Force

Service Manual

Force 30
Force 40

Valleylab Inc
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Foreword

The following service instructions are for use only by personnel qualified to repair and service the equipment described in this manual.

Caution: Federal (USA) law restricts this device to sale by or on the order of a physician.

Effective Date: April 1992   Valleylab Part No.: 945 100 153

Equipment covered in this manual: Force 30, 40 Electrosurgical Generators
110 – 120 V~ nominal
220 – 240 V~ nominal
(user selected)

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Purpose And Scope

This Service Manual contains information required to calibrate, troubleshoot, maintain, and install the Force 30 and Force 40 Electrosurgical Generators. Instructions for the operation of the Force generator and cautions and warnings concerning electrosurgery are beyond the scope of this manual. The reader is directed to the Force 30,40 Instruction Manual supplied with the generator.

Limited Warranty

Valleylab Inc warrants each product manufactured by it to be free from defects in material and workmanship under normal use and service for the period(s) set forth below. Valleylab's obligation under this warranty is limited to the repair or replacement, at its sole option, of any product, or part thereof, which has been returned to it or its Distributor within the applicable time period shown below after delivery of the product to the original purchaser, and which examination discloses, to Valleylab's satisfaction, that the product is defective. This warranty does not apply to any product, or part thereof, which has been repaired or altered outside Valleylab's factory in a way so as, in Valleylab's judgment, to affect its stability or reliability, or which has been subjected to misuse, neglect or accident.

The warranty periods for Valleylab's products are as follows:

Electrosurgical Generators	One Year from date of shipment.
Mounting Fixtures (All Models)	One Year from date of shipment.
Footswitches (All Models)	One Year from date of shipment.
Patient Return Electrodes	Shelf life only, as stated on packaging.
Sterile Disposables	Sterility only, as stated on packaging.

This warranty is in lieu of all other warranties, expressed or implied, including, without limitation, the warranties of merchantability and fitness for a particular purpose, and of all other obligations or liabilities on the part of Valleylab. Valleylab neither assumes nor authorizes any other person to assume for it any other liability in connection with the sale or use of any of Valleylab's products. Notwithstanding any other provision herein or in any other document or communication, Valleylab's liability with respect to this agreement and products sold hereunder shall be limited to the aggregate purchase price for the goods sold by Valleylab to customer. There are no warranties which extend beyond the terms hereof. Valleylab disclaims any liability hereunder or elsewhere in connection with the sale of this product, for indirect or consequential damages.

This warranty and the rights and obligations hereunder shall be construed under and governed by the laws of the State of Colorado, USA. The sole forum for resolving disputes arising under or relating in any way to this warranty is the District Court for the County of Boulder, State of Colorado.

Valleylab Inc, its dealers and representatives, reserve the right to make changes in equipment built and/or sold by them at any time without incurring any obligation to make the same or similar changes on equipment previously built and/or sold by them.

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Valleylab UK
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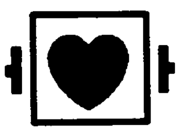
ATTENTION:
REFER TO THE
ACCOMPANYING
DOCUMENTS



TYPE CF EQUIPMENT
LOW LEAKAGE
SUITABLE FOR CARDIAC USE
DEFIBRILLATOR–PROOF

DRIP–PROOF

THE GENERATOR IS
HIGH–FREQUENCY ISOLATED
PER IEC 601–2–2

Introduction

The Force 30 and Force 40 Electrosurgical Generators are designed for ceiling or cart mounting. The models available in this Force series are: Force 30, Force 40, and the Force 40S (Simutaneous Coag feature).

All generators are configured to operate at 220–240 V~ nominal. A kit is available from Valleylab to convert the generator to 110–120 V~ operation.

The differences between the two major models are the maximum power settings and the number of available functions. These differences are summarized in the following tables.

Note: "–" indicates the mode is not available on that particular model.

Maximum Power Setting (watts)

Mode	Force 40	Force 30
Pure Cut	300	300
Blend 1	250	250
Blend 2	200	–
Desiccate	200	200
Fulgurate	150	150
Spray Coag	150	–
Standard Bipolar	50	50
Precise Bipolar	50	50

Features

Feature	Force 40	Force 30
Handswitching Outputs	2	2
Footswitching Output	yes	yes
Simultaneous Coag	option	–
Isolated Outputs	yes	yes
Power Control	yes	yes
Autoranging REM	yes	yes
Blend 2	yes	–
Spray Coag	yes	–

The Force 30, 40 generators are enclosed in the same metal and molded plastic enclosure. The front panel contains touch membrane switches, lighted indicators, digital displays, high voltage output receptacles, and a monopolar footswitch receptacle.

The rear panel contains the power entry module, a line voltage selector switch, a volume control potentiometer, a handle, and monopolar and bipolar footswitch receptacles.

Section 1 Installation

Notify Valleylab to arrange for repair or replacement of any parts damaged from shipping. All returns must have the approval from the Valleylab Customer Service Department. The return authorization number must be displayed on the package label.

Carefully remove the Force generator and all accessories from the shipping package. Save all cartons and packing materials to use when transporting the generator or when returning it for service.

If you have any questions concerning the contents, contact Valleylab Customer Service at 1–800–255–8522 or your Valleylab representative.

Responsibility of the Manufacturer

Valleylab Inc is responsible for the effects on safety, reliability and performance of the equipment only if:

- assembly operations, extensions, readjustments, modifications or repairs are carried out by persons authorized by Valleylab Inc.
- the electrical installation of the relevant room complies with local codes and requirements such as IEC and BSI.
- the equipment is used in accordance with the instructions for use.

Environmental Conditions

Transport and Storage

Ambient Temperature: Between –40 and +70 degrees C.
Relative Humidity: Between 10% and 100%, noncondensing.
Atmospheric Pressure: Between 500 and 1060 millibar.

Operation

Ambient Temperature: Between +10 and +40 degrees C.
Relative Humidity: Between 30% and 75%, noncondensing.
Atmospheric Pressure: Between 700 and 1060 millibar.

Preparing the Generator for Use

The electrosurgical generator may be placed on a mounting cart (available from Valleylab) or be installed in a ceiling mount system. It is recommended that carts have conductive wheels. Refer to hospital procedures or local codes for detailed information.

Provide at least four to six inches of space around the sides and top of the generator for convection cooling. Under continuous use for extended periods of time, it is normal for the top and rear panel to be warm.

DANGER

Explosion Hazard. Do not install the electrosurgical generator in areas using flammable anesthetics, gases, liquids, or objects.

Power Requirements

The Force 30, 40 Electrosurgical Generator is designed to operate between 85 – 140 V~ or 170 – 280 V~, 50–60 Hz. The output will remain constant over the ranges of 90–135 V~ or 180–270 V ~, 50–60 Hz.

Power Plug

The Force generator is shipped with a hospital grade power plug. The Valleylab representative in your country will equip your Valleylab generator with the proper connector for your operating room, if different from that supplied.

The connector meets all requirements for safe grounding. Its purpose should not be defeated by using extension cords or three–prong to two–prong adapters. The power cord assembly should be periodically inspected by qualified personnel. Cords should always be grasped by the plug. **Do not** pull on the cord itself.

Proper Grounding

An important consideration in assuring patient safety while using electrical equipment is proper grounding. The ground wire in the power cable is connected to the chassis and insures that no dangerous currents will flow from the cabinet of the generator in the event of an internal electrical failure.

Undesirable 50–60 Hz leakage currents are also affected by the polarization of the input 50–60 Hz power to the generator. It is the responsibility of the user to assure proper grounding and polarity in the power outlets furnishing power to the Force generator.

Preoperational Checkout

Refer to Section 5, Power Up Self–Test.

Routine Maintenance and Inspections

Valleylab recommends that the Force generator be inspected by qualified service personnel twice a year. This Service Manual describes the recommended inspection, testing, and calibration procedures. For major repairs, the generator can be returned to Valleylab. If desired, Valleylab will supply any parts or information needed to repair the Force generator.

Cleaning Instructions

Clean the generator using standard hospital procedures. Use a mild detergent and damp cloth to clean the generator cover, keyboard and cord. Do not allow fluids to enter the chassis. Do not use alcohol, caustic, corrosive, or abrasive cleaning materials. The generator cannot be sterilized.

Recommended Electrosurgical Accessories

Valleylab E7507/E7509 REM PolyHesive II Patient Return Electrode
Valleylab E2515/E2516 Disposable Handswitching Pencil
Valleylab E2525 Reusable Handswitching Pencil
Valleylab E2517 Disposable Power Control Pencil
Valleylab Bipolar Forceps
Valleylab E2400 Disposable Insulating Holster
Valleylab E6008B Monopolar Footswitch
Valleylab E6009 Bipolar Footswitch

Reusable Pencil Cleaning And Reprocessing Directions
(For Valleylab Reusable Handswitching Pencils)

NOTE
These directions are not intended for electrosurgical accessories not manufactured by Valleylab. Refer to the instructions provided by the manufacturer.

Cleaning

1. The pencil should be processed with other delicate surgical instruments in order to protect the electronic components.
2. If a disposable electrode has been used in the pencil, remove and discard. Remove all gross matter (blood, mucus, tissue) by wiping the entire pencil with a cloth or gauze pad and a mild cleaning solution or blood dissolving detergent. Remove any cleansing agents by wiping the pencil with a water–dampened cloth. Do not immerse the pencil in reprocessing solutions.
3. Dry thoroughly.
4. Sterilize the pencil using standard hospital procedures for Ethylene Oxide sterilization or steam autoclave sterilization, following the handling recommendations below.

Ethylene Oxide (EtO) Processing

1. Coil the cord loosely prior to inserting the pencil into an EtO pouch. Tight "bunching" or wrapping of the cord will decrease the useful life of the pencil.
2. Estimated number of uses when reprocessed by this method: 20

Steam Autoclave Processing

1. Do not autoclave the pencil unwrapped.
2. Lay the pencil body in the center of the wrapping material as shown. (Fig. 1)
3. Fold the material over the pencil body and proceed to coil the cord around the material lengthwise . (Fig. 2)

NOTE
Keep the pencil body, dord and plug connector from contacting each other to prolong the life of the pencil. Do not use rubber bands, string, or tape to secure the cord.

4. Apply a second wrapping material to the packet produced in Step 2 above (Fig. 3). Tape and autoclave.
5. Do not exceed a processing temperature of 135°C (275°F) for 20 minutes. The number of uses will be reduced when this product is steam autoclaved.

Recommended wrapping procedure for normal autoclaving:

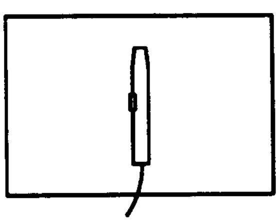


Fig. 1

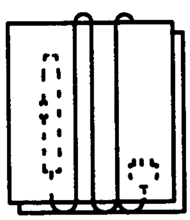


Fig. 2

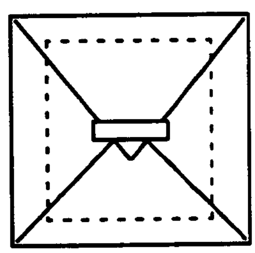


Fig. 3

Testing

During surgical procedure set up, inspect product and confirm product function.

1. Insert the pencil connector into the appropriate active handswitch receptacle on the generator. The patient return electrode must be in place on the patient.
2. Using the generator front panel ***On/Off*** switch, turn the generator ***On***.
3. The generator will conduct a self–test and power settings will display 1 watt. Do not press the ***Reset*** button.

CAUTION

Set Cut and Coag power settings to the lowest setting before testing the pencil.

NOTE

Observe the generator. If an error code (119–122) appears in the power setting displays and a tone sounds, this indicates a malfunctioning accessory. Discard the pencil.

4. Press the yellow ***Cut*** button on the pencil and verify that the yellow lamp in the Cut mode illuminates. If the blue Coag lamp illuminates, discard the pencil.
5. Press the blue ***Coag*** button on the pencil and verify that the blue lamp in the Coag mode illuminates. If the yellow Cut lamp illuminates, discard the pencil.

NOTE

If either the Cut or Coag lamp does not illuminate, discard the pencil.

CAUTION

Inspect the pencil and cord for breaks, cracks, nicks, or other damage before use. If damaged, **do not use**. Failure to observe this precaution with every use may result in injury or electrical shock to the patient or operating room personnel.

6. Place the generator in the *Off* mode until ready for surgery.

Section 2 Performance Specifications

Specifications are subject to change without notice.

In this Section, "typical" refers to a specification that is within ± 20% of a stated value at room temperature (25° C) and nominal input power voltage.

Output Configuration

Isolated output.

Low Frequency Leakage (50–60 Hz)

All patient–connected terminals tied together:

Source Current Polarity	Ground	Leakage (110–120V~)	Leakage (220–240V~)
Normal	intact	< 10 µA	< 2.0 µA
Normal	open	< 100 µA	< 50 µA
Reverse	open	< 100 µA	< 50 µA

High Frequency Risk Parameters

	Leakage
Monopolar RF leakage current	< 150 mA RMS
Bipolar RF leakage current	< 50 mA RMS

REM Contact Quality Monitor

Measurement Frequency	Measurement Current	Acceptable Resistance Range Single area pad	Dual area pad
70 ± 5 kHz	< 10 mA	< 20 ohms	5 – 135 ohms

If the impedance measured is outside the acceptance range, a REM fault condition will occur. In the REM mode, if resistance increases by more than 40% above the nominal value or 135 ohms resistance, an alarm will be generated.

Audio Volume

The audio keying tones are adjustable. The alarm tones are not adjustable.

	Audio Level @ 1 meter
Keying Tone	45 to > 65 dBA
Alarm Tone (Fixed)	> 65 dBA

Input Power Source

Nominal Voltage:		110–120 V RMS	or	220–240 V RMS
Regulation Voltage		90–135 V RMS	or	180–270 V RMS
Operating Range:		85–140 V RMS	or	170–280 V RMS
Current:	Idle	0.4 A, max	or	0.2 A, max
	Cut	7.0 A, max	or	3.5 A, max
	Coag	4.0 A, max	or	2.0 A, max
	Bipolar	2.0 A, max	or	1.0 A, max

Weight

20 lb (9.1 kg)

Overall Dimensions

7.8 in. H x 16.1in. W x 11.9 in. D (199 mm x 409 mm x 303 mm)

Classification

Class I Equipment per IEC 601–1

Protection against electric shock is provided by connection of accessible conductive parts to the protective earth conductor in such a way that they cannot become live in the event of a failure of basic insulation.

Type CF Equipment per IEC 601–1

The Force 30,40 provides a high degree of protection against electric shock, particularly regarding allowable leakage currents and has a CF type isolated (floating) applied part. The applied part may be used on the heart.

Defibrillator–Proof

The neutral electrode terminals of the Force 30,40 can withstand the effects of defibrillator discharge.

Drip Proof per IEC 601–1

The Force 30,40 enclosure will prevent reasonable amounts of falling liquid from interfering with the generator's safe and satisfactory operation.

Intermittent Operation

The generator is cooled by natural convection. Under maximum power setting and rated load conditions (Pure Cut, 300 watt setting, 300 ohm load) the Force 30,40 is suitable for 10 seconds on, 30 seconds off operation for one hour. With lesser settings and other load impedances, the Force 30,40 can be used for greater activation durations without generating excessive internal temperatures.

Note: Power readouts agree with actual power into rated load to within ± 15% or ± 5 watts, whichever is greater. Dosage error occurs when the measured output power exceeds the displayed units by 35 watts or 35%, whichever is greater.

Force 30

Output Waveform

Cut	500 kHz sinusoid.
Blend	500 kHz bursts of sinusoid @ 50% duty cycle, recurring @ 31.25 kHz.
Desiccate	500 kHz damped sinusoidal bursts with a repetition frequency of 250 kHz.
Fulgurate	500 kHz damped sinusoidal bursts with a repetition frequency of 62.5 kHz.
Standard Bipolar	500 kHz sinusoid.
Precise Bipolar	500 kHz sinusoid.

Output Characteristics

Mode	Maximum (open circuit) P–P voltage	Rated Load (ohms)	Nominal Power (watts)	Crest Factor (typical)
Cut	3300	300	300	2.1 @ 100W
Blend	3800	300	250	3.5 @ 100W
Desiccate	3500	300	200	3.5 @ 100W
Fulgurate	6500	300	150	6.0 @ 100W
Standard Bipolar	550	100	99	1.9 @ 20W
Precise Bipolar	550	100	70	1.9 @ 20W

Note: Power readouts agree with actual power into rated load to within ± 15% or ± 5 watts, whichever is greater. Dosage error occurs when the measured output power exceeds the displayed units by 35 watts or 35%, whichever is greater.

Force 40

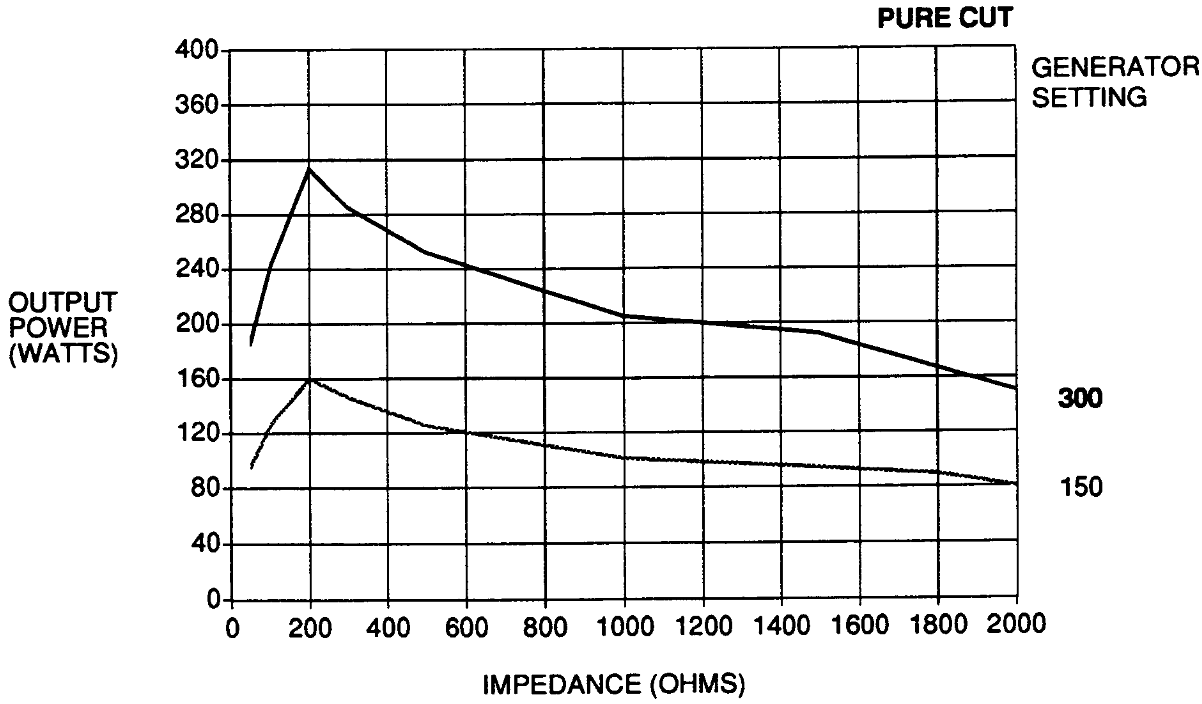
Output Waveform

Cut	500 kHz sinusoid.
Blend 1	500 kHz bursts of sinusoid @ 50% duty cycle, recurring @ 31.25 kHz.
Blend 2	500 kHz bursts of sinusoid @ 37.5% duty cycle, recurring @ 31.25 kHz.
Desiccate	500 kHz damped sinusoidal bursts with a repetition frequency of 250 kHz.
Fulgurate	500 kHz damped sinusoidal bursts with a repetition frequency of 62.5 kHz.
Spray Coag	500 kHz damped sinusoidal bursts with a repetition frequency of 31.25 kHz.
Standard	500 kHz sinusoid.
Precise	500 kHz sinusoid.

Output Characteristics

Mode	Maximum (open circuit) P–P voltage	Rated Load (ohms)	Nominal Power (watts)	Crest Factor (typical)
Cut	3300	300	300	2.1 @ 100W
Blend 1	3800	300	250	3.5 @ 100W
Blend 2	4000	300	200	4.0 @ 100W
Desiccate	3500	300	200	3.5 @ 100W
Fulgurate	6500	300	150	6.0 @ 100W
Spray Coag	9000	300	150	8.5 @ 100W
Standard	550	100	99	1.9 @ 20W
Precise	550	100	70	1.9 @ 20W

All Monopolar output measurements are made using the procedures described in IEC 601–2–2.



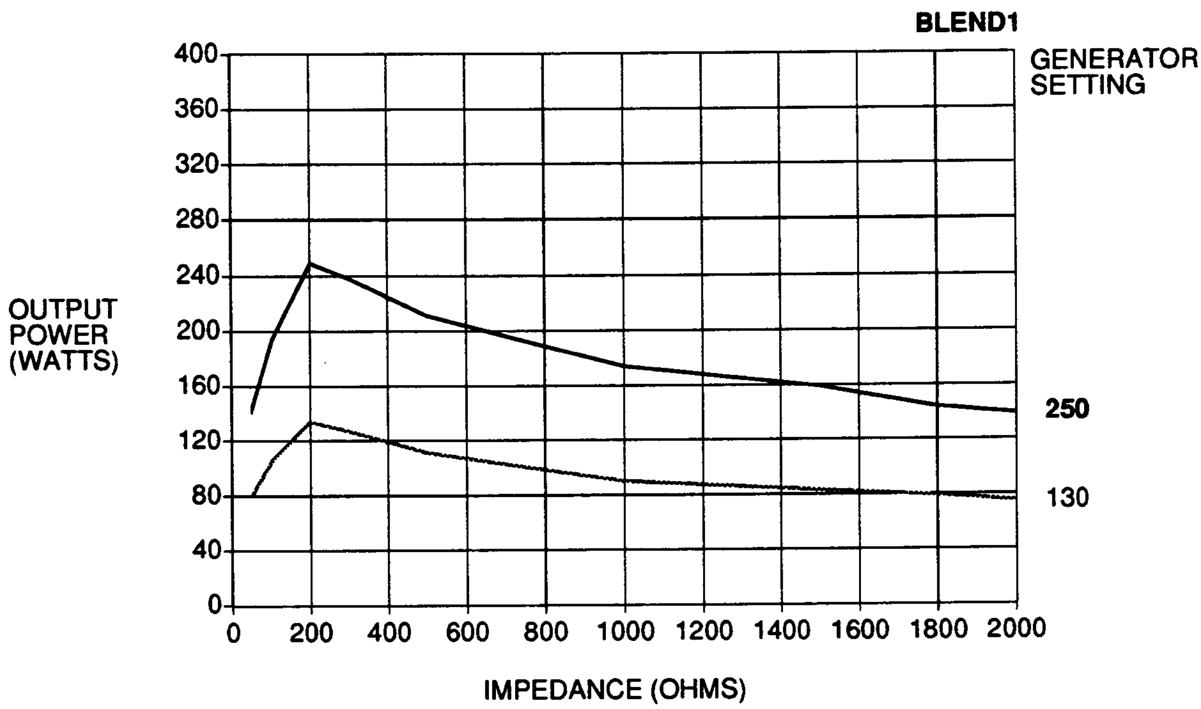
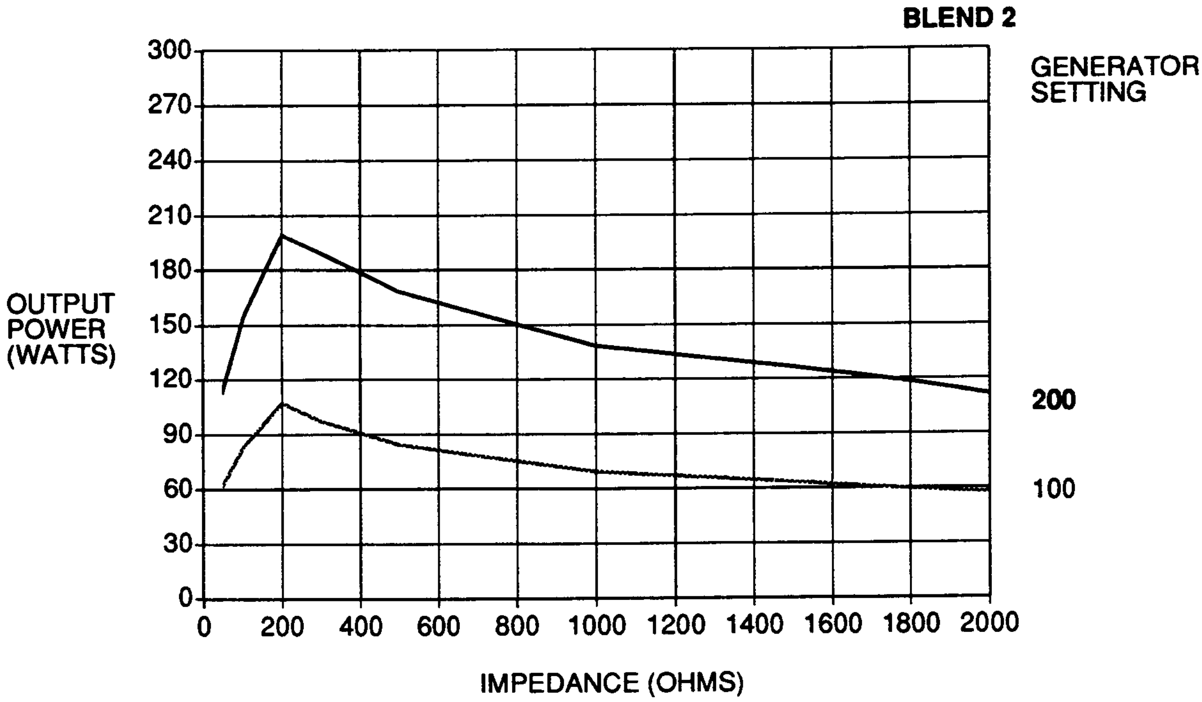
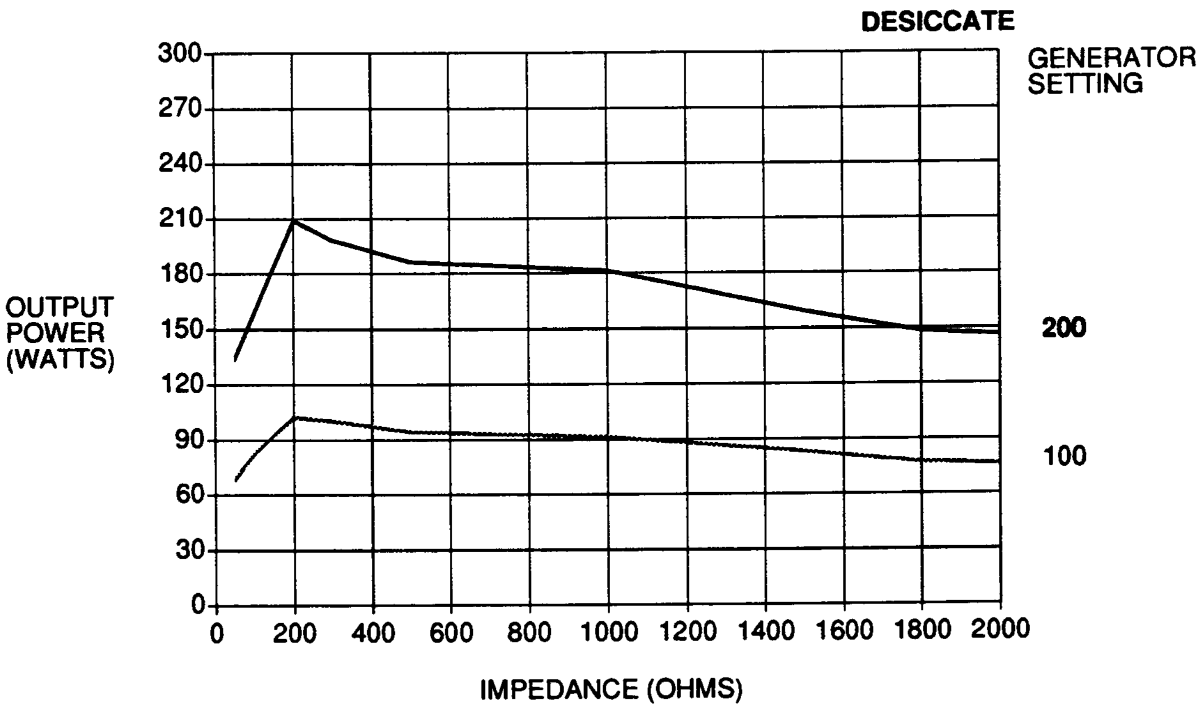
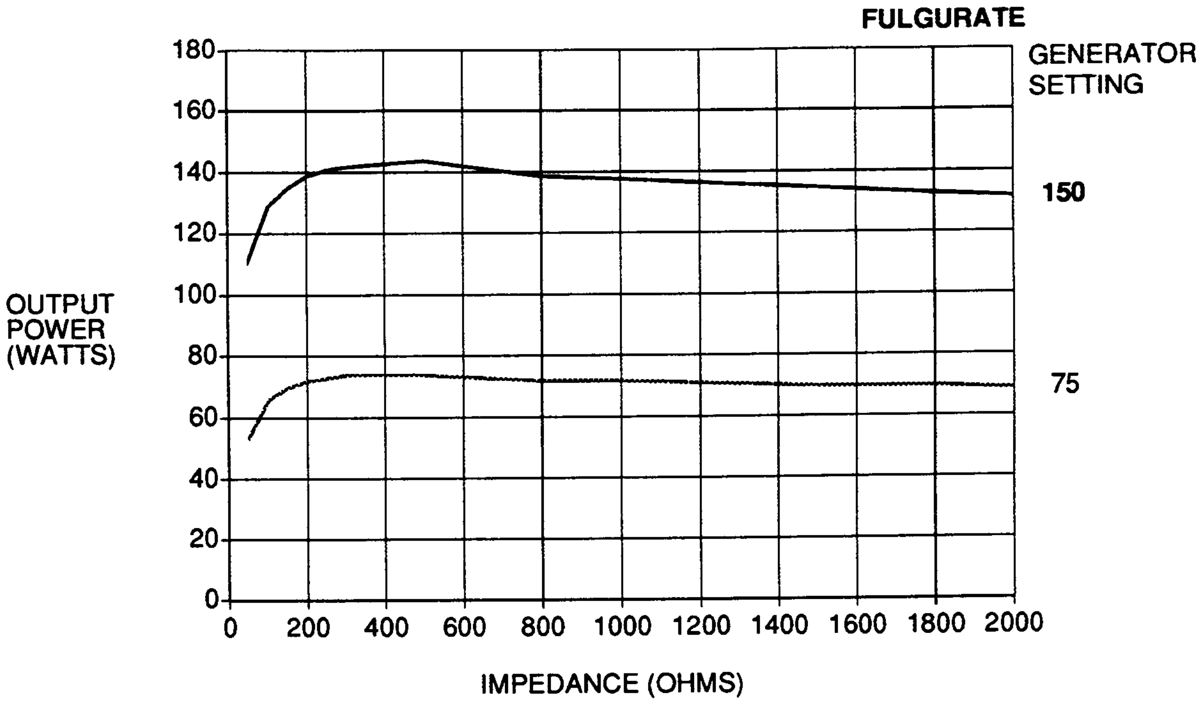


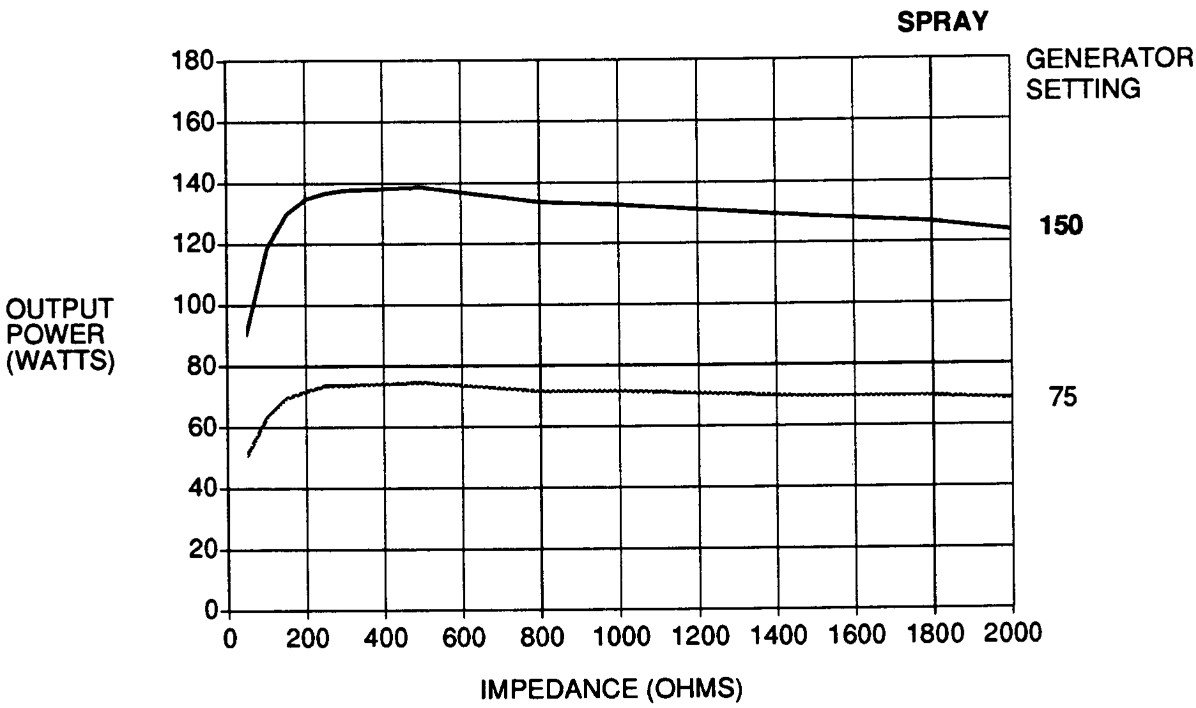
Figure 2.1 Force 40 Output Power vs Load





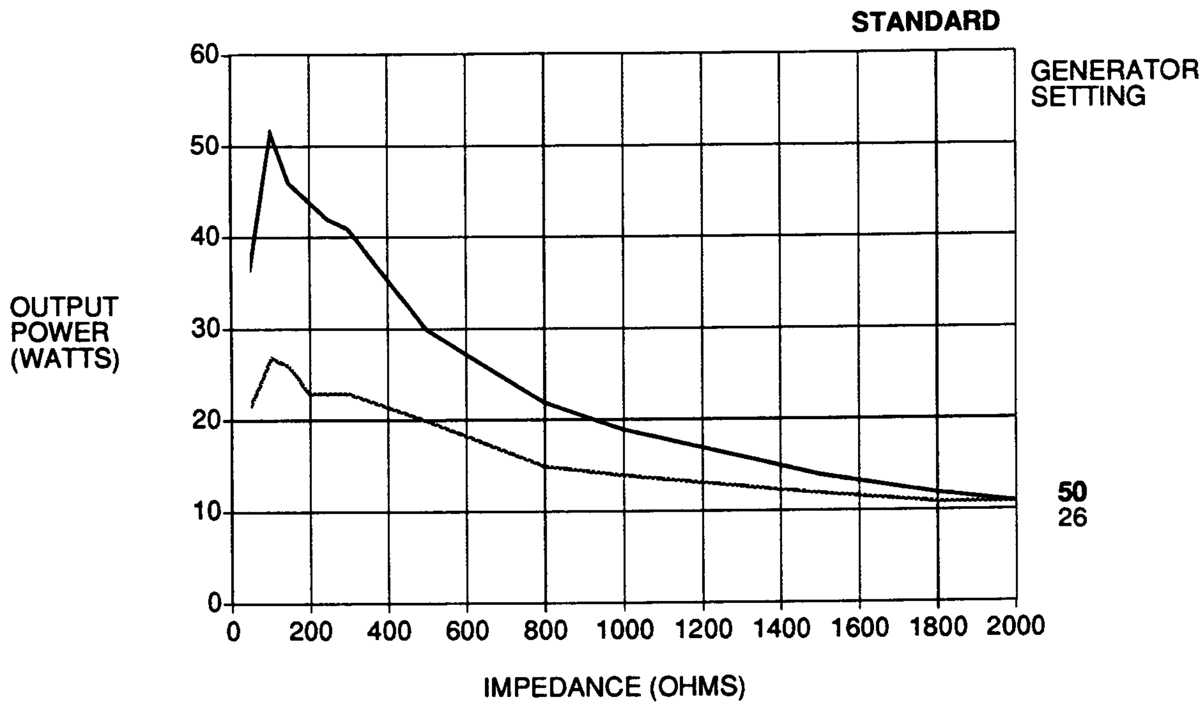
2.1 Force 40 Output Power vs Load (cont'd)

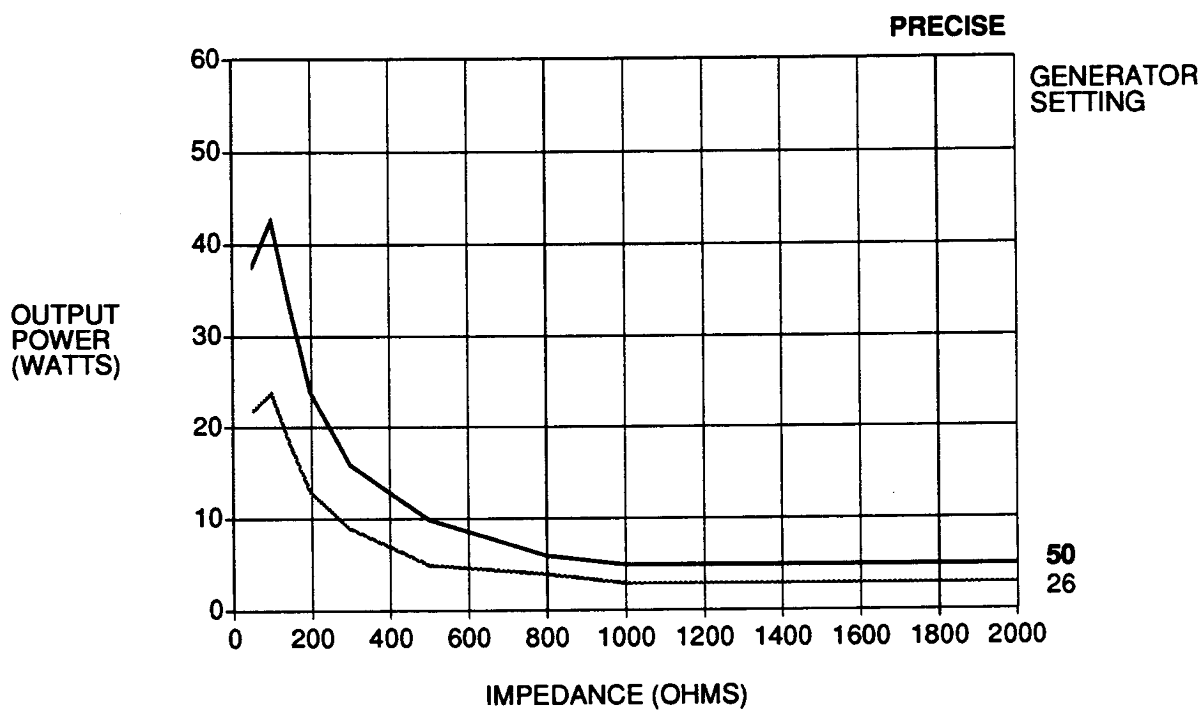




2.1 Force 40 Output Power vs Load (cont'd)

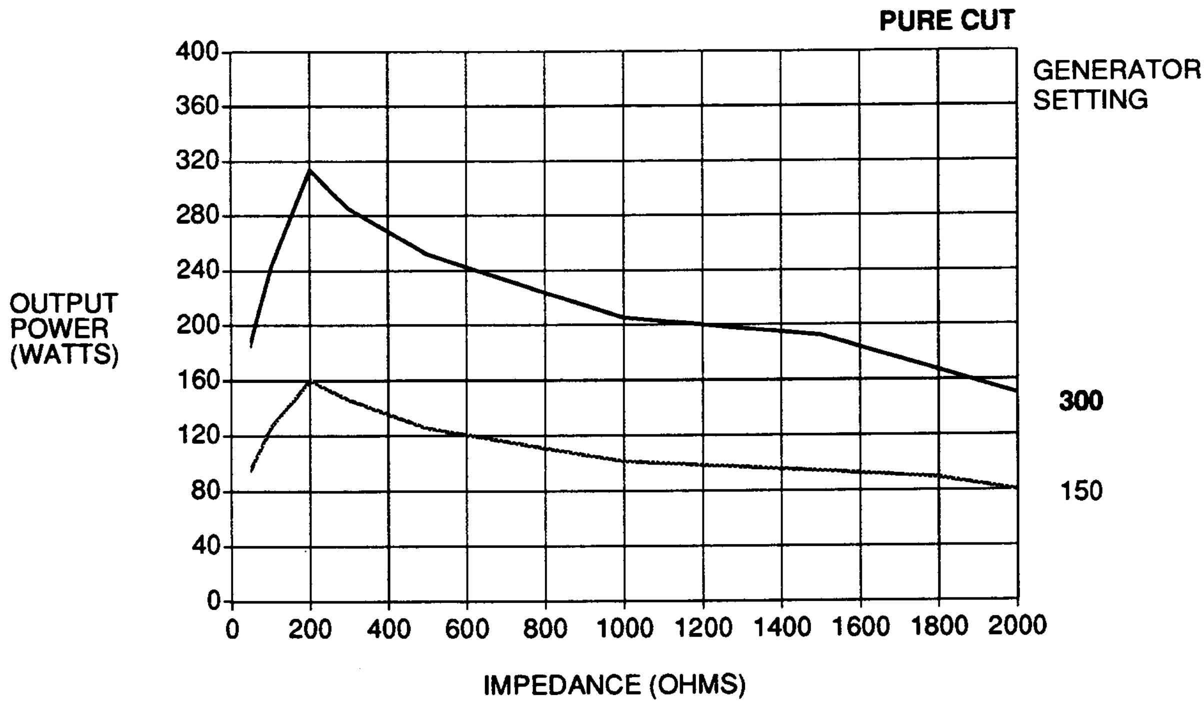
Bipolar measurements are made using bipolar forceps on the insulating surface described in IEC 601–2–2.





2.1 Force 40 Output Power vs Load (cont'd)

All monopolar output measurements are made using the procedures described in IEC 601–2–2.



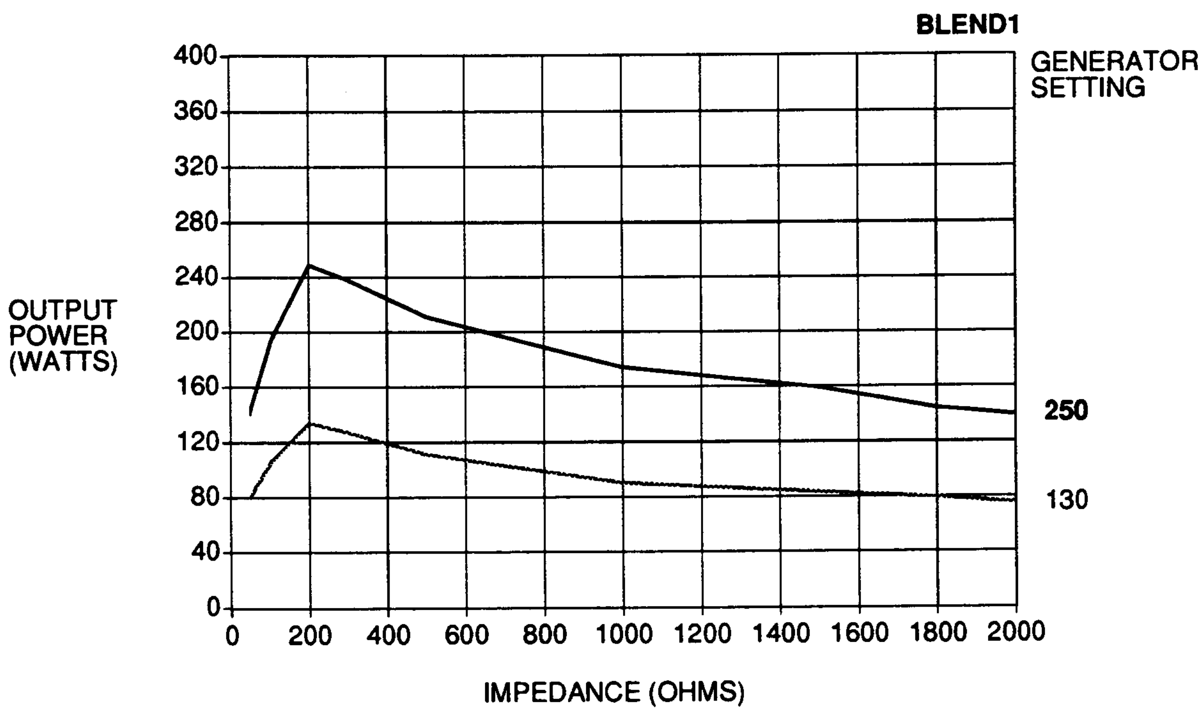
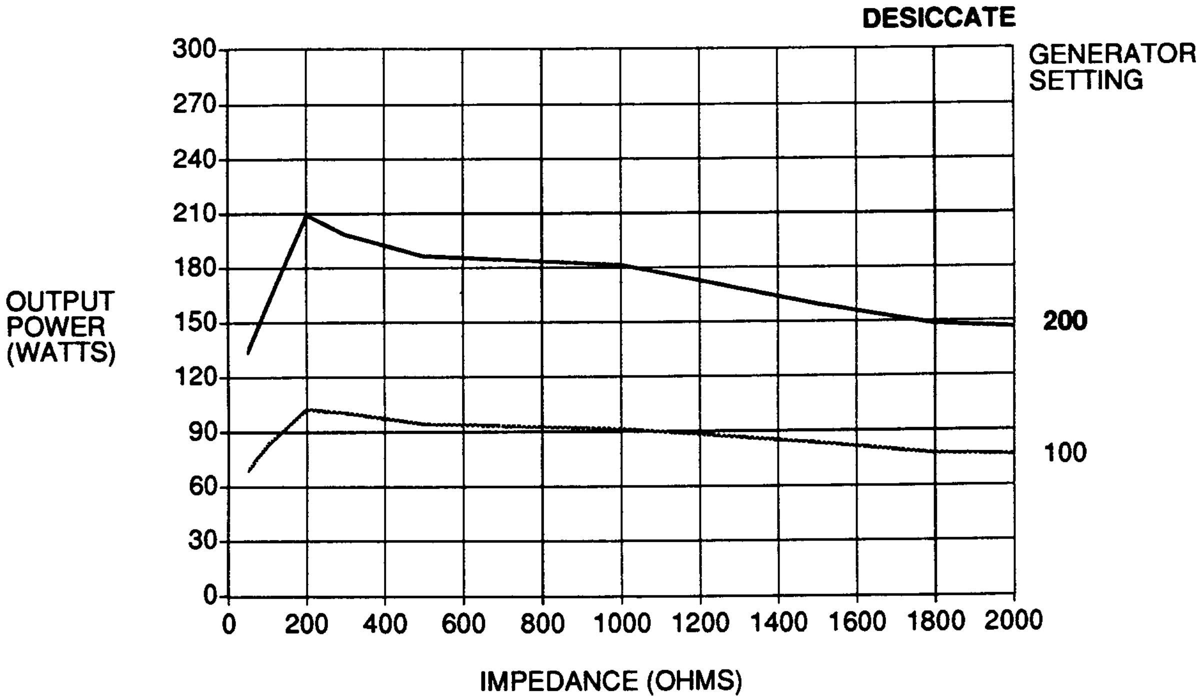
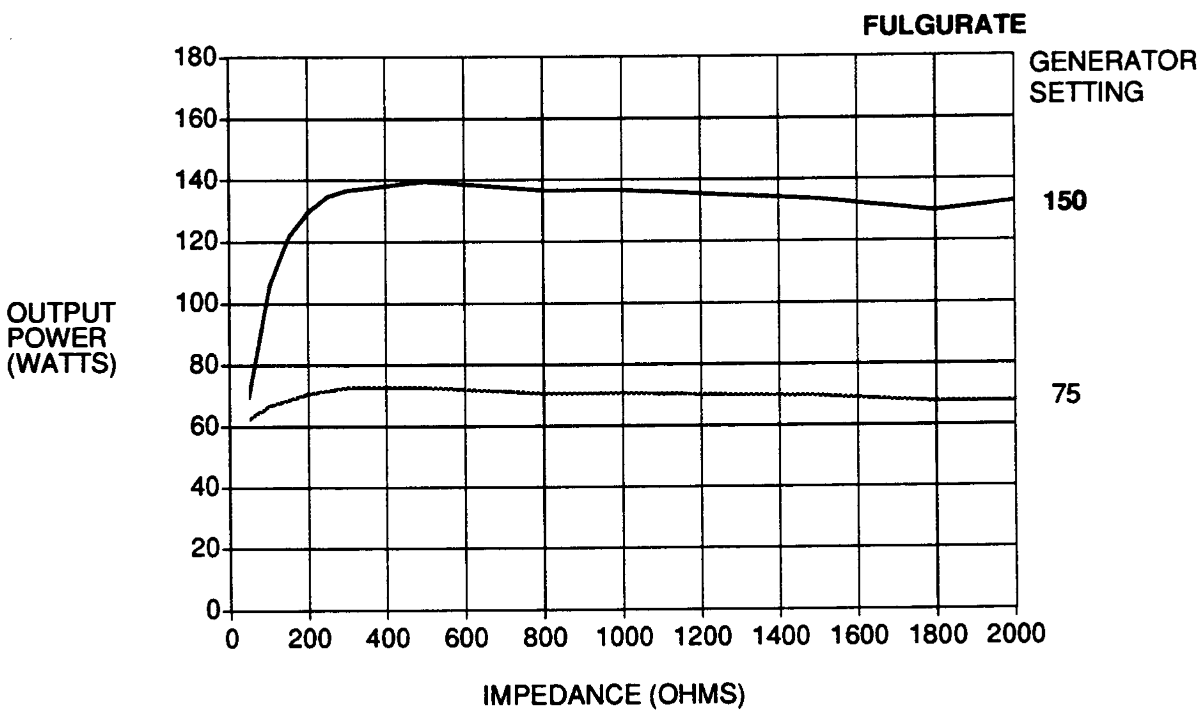


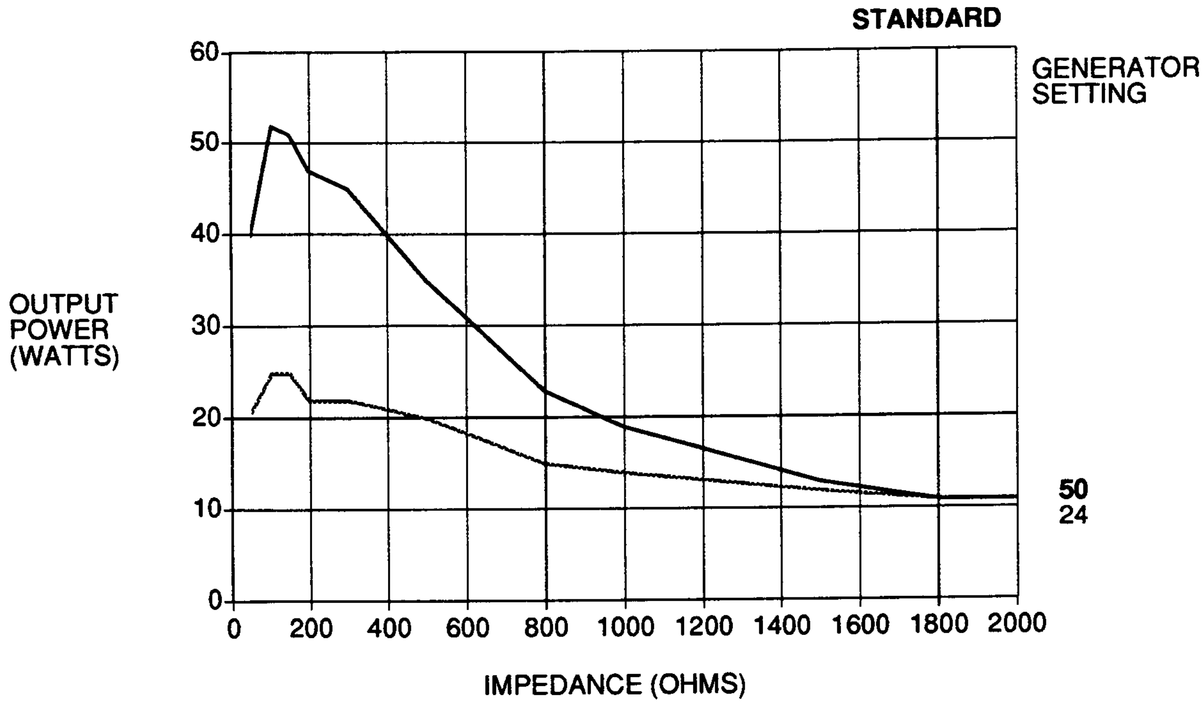
Figure 2.2 Force 30 Output Power vs Load

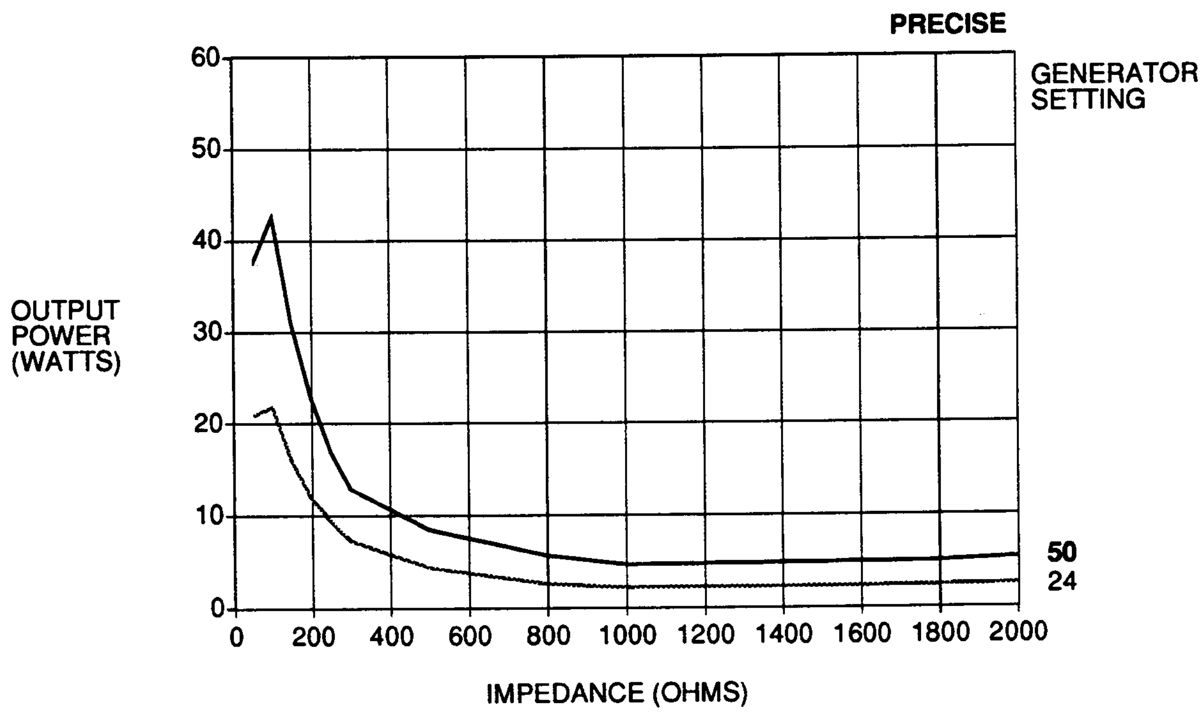




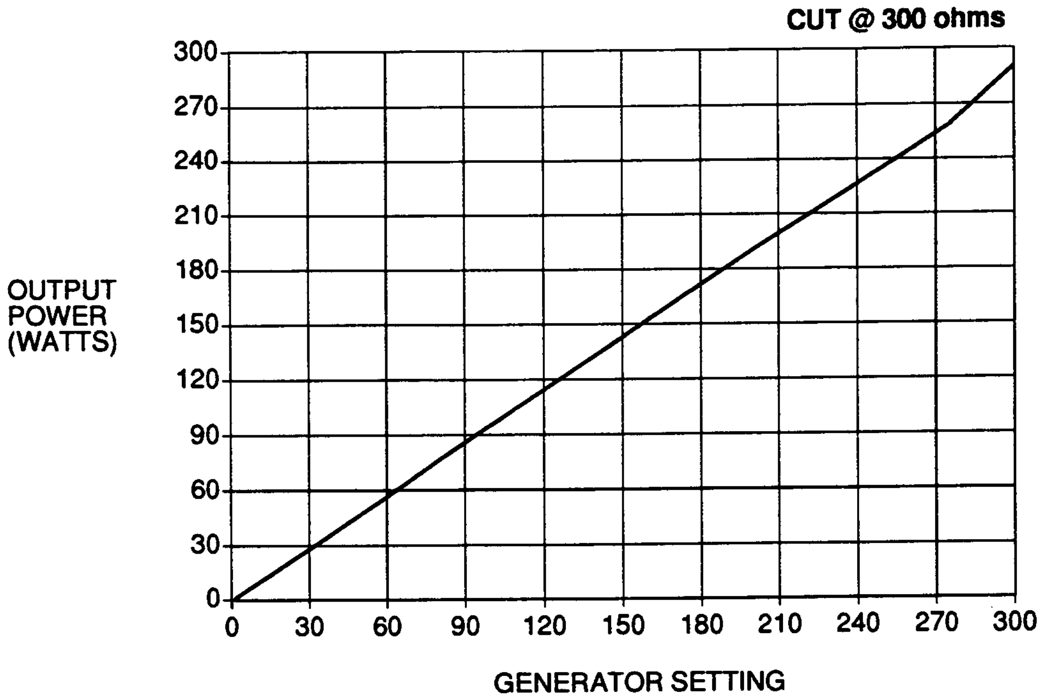
2.2 Force 30 Output Power vs Load (cont'd)

Bipolar measurements are made using bipolar forceps on the insulating surface described in IEC 601–2–2.





2.2 Force 30 Output Power vs Load (cont'd)



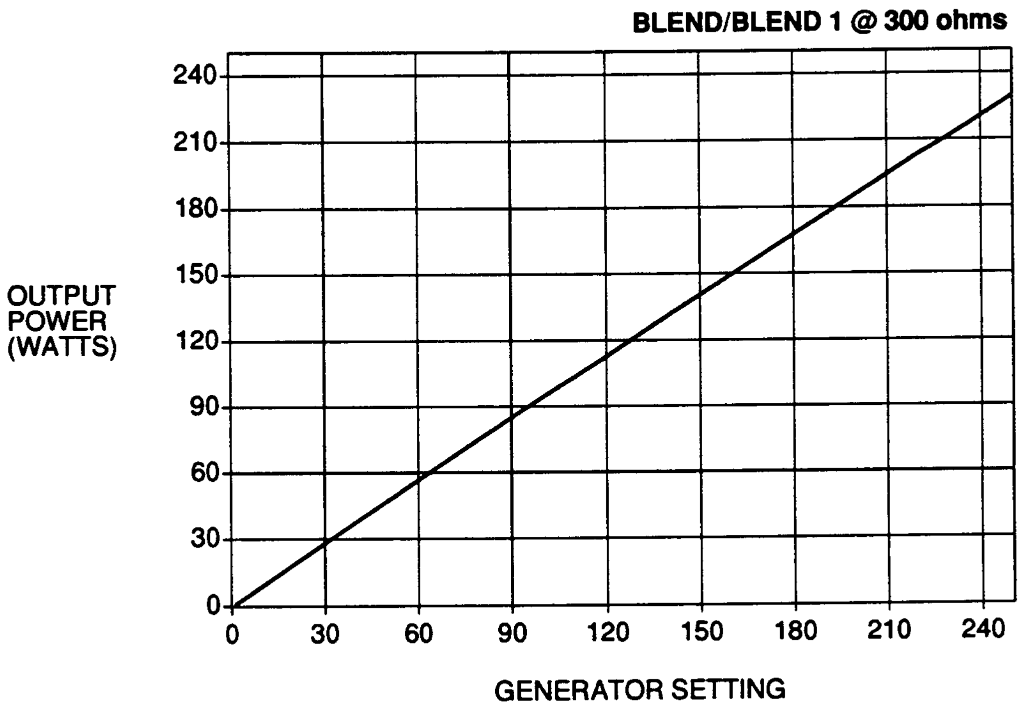
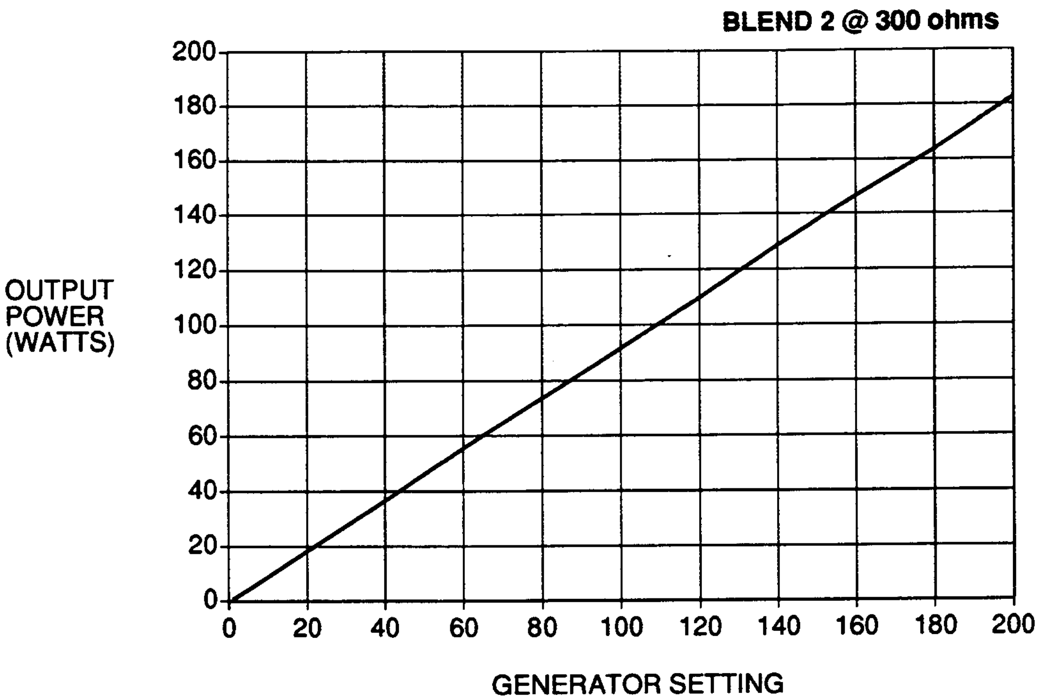
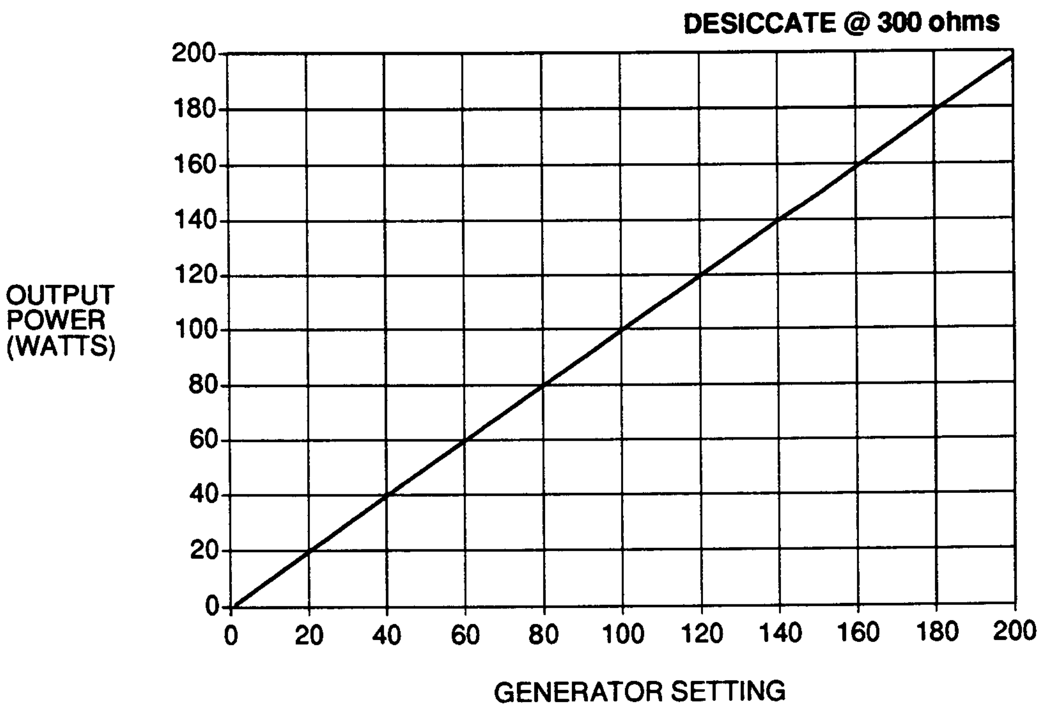
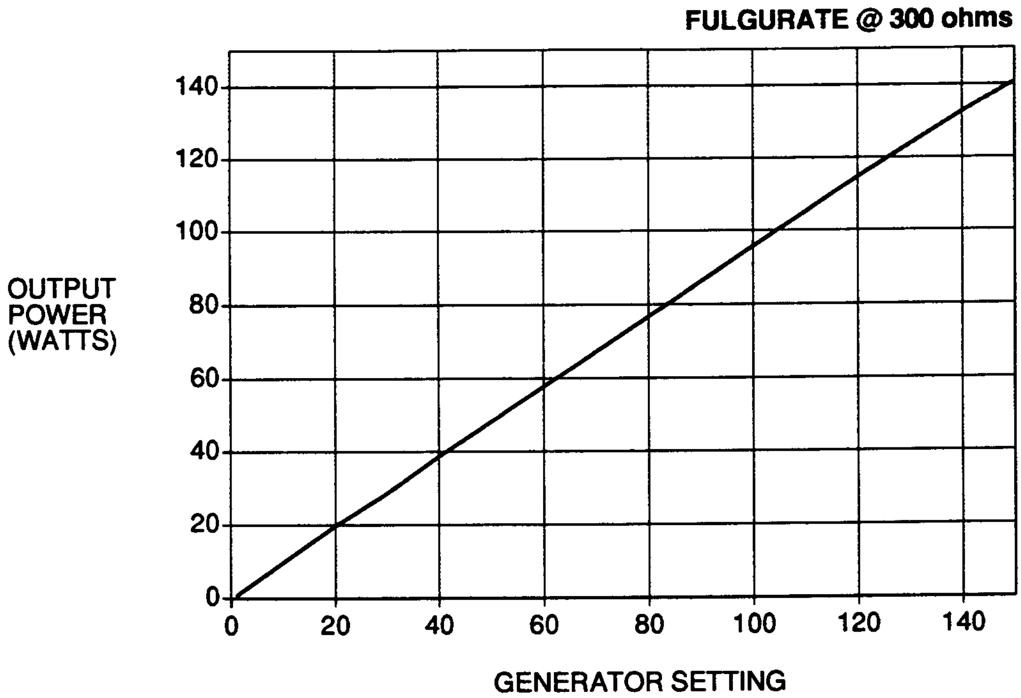


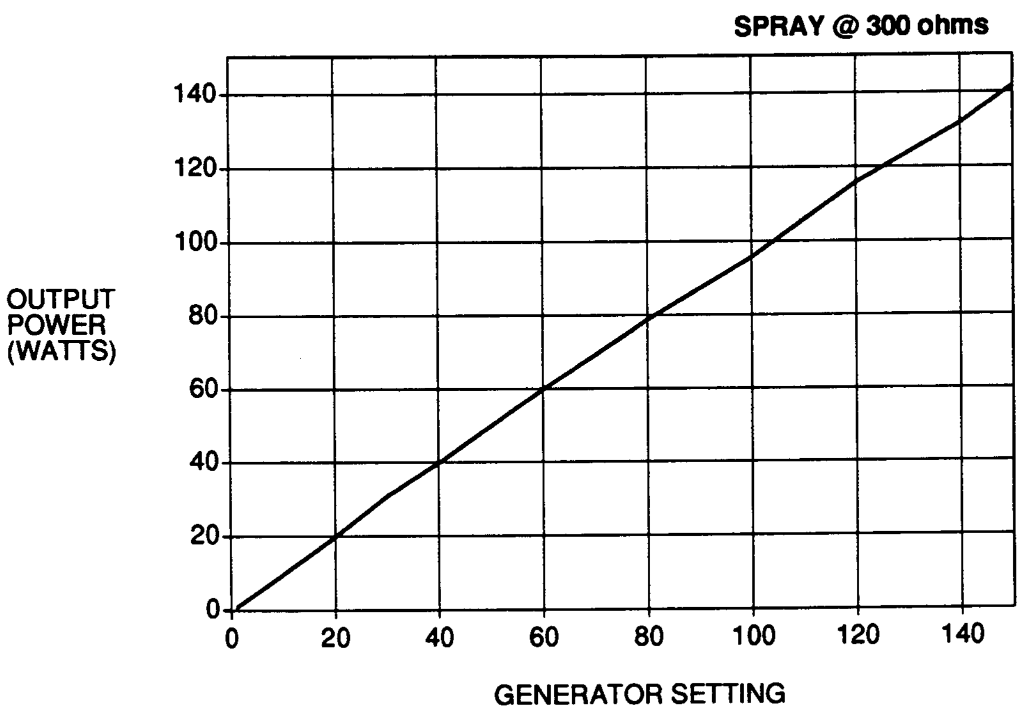
Figure 2.3 Output Power vs Generator Setting



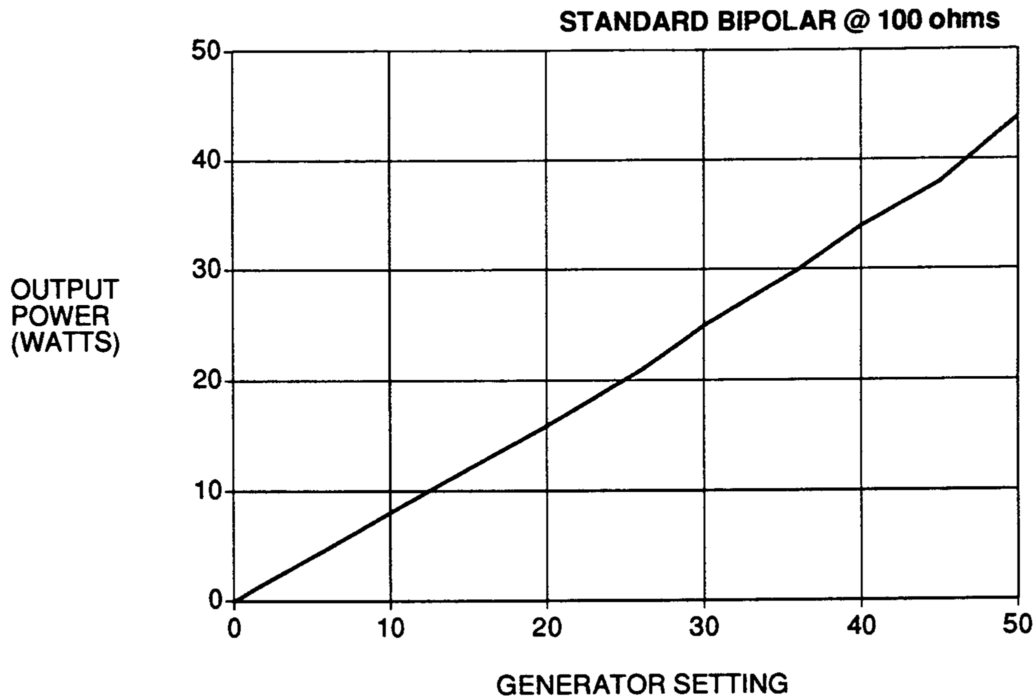


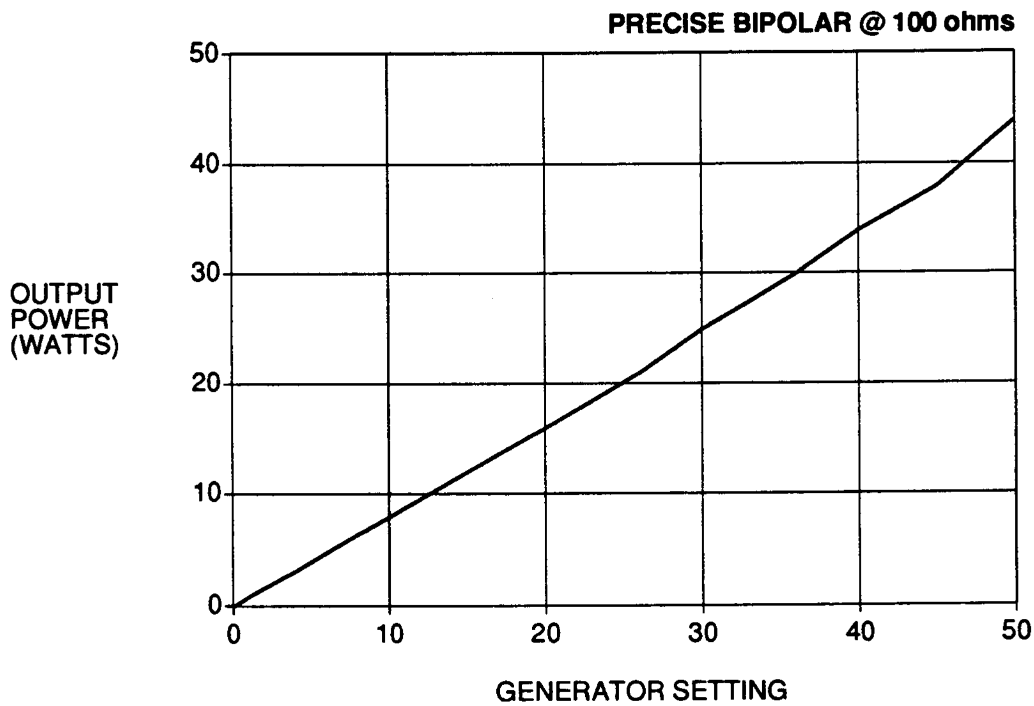
2.3 Output Power vs Generator Setting (cont'd)





2.3 Output Power vs Generator Setting (cont'd)





2.3 Output Power vs Generator Setting (cont'd)

Section 3 Functional Description

Overview

The Force 30, 40 generators contain five printed circuit boards (PCBs). The PCBs are identical in all models. The differences between the electronic capabilities of the different generator models are implemented in software. At any given (and available) power setting, the output performances of all models are identical. The five PCB's are:

Microcontroller Board
Display Board
Interface Board
Power Supply/RF Board (PSRF)
REM Filter Board

A Functional Block Diagram appears at the end of this section. Section 9 contains schematics for the PCBs.

Microcontroller Board

Microcontroller / Memory / I/O

The microcontroller used to control the Force 30, 40 generators is U22. The device has an addressable memory range of 64K. The lower 8 bits of the address line are multiplexed in the microcontroller with the lower 8 bits of the data bus. Demultiplexing of these signals is done with the address latch enable signal and a level triggered latch (U23).

The microcontroller addresses both an external ROM (U24) and external RAM (U25). The ROM occupies the lower 56K of the address space, and the RAM takes the rest of the total 64K, except for the last 16 bytes which are used for memory–mapped I/O.

A PAL (U26) is used to decode addresses external to the microcontroller IC, and generates the chip–select signals for either external ROM, external RAM, or an I/O device as a function of the address being accessed. When an external I/O address is being accessed, address bits A1 – A3 of the external address are further decoded by a demultiplexing IC (U18) which decodes the memory access to the DACs as well as generating the two control signals INPUT/ (pin 12) and OUTPUT/ (pin 11) that control two 8–bit input and output ports on the data bus of the microcontroller, respectively.

The 8–bit input is buffered by an 8–bit buffer (U4A, U4B) and the output is buffered by a level–triggered latch (U20). Note that to generate the proper chip–select signals for these two buffers, the respective control signals must be logically NORed with write (in U3A) and ORed with read control signals (in U3C, U3B), to fully specify which of the buffers is being accessed and to generate the correct polarity on the chip–select control pins.

Three digital–to–analog converters (U16, U17, U19) on the external data bus of the microcontroller, generate the analog control voltages ECON, LCON, and ICON, respectively.

ECON is an analog control voltage which determines the output voltage of the high voltage power supply on the PSRF PCB.

ICON is the analog control voltage which controls the absolute maximum RF current in the RF output stage. It mainly controls the low impedance current and thereby controls the low impedance roll–off of the power curve.

LCON is an analog voltage which controls the RF leakage of the generator.

All three of these analog voltages are calculated by the microcontroller as a function of the power level and function of the activated mode.

Each of the DACs has a non–inverting buffer amplifier on its output (U9C, U9B, U9D, respectively) to convert the output current signal of the DAC to an analog voltage. The DACs require a negative reference voltage of –3.68 volts (supplied on pin 13 by AD–VREF). That signal is supplied by a voltage reference (U6) whose output is inverted and amplified (U9A) to generate the required voltage.

Serial Communication on the IIC Bus

The microcontroller communicates with serial circuits on the Display and Interface PCBs, via the IIC bus. This consists of a serial data line (IIC– DATA) and a serial clock line (IIC–CLK). Each line is driven by the microcontroller via a MOSFET (Q1 and Q2, respectively) and a pull–up resistor connected to the +5 volt supply rail. (Any other device that drives these lines also must do so with a "wired–AND" output such as the drain terminal of an N–channel MOSFET.)

A device that sends a message is a "transmitter," and a device that receives a message is a "receiver."

The device that controls the message is the "master" and the devices which are controlled by the master are "slaves." In the Force 30, 40 generators, the microcontroller is the only master. Some of the slave ICs are transmitters (e.g. the input ports) and some are receivers (e.g. the output ports, DACs, display drivers, etc.).

Both data and clock lines remain high when the bus is not busy.

The start condition (S) is defined as a high–to–low transition of the data line while the clock is high. The stop condition (P) is defined as a low–to–high transition of the data line while the clock is high.

Data transfer may be initiated only when the bus is not busy. There is no limit to the number of data bytes transferred from transmitter to receiver between the start and stop conditions.

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the high period of the clock pulse, as changes on the data line during this time will be interpreted as control signals.

Each 8–bit byte is followed by 1 acknowledge bit. The acknowledge bit is a high level placed on the bus by the transmitter, whereas the master generates an extra acknowledge–related clock pulse.

A slave receiver that is addressed must generate an acknowledge after the reception of every byte. Also, a master must generate an acknowledge after the reception of every byte that has been clocked out of the slave transmitter. A device that acknowledges has to pull down the SDA line during the acknowledge clock pulse, so that the SDA line is stable low during the high period of the acknowledge–related clock pulse, with setup and hold times taken into account.

A master receiver must signal an end–of–data to the transmitter by not generating an acknowledge on the last byte that has been clocked out of the slave. In this event, the transmitter must leave the data line high to enable the master to generate a stop condition.

The maximum IIC–CLK bus clock speed is 100 kHz. No minimum bus clock speed is specified. The frequency is generated inside the microcontroller via high speed output (HSO) bit 1, by the software.

IIC–DATA is driven by the inverted output of the microcontroller's port 2 bit 7, and is read on port 2 bit 6. The line driver employs a MOSFET (Q1), to permit bidirectionality on the bus. When the microcontroller is receiving data from the bus, it sets the output bit low to turn off the MOSFET and relinquish control of the IIC bus. The slave transmitter can then let the line go high, or pull it low, as required.

To send data out, the microcontroller writes parallel data out to bit 7 of port 2 bit by bit (serially), at the same frequency as the IIC–CLK rate. Each slave on the IIC bus is assigned a unique address which is determined by the voltage(s) at the address pin(s) of each IC, in a manner that varies from one IC type to another.

Footswitch Decoding

The rear panel Bipolar and Monopolar footswitches, and the front panel Monopolar footswitch, all are decoded by circuitry on the Microcontroller PCB. Transformers T1 through T3 provide electrical isolation from the logic level circuitry, and reflect the switch impedances back to the control circuitry through the 1–to–1 turns ratio.

The primary windings of the transformers are driven, through a buffer (U11), by the ISOCLK signal, which is created by dividing down the signal on the CLKOUT line of the microcontroller with a counter (U2A, U2B). When the generator is in the Standby mode and the ISOCLK frequency does not need to be generated, the microcontroller shuts the ISOCLK off by setting ISODIS (isolated clock disable) signal high, which clears the counter (U2).

The ISOCLK frequency is used as the fundamental clocking frequency for the isolated footswitch decode circuitry, for the REM impedance detection circuitry, and for the dosage error test–circuitry. The ISOCLK signal switches the voltage across the primary of the isolating footswitch transformer, as well as synchronously clocking the decode circuitry to measure the voltage across the reflected impedance. This is done for each footswitch by applying the switch signal to a voltage divider made up of the reflected impedance to ground in series with a known impedance.

Each synchronous detector time–averages the sampled voltage through a lowpass filter (e.g. R9, C9), and this signal is then compared to Viso (a reference voltage which sets the allowed maximum switching impedance) by a comparator (U5A and U8). If the sampled voltage is less than Viso, a switch closure is acknowledged and the output of the comparator goes low. That output is buffered (U4) and then appears as a "high" on the microcontroller's data bus.

The magnitude of Viso is empirically defined as the voltage generated by a load on the secondary of the transformer, equal to the maximum switching impedance (200 ohms) at which the footswitches are specified to operate. It is set by a voltage divider (R5, R13) supplied by a +2.5 volt zener diode (U6) powered from the +5 volt supply rail.

The input buffer (74HC240 – U4B) receives in addition two signals (HSW1 and HSW2) from the Handswitch receptacle, and the dosage error signal (DOS– ERR/). All three of these signals are generated on the Interface PCB, and therefore (as for all signals that are passed between the PCBs), all pass through low–pass filters (R6–R8, C5–C7), to reduce RF interference.

Watchdog Timer

At power–up, after the +5 volt supply rail has remained above +4.75 volts for a given amount of time, the watchdog timer IC (U21) releases the RESET/ line and allows the microcontroller to execute a hardware reset. Thereafter, the watchdog IC monitors the +5 volt supply rail and, when it drops below +4.75 volts, shuts the microcontroller off by taking the RESET/ signal low.

In addition, the watchdog timer monitors the input of the WATCHDOG line and checks that it is toggled every 0.6 seconds by the microcontroller. During normal execution of the microcontroller software, the watchdog timer is toggled regularly while the program is proceeding in the proper sequence. If the watchdog timer is toggled at less than the proper frequency, the watchdog IC resets the microcontroller in the same way as it does at power up.

Voltage Regulators

The voltage regulators on the Microcontroller Board (U27, U10, U13) generate +5 V, –12 V, and +12 V supply rails for the logic on the Microcontroller Board, from raw supply voltages of +9 V, –15 V, and +15V, respectively.

Each of these ICs are provided with bypass capacitors at both input and output to reduce power supply noise (C87, C88, C20, C19, C25, C29).

The reverse–biased diode connected from input to output of each 3–pin regulator IC (CR3, CR1, CR2) protects the regulator from damage from reverse discharge in the event of a short circuit on the input side.

Display Board

7–Segment LEDs

The 7–segment LEDs that display power settings are controlled by two multiplexed display driver ICs (U6, U11). Each IC multiplexes two pairs of 7–segment LEDs with decimal points.

The desired state of each segment (on or off) is sent by the microcontroller to the driver IC over the IIC bus. Both of the control lines for this bus (IIC–CLK and IIC–DATA) are heavily filtered at the input to the Display PCB (R14–R19, C13, C14, and R45–R50, C28, C27) to prevent RF interference from corrupting the displays.

Each display driver IC selects one or the other pair of displays via the output multiplex pins MX1 (pin 11) and MX2 (pin 14). The signals at these pins are complementary, and switch at a frequency set by the capacitor (C15, C29) connected to pin 2 of the driver.

The MX1 and MX2 pins are buffered by NPN transistors (Q1, Q2, Q4, Q6) which each drive the anodes of a pair of 7–segment displays (D1–D8). Sixteen other output lines (7 segments + a decimal point, x 2 for two digits; for example, DSP0–A0 to DSP0–A7 and DSP0–B0 to DSP0–B7, in the case of U6) are connected directly to the cathodes of the LED segments and decimal points.

The driver circuits inside the ICs are controlled current sources, and the amount of current (and hence the brightness of the LED displays) can be set by the microcontroller via the IIC bus. External current limiting resistors are therefore not required.

LED Lamps

The LED lamps also are controlled by the IIC bus and a display driver IC (U9).

The anodes of the lamps are interconnected in two groups. The display driver IC selects one or the other group of LED lamps via the output multiplex pins MX1 (pin 11) and MX2 (pin 14). The signals at these pins are complementary, and switch at a frequency set by the capacitor (C26) connected to pin 2 of the driver.

The MX1 and MX2 pins are buffered by NPN transistors (Q3, Q5) which drive the anodes of the LED lamps.

Each lamp is controlled individually by one of the 16 output lines of the display driver IC. The 16 driver circuits inside the IC are controlled current sources, and the amount of current (and hence the brightness of the LED lamps) can be set by the microcontroller via the IIC bus. External current limiting resistors are therefore not required.

The incandescent lamps which indicate delivery of RF power in the Bipolar, Cut, and Coag modes (D9, D10, D11) also are controlled by U9, but require external buffering because the drive current requirements for these lamps exceed the capabilities of the IC. A driver IC (U10) is used to buffer the signal lines that control these incandescent display lamps.

The address pin (pin 1) of each of the multiplexed display drivers is tied to an analog value (+5IIC for U6; 0 volts for U11) which defines a unique display address for that IC on the IIC bus.

REM Lamp

The REM indicator uses two bidirectional LED arrays (D27, D28) that each can emit either green or red light. (Each contains eight LEDs, four red and four green, connected in pairs anode–to–cathode and vice versa, so that the direction of current flow through the four pairs determines which LEDs are lit).

Each 8–LED lamp is driven by four MOSFETs (Q10, Q11, Q14, Q17, and Q12, Q13, Q15, Q16) connected in a full bridge configuration. Turning on FETs Q12 and Q10 (for example) will light the red LEDs in one of the two lamps, or turning on FETs Q11 and Q13 will light the green LEDs. The microcontroller sets two of the output pins (P12 and P13) of driver IC U9 to determine which color is to be emitted from each of the two LED arrays.

The address pin (pin 1) of the multiplexed display driver (U9) is tied to an analog value (derived from the +5 V supply rail by a potential divider; R42, R43 in this case) which defines a unique display address for that IC on the IIC bus.

EEPROM

The features of the Force 30, 40 generators are selected by software, and all calibration (except for offset potentiometer settings) is performed by software. The values and flags used by the software to control the generator are contained in EEPROM, and are retained even when the generator is turned off.

The EEPROM IC (U1 on the Display PCB) is read from and written to (via the IIC bus; address 000, set on pins 1–3)

- at power up,
- at turn on (when toggled into Ready mode)
- at turn off (when the generator is toggled into Standby mode).

A copy of the contents of the EEPROM is maintained in RAM during normal operation of the generator. Each time the chip is read, the microcontroller recomputes the EEPROM checksum to ensure data integrity.

Front Panel Buttons

The only button that is active when the generator is in the Standby mode is the ***On/Off*** button. The only buttons active when the generator is providing RF output are the ***On/Off*** key and the ***Power Up/Down*** buttons.

Each button is monitored separately, so several buttons may be pressed at once to achieve the same result as pressing first one and then the other (providing that they do not contradict each other). For example, the user may raise the power in Cut and Coag at the same time by pressing the ***Cut Up*** and the ***Coag Up*** buttons simultaneously.

All the buttons are membrane momentary contact switches with tactile feel. All have debounce times of 60 mS. The ramp rate for continuous switch depression of the ***Up/Down*** buttons is six settings per second. The delay time for ramping to start is 0.5 seconds.

The states of the keys on the keyboard also are transmitted on the IIC bus. The keyboard interface ICs (U5, U7, U8) each monitor inputs on pins P0 – P7 and generate a signal (IIC–INT0, IIC–INT1, or IIC–INT2) when an input changes state.

The microcontroller polls those signals and responds by reading whichever IIC input port has changed its state. The IIC input port IC automatically removes its signal (IIC–INTn) after the IIC bus access has ended.

Each output must be written with a 1 before it can be read, because the ports are bidirectional.

The different addresses for these IIC input port ICs are programmed on pins 1–3, to give each IC a unique address location in the IIC input address space.

REM Switch

The REM switch is contained in the plastic housing that is standard on all Valleylab generators equipped with the REM feature. The housing contains a microswitch that is activated when the REM activation pin on the patient return electrode cord is plugged in. This signal is transmitted to the Display Board in the same manner as a standard key closure, for interpretation by the microcontroller. The REM signal (REM SWITCH) interfaces to a IIC input port IC (U7, pin 7).

Power Control Pencil Detector

The presence of a Valleylab Power Control Pencil is detected via an infrared (IR) transmitter/receiver pair (OPT1) which detects the insertion of the mechanical pin on the Power Control Pencil cord into the ***Power Control Handswitch Active*** receptacle. The amount of reflected IR radiation required to sense the presence of the pin is set by R44 (which sets the transmitter LED's drive current) and by R52 (which sets the sensitivity of the photo transistor receiver).

As with the REM switch, the signal indicating that a Power Control Pencil is plugged in is transmitted to the Display Board in the same manner as a standard key closure, via the POWER PENCIL signal into an IIC input port IC (U7, pin 6), for interpretation by the microcontroller.

Voltage Regulators

The 3–pin regulators on the Display Board (U2, U3, U4) generate the +5 IIC, +5 LED, and +12 V supply rails, respectively, from unregulated +9 V and +12 V supplies.

The IIC I/O port ICs are very sensitive to voltage differences between their supply rail and the bus values. If the bus lines rise above the supply rail by even 0.1 volts, the IIC ICs may not function properly. For this reason, the IIC supply rail (+5 IIC) must be transmitted to the Interface PCB to supply the IIC I/O ports at the far end of the IIC bus.

Also, the IIC and LED power supplies are segregated to isolate the IIC bus from the current surges that occur in the display power supply as the multiplexed drive circuitry turns the LEDs on and off.

The reverse–biased diode (CR1, CR2, CR3) connected from input to output of each 3–pin regulator IC protects the regulator from damage from reverse discharge in the event of a short circuit on the input side.

Interface Board

Audio

The audio control circuit has two control parameters. The first is the frequency of the target audio tone. This is set by the microcontroller.

The audio frequencies for the different tones and alarms that the generator sounds, are generated by the microcontroller in the same way that the IIC clock is generated. Output HS0.3 (High Speed Output 3) is used as a frequency output. This signal is buffered (U5B) before exiting the Microcontroller PCB as the AUDIO–FREQ signal.

Second, the software controls the volume of the tone by setting a volume throttle signal and a minimum volume level signal through a DAC (U26) on the IIC bus. The AUDIO–THROTTLE signal is attenuated by a potential divider formed by a resistor (R97) and the volume potentiometer on the rear panel. The output from the potential divider is buffered by a voltage follower (U24A) to prevent loading from affecting its value, and added to the minimum volume signal (AUDIO–MIN) by a negative summing amplifier (U24B) to create the audio volume signal.

Thus, if the potentiometer is set to zero ohms, the volume is at 45 dB, the minimum set by the software. If the potentiometer is set at 10k ohms, the volume is at its maximum of 65 dB.

For audio alarms, the software sets the AUDIO–THROTTLE signal to zero (so that the potentiometer has no effect), and sets the AUDIO–MIN signal to cause a 65 dB output. The resulting audio signal is modulated by the audio frequency (AUDIO–FREQ) and then is used as the input to an inverting power amplifier (U25) which drives the speaker.

The capacitor (C88) in series with the speaker ensures that DC will not flow through it. An RC filter network at the input to the amplifier (C82, R101, C83) shapes the signal to create the audio tone.

Note that the DAC on the IIC bus (U26) has filtering on its two input lines (IIC–CLK, pin 4 and IIC–DATA, pin 3). The DAC uses the +12 V supply rail as its voltage reference, via a low–pass filter (R104, C85) to minimize power supply noise on the audio output.

Relays

An IIC output latch (U29) interfaces the IIC bus to several I/O signals on the Interface PCB. Four of these signals (xxxRly) are relay drive lines which (via high voltage relays) steer the RF output to the proper output receptacles.

The relay drive lines are amplified by a driver IC (U32) with internal clamp diodes for the relay coils. On the outputs of the driver IC, bypass capacitors to ground (C100, C103–C105) prevent RF noise from coupling through the relay contacts back into the coils and from there, back into the driver IC where RF noise might cause spurious activation or deactivation of the relay.

Four other control signals are latched by the IIC interface IC (U29). These signals are:

- TEST (used during power up to test the dosage error circuitry)
- MUX0 (used to control the definition of FREQ3 between PWR–BIP and PWR–MONO)
- AUTO (not used)
- DOSCLK (used to clear the dosage error latch)

The definitions and uses of these signals are described elsewhere in this document.

Handswitch Key Sense

The configuration of the handswitch keying sense circuitry is similar to that used on the Microcontroller Board, except for the addition of a diode bridge (CR25–CR29) on the secondary (the RF side) of each impedance–reflecting ISOBLOC transformer (T3–T7). Each bridge blocks RF from the active accessory from coupling through the ISOBLOC transformer into the sense circuitry, and rectifies the impedance sense voltage from the sense circuitry so that it becomes DC on the RF–environment side of the transformer (thereby reducing EMI emissions from the accessories).

Each impedance is sensed by reflecting it back through the transformer (1–to–1 coupling) as one half of a voltage divider whose output is detected synchronously and compared to a reference voltage. The synchronous detection further improves RF noise rejection.

Each sensed voltage is low–pass filtered by an RC network and then compared to a reference voltage (ISOREF1) by a comparator (U22A, U9). The value of ISOREF1 determines the maximum impedance at which keying will occur. The output of the comparator goes low when the corresponding key closure is sensed.

A multiphase clock (ISOCLK/ and ISOCLK2) is used to sense the key closures of either the COAG (ACC–COAG) or the CUT (ACC–CUT) keys on the electrosurgical accessory. The two clocks are generated 180° out of phase by an inverter (U6B). The multiphase clock minimizes EMI emissions.

The handswitch keying circuit has much the same topology as the accessory keying circuit, with the addition of a 330 ohm resistor (R110) in parallel with the switches being sensed, as well as the addition of a second AC voltage source via a MOSFET (Q1) on the primary, which can be switched into the circuit using HSW0 as the control line into a NAND gate (U23C). The second AC source makes it possible to decode all four switch closures on the Power Control Pencil, using just two signal lines (HSW1 and HSW2). Note that a total of two samples on these lines is required by the microcontroller to determine actual switch closure, one when HSW0 is high and one when it is low.

The following chart shows the reflected impedance on each of the transformers as a function of the input signal and the key being pressed:

	None		Cut		Coag		Up		Down	
	T3	T4	T3	T4	T3	T4	T3	T4	T3	T4
HSW0=0:	– –	>>>	– –	>>>	– –	0	– –	R110	– –	0
HSW0=1:	R110	>>>	0	>>>	R110	0	>R110	>R110	0	0

where >>> = near–infinite impedance
– – = no signal

ISOREF1 is the reference voltage for all of the key closure impedance level comparisons performed on the Interface PCB. It is derived from a zener diode (U10) whose output is divided to the proper voltage level by a potential divider (R48, R49). The output of the divider is low–pass filtered to remove RF noise.

ISOREF1 is set so that the Handswitch impedances tabulated above cause the following outputs from the comparators:

	None		Cut		Coag		Up		Down	
U9	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1
HSW0=0:	0	1	0	1	0	0	0	0	0	0
HSW0=1:	1	1	0	1	1	0	1	1	0	0

RF Sense

The output power of the generator is measured by sensing both the voltage and current, then multiplying them together.

The output current is sensed in both Monopolar and Bipolar by the use of current transformers (T1 and T8, respectively). In Bipolar (T8) two primary turns are needed to ensure a sufficiently large coupling efficiency and resulting signal at the 0.1 watt settings of the generator.

The output voltage is sensed via capacitive dividers (e.g. C108, C109, C110, C11) to minimize power dissipation in the sense circuitry, and to provide electrical isolation. This is similar to the circuitry used in 1000X oscilloscope probes. Bleeder resistors across the capacitors in the divider provide discharge paths. This is accomplished in the Monopolar circuitry by R12 and R13, which provide DC bias for the V–, V+ multiplier inputs, and similarly in the Bipolar circuitry by R84 and R85. The back–to–back zener diodes (e.g. CR6 and CR8) ensure that the signal voltages do not overload the input stages of the multipliers.

The sensed voltage and sensed current signals are then fed to four multiplier ICs with buffered outputs:

U2 (Monopolar power)
U17 (Bipolar V x V)
U14 (Bipolar power)
U19 (Bipolar I x I)

In the monopolar mode, multiplier U2 multiplies the sensed voltage by the sensed current and thereby generates a signal proportional to the output power. That computed power signal is used for two purposes.

1) While the generator is activated, this signal is compared to a dosage error limit value set by the microcontroller to determine if too much power is being delivered.
2) During calibration of the Monopolar modes, the computed output power is used to set the scale factors for the various modes. Each scale factor is a multiplication factor that relates ECON to the high voltage power supply voltage (HVDC) needed to enable the RF stage to deliver a given power into a known impedance. That multiplication factor has been found to be constant across the power range for any given mode (i.e. ECON is linearly proportional to the HVDC level) whereas the relationship between the output power and the HVDC level is a square root function (P = V x V/R).

In the bipolar mode, the computed power signal from multiplier U14 serves three purposes. The first two are identical to those of the monopolar mode. The additional use is in a microcontroller feedback algorithm which is active while RF power is being generated.

A third multiplier IC (U17) calculates the square of the sensed bipolar voltage, and a fourth multiplier IC (U19) calculates the square of the sensed bipolar current. The microcontroller uses both of those computed signals to determine the bipolar power output and the impedance of the load.

Using those values the microcontroller then reduces the power into high impedance loads at a rate (change of power versus change of impedance) that depends upon the operating mode (Standard versus Precise). The microcontroller uses ICON to limit the output power into low impedances (≤100 ohms).

The current multiplier (U19) is utilized at current levels below 400 mA. The voltage multiplier (U17) operates at power levels up to 250 volts RMS. This dual approach allows maximum resolution of readings over the full range of load impedances and output power.

The outputs of all the multipliers are analog voltages. Each analog voltage is encoded into a pulse train frequency by a voltage–to–frequency converter (VFC) before being transmitted to the Microcontroller PCB, to increase noise immunity in the RF environment as well as to increase resolution when the signal is read by the microcontroller.

The VFC circuits each consist of a VFC IC (U3, U11, U16, U20) and a preamplifier integration stage (U1A, U7B, U18A, U18B). U11, U16, and U20 use a 10k multiturn potentiometer to zero–out voltage offsets in the multipliers. That adjustment is made at a VFC output frequency of 1 kHz.

The frequency–encoded signals derived from U19 (Bipolar I x I) and U17 (Bipolar V x V) multipliers emerge on the FREQ2 and FREQ1 lines, respectively. FREQ3 is switched by transmission gates (U4D, U21A) between the frequency–encoded signals derived from the Monopolar power multiplier (U2, U1A, U3) and the Bipolar power multiplier (U14, U7B, U11). The MUX0 signal determines which of the latter two modes is being sensed.

At the microcontroller these pulse trains are input to High Speed Inputs (HSI.1 to HSI.3) where an internal high speed event capture module digitizes the input frequencies over a 54,000–count range (1000.0 Hz – 6400.0 Hz with ± 0.1 Hz resolution).

Dosage Error

The dosage error circuitry disables the generator if output power exceeds a specified percentage of the front panel power setting.

The microcontroller generates a frequency proportional to the output power setting (DOS–FREQ) and this is converted to a positive voltage (DOSLMT) by a frequency–to–voltage converter IC (U13).

The dosage error circuitry (U7A, pin 2) subtracts that power setting signal from the sum of the powers computed by the Monopolar power and the Bipolar power multipliers (U2 and U14, respectively) and adds in a dosage offset (a zero trim voltage which can be adjusted by potentiometer R26).

The sum of those four signals...

a) two **negative–going** voltages linearly proportional to the measured monopolar and bipolar output powers (from the two power multipliers)

b) a **positive** voltage proportional to the maximum permitted power (i.e. proportional to the front panel power setting) derived from DOS–FREQ

c) an offset **zero–trim** voltage (from R26)

... is low–pass filtered (R34, C41) to increase noise immunity (e.g. to suppress transient "overdoses" lasting less than 1 mS) and then compared to ground potential (U12A).

If the sum of those four values exceeds zero (meaning that the measured output power exceeds the dosage limit derived from the front panel power setting), then U12A will switch high (via MOSFET Q4) to preset the DOSERR latch (U31B), taking DOSERR/ low (pin 8) and indicating a dosage error.

The MOSFET (Q4) is required to shift the voltage swing from +5/–12 volts at the output of U12A, to 0/+5 volts for compatibility with U31B. It also it inverts the output signal of U12A since the preset input to the dosage error latch (U31B) is negative–true.

During run mode, the only way to reset the latch and clear this error is to turn the generator OFF and then back ON (from the front or rear panel).

During calibration mode, the microcontroller controls the DOSCLK line (U31B, pin 11) so that potentiometer R26 can be set to compensate for the combined output offsets of the two power multipliers (U2, U14). In addition, in the calibration mode, the microcontroller checks that it has control over the dosage error signal by slowly decreasing the frequency (DOS–FREQ) until an error condition occurs. This value is then stored in the EEPROM as a reference value for subsequent power on reset calibration checks.

Note: The nominal range for the dosage error frequency (DOS–FREQ) is 120 Hz offset and 1 Hz/watt of RF power. Dosage error occurs when the measured output power exceeds the output power displayed on the front panel by 35 watts, or 35%, whichever is greater. Thus, for a 100 watt setting and a limit of 135 watts before dosage error, the nominal frequency would be 255 Hz. This gives a nominal maximum frequency of 525 Hz (for 300 watts with a limit of 405 watts). The absolute maximum dosage error frequency (DOS–FREQ) that the microcontroller will generate is 600 Hz.

RF Sense / Dosage Error Gain Test

During power on reset, the microcontroller outputs the stored calibration value for DOS–FREQ to confirm that it does still cause a dosage error.

Next, it applies test signals V–CLK and I–CLK (5 volt peak–to–peak pulse waveforms derived from ISOCLOCK) to the inputs of all four multipliers (U2, U17, U14, U19) via transmission gates (U4A, U4B, U21B, U21C). All four transmission gates are enabled simultaneously by the TEST line, which also enables I–CLK and V–CLK via a NAND gate (U23A).

The microcontroller sets the test frequency (DOS–FREQ) slightly higher than the already known (calibrated) value required for a dosage error condition to be cleared. It then gradually decreases the frequency until the circuit indicates a dosage error (via DOSERR\). If the gains of the multipliers and the dosage error circuitry lie within their allowed tolerances, this frequency will lie within the tolerance range of the calibrated value, and the self–test succeeds. If not, the self–test fails and the generator cannot be activated.

When the test is completed, the software removes the TEST signal, sets DOS– FREQ back to the calibrated offset value, and toggles the dosage clock (DOSCLK) signal until the dosage error condition (DOSERR\) clears. If the condition remains after several attempts, a dosage error alarm sounds and the generator cannot be activated.

REM Circuitry

The HV REM transformer (T2) acts as an isolated impedance sensing device that is connected directly to the REM Filter Board. The REMOUT DC voltage from the REM Filter Board is converted to a frequency using a VFC (U5) and its associated integrating amplifier (U1B). The resulting frequency–encoded signal (FREQ0) is passed back to microcontroller input HSI.0, so that firmware algorithms can perform the REM monitoring requirements.

Voltage Regulators

There are four 3–pin regulators on the Interface PCB. One (U27) converts an unregulated +9 V supply to a +5 V supply rail. Two others (U28, U30) convert unregulated ± 15 V supplies to ± 12 V supply rails. The fourth (U33) creates an isolated +12 V supply rail from the +15 V unregulated supply, to power the relay drive lines only. This is to ensure that turn off spikes from the relay coils do not interfere with the control logic on the Interface PCB.

All four regulators have reverse–biased diodes (CR21 – CR24) connected across them to protect them against damage from reverse discharge in the event of a short circuit across an input.

REM Filter Board

U3 and U4 form an RC Oscillator that drives T1, the low voltage REM transformer. The LV REM transformer is connected directly to the HV REM transformer on the Interface Board. A synchronous detector (U1) outputs a DC voltage that is proportional to the impedance across the LV REM transformer secondary. U2 is used as a summing amplifier for the detected signal and a difference amplifier for any noise that is not filtered. The REMOUT voltage at C6 is input to the Interface Board.

Power Supply/RF Board

AC Line Hardware

> **WARNING**
>
> The AC Line circuitry has potentially lethal AC and DC voltages. It is not isolated from the AC line.
>
> High voltages exist on the power connector, power switch, the aluminum heatsinks, and certain components on the PSRF Board.
>
> Take appropriate precautions (such as use of isolated tools and equipment; use of the "one hand rule", etc.) when taking measurements in or troubleshooting in this area of the generator.

AC line power enters the generator through the ***Power*** switch, EMI suppressor, line voltage ***Power Select*** switch, and line fuses, all mounted on the rear panel.

The line voltage ***Power Select*** switch is a recessed red plastic switch. The selected nominal line voltage range (110–120 or 220–240 V~, 50–60 Hz) is indicated beside it.

The generator is used with a 16 AWG 3–conductor line cord with a 220 volt plug, or with a 110 volt hospital grade three–pin plug, terminated with a three–pin receptacle at the generator end.

LVDC Power Supply

The low voltage power supply for the Force 30,40 generators consists of a 110–220 V~ line transformer (T4) mounted on the back panel.

One of its three secondaries is center–tapped (to provide a ground return) and feeds a full wave bridge rectifier (CR18) which supplies the raw ± unregulated rail (+15UR, –15UR).

The other two windings each feed a full wave bridge rectifier (CR19, CR20) which supply the raw +9 V and +15 V rails, respectively.

All the raw supplies are regulated on the various PCBs, as required. In this manner, cross–coupling of noise between shared power supply rails is greatly reduced.

A green LED (CR26) on the PSRF Board indicates that the unregulated +9 V supply is on.

HVDC Power Supply

> **WARNING**
>
> The HVDC Power Supply circuitry has potentially lethal AC and DC voltages. It is not isolated from the AC line.
>
> High voltages exist on the power connector, power switch, the aluminum heatsinks, and certain components on the PSRF Printed Circuit Board.
>
> Take appropriate precautions (such as use of isolated tools and equipment; use of the "one hand rule", etc.) when taking measurements in or troubleshooting in this area of the generator.

The AC line also feeds directly to the high voltage full wave bridge (CR80) and the 120 V voltage doubler on the PSRF PCB. The unregulated output voltage (between the +VDC and –VDC rails) is approximately 310 VDC, at nominal line voltage and no load.

This unregulated HVDC supply is smoothed by line capacitors (C1 and C2) and then used as the raw input voltage to a full bridge DC–to–DC converter. Bleeder resistors (R1 and R2) discharge the capacitors when the AC line is disconnected. Filter capacitor C3 reduces the effect of wiring inductance between the input capacitors and the full bridge DC–to–DC converter.

The full bridge consists of four FETs (Q1–Q4) which operate at AC line potential. The gate driver circuitry for each FET is transformer–coupled through T2 to provide isolation from the AC line, and consists of a 51 ohm resistor (R5, R7, R12, R10) to eliminate turn off oscillations, and a 1k ohm gate–capacitance bleed resistor (R6, R8, R13, R11) to speed up switching.

Note: T2 consists of two transformers electrically and magnetically isolated from each other, but are assembled side by side into the same case. T2A is magnetically coupled to T2B, and T2C is coupled into T2D.

The FETs switch the main switching transformer (T1) back and forth across the unregulated HVDC supply (+VDC to –VDC). A capacitor (C5), in series with the primary winding of the transformer, prevents DC current from flowing through it. A snubber circuit across the primary winding (R9 and C4) reduces inductive spikes and reflected secondary diode–switching spikes. A current transformer (W1), in series with the primary winding, is used by control circuitry to sense and limit the primary current.

The output from the switching transformer is full wave rectified by a high voltage diode bridge (CR1–CR4). A snubber on the secondary (R21, C30) reduces the diode–switching spikes. The raw DC output voltage is filtered by L1, C66 and C67, and then reduced by a voltage divider (R26, R25) for feedback into the regulator IC (U1).

The regulated DC output from this supply is the high voltage DC input to the RF stage of the generator.

ECON

The microcontroller controls the high voltage DC output via the analog value of ECON (generated by U16 on the Microcontroller Board).

ECON is compared to the feedback voltage from the voltage divider (R26, R25), and sets the pulse–width duty cycle of the drive circuitry for the full bridge arrangement of the FETs. The low–pass filter on ECON (R28, C10) reduces RF noise on this signal.

The feedback voltage passes through a two–pole/two–zero filter (R23, R24, C13, R27, C11, C12) to increase the bandwidth of the supply beyond that of the output L–C filter (L1, C66, C67). In addition, the feedback filter ensures that no power supply oscillations occur at the zero crossings of the feedback circuit.

The output of the pulse–width modulation (PWM) regulator IC (U1) is a pair of 180° out of phase signals that are pulse–width modulated as a function of the difference between ECON and the feedback voltage from the power supply output (i.e. the HVDC line). These two output signals, from pins OUTA, OUTB of U1, are applied to the primaries of the two isolating gate–drive transformers (T2A/B and T2C/D) via totem pole amplifiers (Q8, Q9, and Q6, Q7). The capacitors in series with the primaries (C7, C6) ensure that no DC current flows through them.

The output of the current transformer (W1), in series with the primary of the main switching transformer, is full wave rectified (CR5 – CR8) and then filtered (R15, R30, C17) and compared to a reference value of 0.3 V inside the PWM regulator IC (U1). If the current in the primary exceeds its limit, the high voltage supply is automatically shut off and then repeats the same soft–start sequence that was initiated when AC line power was first applied.

The soft start capacitor (C9) sets the soft start time for the power supply. A constant current source inside the PWM regulator IC (U1) charges this capacitor and the resulting ramp voltage gradually increases the output pulse width until the output voltage (HVDC) reaches the level set by ECON. Rt and Ct (R16, C8) set the fundamental operating frequency of the supply (100 kHz).

Dosage Error

The DOSERR/ signal is coupled into the PWM regulator IC in parallel with the current limit signal. If a dosage error occurs, the current limit reference voltage is pulled low (via Q5, R96) and the supply is shut off.

Ton Generation

An 8 MHz packaged crystal oscillator (U2) generates the reference frequency signal for the RF stage. The oscillator is controlled by the signal OSC–EN and a MOSFET (Q10) and runs only when RF is to be generated to minimize RF noise within the generator.

The 8 MHz output from the oscillator feeds a series of counters (U3) that generate eight address lines (A0–A7) for a PROM (U4) which is programmed to generate the appropriate pulse trains to drive the different generator modes. The microcontroller drives the three remaining (and most significant) address lines (the MODE0–MODE2 lines are filtered to produce M0–M2, which are applied to pins A8–A10), and these operate as a "mode bank select" signal which selects which pulse train to generate.

The counter's outputs toggle the input lines of the selected "switch bank" sequentially, and thereby generate the Ton–drive set signal (TON–START) and the Ton–drive reset signal (TONSTP), which are synchronized with the 8 MHz fundamental clock by two clocked flip–flops (U5A, U5B). Note that if a dosage error occurs TON–START is disabled and TON–STP is enabled.

A programmed PAL (U7) inverts the 8 MHz signal (OSC) to generate OSC/. Additionally, the mode select lines are decoded to activate leakage control (via LDSEL) in the Monopolar modes only.

The PAL (U7) also generates the bipolar active signal (BIPSEL).

Another output signal (RF–LMT) is used by the microcontroller in the calibration mode to determine whether the RF current limit (ICLAMP) feedback circuit is active. The RF current feedback circuits set a flip–flop within the PAL by taking RF–SET high. The microcontroller monitors the state of the flip–flop by reading RF–LMT, and resets it with RF–RESET.

Whenever the mode line inputs (M0–M2) supply a valid code to the PROM (U4), the OSC–EN signal is held high (true) to enable the 8 MHz oscillator (U2). Since the PROM is clocked at 8 MHz, the output signals TON–START and TONSTP are clocked (i.e. updated) at 125 nS intervals.

The length of TONSTP, the Ton drive reset pulse, varies with the mode selected. The actual on and off times of TON–START and TONSTP depend upon what has been programmed into the PROM.

Clamp Signals

The two signals TON–START and TONSTP, in conjunction with several feedback signals (ICLAMP/, HVCLAMP, LCLAMP, H–IMP/ and OSC–EN), generate the basic RF pulse drive signal (TON/) for the RF stage.

The second PAL (U9) is programmed as a TON flip–flop, which is set and reset by the inputs TON–START and TONSTP. The RF drive signal TON/ (active low) is generated as the basic pulse drive for the RF stage. TON/ is turned on by the rising edge of TON–START and turned off by the rising edge of TONSTP.

If the OSC–EN signal is low, the TON/ pulse does not set the flip–flop and therefore drive pulses are not generated.

If H–IMP is not active, the ICLAMP/ signal will reset the flip–flop immediately and stop the generation of the RF drive–pulses. The next TON– START pulse will initiate the next drive pulse.

The LCLAMP/ (leakage control) signal inhibits the TON/ drive pulses when keying into high impedance loads, if HVCLAMP (the high voltage clamp) is not active (i.e. is low). LCLAMP disables the pulse drivers for an extended period of time. See the circuit description that follows.

The ICLAMP signal is not active in the Fulgurate or Spray Coag modes of the generator.

The high impedance input (H–IMP) ensures that the high impedance RF leakage (LCLAMP) and the RF stage current control (ICLAMP) feedback loops do not compete in trying to control the TON/ drive train.

ONESHOT–1 is used as an input for leakage control when pulses are separated by more than approximately 15 µS, as in several of the Coag modes. This reduces power dissipation in the load resistor used to reduce the RF leakage. The ONESHOT–1 signal is generated at the start of each TON–START pulse, and lasts for 15 µS.

RF–SET is high whenever the ICLAMP/ circuit has shortened a TON/ pulse.

Load Enable

A 150 ohm, 50 W load resistor is connected across the RF transformer primary winding (J12, pins 1 and 3) at all times, to limit the peak primary voltage.

The LOAD–EN/ signal turns on a MOSFET (Q18) via a high speed driver IC (U28) at the behest of the leakage control circuitry, and this connects a second 150 ohm, 50 W resistor across the RF transformer primary winding via pins 1 and 2 of J12. This second 150 ohm resistor reduces the ringing of the output voltage into high impedances.

ICON

The current in the RF output stage is measured by sampling the current through one of the four RF stage FETs, with a current transformer (T5). Because of the uniformity of the electrical characteristics of the FETs, the ratio of the sampled current (ISENSE) to the total current is nearly constant over the operating current range.

The sampled current signal (ISENSE) consists of a low duty cycle train of negative–going pulses which, because of the transformer coupling, has a baseline that is at a positive potential relative to ground. Transmission gate U19C is opened (by TONSTP) only in between the negative excursions of the signal. The positive baseline of the ISENSE signal therefore charges C75, and the resulting voltage is fed to one input of an op–amp (U20B), with the other input connected to the raw ISENSE signal. Since the positive baseline component of ISENSE appears at both input terminals of the op–amp (U20B), it is a common mode signal and is removed. The output from the op–amp is a train of negative–going pulses with amplitudes (referred to ground potential) proportional to the primary current pulses in the RF transformer.

A second transmission gate (U19B) is opened (by TONSTP\) only for the duration of each negative–going pulse, and so C52 charges to the (negative) average value of that ground–referred pulse train. That (negative) level is then summed (U20A) with the (positive) ICON control signal from the microcontroller, to obtain a DC level that is a function both of the generator's power setting (via ICON) and of the delivered output current (via ISENSE).

Potentiometer R56 trims the gain of IPK– through summing amplifier U20A. Note that the clamp zener diodes (CR24, CR25) are needed to prevent voltage overload on input pin 3 of U17 (also TP14).

The DC level (TP14) is then compared (U17) with a ramp signal initiated by TONSTP\ (Q11). If the output current is excessive, a negative–going pulse appears on ICLAMP\ to reset the TON flip–flop and truncate the drive pulse to the RF output FETs. The larger the excess of output current, the more the comparator (U17) advances the leading edge of the truncating ICLAMP\ pulse. In this way, the current output from the generator is limited on a pulse–by–pulse basis.

The ramp waveform is obtained by charging C48 (via R52) from a positive baseline of approximately +2.5 V to approximately –0.7 V, and then recharging C48 ("fly back," via R51) back to +2.5 V.

LCON

The leakage control (LCON) circuitry limits the RMS output leakage current by pulse–width modulating the drive pulse train to the FET drivers of the RF output stage. The fundamental frequency for the RF leakage control circuitry is 7.8125 kHz, and therefore it works by inhibiting strings of consecutive drive pulses, rather than by truncating individual pulses (as in the case of the current control circuitry described in the previous Section).

The VSENSE signal is obtained from a potential divider (R85, R77) connected from the primary of the RF output transformer (T6) to ground. It is therefore directly proportional to the negative peaks of the voltage applied to the primary winding of the RF output transformer.

VSENSE is input to a negative peak detector (U21B) so that a negative voltage (VPEAK–), proportional to the negative peaks of the voltage applied to the primary winding of the RF output transformer, is developed across C62. Note that for a given RF output power, the magnitude of this voltage varies with the load impedance.

This (negative) signal is summed (U18B) with the (positive) LCON control signal generated by the microcontroller, and the result (TP17) is then compared (U16) with a negative–going ramp (WAK–RAMP) initiated by WAK–FREQ, a low duty cycle pulse train derived from (and therefore locked to) the 8 MHz clock that drives the PROM (U4).

If the RMS output leakage current is excessive, a negative–going pulse appears on LCLAMP\ to disable the TON flip–flop in the second PAL (U9), and thereby inhibit a string of drive pulses to the RF output FETs. The larger the excess of leakage current, the longer the LCLAMP\ pulse. In this way, if the RMS leakage current is found to be rising, the generator pulse–width modulates the RF output in order to reduce it again.

The WAK–RAMP waveform is obtained by charging C56 (via R47, R43) from a positive baseline of approximately +3.0 V to approximatley –0.5 V, and then discharging C56 ("fly back," via R47) back to +2.5 V. Note that C56 does charge up to the point where the clamp zener diodes (CR16, CR17) become operative.

Potentiometer R65 trims the gain of VPEAK– through summing amplifier U18B.

The H–IMP/ signal prevents ICLAMP\ from truncating drive pulses into "high impedance" loads, at a fixed value of VSENSE that corresponds to a load impedance of approximately 500 ohms.

H–IMP/ (derived from U15, pin 7) is generated by taking the signal at TP17 (the result of the summation of the negative peak voltage signal (derived from VSENSE) with the LCON control voltage – see above), and comparing that result with a fixed threshold voltage set by R35 and R36.

RF Output Stage

The TON/ pulse drive signal drives four inverting driver ICs (U24–U27). These drivers drive the gates of the four FETs (Q14–Q17) in the RF output stage.

The resistor in series with each gate (R86, R88, R90, R92) eliminates turn off oscillations, while the resistor in parallel with each gate (R87, R89, R91, R93) speeds up discharge of the gate capacitance when the FET is turning off. The diodes (CR32–CR35), in series with the drains of the FETs, protect those devices against the negative voltage swings of the primary of the RF output transformer (T6).

The primary of the RF transformer (T6) is split into two windings. Resonating capacitors C94 and C95 are always connected in the circuit. However, C93 also is switched into the circuit in some operational modes of the generator. The resonating capacitances and windings of the primary of the RF output transformer are selected by relay K1.

The relay (K1) is driven by a MOSFET (Q13). A diode (CR27) protects the MOSFET from voltage spikes from the relay coil.

Voltage Regulators

There are seven 3–pin voltage regulators on the PSRF Board. Four regulators (U11, U14, U23, U29) generate +12 V from a raw +15 V supply. One regulator (U10) generates –12 V from a raw –15 V supply. One regulator (U12) generates +5 V from the raw +9 V supply. The seventh regulator (U13) generates –5 V from the raw –15 V supply. Each 3–pin regulator has a reverse–biased diode (CR10–CR14, CR31, CR36) connected from input to output to protect against reverse discharge.

The use of multiple regulators eliminates cross–coupling between the regulated voltage supply rails in different areas of the circuitry (e.g. low power control logic versus the high current FET driver supplies).

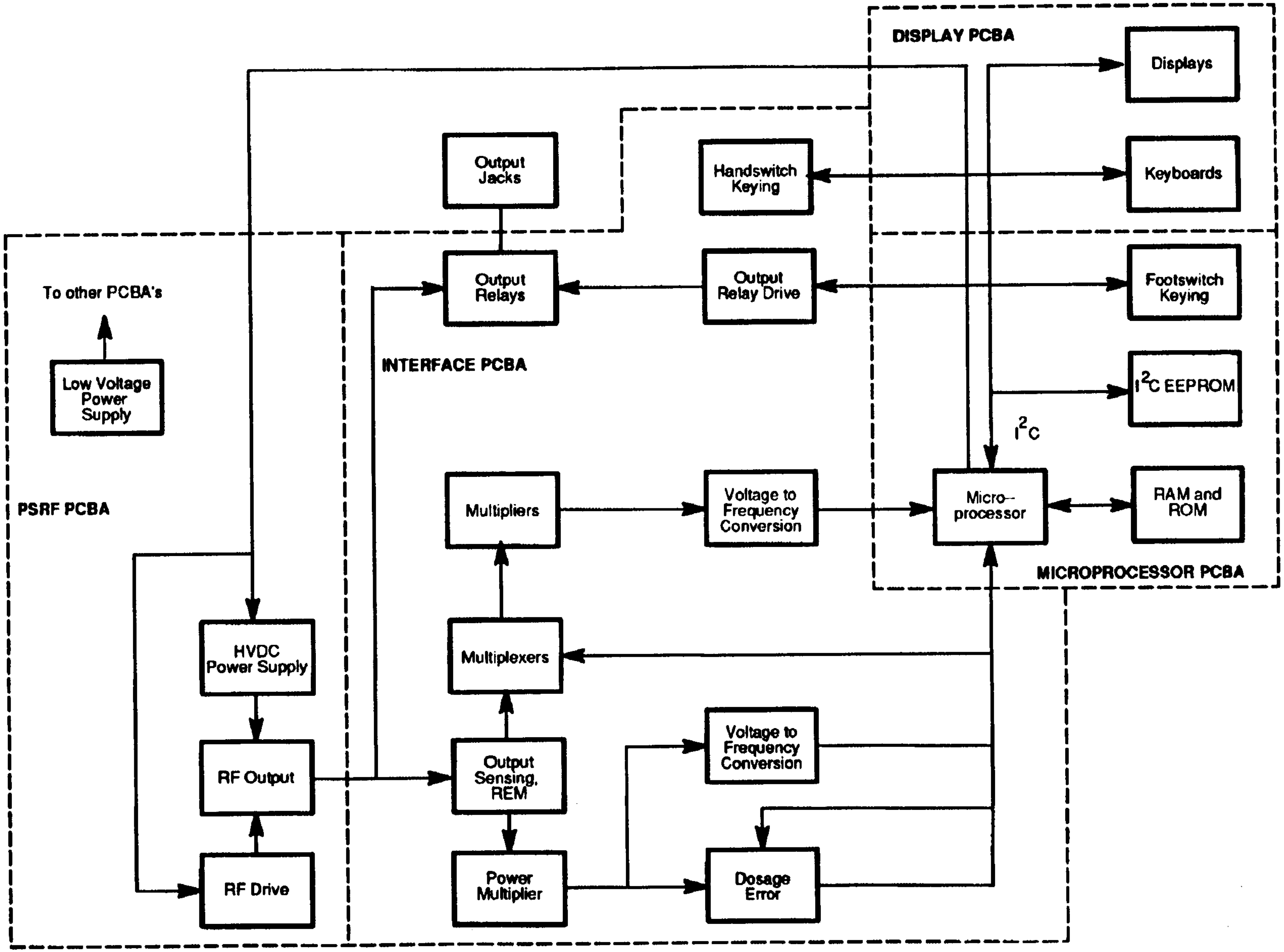


Figure 3.1 Functional Block Diagram

Section 4 Descriptions Of Controls, Indicators, and Receptacles

Introduction

While the generator is delivering RF output power, some features are fully functional while others are disabled or limited.

Those which are fully functional include:

- Autoranging REM (except when activated in any bipolar mode)
- front panel On/Off control
- volume control
- activation control (footswitch, handswitch, etc.)

Disabled functions include:

- front panel footswitch select
- waveform select (both for mode activated and other modes)
- Power Control Pencil Up/Down control
- Reset
- Autoranging REM when generator is activated in any bipolar mode

Limited functions include:

- front panel power control which is limited to a 50% increase or decrease in the power setting

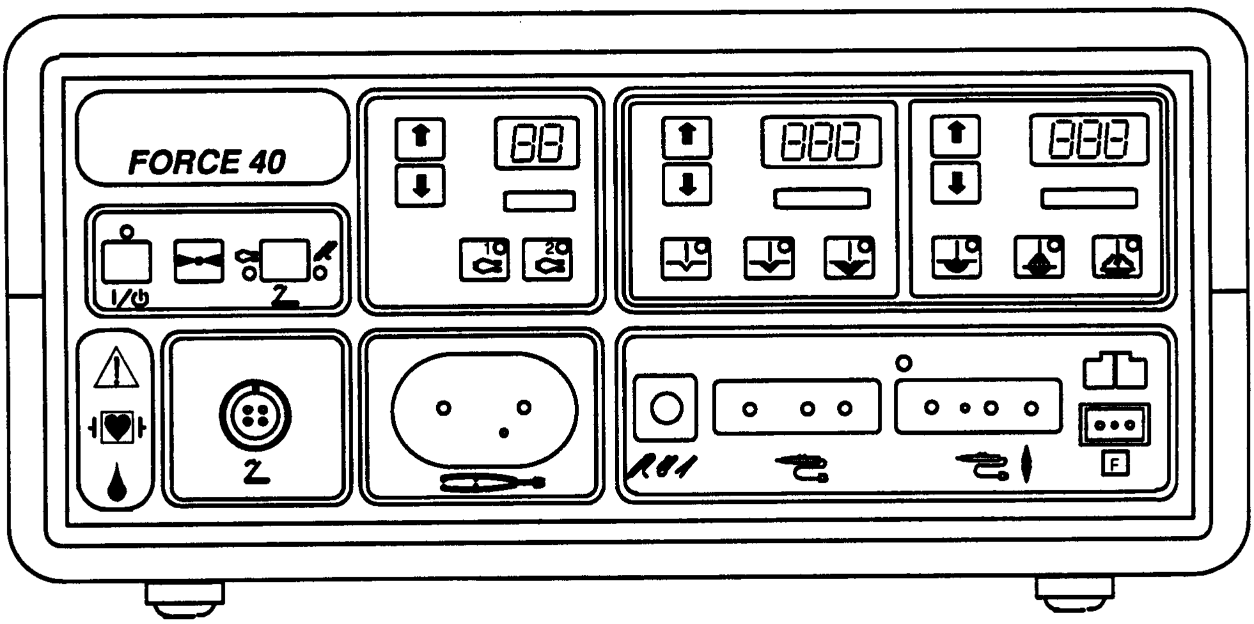


Figure 4.1 Force 40 Front Panel

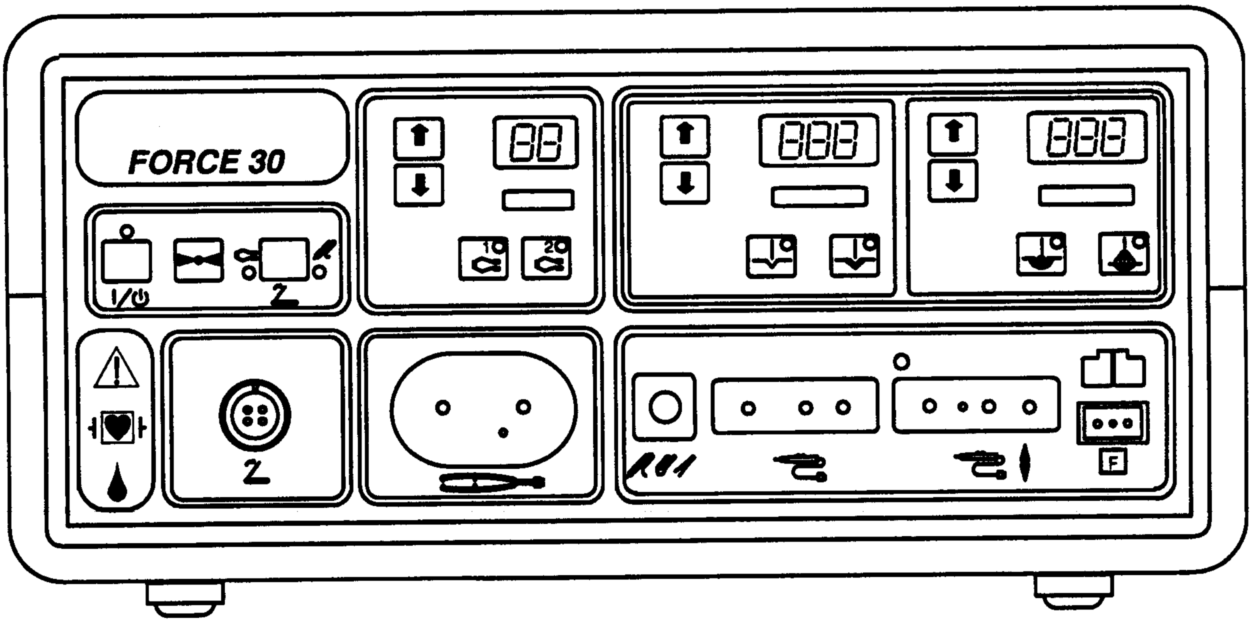


Figure 4.2 Force 30 Front Panel

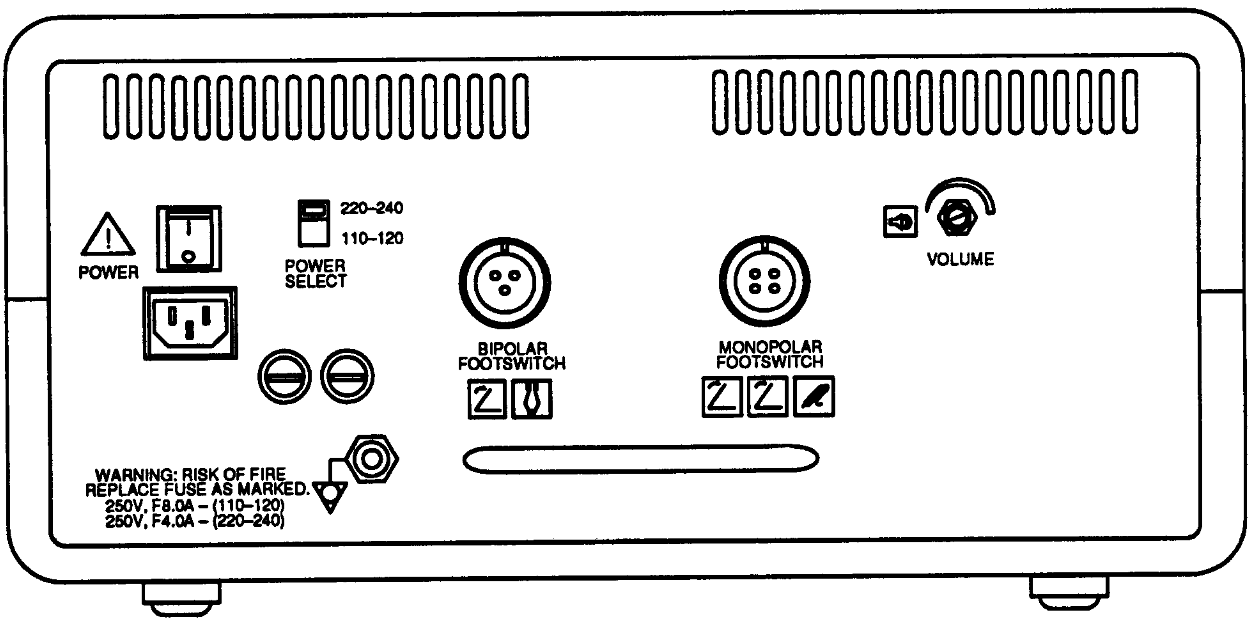
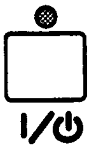


Figure 4.3 Rear Panel

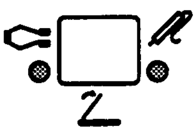
Status



On/Off – This button toggles the generator between an "on" and "off" state. In the off state, the generator is not available for use. In the on state, the indicator illuminates, modes and power levels can be set, and the generator can be activated.

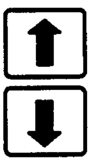
Turning the generator off using this button places the current mode and power level settings into memory.

Reset – Pressing this button causes the front panel to display the mode and power settings that were last stored in memory using the front panel ***On/Off*** button.

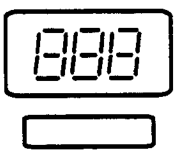


Footswitch Selector – This button toggles between the Monopolar and Bipolar function of the footswitch receptacle on the front panel. The indicator on the left of the button illuminates when the bipolar footswitching mode is selected. The indicator on the right illuminates when the monopolar footswitching mode is selected.

Power Controls



Power Up/Down – Increases or decreases power in the selected mode. A single press of the key changes the power by one setting. Continuously pressing the key gradually increases/decreases the power to maximum/minimum level.



Power Setting Display – The digital power setting display is visible on the generator in the ***On*** state. The number displayed indicates the nominal power, in watts, which will be delivered to the patient when the mode is activated. In the ***Off*** state the displays are blank.
The color–coded indicator located directly under each power setting display (Cut, Coag, Bipolar) illuminates when that output power has been activated. One of the three distinct mode indicator tones will sound in conjunction with the visual output power indicator.

POWER CONTROL **Power Control Feature** – Inserting a Valleylab Power Control Handswitching Pencil into the the ***Power Control*** output receptacle automatically activates this feature.

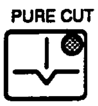
The ***Power Control*** indicator will illuminate and the audio alarm will sound once when this feature is activated. When this indicator is illuminated, power changes can be made by the surgeon using the Power Control pencil.

Bipolar

Standard – Selects the Microbipolar mode for standard desiccation. The button indicator will illuminate when this mode is selected.

Precise – Selects the Microbipolar mode for fine desiccation. The button indicator will illuminate when this mode is selected.

Monopolar Cut



Pure Cut – Selects Cut with lowest level of hemostasis. The button indicator will illuminate when this mode is selected.

Blend/Blend 1 – Selects Cut with minimum hemostasis. The button indicator will illuminate when this mode is selected.

Blend 2 – Selects Cut with maximum hemostasis. The button indicator will illuminate when this mode is selected.

Monopolar Coag

Desiccate – Selects coagulation current waveform for low voltage desiccation. The button indicator will illuminate when this mode is selected.

Fulgurate – Selects coagulation current waveform for general fulguration applications. The button indicator will illuminate when this mode is selected.

Spray – Selects coagulation current waveform for high performance fulguration. The button indicator will illuminate when this mode is selected.

Alarms

REM Alarm Indicator – This indicator illuminates red until a patient return electrode is connected to the generator. The indicator flashes red when the patient contact quality monitoring system senses that contact between the REM patient return electrode and the patient is not adequate. The audio tone will sound twice when the condition is first detected. The generator will not produce output power when this alarm condition exists.

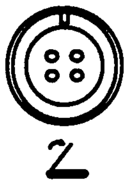
The alarm condition is cleared and the indicator changes to green when the REM Contact Quality Monitoring System senses that the patient/pad contact resistance is within the acceptance range.

If a non–REM patient return electrode is inserted into the ***Patient*** receptacle this indicator does not illuminate, unless the generator detects a break in continuity between the patient return electrode and the generator. In this case, the indicator illuminates red.

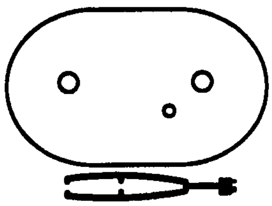
Do not apply a patient return electrode in a Bipolar–only procedure. When the Bipolar forceps are connected to the Bipolar receptacle, the REM indicator will light, but the generator can be activated in Bipolar.

Dosage Error Alarm – If the measured generator output exceeds the output power displayed on the front panel by 35 watts or 35%, whichever is greater, an alarm will sound, the error code "87" will appear in the Power Setting Display, and the generator will not deliver output power. To reset, turn the generator OFF then ON using the ***On/Off*** button on the front panel. There is not an indicator for this alarm.

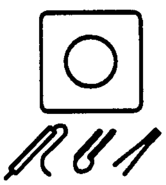
Front Panel Receptacles



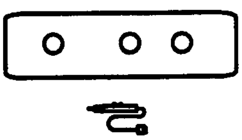
Monopolar Footswitch Receptacle – This four–pin receptacle accepts a two–treadle Monopolar footswitch connector. Connecting a monopolar footswitch to this receptacle allows the surgeon to use the footswitch in either the Monopolar or Bipolar mode, by using the ***Footswitch Select*** button on the front panel.



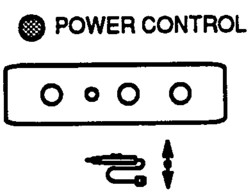
Bipolar Active Receptacle – This receptacle will accept three–pin handswitching bipolar accessories. These accessories can also be footswitch activated. This receptacle will also accept two–pin bipolar footswitching accessories.



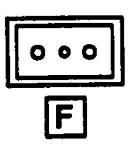
Monopolar Active Footswitch Receptacle – This receptacle accepts standard one–pin footswitching accessories which can be activated by either the footswitch receptacle located on the front panel or the footswitch receptacle located on the rear panel. Some accessories may require a universal 1/4 inch adapter. Do not connect bipolar active accessories to this receptacle.



Monopolar Active Handswitch Receptacle – This receptacle accepts standard three–pin handswitching active accessories. Cut and Coag modes may be activated at this receptacle. Power output from this receptacle is activated only by using the handswitch mechanism. Do not connect bipolar active accessories to this receptacle.

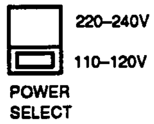


Power Control Monopolar Active Handswitch Receptacle – This receptacle accepts both standard three–pin handswitching active accessories and the Valleylab Power Control Pencil. The indicator illuminates when a Power Control Pencil is inserted in this receptacle. Power output from this receptacle is activated only by using the handswitch mechanism. Cut and Coag modes may be activated at this receptacle. Note: The Power Control feature is only functional through this receptacle. Do not connect bipolar active accessories to this receptacle.

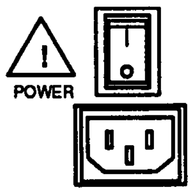


Patient Return Electrode Receptacle – This two–pin receptacle accepts the patient return electrode connector used in monopolar procedures. The receptacle will accept both REM (dual–section) and conventional patient return electrode connectors.

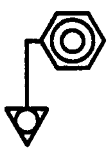
Rear Panel Functions



Input Power Source Switch – The Force generator will operate on either 115 V~ power (nominal) or 220 V~ power (nominal).

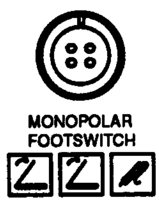


Power Switch – This switch assembly meets IEC power on/off requirements and includes a fuse and power cord receptacle. To reduce risk of fire, replace fuse with type and rating as marked.



Equipotential Ground Lug – This lug may be connected to earth ground with the furnished equipotential grounding cable.

Bipolar Footswitch Receptacle – This three–pin receptacle accepts a single–treadle bipolar footswitch connector. Only bipolar output can be activated from this receptacle.



Monopolar Footswitch Receptacle – This four–pin receptacle accepts a two–treadle Monopolar footswitch connector. Only monopolar output can be activated from this receptacle.

Audio Volume Control – The volume of the Cut, Coag, and Bipolar mode indicator tones produced when the generator is activated may be adjusted with this control. The volume of the audio tone for alarm conditions is not adjustable.

Section 5 Testing And Calibration

This section describes the procedures to functionally test and calibrate the Force 30, 40 Electrosurgical Generators.

Recommended Test Equipment

Description	Specifications
Voltmeter	AC true RMS, AC + DC true RMS Input impedance: 10M ohms Frequency range: 2 MHz max Resolution 0.05% of range (Fluke 8920A)
Wide Band Current Transformer	Output volts per amp: 0.100 (Pearson 411)
Decade Resistor	0 – 200 ohm, ± 1% , 1/4 W. 1 ohm steps. Non–inductive, make–before–break contacts.
Resistive Loads	100 (2 units), 200, 300, 500 ohm, all 250 watt, 1% tolerance Non–inductive (Dale NH–250)
Isolated Milliammeter	0 – 250 mA true RMS thermal converter (Simpson model 05350)
Oscilloscope	Tektronix 2445, or equivalent
Leakage Table	Per IEC specifications

If substitute equipment is used, it must meet or exceed the specifications of the recommended equipment.

General Test And Calibration Information

WARNING

High voltages exist on the power connector, power switch, the aluminum heatsinks, and certain components on the PSRF Printed Circuit Board.

Take appropriate precautions (such as use of isolated tools and equipment; use of the "one hand rule", etc.) when taking measurements in or troubleshooting in these areas of the generator.

CAUTION

The electrosurgical generator contains static–sensitive devices. Open chassis only at a static free work station. The technician must wear an ESD wrist strap while working within the chassis. Do not remove PCBAs unless necessary. Handle PCBAs only by the edges.

Observe Electrostatic Discharge (ESD) control procedures when working within the electrosurgical generator.

Use the generator chassis as reference ground. Select ground points carefully to avoid ground–loop errors.

When testing RF equipment, proper testing procedures must be followed in order to duplicate factory test data. Keep test leads as short as possible. Lead inductance and stray capacitance can affect meter readings adversely.

Use of uncompensated scope probes may cause large errors in the measurement of high voltage RF waveforms. When fractional microampere leakage currents are measured, accidental capacitive or inductive coupling may cause order–of–magnitude errors in the observed values.

Pretest Inspection

Front Panel

1. Check the following front panel receptacles for damage or corrosion:
   a. Bipolar
   b. Monopolar Handswitch
   c. Monopolar Footswitch
   d. Monopolar Handswitch (Power Control)
   e. Patient
   f. Footswitch Connector

2. Using a banana jack, check each connector for obstruction and secure fit. Use a 1/4 inch jack (universal active adapter) in the footswitching receptacle and check for a secure fit. If the connections are loose, replace the staked control panel assembly.

3. Check the ***Patient*** receptacle for damaged or bent pins. Check the center REM connection for a broken pin or obstruction.

Rear Panel

1. Check the following for damage or corrosion:
   a. On/Off switch
   b. Volume control
   c. Monopolar Footswitch Connector
   d. Bipolar Footswitch Connector
2. Remove the fuse and inspect fuse housing and cap for damage or corrosion.
3. Install fuse and check for secure fit.
4. Remove the power cord retaining bracket and power cord.
5. Disassemble the power cord connector and inspect for damage or corrosion. Ensure that connector screws are tight.
6. Assemble power connector and inspect power cord for damage.
7. Clean power cord with a damp cloth and mild detergent.

Chassis Inspection

1. Remove top cover.
2. Visually inspect each board for damaged components, wires, cracks and corrosion.
3. Check that all connectors are fully seated.
4. Install the top cover.
5. Wipe top cover and control panel with a damp cloth moistened with a mild detergent.
6. Install power cord assembly and secure with bracket and two screws.

Power Up Self–Test

1. Connect a footswitch to the generator.
2. Plug the generator power cord into a hospital grade, grounded receptacle.
3. Place the power switch on the rear panel to the ***On*** position.
4. Press the ***On/Off*** button on the front panel to illuminate the "power on" indicator.
5. The generator will conduct a self–test. Check the following:

   a. The generator first performs several internal tests which take approximately four seconds.

   b. The green "power" indicator illuminates.

   c. A power–up tone sounds at a frequency of 440 Hz at 45 (+5/–0) dB to 65 (+10/–5) dB.

   d. All digital display segments light (all "8"s) sequentially.

   e. Mode, alert, and power indicator lamps are illuminated sequentially.

6. After the internal self–check and display test, the generator displays the following:

   a. Each digital display indicates 1 watt.

   b. The ***Monopolar Footswitch*** indicator is illuminated.

   c. Bipolar is in the Standard mode.

   d. Coag is in the Desiccate mode.

   e. Cut is in the Pure Cut mode.

   f. The REM indicator is illuminated (if no patient return electrode connected to the generator). See Section 4, REM Alarm Indicator

   g. The ***Power Control*** indicator will illuminate only if a Power Control Pencil is installed.

If an error results from the self–tests during initialization or from any of the self– tests done during operation, dashes (– –) are displayed in the Bipolar and Coag displays and an error code (a number between 0 and 999) is displayed in the Cut display. During this time, a series of five alarm tones is sounded at a frequency of 659 Hz at a volume of 65 dB (+5 dB or –0 dB).

If several errors are detected, their codes are displayed in turn at a maximum rate of 1 every 12 seconds.

The error codes are listed at the end of this Section with explanations for each. All errors will prevent generator activation until the generator is turned off and back on and/or the problem is corrected.

7. Press the ***On/Off*** button to return to the Standby mode.

Calibration

General Instructions

Calibration is performed in 16 Steps. Each Calibration Step contains substeps that must be performed completely in order to continue to the next Calibration Step. Calibration Step 15 saves the calibration values.

If at any time an error code appears, check the error code list at the end of this Section and correct the error before proceeding.

An error code 91, which occurs after pressing the Bipolar Up key (to move to the next Calibration Step), indicates that the previous Step was unsuccessful. If this occurs, go back and try again. If it still occurs, there is a hardware problem with the circuit being calibrated. This problem must be corrected before the next Step can be done. Failure to correct error codes before proceeding or failure to follow these instructions may result in damage to the generator.

To maximize the accuracy of calibration, set the currents as close as possible (within ± 1 mA) to the value specified in the procedure.

All currents in this procedure are RMS unless indicated otherwise.

Setting Up for Calibration

1. Check that the power switch on the rear panel is set to the ***Off*** position.
2. Remove the six top cover retaining screws (three screws on each side and two on rear) and lift off the top cover.
3. Inspect interior of generator for loose screws, debris, and loose connector wiring.
4. Replace the top cover. The screws need not be replaced at this time.
5. Place the power switch on the rear panel to the ***On*** position.
6. Allow the generator to warm up for a minimum of ten minutes.

Multiplier Offset Calibration

1. Connect an oscilloscope probe to the following test points and adjust the corresponding potentiometer so that the measured frequency is approximately 1 kHz.

   R74, TP5 R112, TP6 R42, TP4

2. Place a drop of epoxy on each of the three potentiometer screws to ensure that they cannot be changed.
3. Turn R26 so that the wiper is at –12 volts (fully clockwise). (Do not apply epoxy to this screw yet.)
4. Press the ***On/Off*** button on the front panel to place the generator in the Ready mode.
5. When the self tests are complete, enter the Calibration mode.

REM Filter Board Calibration

1. Disconnect any load from the REM adapter.
2. Connect an oscilloscope probe fro the right side of R19 to ground and adjust the potentiometer R14 for maximum peak to peak output. The output must exceed 8.0 Vp–p. The frequency must be 70 kHz ± 4 kHz.
3. Connect a voltmeter from the left side of R13 to ground and adjust the potentiometer R8 for –2.00 volts DC.
4. Place a drop of epoxy on each potentiometer screw.

Calibration Steps

To enter the calibration mode, press the ***Reset***, ***Standard***, and ***Precise*** buttons simultaneously. The front panel will display the Calibration Step number in the Bipolar Display, and numerical information related to the current Step will appear in the Cut and Coag Displays. Step 16 does not have a display.

Step 1 – Model And Option Display And Dosage Error Offset Adjustment

1. Place a probe on TP12 and press the ***Cut Up*** button to start dosage error offset potentiometer calibration. (Frequency on C43, either side, or U13 pin 1 should change to 120 Hz.) The voltage at TP12 should be low (about 0 volts.)
2. Turn the potentiometer R26 until the voltage at TP12 just switches high (about 5 volts.)
3. Place a drop of epoxy on the potentiometer screw to ensure that it cannot be changed.
4. Press the ***Cut Up*** button to end dosage error offset potentiometer calibration.
5. Verify that the number displayed in the Cut window is identical to the model number on the upper left corner of the front panel.

   If the generator has Simultaneous Coag, verify that an S appears in the Coag display window.
6. Press the ***Bipolar Up*** button to proceed to calibration **Step 2**. If a dosage error occurs, repeat substeps 2 through 5.

Step 2 – Monopolar Calibration

1. Ensure that the speaker is plugged into the Interface Board, and replace the cover on the generator. (Failure to do so may result in inaccurate calibration of the generator.)
2. Connect a 300 ohm load across any monopolar active output and the patient return, with a current transformer around the active wire.
3. Activate the generator using the appropriate method for whichever output is connected to the load (for example, if using the 1/4 inch ***Monopolar Active Footswitch*** receptacle jack, activate the generator with the front or rear monopolar footswitch).
4. Use the ***Coag Up*** and ***Down*** buttons to increase and decrease the ECON setting (which is displayed in the Cut and Coag display windows) until the current is 600 mA. Note that holding down the key causes the value to increment by 10's, whereas individual key presses each result in a change of 1.

Note that the RF current should be 600 mA ± 200 mA before changing the ECON setting. If this is not the case, check the setup and the RF output circuitry for problems.

5. Deactivate the generator, then press the ***Bipolar Up*** button to proceed to calibration **Step 3**.

Step 3 – Bipolar Current Calibration

1. Connect a 100 ohm load across the bipolar output jacks with a current transformer around the active wire. Do not use a bipolar forceps cord for this Step; use standard test leads with banana plugs.
2. Toggle the ***Footswitch Select*** switch to ***Bipolar*** if the monopolar footswitch is connected to the front panel footswitch jack or connect a bipolar footswitch to the rear panel. Activate the generator using the footswitch.

3. Use the ***Coag Up*** and ***Down*** buttons to increase and decrease the ECON setting (which is displayed in the Cut and Coag display windows) until the current is 400 mA.

Note that the RF current should be 400 mA ± 100 mA before changing the ECON setting. If this is not the case, check the setup and the RF output circuitry for problems.

4. Deactivate the generator, then press the ***Bipolar Up*** button to proceed to calibration **Step 4**.

Step 4 – Bipolar Power And Voltage Calibration

1. Press either front panel footswitch pedal or the rear bipolar footswitch, to activate the generator.

2. Use the ***Coag Up*** and ***Down*** buttons to increase and decrease the ECON setting (which is displayed in the Cut and Coag display windows) until the current is 700 mA.

Note that the RF current should be 700 mA ± 200 mA before changing the ECON setting. If this is not the case, check the setup and the RF output circuitry for problems.

3. Deactivate the generator and press the ***Bipolar Up*** button to proceed to calibration **Step 5**.

Step 5 – Sense Power And Voltage Calibration

1. Connect a 500 ohm load across the bipolar output jacks with a current transformer around the active wire.

2. Press either front panel footswitch pedal or the rear bipolar footswitch to activate the generator.

3. Use the ***Coag Up*** and ***Down*** buttons to increase and decrease the ECON setting (which is displayed in the Cut and Coag display windows) until the current is 15 mA.

4. Deactivate the generator, then press the ***Bipolar Up*** button to proceed to calibration **Step 6**.

Step 6 – ECON Calibration

1. Perform the following substeps (2 through 4) for each available mode (Pure Cut, Blend 1, Fulgurate, Precise, etc.) with a 100 ohm load across the bipolar output jacks and a 300 ohm load connected to any active monopolar receptacle and the patient receptacle.

2. Press the footswitch or handswitch which controls the output jack of the mode selected, to activate the generator. The software will immediately set ECON to create a low power RF output.

3. The software will then change ECON to create a higher RF output.

4. The software will then reset ECON to 0 and deactivate the generator. It is now ready to be activated in the next mode.

5. Select the next mode and repeat substeps 2 through 4 until all modes are done.

6. Press the ***Bipolar Up*** key to proceed to calibration **Step 7**.

Step 7 – ICON Calibration

1. Perform substeps 2 and 3 for each available mode (Pure Cut, Blend 1, Fulgurate, etc.) using the following load values for the corresponding modes:

Standard bipolar	100 ohms
Precise bipolar	100 ohms
Pure Cut	200 ohms
Blend 1	200 ohms
Blend 2	200 ohms
Desiccate	200 ohms
Fulgurate	skip
Spray Coag	skip

2. Press the appropriate mode–selection button to activate the generator. The software will set the output power to a value based on the mode activated, and will find the appropriate ICON.

3. When ICON stops changing for the second time and the generator deactivates itself, release the activation input and set up the next mode to be calibrated.

4. When the calibration of all modes is completed, press the ***Bipolar Up*** button to proceed to calibration **Step 8**.

Step 8 – LCON Calibration

1. Place the generator on one end of the leakage table. Connect an electrosurgical pencil to the ***Monopolar Active Handswitch*** receptacle (not the Power Control receptacle) and a patient return electrode to the ***Patient*** receptacle. Connect, in series, a 200 ohm load from the pencil to an RF millammeter to the equipotential lug on the rear panel. Place a current transformer around the wire from the load to ground. Connect the current transformer to an RMS meter.

2. Perform the following two substeps in each of the monopolar modes (Pure, Blend 1, Blend 2, Desiccate, Fulgurate, and Spray). Note: Bipolar leakage calibration is not required.

3. Activate the RF output by pressing the appropriate key on the pencil and use the ***Coag Up*** and ***Down*** buttons to change LCON until the current is between 125 mA and 130 mA. The software will set the power to the maximum for that mode.

4. Activate the RF output in the same mode and use the ***Coag Up*** and ***Down*** buttons to change LCON until the current is $\leq$ 120 mA or until the LCON value will go no higher. The software will set the power to on half of the maximum for that mode and will limit the LCON value to 90% of the previous level.

Note: Once a mode is calibrated, it may not be recalibrated unless this calibration step is exited and re–entered. Only those modes which have been changed will be stored. Thus, only certain modes may be recalibrated, if desired.

5. Press the ***Bipolar Up*** button to proceed to **Step 9**.

Step 9 – Dosage Error Calibration

1. Press the ***Cut Up*** or ***Down*** button to start calibration. The software will ramp the dosage error frequency value down to determine the offset. This value is shown in the Coag display window. The software will then increase the frequency to 350 Hz, turn the dosage error gain test signal on, and find the dosage error gain test frequency.

2. When the frequency value stops changing and is set to 600 Hz, connect a 300 ohm load to any monopolar output receptacle and the patient receptacle, and connect a 100 ohm load to the bipolar output. Perform substeps 3 and 4 for both monopolar and bipolar (in either order).

3. Press the appropriate input to activate the generator in Pure Cut or Standard Bipolar. The software will activate the generator at 300 watts for monopolar, and at 50 watts for bipolar, and ramp the dosage error frequency down until there is a dosage error condition.

4. When the generator is no longer activated, release the footswitch and repeat substep 3 for the next mode. If both modes have been calibrated, press the ***Bipolar Up*** button to proceed to calibration **Step 10**.

Step 10 – REM Contact Quality Monitor Calibration At Open Circuit

1. Disconnect any load from the REM adapter.

2. Press the ***Cut Up*** or ***Down*** button to notify the software that the REM resistance has been set to an open load (generator will sound a tone to confirm key press).

3. Press the ***Bipolar Up*** button to proceed to calibration **Step11**.

Step 11 – REM Calibration at 10 Ohms

1. Connect a decade resistance box to the REM adapter and set it to 10 ohms.

2. Press the ***Cut Up*** or ***Down*** button to notify the software that the REM resistance has been set to 10 ohms (the generator will beep to confirm the key–press).

3. Press the ***Bipolar Up*** button to proceed to calibration **Step 12**.

Step 12 – REM Calibration at 135 Ohms

1. Set the decade resistance box to 135 ohms.

2. Press the ***Cut Up*** or ***Down*** button to notify the software that the REM resistance has been set to 135 ohms (the generator will sound a tone to confirm the key–press).

3. Press the ***Bipolar Up*** button to proceed to the next step. Note: **Step 13** is for Valleylab internal use only. The calibration will skip to **Step 14**.

Step 13 – Valleylab Use Only

This Step is for internal Valleylab use only.

Step 14 – Service Mode

This Step is for internal Valleylab use only. Press the ***Bipolar Up*** button to proceed to **Step 15**.

Step 15 – Save Calibration Values

1. When **Step 15** appears in the Bipolar Display, turn the generator ***Off*** by pressing the ***On/Off*** button on the front panel.

2. Wait at least 2 seconds, and then turn off AC line power by turning the rear panel ***Power*** switch ***Off***.

Step 16 – Adjust 100 ohm Current

1. Turn the rear power switch ***ON***. Press the ***ON/OFF*** button on the front panel to turn the generator ***ON***.
2. Connect a 100 ohm load across the 1/4 inch footswitching receptacle and the patient receptacle with a current transformer around the active wire.
3. Activate the generator in ***Pure Cut*** at maximum setting using the footswitch.
4. Turn R56 on the PSRF Board counterclockwise until current output is 1.5 ± 0.05 amperes.
5. Turn the generator ***Off***.

Summary Table of the Calibration Steps

Calibration Step	Bipolar Display	Cut Display	Coag Display
Model/Options*	1	Model Number (30,40)	Sim Option (– – – ,– – S)
Mono Analog	2	1000's digit of ECON	Lower 3 digits of ECON**
Bipolar Current	3	1000's digit of ECON	Lower 3 digits of ECON
Bipolar Power & Voltage	4	1000's digit of ECON	Lower 3 digits of ECON
Sense Power & Voltage	5	1000's digit of ECON	Lower 3 digits of ECON
ECON	6	1000's digit of ECON	Lower 3 digits of ECON
ICON	7	1000's digit of ICON	Lower 3 digits of ICON
LCON	8	1000's digit of LCON	Lower 3 digits of LCON
Dosage Error	9		Dosage frequency
REM at open	10		REM target (999 = open)
REM at 10 ohms	11		REM target (10 ohms)
REM at 135 ohms	12		REM target (135 ohms)

* Factory set; not adjustable in the field.

** Use Coag Up/Down keys to change setting

Error Codes

Code	Diagnosis
0	IIC output fail channel 0 (bipolar/cut display) – Display Board U6
1	IIC output fail channel 1 (cut/coag display) – Display Board U11
2	IIC output fail channel 2 (led display) – Display Board U9
3	IIC output fail channel 4 (audio volume dac) – Interface Board U26
4	IIC output fail channel 5 (coag up key, etc.) – Display Board U8
5	IIC output fail channel 6 (cut dwn key, etc) – Display Board U7
6	IIC output fail channel 7 (micro key, etc) – Display Board U5
7	IIC output fail channel 8 (relays, etc) – Interface Board U29
9	EEPROM checksum error
10	IIC output not being written correctly to channel 8 – Interface Board U29
26	unable to calibrate ECON due to bad frequency reading on power or power_bip
35	DOSAGE FREQ OUT OF BOUNDS
36	DOSAGE FREQ OUT OF BOUNDS
39	EEPROM failed to respond – Display Board U1
41	EEPROM read failed – Display Board U1
45	EEPROM write failed – Display Board U1
55	invalid handswitch reading – Interface Board handswitch circuit problem
56	HSI overflow – Interface Board frequencies out of bounds
57	WARNING – HSI4 interrupt – Interface Board frequencies out of bounds
73	unable to calibrate monopolar power due to freq out of range – Interface Board power sense
74	unable to calibrate bipolar power and voltage due to freq out of range – Interface Board
75	unable to calibrate bipolar current due to freq out of range – Interface Board
84	SEVERE RAM check failed – Microcontroller Board U25
86	dosage error gain test failed – recalibrate both power multipliers and dosage error
87	dosage error while active

Code	Diagnosis
91	calibration failed
100	conversion setup error – Interface Board – FREQ0 (REM) out of range
101	conversion setup error – Interface Board – FREQ1 (Bipolar V^2) out of range
102	conversion setup error – Interface Board – FREQ2 (Bipolar I^2) out of range
103	conversion setup error – Interface Board – FREQ3 (Bipolar Power) out of range
104	conversion setup error – Interface Board – FREQ3 (Monopolar Power) out of range
108	one or more of the following keys may be stuck: Coag Up, Coag Dwn, Spray Coag, Fulgurate, Desiccate, BL2, BL1, Cut Up
109	one or more of the following keys may be stuck: Cut Dwn key, Pure Cut key
110	one or more of the following keys may be stuck: Precise, Standard, Bipolar Up, Bipolar Dwn, Ftsw Sel, Rst, On
111	rear bipolar footswitch may be stuck
112	rear coag footswitch may be stuck
113	rear cut footswitch may be stuck
114	front coag footswitch may be stuck
115	front cut footswitch may be stuck
116	monopolar handswitch accessory cut key may be stuck
117	monopolar handswitch accessory coag key may be stuck
118	bipolar handswitching forcep input may be stuck
119	monopolar power control handswitch accessory cut key may be stuck
120	monopolar power control handswitch accessory coag key may be stuck
121	monopolar power control handswitch accessory up key may be stuck
122	monopolar power control handswitch accessory down key may be stuck
124	dosage error not true on start up – adjust pot or correct circuit problem
130	EPROM checksum test failed – bad EPROM – re–burn and try again
135	EEPROM segment 0 (cal_u_table) value out of range
136	EEPROM segment 1 (audio_table) value out of range
137	EEPROM segment 2 (econ_table) value out of range
138	EEPROM segment 3 (icon_table) value out of range

Code	Diagnosis
139	EEPROM segment 4 (icon_offset_table) value out of range
141	EEPROM segment 6 (gen_settings_table) value out of range
144	EEPROM segment 9 (Icon_table) value out of range
145	EEPROM segment 10 (Icon_offset_table) value out of range
161	dosage error won't clear – need to calibrate dosage error

Section 6 Component Replacement

WARNING

High voltages exist on the power connector, power switch, the aluminum heatsinks, and certain components on the PSRF Printed Circuit Board.

Ensure that the equipment is disconnected from the AC line before disassembling the generator or replacing components.

CAUTION

The electrosurgical generator contains electrostatic sensitive components. When repairing the generator, work at a static control workstation. Wear a grounding strap when handling electrostatic sensitive components. Handle the circuit boards by their nonconductive edges. Use an antistatic container for transport of electrostatic sensitive components and circuit boards.

The following are guidelines that relate to installing and mounting components on the circuit boards.

1. Install all nonpolarized components so that the value, tolerance, and part number are visible.
2. Install polarized components so that the positive symbol (+), negative symbol (–), or other polarization markings are visible and the correct polarity.
3. Components with coating on the leads may have the coating removed only to the point where that lead enters the component body. For example, use a soldering iron to remove coating on the leads.
4. Center the component body between bends (except for miniature diodes, it is desirable to leave the cathode lead longer than the anode lead for identification). Line up the leads, where required, with the mounting holes prior to installation.
5. Position lead–mounted components so that the major axis of the component is parallel to any two of the three major planes (sides) of the Unit. Mechanically support any component having a weight in excess of 1/2 ounce by means other than the leads.
6. Properly insulate all component leads which are, or could be, forced into a shorting condition with another component lead or circuit.
7. Do not stress component leads between mounting pins. Provide an adequate strain relief to prevent damage to the component and solder pins.
8. When installing components on circuit boards with the circuitry on the component side of the board, insulate the sleeving of the components with metallic bodies.
9. Mount resistors rated at 2 watts or less flush to the circuit board (0.0 – 0.006 inch clearance).
10. Mount resistors of greater than 2 watts or more 0.25 ± 0.06 inch from the surface of the printed circuit board.
11. Radial lead capacitors (dip): if installation requires bending the lead, the bend should be no closer to the body than 0.06 inch. Mounting height should be 0.032 – 0.25 inch from the board surface to the potting material .

12. Soldered surfaces should be clean and free of contaminants that would result in poor soldering.
13. Control soldering temperature to prevent damage to components or circuitry.
14. Remove flux residue on the board surface. For example, use isopropyl alcohol and a brush to remove the flux residue.

Section 7 Factory Service

Returning the Generator for Service

Before you return the electrosurgical generator to Valleylab, call the Valleylab Service Department (1–800–255–8522) for a Return Authorization Number, or call your Valleylab representative for assistance. Have the following information ready:

- Hospital/clinic name/customer number
- Technician's name
- Telephone number
- Department/address
- City, state, and ZIP code
- Model number
- Serial number
- Description of problem
- Type of repair to be done

Attach a tag with this same information to the generator when shipping it for service.

Returning the Force 30, 40 Generator

Package the generator in the original packaging container, if available. If the original packaging is not available, use the following guidelines for packaging:

- Use a packing container with double wall construction.
- Place a plastic bag over the generator.
- Use non–abrasive packing material that will not damage the surface of the generator.
- Use four crossed straps to secure the box.

Returning Circuit Boards and Other Subassemblies

When packaging circuit boards or other subassemblies, use the following guidelines:

- Place each PCBA or subassembly in an ESD (Electrostatic Discharge) bag or container.
- Provide a separate packing container for each PCBA or subassembly.

Ordering Replacement Parts

When ordering replacement parts for the generator, include this information:

- Model Number (located on the rear of the unit)
- Serial Number (located on the rear of the unit)
- Part Number (refer to Section 8, "Service Parts List")

Section 8 Service Parts List

All components must be replaced with parts of identical construction and value. Replacement part ratings and tolerances must be equal or better than original. Generator performance can be adversely affected by substitution of lower grade parts.

Note: SAFETY CRITICAL COMPONENTS must be replaced only with parts obtained from Valleylab. Patient safety can be adversely affected by use of alternate components. Safety Critical Components are marked with an asterisk (*) in the following listings:

Display PCBA 201 275 000

REFERENCE DESIGNATOR	DESCRIPTION	VALLEYLAB PART NUMBER
Resistors		
R1, 4, 8, 13, 14, 19, 23, 26, 29, 32, 36, 39, 47, 50	56k Ω ± 5%, 1/4W	234 024 105
R2, 5, 7, 12, 15, 18, 22, 27, 30, 33, 37, 40, 46, 49	100 Ω ± 5%, 1/4W	234 024 039
R3, 6, 9, 10, 16, 17, 21, 28, 31, 34, 38, 41, 45, 48	12k Ω ± 5%, 1/4W	234 024 089
R11, 24, 25	4.3 k Ω ± 5%, 1/4W	234 024 078
R20	43 Ω ± 5%, 1/2W	234 014 081
R35	51 Ω ± 5%, 1/2W	234 014 083
R42	1.2 k Ω ± 5%, 1/4W	234 024 065
R43	750 Ω ± 5%, 1/4W	234 024 060
R44	82 Ω ± 5%, 1/4W	234 024 037
R51	1 Ω ± 5%, 1/2W	234 014 046
R52	1M Ω ± 5%, 1/4W	234 024 135
R53, 54	100 Ω ± 5%, 1/2W	234 014 088
R55, 56	1k Ω ± 5%, 1/4W	234 024 063
RA1 – 4	1k SIP	234 100 134
Capacitors		
C1, 10, 16, 17, 20, 23, 30, 31, 32	0.1 µf ± 20%, 50V	204 118 007
C2, 3, 13, 14, 18, 19, 24, 25, 27, 28	100pf ± 15%, 100V	204 200 013
C4 – 9	1 µf ± 20%, 50V	204 118 014
C11, 12, 21, 22	0.01 µf ± 20%, 50V	204 118 001
C15, 26, 29	0.0033 µf ± 20%, 100V	204 200 031
C33	0.001 µf ± 20%, 100V	204 200 025
Integrated Circuits		
U1*	X2402	210 720 008
U2, 3	LM7805	210 300 083
U4	LM7812	210 300 085
U5, 7, 8	PCF8574	210 760 016
U6, 9, 11	SAA1064	210 800 015
U10	DS3669	210 800 017

* If this component is replaced, the generator must be returned to Valleylab for full recalibration.

Transistors

Q1 - 6	2N3904	239 015 000
Q7	VN10KM	239 200 012
Q8, 9, 12, 13, 15, 16	IRFD110	239 200 027
Q10, 11, 14, 17	IRFD9120	239 200 028

LEDs/Lamps

D1–8	7–Segment Display	239 750 051
D9, 10, 11	Lamp RF Ind. 12V	215 200 077
D12–14, 16–18, 20–26	LED	239 750 063
D27, 28	Bicolor Lamp (red/green)	239 750 052

Miscellaneous

OPT1	Reflective Sensor OPB703A	239 750 053
CR1–3	Diode 1N4148	239 014 000
	Heatsink	223 400 546

Interface PCBA 201 276 002

REFERENCE DESIGNATOR	DESCRIPTION	VALLEYLAB PART NUMBER

Resistors

R1, 15, 50, 73, 76, 93	75 k Ω ± 5%, 1/4W	234 024 108
R2	910 k Ω ± 5%, 1/4W	234 024 134
R3, 9, 53, 65, 66, 68, 79, 80, 89	33.2 k Ω ± 1%, 1/8W	234 201 435
R4, 7, 16, 46, 51, 75, 91, 104, 111	100 Ω ± 5%, 1/4W	234 024 039
R5	7.5 k Ω ± 1%, 1/8W	234 201 373
R6, 70	13 k Ω ± 1%, 1/8W	234 201 396
R8, 14, 43, 72, 92	27 k Ω ± 5%, 1/4W	234 024 097
R10, 11	100 k Ω ± 1%, 1/8W	234 201 481
R12, 13, 34, 35, 84, 85	100 k Ω ± 5%, 1/4W	234 024 111
R17, 56	6.49 k Ω ± 1%, 1/8W	234 201 367
R18	56 k Ω ± 5%, 1/4W	234 024 105
R19, 21, 28, 29, 30, 32, 39, 40, 44, 45, 94, 102	330 Ω ± 5%, 1/4W	234 024 051
R20	1M Ω ± 5%, 1/4W	234 024 135
R23	464 Ω ± 1%, 1/8W	234 201 257
R24, 110	332 Ω ± 1%, 1/8W	234 201 243
R25, 86	120 k Ω ± 5%, 1/4W	234 024 113
R26	TRIMPOT 5 k	236 010 006
R27	47 k Ω ± 5%, 1/4W	234 024 103
R31, 36, 37, 38, 59, 60, 90, 103, 107	10 k Ω ± 5%, 1/4W	234 024 087
R33	51.1 k Ω ± 1%, 1/8W	234 201 453
R41, 77, 87, 97	220 k Ω ± 5%, 1/4W	234 024 119
R42, 74, 112	TRIMPOT 10 k	236 010 007
R47, 98	1 k Ω ± 5%, 1/4W	234 024 063
R48	3.01 k Ω ± 1%, 1/8W	234 201 335

R49, 69, 71	2.00 k Ω ± 1%, 1/8W	234 201 318
R52	56.2 k Ω ± 1%, 1/8W	234 201 457
R54, 64, 67, 78	332 k Ω ± 1%, 1/8W	234 201 531
R55	6.19 k Ω ± 1%, 1/8W	234 201 365
R57	12.1 k Ω ± 1%, 1/8W	234 201 393
R58	4.32 k Ω ± 1%, 1/8W	234 201 350
R61	470 Ω ± 5%, 1/4W	234 024 055
R62	15 k Ω ± 1%, 1/8W	234 201 402
R63	249 k Ω ± 1%, 1/8W	234 201 519
R81	200 k Ω ± 5%, 1/4W	234 024 118
R82	5.11 k Ω ± 1%, 1/8W	234 201 357
R83	2.67 k Ω ± 1%, 1/8W	234 201 330
R88	200 k Ω ± 1%, 1/8W	234 201 510
R95, 105, 106, 108, 109	200 Ω ± 5%, 1/4W	234 024 046
R96	3.9 k Ω ± 5%, 1/4W	234 024 077
R99	91 k Ω ± 5%, 1/4W	234 024 110
R100	6.2 k Ω ± 5%, 1/4W	234 024 082
R101	3.3 k Ω ± 5%, 1/4W	234 024 075

Capacitors

C1, 6, 24, 44, 62, 67	0.01µf ± 10%, 50V NPO	204 200 284
C2, 5, 8, 10, 13, 16, 18, 19, 21, 22, 26–31, 33–37, 39, 42, 43, 48, 49, 50, 53, 55, 57, 60, 63, 66, 68,69, 72, 73, 74, 76–81, 86, 87, 95, 101, 102	0.01 µf ± 20%, 50V	204 118 001
C3, 11, 12, 47, 54, 64	1000pf ± 10%, 50V NPO	204 200 273
C7, 17, 52, 59, 71, 84	1000pf ± 15%, 100V	204 200 025
C9, 51, 58, 70	22 pf ± 15%, 100V	204 200 005
C14, 25, 32	10 µf ± 10%, 25V	204 102 008
C15, 23, 40, 56, 75	1500 pf ± 10%, 50V NPO	204 200 275
C38, 46, 82, 83, 85, 89, 90, 93, 94, 98, 106, 107, 117–124, 127, 128	0.1 µf ± 20%, 50V	204 118 007
C41, 99, 100, 103–105, 133	1 µf ± 20%, 50V	204 118 014
C45	0.47 µf ± 20%, 50V	204 118 012
C61, 65	330pf ± 5%, 50V NPO	204 200 268
C88	220 pf ± 20%, 35V	204 500 124
C91, 92, 96, 97	100pf ± 5%, 100V	204 200 013
C108–110, 113–115, 125, 126, 129, 130	10 pf ± 20%, 6 kV	204 200 286
C111, 112	0.0022 µf ± 10%, 6 kV	204 025 044
C116, 131, 132	0.0047 µf ± 20%, 6 kV	204 025 050

Integrated Circuits

U1, 7, 18, 24	LF412	210 400 016
U2, 14, 17, 19	XR–2228	210 100 030
U3, 5, 11, 16, 20	LM331	210 740 007
U6	74HC14	210 230 004
U8, 15, 21	DG445	210 200 041
U9	LM339	210 300 015
U10	LM336	210 300 016
U12, 22	LM393	210 300 011
U13	LM2917	210 750 003
U23	74HC00	210 300 007
U25	LM386	210 400 019
U26	TDA8444	210 750 004
U27	LM7805C	210 300 083
U28, 33	LM7812C	210 300 085
U29	PCF8574	210 760 016
U30	LM7912C	210 300 087
U31	74HC74	210 230 006
U32	DS3669	210 800 017

Diodes

CR1, 7, 12, 13, 20–24	1N4148	239 014 000
CR2, 3, 6, 8–10, 14–19	1N5236B	239 600 636
CR11	1N5817	239 700 005
CR25–29	VSB52	239 700 025

Relays

K1 – 4	HV Reed Relay	230 009 000

Miscellaneous

Q1–3	FET VN10KM	239 200 012
Q4	FET IRFD110	239 200 027
T1, 8	Inductor, Current Sense	251 300 008
T2–7	Transformer, IsoBloc	251 300 006
	Heatsink	223 400 546

Microprocessor PCBA — 201 278 003

REFERENCE DESIGNATOR	DESCRIPTION	VALLEYLAB PART NUMBER
Resistors		
R1, 3, 6–9, 14–22, 24–28, 34–39	330 Ω ± 5%, 1/4W	234 024 051
R2	100 k Ω ± 5%, 1/4W	234 024 111
R4, 23	10 k Ω ± 5%, 1/4W	234 024 087
R5	1.8 k Ω ± 5%, 1/4W	234 024 069
R10	1 k Ω ± 5%, 1/4W	234 024 063
R11	10 k Ω ± 1%, 1/8W	234 201 385
R12	6.81 k Ω ± 1%, 1/8W	234 201 369
R13, 29–32	2.2 k Ω ± 5%, 1/4W	234 024 071
R33	270 Ω ± 5%, 1/4W	234 024 049
RA1, RA3	Resistor Array 3.3 k	234 100 097
RA2	Resistor Array 1 k	234 100 168
Capacitors		
C1, 2, 5–7, 9, 13, 14, 17, 21–23, 26, 28, 35–38, 41–52, 54–58, 65–70, 72–77, 79, 81, 84	0.01 µf ± 20%, 50V	204 118 001
C3, 4, 8, 10–12, 15, 16, 18, 19, 24, 27, 29–31, 53, 59–64, 71, 78, 83, 85, 86, 88	0.1 µf ± 20%, 50V	204 118 007
C20, 25, 87	1 µf ± 20%, 50V	204 118 014
C32–34, 39, 40	330 pf ± 5%, 100V	204 200 019
C80, 82	22 pf ± 5%, 100V	204 200 005
Integrated Circuits		
U1	DS8921	210 800 013
U2	74HC393	210 220 393
U3	74HC02	210 230 011
U4	74HC240	210 230 009
U5	LM393	210 300 011
U6	LM336	210 300 016
U7, 12	DG445	210 200 041
U8	LM339	210 300 015
U9	LF444	210 400 017
U10	79L12	210 300 092
U11, 14, 15	74HC14	210 230 004
U13	LM78L12	210 300 091
U16	DAC1230	210 750 005
U17, 19	DAC1006	210 750 000
U18	74HC138	210 230 003
U20, 23	74HC373	210 230 001
U21	DS1232	210 760 015
U22	80C196	210 710 004
U24	27512 EPROM	210 730 092
U25	6264 SRAM	210 770 001

U26	PAL14L4	210 790 005
U27	LM7805CT	210 300 083

Transistors

Q1, Q2	VN10KM	239 200 012

Diodes

CR1–3	1N4148	239 014 000

Crystals

X1	11 MHz	250 010 015

Transformers

T1, 2, 3	Dual Pulse Transformer	251 300 010

Miscellaneous

	Heatsink	223 400 546

Power Supply PCBA 201 277 000

REFERENCE DESIGNATOR	DESCRIPTION	VALLEYLAB PART NUMBER

Resistors

R1, 2	20 k Ω ± 5%, 8W	234 000 017
R3, 4	Thermistor	240 003 003
R5, 7, 10, 12	51 Ω ± 5%, 1/4W	234 024 032
R6, 8, 11, 13, 37, 42, 44, 49, 54, 77, 81, 82, 87, 89, 91, 93, 95, 96	1 k Ω ± 5%, 1/4W	234 024 063
R9	150 Ω ± 5%, 20W	234 400 251
R14, 84	100 Ω ± 5%, 1/4W	234 024 039
R15	6.98 k Ω ± 1%, 1/8W	234 201 370
R16	1.8 k Ω ± 5%, 1/4W	234 024 069
R17, 20	27 Ω ± 5%, 1/4W	234 024 025
R18, 19	4.7 Ω ± 5%, 1/2W	234 014 060
R21	150 Ω ± 5%, 8W	234 400 250
R22, 40	200 k Ω ± 5%, 1/4W	234 024 118
R23	1.6 k Ω ± 5%, 1/4W	234 024 068
R24, 31–34, 39, 46, 66, 78	10 k Ω ± 5%, 1/4W	234 024 087
R25	2.7 k Ω ± 5%, 1/4W	234 024 073
R26, 64, 71, 73–75	100 k Ω ± 5%, 1/4W	234 024 111
R27	330 Ω ± 5%, 1/4W	234 024 051
R28	68 k Ω ± 5%, 1/4W	234 024 107
R29, 79	10 Ω ± 5%, 1/4W	234 024 015
R30	787 Ω ± 1%, 1/8W	234 201 279
R35	39 k Ω ± 5%, 1/4W	234 024 101

R36, 41	2 k Ω ± 5%, 1/4W	234 024 070
R38, 50, 83	10M Ω ± 5%, 1/4W	234 024 158
R43	91 k Ω ± 5%, 1/4W	234 024 110
R45	430 Ω ± 5%, 1/4W	234 024 054
R47	75 k Ω ± 5%, 1/4W	234 024 108
R48, 60	20 k Ω ± 5%, 1/4W	234 024 094
R51	390 Ω ± 5%, 1/4W	234 024 053
R52	9.09 Ω ± 1%, 1/8W	234 201 381
R53, 68	470 Ω ± 5%, 1/4W	234 024 055
R55, 72	5.1 k Ω ± 5%, 1/4W	234 024 080
R56, 65	Trimpot 20 k	236 200 080
R57	430 k Ω ± 5%, 2W	234 024 126
R58	51 k Ω ± 5%, 1/4W	234 024 104
R59	30 k Ω ± 5%, 1/4W	234 024 098
R61	47 k Ω ± 5%, 1/4W	234 024 103
R62	270 k Ω ± 5%, 1/4W	234 024 121
R63	18 k Ω ± 5%, 1/4W	234 024 093
R67	4.7 k Ω ± 5%, 1/4W	234 024 079
R69, 70	510 Ω ± 5%, 1/2W	234 014 096
R76	2.2 k Ω ± 5%, 1/4W	234 024 071
R85	27 k Ω ± 5%, 1/2W	234 014 006
R86, 88, 90, 92, 94	4.7 Ω ± 5%, 1/4W	234 024 007
R97, 98	150 Ω , 50W	234 003 005

Capacitors

C1, 2	1000 µf +50% – 10%, 400V	204 500 159
C3	2 µf ± 10%, 400V	204 400 001
C4	0.0015 µf ± 5%, 500V	204 105 030
C5	1 µf ± 10%, 250V	204 400 153
C6, 7, 32, 34, 36, 38, 40, 83, 102	1 µf ± 20%, 50V	204 118 014
C8, 10, 12, 16, 22, 25, 81, 84, 87, 90, 97	0.01 µf ± 20%, 50V	204 118 001
C9, 13–15, 18–21, 23, 24, 26, 27, 29, 31, 33, 35, 37, 39, 41–47, 49, 55, 57, 60, 63, 64, 65, 72, 73, 76–79, 82, 85, 88, 91, 98, 101	0.1 µf ± 20%, 50V	204 118 007
C11	0.47 µf ± 20%, 50V	204 118 012
C17	180 pf ± 20%, 100V	204 200 016
C28	1500 pf ± 10%, 50V NPO	204 200 275
C30	680 pf ± 5%, 500V	204 105 022
C48	330 pf ± 15%, 100V	204 200 019
C50, 59	1000 pf ± 15%, 100V	204 200 025
C51, 53, 58, 62	0.047 µf ± 20%, 50V	204 118 005
C52, 75	220 pf ± 10%, 50V NPO	204 200 266
C54, 61	0.33 µf ± 20%, 50V	204 118 011
C56	750 pf ± 10%, 500V	204 106 031
C66, 67	15 µf ± 10%, 200V	204 400 150
C68, 69	4700 µf +30% – 20%, 35V	204 500 158
C70, 71	470 µf +30% – 20%, 35V	204 500 125

C86, 89, 92, 99, 100	22 µf ± 20%, 35V	204 102 030
C93	9100 pf ± 5%, 500V	204 085 007
C94, 95	7500 pf ± 5%, 500V	204 080 000
C103	100 pf ± 5%, 100V	204 200 013

Integrated Circuits

U1	UC3825	210 300 081
U2	8 MHz X–TAL	250 010 017
U3, 6	74F393	210 220 394
U4	82S185A PROM Programmed	210 730 088
U5	74HC74	210 230 006
U7	16L8 PAL Programmed	210 790 006
U8	74HC123	210 230 012
U9	16L8 PAL Programmed	210 790 007
U10	LM7912C	210 300 087
U11, 14, 23, 29	LM7812	210 300 085
U12	LM7805	210 300 083
U13	LM7905	210 300 093
U15, 16, 17, 22	LT1016	210 410 000
U18	TL052	210 400 020
U19	DG445	210 200 041
U20	MC34082	210 400 021
U21	LM319	210 410 001
U24–28	TSC4429	210 800 014

Diodes

CR1–4	FES8JT	239 700 051
CR5–15, 27, 28, 30, 31, 36	1N4148	239 014 000
CR16, 17	1N5228	239 075 000
CR18–20	Full Wave Bridge 200V	239 700 050
CR21	1N5239	239 600 638
CR22–25	1N5235	239 600 637
CR26	LED	239 750 011
CR32–35	MUR880	239 700 055
CR37	1N5231B	239 600 003
CR80	MDA3504	239 700 003

Transistors

Q1–4	IRFBC40	239 200 026
Q5, 10, 12, 13	VN10KM	239 200 012
Q6, 8	IRFD110	239 200 027
Q7, 9	IRFD9120	239 200 028
Q11	2N3906	239 047 000
Q14–17	APT8075	239 200 033
Q18	BUZ80	239 200 020

Transformers

T1	Switching Transformer	251 200 047
T2	Pulse Transformer	251 300 014
T3, 5	Transformer PE–52686	251 300 008
T6	RF Output Transformer	251 200 052

Miscellaneous

F1	Fuse, F6.3 Amp	215 100 041
K1	Relay AZ421	230 007 002
L1	Inductor, 0.75mH	251 039 000
L2	Cut Inductor, 4.1 µH	251 100 077
2	Heatsink	223 400 521
16	Heatsink	223 400 508
17	Heatsink	223 400 529
25	Heatsink	223 400 546
39	Heatsink	223 400 543

REM Filter PCBA 201 299 000

REFERENCE DESIGNATOR	DESCRIPTION	VALLEYLAB PART NUMBER
Resistors		
R1–4	100 k Ω ± 5%, 1/4W	234 024 111
R5, 12	15 k Ω ± 5%, 1/4W	234 024 091
R6, 9–11	5.6 k Ω ± 5%, 1/4W	234 024 081
R7	1 k Ω ± 5%, 1/4W	234 024 063
R8	Trimpot 2 k Ω	236 010 105
R13	10 k Ω ± 5%, 1/4W	234 024 087
R14	Trimpot 20 k Ω	236 010 108
R15, 22	8.2 k Ω ± 5%, 1/4W	234 024 085
R17, 18	2 k Ω ± 5%, 1/4W	234 024 070
R19, 24	4.7 k Ω ± 5%, 1/4W	234 024 079
R21	12 k Ω ± 5%, 1/4W	234 024 089
Capacitors		
C1–5, 14, 15, 19–21	0.01 mf ± 20%, 50V	204 118 001
C6, 12, 13	1.0 µf ± 20%, 50V	204 118 014
C7, 8, 9	0.1 µf ± 20%, 50V	204 118 007
C10, 11	10 µf ± 10%, 25V	204 102 008
C16, 17	0.22 µf ± 10%, 250V	204 400 120
C18	330 pf ± 5%, 500V	204 105 014
Integrated Circuits		
U1, 5	IC Quad Analog Switch	210 200 041
U2	LF412	210 400 016
U3	74HC14	210 230 004
U4	4013B	210 027 001
U6	LM393N	210 300 011
Transformers		
T1	Transformer – RF Input	202 900 017

Section 9 Assemblies and Schematics

Electronic Interface Between Boards

Cable # 1: Low Voltage Interconnect Cable
Pin Assignments

1	Frame Ground
2	digital ground
3	IIC–DATA
4	digital ground
5	IIC–CLK
6	digital ground
7	IIC–INT0
8	digital ground
9	+9 unregulated
10	+15 unregulated
11	IIC–INT1
12	digital ground
13	IIC–INT2
14	digital ground
15	+5 IIC
16	digital ground
17	digital ground
18	AUDIO–FREQ
19	digital ground
20	VPOT
21	digital ground
22	DOS–FREQ
23	digital ground
24	DOSERR\
25	digital ground
26	FREQ0
27	digital ground
28	FREQ1
29	digital ground
30	FREQ2
31	digital ground
32	FREQ3
33	digital ground
34	BIPHSW
35	digital ground
36	ACC–CUT
37	digital ground
38	ACC–COAG
39	digital ground
40	ISOCLK
41	digital ground
42	HSW0
43	digital ground
44	HSW1
45	digital ground
46	HSW2
47	analog ground
48	–15 unregulated
49	analog ground
50	+15 unregulated

Connector #1: Microcontroller Board to PSRF Board

Signals A15 through C16 are for the isolated footswitch circuits. The remaining signals are low voltage analog and digital lines.

A1	IIC–DATA
B1	IIC–CLK
C1	IIC–INT0
A2	IIC–INT1
B2	IIC–INT2
C2	AUDIO–FREQ
A3	digital ground
B3	DOS–ERR\
C3	DOS–FREQ
A4	digital ground
B4	FREQ0
C4	FREQ1
A5	digital ground
B5	FREQ2
C5	FREQ3
A6	digital ground
B6	BIPHSW
C6	ACC–CUT
A7	ACC–COAG
B7	ISOCLK
C7	HSW0
A8	digital ground
B8	HSW1
C8	HSW2
A9	digital ground
B9	MODE0
C9	MODE1
A10	digital ground
B10	MODE2
C10	CUTREL
A11	RF–RESET
B11	RF–LMT
C11	ECON
A12	ICON
B12	LCON
C12	AUTOPOT
A13	–15 unregulated
B13	+15 unregulated
C13	+9 unregulated
A14	reserved for isolation
B14	reserved for isolation
C14	reserved for isolation
A15	RFJBIP
B15	RFJCOG
C15	RFJCUT
A16	FFJCOG
B16	FFJCUT
C16	FJCOM

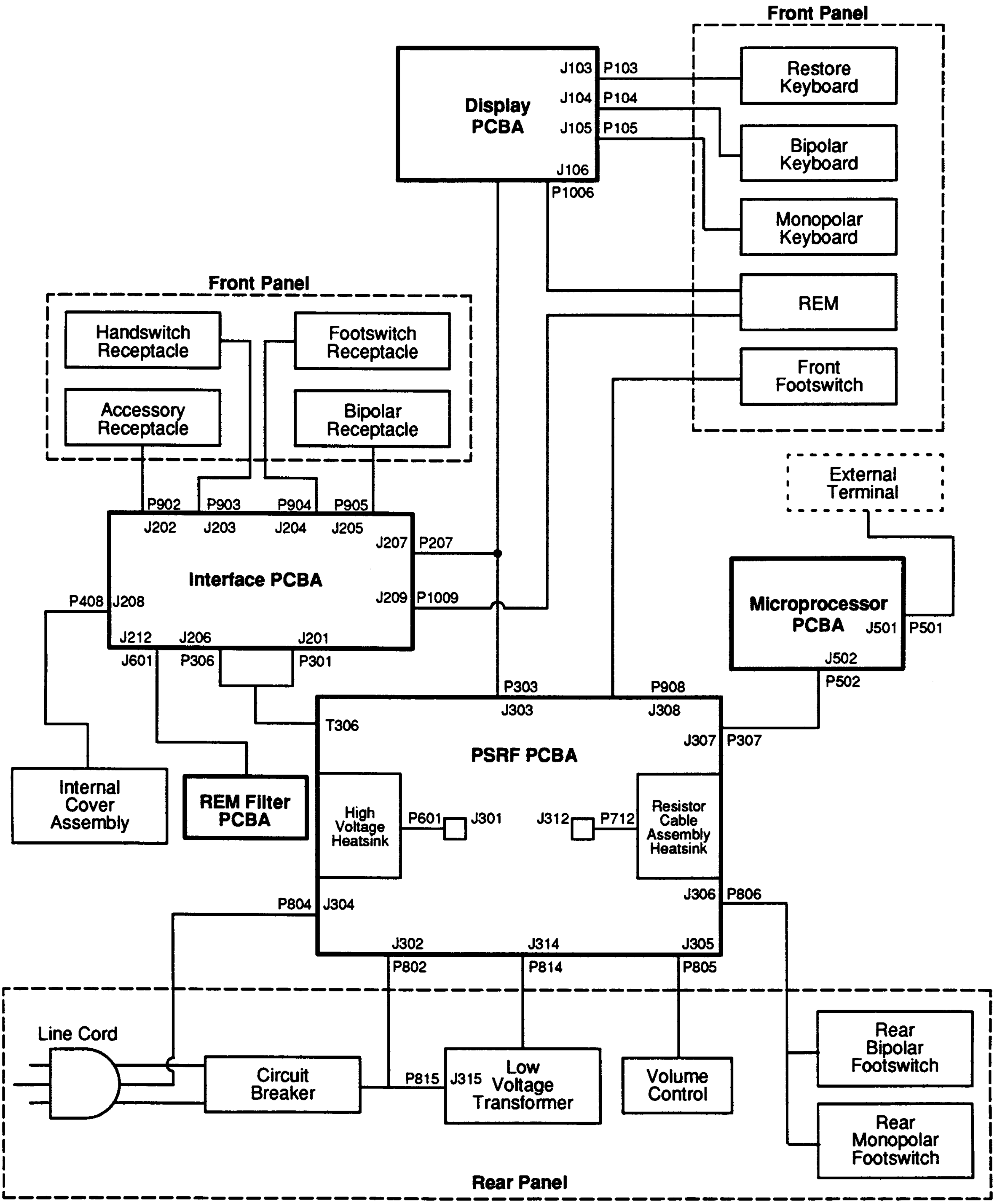


Figure 9.1 System Interconnect Diagram

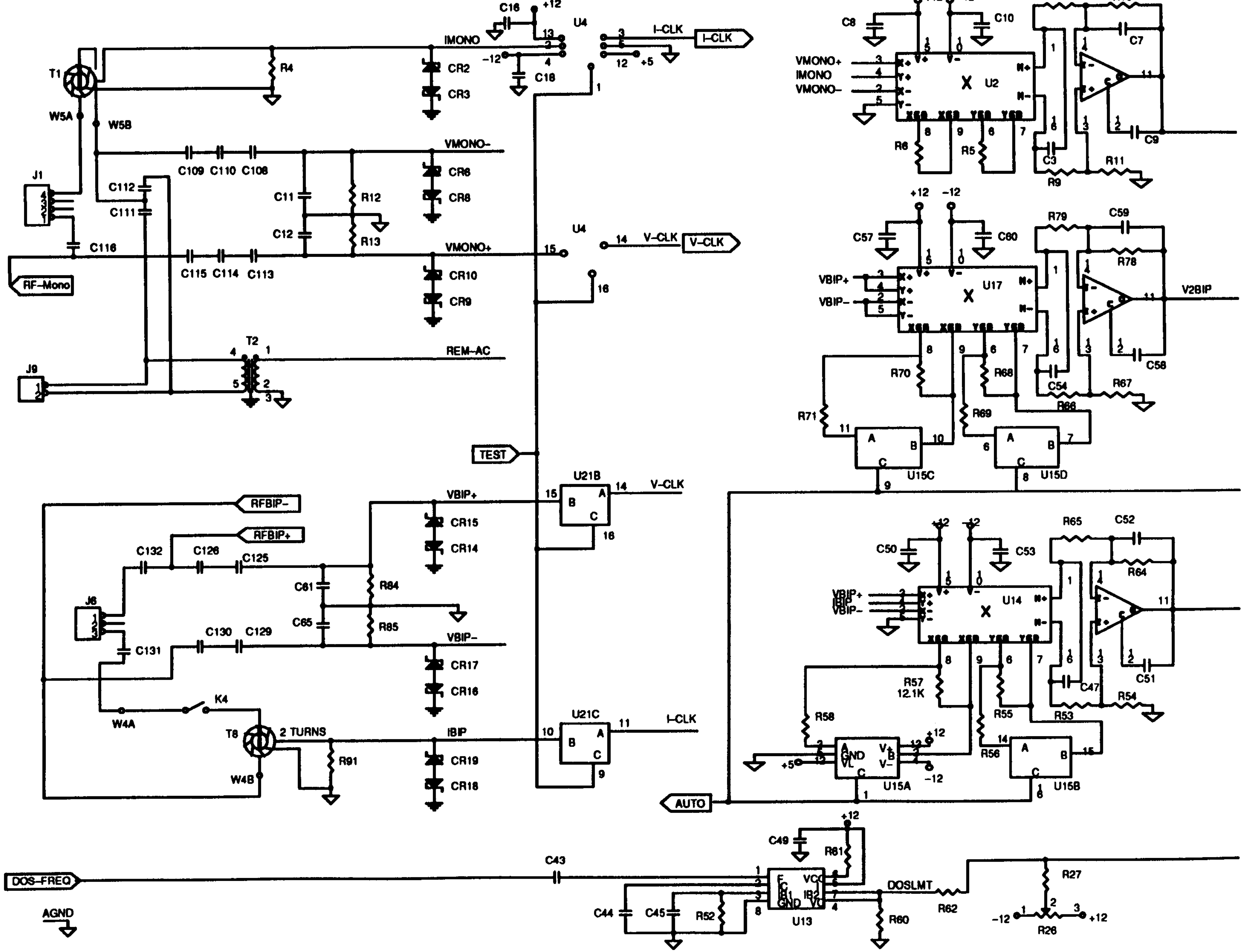
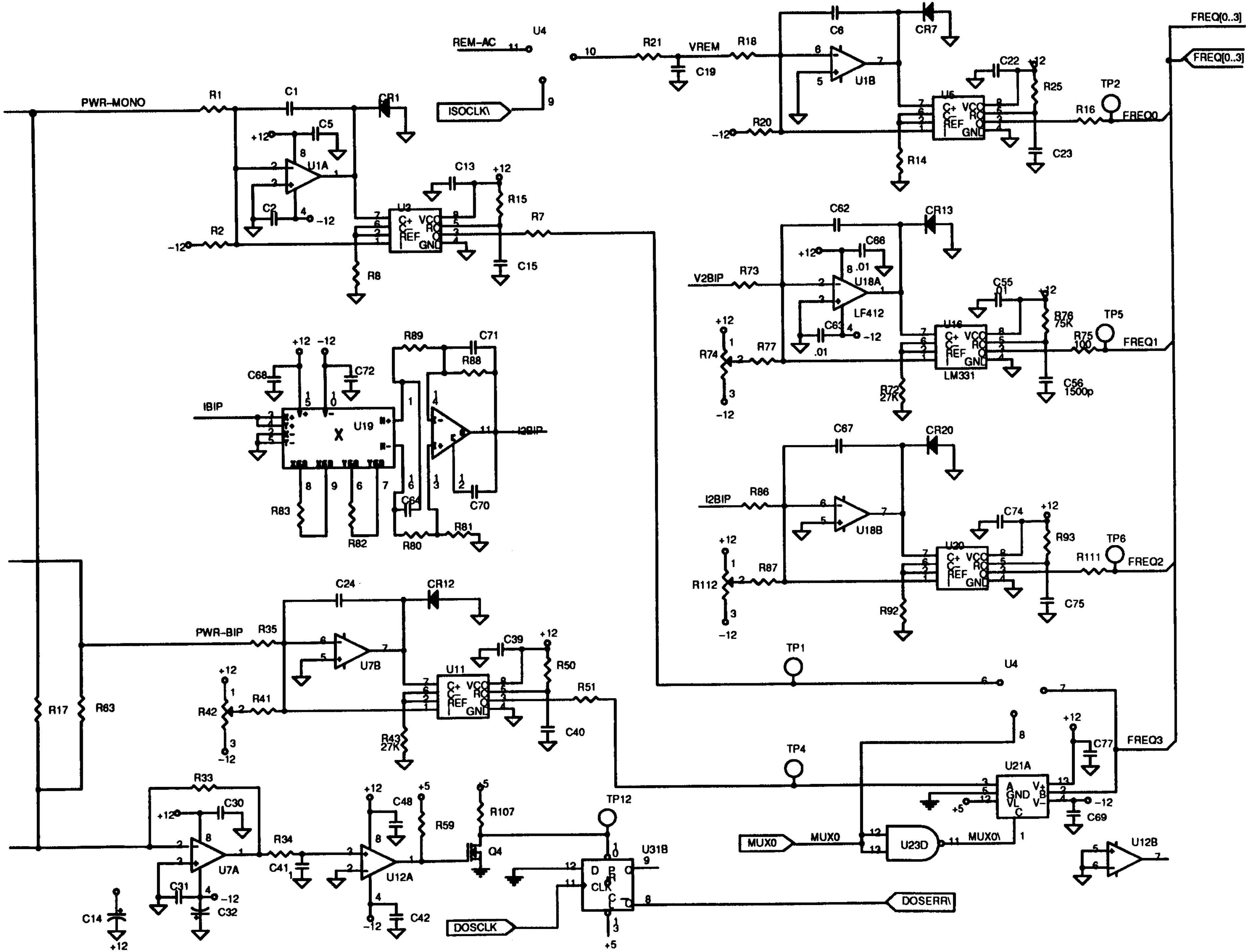
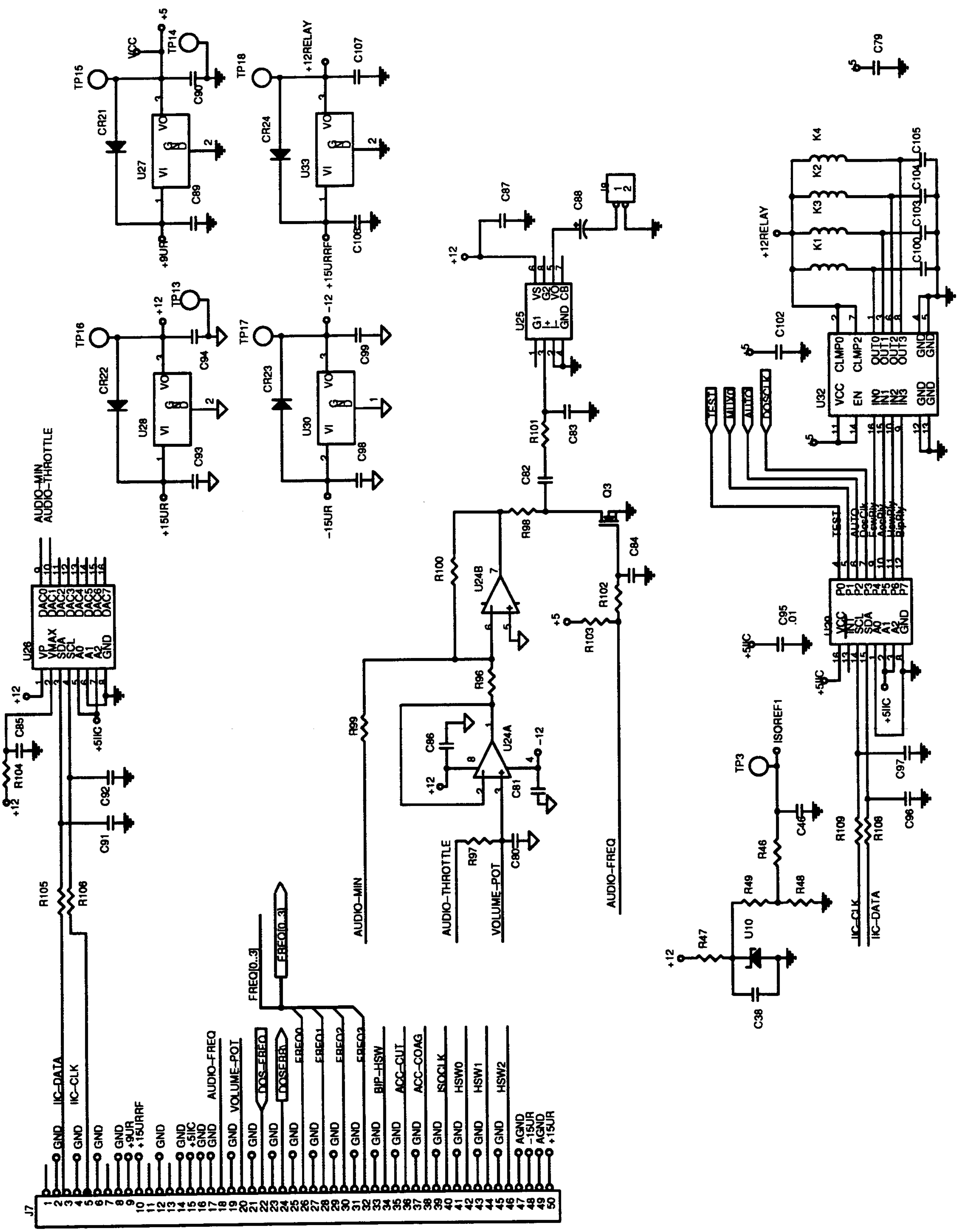
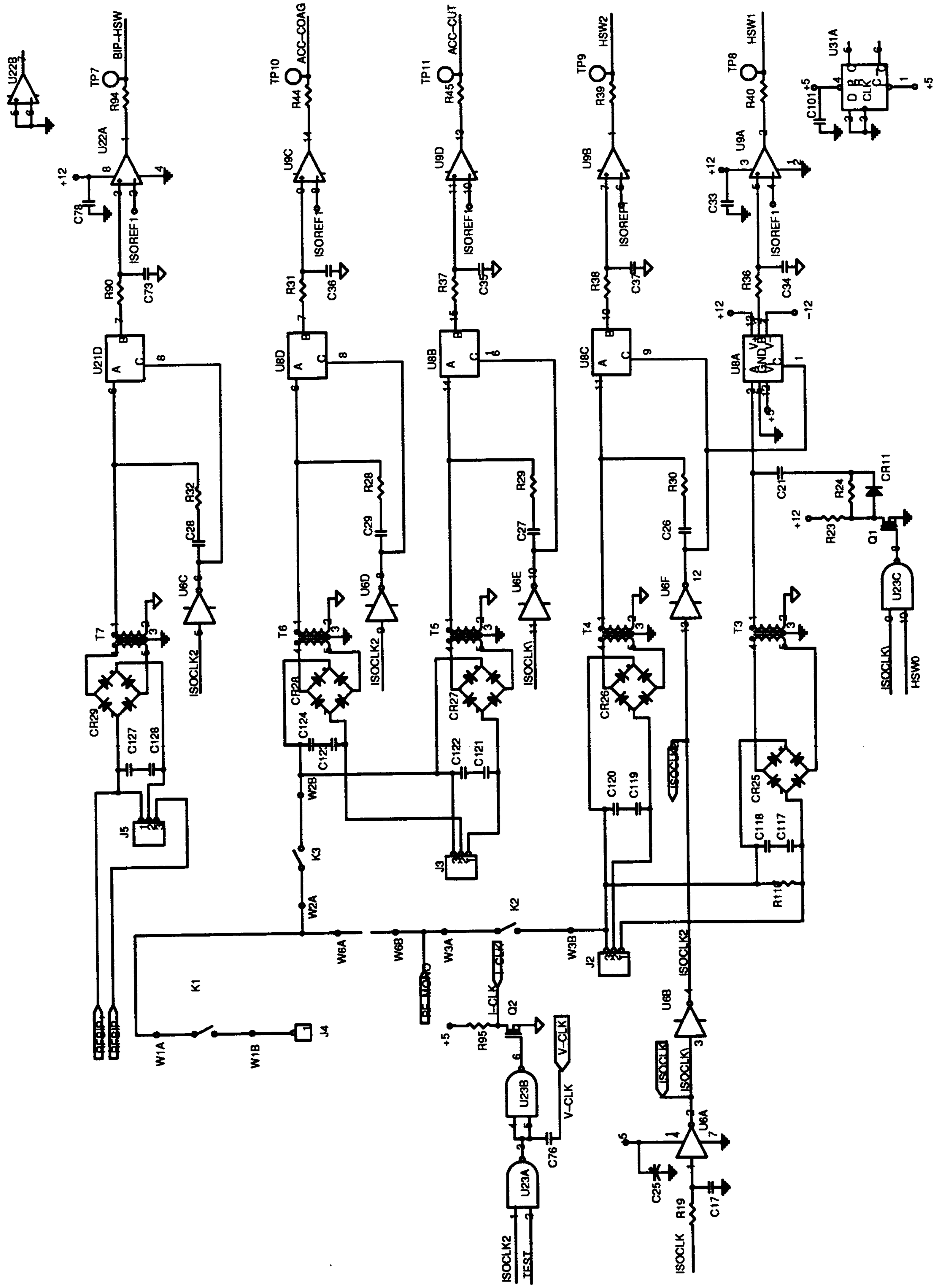


Figure 9.2 Interface Schematic


PWR-MONO
REM-AC
ISOCLK\
VREM
V2BIP
IBIP
I2BIP
PWR-BIP
MUX0
MUX0\
DOSCLK
DOSERR\
FREQ[0..3]
FREQ0
FREQ1
FREQ2
FREQ3
TP1
TP2
TP4
TP5
TP6
TP12
U1A
U1B
U2
U4
U6
U7A
U7B
U11
U12A
U12B
U16
U18A
U18B
U19
U20
U21A
U23D
U31B
Q4
LF412
LM331
CR1
CR7
CR12
CR13
CR20
+12
-12
+5



9.2 continued



9.2 continued

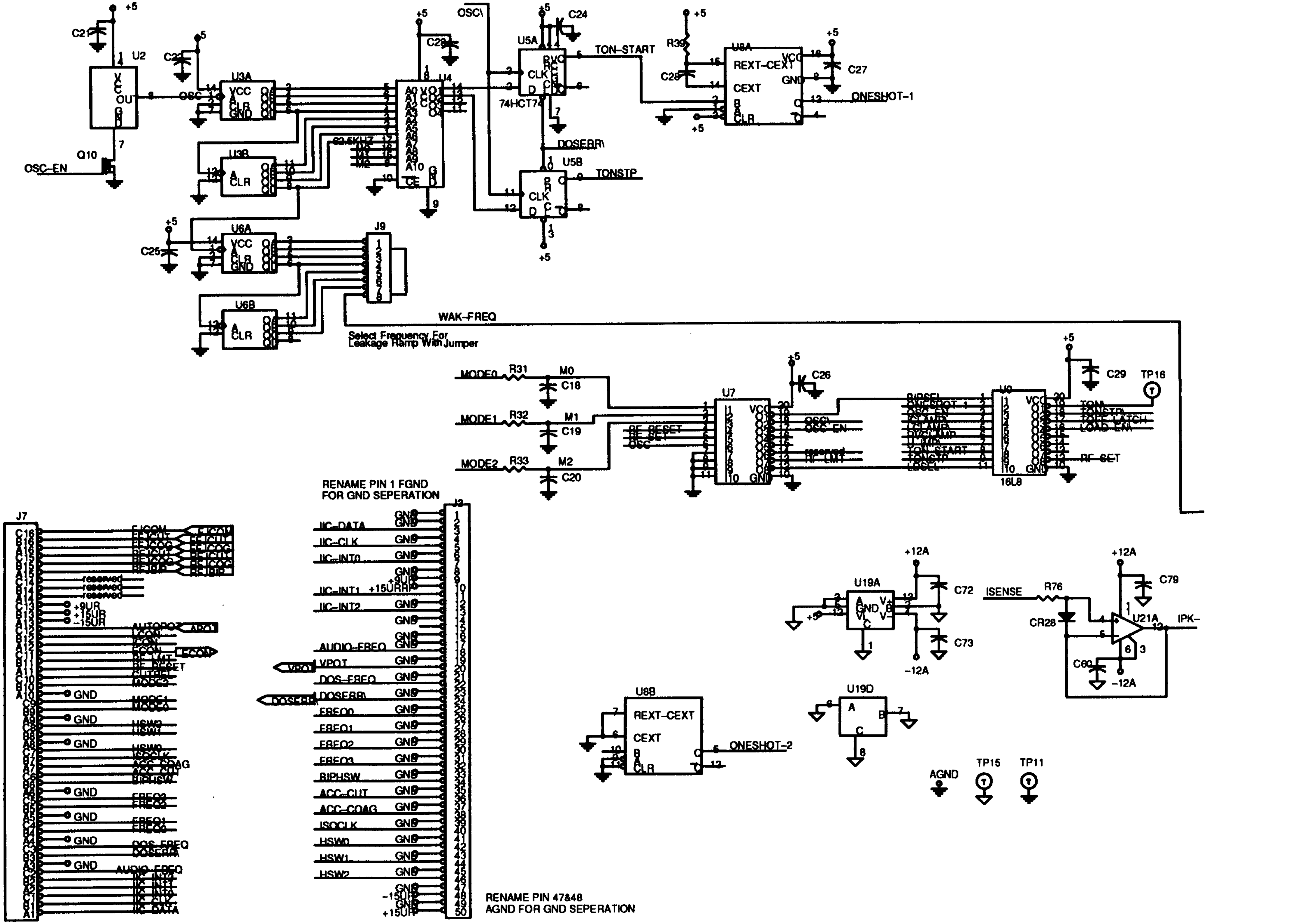
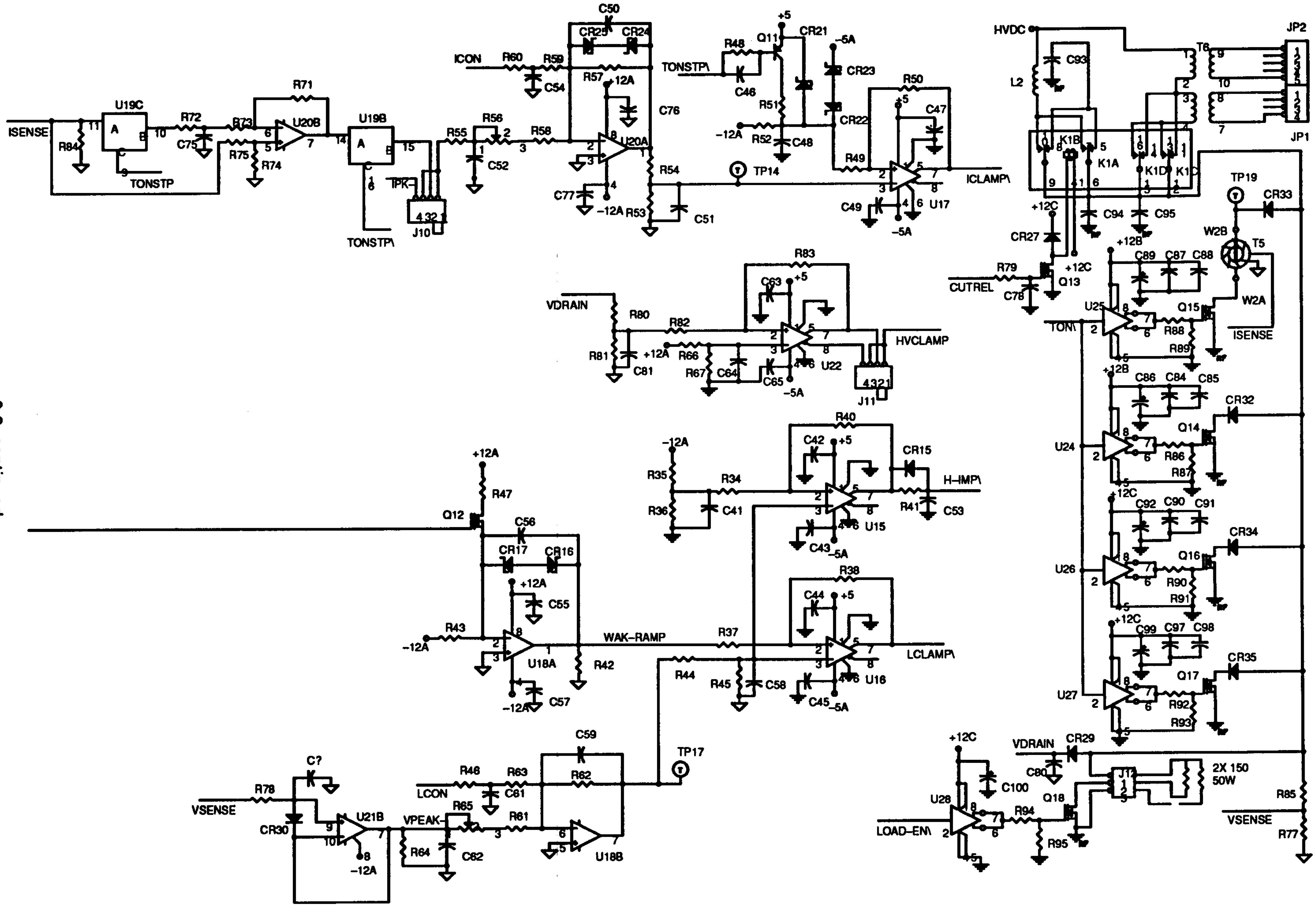
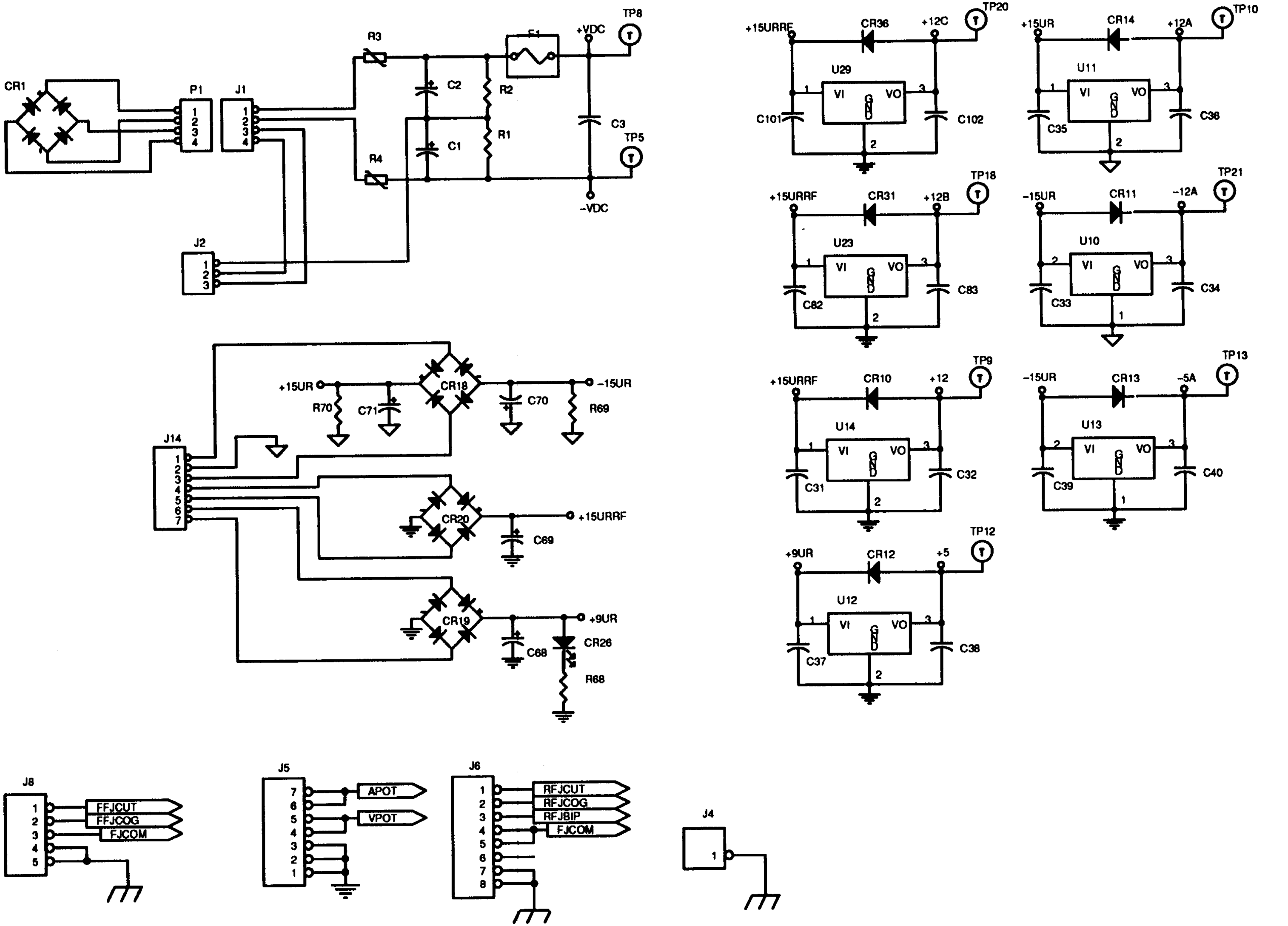
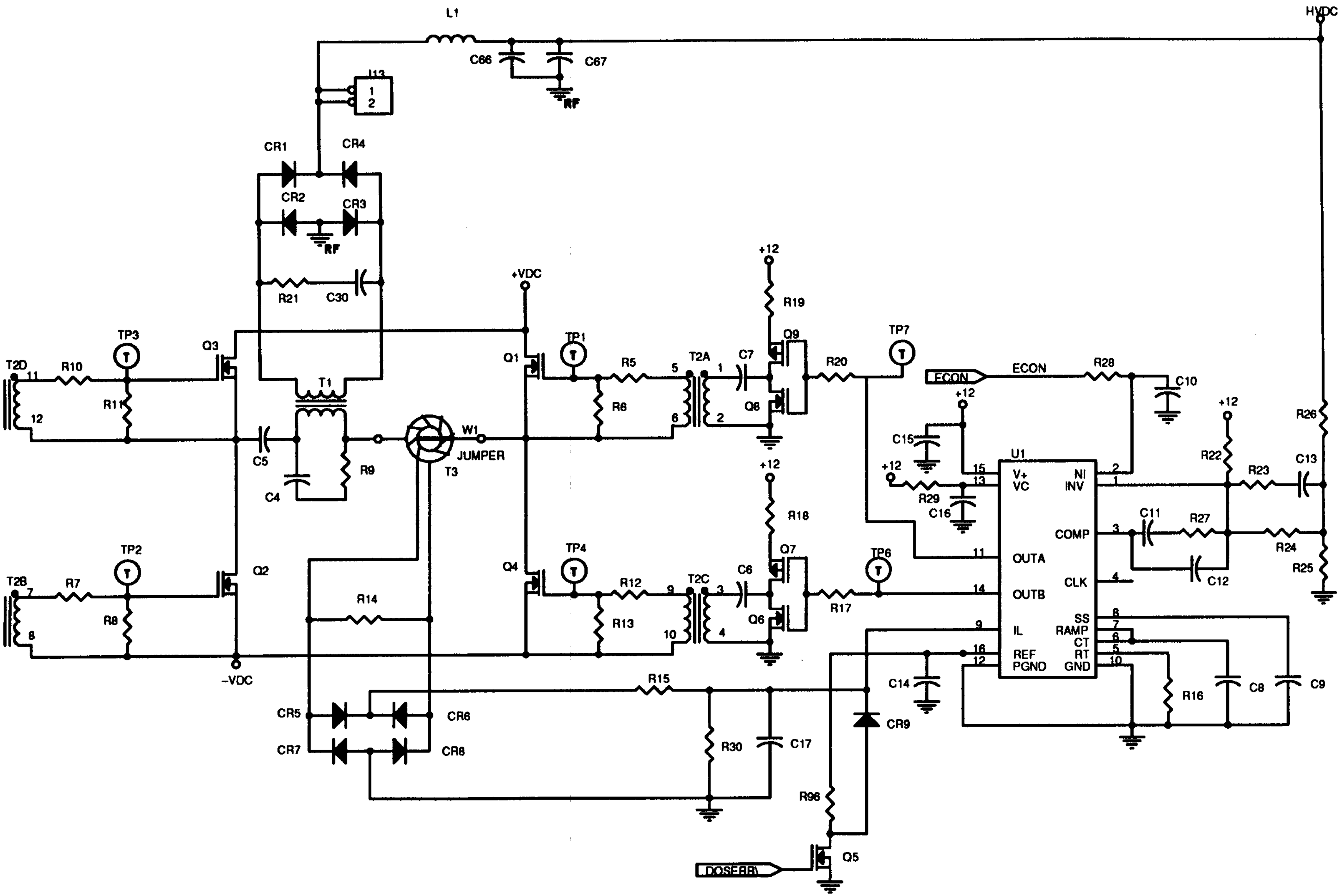


Figure 9.3 Power Supply/RF Schematic


ISENSE
TONSTP
TONSTP\
ICON
TONSTP\
ICLAMP\
HVDC
JP2
JP1
TP14
TP19
CUTREL
VDRAIN
HVCLAMP
TON\
ISENSE
H-IMP\
WAK-RAMP
LCLAMP\
TP17
VSENSE
LCON
VPEAK
LOAD-EN\
VDRAIN
2X 150
50W
VSENSE


CR1
P1
J1
J2
R3
R4
C2
C1
R2
R1
F1
+VDC
-VDC
C3
TP8
TP5
J14
+15UR
-15UR
CR18
R70
C71
C70
R69
CR20
+15URRF
C69
CR19
+9UR
C68
CR26
R68
+15URRF
CR36
+12C
TP20
U29
VI
VO
GND
C101
C102
+15UR
CR14
+12A
TP10
U11
C35
C36
+15URRF
CR31
+12B
TP18
U23
C82
C83
-15UR
CR11
-12A
TP21
U10
C33
C34
+15URRF
CR10
+12
TP9
U14
C31
C32
-15UR
CR13
-5A
TP13
U13
C39
C40
+9UR
CR12
+5
TP12
U12
C37
C38
J8
FFJCUT
FFJCOG
FJCOM
J5
APOT
VPOT
J6
RFJCUT
RFJCOG
RFJBIP
FJCOM
J4

9.3 continued



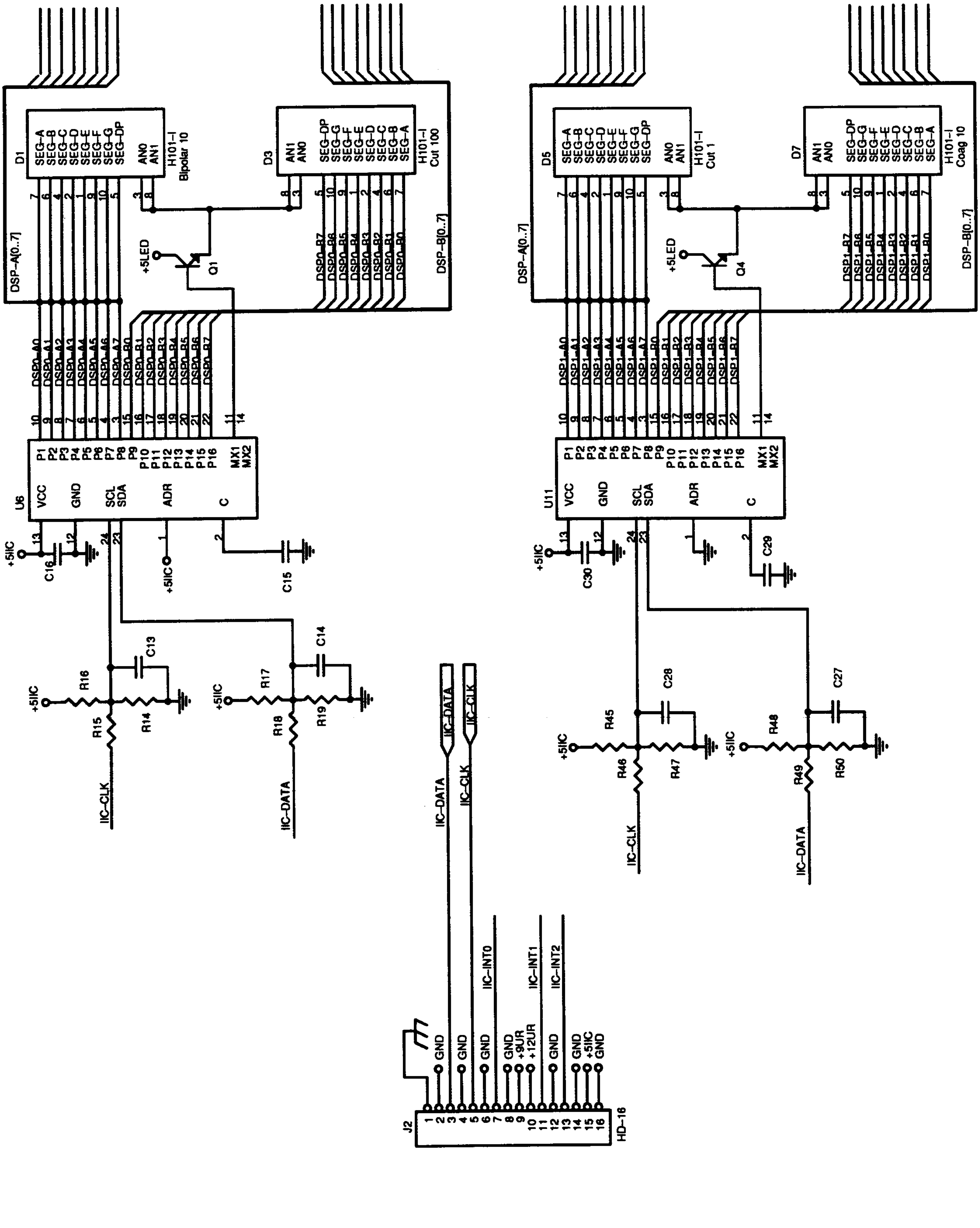
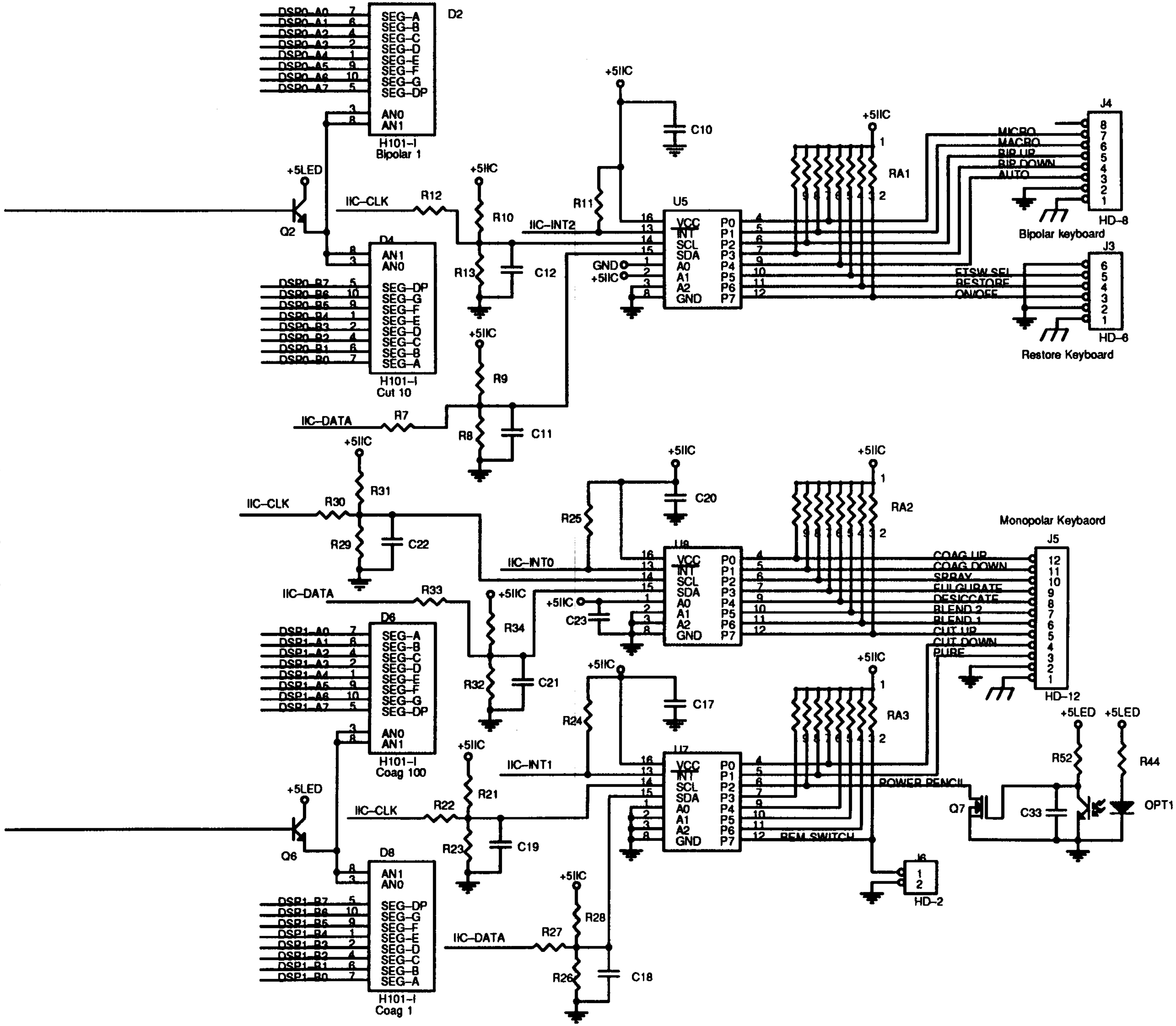
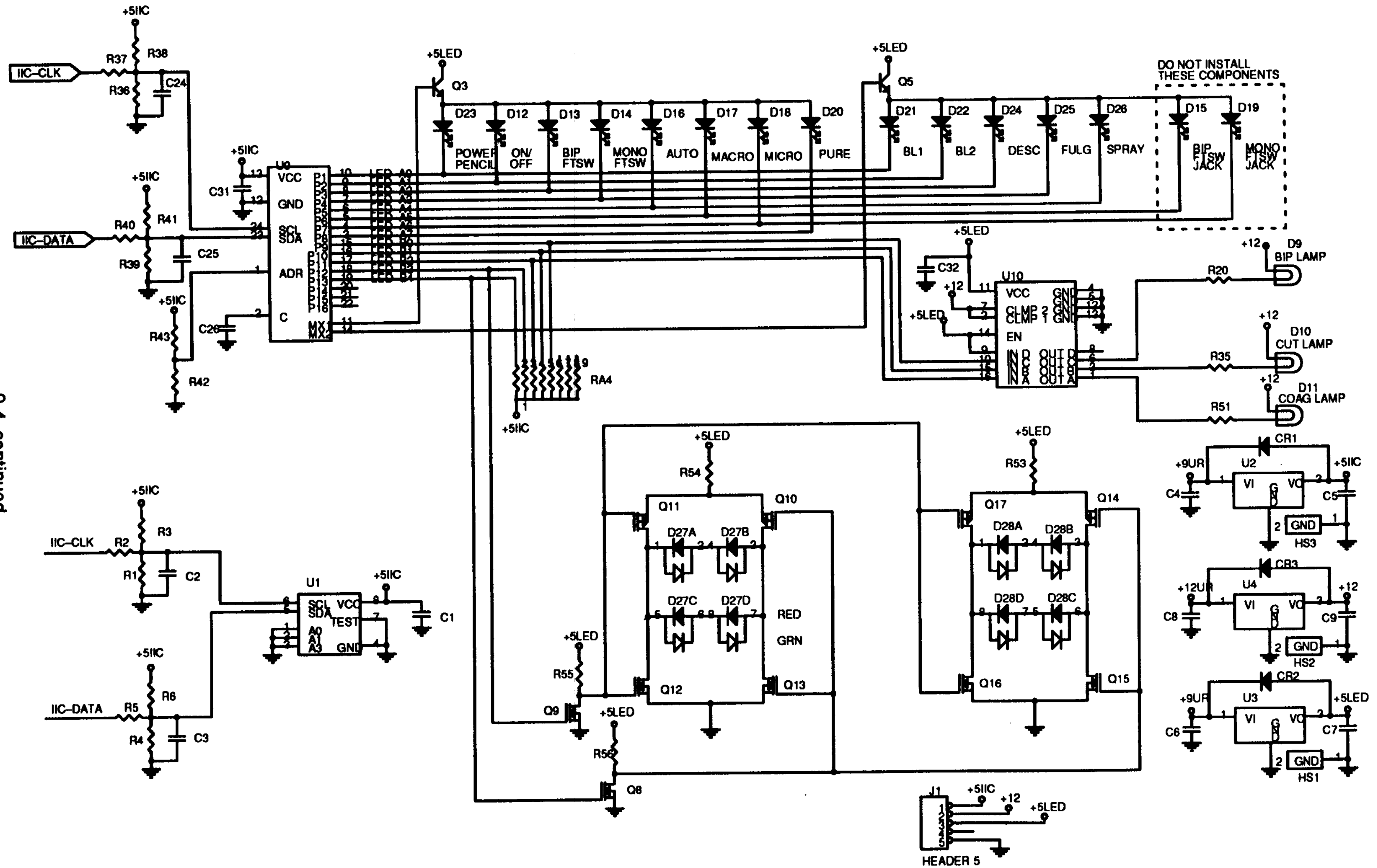


Figure 9.4 Display Board Schematic


D2
H101-I
Bipolar 1
D4
H101-I
Cut 10
D6
H101-I
Coag 100
D8
H101-I
Coag 1
U5
U9
U7
RA1
RA2
RA3
J4
HD-8
Bipolar keyboard
J3
HD-6
Restore Keyboard
Monopolar Keybaord
J5
HD-12
J6
HD-2
MICRO
MACRO
BIP UP
BIP DOWN
AUTO
FTSW SEL
RESTORE
ON/OFF
COAG UP
COAG DOWN
SPRAY
FULGURATE
DESICCATE
BLEND 2
BLEND 1
CUT UP
CUT DOWN
PURE
POWER PENCIL
REM SWITCH
IIC-CLK
IIC-DATA
IIC-INT0
IIC-INT1
IIC-INT2
+5IIC
+5LED
Q2
Q6
Q7
OPT1

9.4 continued



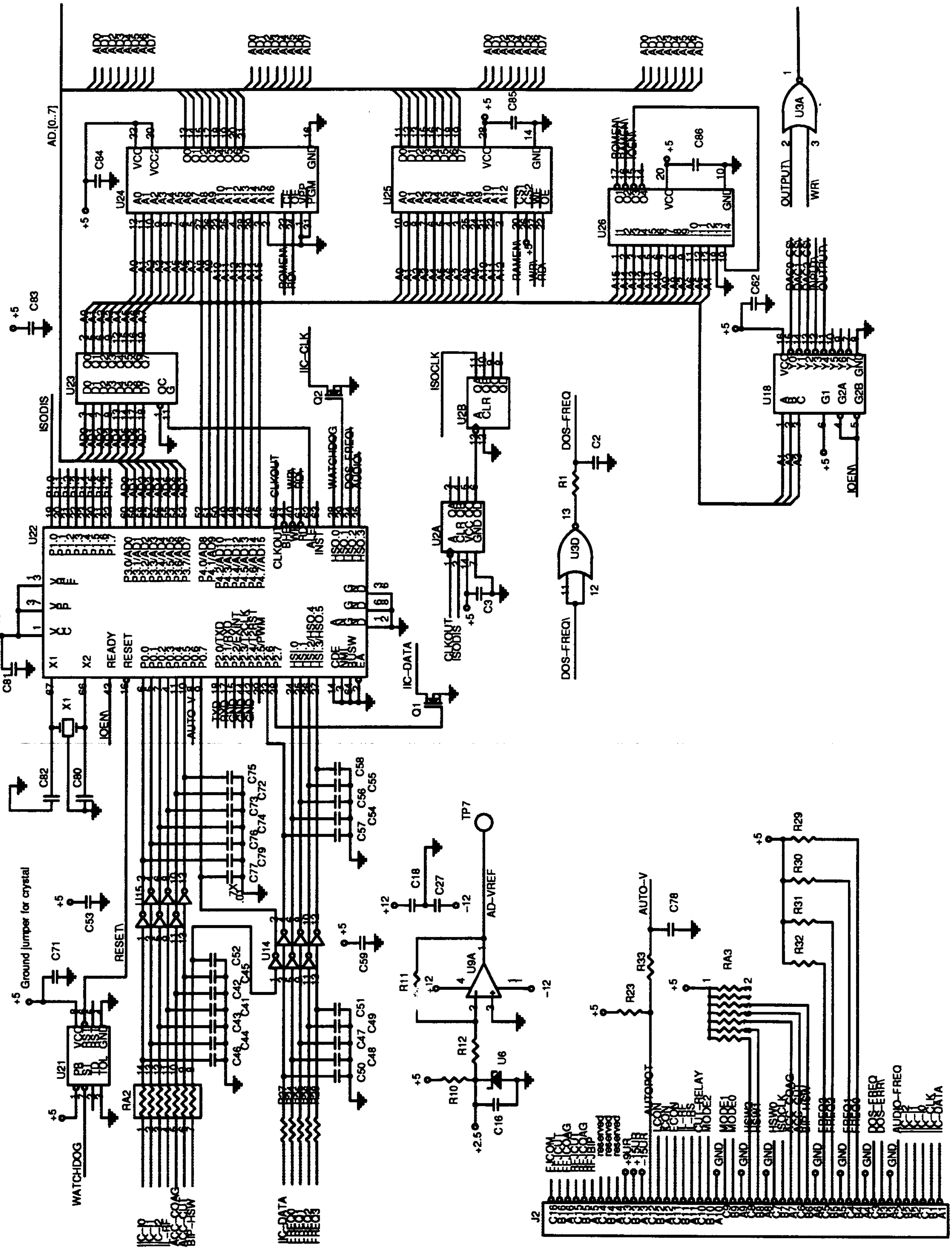
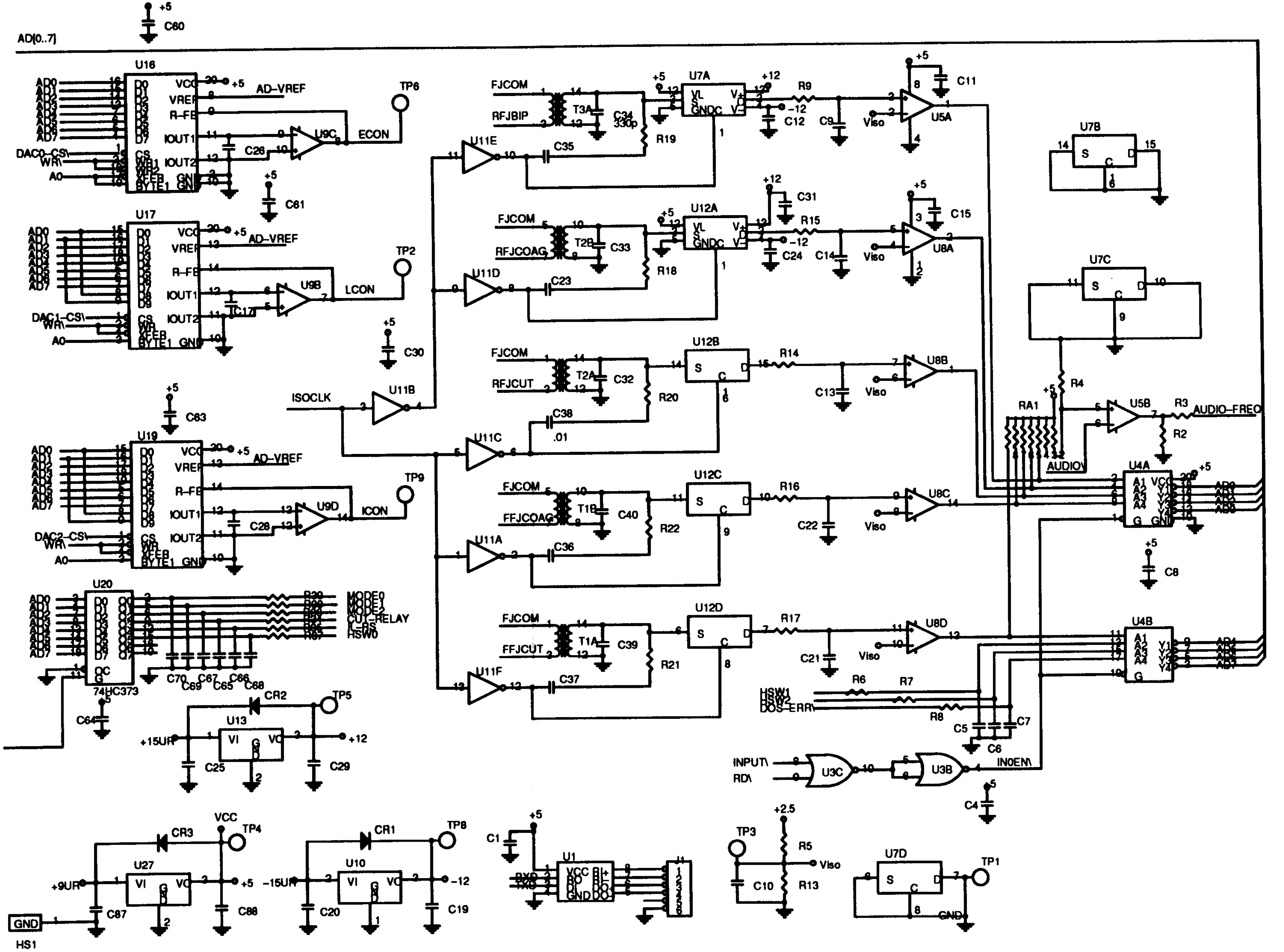
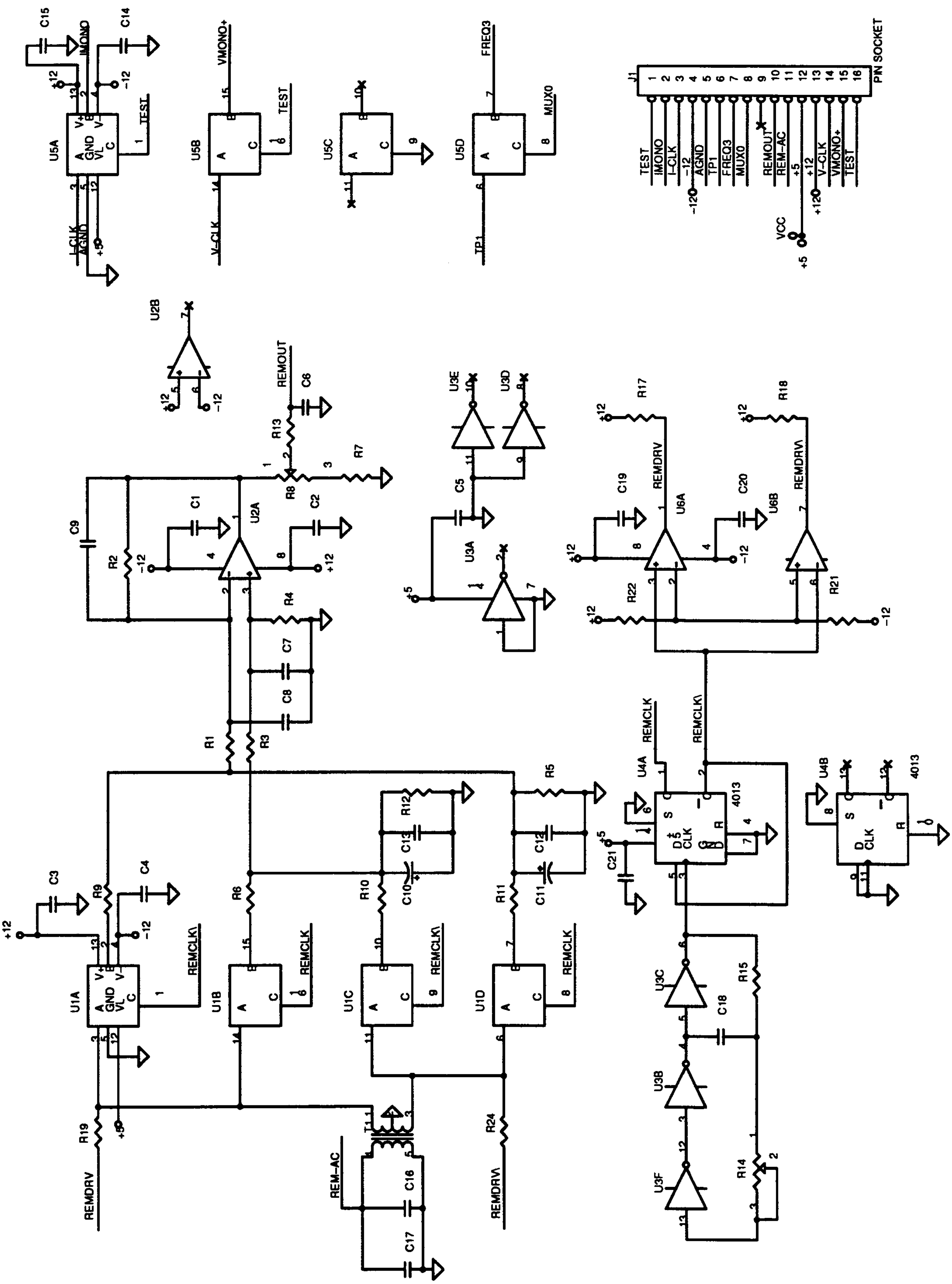


Figure 9.5 Microcontroller Board Schematic


AD[0..7]
+5
C60
U16
AD0
AD1
AD2
AD3
AD4
AD5
AD6
AD7
D0
D1
D2
D3
D4
D5
D6
D7
VCC
VREF
R-FB
IOUT1
IOUT2
CS
WR1
WR2
XFER
BYTE1
GND
DAC0-CS\
WR\
A0
AD-VREF
U9C
ECON
TP6
C26
C61
U17
DAC1-CS\
U9B
LCON
TP2
C17
C30
U19
DAC2-CS\
U9D
ICON
TP9
C28
C63
U20
74HC373
OC
G
MODE0
MODE1
MODE2
CUT-RELAY
HSW0
C70
C69
C67
C65
C66
C68
C64
U13
CR2
TP5
+15UR
VI
VO
+12
C25
C29
U27
CR3
VCC
TP4
+9UR
C87
C88
GND
HS1
U10
CR1
TP8
-15UR
-12
C20
C19
ISOCLK
U11B
U11C
U11D
U11E
U11A
U11F
FJCOM
RFJBIP
T3A
C34
330p
C35
R19
U7A
VL
GNDC
V+
V-
R9
C12
C9
Viso
U5A
C11
RFJCOAG
T2B
C33
C23
R18
U12A
C31
R15
C24
C14
U8A
C15
RFJCUT
T2A
C32
C38
.01
R20
U12B
R14
C13
U8B
FFJCOAG
T1B
C40
C36
R22
U12C
R16
C22
U8C
FFJCUT
T1A
C39
C37
R21
U12D
R17
C21
U8D
U7B
U7C
RA1
R4
U5B
R3
AUDIO-FREQ
R2
AUDIOV
U4A
U4B
C8
HSW1
HSW2
DOS-ERR\
R6
R7
R8
C5
C6
C7
INPUT\
RD\
U3C
U3B
INOEN\
C4
C1
U1
RXD
TXD
J1
TP3
+2.5
R5
R13
C10
U7D
TP1



9.6 REM Filter Board Schematic