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HIGH POWER LINEAR RF PULSE AMPLIFIER

Model 50-S26B-128

4975 NORTH 30th STREET

COLORADO SPRINGS, COLORADO 80919

UNITED STATES OF AMERICA

October 2005

MKS Part No. ZMX-X191
Revision C

Table of Contents

1.0 PRODUCT DESCRIPTION

The model 50-S26B-128 is a Single Channel linear, pulsed, RF power amplifier intended for use as part of a 3T Magnetic Resonance Imaging (MRI) system.

This model is Class 1, ordinary equipment without applied parts. It is to be used in an area where no flammable anesthetics or gasses are present.

The system has been designed to comply with IEC-601-1. It is certified to the Safety Directive.

1.1 SAFETY CONCERNS

The amplifier must be installed, operated, and serviced by qualified personnel.

The model 50-S26B-128 is capable of delivering in excess of 35,000 watts peak RF power at 128 MHz into a 50-Ohm load. This power level can cause severe RF burns and other injuries if misused. Never operate the amplifier without properly terminating it into a suitable load.

The user accepts full responsibility for the proper use of the amplifier and for all safety issues concerning the use of RF power for medical purposes.

1.2 SAFETY WARNINGS

LETHAL VOLTAGES ARE PRESENT INSIDE THE AMPLIFIER. DO NOT OPERATE THE AMPLIFIER WITH THE COVERS REMOVED.

DO NOT PLACE HEAVY OBJECTS OR LIQUIDS ON TOP OF THE AMPLIFIER.

DO NOT BLOCK THE AMPLIFIER COOLING AIR INTAKE OR EXHAUST PORTS.

SAFETY STATEMENTS ARE PROVIDED IN APPROPRIATE AREAS THROUGHOUT THIS MANUAL.

MKS IS NOT RESPONSIBLE FOR CORRECT INSTALLATION, APPLICATION, USE, OR PATIENT SAFETY, WHEN THIS AMPLIFIER IS USED IN A MAGNETIC RESONANCE IMAGING OR OTHER SYSTEM.

1.3 FACTORY TECHNICAL ASSISTANCE

MKS will make available on request information to assist the user's appropriately qualified technical personnel to repair those parts of the amplifier, which are designed and designated as a Field-Repairable Unit (FRU).

1.4 PRODUCT IDENTIFICATION

The RF Amplifier system has a serial number label attached to the rear of the amplifier.

This label contains the following information:

Model Number:	50-S26b-bbb where b = revision (if applicable) bbb = operating frequency range
Serial Number:	GEyyww### where yy = year produced ww = week produced ### = serial number 3 or 4 digit
Part Number:	Customer's part number
Amplifier Class:	Class 1
Frequency:	RF operating frequency
Max RF Output:	Maximum pulsed output Maximum average output
MKS mailing address:	Address for information
Country of origin:	Made in USA
Safety Registration	Product is CSA listed
Compliance	Model complies with IEC 601-1

1.5 PRODUCT MARKINGS

Dangerous Voltage 

Alternating Current 

Earth (Ground: Functional) 

Protective Earth (Ground) 

Equipotentiality 

Attention, consult accompanying documents 

Off (power: disconnection from the mains) 

On (power: connection to the mains)

1.6 GENERAL SPECIFICATIONS

MAXIMUM OUTPUT POWER:

Mode Body: 35 kW

Mode Head: 4 kW

AMPLIFIER GAIN

Mode Body: 75.4 ± 0.5 dB

Mode Low: 66.0 ± 0.5 dB

MAXIMUM PULSE ENERGY:

Mode Body: 175 joules

Mode Head: 80 joules

OPERATING FREQUENCY RANGE:

127.7 ± 0.275 MHz

NOMINAL LOAD IMPEDANCE:

50 Ohms

MAXIMUM RF PULSE

Mode Body: 100 msec @ 1750 watts

Mode Head: 100 msec @ 800 watts

MAXIMUM UNBLANK

Mode Body: 256 msec

Mode Head: 256 msec

GATING DUTY CYCLE

Mode Body: 60% maximum

Mode Head: 60% maximum

MAINS

208 VAC ± 10%, 50 / 60 Hz, three phase delta 40 A

OPERATING ENVIRONMENTAL CONDITIONS:

Ambient temperature range 0 to + 35 degrees C

Humidity 90 % relative, non-condensing

STORAGE ENVIRONMENTAL CONDITIONS:

Ambient temperature range – 40 to + 70 degrees C

Humidity 95 % relative, non-condensing

2.0 INSTALLATION

CAUTION!

To avoid condensation problems allow the shipping crate to warm to room temperature for two hours before opening. Once the amplifier is uncrated allow it to warm to room temperature for one hour before applying power.

All connections to the amplifier are made either by hand or with standard tools. The front panel is shown in Figure 1. The rear panel is shown in Figure 2. Follow these steps:

1) Before making electrical connections inspect the amplifier for any evidence of shipping damage.
2) Connect the AC mains power connection per section **2.1** of this technical manual.
3) Make the necessary control connections to the host **MRI system**.
4) Make appropriate connections to the amplifier **RF Input** and **RF Output**.

Figure 1: Amplifier Front View

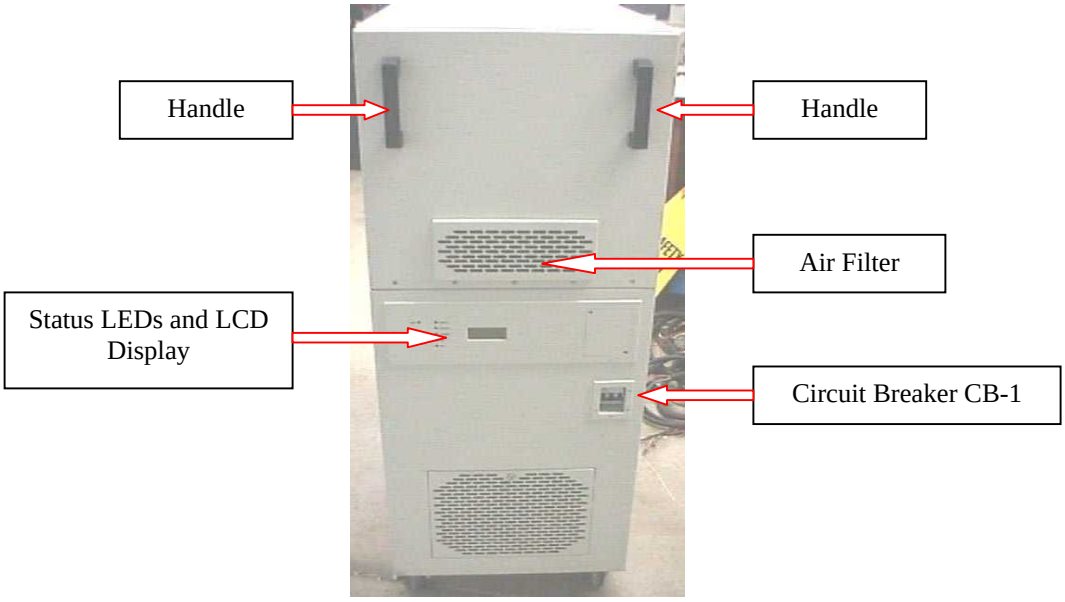
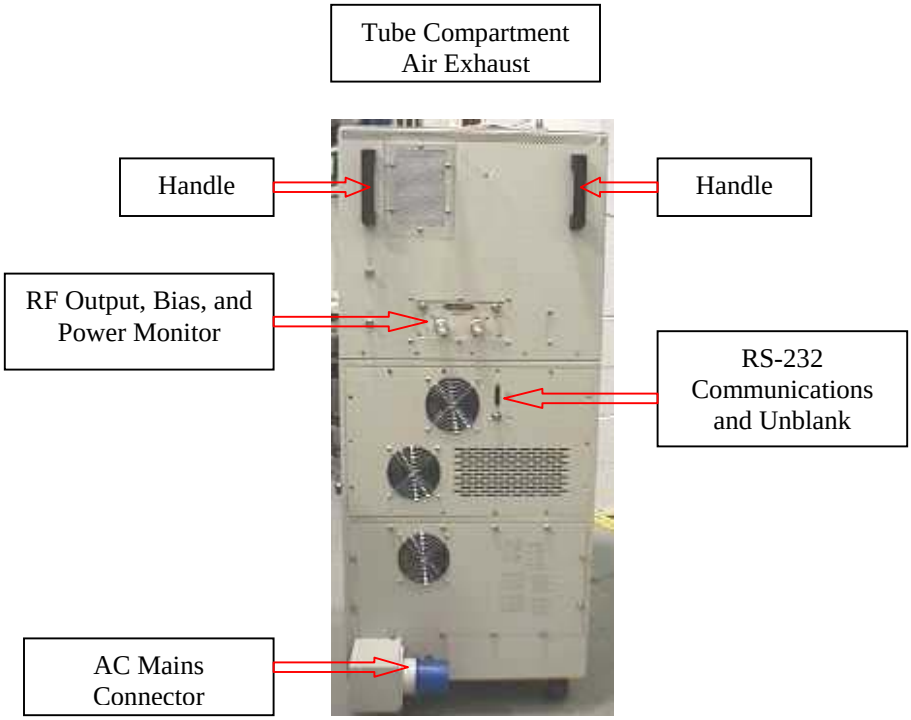


Figure 2: Amplifier Rear View



Refer to the host MRI system manual(s) to determine the proper use of this amplifier with the MRI system.

2.1 AC LINE (MAINS) CONNECTION

DANGER: HAZARD OF ELECTRIC SHOCK OR BURN!

TURN "OFF" THE MAINS POWER SOURCE BEFORE REMOVING ANY AMPLIFIER ACCESS PANEL OR HANDLING WIRING. REPLACE THE ACCESS PANEL BEFORE TURNING THE MAINS POWER SOURCE "ON"!

The amplifier operates from 208 VAC ±10 %, 50 / 60 Hz.

There is a single mains power circuit breaker, CB-1 (40A), located on the **front** of the Power Supply (lower) deck.

The mains AC power connector is located on the **rear** of the Power Supply (lower) deck. Refer to Figure 3 for connection details.

Figure 3: Mains Power Connection

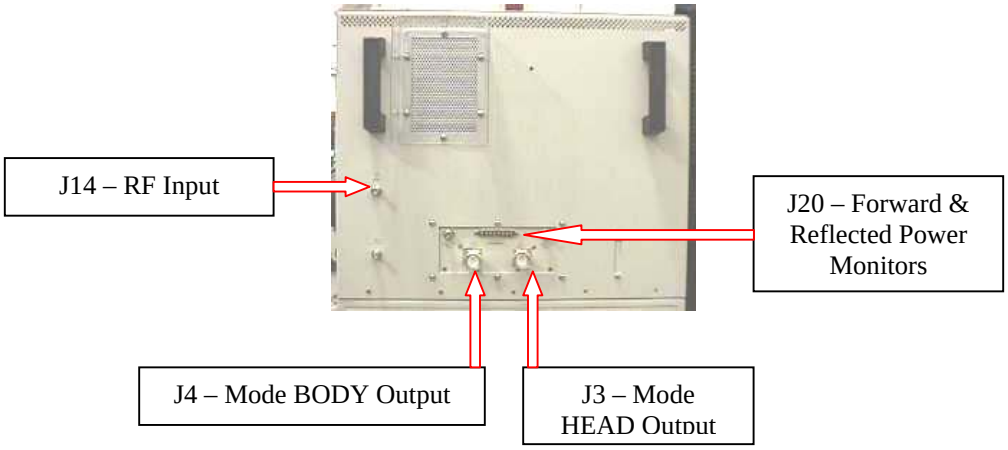
An EMI filter is in series with the mains input to the remainder of the amplifier.

2.2 MRI SYSTEM INTERFACE CONNECTIONS

These MRI System Interface Connectors are shown in Figure 4, “RF Interface Connectors”:

1) J14 -- RF Input
2) J4 – Mode BODY RF Output
3) J3 – Mode HEAD RF Output
4) J20 – Forward & Reflected Power Monitors

Figure 4: RF Interface Connectors



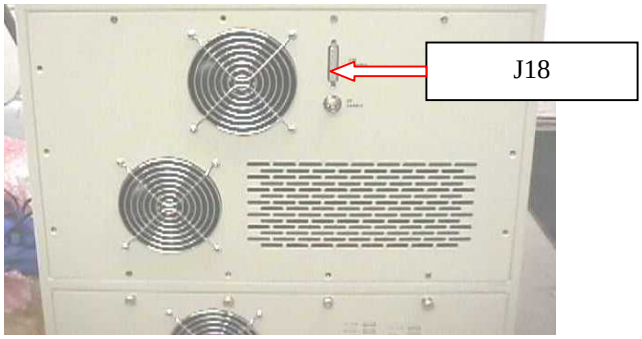
5) J18 -- RS-232 Control (Refer to Figure 5)

5a) Via a "D" subminiature 25-pin female connector

Pin Out:

Pin # 1	Chassis Ground (ground or amplifier common)
Pin # 2	TX Data from the amplifier
Pin # 3	RX Data to the amplifier
Pin # 5	CTS to the amplifier
Pin # 7	Signal Ground
Pin # 20	DTR from the amplifier

Figure 5: J18 – RS-232 Control



2.2.1 RS-232 CONTROL – J18

The maximum allowable applied voltage to the RS-232 connections below is ± 12 VDC. All other input signals have a maximum allowable applied voltage of 5.25 volts except where noted. If these levels are exceeded the amplifier may be damaged.

2.2.2 RF INPUT – J14

BNC Connector - RF input driving signal to the amplifier. Nominal level at this connector is **zero (0) dBm**.

2.2.3 RF OUTPUT – J4 & J3

Two connectors are used, one for each mode:

1) J4 -- Mode **BODY** is a type 7-16 DIN female coaxial cable connector capable of handling a peak power of 35,000 watts.
2) J3 -- Mode **HEAD** is a type 7-16 DIN female coaxial cable connector.

Do not operate the amplifier at rated power without a body / head coil or other suitable load.

3.0 AMPLIFIER CONFIGURATION

3.1 GENERAL OVERVIEW

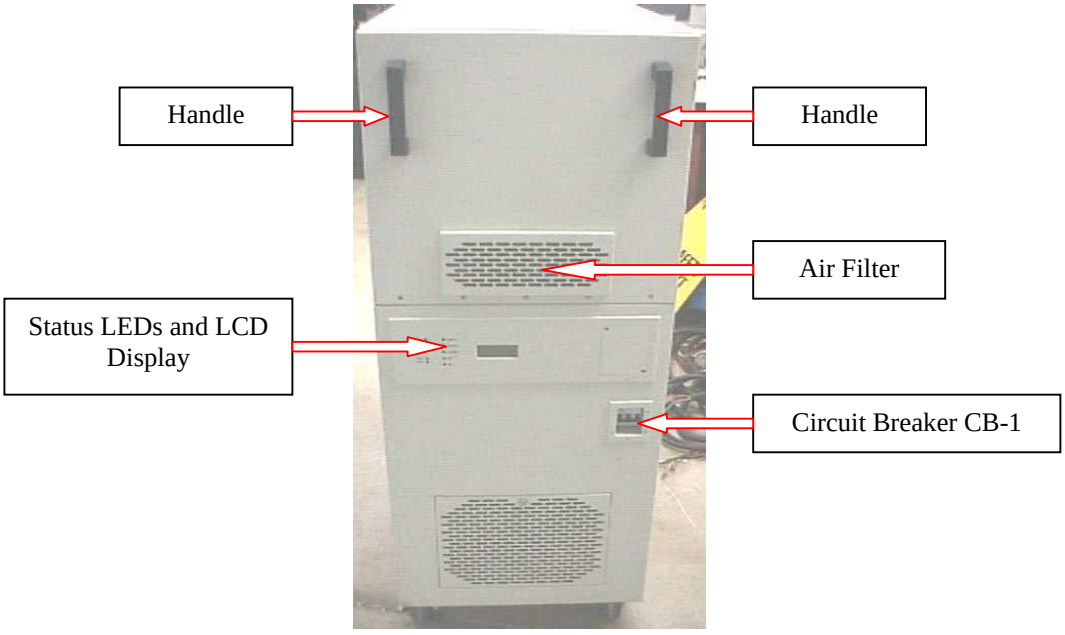
The amplifier is linear and fully automatic. It is capable of delivering in excess of 35 kW at 127.7 MHz into a load VSWR of 1.5:1 in mode Body. Typical gain at 35 kW output will be 75.5 dB. The amplifier consists of a solid-state pre-amplifier / driver followed by two cathode-driven, grounded-grid, and vacuum-tube power amplifier stages. Each vacuum-tube stage provides a gain of approximately 11.5 dB. The remainder is supplied by the solid-state pre-amplifier / driver (SSD).

All major functions are controlled and monitored by a microprocessor (uP) based control system. The uP provides amplifier and MRI system protection from excessive average- and peak-power operation. The amplifier is remotely controlled during normal MRI system operation. Amplifier performance can be monitored by the system status LEDs and LCD indicator screen. These are identified in Figure 6, “Complete Amplifier”).

3.2 MAJOR ASSEMBLIES

The amplifier is divided into two major assemblies; the Power Supply deck and the RF deck. Figure 6 shows the front panels of the complete amplifier.

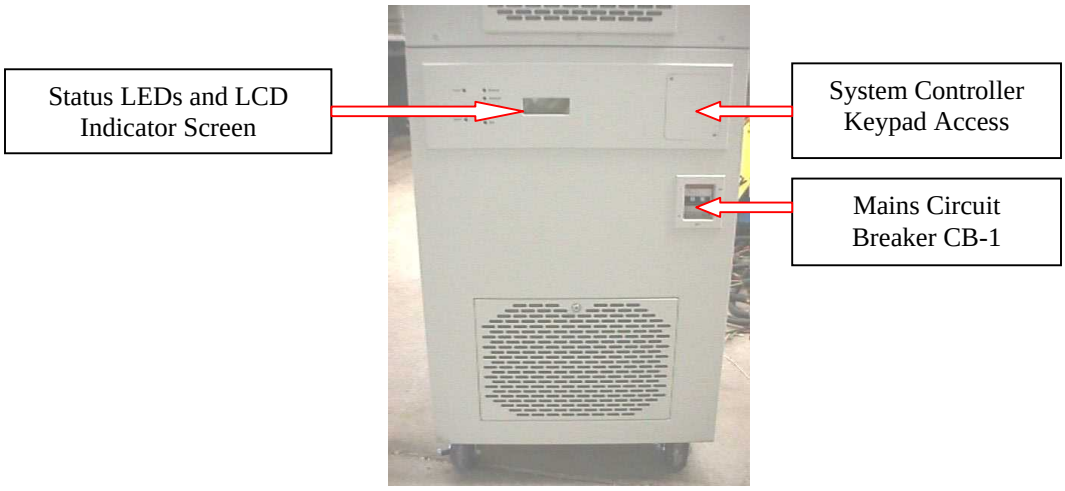
Figure 6: Amplifier Front



3.2.1 POWER SUPPLY (Lower) DECK

The Power Supply deck front panel is shown in figure 7.

Figure 7: Power Supply Front

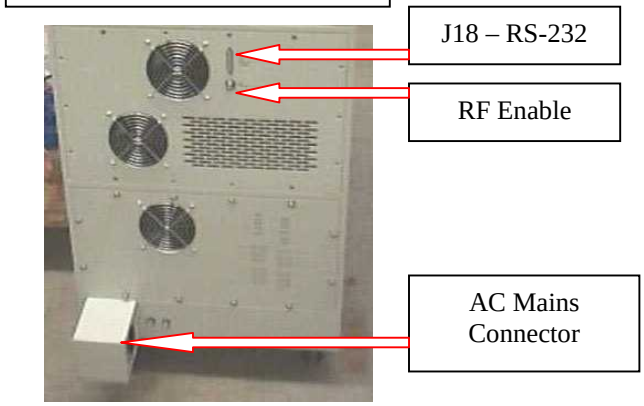


The Power Supply Deck contains:

1) Isolation transformer and Mains EMI Filter
2) Amplifier Circuit
3) Housekeeping Power Supply (Turns “ON” when AC is applied to the amplifier and Circuit Breaker CB-1 is ON. (This supply powers the System Controller.)
4) Low Voltage power supplies (filaments, solid state driver, and vacuum tube bias.)
5) High Voltage power supplies and their associated energy storage (capacitor) modules.
6) System controller
7) Status LEDs and LCD Indicator Screen

The Power Supply deck rear panel is shown in Figure 8.

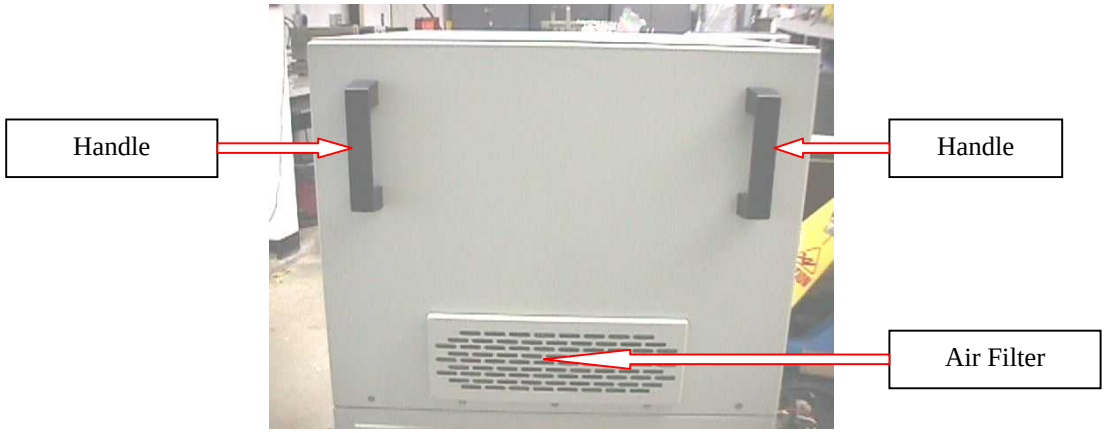
Figure 8: Power Supply Rear



3.2.2 RF AMPLIFIER (Upper) DECK

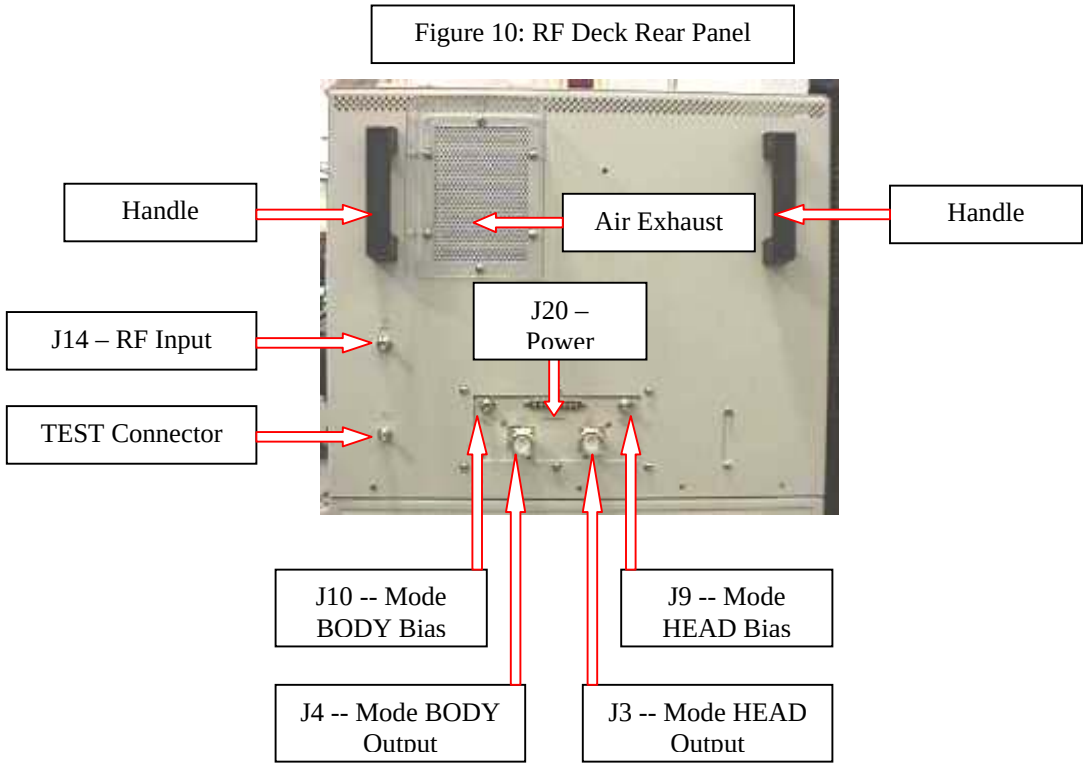
The RF Deck Front Panel is shown in Figure 9.

Figure 9: RF Deck Front Panel



The RF Deck Rear Panel is shown in Figure 10.

Figure 10: RF Deck Rear Panel



The RF Amplifier Deck includes the following assemblies:

1) 300 watt Solid State Driver with a nominal gain of 54.5 dB.
2) Intermediate vacuum tube power amplifier (IPA) with a nominal gain of 11.5 dB.
3) Vacuum tube power amplifier (PA) with a nominal gain of 11.5 dB.
4) RF Coupler module
5) RF Detector module (in conjunction with coupler provides system forward and reflected power detection for use with internal peak and average power monitoring.)
6) RF Deck Cooling Blower

3.2.3 OPERATING MODES

- BODY (High) 35,000 Watts Peak
- HEAD (Low) 4,000 Watts Peak

4.0 AMPLIFIER CONTROL

CAUTION – Switching OFF the mains circuit breaker prior to cycling the amplifier to "OFF" state will result in erroneous faults 38, 42, and / or 81 being recorded in the fault log.

The amplifier is controlled, during normal operation, via the RS-232 interface, J18, located on the Power Supply (lower) deck rear panel.

Once the desired operating parameters are selected, and the amplifier is commanded to either "Standby" or "Operate", it will automatically execute its turn-on sequence, check operating conditions, and set output power trip points. Correspondingly, when the system is commanded "Off", a turn-off sequence is executed.

The amplifier contains a System Controller that monitors several internal parameters and provides management, monitoring, and diagnostics. The controller protects the amplifier from most abnormal operating conditions by switching the unit either to "Standby" or "Off" when a fault condition is detected. The amplifier cannot be damaged by an incorrect command or command input sequence.

4.1 SAFETY INTERLOCKS

Safety interlocks are provided to protect the amplifier, service personnel, and the MRI system. They provide operational safety but cannot replace a competent system operator. These safety interlocks are described in sections **4.1.1**, **4.1.2**, and **4.1.3**.

4.1.1 LOGIC SHUTDOWN INTERLOCK (Fault 42)

A factory-installed jumper on the System Controller board, JP11, disables the Logic interlock. The jumper holds the Logic control line "low". This fault will occur **only** if jumper JP11 is missing from the System Controller circuit board. If JP11 is not present when the Operate command is issued the amplifier will declare Fault 42 and remain in STANDBY. This fault must be cleared before the system will respond to any new command.

If the amplifier is in OPERATE and the Logic interlock is not disabled Fault 42 will be declared and the amplifier will return to STANDBY. The fault must be cleared before the system will respond to any new command.

4.1.2 WATCH-DOG TIMER

The watch-dog timer is a free-running circuit that attempts to generate a hardware reset every 100 milliseconds. The amplifier control software requires a successful "pass" through the control loop. Otherwise, if a fault is detected any time during the 100 millisecond period, the watch-dog is not reset and is then allowed to switch the amplifier OFF. No fault code is generated by a watch-dog reset. If no other faults are detected the amplifier can immediately be turned on again.

4.1.3 PANEL AND SYSTEM INTERLOCKS

CAUTION – Switching OFF the mains circuit breaker prior to cycling the amplifier to "OFF" state will result in erroneous faults 38, 42, and / or 81 being recorded in the fault log.

The RF Deck top- and left-side panels and the Power Supply fuse access panel are provided with safety interlocks. The interlocks do not allow operation unless these panels are securely in place. **Normal operation never requires panel removal.** (Panel removal is required when replacing certain FRUs, for example the RF Deck top panel is removed to gain access to the temperature probe. In this example the amplifier must be turned off first. If it is not, and an interlocked panel is removed, the amplifier will then immediately fault and turn itself off.). **Interlocks must never be defeated.** In addition, after the amplifier has been turned off, any following service procedure must not begin until after a wait-period of at least three minutes. The wait-period allows high voltages within the amplifier to discharge.

WARNING: DO NOT JUMPER OR OTHERWISE OVERRIDE SYSTEM INTERLOCKS OR ATTEMPT TO OPERATE THE AMPLIFIER WITH ANY OF THE COVER PLATES OR PANELS REMOVED. THE PLATES AND PANELS ARE ESSENTIAL PARTS OF THE AMPLIFIER COOLING SYSTEM.

4.2 SYSTEM CONTROLLERS

The amplifier system controllers perform three major functions:
1) Communications with external components via the RS-232 port.
2) Controlling the amplifier; i.e., setting tube bias and un-blanking signal control.
3) Monitoring amplifier functions for faults.

5.0 SYSTEM COMMUNICATIONS

5.1 RS-232 SERIAL INTERFACE

5.1.1 INTERFACE PARAMETERS

The amplifier is configured as a DTE. Connection is via a female 25-pin "D" subminiature connector, J18.

The RS-232 parameters are:

a) 8 data bits
b) 1 stop bit
c) No parity
d) Baud rate: set to 9600 baud
e) Control lines used: CTS (Clear-To-Send) and DTR (Data-Terminal-Ready)

5.1.2 COMMAND / READBACK STRUCTURE – See 10.0 Appendix "A"

6.0 FAULT-FINDING AND DIAGNOSTICS

6.1 SYSTEM FAULT REPORTING

The control system continuously monitors the amplifier for malfunctions or over-drive conditions. If an abnormal condition occurs the amplifier switches to STANDBY or OFF depending on the severity of the problem encountered.

6.2 SYSTEM FAULT CODES

CAUTION – Switching OFF the mains circuit breaker prior to cycling the amplifier to "OFF" state will result in erroneous faults 38, 42, and / or 81 being recorded in the fault log.

Below is a listing of fault codes and fault descriptions. Following the fault description is the corrective action necessary to eliminate the fault.

Note: a "fault" must be repeatable to be considered valid. A single, one-time, fault occurrence may indicate an intermittent condition that existed at the time the fault was declared.

A particular fault, for example "Fault #14, PA BIAS LOW" as would be displayed on the operating console, requires the operator to follow certain actions in sequence. Specifically, the amplifier must be returned to operational service and the system must be restored to the operational condition(s) that led to the fault. To be considered valid the fault must re-occur **every time** the system is returned to operational service and the test sequence is repeated; otherwise the fault is "intermittent". In the case of an intermittent fault further corrective action is not possible until the fault becomes permanent.

DO NOT REPLACE COMPONENTS (FRU) UNTIL THE FAULT IS DETERMINED TO BE VALID!

Definitions

HV = High Voltage	SSD = Solid-State Driver
IPA = Intermediate Power Amplifier	PMU = Power monitoring unit
PA = Final Power Amplifier	V = volt
PS = Power Supply	W = watt

6.3 FAULT CODE LIST and CORRECTIVE ACTIONS

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
01	Phase Loss	Standby	1.Temporary or permanent loss of one or more of the low voltage transformers. 2. Open fuse(s)	1. Reboot Scanner 2. If the error persists call service	1. If the Fault persists check voltage on each mains phase at input to amplifier. 2.Check fuses F3, F4, F5 and replace if needed. 3. Check Low Voltage Transformer Phase A, B, C fuses and replace if needed. 4. If the fault persists replace the Amplifier system.
02	SCR Overtemp	Standby	1. Blocked Airflow 2. PS Fan(s) Failure 3. Defective PS deck	1. Allow amplifier to cool for 20 minutes and attempt then reboot scanner. 2. Use a GE released sequence 3. If the error persists call service.	1. Check PS air filters and clean or replace if needed. 2. Verify that nothing is obstructing the airflow from the front or the rear of the amplifier. 3. If the fault persists replace the Amplifier system.
03	HV Trans-former Overtemp	Standby	1. Blocked Airflow 2. PS Fan(s) Failure 3. Defective PS deck	1. Allow amplifier to cool for 20 minutes and then attempt to reboot. 2. Use a GE released sequence 3. If the error persists call service.	1. Check PS air filters and clean or replace if needed. 2. Verify that nothing is obstructing the airflow from the front or the rear of the amplifier. 3. If the fault persists replace the Amplifier system.
04	LV or HV Transformer Overtemp	Off	1.Blocked Airflow 2. Defective PS deck	1. Allow amplifier to cool for 20 minutes and then attempt to reboot the scanner.- 2. System standby then system on 3. If the error persists call service.	1. Check PS air filters and clean or replace if needed. 2. Verify that nothing is obstructing the airflow from the front or rear of the amplifier. 3. If the fault persists replace the Amplifier system.

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
05	LV PS Overtemp	Off	1. Blocked Airflow 2. Defective PS deck	1. Allow amplifier to cool for 20 minutes and then attempt to reboot the scanner. 2. System standby then system on 3. If the error persists call service.	1. Check PS air filters and clean or replace if needed. 2. Verify that nothing is obstructing the airflow from the front or rear of the amplifier. 3. If the fault persists replace the Amplifier system.
11	9 V PS Low	Off	Defective PS deck	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.
12	SSD +15 V PS Low	Off	Defective RF deck	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.
13	SSD +15 V PS High	Off	Defective RF deck	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.
14	PA Bias Low		1. Internal tube arc (this is common for oxide cathode tubes during the first hours of operation and after transit – this arc will not cause any damage) 2. Open PS fuse 3. Defective PA tube 4. Defective PS deck	1. System standby then system on 2. Attempt restart three times 3. If the error persists call service.	1. Check Fuse F9, F10, F11 and replace if needed 2. If the fault persists replace the Amplifier system.
15	PA HV Low	Standby	1. Energy required by pulse sequence exceeds amplifier capability resulting in low PA HV. 2. Incorrect Mains tap 3. Interconnect cable loose 4. Defective PS deck	1. Reboot scanner 2. Use a GE released sequence. 3. If the error persists call service.	1. Verify that the 4-pin barrel interconnect cable between the RF and PS deck is secure. 2. If the fault persists replace the Amplifier system.
16	IPA HV Low	Standby	1. Energy required by pulse sequence exceeds amplifier capability resulting in low IPA HV. 2. Incorrect Mains tap 3. PS failure	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Verify that the 4-pin barrel interconnect cable between the RF and PS deck is secure. 2. If the fault persists replace the Amplifier system.
18	SSD 5 V PS Low	Off	Defective RF deck	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.
19	SSD 5 V PS High	Off	Defective RF deck	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
23	9 Volt PS High	Off	Defective PS deck	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.
24	SSD -15 V PS Low	Off	Defective RF deck	1. System standby then system on 2. If the error persists call service.	1. Check fuses F6, F7, F8 and replace if needed. 2. If the fault persists replace the Amplifier system.
25	SSD -15 V PS High	Off	Defective RF deck	1. System standby then system on 2. If the error persists call service.	1. Check fuses F6, F7, F8 and replace if needed. 2. If the fault persists replace the Amplifier system.
26	IPA Bias Low	Off	1. Internal tube arc (this is common for oxide cathode tubes during the first hours of operation and after transit – this arc will not cause any damage) 2. Open PS fuses 3. Defective IPA tube 4. Defective PS deck	1. System standby then system on 2. Attempt restart three times 3. If the error persists call service.	1. Check Fuse F9, F10, F11 and replace if needed. 2. If the fault persists replace the Amplifier system.
27	PA HV High	Standby	1. Incorrect Mains tap 2. Defective PS deck	1. Reboot scanner 2. If the error persists call service.	If the fault persists replace the Amplifier system.
28	IPA HV High	Standby	1. Incorrect Mains tap 2. Defective PS deck	1. Reboot scanner 2. If the error persists call service.	If the fault persists replace the Amplifier system.
29	PA Plate Current (I_p) High	Standby	1. Incorrect load 2. Excessive RF drive level for load. 3. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Confirm system Tx/Rx circuitry is functioning properly. 2. Verify that the amplifier is terminated into a suitable RF load. 3. If the fault persists replace the Amplifier system.
30	IPA Plate Current (I_p) High	Standby	1. Incorrect load 2. Excessive RF drive level for load 3. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Confirm system Tx/Rx circuitry is functioning properly. 2. Verify that the amplifier is terminated into a suitable RF load. 3. If the fault persists replace the Amplifier system.

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
31	PA Grid Current (Ig) High	Standby	1. Incorrect load 2. Excessive RF drive level for load 3. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Confirm system Tx/Rx circuitry is functioning properly. 2. Verify that the amplifier is terminated into a suitable RF load. 3. If the fault persists replace the Amplifier system.
32	IPA Grid Current (Ig) High	Standby	1. Incorrect load 2. Excessive RF drive level for load 3. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Confirm system Tx/Rx circuitry is functioning properly. 2. Verify that the amplifier is terminated into a suitable RF load. 3. If the fault persists replace the Amplifier system.
35	50 Volt PS Low	Off	1. Open PS fuses 2. Defective PS deck 3. Defective RF deck	1. System standby then system on 2. If the error persists call service.	1. Check Fuse F15, F16, F17 and replace if needed. 2. Remove the right side panel of the RF deck. Remove the D-sub connection labeled “SSD”. While starting the warm up sequence monitor the DC voltage between the two pins of the connector. 3. If 60-64VDC was measured prior to the fault, replace the Amplifier system. 4. If the fault persists replace the Amplifier system.
36	50 Volt PS High	Off	Defective 50V PS	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.
37	PA Filament OV	Off	Defective PS deck	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.
38	PA Filament UV	Off	1. Defective PS deck 2. Defective PA Filament PS CAUTION – Switching OFF the mains circuit breaker prior to cycling the amplifier to “OFF” state will result in. erroneous faults 38, 42, and / or 81 being recorded in the fault log	1. System standby then system on 2. If the error persists call service.	1. Check Fuses F18, F19, F20 and replace if needed. 2. If the fault persists replace the Amplifier system.

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
39	IPA Filament OV	Off	Defective PS deck	1. System standby then system on 2. If the error persists call service.	If the fault persists replace the Amplifier system.
40	IPA Filament UV	Off	Defective PS deck	1. System standby then system on 2. If the error persists call service.	1. Check Fuses F21, F22, F23 and replace if needed. 2. If the fault persists replace the Amplifier system.
41	PA Air Flow	Off	1. Temporary or permanent loss of one or more of the low voltage transformers 2. Blocked airflow in RF deck. 3. Loose deck interconnect cable 4. Open fuse in the amplifier 5. Defective RF deck	1. System standby then system on 2. If the error persists call service.	1. If the fault persists check voltage on each mains phase at input to amplifier. 2. Verify that nothing is obstructing the airflow in front or the rear of the amplifier. 3. Check RF deck air filters and clean of replace if needed. 4. Verify that the interconnect cable P5 between the RF and PS deck is secure. 5. Check the fuses F1, F2 and replace if needed. 6. Check the Low Voltage Transformer Phase A, B, C fuses and replace if needed. 7. Replace the temperature probe 8. If the fault persists replace the Amplifier system.
42	Logic Shutdown	Standby	1. Interface connection problem 2. Missing J11 jumper on System Control Board. 3. Defective PS deck CAUTION – Switching OFF the mains circuit breaker prior to cycling the amplifier to “OFF” state will result in. erroneous faults 38, 42, and / or 81 being recorded in the fault log	1. Check to determine if the MRI system is in a state that allows the amplifier to be enabled. 2. Reboot scanner 3. If the error persists call service.	1. Verify JP11 is present on System Controller board. 2. If the fault persists replace the Amplifier system.
44	DSP Failure	Off	1. Disruption in system power 2. Defective PS deck	1. System standby then system on 2. If the error persists call service.	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS. Wait ten seconds. Then turn CB1 back ON. 2. System Standby then system On 3. If the fault persists replace the Amplifier system.

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
45	PS Cover Open	Off	One of the PS deck access covers is off or loose.	1. System standby then system on 2. If the error persists call service.	1. Verify all PS access covers are in place and tight. 2. Check function of switches
46	RF Deck Cover Open	Off	1. One of the RF deck access covers is off or loose. 2. Loose deck interconnect cable	1. System standby then system on 2. If the error persists call service.	1. Verify all RF deck access covers are in place and tight. 2. Verify that the P1 interconnect cable between the RF and PS deck is secure.
47	PA Air Too Hot	Standby	1. Selected RF pulse sequence exceeds amplifier power dissipation capability. 2. Blocked PA air exhaust 3. Defective temperature probe 4. Equipment room ambient is > 40 degrees C. 5. Defective RF deck	1. Allow amplifier to cool for 20 minutes and attempt then reboot scanner. 2. Use a GE released sequence. 3. If the error persists call service.	1. Check RF deck air filters and clean or replace if needed. 2. Replace the temperature probe 3. Ensure equipment room ambient is < 40 degrees C. 4. If the fault persists replace the Amplifier system.
48	PA Air Temperature Monitor	Off	1. Blocked PA air exhaust 2. Equipment room ambient is > 40 degrees C. 3. Defective RF deck	1. System standby then system on 2. If the error persists call service.	1. Check RF deck air filters and clean or replace if needed. 2. Ensure equipment room ambient is < 40 degrees C. 3. If the fault persists replace the Amplifier system.
50	Non-Fatal Fault in Standby	Off	1. Disruption in system power 2. Defective PS deck	1. System standby then system on 2. If the error persists call service.	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS. Wait ten seconds. Then turn CB1 back ON. 2. System Standby then system On 3. If the fault persists replace the Amplifier system.
58	SSD Driver Temp High	Standby	1. Selected RF pulse sequence may exceed amplifier capabilities. 2. Blocked airflow. 3. Equipment room ambient is > 40 degrees C. 4. RF deck blower defective. 5. Defective SSD	1. Allow amplifier to cool for 20 minutes and attempt then reboot scanner. 2. Use a GE released sequence. 3. If the error persists call service.	1. Check RF deck air filters and clean of replace if needed. 2. Ensure the equipment room ambient is < 40 degrees C. 3. If the fault persists replace the Amplifier system.
59	SSD Preamp Temp High	Standby	1. Selected RF pulse sequence may exceed amplifier capabilities. 2. Blocked airflow 3. Equipment room ambient is > 40 degrees C. 4. Defective RF deck	1. Allow amplifier to cool for 20 minutes and attempt then reboot scanner. 2. Use a GE released sequence. 3. If the error persists call service.	1. Check RF deck air filters and clean of replace if needed. 2. Ensure the equipment room ambient is < 40 degrees C. 3. If the fault persists replace the Amplifier system.

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
61	PA Bias Current	Standby	1. Open fuse 2. Failed PA tube 3. Defective PS deck	1. Reboot scanner 2. If the error persists call service.	1. Check fuses F18, F19,F20 and replace if needed. 2. If the fault persists replace the Amplifier system.
62	IPA Bias Current	Standby	1. Open fuse 2. Failed IPA tube 3. Defective PS deck	1. Reboot scanner 2. If the error persists call service.	1. Check fuses F21, F22, F23 and replace if needed. 2. If the fault persists replace the Amplifier system.
63	NVRAM Failure	Off	1. Disruption in system power 2. Defective PS deck	1. System standby then system on. 2. If the error persists call service.	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS. Wait ten seconds. Then turn CB1 back ON. 2. System Standby then system on 3. If the fault persists replace the Amplifier system.
64	PMU Failure	Off	1. Disruption in system power 2. Defective PS deck	1. System standby then system on. 2. If the error persists call service.	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS. Wait ten seconds. Then turn CB1 back ON. 2. System Standby then system on 3. If the fault persists replace the Amplifier system.
66	SSD EPROM Failure	Off	1. Poor deck interconnect cable connection 2. Defective RF deck	1. System standby then system on. 2. If the error persists call service.	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS. Wait ten seconds. Then turn CB1 back ON. 2. System standby then system on 3. Verify that P3 and P4 interconnect cables between the RF and PS decks are secure. 4. If the fault persists replace the Amplifier system.
67	IPA Tube Arc	Standby	1. Internal tube arc (this is	1. System standby then system	If the fault persists replace the

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
			common for oxide cathode tubes during the first hours of operation and after transit – the arc will not cause any damage). 2. Defective RF deck	on 2. Attempt restart three times 3. If the error persists call service.	Amplifier system.
68	PA Tube Arc	Standby	1. Internal tube arc (this is common for oxide cathode tubes during the first hours of operation and after transit – the arc will not cause any damage). 2. Defective RF deck	1. System standby then system on 2. Attempt restart three times 3. If the error persists call service.	If the fault persists replace the Amplifier system.
71	SSD Overdrive	Standby	1.RF input level is too high 2. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Check the RF input to the amplifier. 2. If the fault persists replace the Amplifier system.
73	SSD Reflected Power	Standby	1. Defective IPA tube 2. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	If the fault persists replace the Amplifier system.
74	DSP Comm. Failure	Off	1. Disruption in system power 2. Defective PS deck	1. System standby then system on 2. If the error persists call service.	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS. Wait ten seconds. Then turn CB1 back ON. 2. System Standby then system on 3. If the fault persists replace the Amplifier system.
75	DSP Interrupt	Off	1. Disruption in system power 2.Defective PS deck	1. System standby then system on 2. If the error persists call service.	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS. Wait ten seconds. Then turn CB1 back ON. 2. System Standby then system on 3. If the fault persists replace the Amplifier system.
87	IPA Plate Over Current	Standby	1. RF input level too high 2. High load or “no-load” 3. Defective IPA tube 4. Defective PA tube	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Confirm system Tx/Rx circuitry is functioning properly. 2. If the fault persists replace the Amplifier system.
88	PA Plate Over Current	Standby	1. RF input level too high	1. Reboot scanner	1. Confirm system Tx/Rx circuitry is functioning

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
			2. High load or "no-load" 3. Defective PA tube	2. Use a GE released sequence 3. If the error persists call service.	properly 2. If the fault persists replace the Amplifier system.
93	Amp Enable Line	Standby	1. Amplifier un-blanked too long. 2. Defective System Controller 3. Defective PS deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Verify that an approved RF sequence is being used. 2. If the fault persists replace the Amplifier system.
94	Duty Cycle	Standby	1.The RF average power over a 300 msec period was excessive. 2. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	If the fault persists replace the Amplifier system.
95	Forward Power HIGH	Standby	1. The RF peak power exceeded 35,500 watts in mode High or 4,500 watts in mode Low. 2. High load VSWR or "no-load" 3. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Confirm system Tx/Rx circuitry is functioning properly. 2. Verify that the RF drive level is accurate. 3. Verify amplifier calibrations 4. If the fault persists replace the Amplifier system.
96	Reflected Power HIGH	Standby	1. High load or "no-load" 2. Excessive RF drive level for load VSWR. 3. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Confirm system Tx/Rx circuitry is functioning properly. 2. Check to make sure the RF output cable is secure on the amplifier. 3. Verify that the amplifier is terminated into a suitable RF load. 4. If the fault persists replace the Amplifier system.
97	Average Power Trip	Standby	1. The RF average power over a three-second period was excessive. 2. Defective RF deck	1. Reboot scanner 2. Use a GE released sequence 3. If the error persists call service.	1. Verify that an approved RF sequence is being used. 2. If the fault persists replace the Amplifier system.
99	Undefined	Off	Defective system controller	1. System standby then system on 2. If the error persists call service	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS. Wait ten seconds. Then turn CB1 back ON. 2. System Standby then system on 3. If the fault persists replace the Amplifier system.

6.4 SYSTEM PERFORMANCE ISSUES (No Fault Code Reported)

Fault Code	Fault Description	State after Fault	Probable Cause	Customer Action	Service Action
None	Front panel LED's are blinking	N/A	1. Disruption in system power 2. Defective RF deck	1. Re-initialize the amplifier via the MRI system software 2. Call service	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS deck. Wait ten seconds. Then turn CB1 back ON. 2. If the fault persists replace the Amplifier system.
None	Forward and reflected power monitor issues (DiCo monitor)	N/A	1. Loose or damaged interface connections 2. Loose deck interconnect cables 3. Defective RF deck	Call service	1. Verify that J20 monitor connections on the rear of the amplifier have no damage and is secure. Connect if needed. 2. Verify that the deck interconnect cable P6 is secure. 3. If the fault persists replace the Amplifier system.
None	No power to the amplifier	N/A	1. Amplifier circuit breaker(s) are off 2. Loss of AC Mains voltage 3. Open fuse in the PS deck 4. Defective PS deck	Call service	1. Verify that CB1 breakers are on 2. Verify that AC voltage is present to the amplifier. 3. Check fuses F12-F15 and replace if needed. 4. If the fault persists replace the Amplifier system.
None	RF characteristics issues: Unstable output, RF noise or spikes	N/A	1. Loose RF output cable 2. Loose PA tube clamp 3. Defective RF deck	Call service	1. Verify that the RF output cable is secure and that there are no signs of arcing at the connector. Correct if needed. 2. Verify that the PA tube clamp is properly installed with no loose hardware. 3. If the fault persists replace the Amplifier system.
None	All front panel LED's are ON	N/A	System Controller Fault	1. Re-initialize the amplifier via the MRI system software 2. Call service	1. Re-initialize the amplifier by turning OFF circuit breaker CB1 on the PS deck. Wait ten seconds. Then turn CB1 back ON 2. If the fault persists replace the Amplifier system.

7.0 TUBE-INDUCED FAULTS

The amplifier tubes may experience inter-electrode arcing during their lifetimes. When arcing occurs the amplifier System Controller usually declares a “tube arc fault”. The fault can, at the least, turn off the high voltage plate power supplies and switch the amplifier from OPERATE to STANDBY. The amplifier may also be commanded OFF under certain conditions.

EIMAC, the tube manufacturer, describes inter-electrode arcing as a normal phenomenon for some types of power-grid tubes. Arcing may occur at any time when the amplifier is in OPERATE; that is, whenever tube filament power and plate voltage are applied. An arc can occur during the transition from STANDBY to OPERATE as the plate power supply is being turned on. It may instead occur some time after the amplifier has successfully transitioned to OPERATE. An arc can occur with or without a driving RF signal present.

Arcing is typically intermittent and cannot be predicted. It does tend to appear more often in relatively new tubes (within the first few hundred hours of operation) and in a tube approaching end-of-life.

We have no evidence that suggests an arc in one tube may induce an arc in another.

The arc is usually triggered by the presence of a conductive gas “cloud” within the tube. Gas generation can be a by-product of the manufacturing process. (The cathode is oxide coated; tubes using this cathode type are not subjected to high temperature “curing” and, as a result, trace element gasses may leach from the copper anode during operation.)

EIMAC recommends the inclusion of current-limiting resistance in the plate power supply to minimize the possibility of tube and / or supply damage in the event of an arc. All MRI system amplifiers produced by MKS contain this recommended current-limiting resistance.

When the amplifier is in OPERATE plate current is continuously monitored. If an arc is detected, the amplifier’s HV power supply is switched "OFF" for **all** tubes, not just the one affected.

8.0 FIELD REPLACEABLE UNITS (FRU) & INSTALLATION

Field Replaceable Units (FRU) within this system are limited as listed below:

Field Replaceable Unit (FRU)	MKS Part Number
3T RF Generator System	50-S26B-128
Temperature Probe	ARX-X532-SP
Air Filter Kit	AUX-X082-SP
Fuse Kit	AUX-X074-SP

WARNING: MANY COMPONENTS WITHIN THE AMPLIFIER ARE STATIC SENSITIVE! TAKE APPROPRIATE CAUTIONS WHEN REMOVING OR INSTALLING ANY SYSTEM PART.

8.1 AIR FILTER REPLACEMENT

Air filters are located on the front of the RF (upper) and Power Supply (lower) decks. They are comprised of a removable filter element that is press-fit into a metal frame.

The filter frame on the RF deck is friction-fit to the panel with "J" hooks. To remove it, place your hands at each side of the filter and firmly push it up. You will feel it "travel" approximately ½ inch (1.25 cm). Then pull it straight out to disengage the "hooks".

The filter frame on the Power Supply deck is secured to the panel with a single slot-head screw. Turn the screw counter-clockwise (to the left) to unlock the frame. When the screw is free pull the frame straight out.

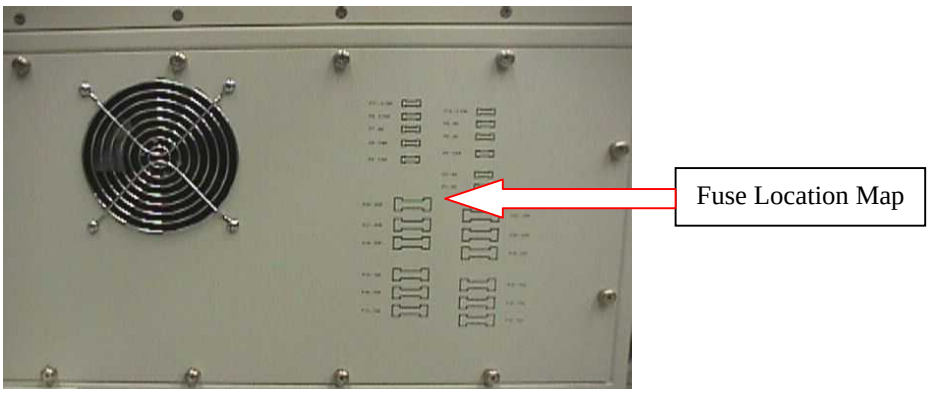
The filter elements can be washed, or replaced, as necessary.

After installing the press-fit element reattach its frame to the appropriate deck.

8.2 FUSE REPLACEMENT

The majority of the amplifier fuses are located on the fuse board, which is mapped out on the removable fuse panel. There are three other fuses for the low voltage transformer phase (A, B, C) that are located behind the fuse board and are discussed in detail in section 8.8.1. All of the fuses are accessible by removing the fuse panel on the backside of the Power Supply deck. The panel has a directly-visible fuse location "map" printed on it. The panel is mounted above the mains primary connection point and is shown in Figure 33.

Figure 33: Removable Fuse Panel

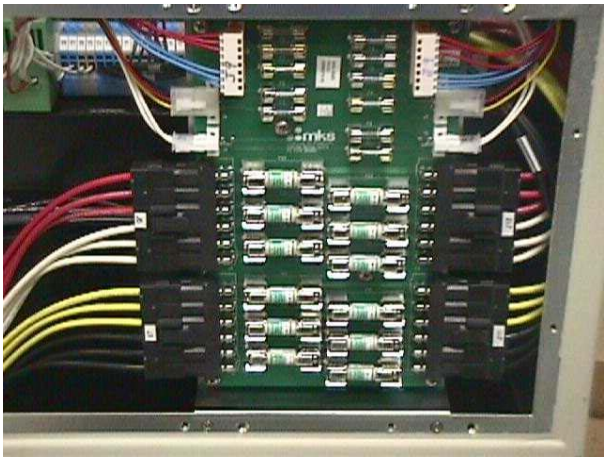


Caution: When removing the Fuse Panel take care not to damage the cooling fan cable. Very little cable slack is available.

Some amplifier fault descriptions list a condition caused by no- or low-supply voltages. These faults may be caused by a defective fuse. Amplifier faults are described in Section 6.0, "System Fault Codes". Check the appropriate fuse before replacing any other FRU.

The spare fuse kit contains replacements for each fuse used within the amplifier. The fuse board is shown in Figure 34 "Fuse Board".

Figure 34: Fuse Board



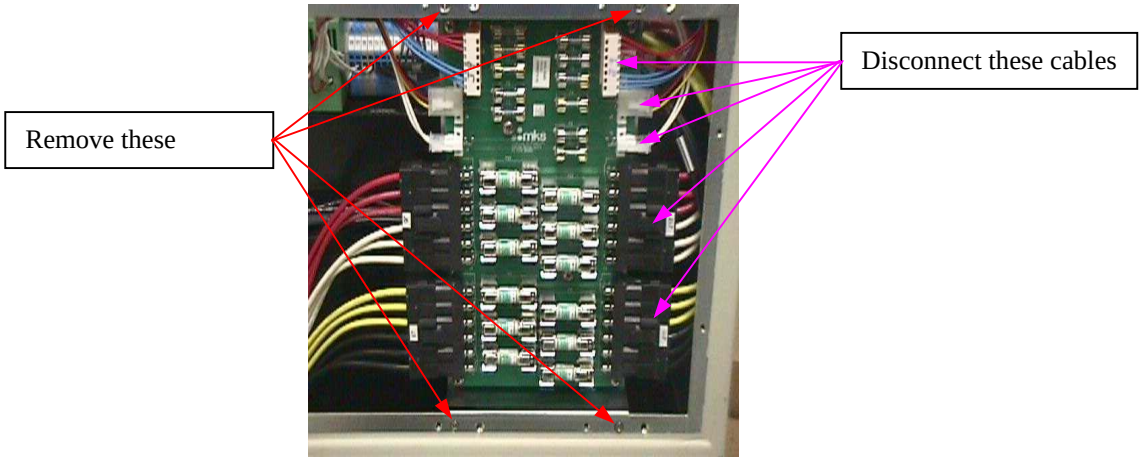
The fuses are identified by circuit designator, function, current and rating.

Fuse Designation	Circuit Function	Current Rating
F1, F2	Blower	4 Ampere
F3, F4, F5	Phase Reference	250 Milliampere
F6, F7, F8	- 15 Volt Supply	4 Ampere
F9, F10, F11	+ Bias Supply	3.15 Ampere
F12, F13, F14	+ 15 Volt Supply	10 Ampere
F15, F16, F17	+ 56 Volt Supply	15 Ampere
F18, F19, F20	PA Filament Supply	20 Ampere
F21, F22, F23	IPA Filament Supply	20 Ampere

8.2.1 LOW VOLTAGE TRANSFORMER PHASE (A, B, C) FUSE REPLACEMENT

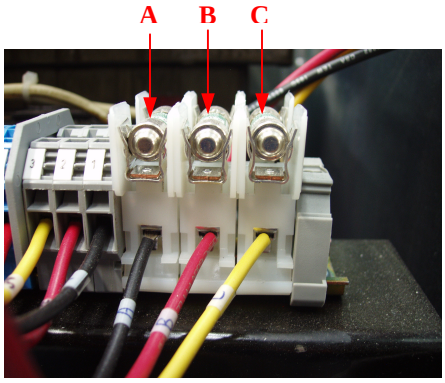
The fuses for the low voltage transformer phase (A, B, C) are located behind the fuse board, which must be moved in order to gain access to them. Figure 36 shows the low voltage transformer fuses with the fuse board removed.

Figure 35: Fuse Board



1) Disconnect the 5 cable connections from the fuse board. See Figure 35
2) Remove the 4 screws that hold the fuse board in place using a # 2 philips head screwdriver. See Figure 35

Figure 36: Close up of the Low Voltage Transformer



3) Slide the fuse board over to the left for better access and remove the Low voltage fuses.
   a) Check the fuses for continuity. If any of the fuses are bad replace all 3 fuses.
   b) Make sure that each of the fuses are properly seated into the Fuse Holders.
4) Reconnect the cable connector's back to the fuse board.
5) Screw the fuse board holder back into place.
   a) Should also do a continuity check on all the fuses on the fuse board and replace any that are open.
6) Secure the fuse panel back into place.

8.3 TEMPERATURE PROBE REPLACEMENT

The location of the temperature probe will depend on the revision level of the amplifier being serviced. For revision 08 and lower amplifiers the probe is located within the PA tube compartment. On amplifiers revision 09 and above the probe is located outside of the PA tube compartment exhaust port.

8.3.1 ORIGINAL LOCATION

Tools required:

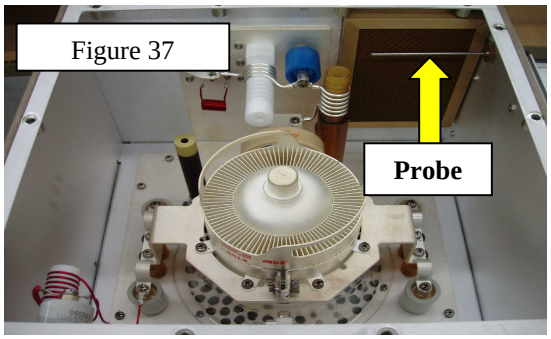
1) Blade-type screwdriver 3) ¾ or 11/16 inch wrench (both sizes were used)
2) #2 cross type screwdriver

Before following the removal and installation steps below ensure that AC power has been removed from the amplifier, the mains circuit breaker is shut off and wait 6 minutes to allow for the amplifier high voltage to discharge.

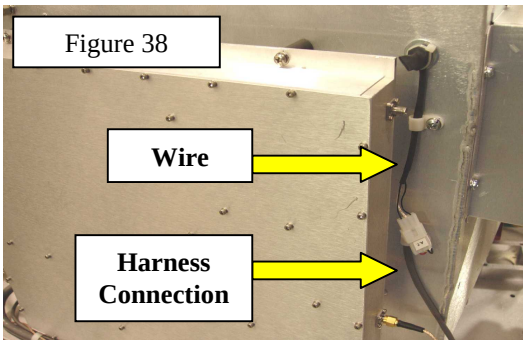
Do not touch anything inside the amplifier's tube compartment until the item you must handle or touch is specifically discharged with a known-functional device such as a chassis-connected shorting stick or similar!

Do not apply power with any cover removed or interlock defeated as damage to tubes and other components is likely.

1) Using a blade-type screwdriver remove the top and right side panels of the RF deck.
2) Using the #2 cross type screwdriver remove the tube compartment cover
3) The temperature probe will be visible inside the rear of the tube compartment. See Figure 37



3) Remove the wire clip located on the side of the RF deck and disconnect the harness. See Figure 38



4) Remove the nut that secures the temperature probe to the tube compartment wall. The part can now be removed from the RF deck.
5) Reverse the previous steps to install the new temperature probe.

8.3.2 NEW LOCATION

Tools required:

1) Blade-type screwdriver 3) ¾ or 11/16 inch wrench (both sizes were used)
2) #2 cross type screwdriver 4) 5/16 inch torque wrench

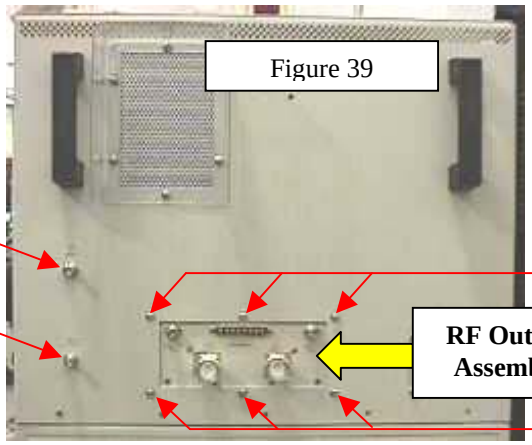
Before following the removal and installation steps below ensure that AC power has been removed from the amplifier, the mains circuit breaker is shut off and wait 6 minutes to allow for the amplifier high voltage to discharge.

Do not touch anything inside the amplifier's tube compartment until the item you must handle or touch is specifically discharged with a known-functional device such as a chassis-connected shorting stick or similar!

Do not apply power with any cover removed or interlock defeated as damage to tubes and other components is likely.

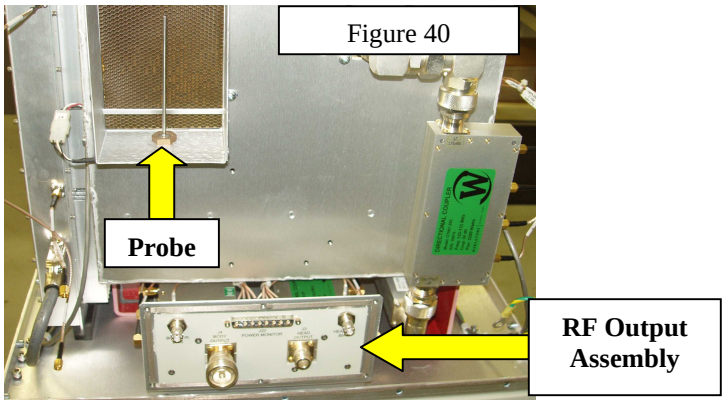
1) On the rear panel of the amplifier is the RF output assembly. This connection is secured to the panel with 6 screws. See Figure 39.

Figure 39



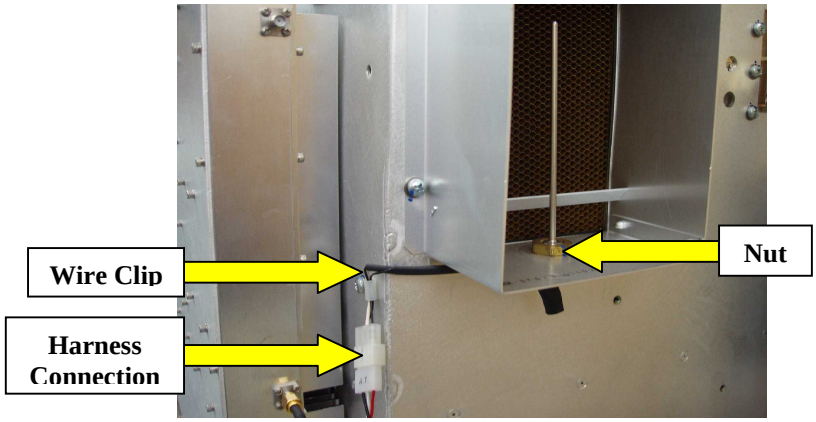
2) Remove the six screws from the front side of the rear panel and remove the two SMA connectors from the backside of the rear panel.
3) Using a blade-type screwdriver remove the top, left and right side panels of the RF deck.
4) Disconnect the green ground wire that is secured to the inside of the rear panel.
5) Remove the seven remaining screws from the lower edge of the rear panel. Start with the ones on each side using a philips screwdriver then remove the five screws from the bottom using a flat blade screwdriver. **Note: These are the last screws holding the panel to the amplifier. Make sure to keep the panel from falling over or dropping while the screws are being removed. Damage to the panel could occur.**
6) After removal of the rear panel the temperature probe will be visible. See Figure 40.

Figure 40



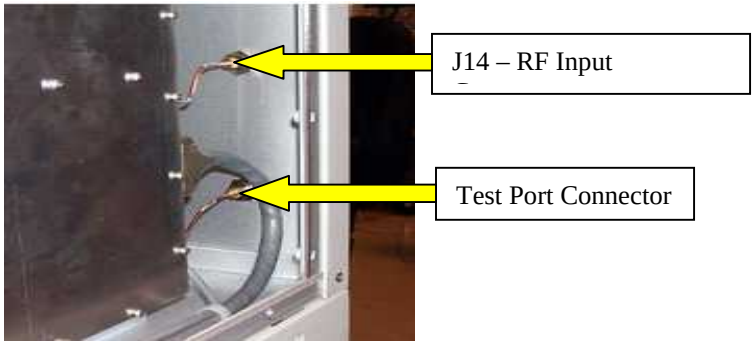
7) Remove the wire clip located on the side of the RF deck and disconnect the harness. See Figure 41.
8) Remove the nut that secures the temperature probe to the RF deck air exhaust port. The part can now be removed from the RF deck. See Figure 41.

Figure 41



9) Install the new temperature probe and tighten the nut.
10) Secure the rear panel back on to the RF deck using the seven screws removed in step 5 (Do not secure these screws down completely).
11) Reconnect the ground wire to the rear panel.
12) Reconnect the top cable labeled "J14" to the J14 – RF Input connector. See Figure 42
13) Reconnect the bottom cable labeled "Test" to the Test Port connector. See Figure 42
14) Torque both J14 and Test SMA connectors to 12 in-lbs.
15) Reinstall the six screws that mount the RF output assembly to the rear panel.

Figure 42



16) Reinstall side RF deck panels while leaving the screws loose.
17) Reinstall the top cover. All screws should be started loose before they are tightened down to make is easier to get all screws installed. **Use caution so that no screws are cross-threaded.**
18) Once the top panel screws are started all panel screws can be secured down.

9 PREVENTIVE MAINTENANCE

No planned maintenance is required for the amplifier. Periodically remove and clean the air filters from the amplifier panels.

10 SYSTEM COMMUNICATIONS – APPENDIX "A"

10.1 RS-232 SERIAL INTERFACE -- J18

The amplifier is configured as a DTE. Connection is via a female 25-pin "D" subminiature connector, J18, located on the Power Supply (lower) deck rear panel.

The RS-232 parameters are:

a) 8 data bits
b) 1 stop bit
c) No parity
d) Baud rate: set to 9600 baud
e) Control lines used: CTS (Clear-To-Send) and DTR (Data-Terminal-Ready)

10.2 SYSTEM COMMANDS

All commands are not available unless the amplifier is set to TEST=ON. Some commands are available only when the amplifier is set to TEST=LOCAL; these are listed below.

All command inputs are composed of upper- or lower- case ASCII characters terminated with a carriage return <CR>. Linefeed <LF> characters are ignored. Upon receipt of a carriage return, the command is decoded and executed. The "?" can be issued with a command to return the command's current status (e.g. TIME=? returns the current time in 24-hour format).

Valid Commands:

APWR= ?

ATTNH=<0-31 | ?>

ATTNL=<0-31 | ?>

AVEP= < ? | RESET >

DATE= < Ddd | Mmm | Yyy | ? >

where dd = 0 - 31 day
where mm = 0 - 12 month
where yy = 0 - 99 year

DOSH= < 0 - 1400 W | ? >

DOSL= < 0 - 400 W | ? >

Valid Commands (Continued):

ECHO=< ? | ON | OFF >

FAULT= < ? | 0 - 255 | CLEAR >

FREQ= < ? >

FPWR= < ? >

HOURS= < ? | AMP | PA | IPA | SITE | CLRPA | CLRIPA | CLRSITE >

IDENT= < ? >

MODE= < LOW | HIGH | ? > available only after TEST=LOCAL

OPER= < OFF | STBY | ON | ? > available only after TEST=LOCAL

PWRH= < 0 - 38,500 W | ? >

PWRL= < 0 - 5000 W | ? >

RPWR= < ? >

TEST= < ? | ON | OFF | AMP | CHKSUM | FWREV | LOCAL >

TIME = < Hhh | Mmm | Sss | ? >

where hh = 0 - 24 hours
where mm = 0 - 59 minutes
where ss = 0 - 59 seconds

VVAH=?

VVAL=?

Spaces after the equal sign and the case of the characters are ignored. Thus, the following command inputs are equivalent:

OPER=STBY
oper= sTbY

Valid Responses from the Amplifier:

Note: ♦= space character

Parent Command	Amplifier Response
ATTNH=	a1_ATTNH=♦
ATTNL=	a3_ATTNL=♦
DATE=	d1_DATE=♦
"ENTER" pressed without a command	e1_SYNTAX♦ERROR
FAULT=	f1_FAULT♦♦
HOURS=AMP	h1_AMPHOURS=♦
HOURS=PA	h2_PAHOURS=♦
HOURS=IPA	h3_IPAHOURS=♦
HOURS=SITE	h4_SITEHOURS=♦
TEST=FWREV	i1_FIRMWARE=♦
TEST=CHKSUM	i2_CHECKSUM=♦
IDENT=?	id_IDENT=♦
TEST=OFF	l3_OFF
TEST=ON	l4_ON
MODE=?	n1_LOW or n3_HIGH (depending on current mode)
FREQ=?	r1_FREQ=123.2
MODE=LOW	x3_ready
MODE=HIGH	x3_ready
DOSH=	p1_DOSH=♦
DOSL=	p3_DOSL=♦
PWRH=	p5_PWRH=♦
PWRL=	p7_PWRL=♦
FPWR=	r3_FPWR=♦
APWR= or AVEP=	r5_APWR=♦
AVEP=RESET	r6_AVERAGE♦POWER♦RESET
OPER=OFF	s1_OFF
OPER=STBY	s2_STBY
OPER=ON	s3_ON
TIME=	t9_TIME=♦
VVAH=	v1_VVAH=♦
VVAL=	v3_VVAL=♦
SEE 10.2.19	x1_WORKING (Response)
SEE 10.2.19	x2_DONE (Response)
SEE 10.2.19	x3_READY (Response)
SEE 10.2.19	x4_OK (Response)
SEE 10.2.19	x5_BUSY
SETBIAS	X10_SETBIAS_DONE

Note: ♦ = space character

10.2.1 APWR= ?

The APWR command returns the average power output from the amplifier in watts. The returned message when the amplifier is producing an average power of 1000 watts is:

r5_APWR=♦1000

10.2.2 AVEP=< RESET | ? >

This command is used to reset the average power accumulator to 0. The command may be issued at any time.

The returned message is:

r6_AVERAGE POWER RESET for an AVEP=RESET command
r5_APWR=xxxx where xxxx is the average power in watts for an AVEP=? or APWR=? command

10.2.3 DATE= < Ddd | Mdd | Ydd | ? >

The DATE command is used to set and read the system's real time clock. The format for the DATE command is shown below:

DATE= Ddd (set the day-of-the-month)

Where dd is a number between 1 and 31.

DATE= Mdd (set the month-of-the-year)

Where dd is a number between 1 and 12.

DATE= Ydd (set the year)

Where dd is a number between 00 and 99. Only the last two digits of the year are entered. Years between 90 and 99 will be taken as 1990 to 1999. Years between 00 and 89 will be taken as 2000 to 2089.

DATE=? returns the message

d1_DATE=♦dd-mm-yyyy

10.2.4 DOSx

DOSH= xxxx where 0 < xxxx < 1875 watts
DOSL= xxx where 0 < xxx < 850watts

The DOSx command is used to set the average output power trip point

where x = H for mode HIGH
x = L for mode LOW

Whenever a DOSx command is issued the amplifier will return the average power output trip point in watts for mode x. The response is the same for the DOSx=?. The response will be:

p1_DOSH=♦xxxx for mode HIGH
p3_DOSL=♦xxxx for mode LOW

Note: The result is NOT padded to 4 characters. (e.g,. 25 not 0025)

10.2.5 ECHO= < ON | OFF >

The ECHO= command enables or disables the system's character echoing.

When ECHO=ON the system will echo each character sent.

The default setting of the ECHO command is ON.

10.2.6 FAULT= < ? | 0 - 255 >

A record of the last 256 faults is stored in nonvolatile RAM. The command allows access to the record (and to individual faults) for troubleshooting purposes.

The command returns the fault code plus a short description of the fault. The command format is:

FAULT= ? or 0

which returns the last fault that occurred, e.g.

f1_FAULT♦ ♦xx♦My♦Sz♦T:dd-mm-yyyy♦hh:mm:ss♦SHORT FAULT DESCRIPTION

The command: FAULT= 1 returns the fault that occurred before the "FAULT= 0". FAULT= 2 returns the fault that occurred before the "FAULT= 1" and so on. A listing of the last 256 faults can be obtained.

The first number, xx, is the fault code. A fault code of "00" indicates no fault.

The second set of characters, My, indicates the operational mode.

M1 = Mode LOW M3 = Mode High

The third set of characters, Sz, indicates the state.

S1 = OFF State
S2 = Power-On Sequence
S3 = Standby
S4 = High Voltage On Sequence
S5 = Operate State
S6 = Test Sequence

Next listed is the date and time stamp followed by a short description of the fault. See section 6.2 for a listing of the descriptions associated with each fault.

10.2.7 FREQ= < ? >

A FREQ=? command returns the center frequency:

r1_FREQ=♦123.2♦Mhz

10.2.8 FPWR= < ? >

This command returns the most recent peak forward output power.

When operating forward power is sampled every 10 microseconds. The maximum sample is stored in memory. When the FPWR=? command is issued, the amplifier returns the maximum power sample then clears the memory.

The command format is:

FPWR= ? returns:
r3_FPWR=♦xxxxx
Where xxxxx is the forward power in watts.

10.2.9 HOURS= < ? | AMP | PA | IPA | SITE | CLRPA | CLRIPA | CLRSITE >

The amplifier logs total on-time system and individual tube filament hours. Filament hours may be reset to zero after tube replacement. The total system on-time cannot be reset. Hour returns are displayed to a maximum of six places.

The command format is:

HOURS= ? or AMP
h1_AMPHOURS=♦12356 (0 - 199999)

HOURS= PA
h2_PAHOURS=♦♦♦♦10 (0 - 199999)

HOURS= IPA
h3_IPAHOURS=♦2000 (0 - 199999)

HOURS= SITE
h4_SITEHOURS=♦10000 (0 - 199999)

The HOURS= CLRPA or CLRIPA commands reset the clocks on the PA and IPA tubes. The CLRSITE command resets the site clock (for example, when a system is replaced). The format is:

HOURS= CLRPA
h2_PAHOURS=♦♦♦♦♦0

HOURS= CLRIPA
h3_IPAHOURS=♦♦♦♦♦0

HOURS= CLRSITE
h4_SITEHOURS=♦♦♦♦♦0

10.2.10 IDENT= < ? >

The IDENT command retrieves the system model and serial numbers. Example:

IDENT= ? returns: id_IDENT=♦50-S26B-123♦GE03210001

The first character set indicates the model number. The second indicates the unit serial number. The serial set contains a date code. The first two numbers (03) are the year built. The next two (21) are the week when the unit was shipped. The remaining numbers (0001) indicate the unit number.

10.2.11 MODE= < | LOW | HIGH | ? > (Applicable only in local command mode)

The MODE command reconfigures the amplifier for the desired RF output level.
The power levels for the S26B-128 are: LOW 8,000 watts and HIGH 35,000 watts.

A MODE=? inquiry returns the present amplifier mode.

n1_LOW n3_HIGH

When the mode is set (MODE=HIGH) or (MODE=LOW) the amplifier will respond with "x3_ready".

10.2.12 OPER=< OFF | STBY | ON | ? > (Applicable only in local command mode)

The Amplifier has three operational states: OFF, STANDBY, and ON (or OPERATE). In the OFF state, only the System Controller has keep-alive power applied. The System Controller monitors a few basic parameters and waits for the next command.

In the STANDBY state all power supplies except the high voltage are on. (The tubes require 200 seconds warm-up before a driving signal can be applied to them.) The System Controller is monitoring critical parameters and waiting for the next input command.

In the ON (or OPERATE) state, the amplifier is ready for operation. All power supplies are on; the tubes are ready to receive the driving signal. The System Controller continues to monitor all critical performance parameters and waits for the next command.

OPER=OFF turns the amplifier OFF.

OPER=STBY switches the amplifier from OFF or OPERATE to STANDBY.

OPER=ON switches the amplifier to OPERATE.

OPER=? asks the amplifier to return its present state, i.e. one of the following:

s1_OFF or s2_STBY or s3_ON
x1_WORKING (a state change is underway)
x3_READY (after state change is completed; awaiting next command)

10.2.13 PWRx

PWRH= xxxxx where 0 < xxxxx < 38,500 watts
PWRL= xxx where 0 < xxx < 8800 watts

The PWRx command is used to set the peak power trip point

where x = H for mode HIGH
x = L for mode LOW

Whenever a PWRx=? inquiry is issued the amplifier will return the peak power trip point in watts for mode x. The response will be:

p5_PWRH=xxxxx for mode HIGH Note: The result is NOT padded.
p7_PWRL=xxx for mode LOW

10.2.14 TEST= < ? || LOCAL | ON | OFF | CHKSUM | FWREV | >

The responses to the TEST=:

Test=Command	Response
TEST=FWREV	i1_FIRMWARE=♦UPX-X###-x
TEST=CHKSUM	i2_CHECK SUM=♦hhhh hhhh is the hex check sum
TEST=OFF	l3_OFF
TEST=ON	l4_ON
All TEST= Commands end with this response	x3_READY

10.2.15 TIME=<| Hdd | Mdd | Sdd |?>

The TIME command is used to read and set the real time clock. The format for the TIME command is:

TIME= Hdd (set hours)
t9_TIME= hh:mm:ss

Where dd is a number between 0 and 23.

TIME= Mdd (set minutes)
t9_TIME= hh:mm:ss

Where dd is a number between 0 and 59.

TIME= Sdd (set seconds)
t9_TIME= hh:mm:ss

Where dd is a number between 0 and 59.

TIME= ? (returns the current time)
t9_TIME= hh:mm:ss

10.3 MESSAGES FROM THE AMPLIFIER

NOTE: NOT ALL MESSAGES ARE RETURNED FROM THE AMPLIFIER IN NORMAL OPERATION. THE TEST=ON COMMAND MUST BE SENT TO TURN ON ALL THE MESSAGES FROM THE AMPLIFIER.

♦ = space character

In response to each command entered, the amplifier transmits a message to the MRI control system indicating the command has been received and is being executed. These messages also tell the MRI control system the amplifier status. A two-digit alphanumeric string precedes each message in order to allow easier decoding by MRI system software.

a1_ATTNH=xx — This is the response to the ATTNH=? command.

a3_ATTNL=xx — This is the response to the ATTNL=? command.

d1_DATE=♦dd-mm-yyyy — This is the response to the DATE=? command.

e1_SYNTAX♦ERROR — This message is transmitted if an improper command is entered.

e2_AMPLIFIER♦NOT♦TUNED♦AT♦THIS♦FREQ/MODE
This message is transmitted whenever an incorrect frequency/mode combination is commanded.

f1_FAULT♦xx♦My♦Sz♦T:dd-mm-yyy♦hh:mm:ss♦"Short fault description"

This message is transmitted whenever a fault is detected. The xx indicates the fault number. The My indicates the amplifier mode. The Sz indicates the amplifier state.

When a fault is detected by the System Controller the amplifier automatically switches to STANDBY or OFF depending on the severity.

When the FAULT=? command is issued a short description of the fault follows the code number.

h1_AMPHOURS=♦dddddd (0 - 199999)
h2_PAHOURS=♦dddddd (0 - 199999)
h3_IPAHOURS=♦dddddd (0 - 199999)
h4_SITEHOURS=♦dddddd (0 - 199999)

This is the response to the HOURS= ? , AMP, PA, IPA, SITE command.

10.3 MESSAGES FROM THE AMPLIFIER (Continued)

i1_FIRMWARE=♦

i2_CHKSUM=♦

id_IDENT=♦50-S26B-128♦GE9921001
Amplifier response to the IDENT=? command for a 50-S26B-128 amplifier; the appropriate model will always be reflected .

l3_OFF
l4_ON
Responses to the TEST=< ON | OFF > command

m1_STATE♦CHANGE♦IN♦PROGRESS
This message signals a state change is in progress: e.g., going from the OFF state to STANDBY, or from STANDBY to ON.

MEMR=

n1_LOW
n3_HIGH
This is the response to the MODE=? command.

p1_DOSH=♦xxxx where 0 < xxxx < 1400 W Response to the DOSH= command

p3_DOSL=♦xxx where 0 < xxx < 400 W Response to the DOSL= command

p5_PWRH=♦xxxxx where 0 < xxxxx < 30000 W Response to the PWRH= command

p7_PWRL=♦xxx where 0 < xxx < 800 W Response to the PWRL= command

r1_FREQ=♦dd.dd♦MHZ This is the response to the FREQ=? command.

r3_FPWR=♦xxxx Response to the FPWR=? command

r5_APWR=♦xxxx Response to the APWR=? and AVEP=? commands.

r6_AVERAGE♦POWER♦RESET
This is the response to the AVEP=RESET command. The average power accumulator has been reset to 0.

s1_OFF This message is transmitted whenever the OFF state is entered.

10.3 MESSAGES FROM THE AMPLIFIER (Continued)

s2_STBY	This message is transmitted whenever the STANDBY state is entered.
s3_ON	This message is transmitted whenever the ON state is entered.
t9_TIME= hh:mm:ss	This is the response to a TIME=? command.
x1_WORKING	This message is transmitted when the amplifier leaves the OFF state, STANDBY state or the ON state to perform a task followed by one of the two following messages.
x2_DONE	This message is transmitted when a Mode change is completed.
x3_READY	This message is transmitted whenever a commanded task is completed.
x4_OK	This message is transmitted after a fault is detected. The amplifier then switches either to STANDBY or OFF, provided there are no further faults.
x5_BUSY	This message is transmitted whenever the system is busy.

EXAMPLES OF COMMANDS AND THE RESULTING MESSAGE SEQUENCE:

Beginning with amplifier Off:

OPER=STBY

x1_WORKING
m1_STATE♦CHANGE♦IN♦PROGRESS
s2_STBY
x3_READY

From the Standby state:

FREQ=♦12X.XXX (“X” will be replaced appropriate to the model)
x2_DONE

OPER=ON
x1_WORKING
m1_STATE♦CHANGE♦IN♦PROGRESS
s3_ON

x3_READY

10.3 MESSAGES FROM THE AMPLIFIER (Continued)

Fault message sequence:

f1_FAULT♦♦89♦PA♦HV♦NO♦LOAD♦LOW
x1_WORKING
s2_STBY
x4_OK

When the primary AC power is first applied, the following message is transmitted:

MKS♦INC.
MODEL♦♦(amplifier model number)
FIRMWARE♦PN:♦UPX-X###-r
COPYRIGHT♦(year released)

Note: The Firmware part number’s ### are numbers and the lower case "r" is the revision level: A, B, C etc.