Service Manual

Hyfrecator® 2000

ELECTROSURGICAL UNIT

Serving the Physician Since 1937

CONMED® CORPORATION

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The revision level of this manual is specified by the highest revision letter found on either the inside front cover or enclosed errata pages (if any).

Effective use of this Service Manual depends on the user having ready access to the Hyfrecator® 2000 Operator's Manual, Cat No. 7-900-OM-ENG, available separately from Conmed Corporation Customer Service.

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1.0 GENERAL INFORMATION

1.1 Foreword

This Service Manual has been prepared to guide the qualified biomedical electronics technician through all aspects of preventative maintenance and repairs necessary to keep the Hyfrecator® 2000 Electrosurgical Unit (ESU) up to original factory specifications.

CONMED Corporation reserves the right to alter the specifications of the Hyfrecator® 2000. It is important to have access to the Operator's Manual supplied with each unit in order to restore original specifications. The Operator's Manual may also lead to a better understanding the unit's unique features and what the user may expect from it. The current version of the Hyfrecator® 2000 Operator's Manual may be ordered from CONMED, as indicated on the inside front cover of this manual.

Although this ESU has been designed for many years of trouble-free use and features a number of designed-in aids to simplify maintenance, it is assumed that the technician servicing the Hyfrecator® 2000 has a basic understanding of digital, analog and high-frequency power electronics, including through-hole printed wiring board (PWB) component replacement methods, and is familiar with troubleshooting using an oscilloscope and digital voltmeter. Further, the technician should be able to perform standard biomedical safety testing, such as measuring low-frequency leakage current.

The service technician should have ordinary electronic service tools and test equipment at his disposal. In addition, nearly all service actions include verification of RF output power calibration using an electrosurgical tester, or equivalent bench setup, capable of presenting 200, 500 and 1000 ohm non-reactive loads and able to measure RMS RF currents from 40 to 400 mA with a traceable accuracy of at least 5%. Although not essential, a high voltage, high frequency oscilloscope probe, such as the Tektronix P6015A can be a useful troubleshooting tool.

A properly equipped bench should also have a functioning Hyfrecator® 2000 handswitched accessory on hand to facilitate normal testing and service. This accessory may be ordered through CONMED Customer Service.

The Hyfrecator® 2000 has been certified for conformance to:
• Underwriters Laboratories UL544
• Canadian Standards Association CSA 22.2 #125
• IEC 60601-1

1.2 Intended Use

The Hyfrecator® 2000 ESU is intended for use only by physicians for purposes of minor surgical treatments where electrosurgical desiccation, coagulation or fulguration is indicated for hemostasis or tissue destruction. It may also be used for excision of lesions where marginal thermal damage is not contraindicated.

As with all ESUs, these effects are achieved through passage of high-frequency current originating at the active electrode through the patient's tissue. This current is in the 500 kHz range to prevent neuromuscular stimulation. Current injected into the patient may be returned to the ESU via several possible paths:

- In monopolar applications, where a single-pole active electrode is used at the surgical site, current may be returned either through a large-area return electrode in contact with the patient's skin, or simply through the patient's body capacitance to earth. The current is then returned through the green-yellow earth conductor in the unit's mains power cord. The return electrode jack is capacitively referenced to earth.

• In bipolar applications, two-pole active electrodes or forceps are used, and the current simply passes through the tissue pinched between these two poles, with negligible involvement of an earth path.

Some of the intended effects rely on a hot electrical arc being struck between the monopolar active electrode and the target tissue. These arcs require peak voltages in the kV range, and thus can present a burn hazard to the technician. See Section 2.3 for methods to avoid this hazard.

1.3 Warranty

As manufacturer of the CONMED HYFRECATOR® 2000 and other high quality medical equipment, CONMED warrants all of its products to be free from defects in material and workmanship under normal operation and use. The warranty period for the CONMED HYFRECATOR® 2000 is twelve (12) months to the product's original owner.

NOTE: The warranty card must be returned by the original owner to CONMED within ten (10) days of receipt of the invoice.

A ninety (90) day warranty is provided for standard and optional accessories. The ninety (90) day warranty includes the power up/down switching handle and cord. There is no warranty on disposable, single-use items.

The warranty is limited to the repair or replacement (at the manufacturer's discretion) of any HYFRECATOR® 2000 (or part thereof) that is returned to the manufacturer within the specified warranty period and which, after examination, is found to be defective.

Transportation of the HYFRECATOR® 2000 must be prepaid by the sender. The unit will be returned prepaid to the owner by the same manner of transportation used in shipping the product to the manufacturer.

The warranty does not apply to any product, or integral part thereof, that has been altered or serviced by anyone other than the manufacturer. Nor does it apply toward any product that has been damaged as a result of accident, abuse, misuse or negligence on the part of the user.

1.4 Factory Service

CONMED is proud of its long tradition of excellent Technical Service. Expert advice on all aspects of servicing the Hyfrecator® 2000 is available at no charge during normal business hours at the telephone numbers appearing on the inside front cover of this manual.

Whether under warranty or not, this unit may be returned to the factory for service. Non-warranty service will, of course, be charged at the current rate. Before returning the unit, contact CONMED Technical Services for return authorization and shipping instructions.

2.0 PRODUCT DESCRIPTION

This Section contains relevant "Quick Start" excerpts of the technical data supplied in the Hyfrecator® 2000 Operator's Manual, Cat. No. 7-900-OM-ENG. Refer to that document for further details.

2.1 Controls, Displays and Connectors

The Hyfrecator® 2000 controls are marked with IEC and ISO symbols which should be familiar to an experienced biomedical technician. See the Operator's Manual, Section 3, for detailed definitions.

• Mains Power

AC Mains power is controlled by a rocker switch on the right-hand side of the unit. Mains power is supplied by a 3-conductor cord connected to the CEE-22 mains inlet on the bottom of the unit. This cord MUST be connected to a safety-earthed AC mains source corresponding to the unit's mains rating marked on the rear. The green-yellow lead in this cord serves to return monopolar RF current to the unit through the patient's body capacitance to earth.

• Mode Selection

A three-position slide switch marked "HI - LO - BI" sets the operating mode. This switch also exposes only the RF output jacks appropriate to the selected mode. The active accessory RF plug must be disconnected from the RF jacks to allow movement of the mode switch.

• Power Adjustment

RF output power may be adjusted using either the power control knob or the up/down push-buttons on the handswitched active accessory. The selected power in watts to rated load appears on the two-digit LED display. HI and BI may be set in 1 W increments from 0 to 35 W, and LO is adjustable from 0.0 to 9.9W and 10 to 20 W. Note that each mode has its own independent power setting.

• Output Activation

Activation of RF output is controlled by either a handswitched accessory or an optional footswitch connected to the four-pin quick-release connector on the bottom of the unit. Activation is accompanied by illumination of the blue LED below the power display and a steady, audible tone.

• Tone Volume

The activation tone volume may be set using the screwdriver adjustment on the rear panel. The tone remains audible at the minimum setting.

• RF Output Connections

P/P (Patient Plate): Recessed male 0.08" (2 mm) pin for connection to the optional Patient Plate cord. Serves as an RF current return pole for Monopolar output. It is also capacitively coupled to earth via the mains cord to couple return current through the patient's body capacitance when a patient plate is not in use.

HI and LO: Monopolar active output, capacitively referenced to earth and the P/P jack. Intended for connection to the 0.25" (6 mm) RF banana plug on monopolar active accessories.

BI: Two 0.25" (6 mm) jacks for connection to a two-conductor bipolar active accessory cord. These connections are not referenced to earth or the P/P connector.

2.1.1 Power Setting Storage

Upon each power-up, the power settings for all three modes are returned to the values previously stored. During use, settings are automatically stored to non-volatile memory (EEPROM) each time the following sequence occurs:

1. Any power setting is changed, AND,
    the unit is activated, OR,
    the mode is changed, OR,
    2.5 seconds pass without a power adjustment.

Setting changes made immediately before powering down will not be stored. Mains power is not required to retain these settings, and the expected EEPROM storage life is greater than 10 years.

Some service actions such as recalibration will alter the stored settings. As a favor to the user, note the power-up settings when the unit is received and restore them before returning it to service. If the stored settings are unknown, it is safest to set them all to zero.

2.2 Specifications

Refer to the Operator's Manual supplied with the unit you are servicing for the complete set of specifications for that unit. The following partial specifications apply to units in production at the time this manual was revised, and are only those relevant to service actions.

Mains: All models are rated for 50-60 Hz AC single-phase mains power.

Catalog Number	Mains Voltage, V +/- 10%	Mains Current, A, maximum	Mains Fuses, 5x20mm Type T
7-900-100	100	0.9	1.25A
7-900-115	115	0.8	1.25A
7-900-220	220	0.5	0.63A
7-900-230	230-240	0.5	0.63A

Note: Mains ratings as supplied from the factory are marked on the rear panel nameplate. See Section 2.4 for instructions on altering the mains voltage rating.

Mains cord: 3 conductor #18 AWG (1.5 mm^2) Cu, 10 ft (3m), UL SJT with IEC-320-C13 (250 V 6 A) inlet connector.

Safety:
IEC Ratings: Class 1, Type BF Defibrillator-proof.
Patient 50/60 Hz risk current without earth connection: $<50\ \mu$A

Calibration Accuracy (RF power output to Rated Load vs. Power Display):

LO and BI:	0 to 10 W: Greater of 90 mW or 10% of setting
	10 to maximum setting: 10% of setting
HI:	Greater of 1 W or 10% of setting

Environmental:
Operation: 50°F to 104°F (10°C to 40°C); 10-95% Relative Humidity, non-condensing
Storage: -40°F to 158°F (-40°C to 70°C); 0 -95% Relative Humidity, non-condensing

Output Ratings:

Mode, W	Power, max	Load, Ohms	Voltage, KV(p-p)	Pulse Rate, KHz
HI	35	1000	8.0	24.2
LO	20	500	3.0	32.3
BI	35	500	3.0	32.3

Duty Cycle: Intermittent, 30s/30s active/idle

Output Waveform: Clipped, damped sinusoid with 450 +/- 50 KHz dominant frequency repeated at pulse rate shown above. See section 5.1.4 for RF output oscillograms.

2.3 Service Precautions

WARNING: Shock Hazard
Hazardous voltages are accessible when the enclosure is opened.
Mains component terminals and components in the HV power supply and RF Power Amplifier present a lethal shock hazard.

• Disconnect the mains cord during any service action which does not require power.

• High voltage on the PRHV filter capacitors may require more than 90 seconds to bleed down to 10V after mains power is removed. Wait until the red LED A2DS1 becomes dark before working in this area of the Power Board.

• High voltage in the intermediate circuitry is well isolated from earth and thus presents negligible risk, EXCEPT when this circuitry is earthed via test probes or to avoid a burn hazard. (See below.)

WARNING: RF Burn Hazard
DO NOT touch RF output terminals or internal components while the unit is activated.

This unit is intended to produce thermal lesions (burns) in living tissue. These effects will be produced inadvertently if the RF output circuitry or related components are touched while the unit is activated.

The intermediate circuitry, including the mains transformer frame, is isolated from earth and is lightly coupled via stray capacitance to the RF output. Therefore, mild but alarming burns or “shocks” may occur if intermediate components are touched during activation. This risk may be avoided by connecting the GND test point A2TP1 to earth ground while troubleshooting. However, this action also increases the risk of a shock hazard from HV components.

CAUTION: Thermal Burn Hazard
Hazardous temperatures may appear on some component surfaces.

During and after activation, power conversion devices, especially those bearing heatsinks, may develop surface temperatures hot enough to burn skin. Burn risk may be minimized by avoiding contact with these components until they have cooled, and by minimizing activation time and duty cycle.

CAUTION: Component damage is possible during service.

Improper service practices may destroy sensitive components in this unit and may void the warranty. Observe sound, conventional electronic service practices, with particular attention to the following:

• Electrostatic Discharge (ESD): This unit contains ESD sensitive components. Use effective ESD suppression techniques during all service actions.

• Common-Mode High Voltage: Whenever mains power is applied, and especially when the unit is activated, high common-mode voltages will appear on all parts of the intermediate circuitry. Connect circuit common A2TP1 to earth ground before making measurements. Even small currents drawn through earth-isolated test probes or body capacitance may destroy some sensitive semiconductors.

• Minimize Activation Time: This unit will overheat during continuous activation, especially with low impedance loads. Observe rated duty cycle. Restrict activation into short circuit loads to less than 5 seconds.

• Component Replacement: Replacement components should be as specified in the parts lists in Section 5 of this manual. Consult CONMED Technical Services for custom components or acceptable substitutes.

• Housing fasteners: To avoid stripping threads during reassembly, rotate housing screws counterclockwise with light pressure to find the original threads in housing bosses.

CAUTION: Test Equipment damage possible during service.

This unit produces voltages which may exceed common test equipment ratings. To avoid damage to your equipment, ensure that their ratings are adequate, with particular attention to the following:

• The common mode peak RF voltage in the intermediate circuitry may rise as high as several kV during activation. Connect A2TP1 GND to earth to avoid this hazard.

• Peak RF output voltages with respect to earth may exceed 8000 V. Common oscilloscope probes will arc over at this level and may destroy your oscilloscope input circuits. Do not attempt to measure RF output voltage unless your oscilloscope probe is adequately rated.

• Use only heavily insulated test leads in good condition on RF output connections. Ordinary test leads may break down and allow output current to flow through unintended paths.

2.4 Mains Voltage Strapping

This unit may be field-strapped to any of the rated mains voltages shown in Section 2.2 of this manual. Use the following procedure:

1. Unsolder the zero-ohm resistors from the A2 PWB, JP1 through JP5 and reinstall them for the desired mains rating according to Table 1 in Figure 5.8. Insulated, solid hookup-wire jumpers may be used instead of zero-ohm resistors.

2. Replace mains fuses A2F1 and A2F2 per Table 2, Figure 5.8.

3. Use an indelible marking pen to alter the mains voltage and current ratings on the nameplate according to Section 2.2 specifications. DO NOT alter the model number or serial number.

4. Reassemble the unit, connect it to the new mains voltage source and perform Mains Leakage and RF Power Output testing according to Section 4.2 of this manual.

2.5 Environmental Protection

At the end of its service life, the Hyfrecator® 2000 should be disposed of locally in accordance with local regulations. Component materials are:

- Thermoplastic enclosure and stainless steel mounting plate.
- Thermoset printed wiring boards containing miscellaneous electronic components.
- Power transformer made of steel and copper.
- Mains cord and pencil accessory made of thermoplastic and copper.
- Accessory electrodes are stainless steel and thermoplastic.
- Electrodes contaminated with biological waste should be disposed of as biologically hazardous material.
- Shipping container and packing material are a combination of cardboard and plastic film.

3.0 THEORY OF OPERATION

The Hyfrecator® 2000's fault detection and Fault Code displays expedite troubleshooting. However, the biomedical technician must understand more fully how the unit was designed to operate in order to isolate and repair less common problems. This Section is intended to provide that background.

3.1 Overview

The Hyfrecator® 2000 electronics comprises two printed wiring board (PWB) assemblies, the Display/Control Assembly (A1), and the Power Assembly (A2). Refer to Figure 5.6 for a block diagram of the system.

Component reference designators are formally listed as the assembly first, the component second, then the pin number. Example: Pin 5 of U3 on the Power board assembly would be referred to as A2U3-5.

The A2 Power Assembly contains most of the power supplies, the Radio Frequency (RF) Power Amplifier (PA), the RF output circuitry, the accessory switch isolation, the volume control, speaker amplifier and speaker. These functions are controlled and monitored by the A1 Display/Control assembly, which contains the Control microcontroller, the Monitor microcontroller, calibration and power memories, LED displays, mode selector switch, some of the power supply, and the power setting encoder. The following sections detail the circuit operation of each of these blocks.

With the exception of the line voltage side of T1 and the monopolar (HI & LO) patient connection circuitry, all of the Hyfrecator® 2000 circuitry is isolated from ground. The patient connections are capacitively RF referenced to earth ground. As a result of the circuitry isolation, an external safety ground (earth) lead must be connected to the intermediate circuit signal common ground to make meaningful measurements and to avoid damage to components, test equipment and yourself.

3.2 A2 Power PWB

Refer to Figure 5.8 for a schematic diagram of this PWB. The "A2" reference designator prefix for components may be assumed, as it is not used in the following description for clarity.

3.2.1 Power Supplies

AC mains power is isolated and converted to several low voltage and one high voltage (HV) source of DC power used by other circuitry.

3.2.1.1 Mains & Isolation

AC mains (line) power enters through a detachable cord and is routed through the power switch on the side of the unit. From the switch, mains power passes through Fuses F1 and F2, which guard against overcurrent faults. The fuse ratings correspond to the unit's mains voltage rating (See Figure 5.8, Table 2).

Earth ground is connected directly from the mains inlet connector to the patient circuitry on the A2 assembly. Its main function is to provide a functional earth return for monopolar RF current when no patient plate is in use. Interruption of the earth conductor does not create a shock hazard, but it may allow the patient plate voltage to become high enough to cause a burn to the user or patient.

The Hyfrecator® 2000 is powered from the 50-60 Hz AC mains at one of four strappable voltage ratings. The factory selection appears on the nameplate on the rear of the enclosure. Mains voltage selection is made on the A2 Power PWB using jumpers JP1-5. See Figure 5.8, Table 2. The procedure for changing the mains voltage is in Section 2.4 of this manual.

Transformer T1 provides mains isolation and converts the AC mains voltage to those AC voltages required by the internal DC power supplies. Note that the secondary windings are protected by embedded, non-replaceable thermal fuses. These fuses will open only if an unusual overload fault causes the winding temperature to become dangerously high before the mains fuses can open.

3.2.1.2 Low Voltage Supplies

Low voltage DC power, +24UNREG, is derived from the full wave rectified and filtered output of the low power secondary, T1-16 and T1-18. VR1 produces the +12 volt regulated power, +12V. A low current source of regulated +5 VDC for A2 circuitry, +5VR, is provided by U2-14. +24UNREG and +12V power the A1 Display/Control PWB as detailed in Section 3.3.5.3.

3.2.1.3 Pre-Regulated High Voltage (PRHV) Supply

Unregulated high voltage dc power, PRHV, is derived from the full wave rectified and filtered output of the high power secondary of T1-13 and T1-14. Resistor R15 and LED DS1 act as an indicator that high voltage is present, and as a bleeder to discharge filter capacitor C13. PRHV provides about +150 VDC bulk power to the High Voltage (HV) Switching Regulator that feeds the RF Power Amp.

3.2.1.4 High Voltage Switching Regulator

RF output power varies approximately as the square of the HV voltage. The value of HV during activation is set by A1 signal VCON, in accordance with the user's power setting for a given mode. See Figure 5.5 for nominal HV voltage vs. power setting.

Switchmode controller U2 and power FETs Q2 and Q4 are the major active components of a buck switching supply that chops PRHV down to the RF PA supply voltage, HV. HV is regulated to (R33+R31)/R31, or about 20 times VCON when /HVEN is low. When /HVEN is high, the power supply shuts off, and HV bleeds off to under 1V over several seconds. R20 and C7 form part of a free-running sawtooth oscillator which sets the switching frequency to approximately 1/(R20*C7), or about 90 kHz.

Q2 and R37 drive the gate of P-channel MOSFET Q4; when Q2 is on, Q4 is on. R36 provides Q4 turnoff gate bias, and diodes D5 and D6 protect the gate of Q4 against over voltage. This DC drive combination allows Q4 conduction duty cycles to vary over a much greater range than would be possible with a gate drive transformer.

When Q4 is switched on, the current through L1 and into C12 and C18 ramps up, causing HV to rise. When HV reaches a voltage set by VCON and a sawtooth waveform at U2-5, Q4 is switched off by U2. D4 then conducts the inductor current, which then begins to ramp down. The conduction duty cycle of Q4 is roughly proportional to the ratio HV/PRHV. Thus if PRHV increases, the Q4 conduction time decreases, or as VCON increases, the on-time increases.

R34 is the first stage of a voltage divider for the High Voltage Sense (HVSENS) monitoring circuit located on the A1 PWB.

3.2.2 RF Generation

Voltage-controlled DC power from the HV regulator is converted to radio frequency (RF) output power by the RF Power Amp and coupled to the RF Output jacks through the patient circuits. The output power of the unit is determined by the gate pulse width and frequency, and the high voltage supply, HV, to the RF Generator. All of these parameters are set by the Control microcontroller on the A1 PWB.

3.2.2.1 RF Gate Drive & Monitor

The 24-33 KHz RF gating waveform /GATE from the A1 PWB is amplified and inverted by U1A to drive the gate pin of RF PA MOSFET Q3. The /GATE waveform is fixed by the mode selection and does not vary with power setting, except that no gate drive is generated at zero power settings.

R6 feeds a sample of the Q3 gate waveform, GATEMON, to a duty cycle monitor on the A1 PWB.

3.2.2.2 RF Power Amplifier (PA)

When /GATE is low, Q3 switches on, and current ramps up in the primary of T3, building energy in its magnetic field. When /GATE goes high, Q3 turns off, and T3's magnetic energy is released into the resonant RF output circuits.

Capacitor C20 and the primary inductance of T3 form a resonant circuit which determines the 450 KHz component of the RF output. Unconstrained, this ringing RF waveform would normally swing negative and forward bias the slow intrinsic diode in Q3. This power-wasting process is averted by fast recovery diodes D7 and D8 which clamp the ringdown voltage to ground and shunt the swinging current back into the HV supply. These diodes are responsible for the clipped appearance of the RF output waveform.

3.2.2.3 Patient Circuits

T3 steps its primary RF voltage up to the final levels for effective surgical use. Capacitor C37 provides the connection for return RF current through the earth lead in the mains cord for use in monopolar mode with no return plate. Coupling capacitor C36 and J8 provide a return path for the optional patient plate. Accurate RF power measurements may be made using either the patient plate connection or earth.

C31, C32, and C38 provide additional high pass filtering to reduce neuromuscular stimulation and to provide some load regulation curve shaping.

Bipolar (BI) RF output is developed by a separate T3 secondary to output jacks J6 and J7. This circuit is isolated from both earth and the patient plate connection, thus providing a fully isolated bipolar output.

3.2.3 Isolated Switch Detector

The push-button switches in the handswitching accessory share a common conductor with the RF output voltage. The Isolated Switch Detector conveys switch closure information to the intermediate circuitry on the A1 PWB while maintaining common-mode electrical isolation via a combination of magnetic and optical coupling. This circuit also operates with the optional footswitch.

T2 and Q5 form a self-oscillating power inverter which converts +12 VDC into a 45 KHz AC voltage across the primary of T2. Q5-b is biased into initial conduction by R38 & R39, aided by feedback winding T2-2&3. When T2 primary current rises to about 200 mA, the T2 core saturates, and the feedback winding reverses polarity, switching Q5 off. T2's energy then rings with C25 for 1/2 cycle, after which Q5 turns on again for another cycle.

The 45 KHz AC secondary voltage, T2-5&6, is rectified and filtered by D9 and C30 to produce the Isolated Power Supply (IPS) of about 5.3 VDC with no load.

Connector J2 is located on the bottom of the unit and accepts the plug from either a handswitch accessory or a footswitch. When the footswitch is used, only the /ACTIVE signal and IPS- are used, and there is no connection to the RF lead. When the handswitching accessory is used, IPS- is connected to the RF lead and acts as a common lead for the power increase (/HPUP), power decrease (/HPDN), and activation signals (/HACT).

Each of these switch closures connects IPS power to the LED of an associated optoisolator (U3, U4, or U5), the phototransistors of which which develop signals /ACTIVE, /POWUP and /POWDN via +5V pullups on the A1 PWB.

3.2.4 Tone Generator and Monitor

Activation and alarm tones are developed on the A1 PWB as a 5V CMOS signal, /TONE. The A2 Tone Generator amplifies /TONE and delivers it at an adjustable volume level to loudspeaker LS1.

Buffer U1B inverts /TONE and boosts it to 12V. Screwdriver-adjustable volume potentiometer R47 and R14 set the level of the tone signal fed to emitter follower Q1, which then drives 60 Ω speaker LS1.

Tone Monitor circuitry samples the LS1 audio voltage and develops a proportional analog signal TONEMON which is used by the A1 monitor to determine activation tone presence. TONEMON varies from about +0.12 V at minimum volume to about +4.5 V at maximum.

3.3 A1 Display/Control PWB

Refer to Figure 5.7 for a schematic diagram of this PWB.

The A1 Display/Control Assembly performs the following functions:

User Interface:
- Power setting display for selected Mode.
- Power adjustment by front panel knob and up/down switches on the 3-button accessory.
- Non-volatile (EEPROM) storage of power settings.
- Generation of button clicks and activation tones.
- Activation in response to hand or foot switch closures.
- Illumination of the blue Activation LED.
- Fault code generation and display.

RF Output Control:
- PA drive waveform generation per selected mode.
- HV Supply voltage control per the power setting.

Fault Detection:
• Stuck activation or power adjust button on power-up.
• Incorrect waveform frequency or duty cycle.
• Incorrect HV voltage.
• Activation tone failure.
• Corrupted EEPROM calibration data.
• Incorrect LED power display.
• Microprocessor malfunction.

Fail-Safe RF Shutdown:
• Two redundant PA drive shutdowns.
• Two redundant HV shutdowns.

Service mode:
• Tools-only access via internal jumper.
• Mode switch selection of Calibration, diagnostics (Pseudorun) or Last Fault Code recovery.
• Two-point calibration for each Mode from user controls; no trimming potentiometers or selected components.
• Protected EEPROM storage of last calibration settings.

3.3.1 Dual-Channel Architecture

The A1 assembly incorporates two independent microcontrollers for Control (U1) and Monitor (U2). Both microcontrollers are single-chip Microchip® PIC16C RISC devices, each incorporating program ROM, RAM, clock oscillator, reset generator and 5-channels of 8-bit analog-to-digital conversion (ADC). Each microcontroller operates with its own 1K bit serial Electrically Erasable Programmable Read Only Memory (EEPROM), U3 and U4.

All of the Hyfrecator® 2000's normal functionality is provided by the Control microcontroller. The Monitor microcontroller serves only as a "watchdog", searching for combinations of signals appearing in the control channel which are indicative of potentially hazardous faults. Except during Power On Self Test (POST) and upon detection of a fault, the Monitor microcontroller's function is transparent to the Control microcontroller. The only normal user function provided by the Monitor microcontroller is illumination of the Active LED.

The two microcontrollers and their associated hardware are well isolated from one another, such that no single component failure occurring during a procedure can allow a hazard to persist for over 1/2 second. For example, each microcontroller has its own +5V regulator, each supplied from different sources. Input signals provided to both microcontrollers are resistively isolated to prevent a shorted input pin on one microcontroller from corrupting the signal read by the other.

This dual-channel architecture and fault detection process has successfully passed IEC 60601-1-4 Functional Safety testing and virtually guarantees that no patient or staff injury can result from a single system component failure.

3.3.2 A1 Signal Descriptions

This section describes all signals present on the A1 PWB.

3.3.2.1. Mnemonic Conventions

Signal mnemonics use the following conventions:

- A leading slant (/) indicates a logic signal which is active low.
- A ".C" or ".M" suffix indicates a signal specific to the Control or Monitor microcontroller, respectively.
- In general, a leading V indicates an analog signal.

The "A1" reference designator prefix for components may be assumed, as it is not used in the following sections for clarity.

3.3.2.2 Signal Levels

All logic signals are nominal 5 V CMOS rail-to-rail levels (GATEMON excepted). All analog signals fall in the 0.0 to +5.0 V range. Microcontroller ADC reference voltages are identical to the local Vdd (+5C or +5M). All signal voltages are referenced to A1 signal common (GND A1TP3).

3.3.2.3 DC Power Signals

Control power is provided by unregulated +24 V (+24U) from A2 and feeds TO-220 +5V 2% regulator VR2 to supply +5C (A1TP4).

Monitor power is supplied from +12V, and is regulated down to +5.0 V +/- 2% (+5M) on A1TP5 by TO-92 regulator VR1.

3.3.2.4 External Input Signals

/ACTIVE - Activation hand or foot switch closed.
/POWDN - Accessory power down button closed.
/POWUP - Accessory power up button closed.
HVSENSE - Analog signal proportional to HV (42.3 mV/V). R5 forms the lower half of the HV voltage divider string.
TONEMON - From A2 tone drive monitor. +0.10 V minimum with tone active.
GATEMON - Same as PA GATE drive (0/+12V).

3.3.2.5 External Output Signals

VCON - HV setpoint voltage (19.66*VCON); +5C x HVPWM duty cycle.
/GATE - CMOS-level PA gate drive (active low).
/TONE - Audible tone drive signal.
/HVEN - HV power supply enable.

3.3.2.6 On-Board I/O Signals

- /ϕ1, /ϕ2 - Two-bit grey-coded rotary encoder output (power adjust).
- SDA, SCL - IIC serial EEPROM data and clock signals (.C & .M)
- VCAL - Three-state analog signal representing Service jumper (J2) presence (0.0V), normal run (+5.0V) or Monitor microcontroller fault status (+2.5V) to Control microcontroller.
- VGATE - Driven by GATEMON analog duty cycle monitor signal. Nominally +2.1 to 2.6 V, GATE active.
- /GATE.M - Isolated version of /GATE; used for PA drive frequency monitor.
- GATENA - Monitor GATE enable; forces PA drive off via Q3 when low.
- PSETO.0:7 - LED segment drive and Control-to-Monitor settings/fault code signal bus.
- LED1:8 - LED anode drive, current limited by RN1.
- LED1S - Ones LED digit drive.
- LED10S - Tens LED digit drive.
- /GATEPWM - PA gate drive signal; frequency and duty cycle determined by Mode selection.
- HVPWM - Variable duty cycle CMOS signal; same frequency as /GATEPWM. Sets HV voltage per power setting. (see VCON above).
- VMODE - Three-state analog representation of Mode switch position.

3.3.2.7 Control/Monitor Communication

The two microcontrollers communicate with one another via three paths:

• Functional ESU Signals: i.e, HV voltage, gate frequency, duty cycle, and tone generation. Direction is from Control to Monitor.

• 10-bit LED drive bus (PSETO0:7, LED1S, and LED10S): Direction is from Control to Monitor during normal Run Mode. During POST and Fault Code display, the direction is from Monitor to Control.

• VCAL Signal: From Monitor to Control. Upon detecting a fault,the Monitor pulls VCAL.M to ground, and through the voltage divider formed by RN4A and RN4B, causes VCAL.C to go to about 2.5 VDC.

3.3.3 Power-Up Behavior

When power is applied, +5M and +5C will rise towards their regulated voltage levels. These voltages are presented to the /MCLR (Master Clear) inputs of each microcontroller. After reaching about +4.2 Vdc, and each microcontroller 4 MHz clock oscillator has started, the microcontrollers begin executing their programs stored in on-board program memory. These programs set up I/O ports, read and validate data from their respective non-volatile EEPROMS, and perform some error-detection processes, such as stuck-on faults on any of the three accessory button signals, /ACTIVE, /PWDN and /POWUP.

Both microcontrollers then check their VCAL inputs to determine which operating mode to enter.

3.3.4 Operating Modes

The Hyfrecator® 2000 can power up in either of two modes, Run or Service.

• Run Mode: Used in normal clinical service.

• Service Mode: Accessible only when the unit's enclosure is opened.

3.3.4.1 Run Mode

Normal operation (Run Mode) occurs when the unit is powered up with the Service Jumper (A1J1) open-circuited such that VCAL is greater than +3.75 Vdc. Entry to Run Mode is accompanied by execution of the Power On Self Test cycle described in Section 3.3.5.3. After the POST cycle completes, the Power display shows the last power setting for the selected Mode as it was read by the Control microcontroller from its EEPROM. The operator may then change modes at will, and the most recent power setting used in that mode will appear in the power display. The power setting for each mode is independently adjustable using either the power control knob on the front panel or the up/down buttons on the handswitched accessory. RF output may be activated by pressing the activation button on the handswitched accessory or by closing the optional footswitch. Activation is accompanied by an audible tone and illumination of the blue activation LED.

3.3.4.1.1 Output Mode Selection

The unit may be set to operate in the High Voltage (Hi), Bipolar (Bi) or Low Voltage (Lo) mode via the Mode Selector switch, S1. S1 comprises a set of gold-plated pads on the solder side of the A1 PWB which are selectively shorted together by a moving contact mounted on the Mode Selector mechanism secured to the front panel.

Switch S1 drives a discrete digital-to-analog converter made up of R9, R10, R12 and R13. The analog output signal, VMODE, assumes a DC voltage unique to each of the three positions of S1:

MODE	VMODE
HI	+0.75 to +1.75 V
BI	+2.00 to +3.00 V
LO	+3.25 to +4.25 V

VMODE is provided to both the Control and Monitor microcontrollers via isolation resistors as VMODE.C and VMODE.M. The Control microcontroller uses VMODE.C to select the appropriate gate drive waveform on /GATEPWM and to present that mode's power setting on the LEDs.

If Vmode falls outside of the 0.5V tolerance range, due to S1 being set to an intermediate position or a component fault, the Control microcontroller will present "--" on the LED display, and activation is inhibited.

The Monitor microcontroller uses VMODE.M to validate the gate drive and the mode data presented to it by the Control microcontroller on the PSET bus. If the Monitor microcontroller disagrees with these Control actions, a fault is declared.

3.3.4.1.2 Power Display

Power settings are presented on the two-digit numeric LED displays, X1 and X2, as Watts deliverable to the rated load resistance for the selected mode (500 Ω for LO and BI, 1000 Ω for HI). The Control microcontroller drives the segment data LED1:8 via current limiting resistor pack RN1 to X1 or X2 in alternating fashion at a 100 Hz scan rate. The active common-cathode LED digit is selected by LED1S and LED10S which drive Q1 and Q2, the digit drivers. Each digit is driven continuously for 4 msec followed by a 1 msec blanking period before the other digit is selected.

3.3.4.1.3 PSET Transfer

During the 1 msec LED blanking period, the Control microcontroller turns both Q1 and Q2 off and presents an 8-bit code, PSET, on the PSETO0:7 bus to the Monitor microcontroller. This transfer is necessary because the Monitor microcontroller does not have direct access to user power adjustment inputs.

PSET contains data showing the current operating mode and power setting, as well as codes for invalid VMODE voltage and Control-detected fault conditions. Certain ranges of PSET values are unused and considered invalid.

The Monitor microcontroller uses PSET to set fault limits on HV, gate frequency and gate duty cycle, and to validate VMODE. It also compares PSET to the power display data driven to the LEDs. If PSET presents a Control-detected fault code, the Monitor microcontroller will initiate a fault detection shutdown and display that code on the LEDs.

3.3.4.1.4 Power Adjustment

While the unit is idle, the operator may change the power setting either by turning the 36-step/revolution incremental encoder, S2, or by pressing the remote Up/Down buttons on the accessory. The effect of the adjustments appear immediately on the power LEDs and on PSET. Power adjustments can be made in the smallest steps displayable in the mode: 1 watt, or in LO under 10 W, 0.1 W. Each step change using the remote buttons is announced by an audible click from the tone generator; no sound is produced with encoder adjustments.

Power cannot be decreased below zero or above the maximum setting for that mode. Encoder adjustments are ignored if either remote button is depressed. Attempts to change power or mode while activated are ignored.

Both adjustment methods feature a fast slew mode to expedite large power changes:

• If the encoder is rotated faster than about 1 revolution per second, the step size increases fivefold.

• If a remote adjust button is closed for over 600 msec, steps will occur at 5 per second for the next second or until the button is released. If the button is held even longer, the step rate increases to 16 per second, and step size doubles.

3.3.4.1.5 Setting Storage

Power setting data is stored separately in the Control microcontroller RAM for each Mode for immediate retrieval if the Mode selection is changed. These settings are also copied to the Control EEPROM, U3, if any power setting is changed. The EEPROM storage cycle is armed upon any power adjustment, and is subsequently executed upon the earliest of three events: activation, mode change or 2.5 seconds elapsed with no power adjustments. Settings for all three modes are stored in the same cycle.

The EEPROM contents are expected to remain intact with no power or batteries for at least 10 million write cycles, well beyond the service life of the Hyfrecator® 2000.

The settings data is stored redundantly for error detection. On power-up, if the setting data has been corrupted, all Last Settings will default to zero. This fault is not deemed serious enough to justify disabling the unit. If the Control microcontroller is unable to access the EEPROM during an attempted settings write, however, a fault will be declared to avoid unexpected high settings during the next power-up.

3.3.4.1.6 Activation

Until the unit is activated, the Control microcontroller forces all drive signals to inactive states: HVPWM = low, /GATEPWM = high, /TONE = low. Further, the Monitor microcontroller holds /HVENA inactive (high), so the ACTIVE LED X3 is dark and the HV Regulator is idle. GATENA is held high, however, so that the Monitor can detect activation, valid or otherwise, via the /GATE.M signal. The only visible activities during this idle state are the two 4 MHz oscillators and the 10 msec LED & PSET cycle on the PSETO & LED drive lines.

Although not externally visible, both microcontrollers are continuously performing fault detection tests, in particular those that verify that no RF output is being generated. See Section 3.3.5 for descriptions of these tests.

Activation starts in the following sequence:

1. /ACTIVE goes low in response to the user's closing the hand or foot switch.

2. After /ACTIVE is low for 20 msec, and there is no pending EEPROM write or power or mode change process pending, the Control microcontroller begins generating /GATEPWM per the current mode and HVPWM per the power setting, and turns on the /TONE signal.

3. Upon detecting gate drive activity on /GATE.M, the Monitor microcontroller pulls /HVEN low, thus enabling the HV Regulator and turning on the ACTIVE LED.

Once activation has commenced, the Control microcontroller simply keeps its drive signals running, while ignoring any further power or mode changes. Both microcontrollers continue their fault detection processes. In particular, the Monitor is busy verifying that RF output is correct and that activation is accompanied by an audible tone (TONEMON) and /ACTIVE.M being low. See Section 3.3.5 for descriptions of these tests and fault shutdown processes.

Activation is normally terminated when the user releases the activation switch. Deactivation proceeds as follows:

1. /ACTIVE goes high.

2. After 20 msec, the Control microcontroller returns HVPWM, /GATEPWM and /TONE to their idle states, and re-enables power and mode change inputs.

3. Upon seeing /GATE.M activity cease and /ACTIVE.M go high, the Monitor takes /HVEN high to turn off the ACTIVE LED and the HV supply, and restores idle state fault testing.

3.3.4.1.7 Gate Waveform Generation

The PA gate drive waveforms originate in the Control microcontroller and appear first as /GATEPWM. Each of the three Modes has its own waveform period and ON-time (T_{ON}) which do not vary with power setting or calibration adjustments. Note: due to the inversion in PA gate driver A2U1B, /GATEPWM is low (0 Vdc) during T_{ON}.

Mode	Period (μsec)	T_{ON} (μsec)
HI	41.0	3.75
LO	31.0	3.00
BI	31.0	3.75

When the unit is idle or declaring a fault, /GATEPWM is off (+5 VDC). Each of these waveforms are generated with HV off during the first three steps of the POST cycle.

/GATEPWM feeds the emitter of Q3, which enables /GATEPWM to pass through to the /GATE output when Monitor signal GATENA is high. GATENA is normally high, but is taken low during POST testing and during fault shutdown to redundantly prevent RF output.

3.3.4.1.8 HV Voltage Control

RF output power level is controlled by the HV voltage, which is set by VCON, developed by the Control microcontroller. VCON is an analog signal developed by passing a high frequency, variable duty cycle CMOS signal, HVPWM, through a low-pass filter, R1 C3. The HVPWM period is identical to that of /GATEPWM, but its T_{ON} varies in 0.25 μsec steps with power setting.

Unlike /GATEPWM, HVPWM varies not only with power setting, but also from unit to unit in accordance with calibration variables stored in the Control EEPROM in Service CAl mode. See Section 3.3.4.2.2.

3.3.4.1.9 Tone Generation

The audible tone signal /TONE is generated by the Control microcontroller to announce activation and fault shutdown to the user. These two tones are audibly distinct. The activation tone serves an essential safety function to alert the user that the RF output is "hot". Since the activation circuit is a single channel, numerous possible short circuit faults may result in inadvertent activation. The activation tone has a fundamental frequency of 962 Hz, but it is not a 50% duty cycle square wave (See Figure 5.4). This waveform's harmonic content was developed in order to minimize audible nulling and peaking due to reflections occurring in an acoustically "live" clinical setting.

The alarm tone is a simple 651 Hz square wave created by a short endless software loop in the final phase of the fault shutdown process.

3.3.4.2 Service Mode

The Service Mode is provided to expedite maintenance of the Hyfrecator® 2000. Service Mode provides for power calibration adjustments, recovery of the last fault code or operation with no fault detection active.

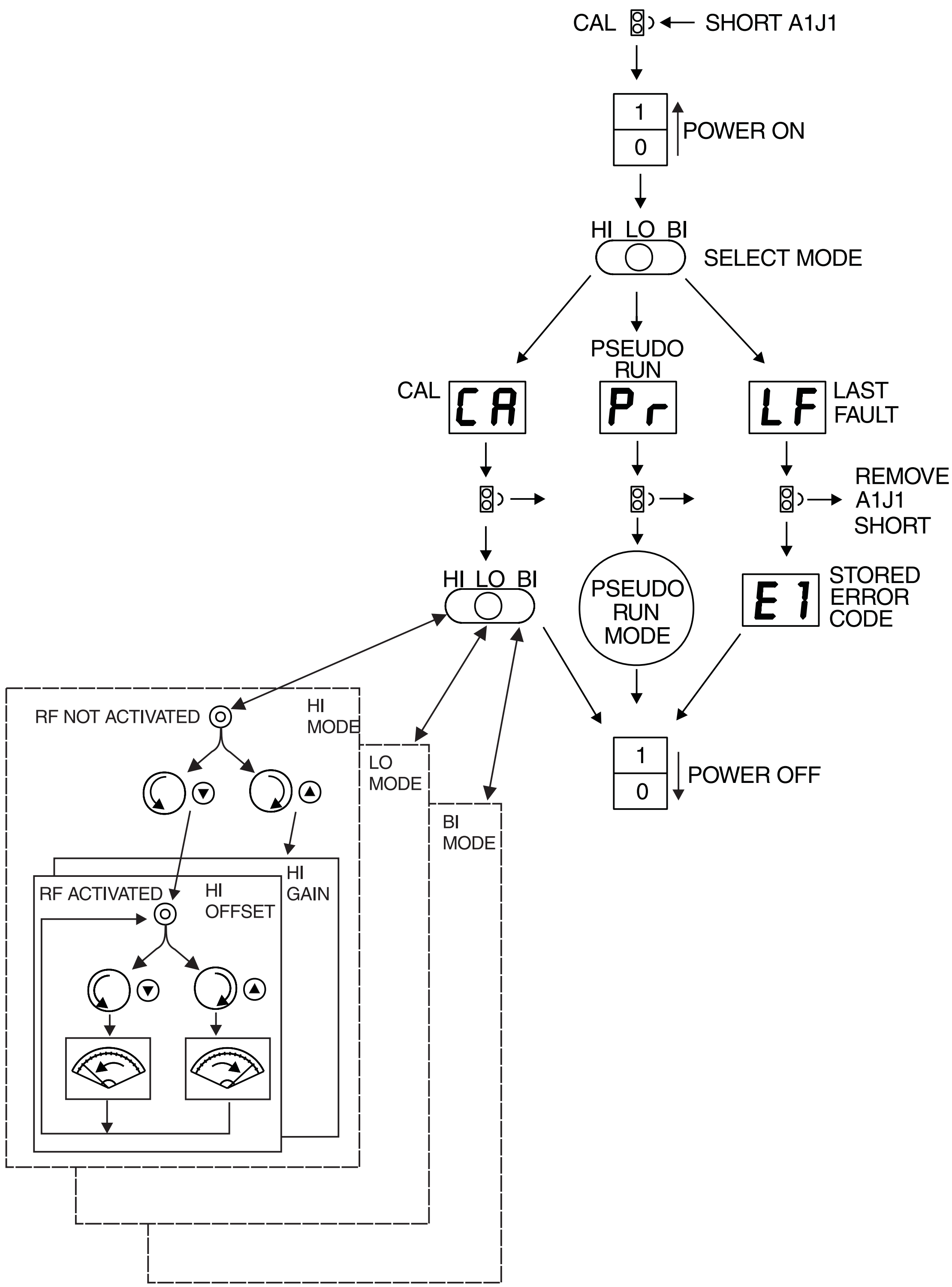
3.3.4.2.1 Service Mode Entry

Service Mode is entered when the 2-pin Service connector (A1J1) on the A1 Control/Display Assembly is shorted during power-up. Both microcontrollers will enter normal initialization, but the power-up testing normally performed during Run Mode is skipped. The existing stored Calibration variables are used if the EEPROMs read without errors, otherwise factory default values of OFST = 0 and GAIN = 1.0 are loaded. The POST cycle is not run, and there is no stuck switch detection.

Successful entry is confirmed by the Service Mode Menu display. While J1 remains shorted, the Power Display will show one of the three available Service modes. The desired mode is selectable via the Mode Selector switch.

Figure 3.1 Service Mode Menu Diagram

This figure presents a flow map of all functions available in Service Mode.



Service Mode	Mode Switch	LED Display	Service Function
Cal	Hi	CA	Output power calibration adjustment.
Pseudo-run	Lo	Pr	Normal run without fault detection.
Last Fault	Bi	LF	Last fault code presented from EEPROM.
n/a	Invalid	--	Invalid Service Mode - “-E” shutdown.

The selected mode will be invoked upon removal of the short on J1. Once a Service Mode is entered, the only means of exit is to turn off power to the unit.

The absence of fault detection in Service Mode allows troubleshooting to proceed without interruption by fault shutdown. The only faults allowed in Service Mode are:

• Invalid Service Mode: This indicates a problem with VMODE, which can be checked with a DVM while the J1 short is in place.

• Control EEPROM Write Fault, if the calibration values cannot be stored. This may be corrected through EEPROM replacement.

The values stored as Last Settings may be changed during during Service Mode. As a service to the physician, the Last Settings stored when the unit was delivered to you should be noted and restored before returning it. If those settings are unknown, it’s safest to set them all to zero.

3.3.4.2.2 Service Calibrate Mode

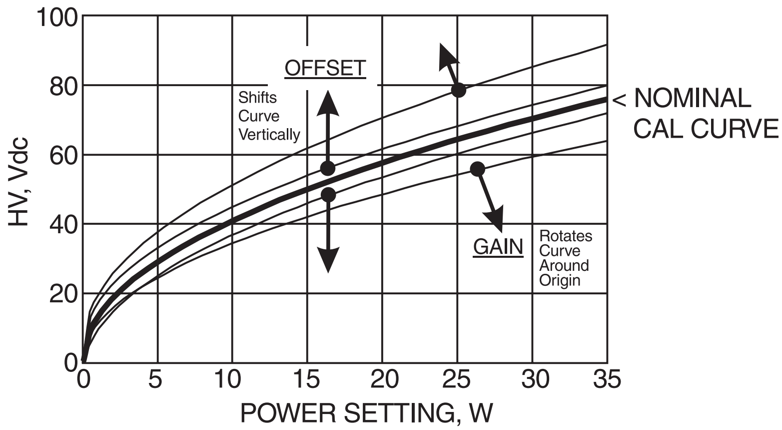
This mode provides for correction of unit-to-unit variations affecting the relationship between RF power output and the Control microcontroller HVPWM duty cycle, which ultimately establishes the HV voltage used to control power. Further, it allows the Monitor microcontroller to “memorize” the exact VGATE voltage corresponding to each Mode’s PA gate drive waveform.

HVPWM T_{ON} for a given Mode and power setting originates in a Control microcontroller lookup table representing the “nominal” Hyfrecator® 2000. This nominal value is adjusted to the characteristics of a particular unit by multiplying it by a Gain factor and then adding an Offset. The values of Gain and Offset for a particular unit are established for each Mode in the Service Calibration mode, where they are written to the Control EEPROM. A similar table for HVSENS appears in the Monitor microcontroller ROM, and a similar Offset and Gain calibration process is performed.

There are six HVPWM Calibration (Cal) variable adjustments. Each of the three operational Modes has its own pair of Offset and Gain adjustments. These variables are actually numbers stored in the Control and Monitor EEPROMs during Service Calibration Mode and read back later during each power-up cycle. There are no trimpots or selected components involved in calibrating the Hyfrecator® 2000.

Selection and adjustment of each Calibration variable is done simply using the normal power setting means, encoder or up/down buttons. The only test equipment required is an ESU analyzer capable of presenting 500 and 1000 ohm non-reactive 50W or greater loads, and able to read HF power from 2.0 to 28 watts, or rms RF current from 40 to 300 mA.

Figure 3.2 Effects of Offset & Gain Adjustments



Calibration variable selection is done *while the unit is deactivated* using first the Mode Selector switch to set the Mode to be calibrated, and then by the power buttons or encoder to select between the Offset and Gain variable for that Mode.

The Power Display will show which of the two variables is selected in the form of a Target Power. This is the power in Watts which should be delivered to Rated Load when the unit is activated. Offset targets are either 2.0 or 3 W, and Gain targets are 16 or 28 W, depending on Mode. During Service CAl Mode, the PSET bus is driven in the same sequence as in Run Mode, except that each LED is driven for 5 msec rather than 4 msec, for a repetition period of 12 msec.

Once a calibration variable has been selected, the unit may be activated using the handswitched accessory or the footswitch. *While activated*, the power adjust buttons or encoder will cause the selected variable to increase or decrease, thus causing HVPWM duty cycle and the measured RF output power to vary accordingly. The adjustments are made until the RF output power measured on the ESU analyzer matches the Target Power presented on the Power Display LEDs. When the measured RF output is adjusted as closely as possible to the displayed Target Power, keep the unit activated for about 1 second without any adjustment to allow the Monitor to acquire an accurate measurement, then deactivate.

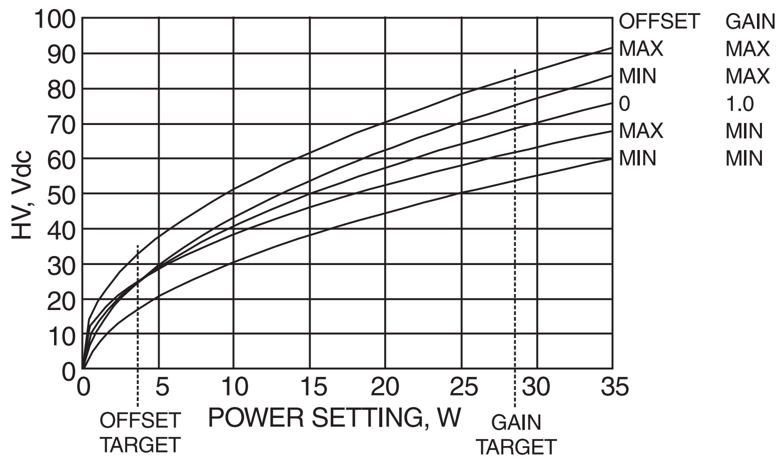
The adjusted values are stored on deactivation in both Control and Monitor EEPROMs, where they are read back on subsequent power-ups. The Monitor also stores the Gate Duty Cycle monitor voltage VGATE, which it measures during activation to allow for accurate fault detection.

> NOTE: The Control microcontroller will perform a storage cycle ONLY if there was some adjustment while the unit was activated. To make sure that the Calibration variable is updated, step the setting up and back while activated, even if the output appears correct with no adjustment.

The calibration process should alternate between Offset and Gain until both Target powers are matched within allowable specified tolerances. Because HVPWM can change only in discrete increments, it may not be possible, nor is it necessary, to adjust output precisely to the Target Power.

Gain and Offset adjustments have range limits which should permit any unit to be calibrated easily, provided there are no failed power-determining components. If RF output stops changing well short of the target while making an adjustment, such a failure should be suspected and corrected before calibration is continued.

Figure 3.3 Limits of Calibration Adjustments



It is possible to adjust Gain and Offset such that the HVPWM duty cycle hits 100%. Any further increase will force HVPWM to turn off, thus causing RF output to drop to zero. If this occurs, and reducing the CAl variable restores output, then repairs are clearly indicated.

> HINT: Since both Offset and Gain affect HVPWM at all power settings, there is some interaction between their adjustments. Thus if Offset is adjusted precisely to the Offset Target, and then Gain is raised, you may find that the Offset output has also increased slightly. This can turn calibration into an unnecessarily lengthy and tedious process if one attempts to set Offset and Gain alternately as closely as possible to the Target values.
>
> With a little practice, you will learn to anticipate the interaction and make your adjustments a bit off in the correct direction such that the other adjustment will correct both Offset and Gain outputs. Offset has a greater relative affect on low settings than on high settings, and the opposite is true for Gain. A full calibration can be completed by an experienced technician in under 2 minutes.

It is necessary to enter Service CAl Mode only if periodic maintenance checks in normal Run Mode indicate that the output power is out of spec, or after performing repairs to the unit. This mode is also useful in recovering from fault codes which indicate corrupted EEPROM data, or if either EEPROM is replaced. If the EEPROM calibration data is corrupted, Offset will default to zero and Gain will default to 1.0 if Service Mode is entered on power-up. Otherwise, the values from the last calibration will be used as baselines for this session.

If periodic maintenance tests indicate that one Mode requires recalibration, it's a good idea to check all six CAl variables, since drift of one component may affect all Modes to differing degrees.

3.3.4.2.3 Service Pseudo-run Mode

This mode allows the unit to be operated in normal run, but with all tests which would otherwise cause a fault termination disabled. This allows troubleshooting to proceed with live signals. Caution should be used, however, if the fault code indicates excessive RF output power, because continued operation at power levels well above specification may damage components in the HV supply or RF output stages. In this event, PA drive can be disabled simply by shorting A1Q3-B to ground.

3.3.4.2.4 Service Last Fault Recovery Mode

This mode simply pulls up the last Fault Code presented from Monitor EEPROM and displays it. This is a useful troubleshooting aid if the user's complaint did not note that information. If there was no prior Fault Code stored, "-0" will be displayed.

3.3.5 Control/Monitor Interaction

Section 3.3.2.2 describes the three channels over which the Control and Monitor microcontrollers communicate. This section provides more detail regarding the content and effect of that interaction.

3.3.5.1 Fault Detection Protocol

The Monitor microcontroller's primary role in the Hyfrecator® 2000 is to prevent faults in the Control channel from becoming a hazard to the patient or the physician. Upon detection of any fault which can create such a hazard (see Section 3.3), the Monitor microcontroller takes action to ensure that no further RF output can be generated, and notifies the Control microcontroller to release the PSET bus and to sound a Fault tone. Once the Control microcontroller complies, the Monitor microcontroller drives a Fault code unique to the class of fault detected onto the PSET bus, which appears as a Fault Code on the LED display. The Fault Code is also stored in the Monitor EEPROM for later recovery in Service Last Fault (LF) mode. Once in this state, the Hyfrecator® 2000 will not respond to any further input, short of powering down.

In order to avoid nuisance shutdowns due to harmless transient deviations over fault limits, the Monitor microcontroller will give a detected fault 360 msec to correct itself before initiating Fault Shutdown. If the fault clears in that time, it must remain clear for at least 120 msec in order to reset the 360 msec timer.

Upon initiating Fault Shutdown, the Monitor microcontroller redundantly disables RF output by taking GATENA low and /HVENA high, which removes both PA gate drive and turns off the HV Regulator independently from any contrary action by the Control microcontroller.

The Control microcontroller is notified of the Fault via the VCAL signal. The Monitor changes its VCAL.M analog input to a digital output in a low state, thus causing VCAL and VCAL.C to drop to approximately +2.5 VDC. The Control microcontroller samples VCAL.C every 10 msec. Upon observing VCAL.C go to this state, the Control microcontroller immediately releases the PSET and LED drive buses by changing them to inputs and enters an endless loop which toggles the /TONE line to produce the Fault tone.

Some Monitor-detected faults may be caused by failure of the Control microcontroller. In such cases, RF shutdown will still be effected, but the Fault Code may not appear and the fault tone may not be sounded because of failure of the Control microcontroller to respond to VCAL.C.

The Control microcontroller performs its own sequence of fault detection tests on signals and internal conditions which cannot be observed by the Monitor. These include activation or power-adjust inputs during power-up, Control EEPROM data errors and several abnormal internal processing faults.

When the Control microcontroller detects one of these faults, it replaces the normal Power Display data on the PSET bus with a binary fault code in the 1-to-10 decimal range, which is outside the range of possible PSET values. The value of this code indicates the class of fault detected. The Monitor acknowledges having read this code by pulling VCAL to 2.5 VDC, and fault shutdown proceeds exactly as with a Monitor-detected fault. Control-detected faults are not attributable to expected transients, therefore no timing allowance is provided and Fault Shutdown will be effected immediately.

3.3.5.2 Fault Code Generation

Fault Codes are intended not only to notify the user that the unit has shut down, but also to assist the biomedical technician in diagnosing the problem.

Fault codes produced by the Monitor all have a hyphen (-) in the 10's LED digit, while Control-detected faults show an "E" there. The one's digit is specific to the fault each detects. A list of fault codes along with a description of the faults they are associated with appears in the Appendix at the end of this manual. Note that there are some faults which may not produce a fault code display or even a fault tone, even though the unit has shut down. Examples include a defective or stalled Control microcontroller which refuses to relinquish the LED bus, or a defective Monitor microcontroller which fails to deliver the expected POST test sequences to the Control microcontroller.

3.3.5.3 Power On Self Test (POST)

At least one half of every hazardous two-component failure, such as failure of the tone monitor circuit followed later by tone generator failure, is detected on every power-up during the POST cycle. The POST cycle is evidenced by the "twirling baton" LED display and "four beep" tone. The POST cycle is driven by the Monitor microcontroller, and at each of its eight steps, the Control microcontroller generates a predetermined PA gate drive or HV setpoint signal, and turns the tone on or off. At each step, the Monitor verifies that the PA drive frequency and duty cycle, HV voltage and tone monitor signals are within expected ranges. In addition, the Monitor microcontroller verifies its own ability to disable PA drive and HV.

PA drive and HV tests are performed during separate steps to prevent generation of live RF. Although the Monitor continuously verifies that the LED drive signals are correct relative to power setting, the user is relied upon to detect other LED display faults, such as dead segments. The "twirling baton" display facilitates this detection.

Prior to POST, each microcontroller independently tests for certain faults, such as errors in the EEPROM data and activation or power adjust signals in the active state. Announcement of such faults are delayed until after POST.

The states of various Control-generated signals at each step of the POST cycle are detailed in Table 3.1.

POST Step	LED Segment	Tone	PA Gate Waveform	Hi Mode Power Setting, W	/HVENA (Blue LED)	HV, VDC +/- 10%
1	a	Off	Lo	0	On	0
2	b	On	Hi	0	On	0
3	c	Off	Bp/Off	0	On	0
4	d	On	Off	1	On	13
5	e	Off	Off	4	On	26
6	f	On	Off	15	On/Off	50
7	g	Off	Off	25	Off	Falling
8	dp	On	Off	25	On	64

Table 3.1 POST Test Sequence

During the first three POST steps, PA Gate waveforms for each Mode are tested. The Monitor also leaves /HVENA on (low) to verify that HV remains near zero as set by the Control microcontroller. The last half of the 3rd step verifies that GATENA can disable the PA gate drive.

During the last five POST cycle tests, HV is tested for accuracy, using current HI Mode calibration values, at four successively larger values. The last part of steps 6 and 7 verify that HVENA is able to cause HV to drop.

After a successful POST, the Monitor microcontroller relinquishes control of the LED drive to the Control microcontroller, and the Hyfrecator® 2000 enters normal operation, or "run mode".

Because there is no PA gate drive during HV tests, HV discharges slowly, so POST will end with some residual voltage remaining. If activation occurs while HV is still discharging, the loading effect of the PA will pull HV down quickly.

4.0 MAINTENANCE

This section describes technical procedures for conducting periodic preventative maintenance, safety and performance testing, along with procedures for calibrating the RF output to ensure that the Hyfrecator® 2000 continues to operate within the original factory specifications.

Guidance on troubleshooting and repair are also included to help you return the unit to service quickly in the event a unit fails to pass a test or fails to perform to the physician's expectations.

4.1 General Maintenance Information

The Hyfrecator® 2000 has been designed to give the user many years of trouble-free service. The service life may be extended indefinitely with proper care in use and application of simple periodic Preventative Maintenance (PM).

In the event that a unit fails to meet its performance or safety specifications, as discovered by the user or during PM, this manual should be referred to for procedures and tips intended to expedite its return to service. Warranty service and assistance in correcting difficult problems is freely available from Technical Services through telephone or fax. See the contact information on the inside front cover of this manual.

Before engaging in ANY maintenance action, please familiarize yourself with the service precautions in Section 2.2. Despite its small size and low power, the Hyfrecator® 2000 is capable of delivering a serious shock or burn injury to the unwary technician.

4.2 Preventative Maintenance

A Preventative Maintenance (PM) check should require no more than a few minutes time in the hands of a properly trained and equipped biomedical electronics technician, as described in Section 1.0.

If the unit passes all of the PM tests described below, it may be returned to service with confidence that it is safe and will conform to factory specification.

4.2.1 Physical Inspection and Cleaning

1. Upon receipt of a Hyfrecator® 2000 for PM, first review any documents which may have been provided by the user for indications of possible malfunctions or otherwise unsatisfactory performance which may require more than simple PM checks. Also, inventory any accessories, cables or cords which may have been enclosed with the unit so that they may be checked and returned.

2. Note the AC mains rating and serial number, along with notations of any alterations or prior service, appearing on the rear panel of the unit.

3. Check the enclosure for signs of physical damage, such as dented or cracked plastic, misaligned connector pins, loose parts inside or evidence of possible fluid penetration. Verify that the power control knob is secure on the encoder shaft and that it doesn't rub on the front panel. Check the power and accessory cords for cuts or signs of mechanical stress. Check accessories and their connectors for signs of corrosion or other damage.

If any visible sign of damage is found, log it and look further to discover if any internal damage has occurred. Complete any necessary corrective action before proceeding with the PM.

4. If the unit appears physically sound, the enclosure, cords and accessories may be cleaned using a cloth or paper towel dampened with mild soap and water. More aggressive solvents or abrasives may remove

markings or blur the power display image, so they should be used only when necessary and sparingly. Thoroughly dry the unit and cords with a lint-free cloth before applying power.

4.2.2 DC Isolation Tests

This test verifies that the patient output jacks are isolated at DC from earth and from one another. Failure of this isolation will put the patient at risk of electrical shock.

1. Disconnect the power cord from the unit's AC inlet connector and any accessory connected to the handswitch connector.

2. Set your DC ohmmeter to the 20 megohm or higher range, and connect one lead to the P/P jack. Verify that over 20 megohms appears between the P/P jack and the following terminals:

- AC inlet ground (earth).
- HI output.
- LO output.
- Either BI output jack.
- Any one of the handswitch pins.

3. Move the first lead from the P/P jack to either BI jack. Repeat this test to the following terminals:

- Opposite BI jack.
- Any one of the handswitch pins.

NOTE: You may observe a normal "capacitor charge" response on some of these tests. Verify that the reading settles above 20 megohms within a few seconds.

If any of these tests fail, correct the fault before applying power. See Section 4.4.8.

4.2.3 Functional Testing

This series of tests verifies that all of the displays and controls are functioning properly and that all Power On Self Tests (POST) will pass.

1. Connect the power cord and a handswitching accessory supplied by the user to the unit. Use your own Hyfrecator® 2000 handswitching accessory if the user's is not available. Leave the accessory RF lead disconnected from the unit for now.

2. The unit may be operated safely for PM while resting on its rear panel.
3. Set the unit's power switch to OFF (O), and connect the power plug to a source of AC mains power equal to the unit's nameplate rating.

> NOTE: The Hyfrecator® 2000 relies upon a sound earth connection to the AC power plug for functional return of monopolar RF current. Do NOT use an AC source which lacks a proper earth connection.

4. While observing the Power Display, turn the power switch On (I). Verify a normal Power On Self Test (POST) display and tone test. Each segment, including the decimal point, of both power LEDs should illuminate one at a time in a "rotating" sequence over about two seconds, and the audible tone should sound four times.

If this normal POST sequence is not observed, or if a Fault Code appears, refer to Section 4.4.3 for corrective action.

5. After a normal POST start up, and BEFORE making any power changes, note the as-delivered position of the Mode Selector switch. Then note the stored power settings in each of the three modes so that they may be restored before returning the unit to the user. Verify that the Mode Selector moves smoothly and snaps into each position.

In any Mode, if the display indicates "--", the Mode Switch on the A1 Control/Display PWB requires repair. See Section 4.4.9.

6. Select LO mode and rotate the power control knob counterclockwise until the power display stops at "0.0". Verify that the encoder detents feel uniform with no signs of binding or eccentricity.

7. Slowly rotate the power control knob clockwise from the "0.0" setting at least one full revolution (36 steps), verifying that the power display advances by 0.1 at each step.

8. Using the handswitched accessory, briefly press and release each power adjustment button several times, verifying that the power display changes by 0.1 in the proper direction and that the unit sounds an audible "click" on each press.

9. Briefly press and release the handswitch activation button. Verify that the audible activation tone sounds and that the blue activation LED illuminates. Stress the handswitch cable near the strain reliefs, checking for possible internal open or short circuits.

10. Verify that the power cord retention is sound and that the handswitch connector locks and releases easily.

11. Turn the unit on its side. Using a small screwdriver, rotate the tone volume control over its full range while the unit is activated. Verify that the tone volume changes smoothly, remaining audible over the full adjustment range. Restore the user's original volume setting.

12. Attach footswitch and test for proper unit activation when it is depressed.

4.2.4 Mains Frequency Leakage

These tests verify that the low frequency source current appearing on the unit's RF output jacks are safely within the requirements of IEC 60601-1 patient leakage. The monopolar circuits (HI and LO) are Type BF and the Bipolar (BI) circuit is IEC Type CF.

Each of the four RF output jack pins, the P/P pin and the handswitching circuit is tested separately against earth ground with both AC mains polarities and with the protective earth circuit open in single fault condition (SFC) and connected in normal condition (NC).

Connection to the four RF output jacks may be made using a test lead with a male "banana" plug. Connection to the P/P jack may be done using an alligator clip. Connection to the handswitching circuit is via the male RF plug on the handswitching cable.

NOTE: These tests are conducted with the AC switch ON (1), but the unit is NOT activated. Activation will damage your leakage current test equipment.

The maximum allowable mains frequency currents in microamps (μA) for each jack are:

Connection	SFC	NC
HI, LO, P/P	150 μA	50 μA
Either BI	50 μA	10 μA
Handswitch RF	150 μA	50 μA

These tests are performed most conveniently using any good-quality biomedical electrical safety tester. If you do not possess such a tester, then it is possible to construct your own using a millivoltmeter and a simple RC network constructed according to IEC 60601-1, Clause 19.4 e).

NOTE: There should be at least a 3-to-1 difference in measured leakage current between the SFC and NC (earth open and connected). Absence of a noticeable change indicates a possible open circuit fault in the mains cord or the earth-reference capacitor in the RETURN circuit on the A2 PWB. See Section 4.4.8.

4.2.5 RF Output Power Testing

These tests verify that the Hyfrecator® 2000 is able to deliver RF output power as indicated on the power display with specified accuracy.

NOTE: RF power measurements are difficult to achieve with accuracies better than 5%. Thus, it is quite possible to find output power errors which exceed the specified 10% tolerance if a different instrument is used to check power from that used to calibrate the unit. Therefore, it is advisable to use the same instrument for both calibration and later output testing. However, output errors of less than 20% are generally not clinically noticeable.

RF power measurements are best made using a commercial, recently calibrated electrosurgical unit (ESU) tester having both 500 and 1000 ohm test loads.

Alternatively, a commercial 500-ohm-only tester can be used with an external series 500-ohm 20 W (minimum) non-inductive resistor In this case, power readings should be doubled, since the tester is receiving only half of the output power.

An acceptable tester may be constructed using non-inductive power resistors and thermocouple RF ammeters (150, 250 and 500 mA full scale). Alternately, a broadband (10 kHz to 5 MHz) current probe with a true-RMS high-frequency AC voltmeter with specified accuracy to at least 5 MHz may be used. Power (P) in watts may be calculated from measured output current using the formula:

$$P = I^2R$$

where I = RMS output current (Amperes) to the load resistance R (Ohms). Acceptable output currents according to Hyfrecator® 2000 specifications as of the time this manual was last edited have been calculated in the table below.

Procedure:

1. Using well-insulated test leads, connect the ESU tester Plate or Return input and Active input to the Hyfrecator® output jacks indicated in the table below.

2. Set the tester to read output power and select the indicated test load. Set the Hyfrecator® to the indicated mode and power setting.

3. Activate the unit using a handpiece or footswitch. Allow the reading to settle for about 2 seconds before recording the test results.

4. Compare your reading to the limits shown.

ESU Tester Inputs		Test Load	Mode	Power	Output (W)		Output (mA)	
Return	Active	Ω	Switch	Setting	Min	Max	Min	Max
P/P	HI	1000	HI	5	4.0	6.0	63	77
P/P	HI	1000	HI	17	15.3	18.7	124	137
P/P	HI	1000	HI	35	31.5	38.5	177	196
P/P	LO	500	LO	1.0	0.9	1.1	42	47
P/P	LO	500	LO	5.0	4.5	5.5	95	105
P/P	LO	500	LO	10	9.0	11.0	134	148
P/P	LO	500	LO	20	18.0	22.0	190	210
BI 1	BI 2	500	BI	5	4.5	5.5	95	105
BI 1	BI 2	500	BI	17	15.3	18.7	175	193
BI 1	BI 2	500	BI	35	31.5	38.5	251	277

Table 4.1 RF Output Power Test Limits

If some of your readings fall just slightly outside these min/max ranges, it is possible that the unit was calibrated using a different ESU tester, or there has been some drift in component values since the last calibration. In this case, it is best to perform a recalibration. See Section 4.3.

If your readings are significantly outside limits, or if no output was measured, AND the unit executed a normal POST per Section 4.4.2, then double-check your instrument and test setup. POST testing is quite unlikely to allow a unit to deliver drastically inaccurate power; but POST cannot detect most component failures in the PA and Output circuitry. If your instrumentation is functioning properly, then proceed with troubleshooting the unit per Section 4.4.8.

4.2.6 RF Leakage Test

This test verifies the integrity of the RF earth-referencing circuitry for HI and LO modes and proper RF isolation for the BI outputs. Failure of these tests indicates that the patient may be at risk of alternate site burns. This test should be performed only after the unit has yielded satisfactory results from the preceding PM tests.

Procedure:

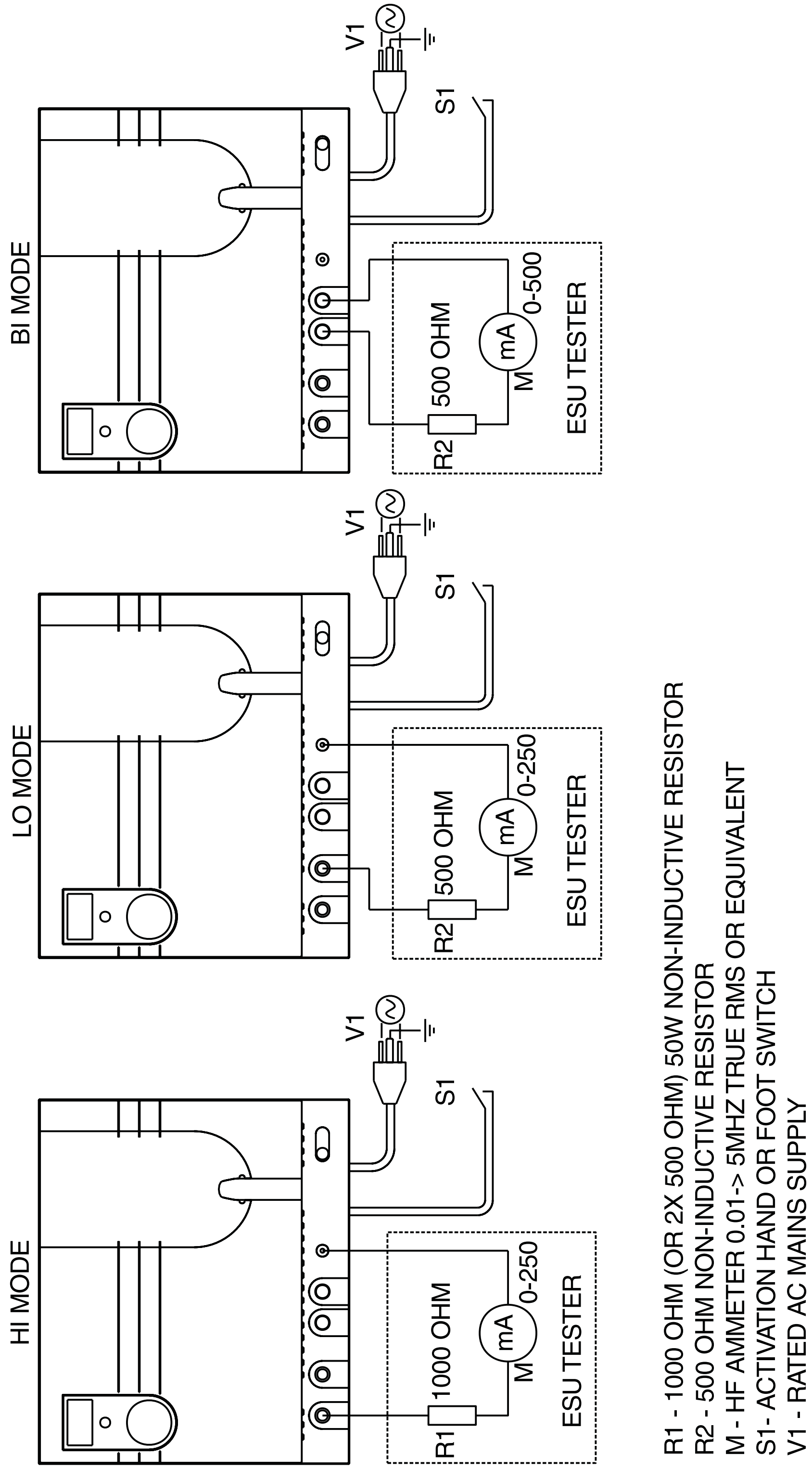
1. Referring to Figure 4.2, collect the resistors and RF ammeter listed in the Legend. Test leads should be well insulated and no more than 1m (3 ft) long.

   NOTE: The resistors must be non-inductive; the power ratings shown are minimum values, and higher ratings are acceptable. The most commonly used HF RMS ammeter is an analog reading RF ammeter of the thermocouple variety. Other satisfactory instruments include an HF current transformer connected to an HF true-RMS voltmeter, or the RF leakage feature of an ESU tester.

2. Connect the unit to an AC mains power source according to the unit's nameplate rating. This source MUST provide a positive earth ground for the power plug. Make sure that you have an equally positive earth ground terminal available on your test bench.

3. Turn the unit ON and set the controls for 35W HI. Connect the resistors and RF ammeter according to Figure 4.2a, and activate using a handswitched accessory or footswitch, S1. Verify RF leakage current is in the range of 40 to 80 mA.

Figure 4.1 RF Output Power Test Setup



4. Set the unit's controls to 35W BI and connect the test setup per Figure 4.2b. Activate and verify less than 42 mA. Repeat for the other BI output per Figure 4.2b.

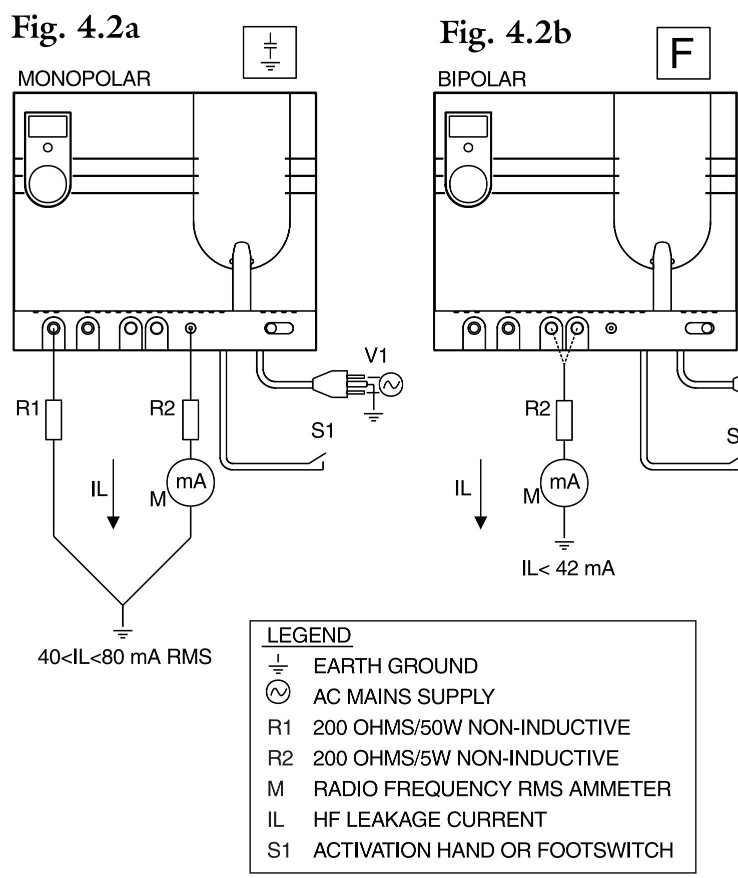
Low readings from HI are probably due to a shorted capacitor in the RETURN circuit, while high readings point to an open capacitor. High readings on BI indicate that the RF output transformer A2T3 may be defective. See Section 4.4.8 for troubleshooting and repair guidance.

4.2.7 Return to Service

If all of the above PM tests yield satisfactory results, the unit may be put back in service. Before doing so, be sure to return the stored power settings and the mode selection to those noted in Section 4.2.3. Simply adjust the power setting to the noted value in each of the three modes and briefly activate the unit. Cycle the power switch to verify a normal POST sequence and recheck the power settings in each mode. Then turn the power switch OFF (0) and return the mode switch to the original selection.

If the unit is to be shipped via a commercial carrier, it is best to use the original Hyfrecator® 2000 shipping carton and materials. Otherwise, the unit should be enclosed in a polyethylene bag and placed in an undamaged cardboard carton surrounded by a minimum of 4" (10 cm) thickness of polystyrene shipping beads or 2" (5 cm) of "bubble wrap" packing material.

Figure 4.2 RF Leakage Test Setups



4.3 Recalibration of RF Output Power

This Section describes how to adjust RF output power to the original Hyfrecator® 2000 factory specifications. Recalibration need not be performed as part of normal PM checks, but should be done in the following circumstances:

• If PM testing indicates that the calibration has drifted.

• After any repair involving component replacement.

• To help restore operation in Run Mode if the POST test yields a fault code related to gate drive, HV voltage or EEPROM data errors.

> NOTE: Recalibration should be performed only using an ESU tester with 500 and 1000 ohm test loads, and having a current calibration certificate.

4.3.1 Service Mode Entry

This procedure places the unit in Service Mode:

1. Turn the unit OFF (O) and open the enclosure (Section 5.1.1).

2. Connect a temporary short circuit between the two CAL jumper pins (A1J2).

3. Set the Mode Selector to HI and turn the unit ON (I). Verify that the power display reads “CA”. The unit is now in Service Mode.

4.3.2 RF Output Adjustment

Enter Service Mode per 4.3.1 above and leave the Mode Selector set to HI to enter “CA” (Calibrate).

1. Remove the CAL jumper. The unit is now operating in Service Calibration Mode and set to adjust HI mode Offset. The Target Power for that setting appears in the power display. The control panel may be set in place on the rear enclosure for the balance of this procedure.

> NOTE: A detailed description of the inner workings of this mode appears in Section 3.3.4.2.3. The rest of this procedure assumes that you are familiar with these operations.

2. Calibrate HI Mode:

2a. Connect an ESU output tester, set to measure RF output power to 1000 Ω, to the HI and P/P connections.

NOTE: Target Powers are displayed in units of Watts. If your ESU tester displays only current, use the following table to convert target power to RMS RF output current.

Target Power, W	Rated Load, Ohms 1000 (HI)	500 (LO, BI)
2.0	--	63 mA
3	55 mA	77 mA
16	--	179 mA
28	167 mA	237 mA

Table 4.2 Target Currents

If your unit displays target powers different from those shown above, you may compute target current as:

$It\ (mA) = 1000 \times \sqrt{(Pt / Rl)}$

where Pt is displayed power in Watts, and Rl is load resistance in ohms.

2b. While activating the unit, use either the power adjust knob or accessory push-buttons to increase RF output power until it is as close as possible to the target power appearing on the unit's LED display.

2c. Leave the unit activated for about 1 second after the last adjustment before deactivating.

2d. Deactivate. This adjustment is now stored in EEPROM.

2e. Use either power adjust control to select HI Gain - this is the larger of the two available target values. Repeat steps 2.2-2.4.

2f. While deactivated, reselect the Offset target, then activate and readjust output if necessary.

> NOTE: The Offset and Gain adjustments interact to a degree. With a little experience, you will learn to anticipate this interaction and compensate by intentionally making adjustments of each slightly off-target.

> NOTE: If RF output power drops to zero during an adjustment attempt, or if it is impossible to reach a target, verify that your test setup is correct and operating properly before assuming a fault with the unit.

2g. Repeat Offset and Gain adjustments until RF output power is as close as possible to both Target powers.

NOTE: It may not be possible to obtain perfect matches to target values, since adjustments are made in steps. However, it is easily possible to set power to within 5% or current to within 3% of target.

3. Calibrate LO Mode:

3a. Move the ESU tester lead from the HI output jack, move the Mode Selector to LO, and reconnect the ESU tester to the LO and P/P jacks.

3b. Set the ESU tester load to 500 Ω.

3c. Using the same technique as for HI (steps 2b to 2g), set LO Mode Offset and Gain as closely as possible to the LO Targets.

4. Calibrate BI Mode:
4a. Remove BOTH ESU output test leads from the unit. Select BI Mode, and connect the ESU tester leads to the two BI output pins.

4b. Set the ESU tester load to 500 Ω.

4c. Using the same technique as for HI (steps 2b to 2g), set BI Mode Offset and Gain as closely as possible to the BI Targets.

4.3.3 Calibration Verification

After all three modes have been calibrated to your satisfaction, turn the unit power OFF (0) and back ON (1) and confirm a normal POST power-up.

> NOTE: If Fault Code "-1", "-2" or "-3" appears, it is possible that the unit was not left activated long enough after one of the Calibration adjustments to allow accurate HV or VGate measurement (see step 2.2 above). Re-enter Service Calibration and activate the unit for at least one second, without adjustment, at each of the six Target settings.

1. Repeat the RF output power tests using the procedure in Section 4.2.5 above.

2. If RF output power tests yield satisfactory results, continue with the RF leakage tests of Section 4.2.6.

4.4 Troubleshooting and Repair

This Section contains advice on how to diagnose and correct problems reported by the user or discovered during routine PM testing.

It is impossible to anticipate every symptom and its likely cause or causes, so one should be prepared to depart from this advice if the problem is not resolved quickly. A review of the Section 3, Theory of Operation, coupled with the proper electronic service tools and skills should be relied upon for correcting more elusive problems.

This section is oriented toward component-level troubleshooting and repair. Most replacement components may be obtained from local sources, but some, such as programmed microcontrollers, transformers and mechanical components are available only from CONMED. See Section 5.1.3 for ordering information.

Of course, a unit may be restored to service far more quickly by exchanging complete printed wiring boards (PWBs). If this method is preferred, spare PWBs may be also be ordered from CONMED.

Expert advice, as well as instructions on returning a unit for factory or warranty service is freely available from the CONMED Technical Services Department. Contact information appears on the inside front cover of this manual.

4.4.1 Using Fault Codes

The Hyfrecator® 2000 features an extensive set of built-in fault-detection and reporting processes intended to prevent component failures from becoming hazardous to the patient or user. Details on these processes appear in Section 3 of this manual.

If any of these processes detect a fault, it will cause the unit to shut off RF output and to present a unique display on the power LEDs, indicating the test process which failed. These Fault Codes can be very helpful in diagnosing problems. A summary of Fault Codes along with the associated test and possible causes appears in the Appendix at the end of this manual.

In most cases, the faulty component may be quickly discovered based on the fault code and some simple troubleshooting, possibly aided by the Service Pseudo-Run mode (Section 3.3.2.4.3). However, you should be aware that some non-hazardous faults, such as no RF output, may be caused by component failures which are not automatically detectable, and instead will be discovered only by the user or during PM testing. Further, some automatic test failures may be caused by multiple component failures or by uncommon component failure modes.

4.4.2 User Error and Accessory Faults

Some Fault Codes reported by the user may not be reproducible when you test the unit on your bench. In many cases, they may be caused by inappropriate actions by the user, or by faults in accessories which may not have been supplied with the unit.

The most common is Fault Code "E7", which will appear if any accessory or footswitch contact closure is detected upon power-up. This test is conducted once every power-up before the POST sequence appears, but is reported only after POST completes. This test is intended to prevent unintentional activation or power changes due to possible short-circuits in an accessory.

Some users may inadvertently operate these switches during power up, or a brief power outage may cause the unit to restart while it is being activated. A brief interview with the user may be all that is necessary to diagnose and correct this problem.

Of course, permanent or intermittent shorts in an accessory may also produce this problem, and proper diagnosis requires that the accessory accompany the unit for service. As a rule, it is advisable to ask the user to send all switch accessories with the unit, even if the symptoms reported may not initially indicate an accessory problem.

4.4.3 Interpreting Faults During POST

If a unit consistently fails during POST testing, close observation of the last LED segment lit before a Fault Code appears will reveal the step which failed. This information, coupled with the Fault Code, can help expedite diagnosis. A step-by-step description of the POST tests appears in Section 3.3.5.3.

Incorrect Calibration variable values can cause some POST Faults, even without a corresponding hardware fault. Such failures may be corrected easily by performing a careful recalibration in Service Calibration Mode, making sure that the unit is activated for at least 1 second after the Offset and Gain variables are correctly set.

There are a number of faults which will prevent POST from running, including failure of either microcontroller and shorts on the PSET or LED buses. If the unit powers up with no displays and no tones, first verify that both +5C and +5M are present and correct on the A1 PWB.Then attempt entry to Service Pseudo-Run mode. If the unit operates normally and the LED displays are correct, then it is likely that the Monitor microcontroller has failed. If Service Mode is not accessible, then the Control microcontroller is suspect. If the power display in Pr Mode is abnormal, then a PSET or LED bus problem is probable.

4.4.4 Using Pseudo-Run Mode

Pseudo-Run Mode is a built-in diagnostic aid that allows troubleshooting problems which cause fault detection processes to shut the unit down. In this mode, all fault-detection processes are bypassed, and the unit can be operated as if it were in normal Run Mode. See Section 3.3.4.2.3 for details.

> NOTE: Pseudo-Run should be entered only if one is reasonably sure that the problem is not one which could cause further component damage if not interrupted by a Fault shutdown. Examples include shorted components in the HV or PA section causing Low HV reports, or an overload on the Gate or Tone drivers.

Pseudo-Run is entered via Service Mode (power up with A1J2 "CAL" shorted) with the Mode Selector set to LO (display "Pr") before removing the CAL short. POST is not run in Pr mode.

Pseudo-Run terminates only by switching off the mains power. It is possible that the Last Setting or Calibration values in the EEPROMs may be altered in this mode, so RF output should be rechecked and recalibrated, if necessary, and power settings restored after the unit is repaired.

4.4.5 Using Recalibration

Some of the fault detection processes are very sensitive to detect some faults in accordance with safety standards requirements. In particular, limits on HV and VGATE voltage are quite tight. These limits are based on measurements made by the Monitor microcontroller while the unit is activated in Service Calibration Mode. If a calibration is rushed, such that the values of these signals are not stable for at least 1/2 second, it is possible that they might be read and stored in the Monitor EEPROM slightly lower than otherwise. This may result in chronic or acute POST failures, or Fault shutdowns during operation at certain power settings, even with no RF output faults present.

The Control microcontroller writes to its EEPROM upon every power adjustment, and the same EEPROM is used to store calibration data. If an EEPROM write cycle is in progress when power is shut off, data not only in the stored settings area but also in the calibration area of the EEPROM might possibly become corrupted. This will cause an "E5" fault shutdown on every subsequent power-up until the unit is properly recalibrated per Section 4.3.

4.4.6 Fault Isolation Techniques

Experienced electronic technicians have developed many varied methods for determining exactly which component in a system is responsible for that system's malfunction. The best method to use varies depending upon the complexity of the system, accessibility of signals, complexity of suspect components and the technician's understanding of how the system should operate without a failure. In general, fault isolation techniques fall into three general classes:

1. Signal Tracing

This method involves injecting a signal at or near the input end of a suspected signal chain and looking for the expected effect farther down the chain. The choice of which chain to investigate is based on the technician's hypothesis of which part of the system could fail in such a way to explain all of the known symptoms. This method is effective only when you understand approximately how each stage in the chain affects its input signal.

One may start looking at the output of the first stage, and then on to the next, and so on until the output signal fails to respond as expected. One may conclude that the fault is in the last stage checked. The stage so discovered may be a single replaceable component, such as an IC or transformer, or an entire subassembly.

A variation on this scheme, called "divide and conquer", is to start looking for the expected response at the farthest output. If the response there is OK, then the problem with the system is not likely related to the signal chain first suspected, and another theory can be formulated. This can save time if one is not confident in the initial hypothesis. If the fault does appear at the end of the chain, then look midway down the chain to discover in which half it is located, then go to the middle of that half.

Another variation is to monitor the same point in the system while injecting test signals at different points upstream in the chain. This method can be more difficult, because some signal stages may not be amenable to signal injection, and it may be difficult to find a source for a proper signal.

Signal tracing is most effective where signal chains have only a few inputs and outputs, such as simple amplifiers and power supplies. Digital systems having many inputs or complex single-chip processors may not yield well to this method, unless one separates the signal chain into parts, each ending at a processor pin.

2. Board-Swapping

This method is probably the least time-consuming in getting a system back into service, but it also can be the most costly in terms of replacement costs if the defective board is simply replaced rather than being repaired. It also requires a local stock of spare boards or a spare system which can be "cannibalized".

Board-swapping does pose the risk, in that the problem may reappear later, unless the defect in the replaced board is confirmed by component level troubleshooting, or duplication of symptoms when installed in another properly functioning system. All too often, the process of removing and replacing a board may jar an intermittent component elsewhere in the system, or restores a marginal connector's continuity.

3. Shot-Gunning

This method is the component-level variation of board-swapping, where individual replaceable components are replaced one at at time until the symptoms disappear. In some cases, a suspect component may be left in the circuit and temporarily shunted with a known-good part; this method works well for open-circuit faults on simple two-lead components such as capacitors and resistors.

Shot-gunning can be effective where the number of suspect components is small, and signal tracing fails to isolate the problem further. However, it can also be both time-consuming and costly if the replaced component count becomes large. Further, repetitive board removal and component desoldering and installation may create failures where none existed before. Service-induced failures will void the factory warranty, and may require replacement of an entire subassembly.

The best method to use on the Hyfrecator® 2000 cannot be prescribed, since it depends upon the technician's skill, understanding of and experience with the unit. However, if your service organization has service responsibility for about twenty or more Hyfrecator® 2000's, it may be effective to stock at least one set of spare PWBs to allow for rapid turnaround, and perhaps one known-good Hyfrecator® 2000 to use in confirming a suspected bad PWB and for troubleshooting to the component level after the repaired unit is returned to service.

A stock of replacement spare components most likely to fail will also minimize downtime. Recommended spares are denoted by an asterisk (*) in the parts lists appearing in Section 5.

4.4.7 A1 Control/Display PWB Problems

This PWB is the more complex of the two in the system and thus the most difficult to troubleshoot. Additionally, it lies midway between system input signals which originate on the A2 Power PWB and the HV power supply, RF PA and tone generator control signals used by the A2 PWB. Thus, some faults on the A1 PWB can produce the same symptoms as other faults on the A2 PWB.

If the symptoms involve a Fault Code, refer to the Appendix and Section 4.4.1 for fault isolation guidance. If the symptoms do not include a Fault Code, and the POST display appears normally, then the problem is most likely on the A2 PWB. This is most easily confirmed by moving the A1 PWB to a properly functioning spare Hyfrecator® 2000 and verifying that the symptoms have disappeared.

NOTE: Since Calibration data which is affected by A2 performance is stored in A1U3 and A1U4 EPROMs, this board swap may produce a Fault Code either during POST or during activation. In this case, simply enter Service Pseudo Run (Section 4.4.4) rather than recalibrate with the new A2.

Some intermittent problems may be traced to bad connections at either end of the 16-conductor ribbon cable between A2 and A1. Although it may be possible to repair such failures, it is difficult to perform a reliable insulation displacement connection without the proper tool. It is preferred to simply replace the faulty harness assembly.

4.4.7.1 Verifying Microcontroller Faults

The most straightforward method of confirming that one of the microcontrollers, U1 or U2, is defective is to replace it. However, these components are costly and available only from the factory, and desoldering may damage a possibly good microcontroller or the PWB. Thus, it is worth taking some time to verify that the a microcontroller is defective before pursuing replacement.

Some Fault Codes are specific to internal microcontroller processes. However, these processes rely on the presence of clean +5V power of the correct voltage (+4.5 to + 5.5V) on VDD (pin 20) and MCLR (pin 1), and good ground on pins 8 and 19. Use both an oscilloscope and a multimeter to verify these signals directly on the microcontroller pins.

A 4 MHz clock must also be present on each microcontroller and operating within 20 kHz of 4.00 MHz. This may be checked with an oscilloscope probe with a 10K 1/4W series isolation resistor at the tip on pin 10; loading pin 9 with this probe may cause the oscillator to stop. Oscillator failure may be caused by either the microcontroller or the resonator. A resonator failure may be confirmed by exchanging Y1 and Y2 or by "shot-gunning" a new resonator.

If +5 V power and the clock are functioning correctly, then proceed with microcontroller replacement.

If the +5 voltage is incorrect, +12V or +24U may be low or noisy, or the 5V regulator may be faulty; separate +5V regulators are used for each microcontroller. If +5V power exceeds +6.5V, the corresponding regulator has probably failed, and the microcontroller very likely has been permanently damaged. Correct the +5V problem before installing a new microcontroller.

If over 100 mV of noise is detected, a bypass capacitor on either the 5V regulator input or output may be open. VR1 (+5M) is current-limited at 100 mA, and a ground short on any of the U2 Monitor microcontroller output pins may easily draw greater than this. If noise on +5M appears "squarish" and is not synchronous to the mains frequency, check U2 output signals for the ability to swing to greater than +4V. If 25-30 kHz noise appears on +5M only during activation, Q4 may be shorted.

The +5C regulator VR2 is current-limited at over 1000 mA, so noise appearing on that signal is unlikely to be caused by output line shorts on U1; such a short is more likely to permanently damage U2. VR2 relies on the A1 PWB as a heatsink. When replacing VR2, first tighten the bolt clamping the tab to the PWB, then solder the leads; this ensures that mechanical stress is not transferred to the VR2 I.C. die bonds.

The two EEPROMs are also powered by +5V, but high Vcc current faults in those devices are more likely to yield EEPROM Fault Codes on power-up than to produce noise on +5V.

4.4.7.2 Gate Waveform Problems

The frequency and duty cycle of the gate waveform driving the RF PA FET are tested by the Monitor microcontroller fully during POST and continuously during activation. So faults in either of these parameters, including absence of gate drive, are most likely to generate a "-3" Fault Code during POST. If POST detects /GATE activity during the first step, with GATENA low, it will also declare a "-7".

If POST declares a "-3" fault during one of the first three steps, it is possible that VGATE may have drifted into the fault threshold or that the previous calibration was not done correctly. If so, then a simple recalibration may be all that is necessary to restore service. See Section 4.2.6.

After POST, the Monitor microcontroller uses the presence of activity /GATEMON to detect activation, and then verifies that against /ACTIV.M. Disagreement will yield a "-7" code.

Since gate drive problems are likely to force a Fault shutdown, effective troubleshooting can be done only in Service Pseudo-Run mode. (Section 4.4.4)

Since the PA FET is operated in saturation, slight deviations in amplitude are not detected automatically, nor are they likely to cause RF power to deviate measurably. However, if /GATE or GATE signals swing well below specification, the Monitor microcontroller may declare a Fault, even if the frequency and duty cycle are correct. Such faults are also likely to be associated with low output power.

Thus the first place to look when troubleshooting gate waveform faults is GATEMON on A2TP7, which should appear as shown in Figure 5.4. If the amplitude of the signal is low or distorted, the problem is most likely on the A2 PWB (Section 4.4.9). But first check /GATE on A2TP8, which should swing a full 5V; if not, check /GATEPWM on A1U1-12 for full 5V swing. Low, or no amplitude on /GATE may be caused by an input short on A2U1, open Q3, R14 or R15. Low amplitude on /GATEPWM is most likely due to a faulty output on U1.

If the GATEMON amplitude appears correct, check the period and duty cycle in each of the 3 modes (See 3.3.4.1.7 for correct values); the power must be set above 0 to get a gate signal.

If GATE period appears incorrect, then verify that the same period appears on /GATEPWM. If that is incorrect, then check the U1 oscillator frequency (Section 4.4.7.1). If Y1 is running at 4.00 MHz, then U1 is defective; if Y1's frequency error exceeds 20 KHz, replace Y1. If the GATEMON frequency is different from /GATEPWM, then it is possible that A2U1 is oscillating, so replace it.

If gate frequency is correct, and the T_{ON} (duty cycle) is incorrect, check the T_{ON} (low) of /GATEPWM. If that is incorrect, then replace A1U1. If /GATEPWM is correct, change A2U1.

4.4.7.3 VGATE Problems

The circuitry around A1Q4 converts the duty cycle into an analog signal VGATE which is directly proportional to duty cycle. A fault in this circuitry may result in a false Fault Code "-3" generation.

If both GATEMON frequency (period) and duty cycle appear correct per 3.3.4.1.7 data, then verify that the GATEMON signal appears undistorted on A1Q4-G. If OK, then verify that A1Q4-S pulls up to +5M when GATEMON is high, and drops to about 2.1 to 2.5 V (VGATE) when GATEMON is low. If not, replace Q4, RN4D or C33, as required depending on whether VGATE is stuck high, low, or has extreme ripple.

If GATEMON and VGATE are functional, then a simple recalibration to restore the correct VGATE readings may be all that is necessary to restore service. See Section 4.3.

4.4.7.4 VCON Problems

VCON is the signal used to set the value of HV on the A2 PWB to produce RF output power corresponding to the displayed power setting.

If the unit declares a "-1" or "-2" Fault Code during POST or in operation, then it is possible that VCON is out of range. However, the more likely source of difficulty is in the HV power supply on the A2 PWB. VCON is an analog signal that is produced by low-pass filtering (R1, C3) a duty-cycle modulated 5V CMOS signal, HVPWM. The period of HVPWM is identical to that of /GATEPWM, and the duty cycle varies in 250 nsec steps from 0% at zero power setting up to a maximum value of 70% to 85%, depending upon mode and calibration.

If the unit declares a "-1" or "-2" Fault, enter Service Pseudo-Run per Section 4.4.4 and set zero power in HI Mode. Observe HVPWM on an oscilloscope and activate the unit. The signal should be a constant low level. If not, replace A1U1. Then set 1W and activate. You should see a 41 μsec period CMOS pulse signal swinging from near 0V to near +5V. The signal should go high (T_{ON}) for less than 8 μsec. As the power setting is advanced, T_{ON} should advance steadily to between 30 and 38 μsec at full power. If HVPWM does not go to +5V, check +5C between 4.8 and 5.2 Vdc. If +5C is correct, then replace U1.

If HVPWM is behaving, adjust HI power for about 50% duty cycle (12 - 16W). Read VCON on a multimeter and check for ripple on VCON with the oscilloscope. VCON should read approximately 2.5Vdc. If not, check the value of R1 (1K 5%). If R1 is OK, the problem may lie in the VCON input circuitry on A2. The ripple should appear as a triangle wave with a period of 41 μsec and peak-to-peak voltage of 0.2 to 0.8V. If ripple is excessive, replace C3.

4.4.7.5 Display Problems

The LED display is driven by the Monitor microcontroller U2 during POST and during Fault Code display. POST generates a segment test sequence where each segment of both power display LEDs are lit one at a time in a rotating sequence, starting at the top segment and ending with the decimal point. During POST, the blue activation LED is also switched on and off. After POST, the Control microcontroller takes over control of the power display. See Section 3.3.5.3 for a detailed description of POST tests.

Careful observation of repeated POST cycles should confirm that each segment can be turned on and off for both digits. If the same segment on BOTH digits fail to light, and POST proceeds otherwise normally, then one of the resistors in RN1 has opened. If the POST pattern appears on only ONE of the digits, AND that digit also fails to light with any power setting in Run mode, then either the corresponding driver, Q1 or Q2, or its drive resistor, R6 or R8, has failed open.

If the POST sequence yields the appearance that a second segment in one or both digits may be lit, perhaps dimly, and POST proceeds normally, there may be a short between segment lines LED1:8. This may be confirmed by observing LED behavior in Run Mode as power is adjusted.

4.4.7.6 Mode Setting Problems

The position of the Mode Selector slide plate is conveyed to the A1 PWB via a shorting contact attached to an extension of the plate running across gold-plated pads on the LED side of the A1 PWB. These contacts form the inputs for a simple digital-to-analog converter (DAC) to set VMODE, which is read by both microcontrollers.

The most common Mode Selector problem is mechanical misalignment of the moving contact relative to the A1 PWB and the Mode Selector slide plate resulting in open-circuit faults. This fault will cause the unit to operate with LO Mode waveforms and LO Mode displays, i.e., 0.1W resolution at less than 10 W and 20W maximum setting, when the Mode Selector is set to HI or BI. The user may also complain of atypical output performance.

High-resistance contacts, due to contamination, or trace shorts in the A1 VMODE DAC may also cause misbehavior. These faults may cause VMODE to go to an out-of-range state, which will yield a "--" display in one or more of the Mode Selector positions. Activation is inhibited in this state. See 3.3.4.1.1 for VMODE voltages.

> NOTE: If VMODE is out of range when Service Mode is selected, and the Calibration jumper is removed, an “E9” Fault Code will appear.

If the Monitor microcontroller reads a VMODE voltage which is out of range or inconsistent with the Mode data presented by the Control microcontroller on the PSET bus during activation, a “-8” Fault Code will appear. In this case, verify that +5C and +5M are +4.9 to +5.1 VDC, and that both VMODE.C and VMODE.M are equal within 40 mV and are in range for all three mode selections. If VMODE.C and VMODE.M differ significantly, one microcontroller may be drawing excessive input current or either RN4B or RN4C may have failed to high resistance. Comparison to VMODE will help resolve whether the problem is on the Control or Monitor side.

If both VMODE signals are equal but out of range in one or more modes, the problem is probably in the Mode Selection switch. Mode switch troubleshooting should begin with verification that the A1 PWB is properly mounted parallel to the front panel and with all three mounting screws snug to ensure correct alignment with the Mode Selector contact.

If the problem persists with A1 correctly positioned, remove A1, leaving the harness to A2 connected. This will let you inspect the pads and moving contact for obvious difficulties.

With A1 dismounted, the Mode Selector switch is disabled, and, absent electrical faults on the A1, LO Mode will be forced. HI or BI Modes may be selected by connecting a jumper from GND (TP3) to TP1 (HI) or TP2 (LO). This fault isolation technique can also help determine whether the trouble is in the A1 PWB circuitry or in the switch.

Contamination on the switch contact points or gold plated pads may be removed by gentle wiping with a clean rag dampened with alcohol or contact cleaner. Do not use abrasives or excessive force which may remove plating or deform the moving contact.

The moving contact is a snap-fit onto the Mode Selector slide plate and is normally removable only by lifting it gently over the round alignment boss. If the contact's mounting surface has been deformed, it may fall off the slide plate. A deformed contact may be repaired after removal from the slide plate using pliers to restore the mounting surface to a flat condition. When relaxed, the two contact points should lie .37" - .41" (9.5 - 10.5 mm) above the mounting surface. If the contact is excessively deformed or cracked, or if the bright plating is worn off the contact points, the contact should be replaced.

The Mode Selector slide plate normally has no more than .060" (1.5 mm) lateral free play at the contact tip. Excessive play may indicate loose or missing screws on the Mode Selector retainer, or excessive wear. Excessively worn parts cannot be repaired.

4.4.7.7 Encoder Problems

This section relates to difficulties with causing the power setting, as displayed on the seven-segment LEDs, to respond properly to operation of the power setting encoder. If the unit appears to respond to encoder rotation but the LED display is incorrect, see Section 4.4.7.5. If the problem is incorrect RF output power or Fault Codes, see Section 4.4.9 or 4.4.1.

> NOTE: Accessory power adjustment commands, intentional or due to a fault, will cause encoder changes to be ignored. See 4.4.7.8

The encoder A1S1 is a 36-position 2-pole rotary switch which, in conjunction with pullups RN2H and RN2B, produces a pair of CMOS signals, $\phi 1$ and $\phi 2$, read by the Control microcontroller.

Only one of these signals changes for each step, and the pair repeat the same 2-bit sequence every four steps; the sequence is reversed between clockwise and counterclockwise rotation.

The encoder is best tested in LO Mode, which presents over 36 successive power settings, thus allowing the encoder to be run through at least one full rotation to check all of the stationary contacts. The LED display should advance exactly one step for each "click" of the encoder. Be careful not to exceed 30 steps/second, which is the threshold for the fast slew mode.

A fault in the encoder will upset this sequence. For example, one line stuck low or high will appear to the microcontroller as alternating clockwise and counterclockwise rotations, and the power display will step back and forth between two adjacent settings. A multimeter or oscilloscope can be used to find which signal is not responding. A signal stuck-high might be due to a dirty contact, which may be corrected with contact cleaner. A signal stuck-low may be due to a short to GND or open RN2 pullup.

If S1-C is open (not grounded), then $\phi 1$ and $\phi 2$ will always be high, regardless of rotation, and the display will be unresponsive.

If $\phi 1$ and $\phi 2$ appear to be behaving correctly at U1-6 and -7, then the Control microcontroller is likely to be at fault.

4.4.7.8 Accessory Push-Button Problems

The handswitching accessory supplied with the Hyfrecator® 2000 has three normally-open push-buttons for activation, power increase and power decrease. These buttons share a common return line with the RF output, and thus must be isolated from the internal circuitry. The accessory is subject to flexing and sterilization, and the handswitch isolation circuitry is relatively complex. Thus, complaints about button operation may be expected to be relatively more frequent than others.

An accessory having a solid short-circuit from a button line to the RF line will yield an “E7” Fault Code on power-up. If users calls in with this problem, ask them to power up with the accessory disconnected. If the “E7” fault persists, then the unit is defective. Otherwise, the user should be advised to replace the accessory, since it has most likely been used past its service life.

If the complaint is failure of one or more buttons to respond, and the user does not have a functional accessory to test with, then either the accessory or unit may be at fault, and both should be sent in for service together. Testing the unit with a functioning accessory will easily determine whether the accessory or unit is defective. Intermittent accessory shorts may be found by flexing the accessory cord, particularly near the strain reliefs and at points of visible damage.

NOTE: The unit will not respond to accessory power change attempts beyond the setting limits.

If the problem persists with a functioning accessory, then signal tracing might start by observing /ACTIV, /POWDN and /POWUP at A1J1-2, -1 and -3. These active-low signals are normally +5V, and should drop to < 0.5V when the corresponding accessory button is pressed.

If one or more signals remain high on button closure, then the problem may be an open-circuit in the ribbon harness or, more likely, in the handswitch isolation circuitry on the A2 PWB. See Section 4.4.8. If one signal is stuck low (“E7” Fault), then then one of the pullups R2 or R4 may have opened, but a short to GND is more likely, probably in one of the bypass capacitors on either A1 or A2.

4.4.7.9 EEPROM Problems

A1U3 and U4 are serial EEPROMS used to store Control and Monitor calibration data, power settings and the last fault code. These devices are guaranteed to operate for over 10 million write cycles, have unlimited read life, and are expected to operate for more than 10 years of daily use.

The EEPROMs are read by their corresponding microcontrollers once every power-up, and the integrity of the data is verified by sensitive redundancy codes. Calibration data errors or failure of an EEPROM to respond to read commands will result in generation of a Fault Code and shutdown. If the Last Setting data in U3 is in error, the unit will default to zero power on power-up, but will otherwise operate properly. These are the only symptoms of detected EEPROM faults, and thus they are easy to diagnose.

Before replacing a suspect EEPROM, first verify that the pullup resistors on the SDA and SCL lines are intact, and that +5V power and GND appear on the EEPROM pins. If a Read Error was declared, it may be possible to correct the problem by performing a recalibration. See Section 4.3.

If the problem persists, the suspect EEPROM should be replaced. Since the replacement device will not contain valid calibration data, the unit must be recalibrated before returning to service. If the user’s preferred Last Settings are known, they should be restored. Otherwise, set them to zero. See Section 2.1.1.

4.4.8 A2 Power PWB Problems

The A2 PWB operates with high voltages and currents, and contains a number of heat-producing components. These stresses place it at greater risk for component failure than the A1 PWB.

If the symptoms do not include a Fault Code, and the POST display appears normally, then the problem is most likely on the A2 PWB. This is most easily confirmed by moving the A1 PWB to a functioning spare Hyfrecator® 2000 and verifying that the symptoms have disappeared.

NOTE: Since Calibration data which is affected by A2 performance is stored in A1U3 and A1U4 EEPROMs, this board swap may produce a Fault Code either during POST or during activation. In this case, simply enter Service Pseudo Run (Section 4.4.4) rather than recalibrate with the new A2.

Some intermittent problems may be traced to bad connections at either end of the 16-conductor ribbon cable between A2 and A1. Although it may be possible to repair such failures, it is difficult to perform a reliable insulation displacement connection without the proper tool. It is preferred to replace the faulty harness assembly.

If the symptoms involve a Fault Code, refer to the Appendix and Section 4.4.1 for fault isolation guidance. Most Fault Codes may be caused by failures on either the A1 or A2 PWBs.

4.4.8.1 Mains Power Problems

The most common mains problem is a total loss of mains power. Fault isolation should begin by verifying proper mains voltage present at the IEC 320 mains inlet pins accessible from the interior of the unit. Absence of mains there may be caused by a defective mains cord or connector (and of course, a nonfunctional AC mains socket).

If the correct mains voltage is present at the inlet, connect a DC voltmeter to +24UNREG (TP13) and GND (TP1) and turn the mains switch ON. If +24UNREG rises to between +21 and +27 Vdc, then the mains components are not at fault; move on to Section 4.4.8.2 to check the LV supplies. If +24UNREG came up too high or too low, then the mains strapping jumpers JP1 - JP5 may be installed incorrectly. If the strapping is correct and +24UNREG came up below +21V, see Section 4.4.8.2 to troubleshoot the LV supply.

If +24UNREG remained at zero, check the power cable; then the mains switch for proper on/off operation by observing mains voltage at the ends of A2F1 and F2, closest to the mains inlet.

Verify that mains voltage also appears on the load ends of F1 and F2 with the power switch on (1). If one or both fuses are blown, verify it is of the proper rating, and inspect the unit for visible signs of overload, foreign objects, or possible fluid intrusion. Then, use an ohmmeter between GND (TP1) (-lead) and the following: +24UNREG (TP13), PRHV (TP3) and HV (TP4), looking for normal capacitor charge to >30 KΩ and no shorts.

If no possible overloads were discovered, replace the blown fuse(s). Disconnect the mains cord, turn the power switch ON and check DC resistance at the mains inlet pins for approximately 0.06 Ω per rated mains volt with the mains switch on, e.g., for a 115V rated unit, you should read about 0.06 x 115 = 7 Ω.

If the resistance reads within 5 and 20 Ω, verify that mains voltage strapping jumpers JP1 - JP5 are properly installed and soldered in for the rated mains voltage per Figure 5.8, Table 1. If the jumpers are correct and the resistance reads open circuit, then remove the A2 PWB and test for an open primary in A2T1. This is a highly unlikely failure, and T1 is both costly and difficult to replace, so it is prudent to confirm the defect before proceeding.

4.4.8.2 Low Voltage DC Power Problems

There is one bulk source of unregulated Low Voltage (LV) DC power, +24UNREG, used to feed the +12V regulator A2VR1 and the +5C regulator A1VR2. There are no other loads which use +24UNREG. The +12V regulator supplies all of the remaining loads, including the High Voltage (HV) controller, A2U2; the stable reference +5VR output from A2U2 is also used as pullup bias in the tone and PA gate drive circuitry. Thus, if the +24UNREG supply is nonfunctional, so is the unit.

Check voltage on +24UNREG with A1 disconnected and the AC mains set at rated voltage. It should be +21 to +27 VDC.

If +24UNREG reads zero, and the mains circuitry checks out properly per 4.4.8.1 above, then check for 18 to 25 VAC on the T1 LV secondary, pins 16 and 18. If the LV AC is acceptable, then most likely BR1 has opened. If LV AC is also zero, then it is possible that the thermal fuse embedded in the winding has opened. If so, then A2T1 must be replaced. However, verify the open circuit using an ohmmeter before proceeding with this difficult and costly replacement.

The T1 thermal fuses open only when the winding temperature becomes dangerously high, probably due to a short circuit failure. Isolate and correct this fault before installing a new transformer.

If +24UNREG is not zero but well under +21V, verify correct mains strapping per Figure 5.8, Table 1. If correct, suspect a fault in BR1 or C1 or on either of the +24UNREG or +12V lines, detectable by ohmmeter. Disconnecting the ribbon harness can help isolate the fault to A1 or A2. If +24UNREG is low only with A1 connected, check A1TP4 (+5C) and A1TP5 (+5M); both should be +4.9 to +5.1 VDC.

If +24UNREG is well above +27V, recheck AC mains voltage and verify mains voltage strapping per Figure 5.8, Table 1.

If +24UNREG is acceptable, check +12V from +11.4 to +12.6 VDC. If it is high and within a few volts of +24UNREG, verify GND on VR1-2 (center pin) before removing VR1 for replacement. While VR1 is removed, verify no shorts between +24UNREG and +12V with A1 connected. If confirmed, then replace VR1 and recheck +12V and A1 +5M, since A1VR1 may have been damaged by excessive power dissipation.

If +12V is low or zero, isolate by disconnecting A1 and then checking for shorts. A short on +5M will cause A1VR1 to enter current limit or thermal shutdown, but if A1VR1 is shorted, damaged components powered by +5M may also cause an overload on +12V.

4.4.8.3 HV Supply Problems

Most HV Supply problems will first appear during POST or in operation as Fault Code “-1” or "-2". Note that failure of HVENA to shut down HV during one of the first three steps of POST will also yield a “-2” Fault.

If a “-1” (HV Low) is declared, power up and verify that the red LED DS1 lights. If DS1 stays dark, power down immediately to prevent possible damage to A2T1.

If DS1 lights, check PRHV at A2TP3. It should be +130 to +170 Vdc with mains voltage set at rated. If PRHV is high, turn the unit OFF (0) and check that the mains voltage and mains straps are correct per Figure 5.8, Table 1.

If PRHV is zero, and +24UNREG is +21 to +27Vdc, then check the HV secondary A2T1-13 and -14 for 65 to 130 VAC. Loss of HV AC secondary power is likely due to an opened thermal fuse, and A1T1 must be replaced; use an ohmmeter to verify this failure before proceeding with replacement.

If HV AC is correct, A2BR2 has probably failed open. If HV AC is not zero, but very low, turn power OFF (0) to prevent the thermal fuse from opening and seek out short circuit failures in BR2 and C13.

If PRHV is correct, and HV bleeds off properly, power down and enter Service Pseudo Run mode per Section 4.4.4. Set LO Mode at 5.0 W. While inactive, HV should remain below 0.1 VDC. While active, HV should rise to +18 to +25 Vdc, and fall back to near zero after deactivation.

If HV appears functional, then a simple recalibration may be all that is required. See Section 4.3. If recalibration fails to correct the problem, check resistance of R1, 2, 17, 19, 27, 31, 33 and 34 and A1R1 and A1R5; verify that C10 is not open or shorted.

If HV reads near zero during 5.0W activation, turn the power off, let HV bleed off and use an ohmmeter to verify absence of shorts on the HV bus. If HV appears shorted, the most likely faulty devices are A2Q3, D8 and D4, although other faults are also possible.

If HV is not shorted, power up in Service Pseudo Run again and activate LO 5.0W. Verify that /HVEN (TP11) goes to < 0.5 V on activation, and that VCON (TP12) rises to +0.9 to 1.3 VDC; if either of these signals is faulty, check the ribbon harness for opens and shorts, or the A1 PWB may be at fault; see Section 4.4.7.4.

If /HVEN and VCON are correct, verify +12V on A2U2-5, +5VR on U2-14 and an 80 KHz sawtooth wave on U2-5. If these signals are not as described, then the problem is in the circuitry surrounding U2.

If U2 appears to operate properly, check for an 80 kHz 0-6V square wave at Q2-G during activation; if this signal is absent or the wrong voltage, U1, R30 or R32 may be faulty, or Q2 has a gate-source short.

If Q2-G is functioning properly, verify a 0 - 140V (approximately) 80 KHz square wave on Q2-D. If absent, Q2 or R37 is open.

If Q2-D is correct, verify a 6V p-p square wave superimposed on about +140V on Q4-G. If absent, check D5, D6, R36 and Q4G-S for shorts.

If Q4-G reads correctly, Q4 or L1 may be open.

If Fault Code “-2” (HV High) appears, check HV on A2TP4 with the unit powered up but not activated. HV should drop down to less than 1 V within 10 seconds after POST terminates. If HV remains nearly equal to PRHV, check A2U1-9; it should be < 0.1 VDC; - if not, U1, C7 or R20 may have failed. If A2U1-9 is acceptable, then A2Q4 or Q2 may be shorted or R38 may be open. Verify using an ohmmeter with power OFF (0) and HV reduced to near zero.

If HV appears correct, and the blue LED is ON continuously, A1U2 may be at fault. See Section 4.4.7.1. If HV is OK, and the blue LED lights ONLY during activation, then a simple recalibration may cure the problem. See Section 4.3. If recalibration fails to correct the problem, check resistance of R1, 2, 17, 19, 27, 31, 33 and 34 and A1R1 and A1R5; verify C10 is not open or shorted.

4.4.8.4 Switch Isolator Problems

The Switch Isolator circuitry transfers handswitch and footswitch contact closure information across a high voltage patient isolation boundary comprising both magnetic and optical isolation. Symptoms of failures in the Switch Isolator include:

• Excessive patient leakage current or reduction of peak RF output voltage due to isolation barrier breakdown.

• False switch information, including stuck-closed and stuck-open.

The most likely isolation breakdown fault is an insulation failure in the A2T2 transformer. This fault may be confirmed visually by discoloration of T2's potting or by relief of leakage and/or performance symptoms when T2-5 & 6 secondary is disconnected from the PWB. In this test, the unit can be activated by shorting /ACTIVE (A1P1-2) to GND. Polarity of T2 should be suspect if it has been removed during service. This can also damage A2Q5.

> NOTE: All T2 windings are polarity-sensitive. The "dotted" winding ends are marked with a short length of heatshrinkable tubing, and the corresponding pads on the A2 PWB are marked with a small rectangle.

Other less likely isolation barrier faults include A2U3, 4, or 5 optoisolator breakdown or PWB insulation failure due to contamination.

The most common cause of stuck button problems is a defective switching accessory, which may be confirmed by testing with a properly functioning accessory; See Section 4.4.7.8.

If all three of the isolated switches appear stuck open, then the isolated power supply may be faulty. Unplug the 4-pin A2J2 and check IPS+ (A2TP5) to IPS- (A2TP6) for 5.2 to 5.4 Vdc. If this is correct, then there is probably an open in the J3 harness or accessory connector.

If isolated 5V is absent or low, check for a correct waveform per Figure 5.4 on D9-A; if it looks acceptable, then D9, C30 or R42 may be at fault. Otherwise the power oscillator on A2T2 primary is probably inoperative. Check for a correct waveform on A2Q5-C and +12V on T2-1; if both are good, then T2 secondary may be open. Otherwise, A2Q5 has probably failed. If T2 has been replaced, verify correct installation and polarity of all T2 connections to the A2 PWB. T2 is secured to the PWB using double-sided adhesive tape.

4.4.8.5 RF Output Problems

The Hyfrecator® 2000 POST processes verify that the RF PA gate drive signals and HV voltage are correct per the last RF Output Calibration. So, if RF output power or voltage is incorrect, and POST executes without a fault code, then the possible causes are limited to the PA and output circuitry.

If RF output is present but incorrect, and it varies with mode and power setting, then a simple recalibration to compensate for component aging may be all that is required. See Section 4.3.

If Calibration fails to correct the problem and RF output remains low, Check C19 and D8. If C19 is open, RF output power will be low, and there will be excessive high-frequency noise on HV. If D8 is open, then the waveform at D8-K will “swing freely” negative.

If RF output power is too high and can’t be brought down during Calibration, one of the output coupling capacitors, C31-C38 may be shorted.

If there is no RF output, and POST runs correctly, then compare the waveform at A2D8-K during activation to those in Figure 5.4. If it is a constant DC level equal to HV (TP4), then Q3 or R23 may be open or disconnected. If D8-K reads near zero, then D7 or T3’s primary may be open.

If RF output is absent in just one mode, one of the corresponding output coupling capacitors C31-C34 may be open, or the corresponding T3 winding may be open or disconnected. If BI output is OK, but both HI and LO are absent, check the jumper E1-E2 and capacitors C36 and 38 for open circuits.

If RF output power differs, depending upon whether it is measured using the P/P connector or earth ground, check C37.

4.4.8.6 Tone Generator Problems

The Hyfrecator® 2000 POST processes verify the integrity of the tone generator, so most problems in this area will yield a “-F” Fault Code. This fault code appears if TONEMON is < 0.1 Vdc when a tone is expected, or >0.1 Vdc when no tone is expected.

If POST runs properly, but the tone is weak or inaudible, first try adjusting the tone volume A2R47, accessible through the rear panel. Then check A2LS1 for a short; it should read around 60 Ω DC. If these tests pass, then replace LS1.

If no tone is audible while “-F” is displayed, verify a 5 Vpp, 651 Hz square wave on /TONE (TP9); if absent, check the ribbon harness for opens or shorts or A1U1 for faults (4.4.7). If /TONE is present, verify that this signal is boosted to 12 Vpp on U1-5, and then on A2D1-A with an amplitude that varies with volume control setting. If this is proper, then check for a tone signal on A2Q1-E; if it reads 0V DC, replace Q1, otherwise LS1 or R11 is open.

If POST yields a "-F", and the fault tone is clearly audible, then the problem is most likely in the tone detector circuit. With the fault code sounding, TONEMON should read at least +0.1 Vdc and should vary as the tone volume, A2R47, is adjusted. If this is correct, then BRIEFLY short /TONE (TP9) to GND (TP1) and verify that the tone silences and /TONE drops well below 0.1 VDC. If both of these tests pass, then the ribbon harness may be open or the problem lies on the A1 PWB.

If TONEMON remains < 0.1V when a tone is audible at minimum volume, verify +5VR on R13 and D2, then check for an audio waveform with a slight positive DC bias on A2D3-A. If present, then check D3, D2, and R7 for opens and D3, C16, R9, and the ribbon harness for shorts.

If TONEMON is well above 0.1 Vdc while POST is running or when idle in Service Mode (See 4.4.4), then check D2 for a short or R8 open.

5.0 TECHNICAL DATA

5.1 General

This section contains detailed information about the construction of the Hyfrecator® 2000 necessary for gaining access to internal subassemblies and for component-level troubleshooting and repair. This information is sufficient to guide an experienced technician toward any repair of this unit. Sections 3 and 4 contain additional information which may prove helpful to those who are unfamiliar with this unit or electrosurgical generators in general.

The Preventative Maintenance procedures are found in Section 4, and should be used in order to ensure that the equipment performs properly and safely.

5.1.1 Disassembly and Reassembly

Figure 5.1 shows the assembly breakdown of the Hyfrecator® 2000. It details the locations of all fasteners, structural components, connectors, and the Printed Wiring Board (PWB) assemblies.

WARNING: Dangerous voltages are present inside this unit.
Disconnect AC power before opening the enclosure.

CAUTION: Many of the Hyfrecator® 2000 electronic components may be damaged or destroyed by Electrostatic Discharge (ESD). Perform all service actions using appropriate ESD protection.

Interior access is gained by removing the six self-tapping screws recessed into the rear of the enclosure. Once these fasteners are removed, place the unit on a flat work surface facing upwards. Carefully lift the front panel upwards from the rear enclosure and rotate it along the top edge to a face down position, avoiding strain on the ribbon harness. CAUTION: Do not stress the ribbon cable. It is not intended to be bent excessively, or to support the weight of the top or bottom assemblies.

The component sides of both the A1 Control/Display and the A2 Power PWBs are now accessible for troubleshooting and access to Service Mode. The only electronic components which now remain hidden are the Power and Activation LEDs (A1X1-X3), encoder (A1S1), Mode Selector switch (A1S2) and the tone volume potentiometer (A2R47)

Reassembly of the housing is done in the reverse order, after verifying the removal of contaminants and foreign objects, that all internal assemblies are correctly and securely mounted, all connectors are mated, and any Calibration jumper on A1J2 is removed. A quick power-up functional check may be appropriate before proceeding with final closing of the unit.

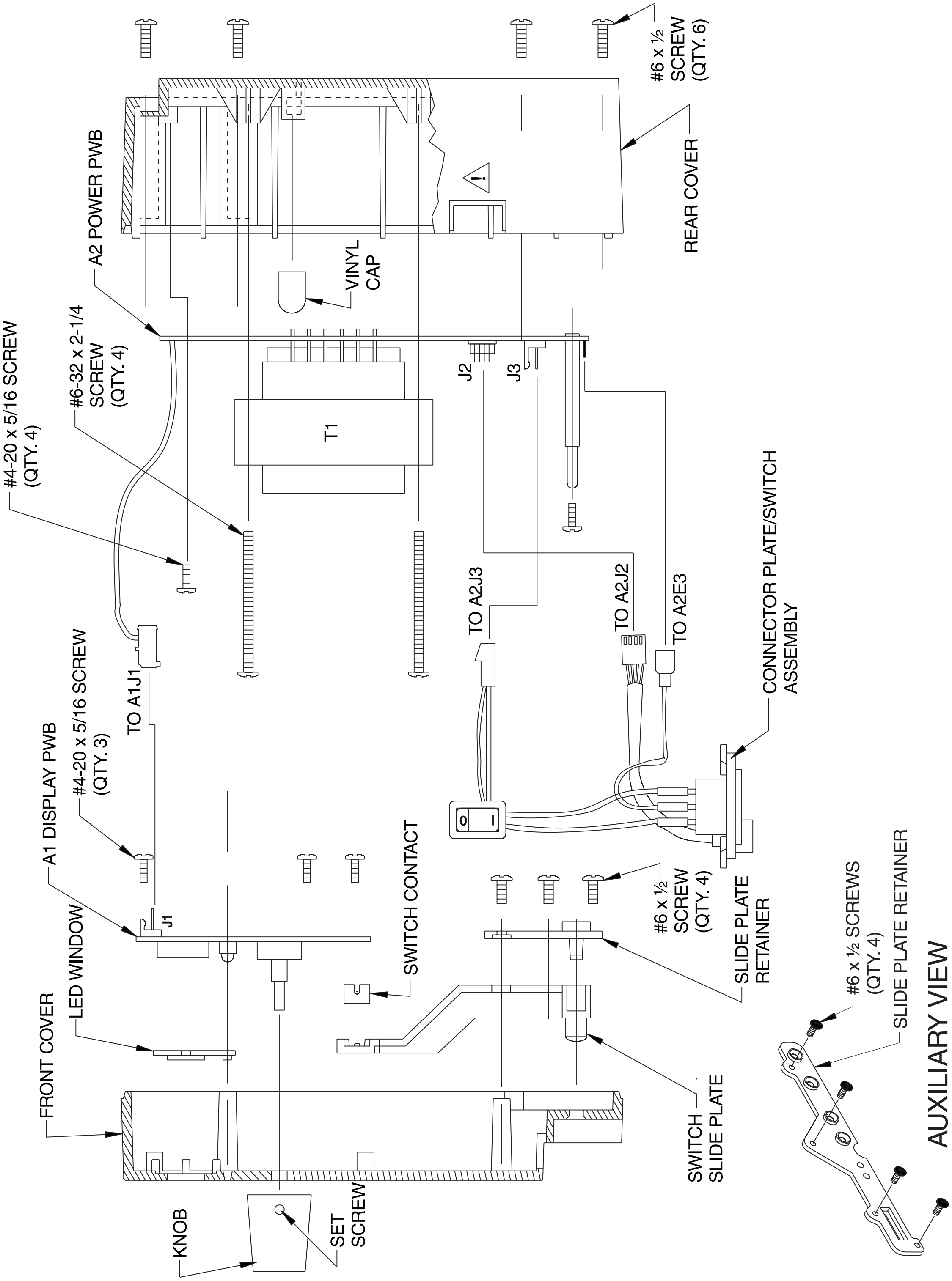
The front panel is most easily fitted in place by first aligning the P/P pin and RF output jacks with their holes on the front panel, then fitting the seam between the enclosure halves. While holding the properly mated enclosure halves together, place the unit face-down on a flat work surface and install the six self-tapping enclosure screws.

> CAUTION: The threads in the plastic mounting bosses may be stripped by cutting new threads or excessive torque. Once the threads are stripped, the enclosure must be replaced to restore proper mechanical integrity.

When reinstalling self-tapping screws, first find the original threads by placing the screw tip into the boss and rotating it backwards (CCW) until you feel the screw drop sharply. Then carefully run the screw in a few turns; there should be little resistance felt until the screw is fully seated. Use no more than moderate hand torque to complete tightening the screws.

After the enclosure is reassembled, inspect and clean the exterior per Section 4.1.

Figure 5.1 Assembly Breakdown



5.1.1.1 Front Panel

The front and rear panel assemblies may be separated, if necessary, by disconnecting the ribbon harness connector A1P1 from the A1 PWB. This is done most easily with the A1 PWB removed from the front panel.

> CAUTION: When disconnecting A1P1, pull only on the connector housing, not the ribbon harness. Do not stress the harness connections on the A2 PWB.

The A1 PWB may be separated from the front panel by first using a 2 mm hex Allen wrench to loosen the set screw on the power control knob. After the knob is removed, remove the three self-tapping A1 PWB mounting screws.

> CAUTION: When the A1 PWB is removed, the moving contact on the Mode Selector may be deformed or dislodged due to mishandling. The window for the power display and activation LEDs is held in place by the A1 PWB and will fall free if the front panel is turned right side up.

> NOTE: The Mode Selector switch functions only when the A1 PWB is secured to the front panel. This function may be simulated while A1 is free by use of a clip lead from GND (A1TP3) to HI (A1TP1) or BI (A1TP2).

If necessary to correct a Mode Setting problem, (See Section 4.4.7.6), the Mode Selector sliding contact may be removed from the slide plate by carefully lifting the end with the hole off the locating boss, and then sliding out from under the retaining ears. Use minimum force to avoid deforming this part.

The Mode Selector slide plate and retainer need be removed only for replacement due to obvious mechanical or aesthetic damage. They are secured to the front panel by four Phillips-head self-tapping screws.

Reassembly of the front panel is done in the reverse order of disassembly, using the screw thread technique noted in 5.1.1.1 above and the following advice:

> NOTE: Be sure the LED window and Mode Selector are in place before installing the A1 PWB. When installing the A1 PWB, it is normal for the Mode Selector contact spring force to hold the PWB slightly above the normal seated position on the mounting bosses.

> NOTE: Before installing the knob on the A1S1 encoder shaft, make sure the A1 PWB is properly secured against its mounting bosses. Then locate the set screw about 180 degrees OPPOSITE from the shaft flat. Loosen the set screw enough to allow the knob skirt to contact the front panel, then pull it back slightly to clear the front panel (no more than .040" (1 mm)) before tightening the set screw with light hand torque.

5.1.1.2 Rear Enclosure

The A2 PWB may be separated from the rear enclosure by removing the four Phillips-head self-tapping screws in the corners of the PWB and the four long Phillips-head machine screws passing through the frame of the A2T1 power transformer. While lifting the A2 PWB by the power transformer frame, slide the A3 connector plate and S1 power switch upward out of their slots in the rear housing.

The A3 connector plate assembly may be removed from the A2 PWB per Section 5.1.1.3.

The A2 is reinstalled in the reverse order, with regard to the screw thread technique noted in 5.1.1.1 above and the following advice:

CAUTION: Excessive torque on the A2T1 power transformer mounting screws will crack the PWB, and too little may allow the transformer to hum during operation or to vibrate during shipment, breaking its connections to the PWB.

Tighten the four A2T1 power transformer mounting screws to 50 in.-oz. (0.35 N-m)+/- 10%. If no torque screwdriver is available, run all four screws in until the heads just contact the transformer frame, then tighten each screw ONE more turn, working in diagonal order. After the A2T1 screws are torqued, secure the screw heads to the transformer frame using a gap-filling cyanoacrylate adhesive, such as Loctite® TakPak®.

5.1.1.3 Connector Plate

The A3 connector plate and S1 power switch may be separated by disconnecting A2J2, A2J3 and E3. The plate and switch simply slide into mating slots in the rear housing.

The S1 power switch may be removed by disconnecting the four flat blade wire connectors. Make note of the switch orientation and order of wire colors to ensure proper installation of a replacement switch.

The AC mains inlet snaps into the connector plate and may be removed after disconnecting its wires to S1 and A2E1.

The 4-wire accessory harness A3W1 cannot be removed from the connector plate without destroying it, and the connectors require special tooling for disassembly and reassembly. Therefore, this harness is replaceable only as a unit, factory-assembled with a new connector plate, not including the AC mains inlet and round hole filler plug.

5.1.2 Component Replacement

This section provides special guidance and precautions regarding the proper methods for replacing particular components on the two PWBs. This advice assumes that you have at least ordinary electronic repair tools and skills, including those related to soldering and unsoldering through-hole components.

In general, the PWB should be removed to allow access to the circuit side for unsoldering, solder clearance, lead trimming, flux removal, and inspection. Most axial-leaded devices can be replaced entirely from the component side, but this requires careful lead preparation and precludes complete inspection for possible bridging or solder splashes, and thus is not recommended.

5.1.2.1 A1 PWB Components

A1VR2 - This TO-220 device relies on thermal contact with the PWB to dissipate heat. Unsoldering the old part is simplified by first removing the screw and nut securing its tab to the PWB. Before installing a replacement VR2, clear the PWB pads of solder. Then, using two pliers to avoid transferring stress to the package, form the leads so that they fit freely into their pads with the screw holes aligned and the package flat against the PWB surface without being forced. Before soldering the leads to the pads, install and hand-tighten the tab mounting screw and nut; the nut is on the component side in contact with the TO-220 tab.

A1Q4 - This ESD-sensitive device may be protected during installation by wrapping all three leads with a length of bare wire until it is soldered in. Use the TO-92 lead preparation advice given below.

TO-92 devices - All TO-92 devices are installed with the center lead formed about .05" (1.2 mm) toward the flat side of the package. First bend the center lead by hand outward about 30 degrees, then use needle-nose pliers to form a second bend about 1/8" (3 mm) below the package to bring the lead back parallel to the other two. Solder the leads with the package about 1/8" (3 mm) above the PWB surface.

DIPs - The 20-pin uCs, U1 and U2, may be difficult to desolder with their leads intact without risking overheating the PWB traces. A simpler and safer method is first to cut each lead off the device flush with the PWB, then use a vacuum unsoldering tool to clear each pad of both solder and the lead remnants. This method is also applicable to the smaller DIPs, which may be more easily desoldered intact, however.

EEPROMs - If A1U3 or U4 is replaced, the unit must undergo a complete recalibration (Section 4.3) to store valid data in the replacement device. Otherwise, an EEPROM read error Fault Code will appear after each power-up.

RNs - If only one or two resistor elements in a network DIP has failed open, a typical failure mode, then an expedient and acceptable repair is simply to lap solder an external 1/8 or 1/4W resistor across the affected DIP pins. Of course, complete DIP replacement is the preferred method, since it restores both the mechanical and electrical “as-built” condition. Replacement is the only acceptable repair where a resistor element has failed to a resistance less than an open circuit.

LEDs - These devices are mounted on the circuit side, facing the front panel. The clearance between the LED packages and the green window must be correct for proper fit of A1 into the front panel and to ensure good visibility. The 7-segment devices mount with all four corner ears touching the PWB. The blue X3 LED is mounted using a nylon spacer so that its tip is .040" (10 mm) above the PWB; the longer lead is the anode (+).

A1S1 Encoder - This device is mounted on the circuit side, facing the front panel. First thoroughly desolder the three signal leads so that they are free to move in their holes. Then desolder the two mounting tabs as well as possible. If the tabs remain rigidly soldered, alternately heat each tab to melt the solder, while gently pulling on the encoder shaft and working each tab out by small increments. Install the replacement with particular attention to keeping the locating ears flush with the PWB surface to ensure a correct fit into the front panel.

> NOTE: Any antirotation tab on the shaft side of the replacement encoder body must be cut off flush to the component before installation.

5.1.2.2 A2 PWB Components

RF Output Jacks - The upper ends of these components must be held in accurate alignment in order to fit properly into the front panel. A single replacement jack may be aligned for soldering by using the Mode Selector retainer plate from the front panel as an alignment jig. A small damp rag wrapped around the top end of the jack will prevent soldering heat damage to the retainer.

A2Q3 & Q4 - These heatsink-mounted components are most easily removed by detaching them from the heatsink before unsoldering the leads. To avoid stressing the internal lead bonds, the replacement device should be bolted to the heatsink (screw head against the device package), before the leads are soldered to the PWB. No heatsink compound or insulator pad is required.

Optoisolators - A2U3, A2U4, and A2U5 are covered with a 0.65" (17 mm) length of glued heatshrinkable tubing to gain adequate creepage distance between the patient-connected circuitry and the intermediate circuit. Clear tubing is preferred, since it will not obscure the pin 1 mark. If proper tubing is unavailable, the device leads may be adequately insulated by covering them thoroughly from the device body to the PWB pads with a good grade of silicone sealant.

A2J3 - The center pin of this connector is removed from the connector housing to gain adequate clearance between the mains line and neutral circuits.

Volume Control - A2R47 is mounted on the circuit side.

A2T2 - The switch isolator transformer is secured to the PWB using double-sided adhesive tape. Both mounting surfaces should be cleared of old adhesive and wiped clean with alcohol before installing the replacement device. Refer to Figure 5.8 for correct orientation. Winding 5-6 is the heavy twisted pair, 1-4 is the white pair and 2-3 is the small red pair. Leads marked with heatshrinkable tubing should connect to the PWB pads with the silkscreened rectangular marks. Small wire ties should be placed on the ends of each pair after soldering to prevent a free end from reducing the necessary patient-to-intermediate circuit clearance.

Jumper E1-E2 - This 10 KV-rated wire is terminated with insulation-retaining terminals to prevent a loose end from violating patient circuit clearances. If similar terminals are unavailable, replacement wire ends may be adequately secured to the PWB after soldering, by using a small amount of silicone sealant. A plastic standoff limits free motion of this wire.

Output transformer - A2T3 is mounted using its five PWB pins. The BI secondary 3-6 is connected to the PWB via flying leads, and lead 3 is marked by a small piece of heatshrinkable tubing. A small wire tie should be placed over the ends of leads 3-6 after soldering to prevent a free end from violating patient circuit clearance.

A2R37 - This power resistor can become quite hot during extended activations, so it should be mounted with its body 0.1" - 0.2" (2.5 mm - 5 mm) above the PWB to prevent PWB heat damage.

A2R3 - This power resistor may not be installed on all PWBs.

A2J1 - This ribbon harness is factory-terminated with connector A1P1 using special tooling, so field repairs of broken conductors at the connector end cannot be made reliably. A harness wire broken at the A2 PWB end can be repaired by slicing the plastic web on either side of the wire back far enough to allow it to be stripped, and then reconnecting it to its A2J1 pad with a short, bare jumper. However, replacement of the entire harness is more reliable and far less time-consuming.

A2LS1 - The protective cover over the sound hole on a replacement part should be removed and discarded before returning the unit to service.

A2JP1through A2JP5 - Up to three of these zero-ohm resistors are used to set the rated AC mains voltage for the unit according to Figure 5.8, Table 1. They may be replaced with bare 0.5mm (#24 AWG) solid wire if necessary.

A2F1 and A2F2 - The ratings of these 5 x 20mm time delay fuses vary depending on mains voltage. Refer to Figure 5.8, Table 2.

A2D7 and A2D8 - These power diodes rely on their leads for heat transfer and should be installed with minimum lead length between the device body and the PWB.

5.1.3 Parts Ordering Information

Specifications for all Hyfrecator® 2000 replacement parts appear in the parts lists in Section 5.2. All of these components may be ordered by CONMED Part Number (P/N), although the more common electronic devices may be obtained through your local electronics distributor. However, some custom-made components, such as transformers, programmed microcontrollers and enclosure parts are available only through CONMED Corp.

Replacement parts orders are handled by Customer Services. Contact information is found on the inside front cover of this manual. Be sure to have the CONMED part number(s), unit model, and serial number handy to expedite processing.

If you anticipate servicing a number of Hyfrecator® 2000's on a regular basis, you may wish to have a stock of spare parts on hand to expedite repairs. Recommended spares are denoted by an asterisk (*) in the Section 5.2 parts lists.

5.1.4 Waveforms

This section shows oscilloscope waveforms of various Hyfrecator® 2000 signals under typical operating conditions. They may be helpful in troubleshooting if you observe large, obvious deviations in your unit. Slight deviations from unit to unit are normal, however, and do not necessarily indicate a defect.

Unless otherwise indicated, all waveforms are taken using an oscilloscope with 20 MHz or greater vertical bandwidth with a 10 megohm or greater probe.

5.1.4.1 RF Output

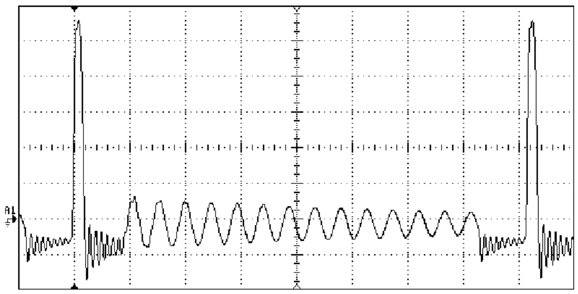
CAUTION: These waveforms should be measured only using a high voltage oscilloscope probe with at least 20 MHz bandwidth, such as a Tektronix P6015A or equivalent. A lesser probe will arc over, possibly destroying both the probe and the oscilloscope input circuitry.

> NOTE: "O.C." means Open Circuit, i.e., no RF load resistor connected. Load resistors are 50W or greater, non-inductive.

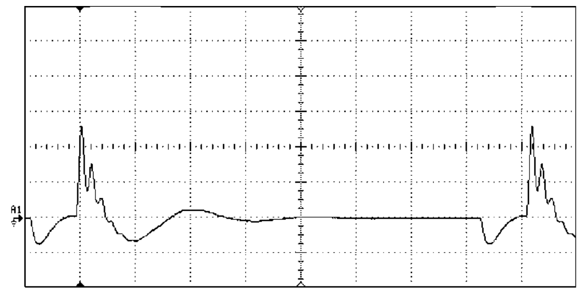
5.2 Schematics, Assembly Drawings & Parts Lists

The section that follows the waveforms contains the system block diagram, interconnect diagram, parts lists for the main assembly and each printed wiring board, the circuit board layouts, and schematics.

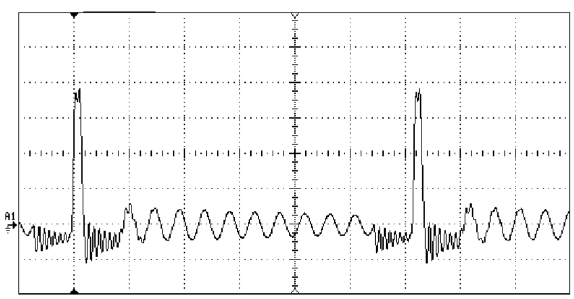
Figure 5.2 RF Output Waveforms



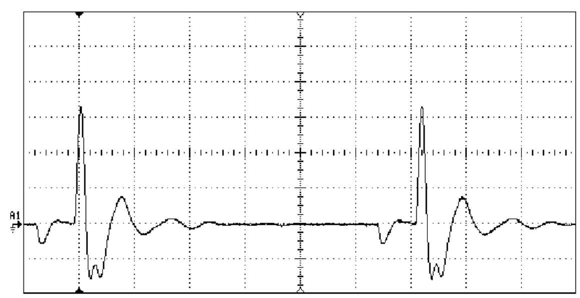
HI Mode, 35W O.C.
1000 V/div., 5μs/div.



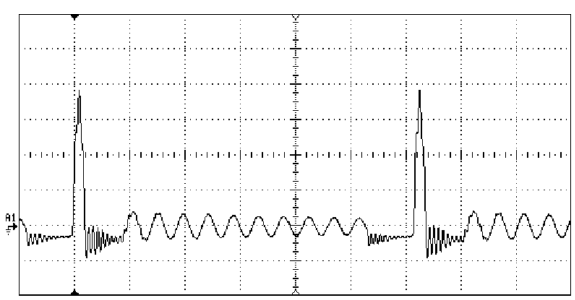
HI Mode, 35W 1000 Ohm Load
500 V/div., 5μs/div.



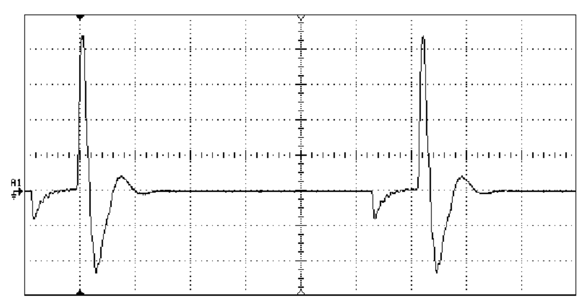
LO Mode, 20W O.C.
500 V/div., 5μs/div.



LO Mode, 20W 500 Ohm Load
200 V/div., 5μs/div.

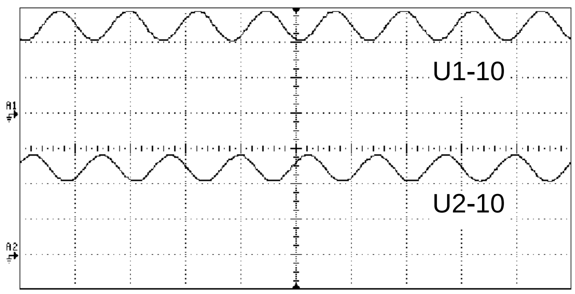


BI Mode, 35W O.C.
500 V/div., 5μs/div.

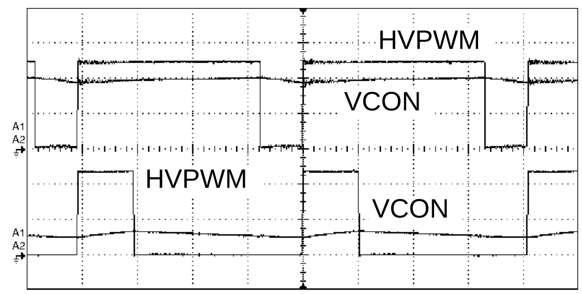


BI Mode, 35W 500 Ohm Load
200 V/div., 5μs/div.

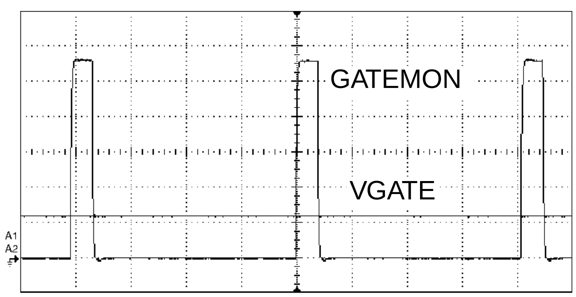
Figure 5.3 A1 PWB Waveforms



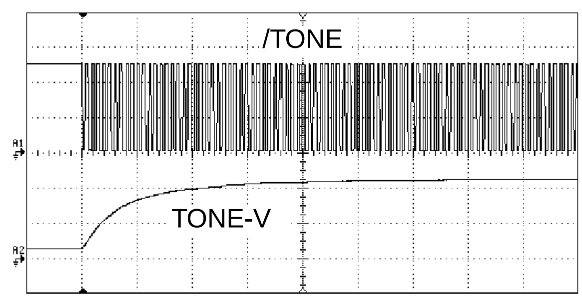
U1 & U2 OSCOUT via 10K Isolation Resistor
1 V/div., 200 ns/div.



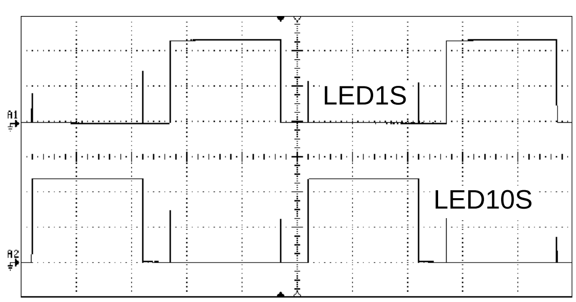
HVPWM & VCON, 35W & 3W HI
2 V/div., 5μs/div.



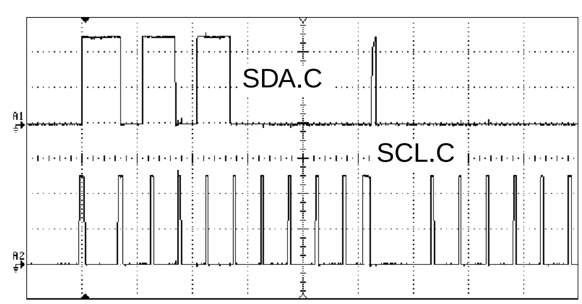
GATEMON & VGATE, 3W HI
2 V/div., 10μs/div.



/TONE & TONE-V, During POST, Min. Volume
A1: 2 V/div., A2: 100 mV/div., 5ms/div.

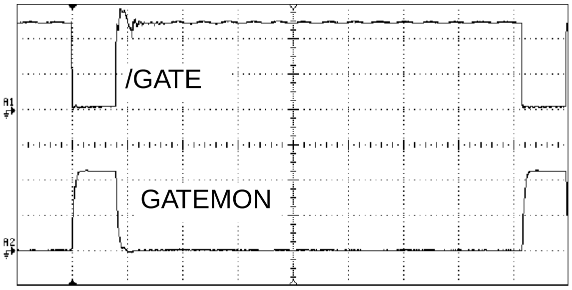


LED1S & LED10S, Service Pseudo-Run Mode
2 V/div., 2ms/div.

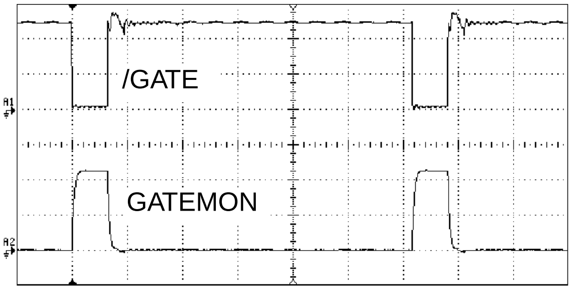


SDA.C & SCL.C, Service Pseudo Run Mode
(After power change.)
2 V/div., 20μs/div.

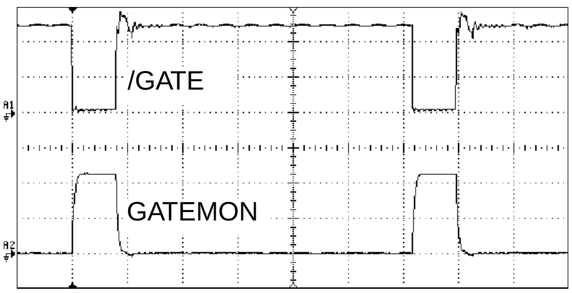
Figure 5.4 A2 PWB Waveforms



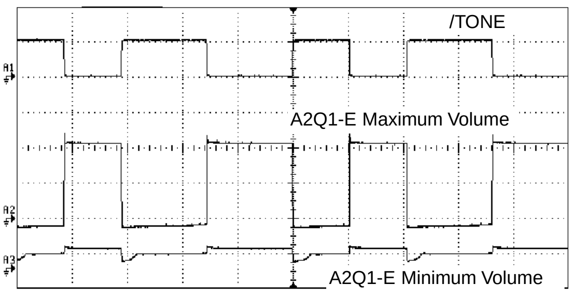
/GATE & GATEMON, 35W HI
A1: 2 V/div., A2: 5 V/div., 5μs/div.



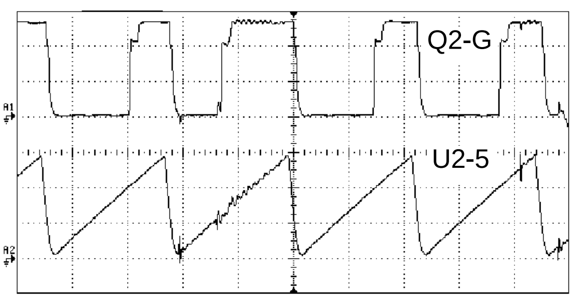
/GATE & GATEMON, 20W LO
A1: 2 V/div., A2: 5 V/div. 5μs/div.



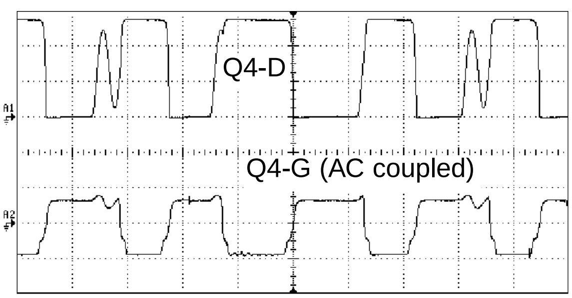
/GATE & GATEMON, 35W BI
A1: 2 V/div., A2: 5V/div., 5μs/div.



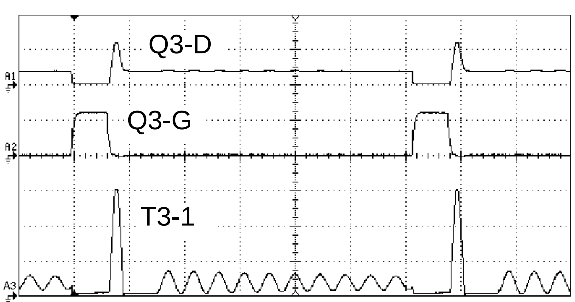
/TONE & A2Q1-E, Min. and Max. Volume
5 V/div., 200μs/div.



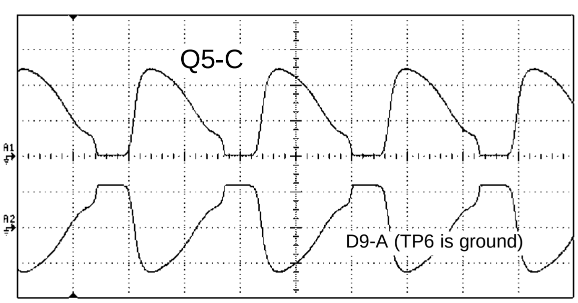
U2-5, Q2-G, 20 W LO, O.C.
A1: 2 V/div., A2: 1 V/div., 5μs/div.



Q4-G, Q4-D, 20 W LO, O.C.
A1: 50 V/div., A2: 5 VAC/div., 5μs/div.

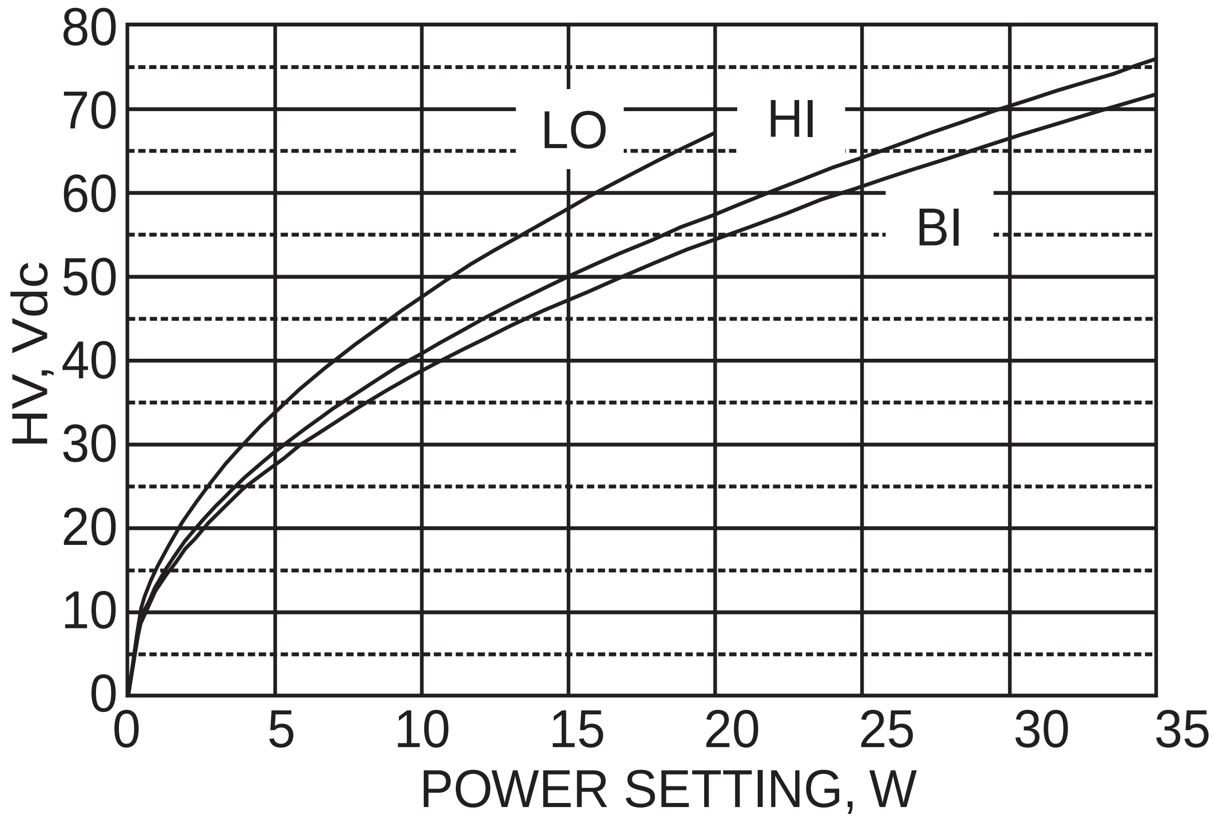


Q3-G, Q3-D, T3-1, 20 W LO, O.C.
A1-500 V/div., A2-10 V/div., A3-200 V/div., 5μs/div.



Q5-C, D9-A, Not Activated
A1-10 V/div., A2-5 V/div., 10μs/div.

Figure 5.5 Nominal HV vs. Power Setting



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Appendix
Fault Codes

See Section 4.4.1 for a discussion of troubleshooting using Fault Codes.

Controller-Generated Fault Codes

Fault Code	Meaning	Possible Remedies
E1 - E3	Control microprocessor process errors.	Replace A1U1
E4	Power adjust overflow. Mode change during power slew.	Possible user error. If can't duplicate, and power adjustment and mode selection is correct individually, replace A1U1.
E5	Control EEPROM read error.	Enter Service Cal and readjust High Mode Offset and Gain up one and back to restore defaults. If Run Mode still shows E5, replace A1U3 and recalibrate.
E6	Control EEPROM write error.	Normally encountered only after making power or cal changes. Verify SDA.C & SCL.C swing 0 to +5V during POST and U3 power, gnd are good. Otherwise, replace A1U3 & recalibrate.
E7	Pencil button or footswitch contact closure sensed on power-up (before POST).	Verify /ACTIVE.C, /POWDN and /POWUP all +5V immediately on power up with no accessory connected to A2J2. If correct, repeat with accessory connected, otherwise possible shorted signal line. Otherwise, shorted accessory lines, switches.
E8	HVPWM duty set over 97.5%.	If this occurs only at higher power settings, check RF output power; possible "weak" HV, PA drive, bad part in RF generator or output sections. If RF output is excessive, recalibrate. Otherwise, replace A1U1.
E9	Service mode: A1J2 short removed with "--" display.	Verify VMODE.C voltages in range at all 3 mode switch settings.Verify mode switch slider position correct and touching A1. Clean mode switch contact pads.

Monitor-generated Fault Codes

Fault Code	Meaning	Possible Remedies
-0	In Service Last Fault only: No fault code stored.	Unit has never declared a fault.
-1	POST detected low HV.	HV supply output low. Try Service Pr Mode output checks. If HV low, repair. Otherwise verify HVSENS = VCON x 0.8 to 0.84. Otherwise, attempt full recalibration. Otherwise, replace A2U2.
-2	HV too high for power setting.	If during POST, enter Service Pr mode. Verify HV < 3V at zero power setting and rises smoothly with setting. If so, attempt recalibration. Otherwise verify HVSENS = VCON x 0.8 to 0.84. Verify HVPWM duty varies smoothly up from 0 with setting. Replace A1U1, A1U2. Possible open A2Q3, D3, T3, no Q3 gate drive.
-3	Gate frequency or duty cycle error.	In Service Pr mode, verify correct A2Q3 gate period, on-time and voltage all 3 modes. Use minimum non-zero power. If correct, verify VGATE in 2.1 to 2.6V range when active; check A1Q4 & associated RCs.
-4	Monitor EEPROM error.	Verify SDA.M & SCL.M swing 0 to +5 pre-POST. If not, check RN3A & B, Vcc. If OK, attempt recalibration. Otherwise, replace A1U4 & recalibrate.
-5	Monitor EEPROM read error.	Attempt recalibration. If no improvement, replace A1U4 & recalibrate.
-6	Processor error.	Replace A1U2.
-7	Gate drive w/o /ACTIVE.M.	Verify /ACTIVE.M swings 0 to +5 with hand or footswitch. If correct, verify GATE= +5 when not active. Verify ACTIVE.C not stuck low. Replace A1U1.
-8	PSET6:7 inconsistent with VMODE.	Verify VMODE.C = VMODE.M = VMODE. Verify VMODE well within specification range. Verify +5C & +5M good to +/- 2%. Replace A1U1 or A1U2.

Monitor-generated Fault Codes, continued

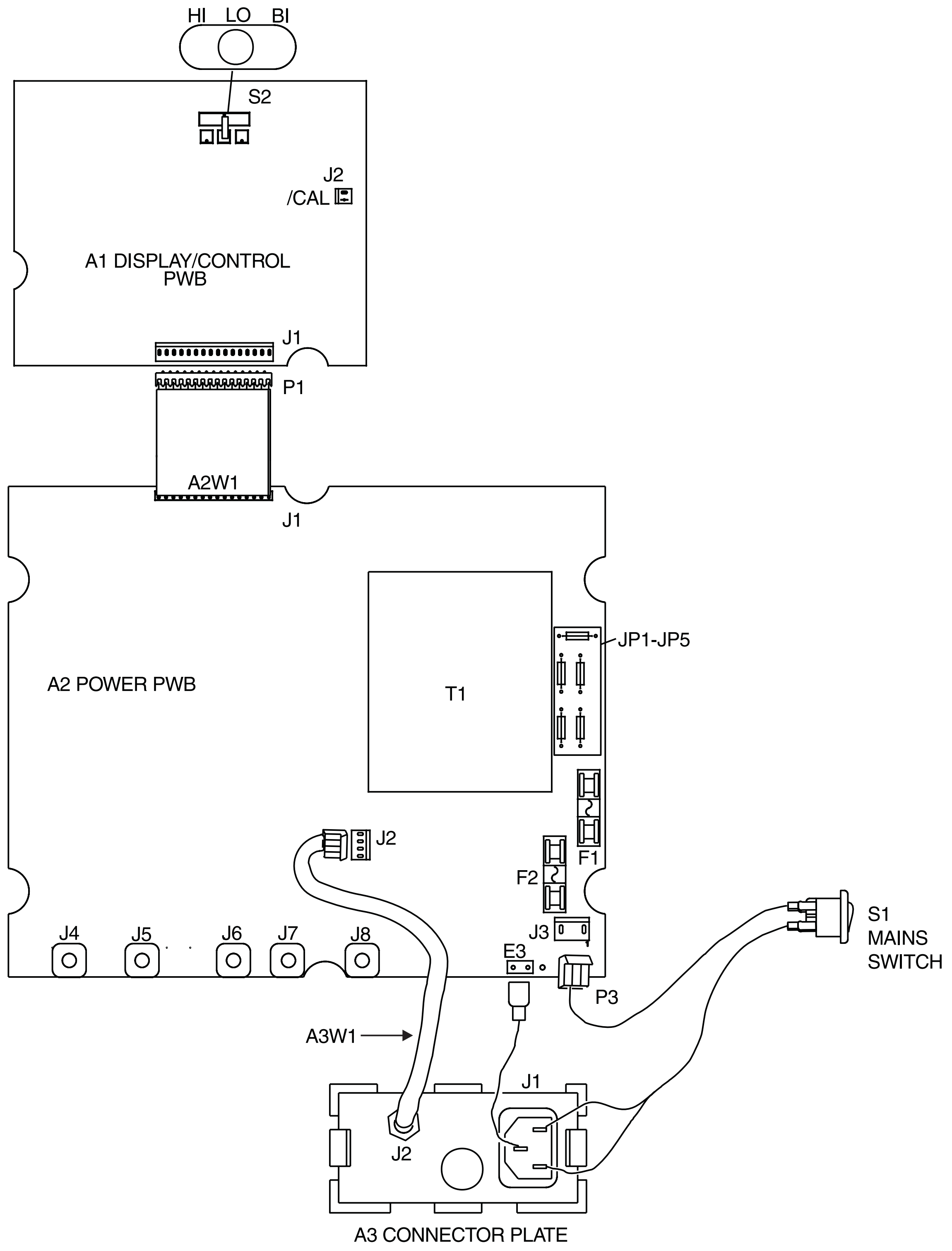
Fault Code	Meaning	Possible Remedies
-9	PSET & LED scan rate incorrect.	Check LED1S & LED10S with an oscilloscope. Verify 1S high for 4 msec, then both low, then 10s high 4 msec, then both low in continuous cycle. Verify both swing 0 to +5V. Replace A1U1 or A1U2.
-A	PSET byte inconsistent with LED drive.	Verify normal sequence of LED bars during POST. Enter Service Pr mode, verify PSET bus and LED drive lines swing 0 to +5 as power is adjusted. Verify clocks at 4.00 MHz both microcontrollers pin 10 (use 10K probe isolator resistor). If defective, replace Y1 or Y2, otherwise replace A1U1 or A1U2.
-B	Monitor process error.	Replace A1U2.
-C	Monitor interrupt error.	Replace A1U2.
-D	Invalid PSET value on PSET bus.	Troubleshoot same as -9.
-E	VMODE.M out of range on activation.	Troubleshoot same as -8. Replace A1U2.
-F	Tone not detected during activation.	In Service Pr mode, verify complaint by ear. Attempt volume adjust. If tone is heard, verify TONEMON > 0.1V during activation, < 0.3V idle. If no tone, verify /TONE 0-5V about 1 KHz. If correct, verify 12Vpp tone signal at A2U1-5, 10Vpp at A2Q1-E at max volume. Check LS1 dc continuity, R11.

No Fault Code failure.

If unit powers up or “dies” silent with no displays, verify +5M and +5C are correct, verify microcontroller clocks per -C fault, verify /MCLR both microcontroller pins 1 at +5. Replace A1U1 then A1U2.

Figure 5.6 Top Assembly Parts List, Interconnect and Functional Block Diagrams

REF. DES.	CONMED P/N	DESCRIPTION
N/A	**61-5710-XXX**	**HYFRECATOR 2000 ASSEMBLY**
A1	61-5741-001	ASSY.,PWB, DISPLAY,A1
A2	61-5744-100	ASSY,PWR PWB, A2 100V HYF 2000
A2	61-5744-115	ASSY,PWR PWB, A2 115V HYF 2000
A2	61-5744-220	ASSY,PWR PWB, A2 220V HYF 2000
A2	61-5744-230	ASSY,PWR PWB, A2 230V HYF 2000
N/A	24466-10	SWITCH CONTACT
N/A	61-5709-001	ASSY,CONNECTOR PLATE/SWITCH,A3
N/A	62-5642-001	SWITCH SLIDE PLATE, HYF 2000
N/A	62-5696-001	FRONT COVER,HYF 2000,SLKSCRN
N/A	62-5698-001	LED WINDOW HYFRE. 2000
N/A	62-5707-001	KNOB,ROTARY,GREY,.93"DIA x.73"
N/A	62-5708-001	SLIDE PLATE RETAINER, HYF 2000
N/A	62-5766-001	REAR COVER,HYF 2000,SLKSCRN
N/A	62-5767-001	LABEL,INSTRUCTIONS & WARNINGS (115V ONLY)
N/A	62-5779-001	CAP, VINYL
N/A	DI09-0608-F	SCREW,#6x1/2,TYPE B,PH,SELFTAP
N/A	DI09-0636-A	SCREW #6-32 x 2 1/4 PAN HEAD
N/A	DI16-0405-A20	SCREW, #4-20x5/16 PH,PLASTITE
A3	**61-5709-001**	**CONNECTOR PLATE ASSEMBLY**
A2P3	62-1389-003	CONNECTOR,4 PIN,.100
A2P4	62-3682-003	HOUSING CONN 0.156 LOK 3P
A3J1	62-2967-003	RECEPTACLE IEC SNAP-IN
A3J2	62-5712-001	RECEPTACLE 4 PIN PANEL MT
A3S1	62-5765-001	SWITCH PWR ROCKER HYFRE. 2000
N/A	62-3682-201	TERMINAL 18-24 2478
N/A	62-0436-002	WIRE STR 18AWG BRN
N/A	62-0433-012	WIRE STR 24AWG,YELLOW
N/A	62-0433-001	WIRE STR 24AWG BLU
N/A	62-0437-005	WIRE STR 16AWG GRN/YEL UL1007
N/A	62-0436-009	WIRE STR 18AWG WHT
N/A	62-0620-004	TUBE HS RNF100 TYPE1 3/16
N/A	62-0620-008	TUBING,HEATSHRINK,1/2" BLK
N/A	62-1388-001	TERMINAL CRIMP
N/A	62-0288-008	TERMINAL,SLP-ON,FEM,R,22-18AWG
N/A	62-0433-002	WIRE STR 24AWG BLK
N/A	62-0436-008	WIRE STR 18AWG BLK
N/A	62-0436-005	WIRE STR 18AWG BLU
N/A	62-5685-001	PLATE, CONNECTOR, HYF 2000
N/A	62-5706-001	DOME PLUG
N/A	62-0288-009	TERMINAL SLIP ON .110 RED
N/A	62-5712-002	SOCKET, CONTACT, 4 PIN RECEPT.
N/A	62-0433-007	WIRE STR 24AWG,RED



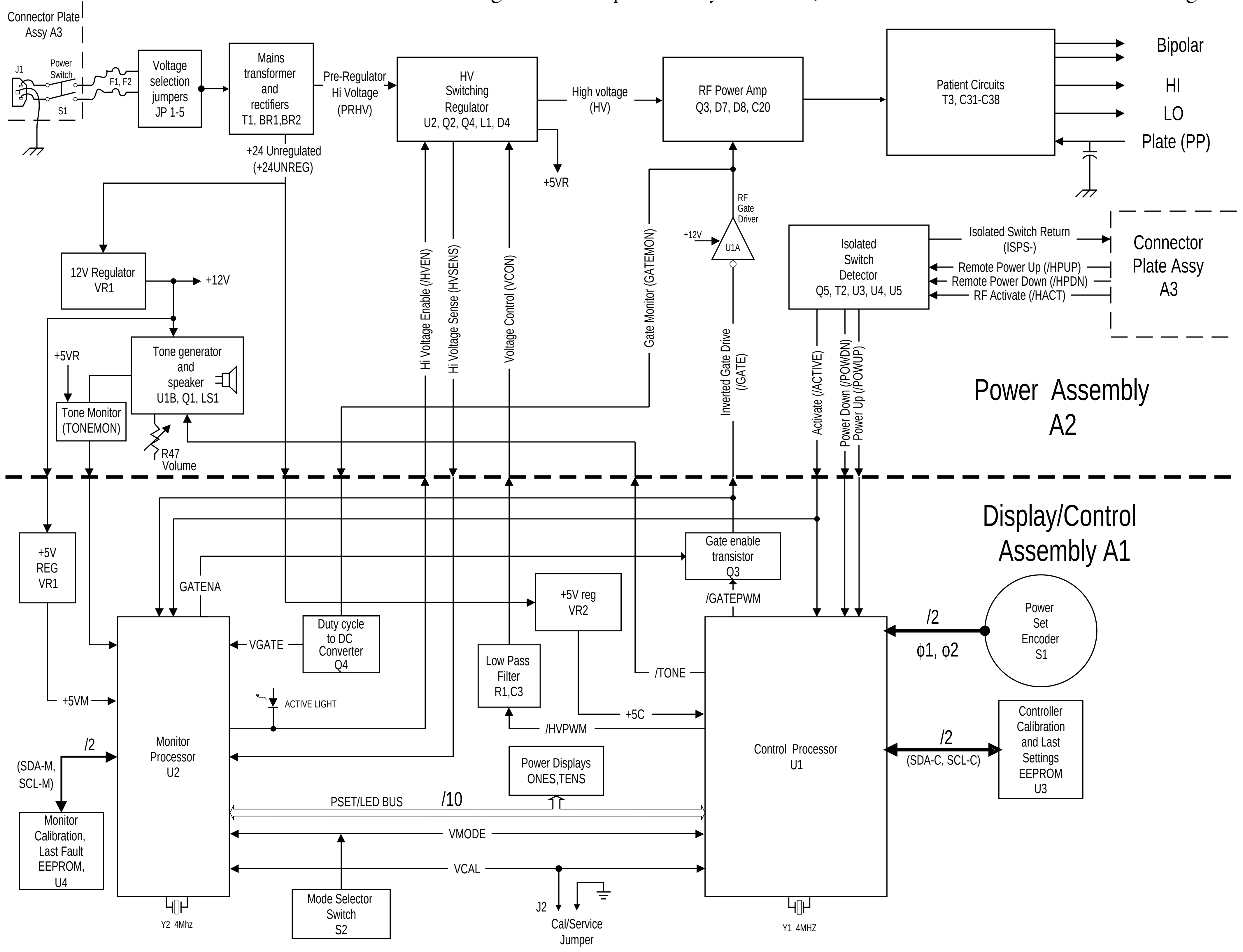
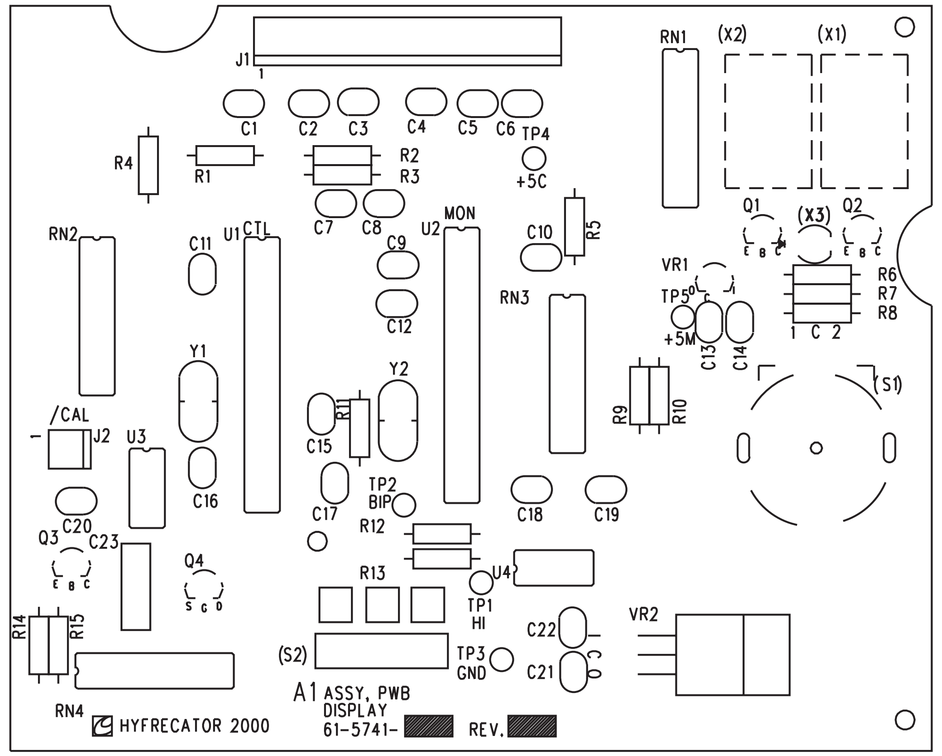
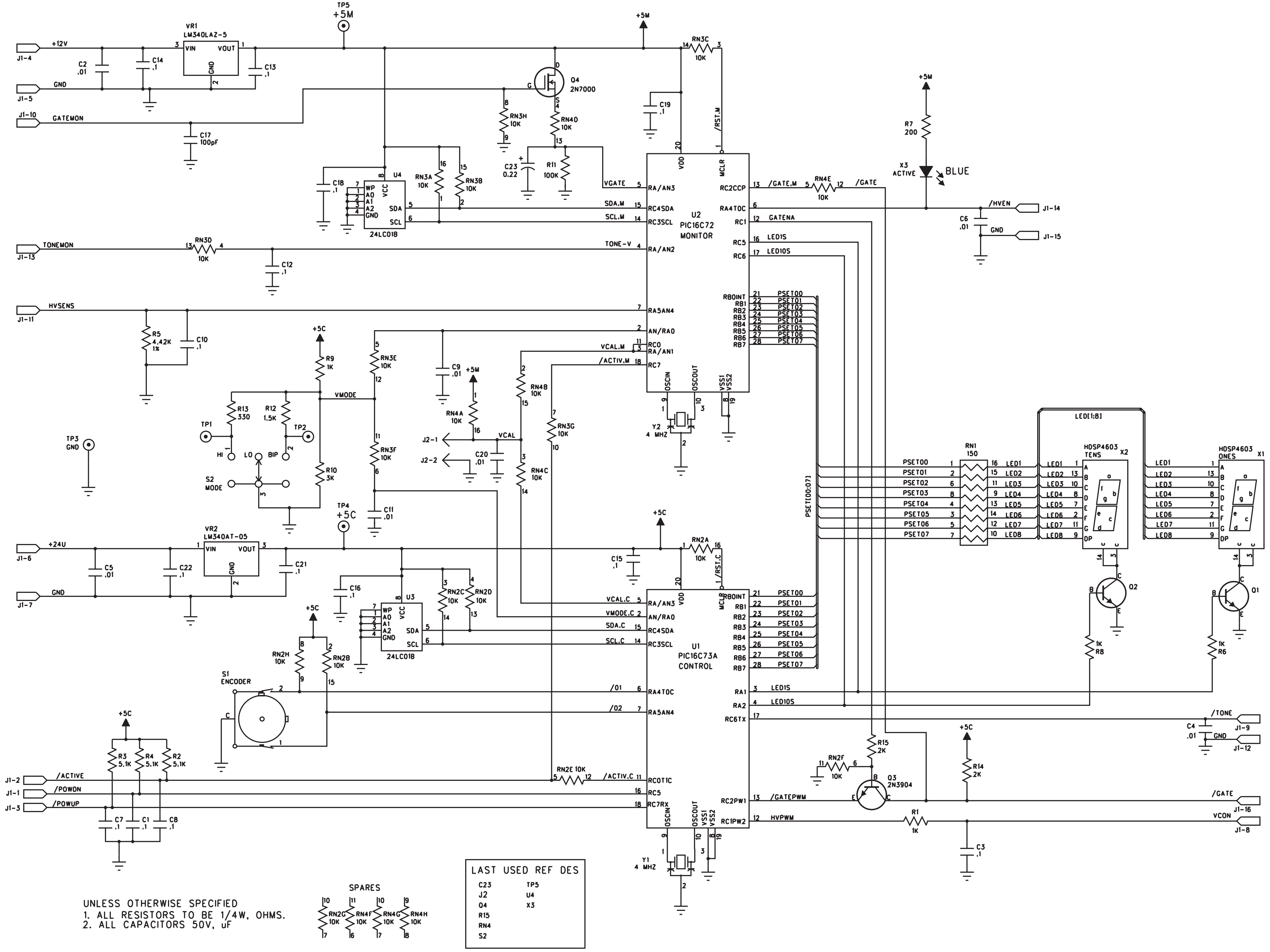


Figure 5.7 A1 Control/Display PWB Parts List, Layout and Schematic

REF. DES.	CONMED P/N	DESCRIPTION
C1,3,7,8,10, 12-16,18,19, 21,22	62-0267-002	CAP, 0.10 uF 50V 20% CERAMIC
C17	62-0267-004	CAP, 100pF DIP CER 50V
C2,4,5,6,9, 11,20	62-0267-001	CAP, 0.01uF, 50V, 20% CER
C23	62-1677-006	CAP,METPE.022UF 63V 10%
FOR VR2	62-0343-001	NUT KEPS 4-40
FOR VR2	62-3608-004	SCREW 4-40X5/16 PN HD PHL
J1	62-2845-015	RECEPTACLE STRAIGHT 16PIN
J2	62-3402-001	RECEPTACLE 9-PIN
Q1,2,3	62-4239-001	TRANSISTOR, NPN, 2N3904
*Q4	010630001	TRANSISTOR,FET, 2N7000
R1,6,8,9	62-0364-063	RES, 1K 1/4W 5% CF
R10	62-0364-074	RES, 3K, 1/4W, 5%
R11	62-0364-111	RES, 100K, 1/4W, 5%
R12	62-0364-067	RES, 1.5K, 1/4W, 5%
R13	62-0364-051	RES, 330, 1/4W, 5%
R14,15	62-0364-070	RES, 2K, 1/4W, 5% CF
R2,3,4	62-0364-080	RES, 5.1K, 1/4W, 5%
R5	62-0961-255	RESISTOR 4.42K
R7	62-0364-046	RES, 200, 1/4W, 5% CF
RN1	62-3463-001	RES,NETWORK 16 DIP 150 OHM
RN2,3,4	62-3463-008	RESISTOR NETWORK DIP 10K 2%
*S1	62-4920-001	SWITCH,ROTARY ENCODER 2-BIT
TP1-5	020361101	TEST POINTS
*U1	61-5714-001	IC CONTROL,PROGRAMMED,HYF 2000
*U2	61-5716-001	IC MONITOR,PROGRAMMED,HYF 2000
*U4,3	62-3466-005	IC EEPROM 24LCO1B,MICROCHIP
VR1	62-1719-001	REGULATOR VOLT 5V LM340LAZ-5.0
VR2	010287001	I.C.REGULATOR,5VDC,2%,LM340AT5
X1,2	010652001	LED DISPLAY HP HDCP-4603
X3	62-4946-002	LED BLUE LM934MBC KINGBRIGHT
X3	62-5396-001	MOUNT, L.E.D.
Y1-2	62-5158-001	RESONATOR PIEZO 4MHZ CST4.00MGW

*RECOMMENDED SPARES





REF. DES.	CONMED P/N	DESCRIPTION
BR1-2	62-0258-006	BRIDGE RECTIFIER 400V, 1.5A, WO4G
C1,10,21, 22,23	62-0267-001	CAP, 0.01uF, 50V, 20% CER
C12,18	62-4799-001	CAP.,ELECT.,100uF,100V LOW ESR
C13	62-5191-001	CAP., ELECT, 680uF 200V
C14	62-5188-001	CAP., ELECT. 1000uF, 35V
C19	62-1677-011	CAP, .1uF 250V 10% PE
C2,3,4,6,8, 9,11,15,16, 26,27,28	62-0267-002	CAP, 0.10 uF 50V 20% CERAMIC
C20	62-1676-004	CAP., POLYPROP, 2KV, .0033uF
C24,30	62-0268-001	CAP, 10uF, 16V 20% ELECT.
C25	62-3575-007	CAP, MET, .033MFD, 50V 5%
C29	62-5686-474	CAP .47 uF 63V
C31,38	62-5404-004	CAP.,CER.,1KV, 2200pF +/- 20%
C32	62-5404-002	CAP.,CER., 2KV, 1000pF +/- 20%
C33,34	62-5404-003	CAP.,CER., 1KV, 3300pF +/- 20%
C36,37	62-1677-010	CAP., MPE 0.047uF, 630V, 10%
C5	62-5404-005	CAP.,CER., 1KV, 560pF +/- 20%
C7	62-3575-002	CAP, MET, .01MFD, 50V, 5%
D1,2,3,6,9	62-0289-001	DIODE SIGNAL 1N4148
D4	62-5190-001	DIODE, 50NS, 200V, 1A
D5	62-0292-005	DIODE,ZENER,500mW,6.8V, 5%, 1N5235B
*D7,8	62-1683-001	DIODE, 4A 1000V
DS1	62-4056-001	LED, RED
E1,2	62-5774-001	TERMINAL, CRIMP, 18-24 AWG
E3	62-0286-002	TERMINAL SLIPON MALE 0.25"
F1-2	62-0295-002	FUSE CLIP 5mm
F1,F2	62-3926-015	FUSE,1.25A,TIME DELAY,5 X 20 (-100.-115)
F1,F2	62-3926-113	FUSE, 630mA,TIME DELAY,5 X 20 (-220,-230)
FOR Q3 & Q4	62-0343-001	NUT KEPS 4-40
FOR Q4	62-3608-004	SCREW 4-40X5/16 PN HD PHL
FOR Q3	62-3608-006	SCREW,4-407/16 PN HD PHL
J1	62-5196-001	RIBBON CABLE\CONN,HYF 2000
J2	62-2845-003	RECEPTACLE 0.1" 4 PIN MALE MOLEX
J3	62-3598-004	HEADER, STR. PIN, 3 CKT, TIN MOLEX
J4,5,6,7	24466-29	SOCKET, HYFRECATOR
J8	62-5694-001	POST ARM CONTACT PLATED
JP1,2,4	62-3062-001	RES,ZERO OHM (-100,-115)
JP3,5	62-3062-001	RES,ZERO OHM (-220)
JP2,5	62-3062-001	RES,ZERO OHM (-230)
L1	62-5193-001	INDUCTOR, 1000uH, +/-15%
LS1	62-5405-001	TRANSDUCER, AUDIO, AT-202, PROJECTS UNLTD.
N/A	62-0260-001	CABLE TIE .085 WIDE
N/A	62-0622-002	WIRE HI VOLTAGE #22 10KV
N/A	62-1539-002	HS TUBING, ADHESIVE LINED
N/A	62-4240-001	STANDOFF, NYLON WIRE 1"
N/A	62-4842-002	TAPE, FOAM 5/8" x 5/8" DOUBLE SIDED
Q1	62-4239-002	TRANSISTOR NPN 2N4401
*Q2	62-5194-001	POWER MOSFET, 200V, 1.5 OHM, IRF610
*Q3	62-5197-001	PWR MOSFET,N-CHAN,2.0 OHM,900V
*Q4	62-5195-001	PWR MOSFET,P-CHAN,1.5 OHM,200V, IRF9620
Q5	62-4239-001	TRANSISTOR, 2N3904
R1	62-0364-063	RES, 1K 1/4W 5% CF
R11	62-0364-019	RES, 15, 1/4W, 5%
R14	62-0364-062	RES, 910, 1/4W, 5%
R15	62-4609-001	RES, 51K 2W, 5%
R17,19	62-0961-193	RES, 1K, 1/4W, 1%
R2,13	62-0364-135	RES, 1.0M, 1/4W, 5% CF
R20	62-0961-197	RES, MF, 1.10K 1/4W 1%
R21,22,29	62-0364-075	RES, 3300, 1/4W, 5% CF
R23	62-0364-012	RES, 7.5, 1/4, 5%
R31	62-0961-263	RES, MF, 5.36K 1/4W 1%
R33,34	62-0961-385	RES, 100K, 1/4W, 1%
R36	62-0364-054	RES, 430, 1/4W, 5%
R37	62-1693-006	RES FLAMPRF,5.1K,3W,5%
R38	62-0364-066	RES, 1.3K 1/4W 5%
R40,44,46	62-0364-045	RES, 180, 1/4W,5%
R41,43,45	62-0364-039	RES, 100 1/4W 5% CF
R42	62-0961-289	RES, MF, 10.0K, 1/4W, 1%
R47	BI17-502T640	POTENTIOMETER, 5K, BOURNS
R6,30,32,39	62-0364-057	RES, 560 1/4W 5%
R7	62-0364-098	RES,30K,1/4W, 5%
R8,27	62-0364-103	RES, 47K, 1/4W, 5%
R9,12,16	62-0364-111	RES, 100K, 1/4W, 5%
T1	62-5753-002	TRANSFORMER, LINE, HYF 2000
T2	62-5407-001	TRANSFORMER,HDSWITCH,HYF 2000
T3	62-5756-001	TRANSFORMER, OUTPUT, HYF 2000
TP1-6	020361101	TEST POINTS
U1	010561001	IC,FET DRIVER
U2	62-5203-001	I.C.,PULSE WIDTH MODULATION, TL494
*U3-5	62-4238-001	IC, OPTOISOLATOR OPI1264A
*VR1	62-0417-005	REGULATOR VOLTAGE 12V, 7812
XQ3, XQ4	040440002	HEAT SINK
XVR1	62-5406-001	HEATSINK TO-220

*RECOMMENDED SPARES

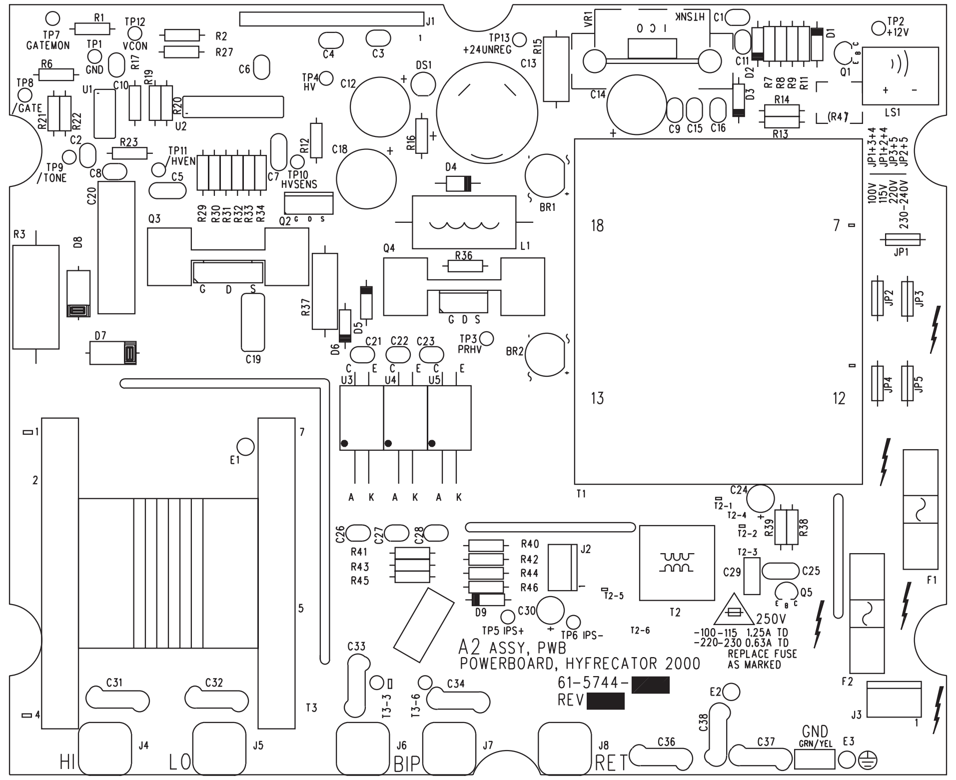


Figure 5.8 A2 Power PWB Parts List, Layout and Schematic