the Product or parts as established by MOTOROLA.

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VII. Governing Law

This Warranty is governed by the laws of the State of Illinois, USA.

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Model Numbering, Charts, and Specifications

Mobile Radio Model Numbering Scheme

Typical Model Number:	**T**	**0**	**4**	**S**	**L**	**F**	**9**	**P**	**W**	**7**	**A**	**N**	**S**	**P**	**0**	**1**
Position:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**

Position 1 - Type of Unit

D = Dash-Mounted Mobile Radio
M = Motorcycle Mobile Radio
T = Trunk-Mounted Mobile Radio

Positions 2 & 3 - Model Series

04 = ASTRO

Position 4 - Frequency Band

A = Less than 29.7MHz
B = 29.7 to 35.99MHz
C = 36 to 41.99MHz
D = 42 to 50MHz
F = 66 to 80MHz
G = 74 to 90MHz
H = Product Specific
J = 136 to 162MHz
K = 146 to 178MHz
L = 174 to 210MHz
M = 190 to 235MHz
P = 336 to 410MHz
Q = 403 to 437MHz
R = 438 to 482MHz
S = 470 to 520MHz
T = Product Specific
U = 806 to 870MHz
V = 825 to 870MHz
W = 896 to 941MHz
Y = 1.0 to 1.6GHz
Z = 1.5 to 2.0GHz

Values given represent range only; they are not absolute.

Position 5 - Power Level

A = 0 to 0.7 Watts
B = 0.7 to 0.9 Watts
C = 1.0 to 3.9 Watts
D = 4.0 to 5.0 Watts
E = 5.1 to 6.0 Watts
F = 6.1 to 10 Watts
G = 10.1 to 15 Watts
H = 16 to 25 Watts
J = 26 to 35 Watts
K = 36 to 60 Watts
L = 61 to 110 Watts

Position 6 - Physical Packages

A = RF Modem Operation
B = Receiver Only
C = Standard Control; No Display
D = Standard Control; With Display
E = Limited Keypad; No Display
F = Limited Keypad; With Display
G = Full Keypad; No Display
H = Full Keypad; With Display
J = Limited Controls; No Display
K = Limited Controls; Basic Display
L = Limited Controls; Limited Display
M = Rotary Controls; Standard Display
N = Enhanced Controls; Enhanced Display
P = Low Profile; No Display
Q = Low Profile; Basic Display
R = Low Profile; Basic Display, Full Keypad

Position 7 - Channel Spacing

1 = 5kHz
2 = 6.25kHz
3 = 10kHz
4 = 12.5kHz
5 = 15kHz
6 = 20/25kHz
7 = 30kHz
9 = Variable/Programmable

Position 8 - Primary Operation

A = Conventinal/Simplex
B = Conventional/Duplex
C = Trunked Twin Type
D = Dual Mode Trunked
E = Dual Mode Trunked/Duplex
F = Trunked Type I
G = Trunked Type II
H = FDMA* Digital Dual Mode
J = TDMA** Digital Dual Mode
K = Single Sideband
L = Global Positioning Satellite Capable
M = Amplitude Companded Sideband (ACSB)
P = Programmable
S = Integrated Voice and Data

** FDMA = Frequency Division Multiple Access*
*** TDMA = Time Division Multiple Access*

Position 9 - Primary System Type

A = Conventional
B = Privacy Plus
C = Clear SMARTNET
D = Advanced Conventional Stat-Alert
E = Enhanced Privacy Plus
F = Nauganet 888 Series
G = Japan Specialized Mobile Radio (JSMR)
H = Multi-Channel Access (MCA)
J = CoveragePLUS
K = MPT1327* - Public
L = MPT1327* - Private
M = Radiocom
N = Tone Signalling
P = Binary Signalling
Q = Phonenet
W = Programmable
X = Secure Conventional
Y = Secure SMARTNET

** MPT = Ministry of Posts and Telecommunications*

Position 10 - Feature Level

1 = Basic
2 = Limited Package
3 = Limited Plus
4 = Intermediate
5 = Standard Package
6 = Standard Plus
7 = Expanded Package
8 = Expanded Plus
9 = Full Feature/ Programmable

Position 11 - Version

Version Letter (Alpha) - Major Change

Position 12 - Unique Model Variations

C = Cenelec
N = Standard Package

Positions 13 - 16

SP Model Suffix

MAEPF-27247-O

ASTRO Digital Spectra Motorcycle 15 Watt (Ranges 1 and 2) Model Chart

Model Number	Description
M04JGF9PW4AN	Model W4 (136-162 MHz), Range 1, 15 Watt, 128 Channels
M04JGF9PW5AN	Model W5 (136-162 MHz), Range 1, 15 Watt, 128 Channels
M04JGH9PW7AN	Model W7 (136-162 MHz), Range 1, 15 Watt, 128 Channels
M04KGF9PW4AN	Model W4 (146-174 MHz), Range 2, 15 Watt, 128 Channels
M04KGF9PW5AN	Model W5 (146-174 MHz), Range 2, 15 Watt, 128 Channels
M04KGH9PW7AN	Model W7 (146-174 MHz), Range 2, 15 Watt, 128 Channels
M04RGF9PW4AN	Model W4 (438-470 MHz), Range 2, 15 Watt, 128 Channels
M04RGF9PW5AN	Model W5 (438-470 MHz), Range 2, 15 Watt, 128 Channels
M04RGH9PW7AN	Model W7 (438-470 MHz), Range 2, 15 Watt, 128 Channels
M04UGF9PW4AN	Model W4 (800 MHz), 15 Watt, 128 Channels
M04UGF9PW5AN	Model W5 (800 MHz), 15 Watt, 128 Channels
M04UGH9PW7AN	Model W7 (800 MHz), 15 Watt, 128 Channels

M04JGF9PW4AN	M04JGF9PW5AN	M04JGH9PW7AN	M04KGF9PW4AN	M04KGF9PW5AN	M04KGH9PW7AN	M04RGF9PW4AN	M04RGF9PW5AN	M04RGH9PW7AN	M04UGF9PW4AN	M04UGF9PW5AN	M04UGH9PW7AN	Item No.	Description
X	X	X										HLD6066_	VHF Power Amplifier Board, 25-Watt
X	X	X	X	X	X	X	X	X	X	X	X	HKN6062_	Cable, Control Head to Radio
X	X	X										HLD4342_	VHF VCO Carrier
			X	X	X							HLD4343_	VHF VCO Carrier, CEPT
			X	X	X							HLD6032_	VHF Power Amplifier Board, Range 2, 25-Watt
X	X	X										HLD6061_	VHF VCO, Range 1, 136-162 MHz
			X	X	X							HLD6062_	VHF VCO Board, Range 2, 146-174 MHz
						X	X	X				HLE6046_	UHF VCO Carrier, Range 2
						X	X	X				HLE6062_	UHF RF Power Amplifier Board, Range 2, 25-Watt
						X	X	X				HLE6102_	UHF VCO Board, Range 2
									X	X	X	HLF6078_	800 MHz RF Power Amplifier Board, 15-Watt
									X	X	X	HLF6079_	800 MHz VCO Board
									X	X	X	HLF6080_	800 MHz VCO Carrier Board
X	X	X	X	X	X	X	X	X	X	X	X	HLN1368_	White Motorcycle Enclosure and Hardware
X	X	X	X	X	X	X	X	X	X	X	X	HLN6127_*	Low-Power Dash Hardware
X	X	X	X	X	X		X	X		X	X	HLN6193_	MPL Button Kit
X	X	X	X	X	X	X	X	X	X	X	X	HLN6342_*	Motorcycle Hardware
X	X	X	X	X	X	X	X	X	X	X	X	HLN6365_	Interface Board Kit
X	X	X	X	X	X	X	X	X	X	X	X	HLN6418_*	Transceiver Hardware
	X	X		X			X			X		HLN6444_*	W5 Motorcycle Control Head Hardware
					X			X			X	HLN6445_*	W7 Motorcycle Control Head Hardware
	X											HLN6454_	Motorcycle Control Head Board Kit
X	X	X	X	X	X	X	X	X	X	X	X	HLN6458_	Vocoder Controller
X			X									HLN6459_	Interface Board
		X			X			X			X	HLN6523_*	W7 Button Kit
	X			X			X			X		HLN6548_*	W5 Button Kit
						X			X			HLN6549_*	W4 Button Kit
X	X	X	X	X	X	X	X	X	X	X	X	HLN6562_	Motorcycle Command Board Kit
	X	X		X	X		X	X		X	X	HLN6563_	Motorcycle Control Head
X			X			X			X			HLN6571_	Spare Button Kit
X	X	X	X	X	X	X	X	X	X	X	X	HMN1079_	Weatherproof Microphone
X	X	X										HRD6001_	VHF Receiver Board, Range 1, Standard
			X	X	X							HRD6002_	VHF Receiver Board, Range 2, Standard
						X	X	X				HRE6002_	UHF Receiver Board, Range 2, Standard
									X	X	X	HRF6004_	800 MHz FX Front-End
			X	X	X							HRN4009_	VHF RF Board
						X	X	X				HRN4010_	UHF RF Board
X	X	X										HRN6014_	VHF RF Board, ASTRO
									X	X	X	HRN6019_	800 MHz RF Board, ASTRO
X	X	X	X	X	X	X	X	X	X	X	X	HSN6003_	Weatherproof Speaker
X			X			X			X			PMLN4019_	W4 Motorcycle Control Head
								X				RAE4024_	UHF Antenna, Quarterwave
									X	X	X	RAF4011_	800 MHz Antenna, 3 dB Gain

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra Motorcycle 15 Watt (Ranges 3 and 3.5) Model Chart

Model Number	Description
M04RGF9PW4ANSP02	Model W4 (450-482 MHz), Range 3, 15 Watt, 128 Channels
M04RGF9PW5ANSP02	Model W5 (450-482 MHz), Range 3, 15 Watt, 128 Channels
M04RGF9PW4ANSP01	Model W4 (453-488 MHz), Range 3.5, 15 Watt, 128 Channels
M04RGF9PW5ANSP01	Model W5 (453-488 MHz), Range 3.5, 15 Watt, 128 Channels
M04RGH9PW7ANSP01	Model W7 (453-488 MHz), Range 3.5, 15 Watt, 128 Channels

M04RGF9PW4ANSP02	M04RGF9PW5ANSP02	M04RGF9PW4ANSP01	M04RGF9PW5ANSP01	M04RGH9PW7ANSP01	Item No.	Description
X	X	X	X	X	HKN6062_	Cable, Control Head to Radio
X	X				HLE6000_	UHF VCO Carrier, Range 3
		X	X	X	HLE6000DSP01	UHF VCO Carrier, Range 3.5
X	X				HLE6043_	UHF RF Power Amplifier Board, Range 3, 40-Watt
		X	X	X	HLE6043CSP01	UHF RF Power Amplifier Board, Range 3.5, 40-Watt
X	X				HLE6103_	UHF VCO Hybrid, Range 3
		X	X	X	HLE6103BSP01	UHF VCO Hybrid, Range 3.5
X	X	X	X	X	HLN1368_	White Motorcycle Enclosure and Hardware
X	X	X	X	X	HLN6127_*	Low-Power Dash Hardware
	X		X	X	HLN6193_	MPL Button Kit
X	X	X	X	X	HLN6342_*	Motorcycle Hardware
X	X	X	X	X	HLN6365_	Interface Board Kit
X	X	X	X	X	HLN6418_*	Transceiver Hardware
	X		X		HLN6444_*	W5 Motorcycle Control Head Hardware
				X	HLN6445_*	W7 Motorcycle Control Head Hardware
X	X	X	X	X	HLN6458_	Vocoder Controller
				X	HLN6523_*	W7 Button Kit
	X		X		HLN6548_*	W5 Button Kit
X		X			HLN6549_*	W4 Button Kit
X	X	X	X	X	HLN6562_	Motorcycle Command Board Kit
	X		X	X	HLN6563_	Motorcycle Control Head
X	X	X	X	X	HLN6571_	Spare Button Kit
X	X	X	X	X	HMN1079_	Weatherproof Microphone
X	X				HRE6003_	UHF Receiver Board, Range 3, Standard
		X	X	X	HRE6003BSP01	UHF Receiver Board, Range 3.5, Standard
X	X	X	X	X	HRN6020_	UHF RF Board, ASTRO
X	X	X	X	X	HSN6003_	Weatherproof Speaker
X		X			PMLN4019_	W4 Motorcycle Control Head
X	X	X	X	X	RAE4024_	UHF Antenna, Quarterwave

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra VHF 10–25 Watt Model Chart

Model Number	Description
D04JHH9PW3AN	Model W3 (136-145.9 MHz), 10-25 Watt, 255 Channels
D04JHF9PW4AN	Model W4 (136-162 MHz), 10-25 Watt, 128 Channels
D04JHF9PW5AN	Model W5 (136-162 MHz); 10-25 Watt, 128 Channels
D04JHH9PW7AN	Model W7 (136-162 MHz), 10-25 Watt, 255 Channels
T04JHH9PW9AN	Model W9 (136-162 MHz), 10-25 Watt, 255 Channels
D04KHH9PW3AN	Model W3 (146-145.9 MHz), 10-25 Watt, 255 Channels
D04KHF9PW4AN	Model W4 (146-174 MHz), 10-25 Watt, 128 Channels
D04KHF9PW5AN	Model W5 (146-174 MHz), 10-25 Watt, 128 Channels
D04KHH9PW7AN	Model W7 (146-174 MHz), 10-25 Watt, 255 Channels
T04KHH9PW9AN	Model W9 (146-174 MHz), 10-25 Watt, 255 Channels

D04JHH9PW3AN	D04JHF9PW4AN	D04JHF9PW5AN	D04JHH9PW7AN	T04JHH9PW9AN	D04KHH9PW3AN	D04KHF9PW4AN	D04KHF9PW5AN	D04KHH9PW7AN	T04KHH9PW9AN	Item No.	Description
X	X	X	X	X						HRD6001_	Front-End Receiver Board Kit (Range 1, 136-162 MHz)
					X	X	X	X		HRD6002_	Front-End Receiver Board Kit (Range 2, 146-174 MHz)
X	X	X	X	X		X	X	X		HRN6014_	RF Board Kit
X	X	X	X	X		X	X	X	X	HLD4342_	VCO Board Kit
X	X	X	X	X						HLD6061_	VCO Hybrid Kit (Range 1, 136-162 MHz)
					X	X	X	X	X	HLD6062_	VCO Hybrid Kit (Range 2, 146-174 MHz)
X	X	X	X	X	X	X	X	X	X	HLN5558_	Command Board Kit
X	X	X	X	X	X	X	X	X	X	HLN6458_	VOCON Board Kit
X	X	X	X	X		X	X	X	X	HLD6066_	Power Amplifier Board
				X					X	HLN6344_	Interface Board
	X	X	X			X	X	X		HLN6401_	Control Head Interconnect Board
	X					X				AAHN4045_	W4 Control Head
		X	X				X	X		HLN6396_	W5,W7 Control Head Board
				X					X	HCN1078_	W9 Control Head
	X	X	X			X	X	X		HMN1080_	Microphone
				X					X	HMN1061_	Microphone
X	X	X	X	X	X	X	X	X	X	HSN4018_	Speaker
				X					X	HLN4921_	Control Head (W9) Trunnion
				X					X	HLN5488_	Radio Microphone Installation Hardware (W9 Trunnion)
X	X	X	X		X	X	X	X		HLN6015_	Trunnion/Hardware (Dash Mount)
	X	X	X			X	X	X		HLN6060_	Dash-Mount Hardware
X				X	X				X	HLN6185_*	Remote-Mount, SECURENET Control-Head Hardware
X	X	X	X	X	X	X	X	X	X	HLN6418_*	Transceiver Hardware
		X					X			HLN6440_*	Control Head without Keypad Hardware
			X					X		HLN6441_*	Control Head with Keypad Hardware
						X				HLN6493_*	Plug Kit
				X					X	HLN4952_	Fuse Kit
				X					X	HKN4356_	Radio Cable (Length -17 Feet)
X	X	X	X		X	X	X	X		HKN4191_	Power Cable (Length - 20 Feet)
				X					X	HKN4192_	Power Cable (Length - 20 Feet)
				X					X	HLN6481_*	Systems 9000 E9 Clear Button Kit
	X					X				HLN6549_*	C4 Button Kit
	X					X				HLN6105_	Emergency/Secure/MPL Button Kit
		X	X				X	X		HLN6193_	Emergency/MPL Field Option Button Kit
		X					X			HLN6548_*	SMARTNET Button Kit
			X					X		HLN6523_*	SMARTNET Button Kit
				X					X	HLN6167_	Option Button Kit
					X					HLD4343_	VCO Board Kit; VHF CEPT
					X					HLD6032_	Power Amplifier Board Kit
X					X					HLN6127_	Hardware, Radio Dash Low-Power
X					X					HLN6459_	W3 Interface Board
X					X					HMN4044_	ASTRO Handheld Control Head (W3)
					X					HRN4009_	RF Board Kit

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra VHF 10–25 and 50–110 Watt Model Chart

Model Number	Description
D04JKH9PW3AN	Model W3 (136-145.9 MHz), 25-50 Watt, 128 Channels
D04JKF9PW4AN	Model W4 (136-162 MHz), 25-50 Watt, 128 Channels
D04JKF9PW5AN	Model W5 (136-162 MHz); 25-50 Watt, 128 Channels
D04JKH9PW7AN	Model W7 (136-162 MHz), 25-50 Watt, 255 Channels
T04JKH9PW9AN	Model W9 (136-162 MHz), 25-50 Watt, 255 Channels
D04KKF9PW3AN	Model W3 (146-174 MHz), 25-50 Watt, 128 Channels
D04KKF9PW4AN	Model W4 (146-174 MHz), 25-50 Watt, 128 Channels
D04KKF9PW5AN	Model W5 (146-174 MHz), 25-50 Watt, 128 Channels
D04KKH9PW7AN	Model W7 (146-174 MHz), 25-50 Watt, 255 Channels
T04KKH9PW9AN	Model W9 (146-174 MHz), 25-50 Watt, 255 Channels
T04JLH9PW3AN	Model W3 (136-145.9 MHz), 50-110 Watt, 128 Channels
T04JLF9PW4AN	Model W4 (136-162 MHz), 50-110 Watt, 128 Channels
T04JLF9PW5AN	Model W5 (136-162 MHz), 50-110 Watt, 128 Channels
T04JLH9PW7AN	Model W7 (136-162 MHz), 50-110 Watt, 255 Channels
T04JLH9PW9AN	Model W9 (136-162 MHz), 50-110 Watt, 255 Channels
T04KLH9PW3AN	Model W3 (146-174 MHz), 50-110 Watt, 255 Channels
T04KLF9PW4AN	Model W4 (146-174 MHz), 50-110 Watt, 128 Channels
T04KLF9PW5AN	Model W5 (146-174 MHz), 50-110 Watt, 128 Channels
T04KLH9PW7AN	Model W7 (146-174 MHz), 50-110 Watt, 255 Channels
T04KLH9PW9AN	Model W9 (146-174 MHz), 50-110 Watt, 255 Channels

D04JKH9PW3AN	D04JKF9PW4AN	D04JKF9PW5AN	D04JKH9PW7AN	T04JKH9PW9AN	D04KKF9PW3AN	D04KKF9PW4AN	D04KKF9PW5AN	D04KKH9PW7AN	T04KKH9PW9AN	T04JLH9PW3AN	T04JLF9PW4AN	T04JLF9PW5AN	T04JLH9PW7AN	T04JLH9PW9AN	T04KLH9PW3AN	T04KLF9PW4AN	T04KLF9PW5AN	T04KLH9PW7AN	T04KLH9PW9AN	Item No.	Description
X	X	X	X	X						X	X	X	X	X						HRD6001_	Front-End Rcvr Board Kit (Range 1, 136-162 MHz)
					X	X	X	X	X						X	X	X	X	X	HRD6002_	Front-End Rcvr Board Kit (Range 2, 146-174 MHz)
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HRN6014_	RF Board Kit
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HLD4342_	VCO Board Kit
X	X	X	X	X						X	X	X	X	X						HLD6061_	VCO Hybrid Kit (Range 1, 136-162 MHz)
					X	X	X	X	X						X	X	X	X	X	HLD6062_	VCO Hybrid Kit (Range 2, 146-174 MHz)
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HLN5558_	Command Board Kit
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HLN6458_	VOCON Board Kit
										X	X	X	X	X						HLD6064_	Power Amplifier Board (50-110W, Range 1, 136-162 MHz)
X	X	X	X	X	X	X	X	X	X											HLD6022_	Power Amplifier Board (25-50W, Range 1, 136-174 MHz)
															X	X	X	X	X	HLD6063_	Power Amplifier Board (50-110W, Range 2, 146-174 MHz)
				X					X											HLN6344_	Interface Board
	X	X	X		X		X	X												HLN6401_	Control Head Interconnect Board
	X				X						X					X				AAHN4045_	W4 Control Head
											X	X	X	X		X	X	X	X	HLN6486_	High-Power Interconnect Board
											X	X	X			X	X	X		HLN6432_	Control Head Back Housing
		X	X				X	X				X	X				X	X		HLN6396_	W5,W7 Control Head Board
				X					X					X					X	HCN1078_	W9 Control Head
	X	X	X		X		X	X			X	X	X			X	X	X		HMN1080_	Microphone
				X					X					X					X	HMN1061_	Microphone
X	X	X	X	X	X	X	X	X	X											HSN4018_	Speaker
										X	X	X	X	X	X	X	X	X	X	HSN6001_	Speaker
				X					X					X					X	HLN4921_	Control Head (W9) Trunnion
				X					X											HLN5488_	Radio Microphone Installation Hardware (W9 Trunnion)
X				X	X				X											HLN6185_*	Rem-Mount, SECURENET Control-Head Hardware
											X	X	X			X	X	X		HLN6231_	Remote W4, W5, W7 Control-Head Trunnion
										X	X	X	X	X	X	X	X	X	X	HLN6233_*	Option Connector Hardware

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra VHF 10–25 and 50–110 Watt Model Chart (cont.)

Model Number	Description
D04JKH9PW3AN	Model W3 (136-145.9 MHz), 25-50 Watt, 128 Channels
D04JKF9PW4AN	Model W4 (136-162 MHz), 25-50 Watt, 128 Channels
D04JKF9PW5AN	Model W5 (136-162 MHz); 25-50 Watt, 128 Channels
D04JKH9PW7AN	Model W7 (136-162 MHz), 25-50 Watt, 255 Channels
T04JKH9PW9AN	Model W9 (136-162 MHz), 25-50 Watt, 255 Channels
D04KKF9PW3AN	Model W3 (146-174 MHz), 25-50 Watt, 128 Channels
D04KKF9PW4AN	Model W4 (146-174 MHz), 25-50 Watt, 128 Channels
D04KKF9PW5AN	Model W5 (146-174 MHz), 25-50 Watt, 128 Channels
D04KKH9PW7AN	Model W7 (146-174 MHz), 25-50 Watt, 255 Channels
T04KKH9PW9AN	Model W9 (146-174 MHz), 25-50 Watt, 255 Channels
T04JLH9PW3AN	Model W3 (136-145.9 MHz), 50-110 Watt, 128 Channels
T04JLF9PW4AN	Model W4 (136-162 MHz), 50-110 Watt, 128 Channels
T04JLF9PW5AN	Model W5 (136-162 MHz), 50-110 Watt, 128 Channels
T04JLH9PW7AN	Model W7 (136-162 MHz), 50-110 Watt, 255 Channels
T04JLH9PW9AN	Model W9 (136-162 MHz), 50-110 Watt, 255 Channels
T04KLH9PW3AN	Model W3 (146-174 MHz), 50-110 Watt, 255 Channels
T04KLF9PW4AN	Model W4 (146-174 MHz), 50-110 Watt, 128 Channels
T04KLF9PW5AN	Model W5 (146-174 MHz), 50-110 Watt, 128 Channels
T04KLH9PW7AN	Model W7 (146-174 MHz), 50-110 Watt, 255 Channels
T04KLH9PW9AN	Model W9 (146-174 MHz), 50-110 Watt, 255 Channels

D04JKH9PW3AN	D04JKF9PW4AN	D04JKF9PW5AN	D04JKH9PW7AN	T04JKH9PW9AN	D04KKF9PW3AN	D04KKF9PW4AN	D04KKF9PW5AN	D04KKH9PW7AN	T04KKH9PW9AN	T04JLH9PW3AN	T04JLF9PW4AN	T04JLF9PW5AN	T04JLH9PW7AN	T04JLH9PW9AN	T04KLH9PW3AN	T04KLF9PW4AN	T04KLF9PW5AN	T04KLH9PW7AN	T04KLH9PW9AN	Item No.	Description
										X	X	X	X	X	X	X	X	X	X	HLN6132_*	High-Power Installation Hardware
X	X	X	X		X	X	X	X												HLN6015_	Trunnion/Hardware (Dash Mount)
X	X	X	X		X	X	X	X												HLN6060_	Dash-Mount Hardware
										X	X	X	X	X	X	X	X	X	X	HLN6121_*	High-Power Radio Hardware
X	X	X	X	X	X	X	X	X	X											HLN6418_*	Transceiver Hardware
		X					X					X					X			HLN6440_*	Control Head without Keypad Hardware
			X					X					X					X		HLN6441_*	Control Head with Keypad Hardware
										X	X	X	X	X	X	X	X	X	X	HLN6525_*	High-Power Transceiver Hardware
						X					X			X		X		X	X	HLN6493_*	Plug Kit
				X					X	X	X	X	X	X		X	X	X	X	HLN4952_	Fuse Kit
				X					X		X	X	X	X		X	X	X	X	HKN4356_	Radio Cable (Length -17 Feet)
										X	X	X	X	X	X	X	X	X	X	HKN6039_	Cable (Length - 17 Feet)
										X	X	X	X	X	X	X	X	X	X	HKN4051_	Cable and Fuse
X	X	X	X		X	X	X	X												HKN4191_	Power Cable (Length - 20 Feet)
				X					X											HKN4192_	Power Cable (Length - 20 Feet)
				X					X					X					X	HLN6481_*	Systems 9000 E9 Clear Button Kit
	X					X					X					X				HLN6549_*	C4 Button Kit
	X					X					X					X				HLN6105_	Emergency/Secure/MPL Button Kit
		X	X				X	X				X	X				X	X		HLN6193_	Emergency/MPL Field Option Button Kit
		X					X					X					X			HLN6548_*	SMARTNET Button Kit
			X					X					X					X		HLN6523_*	SMARTNET Button Kit
				X					X					X					X	HLN6167_	Option Button Kit
X					X															HLN6459_	W3 Interface Board Kit
X					X					X					X					HMN4044_	ASTRO Handheld Control Head (W3)
X					X					X					X					TLN5277_	Filter Kit
										X					X					HKN6096_	Handheld Control Head "Y" Cable Kit
										X					X					HLN6291_	Installation Hardware Kit
										X					X					HLN6574_	W3 Interconnect Board Kit

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra UHF 10–25 Watt Model Chart

Model Number						Description
D04RHH9PW3AN						Model W3 (438-470 MHz), 10-25 Watt, 255 Channels
	D04RHF9PW4AN					Model W4 (438-470 MHz), 10-25 Watt, 128 Channels
		D04RHF9PW5AN				Model W5 (438-470 MHz), 10-25 Watt, 128 Channels
			D04RHH9PW7AN			Model W7 (438-470 MHz), 10-25 Watt, 255 Channels
				T04RHH9PW9AN		Model W9 (438-470 MHz), 10-25 Watt, 255 Channels
					Item No.	**Description**
	X				AAHN4045_	Front Housing
X	X	X	X	X	HAE4003_	Antenna
X	X	X	X		HKN4191_	Power Cable (Length-20 Feet)
X	X	X	X	X	HLE6046_	VCO Carrier, Range 2
X	X	X	X	X	HLE6062_	Power Amplifier, 25W, Range 2
X	X	X	X	X	HLE6102_	VCO Hybrid Kit, Range 2
X	X	X	X	X	HLN5558_	Command Board Kit
X	X	X	X		HLN6015_	Trunnion
	X	X	X		HLN6073_	Dash-Mount Hardware
	X				HLN6105_	Emergency/Secure/MPL Button Kit
	X				HLN6549_*	C4 Button Kit
	X	X	X		HLN6401_	Control Head Interconnect Board
X	X	X	X	X	HLN6418_*	Transceiver Hardware
X	X	X	X	X	HLN6458_	VOCODER Controller
	X	X	X		HMN1080_	Microphone
X	X	X	X	X	HRE6002_	Receiver, Range 2
	X	X	X	X	HRN6020_	RF Board Kit
X	X	X	X	X	HSN4018_	Speaker
		X			HLN6548_*	SMARTNET Button Kit
		X	X		HLN6193_	Emergency/MPL Field Option Button Kit
		X	X		HLN6396_	DEK Compatible Control Head
		X			HLN6440_*	Control Head without Keypad Hardware
			X		HLN6441_*	Control Head with Keypad Hardware
			X		HLN6523_*	SMARTNET Button Kit
				X	HCN1078_	W9 Control Head
				X	HKN4192_	Power Cable (Length-20 Feet)
				X	HKN4356_	Radio Cable
				X	HLN4921_	Trunnion
				X	HLN4952_	Fuse Kit
				X	HLN5488_	Installation Hardware
				X	HLN6162_*	Remote Hardware
				X	HLN6167_	Option Button Kit
X				X	HSN6185_	Remote-Mount, SECURENET Control-Head Hardware
				X	HLN6344_	Interface Board
				X	HLN6481_*	Systems 9000 E9 Clear Button Kit
				X	HLN6493_*	Plug Kit
				X	HMN1061_	Microphone
X					HLN6127_	Dash Hardware, Low-Power Kit
X					HLN6459_	W3 Interface Board Kit
X					HMN4044_	ASTRO Handheld Control Head (W3)
X					HRN4010_	Low-Power RF Board Kit
X					TLN5277_	Filter Kit

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra UHF 20–40 Watt Model Chart

Model Number	Description
D04QKH9PW3AN	Model W3 (403-433 MHz), 20-40 Watt, 128 Channels
D04QKF9PW4AN	Model W4 (403-433 MHz), 20-40 Watt, 128 Channels
D04QKF9PW5AN	Model W5 (403-433 MHz), 20-40 Watt, 128 Channels
D04QKH9PW7AN	Model W7 (403-433 MHz), 20-40 Watt, 255 Channels
T04QKH9PW9AN	Model W9 (403-433 MHz), 20-40 Watt, 255 Channels
D04RKH9PW3ANSP01	Model W3 (450-482 MHz), 20-40 Watt, 128 Channels
D04RKF9PW4AN	Model W4 (450-482 MHz), 20-40 Watt, 128 Channels
D04RKF9PW5AN	Model W5 (450-482 MHz), 20-40 Watt, 128 Channels
D04RKH9PW7AN	Model W7 (450-482 MHz), 20-40 Watt, 255 Channels
T04RKH9PW9AN	Model W9 (450-482 MHz), 20-40 Watt, 255 Channels
D04SKH9PW3AN	Model W3 (482-512 MHz), 20-40 Watt, 128 Channels
D04SKF9PW4AN	Model W4 (482-512 MHz), 20-40 Watt, 128 Channels
D04SKF9PW5AN	Model W5 (482-512 MHz), 20-40 Watt, 128 Channels
D04SKH9PW7AN	Model W7 (482-512 MHz), 20-40 Watt, 255 Channels
T04SKH9PW9AN	Model W9 (482-512 MHz), 20-40 Watt, 255 Channels

D04QKH9PW3AN	D04QKF9PW4AN	D04QKF9PW5AN	D04QKH9PW7AN	T04QKH9PW9AN	D04RKH9PW3ANSP01	D04RKF9PW4AN	D04RKF9PW5AN	D04RKH9PW7AN	T04RKH9PW9AN	D04SKH9PW3AN	D04SKF9PW4AN	D04SKF9PW5AN	D04SKH9PW7AN	T04SKH9PW9AN	Item No.	Description
	X					X					X				AAHN4045_	Front Housing
X	X	X	X	X											HAE4002_	Antenna, Roof Top
X	X	X	X		X	X	X	X		X	X	X	X		HKN4191_	Power Cable (Length-20 Feet)
				X					X					X	HKN4192_	Power Cable (Length-20 Feet)
				X					X					X	HKN4356_	Radio Cable (Length-17 Feet)
X	X	X	X	X											HLE6045_	VCO Carrier, Range 1
X	X	X	X	X											HLE6049_	Power Amplifier, 40W, Range 1
X	X	X	X	X											HLE6101_	VCO Hybrid Kit, Range 1
				X					X					X	HLN4921_	Trunnion
				X					X					X	HLN4952_	Fuse Kit
				X					X					X	HLN5488_	Installation Hardware
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HLN5558_	Command Board Kit
X	X	X	X		X	X	X	X		X	X	X	X		HLN6015_	Trunnion/Hardware (Dash Mount)
X	X	X	X		X	X	X	X		X	X	X	X		HLN6073_	Dash-Mount Hardware
		X					X					X			HLN6548_*	SMARTNET Button Kit
				X											HLN6162_*	Remote-Mount Hardware
				X					X					X	HLN6167_	Option Button Kit
X				X					X	X				X	HLN6185_*	Remote-Mount, SECURENET Control-Head Hardware
		X	X				X	X				X	X		HLN6193_	Emergency/MPL Field Option Button Kit
		X	X				X	X				X	X		HLN6396_	Control Head Deck Compatible
	X					X					X				HLN6105_	Emergency/Secure/MPL Button Kit
	X					X					X				HLN6549_*	C4 Button Kit
				X					X					X	HLN6344_	Interface Board
	X	X	X			X	X	X			X	X	X		HLN6401_	Control Head Interconnect Board
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HLN6418_*	Transceiver Hardware
		X					X						X		HLN6440_*	Control Head without Keypad Hardware
			X					X					X		HLN6441_*	Control Head with Keypad Hardware
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HLN6458_	VOCODER Controller
				X					X					X	HLN6481_*	Systems 9000 E9 Clear Button Kit
				X					X					X	HLN6493_*	Plug Kit
			X					X					X		HLN6523_*	SMARTNET Button Kit
	X	X	X			X	X	X			X	X	X		HMN1080_	Microphone
X	X	X	X	X											HRE6001_	Receiver R/E, Range 1
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HRN6020_	RF Board
				X					X					X	HMN1061_	Microphone

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra UHF 20–40 Watt Model Chart (cont.)

Model Number	Description
D04QKH9PW3AN	Model W3 (403-433 MHz), 20-40 Watt, 128 Channels
D04QKF9PW4AN	Model W4 (403-433 MHz), 20-40 Watt, 128 Channels
D04QKF9PW5AN	Model W5 (403-433 MHz), 20-40 Watt, 128 Channels
D04QKH9PW7AN	Model W7 (403-433 MHz), 20-40 Watt, 255 Channels
T04QKH9PW9AN	Model W9 (403-433 MHz), 20-40 Watt, 255 Channels
D04RKH9PW3ANSP01	Model W3 (450-482 MHz), 20-40 Watt, 128 Channels
D04RKF9PW4AN	Model W4 (450-482 MHz), 20-40 Watt, 128 Channels
D04RKF9PW5AN	Model W5 (450-482 MHz), 20-40 Watt, 128 Channels
D04RKH9PW7AN	Model W7 (450-482 MHz), 20-40 Watt, 255 Channels
T04RKH9PW9AN	Model W9 (450-482 MHz), 20-40 Watt, 255 Channels
D04SKH9PW3AN	Model W3 (482-512 MHz), 20-40 Watt, 128 Channels
D04SKF9PW4AN	Model W4 (482-512 MHz), 20-40 Watt, 128 Channels
D04SKF9PW5AN	Model W5 (482-512 MHz), 20-40 Watt, 128 Channels
D04SKH9PW7AN	Model W7 (482-512 MHz), 20-40 Watt, 255 Channels
T04SKH9PW9AN	Model W9 (482-512 MHz), 20-40 Watt, 255 Channels

D04QKH9PW3AN	D04QKF9PW4AN	D04QKF9PW5AN	D04QKH9PW7AN	T04QKH9PW9AN	D04RKH9PW3ANSP01	D04RKF9PW4AN	D04RKF9PW5AN	D04RKH9PW7AN	T04RKH9PW9AN	D04SKH9PW3AN	D04SKF9PW4AN	D04SKF9PW5AN	D04SKH9PW7AN	T04SKH9PW9AN	Item No.	Description
					X	X	X	X	X						HAE4003_	Antenna, Quarterwave
						X	X	X	X						HLE6000_	VCO Carrier, Range 3
						X	X	X	X						HLE6043_	Power Amplifier, 40W, range 3
						X	X	X	X						HLE6103_	VCO Hybrid Kit, range 3
						X	X	X	X						HRE6003_	Receiver R/E, Range 3
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	HSN4018_	Speaker
				X					X					X	HCN1078_	W9 Control Head
										X	X	X	X	X	HAE4004_	Antenna, Roof Top
										X	X	X	X	X	HLE6041_	VCO Carrier, Range 4
										X	X	X	X	X	HLE6044_	Power Amplifier, 40W, Range 4
										X	X	X	X	X	HLE6104_	VCO Hybrid Kit, Range 4
										X	X	X	X	X	HRE6004_	Receiver R/E, Range 4
X					X					X					HLN6459_	W3 Interface Board
X					X					X					HMN4044_	ASTRO Handheld Control Head (W3)

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra UHF 50–110 Watt Model Chart

Model Number	Description
T04QLF9PW4AN	Model W4 (403-433 MHz), 50-110 Watt, 128 Channels
T04QLF9PW5AN	Model W5 (403-433 MHz), 50-110 Watt, 255 Channels
T04QLH9PW7AN	Model W7 (403-433 MHz), 50-110 Watt, 255 Channels
T04QLH9PW9AN	Model W9 (403-433 MHz), 50-110 Watt, 255 Channels
T04RLF9PW4AN	Model W4 (450-482 MHz), 50-110 Watt, 128 Channels
T04RLF9PW5AN	Model W5 (450-482 MHz), 50-110 Watt, 128 Channels
T04RLH9PW7AN	Model W7 (450-482 MHz), 50-110 Watt, 255 Channels
T04RLH9PW9AN	Model W9 (450-482 MHz), 50-110 Watt, 255 Channels
T04SLF9PW4AN	Model W4 (482-512 MHz), 50-110 Watt, 128 Channels
T04SLF9PW5AN	Model W5 (482-512 MHz), 50-110 Watt, 128 Channels
T04SLHPW7AN	Model W7 (482-512 MHz), 50-110 Watt, 128 Channels
T04SLHPW9AN	Model W9 (482-512 MHz), 50-110 Watt, 128 Channels

T04QLF9PW4AN	T04QLF9PW5AN	T04QLH9PW7AN	T04QLH9PW9AN	T04RLF9PW4AN	T04RLF9PW5AN	T04RLH9PW7AN	T04RLH9PW9AN	T04SLF9PW4AN	T04SLF9PW5AN	T04SLHPW7AN	T04SLHPW9AN	Item No.	Description
X				X				X				AAHN4045_	Front Housing
X	X	X	X									HAE4002_	Antenna, Roof Top
				X	X	X	X					HAE4003_	Antenna, Quarterwave
								X	X	X	X	HAE4004_	Antenna, Roof Top
X	X	X	X	X	X	X	X	X	X	X	X	HKN4051_	Cable and Fuse
X	X	X	X	X	X	X	X	X	X	X	X	HKN4356_	Radio Cable (Length-17 Feet)
X	X	X	X	X	X	X	X	X	X	X	X	HKN6039_	Cable (Length-17 Feet)
				X	X	X	X					HLE6039_	VCO Carrier, Range 3
								X	X	X	X	HLE6040_	Power Amplifier Board, Range 4
								X	X	X	X	HLE6041_	VCO Carrier, Range 4
X	X	X	X									HLE6045_	VCO Carrier, Range 1
X	X	X	X									HLE6051_	Power Amplifier Board, 100W, Range 1
X	X	X	X									HLE6101_	VCO Hybrid Kit, Range 1
				X	X	X	X					HLE6103_	VCO Hybrid Kit, Range 3
								X	X	X	X	HLE6104_	VCO Hybrid Kit, Range 4
X	X	X	X	X	X	X	X	X	X	X	X	HLN4952_	Fuse Kit
X	X	X	X	X	X	X	X	X	X	X	X	HLN5558_	Command Board Kit
X				X				X				HLN6105_	Emergency/Secure/MPL Button Kit
X	X	X	X	X	X	X	X	X	X	X	X	HLN6121_*	High-Power Radio Hardware
X	X	X	X	X	X	X	X	X	X	X	X	HLN6132_*	Installation Hardware, High-Power
X	X	X		X	X	X		X	X	X		HLN6231_	Remote W4, W5, W7 Control-Head Trunnion
X	X	X	X	X	X	X	X	X	X	X	X	HLN6233_*	Option Connector Hardware
X				X				X				HLN6549_*	C4 Button Kit
X	X	X		X	X	X		X	X	X		HLN6432_	Back Housing, Control Head
X	X	X	X	X	X	X	X	X	X	X	X	HLN6458_	VOCON Board Kit
X	X	X	X	X	X	X	X	X	X	X	X	HLN6486_	Interconnect Board
				X	X			X	X	X		HLN6493_*	Plug Kit
X	X	X	X	X	X	X	X	X	X	X	X	HLN6525_*	High-Power Transceiver Hardware
X	X	X	X	X	X	X		X	X	X		HMN1080_	Microphone
X	X	X	X				X				X	HMN1061_	Microphone
			X									HRE6001_	Receiver Board Kit, Range 1
				X	X	X	X					HRE6003_	Receiver Board Kit, Range 3
								X	X	X	X	HRE6004_	Receiver Board Kit, Range 4
X	X	X	X	X	X	X	X	X	X	X	X	HRN6020_	RF Board
X	X	X	X	X	X	X	X	X		X	X	HSN6001_	Speaker
	X				X				X			HLN6548_*	SMARTNET Button Kit
	X	X			X	X			X	X		HLN6193_	Emergency/MPL Field Option Button Kit
	X	X			X	X			X	X		HLN6396_	W5, W7 Control Head Board

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra UHF 50–110 Watt Model Chart (cont.)

Model Number	Description
T04QLF9PW4AN	Model W4 (403-433 MHz), 50-110 Watt, 128 Channels
T04QLF9PW5AN	Model W5 (403-433 MHz), 50-110 Watt, 255 Channels
T04QLH9PW7AN	Model W7 (403-433 MHz), 50-110 Watt, 255 Channels
T04QLH9PW9AN	Model W9 (403-433 MHz), 50-110 Watt, 255 Channels
T04RLF9PW4AN	Model W4 (450-482 MHz), 50-110 Watt, 128 Channels
T04RLF9PW5AN	Model W5 (450-482 MHz), 50-110 Watt, 128 Channels
T04RLH9PW7AN	Model W7 (450-482 MHz), 50-110 Watt, 255 Channels
T04RLH9PW9AN	Model W9 (450-482 MHz), 50-110 Watt, 255 Channels
T04SLF9PW4AN	Model W4 (482-512 MHz), 50-110 Watt, 128 Channels
T04SLF9PW5AN	Model W5 (482-512 MHz), 50-110 Watt, 128 Channels
T04SLHPW7AN	Model W7 (482-512 MHz), 50-110 Watt, 128 Channels
T04SLHPW9AN	Model W9 (482-512 MHz), 50-110 Watt, 128 Channels

T04QLF9PW4AN	T04QLF9PW5AN	T04QLH9PW7AN	T04QLH9PW9AN	T04RLF9PW4AN	T04RLF9PW5AN	T04RLH9PW7AN	T04RLH9PW9AN	T04SLF9PW4AN	T04SLF9PW5AN	T04SLHPW7AN	T04SLHPW9AN	Item No.	Description
	X				X				X			HLN6440_*	Control Head without Keypad Hardware
		X				X				X		HLN6441_*	Control Head with Keypad Hardware
		X				X				X		HLN6523_*	SMARTNET Button Kit
			X				X				X	HCN1078_	W9 Control Head
			X				X				X	HLN4921_	Trunnion
			X				X				X	HLN6167_	Option Button Kit
			X				X				X	HLN6481_*	Systems 9000 E9 Clear Button Kit

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra 800 MHz Model Chart

Model Number	Description
D04UJF9PW3AN	Model W3 (800 MHz), 35 Watt, 128 Channels
D04UJF9PW4AN	Model W4 (800 MHz), 35 Watt, 128 Channels
D04UJF9PW5AN	Model W5 (800 MHz), 35 Watt, 128 Channels
D04UJF9PW7AN	Model W7 (800 MHz), 35 Watt, 255 Channels
T04UJF9PW9AN	Model W9 (800 MHz), 35 Watt, 255 Channels

D04UJF9PW3AN	D04UJF9PW4AN	D04UJF9PW5AN	D04UJF9PW7AN	T04UJF9PW9AN	Item No.	Description
	X				AAHN4045_	Front Housing
X	X	X	X		HKN4191_	Power Cable (Length-20 Feet)
X	X	X	X	X	HLF6077_	Power Amplifier
X	X	X	X	X	HLF6079_	VCO Hybrid
X	X	X	X	X	HLF6080_	VCO Carrier
X	X	X	X		HLN6015_	Trunnion/Hardware
	X				HLN6040_	Phon/Page/Emer/MPL Button
X	X	X	X	X	HLN6126_*	Mid-Power Dash Mount Radio Hardware
		X	X		HLN6193_	Emergency/MPL Field Option Button Kit
	X				HLN6549_*	C4 Button Kit
	X	X	X		HLN6401_	Control Head Interconnect Board
	X	X	X	X	HLN6418_*	Transceiver Hardware
	X	X	X		HMN1080_	Microphone
X	X	X	X	X	HRF6004_	Front-End Receiver Kit
X	X	X	X	X	HRN6019_	RF Board Kit
X	X	X	X	X	HSN4018_	Speaker
X	X	X	X	X	RRA4914_	Antenna
X	X	X	X	X	HLN5558_	Command Board Kit
		X			HLN6548_*	SMARTNET Button Kit
		X	X		HLN6396_	Control Head Deck Compatible
		X			HLN6440_*	Control Head without Keypad Hardware
X	X	X	X	X	HLN6458_	VOCODER Controller
			X		HLN6441_*	Control Head with Keypad Hardware
			X		HLN6523_*	SMARTNET Button Kit
				X	HCN1078_	W9 Control Head
				X	HKN4192_	Power Cable (Length-20 Feet)
				X	HKN4356_	Radio Cable (Length-17 Feet)
				X	HLN4921_	Trunnion, Control Head w9
				X	HLN4952_	Fuse Kit
				X	HLN5488_	Installation Hardware (W9 Trunnion) Radio Microphone
				X	HLN6167_	Option Button Kit
X				X	HLN6185_*	Remote-Mount, SECURENET Control Head Hardware
				X	HLN6344_	Interface Board
				X	HLN6481_*	Systems 9000 E9 Clear Button Kit
				X	HLN6493_*	Plug Kit
				X	HMN1061_	Microphone

X = Item Included
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra Plus VHF 25–50 and 50–110 Watt Model Chart

Model Number	Description
D04KKH9SW3AN	Model W3 (146-174 MHz), 25-50 Watt, 512 Channels
D04KKF9SW4AN	Model W4 (146-174 MHz), 25-50 Watt, 128 Channels
D04KKF9SW5AN	Model W5 (146-174 MHz); 25-50 Watt, 128 Channels
D04KKH9SW7AN	Model W7 (146-174 MHz),25-50 Watt, 512 Channels
T04KKH9SW9AN	Model W9 (146-174 MHz), 25-50 Watt, 512 Channels
T04KLH9SW3AN	Model W3 (146-174 MHz), 50-110 Watt, 512 Channels
T04KLF9SW4AN	Model W4 (146-174 MHz), 50-110 Watt, 128 Channels
T04KLF9SW5AN	Model W5 (146-174 MHz), 50-110 Watt, 128 Channels
T04KLH9SW7AN	Model W7 (146-174 MHz), 50-110 Watt, 512 Channels
T04KLH9SW9AN	Model W9 (146-174 MHz), 50-110 Watt, 512 Channels

D04KKH9SW3AN	D04KKF9SW4AN	D04KKF9SW5AN	D04KKH9SW7AN	T04KKH9SW9AN	T04KLH9SW3AN	T04KLF9SW4AN	T04KLF9SW5AN	T04KLH9SW7AN	T04KLH9SW9AN	Item No.	Description
X	X	X	X	X	X	X	X	X	X	HRD6002_	Front-End Rcvr Board Kit (Range 2, 146-174 MHz)
X	X	X	X	X	X	X	X	X	X	HRN6014_	RF Board Kit
X	X	X	X	X	X	X	X	X	X	HLD4342_	VCO Board Kit
X	X	X	X	X	X	X	X	X	X	HLD6062_	VCO Hybrid Kit (Range 2, 146-174 MHz)
X	X	X	X	X	X	X	X	X	X	HLN5558_	Command Board Kit
X	X	X	X	X	X	X	X	X	X	HLN6837_	VOCON Board Kit
X	X	X	X	X						HLD6022_	Power Amplifier Board (25-50W, Range 2, 146-174 MHz)
					X	X	X	X	X	HLD6063_	Power Amplifier Board (50-110W, Range 2, 146-174 MHz)
				X						HLN6344_	Interface Board
	X	X	X							HLN6401_	Control Head Interconnect Board
	X					X				AAHN4045_	W4 Control Head
						X	X	X	X	HLN6486_	High-Power Interconnect Board
						X	X	X		HLN6432_	Control Head Back Housing
		X	X				X	X		HLN6396_	W5,W7 Control Head Board
				X					X	HCN1078_	W9 Control Head
O	O	O	O	O	O	O	O	O	O	NTN9801_	ASTRO Spectra Plus UCM
	X	X	X			X	X	X		HMN1080_	Microphone
				X					X	HMN1061_	Microphone
X	X	X	X	X						HSN4018_	Speaker
					X	X	X	X	X	HSN6001_	Speaker
				X					X	HLN4921_	Control Head (W9) Trunnion
				X					X	HLN5488_	Radio Microphone Installation Hardware (W9 Trunnion)
X				X						HLN6185_*	Rem-Mount, SECURENET Control-Head Hardware
						X	X	X		HLN6231_	Remote W4, W5, W7 Control-Head Trunnion
					X	X	X	X	X	HLN6233_*	Option Connector Hardware
					X	X	X	X	X	HLN6132_*	High-Power Installation Hardware
X	X	X	X							HLN6015_	Trunnion/Hardware (Dash Mount)
X	X	X	X							HLN6060_	Dash-Mount Hardware
					X	X	X	X	X	HLN6121_*	High-Power Radio Hardware
X	X	X	X	X						HLN6866_*	Transceiver Hardware
		X					X			HLN6440_*	Control Head without Keypad Hardware
			X					X		HLN6441_*	Control Head with Keypad Hardware
					X	X	X	X	X	HLN6525_*	High-Power Transceiver Hardware
				X					X	HLN6493_*	Plug Kit
				X		X	X	X	X	HLN4952_	Fuse Kit
				X		X	X	X	X	HKN4356_	Radio Cable (Length -17 Feet)
					X	X	X	X	X	HKN6039_	Cable (Length - 17 Feet)
					X	X	X	X	X	HKN4051_	Cable and Fuse

X = Item Included
O = Optional item
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra Plus VHF 25–50 and 50–110 Watt Model Chart (cont.)

Model Number	Description
D04KKH9SW3AN	Model W3 (146-174 MHz), 25-50 Watt, 512 Channels
D04KKF9SW4AN	Model W4 (146-174 MHz), 25-50 Watt, 128 Channels
D04KKF9SW5AN	Model W5 (146-174 MHz); 25-50 Watt, 128 Channels
D04KKH9SW7AN	Model W7 (146-174 MHz),25-50 Watt, 512 Channels
T04KKH9SW9AN	Model W9 (146-174 MHz), 25-50 Watt, 512 Channels
T04KLH9SW3AN	Model W3 (146-174 MHz), 50-110 Watt, 512 Channels
T04KLF9SW4AN	Model W4 (146-174 MHz), 50-110 Watt, 128 Channels
T04KLF9SW5AN	Model W5 (146-174 MHz), 50-110 Watt, 128 Channels
T04KLH9SW7AN	Model W7 (146-174 MHz), 50-110 Watt, 512 Channels
T04KLH9SW9AN	Model W9 (146-174 MHz), 50-110 Watt, 512 Channels

D04KKH9SW3AN	D04KKF9SW4AN	D04KKF9SW5AN	D04KKH9SW7AN	T04KKH9SW9AN	T04KLH9SW3AN	T04KLF9SW4AN	T04KLF9SW5AN	T04KLH9SW7AN	T04KLH9SW9AN	Item No.	Description
X	X	X	X							HKN4191_	Power Cable (Length - 20 Feet)
				X						HKN4192_	Power Cable (Length - 20 Feet)
				X					X	HLN6481_*	Systems 9000 E9 Clear Button Kit
	X					X				HLN6549_*	C4 Button Kit
	X	X	X	X		X	X	X	X	HLN6105_	Emergency/Secure/MPL Button Kit
		X					X			HLN6548_*	SMARTNET Button Kit
			X					X		HLN6523_*	SMARTNET Button Kit
				X					X	HLN6167_	Option Button Kit
X										HLN6459_	W3 Interface Board Kit
X					X					HMN4044_	ASTRO Handheld Control Head (W3)
X					X					TLN5277_	Filter Kit
					X					HKN6096_	Handheld Control Head ”Y” Cable Kit
					X					HLN6291_	Installation Hardware Kit
					X					HLN6574_	W3 Interconnect Board Kit

X = Item Included
O = Optional item
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra Plus 800 MHz Model Chart

Model Number	Description
M04UGF9SW4AN	Model W4 (800 MHz), 15 Watt, 128 Channels
M04UGF9SW5AN	Model W5 (800 MHz), 15 Watt, 128 Channels
M04UGH9SW7AN	Model W7 (800 MHz), 15 Watt, 512 Channels
D04UJH9SW3AN	Model W3 (800 MHz), 35 Watt, 512 Channels
D04UJF9SW4AN	Model W4 (800 MHz), 35 Watt, 128 Channels
D04UJF9SW5AN	Model W5 (800 MHz), 35 Watt, 128 Channels
D04UJH9SW7AN	Model W7 (800 MHz), 35 Watt, 512 Channels
T04UJH9SW9AN	Model W9 (800 MHz), 35 Watt, 512 Channels

M04UGF9SW4AN	M04UGF9SW5AN	M04UGH9SW7AN	D04UJH9SW3AN	D04UJF9SW4AN	D04UJF9SW5AN	D04UJH9SW7AN	T04UJH9SW9AN	Item No.	Description
				X				AAHN4045_	Front Housing, W4 Control Head
			X	X	X	X		HKN4191_	Power Cable (Length-20 Feet)
			X	X	X	X	X	HLF6077_	Power Amplifier
X	X	X						HLF6078_	15W. 800 MHz Power Amplifier
X	X	X	X	X	X	X	X	HLF6079_	VCO Hybrid
X	X	X	X	X	X	X	X	HLF6080_	VCO Carrier
			X	X	X	X		HLN6015_	Trunnion/Hardware
X	X	X		X	X	X	X	HLN6688A_	Phon/Page/Emer/MPL Button
			X	X	X	X	X	HLN6126_	Mid-Power Dash Mount Radio Hardware
X	X	X		X	X	X	X	HLN6645A_	Emergency/MPL Field Option Button Kit
				X				HLN6549_*	W4 Button Kit
				X	X	X		HLN6401_	Control Head Interconnect Board
X	X	X						HLN6365_	Interface Board, Motorcycle
X	X	X	X	X	X	X	X	HLN6418_*	Transceiver Hardware
				X	X	X		HMN1080_	Microphone, Modified Standard
X	X	X	X	X	X	X	X	HRF6004_	Front-End Receiver Kit
X	X	X	X	X	X	X	X	HRN6019_	RF Board Kit
			X	X	X	X	X	HSN4018_	Speaker
			X	X	X	X	X	RRA4914_	Antenna
			X	X	X	X	X	HLN5558_	Command Board Kit
X	X	X						HLN6562_	Command Board, Motorcycle
	X				X			HLN6548_*	SMARTNET Button Kit
					X	X		HLN6396_	Control Head Deck Compatible
					X			HLN6440_*	W5 Control Head without Keypad Hardware
X								PMLN4019_	W4 ASTRO Motorcycle Control Head
	X	X						HLN6563_	Motorcycle Control Head
		X						HLN6445_*	Hardware, Control Head, Motorcycle
					X			HLN6208_	Button, Spectra SecureNET
						X		HLN6441_*	W7 Control Head with Keypad Hardware
		X				X		HLN6523_*	SMARTNET Button Kit
							X	HCN1078_	W9 Control Head
			O	O	O	O	X	HKN4192_	Power Cable (Length-20 Feet)
				O	O	O	X	HKN4356_	Remote Mount Radio Cable (Length-17 Feet)
							X	HLN4921_	Trunnion, Control Head w9
							X	HLN4952_	Fuse Kit
							X	HLN5488_	Installation Hardware (W9 Trunnion)
							X	HLN6167_	Option Button Kit
			X	O	O	O	X	HLN6185_*	Remote-Mount, SECURENET Control Head Hardware
				O	O	O	X	HLN6344_	Interface Board, Remote Mount
							X	HLN6481_*	Systems 9000 E9 Clear Button Kit
							X	HMN1061_	Microphone

X = Item Included
O = Optional
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

ASTRO Digital Spectra Plus 800 MHz Model Chart (cont.)

Model Number	Description
M04UGF9SW4AN	Model W4 (800 MHz), 15 Watt, 128 Channels
M04UGF9SW5AN	Model W5 (800 MHz), 15 Watt, 128 Channels
M04UGH9SW7AN	Model W7 (800 MHz), 15 Watt, 512 Channels
D04UJH9SW3AN	Model W3 (800 MHz), 35 Watt, 512 Channels
D04UJF9SW4AN	Model W4 (800 MHz), 35 Watt, 128 Channels
D04UJF9SW5AN	Model W5 (800 MHz), 35 Watt, 128 Channels
D04UJH9SW7AN	Model W7 (800 MHz), 35 Watt, 512 Channels
T04UJH9SW9AN	Model W9 (800 MHz), 35 Watt, 512 Channels

M04UGF9SW4AN	M04UGF9SW5AN	M04UGH9SW7AN	D04UJH9SW3AN	D04UJF9SW4AN	D04UJF9SW5AN	D04UJH9SW7AN	T04UJH9SW9AN	Item No.	Description
			X					HLN6638_	Radio Hardware
X	X	X	X	X	X	X	X	HLN6837_	Vocoder/Controller
			X	X	X	X		HLN6073_	Radio Hardware
			X					HLN6459_	Interface Board
			X					HMN4044_	Handheld Control Head
			X					HLN6613_	Transceiver Hardware
				X			X	HLN6493_*	Large Black Plug Kit
X	X	X		X	X	X	X	HLN6105_	Spare Button Kit
							X	HLN6675_*	System 9000 Button Kit Secure
X	X	X						HLN6639_*	Radio Hardware
X	X	X						HKN6062_	Cable, Control Head to Radio
X	X	X						HLN6179_	Motorcycle Adapter Control Head Speaker
X	X	X						HKN6032_	Motorcycle Power Cable
X	X	X						HLN6180_	Motorcycle Mounting Hardware
X	X	X						HLN6342_*	Motorcycle Hardware Secure
				X				HLN6249_*	Button, Secure
X	X	X						RAF4011_	800 MHz Antenna, 3 dB Gain
X	X	X						HSN6003_	Motorcycle Waterproof Speaker
X	X	X						HMN1079_	Modified Motorcycle Waterproof Microphone
		X				X		HLN6524_	Button, Conventional
				O	O	O		HKN6432_	Back Housing Kit
				O	O	O		HLN6231_	Hardware, Remote-Mount Dash
	X							HLN6444_*	Hardware, Control Head, Motorcycle

X = Item Included
O = Optional
_ = the latest version kit. When ordering a kit, refer to your specific kit for the suffix number.
** = kit not available. Order piece parts from the Accessories and Aftermarket Division.*

VHF Radio Specifications

GENERAL

FCC Designations: AZ492FT3772, AZ492FT3773

Temperature Range:
- Operating: –30°C to +60°C
- Storage: –40°C to +85°C

Power Supply: 12 Vdc Negative Ground Only

Battery Drain: (Maximum)

10–25 Watt Variable:
- Standby @ 13.8 V: 0.8 A
- Receive at Rated Audio @ 13.8 V: 3.0 A
- Transmit @ Rated Power: 7.0 A

25–50 Watt Variable:
- Standby @ 13.8 V: 0.8 A
- Receive at Rated Audio @ 13.8 V: 3.0 A
- Transmit @ Rated Power: 13.5 A

50–110 Watt Variable:
- Standby @ 13.8 V: 0.9 A
- Receive at Rated Audio @ 13.8 V: 4.0 A
- Transmit @ Rated Power: 27.5 A

Dimensions (H x W x D)

W4, W5, and W7 Models:
- Remote-Mount Control Head: 2.0" x 7.1"x 2.2" (50.8 mm x 180.3 mm x 55.9 mm)
- Dash-Mount Radio: 2.0" x 7.1"x 8.6" (50.8 mm x 180.3 mm x 218.4 mm)

W9 Model:
- Remote-Mount Control Head: 3.4" x 6.5"x 1.7" (86.4 mm x 165.1 mm x 43.2 mm)

Speaker: (excluding mounting bracket) 5.5" x 5.5"x 2.5" (139.7 mm x 139. 7mm x 63.5 mm)

Weight:
- Mid-Power Radio: 6.1 lbs (2.8 kg)
- High-Power Radio: 11.2 lbs (5.1 kg)
- Speaker: 1.5 lbs (0.7 kg)

RECEIVER

Frequency Range:
- Range 1: 136–162 MHz
- Range 2: 146–174 MHz

Channel Spacing: 12.5 kHz, 25 kHz

Input Impedance: 50 Ohm

Frequency Separation:
- Range 1: 26 MHz
- Range 2: 28 MHz

Sensitivity: (per EIA spec. RS204C)

20 dB Quieting: (25/30 kHz Channel Spacing)
- With Optional Preamp: 0.30 μV
- Without Optional Preamp: 0.50 μV

12 dB SINAD (25/30 kHz Channel Spacing)
- With Optional Preamp: 0.20 μV
- Without Optional Preamp: 0.35 μV

Selectivity: (per EIA Specifications)
(Measured in the Analog Mode)
- 25/30 kHz Channel Spacing: –80 dB
- 12.5 kHz Channel Spacing: –70 dB

Intermodulation: (per EIA Specifications)
(Measured in the Analog Mode)
- With Optional Preamp: –70 dB
- Without Optional Preamp: –80 dB

Spurious Rejection:
- With Optional Preamp: –80 dB
- Without Optional Preamp: –83 dB

Frequency Stability:
(–30° to +60°C; 25°C Reference): ±0.00025%

Audio Output: (per EIA Specifications)
(Measured in the Analog Mode):
- 5 Watts at Less Than 3% Distortion
- 10 Watts Optional with Reduced Duty Cycle
- 12 Watts for High-Power Radios

TRANSMITTER

Frequency Range:
- Range 1: 136–162 MHz
- Range 2: 146–174 MHz

Rated Output Power:
- Low-Power Radio: 10–25 Watt Variable
- Mid-Power Radio: 25–50 Watt Variable
- High-Power Radio: 50–110 Watt Variable

Channel Spacing: 12.5 kHz, 25 kHz

Channel Increment Step: 2.5 kHz

Output Impedance: 50 Ohm

Frequency Separation:
- Range 1: 26 MHz
- Range 2: 28 MHz

Frequency Stability:
(–30 to +60°C; 25°C Ref.): ±0.00025%

Modulation Limiting:
- 25 kHz/30 kHz Channel Spacing: ±5.0 kHz
- 12.5 kHz Channel Spacing: ±2.5 kHz

FM Hum and Noise:
(Measured in the Analog Mode): –45 dB

Emission (Conducted and Radiated): –75 dB

Audio Sensitivity:
(For 60% Max. Deviation at 1 kHz): 0.08V ±3 dB

Audio Response:
(Measured in the Analog Mode)
(6 dB/Octave Pre-Emphasis 300 to 3000 Hz): +1, –3 dB

Emissions Designators:
8K10F1E, 11K0F3E, 15K0F2D, 16K0F3E, 20K0F1E, and 15K0F1D
AZ492FT3771: 11K0F1D, 11K0F2D
AZ492FT3772: 10K0F1D, 10K0F2D
AZ492FT3773: 11K0F1D, 11K0F2D

Specifications subject to change without notice.
All measurements are taken in the test mode at 25 kHz channel spacing except where indicated.

UHF Radio Specifications

GENERAL

FCC Designations: AZ492FT4786, AZ492FT4787

Temperature Range:

Operating:	–30°C to +60°C
Storage:	–40°C to +85°C

Power Supply: 12 Vdc Negative Ground Only

Battery Drain: (Maximum)

1–6 Watt Variable:	
Standby @ 13.8 V:	0.7 A
Receive at Rated Audio @ 13.8 V:	3.0 A
Transmit @ Rated Power:	4.0 A
10–25 Watt Variable:	
Standby @ 13.8 V:	0.7 A
Receive at Rated Audio @ 13.8 V:	3.0 A
Transmit @ Rated Power:	7.0 A
20–40 Watt Variable: (30 W Max. in Talk-Around Mode)	
Standby @ 13.8 V:	0.7 A
Receive at Rated Audio @ 13.8 V:	3.0 A
Transmit @ Rated Power:	13.0 A
78 Watt (Range 3 & 4)/110 W (Range 1 & 3):	
Standby @ 13.8 V:	0.8 A
Receive at Rated Audio @ 13.8 V:	4.0 A
Transmit @ Rated Power:	31.5 A

Dimensions (H x W x D)

W4, W5, and W7 Models:	
Remote-Mount Control Head:	2.0" x 7.1"x 2.2" (50.8 mm x 180.3 mm x 55.9 mm)
Dash-Mount Radio:	2.0" x 7.1"x 8.6" (50.8 mm x 180.3 mm x 218.4 mm)
W9 Model:	
Remote-Mount Control Head:	3.4" x 6.5"x 1.7" (86.4 mm x 165.1 mm x 43.2 mm)
Speaker: (excluding mounting bracket)	5.5" x 5.5"x 2.5" (139.7 mm x 139.7 mm x 63.5 mm)

Weight:

Mid-Power Radio:	6.1 lbs (2.8 kg)
High-Power Radio:	11.2 lbs (5.1 kg)
Speaker:	1.5 lbs (0.7 kg)

RECEIVER

Frequency Range:

Range 1:	403–433 MHz
Range 2:	438–470 MHz
Range 3:	450–482 MHz
Range 4:	482–512 MHz

Channel Spacing: 12.5 kHz or 25 kHz

Input Impedance: 50 Ohm

Frequency Separation:

Range 1 and 4:	30 MHz
Range 2 and 3:	32 MHz

Sensitivity: (per EIA spec. RS204C)

20 dB Quieting: (25 kHz Channel Spacing)	
With Optional Preamp:	0.30 µV
Without Optional Preamp:	0.50 µV
12 dB SINAD (25 kHz Channel Spacing)	
With Optional Preamp:	0.20 µV
Without Optional Preamp:	0.35 µV

Selectivity: (per EIA Specifications)

(Measured in the Analog Mode)

25 kHz Channel Spacing:	–75 dB
12.5 kHz Channel Spacing:	–70 dB

Intermodulation: (per EIA Specifications)

(Measured in the Analog Mode)

With Optional Preamp:	–70 dB
Without Optional Preamp:	–75 dB

Spurious Rejection:

With Optional Preamp:	–80 dB
Without Optional Preamp:	–83 dB

Frequency Stability:

(–30° to +60°C; 25°C Reference): ±0.00025%

Audio Output: (per EIA Specifications)

(Measured in the Analog Mode):

5 Watts at Less Than 3% Distortion

10 Watts Optional with Reduced Duty Cycle

12 Watts for High-Power Radios

TRANSMITTER

Frequency Range:

Range 1:	403–433 MHz
Range 2:	438–470 MHz
Range 3:	450–482 MHz
Range 4:	482–512 MHz

Rated Output Power:

Low-Power Radio:	1–6 Watt Variable
Mid-Power Radio:	10–25 Watt Variable
	20–40 Watt Variable
High-Power Radio:	50–110* Watt Variable

Channel Spacing: 12.5 kHz or 25 kHz

Output Impedance: 50 Ohm

Frequency Separation:

Range 1 and 4:	30 MHz
Range 2 and 3:	32 MHz

Frequency Stability:

(–30° to +60°C; 25°C Ref.): ±0.00025%

Modulation Limiting:

25 kHz Channel Spacing:	±5.0 kHz
12.5 kHz Channel Spacing:	±2.5 kHz

FM Hum and Noise:

(Measured in the Analog Mode): –45 dB

Emission (Conducted and Radiated): –70 dB

Audio Sensitivity:

(For 60% Max. Deviation at 1 kHz): 0.08V ±3 dB

Audio Response:

(Measured in the Analog Mode)

(6 dB/Octave Pre-Emphasis 300 to 3000Hz): +1,–3 dB

Emissions Designators:

8K10F1E, 11K0F3E, 15K0F2D, 16K0F3E, 20K0F1E, 15K0F1D, 11K0F1D, and 11K0F2D

Specifications subject to change without notice.
All measurements are taken in the test mode at 25 kHz channel spacing except where indicated.
** Maximum power 78 Watts above 470 MHz.*

800 MHz Radio Specifications

GENERAL

FCC Designations: AZ492FT5759
AZ492FT5751

Temperature Range:
Operating: –30°C to +60°C
Storage: –40°C to +85°C

Power Supply: 12 Vdc Negative Ground Only

Battery Drain: (Maximum)
15 Watt:
Standby @ 13.8 V: 0.7 A
Receive at Rated Audio @ 13.8 V: 3.0 A
Transmit @ Rated Power: 6.5 A
35 Watt: (30 W max. in Talk-Around mode)
Standby @ 13.8 V: 0.7 A
Receive at Rated Audio @ 13.8 V: 3.0 A
Transmit @ Rated Power: 14.0 A

Dimensions (H x W x D)
W4, W5, and W7 Models:
Remote-Mount Control Head: 2.0" x 7.1"x 2.2"
(50.8 mm x 180.3 mm x 55.9 mm)
Dash-Mount Radio: 2.0" x 7.1"x 8.6"
(50.8 mm x 180.3 mm x 218.4 mm)
W9 Model:
Remote-Mount Control Head: 3.4" x 6.5"x 1.7"
(86.4 mm x 165.1 mm x 43.2 mm)
Speaker: (excluding mounting bracket)
5.5" x 5.5"x 2.5"
(139.7 mm x 139.7 mm x 63.5 mm)

Weight:
Mid-Power Radio: 6.1 lbs (2.8 kg)
High-Power Radio: 11.2 lbs (5.1 kg)
Speaker: 1.5 lbs (0.7 kg)

RECEIVER

Frequency Range: 851–869 MHz

Channel Spacing: 12.5 kHz/20 kHz/25 kHz

Input Impedance: 50 Ohm

Frequency Separation: 18 MHz

Sensitivity: (per EIA spec. RS204C)
20 dB Quieting: (25 kHz Channel Spacing):
0.50µV
12 dB SINAD: (25 kHz Channel Spacing):
0.35µV

Digital Sensitivity:
1% BER (12.5 kHz channel): 0.30µV
5% BER (12.5 kHz channel): 0.25µV

Selectivity: (per EIA Specifications)
(Measured in the Analog Mode)
25 kHz Channel Spacing: –75 dB

Intermodulation: (per EIA Specifications)
(Measured in the Analog Mode): –75 dB

Spurious Rejection: –90 dB

Frequency Stability:
(–30° to +60°C; 25°C Reference): ±0.00015%

Audio Output: (per EIA Specifications)
(Measured in the Analog Mode):
5 Watts at Less Than 3% Distortion
10 Watts Optional with Reduced Duty Cycle
12 Watts for High-Power Radios

TRANSMITTER

Frequency Range:
Repeater Mode: 806–824 MHz
Talk-Around Mode: 851–869 MHz

Rated Output Power:
Mid-Power Radio: 15 Watt
High-Power Radio: 35 Watt

Channel Spacing: 12.5 kHz/20 kHz/25 kHz

Output Impedance: 50 Ohm

Frequency Separation: 18 MHz

Frequency Stability:
(–30° to +60°C; 25°C Ref.): ±0.00015%

Modulation Limiting:
25 kHz Channel Spacing: ±5.0 kHz

Modulation Fidelity (C4FM):
12.5 kHz Digital Channel: ±2.8 kHz

FM Hum and Noise:
(Measured in the Analog Mode): –40 dB

Emission (Conducted and Radiated): –60 dBc

Audio Sensitivity:
(For 60% Max. Deviation at 1 kHz): 0.08V ±3 dB

Audio Response:
(Measured in the Analog Mode)
(6 dB/Octave Pre-Emphasis 300 to 3000Hz):
+1,–3 dB

Emissions Designators:
8K10F1E, 15K0F1D, 10K0F2D, 11K0F3E,
15K0F2D, 10K0F1D, 16K0F3E, and 20K0F1E

Specifications subject to change without notice.
All measurements are taken in the test mode at 25 kHz channel spacing except where indicated.

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Chapter 1 Introduction

1.1 General

This manual includes all the information necessary to maintain peak product performance and maximum working time. This detailed level of service (component-level) is typical of some service centers, self-maintained customers, and distributors.

Use this manual in conjunction with the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (Motorola part number 68P81076C20), which helps in troubleshooting a problem to a particular board.

Conduct the basic performance checks first to verify the need to analyze the radio and help pinpoint the functional problem area. In addition, you will become familiar with the radio test mode of operation which is a helpful tool. If any basic receiver or transmitter parameters fail to be met, the radio should be aligned using the radio alignment procedure described in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual*.

Included in other areas of this manual are functional block diagrams, detailed Theory of Operation, troubleshooting charts and waveforms, schematics, and parts list. You should be familiar with these sections to aid in deducing the problem circuit. Also included are component location diagrams to aid in locating individual circuit components, as well as IC diagrams, which identify some convenient probe points.

The Theory of Operation section of this manual contains detailed descriptions of operations of many circuits. Once you locate the problem area, review the Troubleshooting Chart for that circuit to fix the problem.

1.2 Notations Used in This Manual

Throughout the text in this publication, you will notice the use of warnings, cautions, and notes. These notations are used to emphasize that safety hazards exist, and care must be taken and observed.

NOTE: An operational procedure, practice, or condition that is essential to emphasize.

CAUTION indicates a potentially hazardous situation which, if not avoided, may result in equipment damage.

WARNING indicates a potentially hazardous situation which, if not avoided, could result in death or injury.

DANGER indicates an imminently hazardous situation which, if not avoided, will result in death or injury.

You will also find in this publication the use of the asterisk symbol (*) to indicate a negative or NOT logic true signal.

Chapter 2 General Overview

2.1 Introduction

The ASTRO Digital Spectra radio is a dual-mode (trunked/conventional), microcontroller-based transceiver incorporating a Digital Signal Processor (DSP). The microcontroller handles the general radio control, monitors status, and processes commands input from the keypad or other user controls. The DSP processes the typical analog signals and generates the standard signaling digitally to provide compatibility with existing analog systems. In addition it provides for digital modulation techniques utilizing voice encoding techniques with error correction schemes to provide the user with enhanced range and audio quality all in a reduced bandwidth channel requirement. It allows embedded signaling which can mix system information and data with digital voice to add the capability of supporting a multitude of system features.

The ASTRO Digital Spectra radio comes in five models and are available in the following bands; VHF (136-174 MHz), UHF (403-470 MHz or 450-512 MHz), and 800 MHz (806-870 MHz).

The ASTRO Digital Spectra radio comprises seven major assemblies, six of which are in the main radio housing. They are:

- Control-Head Assembly (Dash- or Remote-Mount) — is connected, directly or remotely, to the front of the transceiver by the interconnect board or remote interconnect board and control cable. This assembly contains a vacuum fluorescent (VF) display, VF driver, microprocessor and serial bus interface.
- Power Amplifier (PA) — contains antenna switch, directional coupler/detector, and amplifier(s).
- Front-End Receiver Assembly — contains pre-amplifier, preselector, mixer, and injection filter.
- RF Board — contains receiver I-F amplifier, demodulator, synthesizer logic and filtering circuitry, and digital receiver back-end integrated circuit (IC).
- VCO/Buffer/Divider Board — contains voltage controlled oscillator (VCO), divider, receive and transmit buffers.
- Command Board — contains power control/regulator, digital-to-analog (D/A) IC, serial bus interface, and audio power amplifier (PA).
- VOCON (Vocoder/Controller) Board — contains the microcomputer unit (MCU), its associated memory and memory management integrated circuit, and the digital signal processor (DSP) and its associated memories and support IC.
- VOCON Plus (Vocoder/Controller) Board — the architecture is based on a Dual-Core processor, which contains a DSP Core, an MCORE 210 Microcontroller Core, and custom peripherals. The board also contains memory ICs and DSP support ICs.

2.2 Analog Mode of Operation

When the radio is receiving, the signal comes from the antenna/antenna-switch on the power amplifier board to the front-end receiver assembly. The signal is then filtered, amplified, and mixed with the first local-oscillator signal generated by the voltage-controlled oscillator (VCO). The resulting intermediate frequency (IF) signal is fed to the IF circuitry on the RF board, where it is again filtered and amplified. This amplified signal is passed to the digital back-end IC, where it is mixed with the second local oscillator to create the second IF at 450 kHz. The analog IF is processed by an analog-to-digital (A/D) converter, where it is converted to a digital bit stream and divided down to a baseband signal, producing digital samples. These samples are converted to current signals and sent to the DSP support IC. The digital-signal-processor-support IC digitally filters and discriminates the signal, and passes it to the digital-signal processor (DSP). The DSP decodes the information in the signal and identifies the appropriate destination for it. For a voice signal, the DSP will route the digital voice data to the DSP-support IC for conversion to an analog signal. The DSP-support IC will then present the signal to the audio power amplifier on the command board, which drives the speaker. For signalling information, the DSP will decode the message and pass it to the microcomputer.

When the radio is transmitting, microphone audio is passed to the command board limiter then to the DSP-support IC, where the signal is digitized. The DSP-support IC passes digital data to the DSP, where pre-emphasis and low-pass (splatter) filtering are done. The DSP returns this signal to the DSP-support IC, where it is reconverted into an analog signal and scaled for application to the voltage-controlled oscillator as a modulation signal. Transmitted signalling information is accepted by the DSP from the microcomputer, coded appropriately, and passed to the DSP-support IC, which handles it the same as a voice signal. Modulation information is passed to the synthesizer along the modulation line. A modulated carrier is provided to the power amplifier (PA) board, which transmits the signal under dynamic power control.

2.3 ASTRO Mode of Operation

In the ASTRO mode (digital mode) of operation, the transmitted or received signal is limited to a discrete set of deviation levels, instead of continuously varying. The receiver handles an ASTRO-mode signal identically to an analog-mode signal up to the point where the DSP decodes the received data. In the ASTRO receive mode, the DSP uses a specifically defined algorithm to recover information. In the ASTRO transmit mode, microphone audio is processed identically to an analog mode with the exception of the algorithm the DSP uses to encode the information. This algorithm will result in deviation levels that are limited to discrete levels.

2.4 Control Head Assembly

This section discusses the basic operation and components of each control head assembly.

2.4.1 Display (W3 Model)

The control head assembly for a W3 model has a two-line, 14-character liquid-crystal display (LCD) with eight Status annunciators.

2.4.2 Display (W4, W5, and W7 Models)

The control head assembly for W4, W5, and W7 models has an 8-character, alphanumeric, vacuum fluorescent display. The anodes and the grids operate at approximately 34 Vdc when on and 0 Vdc when off. The filament operates at approximately 2.4 Vac. The voltage for the display is generated by a fixed-frequency, variable duty-cycle controlled “flyback” voltage converter. The switching frequency is approximately 210 kHz. The internal microprocessor controls the voltage converter, which provides approximately 37 Vdc to the vacuum fluorescent (VF) driver and approximately 2.4 Vrms to the VF display.

2.4.3 Display (W9 Model)

The control-head assembly for a W9 model has an 11-character, alphanumeric, vacuum fluorescent display. It needs three separate voltages to operate; the cathode needs 35 V to accelerate electrons to the anode; the grid needs 40 V to totally shut off current flow; the filament needs 3.8 Vac at 80mA. These voltages are obtained from the transformer on the display controller board.

2.4.4 Vacuum Fluorescent Display Driver

This Vacuum Fluorescent (VF) display driver receives ASCII data from the VOCON board, decodes it into display data, and then scans the display with the data. Once properly loaded into the display, data is refreshed without any further processor action. The display driver is periodically reset by the actions of transistors that watch the clock line from the microprocessor to the display driver. When the clock line is held low for more than 600 ms, the display driver resets and new display data follows.

2.4.5 Vacuum Fluorescent Voltage Source (W9 Model)

Voltage for the VF display is generated by a fixed frequency, variable-duty cycle driven, flyback voltage converter. An emitter-coupled stable multi vibrator runs at approximately 150 kHz. The square wave output from this circuit is integrated to form a triangle that is applied to the non-inverting input of half an integrated circuit (IC).

During start up, the inverting input is biased at 3.7 V. A transistor is on while the non-inverting input voltage is below 3.7 V. This allows current to flow in a transformer, building a magnetic field. When the triangle wave exceeds 3.7 V, the transistor turns off and the magnetic field collapses, inducing negative current in the transformer.

This current flow charges two capacitors. As the voltage on one of the capacitor increases beyond 35 V, a diode begins to conduct, pulling the integrated circuit's inverting input below 3.7 V. This decreases the cycle time to produce the 35 V. The 41 V supply is not regulated, but it tracks the 35 V supply.

Similarly, the ac supply for VF filament is not regulated, but is controlled to within one volt by an inductor on the display board.

2.4.6 Controls and Indicators

The control-head assembly processes all the keypad (button) inputs and visual indicators through the microprocessor. Some of the buttons double as function keys for radio options. All buttons are backlit to allow operation in low-light conditions.

2.4.7 Status LEDs

These LEDs are driven by the display driver as though they were decimal points on the VF display. Level shifting transistors are required for this since the display driver uses 39 V for control signals.

2.4.8 Backlight LEDs

The microprocessor operates the backlight LEDs. A transistor supplies base current to the individual LED driver transistors. The driver transistors act as constant current sources to the LEDs. Some backlight LEDs are connected to a thermistor. This circuit allows more current to flow through these LEDs at room temperature and reduces current as the temperature rises.

2.4.9 Vehicle Interface Ports

The Vehicle Interface Ports (VIPs) allow the control head to activate external circuits and receive inputs from the outside world. In general, VIP outputs are used for relay control and VIP inputs accept inputs from external switches. See the cable kit section for typical connections of VIP input switches and VIP output relays.

The VIP outputs are driven by logic within the control head for both the Dash and Remote Mount configuration. Field programming of the radio can define the functions of these pins. The output transistors that drive the VIP outputs can sink 300 mA of current. Primarily, they are used to control external relays. These relays should be connected between the respective VIP output pin and switched B+. Typical applications for VIP outputs are controlling the external horn/lights alarm and activating the horn-ring transfer relay function.

Remote Mount Configuration:

The VIP pins are located on the back of the control head below the area labeled “VIP”. For Remote Mount radios, all three VIP inputs and outputs are available at the rear of the control head. The VIP inputs are connected to ground with either normally-open or normally-closed switches.

Dash Mount Configuration:

For the Dash Mount configuration, only two VIP output pins are available and they are located at the 15-pin accessory connector. VIP input lines are not available in this configuration.

2.4.10 Power Supplies

The +5-V supply is a three-terminal regulator IC to regulate the 12 V SWB+ down for the digital logic hardware.

2.4.11 Ignition Sense Circuits

A transistor senses the vehicle ignition’s state, disabling the radio when the ignition is off. For negative-ground systems, the orange lead is typically connected to the fuse box (+12 V).

NOTE: Refer to the *ASTRO Spectra and Digital Spectra FM Two-Way Mobile Radios Installation Manual* (68P81070C85) for more information on operating the radio independent of the ignition switch.

2.5 Power Amplifier

The power amplifier (PA) is a multi-stage, discrete-transistor RF amplifier consisting of the following:

- Low-level power controlling stage
- Drivers
- Final amplifier
- Directional coupler
- Antenna switch
- Harmonic filter

2.5.1 Gain Stages

The first stage buffers the RF signal, filters harmonics, and acts as a variable amplifier. All of the amplifying stages are matched using transmission lines, capacitors, and inductors and are supplied with DC from either A+, keyed 9.4-V, or 9.6-V sources. Following the last gain stage, PIN diodes switch the signal flow either from the antenna to the receiver, or from the last gain stage to the antenna.

2.5.2 Power Control

A directional coupler and detector network controls power. It senses the forward power from the last gain stage and feeds the detected voltage back to the command board control circuitry where it is compared to a reference voltage set during power-set procedures. The DC feed voltage is corrected and supplied to the “controlled” stage of the power amplifier. Circuitry on the power amplifier board controls the gain of the first stage and is proportional to the DC control voltage.

2.5.3 Circuit Protection

Current and temperature sensing circuitry on the power amplifier board feed sensed voltages to the command board for comparison. If the command board suspects a fault condition, it overrides the power control function and cuts the power back to a level that is safe for the conditions. In addition, some high-power amplifier boards include circuitry that monitors the power supply line. If the battery voltage exceeds or drops below a pre-determined level, the power output of the amplifier is adjusted to ensure proper operation of the transmitter.

2.5.4 DC Interconnect

The ribbon cable connector carries sensed voltages for power and protection to the command board. It also carries A+ feed to the command board for distribution throughout the internal transceiver housing and carries control voltage from the command board to the power amplifier board.

The rear battery connector carries A+ from the battery to the power amplifier board. The red lead goes directly to the A+ terminal on the PA board. The black lead from the battery connector ties to the chassis, and connection to the power amplifier board is made through the board mounting screws.

A+ ground connection for the internal transceiver housing is through the RF coax ground connectors and through the mechanical connection of the power amplifier heatsink to the rest of the radio. During test conditions in which the power amplifier assembly (board and heatsink) is physically disconnected from the rest of the radio, it is acceptable to rely on the coax cable connections to carry ground to the internal housing.

2.6 Front-End Receiver Assembly

The receiver front-end consists of a preselector, a mixer circuit, and an injection filter. The receiver injection (1st local oscillator) comes from the VCO assembly through a coax cable. The injection filter is either fixed-tuned or tuned at the factory depending upon the bandsplit. The output of the filter is connected to the mixer.

The preselector is a fixed-tuned filter. The receiver signal is fed to the preselector from the antenna switch in the PA for the 800 MHz and UHF radios, or the preamp output for VHF. The signal is then sent to the mixer integrated circuit where it is connected to the mixer transistor. The receiver injection is also fed to this point. The mixer output is at the 1st IF center frequency of 109.65 MHz. This signal is sent to the 1st IF amplifier stage on the RF board through a coaxial cable.

2.7 RF Board Basic

The RF board contains the common synthesizer circuits, dual IF receiver and demodulation circuits. A 4-pole crystal filter at 109.65 MHz provides first IF selectivity. (For HRN6014D, HRN6020C, HRN6019C, HRN4009D, HRN4010C and later RF board kits, two 2-pole crystal filters provide first IF selectivity at 109.65 MHz.) The output of the filter circuit is fed directly to the custom digital back-end circuit module. An amplification circuit at 109.65 MHz, the second mixer, the second IF amplifiers (at 450 kHz), the IF digital-to-analog converter, and the baseband down-converter comprise the digital back-end circuit module.

Synthesizing for the first and second VCO is performed by the prescaler and synthesizer ICs. These ICs are programmed through a serial data bus from signals generated on the VOCON board. A DC voltage generated on the command board, sets the synthesizer’s reference oscillator frequency of 16.8 MHz. This voltage is controlled by the digital-to-analog converter (D/A), and is the only element of the RF board requiring alignment.

The second local oscillator runs at 109.2 MHz (low-side injection), or 110.1 MHz (high-side injection) and consists of a VCO which is frequency-locked to the reference oscillator. Part of the local oscillator’s circuitry is in the prescaler IC.

A clamp and rectifier circuit on the RF board generates a negative DC voltage of -4 V (nominal) for increasing the total voltage available to the first VCO and second local oscillator’s VCO. The circuit receives a 300 kHz square wave output from the prescaler IC, then clamps, rectifies, and filters the signal for use as the negative steering line for the two VCOs.

2.8 Voltage-Controlled Oscillator

This section discusses the voltage-controlled oscillator components and basic operation for each band.

2.8.1 VHF Radios

The voltage-controlled oscillator (VCO) assembly utilizes a common-gate Field Effect Transistor (FET) in a Colpitts configuration as the gain device. The LC tank circuit’s capacitive portion consists of a varactor bank and a laser-trimmed stub capacitor. The inductive portion consists of microstrip transmission line resonators. The stub capacitor serves to tune out build variations. Tuning is performed at the factory and is not field adjustable. The varactor network changes the oscillator frequency when the DC voltage of the steering line changes. The microstrip transmission lines are shifted in and out of the tank by PIN diodes for coarse frequency jumps. A third varactor is used in a modulation circuit to modulate the oscillator during transmit.

The VCO output is coupled to a transistor for amplification and for impedance buffering. The output of this stage passes through a low-pass filter where the signal is split into three paths. One path feeds back to the synthesizer prescaler; the other two provide injection for the RX and TX amplification strings. The receive injection signal is further amplified and passed to the RX front-end injection filter. The transmit signal goes to an analog divider, which divides the signal by two. The signal is amplified and buffered and then injected into the transmitter's low-level amplifier.

All transmit circuitry operates from keyed 9.4 V to conserve current drain while the radio is receiving. A transistor/resistor network drives the PIN diodes in the VCO tank. These driver networks provide forward bias current to turn diodes on and reverse the bias voltage to turn the diodes off. AUX 1 AND AUX 2 lines control the PIN diode driver networks.

2.8.2 UHF and 800 MHz Radios

The voltage-controlled oscillator (VCO) assembly generates variable frequency output signals controlled by the two steering lines. The negative steering line increases the tuning range of the VCO, while the positive steering line affects the synthesizer control loop to incrementally change the frequency.

The VCO generates a signal in the required frequency range. For UHF and 800 MHz radios, this signal is fed to the doubler/buffer circuit which, in turn, doubles the VCO output frequency and amplifies it to the power level required by the TX buffer and RX mixer. A PIN diode switch routes the signal to the TX port when the keyed 9.4 V is high. Otherwise, the signal is routed to the RX port. The synthesizer feedback is provided from the output of the doubler stage.

2.9 Command Board

The serial input/output IC provides command board functions including buffers for PTT, channel active, squelch mute, busy, and data transmission, and logic functions for switched B+, emergency, reset, and power control.

The regulator and power control circuits include an unswitched +5 V discrete circuit and the regulator/power control IC, which produces both switched +5 V and 9.6 V. The unswitched +5 V source is used as a reference for its switched +5 V source. Filtered unswitched +5 V is used for the microcontrol circuits. Switched +5 V and 9.6 V are controlled by a digital transistor from the serial input/output IC.The power control circuitry receives power set and limit inputs from the digital-to-analog IC, and feedback from the RF power amplifier. Based on those inputs, the power control circuitry produces a control voltage to maintain a constant RF power level to the antenna.

The reset circuits consist of the power-on reset, high/low battery voltage reset, and the external bus system reset. The reset circuits allow the microcomputer to recover from an unstable situation; for example, no battery on the radio, battery voltage too high or too low, and remote devices on the external bus not communicating. Communication in RS-232 protocol is provided by an IC which interfaces to the rear accessory connector (J2).

2.10 ASTRO Spectra Vocoder/Controller Board

The Vocoder/Controller (VOCON) board, located on the top side of the radio housing, contains a microcontrol unit (MCU) with its flash memory, DSP, and DSP support ICs. The VOCON board controls receive/transmit frequencies, the display, and various radio functions, using either direct logic control or serial communication to external devices. The connector J801 provides interface between the encryption module and the VOCON board for encrypting voice messages.

The VOCON board executes a stored program located in the FLASH ROM. Data is transferred to and from memory by the microcontrol unit data bus. The memory location from which data is read, or to which data is written, is selected by the address lines.

The support-logic IC acts as an extension of the microcontrol unit by providing logic functions such as lower address latch, reset, memory address decoding, and additional control lines for the radio. The VOCON board controls a crystal-pull circuit to adjust the crystal oscillator frequency on the microcontrol unit, so that the E-clock harmonics do not cause interference with the receive channel.

The vocoder circuitry on the VOCON board is powered by a switched +5-V regulator located on the command board. This voltage is removed from the board when the radio is turned off by the control head switch.

The DSP (digital-signal processing) IC performs signaling, voice encoding/decoding, audio filtering, and volume control functions. This IC performs Private-Line/Digital Private Line (PL/DPL) encode and alert-tone generation. The DSP IC transmits pre-emphasized analog signals and applies a low-pass (splatter) filter to all transmitted signals. It requires a 33 MHz crystal to function. An 8 kHz interrupt signal generated by the DSP-support IC is also required for functionality. This device is programmed using parallel programming from the microcontrol unit and the DSP-support IC.

The DSP-support IC performs analog-to-digital and digital-to-analog conversions on audio signals. It contains attenuators for volume, squelch, deviation, and compensation, and it executes receiver filtering and discrimination. The IC requires a 2.4 MHz clock to function (generated by the digital back-end IC) and is programmed by the microcontrol unit’s Serial Peripheral Interface (SPI) bus.

2.11 Radio Power

This section provides information on DC power distribution in ASTRO radios.

2.11.1 General

In the ASTRO radio, power is distributed to seven boards: command, VOCON, control head, synthesizer, receiver front end, RF, and RF power amplifier.

Power for the radio is supplied by the vehicle’s 12-V battery. When using a desktop adapter unit, an external DC power supply can be connected to replace the vehicle’s battery source.

A+ (referred to as incoming unswitched battery voltage) enters the radio through the rear RF power amplifier connector (P1) and is the main entry for DC power. The second path, through P2, pin 5, provides ignition sense to inhibit the RF transmitter when the ignition switch is off.

When the command board regulators are "on," the 9.6-V output sources the command board and RF board circuits. The switched +5 V is routed to the VOCON board. See Figure 2-1.

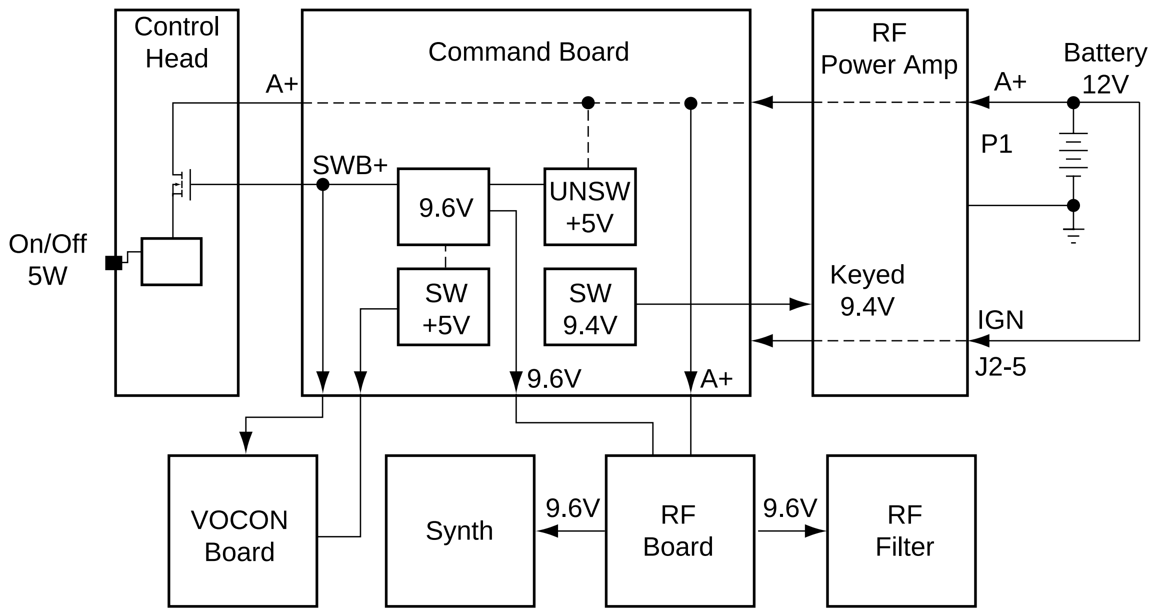


Figure 2-1. DC Voltage Routing Block Diagram

The 9.6 V and the A+ voltage are the main DC power for the RF board. Outputs from the RF board provide DC power to the synthesizer and the receiver front-end filter. The RF board has an internal +5-Vdc regulator that is sourced from the A+ voltage.

The voltage to power the 9.4-V regulator is produced by the command board's 9.6-V regulator. The 9.4 V (referred to as "keyed 9.4 V") is controlled by the VOCON board through P501, pin 45. This DC voltage enables the transmitter's RF power amplifier when the VOCON board senses a lock detect from the synthesizer.

2.11.2 B+ Routing for ASTRO Spectra VOCON Board

Refer to Section 3.4, "ASTRO Spectra Plus VOCON Board," on page 3-38 for information on the ASTRO Spectra Plus.

See Figure 2-2 and your specific schematic diagram.

The A+ power for the radio is derived from the 12-V battery, which is applied to the command board through connector P503, pins 5 and 9. This A+ voltage is routed through the command board to the control head connector, P502, pin 30 and to the VOCON board, J501, pin 38.

The interconnect board couples the A+ voltage from the command board to the control head, where a power FET (Q51) provides the means of controlling the main power source (SWB+) by the on/off switch. SWB+ is routed back to the SIO/IC (U522) on the command board through connector P502. The SIO/ICcontrols the RPCIC enable line.

When the RPCIC enable line toggles low, the 9.6-V and the SW+5-V regulators turn on. The SW+5-V regulator is the main power source for the VOCON board. Digital and analog +5 V are derived by filtering SW+5 V through .005 µH chokes L511 and L510 on the command board. These two 5-V regulated supplies are used to partition the digital logic circuitry from the analog circuitry.

Transistor Q206 controls solid-state power switch Q207, providing SWB+ to the encryption module (if equipped). The "SWB+" and "UNSWB+" encryption voltages both originate from pin 38 of J501 and are fed to the encryption module via J801.

Port PL3 (5-V EN) on the SLIC and Q207 are under the control of the microcontroller unit (MCU), U204. This allows the MCU to follow an orderly power-down sequence when it senses that the B+ sense is off. This sense is provided via resistor network R222 and R223, which provides an input to the A/D port to the MCU.

It should also be noted that a system reset is provided by the undervoltage detector, U407. This device brings the system out of reset on power-up, and provides a system reset to the microcomputer on power-down.

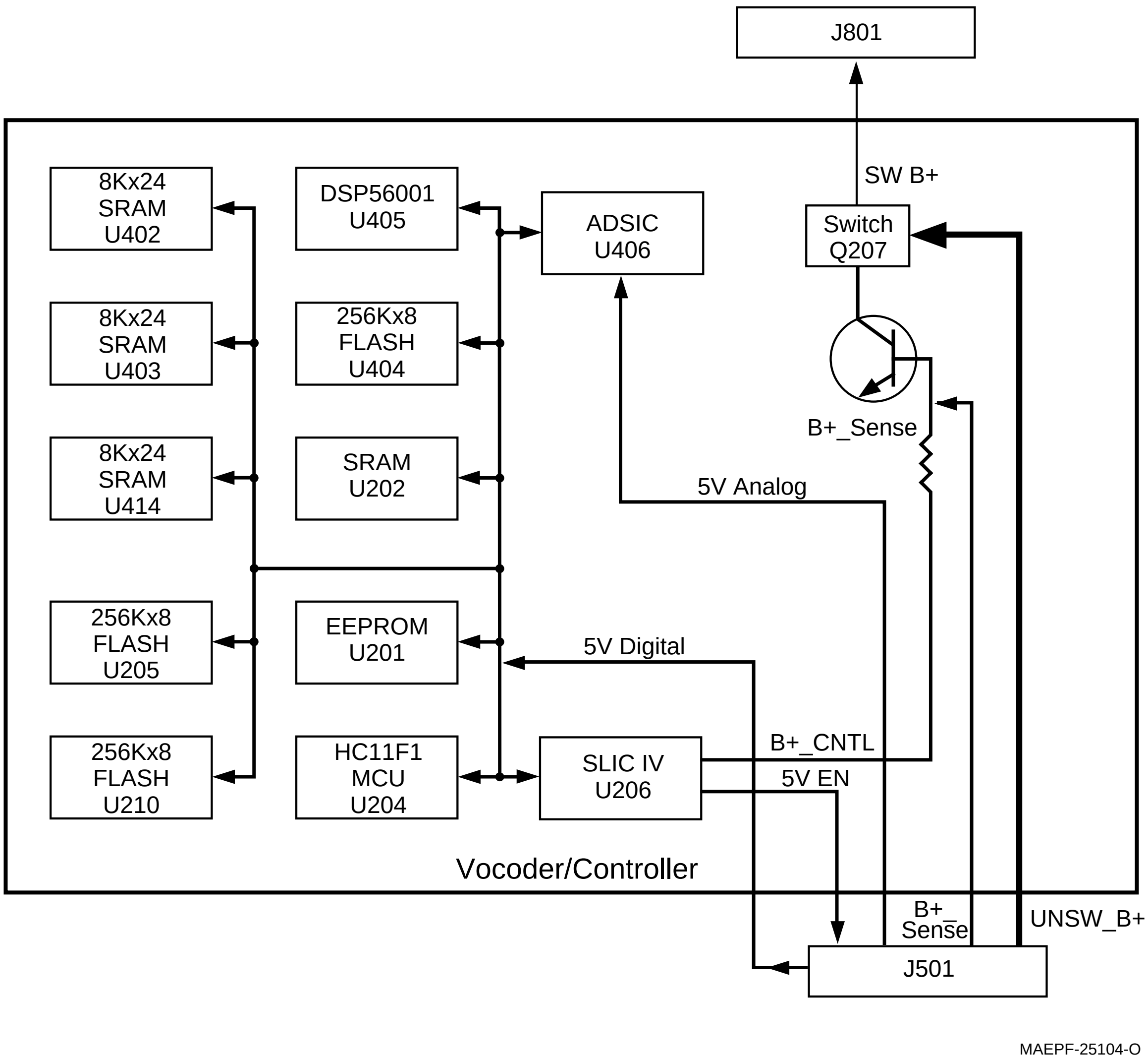


Figure 2-2. ASTRO Spectra B+ Routing for Vocoder/Controller (VOCON) Board

Chapter 3 Theory of Operation

3.1 RF Board

This section provides a detailed circuit description of the ASTRO RF board for VHF, UHF and 800 MHz models. This board contains the common synthesizer circuits (synthesizer section) and dual IF receiver and demodulation circuits (receiver back-end). When reading the theory of operation, refer to your appropriate schematic and component location diagrams located in “Chapter 7. Schematics, Component Location Diagrams, and Parts Lists”. This detailed Theory of Operation will help isolate the problem. However, first use the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) to troubleshoot the problem to a particular board.

3.1.1 General

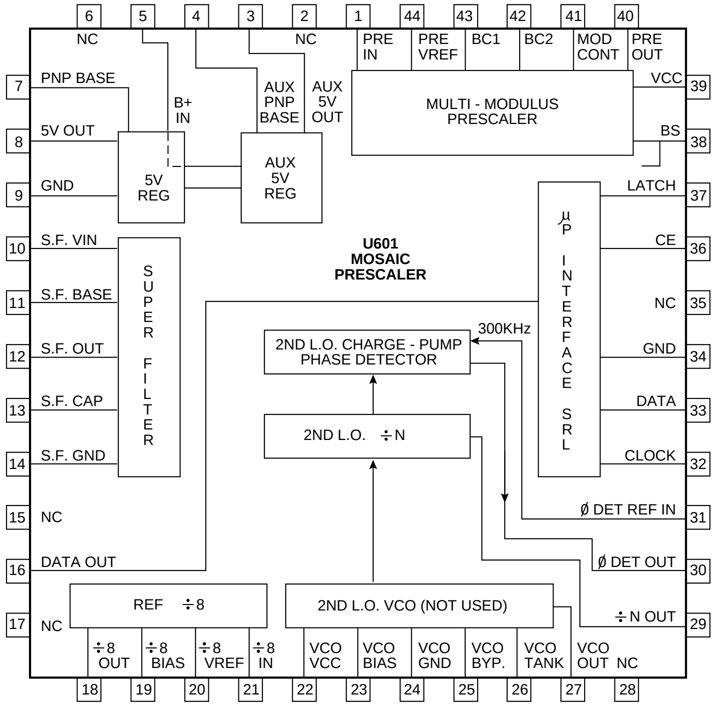
The synthesizer section includes the prescaler IC (U601), the synthesizer IC (U602), and the reference oscillator (U600). The prescaler and the synthesizer chips are completely controlled by the serial data bus.

The prescaler IC (see Figure 3-1) provides the following:

- Multi-dual modulus prescaler
- 5-V regulator
- Super filter 8.6-V regulator
- Fixed divide-by-8 circuit for the reference oscillator
- Programmable divide-by-N and charge pump phase detector to support the second injection VCO

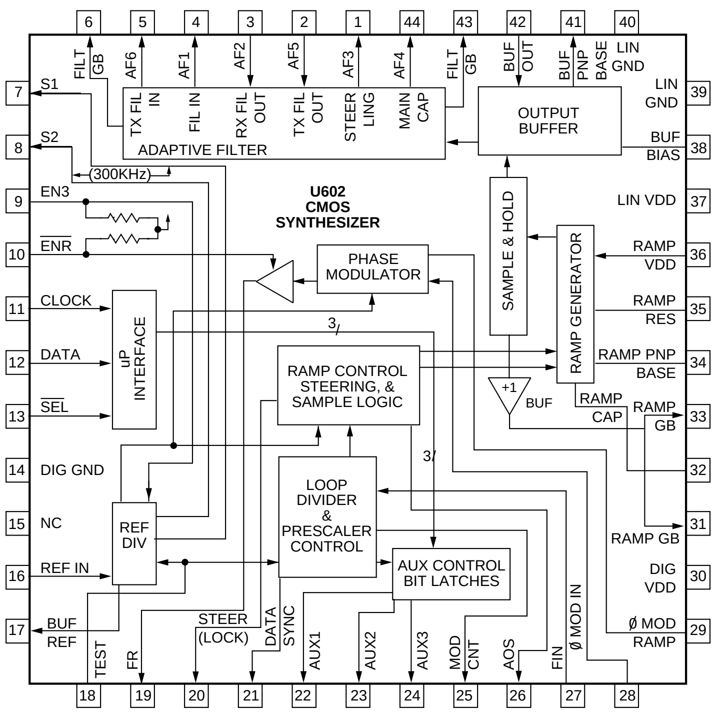
The synthesizer IC (see Figure 3-2) provides:

- Reference divider
- Phase modulator
- Dual-bandwidth adaptive filter
- Ramp generator
- Sample-and-hold phase detector
- Programmable loop divider
- Auxiliary output bits for system control



MAEPF-25181-O

Figure 3-1. Prescaler IC Block Diagram



MAEPF-25182-O

Figure 3-2. Synthesizer IC Block Diagram

The reference oscillator generates the 16.8 MHz signal that serves as the reference for all radio frequency accuracy. It uses a proprietary temperature compensation circuit to keep the radio within its specified frequency tolerance.

The receiver back-end uses the ABACUS II IC (U301) to demodulate all the way to baseband, starting from the first IF.

3.1.2 Synthesizer

This section discusses the synthesizer components and detailed theory of operation.

3.1.2.1 Reference Frequency Generation

The reference oscillator (U600) generates a 16.8 MHz reference signal that is tuned onto frequency via a DC-fed varactor input. The digital/analog IC (U502), which is on the command board and is under the control of the serial data bus, generates the DC voltage to the varactor. The reference signal from U600-3 is capacitively coupled into the prescaler (U601-21), where it is divided by 8. The resulting 2.1 MHz signal is routed to the synthesizer IC (U602).

The 2.1 MHz signal is divided by 7, with the result, a 300 kHz signal, serving the following purposes:

- Input to the prescaler IC for second VCO reference
- A source for the negative voltage generator
- Input to the programmable reference divider

3.1.2.2 First VCO Frequency Generation

For reasons of clarity and simplicity, 800 MHz is used as the example product in all synthesizer text. In the 800 MHz models, the feedback is taken before the doubler circuit of the VCO. Band-to-band and kit-to-kit variations are noted in the text as required.

The first VCO in ASTRO radios is a thick-film hybrid transmission line resonator. Its frequency is controlled by a DC-fed varactor bank.

A transmission line feedback path from J601-1 to C604 couples the output frequency back to the prescaler. The signal from the prescaler output (U601, pin 40) is routed to the synthesizer input (U602, pin 27), where it is divided by the A&B counters of the loop divider. The loop equations required for calculating the counter values are as follows:

NOTE: These are examples — the prescaler modulus and the reference frequency are programmable and vary from band-to-band. The examples that follow are for 800 MHz and assume:
P / P + 1= 255 / 256 and F_r = 6.25 kHz. For UHF and VHF, P / P + 1= 127 / 128 and F_r = 5 kHz.

EQUATION: $N = F_{vco} / F_r$

EXAMPLE: $N = (F_{vco} / F_r)$ = (403 MHz / 6.25 kHz) or N = 64,480

EQUATION: A = (fractional remainder of N / P) (P)

EXAMPLE: A = N / P = (72,000 / 255) = 252.8627; .8627 x 255
or A = 220

EQUATION: B = [N - {A x (P + 1)}] / P

EXAMPLE: B = [64,480 - {220 x (255+1)}] / 255 or B = 32

Plug in the calculated numbers to test the value of N with the following equation:

EQUATION: N = B (P) + A (P + 1)

EXAMPLE: N = (32) (255) + (220) (256) or N = 64,480

The synthesizer generates a modulus control output which instructs the prescaler to divide by either P or P + 1 (that is, 255 or 256). When modulus control is low, the prescaler is dividing by P + l (256) and the A counter is running; when modulus control is high, the prescaler is dividing by P (255) and the B counter is running. One complete cycle of loop division is repeated for each reference period.

Assume that the VCO is operating correctly at 403 MHz, and the reference frequency is 6.25 kHz. The prescaler and loop divider work in tandem to divide the VCO frequency down to the reference frequency. The waveforms in Figure 3-3 depict what happens in a locked system. Notice in the waveforms that the leading edge of F_r goes high to turn on the constant current source Q607. The ramp capacitor (C634) begins to charge through Q607 and R627, charging at a constant rate, while the prescaler and loop divider are dividing the VCO frequency by N (64,480 in the example). At this point, the loop divider generates a loop pulse (F_v) which turns off the current source.

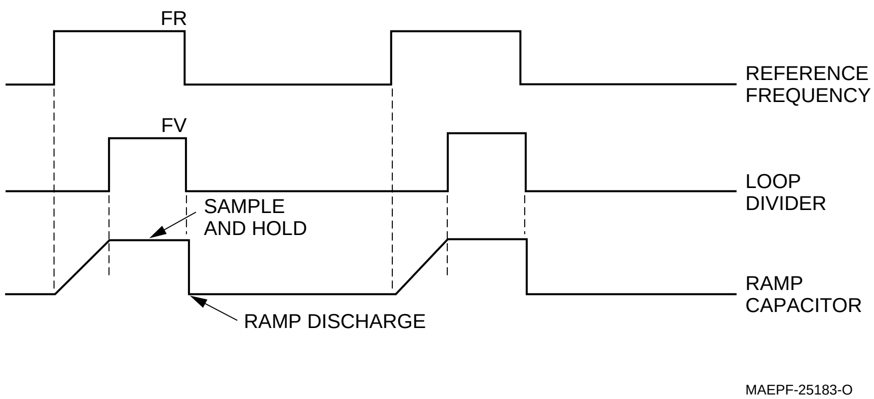


Figure 3-3. Loop Divider Waveforms

The voltage that was on C634 is sampled and held by the phase detector. This voltage is amplified approximately 1.8 times and applied to the VCO varactors via the adaptive loop filter and the steering line. This event is repeated at the reference rate so that frequency errors will always be corrected.

NOTE: In VHF receive mode, for frequencies divisible only by 2.5 kHz (for example, 146.0025 MHz), capacitor C670 will be switched in parallel with C634 by Q670. The reference frequency will be 2.5 kHz instead of 5.0 kHz or 6.25 kHz. In transmit mode, the 2.5 kHz reference is not used.

Assume that the VCO frequency tends to drift low. If this happens, the loop pulse will occur at some later time. The current source still begins at the rising edge of F_r but it stays on longer because the leading edge of F_v has been time delayed. Thus, C634 charges to a higher value and the steering line drives the VCO to a higher frequency. The opposite case also applies.

3.1.2.3 Programmable Reference Divider

The reference frequency for 800 MHz is 6.25 kHz; for VHF and UHF, the typical reference frequency is 5.0 kHz. In VHF radios, the reference frequency is 2.5 kHz for receive frequencies not evenly divisible by 5.0 kHz or 6.25 kHz.

3.1.2.4 Phase Modulator

ASTRO radios use a dual-port modulation scheme. The nature of the synthesizer loop is to track out low-frequency errors. In order to enable low-frequency modulation, such as DPL, the reference signal is modulated with the same signal as the VCO. Effectively, this prevents the low-frequency error in the loop (DPL) from tracking out because the same error is on the reference signal. The net effect is that the leading edge of the reference pulse is time-varying at the same rate as the loop pulse; therefore, there is no phase error between the two signals and low-frequency modulation is allowed to pass.

The phase modulation comparator has two inputs: U602, pins 28 and 29. R625 and C630 form an exponential ramp into the plus side of the comparator on U602, pin 29. This ramp is tickled at the reference rate. R626 and C631 form an integrator through which modulation is applied to the minus side of the comparator. The comparator trips when the ramp voltage reaches the voltage on U602, pin 28. The output of the comparator is the time-shifted leading edge of F_r.

3.1.2.5 Loop Filter

ASTRO radios use a switchable, dual-bandwidth loop filter. They also use adaptive filter switching to achieve fast lock. The output of the phase detector is routed to an external device (Q608), the output of which is routed back into the IC for proper filter path selection.

In normal operation, the high drive buffer output is routed through the appropriate transmission gates into the selected filter. A simplified schematic is shown in Figure 3-4.

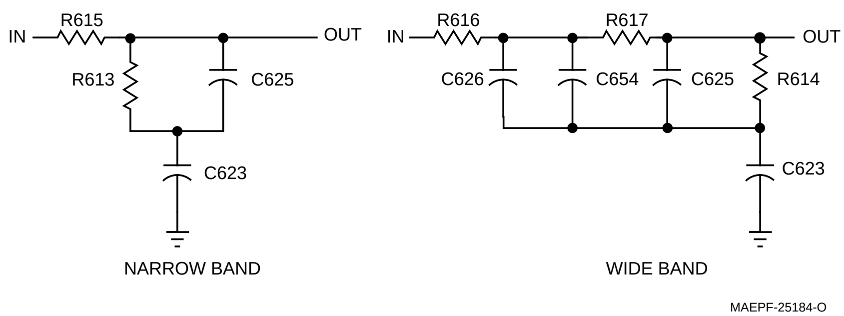


Figure 3-4. Loop Filter Schematic

The loop filters greatly minimize voltage transients that contribute to system hum and noise but, due to their lowpass nature, it takes considerable time to change the average charge in the filters. Therefore, the adapt scheme was implemented. When the radio is changing frequency, the loop goes into the adapt mode. Selected transmission gates in the IC effectively place a short across the resistors in the filter (eliminating associated RC time constants) and quickly charge the loop filter capacitors to the correct steering line voltage for the new frequency. At the end of the adapt sequence, the appropriate filter is reconnected via internal transmission gates.

3.1.2.6 Auxiliary Control Bits

The auxiliary control bits are system control outputs whose states are controlled by the microprocessor via the serial data bus. AUX 1 and AUX 2 are sent to the first VCO to control pin shift states. AUX 3 controls the state of the negative steering line.

3.1.2.7 Second VCO

The second VCO is a grounded-gate, FET Colpitts oscillator. The resonator consists of a fixed inductor and a varactor. A potentiometer, R634, adjusts the negative voltage to the varactor. This adjustment is performed at board test to bring the phase detector output to the center of its linear region; that is approximately 2.25 V. (For HRN6014D, HRN6020C, HRN6019C, HRN4009D, HRN4010C and later RF board kits, a voltage divider consisting of R633 and R635 brings the phase voltage detector output to the center of its linear region (2.25 V), eliminating the adjustment at board test.) The negative voltage is filtered by R611 and C612. The oscillator output is coupled into the IF IC (U301) as a second injection source. It is also fed back to the prescaler (U601, pin 26) for phase locking.

The prescaler contains a programmable, single modulus, divide-by-N circuit, and a charge pump phase detector. The reference frequency (F_r) is 300 kHz and comes in on U601, pin 31. The low-side injection oscillator runs at 109.2 MHz and is divided by 364 inside the IC. The phase detector in the chip compares the divided signal to F_r and either sources or sinks current, as necessary, in order to maintain frequency control.

The phase detector output is routed to the varactor via decoupling choke L604. A divide-by-N test point is also provided from U601, pin 29.

3.1.2.8 Power Distribution

The command board provides all power to the synthesizer in the form of 9.6 Vdc. The prescaler has onboard voltage regulators for 5 V and super filter 8.6 V. The 5-V regulator drives the external series pass device Q602; the super filter's pass device is Q603.

3.1.3 Receiver Back-End

This section discusses the receiver back-end components and detailed theory of operation.

3.1.3.1 First IF

The 109.65 MHz IF signal reaches the RF board via a connector J350. Transistor Q350 amplifies the signal approximately 9dB and supplies the proper impedance for crystal filter Y350. (For HRN6014D, HRN6020C, HRN6019C, HRN4009D, HRN4010C and later RF board kits, amplification circuitry consisting of transistors Q350 and Q354 amplifies the signal approximately 9dB and supplies the proper impedance for crystal filters FL350 and FL351.)

Transistor Q351 supplies filtered A+ for powering Q350 and the receiver front-end. Transistor Q352 switches the filtered A+ supply by reducing the base current from Q351.

NOTE: Since there is 12.5 Vdc on J350, it is important to use a DC block when connecting J350 to an external source.

Y350 is a 4-pole crystal filter, consisting of two independent 2-pole crystal filters contained in a single package. The filter package has a polarization mark located on the top to ensure proper installation.

Y350 supplies the 109.65 MHz IF selectivity and its output passes through a matching network and then goes to ABACUS II IC (U301) pin 30.

(For HRN6014D, HRN6020C, HRN6019C, HRN4009D, HRN4010C and later RF board kits, FL350 and FL351 are 2-pole crystal filters which supply the 109.65 IF selectivity. The output passes through a matching network and goes to the ABACUS II IC (U301), pin 30.)

3.1.3.2 ABACUS II IC

Once in the ABACUS II IC (U301), the first IF frequency is amplified and then down converted to 450 kHz, the second IF frequency. At this point, the analog signal is converted into two digital bit streams by a sigma-delta A/D converter. The bit streams are then digitally filtered and mixed down to baseband and filtered again. The differential output data stream is then sent to the VOCON board where it is decoded to produce the recovered audio.

The ABACUS II IC is electronically programmable, and the amount of filtering, which is dependent on the radio channel spacing and signal type, is controlled by the microcomputer. Additional filtering, which used to be provided externally by a conventional ceramic filter, is replaced by internal digital filters in the ABACUS II IC.

The ABACUS II IC contains a feedback AGC circuit to expand the dynamic range of the sigma-delta converter. The differential output data contains the quadrature (I and Q) information in 16-bit words, the AGC information in a 9-bit word, imbedded word sync information and fill bits dependent on sampling speed. A fractional-n synthesizer is also incorporated in the ABACUS II IC for the 2nd LO generation.

The second LO/VCO is a Colpitts oscillator (see Section 3.1.2.7, "Second VCO," on page 3-6). Its output feeds into the ABACUS II IC on pin 35, providing injection to the second mixer for converting the IF frequency to 450 kHz.

3.2 Command Board

This section of the theory of operation provides a detailed circuit description of the ASTRO Digital Spectra Command Board. When reading the Theory of Operation, refer to your appropriate schematic and component location diagrams located in “Chapter 7. Schematics, Component Location Diagrams, and Parts Lists”. This detailed Theory of Operation will help isolate the problem to a particular component. However, first use the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* to troubleshoot the problem to a particular board.

The command board includes the following integrated circuits:

- U401, U402 — Differential Amplifiers
- U450 — Audio Amplifier
- U500 — Regulator/Power Control IC (RPCIC)
- U501 — 555 Timer
- U502 — D/A Converter
- U503 — Precision Voltage Regulator
- U522 — Serial Input/Output IC (SIOIC)
- U523, U524 — Analog Switch
- U526 — RS232 Level Shifter
- U530 — 8-Bit Shift Register

3.2.1 Microcontroller and Support ICs

The microcontroller and support ICs are located on the VOCON board, and are interconnected to the command board via connector P501. The control lines linking the boards are either drivers or receivers, depending upon their application. The VOCON board is responsible for decoding or encoding ASTRO and analog data, and producing receive audio and transmit deviation.

3.2.2 Serial Input/Output IC

The serial input/output IC (SIOIC), U522, is a special-function logic/linear integrated circuit. In the ASTRO mobile application, the device provides power-on reset, power control, and bipolar driver/ receivers for serial communication. The SIOIC supports the following functions:

1. A buffer for push-to-talk (PTT) to SLIC (U522, pins 37 and 38). Normally a contact closure for PTT is detected by the control head, which sends a command to the VOCON board via the external serial bus protocol. However, some applications require direct PTT control. To generate PTT via the buffer inverter (pin 37), a contact closure to ground at J502, pin 24, or from the accessory connector P503, pin 17, will generate a logic high to the SLIC device (U206, port PH6) on the VOCON board.
2. A buffer for the Busy signal from the VOCON board to the external bus (Busy Out) and the return path back to the VOCON board (Busy RTS). This function is described in Section 3.2.6, "Serial Communications on the External Bus," on page 3-11.
3. A buffer for Data Transmission from the VOCON board to the External Bus and a received data return to the VOCON board. This function is described in Section 3.2.6, "Serial Communications on the External Bus," on page 3-11.
4. Inputs to sense Switched B+ or Emergency enabling the Power Regulators and provide the switched +5-V regulated supply. This function is described in Section 3.2.3, "Power-Up/-Down Sequence," on page 3-9.
5. Power-on reset (POR*) circuits provide reset to the Host processor (U204). This function is described in Section 3.2.5, "Reset Circuits," on page 3-10.

3.2.3 Power-Up/-Down Sequence

Normally, switched B+ (SWB+) enters the command board from P502, pin 31. This voltage is derived from the battery A+ voltage which enters the control head through P502, pin 30. A power FET transistor, located in the control head (W5 and W7 models), provides the means of controlling the main power source via the control head's on/off switch.

When SWB+ or EMERG become active, the RPCIC EN output (U522, pin 15) goes to a logic low, enabling the Switched +5-V and +9.6-V regulators of the RPCIC (U500). Approximately 220 ms after the B+ is active (see Waveform W1), the power-on-reset (POR*) from U522, pin 40 switches to a logic 1 state, enabling the microprocessor on the VOCON board. The microprocessor then completes an initialization sequence and sets Row 5/5-V enable input to a logic low at P501, pin 15. The input provides a low to the SIOIC to hold the 9.6-V enable on. Therefore, if SWB+ or EMERG go inactive, the regulators will remain enabled until the microcontroller turns them off by returning the 9.6/5-V EN state to a logic high. (This is especially true with emergency, since the foot switch is usually momentary.)

The emergency input is provided to enable the radio transceiver to be activated, regardless of the state of the control head's on/off power switch. The emergency input (EMERG) is activated by opening the normally grounded foot switch connected to either P502, pin3 or P503, pin 24. This input is routed to the SIOIC (U522, pin 31) and is internally connected to a pull-up resistor within the IC to provide the logic 1 state change.

This change is inverted through an exclusive OR gate within the IC, outputting a logic 0 at pin 30 and the NOR gate input (internal to the IC) to enable the 9.6-V regulator. The logic low at pin 30 is connected to a time-out timer, which latches the 9.6-V enable output for 100 ms. This delay is required to allow the VOCON microprocessor to initiate its start-up vectors and poll the emergency interrupt input from P501, pin 16. The microprocessor takes control of the 9.6 V (P501, pin 15), holding it active low regardless of the states of other inputs.

The emergency active state depends on the emergency polarity (EMERG POL) input to the SIOIC (U522, pin 32). When the jumper JU502 is installed, emergency is active with the foot switch open. Removing JU502 causes the emergency to go active with the switch closed.

To turn off the radio, SWB+ is taken inactive (- Vdc) by pressing the on/off switch on the control head. The microcontroller periodically audits the SWB+ at its input port (pin 20) to determine if it has returned to a logic high. When it sees the logic high condition (caused by an inactive switch), the microcontroller initiates the power-down sequence, turning the voltage regulators and the radio off.

3.2.4 Regulators

The regulator circuits include an unswitched +5 V (UNSW5V) discrete circuit, and the regulator/ power-control IC (RPCIC) that produces switched +5 V (U500, pin 14) and 9.6 V (U500, pin 17). The UNSW+5-V source is used by the RPCIC as a reference (U500, pin 20) for its switched + 5-V source. This regulated voltage is produced from the A+ voltage and is present when the battery is connected. The regulators within the RPCIC are controlled by the input to pin 24 via a digital transistor, Q538. This device is controlled from an output (9.6/5-V enable) of the SIOIC (U522, pin 15).

The various voltages used by the ICs on the command board are shown in Table 3-1.

Table 3-1. Integrated Circuits Voltages

Integrated Circuit	UNSW5V	SW +5V	SW +9.6V
Serial Input/ Output (SIOIC)	U522-6, -24	U522-3, -12	U522-14
Regulator/ Power Control (RPCIC)	U500-20	U500-14	U500-17
Digital/ Analog IC (DAIC)		U502-1, -28	
Analog Switch			U523-16, U524-14
RS232 Driver (IC)		U526-19	
555 Timer (IC)		U501-8	
8-Bit Shift Register		U530-16	
Differential Amplifiers			U401-4, U402-4

3.2.5 Reset Circuits

The reset circuits consist of the power-on reset (POR), high-/low- battery voltage reset, and the external bus system reset. The reset circuits allow the microcontroller to recover from an unstable condition, such as no battery on the radio, battery voltage too high or too low, and remote devices on the external bus not communicating.

When the battery (A+) is first applied to the radio, the unregulated voltage source powers the unswitched +5-V regulator and the SIOIC internal regulator. The voltage is also sent to the control head, where it is switched on/off by a series FET transistor. The transistor returns the voltage to the command board, via connector P502-31, as switched B+. The switched B+ voltage is sensed by the SIOIC on pin 28, and changes the state of the 9.6-V enable output gate (RPCIC_EN*) to an active “low.” The low state turns on the 9.6-V regulator (U500-24), and its regulated output is fed back to the input of the voltage comparator on the SIOIC (U522-14). The comparator output switches to a logic low upon exceeding the 5.6-V threshold (see Figure 3-5).

The three inputs to the NOR gate (SW9.6-V, RPCIC EN, and RPCIC_EN delayed) must be at a logic low to enable the power-on reset (POR*) to a high logic state. During this power-up sequence, this reset is delayed approximately 170 ms after the B+ voltage is sensed. This delay is needed to allow the supply voltages and oscillators to stabilize before releasing the VOCON board's microprocessor. Figure 3-5 illustrates the internal function of the POR* within the SIOIC device.

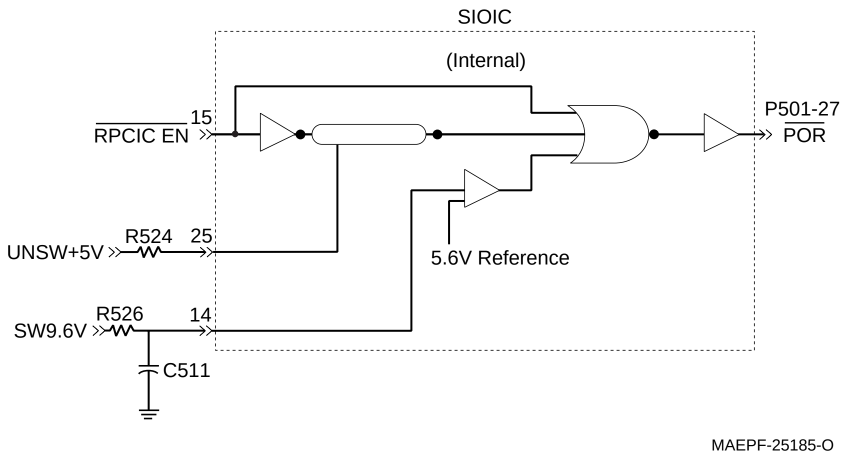


Figure 3-5. Power-on Reset

3.2.6 Serial Communications on the External Bus

Serial communications on the external bus use the BUS+ (J502-25), BUS- (J502-22), and BUSY (J502-9) lines.

These three lines are bidirectional; therefore, numerous devices can be in parallel on the bus. All devices monitor the bus while data is being transmitted at a 9600-baud rate. The transmitted data includes the address of the device for which the data is intended. Examples of the different types of data are: control head display data and button closure data.

Data bus drivers for the BUS+ and BUS- lines are differentially driven, having BUS- inverted from the state of BUS+. The idle states are: BUS+, a logic high; and BUS-, a logic low. The drivers are so designed that any of the devices on the bus can drive these lines to their non-idle state without loading problems.

In a typical transmission, the microcontroller examines the BUSY line. If the BUSY line is in the idle state, the microcontroller sets the BUSY line and then transmits. At the end of transmission, the microcontroller returns the BUSY line to idle. The microcontroller sets the BUSY line via microcontroller pin 30, SIOIC pins 10 and 13, and J502-9.

Data transmission is sent onto the bus asynchronously. When the microcontroller sends data onto the bus, the microcontroller also monitors the transmitted data as a collision detection measure. If a collision is detected as a result of receiving a different data pattern, the microcontroller will stop transmission and try again. The microcontroller monitors and receives data via the BUS+ line (J502-25) to the SIOIC (U522, pin 17) and the BUS- line (J502-22) to the SIOIC (U522, pins 18 and 20), and pin 20 of the microcontroller. Data is transmitted from microcontroller pin 19 to the SIOIC to BUS+ (J501, pin 25), and the SIOIC to BUS- (J501, pin 22).

In the remote version of the radio, option cards can be installed. If data transmission is required, data is transmitted from J502-20 to SIOIC pin 19, then from the SIOIC to BUS+ (J501, pin 25), and the SIOIC to BUS- (J501, pin 22).

3.2.7 Synchronous Serial Bus (MOSI)

The synchronous serial bus is an internal bus used by the microcontroller for communicating with various ICs. The serial bus, called MOSI (master out/ slave in), is used to program the digital-to-analog (D/A) converter IC (U526), the serial-to-parallel shift register (U530) on the command board, and the ABACUS II IC (U301) on the RF board. The MOSI data is sent from the VOCON board's microprocessor (U204) through the ADSIC input/output IC (U406) and enters the command board through P501, pin 9. This serial bus has an associated clock and individual select lines for steering the data to one of the three possible devices.

The clock and data are routed in parallel to all serially programmed ICs. The ICs are programmed one-at-a-time by the microcontroller, with each IC ignoring activity on its clock and data lines unless it has been selected.

3.2.8 Received Audio

The received audio is sent from the ADSIC D/A converter as the SDO signal. The audio enters the command board at P501, pin 40, and is routed to the analog multiplex gate (U524, pin 1). The gate's output (U524, pin 2) is paralleled with the output of a second multiplex gate (U524, pin 9) and sent to voltage divider R455 and R456. The voltage divider provides the required attenuation for minimum/ maximum volume control settings. Capacitor C454 provides a DC block and couples the audio into U450, pin 2 for amplification.

The two multiplex gates provide control of either receive audio or vehicular repeater audio. These gates are controlled by the inputs to U524, pin 13 and U524, pin 6 from the serial shift register, U530. The independent inputs are software selected by the VOCON's microcontroller.

The audio power amplifier (PA), U450, is a DC-coupled-output bridge-type amplifier. The gain is internally fixed at 36 dB. Speaker audio leaves U450 on pins 11 and 13. For dash-mount models, the audio is routed to the speaker via P503, pins14 and 16. The amplifier is biased to one half of the A+ voltage and connected directly to the speaker from the rear accessory connector (J2, pins 6 and 7). *The speaker outputs must NOT be grounded in any way.* An audio isolation transformer must be used if grounded test equipment (such as a service monitor) is to be connected to the speaker outputs.

When the radio is squelched, the audio PA is disabled by the VOCON board's controller, providing a low output state to P501, pin 44 (speaker-enable input). The low input turns off Q401 and Q400, removing SWB+ voltage to the audio PA, U450. When U450, pin 10 does not have SW+B applied, the speaker is totally muted and the audio PA current drain is greatly reduced. Diode CR402 (not normally installed) is used when a vehicular repeater is installed and audio muting is required.

A second output for filtered receive audio is provided to drive accessory hardware. The output of P501, pin 49 (MOD IN/DISC AUDIO) is primarily used for transmitter modulation. In the receive mode, the digital signal processor (DSP), via ADSIC, outputs audio at a fixed level (approximately 800 mV pp). This output can be connected to the accessory connector (P503, pin 21) by selecting the appropriate jumper settings.

3.2.9 Microphone Audio

The mobile microphone connects to the front of the control head through connector P104. Microphone high audio enters the command board via P502, pin 6 and is routed to differential amplifier buffer U402. Resistors R414 and R415 provide 9.6-V bias voltage for the microphone's internal circuitry. Amplifier U402 pre-emphasizes and limits the incoming microphone audio through components C462, R407, C463, and R408, which perform an active filter function. Components R441, R442, C467, C465, R443, C466, and C568 provide de-emphasis, developing the required clamped microphone audio, referred to as "mic audio in" (MAI).

3.2.10 Transmit Deviation

The analog transmit deviation (MAI) enters the VOCON board through P501, pin 39, and is converted to a digital format. The digital representation is processed and pre-emphasized by the DSP processor. The pre-emphasized digital bit stream is converted back to analog by the ADSIC device.

The modulation enters the command board through P501, pin 49 (MOD IN) and P501, pin 48 (REF MOD). The two audio signals are required to compensate for low-frequency non-linearities caused by the loop filter in the VCO. The two transmit modulation signals enter a buffer (U401, pin 5 and U401, pin 3). The outputs are sent to a multiplex gate (U523), used to disable the outputs during the receive mode. The multiplex gate is controlled by the serial shift register (U530), and the control lines (U530, pins 10 and 11) are pulled low in the transmit mode.

The modulation is sent out on U530, pins 14 (MOD IN) and 15 (REF MOD). Modulation from U530, pin 14, is coupled through R400 to a non-inverting amplifier, U401. Resistors R403 and R437 fix the closed-loop output gain to 4. Modulation from U530, pin 15 is coupled through R420 to the second non-inverting amplifier, U401. Resistors R422 and R438 fix the closed-loop output gain to 6. The amplified modulation leaves the command board through J500, pins 11 and 17, and is routed to the RF board to provide the transmit modulation.

3.2.11 RS-232 Line Driver

The U526 device is a driver/receiver IC, capable of interfacing with external hardware that utilizes the RS-232 protocol. The device includes an internal oscillator, a voltage doubler, a voltage inverter, and a level shifter. The IC is sourced by +5 V and outputs digital signals at voltage levels of ±10 Vdc.

The device accepts incoming RS-232 data and converts it to a 5-V logic level. The command board jumper default settings are arranged to have the RS-232 driver normally connected to the accessory outputs, except when ordered as Motorcycle models.

3.2.12 Flash Programming

The command board provides multiplexing of the receive and transmit data inputs from the control head’s microphone connector (P104). The microphone connector is used (during certain conditions) as a Flash programming input port. When the special programming cable is inserted into P104, the “microphone high” line (normally 9.6 V) increases to 13 V, due to internal connections made within the radio interface box (RIB). Zener diode VR401 (and resistor R519), connected to the “Mic Hi” input (P502, pin 6), is forward-biased beyond its breakdown voltage of 11 Vdc. The voltage drop across R516 forward-biases Q401, turning on the transistor. The collector of Q401 pulls the voltage provided by R521 to ground. The change in state causes the multiplex control line (U525, pins 9, 10, 11) to change the gate inputs. The change allows the receive and transmit data paths to be multiplexed to P502, pin 23 (Key Fail), P502, pin 15 (P_RX data), and P502, pin 2 (PTT*/P reset).

3.2.13 Encryption Voltages

The command board produces two voltages that are used by the encryption module: 10-V (9-V on G and earlier boards) constant and 5-V key storage. The constant 10 V is generated using components U604, R608, R609, and C605 (R420, VR403, C457, and Q508 on G and earlier boards) and is fed to pin 38 of P501. On the VOCON board, the 10 V provides continuous unswitched voltage when the vehicular battery is connected to the radio and is also switched via VOCON transistors Q206 and Q207 to provide SWB+ to the encryption module. A 5-V storage circuit comprised of components R532, R533, and C571 (0.47 farad capacitor) provides +5 Vdc to the encryption module via P501 pin 36 to hold encryption keys for a period of three days with no A+ voltage present. Provision is made for a battery holder to replace capacitor C571. The addition of the battery will increase encryption key hold time to approximately one year.

3.2.14 Regulator and Power-Control IC

The regulator and power-control IC (RPCIC), U500, contains internal circuitry for the 9.6-V regulator and the switched +5-V regulator. Refer to Section 3.2.4, "Regulators," on page 3-10 for detailed theory of operation.

The power-control section of the device is responsible for maintaining a constant RF output power. A directional coupler and detector network, located within the RF power amplifier circuit, rectifies the sensed forward power from the last RF gain stage. The detected voltage is routed back to the command board control circuitry (U500) via P503, pin 8. The voltage is then coupled through a buffer amplifier and summed, through a resistor network (R509, R508, and R507), with the transmit power set voltage (U500, pin 6) and the temperature sense voltage. The resulting voltage is applied to the control amplifier's inverting port (U502, pin 2) for automatic RF gain control.

The U500 current-sense inputs, pin 37 (sense +) and pin 38 (sense -), are sourced from the current-sensing resistor on the RF power amplifier. The two inputs are applied to a differential amplifier internal to the RPCIC. The current limit is set by a software-programmable D/A device (U502) that causes a cut back in RF output power when the set limit is exceeded.

The transmitter attack and off times are software programmable to meet domestic and international specifications. Transistors Q514 and Q515 are controlled by a serial shift register (U530). The transistors, when turned on (logic 1 input) cause the output of Q504 (the PA control line) to ramp up slowly to prevent an abrupt RF PA turn-on. The slower rate is required to meet international spurious requirements. When the transistors are turned off, the attack times return to a standard domestic response with fast rise times. Refer to Figure 3-6 for attack time diagrams.

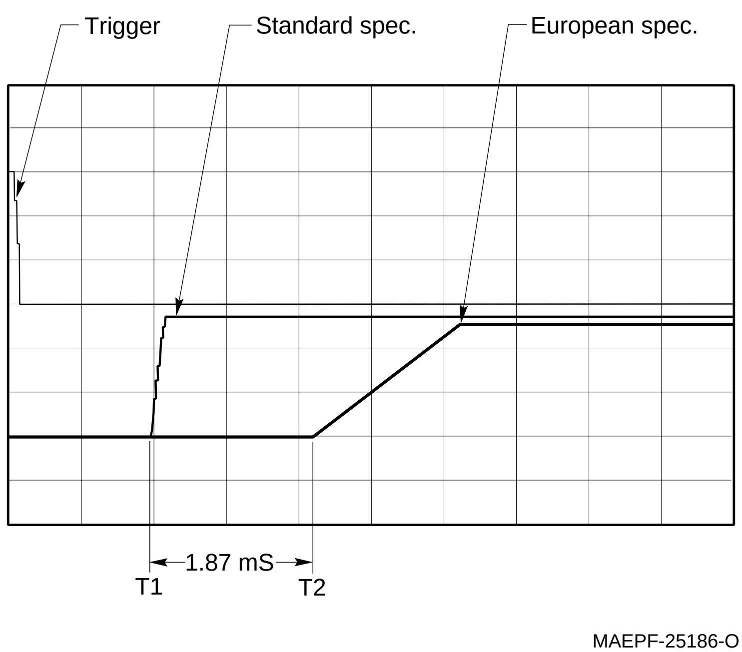


Figure 3-6. Transmitter Attack Time

3.3 ASTRO Spectra VOCON Board

This section of the theory of operation provides a detailed circuit description of an ASTRO Digital Spectra Vocoder/Controller (VOCON) Board. When reading the Theory of Operation, refer to your appropriate schematic and component location diagrams located in "Chapter 7. Schematics, Component Location Diagrams, and Parts Lists". This detailed Theory of Operation will help isolate the problem to a particular component. However, first use the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* to troubleshoot the problem to a particular board.

NOTE: The information in this subsection applies to the **non Plus** VOCON Board. Refer to Section 3.4, "ASTRO Spectra Plus VOCON Board," on page 3-38 for information on the ASTRO Spectra Plus VOCON board.

3.3.1 General

The VOCON board consists of two subsystems; the vocoder and the controller. Although these two subsystems share the same printed circuit board and work closely together, it helps to keep their individual functionality separate in describing the operation of the radio.

The controller section is the central interface between the various subsystems of the radio. It is very similar to the digital logic portion of the controllers on many existing Motorola radios. Its main task is to interpret user input, provide user feedback, and schedule events in the radio operation, which includes programming ICs, steering the activities of the DSP, and sending messages to the display through the control head.

The vocoder section performs all tone signaling, trunking signalling, conventional analog voice, etc. All analog signal processing is done digitally utilizing a DSP56001. In addition it provides a digital voice plus data capability utilizing VSELP or IMBE voice compression algorithms. Vocoder is a general term used to refer to these DSP based systems and is short for voice encoder.

In addition, the VOCON board provides the interconnection between the microcontroller unit (MCU), digital-signal processor (DSP), command board, and encryption board on secure-equipped radios.

3.3.2 Controller Section

Refer to Figure 3-7 and your specific schematic diagram.

The controller section of the VOCON board consists entirely of digital logic comprised of a microcontrol unit (MCU-U204), a custom support logic IC (SLIC-U206), and memory consisting of: SRAM (U202), EEPROM (U201), and FLASH ROM (U205).

The MCU (U204) memory system is comprised of a 32k x 8 SRAM (U202), 32k x 8 EEPROM (U201), and 512k x 8 FLASH ROMs (U205). The MCU also contains 1024 bytes of internal SRAM and 512 bytes of internal EEPROM. The EEPROM memory is used to store customer specific information and radio personality features. The FLASH ROM contains the programs which the HC11F1 executes. The FLASH ROM allows the controller firmware to be reprogrammed for future software upgrades or feature enhancements. The SRAM is used for scratchpad memory during program execution.

The SLIC (U206) performs many functions as a companion IC for the MCU. Among these are expanded input/output (I/O), memory decoding and management, and interrupt control. It also contains the universal asynchronous receiver transmitter (UART) used for the RS232 data communications. The SLIC control registers are mapped into the MCU (U204) memory space.

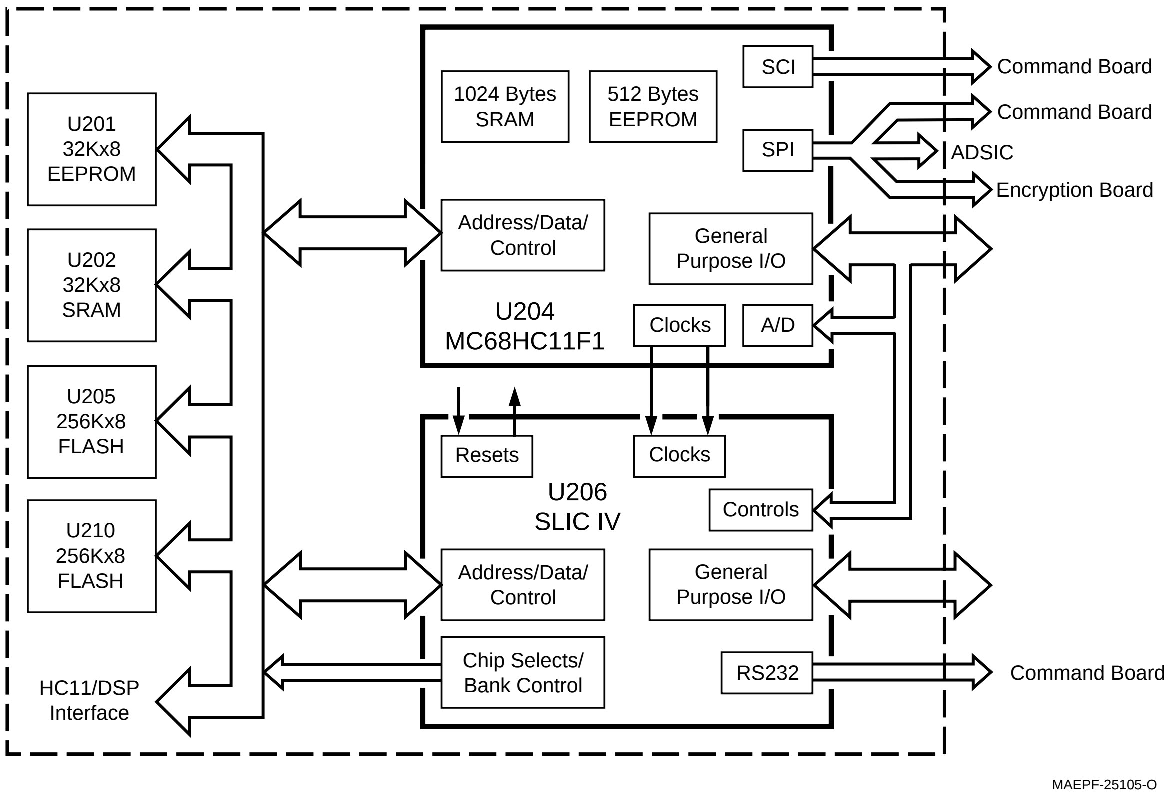


Figure 3-7. VOCON Board - Controller Section

The controller performs the programming of all peripheral ICs. This is done via a serial peripheral interface (SPI) bus. ICs programmed through this bus include the synthesizer prescaler, DAIC, and ADSIC. On secure-equipped model, the encryption board is also controlled through the SPI bus.

In addition to the SPI bus, the controller also maintains two asynchronous serial buses; the SB9600 bus and an RS232 serial bus. The SB9600 bus is for interfacing the controller section to different hardware option boards, some of which may be external to the radio. The RS232 is used as common data interface for external devices.

User input from the control head is sent to the controller via the SB9600 bus. Feedback to the user is provided by the display on the control head. The display is 2 line 14 characters on the W3 model, 8 characters on W4, W5, and W7 models, and 11 characters on the W9 model.

The controller schedules the activities of the DSP through the host port interface. This includes setting the operational modes and parameters of the DSP. The controlling of the DSP is analogous to programming analog signaling ICs on standard analog radios.

3.3.3 Vocoder Section

Refer to Figure 3-8 and your specific schematic diagram.

The vocoder section of the VOCON board is made up of a digital signal processor (DSP) (U405), 24k x24 static-RAM (SRAM) (U414, U403, and U402), 256kB FLASH ROM (U404), and ABACUS II/DSP support IC (ADSIC) (U406).

The FLASH ROM (U404) contains the program code executed by the DSP. As with the FLASH ROM used in the controller section, the FLASH ROM is reprogrammable so new features and algorithms can be updated in the field as they become available. Depending on the mode and operation of the DSP, corresponding program code is moved from the FLASH ROM into the faster SRAM, where it is executed at full bus rate.

The ADSIC (U406) is basically a support IC for the DSP. It provides among other things, the interface from the digital world of the DSP to the analog world. The ADSIC also provides some memory management and provides interrupt control for the DSP processing algorithms. The configuration programming of the ADSIC is performed by the MCU. However some components of the ADSIC are controlled through a parallel memory mapped register bank by the DSP.

In the receive mode, The ADSIC (U406) acts as an interface to the ABACUS II IC, which can provide digital output of I (In phase) and Q (Quadrature) data words directly to the DSP for processing. Or the data can be filtered and discriminated by the ADSIC and data provided to the DSP as raw discriminator sample data. The latter mode, with the ADSIC performing the filtering and discrimination, is the typical mode of operation.

In the transmit mode, the ADSIC (U406) provides a serial digital-to-analog (D/A) converter. The data generated by the DSP is filtered and reconstructed as an analog signal to present to the VCO and Synthesizer as a modulation signal. Both the transmit and receive data paths between the DSP and ADSIC are through the DSP SSI port.

When transmitting, the microphone audio is passed from the command board to the ADSIC, which incorporates an analog-to-digital (A/D) converter to translate the analog waveform to a series of data. The data is available to the DSP through the ADSIC parallel registers. In the converse way, the DSP writes speaker data samples to a D/A in the ADSIC, which provides an analog speaker audio signal to the audio power amplifier on the command board.

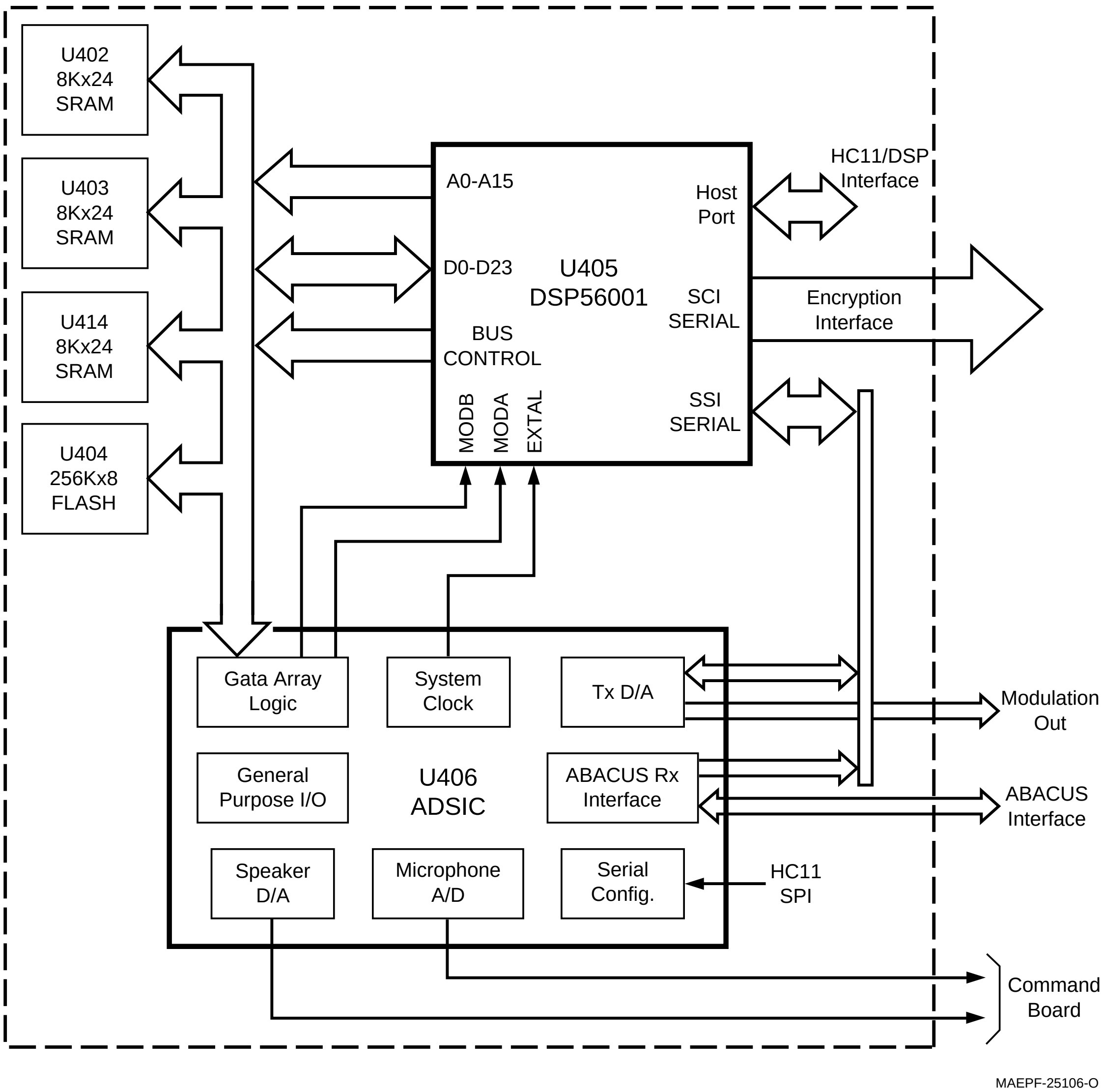


Figure 3-8. VOCON Board - Vocoder Section

3.3.4 RX Signal Path

The vocoder processes all received signals digitally. This requires a unique back end from a standard analog radio. This unique functionality is provided by the ABACUS II IC with the ADSIC (U406) acting as the interface to the DSP. The ABACUS II IC located on the RF board provides a digital back-end for the receiver section. It provides a digital output of I (In phase) and Q (Quadrature) data words at 20 kHz sampling rate through the ADSIC interface to the DSP. Refer to the appropriate transceiver section for details on ABACUS II operation.

The ADSIC interface to the ABACUS II is comprised of the four signals SBI, DIN, DIN*, and ODC (refer to Figure 3-9).

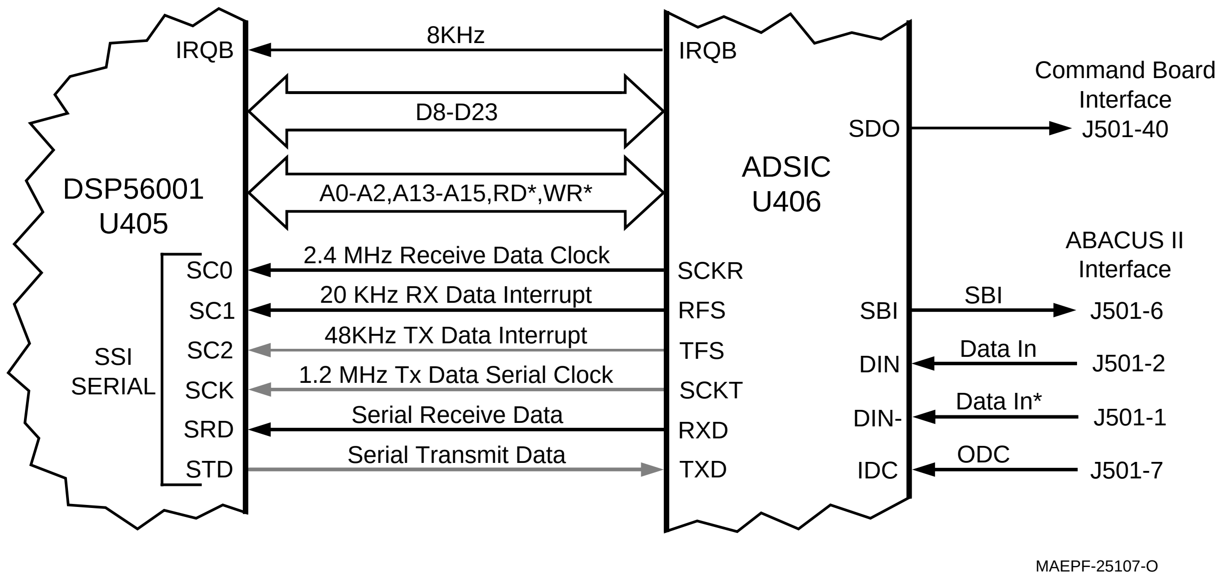


Figure 3-9. DSP RSSI Port - RX Mode

NOTE: An asterisk symbol (*) next to a signal name indicates a negative or NOT logic true signal.

ODC is a clock ABACUS II provides to the ADSIC. Most internal ADSIC functions are clocked by this ODC signal at a rate of 2.4 MHz and is available as soon as power is supplied to the circuitry. This signal may initially be 2.4 or 4.8 MHz after power-up. It is programmed by the ADSIC through the SBI signal to 2.4 MHz when the ADSIC is initialized by the MCU through the SPI bus. For any functionality of the ADSIC to exist, including initial programming, this reference clock must be present. SBI is a programming data line for the ABACUS II. This line is used to configure the operation of the ABACUS II and is driven by the ADSIC. The MCU programs many of the ADSIC operational features through the SPI interface. There are 36 configuration registers in the ADSIC of which four contain configuration data for the ABACUS II. When these particular registers are programmed by the MCU, the ADSIC in turn sends this data to the ABACUS II through the SBI.

DIN and DIN* are the data lines on which the I and Q data words are transferred from the ABACUS II. These signals make up a differentially encoded current loop. Instead of sending TTL type voltage signals, the data is transferred by flowing current one way or the other through the loop. This helps to reduce internally generated spurious emissions on the RF board. The ADSIC contains an internal current loop decoder which translates these signals back to TTL logic and stores the data in internal registers.

In the fundamental mode of operation, the ADSIC transfers raw baseband data to the DSP. The DSP can perform IF filtering and discriminator functions on this data to obtain a baseband demodulated signal. However, the ADSIC contains a digital filter and discriminator function and can provide this baseband demodulated signal directly to the DSP, this being the typical mode of operation. The internal digital IF filter is programmable up to 24 taps. These taps are programmed by the MCU through the SPI interface.

The DSP accesses this data through its SSI port. This is a 6 port synchronous serial bus. It is used by the DSP for both transmit and receive data transferal, but only the receive functions will be discussed here. The ADSIC transfers the data to the DSP on the SRD line at a rate of 2.4 MHz. This is clocked synchronously by the ADSIC which provides a 2.4 MHz clock on SC0. In addition, a 20 kHz interrupt is provided on SC1 signaling the arrival of a data packet. This means a new I and Q sample data packet is available to the DSP at a 20 kHz rate which represents the sampling rate of the received data. The DSP then processes this data to extract audio, signaling, etc. based on the 20 kHz interrupt.

In addition to the SPI programming bus, the ADSIC also contains a parallel configuration bus consisting of D8-D23, A0-A2, A13-A15, RD*, and WR*, This bus is used to access registers mapped into the DSP memory starting at Y:FFF0. Some of these registers are used for additional ADSIC configuration controlled directly by the DSP. Some of the registers are data registers for the speaker D/A. Analog speaker audio is processed through this parallel bus where the DSP outputs the speaker audio digital data words to this speaker D/A and an analog waveform is generated which is output on SDO (Speaker Data Out). In conjunction with the speaker D/A, the ADSIC contains a programmable attenuator to set the rough signal attenuation. However, the fine levels and differences between signal types is adjusted through the DSP software algorithms. The speaker D/A attenuator setting is programmed by the MCU through the SPI bus.

The ADSIC provides an 8 kHz interrupt to the DSP on IRQB for processing the speaker data samples. IRQB is also one of the DSP mode configuration pins at start up. This 8 kHz signal must be enabled through the SPI programming bus by the MCU and is necessary for any audio processing to occur.

For secure messages, the digital signal data must be passed to the secure module for decryption prior to processing speaker data. The DSP transfers the data to and from the secure module through it's SCI port consisting of TXD and RXD. The SCI port is a two wire duplex asynchronous serial port. Configuration and mode control of the secure module is performed by the MCU through the SPI bus.

The ADSIC presents the analog speaker audio to the command board’s audio power amplifier., which drives an external speaker. For more information on this subject, refer to Section 3.2, "Command Board," on page 3-8.

Since all of the audio and signaling is processed in DSP software algorithms, all types of audio and signalling follow this same path. There is, however, one exception. Low-speed trunking data is processed by the host µC through the SCLK port of the DSP. This port is connected to port PA0 on the host µC. The DSP extracts the low-speed data from the received signal and relays it to the host µC for processing.

3.3.5 TX Signal Path

The transmit signal path follows some of the same design structure as the receive signal path described in Section 3.3.4, "RX Signal Path," on page 3-18 (refer to Figure 3-10). It is advisable to read through the section on RX Signal Path that precedes this section.

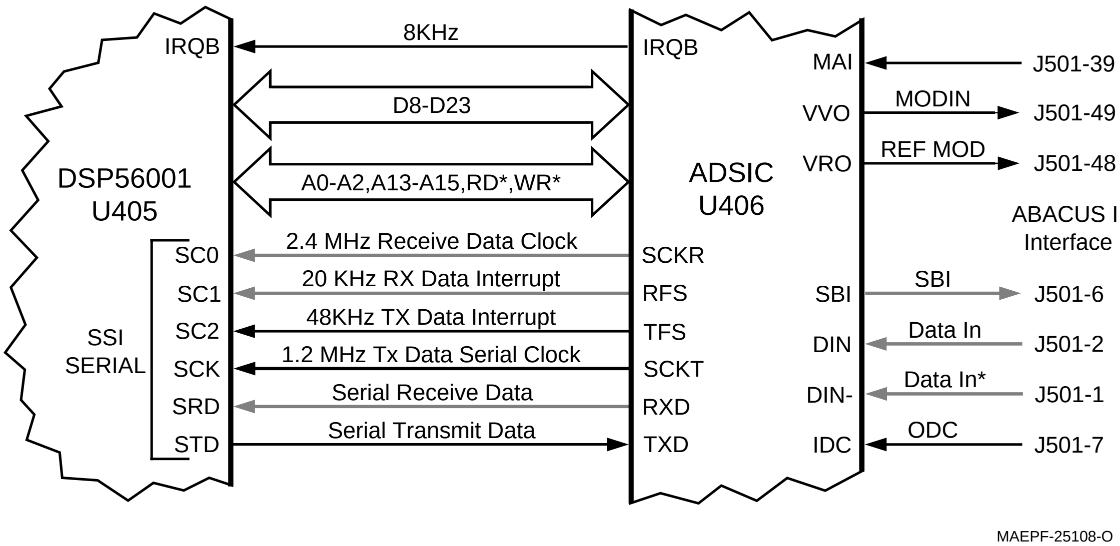


Figure 3-10. DSP RSSI Port - TX Mode

The ADSIC contains a microphone A/D with a programmable attenuator for coarse level adjustment. As with the speaker D/A attenuator, the microphone attenuator value is programmed by the MCU through the SPI bus. The analog microphone signal from the command board is input to the A/D on MAI (Mic Audio In). The microphone A/D converts the analog signal to a digital data stream and stores it in internal registers. The DSP accesses this data through the parallel configuration bus consisting of D8-D23, A0-A2, A13-A15, RD*, and WR*. As with the speaker data samples, the DSP reads the microphone samples from registers mapped into it's memory space starting at Y:FFF0. The ADSIC provides an 8 kHz interrupt to the DSP on IRQB for processing these microphone data samples.

As with the received trunking low-speed data, low speed Tx data is processed by the MCU and returned to the DSP at the DSP SCLK port connected to the MCU port PA0.

For secure messages, the digital signal may be passed to the secure module for encryption prior to further processing. The DSP transfers the data to and from the secure module through its SCI port, consisting of TXD and RXD. Configuration and mode control of the secure module is performed by the MCU via the SPI bus.

The DSP processes these converted microphone samples, generates and mixes the appropriate signalling, and filters the resultant data. This data is then transferred to the ADSIC IC on the DSP SSI port. The transmit side of the SSI port consists of SC2, SCK, and STD. The DSP SSI port is a synchronous serial port. SCK is the 1.2 MHz clock input derived from the ADSIC, which makes it synchronous. The data is clocked over to the ADSIC on STD at a 1.2 MHz rate. The ADSIC generates a 48 kHz interrupt on SC2 so that a new sample data packet is transferred at a 48 kHz rate which sets the transmit data sampling rate at 48Ksp.

These samples are then input to a transmit D/A, which converts the data to an analog waveform. This waveform is the modulation out signal from the ADSIC ports, VVO and VRO. These signals are both sent to the command board, where they go through a gain stage and then to the VCO and Synthesizer. VVO is used primarily for audio frequency modulation; VRO is used to compensate for low-frequency response to pass Digital Private Line (DPL) modulated signals.The transmit side of the transceiver is virtually identical to a standard analog FM radio.

Also required is the 2.4 MHz ODC signal from the ABACUS II IC. Although the ABACUS II IC provides receiver functions, it is important to note that this 2.4 MHz reference is required for all of the ADSIC operations.

3.3.6 Controller Bootstrap and Asynchronous Buses

The SB9600 bus (see Figure 3-11) is an asynchronous serial communication bus, utilizing a Motorola proprietary protocol. It provides a means for the MCU to communicate with other hardware devices. In the ASTRO Digital Spectra radio, it communicates with hardware accessories connected to the accessory connector and the remote interface board.

The SB9600 bus utilizes the UART internal to the MCU, operating at 9600 baud. The SB9600 bus consists of LH/TX_Data (J501-18), LH/RX_Data (J501-17), and Busy_RTS (J501-20) signals. LH/TX_Data and LH/RX_Data are the SCI TXD and RXD ports (U204-PD0 and PD1), respectively. Busy_RTS (U204-PA3) is an active-low signal, which is pulled low when a device wants control of the bus.

The same UART internal to the MCU is used in the controller bootstrap mode of operation. This mode is used primarily in downloading new program code to the FLASH ROMs on the VOCON board. In this mode, the MCU accepts special code downloaded at 7200 baud through the SCI bus instead of operating from program code resident in its ROMs.

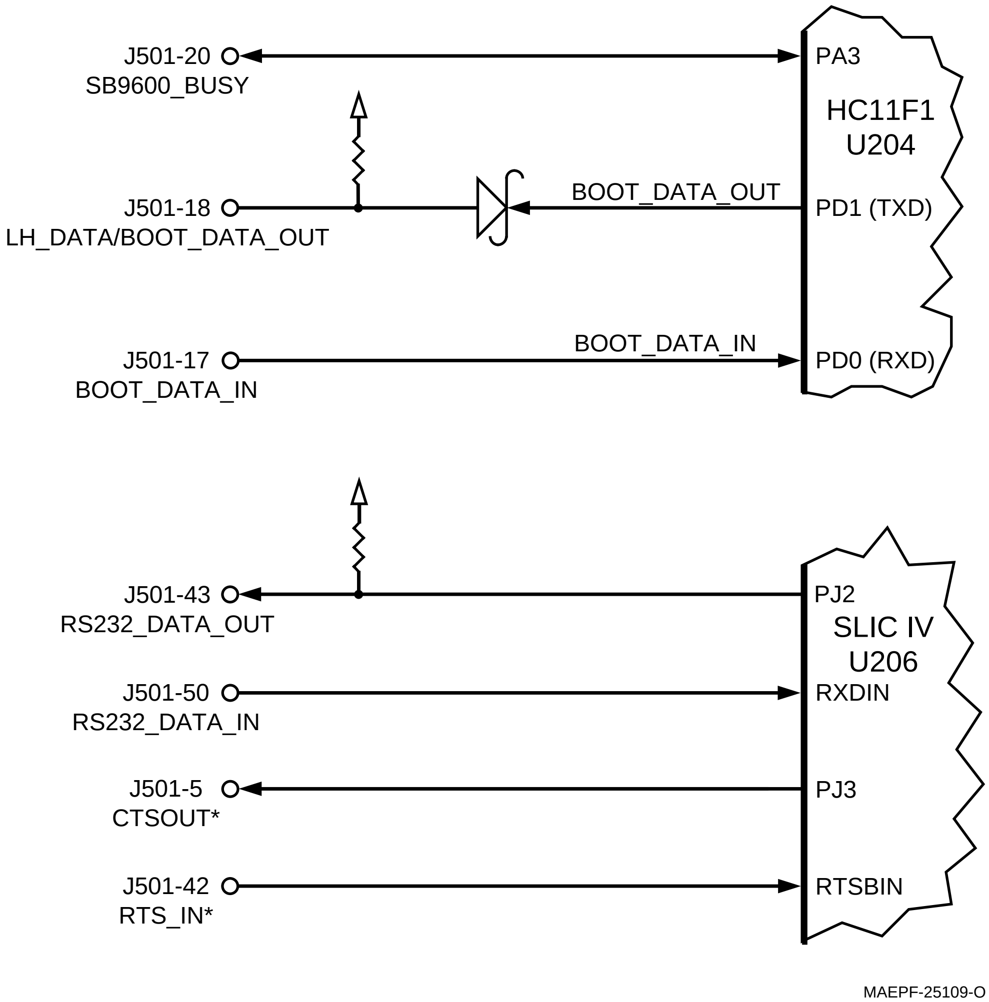


Figure 3-11. Host SB9600 and RS232 Ports

A voltage greater than 10 Vdc applied to J501-31 (Vpp) will trip the circuit comprising Q203, Q204, and VR207. This circuit sets the MODA and MODB pins of the MCU to bootstrap mode (logic 0,0). If the Vpp voltage is raised to 12 Vdc required on the FLASH devices for programming, the circuit comprising VR208, Q211, and Q208 will trip, supplying Vpp to the FLASH devices, U205 and U404.

The ASTRO Digital Spectra radio has an additional asynchronous serial bus which utilizes RS232 bus protocol. This bus utilizes the UART in the SLIC IC (U206). It consists of TX/RS232 (J501-43), RX/RS232 (J501-50), CTS/RS232 (J501-5), and RTS/RS232 (J501-42). It is a four-wire duplex bus used to connect to external data devices.

3.3.7 Vocoder Bootstrap

The DSP has two modes of bootstrap: from program code stored in the FLASH ROM U404, or retrieving code from the host port.

During normal modes of operation, the DSP executes program code stored in the FLASH ROM, U404. Unlike the MCU, however, the DSP moves the code from the FLASH ROM into the three SRAMs, U402, U403, and U414, where it is executed from. Since, at initial start-up, the DSP must execute this process before it can begin to execute system code, it is considered a bootstrap process. In this process, the DSP fetches 512 words, 1536 bytes, of code from the FLASH ROM, starting at physical address $C000, and moves it into internal P memory. This code contains the system vectors, including the reset vector. It then executes this piece of bootstrap code, which basically in turn moves additional code into the external SRAMs.

A second mode of bootstrap allows the DSP to load this initial 512 words of data from the host port, being supplied by the MCU. This mode is used for FLASH programming the DSP ROM when the ROM may initially be blank. In addition, this mode may be used for downloading some diagnostic software for evaluating that portion of the board.

The bootstrap mode for the DSP is controlled by three signals; MODA/IRQA*, MODB/IRQB*, and D23. All three of these signals are on the DSP (U405). MODA and MODB configure the memory map of the DSP when the DSP reset become active. These two signals are controlled by the ADSIC (U406) during power-up, which sets MODA low and MODB high for proper configuration. Later these lines become interrupts for analog signal processing. D23 controls whether the DSP will look for code from the MCU or will retrieve code from the FLASH ROM. D23 by default is pulled high through R404 which will cause the DSP to seek code from the FLASH ROM (U404) if this line is read high out of reset. This line is also connected to an I/O port on the MCU which can configure it for the second, host port, mode of bootstrap.

3.3.8 Serial Peripheral Interface (SPI) Bus

This bus is a synchronous serial bus made up of a data, a clock, and an individual IC unique select line. It's primary purpose is to configure the operating state of each IC. ICs programmed by this include; ADSIC, Synthesizer, Prescaler, DAIC, and, if equipped, the secure module.

The MCU (U204) is configured as the master of the bus. It provides the synchronous clock (SPI_SCK), a select line, and data (MOSI [Master Out Slave In]). In general the appropriate select line is pulled low to enable the target IC and the data is clocked in. The SPI bus is a duplex bus with the return data being clocked in on MISO (Master In Slave Out). The only place this is used is when communicating with the secure module. In this case, the return data is clocked back to the MCU on MISO (master in slave out).

3.3.9 Controller Memory Map

Figure 3-12 depicts the controller section memory map for the parallel data bus as used in normal modes of operation. There are three maps available for normal operation, but map 2 is the only one used. In bootstrap mode, the mapping is slightly different and will be addressed later.

The external bus for the host controller (U204)) consists of one 32Kx8 SRAM (U202), one 32Kx8 EEPROM (U201), one IMEG FLASH ROM U205, and SLIC (U206) configuration registers. In addition the DSP host port is mapped into this bus through the SLIC address space. The purpose of this bus is to interface the MCU (U204) to these devices

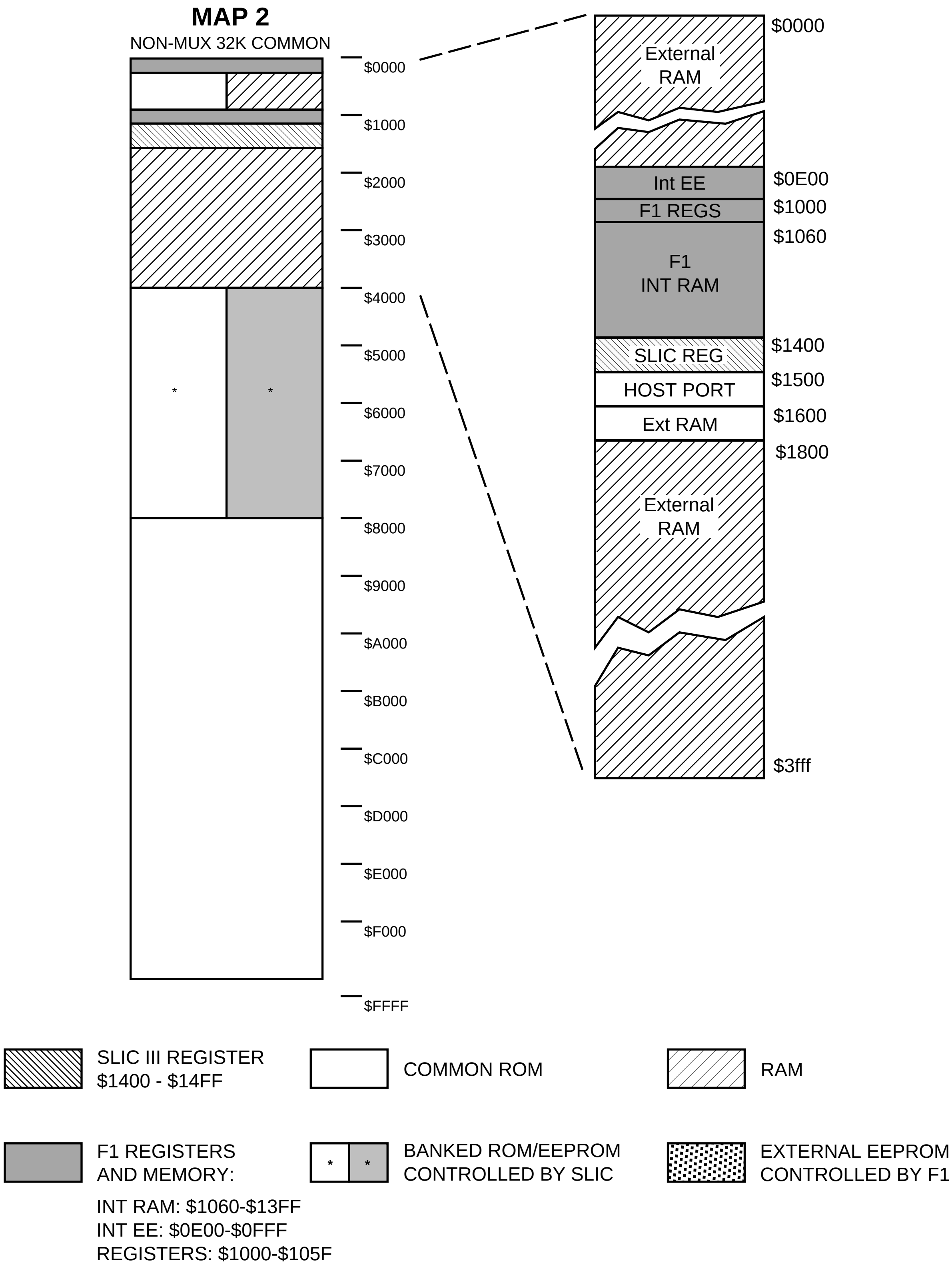


Figure 3-12. Controller Memory Mapping

The MCU executes program code stored in the FLASH ROMs. On a power-up reset, it fetches a vector from $FFFE, $FFFF in the ROMs and begins to execute code stored at this location. The external SRAM along with the internal 1Kx8 SRAM is used for temporary variable storage and stack space. The internal 512 bytes of EEPROM along with the external EEPROM are used for non volatile storage of customer-specific information. More specifically the internal EEPROM space contains transceiver board tuning information and on power-down some radio state information is stored in the external EEPROM.

The SLIC is controlled through sixteen registers mapped into the MCU memory at $1400-$14FF. This mapping is achieved by the following signals from the MCU: R/W*, CSIO1*, HA0-HA4,HA8, HA9. Upon power-up, the MCU configures the SLIC including the memory map by writing to these registers.

The SLIC memory management functions in conjunction with the chip selects provided by the MCU provide the decoding logic for the memory map which is dependent upon the “map” selected in the SLIC. The MCU provides a chip select, CSGEN*, which decodes the valid range for the external SRAM. In addition CSI01* and CSPROG* are provided to the SLIC decoding logic for the external EEPROM and FLASH ROM respectively. The SLIC provides a chip select and banking scheme for the EEPROM and FLASH ROM. The FLASH ROM is banked into the map in 16KB blocks with one 32KB common ROM block. The external EEPROM may be swapped into one of the banked ROM areas. This is all controlled by EE1CS*, ROM1CS*, ROM2CS*, HA14_OUT, HA15_OUT, HA16, and HA17 from the SLIC (U206) and D0-D8 and A0-16 from the MCU (U204).

The SLIC provides three peripheral chip selects; XTSC1B, XTCS2B, and XTCS3B. These can be configured to drive an external chip select when its range of memory is addressed. XTSC1B is used to address the host port interface to the DSP. XTSC2B is used to address a small portion of external SRAM through the gate U211. XTSCB3 is used as general purpose I/O for interrupting the secure module.

In bootstrap mode the memory map is slightly different. Internal EEPROM is mapped at $FE00-$FFFF and F1 internal SRAM starts at $0000-$03FF. In addition, a special bootstrap ROM appears in the ROM space from $B600-$BFFF. For additional information on bootstrap mode, refer to Section 3.3.6, "Controller Bootstrap and Asynchronous Buses," on page 3-22.

3.3.10 Vocoder Memory Map

The vocoder (DSP) external bus consists of three 32k x 8 SRAMs (U401, U402, and U403), one 256k x 8 FLASH ROM (U404), and ADSIC (U406) configuration registers. Refer to Figure 3-13.

The DSP56001A (U405) has a 24 bit wide data bus (D0-D23) and a 16 bit wide address bus (A0 - A15). The DSP can address three 64k x 24 memory spaces: P (Program), Dx (Data X), and Dy (Data Y). These additional RAM spaces are decoded using PS* (Program Strobe), DS* (Data Strobe), and X/Y*. RD* and WR* are separate read and write strobes.

The ADSIC provides memory decoding for the FLASH ROM (U404). EPS* provides the logic:

$$\overline{A15\ x\ (A14 \oplus A13)}$$

and is used as a select for the ROM. The ADSIC provide three bank lines for selecting 16k byte banks from the ROM. This provides decoding for 128k bytes from the ROM in the P: memory space. PS* is used to select A17 to provide an additional 128k bytes of space in Dx: memory space for the ROM.

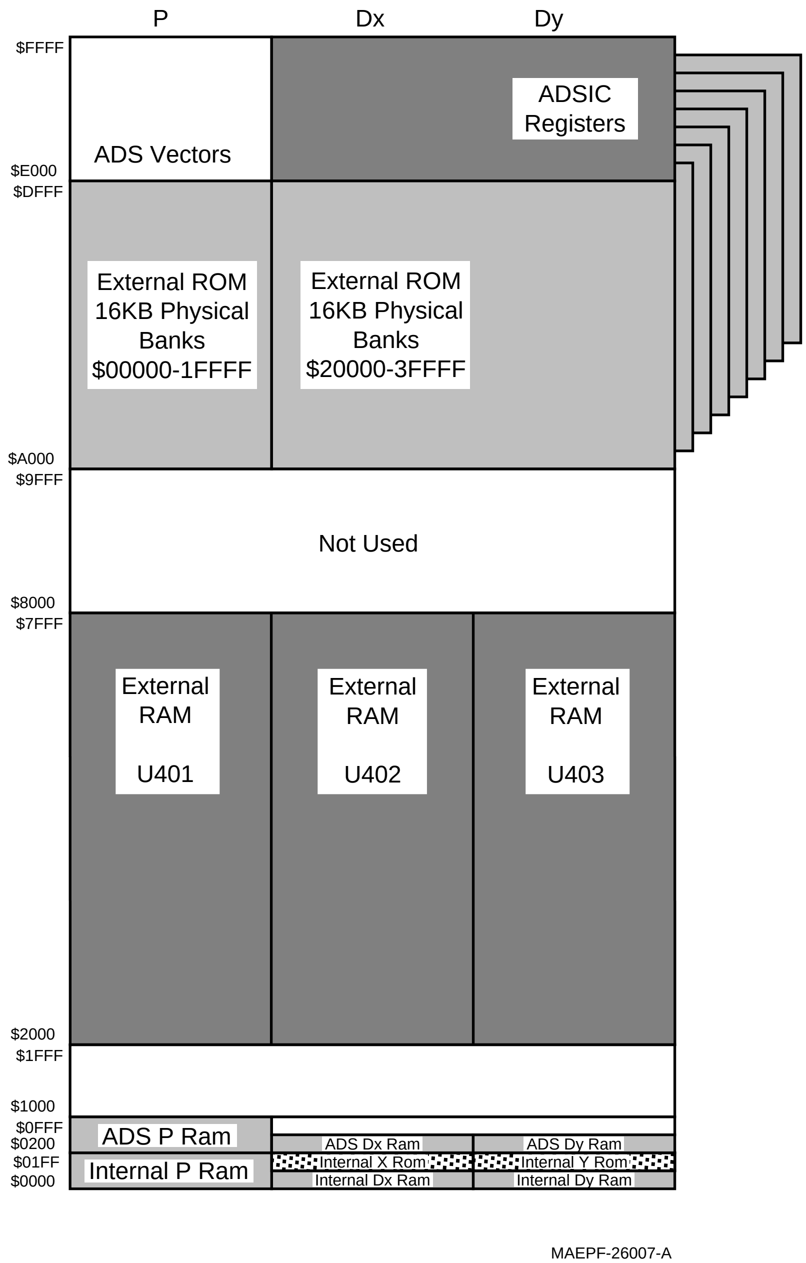


Figure 3-13. Vocoder Memory Mapping

The ADSIC internal registers are decoded internally and start at $E000 in Dy:. These registers are decoded using A0-A2, A13-A15, and PS* from the DSP. The ADSIC internal registers are 16 bits wide, so only D8-D23 are used.

The DSP program code is stored in the FLASH ROM, U404. During normal modes of operation, the DSP moves the appropriate program code into the three SRAMs (U401, U402, and U403) and internal RAM for execution. The DSP never executes program code from the FLASH ROM itself. At power-up after reset, the DSP downloads 512 words (1536 bytes) from the ROM, starting at $C000, and puts it into the internal RAM, starting at $0000, where it is executed. This segment of program code contains the interrupt vectors and the reset vector, and is basically an expanded bootstrap code. When the MCU messages the DSP that the ADSIC has been configured, the DSP overlays more code from the ROM into external SRAM and begins to execute it. Overlays occur at different times when the DSP moves code from the ROM into external SRAM, depending on immediate mode of operation, such as changing from transmit to receive.

3.3.11 MCU System Clock

The MCU (U701) system clock is provided by circuitry internal to the MCU and is based on the crystal reference, Y100. The nominal operating frequency is 7.3728 MHz. This signal is available as a clock at 4XECLK on U701 and is provided to the SLIC (U702) for internal clock timing. The MCU actually operates at a clock rate of 1/4 the crystal reference frequency or 1.8432 MHz. This clock is available at ECLK on U701.

The MCU clock contains a crystal warp circuit comprised of L120, Q102, and C162. This circuit is controlled by an I/O port (PA6) on the MCU. This circuit moves the operating frequency of the oscillator about 250ppM on certain receive channels to prevent interference from the MCU bus noise.

3.3.12 DSP System Clock

The DSP (U405) system clock, DCLK, is provided by the ADSIC (U406). It is based off the crystal reference, Y401, with a nominal operating frequency of 33.0000 MHz. The ADSIC contains an internal clock-divider circuit that can divide the system clock from 33 MHz to 16.5 MHz or 8.25 MHz operation. The DSP controls this divider by writing to the ADSIC parallel registers. The frequency is determined by the processes the DSP is running and, to reduce system power consumption, is generally configured to the slowest operating speed possible.

The additional circuitry of CR402, L401, C416, C417, C419, and C422 make up a crystal warp circuit. This circuit is controlled by the OSCw signal from ADSIC, which is configured by the host through the SPI bus. The crystal warp circuit moves the operating frequency of the oscillator about 400ppM on certain receive channels to prevent interference from the DSP bus noise.

3.3.13 Radio Power-Up/Power-Down Sequence

Radio power-up begins when the user closes the radio on/off switch on the control top, placing 7.5 Vdc on the B+_SENSE line. This signal enables the pass element Q106 through Q105, enabling SW_B+ to the controller board and the transceiver board. B+_SENSE also enables the +5 Vdc regulator, U709. When +5 Vdc has been established, it is sensed by the supervisory IC, U726, which disables the system reset through the delay circuit R208 and C214.

When the MCU comes out of reset, it fetches the reset vector in ROM at $FFFE, $FFFF and begins to execute the code this vector points to. It configures the SLIC through the parallel bus registers. Among other things it enables the correct memory map for the MCU. It configures all the transceiver devices on the SPI bus. The MCU then pulls the ADSIC out of reset and, after a minimal delay, the DSP also. It then configures the ADSIC via the SPI bus, configuring, among other things, the DSP memory map. While this is happening, the DSP is fetching code from ROM U404 into internal RAM and beginning to execute it. It then waits for a message from the MCU that the ADSIC has been configured, before going on.

During this process, the MCU does power diagnostics. These diagnostics include verifying the MCU system RAM, and verifying the data stored in the internal EEPROM, external EEPROM, and FLASH ROMs. The MCU queries the DSP for proper status and the results of DSP self tests. The DSP self tests include testing the system RAM, verifying the program code in ROM U404, and returning the ADSIC configuration register checksum. Any failures cause the appropriate error codes to be sent to the display. If everything is OK, the appropriate radio state is configured and the unit waits for user input.

On power-down, the user opens the radio on/off switch, removing the B+_SENSE signal from the controller board. This does not immediately remove power, as the MCU holds this line active through B+_CNTL. The MCU then saves pertinent radio status data to the external EEPROM. Once this is done, B+_CNTL is released, shutting off SW_B+ at Q106 and shutting down the 5-Vdc regulator U709. When the regulator slumps to about 4.7 Vdc, supervisory IC U726 activates a system reset to the SLIC, which in turn resets the MCU.

3.3.14 VOCON BOARD Signals

Due to the nature of the schematic-generating program, signal names must be different when they are not *directly* connected to the same point. The following tables provide a cross-reference to the various pinouts for the same functional signal.

Table 3-2. VOCON Board Address Bus (A) Pinouts

Bus	U402	U403	U404	U405	U406	U414	U415
A0	A4	A4	20	C2	E9	A4	--
A1	B4	B4	19	D3	E10	B4	--
A2	A3	A3	18	D2	E8	A3	--
A3	B3	B3	17	E2	--	B3	--
A4	A2	A2	16	D4	--	A2	--
A5	B2	B2	15	B1	--	B2	--
A6	J6	J6	14	E3	--	J6	--
A7	K7	K7	13	F1	--	K7	--
A8	J7	J7	3	F2	--	J7	--
A9	K8	K8	2	F3	--	K8	--
A10	B8	B8	31	G1	--	B8	--
A11	A8	A8	1	J2	--	A8	--
A12	B7	B7	12	K1	--	B7	--
A13	J3	--	4	H3	D9	--	2
A14	--	--	5	G2	B9	--	1
A15	K3	K3	11	H2	D10	J3	--

Table 3-3. VOCON Board Address Bus (HA) Pinouts

Bus	U201	U202	U204	U205	U206	U210	U405
HA0	13	10	D2	20	D7	20	E9
HA1	11	9	C2	19	C7	19	F8
HA2	10	8	C1	18	C8	18	F9
HA3	8	7	D1	17	D8	17	--
HA4	2	6	E3	16	E6	16	--
HA5	7	5	E2	15	--	15	--
HA6	6	4	E1	14	--	14	--
HA7	5	3	E4	13	--	13	--
HA8	27	25	F1	3	F6	3	--
HA9	12	24	F3	2	F7	2	--
HA10	24	21	F2	31	--	31	--
HA11	26	23	G1	1	--	1	--
HA12	4	2	F4	12	--	12	--
HA13	28	26	G2	4	--	4	--
HA14	3	1	H1-In	5	H8-In H4-Out	5	--
HA15	--	--	H2-In	11	H7-In K3-Out	11	--
HA16	--	--	--	10	K6	10	--
HA17	--	--	--	6	G5	6	--

Table 3-4. VOCON Board Data Bus (D) Pinouts

Bus	U402	U403	U404	U405	U406	U414
D0	B9	B9	21	G3	--	B9
D1	C8	C8	22	J1	--	C8
D2	C9	C9	23	K3	--	C9
D3	D9	D9	25	L3	--	D9
D4	E8	E8	26	J3	--	E8
D5	E9	E9	27	K4	--	E9
D6	F9	F9	28	H4	--	F9
D7	G9	G9	29	L2	--	G9
D8	G8	G8	--	K2	H10	G8

Table 3-4. VOCON Board Data Bus (D) Pinouts (Continued)

Bus	U402	U403	U404	U405	U406	U414
D9	H8	H8	--	J4	H9	H8
D10	J9	J9	--	K5	H8	J9
D11	J8	J8	--	L5	J8	J8
D12	J2	J2	--	J5	L9	J2
D13	J1	J1	--	K6	K8	J1
D14	H2	H2	--	J6	L8	H2
D15	G2	G2	--	H7	J7	G2
D16	G1	G1	--	L9	K7	G1
D17	F1	F1	--	K8	L7	F1
D18	E1	E1	--	K7	J6	E1
D19	E2	E2	--	J7	K6	E2
D20	D1	D1	--	L8	J5	D1
D21	C1	C1	--	K10	L6	C1
D22	C2	C2	--	J9	L5	C2
D23	B1	B1	--	J10	K5	B1

Table 3-5. VOCON Board Data Bus (HD) Pinouts

Bus	U201	U202	U204	U205	U206	U210	U405
HD0	14	1	C6	21	C3	21	C7
HD1	15	12	B8	22	B1	22	B8
HD2	16	13	C7	23	C2	23	D7
HD3	18	15	D5	25	D4	25	A9
HD4	19	16	C8	26	C1	26	C9
HD5	20	17	D7	27	D2	27	C10
HD6	21	18	D6	28	D3	28	D8
HD7	23	19	D8	29	D1	29	C8

Table 3-6. U204 (MCU)

U204 Pin #	Description	To/From
B1	PE0	R260
B2	PE1 B SENSE/LBAT/PWR DWN	VR214
C3	PE2	N/C
A3	PE3 EMERG	J901-4
D3	PE4	N/C
A2	PE5	N/C
B3	PE6 SPKR COMMON	R263
C4	PE7 EXT SPKR	R261
B7	4XECLK (7.3726 MHz)	U206-A3
J7	PD0 BOOT DATA IN (RXD)	J501-17 U206
G6	PD1 BOOT DATA OUT (TXD)	J501-18 U208
H6	PD2 MISO	J801-7
J6	PD3 MOSI	J501-9 J801-8
G5	PD4 SPI SCK	J501-8 J801-9
H5	PD5 DA SEL*	J501-13
C5	MOD A	Q204C
B5	MOD B	Q204C
G3	PA0 SCLK	U405-C6 U406-C9
J2	PA1 BOOT MODE	U405
H3	PA2 HREQ*	U405-B10
J3	PA3 SB9600 BUSY	J501-20
G4	PA4 IRQA*	U406-F10 U405-H10
H4	PA5 BOOTSTRAP*	U206-E5
J4	PA6 ECLK SHIFT	Q205B
F5	PA7	N/C
E5	RESET/RESET*	U201-31 U206-E4
E6	PG7 CSPROG*	U206-E3
F8	PG6 CSGEN*	U211-1
G8	PG5 CS101*	U206-G1

Table 3-6. U204 (MCU) (Continued)

U204 Pin #	Description	To/From
G7	PG4 ADSIC RST*	U406-A8
F7	PG3 ADSIC SEL*	U406-B8
H8	PG2 DSP RST*	U405-G9
F6	PG1 ROSC/PSC CE*	J501-12
H7	PG0 SYN SEL*	J501-11
B6	R/W*	U405-D9 U206-B3
A5	ECLK (1.8432 MHz)	U206-A4
E8	XIRQ*	R233
E7	IRQ*	U206-E2
A6	EXTAL 7.3728 MHz	Y201
A7	XTAL	Q205C

Table 3-7. U206 (SLIC)

U206 Pin #	Description	To/From
F3	PH0	N/C
F4	PH1	N/C
F2	PH2	N/C
H1	PH3	N/C
G3	PH4	N/C
H2	PH5 INT PTT*	J501-30 U206-H2
H3	PH6 EMC REQ	J801-11
K2	PH7 LOCK DET*	J501-10 U302-41 CR502
B4	PJ0 MOB IRQ*	J501-26
D5	PJ1 VIP IN2	J501-25
A5	RS232 DATA OUT	J501-43
B6	PJ3 CTSOUT*	J501-5

Table 3-7. U206 (SLIC) (Continued)

U206 Pin #	Description	To/From
A6	PJ4	R268
C6	PJ5 OPT SEL2 (KEYLOAD*)	R237
A7	PJ6 VIP IN1	J501-24
D6	PJ7 EMC EN*	J801-10
C9	POR*	U409-2
E4	HC11RST*/RESET*	U204-E5 U201-31
C4	OE*	U201-25 U202-22 U205-32 U210-32
B3	R/W*	U405-D9 U204-B6
E5	BOOTSTRAP*	U204-H4
A2	MEM R/W*	U201-29 U202-27
E3	AV*/CSPROG*	U204-E6
G1	CE*/CS101*	U204-G8
G2	SCNSLB	R252
K5	ROM1CS*	U205-30
F5	ROM2CS*	U210-30
J4	EE1CS*	U201-22
J8	KEYFAIL*	J801-15 J501-21
B2	RS232 DATA IN	J501-50
J2	BOOT DATA IN	J501-17 U204-J7
A3	4XECLK	U204-B7
A4	ECLK	U204-A5
J3	VIP OUT2	J501-23
G4	SPKREN*	J501-44
K8	BUSY OUT*	J501-19
G9	TXPA EN*	J501-14
F8	5V EN*	J501-15

Table 3-7. U206 (SLIC) (Continued)

U206 Pin #	Description	To/From
G7	MICEN	J501-45
J9	B+ CNTL	U409-2 Q206B
E7	VIP OUT1	J501-22
K7	CS3B EMC MAKEUP*	J801-12
G6	CS2B RAM SEL*	U211-2
J7	CS1B HEN*	U405-E8
G8	DISP EN*/LATCH SEL*	J601-4
H9	RED LED	N/C
E8	GRN LED	N/C
E2	IRQ*	U204-E7

Table 3-8. VOCON U405 (DSP)

U405 Pin #	Description	To/From
C1	PS*	U404-6 U406-D8
C3	DS*	
A3	RD*	U404-32 U406-F8
C4	WR*	U404-7 U406-G10
B3	X/Y*	
A4	BR*	R411
B4	BG*/BS*	R432
H10	MODA/IRQA*	U204-G4 U406-F10
H9	MODB/IRQB*	U406-F9
J8	XTAL	R415
K9	EXTAL	U406-G9 (DCLK)
A2	STO	U406-H1
C5	SRO	U406-L3
B6	SCK	U406-G3
B2	SC2	U406-H2

Table 3-8. VOCON U405 (DSP) (Continued)

U405 Pin #	Description	To/From
B5	SC1	U406-J4
B9	SC0	U406-K4
C6	SCLK	U204-G3 U406-C9
A7	TXD/EMC RXD	J801-3
B7	RXD/EMC TXD	J801-4
G9	RESET/DSP RST*	U204-H8
E10	HACK*	R409
B19	HREQ*	U204-H3
E8	HEN*	U206-J7
D9	HR/W*	U204-B6

Table 3-9. VOCON U406 (ADSIC)

U406 Pin #	Description	To/From
D8	PS*	U404-6 U405-C1
G10	WR*	U405-C4 U404-7 U402/3/14-K2
F8	RD*	U405-A3 U404-32 U402/3/14-K6
J9	RSEL	U403-J3 U414-K3
G2	TP1	R407
G1	TP2	N/C
A4	AB1	R402
B8	SEL*/ADSIC SEL*	U204-F7
A8	RST*/ADSIC RST*	U204-G7
F10	IRQA/IRQA*	U204-G4 U405-H10
F9	IRQB/IRQB* 8 kHz	U405-H9

Table 3-9. VOCON U406 (ADSIC) (Continued)

U406 Pin #	Description	To/From
F2	SSW/EPS*	U404-30
C9	SCLK/SPI SCK	U204-G5 J501-8 J801-9
C10	SPO/MOSI	J501-9 J801-8
C1	MA1	U501-39
B5	SDO	U501-40
B1	VRO REFMOD	J501-48
B2	MODIN	J501-49
L3	RXD SRO 2.4 MHz	U405-C5
J4	RFS SC1	U405-B5
K4	SCKR SCO	U405-B9
H1	TXD STO	U405-A2
H2	TFS SC2 48 kHz	U405-B2
G3	SCKT SCK 1.2 MHz	U405-B6
C8	DA4 BNK2	U404-10
C3	DA7B BNK1	U404-11
B6	DA7A BNK0	U404-5
J1		N/C
J2		N/C
K1		N/C
K2		N/C
H3	DIN*/DOUT*	J501-1
K3	DIN/DOUT	J501-2
F3	IDC ODC 2.4 MHz	J501-7
J3	SBI	J501-6
C7	XTL 33 MHz	Y401
C6	EXTL	Y401
K9	OSC*	CR402
G9	DCLK	U405-K9

3.4 ASTRO Spectra Plus VOCON Board

This section of the theory of operation provides a detailed circuit description of an ASTRO Digital Spectra Plus Vocoder/Controller (VOCON) Board. When reading the Theory of Operation, refer to your appropriate schematic and component location diagrams located in "Chapter 7. Schematics, Component Location Diagrams, and Parts Lists" of this manual. This detailed Theory of Operation will help isolate the problem to a particular component. However, first use the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* to troubleshoot the problem to a particular board.

NOTE: The information in this subsection applies to the **Plus** VOCON Board. Refer to Section 3.3, "ASTRO Spectra VOCON Board," on page 3-15 for information on the ASTRO Spectra VOCON (non Plus) board.

3.4.1 General

The ASTRO Spectra Plus VOCON board consists of two subsystems; the vocoder and the controller. Although these two subsystems share the same printed circuit board and work closely together, it helps to keep their individual functionality separate in describing the operation of the radio. The controller section is the central interface between the various subsystems of the radio. It is very similar to the digital logic portion of the controllers on many existing Motorola radios. Its main task is to interpret user input, provide user feedback, and schedule events in the radio operation, which includes programming ICs (Integrated Circuits), steering the activities of the DSP (Digital Signal Processor), and sending messages to the display through the control head. The vocoder section performs functions previously performed by analog circuitry. This includes all tone signaling, trunking signaling, and conventional analog voice, etc. All analog signal processing is done digitally utilizing a DSP56600. In addition it provides a digital voice plus data capability utilizing IMBE voice compression algorithms. Vocoder is a general term used to refer to these DSP based systems and is short for voice encoder. In addition, the ASTRO Spectra Plus VOCON board provides the interconnection between the MCU (microcontroller unit), DSP, command board, and UCM (Universal Encryption Module) on secure-equipped radios.

3.4.2 ASTRO Spectra Plus Controller Section

Refer to Figure 3-14 and your specific schematic diagram located in Chapter 7.

The controller section of the ASTRO Spectra Plus VOCON board consists entirely of digital logic comprised of a microcontroller unit core (Patriot IC-U300), and memory consisting of: SRAM (U302), and FLASH ROM (U301). The Patriot IC is a dual-core processor that contains a DSP56600 core, a MCore 210 microcontroller core and custom peripherals. Note: When the Controller Section references the MCU, it will be referencing the Mcore 210 inside the Patriot IC (U300).

The MCU (U300) memory system is comprised of a 256k x 16 SRAM (U302) and a 2M x 16 FLASH ROM (U301). The MCU also contains 22.5k x 32 of internal SRAM. The FLASH ROM contains the programs that the Patriot IC executes, and is used to store customer specific information and radio personality features (i.e. codeplug information). The FLASH ROM allows the controller firmware to be reprogrammed for future software upgrades or feature enhancements. The SRAM is used for scratchpad memory during program execution.

The controller performs the programming of all peripheral ICs. This is done via a serial peripheral interface (SPI) bus, and through General Purpose Input/Outputs (GPIO) from the Patriot IC. ICs programmed through these interfaces include the Synthesizer, Prescaler, DAIC, and KRSIC (U200) and ADDAG (U201).

In addition to the SPI bus, the controller also maintains two asynchronous serial busses; the SB9600 bus and an RS232 serial bus. The SB9600 bus is for interfacing the controller section to different hardware option boards, some of which may be external to the radio. The RS232 is used as a common data interface for external devices.

User input from the control head is sent to the controller through SB9600 bus messages. Feedback to the user is provided by the display on the control head. The display is 2-line 14 characters on the W3 model, 8 characters on W4, W5, and W7 models; and 11 characters on the W9 model.

The controller schedules the activities of the DSP through the host port interface, which is internal to the Patriot IC (the MCU and DSP are both contained within the Patriot IC). This includes setting the operational modes and parameters of the DSP. The controlling of the DSP is similar to programming analog signaling ICs on standard analog radios.

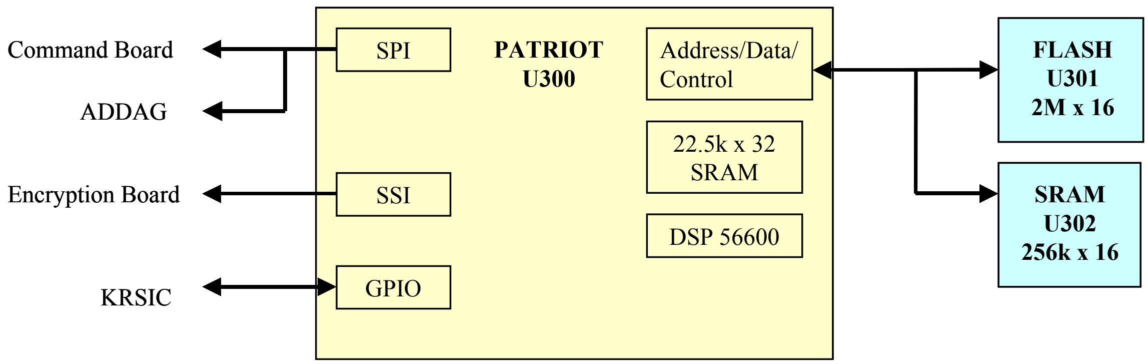


Figure 3-14. ASTRO Spectra Plus VOCON Board - Controller Section

3.4.3 ASTRO Spectra Plus Vocoder Section

Refer to Figure 3-15 and your specific schematic diagram in Chapter 7.

The vocoder section of the ASTRO Spectra Plus VOCON board is made up of a digital signal processor (DSP) core, 84Kx24 Program RAM, 2Kx24 Program ROM, and 62Kx16 Data RAM, which are all integrated into the Patriot IC (U300). The vocoder also contains the KRSIC (U200) and ADDAG (U201).

The FLASH ROM (U301) contains both the program code executed by the DSP and the controller firmware. As with the FLASH ROM used in the controller section, the FLASH ROM is reprogrammable so new features and algorithms can be updated in the field as they become available. Depending on the mode and operation of the DSP, corresponding program code is moved from the FLASH ROM into the faster SRAM, where it is executed at the full bus rate.

The KRSIC and ADDAG IC's are the support IC's for the DSP. In the receive mode, the KRSIC (U200) acts as an interface to the ABACUS IC, which can provide data samples directly to the DSP for processing. In the transmit mode, the ADDAG (U201) provides a serial digital-to-analog (D/A) converter. The ADDAG (U201) also has a function in receive mode for special applications. The data generated by the DSP is filtered and reconstructed as an analog signal to present a modulation signal to the VCO (voltage-controlled oscillator). Both the transmit and receive data paths between the DSP and ADDAG are through the DSP SSI port.

When transmitting, the microphone audio is passed from the command board to the MC145483 CODEC (U402), which incorporates an analog-to-digital (A/D) converter to translate the analog waveform to a data stream. The data is made available to the DSP through the Serial Audio Port (SAP) of the Patriot IC. In the converse way, the DSP writes speaker data samples to a D/A in the CODEC (U402) through the SAP. The CODEC (U402) provides an analog speaker audio signal to the audio power amplifier on the command board.

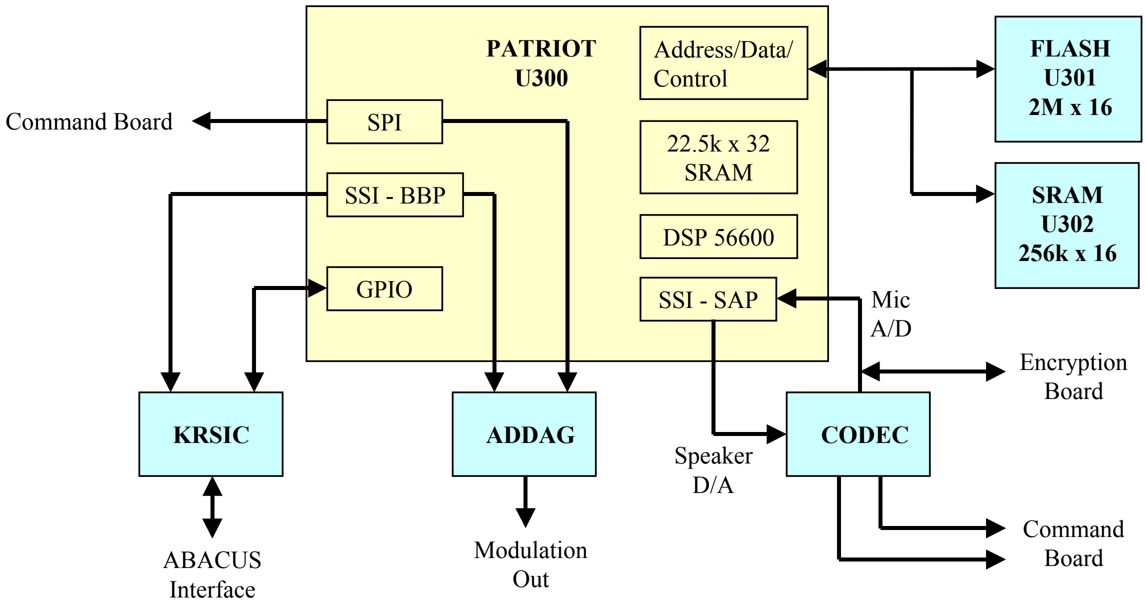


Figure 3-15. ASTRO Spectra Plus VOCON Board - Vocoder Section

3.4.4 ASTRO Spectra Plus RX Signal Path

The vocoder processes all received signals digitally. This requires a unique back end from a standard analog radio. This unique functionality is provided by the ABACUS IC with the KRSIC (U200) acting as the interface to the DSP. The ABACUS IC located on the transceiver board provides a digital back-end for the receiver section. It provides a digital output of I (In phase) and Q (Quadrature) data words at a 20 kHz sampling rate (refer to the Receiver Back-End section for more details on ABACUS operation). This data is passed to the DSP through an interface with the KRSIC (U200) for appropriate processing. The KRSIC interface to the ABACUS is comprised of the four signals SBI, DIN, DIN*, and ODC (refer to Figure 3-16).

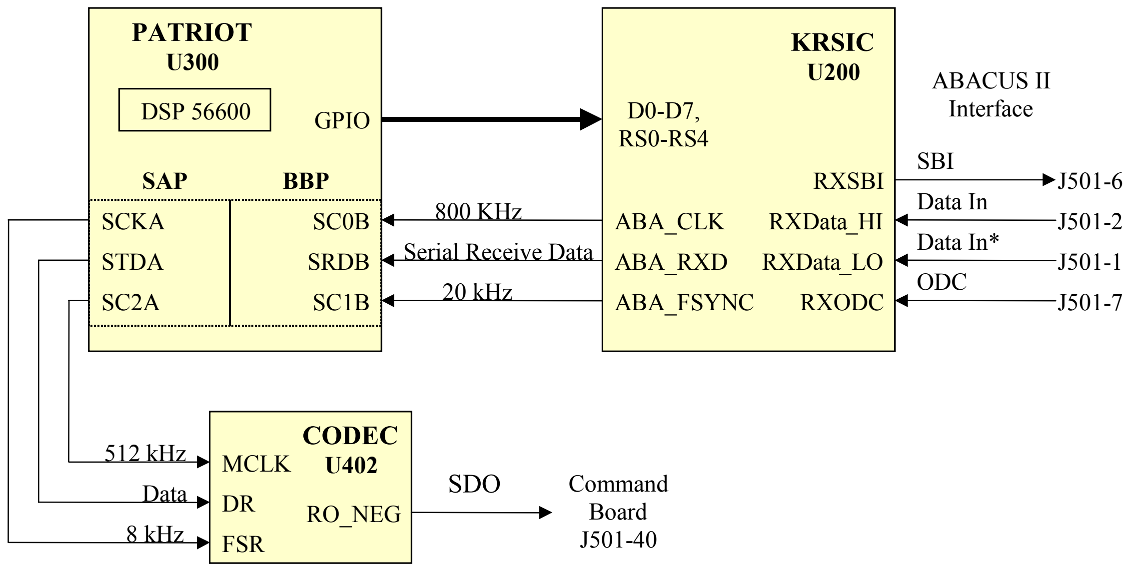


Figure 3-16. ASTRO Spectra Plus RX Mode

NOTE: An asterisk symbol (*) next to a signal name indicates a negative or NOT logic true signal.

ODC is a clock ABACUS provides to the KRSIC. Most internal KRSIC functions are clocked by this ODC signal at a rate of 2.4 MHz and is available as soon as power is supplied to the circuitry. This signal may initially be 2.4 or 4.8 MHz after power-up. It is programmed by the KRSIC through the SBI signal to 2.4 MHz when the KRSIC is initialized by the MCU (in the Patriot IC) through GPIO. SBI is a programming data line for the ABACUS. This line is used to configure the operation of the ABACUS and is driven by the KRSIC. The MCU programs many of the KRSIC operational features through the GPIO interface. When the KRSIC is programmed properly by the MCU, the KRSIC in turn sends this data to the ABACUS through the SBI.

DIN and DIN* are the data lines on which the I and Q data words are transferred from the ABACUS. These signals make up a differentially encoded current loop. Instead of sending TTL type voltage signals, the data is transferred by flowing current one way or the other through the loop. This helps to reduce internally generated spurious emissions on the RF board. There are single-ended driver circuits between the ABACUS and the KRSIC, which are used to convert the differential current driven by the ABACUS. After the driver circuits, the I and Q samples are detected and transferred to a serial transmitter.

The DSP accesses this data through its SSI port. The SSI port is used by the DSP for both transmit and receive data transferal, but only the receive functions will be discussed in this section. The KRSIC transfers the data to the DSP on the SRDB line at a rate of 1.2 MHz. This is clocked synchronously by the KRSIC which provides a 1.2 MHz clock on SC0B. In addition, a 20 kHz interrupt is provided on SC1B, signaling the arrival of a data packet. This means the I and Q sample data packets are available to the DSP at a 20 kHz rate which represents the sampling rate of the received data. The DSP then processes this data to extract audio, signaling, etc. based on the 20 kHz interrupt.

Speaker audio is processed by the DSP (in the Patriot IC), which outputs the audio data words to the speaker D/A inside the CODEC (U402), and an analog waveform is generated on the SDO (Speaker Data Out) line. In conjunction with the speaker D/A, the CODEC (U402) has the ability to attenuate the receive analog output, using three data bits which provide programmable attenuation to set the rough signal attenuation.

For secure messages, the digital signal data must be passed to the secure module for decryption prior to DSP processing of the speaker data. The DSP transfers the data to and from the secure module through it's SSI port consisting of TXD and RXD. The secure module communicates with the DSP through its SPI bus, therefore a SSI to SPI conversion circuit is on the ASTRO Spectra Plus VOCON board to ensure communication between the DSP and the secure module. Configuration and mode control of the secure module is performed by the MCU through the SSI/SPI bus.

The CODEC presents the analog speaker audio to the command board's audio power amplifier, which drives the external speaker. For more information on this subject, refer to Section 3.2, "Command Board," on page 3-8.

Since all of the audio and signaling is processed in DSP software algorithms, all types of audio and signaling follow this same path. There is, however, one exception. Low-speed trunking data is processed by the host uP through the SCLK port of the DSP. The DSP extracts the low-speed data from the received signal and relays it to the host uP for processing.

3.4.5 ASTRO Spectra Plus TX Signal Path

The transmit signal path (refer to Figure 3-17) follows some of the same design structure as the receive signal path described in Section 3.4.4, "ASTRO Spectra Plus RX Signal Path," on page 3-41.

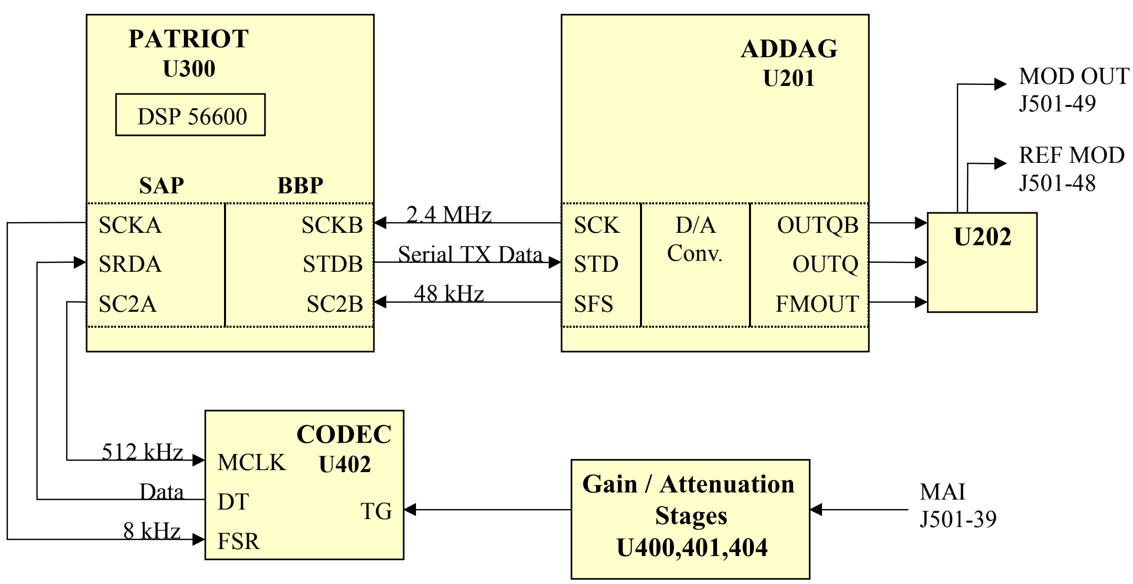


Figure 3-17. ASTRO Spectra Plus TX Mode

The analog microphone signal from the command board is passed to the ASTRO Spectra Plus VOCON on MAI (Mic Audio In). This signal passes through gain and attenuation stages so that the correct amplitude level of the audio is presented to the CODEC input. The CODEC contains a microphone A/D. The microphone A/D converts the analog signal to a digital data stream and transmits them to the SAP of the Patriot IC. The DSP accesses this data through this port. As with the speaker data samples, the DSP reads the microphone samples from registers mapped into its memory space.

As with the received trunking low-speed data, low speed transmit data is processed by the MCU and returned to the DSP. For secure messages, the digital signal data may be passed to the secure module prior to DSP processing before the ADDAG IC. The DSP transfers the data to and from the secure module through it's SSI port consisting of TXD and RXD. The secure module communicates with the DSP through its SPI bus, therefore a SSI to SPI conversion circuit is on the ASTRO Spectra Plus VOCON board to ensure communication between the DSP and the secure module. Configuration and mode control of the secure module is performed by the MCU through the SSI / SPI bus.

The DSP processes these microphone samples, generates and mixes the appropriate signaling, and filters the resultant data. This data is then transferred to the ADDAG IC on the DSP BBP (Baseband Port) - SSI port. The transmit side of the SSI port consists of SC2B, SCKB, and STDB. The DSP BBP-SSI port is a synchronous serial port. SCKB is the 2.4 MHz clock input derived from the ADDAG, which makes it synchronous. The data is clocked over to the ADDAG on STDB at a 2.4 MHz rate. The ADDAG generates a 48 kHz interrupt on SC2B so that a new sample data packet is transferred at a 48 kHz rate, which sets the transmit data sampling rate at 48Ksp.

Within the ADDAG IC, these samples are then input to a transmit D/A, which converts the data to an analog waveform. This waveform is the modulation out signal from the ADDAG ports, FMOUT, OUTQ, and OUTQB. FMOUT is single-ended, while OUTQ and OUTQB form a differential pair. This pair is then sent to an Op-Amp (U202), which outputs a single-ended waveform. FMOUT is passed through an Op-Amp (U202) for attenuation. These signals are both sent to the command board, where they go through a gain stage and then to the VCO and Synthesizer. MODOUT is used primarily for audio frequency modulation; REFMOD is used to compensate for low-frequency response to pass subaudible modulated signals (such as PL).

3.4.6 ASTRO Spectra Plus Controller Bootstrap and Asynchronous Busses

The SB9600 bus (see Figure 3-18) is an asynchronous serial communication bus, utilizing a Motorola proprietary protocol. It provides a means for the MCU to communicate with other hardware devices. In the ASTRO Digital Spectra Plus radio, it communicates with hardware accessories connected to the accessory connector and the remote interface board.

The SB9600 bus utilizes the UART internal to the MCU, operating at 9600 baud. The SB9600 bus consists of LH / TX_Data (J501-18), LH / RX_Data (J501-17), and BUSY_RTS (J501-20) signals. LH / TX_Data and LH / RX_Data are the UTXD1 (K11) and URXD1 (K12) ports of the Patriot IC (U300), respectively. BUSY_RTS (U300-URTS1- L16) is an active-low signal, which is pulled low when a device wants control of the bus.

The same UART internal to the MCU is used in the controller bootstrap mode of operation. This mode is used primarily in downloading new program code to the FLASH ROM (U301) on the VOCON board. In this mode, the MCU accepts special code downloaded at 115k baud through the UART instead of operating from program code resident in its ROMs.

A voltage greater than 11 Vdc applied to J501-31 (Vpp) will trip the circuit comprising VR304, Q300, and U307. This circuit sets the MOD pin (J1) of the MCU to bootstrap mode (logic 1). A voltage greater than 7 Vdc applied to J501-31 (Vpp) will trip the circuit comprising VR305 and Q302. This will not put the MCU in Bootstrap mode, but the software will detect this using pin PA7 (G11), which will allow the user to interface with the Customer Programming Software, Tuner, and Flashport.

The ASTRO Digital Spectra Plus radio has an additional asynchronous serial bus, which utilizes the RS232 bus protocol. This bus utilizes the secondary UART in the Patriot IC (U300). It consists of TX / RS232 (J501-43), RX / RS232 (J501-50), CTS / RS232 (J501-5), and RTS / RS232 (J501-42). It is a four-wire duplex bus used to connect to external data devices.

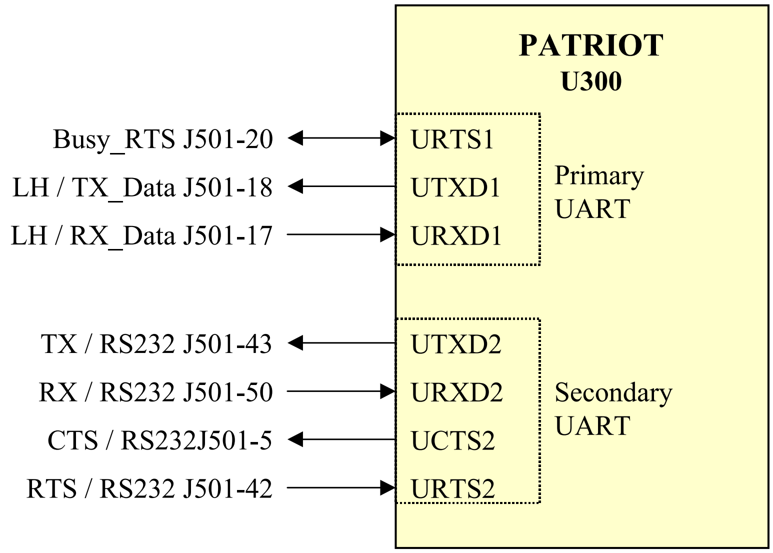


Figure 3-18. ASTRO Spectra Plus Host SB9600 and RS232 Ports

3.4.7 ASTRO Spectra Plus Serial Peripheral Interface Bus

This bus is a synchronous serial bus made up of a data, a clock, and an individual IC unique select line. Its primary purpose is to configure the operating state of each IC. ICs programmed by this include: ADDAG, Synthesizer, Prescaler, and the DAIC.

The MCU within the Patriot IC (U300) is configured as the master of the bus. It provides the synchronous clock (SPI_SCK), a select line, and data (MOSI [Master Out Slave In]). In general the appropriate select line is pulled low to enable the target IC and the data is clocked in. The SPI bus is a duplex bus with the return data being clocked in on MISO (Master In Slave Out). The only place this is used is when communicating with the ADDAG. In this case, the return data is clocked back to the MCU on MISO (master in slave out).

3.4.8 ASTRO Spectra Plus MCU and DSP System Clocks

The MCU within the Patriot IC (U300) needs two clocks for proper operation. A 16.8 MHz sine-wave reference is provided at the CKIH (A6) pin of the Patriot IC (U300). The source of this clock is a 16.8 MHz oscillator (Y400), and its associated filtering circuitry. This clock is also provided to the KRSIC (U200), and the ADDAG IC (U201). The MCU has the capability of running at higher clock rates, which are programmable and based on this 16.8 MHz reference. The DSP within the Patriot IC (U300) also uses the 16.8 MHz provided at the CKIH (A6) pin as a reference.

The Patriot IC (U300) also requires a 32 kHz square-wave clock, provided at the CKIL (J7) pin. This clock is generated by a 32 kHz crystal (Y401), with supporting circuitry for oscillation. This clock is utilized only for the Patriot IC (U300), and is used for reset capability and other Patriot IC (U300) functions.

3.4.9 ASTRO Spectra Plus Voltage Regulators

The ASTRO Spectra Plus VOCON board contains two voltage regulators, a 3-V regulator (U411) and a 1.8-V regulator (U410). SW+5-V, which is routed to the ASTRO Spectra Plus VOCON board from the command board, drives the two regulators. Figure 3-19 shows the DC distribution for the ASTRO Spectra Plus VOCON Board.

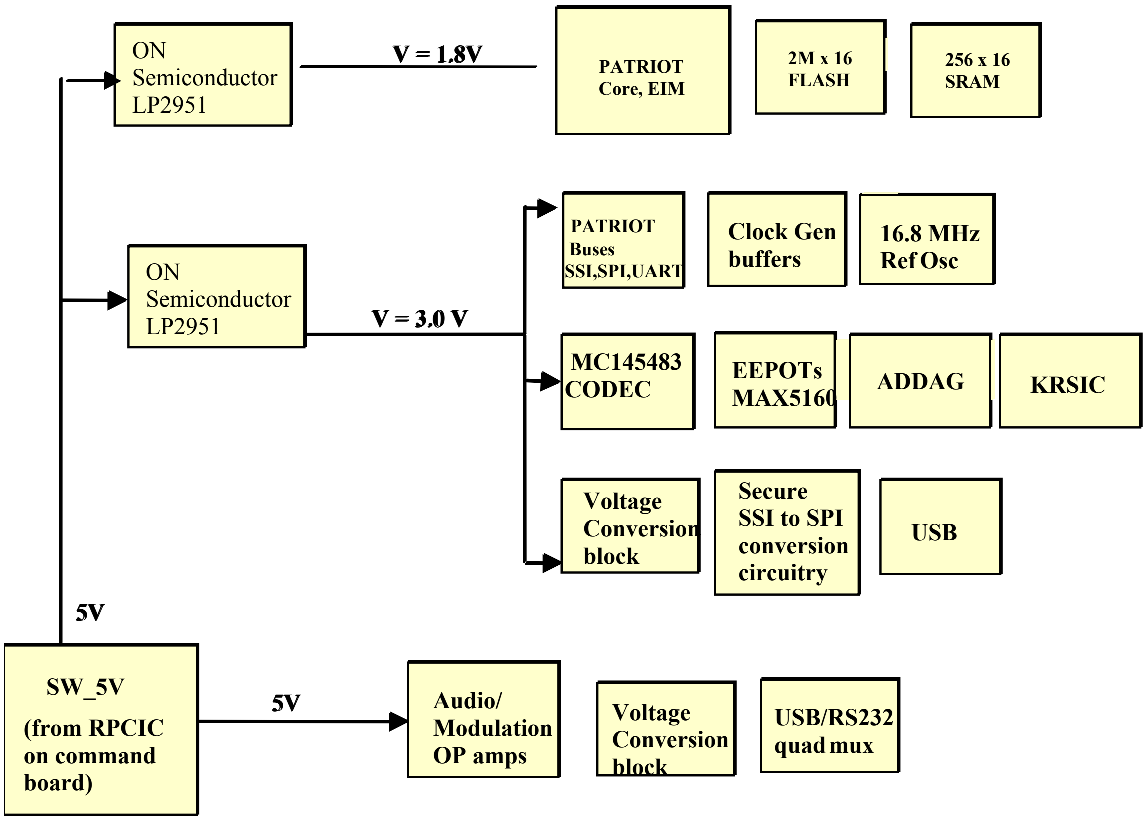


Figure 3-19. ASTRO Spectra Plus VOCON DC Distribution

U410 and U411 are on Semiconductor LP2951CD adjustable regulators. The output voltage of these regulators is determined by the resistive divider network between the regulator output and the error amplifier feedback input. The LP2951 has error output lines which are open collector and requires a pull up resistor (R332). The error line is high when the output voltage is high and low otherwise. U412 is a 4.2-V detect circuit for the SW_5-V line. The output of this detector is tied to the error outputs of the LP2951 regulators as a low voltage detect (LV_detect) circuit. C438 provides delay on the LV_detect line during startup. This is to allow all regulators to settle prior to Patriot U300 coming out of reset.

3.4.10 ASTRO Spectra Plus Radio Power-Up/Power-Down Sequence

The radio power-up sequence begins when the user actuates the control head's on/off switch. The control head then produces the switched B+ (SWB+) output voltage which is routed to the command board. Upon sensing the SWB+ voltage, the command board circuitry powers on the 9.6V and the SW +5-V regulated supplies. The ASTRO Spectra Plus VOCON board contains two voltage regulators, a 3-V regulator (U411) and a 1.8-V regulator (U410). The SW+5-V from the command board is routed to the ASTRO Spectra Plus VOCON board via connector P501, and drives the two regulators. When SW+5-V increases above 4.2 V and after a delay time chosen by C438, the voltage detector (U412) disables the power-on reset to the Patriot IC (U300), enabling the device.

When the MCU comes out of reset, it fetches the reset vector in ROM at $FFFE, $FFFF and begins to execute the code this vector points to. Among other things it enables the correct memory map for the MCU. It configures all the transceiver devices on the SPI bus. The MCU then pulls the ADDAG and KRSIC out of reset. It then configures the ADDAG through the SPI bus configuring among other things, the DSP memory map. While this is happening, the DSP is fetching code from the FLASH (U301) into internal RAM and beginning to execute it. It then waits for a message from the MCU that the ADDAG has been configured, before going on.

During this process, the MCU does power diagnostics. These diagnostics include verifying the MCU system RAM and verifying the data stored in the FLASH ROM. The MCU queries the DSP for proper status and the results of DSP self tests. The DSP self tests include testing the system RAM and verifying the program code. Any failures cause the appropriate error codes to be sent to the display. If everything is OK, the appropriate radio state is configured and the unit waits for user input.

On power-down, the user actuates the radio's on/off switch, removing the SW_B+ signal from the ASTRO Spectra Plus VOCON board. The host processor, after polling ROW3 (G2) and acknowledging the signal loss, begins the power-down sequence. Since the host holds the 9.6-V/5V_EN (enable) line active by controlling the state of the ROW5 / 5_EN line at P501, pin 15, this does not immediately remove power. The host then saves pertinent radio status data to the external FLASH (U301). Once this is done, the ROW5 / 5V_EN line is released (brought to logical 1), turning off 9.6-V and the SW+5-V regulators on the command board. When the SW_+5-V slumps to about 4.2 Vdc, the voltage detector (U412) on the ASTRO Spectra Plus VOCON board activates the system reset to the Patriot IC (U300). This turns off the host processor.

3.5 Voltage Control Oscillator

This section of the theory of operation provides a detailed circuit description of voltage control oscillator (VCO). When reading the Theory of Operation, refer to your appropriate schematic and component location diagrams located in "Chapter 7. Schematics, Component Location Diagrams, and Parts Lists". This detailed Theory of Operation will help isolate the problem to a particular component. However, first use the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* to troubleshoot the problem to a particular board.

3.5.1 VHF Band

3.5.1.1 General

The frequency injection string consists of a voltage-controlled oscillator (VCO) constructed on a ceramic substrate and amplifier and divider stages located on the PC board. The components associated with the PC board may be repaired by conventional methods while the VCO substrate should be replaced as a unit.

3.5.1.2 DC Voltage Supplies

The 9.6-V supply enters the VCO carrier board at P601-2. It powers the receiver amplifier (Q675) and its associated biasing components. The keyed 9.4-V supply enters the carrier board at J601-5, but only during the transmit mode. K9.4 powers the divider (Q681), and the buffer amplifiers (Q682, Q683). The 8.6-V supply enters through P601-12 and passes to MP652, MP653, and MP654 on the VCO substrate. The 8.6 V supplies the output buffer on the VCO substrate, and supplies Q642 and 0643, the PIN diode drivers.

3.5.1.3 VCO

The VCO utilizes a common-gate FET in a Colpitts configuration as the gain device. The LC tank circuit's capacitive portion consists of a varactor bank and a laser-trimmed stub capacitor. The inductive portion consists of microstrip transmission-line resonators. The stub capacitor serves to tune out build variations. Tuning is performed at the factory and is not field adjustable. The varactor network changes the oscillator frequency when the DC voltage of the steering line changes. The microstrip transmission lines are shifted in and out of the tank by PIN diodes for coarse frequency jumps. The varactor bank consists of CR644 CR645 and L648. The positive steering line connects to the cathodes of both varactors through L3647, an RF choke. This line is normally between 0.5 and 8.5 Vdc, depending on the frequency programmed in the synthesizer. The negative steering line connects to the anodes of the varactors through L646 and is normally 3.9 (±0.3) Vdc.

Diode CR643, a third varactor tapped into the main transmission line resonator, modulates the oscillator during transmit. The 8.6 Vdc supplies bias to the cathode. Modulation is coupled to the anode through C639, R636, C636, and R3637, which also provide filtering and attenuation to the modulation path.

Components CR646, C668, and R655 provide automatic gain control for the FET. A hot carrier diode, CR3646, detects the peak RF voltage swings on the source of the FET. A negative voltage, proportional to the magnitude of the RF voltage swing, is applied to the gate of the FET, thereby lowering its gain and accomplishing automatic gain control. Typical DC value of the gate bias is -0.8 to -1.7 V, depending on the state of the oscillator.

PIN diodes, CR640, CR641, and CR642, serve to couple secondary transmission lines into and out of the main oscillator tank, depending on which range the VCO is operating. AUX 1* controls CR642 and CR643; AUX 2* controls CR3640. When AUX 1* goes high, Q643 turns off and a reverse-bias voltage of about 8.6 Vdc is applied to the PIN diodes to turn them off. When AUX1* goes low, Q643 turns on and a forward-bias current of about 15mA is supplied to the PIN diodes to turn them on. The other PIN diode driver network operates similarly.

The VCO output is coupled through C672 to Q645 to amplify the signal and provide load isolation for the VCO. The collector voltage of Q645 is normally about 5 Vdc.

3.5.1.4 Synthesizer Feedback

The synthesizer locks the VCO on frequency by the VCO feedback to the prescaler IC on the RF board. The output of the VCO goes into a low-pass filter consisting of C685, L676, and C687. After it is filtered, the signal splits into three directions - the majority of which passes to the RX buffer through a 2db attenuator. A smaller portion of the signal passes through C679 to the divider. Finally, another small portion of the signal is fed back to the RF board through C676 to P601 -1. Although on a DC connector, P601 -1 is an RF-sensitive node. To measure the synthesizer feedback power, use a high-impedance probe, or operate the VCO in an external fixture.

3.5.1.5 RX Buffer Circuitry

After the low-pass filtering state, VCO power is attenuated 2dB by R678, R680, and R679. The RX buffer is a 50-ohm in-and-out stage that uses L681 and C689 for the input match and C691, L678, C692, and R699 for the output match. The 9.6 Vdc supplies the RX buffer for a gain of about 10db. Components R677 and C686 help to filter out some of the 9.6-V supply's noise from the RX buffer. Transistors Q677, Q678, and associated resistors set the bias level of the RX buffer device, Q675. The collector voltage and current should be near 6.6 V and 29 mA, respectively. Resistor R682 feeds the base of 0675 while L677 is used as the collector choke; R681, C690, and C688 are added to increase stability. The cable from the RX frontend is plugged into J642.

3.5.1.6 Frequency Divider and TX Buffer Circuitry

During transmit, the VCO oscillates at twice the transmit frequency. A frequency-divider circuit following the VCO buffer divides the VCO's output frequency by two. The circuit is known as a "regenerative frequency divider" in which a mixer and a feedback amplifier are used to divide the frequency of the input signal. The divider circuit consists of transformers T601 and T602, diodes CR601, CR602, amplifier Q681, and the associated bias circuitry. The divider action of this circuit can be understood by tracing the signal through the circuit as follows: The 300 MHz range signal from the VCO buffer is fed into the primary of T602. Note that T602, T601, and diodes CR601 and CR602 form a balanced mixer. (CR601 and CR602 are actually two diodes in one SOT-23 package.) To analyze the frequency division action of the circuit, it must be assumed that the divided output frequency of 150 MHz already exists at the secondary of T601. This 150 MHz signal passes through the low-pass filter consisting of L661, L662, and C651. The 150 MHz signal is now at the input of the amplifier device, Q681. The amplified 150 MHz signal is now applied back into the balanced mixer by the center tap of T601. The difference frequency of the two applied signals (300 MHz and 150 MHz) is 150 MHz, which is half the VCO's frequency. The difference frequency is output through the secondary of T601 where it had been previously assumed to exist. This completes the feedback loop.

The 150 MHz signal is tapped off of the emitter resistor of Q681 and is amplified by the buffer stage, Q682. Transistor Q683 amplifies the signal to 10dBm, which is the level required by the power amplifier. The signal passes through a low-pass filter before exiting the board through J641.

3.5.2 UHF Band

3.5.2.1 General

The VCO is located on an alumina substrate with a metallic cover. The buffer-doubler-buffer section is located on the PC board and may be repaired using normal repair methods.

3.5.2.2 Super Filter 8.6 V

Super-filtered 8.6 V enters the carrier board at J601-12, through an R-C filter, then on to the drain of Q9610 and the collector of Q9635.

3.5.2.3 VCO

The oscillator consists of Q9610, the main transmission line (T-line), varactor bank (CR9616-9617, C9616-9617, L9616) and feedback capacitors (C9611-9613). Components CR9610, C9614, and R9613 form an AGC circuit to prevent breakdown of the FET. Components CR9626 and C9626 form a bandshift circuit to shift the oscillator frequency up 50 MHz; C9630-9631 and CR9630 form the Receive shift circuit which shifts the VCO up 50 MHz. The main modulation circuit consists of C9621 and CR9621 in conjunction with the deviation compensating capacitors (C9622 and C9623). Finally, transistor (Q9635), resistors (R9635-9639), and capacitors (C9635-9636, C9638) form the output buffer.

This VCO utilizes both a positive and negative steering line. The SL- should be -4.O V (±.3 V) at all times. The SL+ will range from 1 to 8 V, depending on frequency and AUX bits.

3.5.2.4 Receive Mode (AUX2* Low)

When AUX2* input is low, the receive pin diode, CR9630, is forward biased by 8.6-V supply thru Q5650 and R5652. This current is then sunk into the RF board thru R5654. At this time the voltage divider output of R5649, R5651, and R5653 will keep Q5651 turned off.

3.5.2.5 Transmit Mode (AUX2* High)

When AUX2* is high (8.4 V), Q5650 will be off and Q5651 will be on. This puts -8 V on the anode of CR9630 and +8.4 V on its cathode. With approximately 16-V reverse bias on the diode, the receive bandshift T-line is removed from the circuit.

3.5.2.6 Bandshift Circuit

R9625, C9625, L9628, and C9628 form a bandshift circuit which shifts the frequency of the oscillator slightly. There is one bandshift in receive and one in transmit. The circuitry works similar to the receive pin circuitry but with the cathode of CR9626 returned to ground. This results in a maximum of 8-V reverse bias on this diode.

3.5.2.7 Output Buffer

Transistor (Q9635), resistors (R9635-9639), and capacitors (C9635-9636, C9638) form a simple common-emitter buffer to provide isolation to the VCO and an output power of +10 dBm.

3.5.2.8 First Buffer

The VCO output is coupled to the first buffer via blocking capacitor (C5661), resistive pads (R5661 and R5662), and a high-pass filter (L5660 and C5662). Q5660 is a self-biased, common-emitter amplifier which provides approximately + 10 dBm drive to the doubler as well as reverse isolation to the VC0.

3.5.2.9 Doubler

The first buffer output is coupled to the input of the doubler by C5663. Q5660 doubles the drive frequency and increases power by approximately 3 dB as a result of the high and low impedances presented to its collector at the doubled frequency and drive frequency, respectively. The collector impedances are presented by an elliptical high-pass filter (C5670-C5674, L5670, and L5671). The filter is terminated in a resistive pad (R5676-R5678) which also serves to terminate one end of the elliptical low-pass filter (C5675, C5677, and L5672-L5674). In addition to filtering, the low-pass filter provides part of the impedance match required between the resistive pad and the second buffer. The remaining impedance match is accomplished with L5680 and C5680, configured to provide additional high-pass selectivity.

3.5.2.10 Synthesizer Feedback

The base of Q5680 provides the tap location for the synthesizer feedback buffer. C5685-C5686 and L5681 provide low-pass filtering. R5630, R5631 and R5632 is a resistive pad. Q5630 provides approximately -5 dBm to the RF board.

3.5.2.11 Second Buffer

The second buffer, Q5680, is a common-emitter amplifier with approximately 12 dB gain. It is biased to 40 mA. with an active current source, Q5681 and R5580-R5587, which ensures saturated operation.

3.5.2.12 Receive/Transmit Switch

In the receive mode where K9.4-V is off, Q5640 conducts current to turn on the part of CR5690 (a dual-common cathode pin diode) that is in series with the receive path, and the part of CR5691 that is in shunt with the transmit path. The output of Q5680 is then coupled to a resistive pad R5697-R5699 which sets the power out of J5642 to approximately +12 dBm.

In the transmit mode, K9.4-V applies 9.4 V to the anode of CR5640, thus turning off Q5640. K9.4-V is also applied to resistors R5688 and R5694 which turn on the parts of CR5690 and CR5691 that are in series with the transmit path. The output of Q5680 is then coupled to a resistive pad (R5689-R5691) which sets the power out of J5641 to approximately +16 dBm.

3.5.3 800 MHz Band

3.5.3.1 General

The VCO is located on an alumina substrate with a metal cover. The buffer-doubler-buffer section is located on the PC board and may be repaired using normal repair methods.

3.5.3.2 Super Filter 8.6 V

Super filter 8.6 V is applied to the VCO carrier board at J601-12. From there, SF8.6 passes to the drain of Q9641, to the emitters of Q9643 and Q9644, and to the collector of Q9642.

3.5.3.3 VCO

Q9641, the main and transmit/TalkAround transmission lines, and the varactors CR9641 through CR9644 form the major circuitry of the oscillator. CR9645, C9648, C9647, and R9641 make up an automatic gain control (AGC) circuit.

The positive steering line connects to the cathodes of the four varactors and the negative steering line connects to the anodes. The negative line should be -4.0 ±0.3 V and the positive line can go as high as 9 V, allowing a difference of 15 to 16 V between the two. Normally, at room temperature, the positive steering line will be between 1.5 and 5.5 V and will fluctuate with temperature change in the radio. Modulation is connected to the negative steering line via R9651 and C9651.

When the radio is transmitting, the oscillator's frequency will be in the 403 to 412 MHz range. When receiving, the frequency will be between 370.675 and 379.675 MHz. If the radio is in the TalkAround mode, the frequency will be between 425.5 and 434.5 MHz. The transmit and TalkAround ranges are produced by coupling an additional length of transmission line to the main transmission line and is done by a high or low on the AUX 1* or AUX 2* input lines.

3.5.3.4 Receive Mode-AUX 1* and AUX 2* High

When AUX 1* is HIGH, 8.6 V is applied to the cathode of CR9646. Q9643 is turned off and Q9647 is turned on placing approximately -6.2 V at the anode of CR9646 reverse biasing it. Likewise with AUX 2* high the same occurs except CR9647 is reversed biased with Q9644 off and Q9646 on. This isolates the TRANSMIT/TALKAROUND transmission line from the MAIN transmission line.

3.5.3.5 Transmit Mode-AUX 1* High; AUX 2* Low

When AUX 1* is high, the same occurs as mentioned above, however, with AUX 2* low, CR9647 is forward-biased, connecting the TRANSMIT/TALKAROUND transmission line through C9658 and C9657 to the MAIN transmission line.

3.5.3.6 TalkAround Mode-AUX 1* Low; AUX 2* Low

With AUX 1* and AUX 2* low, CR9647 and CR9646 are forward-biased, connecting the TRANSMIT/TALKAROUND transmission line through C9656, C9655, C9657, and C9658 to the MAIN transmission line.

3.5.3.7 VCO Buffer

Q9642 amplifies and provides reverse isolation to the oscillator. The frequency is then applied to the buffer-doubler-buffer section of the VCO carrier board.

3.5.3.8 First Buffer Circuit

The VCO output is coupled to the first buffer section through C9677. Q9660 amplifies and provides additional isolation between the doubler and the VCO.

3.5.3.9 Doubler

The first buffer output is coupled to the doubler section through C9662 and a lowpass input match circuitry (C9675, L9675, C9676, and L9676), which serves two purposes: it matches the input of the doubler to 50 ohms, and improves isolation between the VCO and doubler. It also keeps the desired doubler output frequency from getting to the synthesizer. The synthesizer feedback frequency is via C9674 and R9669.

Q9675 doubles the frequency applied to its base. The components on the collector are built so that a 400 MHz signal is effectively shorted to ground, while the 800 MHz signal sees high impedance to ground. The doubler is coupled to the buffer through C9681, and into a 50-ohm matching network made up of C9683 and L9680.

Doubler-biasing differs between receive mode and transmit mode. For receive, R9677, R9678, and R9676 (in parallel to dissipate power) plus R9679 and R9680 bias the base of Q9675 to 0.7-V potential, if NO input RF power is applied to the base. For transmit mode, keyed 9.4 V is fed through CR9694 and another parallel resistor network R9674 and R9675. This raises the current to the collector of Q9675 via L9678, producing more power out.

3.5.3.10 Second Buffer

The second buffer circuit is Q9676 with a 460 MHz trap, made up of L9682 and C9686, on the collector. The signal is coupled by series LC network of L9683 and C9687. For the receive mode, Q9676's gain is approximately 1 to 4 dB; in transmit, its gain is approximately 7 dB.

In receive mode, K9.4-volts is off so that the base voltage of Q9692 is controlled by voltage divider, R9694 an R9695. With temperature changes, the emitter-base junction of Q9691 tracks that of Q9692's, stabilizing the collector current and collector voltage of Q9676. R9690, R9691, and R9692 set the current level to the collector of Q9676 in receive.

In transmit mode, K9.4-volts is applied to CR9693 and through R9697, R9699, and R9693, increasing the current flow to Q9676. K9.4-volts on the anode of CR9690 increases the voltage on the base of Q9692. This increases voltage at Q9692's emitter and Q9676's collector. In the transmit mode, the buffer draws approximately 60 mA.

3.5.3.11 $\overline{\text{K9.4 V}}$ Switch

In the receive mode, K9.4-volts is off. CR9691 is reverse-biased, CR9692 is forward-biased; therefore Q9693 conducts to produce 9.4 V on the collector. This forward-biases CR9678 and CR9677, allowing RF to pass through C9688. R9687, R9688, and R9689 drop the 12 dBm signal on the anode of CR9678 down to 0 to 5 dBm. This is the receiver injection signal which is applied to the first mixer in the front end of the radio.

In the transmit mode, K9.4-volts is on. Q9693 turns off, reverse biasing CR9678 and CR9677. However, CR9675 and CR9676 are forward-biased, allowing the RF signal to pass through C9689. The signal (approximately 20 dBm) at the junction of CR9675 and CR9677, is attenuated about 1 dB across the diodes. The transmit signal, at approximately 18 to 23 dBm, is applied to the power amplifier via C9689.

3.6 Receiver Front-End

This section of the theory of operation provides a detailed circuit description of receiver front-end (RXFE). When reading the Theory of Operation, refer to your appropriate schematic and component location diagrams located in "Chapter 7. Schematics, Component Location Diagrams, and Parts Lists". This detailed Theory of Operation will help isolate the problem to a particular component. However, first use the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* to troubleshoot the problem to a particular board.

3.6.1 VHF Band

3.6.1.1 General

The Receiver Front-End (RXFE) performs the first conversion of the received signal. The inbound signal is mixed with the high side injection signal, to produce the 109.65 MHz first IF. The pre-amp/ mixer configuration of the RXFE includes a preamplifier, a factory-tuned, 5-pole L.C. preselector unique for two ranges, a fixed injection filter, and a double balanced mixer.

3.6.1.2 Theory of Operation

The RF input from the PA first enters the high pass filter consisting of components L3200, L3201, L3202, C3200, C3201, C3209, and C3210. The high pass filter attenuates signals below the receiver passband for both RF frequency ranges.

A pair of Schottky diodes (CR3200) located before the high pass filter and after the 5-pole L.C. preselector, limit the signal amplitude going into the preamplifier. A second pair of Schottky diodes (CR3201) located after the 5-pole L.C. preselector, further provide signal protection to the mixer.

The RF board supplies DC voltage to the pre-amp. Transistors Q3200 and Q3201 stabilize the bias for pre-amp device Q3202 through temperature changes. R3206, R3200, R3210, R3208, and R3209 are adjusted to meet radio performance specifications for High or Low sensitivity.

The factory-tuned preselector filter accepts RF input frequencies ranging from 136-162 MHz (Range 1) or 146-174 MHz (Range 2). L3100, L3101, L3102, L3103, L3104 comprise the set of inductors which are tuned by the factory.

The double-balanced mixer has an injection level of +20 dBm, common for both ranges; at its output, a diplexer helps terminate the IF port at all frequencies of interest, and forms the bandpass filter.

From the pre-amp input to the IF output, there should be a conversion gain of -1.5 to +3.5 dB for high sensitivity, and +7.0 to +10 dB for low sensitivity specifications.

3.6.2 UHF Band

3.6.2.1 General

The receiver ceramic filter has a typical insertion loss of about 0.5 to 1.5 dB; it should not have a loss greater than 2.0 dB. If any soldering must be done on the filter, be very careful not to get any solder on the filter tuning pads.

The injection filter is a printed pattern on the substrate which is laser-tuned at the factory. The insertion loss of this filter is about 3 dB.

3.6.2.2 Theory of Operation

The factory-tuned ceramic preselector filter accommodates RF input frequencies ranging from 438 to 470 MHz (Range 2), 450 to 482 MHz (Range 3), or 482 to 512 MHz (Range 4). The injection filter is tuned to pass frequencies from 549 to 580 MHz for Range 2, 559 to 592 MHz for Range 3, or 592 to 622 MHz for Range 4. Each frequency is connected at a node just before C9138 via a transmission line which acts as a high impedance input to the other frequency.

The RF board supplies DC voltage to bias the mixer Q125. Transistor Q126 controls the voltage to the base of Q125. The voltage at the collector of Q125 should be approximately 10 V.

3.6.3 800 MHz Band

3.6.3.1 General

The receiver ceramic filter has a typical insertion loss of about 1.6 to 1.7 dB; it should not have a loss greater than 2.5 dB. If any soldering must be done on the filter, be very careful not to get any solder on the filter tuning pads.

The injection filter is a printed pattern on the substrate which is laser-tuned at the factory. The insertion loss of this filter is about 3 dB.

3.6.3.2 Theory of Operation

The factory-tuned ceramic prescaler filter accommodates RF input frequencies ranging from 851 to 870 MHz. The injection filter is tuned to pass frequencies from 741 to 760 MHz. Each frequency is connected at a node just before C8126 via a transmission line which acts as a high impedance input to the other frequency.

DC voltage, supplied from the RF board, biases the mixer Q8126. Transistors Q8127 and Q8128 control the voltage to the base of Q8126. Q8128 acts as a diode to maintain a voltage on the base of Q8127, which keeps the bias of Q8126 stable through temperature changes. The voltage for the collector of Q8126, which passes through R8128, L8131, and L8130 should be approximately 8 volts.

C8129, L8129, C8131, and L8130 form the output network for the mixer. C8131 is a large capacitor that appears as a short to all frequencies of interest. The remaining components form a bandpass filter centered at the IF frequency.

R8130, R8129, and R8131 form an attenuator on the output path to stabilize both the mixer output impedance and the source impedance for the IF amplifier.

From the input to the ceramic filter to the IF output, there should be an 8 dB power gain presented to the IF. If the beta of Q8126 falls below 60, the mixer (Q8126) is probably bad and must be replaced.

3.7 Power Amplifiers

This section of the theory of operation provides a detailed circuit description of the power amolifiers. When reading the Theory of Operation, refer to your appropriate schematic and component location diagrams located in “Chapter 7. Schematics, Component Location Diagrams, and Parts Lists”. This detailed Theory of Operation will help isolate the problem to a particular component. However, first use the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* to troubleshoot the problem to a particular board.

3.7.1 VHF Band Power Amplifiers

3.7.1.1 High-Power Amplifier

3.7.1.1.1 Transmitter

The high-power ASTRO Spectra amplifier is discussed in the following text. A block diagram of the circuit is shown on the foldout drawing.

Transmit Low Level Amplifier (LLA)

The LLA is the first stage of the PA and provides a gain that is a function of the control voltage. This control voltage comes from the Regulator Power Control IC (RPCIC) on the command board. The magnitude of the control voltage depends on PA output power, temperature, and final amplifier current drain. See Section 3.7.1.1.3, "Power Control Circuitry," on page 3-57 for a detailed explanation of the power control circuitry.

The LLA, Q3801, is unique in that its gain is controlled by varying the collector's current rather than its voltage. Q3801 and associated circuitry (Q3806 Q3802, R3804, and R3818) are best described as a voltage-controlled current source. This means that the collector current of Q3801 is controlled by the magnitude of the control voltage.

Second Amplifier Stage

The second stage of the PA, Q3804, amplifies the output of the LLA to a level sufficient to drive the third stage device, Q3805. Q3804 amplifies the LLA output from approximately 300 mW to 3.0 Watts.

Driver Stage (Q3805)

The third stage uses a 3.0-Watt input to 30-Watt output device. It is driven by the second stage through a matching circuit that consists of C3824, L3808, C3819, and C3820. L3812 and L3809 give the device a zero-Vdc base bias (required for Class-C operation). The network of L3811, L3810, R3819, and C3821 provide A+ to the collector.

Final Stage (Q3870 AND Q3871)

The final amplifier stage is the parallel combination of two 15-Watt input to 75-Watt output RF transistors. The matching network, from the collector of the driver device Q3805 to the bases of the final devices Q3870 and Q3871, utilizes transmission lines as part of a combination matching network and power splitter. The capacitors C3860, C3861, C3862, and C3863 are on the bottom side of the PC board underneath the base leads of Q3870 and Q3871.

The DC bias path for the base of Q3870 is via L3930 and L3931. Q3871 has a similar network. R4007, R4008, and R3859 improve division of driver power between the final devices Q3870 and Q3871.

A feedback network consisting of C3870, R3870, and L3870 suppresses parasitic oscillations in Q3870. Q3871 has a similar network.

The final stage output network serves the dual purpose of impedance matching and power combining of the two final devices. R3872 and R3873 help balance the load impedances presented to the collectors of the final devices. Filtered A+ is routed to the final amplifier devices via the current sense resistor R3841, the ferrite bead L3881, and the coil L3880. The final stage output network terminates at C3889, which is the input to the antenna switch. The circuit impedance is 50 ohms at this point.

3.7.1.1.2 Antenna Switch and Harmonic Filter

Antenna Switch

The antenna switch utilizes PIN diodes to form a low loss, high isolation RF relay. During transmit, PIN diodes CR3901, CR3902, and CR3903 are forward biased during transmit via the K9.4 supply and resistors R3900, R3901, R3902, and R3903. In this state, a low loss path exists from the final amplifier through PIN diode CR3901 and into the harmonic filter. PIN diodes CR3902, and CR3903 effectively shunt the path to the receiver front-end which protects the preamp or mixer device from excessive RF levels. A properly functioning switch will pass less than 10 mW of transmit power to the receiver front-end.

During receive, all three PIN diodes remain unbiased. This opens a low loss path from the harmonic filter to the receiver.

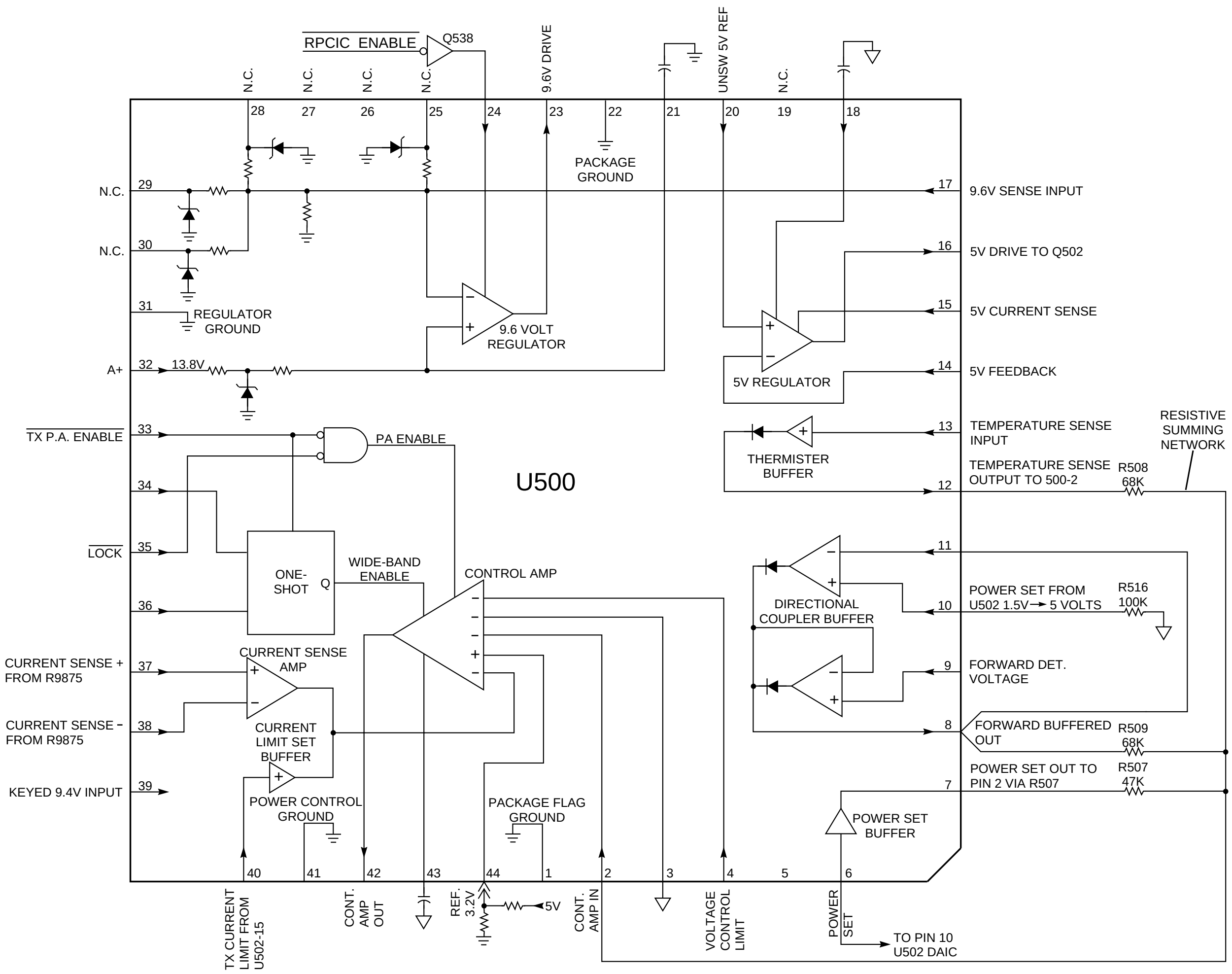
Harmonic Filter

The harmonic filter is a 7-pole low-pass filter consisting of screened plate capacitors and air-wound coils on a 0.035 inch thick ceramic substrate. The filter's primary function is to.attenuate harmonic energy generated by the amplifier stages. The filter also adds some selectivity for the receiver.

3.7.1.1.3 Power Control Circuitry

Command Board Circuitry

Inside U500, the Regulator Power Control IC (see Figure 3-20) is an operational amplifier that has four inverting inputs, and one non-inverting input (at pin 44) which is the reference input for the entire power control loop of the power amplifier. The 3.2-V reference voltage at U500-44 is produced by dividing SW +5-V with the voltage-divider circuit, R514 and R515.



REGULATOR/POWER CONTROL IC U500

MAEPF-22034-O

Figure 3-20. RPCIC Block Diagram

The power control loop is controlled by the microprocessor U204 on the VOCON board. Through the SLIC IC U206, the microprocessor enables the RPCIC by pulling TX PA ENABLE (U500 pin 33) low while the radio synthesizer is locked (U500 pin 35). U520 writes data to a digital-to-analog converter, U502, to change and control the power-set voltage from pin 10 of U502 to pin 6 of U500. The voltage on this line, 1.5 to 5 V, will be inversely proportional to the power out of the PA, with 5 V producing the lowest power output. This voltage may be set with RSS (Radio Service Software) or CPS (Customer Programming Software). On U500, the voltage at pin 6 is buffered internally and exits on pin 7. Through R507, it is connected to pin 2 of U500. Note that pin 2 of U500 is the summing point of three voltages: forward detect voltage, power set voltage, and temp-sense.

Control Voltage Limiter

R3807 and R3808 form a voltage divider that connects to control voltage drive. The output of this voltage divider is connected to the control-voltage-limit input (pin 4) of the RPCIC. If the voltage at this input reaches 3.2 V, then the control voltage will be clamped to a maximum value. For the high-power VHF PA, this maximum value is 9 V. This voltage control limit is set by the values of R3807 and R3808.

Current Limiter

U204, the processor on the VOCON board, sends data to U502, the digital-to-analog converter, to properly set the voltage on U502, pin 15, which is the TX CURRENT LIMIT control line to the RPCIC (U500, pin 40). Sixteen different voltages, ranging from 1.5 to 4.5 V, can be programmed from U502.

The collector current of the 110-Watt amplifier is monitored by sensing the voltage across R3849. CURRENT SENSE + connects to one end of R3849; CURRENT SENSE - connects to the other end. These lines connect to the command board on U500 pins 37 and 38, respectively. If the TX CURRENT LIMIT is set for 1.5 V, then the voltage difference between U500 pins 37 and 38 must be 0.1 V before the current through R3849 is reduced. If U500 pin 40 is programmed for 4.5 V, then the difference of potential between pins 37 and 38 must exceed 0.3 V before current limiting begins. The voltage across R3849, where current sense occurs, can be determined by multiplying the voltage on U500 pin 40, by 0.067. When current is being limited, the output of the op-amp (U500, pin 42) begins shutting down the conduction of Q503 and Q504, reducing PA control voltage, and reducing drive to the final amplifier to, effectively, control the final amplifier's maximum current.

Forward Power Limiter

After the harmonic filter a parallel pair of microstrip lines form a forward power sensing directional coupler and detector. The output of this directional coupler/detector is a DC voltage that is proportional to the forward RF power from the final amplifier. During normal transmission, the DC voltage from the forward detect line to the RPCIC ranges from 2 to 5.0 V. This voltage connects to U500 pin 9, the directional coupler buffer input.

The directional coupler's buffered output, U500 pin 8, is summed to pin 2 with the digital/analog buffer's output through R509 and R507, respectively. In typical operation, the closed loop operation of the circuit attempts to keep the voltage at U500 pin 2 a constant value of 3.2 V. The control amp will maintain this condition by increasing or decreasing the control amp output voltage. This control amp output voltage is routed to the LLA via transistors Q503 and Q504. The output of Q504 is designated "control voltage drive" and is routed to J1 pin 2 of the PA board.

Since control voltage drive controls the gain of the LLA, it determines the drive level to the following stages and thus the output power of the final amplifier. The output power of the final stage is detected by the directional coupler and is routed back to U500 pin 2 via the buffer and R507. Thus the loop is complete and forward power is maintained a constant value. The voltage at pin 2 will drop below 3.2 V during low line voltage conditions where the PA cannot produce rated power. Current limit and voltage control limit circuits will also affect the voltage at pin 2 as described in the following.

Temperature Sensing

The temperature-sensing circuit of the PA works with the RPCIC to protect the PA devices from excessively high temperatures. On the PA board, this circuit (formed by resistors R3916, R3841, and thermistor RT3842), provides a temperature dependent voltage to the RPCIC via J1 pin 6. As the PA temperature increases, the resistance of RT3842 decreases, causing the voltage at pin 6 to increase. This voltage is routed to the RPCIC, U500 pin 13, which is the input to the thermistor buffer. The buffer's output on pin 12 is connected to pin 2 via resistor R508. Note that pin 2 is the control amp input and is a summing point for temperature, forward-power detect, and power set signals. If the PA temperature becomes high enough so that the voltage at pin 7 exceeds 3.2 V, the thermistor buffer starts supplying current to the node at pin 2. Due to the fixed output current of the power-set buffer, the control loop can maintain 3.2 V at pin 2 only by reducing the forward-power detect voltage and, therefore, reducing the PA output power. Since power output is reduced, the generated heat is reduced to a safe level. If temperature decreases, the power output of the PA gradually increases to its nominal value.

NOTE: Under severe environmental conditions, more than one circuit may be attempting to reduce power output at the same time (i.e., during high VSWR conditions, the current limiter may initially reduce power, but eventual heat buildup will cause further power reduction by the thermal cut-back circuit).

The temperature sense circuitry can easily be tested by placing an ordinary leaded 4.7k ohm resistor across RT3842. PA output power should drop significantly if this circuit is working properly.

3.7.1.2 25/10-Watt Power Amplifier

Transmitter

The 25/10-Watt Spectra power amplifier is discussed in the following text.

Transmit Low Level Amplifier (LLA)

NOTE: The minimum input drive level to the PA into J3850 is 10 mW. Refer to the synthesizer section if input drive is less than 10 mW.

The Low Level Amplifier, the first stage of the PA, provides a gain that is a function of a control voltage. This control voltage comes from the Regulator Power Control IC (RPCIC) on the command board. The magnitude of the control voltage depends on PA output power, temperature, and final amplifier current drain.

The LLA, Q3801, is unique in that its gain is controlled by varying the collector's current rather than its voltage. Q3801 and associated circuitry (Q3806, Q3802, R3804, and R3818) are best described as a voltage-controlled current source. This means that the collector current of Q3801 is controlled by the magnitude of the control voltage. Proper operation of the LLA can be checked by monitoring the voltage across the resistor R3804. The voltage should measure in the range of 0.1 V to 1.0 V, depending on the value of control voltage. A 0.1-V reading corresponds to a low control voltage (1 to 5 V) and a 1.0 V reading corresponds to a high control voltage (up to control voltage limit).

Driver Stage

The second stage of the PA, Q3804, is the driver. The purpose of this stage is to amplify the output of the LLA to a level sufficient to drive the final device, Q3850. Input power to this stage is approximately 100 mw; output power from this stage is 3.5 Watts.

Final Stage

The final device is a 3- to 33-Watt device and is driven by the driver through a low-pass matching circuit that consists of C3815, C3816, C3817, L3811, C3819, C3821, C3822, C3823 and associated transmission lines. Base network, L3852, L3851, and R3815, R3819 provide the zero-DC bias required by the final device's Class-C operation. L3852 and L3851 provide the DC path from base to ground. R3815 and R3819 help lower the network's Q at low frequencies. The collector DC network consists of L3875, L3876, R3876, R3877, C3880, C3885, C3881, C3882, and CR3875. This network provides the A+ voltage to the final while blocking RF from getting up the DC line. L3875 and L3876 provide the DC path and block RF. R3876 and R3877 resistively load down the final's collector at low frequencies and prevent unwanted oscillations. C3881, C3882, C3880, and C3885 are all bypass capacitors ranging from very low frequencies up to VHF frequencies. R3875 is the current-sense resistor. CR3875 protects against reverse polarity. Finally, the RF signal goes through a low-pass matching network (C3875, C3877, C3878, C3879, L3877, and associated transmission lines) to the rest of the output network (Directional Coupler, Antenna Switch, and Harmonic Filter).

3.7.1.2.1 Antenna Switch and Harmonic Filter

Antenna Switch

The antenna switch's impedance inverter circuit, made up of C3920 and L3920, takes the place of a quarter-wave microstrip line. During transmission, Keyed 9.4 V forward-biases CR3921, producing low impedance on CR3921's anode and high impedance on the C3920/L3920 node. Effectively, this isolates the transmitted power from the receiver. C3910 couples the power to the harmonic filter and on to the antenna.

Total TX to RX isolation exceeds 50 dB from 136-174 MHz. The impedance inverter contributes approximately 30 db to transmit isolation. A second shunt switch, made up of CR3922, L3921, C3922, and C3921, provide additional isolation. C3926 and C3923 block DC.

During RX, CR3920 has an OFF capacitance of approximately 1 pF. CR3921 and CR3922, incorporated in the RX match, have similar OFF capacitance.

Harmonic Filter

The 25/10-Watt harmonic filter is a 7-pole, low-pass filter, consisting of high-Q chip capacitors (C3911, C3913, C3912, and C3914) and discrete inductors (L3911, L3912, and L3913). The filter's primary function is to attenuate harmonic spurs generated by the transmitter. It also adds low-pass selectivity for the receiver. L3914 protects the PA from static discharge.

3.7.1.2.2 Power Control Circuitry

Command Board Circuitry

Inside U500, the Regulator Power Control IC (see Figure 3-21), is an operational amplifier that has four inverting inputs, and one non-inverting input (at pin 44) which is the reference input for the entire power control loop of the power amplifier. The 3.2-V reference voltage at U500-44 is produced by dividing SW +5-V with the voltage-divider circuit, R514 and R515.

The power control loop is controlled by the microprocessor U204 on the VOCON board. Through the SLIC IC U206, the microprocessor enables the RPCIC by pulling TX PA ENABLE (U500 pin 33) low while the radio synthesizer is locked (U500 pin 35). U520 writes data to a digital-to-analog converter, U502, to change and control the power-set voltage from pin 10 of U502 to pin 6 of U500. The voltage on this line, 1.5 to 5 V, will be inversely proportional to the power out of the PA, with 5 V producing the lowest power output. This voltage may be set with RSS (Radio Service Software) or CPS (Customer Programming Software).

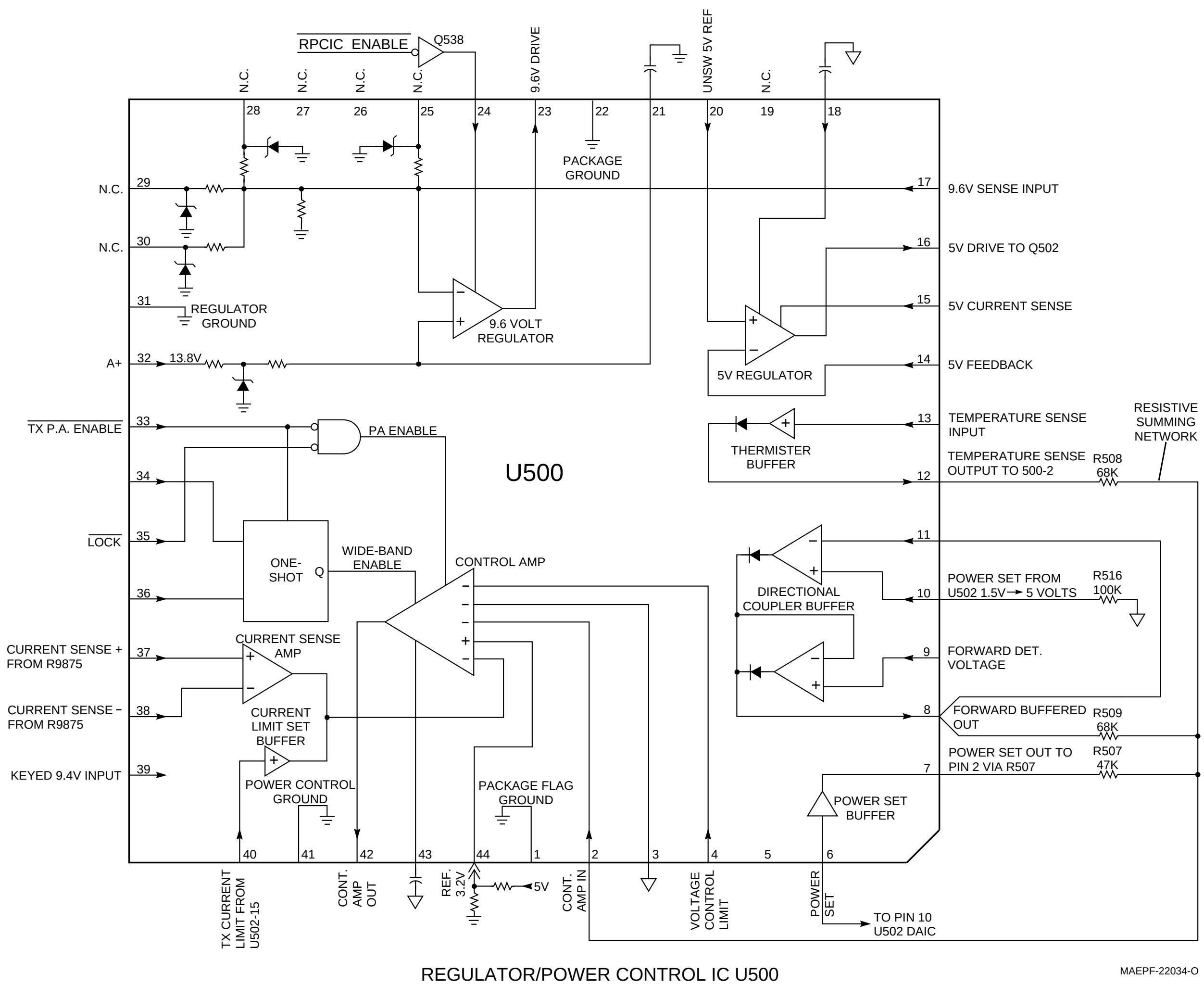


Figure 3-21. Regulator/Power Control IC Block Diagram

Control Voltage Limiter

R3813 and R3814 form a voltage divider that connects to control voltage drive. The output of this voltage divider is connected to the control-voltage-limit input (pin 4) of the RPCIC. If the voltage at this input reaches 3.2 V, then the control voltage will be clamped to a maximum value. For the 25/10-Watt VHF PA, this maximum value is 9.2 V. This voltage-control limit is set by the values of R3813 and R3814.

Current Limiter

U204, the processor on the VOCON board, sends data to U502, the digital-to-analog converter, to properly set the voltage on U502, pin 15, which is the TX CURRENT LIMIT control line to the RPCIC (U500, pin 40). Sixteen different voltages, ranging from 1.5 to 4.5 V, can be programmed from U502.

The collector currents of the 25/10-Watt amplifier is monitored by sensing the voltage across R3875. CURRENT SENSE + connects to one end of R3875; CURRENT SENSE - connects to the other end. These lines connect to the command board on U500, Pins 37 and 38, respectively. If the TX CURRENT LIMIT is set for 1.5 V, then the voltage difference between U500, Pins 37 and 38 must be 0. 1 V before the current through R3875 is reduced. If U500, pin 40 is programmed for 4.5 V, then the difference of potential between Pins 37 and 38 must exceed 0.3 V before current limiting begins. The voltage across R3875, where current sense occurs, can be determined by multiplying the voltage on U500, pin 40, by 0.067. When current is being limited, the output of the op-amp (U500, pin 42) begins shutting down the conduction of Q503 and Q504, reducing PA control voltage, and reducing drive to the final amplifier to control the final amplifier's maximum current.

Forward Power Limiter

After the final amplifier, a parallel pair of non-symmetrical microstrip lines form a forward power-sensing directional coupler. Because of increased coupling with frequency, C3902 is used to compensate and filter out harmonics. R3905, R3906, C3903, and L3903 provide DC bias to CR3900, which rectifies the signal. During normal transmission, the DC voltage from the forward-detect line to the RPCIC ranges from 1.5 to 5.0 V. This voltage connects to U500, pin 9, the directional coupler buffer input.

The directional coupler's output, U500 pin 8, is summed to pin 2 with the digital/analog buffer's output through R509 and R507, respectively.

Closed loop operation reduces the control amp's output (pin 42), reduces the power amplifier's gain, and reduces power output to maintain the coupler buffer output (U500, pin 2) at 3.2 V regardless of the D/A voltage level. If the D/A voltage is high (4.5 V), little detected voltage is needed to keep pin 2 at 3.2 V, and the power, consequently, is low. If the D/A voltage is low (1.5 V), a large forward detected voltage is needed to keep pin 2 at 3.2 V and power, consequently, is at maximum value. The voltage at pin 2 drops below 3.2 V under proper operation during low line voltage conditions where the PA cannot produce rated power, or if, under any conditions, the control voltage, or the final device current exceeds safe levels.

Temperature Sensing

The temperature-sensing circuit of the PA works with the RPCIC to protect the PA devices from excessively high temperatures. On the PA board, this circuit, formed by resistors R3878, R3879, and thermistor RT3876, provides a temperature-dependent voltage to the RPCIC via P0853, pin 7. As the PA temperature increases, the resistance of RT3876 decreases, causing the voltage at pin 7 to increase. This voltage is routed to the RPCIC, U500, pin 13, which is the input to the thermistor buffer. The buffer's output on pin 12 is connected to pin 2 via resistor R508. Note that pin 2 is the control amp input and is a summing point for temperature, forward-power detect, and power set signals. If the PA temperature becomes high enough so that the voltage at pin 7 exceeds 3.2 V, the thermistor buffer starts supplying current to the node at pin 2. Due to the fixed output current of the power-set buffer, the control loop can maintain 3.2 V at pin 2 only by reducing the forward-power detect voltage and, therefore, reducing the PA output power. Since power output is reduced, the generated heat is reduced to a safe level. If temperature decreases, the power output of the PA gradually increases to its nominal value. Temperature cutback should occur at about 140°F (60°C).

The temperature sense circuitry can easily be tested by placing an ordinary leaded 4.7k ohm resistor across RT3876. PA output power should drop significantly if this circuit is working properly.

NOTE: Under severe environmental conditions, more than one circuit may he attempting to reduce power output at the same time (i.e., during high VSWR conditions, the current limiter may initially reduce power, but eventual heat buildup will cause further power reduction by the thermal cut-back circuit).

3.7.1.3 50-Watt Power Amplifiers

3.7.1.3.1 Transmitter

The 50-Watt ASTRO Spectra power amplifiers (PA's) are discussed in the following text. A block diagram of the circuit is shown in Figure 3-22.

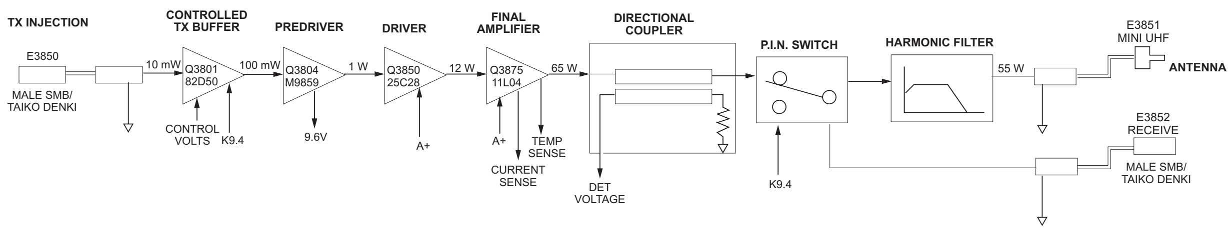


Figure 3-22. 50-Watt Power Amplifier Block Diagram

Transmit Low Level Amplifier (LLA)

NOTE: The minimum input drive level to the PA into J3850 is 10 mW. Refer to the synthesizer section if input drive is less than 10 mW.

The LLA, the first stage of the of the PA, provides a gain that is a function of a control voltage. This control voltage comes from the Regulator Power Control IC (RPCIC) on the command board. The magnitude of the control voltage depends on PA output power, temperature, and final amplifier current drain.

The LLA, Q3801, is unique in that its gain is controlled by varying the collector's current rather than its voltage. Transistor Q3801 and associated circuitry (Q3806, Q3802, R3804, and R3818) are best described as a voltage-controlled current source. This means that the collector current of Q3801 is controlled by the magnitude of the control voltage. Proper operation of the LLA can be checked by monitoring the voltage across the resistor R3804. The voltage should measure in the range of 0.1 V to 1.0 V, depending on the value of control voltage. A 0.1-V reading corresponds to a low control voltage (1 to 5 V) and a 1.0-V reading corresponds to a high control voltage (up to control voltage limit).

Predriver Stage

The second stage of the PA, Q3804, is the predriver. The purpose of this stage is to amplify the output of the LLA to a level sufficient to drive the driver device, Q3850. Input power to this stage is approximately 100 mW; output power from this stage is 1.0 Watt.

Driver Stage

The driver is a 1.2- to 15-Watt device. It is driven by the predriver device through a matching circuit that consists of C3815, C3816, C3817, C3818, and L3811. A ferrite bead L3810, and a parallel resistor, R3815, give the driver a zero-DC bias required for the driver's Class C operation, and provides a low Q network to prevent unwanted oscillations. The network of L3851, L3854, C3858, C3856, C3855, and R3850 provide A+ to the collector. L3851 and L3854 provide the DC path and block RF from coming up the DC line. R3850 resistively loads down the collector at low frequencies, preventing unwanted oscillations. C3856, C3855, C3858, and C3855 are bypass capacitors.

Final Stage

The final device is a 12- to 75-Watt device and is driven by the driver through a low pass matching circuit that consists of C3850 through C3854 and associated transmission lines. Base network, L3852, L3853, and R3851, provide the zero-DC bias required by the final device's Class C operation. L3852 and L3851 provide the DC path from base to ground. R3851 helps lower the network's Q at low frequencies. The collector DC network consists of L3875, L3876, R3876, C3880, C3885, C3881, C3882, and CR3875. This network provides the A+ voltage to the final stage while blocking RF from getting up the DC line. L3875 and L3876 provide the DC path and block RF. R3850 resistively loads down the final stage's collector at low frequencies and prevents unwanted oscillations. C3881, C3882, C3880, and C3885 are all bypass capacitors ranging from very low frequencies up to VHF frequencies. R3875 is the current sense resistor. CR3875 protects against reverse polarity. Finally, the RF signal goes through a low pass matching network (C3875, C3876, C3877, C3878, C3879, L3877, and associated transmission lines) to the rest of the output network (directional coupler, antennal switch, and harmonic filter).

3.7.1.3.2 Antenna Switch and Harmonic Filter

Antenna Switch

The antenna switches impedance inverter circuit, made up of C3920 and L3920, takes the place of a quarter-wave microstrip line. During transmission, keyed 9.4 V forward biases CR3921, producing a low impedance on CR3921's anode and a high impedance on the C3920/L3920 node. Effectively, this isolates the transmitted power from the receiver. C3910 couples the power to the harmonic filter and on to the antenna.

Total TX to RX isolation exceeds 55dB from 136-174MHz. The impedance inverter contributes approximately 35dB to transmit isolation. A second shunt switch made up of CR3922, L3921 and C3921, provide additional isolation. Capacitors C3922 and C3923 block DC.

During RX, CR3920 has an OFF capacitance of approximately 1 pF. CR3921 and CR3922 incorporated in the RX match have a similar OFF capacitance.

Harmonic Filter

The 50-Watt harmonic filter is a 7-pole, low-pass filter, consisting of high Q chip capacitors (C3911 thru C3914) and discrete inductors (L3911 thru L3913). The filter's primary function is to attenuate harmonic spurs generated by the transmitter, It also adds low-pass selectivity for the receiver. L3914 protects the PA from static discharge.

3.7.1.3.3 Power Control Circuitry

Command Board Circuitry

Inside U500, the Regulator Power Control IC (Figure 3-23), is an operational amplifier that has four inverting inputs, and non-inverting input at pin 44 which is the reference input for the entire power control loop of the power amplifier. The 3.2-V reference voltage at U500-44 is produced by dividing SW +5-V with the voltage-divider circuit, R514 and R515.

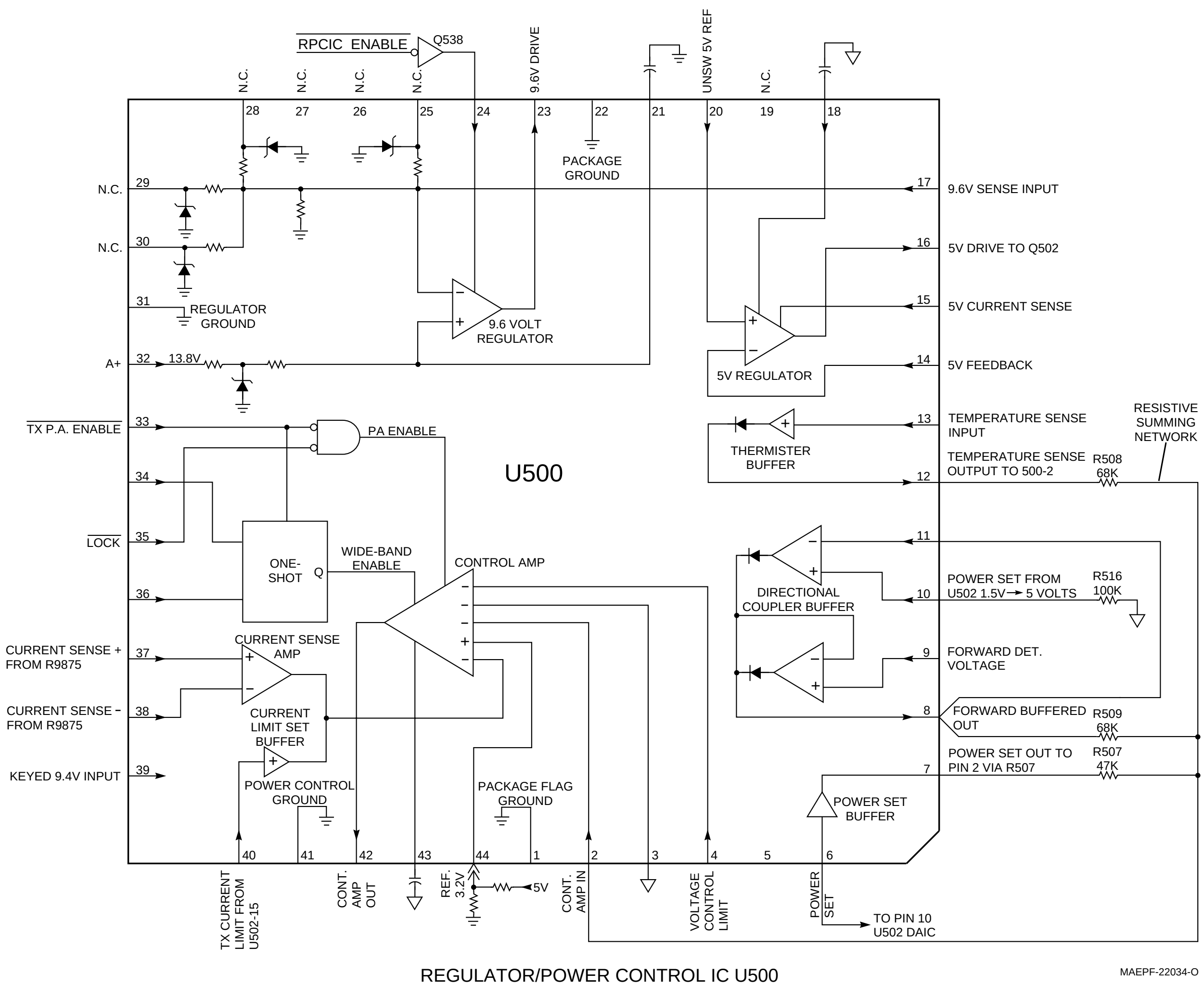


Figure 3-23. Regulator/Power Control IC Block Diagram

The power control loop is controlled by the microprocessor U204 on the VOCON board. Through the SLIC IC U206, the microprocessor enables the RPCIC by pulling TX PA ENABLE (U500 pin 33) low while the radio synthesizer is locked (U500 pin 35). U520 writes data to a digital-to-analog converter, U502, to change and control the power-set voltage from pin 10 of U502 to pin 6 of U500. The voltage on this line, 1.5 to 5 V, will be inversely proportional to the power out of the PA, with 5 V producing the lowest power output. This voltage may be set with RSS (Radio Service Software) or CPS (Customer Programming Software).

Control Voltage Limiter

R3807 and R3808 form a voltage divider that connects to control voltage drive. The output of this voltage divider is connected to the control-voltage-limit input, pin 4 of the RPCIC. If the voltage at this input reaches 3.2 V, then the control voltage will be clamped to a maximum value. For the 50-Watt VHF PA, this maximum value is 8 V. This voltage control limit is set by the values of R3807 and R3808.

Current Limiter

U204, the processor on the VOCON board, sends data to U502, the digital-to-analog converter, to properly set the voltage on U502, pin 15, which is the TX CURRENT LIMIT control line to the RPCIC, U500, pin 40. Sixteen different voltages, ranging from 1.5 to 4.5 V, can be programmed from U502.

The collector current of the amplifier is monitored by sensing the voltage across R3875; CURRENT SENSE + connects to one end of R3875; CURRENT SENSE - connects to the other end. These lines connect to the command board on U500, pins 37 and 38 respectively. If the TX CURRENT LIMIT is set for 1.5 V, then the voltage difference between U500, pins 37 and 38 must be 0.1 V before the current through R3875 is reduced. If U500, pin 40 is programmed for 4.5 V, then the difference of potential between pins 37 and 38 must exceed 0.3 V before current limiting begins, The voltage across R3875, where current sense occurs, can be determined by multiplying the voltage on U500, pin 40, by 0.067 V. When current is being limited, the output of the operational amplifier, U500, pin 42 begins shutting down the conduction of Q503 and Q504, reducing PA control voltage, and reducing drive to the final amplifier to effectively control the final amplifier's maximum current.

Forward Power Limiter

After the final amplifier, a parallel pair of non-symmetrical microstrip lines form a forward power-sensing directional coupler. Because of increased coupling with frequency, C3902 is used to compensate and filter out harmonics. R3905, R3906, C3902, and L3903 provide DC bias to CR3900, which rectifies the signal. During normal transmission, the DC voltage from the forward-detect line to the RPCIC ranges from 2 to 4.5 V. This voltage connects to U500, pin 9, the directional coupler buffer input.

The directional coupler's output, U500 pin 8, is summed to pin 2 with the digital/analog buffer's output through R509 and R507 respectively.

Closed loop operation reduces the control amplifier's output pin 42, reduces the power module's gain, and reduces power output to maintain the coupler buffer output U500, pin 2 at 3.2 V regardless of the D/A voltage level. If the D/A voltage is high (4.5 V), little detected voltage is needed to keep pin 2 at 3.2 V, and the power, consequently, is low. If the D/A voltage is low (1.5 V), a large forward detected voltage is needed to keep pin 2 at 3.2 V and power, consequently, is at maximum value. The voltage at pin 2 drops below 3.2 V under proper operation during low line voltage conditions where the PA cannot produce rated power, or if, under any conditions, the control voltage, or the final device current exceeds safe levels.

Temperature Sensing

The temperature-sensing circuit of the PA works with the RPCIC to protect the PA devices from exclusively high temperatures. On the PA board, this circuit, formed by resistors R3878 thru R3880 and thermistor RT3877, provides a temperature-dependent voltage to the RPCIC via P0853, pin 7. As the PA temperature increases, the resistance of RT3875 decreases, causing the voltage at pin 7 to increase. This voltage is routed to the RPCIC, U500, pin 13, which is the input to the thermistor buffer. The buffer's output on pin 12 is connected to pin 2 via resistor R508. Note that pin 2 is the control amplifier input and is a summing point for temperature, forward-power detect, and power set signals. If the PA temperature becomes high enough so that the voltage at pin 7 exceeds 3.2 V, the thermistor buffer starts supplying current to the node at pin 2. Due to the fixed output current of the power-set buffer, the control loop can maintain 3.2 V at pin 2 only by reducing the forward-power detect voltage and therefore, reducing the PA output power. Since power output is reduced, the generated heat is reduced to a safe level, If temperature decreases, the power output of the PA gradually increases to its nominal value. Temperature cutback should occur at about 140 degrees F (60 degrees C).

The temperature sense circuitry can easily be tested by placing an ordinary leaded 4.7k ohm across RT3875, PA output power should drop significantly if this circuit is working properly.

NOTE: Under severe environmental conditions, more than one circuit may be attempting to reduce power output at the same time (i.e. during high VSWR conditions). The current limiter may initially reduce power, but eventual heat buildup will cause further power reduction by the thermal cut-back circuit.

3.7.2 UHF Band Power Amplifiers

3.7.2.1 High-Power Amplifier

3.7.2.1.1 Transmitter

The high-power Spectra amplifier is discussed in the following text. A block diagram of the circuit is shown in.

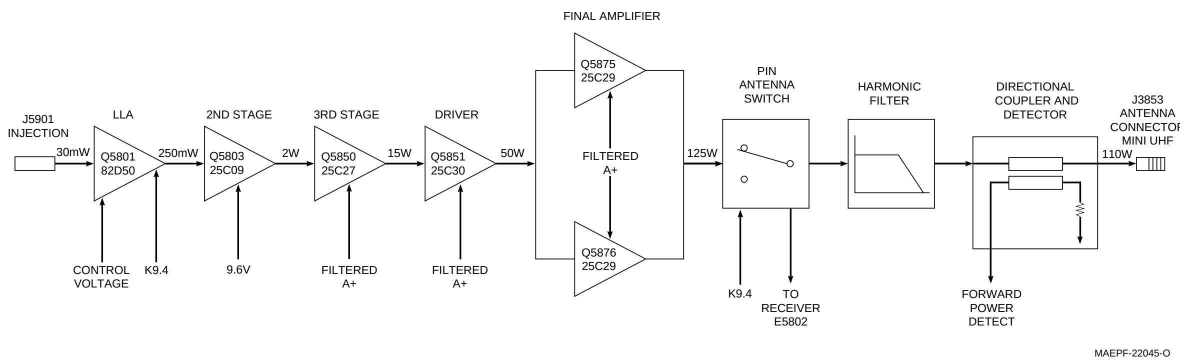


Figure 3-24. UHF High-Power, Power Amplifier Block Diagram

Transmit Low Level Amplifier (LLA)

The LLA is the first stage of the PA and provides a gain that is a function of a control voltage. This control voltage comes from the Regulator Power Control IC (RPCIC) on the command board. The magnitude of the control voltage depends on PA output power, temperature, and final amplifier current drain.

The LLA, Q5801, is unique in that its gain is controlled by varying the collectors current rather than its voltage. Q5801 and associated circuitry (Q5806, Q5800, R5805, and R5818) are best described as a voltage-controlled current source. This means that the collector current of Q5801 is controlled by the magnitude of the control voltage.

Second Amplifier Stage

The second stage of the PA, Q5803, amplifies the output of the LLA to a level sufficient to drive the third stage device, Q5850. Q5803 amplifies the LLA output from approximately 250 mW to 2.5 Watts.

Third Amplifier Stage

The third stage uses a 2.5-Watt input to 16-Watt output device. It is driven by the second stage through a matching circuit that consists of C5851, C5852 C5850, C5858, and L5850. L5851 and L5852 give the device a zero-Vdc base bias (required for Class-C operation). The network of L5853, L5854, C5856, C5857, and R5850 provide A+ to the collector.

Driver Stage

The driver stage uses a 15-Watt input to 50-Watt output device. It is driven by the third stage through the matching network consisting of C5853, C5854, C5855, C5861, C5862, and associated transmission lines. The DC bias path for the base is provided by L5855 and L5857. C5859, R5851, and C5860 are for the purpose of suppressing parasitic oscillations. Note that the capacitors C5861, C5862, C5863, and C5864 are placed on the bottom side of the PC board.

Final Stage

The final amplifier stage is the parallel combination of two 25-Watt input to 75-Watt output RF transistors. The matching network from the collector of the driver device Q5851 to the bases of the final devices Q5875 and Q5876 utilizes transmission lines as part of a combination matching network and power splitter. The capacitors C5885, C5886, C5887, and C5888 are on the bottom side of the PC board underneath the base leads of Q5875 and Q5876.

The DC bias path for the base of Q5875 is via L5877 and L5879. Q5876 has a similar network. R5878 improves division of driver power between the final devices Q5875 and Q5876.

A feedback network consisting of C5890, R5879, and L5881 suppresses parasitic oscillations in Q5875. Q5876 has a similar network.

The final stage output network serves the dual purpose of impedance matching and power combining of the two final devices. C5891, C5892, C5893, and C5894 are on the bottom side of the PC board underneath the collectors of the final devices. These capacitors are especially critical in terms of their exact physical placement.

R5881 and R5882 help balance the load impedances presented to the collectors of the final devices. Filtered A+ is routed to the final amplifier devices via the current sense resistor R5875, the ferrite bead L5884, and the coil L5882. The final stage output network terminates at C5900 which is the input to the antenna switch. The circuit impedance is 50 ohms at this point.

3.7.2.1.2 Antenna Switch and Harmonic Filter

Antenna Switch

The antenna switch utilizes PIN diodes to form a low loss, high isolation RF relay. During transmit, PIN diodes CR5900, CR5902, CR5904, and CR5905,are forward biased during transmit via the K9.4 supply and resistors R5901, R5900, R5908, and R5909. In this state, a low loss path exists from the final amplifier through PIN diode CR5900 and into the harmonic filter. PIN diodes CR5902, CR5904, and CR5905 effectively shunt the path to the receiver front-end, which protects the preamp or mixer device from excessive RF levels. A properly functioning switch will pass less than 10 mW of transmit power to the receiver front-end.

During receive, all four PIN diodes remain unbiased. This opens a low loss path from the harmonic filter to the receiver

Harmonic Filter

The harmonic filter is a 9-pole low-pass filter consisting of screened plate capacitors and air-wound coils on a 0.035 inch thick ceramic substrate. The filter's primary function is to attenuate harmonic energy generated by the amplifier stages. The filter also adds some selectivity for the receiver.

3.7.2.1.3 Power Control Circuitry

Command Board Circuitry

Inside U500, the Regulator Power Control IC (Figure 3-25) is an operational amplifier that has four inverting inputs, and one non-inverting input (at pin 44) which is the reference input for the entire power control loop of the power amplifier. The 3.2-V reference voltage at U500-44 is produced by dividing SW +5-V with the voltage-divider circuit, R514 and R515.

The power control loop is controlled by the microprocessor U204 on the VOCON board. Through the SLIC IC U206, the microprocessor enables the RPCIC by pulling TX PA ENABLE (U500 pin 33) low while the radio synthesizer is locked (U500 pin 35). U520 writes data to a digital-to-analog converter, U502, to change and control the power-set voltage from pin 10 of U502 to pin 6 of U500. The voltage on this line, 1.5 to 5 V, will be inversely proportional to the power out of the PA, with 5 V producing the lowest power output. This voltage may be set with RSS (Radio Service Software) or CPS (Customer Programming Software).

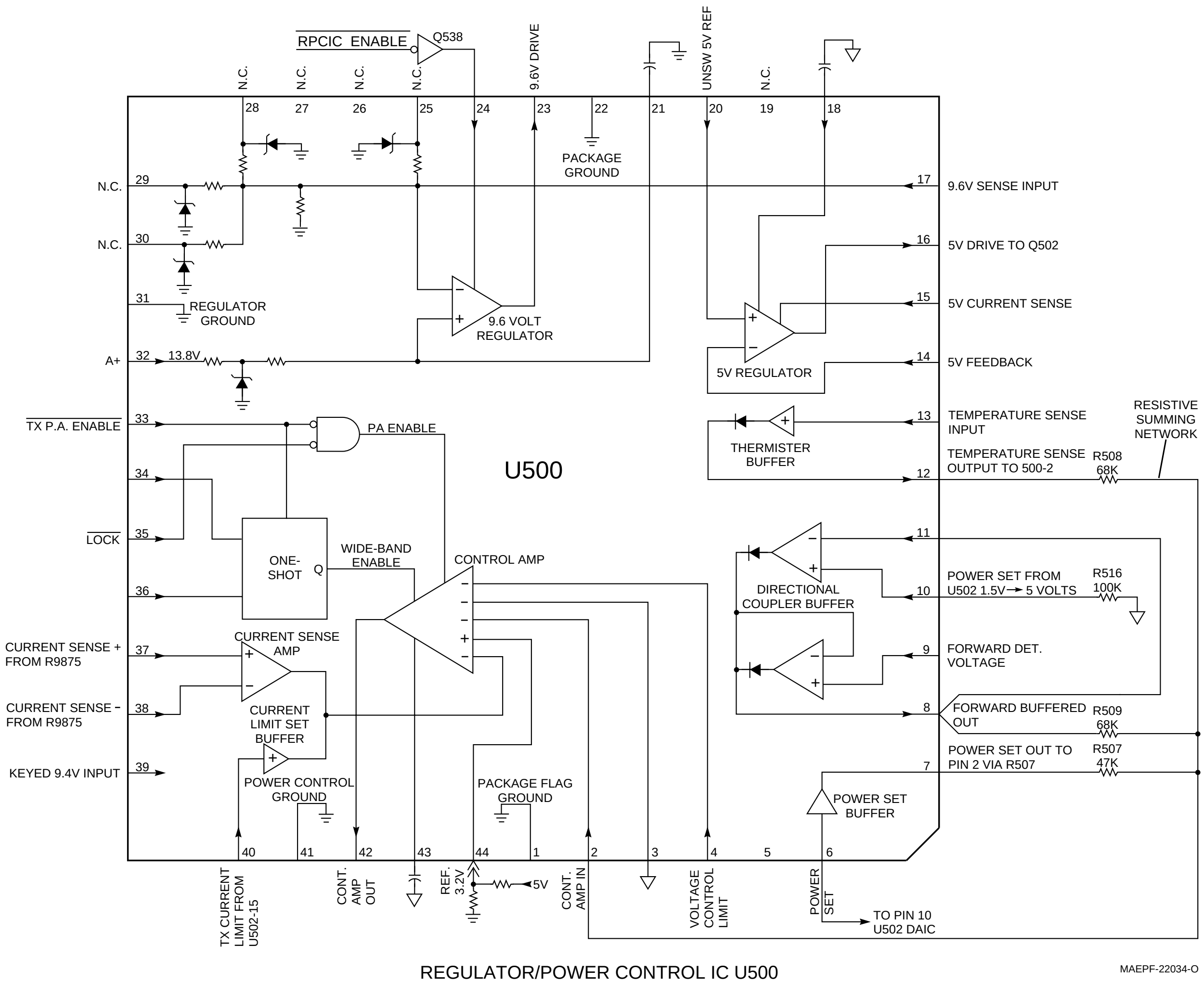


Figure 3-25. RPCIC Block Diagram

Control Voltage Limiter

R5807 and R5808 form a voltage divider that connects to control voltage drive. The output of this voltage divider is connected to the control-voltage-limit input (pin 4) of the RPCIC. If the voltage at this input reaches 3.2 V, then the control voltage will be clamped to a maximum value. For the high-power UHF PA, this maximum value is 10 V. This voltage control limit is set by the values of R5807 and R5808.

Current Limiter

U204, the processor on the VOCON board, sends data to U502, the digital-to-analog converter, to properly set the voltage on U502, pin 15, which is the TX CURRENT LIMIT control line to the RPCIC (U500, pin 40). Sixteen different voltages, ranging from 1.5 to 4.5 V, can be programmed from U502.

The collector current of the high-power amplifier is monitored by sensing the voltage across R5875. CURRENT SENSE + connects to one end of R5875; CURRENT SENSE - connects to the other end. These lines connect to the command board on U500 pins 37 and 38, respectively. If the TX CURRENT LIMIT is set for 1.5 V, then the voltage difference between U500 pins 37 and 38 must be 0.1 V before the current through R5875 is reduced. If U500 pin 40 is programmed for 4.5 V, then the difference of potential between pins 37 and 38 must exceed 0.3 V before current limiting begins. The voltage across R5875, where current sense occurs, can be determined by multiplying the voltage on U500, pin 40 by 0.067. When current is being limited, the output of the op-amp (U500, pin 42) begins shutting down the conduction of Q503 and Q504, reducing PA control voltage, and reducing drive to the final amplifier to, effectively, control the final amplifier's maximum current.

Forward Power Limiter

After the harmonic filter a parallel pair of microstrip lines form a forward power sensing directional coupler and detector. The output of this directional coupler/detector is a DC voltage that is proportional to the forward RF power from the final amplifier. During normal transmission, the DC voltage from the forward detect line to the RPCIC ranges from 2 to 5.0 V.

This voltage connects to U500 pin 9, the directional coupler buffer input.

The directional coupler's buffered output, U500 pin 8, is summed to pin 2 with the digital/analog buffer's output through R509 and R507, respectively. In typical operation, the closed loop operation of the circuit attempts to keep the voltage at U500 pin 2 a constant value of 3.2 V. The control amp will maintain this condition by increasing or decreasing the control amp output voltage. This control amp output voltage is routed to the LLA via transistors Q503 and Q504. The output of Q504 is designated "control voltage drive" and is routed to J1 pin 2 of the PA board.

Since control voltage drive controls the gain of the LLA, it determines the drive level to the following stages and thus the output power of the final amplifier. The output power of the final stage is detected by the directional coupler and is routed back to U500 pin 2 via the buffer and R507. Thus the loop is complete and forward power is maintained a constant value. The voltage at pin 2 will drop below 3.2 V during low line voltage conditions where the PA cannot produce rated power. Current limit and voltage control limit circuits will also affect the voltage at pin 2 as described in the following discussion on temperature sensing.

Temperature Sensing

The temperature-sensing circuit of the PA works with the RPCIC to protect the PA devices from excessively high temperatures. On the PA board, this circuit, (formed by resistors R5857, R5843, R5858, and thermistor RT5875), provides a temperature dependent voltage to the RPCIC via J1 pin 6. As the PA temperature increases, the resistance of RT5875 decreases, causing the voltage at pin 6 to increase. This voltage is routed to the RPCIC, U500 pin 13, which is the input to the thermistor buffer. The buffer's output on pin 12 is connected to pin 2 via resistor R508. Note that pin 2 is the control amp input and is a summing point for temperature, forward-power detect, and power set signals. If the PA temperature becomes high enough so that the voltage at pin 7 exceeds 3.2 V, the thermistor buffer starts supplying current to the node at pin 2. Due to the fixed output current of the power-set buffer, the control loop can maintain 3.2 V at pin 2 only by reducing the forward-power detect voltage and, therefore, reducing the PA output power. Since power output is reduced, the generated heat is reduced to a safe level. If temperature decreases, the power output of the PA gradually increases to its nominal value.

NOTE: Under severe environmental conditions, more than one circuit may be attempting to reduce power output at the same time (i.e., during high VSWR conditions, the current limiter may initially reduce power, but eventual heat buildup will cause further power reduction by the thermal cut-back circuit).

3.7.2.2 40-Watt Power Amplifier

3.7.2.2.1 Transmitter

The 40-Watt ASTRO Spectra power amplifier is discussed in the following text.

Transmit Low Level Amplifier (LLA)

NOTE: The minimum input drive level to the PA into P5850 is 30 mW. Refer to the synthesizer section if input drive is less than 30 mW.

The Low Level Amplifier, the first stage of the PA, provides a gain that is a function of a control voltage. This control voltage comes from the Regulator Power Control IC (RPCIC) on the command board. The magnitude of the control voltage depends on PA output power, temperature, and final amplifier current drain.

The LLA, Q5801, is unique in that its gain is controlled by varying the collector's current rather than its voltage. Q5801 and associated circuitry (Q5806, Q5800, R5805, and R5818) are best described as a voltage-controlled current source. This means that the collector current of Q5801 is controlled by the magnitude of the control voltage. Proper operation of the LLA can be checked by monitoring the voltage across the resistor R5805 The voltage should measure in the range of 0.1 to 1.0 V, depending on the value of control voltage. A 0.1-V reading corresponds to a low control voltage (1 to 5 V) and a 1.0-V reading corresponds to a high control voltage (up to control voltage limit).

Predriver Stage

The second stage of the PA, Q5803, is the predriver which amplifies the output of the LLA to a level sufficient to operate the driver device, Q5850. This stage amplifies the LLA output from, approximately, 250 mW in to 2.0 Watts out.

Driver Stage

The driver is a six-leaded 2.5- to 16-Watt device. It is driven by the predriver device through a matching circuit that consists of C5851, C5852, C5850, C5858, and L5850. L5851 and L5852 give the driver a zero-DC bias (required for the driver's Class-C operation). L5852, a ferrite bead, helps lower the driver base Q and prevent unwanted oscillations. The network of L5853, L5854, C5856, C5857, and R5850 provide A+ to the collector. L5853 and L5854 provide the DC path and block RF from coming up the DC line. R5850 resistively loads down the collector at low frequencies, preventing unwanted oscillations. C5856 and C5857 are bypass capacitors.

Final Stage

The final device is a six-leaded 15- to 50-Watt device and is driven by the driver through a quasi-low pass matching circuit that consists of C5853, C5854, C5855, C5875, C5876, and associated transmission lines. Base network, L5875, L5876, L5883, C5891, R5881, and R5882, provide the zero-DC bias required by the final device's Class-C operation. L5875, L5876, and L5883 provide the DC path from base to ground. C5891, in parallel with L5875, presents a high impedance at UHF frequencies, thus minimizing RF losses in the base network. R5881, R5882, and L5883 resistively load down the base at low frequencies, thus preventing unwanted oscillations. The collector DC network consists of L5878, L5879 R5879, R5880, R5883, R5884, R5875, C5881, C5883 C5884, C5885, C5886, C5893, and CR5875. This network provides the A+ voltage to the final while blocking RF from getting up the DC line. L5878 and L5879 provide the DC path and block RF. R5879, R5880, R5883, and R5884 resistively load down the final's collector at low frequencies and prevent unwanted oscillations. C5881, C5883, C5884, C3885, C5886 and C5893 are all bypass capacitors ranging from very low frequencies up to UHF frequencies. R5875 is the current-sense resistor. CR5875 protects against reverse polarity. Finally, the power goes through a low-pass matching network (C5877, C5878, C5887, C5892, C5880, and associated transmission lines) to the rest of the output network (Directional Coupler, Antenna Switch, and Harmonic Filter).

3.7.2.2.2 Antenna Switch and Harmonic Filter

Antenna Switch

The antenna switch's impedance inverter circuit, made up of C5923 and L5921, takes the place of a quarter-wave microstrip line. During transmission, Keyed 9.4 V forward-biases CR5921, producing low impedance on CR5921's anode and high impedance on the C5923/L5921 node. Effectively, this isolates the transmitted power from the receiver, C5922 couples the power to the harmonic filter and on to the antenna.

Total TX to RX isolation exceeds 45 dB from 450-512 MHz. The impedance inverter contributes approximately 35 dB to transmit isolation. A second shunt switch, made up of CR5922, L5922, and C5924, provides additional isolation. C5926 and C5927 block DC.

During RX, CR5920 has an OFF capacitance of approximately 1 pF, which is tuned out by L5904. CR5921 and CR5922, incorporated in the RX match, have similar OFF capacitances.

Harmonic Filter

The 40-Watt harmonic filter is a 7-pole, low-pass filter, consisting of screened plate capacitors and discrete inductors (1,5924, L5925, and L5926) on a 35-mil alumina substrate. The filter's ground plane is attached to the PA printed circuit board with solder, while input and output connections are made via MP5901 and MP5902. The filter's primary function is to attenuate harmonic spurs generated by the transmitter. It also adds low-pass selectivity for the receiver. L5910, grounded through MP5903, protects the PA from static discharge.

NOTE: When removing any of the discrete coils, take care to avoid leaching the plate capacitor metallization. Removal of the entire hybrid is best accomplished by heating the hybrid/PC board assembly with a heat gun or heat blower until the solder joint reflows.

3.7.2.2.3 Power Control Circuitry

Command Board Circuitry

Inside U500, the Regulator Power Control IC (Figure 3-26), is an operational amplifier that has four inverting inputs, and one non-inverting input (at pin 44) which is the reference input for the entire power control loop of the power amplifier. The 3.2-V reference voltage at U500-44 is produced by dividing SW +5-V with the voltage-divider circuit, R514 and R515.

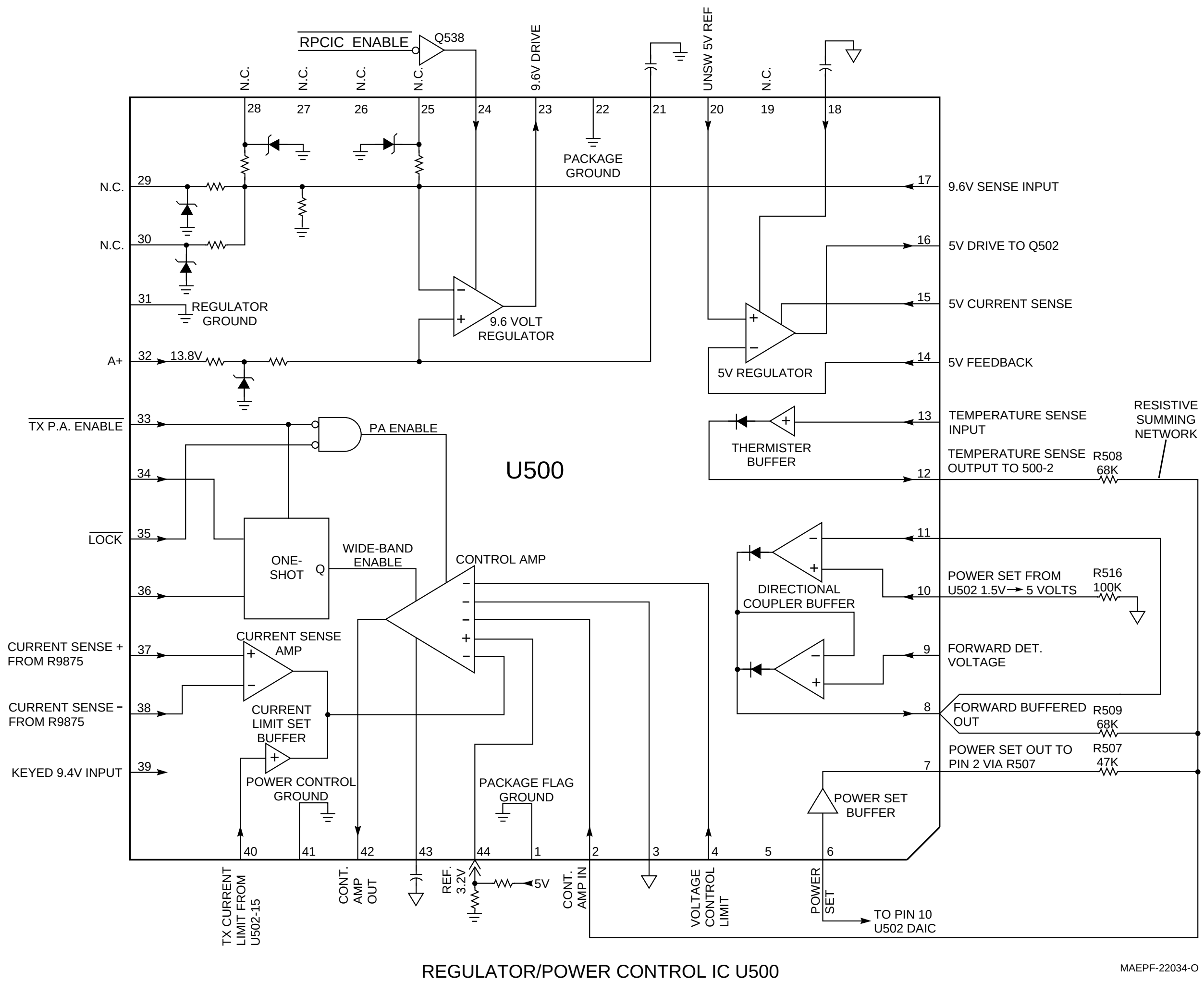


Figure 3-26. RPCIC Block Diagram

The power control loop is controlled by the microprocessor U204 on the VOCON board. Through the SLIC IC U206, the microprocessor enables the RPCIC by pulling TX PA ENABLE (U500 pin 33) low while the radio synthesizer is locked (U500 pin 35). U520 writes data to a digital-to-analog converter, U502, to change and control the power-set voltage from pin 10 of U502 to pin 6 of U500. The voltage on this line, 1.5 to 5 V, will be inversely proportional to the power out of the PA, with 5 V producing the lowest power output. This voltage may be set with RSS (Radio Service Software) or CPS (Customer Programming Software).

Control Voltage Limiter

R5807 and R5808 form a voltage divider that connects to control voltage drive. The output of this voltage divider is connected to the control-voltage-limit input (pin 4) of the RPCIC. If the voltage at this input reaches 3.2 V, then the control voltage will be clamped to a maximum value. For the 40-Watt UHF PA, this maximum value is 10 V. This voltage-control limit is set by the values of R5807 and R5808.

Current Limiter

U204, the processor on the VOCON board, sends data to U502, the digital-to-analog converter, to properly set the voltage on U502, pin 15, which is the TX CURRENT LIMIT control line to the RPCIC (U500, pin 40). Sixteen different voltages, ranging from 1.5 to 4.5 V, can be programmed from U502.

The collector current of the 40-Watt amplifier is monitored by sensing the voltage across R5875. CURRENT SENSE + connects to one end of R5875; CURRENT SENSE - connects to the other end. These lines connect to the command board on U500, Pins 37 and 38, respectively. If the TX CURRENT LIMIT is set for 1.5 V, then the voltage difference between U500, Pins 37 and 38 must be 0. 1 V before the current through R5875 is reduced. If U500, pin 40 is programmed for 4.5 V, then the difference of potential between Pins 37 and 38 must exceed 0.3 V before current limiting begins. The voltage across R5875, where current sense occurs, can be determined by multiplying the voltage on U500, pin 40, by 0.067. When current is being limited, the output of the op-amp (U500, pin 42) begins shutting down the conduction of Q503 and Q504, reducing PA control voltage, and reducing drive to the final amplifier to, effectively, control the final amplifier's maximum current.

Forward Power Limiter

After the final amplifier, a parallel pair of microstrip lines form a forward power-sensing directional coupler. Because of increased coupling with frequency, C5903, L5902, C5904, L5903, and C5905 are used to compensate and filter out harmonics. CR5900 rectifies the signal. R5904, R5905, and RT5904 provide thermal compensation. During normal transmission, the DC voltage from the forward-detect line to the RPCIC ranges from 2 to 4.5 V. This voltage connects to U500, pin 9, the directional coupler buffer input.

The directional coupler's output, U500 pin 8, is summed to pin 2 with the digital/analog buffer's output through R509 and R507, respectively. Closed loop operation reduces the control amp's output (pin 42), reduces the power module's gain, and reduces power output to maintain the coupler buffer output (U500, pin 2) at 3.2 V regardless of the D/A voltage level. If the D/A voltage is high (4.5 V), little detected voltage is needed to keep pin 2 at 3.2 V, and the power, consequently, is low. If the D/A voltage is low (1.5 V), a large forward detected voltage is needed to keep pin 2 at 3.2 V and power, consequently, is at maximum value. The voltage at pin 2 drops below 3.2 V under proper operation during low line voltage conditions where the PA cannot produce rated power, or if, under any conditions, the control voltage or the final device current exceeds safe levels.

Temperature Sensing

The temperature-sensing circuit of the PA works with the RPCIC to protect the PA devices from excessively high temperatures. On the PA board, this circuit, formed by resistors R5878, R5876, R5877, and thermistor RT5875, provides a temperature-dependent voltage to the RPCIC via P0853, pin 7. As the PA temperature increases, the resistance of RT5875 decreases, causing the voltage at pin 7 to increase. This voltage is routed to the RPCIC, U500, pin 13, which is the input to the thermistor buffer. The buffer's output on pin 12 is connected to pin 2 via resistor R508. Note that pin 2 is the control amp input and is a summing point for temperature, forward-power detect, and power set signals. If the PA temperature becomes high enough so that the voltage at pin 7 exceeds 3.2 V, the thermistor buffer starts supplying current to the node at pin 2. Due to the fixed output current of the power-set buffer, the control loop can maintain 3.2 V at pin 2 only by reducing the forward-power detect voltage and, therefore, reducing the PA output power. Since power output is reduced, the generated heat is reduced to a safe level. If temperature decreases, the power output of the PA gradually increases to its nominal value. Temperature cutback should occur at about 140 F (60 C).

The temperature sense circuitry can easily be tested by placing an ordinary leaded 6.8k ohm resistor across RT5875. PA output power should drop significantly if this circuit is working properly.

NOTE: Under severe environmental conditions, more than one circuit may be attempting to reduce power output at the same time (i.e., during high VSWR conditions, the current limiter may initially reduce power, but eventual heat buildup will cause further power reduction by the thermal cut-back circuit).

3.7.3 800 MHz Band Power Amplifiers

3.7.3.1 15- and 35-Watt Amplifiers

3.7.3.1.1 Transmitter

The 15-Watt and 35-Watt ASTRO Spectra power amplifiers are discussed in the following text.

Transmit Buffer

The PA receives 18 to 23 dBm (60 to 200 mW) at the transmit injection (TX INJ) coax. The first stage, TX BUFFER, uses adaptive biasing which varies the base voltage inversely proportional to the input drive level. With Keyed 9.4 V (K9.4) ON and NO DRIVE, Q9800 base voltage should equal the voltage drop across CR9800. R9801 sets the diode current, and R9802 sets the base voltage referenced from CR9800. At the input, L9804, C9801, and C9800 are for matching while C9808 and R9806 prevent interfacing instability. L9800 is the base feed choke and L9801 is the collector choke. R9800 parallels L9800 for added stability. L9805, and C9803 are on the buffer's supply (K9.4) for stability. C9802 and L9802 are for output matching. L9803 and C9804 are added as a "suckout" for half carrier. Like the input, C9807 and R9805 were added at the output to help prevent interfacing instability. The power output of this stage should be greater than 325 mW (25 dBm).

The TX Buffer applies the modulated RF signal to pin 1 of U9850, the Power Amplifier Module, which is a 5-pin, 20-Watt, three-stage amplifier. The control voltage from the power control series-pass transistor, Q9500, controls the gain of the first two amplifier stages of U9850, through pin 2 and pin 3. Battery voltage (A +), connected to pin 4, powers the third stage.

Power Module

The power module (U9850) is the major gain block for both the 15- and 35-Watt amplifiers. The 50-ohm input and output impedances connect to adjacent power stages via 50-ohm microstrip lines. The parallel resistor, R9805, and capacitor C9807, on the input, reduce circuit response at lower frequencies and improve stability. The 350 mW (typical) input power is increased to approximately 15 Watts. The amplifier power is monitored by the power control IC on the command board and adjusted by controlling the voltage on U9850, Pins 2 and 3. A+ is applied directly to the final stage inside the power module via pin 4. No repairs can be made to the module; damaged or failed units must be replaced.

Caution: The power module leads will not tolerate undue stress; handle carefully when repairing.

Final Stage (35-Watt Only)

On the 15-Watt radio, the transmit RF signal from U9850, pin 5, is applied to the 50-ohm microstrip directional coupler. On the 35-Watt radio, the transmit RF signal is applied to the emitter of the final power amplifier Q9880 through the coupling capacitor C9856, the 50-ohm quarter-wave matching transmission line, and the matching capacitors C9875 and C9876. The 100-ohm coupling line, L9930, R9930, R9931, CR9930, and C9930 form an interstage power detector between U9850 and Q9880 to limit the drive into Q9880 to about 17 Watts. L9875, the emitter choke, is also the emitter DC return. The final power amplifier, Q9880, is a 45-Watt, 800 MHz, common-base NPN devise. The Q9880 output match consists of C9877, C9878, a section of the 50-ohm microstrip line, C9879 and the DC blocking capacitor, C9883. L9876 isolates the RF signal from A+. C9880 and C9884 are signal frequency bypass capacitors. L9877 presents a high impedance at low RF frequencies; therefore the collector of Q9880 is resistively loaded by R9876 at low frequencies where the gain is much greater. C9881 and C9882 are low frequency bypass capacitors.

3.7.3.1.2 Antenna Switch and Harmonic Filter

Antenna Switch

35-Watt Power Amplifier:

The antenna switch's impedance inverter circuit, made up of C9922 and L9921, takes the place of a quarter-wave microstrip line. During transmission, K9.4-V forward-biases CR9921, producing a low impedance at its anode end, and a high impedance at the node of C9922 and L9921, to effectively isolate the transmitted power from the receiver. C9921 couples the power to the harmonic filter and on to the antenna.

The impedance inverter contributes approximately 30 dB to transmit isolation. Additional isolation is obtained by the series switch made up of CR9922, L9923, and associated DC bias components. During transmit, CR9922 is reverse-biased, thus creating a small series capacitor that is tuned out by L9923. C9925 is a DC blocking capacitor. The high impedance of the series arm works against the low impedance of the shunt arm (CR9921) to provide approximately 10 to 15 dB additional isolation. Total TX to RX isolation is in excess of 45 dB from 851-870 MHz. The preselector provides over 50 dB isolation from 806-824 MHz.

When receiving, CR9920 has an off capacitance of approximately 1 pF, which is tuned out by L9926. CR9921, with similar off capacitance, is incorporated in the RX match. CR9922 is forward-biased with an ON resistance of approximately 1 ohm. The signal passes CR9922 and through L9922, a series inductor used to complete the RX match. Capacitor C9929 blocks DC.

L9910, at the node of the antenna and harmonic filter, protects the PA from static discharge.

15-Watt Power Amplifier:

The theory for the 15-Watt antenna switch is exactly the same as the 35-Watt except that some of the components are labeled with different numbers. C9921, in the 15-Watt PA, is located after the harmonic filter.

L9922, at the node of the antenna and capacitor C9921, protects the PA from static discharge.

Harmonic Filter

The 15- and 35-Watt harmonic filters are 7-pole, low-pass filters implemented with screened plate capacitors and discrete inductors (L9911, L9912, and L9913) on a 35 mil (0.035") alumina substrate. The filter's ground plane is attached to the PA printed circuit board with solder, while input and output connections are made via "J"-straps MP9856 and MP9857. The filter's primary function is to attenuate harmonic spurs generated by the transmitter and to provide additional low-pass selectivity for the receiver.

NOTE: When removing any of the discrete coils, take care to avoid leaching the plate capacitor metallization. Removal of the entire hybrid is best accomplished by heating hybrid/PC board assembly with a heat gun or heat blower until solder joint reflows.

3.7.3.1.3 Power Control Circuitry

Command Board Circuitry

Inside U500, the Regulator Power Control IC (Figure 3-27), is an operational amplifier that has four inverting inputs, and one non-inverting input (at pin 44) which is the reference input for the entire power control loop of the power amplifier. The 3.2-V reference voltage at U500, pin 44, is produced by dividing SW + 5-V with the voltage-divider circuit, R514 and R515.

The power control loop is controlled by the microprocessor U204 on the VOCON board. Through the SLIC IC U206, the microprocessor enables the RPCIC by pulling TX PA ENABLE (U500 pin 33) low while the radio synthesizer is locked (U500 pin 35). U520 writes data to a digital-to-analog converter, U502, to change and control the power-set voltage from pin 10 of U502 to pin 6 of U500. The voltage on this line, 1.5 to 5 V, will be inversely proportional to the power out of the PA, with 5 V producing the lowest power output. This voltage may be set with RSS (Radio Service Software) or CPS (Customer Programming Software).

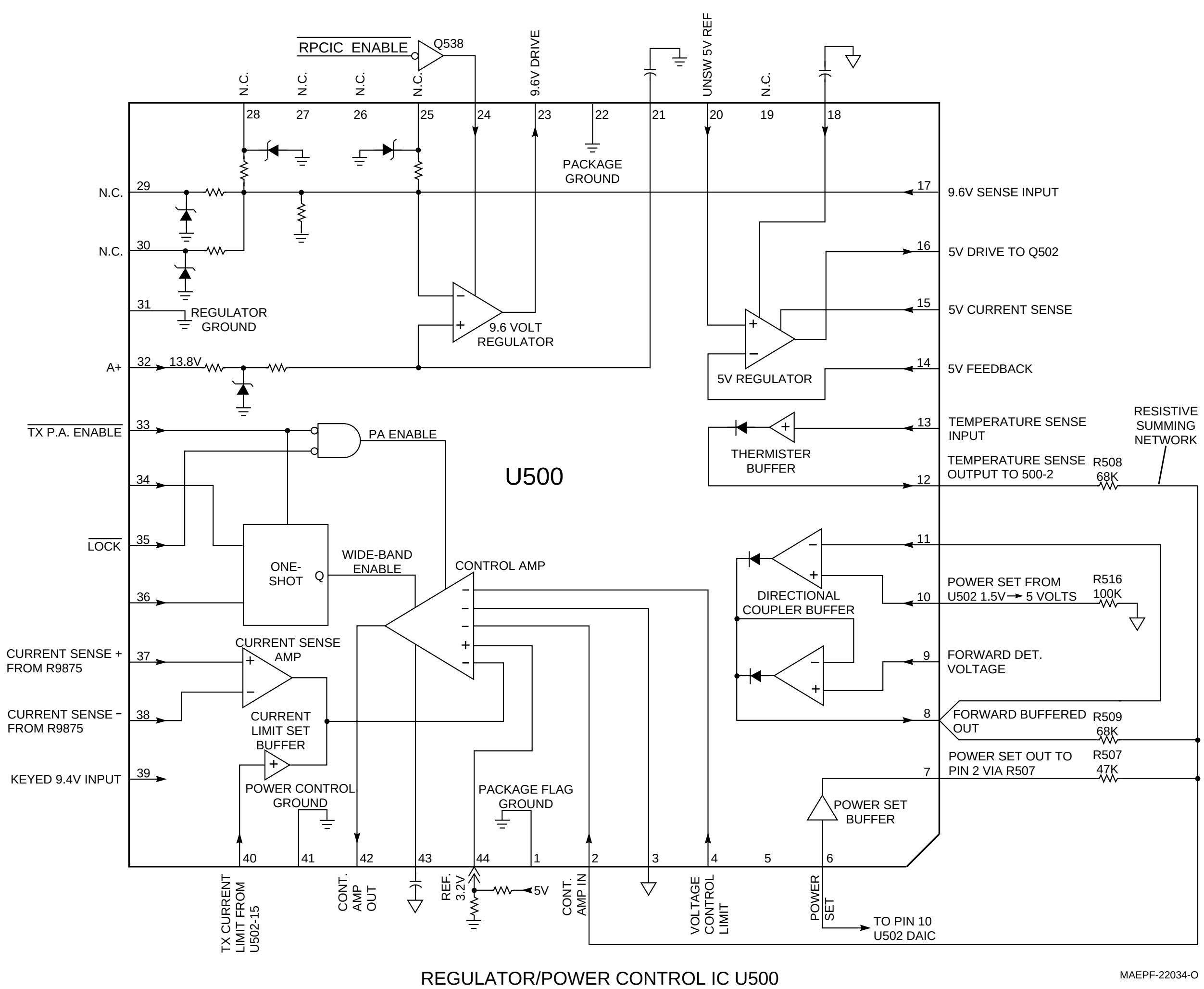


Figure 3-27. RPCIC Block Diagram

Power Module Control Voltage Limiter

R9562 and R9563 connect in series to the emitter of Q9500. The ratio of R9563 and R9562 feed a portion of the control voltage (U9850, Pins 2 and 3) to U500, pin 4. When pin 4 exceeds 3.2 V, the output of the control op-amp (U500, pin 42) is reduced. Eventually, this reduces the control voltage available to the power module (U9850).

The input RF power to the 45-Watt amplifier Q9880) must stay below 17 Watts. Power is coupled from the inter-stage 50-ohm transmission line to a 100 ohm transmission line and rectified by CR9930 on the PA, producing a DC voltage on U500, pin 4. IF this voltage exceeds 3.2 V, the output voltage on U500, pin 42, is reduced, lowering the control voltage and reducing U9850's gain until its RF output power is approximately 17 Watts.

Current Limiter

U204, the processor on the VOCON board, sends data to U502, the digital to analog converter, to properly set the voltage on U502, pin 15, which is the TX CURRENT LIMIT control line to the RPCIC (U500, pin 40). Sixteen different voltages, ranging from 1.5 to 4.5 V, can be programmed from U502.

The collector current of the 45-Watt final amplifier (in the 35-Watt PA only) is monitored by sensing the voltage across R9875. CURRENT SENSE + connects to one end of R9875 and CURRENT SENSE - connects to the other end. These lines connect to the command board on U500, Pins 37 and 38, respectively. If the TX CURRENT LIMIT is set for 1.5 V, then the voltage difference between U500, Pins 37 and 38 must be 0.1 V before the current through R9785 is reduced. If U500, pin 40 is programmed for 4.5 V, then the difference of potential between Pins 37 and 38 must exceed 3 V before current limiting begins. The voltage across R9875, where current sense occurs, can be determined by multiplying the voltage on U500, pin 40, by 0.067. When current is being limited, the output of the op-amp (U500, pin 42), begins shutting down the conduction of Q503 and Q504, reducing base drive to Q9500, reducing drive to the final amplifier to, effectively, control the final amplifier's maximum current.

Forward Power Limiter

The parallel pair of microstrip lines after the final amplifier, form a forward power sensing directional coupler. Because the coupling increases with frequency, the compensation network of L9806 and C9901 is used. CR9900 rectifies the signal, C9900 filters it, and R9905 and R9904 form a voltage divider. During normal transmission, the DC voltage from the forward detect line to the RPCIC ranges from 2 to 4.5 V. This voltage connects to U500, pin 9, the input to the directional coupler buffer.

The directional coupler's output, U500, pin 8, is summed to pin 2 with the digital/analog buffer's output through R509 and R507, respectively. Closed loop operation reduces the control amp's output (pin 42), reduces the power module's gain, and reduces power output to maintain the coupler buffer output U500, pin 2) at 3.2 V regardless of the D/A voltage level. If the D/A voltage is high (4.5 V), little detected voltage is needed to keep pin 2 at 3.2 V, and the power, consequently, is low. If the D/A voltage is low (1.5 V), a large forward detected voltage is needed to keep pin 2 at 3.2 V and power, consequently, is at maximum value. The voltage at pin 2 drops below 3.2 V under proper operation during low line voltage conditions where the PA cannot produce rated power, or if, under any conditions, either the inter-stage power (in 35-Watt models only), the control voltage, or the final device current exceeds safe levels.

3.7.3.1.4 Temperature Sensing

When the radio is keyed, K9.4-V is applied to pin 5 of the PA connector and on one side of thermistor RT9560. As the temperature increases, the resistance of RT9560 decreases, creating more voltage across R9561. This temperature voltage is routed via PA connector pin 7 back to U500, pin 13, which is the input to a thermistor buffer. The thermistor buffer's output on pin 12 is summed to U500, pin 2, and passes through its scaling resistor, R508. When the temperature of the RT9560 causes its value to change enough that the voltage exceeds 3.2 V, the thermister buffer starts supplying current to the node at pin 2. Due to the fixed output of the D/A, the control loop can maintain 3.2 V at pin 2 only by reducing power out and reducing the forward detected voltage. Since output is reduced, the generated heat is held to a safe level. As temp decreases, the power output of the PA gradually increases to its nominal value.

Q9515 and Q9510 switch A+ to one side of R9513. R9513 sums the A+ voltage into the same node as TEMPSENSE. Together with temp-sense the circuitry protects the power amplifier from unsafe operating conditions of high line and high temp.

NOTE: Under severe environmental conditions more than one circuit may be attempting to reduce power output at the same time (i.e., during high VSWR conditions, the inter-stage power limit may initially reduce power, but eventual heat build-up will cause further power reduction by the thermal cut-back circuit).

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Chapter 4 Troubleshooting Procedures

4.1 ASTRO Spectra Procedures

This section will aid you in troubleshooting a malfunctioning ASTRO Digital Spectra radio. It is intended to be detailed enough to localize the malfunctioning circuit and isolate the defective component.

NOTE: Refer to “4.2 ASTRO Spectra Plus Procedures” on page 4-10 for troubleshooting information specific to the ASTRO Spectra Plus radio.

Caution

Most of the ICs are static-sensitive devices. Do not attempt to troubleshoot or disassemble a board without first referring to the following Handling Precautions section.

4.1.1 Handling Precautions

Complementary metal-oxide semiconductor (CMOS) devices and other high-technology devices, are used in this family of radios. While the attributes of these devices are many, their characteristics make them susceptible to damage by electrostatic discharge (ESD) or high-voltage charges. Damage can be latent, resulting in failures occurring weeks or months later. Therefore, special precautions must be taken to prevent device damage during disassembly, troubleshooting, and repair. Handling precautions are mandatory for this radio, and are especially important in low-humidity conditions. DO NOT attempt to disassemble the radio without observing the following handling precautions.

1. Eliminate static generators (plastics, Styrofoam, etc.) in the work area.
2. Remove nylon or double-knit polyester jackets, roll up long sleeves, and remove or tie back loose hanging neckties.
3. Store and transport all static-sensitive devices in ESD-protective containers.
4. Disconnect all power from the unit before ESD-sensitive components are removed or inserted unless otherwise noted.
5. Use a static-safeguarded workstation, which can be accomplished through the use of an anti-static kit (Motorola part number 01-80386A82). This kit includes a wrist strap, two ground cords, a static-control table mat and a static-control floor mat.
6. Always wear a conductive wrist strap when servicing this equipment. The Motorola part number for a replacement wrist strap that connects to the table mat is 42-80385A59.

4.1.2 Voltage Measurement and Signal Tracing

In most situations, the problem circuit may be identified using a dc voltmeter, RF millivoltmeter, and oscilloscope (preferably with 100 MHz bandwidth or more). The “Recommended Test Equipment, Service Aids, and Tools” section in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) outlines the recommended tools and service aids which would be useful. Of special note are:

- 30-80370E06 Extender Cable which provides an extension cable for VOCON board connector J501 and command board connector P501.
- RPX-4725A Command and Control Service Cable Kit which provides extension cables for servicing digital and analog circuits.
- RPX-4724A RF Service Cable Kit which provides interface cables needed to service the RF boards.

In some cases dc voltages at probe points are shown in red on the schematics. In other areas diagrams are included to show time-varying signals, which should be present under the indicated circumstances. It is recommended that a thorough check be made prior to replacement of any IC or part. If the probe point does not have a signal reasonably close to the indicated one, a check of the surrounding components should be made prior to replacing any parts.

Caution

When checking a transistor or module, either in or out of circuit, do not use an ohmmeter having more than 1.5 Vdc appearing across test leads or use an ohms scale of less than x100.

4.1.3 Power-Up Self-Check Errors

Each time the radio is turned on the MCU and DSP perform some internal diagnostics. These diagnostics consist of checking the programmable devices such as the FLASH ROMs, internal and external EEPROMs, SRAM devices, and ADSIC configuration bus checksum. At the end of the power-up self-check routines, if an error exists, the appropriate error code is shown on the display. Self-test errors are classified as either “fatal” or “non-fatal.” Fatal errors will inhibit user operation; non-fatal errors will not. For non-display radios, the error codes may be read using the Radio Service Software (RSS) from the SB9600 bus on the universal connector. Table 4-1 lists self-check error codes, describes the codes, and recommends troubleshooting charts for investigating the cause of the failure.

Table 4-1. Power-Up Self-Check Error Codes

Error Code	Description	Troubleshooting Chart
01/02	External EEPROM checksum non-fatal error	Chart C.2 (p. 4), C.7 (p. 8)
01/81	ROM checksum failure	Chart C.6 (p. 7)
01/82	External EEPROM checksum failure	Chart C.2 (p. 4), C.7 (p. 8)
01/84	EEPROM is blank	Chart C.2 (p. 4), C.8 (p. 8)
01/88	RAM failure - Note: Not a checksum failure	Chart C.2 (p. 4), C.9 (p. 9)
01/90	General hardware failure	Chart C.2 (p. 4), C.5 (p. 7)

Table 4-1. Power-Up Self-Check Error Codes (Continued)

Error Code	Description	Troubleshooting Chart
01/92	Internal EEPROM checksum failure	Chart C.10 (p. 9)
02/81	DSP ROM checksum failure	Chart C.12 (p. 10)
02/82	DSP RAM 1 failure	Chart C.15 (p. 12)
02/84	DSP RAM 2 failure	Chart C.14 (p. 11)
02/88	DSP RAM failure - Note: Not a checksum failure	Chart C.13 (p. 11)
02/90	General DSP hardware failure (DSP start-up message not received correctly)	Chart C.16 (p. 12)
02/A0	ADSIC checksum failure	Chart C.11 (p. 10)
09/10	Secure option not communicating with radio	Chart C.17 (p. 13)
09/90	Secure hardware failure	Chart C.18 (p. 13)

In the case of multiple errors, the codes are logically OR'd and the results displayed. As an example, in the case of an ADSIC checksum failure and a DSP ROM checksum failure, the resultant code would be 02/A1. Following is a series of troubleshooting flowcharts which relate to each of these failure codes.

4.1.3.1 Power-Up Sequence

Upon RESET* going active, the MCU begins to execute code which is pointed to by the vector stored at $FFFE, $FFFF in the FLASH ROM. The execution of this code is as follows:

1. Initialize the MCU (U204).
2. The control head's MCU turns on the:
   - Green LED for the W3 model.
   - TX and Busy LEDs for the W4, W5, W7 and W9 models.
3. Initialize the SLIC (U206).
4. CONFIG register check. If the CONFIG register is not correct, the MCU will repair it and loop.
5. Start ADSIC/DSP:
   - Bring the ADSIC reset line high.
   - Wait 2ms.
   - Bring the DSP reset line high.
6. Start EMC:
   - Set the EMC wake-up line low (emc irq line).
   - Wait 5ms.
   - Set the EMC wake-up line high.
   - Wait 10ms.
   - Set the EMC wake-up line low (emc irq line).
   - Wait 5ms.

- Set the EMC wake-up line high.

7. Begin power-up self-tests.
8. Begin RAM tests:
   - External RAM ($1800-3FFF).
   - Internal RAM ($1060-$1300).
   - External RAM ($0000-$0DFF).
   - Display 01/88 if failure.

The radio will get stuck here if the internal RAM is defective. The radio uses the internal RAM for stack. The RAM routines use subroutines. Thus, if the internal RAM is defective, the radio will get lost testing the external RAM.

9. Begin MCU (host µC) ROM checksum test.
   - Fail 01/81 if this routine fails.
10. Begin DSP power-up tests. The MCU will try this five times before it fails the DSP test.
    - Check for HF2.
      - Fail 02/90 if 100ms.
    - Program the ADSIC.
    - Wait for the DSP power-up message.
      - Fail 02/A0 if 300ms.
      - Fail 02/A0 if wrong message from the DSP.
    - Wait for the DSP status information.
      - Fail 02/90 if 100ms.
      - Fail 02/88 if DSP RAM (U414) fails.
      - Fail 02/84 if DSP RAM U403 fails.
      - Fail 02/82 if DSP RAM U402 fails.
      - Fail 02/81 if DSP RAM fails.
    - Wait for the ADSIC checksum.
      - Fail 02/A0 if 100ms.
      - Fail 02/A0 if failure.
    - Wait for the first part of the DSP version number.
      - Fail 02/90 if 100ms.
    - Wait for the second part of the DSP version number.
      - Fail 02/90 if 100ms.
11. Checksum the codeplug.
    - Test internal codeplug checksums.
      - Fail 01/92 if failure.
    - Test external codeplug checksums.
      - Error 01/02 if non-fatal error; fail 01/82 if fatal error.

12. Power-up the EMC (if it is enabled in the codeplug).
13. Turn off the green LED.
14. Start up operating system.
15. Display for one second:
    - "SELF TEST" for the W3, model.
    - "SELF CHK" for the W4, W5, and W7 models.
    - "SELF CHECK" for the W9 models.
16. Turn off the green LED in the W3 model, or the TX and Busy LEDs in the W4, W5, W7, and W9 models.

Display errors if a fatal error exists at this time.

4.1.4 RF Board Troubleshooting

This information will help you troubleshoot the ASTRO Spectra Radio RF board. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. The principal tools needed to troubleshoot a circuit to the component level are the schematic and the Theory of Operation.

In addition to the schematic and theory, the following troubleshooting information identifies tests and checks designed to help isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation, including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at high frequencies, measurements must be taken very carefully. Notes and cautions are added to the text to alert the reader to this need in areas of greatest sensitivity. However, the need for extreme care does exist in all measurements and tests.

4.1.4.1 Display Flashes "FAIL 001"

This display indicates a synthesizer "out-of-lock" condition. Check the dc power supplies for the correct voltages at the following locations:

Table 4-2. Voltage by Location

VOLTAGE	LOCATION	REMARKS
+5 Vdc	Q602 Collector	
+8.6 Vdc	Q603 Collector	
+5 Vdc +3.25 Vdc	J500 pin 1 J500 pin 2	Power from command board to reference oscillator

1. If any of the dc voltages are not correct, troubleshoot the source of the supplied power and correct the problem. If the voltages are correct, continue with the following checks.
2. Check U602, pin 19 for reference frequency, 0- to 9-V, square wave. If not correct, go to "Incorrect Values at U602, pin 19"; otherwise, continue with the following checks.
3. Check U602, pin 25 for reference frequency, 0- to 9-V, square wave. If not correct, go to "Incorrect Values at U602, pin 25 (MODULUS CONTROL)"; otherwise, continue with the following checks.

4. Check the negative steering line, J601, pin 4. If correct, continue with the following checks.
5. Check the positive steering line, J601, pin 1 or 2 for positive voltage between 1.0 and 8.0 V. If not correct, go to "Incorrect Voltage at Positive Steering Line"; otherwise, continue with the following checks.

NOTE: It is common for both steps 3 and 5 to be incorrect in an "out-of-lock" condition.

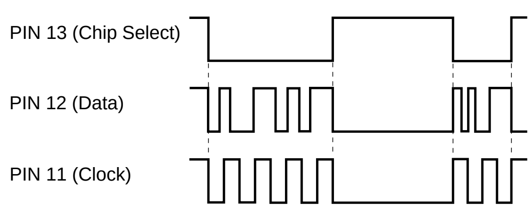
6. Check U602, pin 27 for a 1.5 Vp-p square wave whose frequency is determined in the following equation. If the values are not correct, go to "Incorrect Values at U602, pin 27."

   Freq into U601-1 / Prescaler Modulus;
   for example, F_{in} / P = 455 MHz / 255 = 1.77 MHz, or
   F_{in} / (P+1) = 455 MHz / 256 = 1.76 MHz.

   NOTE: The frequency at U601, pin 40, is seldom exactly equal to "F_{in}" divided by "P" or "P+ 1" because the prescaler is continuously changing from one division to the other. In the above example, P is 255 and P+ 1 is 256.

4.1.4.1.1 Incorrect Values at U602, Pin 19

1. If the reference frequency is not equal to 6.25 kHz (800/900 MHz) or 5.0 kHz (VHF/UHF), check U602-7 for 300 kHz, 0- to 9-V square wave. Then:
   a. If 300 kHz is good, check the power to U602, pins 30 and 37. Also, check the serial data programming by pressing and holding the mode select button and probing pins 11, 12, and 13. The 0- to 5-V logic waveforms should appear similar to the following:



   NOTE: The above waveforms are crude representations.

   b. If the programming appears normal and the power supplies have all checked out correctly, the out-of-lock condition is caused by a defective synthesizer IC (U602).
2. If 300 kHz is not present, check U602, pin 16, for 2.1 MHz, 1.5 Vp-p square wave.
   a. If the signal is present and the power to the chip is normal, the condition is caused by a defective synthesizer IC (U602).
   b. If the signal is not present, check for the same signal at U601, pin 18. If not on pin 18, check the reference oscillator output signal at U601, pin 21; it should be 16.8 MHz, 300 mVp-p. If the reference oscillator signal is present and the prescaler power supply voltages are normal, the prescaler IC(U601)is defective.
   c. If the reference oscillator signal (16.8 MHz) is not present on U601, pin 21, check U600, pin 1 for 3.25 Vdc, pin 2 for ground, pin 3 for 16.8 MHz at 300 mVp-p, and pin 4 for 5 Vdc.

   NOTE: Before concluding that the reference oscillator is defective, remove it from the board, power it up externally, and test it as an independent circuit.

4.1.4.1.2 Incorrect Values at U602 Pin 25 (MODULUS CONTROL)

If the frequency is not 6.25 kHz (or 5.0 kHz for VHF), verify the proper VCO pin-shift logic. See VCO block diagram (Figure 4-1) for pin-shift logic. Also, check the VCO feedback for approximately -10 to 5 dBm at proper VCO frequency. Use the following table:

Table 4-3. Feedback Frequency Ranges

Band	VCO Feedback Frequency
VHF	TX Freq x 2 or RX Freq + 109.65 MHz
UHF	TX Freq or RX Freq + 109.65 MHz
800 MHz	TX Freq / 2 or (RX Freq - 109.65 MHz) / 2

If the VCO is running at approximately the correct level and frequency, proceed to “Incorrect Values at U602, pin 27.”

4.1.4.1.3 Incorrect Voltage at Positive Steering Line

Verify that the VCO is running; check VCO feedback for -10 to 0 dBm. Verify that the feedback buffer (if used) is working check U601-1.

4.1.4.1.4 Incorrect Values at U602, pin 27

Check prescaler (U601) operation; U601-40 should be:

EQUATION: $F = F_{vco} /(P \text{ or } P+1)$

4.1.4.2 Review of Synthesizer Fundamentals

1. The synthesizer is a phase-locked loop system with a sample-and-hold phase detector.
2. In a locked system, the prescaler, in conjunction with the counters in the synthesizer chip, counts the VCO frequency down to the reference frequency. Think of this division process as a time domain function rather than frequency domain.
3. For each reference period (if using 6.25 kHz reference), you have 160 microseconds in which the VCO frequency is divided by N. Recall the equations:

   EQUATION: $N = F_{vco} / F_r$
   EXAMPLE: $N = F_{vco} / F_r$ = 450 MHz / 6.25 kHz or 72,000

   EQUATION: A = (fractional remainder of N/P) (P)
   EXAMPLE: A = N/P = 72,000 / 255 = 282.3529; .3529 x 255 Or A=90

   EQUATION: B = [N - {A x (P + 1)}] / P
   EXAMPLE: B = [72,000 - {90 x (255 +1)}] or 192

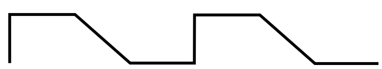
At 450 MHz, there are 72,000 counts of 2.22 nanoseconds each per reference period. When modulus control (MCT) is high, the VCO output is prescaled by 255 (see the diagram below). The output frequency of the prescaler is 1.765 MHz which corresponds to a period, per-cycle, of 567 nanoseconds. The “A” counter runs long enough to count down 90 cycles which equals 51 microseconds. When MCT is low, the prescaled output equals 1.758 MHz which corresponds to a period of 569 nanoseconds. The “B” counter counts 192 cycles which takes 109 microseconds. The total time required for proper loop division is thus 160 microseconds (the reciprocal of 6.25 kHz).

MODULUS CONTROL:	HI	LOW	HI	LOW	HI	LOW
COUNTER:	A	B	A	B	A	B
COUNTER RESET:	90	192	90	192	90	192
PRESCALER DIVIDES BY:	255	256	255	256	255	256
TIME (Microseconds):	51	109	51	109	51	109
LOOP DIV. TIME (Sec):	160		160		160	

4.1.4.3 Second VCO Checks

1. Check for 300 kHz reference frequency at U601, pin 31.
2. Check for 0.5 to 4.0-V phase detector output at U601, pin 30.
3. Check for -12 to -16 dBm at 109.2 MHz feedback (U601, pin 26).
4. Check the divide-by-N test point for a 700-mV p-p waveform at 300 kHz (the second VCO frequency divided by 364). See the example below.

$$\frac{109.2\text{ MHz}}{364} = 300\text{ kHz}$$



NOTE: The second VCO circuit is external to U601 and, while it does depend on U601 for proper phase-locking, it should free-run, open-loop, at some frequency, if U601 fails. If the 8.8-V super filter and the oscillator are “dead,” U601 is defective.

4.1.4.4 Troubleshooting the Back-End

Refer to "Chart C.1 RF Board Back-End," on page 5-3.

4.1.5 Standard Bias Table

Table 4-4, below, outlines some standard supply voltages and system clocks which should be present under normal operation. These should be checked as a first step to any troubleshooting procedure.

Table 4-4. Standard Operating Bias

Signal Name	Nominal Value	Tolerance	Source
UNSW_B+	13.8 Vdc	11.0-16.6 Vdc	J501
SW_B+	13.8 Vdc	11.0-16.6 Vdc	J501
+5V	5.0 Vdc	±10%	J501
+5VA	5.0 Vdc	±10%	J501
RESET	5.0 Vdc	+0.7, - 1.0 Vdc	J501
POR*	5.0 Vdc	+0.7, - 1.0 Vdc	J501
DSP_RST*	5.0 Vdc	+0.7, -1.0 Vdc	U204
ADSIC_RST*	5.0 Vdc	+0.7, -1.0 Vdc	U204
DCLK	33.0000 MHz[a]	±500 ppM	U406
ODC	2.4 MHz	±30 ppM	ABACUS
ECLK	1.8432 MHz	±500 ppM	U204
IRQB*	8 kHz[b]	±500 ppM	U406
+5V	5.0 Vdc	±10%	U202
RX_5V[c]	5.0 Vdc	±10%	U106

a. This number may vary due to the operating mode of the radio when it is measured. The ADSIC contains a divider which may divide the clock by a modulus of 2. Therefore, the actual frequency measured may be clock/2^n. The most common frequency will be 16.5000 MHz nominal.

b. This 8 kHz clock will be present only after the MCU has successfully programmed the ADSIC after power-up. This is a good indication that the ADSIC is at least marginally operational.

c. Receive mode only.

4.2 ASTRO Spectra Plus Procedures

This section will aid you in troubleshooting a malfunctioning ASTRO Digital Spectra Plus radio. It is intended to be detailed enough to localize the malfunctioning circuit and isolate the defective component.

Caution

Most of the ICs are static-sensitive devices. Do not attempt to troubleshoot or disassemble a board without first referring to the following Handling Precautions section.

Please review sections 4.1.1 Handling Precautions on page 4-1 and 4.1.2 Voltage Measurement and Signal Tracing on page 4-2 before continuing. Also, for information on troubleshooting the RF board, refer to Section 4.1.4 RF Board Troubleshooting on page 4-5.

4.2.1 ASTRO Spectra Plus Power-Up Self-Check Errors

Each time the radio is turned on the MCU and DSP perform some internal diagnostics. These diagnostics consist of checking the programmable devices such as the FLASH ROMs and SRAM devices. At the end of the power-up self-check routines any errors produced are recorded. If an error exists, use the Customer Programming Software (CPS) from the RS232 bus on front and rear of the radio to read the error code. Table 4-5 lists self-check error codes, describes the codes, and gives the recommended corrective action.

Table 4-5. ASTRO Spectra Plus Power-Up Self-Check Error Codes

Error Code	Description	Corrective Action
01/02	FLASH ROM codeplug Checksum Non-Fatal Error	Reprogram the codeplug
01/12	Security Partition Checksum Non-Fatal Error	Send radio to depot
01/20	ABACUS Tune Failure Non-Fatal Error	Turn radio off, then on
01/22	Tuning Codeplug Checksum Non-Fatal Error	Send radio to depot
01/81	Host ROM Checksum Fatal Error	Send radio to depot
01/82	FLASH ROM codeplug Checksum Fatal Error	Reprogram the codeplug
01/88	External RAM Fatal Error --Note: Not a checksum error	Send radio to depot
01/90	General Hardware Failure Fatal Error	Turn radio off, then on
01/92	Security Partition Checksum Fatal Error	Send radio to depot
01/93	FLASHport Authentication Code Failure	Send radio to depot
01/98	Internal RAM Fail Fatal Error	Send radio to depot
01/A2	Tuning Codeplug Checksum Fatal Error	Send radio to depot
02/81	DSP ROM Checksum Fatal Error	Send radio to depot

Table 4-5. ASTRO Spectra Plus Power-Up Self-Check Error Codes (Continued)

Error Code	Description	Corrective Action
02/88	DSP RAM Fatal Error --Note: Not a checksum error	Turn radio off, then on
02/90	General DSP Hardware Failure (DSP startup message not received correctly)	Turn radio off, then on
09/10	Secure Hardware Failure	Turn radio off, then on
09/90	Secure Hardware Fatal Error	Turn radio off, then on

NOTE: In cases of multiple errors, the codes are logically OR'd and the results displayed.

4.2.2 ASTRO Spectra Plus Power-Up Self-Check Diagnostics and Repair

The following are additional action items to be utilized for the diagnosis and resolution of the error codes shown in Table 4-5:

Error Code 01/02	This non fatal error will likely recover if the radio's power is cycled. In the event that this does not resolve the issue, the radio should be reflashed. As a last resort, the FLASH ROM U301 should be replaced.
Error Code 01/12	The radio should be sent to the depot for reflahing of the security codeplug.
Error Code 01/20	Cycling radio power should resolve this issue.
Error Code 01/22	The radio should be sent to the depot for reflash of the tuning codeplug followed by re-tuning of the radio.
Error Code 01/81	The radio should be sent to the depot for reflashing of the host code.
Error Code 01/82	The radio should be sent to the depot for reflashing of the radio codeplug.
Error Code 01/88	Reflashing of the radio should first be performed. If this fails to resolve the issue, then replacement of the SRAM U302 is necessary.
Error Code 01/90	Cycle power to radio. Continued failure indicates a likely IC failure. In this event, radio should be sent to the depot for isolation and repair of the problem IC.
Error Code 01/92	The radio should be sent to the depot for reporgramming of the security codeplug.
Error Code 01/93	The radio should be sent to the depot for reflashing of the host code.
Error Code 01/98	Send radio to the depot for replacement of the SRAM U302.
Error Code 01/A2	The radio should be sent to the depot for reflashing of the tuning codeplug followed by re-tuning of the radio.
Error Code 02/81	The radio should be sent to the depot for examination and/or replacement of either the FLASH U301, or the PATRIOT MCU/DSP U300.
Error Code 02/88	Cycle power to the radio. If this does not fix the problem, then the radio should be sent to the depot for reflashing of the DSP code. Continued failure requires examination and/or replacement of the SRAM U302.
Error Code 02/90	Cycle power to the radio. If this fails to fix the problem, then the radio should be sent to the depot for reflashing of the DSP code. Continued failure may require replacement of U300, the PATRIOT MCU/DSP.

Error Code 09/10	Cycle power to the radio. If this fails then follow instructions as per troubleshooting chart C.32
Error Code 09/90	Cycle power to the radio. If this fails then follow instructions as per troubleshooting chart C.32

4.2.3 ASTRO Spectra Plus Standard Bias Table

Table 4-6 outlines some standard supply voltages and system clocks which should be present under normal operation. These should be checked as a first step to any troubleshooting procedure.

Table 4-6. ASTRO Spectra Plus Standard Operating Bias

Signal Name	Nominal Value	Tolerance	Probe Point
SINE32K	32.768 kHz	+/- 400 ppm	R428
CKIH	16.8 MHz		C326
16_8MHz	16.8 MHz		TP401
POR	3.0 V	+/- 5%	J501-29
RESET_OUT	3.0 V	+/- 5%	J501
VCC1.8	1.80 Vdc	+/- 5%	R419
VCC3.0	3.0 Vdc	+/- 5%	R420
SW_B+	13.8 Vdc	11.0-16.6 Vdc	J501-35
VCC5	5.0 V	+/- 10%	J501-34

4.3 VCO Procedures

This section provides band-specific troubleshooting procedures for the VCO.

4.3.1 VHF Band

Use these instructions along with the Theory of Operation, the block diagram, and the schematic to help isolate failures: first, to the individual circuits, and finally, to the failing piece part.

4.3.1.1 VCO Hybrid Assembly

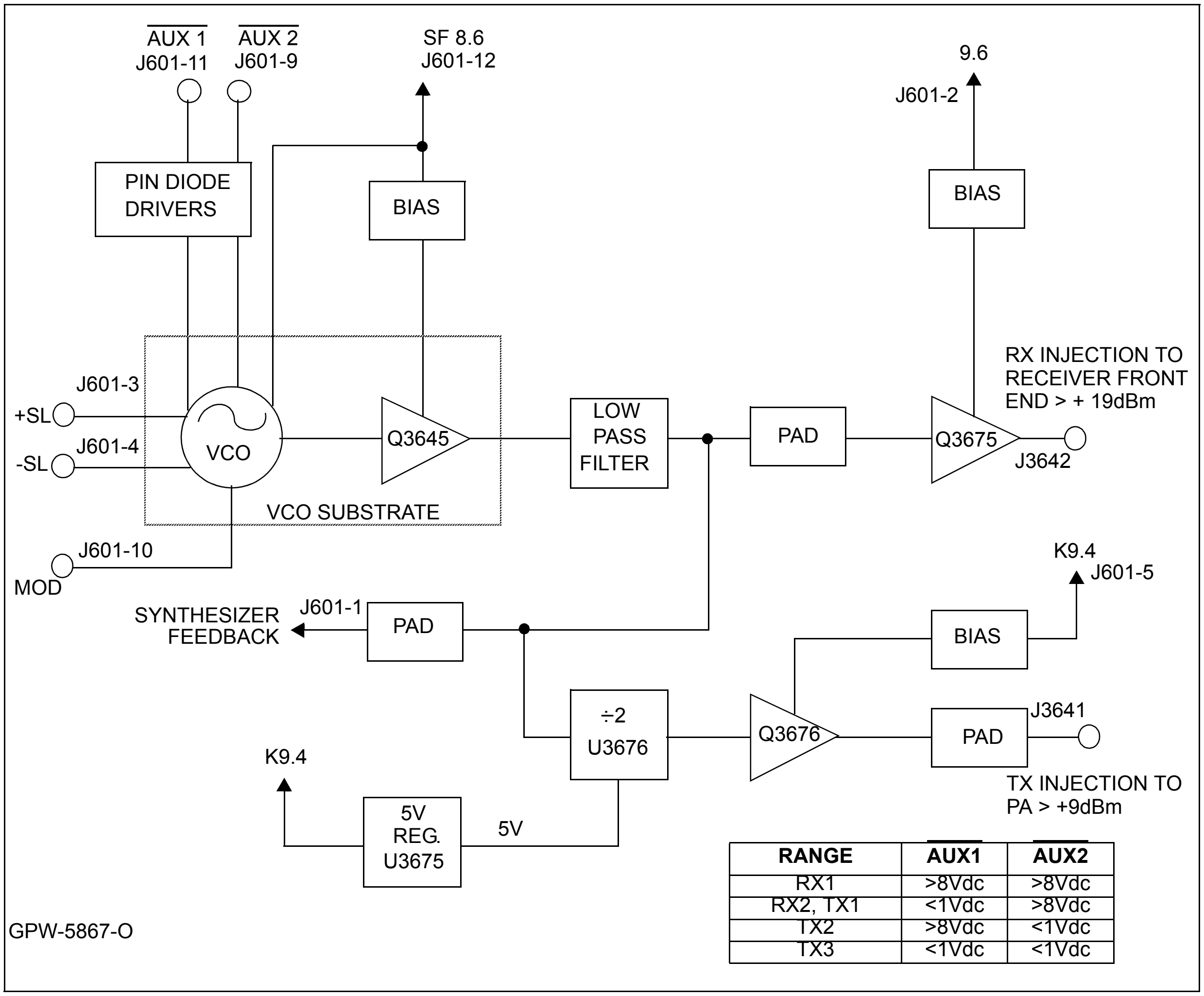
The VCO hybrid substrate is glued to the carrier board. The hybrid is not a field-repairable assembly. If a failure is indicated in this assembly, replace the complete hybrid. You will need a hot-air source to heat and soften the glue to separate the hybrid from the carrier board. If no hot-air source is available, replace the entire carrier board.

4.3.1.2 Out-of-Lock Condition

The probable cause of an out-of-lock condition is a failure in the synthesizer circuit. (See Section 4.1.4.2 Review of Synthesizer Fundamentals on page 4-7.) If the voltages on the AUX 1* and AUX 2* lines do not conform to Table 4-7, troubleshoot the synthesizer.

If the AUX 1* and AUX 2* voltages are correct but the synthesizer feedback level is not within the range indicated, troubleshoot the first buffer on the VCO carrier board. If no problem is found with the first buffer and the level out of the VCO is below that indicated on the block diagram, then replace the VCO assembly.

If the AUX 1* and AUX 2* voltages are correct and the synthesizer feedback level is correct but an out-of-lock condition persists, troubleshoot the synthesizer.



RANGE	AUX1	AUX2
RX1	>8Vdc	>8Vdc
RX2, TX1	<1Vdc	>8Vdc
TX2	>8Vdc	<1Vdc
TX3	<1Vdc	<1Vdc

Figure 4-1. VCO Block Diagram - VHF Band

Table 4-7. VCO Frequency

Mode	AUX 1	AUX 2	Radio Freq (MHz)	VCO Freq (MHz)	Port Freq (MHz)	Port
VHF RANGE 1						
RX	HIGH	HIGH	136.00 - 158.35	245.65 - 268.00	245.65 - 268.00	(RX)
RX	LOW	HIGH	158.35 - 162.00	268.00 - 271.65	268.00 - 271.65	(RX)
TX	LOW	HIGH	136.00 - 145.20	272.00 - 290.40	136.00 - 145.20	(TX)
TX	HIGH	LOW	145.20 - 157.00	290.40 - 314.00	145.20 - 157.00	(TX)
TX	LOW	LOW	157.00 - 162.00	314.00 - 324.00	157.00 - 162.00	(TX)
VHF RANGE 2						
RX	HIGH	HIGH	146.00 - 166.15	255.65 - 275.80	255.65 - 275.80	(RX)
RX	LOW	HIGH	166.15 - 174.00	275.80 - 283.65	275.80 - 283.65	(RX)
TX	LOW	HIGH	146.00 - 150.00	292.00 - 300.00	146.00 - 150.00	(TX)
TX	HIGH	LOW	150.00 - 162.00	300.00 - 324.00	150.00 - 162.00	(TX)
TX	LOW	LOW	162.00 - 174.00	324.00 - 348.00	162.00- 174.00	(TX)

4.3.1.3 No or Low Output Power (TX or RX Injection)

Use the test cables listed in the *Service Aids* section in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20). Measure the power at the synthesizer feedback port - if it is not within the range specified in the block diagram, troubleshoot the first buffer. If failure is found in the first buffer, replace the defective component. If no failure is found in the first buffer and the level out of the VCO (measured with an RF millivoltmeter) is below that indicated in the block diagram, then replace the VCO assembly.

If the level at the synthesizer feedback port is within the indicated range, then troubleshoot the divider, RX, and TX buffer.

4.3.1.4 No or Low Modulation

Under standard test conditions with a 1 kHz tone injected and 4.5 kHz (±50OHz) deviation, there should be at least 0.8-V peak-to-peak present on J601, pin 10 (modulation input). (See the circuit board overlay for location.) If this level is not present, troubleshoot the audio circuitry, if it is present, check the VCO modulation circuitry.

4.3.2 UHF Band

Use these instructions along with the Theory of Operation, the VCO block diagram, and the schematic to help isolate failures, first to the individual circuits, and finally to the failing piece part.

4.3.2.1 VCO Hybrid Assembly

The VCO hybrid substrate is glued to the carrier board. The hybrid is not a field-repairable assembly. If a failure is indicated in this assembly, replace the complete hybrid. You will need a hot air source for heating and softening the glue to separate the hybrid from the carrier board. If no hot air source is available, replace the entire carrier board.

4.3.2.2 Out-of-Lock Condition

The probable cause of an out-of-lock condition is a failure in the synthesizer circuit. (See Section 4.1.4.2 Review of Synthesizer Fundamentals on page 4-7.) If the voltages on the AUX 1*, AUX 2*, or -8V lines at P0601 do not conform to the values shown in Figure 4-2, check the pin shift circuitry on the carrier board for proper operation. If no trouble is found, troubleshoot the synthesizer.

If the AUX1*, AUX2*, and -8-V voltages are correct at P0601, check the pin shift circuitry on the carrier board for proper operation. If no problem is found, probe the level of the synthesizer feed back at P0601-1 using an RF millivoltmeter. The meter should indicate greater than -15 dBm. If it does not, troubleshoot the synthesizer feedback circuitry; then troubleshoot the first buffer on the VCO carrier board. If no trouble is found and the level out of the VCO is below that indicated on the block diagram, then replace the VCO assembly.

If the AUX 1*, AUX2*, and -8-V voltages are correct and the synthesizer feedback level is correct but an out-of-lock condition persists, troubleshoot the synthesizer.

4.3.2.3 No or Low Output Power (TX or RX Injection)

Using an RF millivoltmeter, probe the synthesizer feedback level at P0601-1. If the meter indication is not greater than -15 dBm, troubleshoot the first buffer. If no failure is found and the level out of the VCO (measured into 50 ohms at the RF output of the hybrid) is below that indicated in the block diagram, then replace the VCO assembly.

If the level of synthesizer feedback at P0601-1 is correct, troubleshoot the doubler, second buffer, and then the RX/TX pin diode switch.

4.3.2.4 No or Low Modulation

Under standard test conditions with a 1 kHz tone injected and 4.5 kHz deviation, there should be 700 mV (RMS) ±20% present on P0601-10. If this level is not present, troubleshoot the modulation circuit on the carrier board and then troubleshoot the audio circuitry. If the proper level is present, troubleshoot the modulation circuitry on the VCO kit. If no failure exists, replace the VCO.

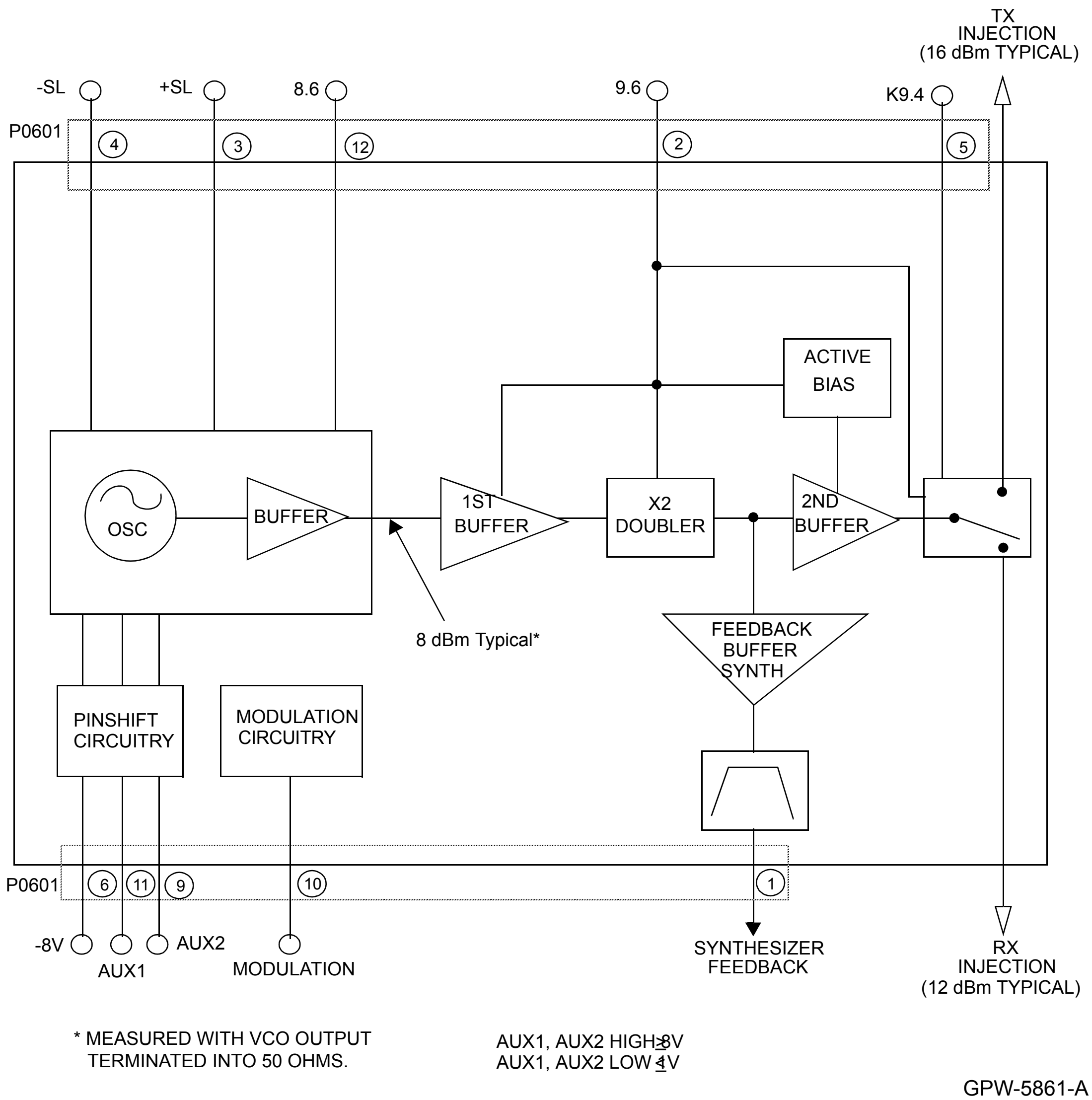


Figure 4-2. VCO Block Diagram - UHF Band

4.3.3 800 MHz Band

Use these instructions along with the Theory of Operation, the block diagram, and the schematic to help isolate failures, first, to the individual circuits, and finally to the failing piece part.

4.3.3.1 VCO Hybrid Assembly

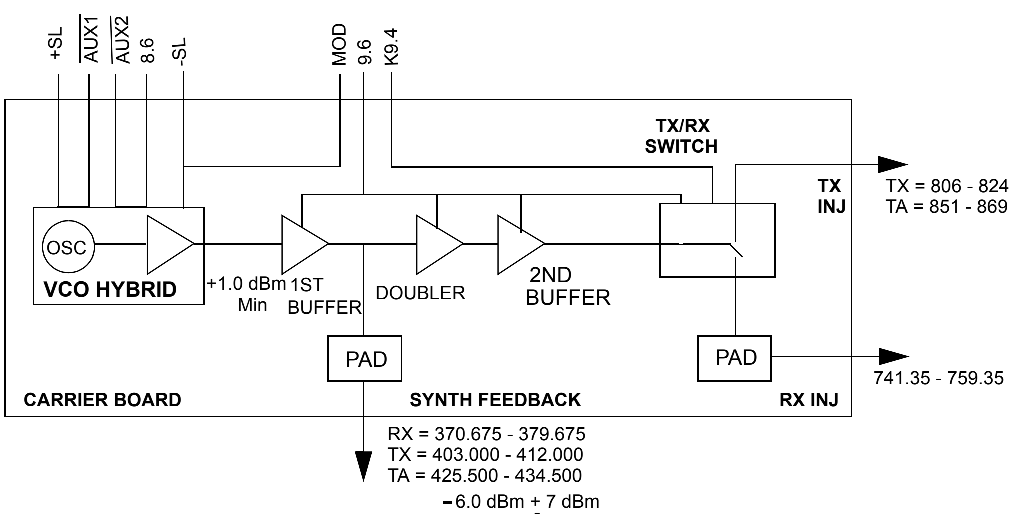
The VCO hybrid substrate is glued to the carrier board. The hybrid is not a field-repairable assembly. If a failure is indicated in this assembly, replace the entire carrier board.

4.3.3.2 Out-of-Lock Condition

The probable cause of an out-of-lock condition is a failure in the synthesizer circuit. (See Section 4.1.4.2 Review of Synthesizer Fundamentals on page 4-7.) If the voltages on the AUX 1* and AUX 2* lines do not conform to the table in Figure 4-3, troubleshoot the synthesizer.

If the AUX 1* and AUX 2* voltages are correct but the synthesizer feedback level is not within the range indicated, troubleshoot the first buffer on the VCO carrier board. If no problem is found with the first buffer and the level out of the VCO is below that indicated on the block diagram, check J straps MP9656-MP9668. If no problem is found with these, replace the entire carrier board.

If the AUX 1* and AUX 2* voltages are correct and the synthesizer feedback level is correct but an out-of-lock condition persists, troubleshoot the synthesizer.



FREQUENCY RANGE	AUX1	AUX2	OUTPUT FREQUENCY
RX	HI	HI	741.35 - 759.35
TX	HI	LOW	806.00 - 824.00
TA	LOW	LOW	851.00 - 869.00

GPW-6395-O

Figure 4-3. VCO Block Diagram - 800 MHz Band

4.3.3.3 No or Low Output Power (TX or RX Injection)

Use the test cables listed in the “Service Aids” in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20). Measure the power at the synthesizer feedback port-if it is not within the range specified in the block diagram, troubleshoot the first buffer. If failure is found in the first buffer, replace the defective component. If no failure is found in the first buffer and the level out of the VCO (measured with an RF millivoltmeter) is below that indicated in the block diagram check J straps MP9656-MP9668. If no problem is found with these, replace the entire carrier board.

If the level at the synthesizer feedback port is within the indicated range, then troubleshoot the doubler, second buffer, and PIN diode switch.

4.3.3.4 No or Low Modulation

Under standard test conditions with a 1 kHz tone injected and 4.6 kHz (±250 Hz) deviation, there should be between 500 and 1000 mV present on J601, pin 10 (modulation input). (See the circuit board overlay for location.) If this level is not present, troubleshoot the audio circuitry. If it is present, check J601, pin 4 (NEG S.L.). The negative steering line should be -4.0 V (±0.3 V). If this is not correct, check the negative steering line circuitry on the RF board and/or check R9651 and C9651 on the carrier board. If no problem is found, check J straps MP9656-MP9668. If no problem is found with these, replace the entire carrier board.

4.4 Receiver Front-End (RXFE)

This section provides band-specific troubleshooting procedures for the receiver front-end.

4.4.1 VHF Band

This information will help you troubleshoot the Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. The principle tools needed to troubleshoot a circuit to the component level are the schematic and the Theory of Operation.

In addition to the schematic and theory, this section includes a troubleshooting chart that will guide you through a sequence of tests and checks designed to isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation including specific precautions and troubleshooting methods.

4.4.2 UHF Band

This information will help you troubleshoot the Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. The principle tools needed to troubleshoot a circuit to the component level are the schematic and the Theory of Operation.

In addition to the schematic and theory, this section includes a troubleshooting chart that will guide you through a sequence of tests and checks designed to isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at 500 MHz, measurements must be taken carefully.

4.4.3 800 MHz Band

This information will help you troubleshoot the Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. The principle tools needed to troubleshoot a circuit to the component level are the schematic and the Theory of Operation.

In addition to the schematic and theory, this section includes a troubleshooting chart that will guide you through a sequence of tests and checks designed to isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at 800 MHz, measurements must be taken carefully.

4.5 Power Amplifier Procedures

This section provides band-specific troubleshooting procedures for the power amplifier.

4.5.1 VHF Band

4.5.1.1 High-Power Amplifier

This information will help you troubleshoot the Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. This section includes troubleshooting information that will help you test and check the circuits to localize and isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation, including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at VHF frequencies, measurements must be taken very carefully. Notes and cautions are added to the text to alert the reader to this need in areas of greatest sensitivity. However, the need for extreme care does exist in all measurements and tests at VHF frequencies.

4.5.1.1.1 General Troubleshooting and Repair Notes

Most of the common transmitter symptoms are not necessarily caused by failure of circuits on the PA board. Failure of command board or synthesizer circuits can disable the transmitter. The initial troubleshooting effort should be toward isolating the problem to one of these areas. If either the control voltage or keyed 9.4 V are zero, then the problem is likely to be in the control circuit or synthesizer. If those voltages are present, then the problem is more likely in the power amplifier circuit.

If, for diagnostic reasons, a chip component needs to be removed to facilitate testing, such as a series capacitor removed to allow for signal insertion, then the component(s) returned to the circuit should be new parts. The application of a soldering iron to many chip components will tend to cause leaching which could lead to failure.

If the harmonic filter is damaged and needs to be replaced, then removal and replacement requires the use of a hot-air source capable of reflowing the solder beneath the filter hybrid. When replacing it, add small amounts of fresh solder paste to the silver regions beneath the ceramic to assure adequate electrical ground contact. Save the original input and output connectors (J-straps); these are not included with the replacement kit. No tuning is required. The harmonic filter may be ordered separately, but if the PA kit is ordered a filter kit comes with the PA kit.

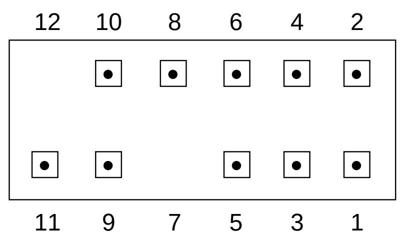
After a PA board is replaced, or if any power control circuitry components are replaced, readjust the power according to instructions in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

Due to high operating frequencies, you must use specified Motorola parts when component replacement is necessary. Substitute components may not work. It is also critical that you use great care when replacing parts. Excessive solder or flux, longer than original leads on coax connectors, misorientation of parts and other commonly benign imperfections, may cause the radio's performance to degrade.

Bench testing the high-power Spectra PA is most easily accomplished if a Spectra control head, control cable, and power cable are available on the test bench. This greatly simplifies the troubleshooting as several supply voltages are provided by the command board. Proper operation of the command board circuitry can be simultaneously verified.

Begin troubleshooting by connecting an RF power meter and appropriate power load to the antenna connector. Connect the control cable and the power cable. Make sure the ignition sense lead is also connected to the positive lead of the power supply. Note that a regulated DC power supply capable of at least 30 A. is necessary to power a high-powered Spectra transmitter. Remove the radio bottom cover. Remove the PA shield by pulling straight up on the plastic handle. This must be done carefully, as the edge of the PA shield can damage components on the PA board if it is removed unevenly. Set the power supply to 13.4 V. The radio may now be turned on. All critical voltages may be measured at connector J1 from the top side of the PA board. A diagram of the connector pin-out, as viewed from the top side of the PA board, is shown below.

Pin Configuration of J1
As Viewed From Top of PA Board



1 Control Voltage Limit
2 Control Voltage Drive
3 Current Sense +
4 Key 9.4V
5 Filtered A+
6 Temp-Sense
7 Not Connected
8 Forward Power Detect
9 9.6V
10 Current Sense –
11 Not Connected

Figure 4-4. Connector Pin-Out - High-Power Amplifier

Key the transmitter. The RF power meter should read at least 100 Watts if it is calibrated. If power is low, the power set must be checked first before suspecting a defective PA or command board. This may be checked using a PC and RSS software. Alternatively, front panel programming may be used. Please refer to the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for programming instructions.

If correct power output can not be obtained by following the power set procedure outlined in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20), it is possible that current limit may be improperly set. This can not be adjusted using front panel programming. A PC with RSS must be used. A simple way to check for current limit engagement is to temporarily short out the current sense resistor R3849 with a piece of 12- or 14-gauge wire. If full power is restored, then RSS must be used to properly set current limit.

If it is verified that both power set and current limit are not related to the power problem, then the synthesizer output must be checked. A milliwatt meter connected to the TX injection cable should indicate at least 10 mW of injection power during key-up. If this is not the case, refer to the RF board and VCO sections of this manual for troubleshooting procedures.

Table 4-8. Power Control DC Voltage Chart

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
J1							
1		0		0	2.0	3.2	Control Voltage Limit
2		0		2.0	7.0	10.0	Drive Voltage
3	10.8	13.6	16.5	10.0	13.0	16.0	Current Sense +
4	0	0	0	9.2	9.4	9.8	Keyed 9.4
5	10.8	13.6	16.5	10.0	13.0	16.0	A+ to Command Board
6		0			1.2		Temp Sense (cutback begins at 3.3-V)
7	-	-	-	-	-	-	Key (no pin)
8		0		13.0	9.3	5.0	Forward Detect Voltage
9	10.8	13.6	16.5	10.0	13.0	16.0	A+ to Command Board
10 11	9.4 10.8	9.6 13.6	9.9 16.5	9.4 9.8	9.6 12.8	9.9 15.8	9.6-V Supply from Command Board Current Sense - (voltage delta 150 mV)
12	-	-	-	-	-	-	Key (no pin or wire)
U500							
1	0	0	0	0	0	0	Ground
2		0			3.2		Control AMP Input
3	0	0	0	0	0	0	Control AMP Input (not used)
4		0		0	2	3.2	Control Voltage Limit (cutback at 3.3 V)
5		9			0		N.C.
6	1.5	3.0	4.5	1.5	3.0	4.5	Power Set from D-A (max power at 1.5 V)
7		0		1.5	3.0	4.5	Power Set Buffer Out
8		0		1.3	3.5	6.0	Coupler Buffer Out
9		0		1.3	3.5	6.0	Forward Detect Volt
10		0			0		Reflected Power Detect (not used)
11		0		1.3	3.5	6.0	Same as pin 8 (not used)
12		0		0	1.2	6.0	Thermister Buffer out (increases as PA gets hot)

Table 4-8. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
J1							
13		0		0	1.2	6.0	Thermister Buffer in
14		5.0			5.0		5-V Sense Input (follows pin 20 ±0.1 V)
15	4.9	5.0	5.7	4.9	5.0	5.7	5-V Current Limit (limits at 5.7 V)
16	5.0	5.7	6.4	5.0	5.7	6.4	5-V Series Pass Drive (6.4 at max current)
17	9.5	9.6	9.9	9.5	9.6	9.9	9.6-V Sense Input
18		7			7		5-V Reg. Compensation Capacitor
19		5.7			5.7		N.C.
20	4.9	5.0	5.1	4.9	5.0	5.1	5-V Reference Input (UNSW5V)
21		1.2			1.2		9.6-V Reg. Compensation Capacitor
22		0			0		N.C.
23		0.9	9.6		1.2	9.6	9.6-V Series Pass Drive
24		2.9			3.3		Regulator Enable/Compensation
25	-	-	-	-	-	-	9.6-V Programming (N.C.)
26		0			0		N.C.
27		13.6			13.6		N.C.
28	-	-	-	-	-	-	9.6-V Programming (N.C.)
29	-	-	-	-	-	-	9.6-V Programming (N.C.)
30	-	-	-	-	-	-	9.6-V Programming (N.C.)
31	0	0	0	0	0	0	Ground
32	10.8	13.6	16.5	10.0	13.0	16.0	Decoupled A+
33	4.0	5.0			0	0.2	$\overline{\text{TX PA Enable}}$ (from U520-25)
34		0			1.3		Control AMP one-shot
35		0			0		$\overline{\text{Lock}}$ (5 V of Synth Out of Lock)
36		0			0.8		Control AMP one-shot
37	10.8	13.6	16.3	10.0	13.0	16.0	A+ (Current Sense +)
38	10.8	13.6	16.3	10.0	13.0	16.0	Current Sense - Voltage Delta 150 mV
39		0		9.2	9.4	9.8	Keyed 9.4-V in
40	1.5	3.0	4.5	1.5	3.0	4.5	Current Limit D-A (max current at 4.5 V)

Table 4-8. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
J1							
41	0	0	0	0	0	0	Ground
42		0			2.2	9.6	Control AMP Output (Approx 1/2-V Control)
43		1.3			7.0		Loop Integrator Capacitor
44		2.1			3.2		Control AMP Reference
Q0500E		13.0			13.0		A+ - CR0500 Drop
Q0501C		12.3			12.3		VQ0500E - B/E Drop
Q0501E		0.2			0.2		V pin 23 - B/E Drop
Q0503E		0			1.5		V pin 42 - B/E Drop (TX)
Q0503C		13.6			9.0		
Q0504B		13.6			12.9		A+ - B/E Drop (TX)

If the command board and synthesizer are functioning properly, the PA must be defective. Details on troubleshooting each circuit of the PA follow.

4.5.1.1.2 PA Functional Testing

NOTE: When setting or measuring RF power at VHF follow these guidelines to avoid measurement errors due to cable losses or non-50-ohm connector VSWR:

- All coaxial cables should be low loss and as short as possible.
- Attenuators and 50-ohm loads should have at least 25 dB return loss.
- Mini UHF to 'N' adapter, P/N 58803671321, should be used at the antenna connector. All other connectors should be 'N' type. No other adapters, barrel connectors, etc. should be used.

Maximum input level to the PA is 20 mW. Too much input power could result in damage to the LLA stage.

Methods of analyzing individual stages of the power amplifiers are detailed below. Most of the stages are Class-C and must be analyzed under relatively high RF power levels. The following information should help in isolation and repair of the majority of transmitter failures.

Testing Low-Level Amplifier (LLA) Circuitry

Proper operation of the LLA can be checked by monitoring the voltage across resistor R3804. The voltage should measure in the range of 0.4 V to 1.0 V, depending on the value of control voltage. A 0.4-V reading corresponds to a low control voltage (4 to 5 V) and a 1.0-V reading corresponds to a high control voltage (up to control voltage limit).

Measure LLA voltages according to Table 4-9. If the DC bias conditions are correct, check to see if the LLA is providing drive power to Q3804. Do so by checking Q3804's collector current under normal drive conditions, as follows:

- Remove L3806 (be sure to reinstall after testing).
- Solder wires to the remaining pads. Place an ammeter in series with Q3804 collector.
- Check for 0.2 to 0.5 A. (depending on control voltage).

NOTE: With no RF drive to the input of the PA, Q3804 collector current should be zero.

Table 4-9. LLA and 2nd Stage Typical Voltages

CONTROL VOLTAGE	RF DRIVE OFF		RF DRIVE ON	
	8.0 V	**6.0 V**	**8.0 V**	**6.0 V**
Q3801 Base Collector	— 0.7 8.3	— 0.7 9.0	— 0.7 8.0	— 0.5 8.8
Q3802 Base Collector Emitter	— 7.7 2.0 8.3	— 8.4 1.4 9.0	— 7.5 2.3 8.0	— 8.2 1.2 8.8
Q3806 Base Collector Emitter	— 5.1 7.7 4.5	— 4.1 8.4 3.4	— 5.1 7.5 4.5	— 4.1 8.2 3.4
Q3804 Base Collector	— 0.5 9.6	— 0.5 9.6	— 0.0 9.5	— 0.2 9.5

NOTE: The LLA voltages change with different control voltages. An example of LLA voltages with control voltage equal to 8.0 V and 6 V is shown.

If Q3804 draws no current under normal conditions, then check for short or open input cable, or for defective parts in the matching circuitry between Q3801 and Q3804.

Testing Second Stage Circuitry Q3804

The second stage is a typical Class-C stage, except the base is biased with resistors R3809 and R3810. The necessary conditions for proper operation of this stage are input drive power, and bias conditions as shown in Table 4-9.

NOTE: If it is necessary to replace Q3804, use a hot-air blower to remove and replace the part. It is important that the replacement device's case be properly soldered to its heatsink. Do so by flowing a small bead of solder around the rim of the device while it is clamped in the hot-air soldering device. The base and collector leads must be hand-soldered on the bottom side of the board.

Troubleshooting the Driver Stage (Q3805)

- Make sure A+ is at the collector.
- Check for shorts and/or opens in the matching circuitry. Also look for faulty components (cracked parts or parts not properly soldered).
- Measure the DC resistance from base to emitter. It should be less than 1-ohm. If not, check L3812 and L3809 for proper soldering, and replace if faulty.
- Check the current drain of Q3805. Remove L3811 and R3819 and solder wires to the pads. With an ammeter connected to these wires, check the collector current drain during transmit. It should be around 2.0 to 4.0 A. If current drain is low, go to next step.
- Desolder the base of Q3805 and bend its lead slightly so it does not contact the PC board. Check the base-emitter and base-collector junction diode voltages using the diode check function of a multimeter. Normal voltage drop should be near 0.6 V. If either junction is open or short circuited replace the device.

Analysis of the Final Amplifier Stage (Q3870 and Q3871)

Extreme care must be taken when troubleshooting the final amplifier due to the high RF currents and voltages present.

A visual inspection of the matching networks should be done first. Check for defective solder joints or burned components. Good soldering of the transistor device leads is essential. Make sure A+ voltage is reaching the collector of each final device.

Check the base-emitter and base-collector junctions of the final devices by removing L3930, L3933, R3859, and R4007. Using the diode check function of a multimeter, the junctions should have a forward voltage drop close to 0.6 V. Replace a final device if it has an open or shorted junction.

Capacitors C3860, C3861, C3862, and C3863 are placed on the bottom side of the PA board underneath the base leads of the final devices. Extreme care should be used when replacing these parts. Exact positioning is critical. Inspect for solder shorts on these capacitors before installing the PA board in the radio chassis.

Installation of the PA board into the radio chassis must be done carefully. The PC board’s screws use a T-15 Torx bit and should be torqued to 12 to 14 inch-pounds. The device screws use a T-8 Torx bit and should be torqued to 12 to 14 inch-pounds. Always apply thermal compound to the area under the device flanges before installing the PA board.

Current drain of the final amplifier may be checked by measuring the voltage across R3849 during transmit. A voltage drop of 0.10 V to 0.15 V indicates the finals are drawing 10 to 15 A., which is within the acceptable range.

Testing the Antenna Switch and Harmonic Filter

Use care when replacing the harmonic filter. Removal of the filter is best accomplished by heating the filter/PC board assembly with a heat gun or heat blower until the solder joint reflows.

Verify that the receive path of the antenna switch and the harmonic filter are functioning by testing the receiver insertion loss as follows:

- Apply a low-level signal source at the antenna connector.
- Verify the conditions indicated in Table 4-8 for RX tests.
- Measure the power at the receive coax.
- If the difference between the input and output (insertion loss) is less than 1 db, then the circuitry is functioning properly.

Additional antenna switch tests are:

- Check CR3901, CR3902, and CR3903 using the diode check function of a multimeter. Note that CR3903 is on the bottom side of the board. This diode affects the receive path only and is unrelated to transmitter problems.
- Check for proper DC current through the PIN diodes; correct current is indicated if approximately 1.5 V is present at the junction of R3900 and L3900 during transmit.

DO NOT measure bias directly at the PIN diodes while in transmit mode unless TX injection is removed.

WARNING

4.5.1.1.3 Power Control and Protection Circuitry

Localizing Problems to a Circuit

Power leveling and current limiting are set to values detailed in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20). These values will vary from unit to unit, depending on the unique variations of each unit. If symptoms indicate that either of these circuits have failed, verify that the radio has been properly aligned before investigating the circuitry.

Temperature sense and control voltage limit are fixed by design and are not influenced by the alignment of the radio. If symptoms indicate that these circuits have failed, then troubleshoot the circuit.

The tests that follow are intended to provide a convenient means of verifying that a particular circuit is functioning properly. These tests will isolate the failure to a minimum number of components. Refer to the Theory of Operation and the schematic for information needed to identify the failed component(s).

Temperature Sense Circuit Test

Temporarily install a 2.2k ohm resistor in parallel with RT3842. Key the transmitter and monitor the output power. The power meter should read approximately one-half the rated power.

Control-Voltage-Limit Circuitry Test

Disconnect the transmitter injection cable from J3850. With all other connections in normal condition, key the transmitter and monitor the control voltage at J1 pin 2. If the voltage exceeds 9.0 V, troubleshoot the control voltage limit circuitry.

Current-Limiting Circuitry Test

When ready to adjust current limit, decrease the relative current limit value with the keyboard per instructions. After several decrements, the current limit should begin to reduce power in 0.5 to 1.0 Watt increments. After this test, reset the current limit to its original value. If the circuitry does not perform as indicated, troubleshoot the current limit circuitry.

Directional Coupler and Power-Leveling Test

The directional coupler combined with the RPCIC form a closed-loop power leveling circuit. This circuit keeps forward power essentially constant under variations of line voltage, frequency, and VSWR.

The directional coupler samples a small amount of forward power during transmit. This power is rectified by a detector diode CR3904. This rectified DC voltage is fed back to the RPCIC where it is compared to a reference voltage. An error voltage is generated which is ultimately translated into the control voltage via RPCIC circuitry and amplifiers Q503 and Q504 on the command board. Control voltage is routed to the LLA stage, thereby completing the feedback loop. In operation, the control loop tends to maintain the forward detected voltage constant versus frequency and line voltage variations. Proper operation can be observed by monitoring the forward detected voltage while varying the supply voltage from 13.4 to 16.1 V. Forward detected voltage should not change more than a few hundreths of a volt. Note that the forward power may not necessarily be level if one of the other protection circuits such as temp-sense or current limit is engaged.

NOTE: If any part of the power leveling circuitry is replaced, perform the power set procedure. See the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for details.

Miscellaneous Circuits and Notes

Diode CR3840 acts as a reverse protect diode. This diode also protects from over-voltage conditions, as it has a Zener breakdown voltage of approximately 28 V. When replacing this diode, care must be taken to place the diode with the cathode marking ring down (towards the PC board)

NOTE: The control voltage drive and K9.4 supplies from the command board are not current limited. A momentary short on either of these supplies will cause damage to transistors on the command board. Use caution when troubleshooting circuits that use these.

4.5.1.2 25/10 Watt Power Amplifier

This information will help you troubleshoot the Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. The principle tools needed to troubleshoot a circuit to the component level are the schematic and the Theory of Operation.

In addition to the schematic and theory, this section includes troubleshooting information that will help you test and check the circuits to localize and isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation, including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at high frequency, measurements must be taken very carefully. Notes and cautions are added to the text to alert the reader to this need in areas of greatest sensitivity

However, the need for extreme care does exist in all measurements and tests at high frequency.

4.5.1.2.1 General Troubleshooting and Repair Notes

Most of the common transmitter symptoms are caused by either failure of the power amplifier or a failure in the control circuitry. The initial troubleshooting effort should be toward isolating the problem to one of those two areas. If either the control voltage or keyed 9.4 V are zero, then the problem is likely to be in the control circuit. If those voltages are present, then the problem is more likely in the power amplifier circuit.

If, for diagnostic reasons, a chip component needs to be removed to facilitate testing, such as a series capacitor removed to allow for signal insertion, then the component(s) returned to the circuit should be new parts. The application of a soldering iron to many chip components will tend to cause leaching which could lead to failure.

After a PA board is replaced, or if any power control circuitry components are replaced, readjust the power according to instructions in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

NOTE: Due to high operating frequencies, you must use specified Motorola parts when component replacement is necessary. Substitute components may not work. It is also critical that you use great care when replacing parts. Excessive solder or flux, longer than original leads on coax connectors, misorientation of parts, and other commonly benign imperfections may cause the radio's performance to degrade.

4.5.1.2.2 PA Functional Testing

To test the PA assembly for proper operation, perform the following steps:

1. Disassemble the PA assembly from the radio, leaving the power cable connected to the rear connector. Replace the PA shield and cover. Disconnect the coax connectors and the ribbon cable. Connect a power meter to the antenna port using minimum cable length.
   a. When setting or measuring RF power, follow these guidelines to avoid measurement errors due to cable losses or non 25/10-ohm connector VSVVR:
      - All cables should be very short and have Teflon dielectric.
      - Attenuators and 25/10-ohm loads should have at least 25 dB return loss.
      - Mini UHF to 'N' adapter, P/N 58-80367B21, should be used at the antenna connector. All other connectors should be 'N' type. No other adapters, barrel connectors, etc. should be used.
   b. Maximum input level to the PA is 20 mW. Too much input power could result in damage to the LLA stage.
2. Apply the input power and DC voltages indicated in Table 4-10 to the power amplifier assembly. To make the DC connections, use small spring-clips or make a test adapter similar to that shown in Figure 4-5.

Table 4-10. DC Voltages and Input Power Chart

Test	Keyed 9.4 V	CONTROL VOLTAGE DRIVE	POWER IN (mW)	A+ .V
Transmit	9.4	See note[a]	10	13.4
Receive	0	0	0	13.4

a. Set initially to zero. Increase value until power equals 28 Watts or 9.2 V maximum. Do NOT exceed 9.2 V.

3. Apply the required input power via an adapter cable. For this application, non 'N' type connectors are acceptable.

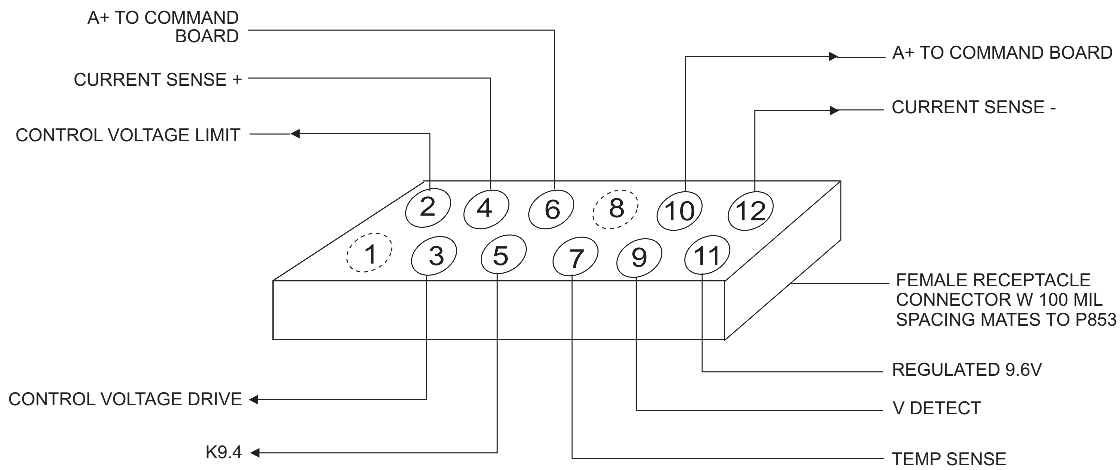


Figure 4-5. PA Test Adapter, 25/10 Watt Power Amplifier

4. With the applied control voltage drive initially at 0 V, slowly increase the voltage until power out equals 28 Watts. Power should rise smoothly with control voltage once the turn-on threshold is reached. Control voltage drive should not exceed 9.2 V.
5. If 9.2 V does not produce 28 Watts, then a failure exists in the power amplifier circuit.
6. Refer to the voltage chart (see Table 4-11). Measure the indicated voltages. If they are not within the limits shown in the chart, then a failure exists in the PA assembly.
7. If the voltages in the chart are correct, verify that the injection is at least 10 mW. (See the VCO troubleshooting section.)
8. If no failure is located from the previous checks, troubleshoot the power control circuitry.

Table 4-11. Power Control DC Voltage Chart

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
P0853							
1	—	—	—	—	—	—	Key (no pin or wire)
2		0		0	2.0	3.2	Control Voltage Limit
3		0		2.0	7.0	9.2	Control Drive Voltage
4	10.8	13.8	16.6	10.4	13.4	16.2	Current Sense +
5	0	0	0	9.2	9.4	9.8	Keyed 9.4
6	10.8	13.8	16.6	10.4	13.4	16.2	A+ to Command Board
7		0			1.2		Temp Sense (cutback begins at 3.3 V)
8	—	—	—	—	—	—	Key (no pin)
9		0		1.5	3.5	5.0	Forward Detect Volt

Table 4-11. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
10	10.8	13.8	16.6	10.4	13.4	16.2	A+ to Command Board
11	9.4	9.6	9.9	9.4	9.6	9.9	9.6-V Supply from Command Board
12	10.8			9.8	13.1	15.9	Current Sense - (voltage delta 150 mV)
U0500							
1	0	0	0	0	0	0	Ground
2		0			3.2		Control AMP Input
3	0	0	0	0	0	0	Control AMP Input (not used)
4		0		0	2	3.2	Control Voltage Limit (cutback at 3.3 V)
5		0			0		N.C.
6	1.5	3.0	4.5	1.5	3.0	4.5	Power Set from D-A (max power at 1.5 V)
7		0	0	1.5	3.0	4.5	Power Set Buffer Out
8		0		1.3	3.5	6.0	Coupler Buffer Out
9		0		1.3	3.5	6.0	Forward Detect Voltage
10		0			0		Reflected Power Detect (not used)
11		0		1.3	3.5	6.0	Same as pin 8 (not used)
12		0		0	1.2	6.0	Thermister Buffer out (increases as PA gets hot)
13		0		0	1.2	6.0	Thermister Buffer in
14		5.0			5.0		5-V Sense Input (follows pin 20 ±0.1 V)
15	4.9	5.0	5.7	4.9	5.0	5.7	5-V Current Limit (limits at 5.7 V)
16	5.0	5.7	6.4	5.0	5.7	6.4	5-V Series Pass Drive (6.4 at max current)
17	9.5	9.6	9.9	9.5	9.6	9.9	9.6-V Sense Input
18		7			7		5-V Reg. Compensation Capacitor
19		5.7			5.7		N.C.
20	4.9	5.0	5.1	4.9	5.0	5.1	5-V Reference Input (UNSW5-V)
21		1.2			1.2		9.6-V Reg. Compensation Capacitor
22		0			0		N.C.
23		0.9	9.6		1.2	9.6	9.6-V Series Pass Drive
24		2.9			3.3		Regulator Enable/Compensation
25	—	—	—	—	—	—	9.6-V Programming (N.C.)

Table 4-11. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
26		0			0		N.C.
27		13.6			13.6		N.C.
28	—	—	—	—	—	—	9.6-V Programming (N.C.)
29	—	—	—	—	—	—	9.6-V Programming (N.C.)
30	—	—	—	—	—	—	9.6-V Programming (N.C.)
31	0	0	0	0	0	0	Ground
32	10.8	13.6	16.5	10.0	13.0	16.0	Decoupled A+
33	4.0	5.0			0	0.2	TX PA Enable (from U520-25)
34		0			1.3		Control AMP one-shot
35		0			0		Lock (5-V of Synth Out of Lock)
36		0			0.8		Control AMP one-shot
37	10.8	13.6	16.3	10.0	13.0	16.0	A+ (Current Sense +)
38	10.8	13.6	16.3	10.0	13.0	16.0	Current Sense - Voltage Delta 150 mV (30 Watt only)
39		0		9.2	9.4	9.8	Keyed 9.4-V in
40	1.5	3.0	4.5	1.5	3.0	4.5	Current Limit D-A (max current at 4.5 V)
41	0	0	0	0	0	0	Ground
42		0			2.2	9.6	Control AMP Output (Approx 1/2-V Control)
43		1.3			7.0		Loop Integrator Capacitor
44		2.1			3.2		Control AMP Reference
Q0500E		13.0			13.0		A+ - CR0500 Drop
Q0501C		12.3			12.3		VQ0500E - B/E Drop
Q0501E		0.2			0.2		V pin 23 - B/E Drop
Q0503E		0			1.5		V pin 42 - B/E Drop (TX)
Q0503C		13.6			9.0		
Q0504B		13.6			12.9		A+ - B/E Drop (TX)

NOTE: For antenna switch transmit bias conditions, RF drive must be removed from PA.

Table 4-12. Antenna Switch DC Voltage Chart

LOCATION		TYPICAL RX	TYPICAL TX NO PRE-DRIVE	COMMENTS
CR3920	ANODE	0	1.6	
	CATHODE	0	0.8	
CR3921	ANODE	0	0.8	
	CATHODE	—	—	
CR3922	ANODE	0	<0.8	
	CATHODE	—	—	

4.5.1.2.3 Localizing Problems

Failure locations often can be determined by externally measured symptoms. Basic symptoms are noted below with probable failure locations.

1. Low Power and High Current
   - Check for improper load conditions caused by high VSWR external to the radio.
   - Check output coax and mini-UHF connector.
   - Check harmonic filter.
   - Check output impedance-matching circuitry from the final device to the harmonic filter.
2. Low Power and Low Current
   - If control voltage drive is equal to 9.2 V, then check per the above.
   - If control voltage drive is less than 9.2 V, then check the control circuitry.
3. Power Intermittently Low (or Zero) and Current Less than 1 A. When Power Drops
   - Check LLA stage.
4. Power Zero and Current Greater Than 3 A.
   - Check harmonic filter, antenna switch, and matching circuits beyond final stage.
5. Power Zero and Current Between 1 and 3 A.
   - Check driver and/or final stages.
6. Power Zero and Current Less Than 1 A.
   - Check LLA/driver circuitry.

4.5.1.2.4 Isolating Failures

Methods of analyzing individual stages of the Power Amplifiers are detailed below. Most of the stages are Class C and must be analyzed under relatively high RF power levels. Generators capable of such levels may not be available in all service shops, therefore the tests below are arranged in order of ascending power. This tends to allow the preceding stage to be the source of RF power for testing the next stage.

Testing Low-Level Amplifier (LLA) Circuitry

The required DC and RF conditions are defined in Table 4-10. Measure LLA voltages according to Table 4-13.

If the above DC bias conditions are correct, check to see if the LLA is providing drive power to the pre-driver, Q3804. Do so by checking Q3804's collector current under normal drive conditions, as follows:

- Remove R3810 and L3806 (Be sure to reinstall after testing.)
- Solder wires to the remaining pads.
- Place an ammeter in series with Q3804 collector.
- Check for 0.1 to 0.5 A. (depending on control voltage).

NOTE: With no RF drive to the input of the PA, Q3804's collector current should be zero.

Table 4-13. LLA and Driver Typical Voltages

CONTROL VOLTAGE	RF DRIVE OFF		RF DRIVE ON	
	9.2 V	6.0 V	9.2 V	6.0 V
Q3801 Base Collector	— 0.7 8.3	— 0.7 9.0	— 0.7 8.0	— 0.5 8.8
Q3802 Base Collector Emitter	— 7.7 2.0 8.3	— 8.4 1.4 9.0	— 7.5 2.3 8.0	— 8.2 1.2 8.8
Q3806 Base Collector Emitter	— 5.1 7.7 4.5	— 4.1 8.4 3.4	— 5.1 7.5 4.5	— 4.1 8.2 3.4
Q3804 Base Collector	— 0.5 13.8	— 0.5 13.8	— 0.0 13.3	— 0.2 13.4

If Q3804 draws no current under normal conditions, then check for shorted or open input cable, or for defective parts in the input network or matching circuitry between Q3801 and Q3804. If all of the above check out OK, then replace Q3801.

Testing Driver Circuitry

The driver is a typical Class-C stage, except the base is biased with resistors R3809 and R3810. The necessary conditions for proper operation of this stage are input drive power, and bias conditions as shown in Table 4-13.

NOTE: If it is necessary to replace Q3804, use a hot-air blower to remove and replace the part. It is important that the replacement device's case be properly soldered to its heatsink. Do so by flowing a small bead of solder around the rim of the device while it is clamped in the hot-air soldering device. The base and collector leads must be hand-soldered on the bottom side of the board.

Troubleshooting the Final Device

- Make sure A+ is at the final's collector; if not, check for shorts and/or opens.
- Check the matching circuitry for shorts and/or opens. Also, check for faulty components.
- Measure the resistance from base to emitter; it should be less than 1 ohm. If not, check for proper soldering on L3852 and L3851; replace faulty component(s).
- Current drain on the final device should be >3.5 A. for 25-Watt operation. If low current, go on to the next step.
- Remove L3851 from the board and check the base-emitter and base-collector junction diode drops. Normal voltage drop should be between 0.4 and 1.0 V. If either junction is outside this range, replace the final device.

NOTE: When replacing either the driver or final device, apply thermal compound on the heatsink surface. Torque the screws to the correct value; see the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

Testing the Antenna Switch and Harmonic Filter

Verify that most of this circuit is functioning properly by testing the receiver insertion loss as follows:

- Apply a low-level signal source at the antenna connector.
- Apply the conditions indicated in Table 4-10 for RX tests.
- Measure the power at the receive coax.
- If the difference between the input and output (insertion loss) is less than 1 dB, then the circuitry is functioning properly.
- Additional antenna switch tests are:
  - Check CR3920, CR3921, and CR3922 with an ohmmeter for forward and reverse continuity.
  - In the transmit mode, adjust control voltage for 28 Watts at the antenna connector. Check for less than 10 mW at the end of the receive input cable. If power exceeds 10 mW, then check CR3922 and associated circuitry. Receiver sensitivity can degrade if power at this port exceeds 10 mW.

- Check for proper DC current through the PIN diodes; correct current is indicated if approximately 1.5 V is present at the junction of C3900 and L3900 during transmit mode.

WARNING

DO NOT measure bias directly at the PIN diodes while in transmit mode unless TX injection is removed.

4.5.1.2.5 Power Control and Protection Circuitry

Localizing Problems to a Circuit

Power leveling and current limiting are set to values detailed in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20). These values will vary from unit to unit, depending on the unique variations of each unit. If symptoms indicate that either of these circuits have failed, verify that the radio has been properly aligned before investigating the circuitry.

Temperature sense and control voltage limit are fixed by design and are not influenced by the alignment of the radio. If symptoms indicate that these circuits have failed, then troubleshoot the circuit.

The tests that follow are intended to provide a convenient means of verifying that a particular circuit is functioning properly. These tests will isolate the failure to a minimum number of components. Refer to the Theory of Operation and the schematic for information needed to identify the failed component(s).

Temperature Sense Circuit Test

Temporarily install a 6.8k ohm resistor in parallel with RT3876. Key the transmitter and monitor the output power. The power meter should read approximately one-half the rated power (12 Watts).

Control-Voltage-Limit Circuitry Test

Disconnect the transmitter injection from the internal transceiver chassis. This will require removal of the power amplifier assembly. With all other connections in normal condition, key the transmitter and monitor the control voltage. If the voltage exceeds 9.2 V, troubleshoot the control voltage limit circuitry.

Current-Limiting Circuitry Test

Refer to Chapter 6 of the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for current limit setting instructions. When ready to adjust current limit, decrease the relative current limit value with the keyboard per instructions. After several decrements, the current limit should begin to reduce power. After this test, reset the current limit to its original value. If the circuitry does not perform as indicated, troubleshoot the current limit circuitry.

Power-Leveling Circuitry Test

With the radio connected for power measurements, vary the line voltage from 12.5 to 16 V. The power should not vary more than 2 Watts. At a line voltage of 13.8 V, vary the frequency using the three test modes. If power varies more than 2 Watts, measure the detected voltage on P0853, pin 9. If this voltage varies more than 0.2 V over line and frequency variations, the power control circuitry (most of which is located on the command board) may be malfunctioning. If the detected voltage varies less than 0.2 V, the problem is likely in diode CR3900, the harmonic filter, the antenna switch, or the output coax. Check continuity through the 12-pin DC connector P0853 on the PA board; check digital/analog circuitry, and check 5-V regulator operation. See Table 4-12, DC Voltage Chart, for typical values.

With the radio connected for power measurements and a disconnected TX injection coax, the detected voltage at P0853, pin 9, should measure approximately 1.3 V.

NOTE: If any part of the power leveling circuitry is replaced, perform the power set procedure. See the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for details.

4.5.1.3 50 Watt Power Amplifiers

This information will help you troubleshoot the ASTRO Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. The principle tools needed to troubleshoot a circuit to the component level are the schematic and the Theory of Operation.

In addition to the schematic and theory, this section includes troubleshooting information that will help you test and check the circuits to localize and isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation, including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at high frequency, measurements must be taken very carefully. Notes and cautions are added to the text to alert the reader to this need in areas of greatest sensitivity. However, the need for extreme care does exist in all measurements and tests at high frequency.

4.5.1.3.1 General Troubleshooting and Repair Notes

Most of the common transmitter symptoms are caused by either failure of the power amplifier or a failure in the control circuitry. The initial troubleshooting effort should be toward isolating the problem to one of those two areas. If either the control voltage or keyed 9.4 V are zero, then the problem is likely to be in the control circuit. If those voltages are present, then the problem is more likely in the power amplifier circuit.

If, for diagnostic reasons, a chip component needs to be removed to facilitate testing, such as a series capacitor removed to allow for signal insertion, then the components (s) returned to the circuit should be new parts. The application of a soldering iron to many chip components will tend to cause leaching which could lead to failure.

After a PA board is replaced, or if any power control circuitry components are replaced, readjust the power according to instructions in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

NOTE: Due to high operating frequencies, you must use specified Motorola parts when component replacement is necessary. Substitute components may not work. It is also critical that you use great care when replacing parts. Excessive solder or flux, longer than original leads on coax connectors, misorientation of parts, and other commonly benign imperfections may cause the radio's performance to degrade.

4.5.1.3.2 PA Functional Testing

To test the PA assembly for proper operation, perform the following steps:

1. Disassemble the PA assembly from the radio, leaving the power cable connected to the rear connector. Replace the PA shield and cover. Disconnect the coax connectors and the ribbon cable. Connect a power meter to the antenna port using minimum cable length.
   a. When setting or measuring RF power, follow these guidelines to avoid measurement errors due to cable losses or non-50-ohm connector VSWR:
      - All cables should be very short and have Teflon dielectric.
      - Attenuators and 50 ohm loads should have at least 25dB return loss.
      - Mini UHF to 'N' adapter, P/N 58-803671321, should be used at the antenna connector. All other connectors should be 'N' type. No other adapters, barrel connectors, etc. should be used.

   b. Maximum input level to the PA is 20 mW. Too much input power could result in damage to the LLA stage.
2. Apply the input power and DC voltages indicated in Table 4-14 to the power amplifier assembly. To make the DC connections, use small spring clips or make a test adapter similar to that shown in Figure 4-6.

Table 4-14. DC Voltages and Input Power Chart

Test	Keyed 9.4 V	CONTROL VOLTAGE DRIVE	POWER IN (mW)	A+ .V
Transmit	9.4	See note[a]	10	13.4
Receive	0	0	0	13.4

a. Set initially to zero. Increase value until power equals 28 wafts or 9.2 V maximum. Do NOT exceed 9.2 V.

3. Apply the required input power via an adapter cable. For this application, non 'N' type connectors are acceptable.
4. With the applied control voltage initially at 0 V, slowly increase the voltage until power out equals 55 Watts. Power should rise smoothly with control voltage once the turn-on threshold is reached. Control voltage should not exceed 8.0 V.
5. If 8.0 V does not produce 55 Watts, then a failure exists in the power amplifier circuit.
6. Refer to the voltage chart (see Table 4-15). Measure the indicated voltages. If they are not within the limits shown on chart, then a failure exists in the PA assembly.
7. If the voltages in the chart are correct, verify that the injection is at least 10 mW (see the VCO Troubleshooting Section).

8. If no failure is located from the previous checks, troubleshoot the power control circuitry.

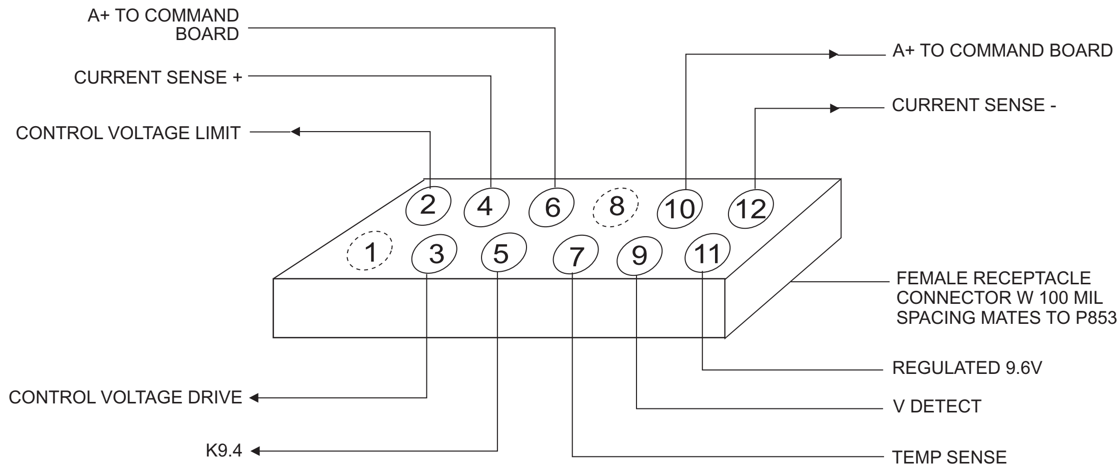


Figure 4-6. PA Test Adapter, 50 Watt Power Amplifier

Table 4-15. Power Control DC Voltage Chart

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
				P0853			
1	—	—	—	—	—	—	Key (no pin or wire)
2		0		0	2.0	3.2	Control Voltage Limit
3		0		2.0	7.0	9.2	Control Drive Voltage
4	10.8	13.8	16.6	10.4	13.4	16.2	Current Sense +
5	0	0	0	9.2	9.4	9.8	Keyed 9.4
6	10.8	13.8	16.6	10.4	13.4	16.2	A+ to Command Board
7		0			1.2		Temp Sense (cutback begins at 3.3 V)
8	—	—	—	—	—	v	Key (no pin)
9		0		1.5	3.5	5.0	Forward Detect Volt
10	10.8	13.8	16.6	10.4	13.4	16.2	A+ to Command Board
11	9.4	9.6	9.9	9.4	9.6	9.9	9.6-V Supply from Command Board
12	10.8			9.8	13.1	15.9	Current Sense - (voltage delta 150 mV)
				U0500			
1	0	0	0	0	0	0	Ground
2		0			3.2		Control AMP Input

Table 4-15. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
3	0	0	0	0	0	0	Control AMP Input (not used)
4		0		0	2	3.2	Control Voltage Limit (cutback at 3.3 V)
5		0			0		N.C.
6	1.5	3.0	4.5	1.5	3.0	4.5	Power Set from D-A (max power at 1.5 V)
7		0	0	1.5	3.0	4.5	Power Set Buffer Out
8		0		1.3	3.5	6.0	Coupler Buffer Out
9		0		1.3	3.5	6.0	Forward Detect Voltage
10		0			0		Reflected Power Detect (not used)
11		0		1.3	3.5	6.0	Same as pin 8 (not used)
12		0		0	1.2	6.0	Thermister Buffer out (increases as PA gets hot)
13		0		0	1.2	6.0	Thermister Buffer in
14		5.0			5.0		5-V Sense Input (follows pin 20 ±0.1 V)
15	4.9	5.0	5.7	4.9	5.0	5.7	5-V Current Limit (limits at 5.7 V)
16	5.0	5.7	6.4	5.0	5.7	6.4	5-V Series Pass Drive (6.4 at max current)
17	9.5	9.6	9.9	9.5	9.6	9.9	9.6-V Sense Input
18		7			7		5-V Reg. Compensation Capacitor
19		5.7			5.7		N.C.
20	4.9	5.0	5.1	4.9	5.0	5.1	5-V Reference Input (UNSW5-V)
21		1.2			1.2		9.6-V Reg. Compensation Capacitor
22		0			0		N.C.
23		0.9	9.6		1.2	9.6	9.6-V Series Pass Drive
24		2.9			3.3		Regulator Enable/Compensation
25	—	—	—	—	—	—	9.6-V Programming (N.C.)
26		0			0		N.C.
27		13.6			13.6		N.C.
28	—	—	—	—	—	—	9.6-V Programming (N.C.)
29	—	—	—	—	—	—	9.6-V Programming (N.C.)
30	—	—	—	—	v	—	9.6-V Programming (N.C.)
31	0	0	0	0	0	0	Ground

Table 4-15. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
32	10.8	13.6	16.5	10.0	13.0	16.0	Decoupled A+
33	4.0	5.0			0	0.2	TX PA Enable (from U520-25)
34		0			1.3		Control AMP one-shot
35		0			0		Lock (5-V of Synth Out of Lock)
36		0			0.8		Control AMP one-shot
37	10.8	13.6	16.3	10.0	13.0	16.0	A+ (Current Sense +)
38	10.8	13.6	16.3	10.0	13.0	16.0	Current Sense - Voltage Delta 150 mV (30 Watt only)
39		0		9.2	9.4	9.8	Keyed 9.4-V in
40	1.5	3.0	4.5	1.5	3.0	4.5	Current Limit D-A (max current at 4.5 V)
41	0	0	0	0	0	0	Ground
42		0			2.2	9.6	Control AMP Output (Approx 1/2-V Control)
43		1.3			7.0		Loop Integrator Capacitor
44		2.1			3.2		Control AMP Reference
Q0500E		13.0			13.0		A+ - CR0500 Drop
Q0501C		12.3			12.3		VQ0500E - B/E Drop
Q0501E		0.2			0.2		V pin 23 - B/E Drop
Q0503E		0			1.5		V pin 42 - B/E Drop (TX)
Q0503C		13.6			9.0		
Q0504B		13.6			12.9		A+ - B/E Drop (TX)

4.5.1.3.3 Localizing Problems

Failure locations often can be determined by externally measured symptoms. Basic symptoms are noted below with probable failure locations.

1. Low Power and High Current
   - Check for improper load conditions caused by high VSWR external to the radio.
   - Check output coax and mini UHF connector.
   - Check harmonic filter.
   - Check output impedance-matching circuitry from the final device to the harmonic filter.
2. Low Power and Low Current
   - If control voltage drive is equal to 8.0 V, then check per the above.
   - It control voltage drive is less than 8.0 V, then check the control circuitry.

3. Power Intermittently Low (or Zero) and Current Less than 1 A. When Power Drops
   - Check LLA stage.
4. Power Zero and Current Greater Than 5 A.
   - Check harmonic filter, antenna switch, and matching circuits beyond final stage.
5. Power Zero and Current Between 2 and 5 A.
   - Check driver and/or final stages.
6. Power Zero and Current Less Than 1 A.
   - Check LLA/driver circuitry.

4.5.1.3.4 Isolating Failures

Methods of analyzing individual stages of the power amplifiers are detailed below. Most of the stages are Class C and must be analyzed under relatively high RF power levels. Generators capable of such levels may not be available in all service shops, therefore the tests below are arranged in order of ascending power. This tends to allow the preceding stage to be the source of RF power for testing the next stage.

Testing Low-Level Amplifier (LLA) Circuitry

The required DC and RF conditions are defined in Table 4-15. Measure LLA voltages according to Table 4-16.

If the above DC bias conditions are correct, check to see if the LLA is providing drive power to the driver Q3804. Do so by checking Q3804's collector current under normal drive conditions, as follows:

- Remove R3810 and L3806 (Be sure to reinstall after testing).
- Solder wires to the remaining pads.
- Place an ammeter in series with the collector of Q3804.
- Check for 0.1 to 0.5 A. depending on the control voltage.

NOTE: With no RF drive to the input of the PA, the collector current of Q3804 should be zero.

Table 4-16. LLA and Pre-Driver Typical Voltages

CONTROL VOLTAGE	RF DRIVE OFF		RF DRIVE ON	
	9.2 V	**6.0 V**	**9.2 V**	**6.0 V**
Q3801 Base Collector	— 0.7 8.3	— 0.7 9.0	— 0.7 8.0	— 0.5 8.8
Q3802 Base Collector Emitter	— 7.7 2.0 8.3	— 8.4 1.4 9.0	— 7.5 2.3 8.0	— 8.2 1.2 8.8
Q3806 Base Collector Emitter	— 5.1 7.7 4.5	— 4.1 8.4 3.4	— 5.1 7.5 4.5	— 4.1 8.2 3.4
Q3804 Base Collector	— 0.5 13.8	— 0.5 13.8	— 0.0 13.3	— 0.2 13.4

If the above DC bias conditions are correct, check to see if the LLA is providing drive power to the pre-driver, Q3804. Do so by checking Q3804's collector current under normal drive conditions, as follows:

- Remove R3810 and L3806 (Be sure to reinstall after testing).
- Solder wires to the remaining pads.
- Place an ammeter in series with the collector of Q3804. Check for 0.1 to 0.5 A. depending the control voltage.

NOTE: With no RF drive to the input of the PA, Q3804's collector current should be zero.

If Q3804 draws no current under normal conditions, then check for a shorted or open input cable, or for defective parts in the input network or matching circuitry between Q3801 and Q3804. If all the above check out OK, then replace Q3801.

Testing Pre-Driver Circuitry

The pre-driver is a typical Class C stage, except the base is biased with resistors R3809 and R3806. The necessary conditions for proper operation of this stage are input drive power, and bias conditions as shown in Table 4-16 above.

NOTE: If it is necessary to replace Q3804, use a hot-air blower to remove and replace the part. It is important that the replacement device's case be properly soldered to its heatsink. Do so by flowing a small bead of solder around the rim of the device while it is clamped in the hot-air soldering device. The base and collector leads must be hand-soldered on the bottom of the board.

Troubleshooting the Driver Stage

- Make sure A+ is at the collector.
- Check for shorts and/or opens in the matching circuitry. Also look for faulty components.
- Measure the DC resistance from base to emitter. It should be less than 1 ohm. If not, check L3810 for proper soldering and replace if faulty.
- Check the current drain of the driver. It should be around 0.5 to 2.5 A. for 50-Watt operation. If current drain is low, go to next step.
- Unsolder the base lead. Making sure the lead is not touching the PC board, check the base-emitter and base-collector junction diode drops. Normal voltage drop should be between 0.4 and 1.0 V. If either junction reads outside this range, replace the driver device.
- Unsolder either L3854, R3875, or L3851 to isolate the driver and final stages. Measure the collector emitter DC resistance. If the resistance is below 5k ohms, then replace the driver device.

Troubleshooting the Final Device

- Make sure A+ is at the final's collector; if not, check for shorts and/or opens.
- Check the matching circuitry for shorts and/or opens. Also, check for faulty components.
- Measure the resistance from base to emitter; it should be less than 1 ohm. If not, check for proper soldering on L3852 and L3853; replace faulty component (s).
- Current drain on the final device should be >6 A. for 50-Watt operation. If low current, go on to the next step.
- Remove L3853 from the board and check the base-emitter and base-collector junction diode drops. Normal voltage drop should be between 0.4 and 1.0 V. If either junction is outside the range, replace the final device.

- Unsolder either L3859, R3875, or L3851 to isolate the driver and final stages. Measure the collector emitter DC resistances. If the resistance is below 5k ohms, then replace the driver device.

NOTE: The position of capacitors C3853 and C3854 is critical to the performance of the circuit. If they are removed for any reason, they must be re-installed as close to the cap of the final device as possible.When replacing either the driver or final device, apply thermal compound on the heatsink surface. Torque the screws to the correct value; see the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

Testing the Antenna Switch and Harmonic Filter

Verify that most of this circuit is functioning properly by testing the receiver insertion loss as follows:

- Apply a low-level signal source at the antenna connector.
- Apply the conditions indicated in Table 4-14 for RX tests.
- If the difference between the input and output (insertion loss) is less than 1 dB, then the circuitry is functioning properly.

Additional antenna switch tests are:

- Check CR3920, CR3921, and CR3922 with an ohm meter for forward and reverse continuity.
- In the transmit mode, adjust the control voltage for 55 Watts at the antenna connector. Check for less than 10 mW at the end of the receive input cable. If power exceeds 10 mW, then check CR3922 and associated circuitry. Receiver sensitivity can degrade if power at this port exceeds 10 mW.
- Check for proper DC current through the PIN diodes; correct current is indicated if approximately 1.5 V is present at the junction of C3900 an L3900 during the transmit mode.

WARNING

DO NOT measure bias directly at the PIN diodes while in transmit mode unless TX injection is removed.

4.5.1.3.5 Power Control and Protection Circuitry

Localizing Problems to a Circuit

Power leveling and current limiting are set to values detailed in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20). These values will vary from unit to unit, depending on the unique variations of each unit. If symptoms indicate that either of these circuits have failed, verify that the radio has been properly aligned before investigating the circuitry.

Temperature sense and control voltage limit are fixed by design and are not influenced by the alignment of the radio. If symptoms indicate that these circuits have failed, then troubleshoot the circuit.

The tests that follow are intended to provide a convenient means of verifying that a particular circuit is functioning properly. These tests will isolate the failure to a minimum number of components. Refer to the Theory of Operation and the schematic for information needed to identify the failed component(s).

Temperature Sense Circuit Test

Temporarily place a leaded 6.8k ohm resistor in parallel with RT3875. Key the transmitter and monitor the output power. The power meter should read approximately 1/2 the rated power (25 Watts).

Control-Voltage-Limit Circuitry Test

Disconnect the transmitter injection from the internal transceiver chassis. This will require removal of the power amplifier assembly. With all other connections in normal condition, key the transmitter and monitor the control voltage. It the voltage exceeds 9.0 V, troubleshoot the control voltage limit circuitry.

Current-Limiting Circuitry Test

When ready to adjust current limit, decrease the relative current limit value with the keyboard per instructions. After several decrements, the current limit should begin to reduce power. After this test, reset the current limit to its original value. If the circuitry does not perform as indicated, troubleshoot the current limit circuitry.

Power-Leveling Circuitry Test

With the radio connected for power measurements, vary the line voltage from 12.5 to 16 V. The power should not vary more than 12.5 to 16 V. The power should not vary more than 2 Watts. At a line voltage of 13.6 V, vary the frequency using the three test modes.

If power varies more than 2 Watts, measure the detected voltage on P0853, pin 9. If this voltage varies more than 0.2 V over line and frequency variations, the power control circuitry (most of which is located on the command board) may be malfunctioning. If the detected voltage varies less than 0.2 V, the problem is probably in diode CR3900, the harmonic filter, the antenna switch, or the output coax. Check continuity through the 12-pin connector P0853 on the PA board; check digital/analog circuitry, and check 5-V regulator operation. See Table 4-15 for typical values.

With the radio connected for power measurements and a disconnected TX injection coax, the detected voltage at P0853, pin 9, should measure approximately 1.3 V.

NOTE: If any part of the power leveling circuitry is replaced, perform the power set procedure. See the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for details.

4.5.2 UHF Band

4.5.2.1 High-Power Amplifier

This information will help you troubleshoot the Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. This section includes troubleshooting information that will help you test and check the circuits to localize and isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation, including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at UHF frequencies, measurements must be taken very carefully. Notes and cautions are added to the text to alert the reader to this need in areas of greatest sensitivity. However, the need for extreme care does exist in all measurements and tests at UHF frequencies.

4.5.2.1.1 General Troubleshooting and Repair Notes

Most of the common transmitter symptoms are not necessarily caused by failure of circuits on the PA board. Failure of command board or synthesizer circuits can disable the transmitter. The initial troubleshooting effort should be toward isolating the problem to one of these areas. If either the control voltage or keyed 9.4 V are zero, then the problem is likely to be in the control circuit or synthesizer. If those voltages are present, then the problem is more likely in the power amplifier circuit.

If, for diagnostic reasons, a chip component needs to be removed to facilitate testing, such as a series capacitor removed to allow for signal insertion, then the component(s) returned to the circuit should be new parts. The application of a soldering iron to many chip components will tend to cause leaching which could lead to failure.

If the harmonic filter is damaged and needs to be replaced, then removal and replacement requires the use of a hot-air source capable of reflowing the solder beneath the filter hybrid. When replacing it, add small amounts of fresh solder paste to the silver regions beneath the ceramic to assure adequate electrical ground contact. Save the original input and output connectors (J-straps); these are not included with the replacement kit. No tuning is required. The harmonic filter may be ordered separately, but if the PA kit is ordered a filter kit comes with the PA kit.

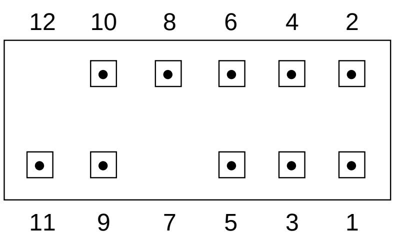
After a PA board is replaced, or if any power control circuitry components are replaced, readjust the power according to instructions in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

NOTE: Due to high operating frequencies, you must use specified Motorola parts when component replacement is necessary. Substitute components may not work. It is also critical that you use great care when replacing parts. Excessive solder or flux, Longer than original leads on coax connectors, misorientation of parts, and other commonly benign imperfections, may cause the radio's performance to degrade.

Bench testing the high-power Spectra PA is most easily accomplished if a Spectra control head, control cable, and power cable are available on the test bench. This greatly simplifies the troubleshooting as several supply voltages are provided by the command board. Proper operation of the command board circuitry can be simultaneously verified.

Begin troubleshooting by connecting an RF power meter and appropriate power load to the antenna connector. Connect the control cable and the power cable. Make sure the ignition sense lead is also connected to the positive lead of the power supply. Note that a regulated DC power supply capable of at least 30 A. is necessary to power a high-power Spectra transmitter. Remove the radio bottom cover. Remove the PA shield by pulling straight up on the plastic handle. This must be done carefully, as the edge of the PA shield can damage components on the PA board if it is removed unevenly. Set the power supply to 13.4 V. The radio may now be turned on. All critical voltages may be measured at connector J1 from the top side of the PA board. A diagram of the connector pin-out as viewed from the top side of the PA board is shown below.

Pin Configuration of J1
As Viewed From Top of PA Board



1 Control Voltage Limit
2 Control Voltage Drive
3 Current Sense +
4 Key 9.4V
5 Filtered A+
6 Temp-Sense
7 Not Connected
8 Forward Power Detect
9 9.6V
10 Current Sense –
11 Not Connected

Figure 4-7. Connector Pin-Out - High-Power Amplifier

Table 4-17. Power Control DC Voltage Chart

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
J1							
1		0		0	2.0	3.2	Control Voltage Limit
2		0		2.0	7.0	10.0	Drive Voltage
3	10.8	13.6	16.5	10.0	13.0	16.0	Current Sense +
4	0	0	0	9.2	9.4	9.8	Keyed 9.4
5	10.8	13.6	16.5	10.0	13.0	16.0	A+ to Command Board
6		0			1.2		Temp Sense (cutback begins at 3.3 V)
7	—	—	—	—	—	—	Key (no pin)
8		0		13.0	9.3	5.0	Forward Detect Voltage
9	10.8	13.6	16.5	10.0	13.0	16.0	A+ to Command Board
10 11	9.4 10.8	9.6 13.6	9.9 16.5	9.4 9.8	9.6 12.8	9.9 15.8	9.6-V Supply from Command Board Current Sense - (voltage delta 150 mV)
12	—	—	—	—	—	—	Key (no pin or wire)
U0500							
1	0	0	0	0	0	0	Ground
2		0			3.2		Control AMP Input
3	0	0	0	0	0	0	Control AMP Input (not used)
4		0		0	2	3.2	Control Voltage Limit (cutback at 3.3 V)
5		9			0		N.C.
6	1.5	3.0	4.5	1.5	3.0	4.5	Power Set from D-A (max power at 1.5 V)
7		0		1.5	3.0	4.5	Power Set Buffer Out
8		0		1.3	3.5	6.0	Coupler Buffer Out
9		0		1.3	3.5	6.0	Forward Detect Volt
10		0			0		Reflected Power Detect (not used)
11		0		1.3	3.5	6.0	Same as pin 8 (not used)
12		0		0	1.2	6.0	Thermister Buffer out (increases as PA gets hot)
13		0		0	1.2	6.0	Thermister Buffer in
14		5.0			5.0		5-V Sense Input (follows pin 20 ±0.1 V)
15	4.9	5.0	5.7	4.9	5.0	5.7	5-V Current Limit (limits at 5.7 V)

Table 4-17. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
J1							
16	5.0	5.7	6.4	5.0	5.7	6.4	5-V Series Pass Drive (6.4 at max current)
17	9.5	9.6	9.9	9.5	9.6	9.9	9.6-V Sense Input
18		7			7		5-V Reg. Compensation Capacitor
19		5.7			5.7		N.C.
20	4.9	5.0	5.1	4.9	5.0	5.1	5-V Reference Input (UNSW5-V)
21		1.2			1.2		9.6-V Reg. Compensation Capacitor
22		0			0		N.C.
23		0.9	9.6		1.2	9.6	9.6-V Series Pass Drive
24		2.9			3.3		Regulator Enable/Compensation
25	v	—	—	—	—	—	9.6-V Programming (N.C.)
26		0			0		N.C.
27		13.6			13.6		N.C.
28	—	—	—	—	—	—	9.6-V Programming (N.C.)
29	—	—	—	—	—	—	9.6-V Programming (N.C.)
30	—	—	—	—	—	—	9.6-V Programming (N.C.)
31	0	0	0	0	0	0	Ground
32	10.8	13.6	16.5	10.0	13.0	16.0	Decoupled A+
33	4.0	5.0			0	0.2	$\overline{\text{TX PA Enable}}$ (from U520-25)
34		0			1.3		Control AMP one-shot
35		0			0		$\overline{\text{Lock}}$ (5-V of Synth Out of Lock)
36		0			0.8		Control AMP one-shot
37	10.8	13.6	16.3	10.0	13.0	16.0	A+ (Current Sense +)
38	10.8	13.6	16.3	10.0	13.0	16.0	Current Sense - Voltage Delta 150 mV
39		0		9.2	9.4	9.8	Keyed 9.4-V in
40	1.5	3.0	4.5	1.5	3.0	4.5	Current Limit D-A (max current at 4.5 V)
41	0	0	0	0	0	0	Ground
42		0			2.2	9.6	Control AMP Output (Approx 1/2-V Control)
43		1.3			7.0		Loop Integrator Capacitor

Table 4-17. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
J1							
44		2.1			3.2		Control AMP Reference
Q0500E		13.0			13.0		A+ - CR0500 Drop
Q0501C		12.3			12.3		VQ0500E - B/E Drop
Q0501E		0.2			0.2		V pin 23 - B/E Drop
Q0503E		0			1.5		V pin 42 - B/E Drop (TX)
Q0503C		13.6			9.0		
Q0504B		13.6			12.9		A+ - B/E Drop (TX)

Key the transmitter. The RF power meter should read at least 100 Watts if it is calibrated. Range 3 UHF radios will have power set to 78 Watts at modes above 470 MHz. R4 UHF radios will be set to 78 Watts on all modes. If power is low, the power set must be checked first before suspecting a defective PA or command board. This may be checked using a PC and RSS software. Alternatively, front panel programming may be used. Please refer to the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for programming instructions.

If correct power output can not be obtained by following the power set procedure outlined in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20), it is possible that current limit may be improperly set. This can not be adjusted using front panel programming. A PC with RSS must be used. A simple way to check for current limit engagement is to temporarily short out the current sense resistor R5875 with a piece of 12- or 14-gauge wire. If full power is restored, then RSS must be used to properly set current limit.

If it is verified that both power set and current limit are not related to the power problem, then the synthesizer output must be checked. A milliwatt meter connected to the TX injection cable should indicate at least 30 mW of injection power during key-up. If this is not the case, refer to the RF Board and VCO troubleshooting procedures in this chapter.

If the command board and synthesizer are functioning properly, the PA must be defective. Details on troubleshooting each circuit of the PA follow.

4.5.2.1.2 PA Functional Testing

NOTE: When setting or measuring RF power at UHF, follow these guidelines to avoid measurement errors due to cable losses or non-50-ohm connector VSWR:

- All coaxial cables should be low loss and as short as possible.
- Attenuators and 50-ohm loads should have at least 25 dB return loss.
- Mini UHF to 'N' adapter, P/N 58803671321, should be used at the antenna connector. All other connectors should be 'N' type. No other adapters, barrel connectors, etc. should be used.

Maximum input level to the PA is 50 mW. Too much input power could result in damage to the LLA stage.

Methods of analyzing individual stages of the power amplifiers are detailed below. Most of the stages are Class-C and must be analyzed under relatively high RF power levels. The following information should help in isolation and repair of the majority of transmitter failures.

Testing Low-Level Amplifier (LLA) Circuitry

Proper operation of the LLA can be checked by monitoring the voltage across resistor R5805. The voltage should measure in the range of 0.4 to 1.2 V, depending on the value of control voltage. A 0.4-V reading corresponds to a low control voltage (4 to 5 V) and a 1.2-V reading corresponds to a high control voltage (up to control voltage limit).

Measure LLA voltages according to Table 4-18. If the DC bias conditions are correct, check to see if the LLA is providing drive power to Q5803**.** Do so by checking Q5803 collector current under normal drive conditions, as follows:

- Remove R5810 and L5806 (Be sure to reinstall after testing).
- Solder wires to the remaining pads.
- Place an ammeter in series with Q5803 collector.
- Check for 0.2 to 0.5 A. (depending on control voltage).

NOTE: With no RF drive to the input of the PA, Q5803 collector current should be zero.

Table 4-18. LLA and 2nd Stage Typical Voltages

CONTROL VOLTAGE	RF DRIVE OFF		RF DRIVE ON	
	10.0 V	6.0 V	10.0 V	6.0 V
Q5801 Base Collector	— 0.7 8.1	— 0.7 9.1	— 0.7 8.0	— 0.3 8.8
Q5800 Base Collector Emitter	— 7.6 2.3 8.1	— 8.5 1.4 9.1	— 7.4 2.8 8.0	— 8.3 1.1 8.8
Q5806 Base Collector Emitter	— 6.4 7.6 5.7	— 3.8 8.5 3.2	— 6.4 7.4 5.7	— 3.9 8.3 3.2
Q5803 Base Collector	— 0.6 9.6	— 0.6 9.6	— 0.0 9.5	— 0.3 9.5

NOTE: The LLA voltages change with different control voltages. An example of LLA voltages with control voltage equal to 10.0 V and 6 V is shown.

If Q5803 draws no current under normal conditions, then check for short or open input cable, or for defective parts in the transmit injection filter or matching circuitry between Q5801 and Q5803.

Testing Second Stage Circuitry Q5803

The second stage is a typical class-C stage, except the base is biased with resistors R5809 and R5806. The necessary conditions for proper operation of this stage are input drive power, and bias conditions as shown in Table 4-18.

NOTE: If it is necessary to replace Q5803, use a hot-air blower to remove and replace the part. It is important that the replacement device's case be properly soldered to its heatsink. Do so by flowing a small bead of solder around the rim of the device while it is clamped in the hot-air soldering device. The base and collector leads must be hand-soldered on the bottom side of the board.

Troubleshooting the Third Stage Q5850

- Make sure A+ is at the collector.
- Check for shorts and/or opens in the matching circuitry. Also look for faulty components (cracked parts or parts not properly soldered).
- Measure the DC resistance from base to emitter. It should be less than 1-ohm. If not, check L5851 and L5852 for proper soldering, and replace if faulty.
- Check the current drain of Q5850. Remove L5854 and R5850 and solder wires to the pads. With an ammeter connected to these wires, check the collector current drain during transmit. It should be around 1.5 to 2.0 A. If current drain is low, go to next step.
- Remove L5851 from the board and check the base-emitter and base-collector junction diode voltages using the diode check function of a multimeter. Normal voltage drop should be near 0.6 V. If either junction is open or short circuited replace the device.

Troubleshooting the Driver Stage Q5851

- Make sure A+ is at the driver's collector. Check for shorts and or opens.
- Check the matching circuitry for shorts and/or opens. Also, check for faulty components. (Cracked parts or parts not properly soldered.)
- Measure the resistance from base to emitter; it should be less than 1 ohm. If not, check for proper soldering on L5855 and L5857. Replace faulty component(s).
- Current drain for this stage should be close to 5 A. If low current, go to the next step.
- Remove L5857 from the board and check the base-emitter and base-collector junction diode drops. Normal voltage drops should be near 0.6 V. If either junction is open or shorted, replace the device.

NOTE: The position of capacitors C5861, C5862, C5863 and C5864 is critical to the performance of the circuit. If they are removed for any reason, they must be re-installed in the exact same physical location from which they were removed.

Analysis of the Final Amplifier Stage (Q5875 and Q5876)

Extreme care must be taken when troubleshooting the final amplifier due to the high RF currents and voltages present.

A visual inspection of the matching networks should be done first. Check for defective solder joints or burned components. Good soldering of the transistor device leads is essential. Make sure A+ voltage is reaching the collector of each final device.

Check the base-emitter and base-collector junctions of the final devices by removing L5877, L5876, and R5878. Using the diode check function of a multimeter, the junctions should have a forward voltage drop close to 0.6 V. Replace a final device if it has an open or shorted junction.

Capacitors C5885, C5886, C5887, and C5888 are placed on the bottom side of the PA board underneath the leads of the final devices. Extreme care should be used when replacing these parts. Exact positioning is critical. Inspect for solder shorts on these capacitors before installing the PA board in the radio chassis.

Installation of the PA board into the radio chassis must be done carefully. The PC board screws use a T-15 Torx bit and should be torqued to 6 to 8 inch-pounds. The device screws use a T-8 Torx bit and should be torqued to 6 to 8 inch-pounds. Always apply thermal compound to the area under the device flanges before installing the PA board.

Current drain of the final amplifier may be checked by measuring the voltage across R5875 during transmit. A voltage drop of 0.10 to 0.15 V indicates the finals are drawing 10 to 15 A., which is within the acceptable range.

Testing the Antenna Switch and Harmonic Filter

Use care when replacing the harmonic filter. Removal of the filter is best accomplished by heating the filter/PC board assembly with a heat gun or heat blower until the solder joint reflows.

Verify that the receive path of the antenna switch and the harmonic filter are functioning by testing the receiver insertion loss as follows:

- Apply a low-level signal source at the antenna connector.
- Verify the conditions indicated in Table 4-17 for RX tests.
- Measure the power at the receive coax.
- If the difference between the input and output (insertion loss) is less than 1 dB, then the circuitry is functioning properly. Additional antenna switch tests are:
  - Check CR5900, CR5902, CR5904, and CR5905 using the diode-check function of a multimeter. Note that CR5904 and CR5905 are on the bottom side of the board. These two diodes affect the receive path only and are unrelated to transmitter problems.
  - Check for proper DC current through the PIN diodes; correct current is indicated if approximately 1.5 V is present at the junction of R5900 and L5900 during transmit.

WARNING

DO NOT measure bias directly at the PIN diodes while in transmit mode unless TX injection is removed.

4.5.2.1.3 Power Control and Protection Circuitry

Localizing Problems to a Circuit

Power leveling and current limiting are set to values detailed in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20). These values will vary from unit to unit, depending on the unique variations of each unit. If symptoms indicate that either of these circuits have failed, verify that the radio has been properly aligned before investigating the circuitry.

Temperature sense and control voltage limit are fixed by design and are not influenced by the alignment of the radio. If symptoms indicate that these circuits have failed, then troubleshoot the circuit.

The tests that follow are intended to provide a convenient means of verifying that a particular circuit is functioning properly. These tests will isolate the failure to a minimum number of components. Refer to the Theory of Operation and the schematic for information needed to identify the failed component(s).

Temperature Sense Circuit Test

Temporarily install a 2.2k ohm resistor in parallel with RT5875. Key the transmitter and monitor the output power. The power meter should read approximately one-half the rated power.

Control-Voltage-Limit Circuitry Test

Disconnect J5901 (transmitter injection) from the PA input. With all other connections in normal condition, key the transmitter and monitor the control voltage at J1 pin 2. If the voltage exceeds 10.0 V, troubleshoot the control voltage limit circuitry.

Current-Limiting Circuitry Test

When ready to adjust current limit, decrease the relative current limit value with the keyboard per instructions. After several decrements, the current limit should begin to reduce power in 0.5 to 1.0 Watt increments. After this test, reset the current limit to its original value. If the circuitry does not perform as indicated, troubleshoot the current limit circuitry.

Directional Coupler and Power-Leveling Test

The directional coupler combined with the RPCIC form a closed-loop power leveling circuit. This circuit keeps forward power essentially constant under variations of line voltage, frequency, and VSWR.

The directional coupler samples a small amount of forward power during transmit. This power is rectified by a detector diode CR5906. This rectified DC voltage is fed back to the RPCIC where it is compared to a reference voltage. An error voltage is generated which is ultimately translated into the control voltage via RPCIC circuitry and amplifiers Q503 and Q504 on the command board. Control voltage is routed to the LLA stage, thereby completing the feedback loop. In operation, the control loop tends to maintain the forward detected voltage constant versus frequency and line voltage variations. Proper operation can be observed by monitoring the forward detected voltage while varying the supply voltage from 13.4 to 16.1 V. Forward-detected voltage should not change more than a few hundreths of a volt. Note that the forward power may not necessarily be level if one of the other protection circuits such as temp-sense or current limit are engaged.

PA Voltage Protection Circuit

Some versions of the PA board may include a voltage protection circuit. This circuit is intended to prevent premature failure of a transmitter operated in extreme conditions. An example of an extreme condition would be operation at above normal battery voltages (greater than 15 V) combined with high temperatures (greater than 500°C or 122°F).

The circuit monitors the A+ voltage from the battery, and it is activated if the A+ voltage exceeds approximately 15 V. R5825 and R5823 form a voltage divider connected to A+. The divided A+ voltage is connected to the base of Q5805. The emitter of Q5805 is connected to Zener diode Z1. This 5-V Zener diode, combined with the voltage divider action of R5825 and R5823, sets the voltage “trip point" at which 05805 turns on (A+ near 15 V). When Q5805 turns on, this provides a path for current to flow through the base-emitter junction of Q5802. Q5802 then acts as a switch to connect the K9.4 voltage supply to R5826 and the directional coupler circuit composed of C5924, R5916, R5905, and R5904. A fixed DC bias voltage is applied to the forward power detector.

This fixed DC bias voltage is summed with the rectified RF signal that is coupled from the output of the transmitter. Since the PA power control requires that the detected voltage is a constant value, the output power of the power amplifier must be reduced by an amount proportional to the applied DC bias. The values of R5916, R5905, and R5904 are chosen such that power is cut in half. The reduced output power decreases the current drain of the transmitter, and therefore reduces the internal temperature of the amplifier devices which increases their lifetime. The circuit disengages and full rated power is restored if the over-voltage condition is corrected.

Low-Voltage Current Drain Cutback

An additional circuit associated with the over-voltage protection circuit is the low-voltage current drain circuit. This circuit acts to reduce the transmitter current drain under conditions of low supply voltage. This action extends the available transmit time when, for example, the transmitter in a vehicular installation must be used when the engine is not running. Operation of this circuit is similar to the over-voltage circuit. R5819 and R5820 form a voltage divider which is connected to the base of transistor Q5804. If the A+ voltage drops below approximately 12 V, Q5804 will begin to conduct. This turns on Q5802, which supplies a DC bias voltage to the forward power detector as explained in the Theory of Operation for the over-voltage protection circuit. The transmitter output power is reduced by the power control, which results in reduced current drain and extended battery life.

NOTE: If any part of the power leveling circuitry is replaced, perform the power set procedure. See the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for details.

Miscellaneous Circuits and Notes

Diode CR5875 acts as a reverse-protect diode. This diode also protects from over-voltage conditions, as it has a Zener breakdown voltage of approximately 28 V. When replacing this diode, care must be taken to place the diode with the cathode marking ring down (towards the PC board).

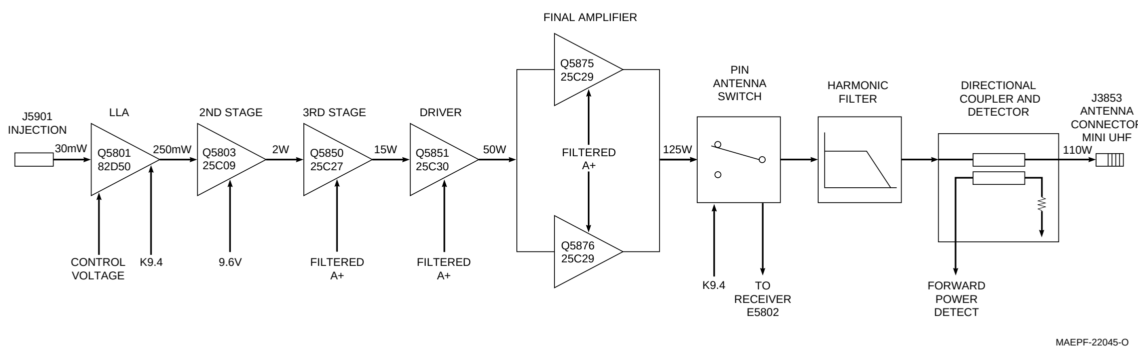


Figure 4-8. Block Diagram for Spectra High-Power Power Amplifier

4.5.2.2 40 Watt Power Amplifiers

This information will help you troubleshoot the Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. The principle tools needed to troubleshoot a circuit to the component level are the schematic and the Theory of Operation.

In addition to the schematic and theory, this section includes troubleshooting information that will help you test and check the circuits to localize and isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation, including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at UHF frequencies, measurements must be taken very carefully. Notes and cautions are added to the text to alert the reader to this need in areas of greatest sensitivity. However, the need for extreme care does exist in all measurements and tests at UHF frequencies.

4.5.2.2.1 General Troubleshooting and Repair Notes

Most of the common transmitter symptoms are caused by either failure of the power amplifier or a failure in the control circuitry. The initial troubleshooting effort should be toward isolating the problem to one of those two areas. If either the control voltage or keyed 9.4 V are zero, then the problem is likely to be in the control circuit. If those voltages are present, then the problem is more likely in the power amplifier circuit.

If, for diagnostic reasons, a chip component needs to be removed to facilitate testing, such as a series capacitor removed to allow for signal insertion, then the component(s) returned to the circuit should be new parts. The application of a soldering iron to many chip components will tend to cause leaching which could lead to failure.

If the harmonic filter is damaged and needs to be replaced, then removal and replacement requires the use of a hot-air source capable of reflowing the solder beneath the filter hybrid. When replacing it, add small amounts of fresh solder paste to the silver regions beneath the ceramic to assure adequate electrical ground contact. Save the original input and output connectors (J-straps); these are not included with the replacement kit. No tuning is required. The harmonic filter may be ordered separately, but if the PA kit is ordered, a filter kit comes with the PA kit.

After a PA board is replaced, or if any power control circuitry components are replaced, readjust the power according to instructions in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

NOTE: Due to high operating frequencies, you must use specified Motorola parts when component replacement is necessary. Substitute components may not work. It is also critical that you use great care when replacing parts. Excessive solder or flux, longer than original leads on coax connectors, misorientation of parts, and other commonly benign imperfections may cause the radio's performance to degrade.

4.5.2.2.2 PA Functional Testing

Test the PA assembly for proper operation as follows:

1. Disassemble the PA assembly from the radio, leaving the power cable connected to the rear connector. Replace the PA shield and cover. Disconnect the coax connectors and the ribbon cable. Connect a power meter to the antenna port using minimum cable length.
   - When setting or measuring RF power at UHF, follow these guidelines to avoid measurement errors due to cable losses or non-50-ohm connector VSWR:
   - All cables should be very short and have Teflon dielectric.
   - Attenuators and 50-ohm loads should have at least 25 dB return loss.
   - Mini UHF to 'N' adapter, P/N 5880367B21, should be used at the antenna connector. All other connectors should be 'N' type. No other adapters, barrel connectors, etc. should be used.
   - Maximum input level to the PA is 50 mW. Too much input power could result in damage to the LLA stage.
2. Apply the input power and DC voltages indicated in Table 4-19 to the power amplifier assembly. To make the DC connections, use small spring--clips or make a test adapter similar to that shown in "Figure 4-9. PA Test Adapter, 40 Watt Power Amplifier".
3. Apply the required input power via an adapter cable. For this application, non N-type connectors are acceptable.
4. With the applied control voltage initially at 0 V, slowly increase the voltage until power out equals 46 Watts. Power should rise smoothly with control voltage once the tum-on threshold is reached. Control voltage should not exceed 10.0 V.
5. If 10.0 V does not produce 46 Watts, then a failure exists in the power amplifier circuit.
6. Refer to the voltage chart (Table 4-20). Measure the indicated voltages. If they are not within the limits shown in the chart, then a failure exists in the PA assembly.
7. If the voltages in the chart are correct, verify that the injection is at least 30 mW. (See the VCO troubleshooting section.)

8. If no failure is located from the previous checks, troubleshoot the power control circuitry.

Table 4-19. DC Voltages and Input Power Chart

Test	Keyed 9.4 V	9.6 V	CONTROL VOLTAGE DRIVE	POWER IN (mW)	A+ .V
Transmit	9.4	9.6	See note[a]	30	13.0
Receive	0	9.6	0	0	13.0

a. Set initially to zero. Increase value until power equals 46 Wafts or 10.0 V maximum. Do NOT exceed 10.0 V.

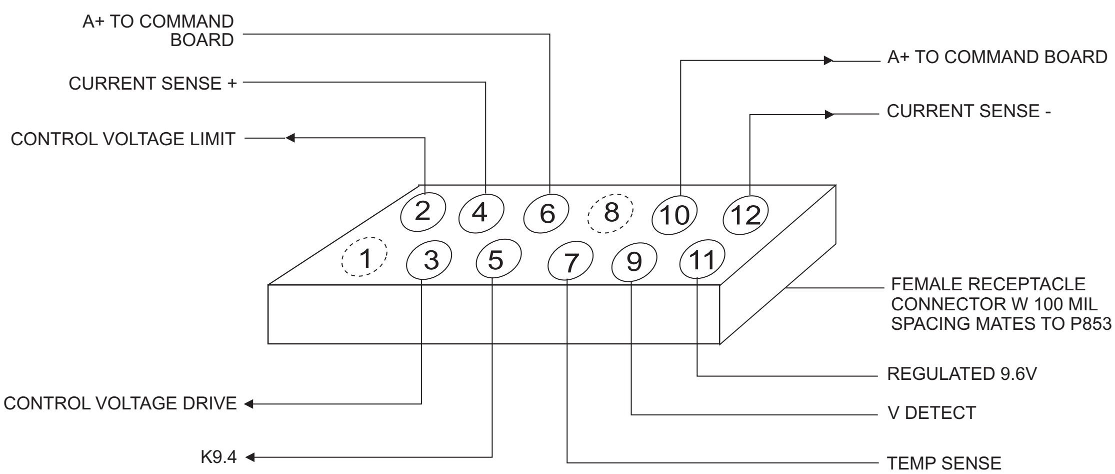


Figure 4-9. PA Test Adapter, 40 Watt Power Amplifier

Table 4-20. Power Control DC Voltage Chart

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
P0853							
1	—	—	—	—	—	—	Key (no pin or wire)
2		0		0	2.0	3.2	Control Voltage Limit
3		0		2.0	7.0	10.0	Drive Voltage
4	10.8	13.6	16.5	10.0	13.0	16.0	Current Sense +
5	0	0	0	9.2	9.4	9.8	Keyed 9.4
6	10.8	13.6	16.5	10.0	13.0	16.0	A+ to Command Board
7		0			1.2		Temp Sense (cutback begins at 3.3 V)
8	—	—	—	—	—	—	Key (no pin)
9		0		13.0	9.3	5.0	Forward Detect Voltage
10	10.8	13.8	16.6	10.4	13.4	16.2	A+ to Command Board
11	9.4	9.6	9.9	9.4	9.6	9.9	9.6-V Supply from Command Board
12	10.8	13.6	16.5	9.8	12.8	15.8	Current Sense - (voltage delta 150 mV)
U0500							
1	0	0	0	0	0	0	Ground
2		0			3.2		Control AMP Input
3	0	0	0	0	0	0	Control AMP Input (not used)
4		0		0	2	3.2	Control Voltage Limit (cutback at 3.3 V)
5		0			0		N.C.
6	1.5	3.0	4.5	1.5	3.0	4.5	Power Set from D-A (max power at 1.5 V)
7		0		1.5	3.0	4.5	Power Set Buffer Out
8		0		1.3	3.5	6.0	Coupler Buffer Out
9		0		1.3	3.5	6.0	Forward Detect Voltage
10		0			0		Reflected Power Detect (not used)
11		0		1.3	3.5	6.0	Same as pin 8 (not used)
12		0		0	1.2	6.0	Thermister Buffer out (increases as PA gets hot)
13		0		0	1.2	6.0	Thermister Buffer in
14		5.0			5.0		5-V Sense Input (follows pin 20 ±0.1 V)

Table 4-20. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
15	4.9	5.0	5.7	4.9	5.0	5.7	5-V Current Limit (limits at 5.7 V)
16	5.0	5.7	6.4	5.0	5.7	6.4	5-V Series Pass Drive (6.4 at max current)
17	9.5	9.6	9.9	9.5	9.6	9.9	9.6-V Sense Input
18		7			7		5-V Reg. Compensation Capacitor
19		5.7			5.7		N.C.
20	4.9	5.0	5.1	4.9	5.0	5.1	5-V Reference Input (UNSW5-V)
21		1.2			1.2		9.6-V Reg. Compensation Capacitor
22		0			0		N.C.
23		0.9	9.6		1.2	9.6	9.6-V Series Pass Drive
24		2.9			3.3		Regulator Enable/Compensation
25	—	—	—	—	—	—	9.6-V Programming (N.C.)
26		0			0		N.C.
27		13.6			13.6		N.C.
28	—	—	—	—	—	—	9.6-V Programming (N.C.)
29	—	—	—	—	—	—	9.6-V Programming (N.C.)
30	—	—	—	—	—	—	9.6-V Programming (N.C.)
31	0	0	0	0	0	0	Ground
32	10.8	13.6	16.5	10.0	13.0	16.0	Decoupled A+
33	4.0	5.0			0	0.2	TX PA Enable (from U520-25)
34		0			1.3		Control AMP one-shot
35		0			0		Lock (5-V of Synth Out of Lock)
36		0			0.8		Control AMP one-shot
37	10.8	13.6	16.3	10.0	13.0	16.0	A+ (Current Sense +)
38	10.8	13.6	16.3	10.0	13.0	16.0	Current Sense - Voltage Delta 150 mV (30 Watt only)
39		0		9.2	9.4	9.8	Keyed 9.4-V in
40	1.5	3.0	4.5	1.5	3.0	4.5	Current Limit D-A (max current at 4.5 V)
41	0	0	0	0	0	0	Ground
42		0			2.2	9.6	Control AMP Output (Approx 1/2-V Control)

Table 4-20. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
43		1.3			7.0		Loop Integrator Capacitor
44		2.1			3.2		Control AMP Reference
Q0500E		13.0			13.0		A+ - CR0500 Drop
Q0501C		12.3			12.3		VQ0500E - B/E Drop
Q0501E		0.2			0.2		V pin 23 - B/E Drop
Q0503E		0			1.5		V pin 42 - B/E Drop (TX)
Q0503C		13.6			9.0		
Q0504B		13.6			12.9		A+ - B/E Drop (TX)

NOTE: For antenna switch transmit bias conditions, RF drive must be removed from PA.

Table 4-21. Antenna Switch DC Voltage Chart

LOCATION		TYPICAL RX	TYPICAL TX NO PRE-DRIVE	COMMENTS
CR5920	ANODE	0	1.6	
	CATHODE	0	0.8	
CR5921	ANODE	0	0.8	
	CATHODE	—	—	
CR5922	ANODE	0	<0.8	
	CATHODE	—	—	

4.5.2.2.3 Localizing Problems

Failure locations often can be determined by externally measured symptoms. Basic symptoms are noted below with probable failure locations.

1. Low Power and High Current
   - Check for improper load conditions caused by high VSWR external to the radio.
   - Check output coax and mini-UHF connector.
   - Check harmonic filter and J-straps for opens and/or shorts.
   - Check output impedance-matching circuitry from the final device to the harmonic filter.
2. Low Power and Low Current
   - If control voltage is equal to 10.0 V, then check per the above.
   - If control voltage is less than 10.0 V, then check the control circuitry.

3. Power Intermittently Low (or Zero) and Current Less than 1 A. When Power Drops
   - Check LLA stage.
4. Power Zero and Current Greater Than 2 A.
   - Check harmonic filter, antenna switch, matching circuits between driver and final stages, and matching circuits beyond final stage.
5. Power Zero and Current Less Than 1 A.
   - Check LLA/pre-driver circuitry.

4.5.2.2.4 Isolating Failures

Methods of analyzing individual stages of the power amplifiers are detailed below. Most of the stages are Class C and must be analyzed under relatively high RF power levels. Generators capable of such levels may not be available in all service shops, therefore the tests below are arranged in order of ascending power. This tends to allow the preceding stage to be the source of RF power for testing the next stage.

1. Testing Low-Level Amplifier (LLA) Circuitry

   The required DC and RF conditions are defined in Table 4-19. Measure LLA voltages according to Table 4-22.

   If the above DC bias conditions are correct, check to see if the LLA is providing drive power to the pre-driver, Q5803. Do so by checking Q5803 collector current under normal drive conditions, as follows:

   - Remove R5810 and L5806 (Be sure to reinstall after testing.)
   - Solder wires to the remaining pads.
   - Place an ammeter in series with Q5803 collector.
   - Check for 0.2 to 0.5 A. (depending on control voltage).

NOTE: With no RFdrive to the input of the PA, Q5803 collector current should be zero.

Table 4-22. LLA and Pre-Driver Typical Voltages

CONTROL VOLTAGE	RF DRIVE OFF		RF DRIVE ON	
	10.0 V	**6.0 V**	**10.0 V**	**6.0 V**
Q5801 Base Collector	— 0.7 8.1	— 0.7 9.1	— 0.7 8.0	— 0.3 8.8
Q5800 Base Collector Emitter	— 7.6 2.3 8.1	— 8.5 1.4 9.1	— 7.4 2.8 8.0	— 8.3 1.1 8.8
Q5806 Base Collector Emitter	— 6.4 7.6 5.7	— 3.8 8.5 3.2	— 6.4 7.4 5.7	— 3.9 8.3 3.2
Q5803 Base Collector	— 0.6 9.6	— 0.6 9.6	— 0.0 9.5	— 0.3 9.5

NOTE: The LLA voltages change with different control voltages. An example of LLA voltages with control voltage equal to 10.0 V and 6 V is shown.

If Q5803 draws no current under normal conditions, then check for short or open input cable, or for defective parts in the transmit injection filter or matching circuitry between Q5801 and Q5803. If all of the above check out OK, then replace Q5803.

2. Testing Pre-Driver Circuitry.

   The pre-driver is a typical class-C stage, except the base is biased with resistors R5809 and R5806. The necessary conditions for proper operation of this stage are input drive power, and bias conditions as shown in Table 4-22, above.

NOTE: If it is necessary to replace Q5803, use a hot-air blower to remove and replace the part. It is important that the replacement device's case be properly soldered to its heatsink. Do so by flowing a small bead of solder around the rim of the device while it is clamped in the hot-air soldering device. The base and collector leads must be hand-soldered on the bottom side of the board.

3. Troubleshooting the Driver Stage

   - Make sure A+ is at the collector.
   - Check for shorts and/or opens in the matching circuitry. Also look for faulty components. (Cracked parts or parts not properly soldered).
   - Measure the DC resistance from base to emitter. It should be less than 1-ohm. If not, check L5851 and L5852 for proper soldering, and replace if faulty.
   - Check the current drain of the driver. It should be around 1.5 to 2.0 A. for 40-Watt operation. If current drain is low, go to next step.
   - Remove L5851 from the board and check the base-emitter and base-collector junction diode drops. Normal voltage drop should be between 0.4 and 1.0 V. If either junction reads outside this range, replace the driver device.

4. Troubleshooting the Final Device

   - Make sure A+ is at the final's collector; if not, check for shorts and/or opens. If A+ is shorted, check C5877 and C5878 first for shorts, by lifting L5878 and measuring the resistance from collector to ground.
   - Check the matching circuitry for shorts and/or opens. Also, check for faulty components. (Cracked parts or parts not properly soldered.)
   - Measure the resistance from base to emitter; it should be less than 1 ohm. If not, check for proper soldering on L5875, L5876, and L5883; replace faulty component(s).
   - Current drain on the final device should be >5 A. for 40-Watt operation. If low current, go on to the next step.
   - Remove L5875 from the board and check the base-emitter and base-collector junction diode drops. Normal voltage drop should be between 0.4 and 1.0 V. If either junction is outside this range, replace the final device.

NOTE: The position of capacitors C5875, C5876, C5877, and C5878 is critical to the performance of the circuit. If they are removed for any reason, they must be re-installed as close to the cap of the final device as possible.
When replacing either the driver or final device, apply thermal compound on the heatsink surface. Torque the screws to the correct value; see the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

5. Testing the Antenna Switch and Harmonic Filter

   Verify that most of this circuit is functioning properly by testing the receiver insertion loss as follows:

   - Apply a low-level signal source at the antenna connector.
   - Apply the conditions indicated in Table 4-19 for RX tests.
   - Measure the power at the receive coax.
   - If the difference between the input and output (insertion loss) is less than 1 dB, then the circuitry is functioning properly.

   Additional antenna switch tests are:

   - Check CR5920, CR5921, and CR5922 with an ohmmeter for forward and reverse continuity.
   - In the transmit mode, adjust control voltage for 44 Watts at the antenna connector. Check for less than 10 mW at the end of the receive input cable. If power exceeds 10 mW, then check CR5922 and associated circuitry. Receiver sensitivity can degrade if power at this port exceeds 10 mW.
   - Check for proper DC current through the PIN diodes; correct current is indicated if approximately 1.5 V is present at the junction of C5920 and L5920 during transmit mode.

DO NOT measure bias directly at the PIN diodes while in transmit mode unless TX injection is removed.

WARNING

4.5.2.2.5 Power Control and Protection Circuitry

1. Localizing Problems to a Circuit

   Power leveling and current limiting are set to values detailed in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20). These values will vary from unit to unit, depending on the unique variations of each unit. If symptoms indicate that either of these circuits have failed, verify that the radio has been properly aligned before investigating the circuitry.

   Temperature sense and control voltage limit are fixed by design and are not influenced by the alignment of the radio. If symptoms indicate that these circuits have failed, then troubleshoot the circuit.

   The tests that follow are intended to provide a convenient means of verifying that a particular circuit is functioning properly. These tests will isolate the failure to a minimum number of components. Refer to the Theory of Operation and the schematic for information needed to identify the failed component(s).

2. Temperature Sense Circuit Test

   Temporarily install a 6.8k ohm resistor in parallel with RT5875. Key the transmitter and monitor the output power. The power meter should read approximately one-half the rated power (25 Watts).

3. Control-Voltage-Limit Circuitry Test

   Disconnect J5901 (transmitter injection) from the internal transceiver chassis. This will require removal of the power amplifier assembly. With all other connections in normal condition, key the transmitter and monitor the control voltage at the node of R5811, C5814,L5808, and R5808. If the voltage exceeds 10.0 V, troubleshoot the control voltage limit circuitry.

4. Current-Limiting Circuitry Test

   When ready to adjust current limit, decrease the relative current limit value with the keyboard per instructions. After several decrements, the current limit should begin to reduce power in 0. 1- to 0.5-Watt increments. After this test, reset the current limit to its original value. If the circuitry does not perform as indicated, troubleshoot the current limit circuitry.

5. Power-Leveling Circuitry Test

   With the radio connected for power measurements, vary the line voltage from 12.5 to 16 V. The power should not vary more than 2 Watts. At a line voltage of 13.6 V, vary the frequency using the three test modes. If power varies more than 2 Watts, measure the detected voltage on P0853, pin 9. 1 this voltage varies more than 0.2 V over line and frequency variations, the power control circuitry (most of which is located on the command board) may be malfunctioning. If the detected voltage varies less than 0.2 V, the problem is likely in diode CR5900, the harmonic filter, the antenna switch, or the output coax. Check continuity through the 12-pin DC connector P0853 on the PA board; check digital/analog circuitry, and check 5-V regulator operation. See Table 4-20 for typical values.

   With the radio connected for power measurements and, disconnected TX injection coax, the detected voltage a P0853, pin 9, should measure approximately 1.3 V.

NOTE: If any part of the power leveling circuitry is replaced, perform the power set procedure. See the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for details.

4.5.3 800 MHz Band

4.5.3.1 15 Watt and 35 Watt Power Amplifiers

This information will help you troubleshoot the Spectra radio. Use this information, along with the Theory of Operation, to diagnose and isolate the cause of failures. The principle tools needed to troubleshoot a circuit to the component level are the schematic and the Theory of Operation.

In addition to the schematic and theory, this section includes troubleshooting information that will help you test and check the circuits to localize and isolate problems.

Prior to troubleshooting, it is important to review the Theory of Operation, including specific precautions and troubleshooting methods. Because much of the radio's circuitry operates at 800 MHz, measurements must be taken very carefully. Notes and cautions are added to the text to alert the reader to this need in areas of greatest sensitivity. However the need to extreme care does exist in all measurements and tests at 800 MHz.

4.5.3.1.1 General Troubleshooting and Repair Notes

Most of the common transmitter symptoms are caused by either failure of the power amplifier or a failure in the control circuitry. The initial troubleshooting effort should be toward isolating the problem to one of those two areas. If either the control voltage or keyed 9.4 V are zero, then the problem is likely to be in the control circuit. If those voltages are present, then the problem is more likely in the power amplifier circuit.

If for diagnostic reasons, a chip component needs to be removed to facilitate testing, such as a series capacitor removed to allow for signal insertion, then the component(s) returned to the circuit should be new parts. The application of a soldering iron to many chip components will tend to cause leaching which could lead to failure.

If the harmonic filter is damaged and needs to be replaced, then removal and replacement requires the use of a hot air source capable of reflowing the solder beneath the filter hybrid. When replacing it, add small amounts of fresh solder paste to the silver regions beneath the ceramic to assure adequate electrical ground contact. Save the original input and output connectors ('J' straps); these are not included with the replacement kit. No turning is required. The harmonic filter may be ordered separately, but if the PA kit is ordered, a filter kit comes with the PA kit.

The pass device may be ordered separately or may be received as part of the hardware kit-it is not part of the PA kit. The PA kit comes with all surface-mount components, including the harmonic filter hybrid, but the harmonic filter cover is not included. Neither does the PA kit include the Power Module, nor, on 35-Watt models, the final device and associated matching capacitors.

After a PA board is replaced, or if any power control circuitry components are replaced, readjust the power according to instructions in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

NOTE: Due to the high frequency of operation, it is imperative that you use specified Motorola parts when component replacement is necessary. At these frequencies, second and third order properties of the components are very important and are part of the circuit's design. Substitute components may not work. It is also critical that you use great care when replacing parts. Excessive solder or flux, longer than original leads on coax connectors, misorientation of parts, and other commonly benign imperfections may cause the radio's performance to degrade.

4.5.3.1.2 PA Functional Testing

To test the PA assembly for proper operation, perform the following steps:

NOTE: The following instructions pertain to both the 15 Watt and 35 Watt power amplifiers. A distinction between the two PA's is given only where necessary.

1. Disassemble the PA assembly from the radio, leaving the power cable connected to the rear connector. Replace the 15-Watt PA shield (or the 35-Watt PA shield and cover). Disconnect the coax connectors and the ribbon cable. Connect a power meter to the antenna port using minimum cable length.

   When setting or measuring RF power at 800 MHz, follow these guidelines to avoid measurement errors due to cable losses or non-50-ohm connector VSWR:

   - All cables should be very short and have Teflon dielectric.
   - Attenuators and 50-ohm loads should have at least 25 dB return loss.
   - Mini UHF to 'N' adapter P/N 5880367B21, should be used at the antenna connector. All other connectors should be 'N' type. No other adapters, barrel connectors, etc. should be used.

   Maximum input level to the PA is 200 mW. Over driving the buffer could result in damage to the PA buffer stage.

2. Apply the input power and DC voltages indicated in Table 4-23 to the power amplifier assembly. To make the DC connections, use small spring-clips or make a test adapter similar to that shown in Figure 4-10.

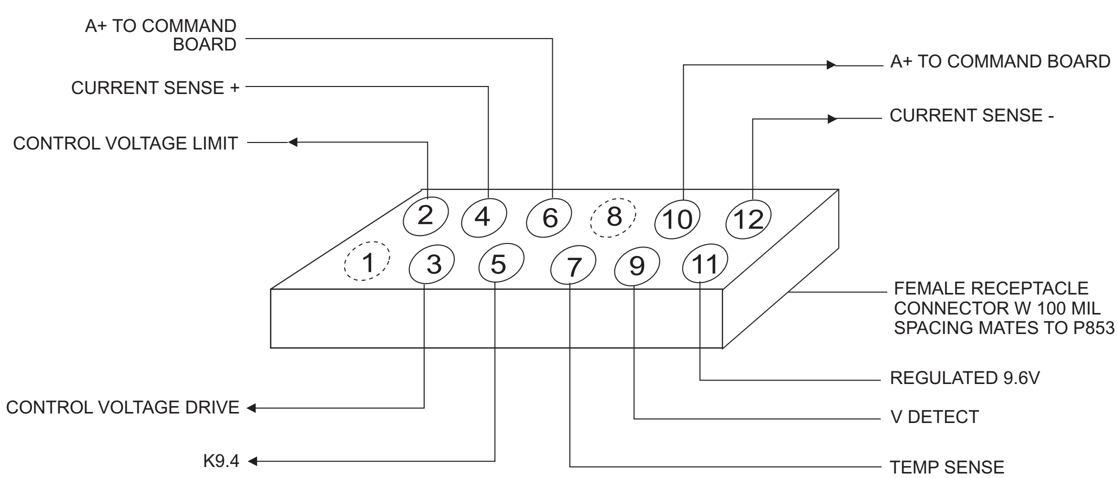


Figure 4-10. PA Test Adapter, 15 and 35 Watt Power Amplifier

Table 4-23. DC Voltages and Input Power Chart

Test	Keyed 9.4 V	9.6 V	CONTROL VOLTAGE DRIVE	POWER IN (mW)	A+ .V
Transmit	9.4	9.6	See note[a]	0.1	13.0
Receive	0	9.6	0	0	13.0

a. Set initially to zero. Increase value until power equals 17 wafts(15-Watt radio) or 38 Watts (35-Watt radio) or 11.0 V maximum.

3. Apply the required input power via adapter cable 30-80373B27 or equivalent. For this application, non N-type connectors are acceptable.
4. With the applied control voltage initially at 0 V slowly increase the voltage until power out equals 17 Watts (15-Watt radio) or 38 Watts (38-Watt radio) Power should rise smoothly with control voltage once the turn-on threshold is reached. Control voltage should no exceed 11.0 V.
5. If 11.0 V does not produce 17 (or 38) Watts, then a failure exists in the power amplifier circuit.
6. Refer to the voltage chart (see Table 4-24). Measure the indicated voltages. If they are not within the limits shown in the chart, then a failure exists in the PA assembly.
7. If the voltages in the chart are correct, verify that the injection is at least 75 mW. (See the VCO troubleshooting section.)
8. If no failure is located from the previous checks troubleshoot the power control circuitry.

Table 4-24. Power Control DC Voltage Chart

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
P0853							
1	—	—	—	—	—	—	Key (no pin or wire)
2		0		0	2.0	3.2	Control Voltage Limit
3		0		2.0	7.0	13.0	Drive Voltage
4	10.8	13.6	16.5	10.0	13.0	16.0	Current Sense +
5	0	0	0	9.2	9.4	9.8	Keyed 9.4
6	10.8	13.6	16.5	10.8	13.6	16.5	A+ to Command Board
7		0			1.2		Temp Sense (cutback begins at 3.3 V)
8	—	—	—	—	—	—	Key (no pin)
9		0		1.3	3.5	6.0	Forward Detect Voltage
10	10.8	13.8	16.5	10.8	13.6	16.5	A+ to Command Board
11	9.4	9.6	9.9	9.4	9.6	9.9	9.6-V Supply from Command Board
12	20.8	13.6	16.5	10.0	13.0	16.0	Current Sense - (voltage delta 150 mV)

Table 4-24. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
U0500							
1	0	0	0	0	0	0	Ground
2		0			3.2		Control AMP Input
3	0	0	0	0	0	0	Control AMP Input (not used)
4		0		0	2	3.2	Control Voltage Limit (cutback at 3.3 V)
5		0			0		N.C.
6	1.5	3.0	4.5	1.5	3.0	4.5	Power Set from D-A (max power at 1.5 V)
7		0	0	1.5	3.0	4.5	Power Set Buffer Out
8		0		1.3	3.5	6.0	Coupler Buffer Out
9		0		1.3	3.5	6.0	Forward Detect Voltage
10		0			0		Reflected Power Detect (not used)
11		0		1.3	3.5	6.0	Same as pin 8 (not used)
12		0		0	1.2	6.0	Thermister Buffer out (increases as PA gets hot)
13		0		0	1.2	6.0	Thermister Buffer in
14		5.0			5.0		5-V Sense Input (follows pin 20 ±0.1 V)
15	4.9	5.0	5.7	4.9	5.0	5.7	5-V Current Limit (limits at 5.7 V)
16	5.0	5.7	6.4	5.0	5.7	6.4	5-V Series Pass Drive (6.4 at max current)
17	9.5	9.6	9.9	9.5	9.6	9.9	9.6-V Sense Input
18		7			7		5-V Reg. Compensation Capacitor
19		5.7			5.7		N.C.
20	4.9	5.0	5.1	4.9	5.0	5.1	5-V Reference Input (UNSW5-V)
21		1.2			1.2		9.6-V Reg. Compensation Capacitor
22		0			0		N.C.
23		0.9	9.6		1.2	9.6	9.6V Series Pass Drive
24		2.9			3.3		Regulator Enable/Compensation
25	—	—	—	—	—	—	9.6-V Programming (N.C.)
26		0			0		N.C.
27		13.6			13.6		N.C.
28	—	—	—	—	—	—	9.6-V Programming (N.C.)

Table 4-24. Power Control DC Voltage Chart (Continued)

LOCATION	RX MODE			TX MODE			COMMENTS
	LOW	TYP	HI	LOW	TYP	HI	
29	—	—	—	—	—	—	9.6-V Programming (N.C.)
30	—	—	—	—	—	—	9.6-V Programming (N.C.)
31	0	0	0	0	0	0	Ground
32	10.8	13.6	16.5	10.0	13.0	16.0	Decoupled A+
33	4.0	5.0			0	0.2	TX PA Enable (from U520-25)
34		0			1.3		Control AMP one-shot
35		0			0		Lock (5-V of Synth Out of Lock)
36		0			0.8		Control AMP one-shot
37	10.8	13.6	16.3	10.0	13.0	16.0	A+ (Current Sense +)
38	10.8	13.6	16.3	10.0	13.0	16.0	Current Sense - Voltage Delta 150 mV (35 Watt only)
39		0		9.2	9.4	9.8	Keyed 9.4-V in
40	1.5	3.0	4.5	1.5	3.0	4.5	Current Limit D-A (max current at 4.5 V)
41	0	0	0	0	0	0	Ground
42		0			2.2	9.6	Control AMP Output (Approx 1/2-V Control)
43		1.3			7.0		Loop Integrator Capacitor
44		2.1			3.2		Control AMP Reference
Q0500E		13.0			13.0		A+ - CR0500 Drop
Q0501C		12.3			12.3		VQ0500E - B/E Drop
Q0501E		0.2			0.2		V pin 23 - B/E Drop
Q0503E		0			1.5		V pin 42 - B/E Drop (TX)
Q0503C		13.6			9.0		
Q0504B		13.6			12.9		A+ - B/E Drop (TX)

NOTE: For antenna switch transmit bias conditions, RF drive must be removed from PA.

Table 4-25. Antenna Switch DC Voltage Chart

LOCATION		TYPICAL RX	TYPICAL TX NO PRE-DRIVE	COMMENTS
CR9920	ANODE	0	1.6	TX Series P.I.N. diode
	CATHODE	0	0.8	(on in TX mode)
CR9921	ANODE	0	0.8	TX Shunt P.I.N. diode
	CATHODE	—	—	(on in TX mode)
CR9922	ANODE	5.15V	<0.2	RX Series P.I.N. diode
	CATHODE	4.45V	8.7	(off in TX mode)
Q9920	COLLEC	5.15V	<0.2	

4.5.3.1.3 Localizing Problems

Failure locations often can be determined by externally measured symptoms. Basic symptoms are noted below with probable failure locations.

1. Low Power and High Current
   - Check for improper load conditions caused by high VSWR external to the radio.
   - Check output coax and mini-UHF connector.
   - Check harmonic filter and J-straps.
   - Check output impedance-matching circuitry from the final device to the harmonic filter.
2. Low Power and Low Current
   - If control voltage is greater than 10 V, then check per the above.
   - If control voltage is less than 10 V, then check the control circuitry.
3. Power Intermittently Low (or zero) and Current less than 1 A. when Power Drops
   - Check Buffer Stage.
4. Power Zero and Current greater than 5 A.
   - Check harmonic filter, antenna switch, and matching circuits beyond final stage.
5. Power Zero and Current between 2 and 5 A.
   - Check Power Module.
6. Power Zero and Current less than 1 A.
   - Check input coax.
   - Check Buffer Stage.

4.5.3.1.4 Isolating Failures

Methods of analyzing individual stages of the Power Amplifiers are detailed below. Most of the stages are Class C and must he analyzed under relatively high RF power levels. Generators capable of such levels may not be available in all service shops, therefore the tests below are arranged in order of increasing power. This tends to allow the preceding stage to be the source of RF power for testing the next stage. If adequate power sources are available, then any stage may be tested with external signal injection.

1. Testing Buffer Circuitry

   The required DC and RF conditions are defined in Table 4-23. With no RF input applied, the collector voltage of Q9800 should be 9.4V. If not, check L9805, L9801, and the feed runners. The base voltage should be 0.6-V (0.7-V without RF). If not, check R9801, CR9800, and related adaptive bias circuitry.

   To check for power out, remove R9805 and lift the output end of C9807. Solder the center conductor of a small-diameter 50-ohm, coax to the vacated pad on the buffer side. Solder the coax's shield to ground. Under the conditions specified in Table 4-23, the measured power should be at least 350 mW. After output power has been tested, replace the resistor and capacitor with new parts.

   An alternate method of testing the buffer's power out is to carefully lift the input lead of the power module (pin 1) from the circuit board and replace it with the center conductor of a small-diameter coax. Solder the shield of the coax. Solder the shield of the coax to the adjacent ground pad.

   To test the input VSWR of the circuit, apply 70 mW to the input. Using a directional coupler, verify that the reflected power is less than 20 mW.

2. Testing the Power Module (U9850)

   The power module is a packaged gain block with 50-ohm input and output impedances. It has three gain stages, the first two of which have controlled voltage applied (for regulating power) and the final stage has A+ applied.

   If the buffer stage has not been confirmed in "working order," an external 400 mW must be injected. Do this by carefully lifting pin 1 of the power module and soldering the center conductor of a small diameter coax to the pin. Solder the shield to the ground pad adjacent to pin 1. To this cable, inject 400 mW. (This application is not so critical to require an 'N' connector on the loose end of the coax.)

   If the buffer stage is confirmed in "working order," then provide 100 mW drive to the buffer (K9.4-V must be applied) to drive the module.

   To measure the output power from the module, remove the series DC blocking capacitor C9879 (15W) or C9856 (35W), then connect a 39 pF blocking capacitor from the center conductor of a small diameter coax to the vacated pad, and finally, ground the shield of the output coax. Use this coax to measure output power.

   Control voltage (Pins 2 and 3) should be 10 V; A+ (pin 4) should be 13.0 V. Apply voltages through the DC connector on the PA board.

   With either 100 mW applied to the buffer or 400 mW applied to the module input, the output power should be at least 15 Watts. If power out is less than 15 Watts, the module is defective and must be replaced.

   NOTE: When replacing the module, apply thermal compound on the heatsink surface. Torque the screws to the correct value; see the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20).

When testing is complete, replace any capacitors or resistors that were removed for testing with new parts.

3. Testing the Final Stage (35-Watt Models Only)

   The final stage is capable of producing over 50 Watts. Be sure to protect power measuring equipment with series attenuation. 30 dB is usually adequate.

   15 Watts are needed to drive the final stage. Because this may exceed the power available at 800 MHz in many repair facilities, these tests consider the module stage as the drive source for the final stage. Therefore, check out the module first to ensure that it operates properly.

   In the course of testing the final stage with the module as the power source, begin with control voltage at zero and increase control voltage smoothly until output of the final stage reaches 40 Watts. If control voltage reaches 10 V, but the power out does not reach 40 Watts, the final stage is defective. Under normal conditions, the protection circuitry limits the power to the final stage to approximately 17 Watts maximum, protecting it from overdrive and damage. Under test conditions, however, the protection circuitry is disabled. Observe the above caution; the power module can produce in excess of 25 Watts.

   Measure the output power by lifting the output side of C9856 and connecting to the center conductor of a small-diameter coax which has its shield grounded. If the output stage does not produce 40 Watts (at 10-V control voltage), then remove the RF drive and perform the following tests:

   - Check continuity from the collector lead to the A+ connector on the back of the radio.
   - Examine the solder connections on all leads of the device (Q9880) and the clamped mica capacitors.

   NOTE: The position of the clamped capacitors adjacent to the device is critical to the performance of the circuit. If they are removed for any reason, they must be re-installed with their leads approximately 70 mil s (0.070 inches) from the final device cap.

4. Testing the Antenna Switch and Harmonic Filter

   Verify that most of this circuit is functioning properly by testing the receiver insertion loss as follows:

   - Apply a low-level signal source at the antenna connector.
   - Apply the conditions indicated in Table 4-23 for RX tests.
   - Measure the power at the receive coax.
   - If the difference between the input and output (insertion loss) is less than 2 dB, then the circuitry is functioning properly.

Additional antenna switch tests are:

- Check CR9922 with an ohmmeter for forward and reverse continuity.
- In the transmit mode, adjust control voltage for 38 Watts at the antenna connector. Check for less than 10 mW at the end of the receive input cable. If power exceeds 10 mW, then check CR9922 and associated circuitry. Receiver sensitivity can degrade if power at this port exceeds 10 mW.
- Check for proper DC current through the PIN diodes; correct current is indicated if approximately 1.5 V is present at the junction of C9920 and L9920 during transmit mode.

DO NOT measure bias directly at the PIN diodes while in transmit mode unless TX injection is removed.

WARNING

4.5.3.1.5 Power Control and Protection Circuitry

1. Localizing Problems to a Circuit

   Power leveling and current limiting (35-Watt models only) are set to values detailed in the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20). These values will vary from unit to unit, depending on the unique variations of each unit. If symptoms indicate that either of these circuits have failed, verify that the radio has been properly aligned before investigating the circuitry.

   Temperature sense, voltage control limit, and interstage drive limit (on 35-Watt models only) are fixed by design and are not influenced by the alignment of the radio. If symptoms indicate that these circuits have failed, then troubleshoot the circuit.

   The tests that follow are intended to provide a convenient means of verifying that a particular circuit is functioning properly. These tests will isolate the failure to a minimum number of components. Refer to the Theory of Operation and the schematic for information needed to identify the failed component(s).

2. Temperature Sense Circuit Test

   Temporarily install a 6.8k ohm resistor in parallel with RT9650. Key the transmitter and monitor the output power. The power meter should read approximately 1/2 the rated power (7.5 Watts or 17.5 Watts).

3. Control-Voltage-Limit Circuitry Test

   Disconnect P9641 (Transmitter injection) from the internal transceiver chassis. This will require removal of the power amplifier assembly. With all other connections in normal condition, key the transmitter and monitor the control voltage on pin 2 of the power module. If the voltage exceeds 12.5 V, troubleshoot the control voltage limit circuitry.

4. Interstage Drive Limiter Circuitry Test (35-Watt models)

   Check this circuit only when the final device Q9880) has failed. With the radio off, check CR9930 and associated components.

5. Current-Limiting Circuitry Test (35-Watt models)

   When ready to adjust current limit, decrease the relative current limit value with the keyboard per instructions. After several decrements, the current limit should reduce power from 0.1 Watt to 0.5 Watt. After this test, reset the current limit. If the circuitry does not perform as indicated, troubleshoot the current limit circuitry.

6. Power-Leveling Circuitry Test

   With the radio connected for power measurements, vary the line voltage from 12.5 to 16 V. The power should not vary more than 3 Watts. At a line voltage of 13.6 V, vary the frequency using the three test modes. If power varies more than 3 Watts, measure the detected voltage on P0853, pin 9. If this voltage varies more than 0.2 V over line and frequency variations, the power control circuitry (most of which is located on the command board) may be malfunctioning. If the detected voltage varies less than 0.2 V, the problem is likely in CR9900, the harmonic filter, the antenna switch, or the output coax. Check continuity through 12 pin DC connector P0853 on the PA board; check digital/analog circuitry, and check 5-V regulator operation. See Table 4-24 for typical values.

NOTE: If any part of the power leveling circuitry is replaced, perform the power set procedure. See the *ASTRO Digital Spectra and Digital Spectra Plus Mobile Radios Basic Service Manual* (68P81076C20) for details.

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Chapter 5 Troubleshooting Charts

5.1 Introduction

This chapter contains detailed troubleshooting flowcharts. These charts should be used as a guide in determining the problem areas. They are not a substitute for knowledge of circuit operation and astute troubleshooting techniques. It is advisable to refer to the related detailed circuit descriptions in the theory section prior to troubleshooting a radio.

5.2 List of Troubleshooting Charts

Most troubleshooting charts (see Table 5-1) end up by pointing to an IC to replace. **It is not always noted, but is good practice, to verify supplies and grounds to the affected IC, and trace continuity to the malfunctioning signal and related circuitry before replacing any IC.** For instance, if a clock signal is not available at a destination IC, continuity from the source IC should be checked before replacing the source IC.

Table 5-1. List of Troubleshooting Charts

Chart Number	Description	Page Number
Chart C.1	RF Board Back-End	5-3
Chart C.2	Command Board	5-4
Chart C.3	Radio Power-Up Fail	5-5
Chart C.4	Bootstrap Fail	5-6
Chart C.5	01/90, General Hardware Failure	5-7
Chart C.6	01/81, Host ROM Checksum Failure	5-7
Chart C.7	01/82, or 002, External EEPROM Checksum Failure	5-8
Chart C.8	01/84, SLIC Initialization Failure	5-8
Chart C.9	01/88, MCU (Host µC) External SRAM Failure	5-9
Chart C.10	01/92, Internal EEPROM Checksum Failure	5-9
Chart C.11	02/A0, ADSIC Checksum Failure	5-10
Chart C.12	02/81, DSP ROM Checksum Failure	5-10
Chart C.13	02/88, DSP External SRAM Failure U414	5-11
Chart C.14	02/84, DSP External SRAM Failure U403	5-11
Chart C.15	02/82, DSP External SRAM Failure U402	5-12
Chart C.16	02/90, General DSP Hardware Failure	5-12
Chart C.17	09/10, Secure Hardware Failure	5-13
Chart C.18	09/90, Secure Hardware Failure	5-13

Table 5-1. List of Troubleshooting Charts (Continued)

NOTE: The term µC is used in several of the following troubleshooting charts; µC = MCU.

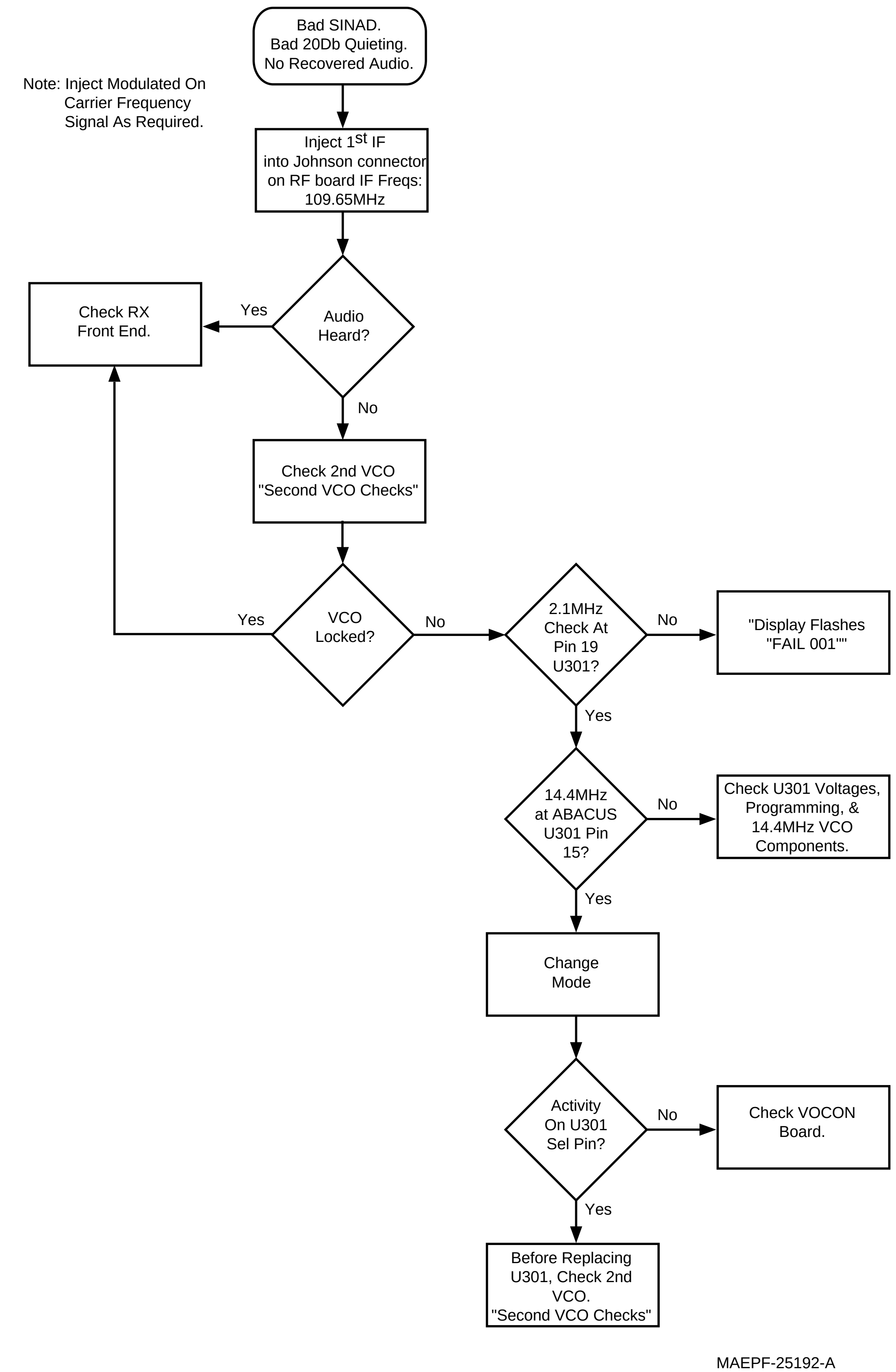


Chart C.1 RF Board Back-End

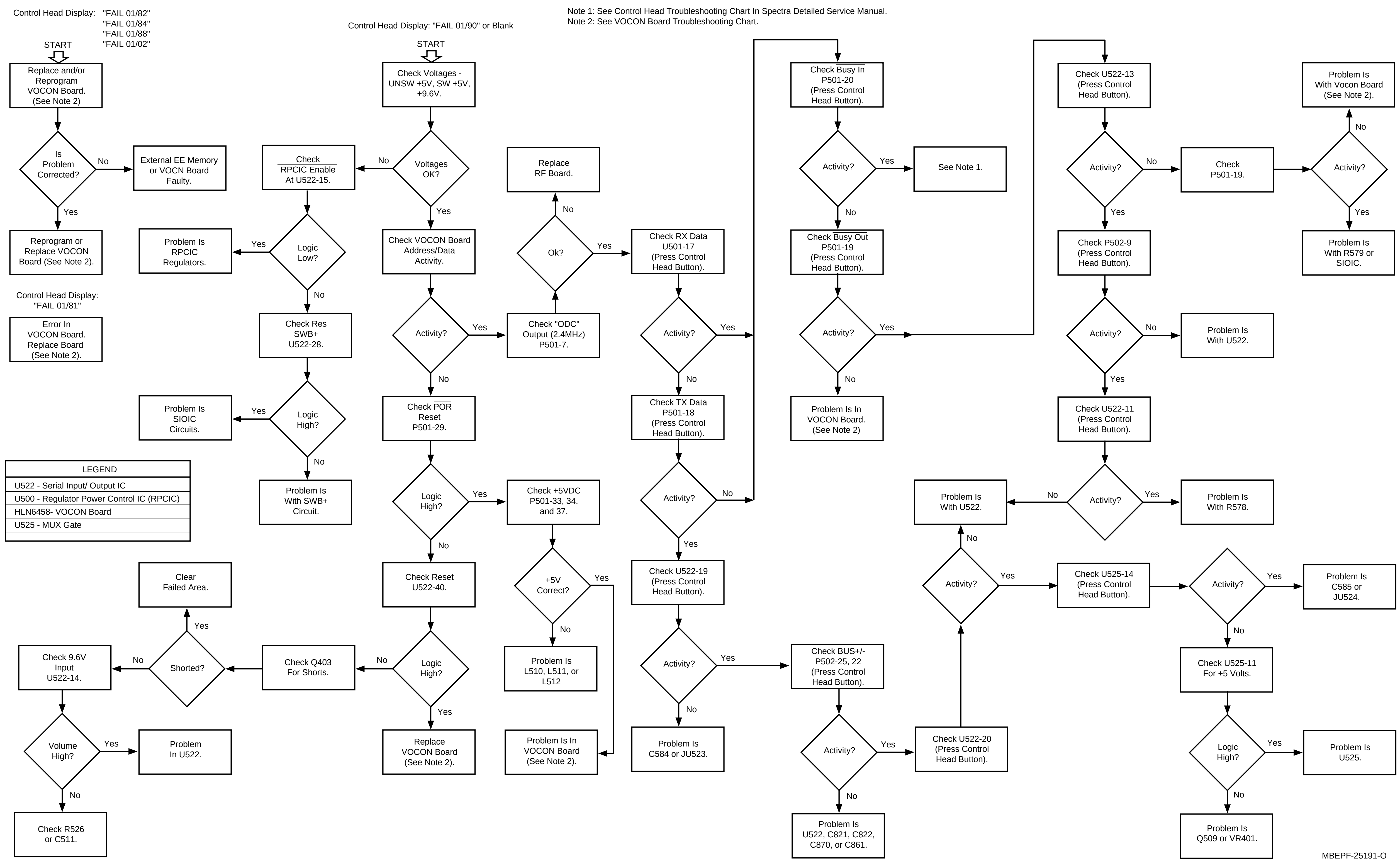


Chart C.2 Command Board

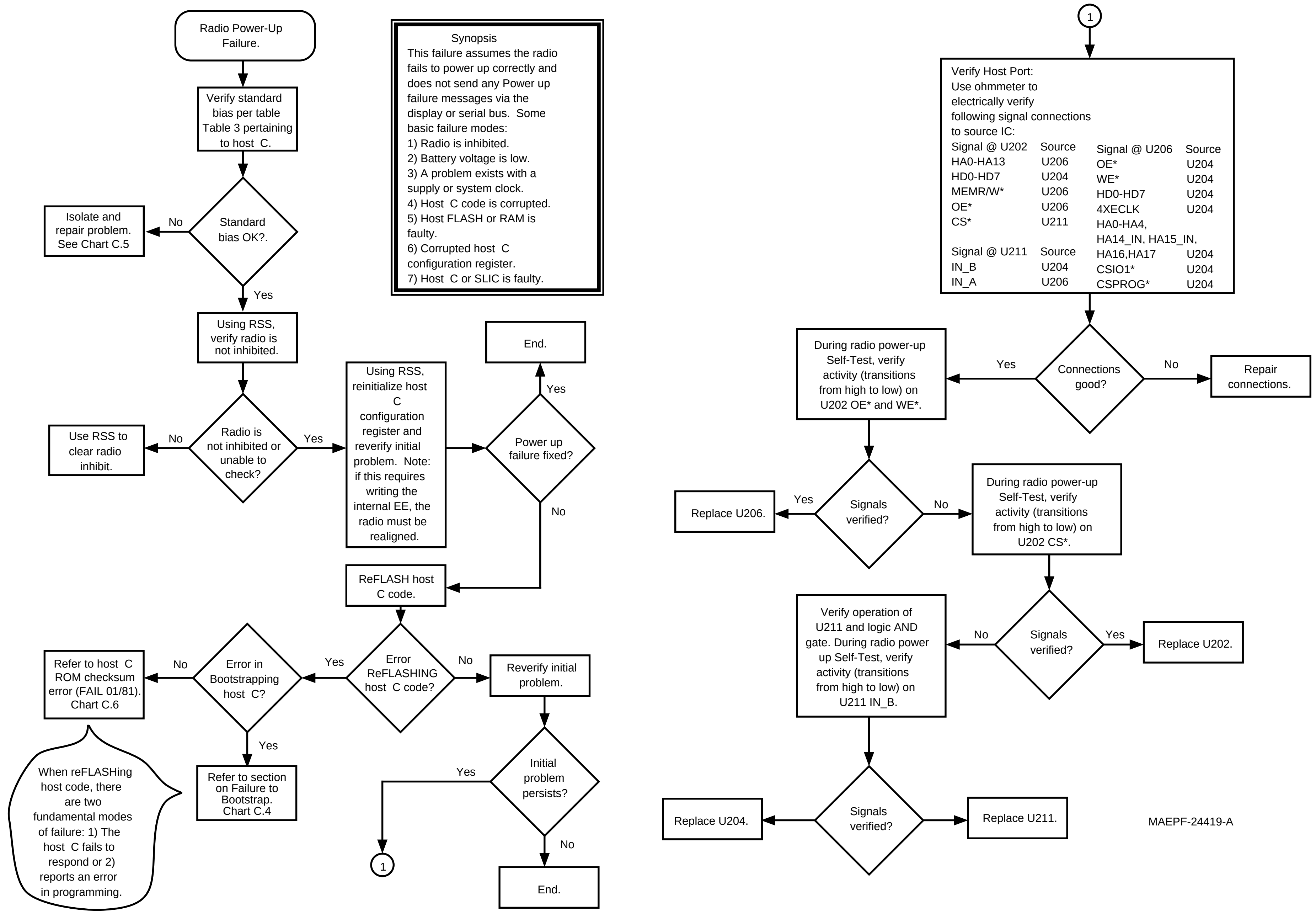


Chart C.3 Radio Power-Up Fail

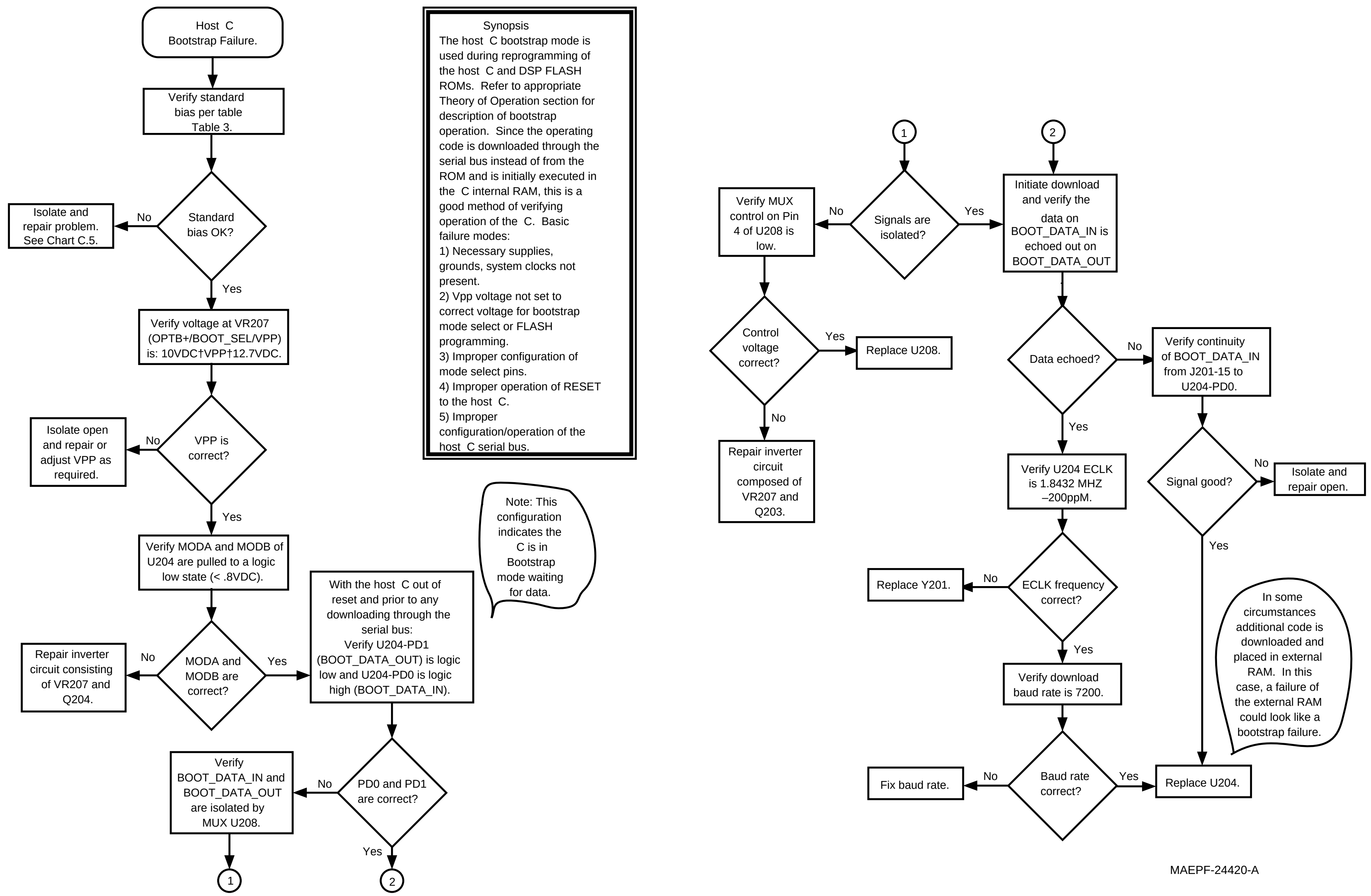


Chart C.4 Bootstrap Fail

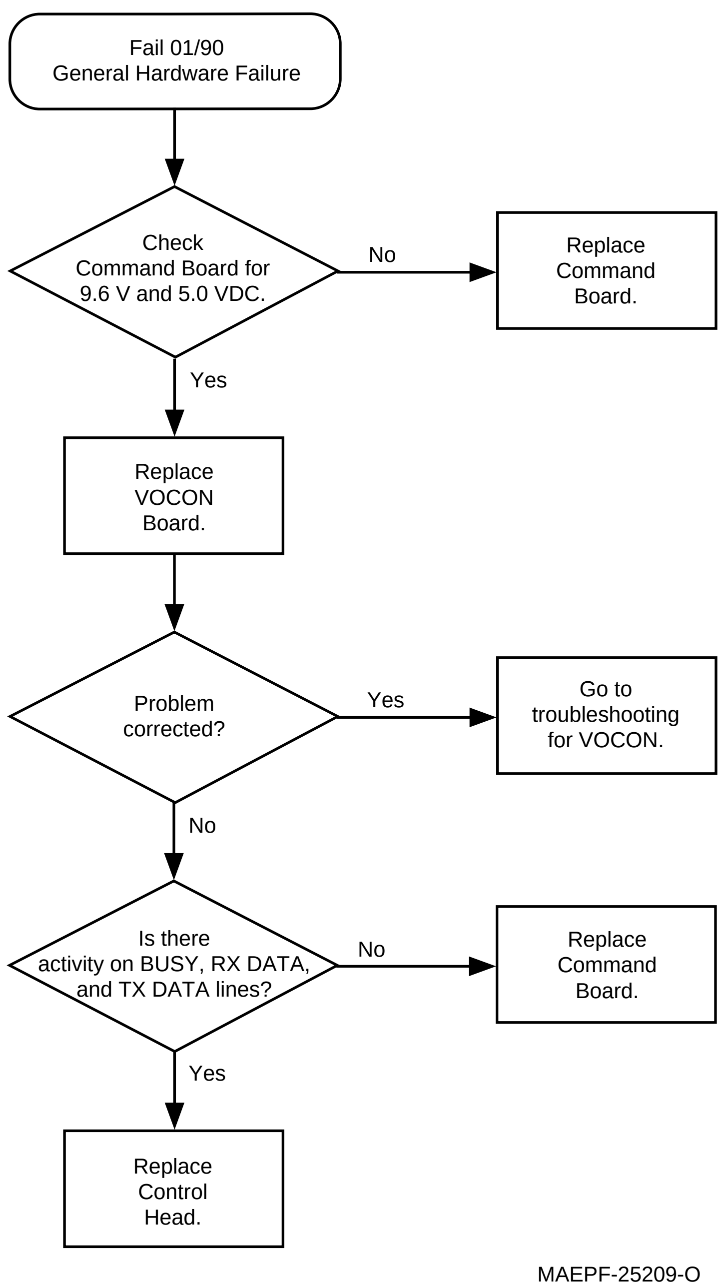


Chart C.5 *01/90, General Hardware Failure*

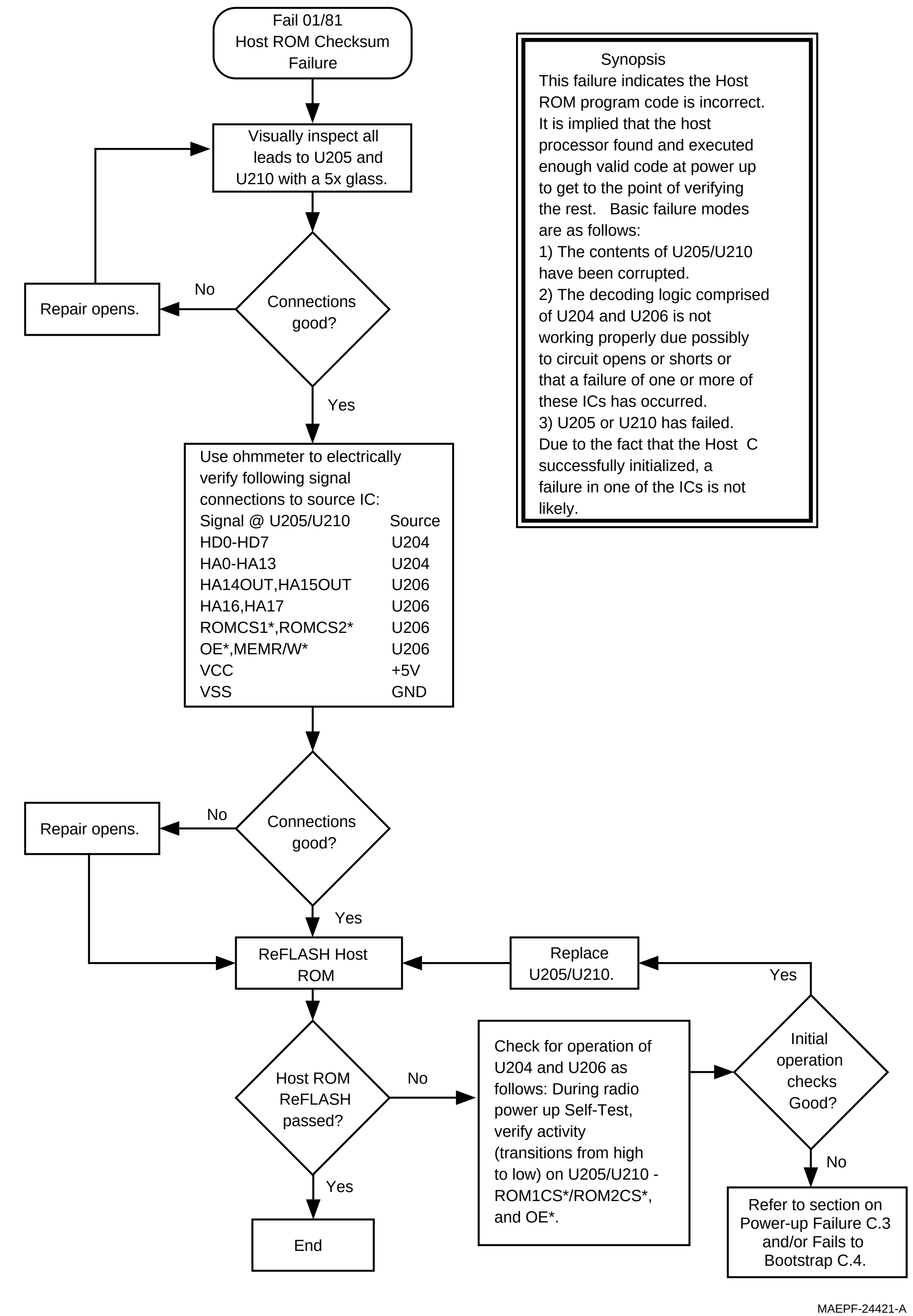


Chart C.6 *01/81, Host ROM Checksum Failure*

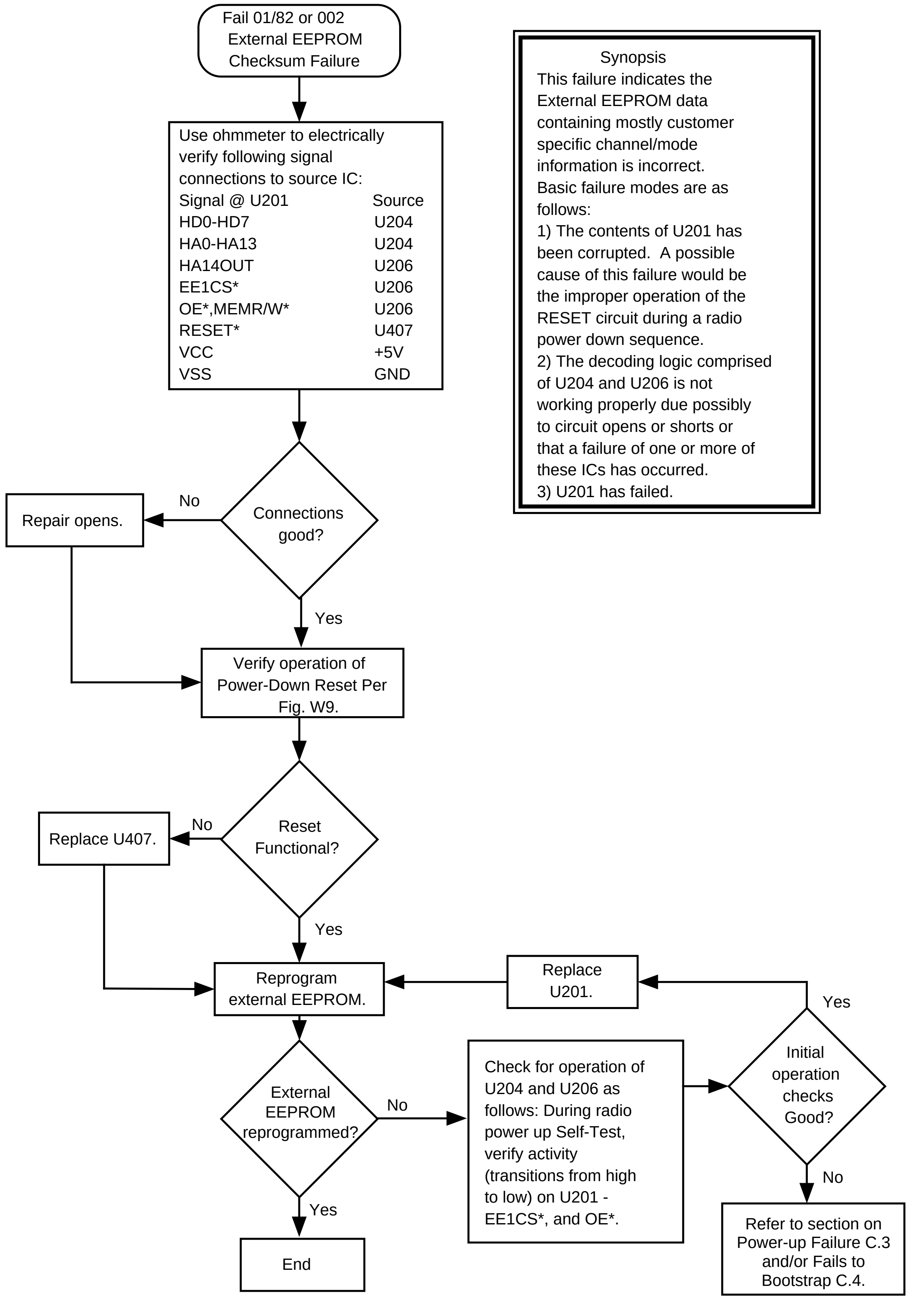


Chart C.7 01/82 or 002, External EEPROM Checksum Failure

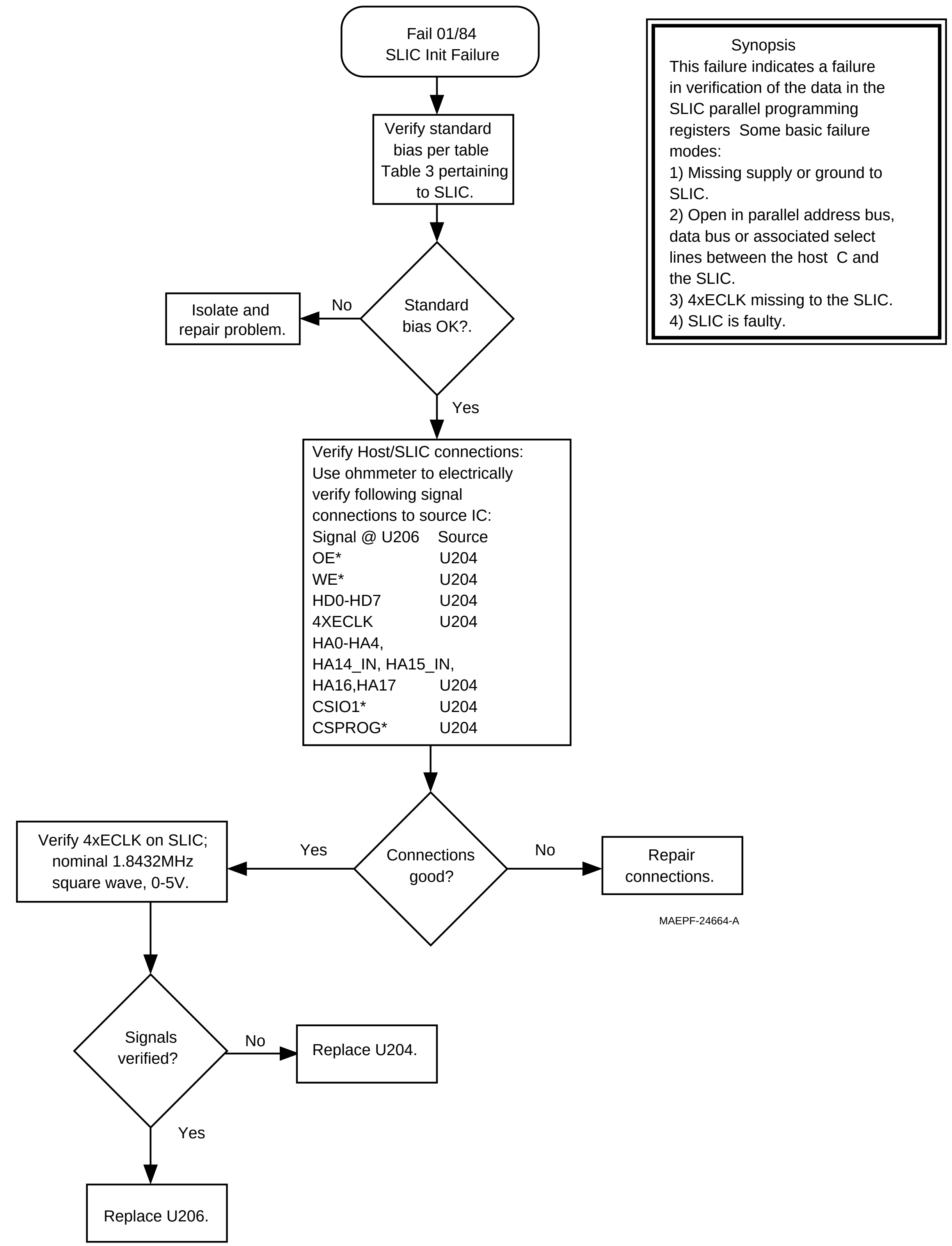


Chart C.8 01/84, SLIC Initialization Failure

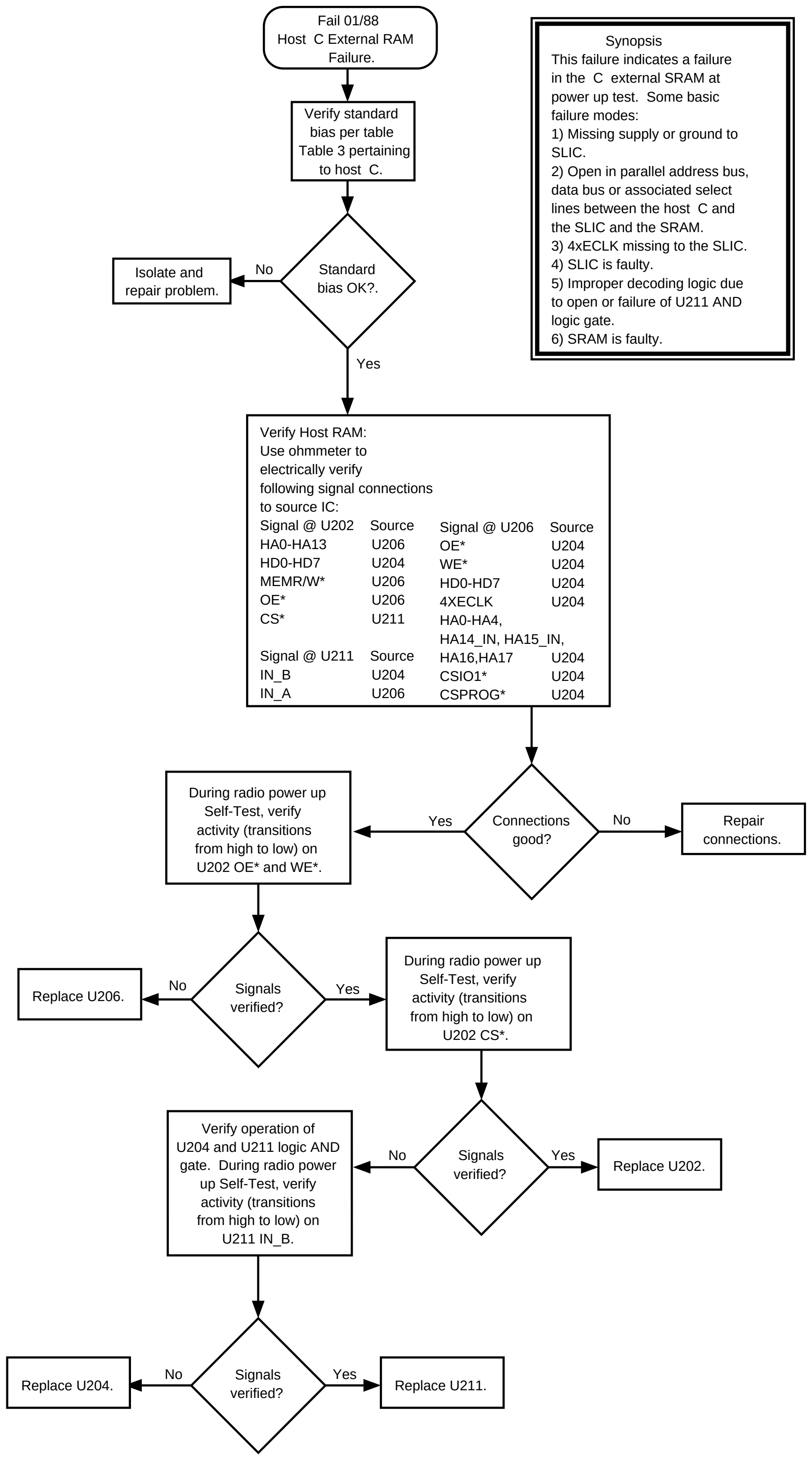


Chart C.9 01/88, MCU (Host mC) External SRAM Failure

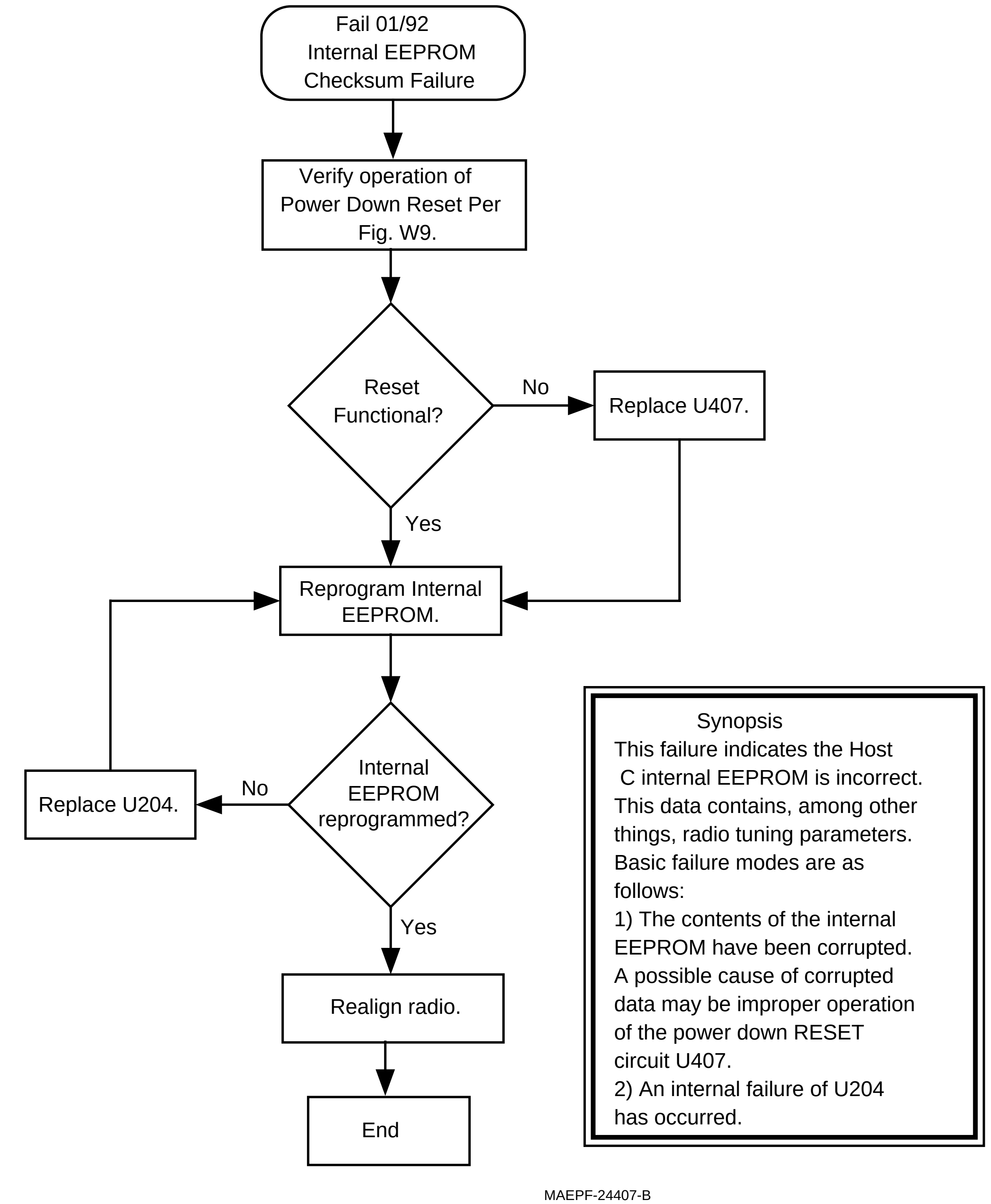


Chart C.10 01/92, Internal EEPROM Checksum Failure

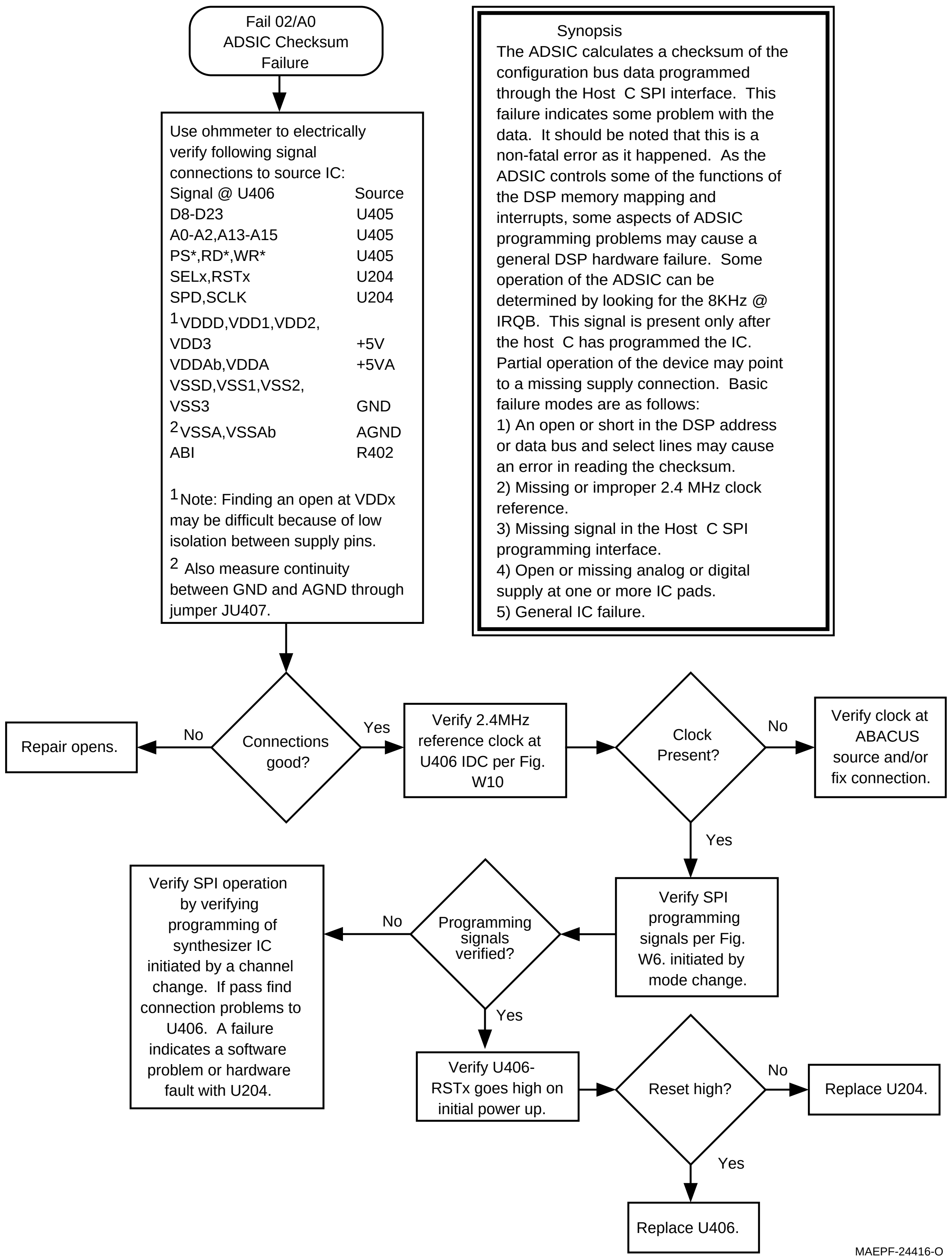


Chart C.11 02/A0, ADSIC Checksum Failure

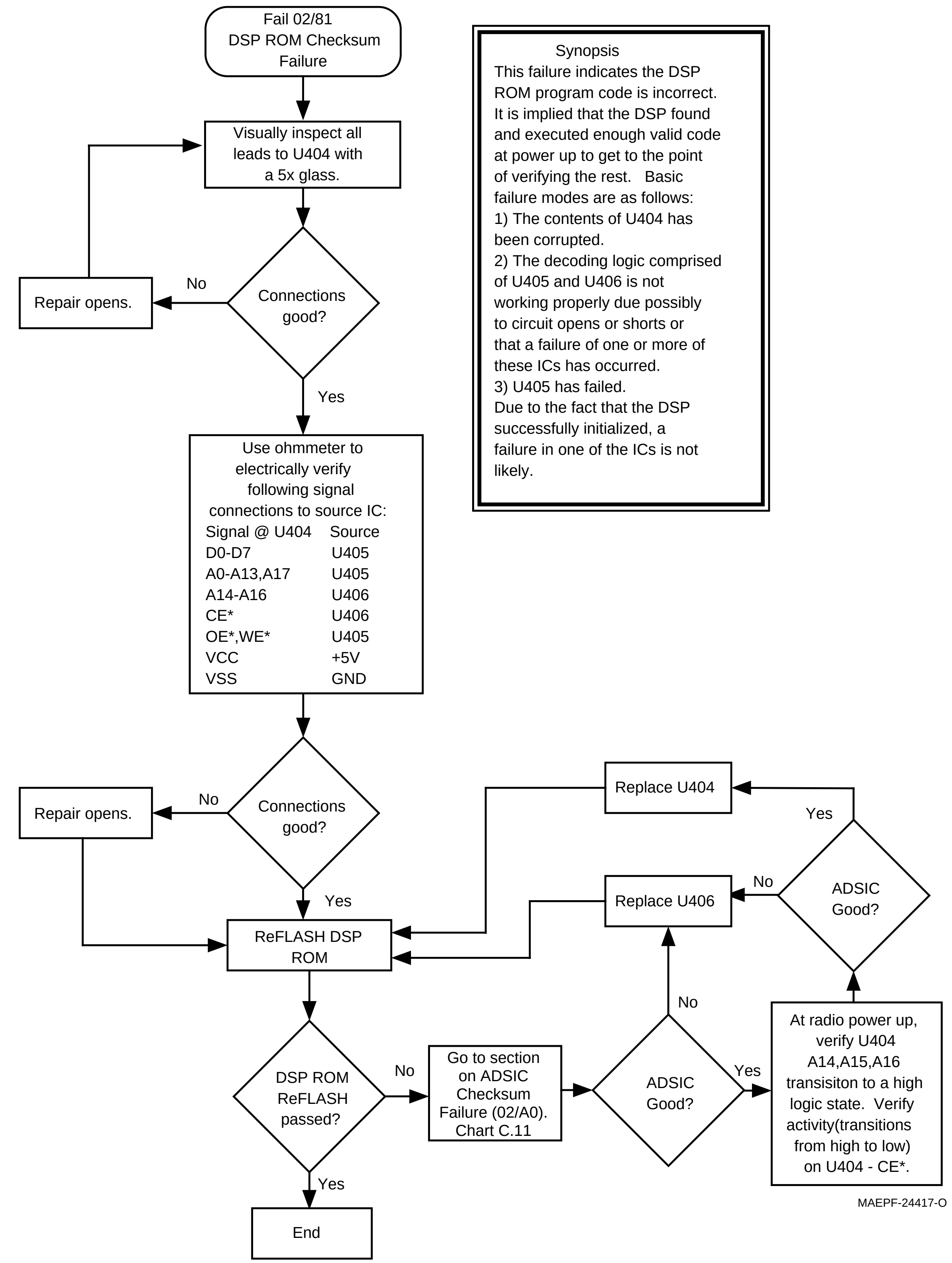


Chart C.12 02/81, DSP ROM Checksum Failure

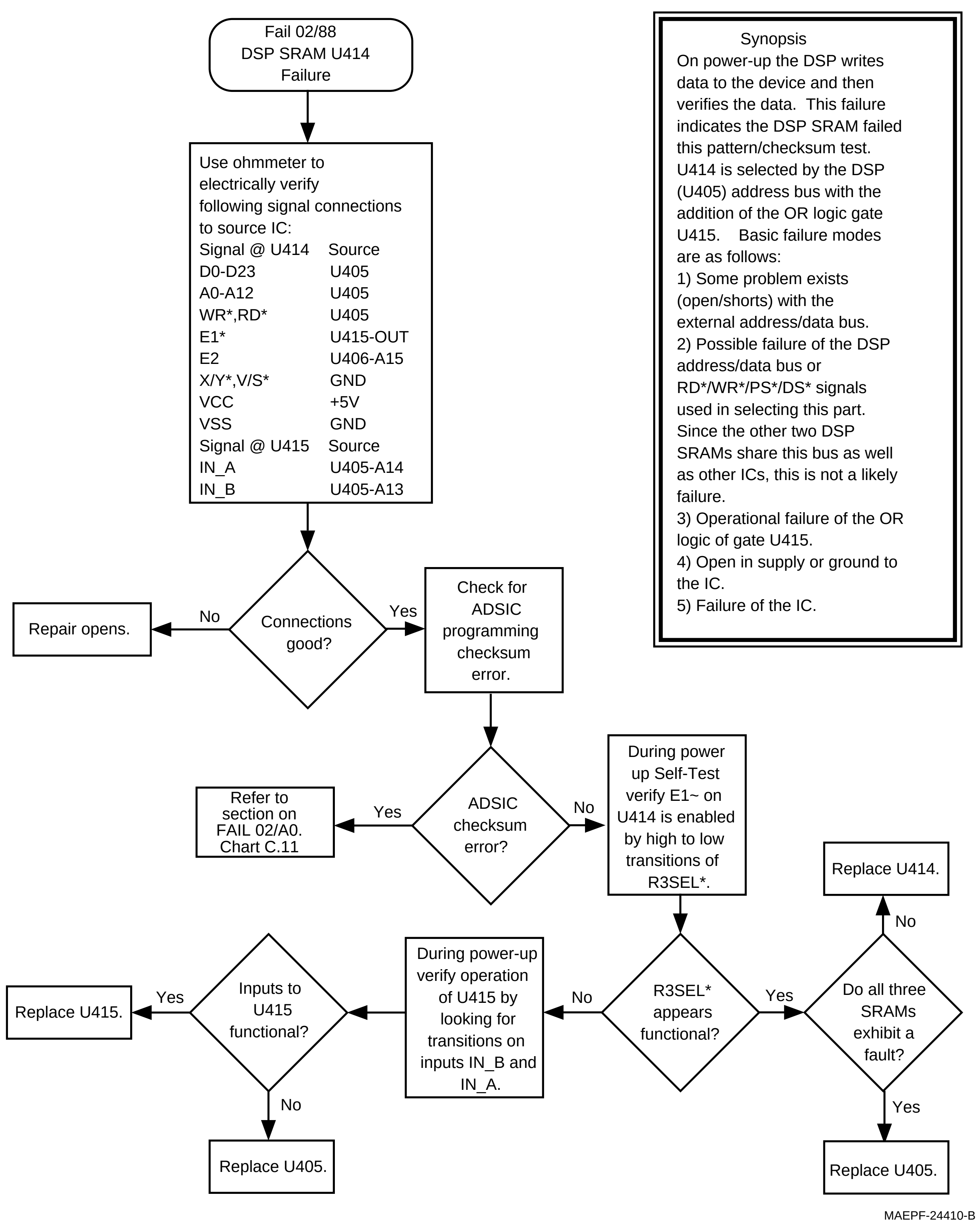


Chart C.13 02/88, DSP External SRAM Failure U414

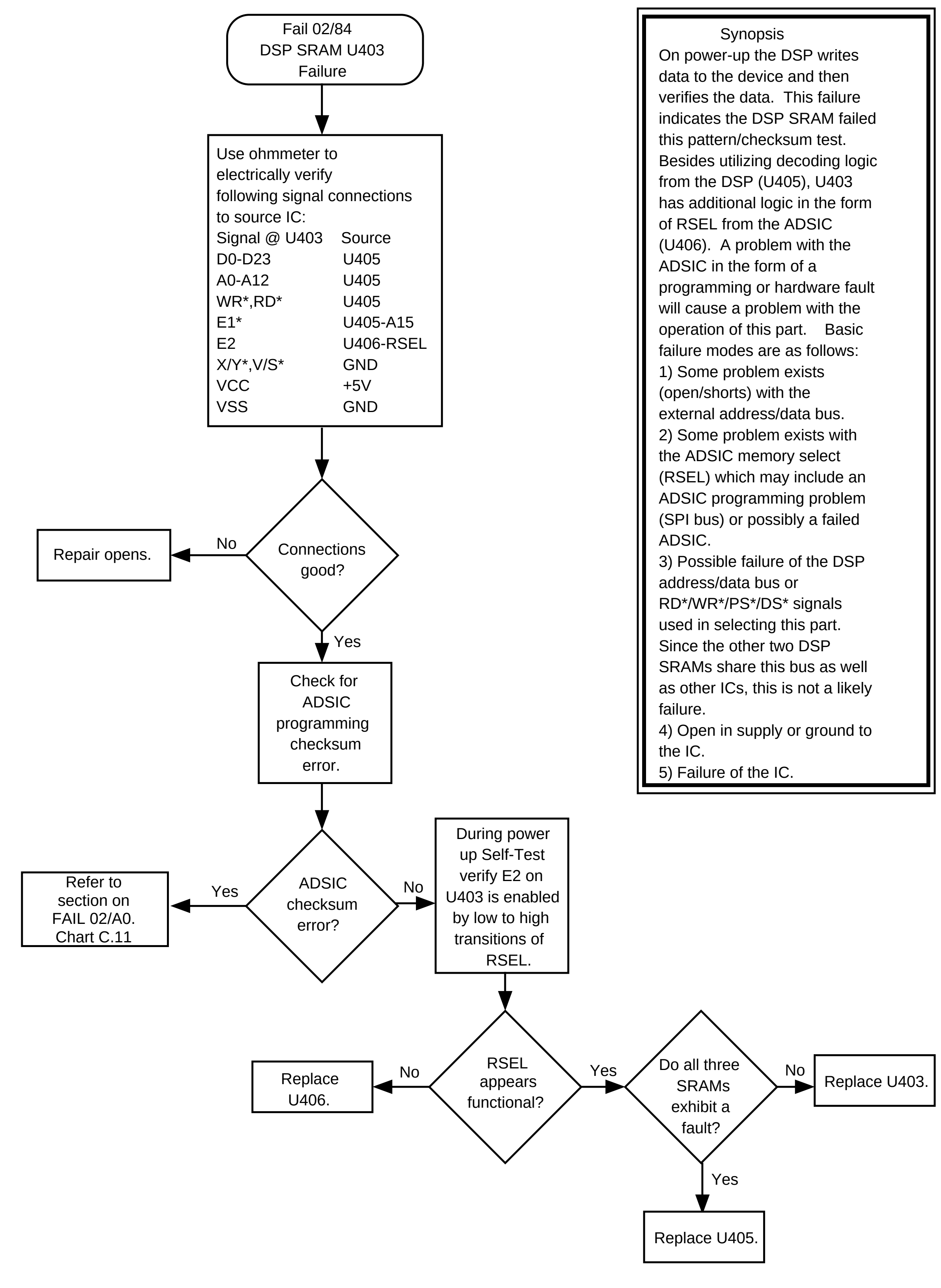


Chart C.14 02/84, DSP External SRAM Failure U403

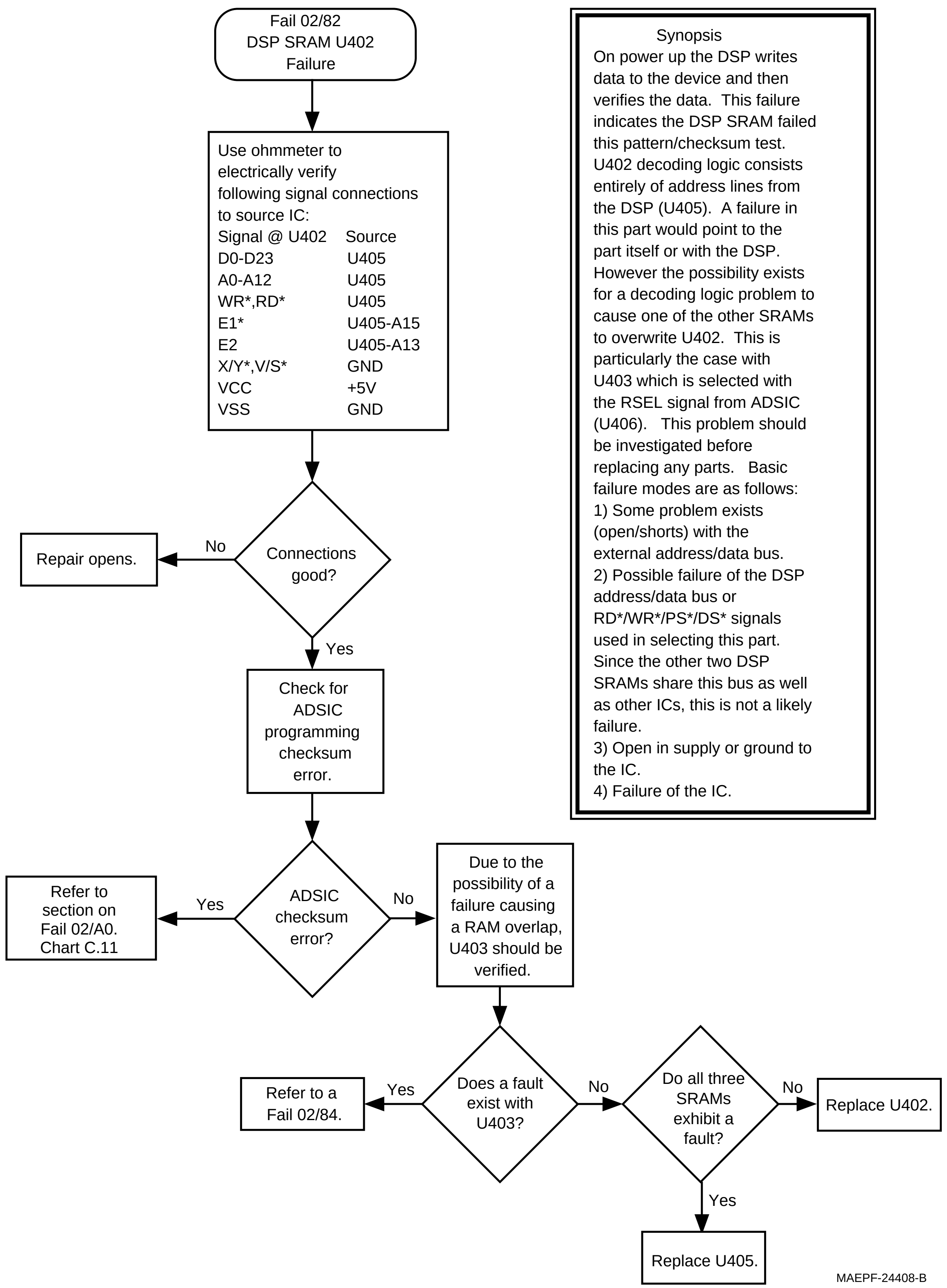


Chart C.15 02/82, DSP External SRAM Failure U402

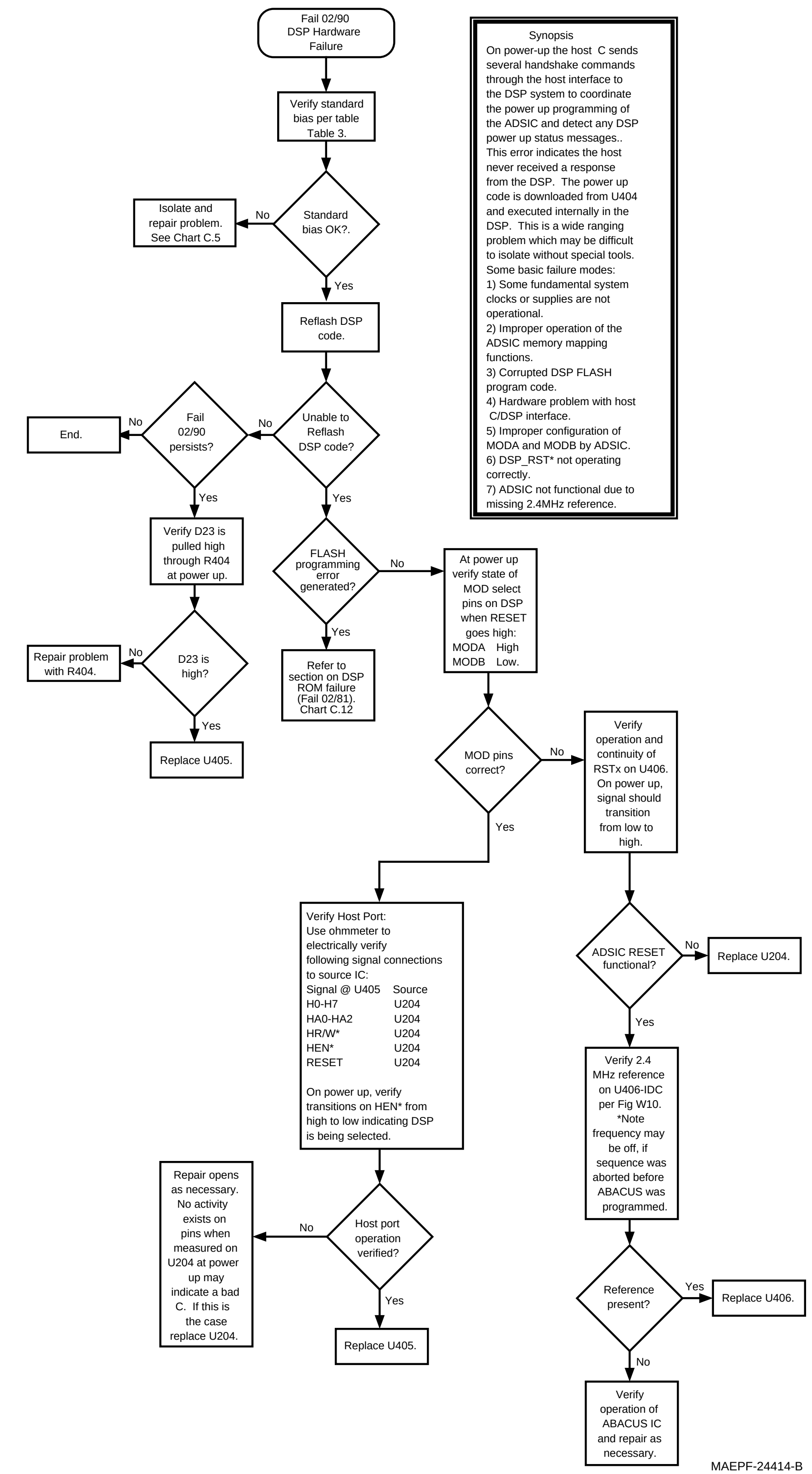


Chart C.16 02/90, General DSP Hardware Failure

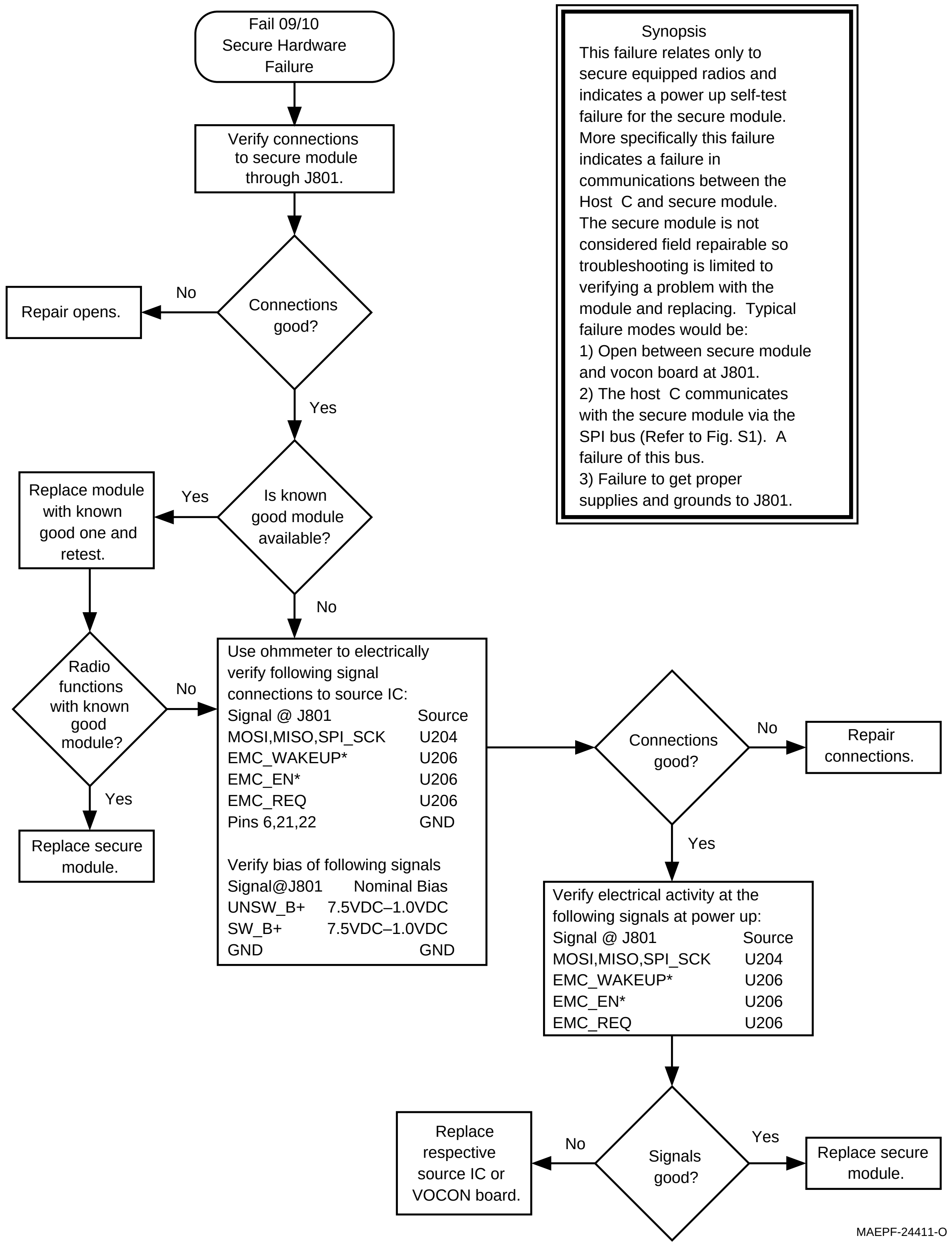


Chart C.17 09/10, Secure Hardware Failure

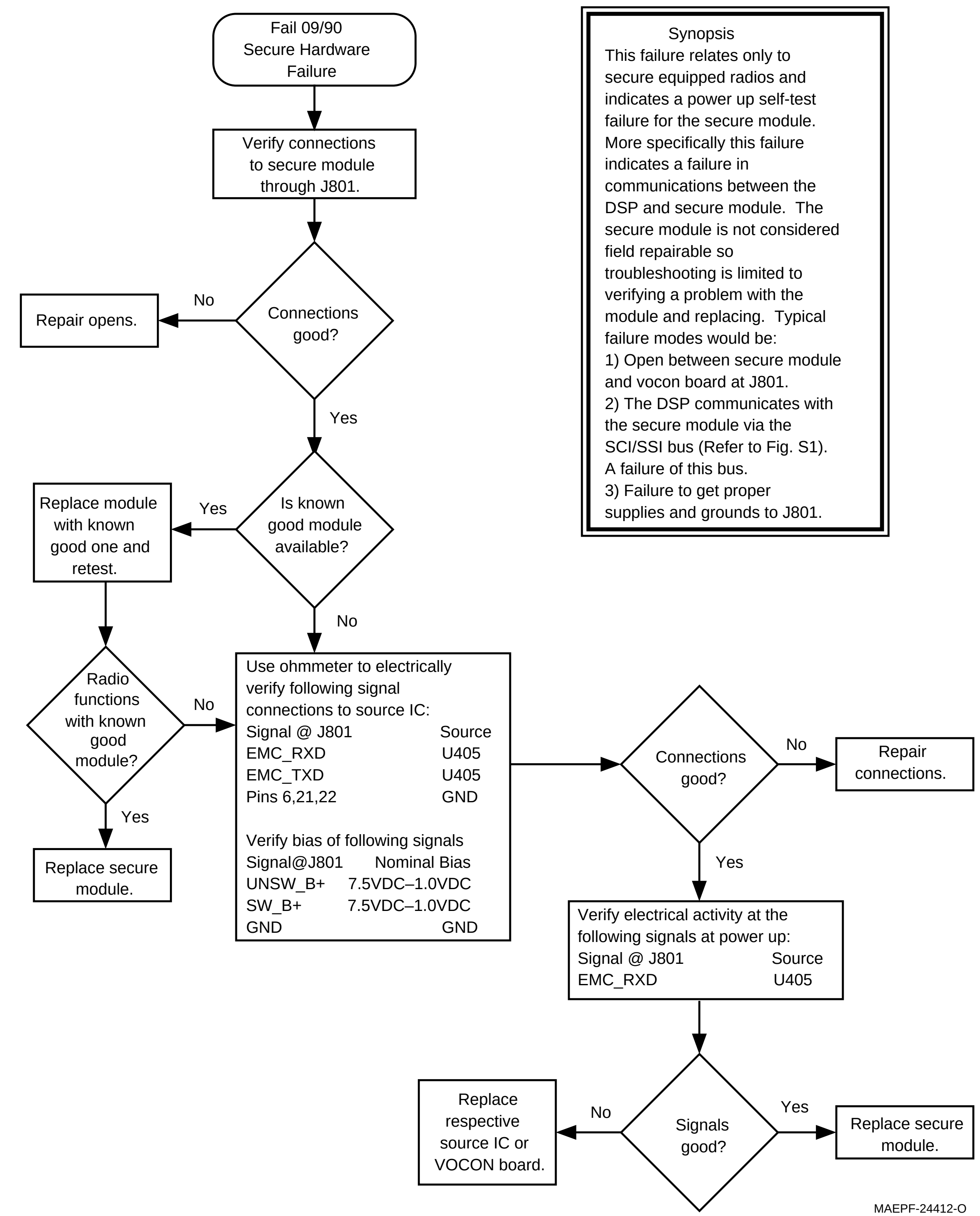


Chart C.18 09/90, Secure Hardware Failure

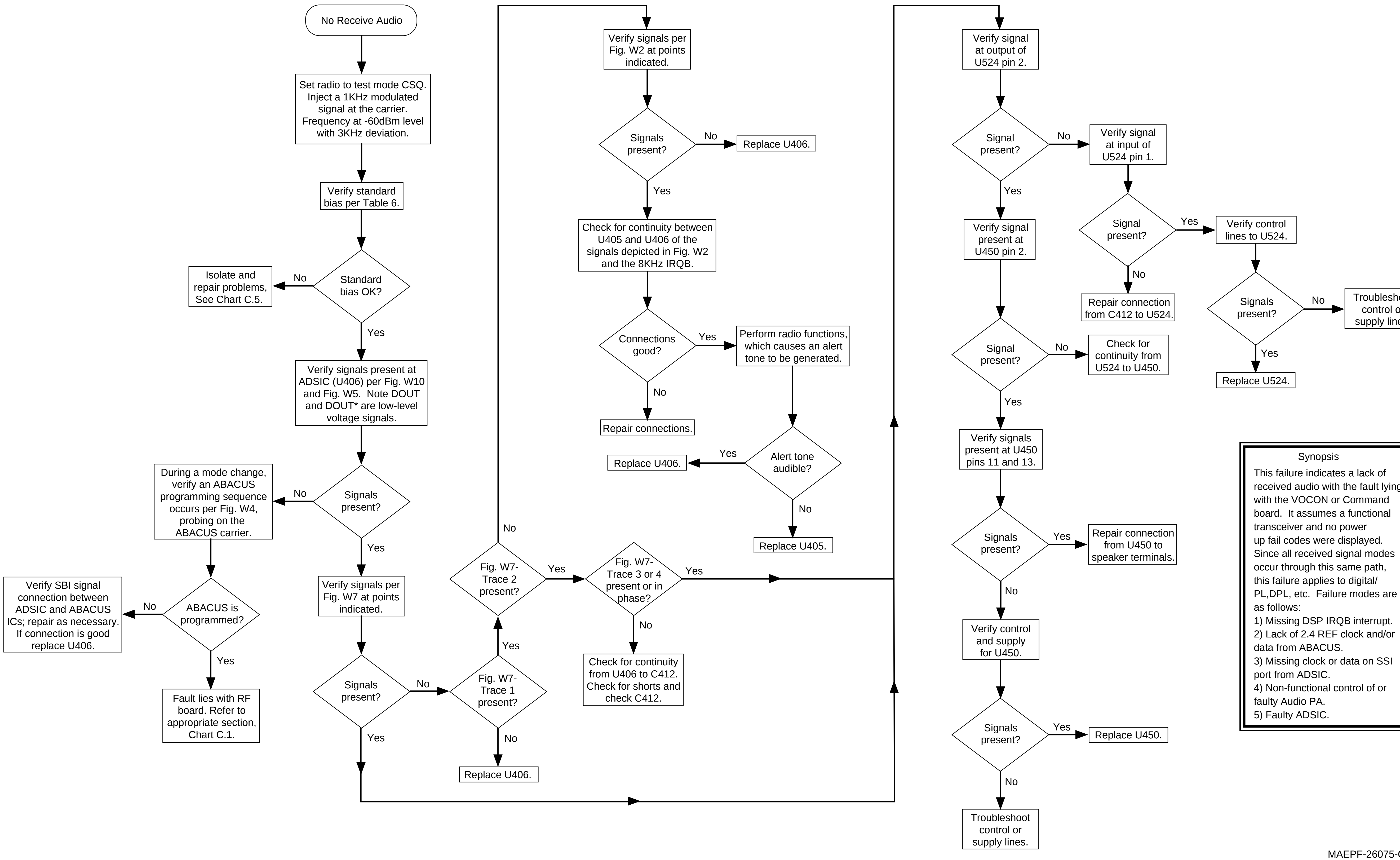
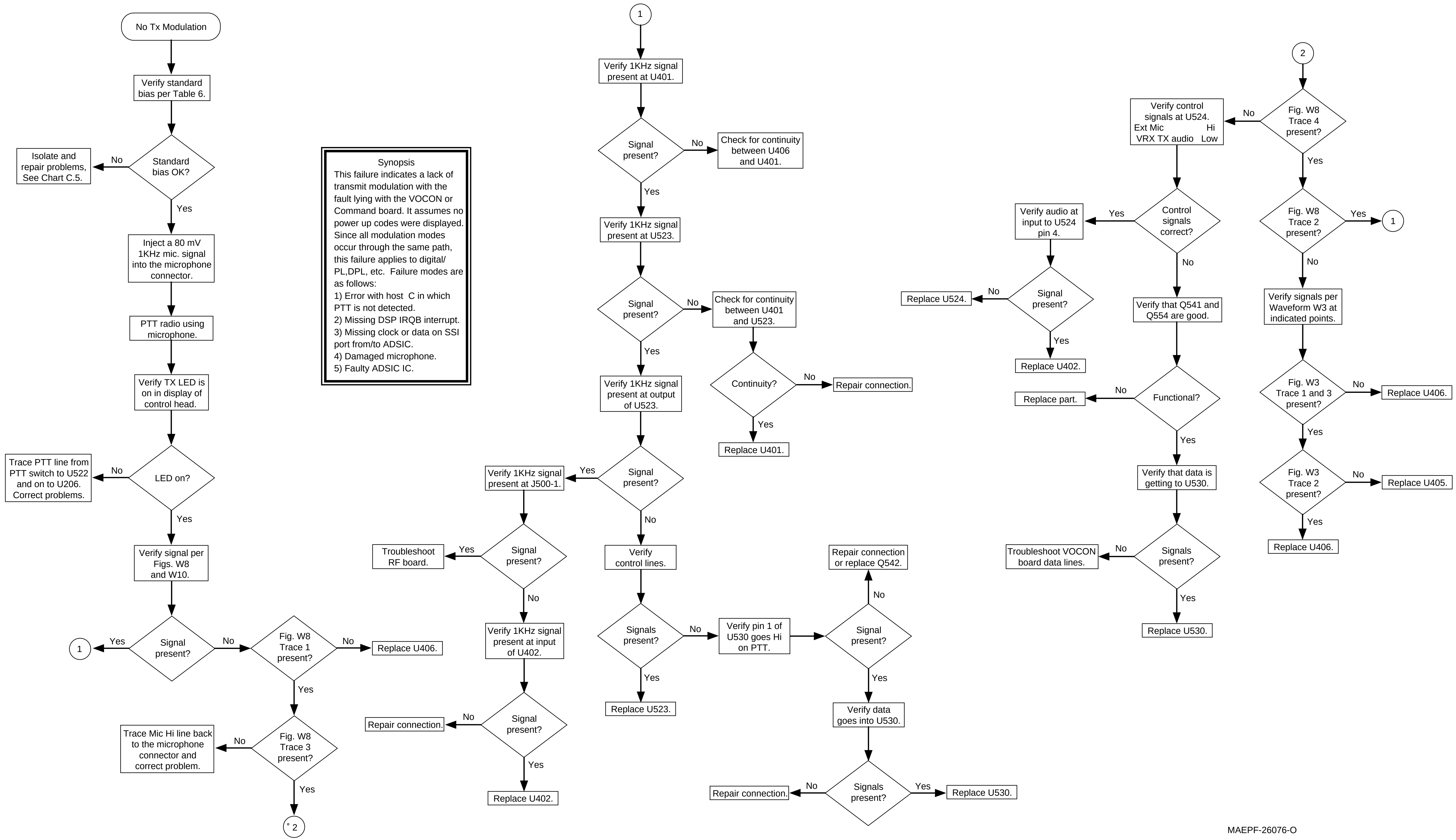


Chart C.19 No RX Audio



MAEPF-26076-O

Chart C.20 No TX Modulation

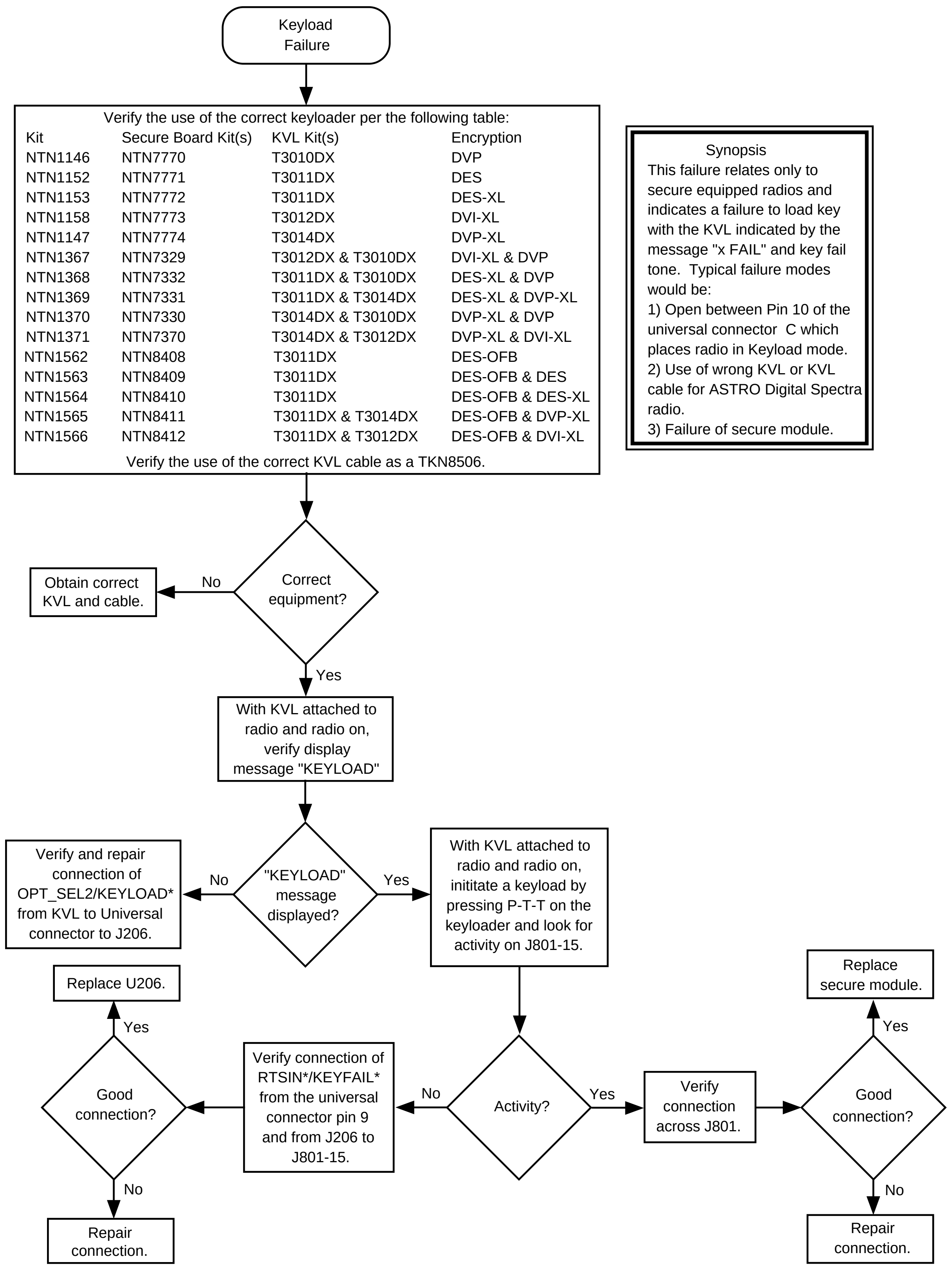


Chart C.21 Key Load Fail

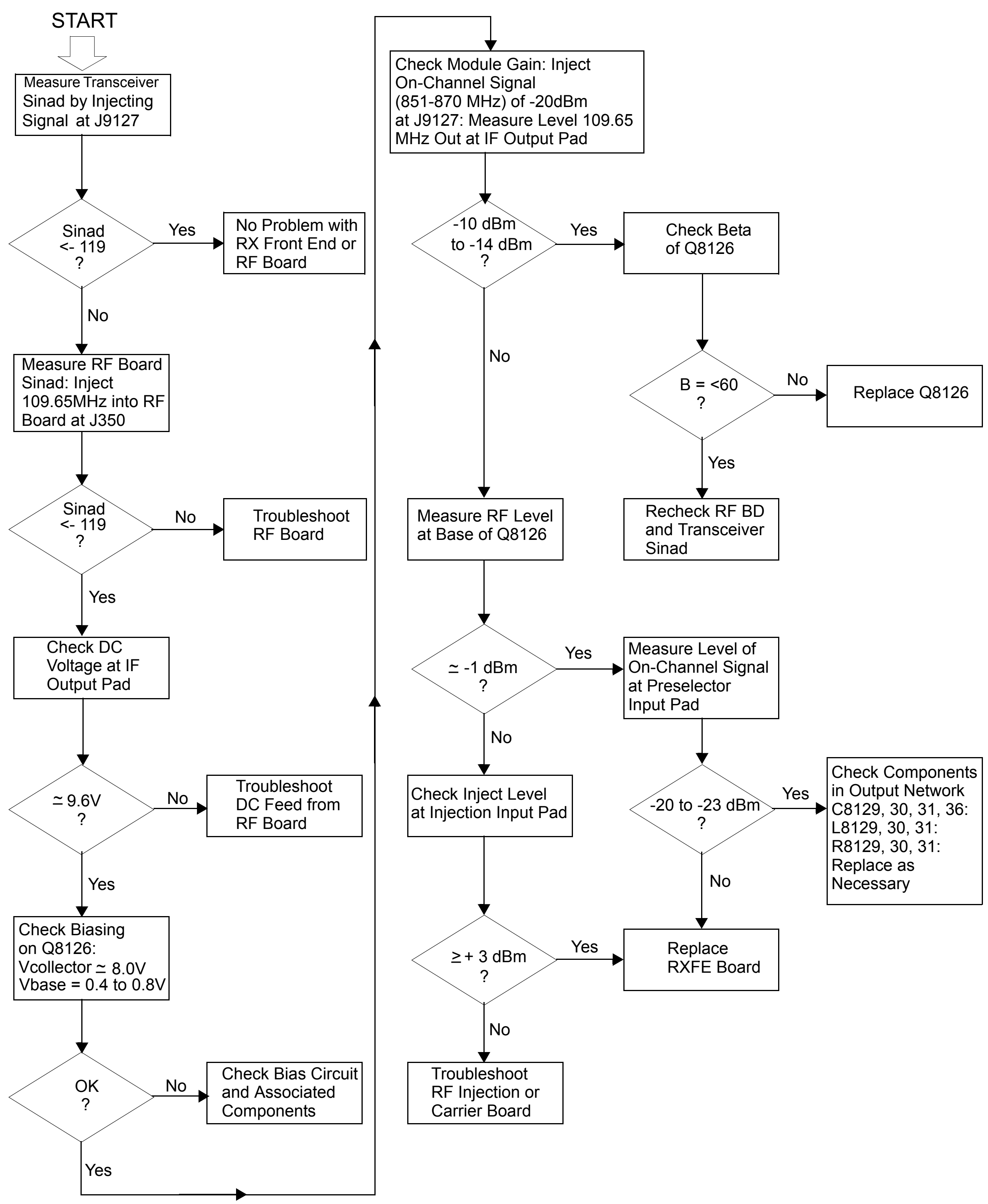


Chart C.22 800 MHz Receiver Front-End Hybrid

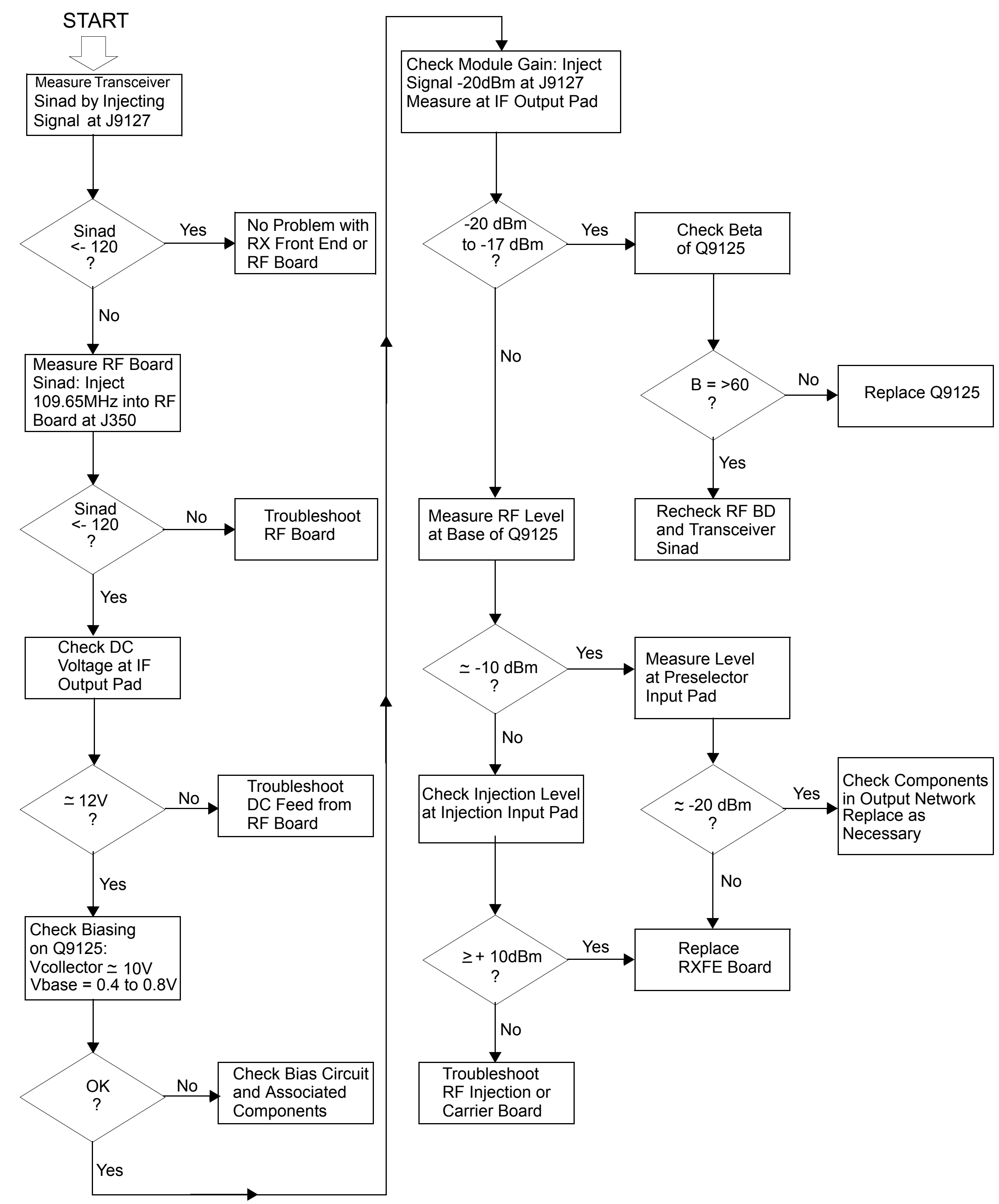


Chart C.23 UHF Receiver Front-End Hybrid

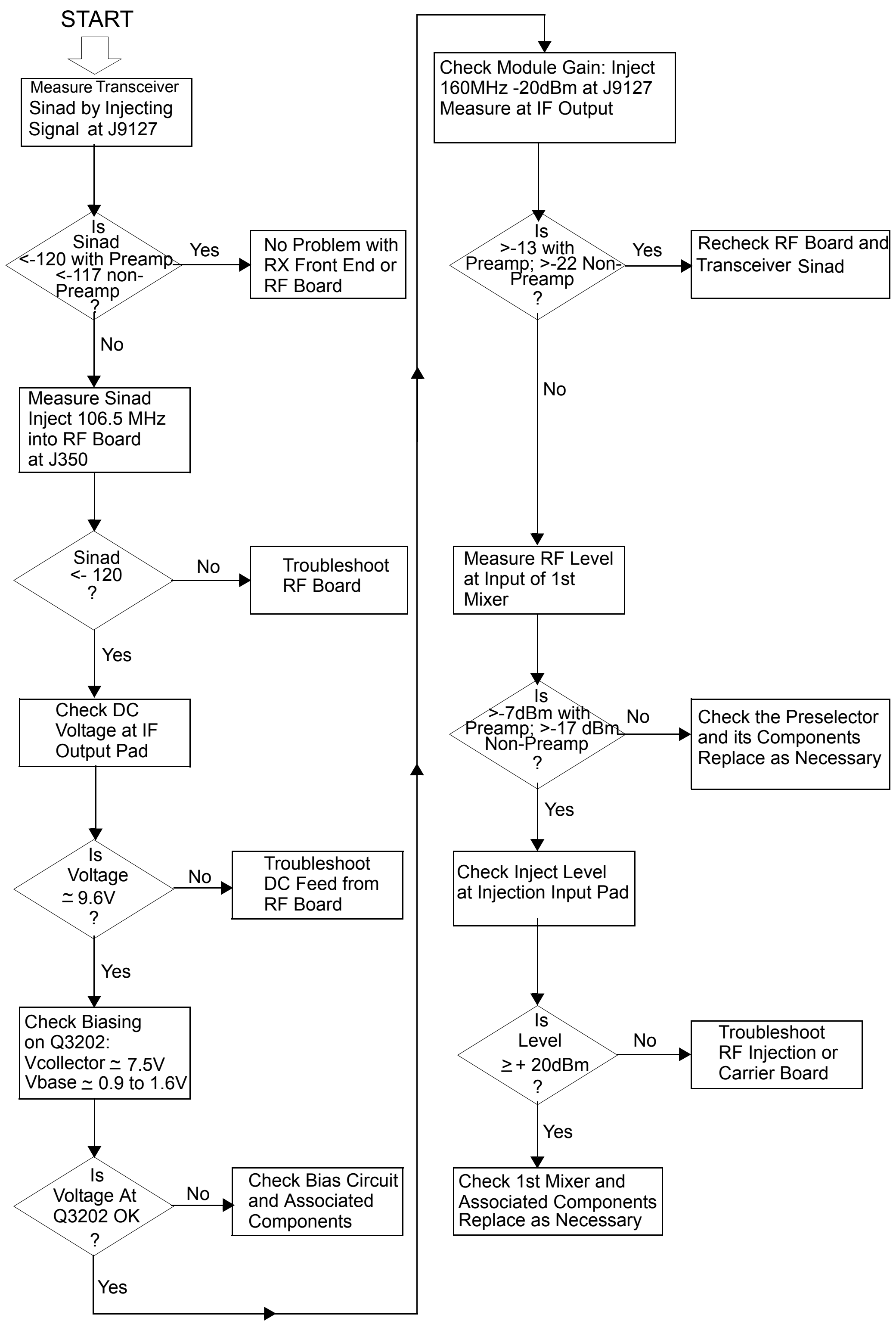


Chart C.24 VHF Receiver Front-End Hybrid

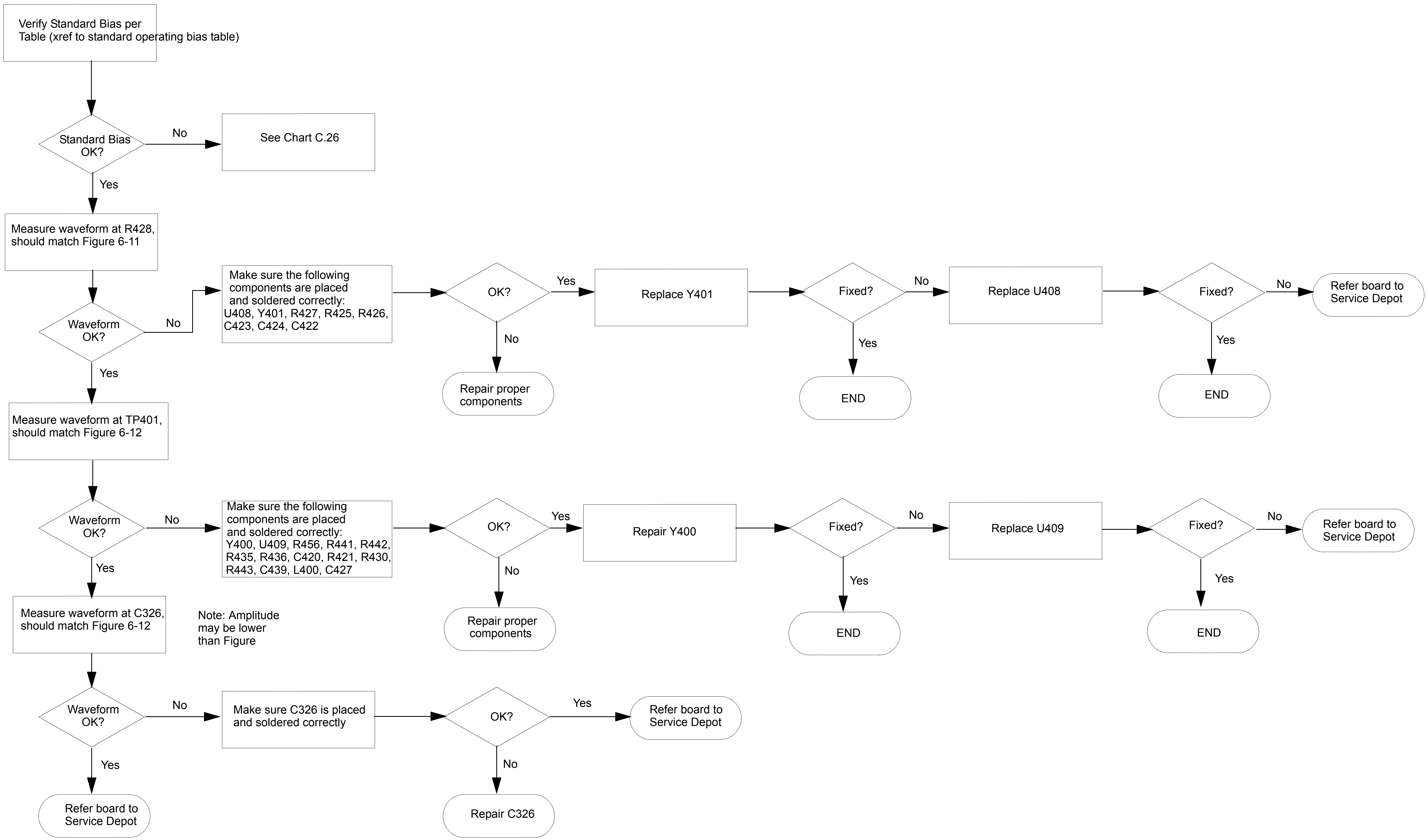


Chart C.25 ASTRO Spectra Plus VOCON Power-Up Failure

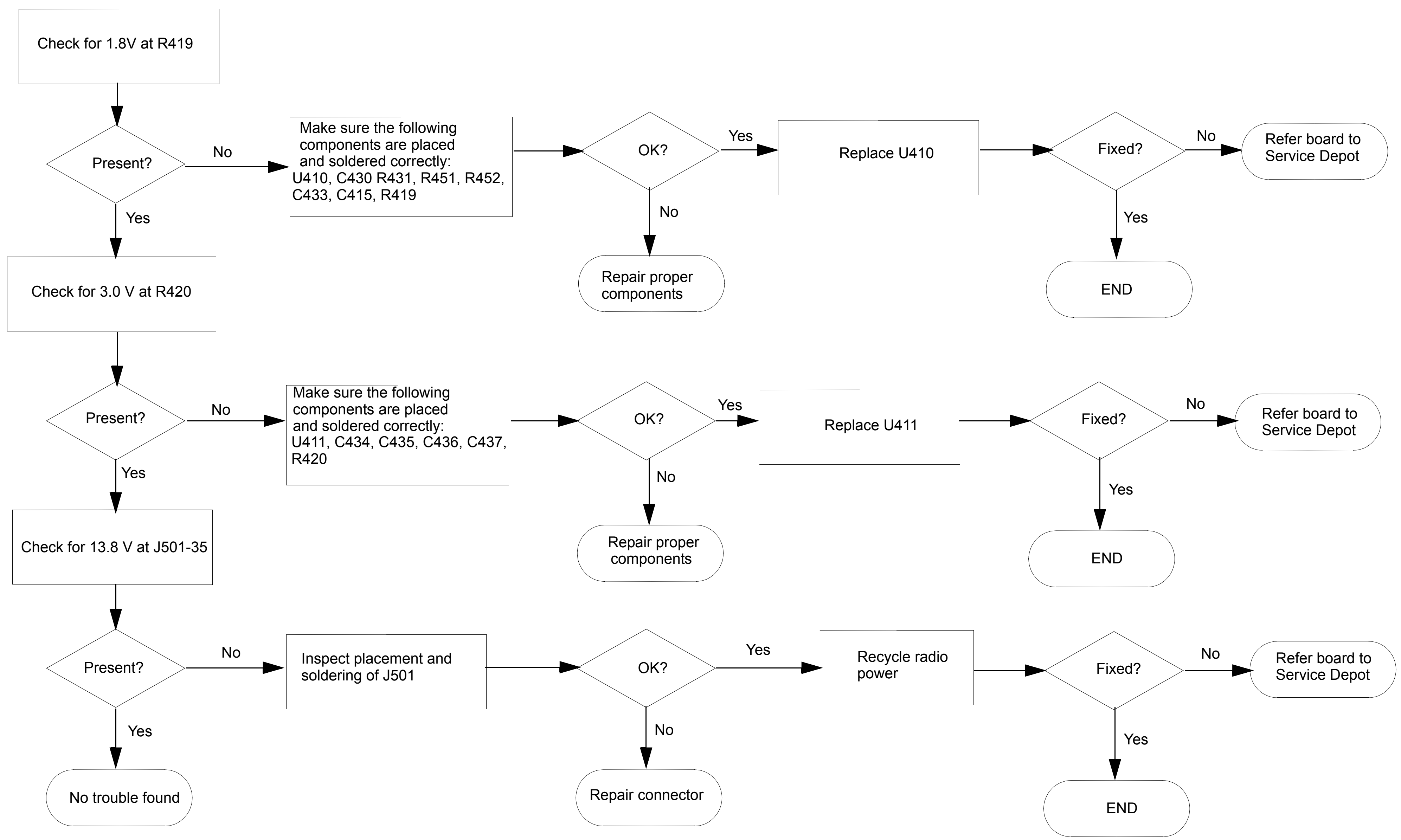


Chart C.26 ASTRO Spectra Plus VOCON DC Supply Failure

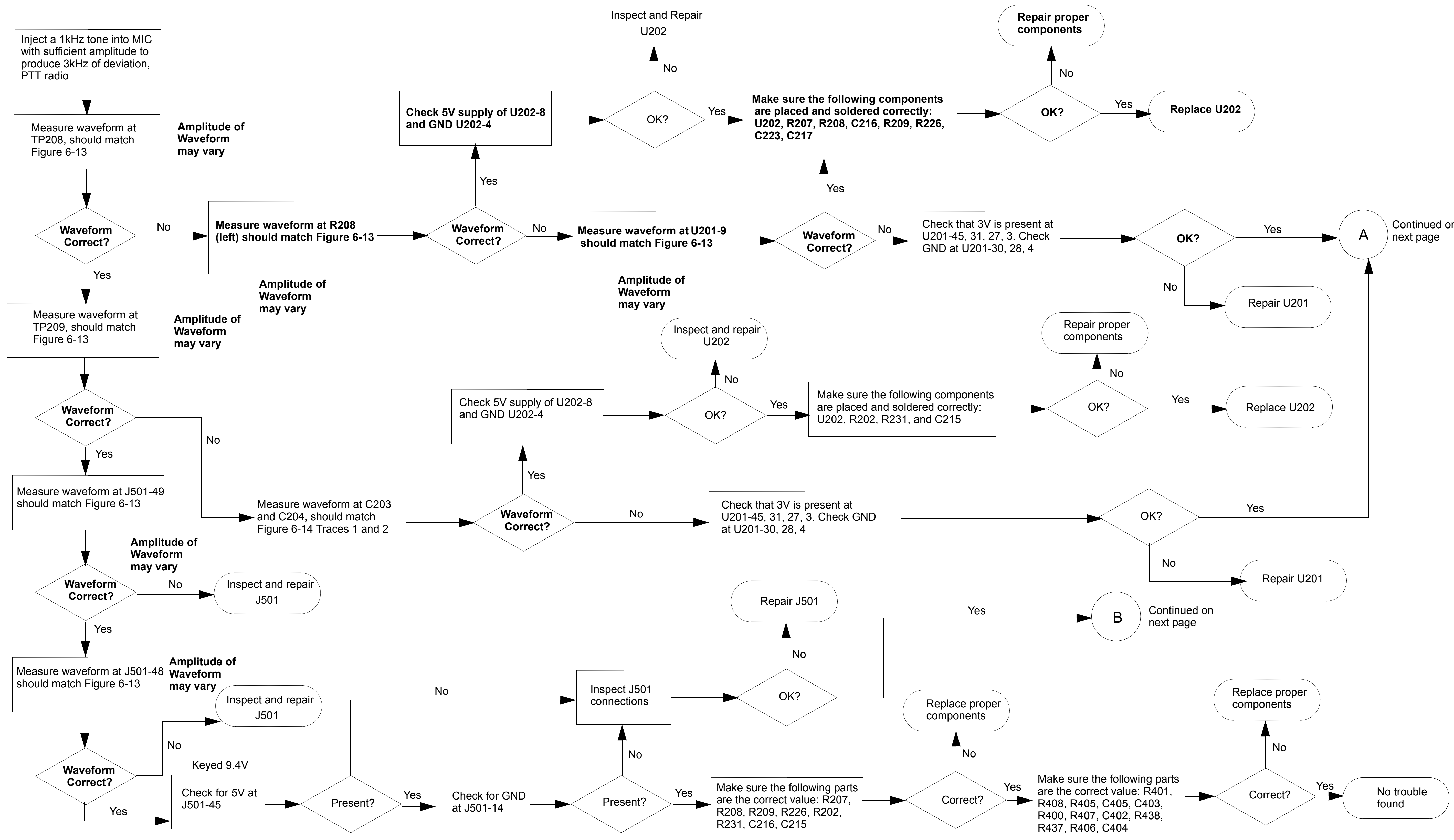


Chart C.27 ASTRO Spectra Plus VOCON TX Modulation Failure Sheet 1 of 4

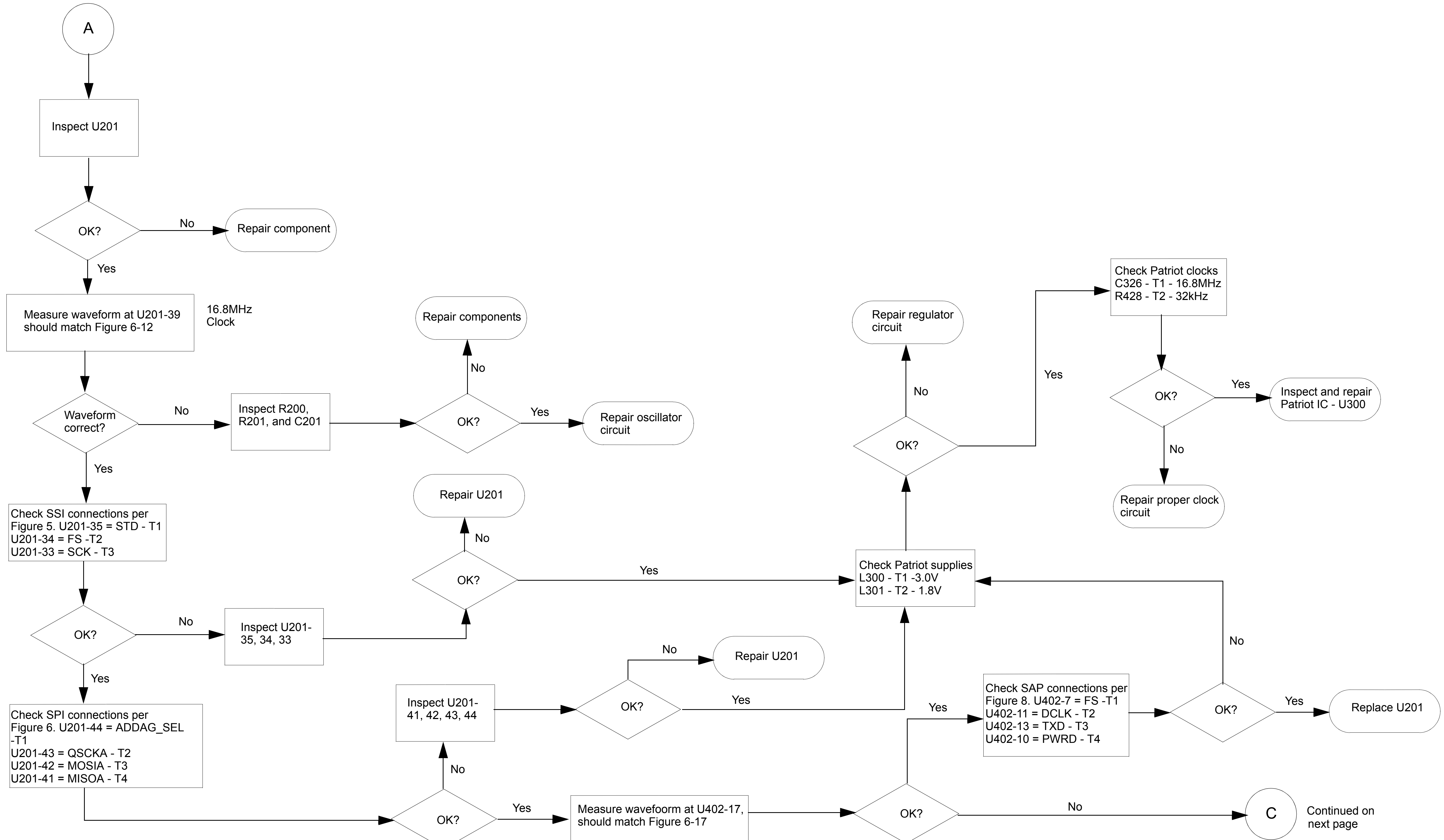


Chart C.28 ASTRO Spectra Plus VOCON TX Modulation Failure Sheet 2 of 4

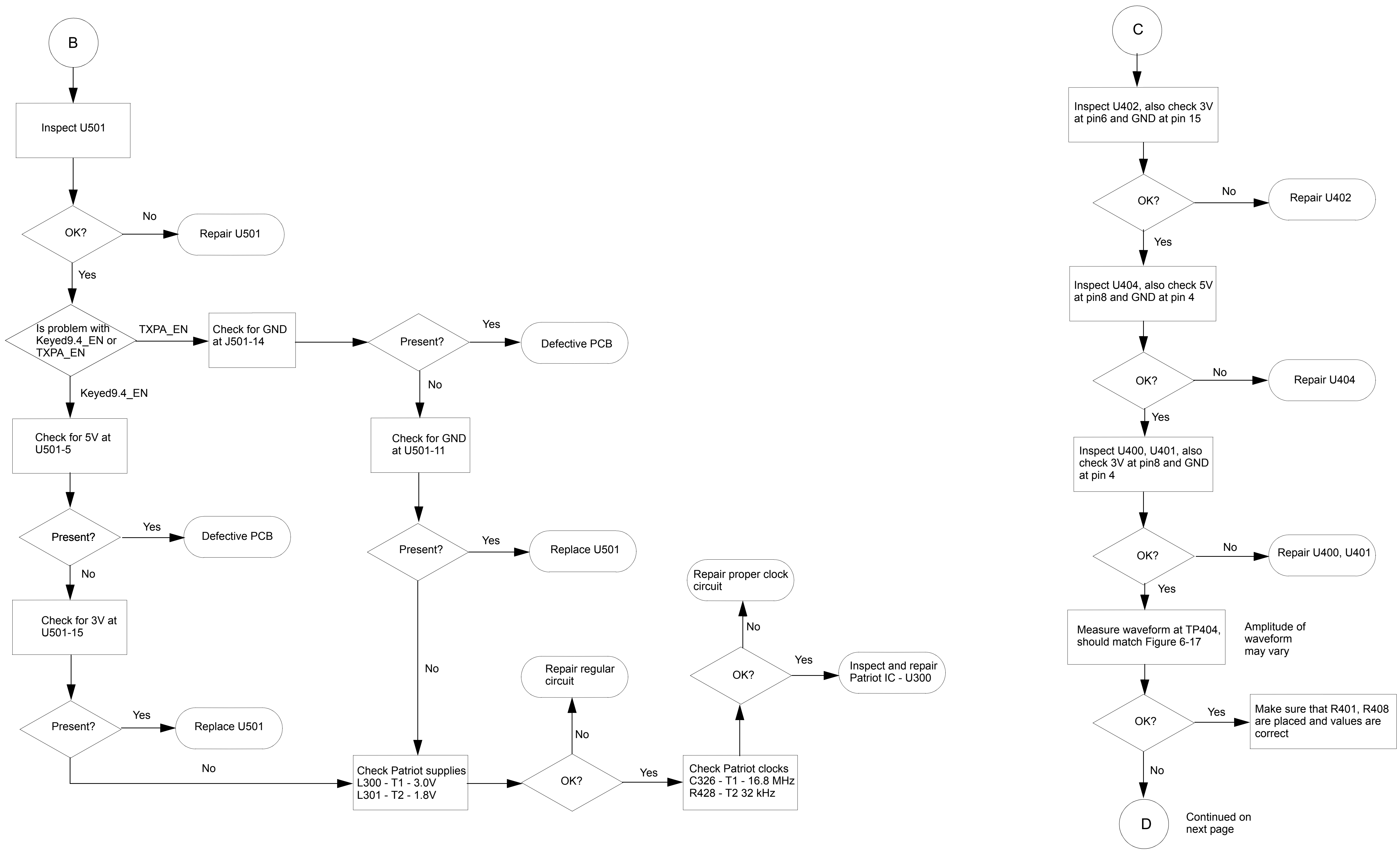


Chart C.29 ASTRO Spectra Plus VOCON TX Modulation Failure Sheet 3 of 4

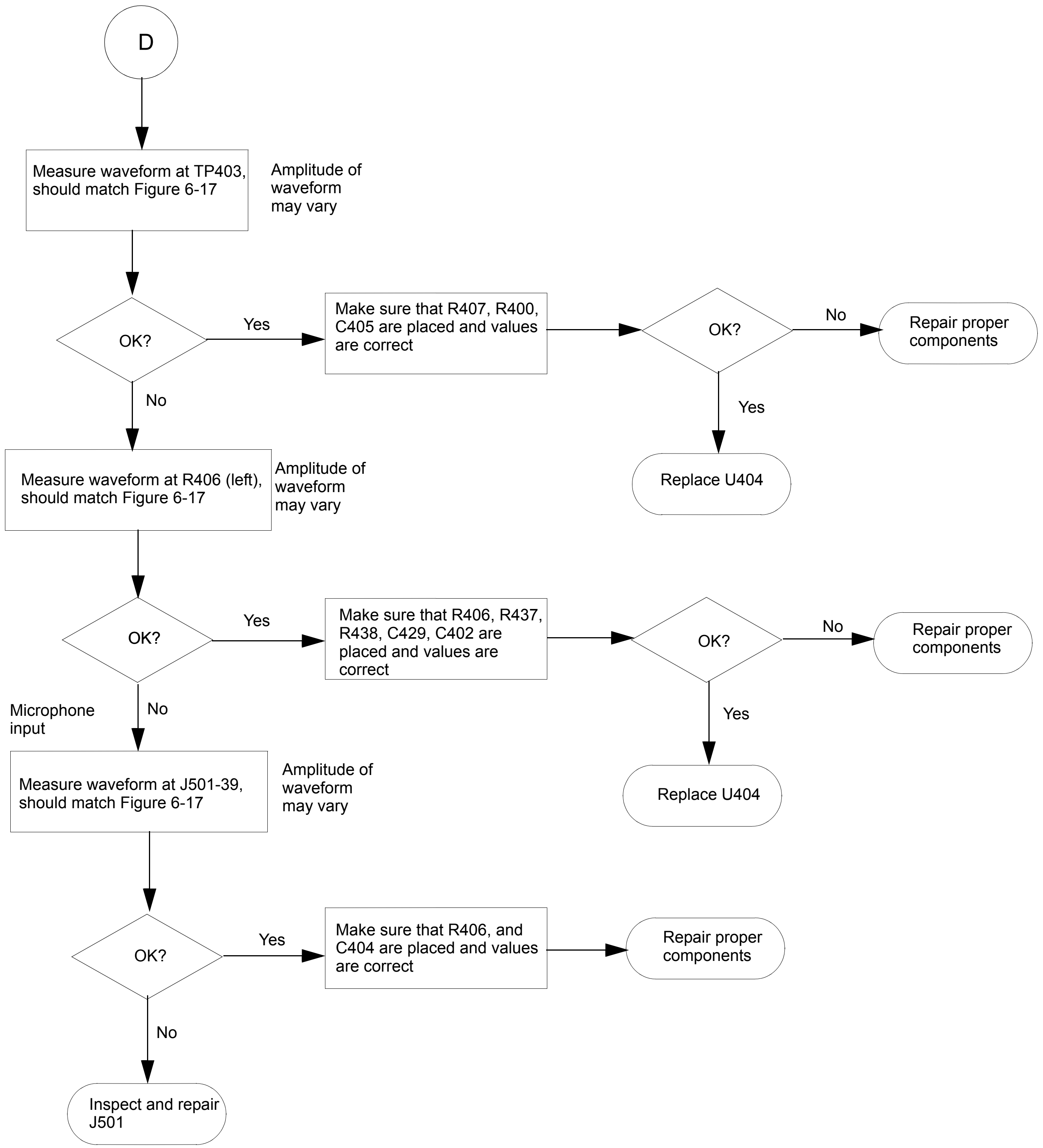


Chart C.30 ASTRO Spectra Plus VOCON TX Modulation Failure Sheet 4 of 4

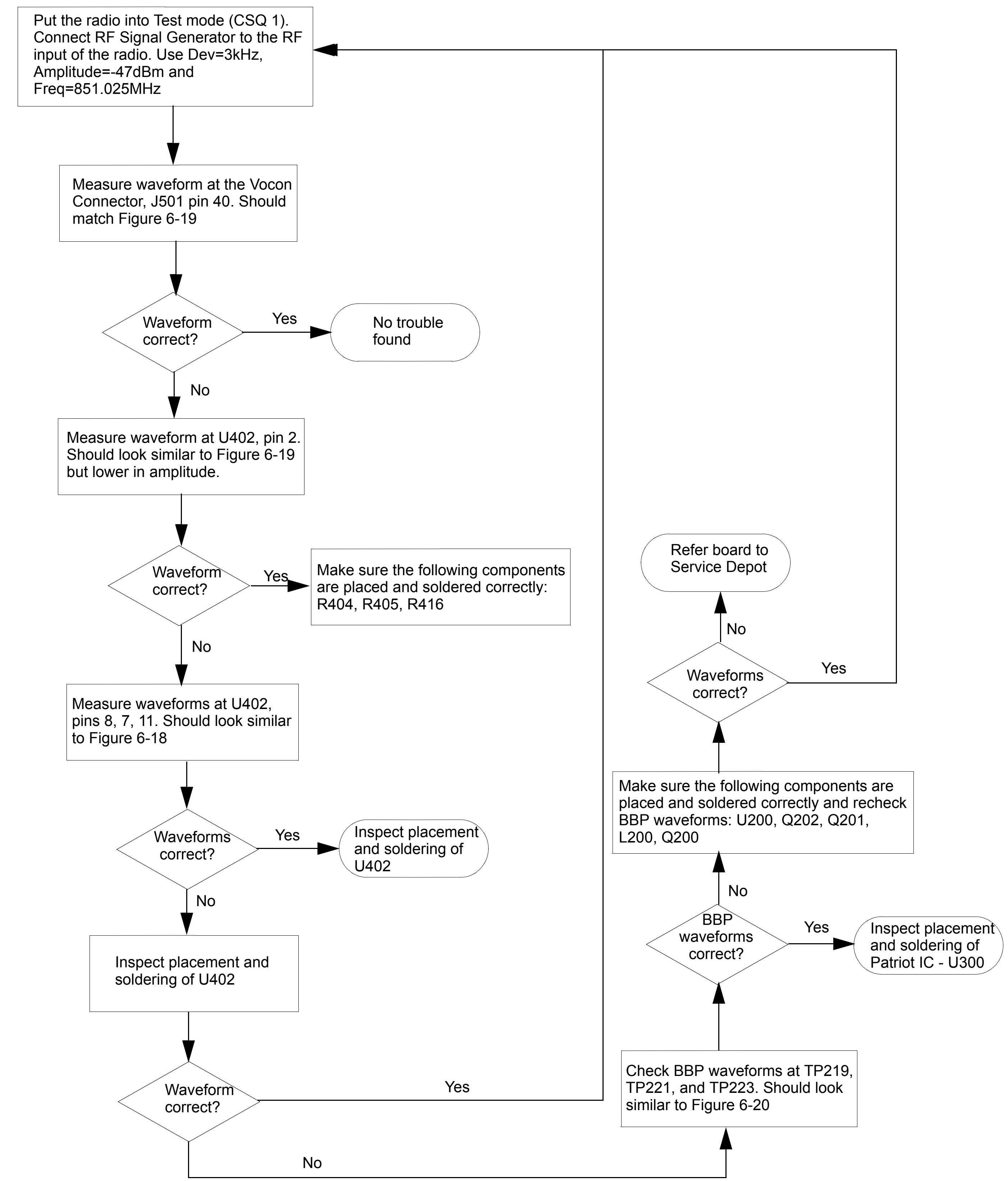


Chart C.31 ASTRO Spectra Plus VOCON RX Audio Failure

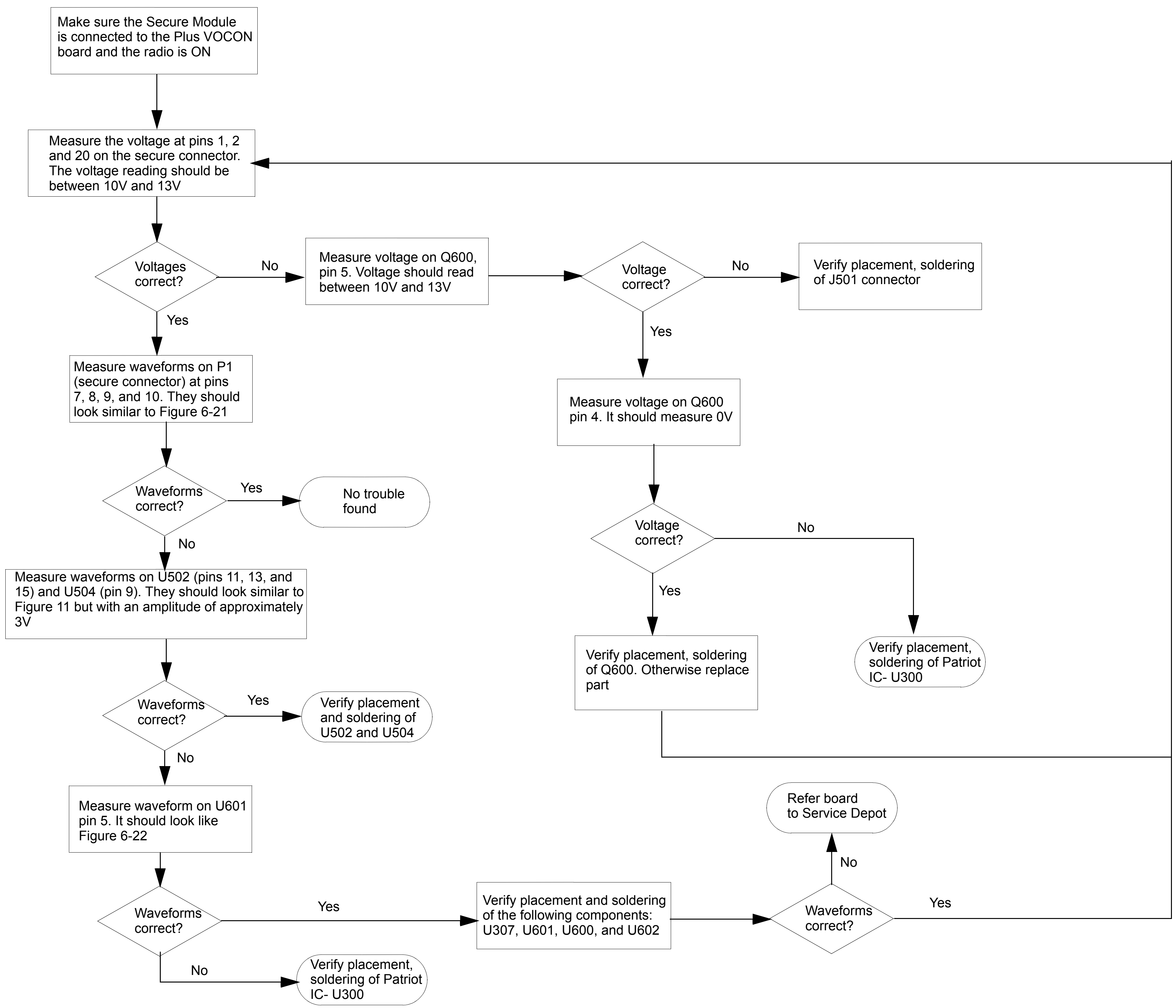


Chart C.32 ASTRO Spectra Plus VOCON Secure Hardware Failure

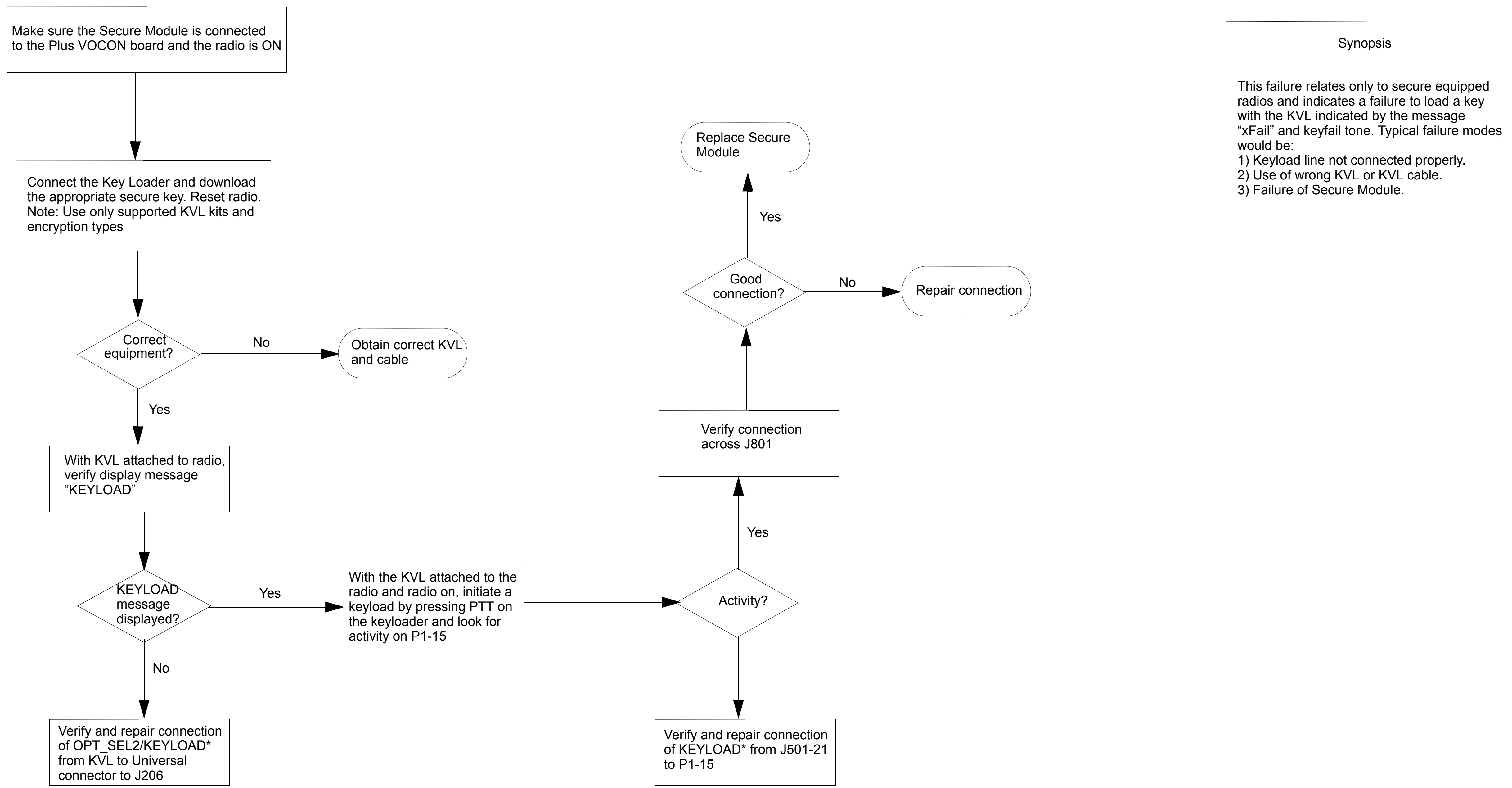


Chart C.33 ASTRO Spectra Plus VOCON Key Load Fail

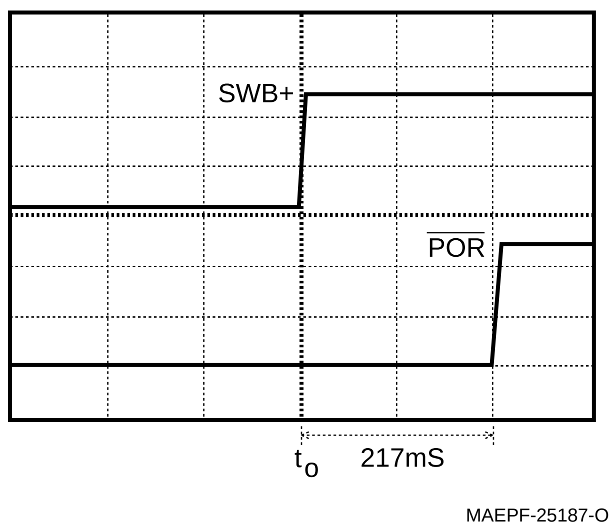
Chapter 6 Troubleshooting Waveforms

6.1 Introduction

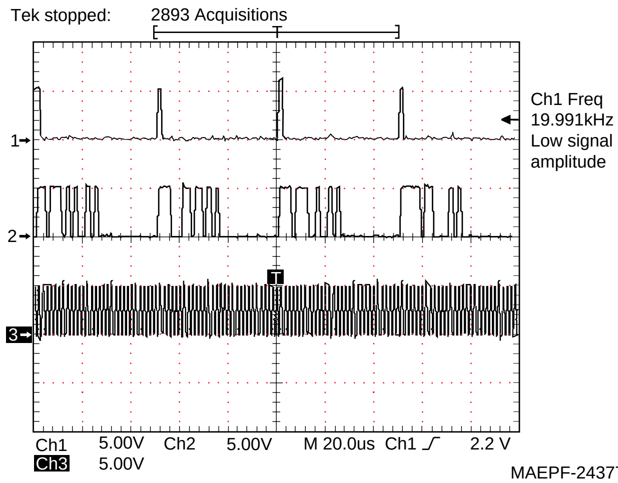
This chapter contains images of waveforms that might be useful in verifying operation of certain parts of the circuitry. These waveforms are for reference only; the actual data depicted will vary depending upon the operating conditions.

6.2 ASTRO Spectra Waveforms

Waveform W1: Power-On Reset Timing



Waveform W2: DSP SSI Port RX Mode

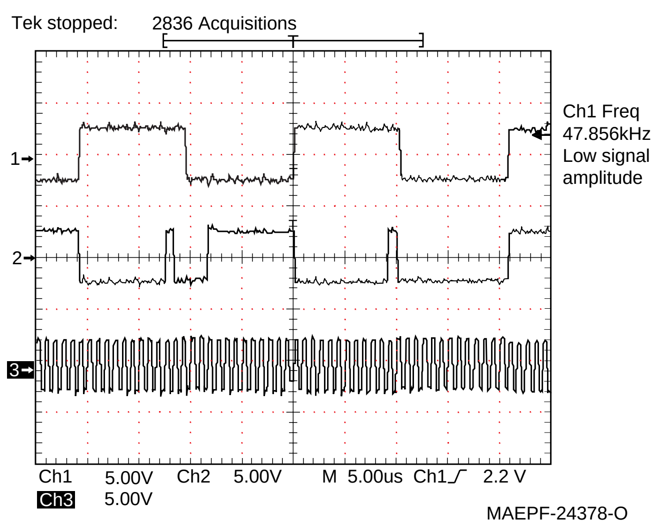


MAEPF-24377-O

W2: DSP SSI Port RX mode.
Receiving
1KHz tone @ 3KHz deviation, -60dBm.
Trace 1 - RFS
Trace 2 - RXD
Trace 3 - SCKR[1] (2.4/0.600MHz)

Note 1: Typically SCKR is a 2.4 MHz clock. In low power modes, as shown here, SCKR is 600KHz.

Waveform W3: DSP SSI Port TX Mode CSQ



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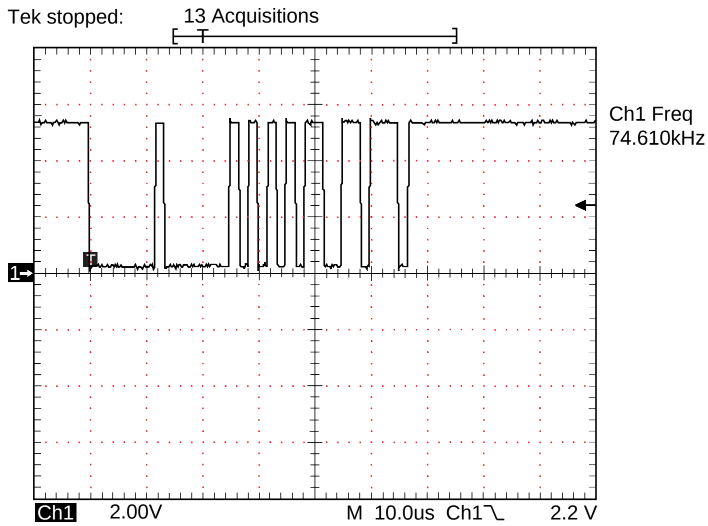
W3: DSP SSI Port TX mode CSQ.
Trace 1 - SC2
Trace 2 - STD
Trace 3 - SCK (1.2MHz)

Waveform W4: ABACUS Programming at Mode Change



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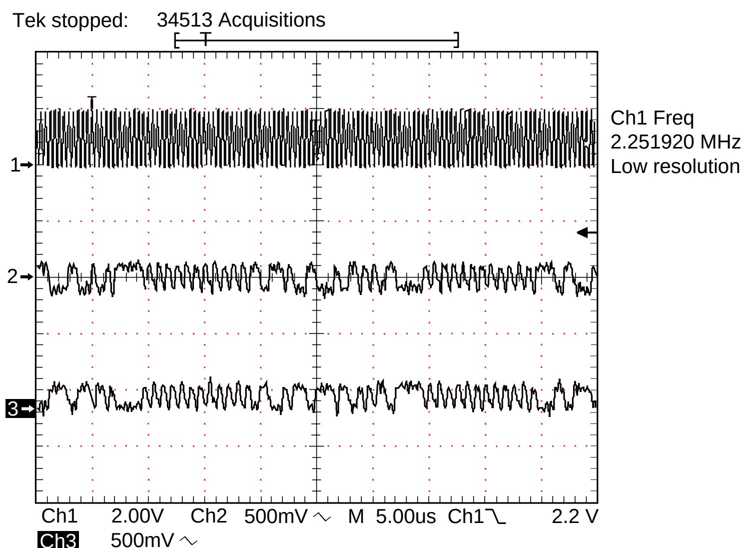
W4: ABACUS programming
captured during mode change.
Trace 1 - (ADSIC) SBI

Waveform W5: ABACUS/ADSIC Interface



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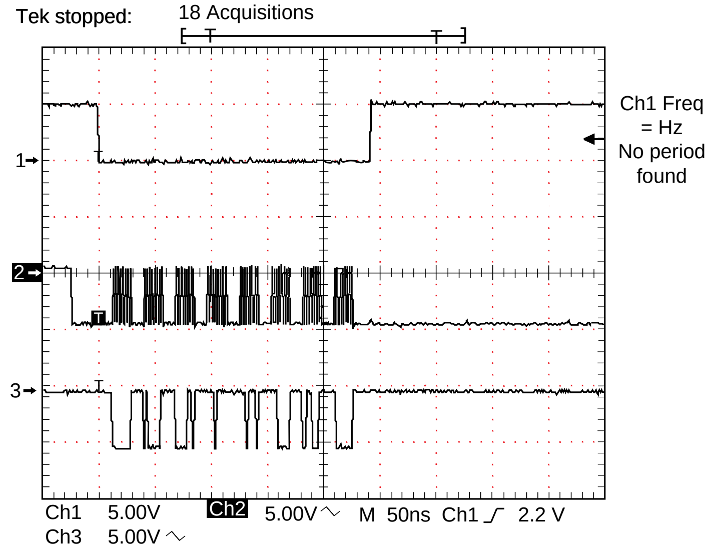
W5: ABACUS/ADSIC Interface.
Receiving 1KHz tone @ 3KHz deviation,
-60dbm.
Trace 1 -IDC (2.4MHz)
Trace 2 - DOUT [2]
TRACE 3 - DOUT*

Note 2: Since these signals are a differential current loop these voltages are very low.

Waveform W6: SPI Bus Programming ADSIC



W6: SPI Bus Programming ADSIC.
Trace 1 - ADSIC_SEL*
Trace 2 - SPI_SCK
Trace 3 - MOSI
Note: These waveforms are typical to any device on the SPI bus.

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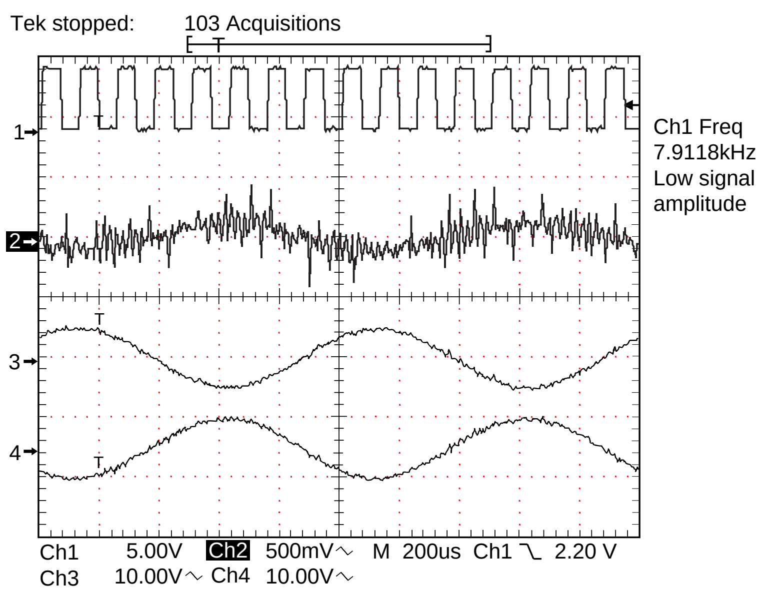
Waveform W7: Receive Audio



W7: Receive audio: Receiving
1KHz tone @ 3KHz deviation, -60dBm. Volume set to rated audio.
Trace 1 - IRQB @ DSP (8KHz)
Trace 2 - SD0 @ C412 on Command Board
Trace 3 - SPKR_LOW Out of U450
Trace 4 - SPKR_HI Out of U450[3]

Note 3: Actual level is dependent upon volume setting.

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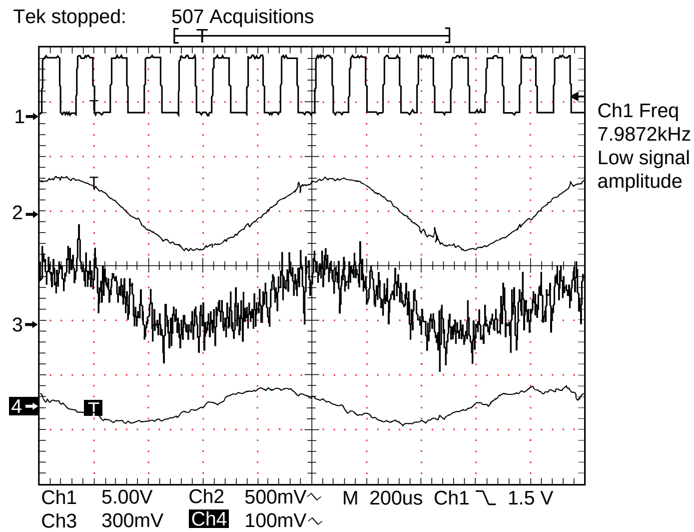
Waveform W8: Transmit Audio



W8: Transmit Audio. 1KHz Tone
which provides 3KHz deviation.
Trace 1 - IRQB @ DSP (8KHz)
Trace 2 - MODIN
Trace 3 - MIC @ node P502/R415
Trace 4 - MAI @ U406

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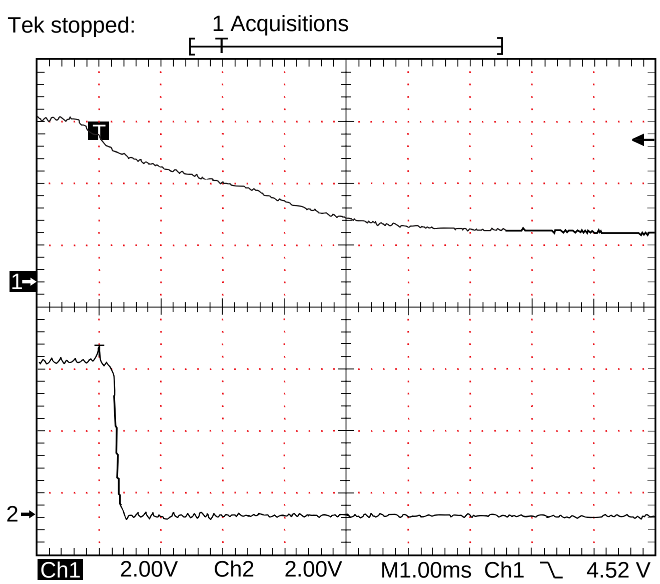
Waveform W9: Power-Down Reset



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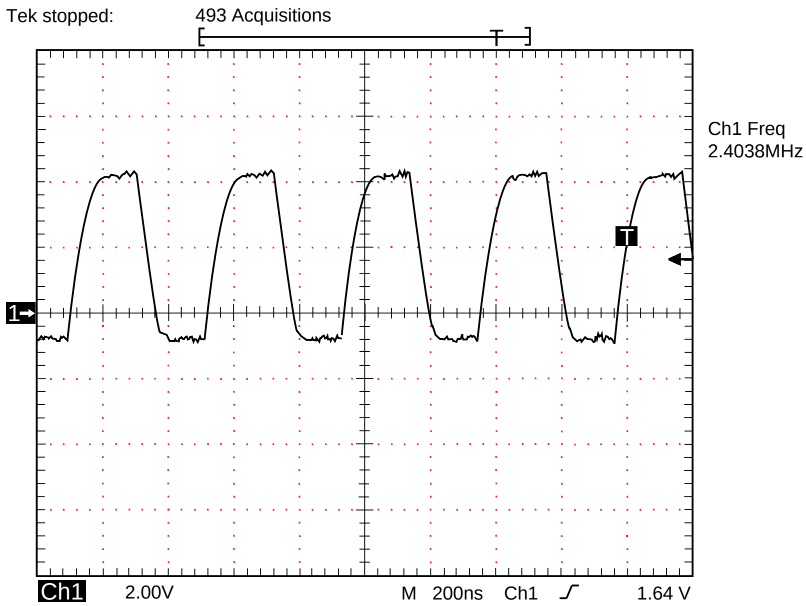
W9: Power Down Reset.
Trace 1 - +5V @ U407 (VDD)
Trace 2 - Reset @ U407 (OUT)

Waveform W10: ADSIC 2.4 MHz Reference



W10 ADSIC 2.4 MHz Reference
Trace 1 - IDC @ U406

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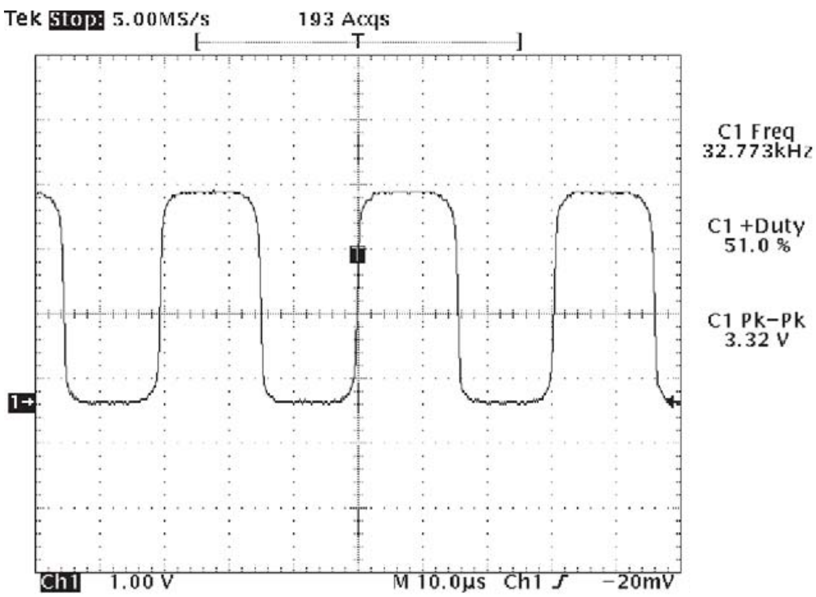
6.3 ASTRO Spectra Digital Plus VOCON Board Waveforms

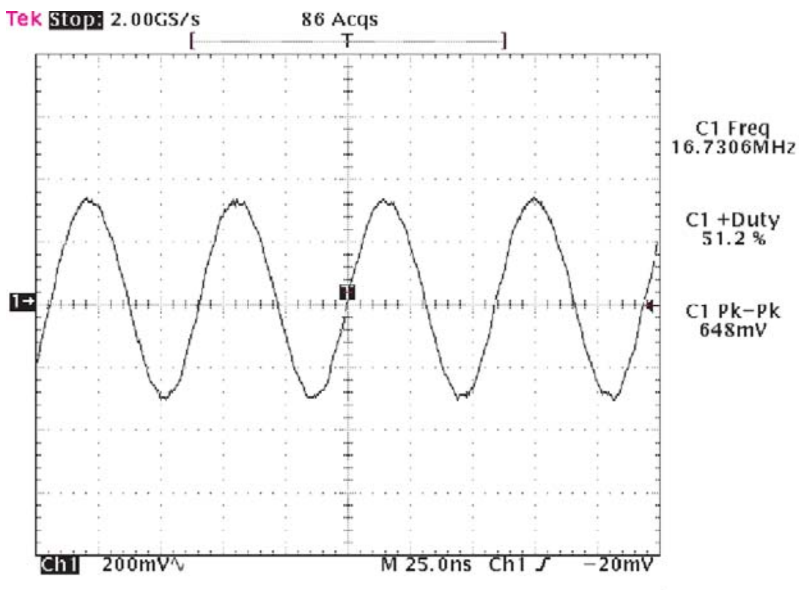
This section contains images of waveforms specific to the ASTRO Spectra Digital Plus VOCON board. These waveforms might be useful in verifying operation of certain parts of the circuitry. These waveforms are for reference only; the actual data depicted will vary depending upon the operating conditions.

32 kHz Clock Waveform



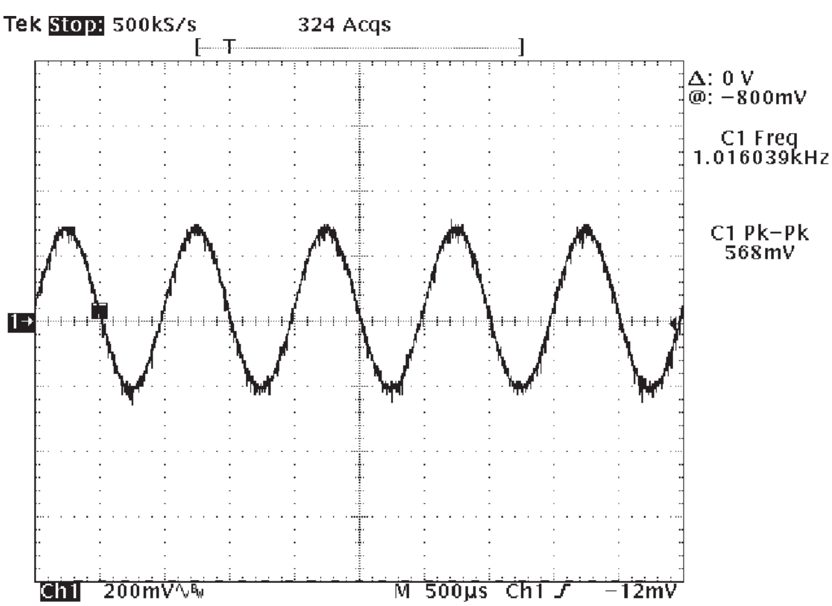
Trace 1 — R428 — 32 kHz Clock

16.8 MHz Clock Waveform



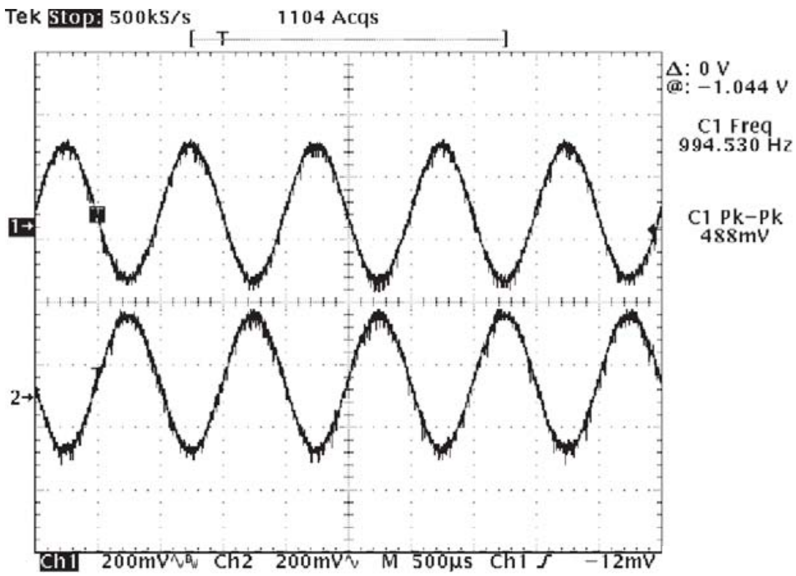
Trace 1 — TP401 — 16.8 MHz Clock

TX Modulation Out Waveform



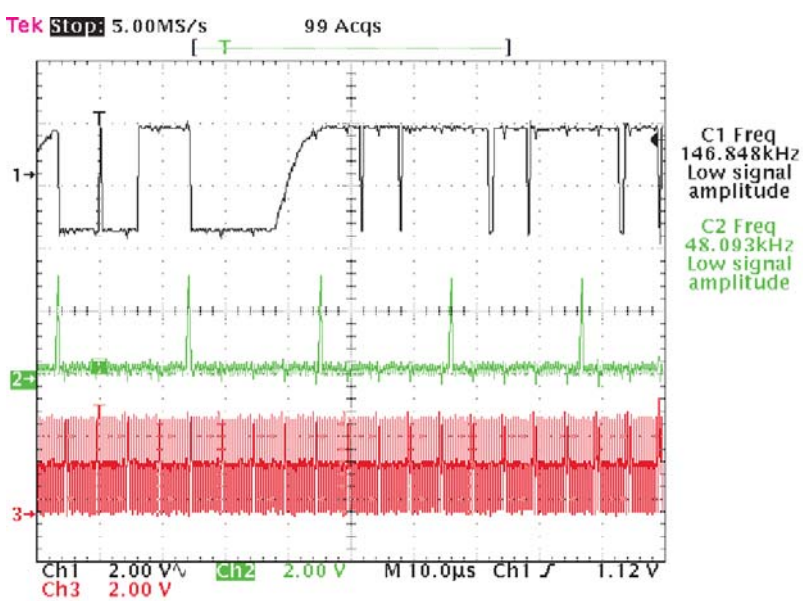
Transmitting
1 kHz tone at 85mVrms into microphone
Trace 1 — U201 — 9

Differential ADDAG Output Waveform



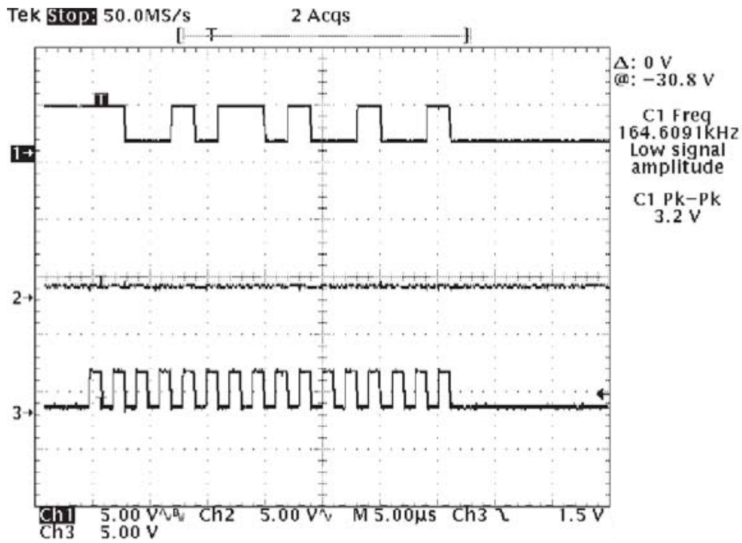
Transmitting
1 kHz tone at 85mVrms into microphone
Trace 1 — U201 — 4
Trace 2 — U201 — 5

TX SSI Waveform



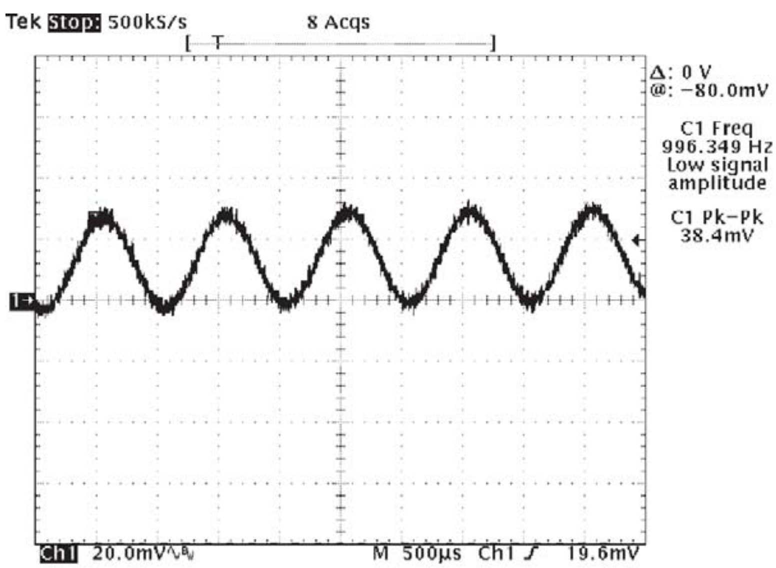
Transmitting
1 kHz tone at 85mVrms into microphone
Trace 1 — U201 — 33 - Data
Trace 2 — U201 — 35 - Frame Sync
Trace 3 — U201 — 34 - Clock

SPI Bus Waveform



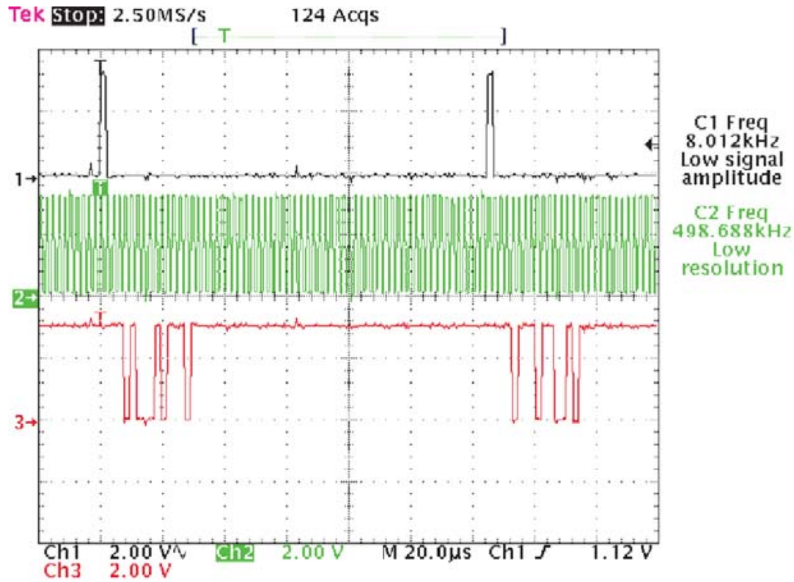
Radio Power Up
Trace 1 — U201 — 41 - Data
Trace 2 — U201 — 43 - Chip Select
Trace 3 — U201 — 42 - Clock

TX 1 kHz Tone Waveform



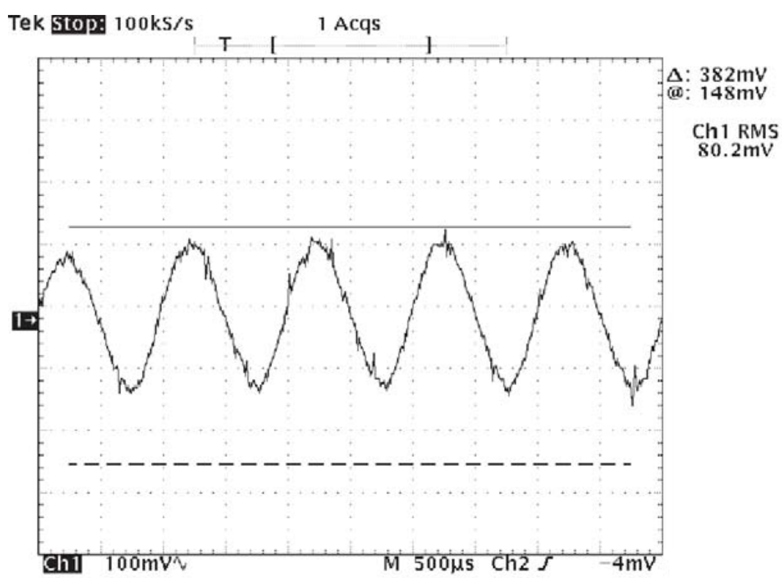
Transmitting
1 kHz tone at 85mVrms into microphone
Trace 1 — U402 — 17

Serial Audio Port Waveform



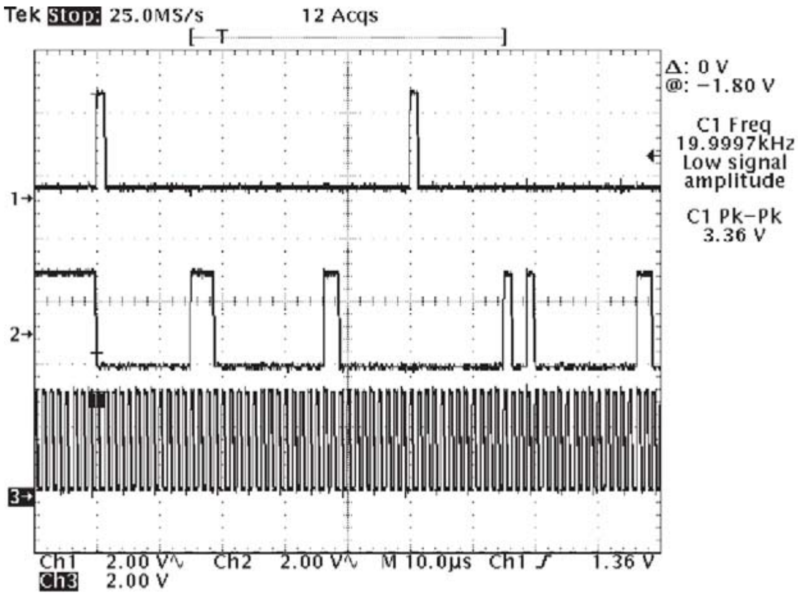
Transmitting
1 kHz tone at 85mVrms into microphone
Trace 1 — U402 — 7 - Frame Sync
Trace 2 — U402 — 11 - Clock
Trace 3 — U402 — 13 - Data

RX Audio Waveform



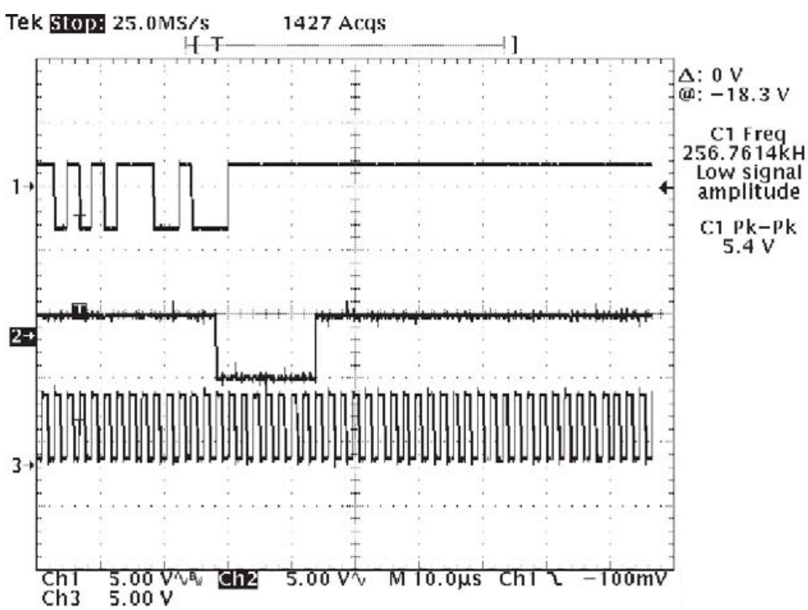
Receiving
1 kHz tone at 3 kHz Dev, -47dBm
Trace 1 — U402 — 2

RX BBP Waveform



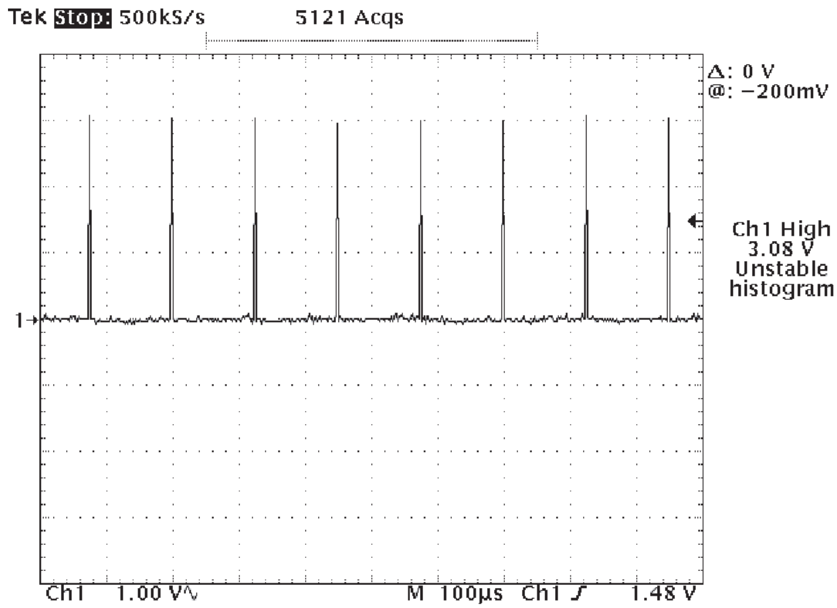
Receiving
1 kHz tone at 3 kHz Dev, -47dBm
Trace 1 — TP221 — Frame Sync
Trace 2 — TP223 — Data
Trace 3 — TP219 — Clock

Secure Interface Waveform



Receiving
1 kHz tone at 3 kHz Dev, -47dBm Secure Mode
Trace 1 — P1 — 8 - Data
Trace 2 — P1 — 10 - SS
Trace 3 — P1 — 9 - Clock

8 kHz Frame Sync for Security Circuitry Waveform



Receiving
1 kHz tone at 3 kHz Dev, -47dBm Secure Mode
Trace 1 — U601 — 5

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