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4- DIAGNOSTICS

Note - for sections 4-1 through 4-4 see file 1305014a
for section 4-5 see file 1305014b
for section 4-6 see file 1305014c
for section 4-7 see file 1305014d

Contains the diagnostic procedures of the Erbtec 20 kilowatt RF Amplifier (for 1.5T systems.)

4-1 Equipment Safety Considerations

The Erbtec 86-013-0000 MRI Amplifier has been designed with considerable attention to safety. Numerous internal points are monitored by the microprocessor to check for irregularities in amplifier operation. For the safety of the patients, operator, and for the safety of the amplifier itself, any internal (and a few external) irregularities detected by the amplifier's microprocessor will cause the amplifier to completely or partially shutdown and issue an associated fault code. Fault code definitions are found in Section 4-2 Fault Codes.

The amplifier has built-in safety “cover interlock" switches that fault the amplifier when a cover panel is removed. This keeps the amplifier in an OFF mode when the covers are removed. If a power-on mode should be required for servicing or diagnostics, these safety switches may be overridden. This level of servicing is generally discouraged and is not ordinarily required. Most diagnostics may be done by first reading significant microprocessor memory locations (see the procedure for RF Amp Firmware (20KW)), and then confirming the diagnosis by making measurements on the troubled module while in an OFF condition.

WARNING!

EXTREME CAUTION IS REQUIRED WHEN OVERRIDING THE COVER SAFETY SWITCHES. THERE ARE LETHAL VOLTAGES/CURRENTS WITHIN EASY ACCESS OF HANDS AND TOOLS WITH THE COVERS OFF AND RUNNING IN EITHER STANDBY OR OPERATE MODES. ONLY HIGHLY TRAINED PERSONNEL COMPLETELY FAMILIAR WITH THIS AMPLIFIER SHOULD ATTEMPT THIS LEVEL OF SERVICING.

Safety switches along edges of amplifier rear panel (one on each side) may be overridden if absolutely necessary by pulling the white switch post out until it clicks. The microprocessor power-up tests will then perceive the cabinet as being closed. Note the warning above!

Two safety pressure switches also exist to detect fan failure. If a full STANDBY or OPERATE mode is required for servicing with panels off, these switches may also need to be defeated by placing a shorting jumper across the Pressure Transducer terminals (there are only two terminals).

WARNING!

HIGH VOLTAGES (+3KV AND +6KV) ARE FULLY ENABLED JUST AS THE AMPLIFIER ENTERS A STANDBY STATE.

4-2 Fault Codes

When a fault is detected, UNBLANK is disabled and the amplifier is returned to a safe operating state. In addition, a fault code is displayed in the two 7-segment (numeric) displays on the front of the amplifier and the red FAULT LED is lit.

These codes are intended to help the technician diagnose a problem. In many cases the fault code may only be valuable as a starting place for diagnostics. The actual source of the problem may be “upstream or downstream" of the indicated problem; for example, an MRF134 drain to ground short on the Solid State Amplifier would result in a fault code 21 indicating that the +24 volt supply (Power Control Board) has failed.

Service personnel should consult the schematics in Chapter 5, *Service Manual* and the procedure for RF Amp Firmware (20KW) Section 3-5 Microprocessor Functional Chronologies of this manual as well as the information contained in this Chapter to locate the root cause of a particular fault code.

The fault codes may be of two general types: fatal and non-fatal. These are defined in Section 4-2-1 Fault Code Listing along with a complete listing of fault codes in Table 19. Probable causes for fault codes are discussed in Section 4-2-2 Fault Code Probable Cause.

TABLE 19
FAULT CODES

Fault	Severity	Steps/gearing
00	Fatal*	Fault interlock is held in the faulted state (high). The red FAULT LED does not light for this fault only.
01	Fatal*	EEPROM contains some data inconsistent with a run; watchdog not enabled or motor tune positions not within motor limits.
02	Fatal*	Dual Port RAM problem.
03	Fatal*	A/D on-board 68HC11 has failed.
04	Fatal*	A/D multiplexer has failed.
05	Fatal*	A/D self-test in microprocessor has failed.
06	Fatal*	A stepping motor coil is open.
07	Fatal*	Illegal opcode trap.
08	Fatal*	External interrupt high does not cause interrupt.
09	Fatal*	External interrupt low does not cause interrupt.
10	Fatal	Solid State Amplifier thermistor unacceptable.
11	Fatal	SCM cable disconnected or handshake incorrect.
12	Fatal	+100 volt supply unacceptable
13	Fatal	+3KV supply unacceptable.
Fatal* is used for fault codes 00 through 09 to indicate that these faults are a part of the initial microprocessor self test which occurs only when the circuit breaker is first turned on.		

4-2-1 Fault Code Listing

Fatal Faults

Fatal faults are conditions that may be unsafe to personnel or the amplifier. If a fatal fault occurs other than in the OFF mode, the amplifier executes an orderly shutdown and returns to the OFF state. The microprocessor prevents the amplifier from again proceeding with its power-up sequence until the internal fault flag is cleared by issuing a “go to off' command (see Chapter 3). Once the red FAULT LED is off (the numerical code will remain displayed), the amplifier may be again commanded into a power-on mode. If the fault condition is still present, the fatal fault sequence will occur again.

Note

"Go To On" Command - Even though the amplifier is on OFF, a “go to on” command must be sent to clear the fault flag.

Non-fatal Faults

Non-fatal faults are used to indicate that an illegal command has been issued or an operational irregularity has been detected which does not warrant complete amplifier shutdown. This level of fault does prohibit an OPERATE mode, but returns the amplifier to STANDBY instead of OFF. The internal flag must be cleared by a “return to standby" command (see the procedure for RF Amp Firmware (20KW)).

Note

"Return To Standby" Command - Even though the amplifier is in STANDBY, a “return to standby” command must be send to clear the fault flag.

4-2-2 Fault Code Probable Cause

Each fault code is listed below along with a “probable cause" description. This brief description is intended to provide a quick best estimate of where the source of trouble is likely to be located. It is virtually impossible to list all of the possible causes. Service personnel should utilize the information in this Section only as a good starting place.

00: The fault interlock is being held high. The microprocessor is stuck in reset or the cable between the Processor Board and the Front Panel Display Board has an open.

01: The microprocessor detects a “checksum" error. This generally indicates that the address bus is faulted or the EPROM contains incorrect data; definitely a Processor Board problem.

02: Dual port RAM apparently has failed; a Processor Board failure.

03: A/D samples generated on the Processor Board have failed; a Processor Board failure.

04: A/D multiplexer apparently has failed. Either the Processor Board has a problem, or possibly one of the 32 analog convertible signals is unusually errant.

05: A/D on-board self-test has failed; a Processor Board failure.

06: Stepping motor coil is apparently open; very possibly an open in the Motor Cavity Cable Harness or connector; less possible cause is a component malfunction on the Processor Board.

07: Illegal opcode trap; a Processor Board failure.

08: External interrupt high does not cause interrupt; a Processor Board failure.

09: External interrupt low does not cause interrupt; a Processor Board failure.

10: Heat sink (Solid State Amplifier) monitor temperature apparently too hot or cold (very unlikely); probably a failed thermistor or loose screw next to thermistor; perhaps a cable problem or Processor Board A/D problem.

11: SCM cable interlock invalid; either the strobe width is too wide, the cable is open, the strobe signal is high impedance, or most likely, the Processor Board has a problem.

12: +100v supply unacceptable; problem could be on the Power Control Board, the Low Voltage Transformer, an AC Switching Module fuse or relay, a bad cable, or a component failure causing excessive loading (including tubes).

13: +3KV supply unacceptable; failure could be on the High Voltage Rectifier/Filter Board (bad capacitors, diode etc.), the 4.5KVA HV Transformer (unlikely), or possibly a bad IPA tube or 7.5 KV capacitor drawing excessive current.

14: IPA tube heater current unacceptable; most likely a bad IPA tube or Power Control Board circuit. Also cabling including feed-through capacitor is highly suspect.

15: -5 volt supply unacceptable; most likely on the Processor Board. Possibly a bad op-amp on one of the other boards which uses the -5 volt supply.

16: +48 volt supply unacceptable; most likely a bad FET circuit on the Solid State Amplifier Board; possibly a bad Power Control Board circuit or cabling problem.

17: +6KV supply unacceptable is identical to the +3KV supply unacceptable except for the PA tube being a possible cause. Most likely a HV Rectifier/Filter Board problem.

18: PA tube heater current unacceptable; most likely located on the Power Control Board, but very possibly a tube problem. Cabling and feed-through capacitors are suspect.

19: +32 volt supply unacceptable; most probable sources of trouble are the AC Switching Module (fuses or transformer T1), the Power Control Board, Motors, and cabling.

20: +2.5 volt reference unacceptable; most likely a failure on the Processor Board or the AC Switching Module transformer T1 or fuses.

21: +24 volt supply unacceptable; this may arise from any of the supply's numerous loads: Solid State Amplifier, Power Control Board, Processor Board, RF Monitor Module, AC Switching Module, and PA Input Board.

22-25: Motor 1, 2, 3, or 4 zero sensor fault; this either indicates motor is stuck at zero, its optical sensor is stuck open, AFT forced the motor into the zero stop, or cabling has failed.

26-29: Motor 1, 2, 3, or 4 zero not found; possibly a problem with motor driver chips on the Processor Board. Most likely a failed motor assembly: zero sensor, stuck washers, or cabling.

30: General motor fault; one or more of the four motors suddenly (by the microprocessor's perception) no longer has the correct number of steps or has a changed zero position. This most likely indicates a motor assembly failure (usually stuck counter washers); possibly a driver failure on the Processor Board.

31: Unused.

32: UNBLANK longer than 20 milliseconds; either the UNBLANK signal generated by external equipment is too long, or the Processor Board has a problem.

33-34: Unused.

35-38: FET 1, 2, 3, or 4 coarse convergence failure; a problem with either the Solid State Amplifier Board (most likely), the Processor Board, or cabling in between.

39-41: Unused.

42-45: FET 1, 2, 3, or 4 fine convergence failure; identical to faults 35-38 probable cause.

46-49: FET 1, 2, 3, or 4 tracked out of adjustable range; this problem is identical in probable cause to faults 35-38 except that an even higher probability exists for the failure to exist on the Solid State Amplifier Board.

50: +100 volt supply soft-start failure; this early failure of the +100 volt supply is probably due to an excessive load by one of the tubes or a circuitry failure on the Power Control Board. It is also very possible that a problem exists in the AC Switching Module relays or fuses; perhaps a failed Low Voltage Transformer (not very likely).

51: +100 volt supply run failure; identical to fault 50 probable cause.

52: IPA tube heater current unacceptable at start; identical to fault 14 probable cause.

53: PA heater current unacceptable at start; identical to fault 18 probable cause.

54: Unused.

55: +3KV supply unacceptable immediately after soft-start; this failure is most likely due to a problem in the High Voltage Rectifier/Filter Board, and very possibly a relay problem in the AC Switching Module. Other sources of the failure could be the 4.5KVA HV Transformer, loading in the VTAC, and bad A/D on the Processor Board.

56: +6KV supply unacceptable immediately after soft-start; identical to fault 55 probable cause.

57: +3KV soft-start failure; differs from fault 55 only in timing.

58: +6KV soft-start failure; identical to fault 56 except for timing.

59: +3KV supply or +6KV supply run failure; shares the same probable causes as faults 55 through 58.

60: IPA AFT does not converge; this indicates that sufficient power exists for AFT but the motors cannot force a zero-phase condition. Problems could exist with the motors, motor drivers, IPA phase detector, Processor Board A/D, IPA tube, or cabling.

61: PA AFT does not converge; identical to fault 60 probable cause.

62: Insufficient power reaching tube output for AFT; most likely this problem is due the Solid State Amplifier oscillator or path switching. Also very likely is a bad connection between Solid State Amplifier and the VTAC. Other potential sources of failure could be the IPA tube, IPA input board, IPA phase detector, Processor Board A/D, and cabling.

63-69: Unused.

70: Change mode command while in operate; if no such command is being issued by the external controlling computer, then the Processor Board is definitely at fault.

71: Frequency command fault; if the frequency command byte is correct, then the Processor Board is the failure.

72: Invalid mode command; identical to fault 70 probable cause.

73: BODY mode forward power too high; if the RF input power to the amplifier is normal, then the failure is most likely in the RF Monitor Module. Possibly the Processor Board A/D has a problem.

74: HEAD mode forward power too high; identical to fault 73 probable cause.

75: BODY mode reflected power too high; if the amplifier load is normal, then the probable cause is the same as for fault 73.

76: HEAD mode reflected power too high; identical to fault 75 probable cause.

77: PA tube grid current too high; most likely an indication that the YC-156 tube is failing. Possible problems on the Power Control Board or Processor Board.

78: IPA tube grid current too high; identical to fault 77 probable cause.

79: PA tube plate current too high; the probable causes are the same as for fault 77 except that the High Voltage Rectifier/Filter Board is also suspect.

80: IPA tube plate current too high; identical to fault 79 probable cause.

81: IPA tube or +3KV arc; a genuine arc will usually leave a visible mark, and will most probably eventually occur again. Tube arcs may occur internally and will not be visible; if these persist, the tube must be replaced. It is also possible that the arc detect circuitry on the Processor Board is giving false indications.

82: Cover interlock 1 (on RF Monitor Module) open; if the Motor Cavity Right Side Cover is in place, then the switch has failed, a cable is open, or Processor Board has failed.

83: Cover interlock 2 (on AC Switching Module) open; identical to fault 82.

84: RF MON cable disconnected; if RF MON cable is correct, then failure is on the Processor Board.

85: Externally controlled +12 volt safety relay not powered; if the RF MON cable is correctly supplying the voltage, then the Processor Board has a problem. (A GE power monitor fault will produce this error code.)

86: PA tube or +6KV arc; identical to fault 81, but with more punch.

87: Arc detect circuit failure; a Processor Board failure.

88: Fan air pressure insufficient; if the fans are turning and the covers are on, then either the pressure transducer has failed, cabling has failed, or an A/D problem exists on the Processor Board (unlikely).

89: Tube air pressure insufficient; identical to fault 88 probable cause.

90: IPA tube idle DC bias current unacceptable; either the tube or the Power Control Board has failed. Possibly a cable, IPA Input Board, or Processor Board A/D problem.

91: PA tube idle DC bias current unacceptable; identical to fault 90.

92: Line voltage too low; if line voltage is always greater than 180 volts, then Processor Board or AC Switching Module has a problem.

93: Microprocessor “Watchdog" failed to fire in time; a Processor Board failure.

94: Microprocessor “Watchdog" intercepted program; a Processor Board failure.

95-99: Unused.

4-3 Fuse Bank

This Section contains a list of all fuse functions and ratings. All replaceable fuses are located in the fuse bank on the rear upper right corner of the amplifier (see Illustration L3001A, RF Amp Overview (20KW)). These fuses are actually a part of the AC Switching Module; schematic 86-013-2110 is useful for information supplemental to this Section.

It is usually a good idea to begin diagnostics with a check of fuses that may directly correspond to a particular fault, as well as all fuses that may be “upstream" of a particular fault (consult amplifier background testing chronology in the procedure for RF Amp Firmware (20KW)). See Table 20 for a list of fuses.

TABLE 20
FUSES

Fuse	Rating	Function
F1	2 amps	Current limit for secondary of AC Switching Module transformer T1 supplying Processor Board
F2	2 amps	Current limit for secondary of T1 (same as F1)
F3	1 amp	Current limit for primary of AC Switching Module transformer T1
F4	1/2 amp	Current limit for BLOWER PHASE1, Blower Assembly
F5	1/2 amp	Current limit for BLOWER PHASE2, Blower Assembly
F6	1 amp	Current limit for primary of AC Switching Module transformer T1.
F7	1 amp	Current limit for FAN PHASE1, air intake fans.
F8	1 amp	Current Limit for FAN PHASE2, air intake fans.
F9	2 amps	Current limit for +32 volt supply.
F10	2 amps	Current limit for 208V P1A primary of Low Voltage Transformer supplying Power Control Board.
F11	2 amps	Current Limit for 208V P1 C primary of Low Voltage Transformer.
F12	2 amps	Current limit for 208V P1 B primary of Low Voltage Transformer.

Note
Fuse Types - All fuses are of type 3AG 250 volt SB (slow blow).

4-4 Circuit Test Points and Factory Adjustments

As an aid to diagnostics and initial factory calibration, several test points have been built into the circuit boards. These points consist of raised metal loops labeled TPx where x is a number. The metal loops allow for easy attachment of test clips. Exact locations of test points and their interconnection within the circuits are to be found in the schematics in Chapter 5, *Service Manual*.

Test points exist on three of the amplifier modules: Processor Board, Solid State Amplifier Board, and the Power Control Board. Test points and adjustments for each of these boards and the adjustments required on the IPA Input Board are discussed in the next four Sections.

4-4-1 Processor Board Test Points

Processor Board Test Points

All test points and jumper pins provided on the Processor Board are fully described in Table 21.

TABLE 21
PROCESSOR BOARD TEST POINTS AND JUMPERS

Point	Signal	Description
TP1	AS (Address Strobe)	Provides quick verification of microprocessor mode. This test point should be a 2MHz square wave, about 25% duty for expanded multiplex address mode.
TP2	RESET	Logic low indicates the microprocessor is in reset.
TP3	Ground	Tied directly to ground on the Processor Board.
TP4	32V RET	Return line (ground reference on Power Control Board) of +32 volt supply
TP5	+32V	Positive side of +32 volt supply originating from Power Control Board.
TP6	+24S	+24 volt supply originating from Power Control Board; switched in line with relay powered externally through RF MON cable (12 volt safety relay)
TP7	+24V	+24 volt supply from Power Control Board.
TP8	+5VR	Regulated +5 volt supply,; powers almost all logic.
TP9	-5V	Regulated minus 5 volt supply

Processor Board Factory Adjustments

There is only one factory adjustment made on the Processor Board.

1. +5 volt supply. Adjust potentiometer R122 until 5.00 volts is obtained at test point TP8.

4-4-2 Solid State Amplifier Test Points

Solid State Amplifier Test Points

All test points and jumper pins provided on the Solid State Amplifier Board are fully described in Table 22.

TABLE 22
SS AMPLIFIER TEST POINTS AND JUMPERS

Point	Signal	Description
TP1	1341 +	+24 volt supply; used for MRF134 FET bias.
TP2	1341-	+24 volt supply after 0.1 ohm resistor used to sense supply current (1 millivolt = 10 milliamps). TP1 and TP2 are used for MRF134 manual bias.
TP3	FET BIAS	Output of current to voltage to transducer utilized by the microprocessor to set and maintain MRF148 and MRF150 FET bias,; 255 milliamps per volt.
W1	UNBLK	Forces UNBLANK on the SS Amplifier to enable the +24 volt supply for biasing the MRF 134 FETs.
W2	Q23 BIAS OFF	Shorts Q23 gate voltage to ground so that Q24 bias may be independently set utilizing TP1 and TP2.
W3	Q24 BIAS OFF	The complement of the W2 jumper; shorts Q24 gate bias so that Q23 may be independently set.

Solid State Amplifier Factory Adjustments

1. **Oscillator power.** Configure Solid State Amplifier Board for oscillator to TEST RF OUT port using the serial “A" command: “AD0".

Measure power and frequency at the TEST port (J2504) on the rear panel and adjust the variable inductor L1 for maximum stable output power (upper mid-range).

CAUTION

Power levels in excess of 15 dBm (30 milliwatts) may be available at the TEST port during this process. Be sure that the measuring device is capable of withstanding this power, or attenuate the signal to a safe level.

2. **Set MRF134 DC drain current bias levels to 225 milliamps.** Place amplifier in OFF mode with Solid State Amplifier Board installed.

Turn potentiometers R121 and R124 fully counter-clockwise to ensure initial zero voltage on the FET gates.

Place jumper across W2 to short bias voltage on FET Q23. Place jumper on W1 to “UNBLANK" the +24 volt supply.

Connect voltmeter capable of accurately measuring millivolts across test points TP1 and TP2 and adjust potentiometer R124 until a voltage of 22.5 millivolts exists across TP1 and TP2.

Move the jumper from W2 to W3 and repeat adjustment on potentiometer R121 as done for R124 to set Q24 bias such that 22.5 millivolts exists across TP1 and TP2.

4-4-3 IPA Input Board Test Points

IPA Input Board Test Points

There are no test points provided on this board.

IPA Input Board Factory Adjustments

1. IPA Input tune. Set up amplifier to measure forward and reflected power for Solid State Amplifier feeding into the VTAC (connector IPA RF IN) using a four port directional coupler.

Adjust “pi" tuning-circuit capacitors TUNE and LOAD for less than -40 dB of reflected power.

2. IPA Phase Adjustment. Set up amplifier to measure its bandwidth centered about 63.860 MHz.

Adjust IPA PHASE capacitor so that HEAD mode bandwidth is consistently centered after executing AFT.

4-4-4 Power Control Board Test Points

Power Control Board Test Points

All test points and jumpers on the Power Control Board are fully described in Table 23.

TABLE 23
POWER CONTROL BOARD TEST POINTS AND JUMPERS

Point	Signal	Description
TP1	+48V	Tied to the +48 volt supply
TP2	PA HTR-	The “negative" output line of the floating 15.2 volt PA tube heater supply (floats on the PA tube cathode potential).
TP3	PA HTR +	The "positive" output line of the PA heater supply
TP4	IPA HTR +	IPA tube heater supply
TP5	IPA CATHODE	IPA tube cathode to grid bias potential.
TP6	PA CATHODE	PA tube cathode to grid bias potential.
TP7	+24V	Tied to the +24 volt supply
TP8	GROUND	Tied to Power Control Board around reference.

Power Control Board Factory Adjustments

1. + 24 volt supply. Set potentiometer R84 to ten turns from fully counter-clockwise position.

Enable the U10 voltage regulator by setting FLT 3 high and adjust potentiometer R92 until +24.00 volts is obtained at test point TP7.

Load supply to 2.2 amps and adjust pot R84 to set current limit to 2.2 amps.

2. IPA tube heater supply. Enable tube heater supply by setting /ENABLE line low.

Adjust potentiometer R108 for 15.2 volts at test point TP4.

3. +48 volt supply. Enable the U1 voltage regulator by setting the /ENABLE line low.

Adjust potentiometer R10 until 48.00 volts is obtained at test point TP1.

4. PA tube heater supply. Enable the tube heater supply by setting/ENABLE line low.

Adjust potentiometer R41 until 15.2 volts is obtained across test points TP3 and TP4.

4-5 RF Signal Path Diagnostics

The RF path through the amplifier may be broken down into essentially three subsections as described in Section 2-1 of the 20KW RF Amp Theory-RF Chain. RF power enters at the Solid State Amplifier (SS Amp), exits at about 80 or 160 watts (nominal BODY or HEAD output with 0.4 milliwatts input), and then enters the vacuum tube amplifier cavity (VTAC) where it is amplified by another 11 or 24 dB. Finally, the RF signal passes through the RF Monitor Module to detect forward and reflected power levels.

This modularity greatly simplifies diagnostics of RF signal path troubles since the signal may be independently measured at each of these three subsections. This quickly narrows the problem down to a single subsection.

This RF diagnostics discussion is orientated towards the three subsection modularity just described; the Solid State Amplifier and the VTAC subsections are discussed separately in the next two Sections; the RF Monitor Module is addressed within the VTAC discussion.

4-5-1 Solid State Amplifier Diagnostics

Pulsed RF enters the SS Amp through connector J2503 RF IN. This connector physically resides on the Solid State Amplifier Board 86-013-2500. RF input is 50 ohm characteristic impedance and designed for -4 dBm (+/- 4 dB) input to produce maximum output power in any mode.

The procedures described in this Section enable the identification of a faulty SS Amp Board, and locates essentially where on the board the problem lies. The diagnostics and trouble shooting are designed towards module replacement. Therefore, once an SS Amp is diagnosed as faulty, it should be replaced with a new one. Refer to the Service Manual for ordering and replacement procedures.

Insufficient Output Power

The most common problem associated with the SS Amp is insufficient power reaching the VTAC. Many things can cause this problem. The first step is to make certain that the SS Amp is the actual failure. If there is insufficient power in both the HEAD and BODY modes, then the SS Amp is very possibly at fault.

There are numerous other potential sources of this kind of trouble in the VTAC and the RF Monitor Module also. And it may even be possible that the Processor Board has configured the RF paths or bias currents incorrectly. The first step is to measure the SS Amp output power.

Checking SS Amp Output Power

This procedure requires removal of the Motor Cavity Right Side Cover and defeating the cover interlock switch in the RF Monitor Module. See the procedure for RF Amp Diagnostics (20KW) Section 4.1 Equipment Safety Considerations for details and cautions.

Begin at the RF IN J2503 connector and measure the RF input power at the RF IN (J2503) connector. Use a standard MR pulse (sine, square, or ramp) with a peak power level of about -4 dBm, about 3 to 5 millisecond pulsewidth, and five percent duty cycle. Connect a 50 ohm, 30 dB, 200 Watt through-line attenuator (or rough equivalent) to output connector P2505 of the SS Amp. Connect an oscilloscope (with 50 ohm input) to the other end of the attenuator.

A 50 ohm terminator should also be connected to the IPA RF IN J2601 connector feeding the VTAC. This ensures that a runaway oscillation will not occur in the tube cavity when the amplifier is brought into OPERATE without the SS Amp connected.

Bring the amplifier into HEAD and OPERATE modes. Measure the peak output power (oscilloscope voltage) from the SS Amp. In HEAD mode, the normal range of output power is between 126 and 200 Watts (51 and 53 dBm) for - 4 dBm input. Therefore, a power level of approximately 160 mW should be present at the input of the oscilloscope for 30 dB of attenuation (approximately 4 volts peak in 50 ohm system).

Repeat the power output measurement for the BODY mode. The normal output power of the SS Amp is between 63 and 100 Watts (48 to 50 dBm) for -4 dBm input. The power to the oscilloscope should be about 80 mW (about 2.8 volts peak).

If only one mode's maximum output power is correct, there is high probability that the step attenuator portion of the SS Amp has failed (or possibly the digital control). Proceed with the Step Attenuator Check-out below.

RF Path Through 30 dB Gain Block

The SS Amp RF path can be subdivided into two blocks by looking at power out of the TEST RF OUT port J2504. The RF path to this port includes the input connector (J2503), step attenuators, signal routing diode switches (EXTOUT, INTRF, EXTRF), and a 30 dB integrated circuit gain block (A1).

Connect 30 dB through-line attenuator and 50 ohm oscilloscope to the TEST RF OUT connector. Put the amplifier into TEST and OPERATE modes. Power out should be between 50 and 80 mW (17 to 19 dBm) for an input power of -4 dBm. Therefore, a power of about 63 microwatts should be input to the oscilloscope (79 millivolts peak for 50 ohm system).

If the power of out this port is correct, but the total SS Amp power out is wrong (at P2505), the problem is in the FET gain stages (Q23-Q28) or associated circuitry, and the SS Amp should be replaced; although there is still a small (very small) possibility of a Processor Board failure setting the FET bias currents incorrectly.

If there is no power out at J2504, then use the oscilloscope to trace the signal to the failure. Observe RF input at the junction of R102 and R103, which is the signal path immediately after the RF input. If there is no RF present here, J2503 is probably open or shorted. Next, look at pins 1, and then 9, of A1 (the IC gain block). A significant gain in the RF envelope should be seen between these two pins. These two measurements will narrow down a complete power failure to the gain block, just after it, or between J2504 and the gain block

No power out of the TEST port could also be a symptom of digital control problems. This may be component failure on the SS Amp board (signal routing PIN switches or logic ICs), or Processor Board problems. A storage oscilloscope can be used to check digital signal flow. The Step Attenuator and Oscillator sections below also give a good indication if digital control is working.

If there is power out, but the power-out level is incorrect, the most likely problem is the step attenuators, or a weak gain block, or even a PIN diode switch with high insertion loss. Proceed to the Step Attenuator Check-out section for further diagnostics.

Step Attenuator Check Out

A convenient method of checking the step attenuator is to use the internal oscillator as a driver to the TEST RF OUT port. It is assumed here that the oscillator is working, since it is only used for automatic fine tuning purposes. AFT problems could cause insufficient overall amplifier output power, but the SS Amp would still output its full power. It is unlikely that both the attenuator and oscillator would fail at the same time (unless digital control has failed).

Put the amplifier into an OFF mode (keep circuit breaker switch on). Disconnect power input to connector J2503 (RF IN), and connect the 30 dB through-line attenuator and 50 ohm oscilloscope (as discussed in the Insufficient Output Power section above) to TEST RF OUT (J2504).

First verify oscillator power. The oscillator is turned on with the serial command listed below (see the procedure for RF Amp Firmware (20KW)). This command as given also sets the step attenuator to zero for full oscillator output power.

Execute serial command “AD0" to enable oscillator and set step attenuator to zero.

Note

OFF Mode - In the OFF mode, the serial “A” command must be enabled by manually putting the GATE (pin 13) of U9 to ground to enable the output latch.

The output power should lie in the range of 10 to 30 mW (10 to 15 dBm); therefore, a nominal power of about 15 microwatts (39 millivolts in 50 ohm system) should be input to the oscilloscope after the attenuator. If the oscilloscope can handle the full power of the oscillator (50 milliwatts or better capability), better resolution will be provided by feeding the TEST RF OUT port directly into the scope.

If no power is output, use the oscilloscope to view oscillator RF at the junction of R94 and R95. Note that the oscillator is forced on by tying the “far" side of R50 to +5 volts.

Step through the attenuator by serially writing “AD1 ", “AD2", and so on to “ADF". The last step (ADF) is the maximum attenuation of approximately 22.5 dB. The attenuation steps are on the order of 1.5 dB per increment (+/- 0.5 dB), which is equivalent to a 29 percent decrease in power (16 percent decrease in voltage) per step.

If the step attenuator can be sequentially stepped, serial communications is working properly. If any attenuator step is grossly out of range, this is a possible cause of low (or possibly high) power output in HEAD and BODY modes. If serial communications is working, and the attenuator steps are all in range, signal loss is likely due to some path attenuation (PIN switch with insertion loss, short), or a weak gain block. It should be safe to assume that the Processor Board is functioning properly; so replace the SS Amp.

Reset the amplifier when finished with the “A" command by turning the main circuit breaker (on the rear of amplifier) off and on again. Remember to unground pin 13 of U9.

FET RF Path Failure Or Convergence Faults

The procedures in this section can be used to determine if the FETs (or associated circuitry) have failed. The failure may be in the form of either insufficient power or an FET convergence fault (coarse or fine).

An FET convergence fault will be issued by the microprocessor if the coarse and fine DACs reach full scale without producing sufficient (target in EEPROM) bias current. If fault code 38, FET 4 coarse convergence failure, occurs, first check the current transducer as discussed next. Otherwise, skip the next two paragraphs.

Put the amplifier in OFF mode, and attach a 50 ohm resistor (50 watts minimum!) between FB2 or FB3 (the 48 volt bus) and ground (negative side of C18 is a convenient ground clip point). Issue a “go to standby" command (see the procedure for RF Amp Firmware (20KW)), and observe the voltage at test point TP3 which is the voltage output of the FET bias current transducer. This must be done before STANDBY is reached. The 50 ohm resistor should draw 0.96 amps, thus producing 3.76 volts at TP3 if the current transducer is working (0.0039 volts per milliamp of +48 volt supply current). Check that +48 volts is present at FB2 or FB3 before doing this test (+48 volt supply comes up during OFF to STANDBY delay).

If the voltage at TP3 is correct, proceed to the next paragraph. Otherwise, check for +48 volts on both sides of R33 to confirm R33 is still functional. Note that diode D19 is parallel with R33 to protect the resistor from +48 volt supply ground shorts. If the voltage across both sides of R33 is a diode drop (0.5 to 0.8) volts, then R33 is open; replace the Solid State Amplifier Board.

If the current transducer is functioning properly, then usually (about 75 percent of the time) a coarse convergence failure (faults 35-38) occurs for an FET other than FET 4. Then either the FET has failed or the coarse adjust bias circuitry for the FET has failed; replace the SS Amp.

An FET fine convergence failure (faults 42-45) or bias tracked out of adjustable range (faults 46-49) could possibly be due to a failure of the fine DACs on the Processor Board (or A/D may have failed, perhaps cabling). Most likely the failure is on the SS Amp. Check the fine DACs on the Processor Board for reasonable output. It may be useful to read the RAM Address Codes (see the procedure for RF Amp Firmware (20KW)) for the coarse and fine DACs to see if reasonable values in agreement with measurements are present.

Oscillator/AFT Circuit

The SS Amp on-board oscillator supplies the signal used for AFT purposes. If the oscillator fails, improper AFT will occur, and insufficient output power and skewed bandwidth may result. If AFT problems are suspected, first check the oscillator function and output power with the procedure described in the Step Attenuator Check Out section above.

If the oscillator is functioning properly, then check for a pulse train exiting the SS Amp output P2505 during AFT (which occurs just as going into OPERATE). Note that AFT must be enabled (see the procedure for RF Amp Firmware (20KW)).

The output power (measured in the same way as described for the Checking SS Amp Output Power section) should nominally be 25 Watts (44 dBm +/- 4 dB) in either HEAD or BODY mode.

If the oscillator is functioning and a pulse train is exiting the SS Amp, then the SS Amp is not the problem. Otherwise, the SS Amp is most likely the problem. Check that the step attenuator is functioning to verify Processor Board digital communications before replacing the SS Amp.

4-5-2 Vacuum Tube Amplifier Cavity Diagnostics

General Notes

It is important to remember that if any of the four motor driven capacitors are disturbed (rotated) by hand, the microprocessor will lose track of their positions. To reset the capacitors refer to the “Z" command as described in the procedure for RF Amp Firmware (20KW). Also, cycling the circuit breaker off and on will cause the amplifier to re-zero the motors as a part of its normal OFF to STANDBY function.

The two vacuum tube stages are normally run “open loop" meaning that there is no intentional RF or envelope feedback path **within** the amplifier. During AFT a form of feedback is used; the two phase detector outputs are driven to a “zero voltage condition" (nominally 2.5 volts) by iteratively stepping the “TUNE" capacitors to center the passband of the tuned circuits.

A phase detector false zero voltage condition can occur if the crystal oscillator section of the Solid State Amplifier Board has failed resulting in no output power to the internal load during AFT. If this condition occurs, power output during normal SIGNA operations may be below normal or even above normal, and the amplifier passband is likely to be skewed.

This Section is organized in a block format addressing “modes" of failure. Consult the most applicable subsection below for the symptoms present.

No BODY output or low BODY output, HEAD output normal.

Connect through-line attenuator(s) of 60 dB to J2804 (BODY output) on the RF Monitor Module. Connect a 50 ohm oscilloscope to the output of the attenuator. Synchronize the scope via its external trigger capability to the UNBLANK signal. Put the bandwidth limit control on the oscilloscope to off.

Place amplifier in BODY and OPERATE modes, and inject -4 dBm of gated drive at 63.860 MHz from the SIGNA system or other equipment into the amplifier's RF input connector (J2503). A 3 millisecond wide RF pulse repeated every 60 milliseconds (or more) is suggested.

The power to the oscilloscope should be about 20 milliwatts (13 dBm) which corresponds to about 1.4 volts peak for a 50 ohm system. If scope reading is within about 10% of desired value, the amplifier is probably functioning normally. The SIGNA output cable/connector in the amplifier rack may be defective, or the amplifier may be saturating prematurely (most likely poor tune or weak PA tube).

To check for saturation, lower and then raise the RF input by a few 1 dB increments. If the scope deflection changes by about 11% per increment, the amplifier is not saturating. Otherwise, the amplifier is saturating; perform the PA Phase Detector diagnostics below before changing the PA tube.

If the amplifier is responsible for the low BODY power (as deduced from above), remove the RF drive and bypass the RF Monitor by connecting the 60 dB through-line attenuator directly to the VTAC BODY output (J2603). This requires removal of the Motor Cavity Right Side Cover and defeating the cover interlock switch in the RF Monitor (see the procedure for Section 4-1 Equipment Safety Considerations). Re-apply the RF input drive and measure the output power. If scope voltage readings are now correct (as defined above), replace the RF Monitor Module.

If direct BODY output is still low, then the PA tube, perhaps one of the power supplies (+6 KV, + 100 V, or PA tube heater), or the RF relay K1 on the PA input board are the most probable causes. Gross mistuning due to a bad PA phase detector is less likely but should be checked before attempting a tube change.

Refer to the procedure for Section 4-7 Power Supply Diagnostics for diagnosing possible problems with the +6KV supply, the + 100 volt supply, and the PA tube heater supply.

RF Relay on PA Input Board

If the BODY output is very low at VTAC J2603 connector (50 mV peak or less at 50 ohm oscilloscope after 60 dB attenuator), vacuum relay K1 is probably not energized. This can be caused by either an open coil or a faulty relay driver.

Open the Left Side Cover and defeat the cover interlock switch in the AC Switching Module (see Section 4-1). Measure the DC voltage between feed-through capacitors C13 and C14 on the Processor Cavity bulkhead (marked +24V and RF RLY1). A reading significantly less than 23 volts (BODY mode) indicates that the driver (on the Processor Board) has failed (or relay coil has possibly shorted).

To test the relay coil, turn the amplifier completely off and measure the resistance between the same two capacitors. If the resistance is markedly higher or lower than 330 ohms (e.g. several kilo ohms or near zero), replace the PA Input Board.

PA Phase Detector

A simple test can be performed to determine if the PA Phase Detector is causing the amplifier to be grossly mistuned. Connect a 10:1 high impedance probe to a second vertical channel of the oscilloscope and set the scope to display 1 volt DC per division. Connect the scope to pin 15 of resistor pack RP148 on the Processor Board and chassis ground. Turn scope bandwidth limit “on".

Inject a -4 dBm signal into the amplifier as before and observe the oscilloscope. The steady state level during the time that the amplifier is BLANKed (i.e. no RF) should be somewhere near 2.5 volts DC (the “zero phase" condition). During UNBLANK (with RF pulse), the level should be within +/- 1 volt of the zero phase condition (2.5 volts). Slowly rotate motor shaft of MOTOR 3 by hand in both directions from its initial value. The phase detector output voltage should swing about +/- 2 volts to either side of the zero phase condition.

If the phase detector voltage remains permanently at one of the limits then check the SMA connectors on the PA Phase Detect Assembly for tightness; replace assembly if loose connectors are not the cause.

If the above diagnostics are inconclusive, perform the Amplifier Tuning and AFT diagnostic procedures in Section 4-6. The PA tube should only be replaced after all other tests pass. Refer to the tube changing instructions in the Service Manual.

BODY output normal, HEAD output low.

This condition should be easily traceable to one of three possible causes. First connect the 60 dB through-line attenuator and 50 ohm oscilloscope to the HEAD output port (J2803) as described above for HEAD normal, BODY low power diagnostic. Put the amplifier in HEAD and OPERATE, and apply -4 dBm of RF drive also as discussed above. The power into the oscilloscope should be about 2 milliwatts (3 dBm) which should be about 0.445 volts peak on the oscilloscope. If somewhere near this level is achieved, the SIGNA output cable/connector in the rack is probably defective.

Otherwise, bypass the RF monitor by connecting the attenuator/scope directly to P2602 connector on the VTAC. This requires removal of the Motor Cavity Right Side Cover and defeating the cover interlock switch in the RF Monitor (see Section 4-1). If the output power is now found to be correct, replace the RF Monitor Module.

The third possible cause is that RF relay K1 on the PA Input Board is stuck in the BODY position due to either mechanical failure, or a bad relay driver on the Processor Board. This situation would give a very low voltage swing on the oscilloscope (3 millivolts peak or less). The relay coil voltage should be zero volts as measured (HEAD mode) between feed-through capacitors C13 and C14 (marked +24V and RF RLY1 in the Processor Cavity). Replace the Processor Board if the relay is being energized (relay should only be energized in BODY mode). Otherwise, replace the PA Input Board since the relay being stuck is the only way for BODY output to be normal and HEAD output very low.

BODY output low, HEAD output low.

There are two primary possible causes of this condition: a defective IPA amplification stage or a defective Solid State Amplifier Board. Refer to Section 4-5-1 Solid State Amplifier Diagnostics and determine if the output power reaching IPA RF IN connector J2601 from the Solid State Amplifier is within specifications.

After the correct Solid State Amplifier power has been established, put the amplifier in the HEAD and OPERATE modes, inject a -4 dBm signal into the amplifier, and set up the 60 dB through-line attenuator and 50 ohm oscilloscope as discussed in the HEAD Low, BODY Normal section above. First connect the 60 dB attenuator to the RF Monitor HEAD output (J2803) and then to the VTAC IPA RF output (J2602) to measure output power. Scope bandwidth limit should be off. The VTAC output measurement requires that the Motor Cavity Right Side Cover be removed and the cover interlock switch be defeated (see the procedure for Section 4-1 Equipment Safety Considerations).

If a significant increase in output level is observed by bypassing the RF Monitor Module, replace it. The power into the oscilloscope should be about 2 milliwatts (3 dBm) which corresponds to about 0.445 volts peak in a 50 ohm system.

If the output power is still low at the VTAC output (J2602), check all IPA power supply voltages as discussed in the procedure for Section 4-7 Power Supply Diagnostics (IPA tube heater, +32 volt supply, and +3KV supply).

The remaining possible causes for low power in both modes are a bad (or misadjusted) VTAC IPA Input Board including mistuning due to a faulty IPA phase detector section, or a weak 3CPX800A7 tube.

Perform the Amplifier Tuning and AFT diagnostics in Section 4-6 to attempt to confirm proper tuning. Also, the PA Phase Detector procedure described on the previous page may be replicated for the IPA phase detect circuitry by looking at pin 1 of RP148 on the Processor Board and manually moving the shaft of MOTOR 2. This is useful if enough power is present to excite the detector (2.5 volts nominal should always be true during BLANKed periods).

If the IPA Input Board and the IPA tube are still both suspect, insert a known good tube (if possible) before changing the IPA Input Board. If the tube is permanently changed, refer to the tube retuning procedures the Service Manual.

Note

IPA Input Board - Prior to committing to an IPA input board change it may be worthwhile to check the tightness of the backnut on the BNC input connector J2601

High Voltage Arcs and Tube Arcs

A fault 81 or 86 simply means that the fault monitor has detected excessive current flow which is usually associated with an arc somewhere in the high voltage circuits (+3 KV or +6 KV). A true tube arc (within a tube) is essentially inaudible due to the tube vacuum. An external arc, which is clearly audible, can be caused by arcing over a dirty tube or more probably one of the 7.5 KV ceramic capacitors within the VTAC.

Since the IPA uses the same 7.5 KV capacitors as the PA, and is run at half the voltage, an arc in this stage is not nearly as likely. There are 7 capacitors within the PA stage that could produce this fault condition. Three are mounted between the PA anode strap and sheet metal inductor L10 (C8-C10); one is mounted on the amplifier top cover (C5), and three (C1-C3) are part of the VTAC Filter Board mounted on the bulkhead.

Low voltage resistance tests of the capacitors will not normally be adequate to detect a failed capacitor. The simplest approach to locating the source of an arc is a process of elimination by isolating certain capacitors from the circuit and placing the amplifier in STANDBY (this brings up the high voltage).

Start by disconnecting the PA anode RF choke (L9) at the tube anode, which will remove C8-C10 (and PA tube) from the HV path, and bring the amplifier to STANDBY. These three capacitors are the most likely source of external arcs. If an arc occurs, remove C5 and repeat. The only capacitors left are those on the VTAC Filter Board. Also, external arcs (with respect to tube) usually leave some trace such as black burn marks or small welds. Make a thorough visual inspection of the tube cavities.

WARNING!

ALWAYS TURN OFF THE AMPLIFIER MAIN POWER AND SHORT ALL CONTACTED VTAC AREAS TO GROUND BEFORE TOUCHING; THE HIGH VOLTAGE CAPACITOR BANK CAN RETAIN A SIGNIFICANT CHARGE. ALWAYS REPLACE THE VTAC RIGHT SIDE COVER WHEN TURNING AMPLIFIER POWER BACK ON.

Return to the procedure for Sections 4-1 through 4-4 of RF Amp Diagnostics (20KW).

4-6 Processor Board Diagnostics

General Notes

A problem on the Processor Board cannot (in general) be diagnosed by using the SCM control port alone. It is usually necessary to connect an RS-232 terminal (Data General, Boot Terminal) or a computer configured for 9600 baud, 1 start bit, 8 data bits, and 1 stop bit. An oscilloscope (preferably a storage scope) will also be needed. Access to the Processor Board is gained from the Processor Cavity with the AC Switching Module lowered to expose the board.

It will be most helpful to have read the procedure for RF Amp Theory-Microprocessor (20KW) on Processor Board theory. The procedure for RF Amp Firmware (20KW) discussion of microprocessor firmware, addresses, and commands will also be referenced frequently.

General Diagnostics

The first step in determining if the Processor Board is faulty is to establish serial communications with the on-board 68HC11 microprocessor. Connect the serial terminal and cycle the amplifier's main circuit breaker off and then on. The “hello" message should appear on the serial terminal. This message is a string of characters sent at the completion of the self test (fault codes 00-09). If a fault code 00-09 arises, replace the Processor Board.

The “hello" message contains a line identifying the amplifier and the firmware revision number, a line containing the serial number of the amplifier that the Processor Board (actually the microprocessor) was installed in (or for), a line indicating total amplifier on-time, two lines identifying the heater on-times of each tube, and finally a line indicating the fault status. If the “hello" message is not transferred, continue with the section below titled No Response.

If the hello message format appears, press the Enter key or type the serial command “S" several times. (Enter is also accepted as the command to return status). The microprocessor should return the string “ready" each time. If this does not occur, continue with the section below titled Incorrect Response.

It may be possible to clear a fault (particularly a microprocessor fault) by recycling the circuit breaker off and on a few times. If the indicated faults cannot be corrected by this method, continue with the procedure Fault Isolation.

No Response

This section is relevant to a Processor Board that does not send the “hello" message (see above) at power-on. This message is approximately 50 characters long and should be sent at 9600 baud, no parity, 1 stop bit. Failure to send this message is an indication that:

1) one (or more) of the power supplies is incorrect:

2) the RS-232 link is incorrect;

3) the oscillator is incorrect:

4) the microprocessor is operating in the wrong mode;

5) the microprocessor is in reset;

6) the microprocessor is being interrupted;

7) something is grossly wrong with the microprocessor.

These items are interactive and are difficult to test independently. The order in which they have been listed above is the order in which faults are most probable. Each item is addressed below.

1. There are two probable power supply failures: the + 5 volt (+/- 0.1 volt) supply and the -5 volt (+/- 0.5 volt) supply. If either of these power supplies is out of tolerance, check prior to the bridge rectifier (BR1) for the correct AC voltage of about 10 volts rms. This measurement will determine whether the problem is on the Processor Board or in the AC Switching Module (fuse, cables, transformer, etc.).

2. The RS-232 can be checked with an oscilloscope. After turning main power on, measure voltage at connector J2204, pin 2 (TxD from controller); it should be -5 volts DC. Pin 5 (CTS from external monitor) should be -3 volts to -12 volts DC. If these are correct, check for data transfer on TxD at the assigned baud rate (9600 usually, possibly 1200 if the microprocessor BAUD register has been altered; see the procedure for RF Amp Theory-Microprocessor (20KW)). If there is no data, the failure is probably on the Processor Board.

Note

Checking the External RS-232 Terminal - Be sure to check that the external RS-232 terminal is indeed operational before deciding to replace the Processor Board for an RS-232 failure

3. The microprocessor E-clock (U16, pin 27) should be a 2 MHz square wave, 50% duty cycle. If not, then either the microprocessor (U16) has failed or the main oscillator (consisting of R8, R9, C18, C19, Q1, and X1) is not working. Replace the Processor Board.

4. The microprocessor will operate in 1 of 4 modes depending on the state of MODA (68HC11 pin 24) and MODB (pin 25) pins at power-on. These two pins should be +5 volts resulting in the “external address mode". This mode can be identified after power-on as follows:

   a) U16, pin 27 “E" should be a 2.0 MHz square wave, 50% duty;

   b) pin 26 “AS" should be a 2.0 MHz square wave, 25% duty;

   c) pin 25 “MODA" should be an asynchronous square wave;

   d) pin 24 “MODB" should be +5.0 volts.

If any of these are incorrect, replace the Processor Board.

5. The 68HC11 /RESET pin 39 should be +5.0 volts DC. If it is fixed at TTL low, then circuitry on the Processor Board is most likely causing a reset. If pin 39 is low-going pulses (pulse width about 2 microseconds occurring every few milliseconds), then the microprocessor itself is causing the problem (watchdog is firing); replace the Processor Board.

6. Microprocessor pin 41 (/IRQ) should be +5.0 volts DC. If it is TTL low, then most likely there is a Processor Board problem associated with U13, U11 or U10. The RF MON and PCM lines should be verified to be correctly functional before replacing the Processor Board.

7. If more than one of the above, or perhaps all of the above are occurring, then a good assumption is that the microprocessor has grossly failed. Replace the Processor Board.

Incorrect Response

This section is most relevant if the Processor Board sends the “hello" message correctly, but does not respond to serial commands. This behavior is most likely an indication that:

1) the RS-232 communications is incorrect;

2) the amp failed its self-test;

3) the watchdog (COP) has fired;

4) something is grossly wrong with the microprocessor.

This section is similar to the “No Response" section above, except that the microprocessor appears to be partially functional since the “hello" message was sent. However, no apparently valid faults are indicated, only incorrect functioning.

1. If the “hello" message was received, the microprocessor portion of serial communications (at least output) is functional. Check the baud rate (9600), parity (none), data bits (8), start bits (1 +), and stop bits (1). Connect an oscilloscope to connector J2204 pin 3 (RxD), and attempt to transfer a few characters from the external serial computer. This will verify whether data is reaching the Processor Board correctly. If data transferal is valid, then the RS-232 circuitry on the Processor Board (maybe including the microprocessor) has failed. Replace the Processor Board.

2. The firmware self-test could fail in such a way that DTR (J2204 pin 20) is left false (-5 volts). For proper communications to occur, the microprocessor should be holding DTR high (+ 5 volts). This failure could prevent the terminal from transferring characters. If cycling the circuit breaker does not correct this problem, and the Processor Board is the source of the -5 volts, then replace the board.

3. The COP watchdog system requires firmware to reset the timer before it times out and forces an interrupt. If this does not occur, then the microprocessor and/or firmware is not operating properly. This situation can be identified by looking at the /RESET pin 39 (U16) which will go low for 2 microseconds every time the COP times out. If this is observed after cycling the circuit breaker, the microprocessor has failed; replace the Processor Board.

Fault Isolation

This section pertains to the most general of problems; that is, the serial communications is working, and a fault is displayed directly related to the Processor Board. Also, this section pertains to a fault code issued for another module, but that module does not seem to be faulty.

The possible problem areas on the Processor Board that could be the source of the trouble are:

a) Motor control,

b) Amplifier tuning and AFT,

c) FET bias control,

d) Analog fault testing.

Each of these topics forms its own section below. Proceed with the most likely candidate based on the fault code exhibited.

Motor Problems

First confirm that serial communications is working as detailed above.

The bottom motor is #1, counting up, with the top motor being #4. The motors can be independently turned to any location while the amplifier is in OFF mode using the serial “T" command:

T<n> <dest>
where n = 1,2,3, or 4 (motor #), and dest = 0 to 65535.

Note

Commanding a Motor Past its Maximum - An attempt to command a motor past its maximum will result in shifting the hardware limit (very noisy). This should not damage any of the hardware, but it should be avoided since the shaft couplings might slip leaving the amplifier mistuned.

The maximum physical step count for each motor is defined in Table 1 in the procedure for RF Amp Theory-Microprocessor (20KW).

CAUTION

The motor drivers can be damaged due to overheating. In the normal usage of the amplifier, the stepping motors are driven for mode changes and/or AFT only. The motor drivers are not designed to turn the motors for extended periods of time without the side panels in place.

The motors use a washer count ring to find the zero location and limit the number of steps. If the zero sensors fail, then mistuning will result. The motor positions can be sampled by reading the Address Codes (see the procedure for RF Amp Firmware (20KW), Commands and Codes). Also, permanent address location 7000h can be used to read the zero sensors to verify that the microprocessor is detecting zero. Absolute address 7000h is defined to be:

bit 0 = cover interlock switch 1;
bit 1 = cover interlock switch 2;
bit 2 = zero sense for MOTOR 1 (high indicates motor at zero);
bit 3 = zero sense for MOTOR 2;
bit 4 = zero sense for MOTOR 3;
bit 5 = zero sense for MOTOR 4;

Confirm that all four motors turn freely while driving their corresponding capacitors using either the serial “T" command or “Z" command. Return the motors to zero with the “Z" command, and confirm that each zero sensor is read correctly.

If all motors fail to turn, the +32 volt supply (from the Power Control Board to the Processor Board) should be examined. If the +32 volt supply on the Processor Board is correct, then the problem is probably on the board; replace it.

If at least 1 motor turns correctly, determine whether a motor assembly or a motor driver (U21 or U22) has failed. Try driving the nonworking motor with a driver from a working motor by connecting the suspect motor harness to a known working connector (P2205-P2208). Be sure to note which connector (P2205-P2208) is the driver when using the “T" command, and return all motor harnesses to their original connectors when finished. Also, try driving a working motor with the suspected driver.

The results of these last tests will determine whether the problem is the motor itself or the driver located on the Processor Board (or perhaps a cable problem from a driver to a motor). If one of the motor driver chips has failed, replace the Processor Board.

Amplifier Tuning and AFT

This section pertains to an amplifier that can be brought into STANDBY and switched between HEAD and BODY modes. The attempt to bring it into OPERATE causes the amplifier to be mistuned (bandwidth skewed or forward power insufficient) or displays a tuning related fault code (forward power too high or perhaps high plate currents). This section also assumes that other more likely candidates such as Solid State Amplifier and VTAC problems have been more or less ruled out.

Make certain that AFT is enabled (see the procedure for Amp Firmware (20KW)), and command the amplifier into STANDBY. There are 2 EEPROM addresses which control the enabling of AFT. B62Bh is the global AFT enable byte where 00 enables AFT, and anything non-zero (normally FFh) disables it. The serial commands “A+" (writes 00) and "A-" (writes FFh) should control AFT. Confirm this by executing “A+" and “A-". If this does not work (read the EEPROM), then the Processor Board has failed.

Also relevant is EEPROM address B625h which dictates whether or not the PA Phase Detector is to be used for BODY mode tuning. A 00 bit value indicates the detector is enabled, FFh (or anything non-zero) indicates it is disabled. The AFT algorithm depends on whether or not the PA Phase Detector is enabled.

If AFT is enabled, then it will occur whenever the amp is brought from STANDBY to OPERATE, and will occur regardless of a mode change having occurred previously. If the PA Phase Detector is enabled, then the AFT algorithm will be tune IPA, tune PA, tune IPA, tune PA, OPERATE; otherwise AFT will be tune IPA, OPERATE.

Command the amplifier into the desired mode, remove RF input (including UNBLANK), and bring the amp into OPERATE. When the amplifier is in OPERATE, read motor positions 1 and 3 (only MOTOR 1 in HEAD mode). The motor positions are found in RAM Address Codes (see Table 15 in the procedure for RF Amp Firmware (20KW)).

Execute AFT by commanding the amplifier to STANDBY and then back to OPERATE. Compare the positions of the IPA and PA tuning capacitors (MOTORs 1 and 3) with the positions taken from the first AFT. If these two compare within 10 steps for MOTOR 1, and within 50 steps for MOTOR 3, then AFT is most likely working correctly. Try the procedure a few more times to ensure that AFT is working consistently. If the motors do not turn at all, check the AFT enable, and refer to Motor Problems above.

If the motors are turning, but AFT is not working correctly, it is possible that the Solid State Amplifier oscillator has failed. Perform the Solid State Amplifier diagnostic section to verify correct oscillator function. If the Solid State Amplifier is not the problem, refer to the VTAC diagnostics to check the phase detectors.

If the motors are turning in response to AFT, then the microprocessor is probably not the problem. However, it is possible that an A/D conversion on the Processor Board is not occurring correctly. Refer to Analog Testing below.

FET Bias Control

Perform these diagnostics if the FET bias network on the Solid State Amplifier Board has identified the FET bias network as faulty, and the problem is apparently not on the Solid State Amplifier.

Note

Solid State Amplifier Diagnostics - Perform the Solid State Amplifier diagnostics first. Any biasing problem with the FETs is most likely located on the Solid State Amplifier Board.

The only problems in FET biasing which can be caused by the Processor Board are the bias targets, serial SPI problems, one A/D channel, and the 0-20 volt DACs used for fine adjustment on the Solid State Amplifier.

A very useful routine for this section of diagnostics is the “ballpark" routine as discussed in the theory sections of Section 2. During normal operation, the ballpark routine is executed as the last step going into STANDBY. It is possible to invoke the ballpark routine with the serial “F" command by using the serial “MW" command to load the “FCMD" EEPROM addresses as follows:

“MWB629 C0" = address of BALLPARK (msb)

“MWB62A 0C" = address of BALLPARK (lsb)

“F" = execute routine.

Each time the “F" command is transferred, the routine will be executed.

The best approach to diagnosing FETs is to use the “F" command to observe the functioning of each of the relevant portions of the biasing system named above.

First confirm the FET bias target currents are correct by reading the RAM Address Codes. It is unlikely that this has failed, but they can be easily verified.

Next observe the FET bias signals (FET1 BIAS - FET4 BIAS) at the outputs of U47-U50 on the Processor Board. The outputs will step from 0-20 volts maximum (20 volts is full range and will probably not be reached during a normal bias algorithm). If there is no output at one of these DACs, replace the Processor Board.

Finally, observe the SPI communications on the MOSI2 line (U27) while issuing an “A" command to address the Solid State Amplifier. This is not a very likely Processor Board problem, or the Front Panel display would also most likely be incorrect. Illustration L3007A and Illustration L3008A in the procedure for RF Amp Theory-Microprocessor (20KW) illustrate the SPI timing.

Analog Testing

This section is intended to provide information for utilizing the Processor Board A/D conversions for general amplifier diagnostics. There really is very little that can actually fail with the Processor Board portion of A/D sampling; the multiplex switches could fail, a connection could become loose or noisy, a resistor could open, or the microprocessor itself could fail. None of these is very likely to occur on a board that has worked in the past. The most likely cause of incorrect A/D samples is the source of the sample.

As mentioned in the Theory of Operation Section, thirty-two analog test points within the amplifier are sampled and tested by the microprocessor. A complete listing of the A/D Address Codes, targets of samples, A/D conversion values, and fault limits is provided in Table 2 in the procedure for RF Amp Theory-Microprocessor (20KW). All A/D channels may be read through the SCM or serial interfaces as described in the procedure for RF Amp Firmware (20KW) Section.

One very useful feature of the amplifier is the capability of providing an internally generated RF pulse to update the A/D readings. This feature is known as the “blast mode". There are four possible versions of the “blast mode" executed with the serial “B" command:

“B1": head mode to head port output;

“B2": head mode to 50 ohm dummy load in RF Monitor Module;

“B3": body mode to body port output;

“B4": body mode to 50 ohm dummy load in RF Monitor Module.

The “blast modes" utilize the Solid State Amplifier's on-board 63.86 MHz oscillator which is normally used for AFT. In all four blast modes, the full power of the oscillator will briefly be unblanked, amplified, and routed to the specified output. This is approximately equivalent to a single RF pulse 100 microseconds wide at approximately -13 dBm input put through the system. After this pulse has completed, all of the RAM variables and A/D samples will be updated by the pulse and may be read to provide useful information.

4-7 Power Supply Diagnostics

Amplifier power supply diagnostics may be subdivided into three subsections: the AC Switching Module, the High Voltage Rectifier/Filter Board, and the Power Control Board. Each of these areas is covered separately in the three following Sections.

It will be very helpful to be familiar with the procedure for the Theory of Operation descriptions in Section 2-3. The A/D sampling of the power supplies by the microprocessor is also an extremely helpful diagnostic tool. Therefore, the procedure for RF Amp Firmware (20KW) will also be referenced extensively.

Some of the diagnostic procedures require measurements to be made on the amplifier while power is on. See the procedure in Section 4-1 for a discussion of the cover interlock switches and the procedure for defeating them. Pay particular attention to the cautions noted there.

WARNING!

LETHAL VOLTAGES AND CURRENTS EXIST WITHIN THIS AMPLIFIER. PLEASE FOLLOW ALL WARNINGS AND CAUTIONS NOTED. SPECIAL HIGH VOLTAGE TEST PROBES ARE REQUIRED TO DIRECTLY MEASURE THE HIGH VOLTAGE SUPPLIES. ANY SUCH PROBE SHOULD BE USED EXTREMELY CAREFULLY. CONSULT SCHEMATICS AND INTERCONNECTION DIAGRAMS THOROUGHLY TO DETERMINE THE DISPERSION OF HIGH-LEVEL VOLTAGES. SHORT ALL PARTS TO BE HANDLED TO GROUND AFTER AMPLIFIER MAIN POWER IS TURNED OFF; SEVERAL LARGE CAPACITORS ARE USED IN THE AMPLIFIER.

4-7-1 AC Switching Module Diagnostics

Introduction

The AC Switching Module performs all of the AC line switching and distribution functions required by the amplifier. The module is designed to be easily replaced in the field in case of a failure. Note that dangerous voltages are present within this module and great care must be taken to avoid electrical shocks.

Many power supply voltage problems can be tracked down to fuse failures. Therefore, it is recommended that one start there when trouble shooting power supply problems. Fuse assignments are described in the procedure for Section 4-3 and on the AC Switching Module schematic 86-013-2110.

Three-phase line power with a safety ground is required by the amplifier. The rated line to line voltage is 208 volts AC (+/- 10%). All three phase-voltages must be present for proper operation of the amplifier's power supplies. Each phase-voltage may be measured on the screw terminals terminating the line cord wires in the AC Switching Module rear panel circuit breaker. The line to safety ground (green/yellow wire marked with a circled ground symbol) nominal voltage in a 208 volt three-phase balanced system is 120 volts AC.

A neutral power return conductor is not needed for this design since all of the amplifier's loads are line to line. Phase rotation of the three-phase power is also not critical, and is therefore not specified for this amplifier.

Fuses

Fuses are used to protect many of the circuits within the amplifier. Section 4-3 Fuse Bank describes the fuse locations and functions as well as the ampere ratings to be used. Turn off the amplifier's rear panel circuit breaker to remove dangerous voltages before removing any fuses for inspection and test.

The best method of checking the “slow blow" fuses used in the amplifier is a resistance test using an ordinary ohmmeter. The DC resistance of a good fuse should be less than two ohms. Replace any fuses with DC resistances substantially higher than this. Be sure to replace fuses as marked on the amplifier.

Control Power Section

Transformer T1 provides two voltages which are used to power continuous control circuits in the amplifier. A dual 10 volt-rms secondary winding is used by the Processor Board for +5 volt and -5 volt regulated supplies. A 25 volt-rms secondary winding powers the +32 volt supply from which the +24 volt regulated supply is also derived. These windings must always be powered when the amplifier's rear panel circuit breaker is on.

A quick test of the +5 volt supply and circuitry is to observe the Front Panel Display Board indicators. If any LED is lit, at least a partial excitation of the +5 volt supply must be occurring. A quick test of the 25 volt-rms winding is to measure the +32 volt supply voltage.

Fuse F3 and F6 protect the T1 transformer primary winding, and fuses F1 and F2 protect the 10 volt-rms secondary windings. However, the 25 volt-rms winding has an embedded thermal fuse which will permanently open if the transformer winding exceeds an elevated temperature. The 25 volt-rms transformer voltage can be measured on the AC Switching Module's rear panel connector J2101 pins 11 to 12. If there is no AC voltage output from the 25 volt-rms winding, replace the AC Switching Module.

The two 10 volt-rms winding voltages can be measured at J2102 pin 3 to 2 and 3 to 4. If these voltages are not correct, check the fuses. If the fuses are not high impedance and the 25 volt-rms output is correct, replace the AC Switching Module.

Low Voltage Power Switching

The low voltage power switching is done with relays K1 and K2. Relay K1 applies power to the two front panel fans through fuses F7 and F8, to the tube cooling Blower Assembly through fuses F4 and F5, and soft starts the +100 volt power supply through fuses F10, F11 and F12.

The +100 volt supply soft-start is accomplished by using 300 ohm resistors to limit the inrush current in two of the three Low Voltage Transformer primary phases. Power switching relay K2 bypasses the current limiting resistors after the filter capacitors receive their initial charge. The soft-start is performed while there is no load on the supply.

A fault 50 or 51 indicates an unsuccessful soft-start sequence. This could result from a missing phase due to relay K1 failure, open fuses F10, F11 or F12, open connector J2101, J2001, or J2402, shorted or open rectifier diode on the Power Control Board (D26 through D31), or a load on the +100 volt supply. The two primary loads on the +100 volt supply (the +48 volt supply regulator and the PA tube heater regulator) should not be enabled by the microprocessor during this time.

Check all fuses for high impedance and replace as needed. See Section 4-7-3 Power Control Board Diagnostics for a detailed diagnostic description of the +100 volt supply.

High Voltage Power Switching

The high voltage power switching is done with relays K3 and K4. Both the +3KV and +6KV supplies are powered from the same three phase rectifier 4.5KVa HV Transformer. The soft-start of these supplies is accomplished by using 100 Ohm resistors to limit the inrush current in two of the three transformer primary phases. Power relay K4 (or solid state switches SW1 and SW2 in AC Switching Module 2) bypasses the current limiting resistors after the filter capacitors receive their initial charge. Refer to Section 4-7-2 High Voltage Power Supply Diagnostics for diagnostics of the high voltage power supplies.

Circuit Breaker Trips

The circuit breaker in the AC Switching Module is used to protect the amplifier wiring and the 4.5KVA HV Transformer against failures not protected by the arc detect and overload circuitry. The circuit breaker is also used as the line disconnect switch.

The breaker should never trip for an overload on a non-high voltage power supply. The protective fuses will always open before the breaker trips (if they are the proper size).

The most probable causes of a circuit breaker trip are a shorted 4.5KVA HV Transformer primary or secondary winding, a high voltage short while in STANDBY or OPERATE, a high voltage arc with a faulty arc detector circuit, welded K4 relay contacts in AC Switching Module (not possible in AC Switching Module 2), and excessive duty cycle of high power RF pulses.

4-7-2 High Voltage Power Supply Diagnostics

Introduction

The +3 KV and +6 KV high voltage power supplies are located in the bottom High Voltage Cavity. The three-phase 4.5 KVA HV Transformer connects directly to the High Voltage Rectifier/Filter Board. The AC Switching Module provides control of the 208 volt three-phase line power required by the transformer primaries. Both of the +3 KV and +6 KV supplies are controlled simultaneously by relays K3 and K4 (K4 is replaced by solid state switches SW1 and SW2 in AC Switching Module 2) in the AC Switching Module.

WARNING!

DANGEROUS VOLTAGES ARE GENERATED WITHIN THE HIGH VOLTAGE POWER SUPPLY CIRCUITRY. THESE VOLTAGES CAN KILL! SPECIAL HIGH VOLTAGE TEST PROBES ARE REQUIRED TO MEASURE THESE VOLTAGES DIRECTLY. ONLY USE EQUIPMENT RATED TO ABOVE 10 KV ON THESE CIRCUITS. BEFORE ACCESSING THE HIGH VOLTAGE CIRCUITRY, WAIT AT LEAST THREE MINUTES AFTER TURNING OFF THE AMPLIFIER'S REAR PANEL CIRCUIT BREAKER. ALWAYS DISCHARGE THE +3 KV AND +6 KV POSITIVE SUPPLY TERMINALS WITH A GROUNDING STRAP BEFORE WORKING WITH THE HIGH VOLTAGE CIRCUITRY.

High Voltage Supply Starting Problems

Both the +3 KV and +6 KV supplies are soft-started at the same time. The soft-start limits the inrush currents into the transformer and subsequently through the rectifiers into the filter capacitors. The capacitor filters store hundreds of Joules of energy and take a substantial time to fully charge up. Multiple microprocessor tests are made on the supply voltage during the charging process. A supply component or load problem reducing the voltage on one supply may be reflected as a low voltage on the other supply; this can make it hard to distinguish the origin of a problem.

Possible sources of a high voltage supply soft start problem are:

1) missing phase-voltage on the transformer primary;

2) shorted winding in the transformer;

3) shorted or open high voltage rectifier diode;

4) load on a supply.

Each of these problems are diagnosed as discussed below.

1. A missing phase-voltage is most likely traceable to the AC Switching Module or connectors. First, check the AC line power on the circuit breaker in the AC Switching Module on both sets of terminals (with breaker on). Secondly, check the resistors R1 and R2 in the AC Switching Module. Finally, observe the soft-start voltages being enabled as going into STANDBY at the AC Switching Module output connectors J2101 and J2006. These steps should verify the existence of the three phase-voltages.

2. The 4.5KVA HV Transformer primary and secondary windings may be checked for opens or shorts with an ohmmeter. Turn the circuit breaker off and measure the primary winding resistances at the J2006 connector and the secondary winding resistances at the “W" terminals on the HV Rectifier/Filter Board.

3. Use a diode checker to verify the operation of diodes D13 through D24 on the HV Rectifier/Filter Board.

4. A soft-start load can be discovered by disconnecting +3 KV and +6 KV cables (one at a time) from the HV Rectifier/Filter Board and restarting the amplifier. If the soft-start fault goes away, the most likely sources of the problem are the tube bias circuitry, the 7.5 KV ceramic capacitors, and the vacuum tube.

High Voltage Run Problems

High voltage problems at the run stage are a little different from soft-start problems in that the system has been running at proper voltage during the soft-start sequence. High voltage run problems may be broken down into two classes: unacceptable voltage faults, and arc related faults. Each of these is discussed below.

1. Unacceptable voltage faults most likely represent a low voltage condition. The first step is to check for low, high, or varying line voltage during STANDBY and during high power operation.

Another cause of these faults is unusually long and frequent UNBLANK commands. This may be checked at the PCM port.

The other most probable cause of this condition is due to the tube bias circuitry or the tube itself. Check tube cathode bias levels on the Power Control Board (Section 4-7-3 Power Control Board Diagnostics), and check for tube failure by reading the RAM Address Codes associated with plate and grid currents during OPERATE. High values (beyond target values) are a sign of a failing tube.

2. Arc related faults indicate that an extremely high load current on either the +3 KV or +6 KV power supply has occurred. Such currents are usually due to an arc condition either within a vacuum tube, across an air gap or inside a high voltage component. Tube arcs usually (but not always) burn off sharp points within the tube and subside quickly. An arc inside a tube usually cannot be heard; whereas, external arcs (in the air) usually sound like a sharp crack.

Surface contamination on high voltage parts caused by finger prints or dust can establish an arc path. Cleaning these surfaces will reduce the possibility of ion tracking of the surface which results in a lower voltage breakdown potential.

High voltage component failures are not always detectable by visual inspection. Internal breakdowns may not leave evidence on the outside surface. The breakdown may also only occur at elevated voltages making ohmmeter testing only effective for severe failures.

Visual inspection and component isolation are the two recommended diagnostic techniques for finding high voltage breakdowns. The fault code defines which tube stage to investigate. Look for arc tracks, cracked components and smoke deposits to pinpoint defective component location. Progressively disconnecting the tube and its high voltage circuitry and restarting the amplifier can be used to isolate the faulty component.

4-7-3 Power Control Board Diagnostics

Introduction

The Power Control Board contains many complex and interactive circuits. It is designed to be a field replacement module requiring no field adjustments. Always check the fuses in the AC Switching Module relevant to the power supply circuitry on the Power Control Board as the first step in diagnosing power supply problems. Also note that often a low power supply voltage is not due to a faulty supply but an abnormal load condition.

Diagnosing problems in the Power Control Board may be complicated by the protective actions of the microprocessor. Invalid voltages and over current conditions will generate a fault condition and a power supply shutdown. A trial Power Control Board substitution can often be the most effective trouble shooting technique for some failures.

+32 Volt Supply

The +32 volt supply should be powered continuously if AC power is being supplied to the amplifier with the rear panel circuit breaker on. The transformer and fusing are located in the AC Switching Module. A convenient test point to measure the +32 volt supply voltage is on the Power Control Board wire through FB12 near connector P2402.

If +32 volts is missing, look at the fuses F3, F6 and F9. Then check connector J2101 for the 25 volt-rms (nominal) output from the AC Switching Module. If the AC voltage is present, then either the bridge rectifier BR1 is bad, or a load is pulling the supply down. If possible, try replacing the Power Control Board, or try removing the loads from the supply (see Table 4 in the procedure for RF Amp Theory-Power Supplies (20KW)).

+24 Volt Regulated Supply

The +24 volt supply is powered from the +32 volt supply and is active whenever the circuit breaker is on. The +24 volt supply is of a complex design incorporating foldback current limiting for protection. The circuit has been adjusted at the factory utilizing calibrated loads to set the current limit point. These adjustments should not need to be made in the field. The current limit circuitry, if misadjusted, can disable the voltage regulator.

If the +24 volt supply is low (test point TP7), first check for proper +32 volt supply voltage at FB12 and for + 12 volts at the anode of D33. The supply's load current may be deduced by measuring the voltage across R98. The supply is in current limit if pin 6 of U9 is below 5 volts. If current limit or very high current exists, attempt to isolate the load (see Table 4 in the procedure for RF Amp Theory-Power Supplies (20KW)).

The microprocessor also can shutdown the regulator through “FLT 3". Check to see if pin 2 of U10 is above 0.4 volts. If it is, try putting pin 2 to ground temporarily to see if the regulator begins working. If it does (including no current limit), the Processor Board is at fault.

Also check the regulator's reference voltage at pin 6 of U10. This voltage should be between 6.8 to 7.5. If not, replace the Power Control Board. If the +24 volt supply is high, check Q27 for shorted emitter to collector and R92 for an open wiper (adjustment should adjust voltage). Replace the Power Control Board.

+100 Volt Supply

The +100 Volt supply is an unregulated supply operating around 100 volts nominally. Three-phase power to its transformer comes from the AC Switching Module. The supply is soft-started through 300 Ohm resistors in two of its three primary lines when power switching relay K1 closes. This limits the inrush current to the transformer, rectifier diodes and filter capacitors on the Power Control Module.

The soft-start occurs at the same time as AC power is switched to the fans and blower (immediately as commanded into STANDBY). The soft-start sequence terminates approximately one second later when power relay K2 bypasses the current limiting resistors. If the fan and blowers don't turn on with a “go to standby" command, the problem is either the Processor Board or the AC Switching Module

+100 Volt Supply Start Problems

The most probable sources of a +100 volt supply soft-start problem are:

1) missing phase to the Low Voltage Transformer primary,

2) shorted or open winding in the Low Voltage Transformer,

3) shorted or open rectifier diode,

4) load on the supply.

Each of these items is diagnosed as discussed below.

1. A missing phase-voltage is most likely due to a problem in the AC Switching Module or in the transformer itself. First, check AC line power in the AC Switching Module both before and after the circuit breaker. Also check the resistors R3 and R4. Finally, look at the output connector J2101 to observe the soft-start voltage output.

2. Check the Low Voltage Transformer primary and secondary winding resistances at connector J2001 for shorts or opens.

3. Use a diode checker to verify the function of diodes D26 through D31 on the Power Control Board.

4. Check the +48 volt supply and the PA tube heater supply for activity during the soft-start sequence. These supplies should not be enabled until after the soft-start sequence.

+100 Volt Supply Run Problems

An unacceptable +100 volt supply voltage during normal amplifier operation would be due to lack of input power, a defective component in the +100 volt supply circuitry, or an excessive load on the supply. All of the diagnostic steps covered above for the soft- start problems apply.

+48 Volt Regulated Supply

The +48 volt supply is a single ended switching-type powered from the +100 volt supply. Current limiting circuitry is built in which will limit the output current to slightly over 2.5 Amps to protect the supply during fault conditions. This supply is used only for the high power RF FET stages on the Solid State Amplifier Board.

CAUTION

High voltages and large quantities of stored energy (external 50,000 microfarad capacitor) require cautious actions when working with the +48 volt supply circuitry. The power switching FET used can be destroyed by excessive gate to source voltages. Be very careful with scope and voltmeter probes.

If the +48 volt supply regulator output voltage is greater than 50 volts (test point TP1) after the +100 volt supply soft start, the failure is on the Power Control Board; replace it.

If the +48 volt supply regulator output voltage is lower than 45 volts after the +100 volt supply soft-start, check Q2 source lead for the presence of +100 volts. If not, replace the Power Control Board.

Check to see if the regulator is in current limit by looking at the voltage drop across R1 and for a voltage greater than 0.4 volts at pin 1 of U1. If the supply shows high current, attempt to isolate the load (probably Solid State Amplifier FETs).

The +48 volt supply regulator is controlled by the microprocessor, if pin 4 of U1 is - greater than 0.5 volts, check the /ENABLE line for a valid low logic. If not, the problem may be on the Processor Board.

If any of the below items are invalid, replace the Power Control Board:

1) pin 14 of U1 reference voltage between 4.75 and 5.25 volts;
2) pulse width ramp signal on pin 5 of U1 is 50 to 60 KHz, 0 to 3 V sawtooth;
3) pin 9 of U1 drive current pulse (0 to about 10 volts);
4) pin 9 of U1 drive current present but Q2 drain static.

PA Heater Regulated Supply

The PA tube heater regulator is a floating push-pull transformer-coupled design powered from the +100 volt supply. This isolation is required because the PA tube's cathode is internally connected to its heater. Measurements on the PA tube heater supply output circuitry past T1 must not be made referenced to ground because of complications from the PA tube's bias circuitry. The loaded (tube heater on) output voltage is factory set to 15.2 volts to compensate for wiring losses.

CAUTION

High voltages and large quantities of stored energy require cautious actions when working with this circuitry. The power switching FETs may be destroyed by excessive gate to source voltages. Be very careful with scope and voltmeter probes.

The PA tube heater supply regulator is normally enabled about one second after the amplifier receives the “go to standby" command. The PA tube heater itself has a very low resistance when it is cold, and the regulator will initially start in current limit of about 18 Amps. The output voltage will gradually climb to 15.2 volts over a period of about 10 seconds as the heater warms up. The supply output current will then stabilize at about 15 amps.

The output current can be estimated by measuring the voltage on pin 16 of U2 and multiplying by 10 for amps (1.5 volts = 15 amps).

PA Heater Supply Starting Problems

The PA tube heater current is measured during the start phase when the heater is cold. If the start current is low, check the cold tube heater for a resistance on the order of 0.15 ohm at both connector J2404 and the terminals above the Blower Assembly labeled PA HTR +/-.

If the start current is high, replace the Power Control Board.

PA Heater Supply Run Problems

The PA tube heater supply current limits may be used to detect PA tube heater failures. The lower limit is about 12 Amps, and the upper limit is around 16 Amps. The typical heater failure will drop its current to about 60% of normal (8 to 9 Amps) because one of the two heater wires opens up.

Diagnosing a genuine tube heater failure and a PA tube heater supply failure may be done as discussed below. The currents indicated in the discussion are calculated from the voltage on pin 16 of U2 as noted above.

If the current is less than 12 Amps and the output voltage measured across test points TP3 and TP2 is about 15 volts, then most likely the tube heater is bad or the wiring is bad. Measure the resistance of the tube heater at the terminals above the Blower Assembly and the resistance of the heater and heater wiring at connector J2404. If the resistance measurements are about one ohm or less, replace the Power Control Board.

If the current is less than 12 amps and the output voltage is also low (less than 15 volts), replace the Power Control Board.

If the current is greater than 16 Amps at about 15 volts output, check for a cable harness short. If the impedance is greater than 0.15 ohms, replace the Power Control Board.

If the current is greater than 16 Amps and the output voltage is greater than 15 volts, then replace the Power Control Board.

IPA Heater Regulated Supply

The IPA tube heater supply is of a linear design powered from the +32 volt supply. The regulator is controlled from the microprocessor and is enabled at the same time as the PA tube heater supply and the +48 volt supply. The IPA tube heater itself is an isolated load and presents a relatively constant load resistance after warm up. Therefore, the regulator is not required to operate over a wide dynamic range. Most of the tube heater current is provided through two fixed resistors, R106 and R107. A variable current is supplied through R105 and regulator VR2. This design automatically limits the inrush current to a cold tube heater. The IPA tube heater supply current can be measured by the voltage drop across R47 which is in the return current path from the tube heater. One volt represents one amp of current.

IPA Heater Supply Start and Run Problems

The microprocessor checks for gross heater current errors one second after receiving the “go to standby" command. After 15 seconds the tube currents are more closely watched, and faults are reported as run problems (fault 14). The diagnostic procedures below apply to any IPA heater fault.

If the current is less than 1 amp and the output voltage at test point TP4 is greater than 15 volts, check the IPA tube heater wiring across TP4 and R48 for resistances greater than 8 ohms. If the resistance is lower, replace the Power Control Board.

If the current is less than 1 amp and the output voltage is under 15 volts, then the regulator circuit has failed; replace the Power Control Board.

If the current is greater than 2 amps and output voltage is less than 15 volts, then check for a cable harness wiring short at connector J2404. If the resistance is greater than one ohm, replace the Power Control Board.

If the current is too high and the output voltage is greater than 15, then the regulator has failed; replace the Power Control Board.

Tube Bias circuitry

The tube bias circuitry controls the operating and cutoff cathode to grid bias voltages for both the IPA and PA vacuum tubes. The operating bias levels are dependent upon the anode voltage and vary from tube to tube. Cutoff bias is required while the amplifier is blanked. Idle current bias is applied to the tube only at the beginning of the UNBLANK period except for the initial bias level set by the microprocessor.

The circuitry utilized by the IPA tube is duplicated with only a few minor variations for the PA tube. The following diagnostics directly relate to the PA circuitry but note where the IPA circuitry may deviate in procedure.

The +3 KV and +6 KV high voltage power supplies can experience problems in their soft- start sequence if the proper tube cutoff bias is not present on the tubes. The lack of cutoff bias problem may reside in a number of places; the following tests will help identify its location.

Check the PA tube cathode voltage at TP6 (IPA tube voltage at TP5) for greater than 100 volts during STANDBY wait (IPA at 32 volts). A low voltage on this line will allow the vacuum tube to conduct current during the high voltage soft-start sequence and result in a fault. The source of this problem can reside on the Power Control Module or with external circuitry (VTAC, HV Rectifier/Filter Board).

Check the TP6 voltage about one second after commanding the amplifier to STANDBY on with connector J2404 disconnected. It should rise up to 100 volts before a tube heater fault returns the system to off (IPA TP5 voltage should be at 32 volts). If the voltage is low, then the problem is probably on the Power Control Board. If the voltage properly returns, then the investigation moves to the external circuitry.

Check the High Voltage Rectifier/Filter Board diodes D1 and D12, the IPA Input Board diode D1, and the PA Input Board diode D1 (isolate the cable harness by unplugging connector J2701, and use an ohmmeter measurement to ground to detect a shorted diode in the VTAC). Also, check the IPA cathode, the PA cathode, and heater wiring for ground faults.

The/PA GATE and /IPA GATE signal lines should be at +5 volts. This signal comes from the Processor Board.

PA and IPA Idle Current Problems

The range of the PA cathode bias generator is +20 to +50 volts, and the IPA cathode bias generator range is +1 to +21 volts. The PA cathode is pulled down from its +100 volt cutoff bias voltage to this bias generator level for periods of less than 20 milliseconds (UNBLANK). The IPA cathode is pulled down from its cutoff bias voltage of +32 volts to its bias generator level during UNBLANK. A digital storage oscilloscope will prove useful in observing these bias transitions.

The Processor Board has two DACs used to set the idle current bias voltages. Buffer amplifiers on the Power Control Board convert these control voltages into rigid bias voltages for the tube cathodes during UNBLANK. DAC output voltage spans are 0 to +20 volts.

The IPA bias voltage on Q21's drain lead should directly reflect its “IPA BIAS REF" DAC control voltage. In STANDBY, this voltage should be +20 volts. The PA bias voltage as measured on Q23's drain lead should span the +20 to +50 volt range and reside at +50 volts during STANDBY, which is due to a "PA BIAS REF" DAC control voltage of +20 volts.

Observe the drain voltage of Q23 during STANDBY. If it is not close to +50 volts with the PA BIAS REF voltage at +20 volts, replace the Power Control Board. The same observation holds for the IPA bias generator if Q21's drain voltage is not close to the +20 volt IPA BIAS REF.

If the DAC voltages (PA and IPA BIAS REF voltages) themselves are not close to the full +20 volts in STANDBY, look for problems with the DAC circuitry on the Processor Board.

REVISION HISTORY

REV	DATE	AUTHOR	PRIMARY REASONS FOR CHANGE
0	June 3, 1998	J. Saperstein	Initial Conversion from Toolbook to Word.
1	Sept 27, 1999	Hawthorne	Combined the 4 130501 docs to one.