HEWLETT PACKARD

43100A DEFIBRILLATOR/MONITOR with RECORDER

PART NUMBER 43100-91909

MICROFICHE NUMBER 43100-90999

Fourth Edition

McMINNVILLE DIVISION
1700 South Baker Street
McMinnville, Oregon 97128

11/86

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WARRANTY STATEMENT (C)
APPLICABLE TO THIS DEFIBRILLATOR PRODUCT ONLY

1. WARRANTY

Hewlett-Packard (HP) warrants this medical product against defects in materials and workmanship for a period of:

1. Five (5) years on instruments
2. Two (2) years on battery
3. All other accessories under standard warranty

If HP receives notices of such defects during the warranty period, HP shall, at its option either repair or replace hardware products which prove to be defective.

HP software and firmware products which are designateed by HP for use with a hardware product, when properly installed on that hardware product, are warranted not to fail to execute their programming instructions due to defects during the warranty period, HP shall repair or replace software media and firmware which do not execute their programming instructions due to such defects. HP does not warrant that the operation of the software, firmware or hardware shall be uninterrupted or error free.

If HP is unable, within a reasonable time, to repair or replace any product to a condition as warranted, Buyer shall be entitled to a refund of the purchase price upon return of the product to HP.

2. PLACE OF PERFORMANCE

Within HP service travel areas, warranty and installation services for products installed by HP and certain other products designated by HP will be performed at Buyer's facility at no charge. Outside HP service travel areas, warranty and installation services will be performed at Buyer's facility only upon HP's prior agreement and Buyer shall pay HP's round trip travel expenses and applicable additional expenses for such services.

On-site warranty services are provided only at the initial installation point. If products eligible for on-site warranty and installation services are moved from the initial installation point, the warranty will remain in effect only if Buyer purchases additional inspection or installation services at the new site.

For product warranties requiring return to HP, products must be returned to a facility designated by HP. Buyer shall prepay shipping charges (and shall pay all duty and taxes) for products returned to HP for warranty services. Except for products returned to Buyer from another country, HP shall pay for return of products to Buyer.

Installation and Warranty services outside the country of initial purchase are included in HP's product price only if Buyer pays HP international prices (defined as destination local currency price, U.S. or Geneva Export price). Service outside the country of initial purchase is subject to the conditions regarding HP service travell areas and initial installation point described above.

3. LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from:

1. Improper or inadequate maintenance by Buyer,
2. Buyer-supplied software or interfacing,
3. Unauthorized modification or misuse,
4. Operation outside of the environmental specifications for the product, or
5. Improper site preparation and maintenance.

THE WARRANTY SET FORTH ABOVE IS EXCLUSIVE AND NO OTHER WARRANTY, WHETHER WRITTEN OR ORAL, IS EXPRESSED OR IMPLIED. HP SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

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THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. IN NO EVENT SHALL HP BE LIABLE FOR DIRECT, INDIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES (INCLUDING LOSS OF PROFITS) WHETHER BASED ON CONTRACT, TORT OR ANY OTHER LEGAL THEORY.

The foregoing limitation of liability shall not apply in the event that any HP product sold hereunder is determined by a court of competent jurisdiction to be defective and to have directly caused bodily injury, death or propery damage; provided, that in no event shall HP's liability for property damage exceed the greater of $50,000 or the purchase price of the specific product that caused such damage.

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2-1. INTRODUCTION

This section describes the theory of operation of the 43100-series defibrillators. Discussion is primarily board oriented and describes various system components relating to the printed circuit board which connects to them.

2-2. SYSTEM OVERVIEW

In addition to basic defibrillator functions, the 43100-series defibrillator/monitors also display the patient ECG waveform and pertinent messages on a CRT and recorder. The following assemblies are included:

A. ANALOG ECG BOARD
- isolates, selects and amplifies the patient's ECG signal
- provides signals for the paddle contact indicator
- provides the 1V ECG output signal

B. CONTROL BOARD
- controls primary instrument functions and ECG processing
- controls recorder operation
- controls signals to provide CRT waveforms and messages
- manages signals from and to the operator controls

C. DEFLECTION BOARD
- supplies focus, cathode and anode voltages to CRT
- processes and amplifies signals for deflection of the CRT beam
- controls intensity of the CRT beam
- controls CRT filament voltage

D. HIGH VOLTAGE CHARGER BOARD
- provides voltages to charge the HV capacitor
- provides an indication of the HV capacitor voltage to the control board
- provides safety discharge of the HV capacitor.

E. HIGH VOLTAGE CIRCUITRY
- delivers current with a specified waveform to a load between the defibrillator paddles
- provides an indication of the discharge current to the control board
- provides a test load for discharge of the main storage capacitor

F. BATTERY CHARGER BOARD
- isolates and conditions line voltage to charge the battery
- provides several low voltages to power other circuitry

G. RECORDER
- motor drive and speed control circuitry
- no paper and low paper sensing
- printhead

2-3. ANALOG ECG BOARD

ECG board (43100-6011X) receives and processes an ECG signal from the patient. The signal is presented to the control board (43100-6010X)for analog-to-digital conversion with the correct amplitude and frequency bandwidth. The ECG is a low level signal (typically about 1 mV) which must be extracted from high level common mode noise signals (typically about 10V) generated by capacitive coupling of the patient to surrounding ac sources. The right leg drive circuit minimizes the common mode potential difference between the patient and floating ground. The ECG board has floating and grounded sections to protect the patient from possible hazards associated with electrical connections to the body. The floating section circuits are electrically isolated from instrument ground. Since the patient is directly connected only to the floating section, the patient is electrically isolated from instrument (and earth) ground.

2-4. PROTECTION CIRCUITRY.

The ECG amplifier input protection circuitry consists of neon lamps (DS1-4), MOVs (Varistors E1-2), and diodes. In addition there are 10K ohm resistors in series with each of the 3 inputs. The neon lamps fire at approximately 100 volts. CR11 and CR12 are three-pellet diodes biased to provide a voltage of approximately 1.7 V. In conjunction with CR1-CR6 and CR19 these diodes clamp the input voltages in the event a large potential is applied between any of the inputs. Relay K2 opens during a defibrillator discharge to protect the Paddle Contact Indicator Circuit and the ECG frontend. DS4 provides additional protection for the PCI circuit.

Varistors E1 and E2 protect relay K1 in the unlikely event that voltage is applied between the Leads and Paddles. E1 and E2 will each fire at approximately 500 volts. CR20, CR21, C4, and C6 provides additional protection of the frontend amplifier when power is off.

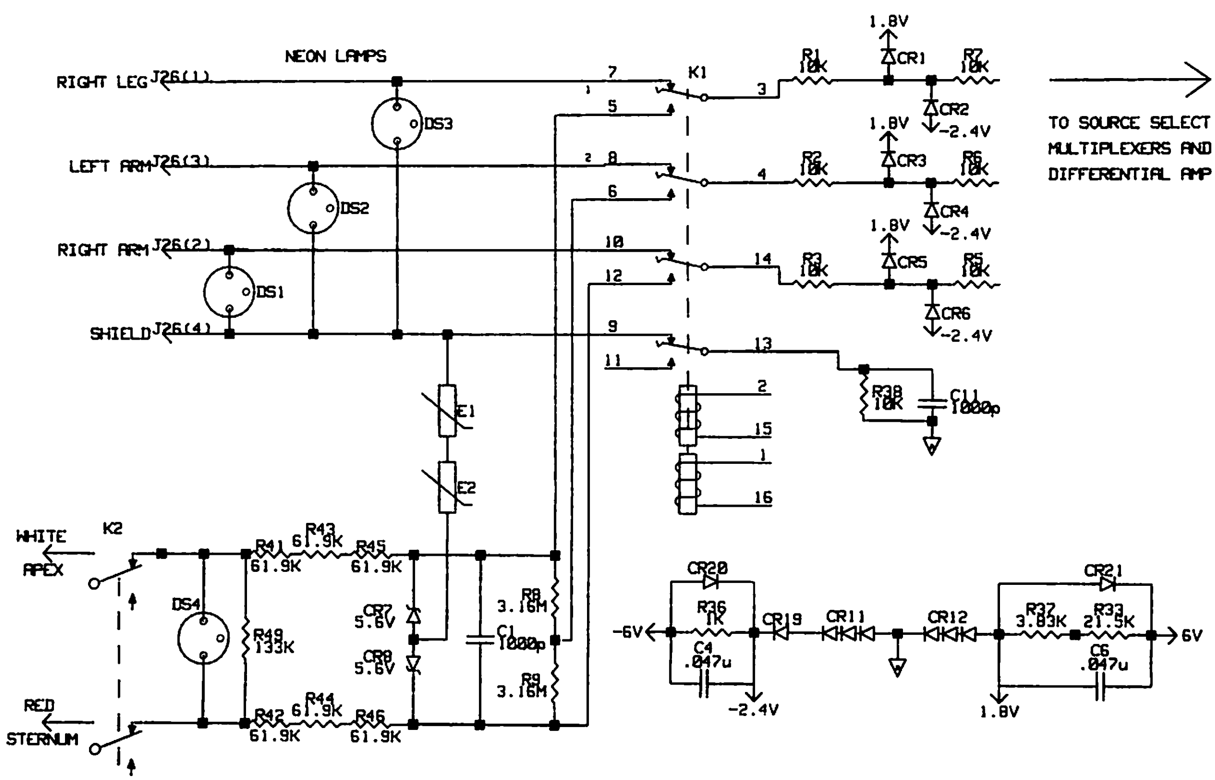


Figure 2-1.

2-5. ECG SOURCE SELECTION.

The ECG input source can be either from the Paddles or the Leads. When using the Leads, positions I, II, and III are available. Relay K1, and multiplexers U1 and U2 switch the input signals to reflect front panel membrane switch requests. The main control microprocessor (U61 on 43100-6010X), in response to operator input from the front panel, controls the two lines ECG Source 0 and ECG SOURCE 1 (P30-8 and P30-10). These two signals are optically coupled to the source select relay and multiplexers via optoisolators U108 and U109. Source select relay K1, which switches between Paddles and Leads, is a latching type relay. The set and reset coils of K1 are pulsed on for approximately 15 msec, determined primarily by R48-C19 or R26-C18, to select leads or paddles as an input source.

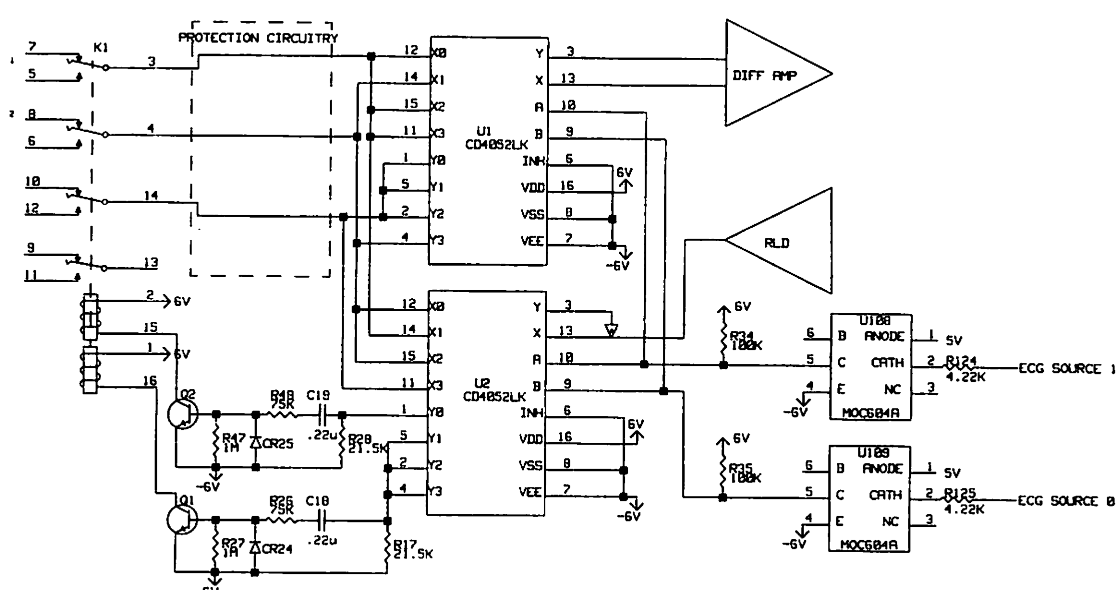


Figure 2-2.

2-6. FIRST GAIN STAGE, DIFFERENTIAL AMPLIFIER.

Op-amps U3A, U3B, and U6A, form a differential amplifier with a bandpass characteristic. The amplifier has very high input impedance. This helps prevent conversion of common mode signals into differential mode signals when the source impedance is unbalanced. The gain of this stage is approximately 37 from .45 Hz to 60Hz with first-order rolloff elsewhere. CR17 and CR18 reduce the time it takes for the amplifier to restabilize after a large offset, e.g. due to defibrillator discharge or a leads off condition. R39, R40, and C5 decouple the amplifier from the chopper circuit switching transients. C2 and C3 control the high and low frequency cut-offs, respectively.

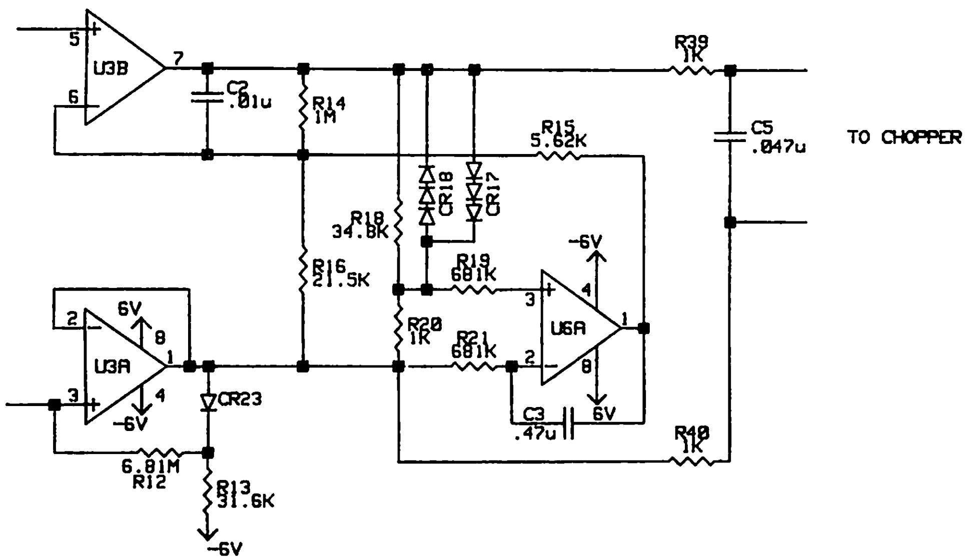


Figure 2-3.

2-7. RIGHT LEG DRIVE.

Op-amp U4A is an inverting amplifier with a gain of ten. Often 50 or 60 Hz common mode interference is present on the patient. Right leg drive is used to reduce the effect of this unwanted signal. The common mode voltage is inverted, amplified, and driven back into the reference electrode of the patient. The feedback loop of this circuit is completed by the patient and forces the floating ground to track the common mode signal present on the patient. U2 switches the RLD signal to be connected to the patient via an otherwise unused electrode.

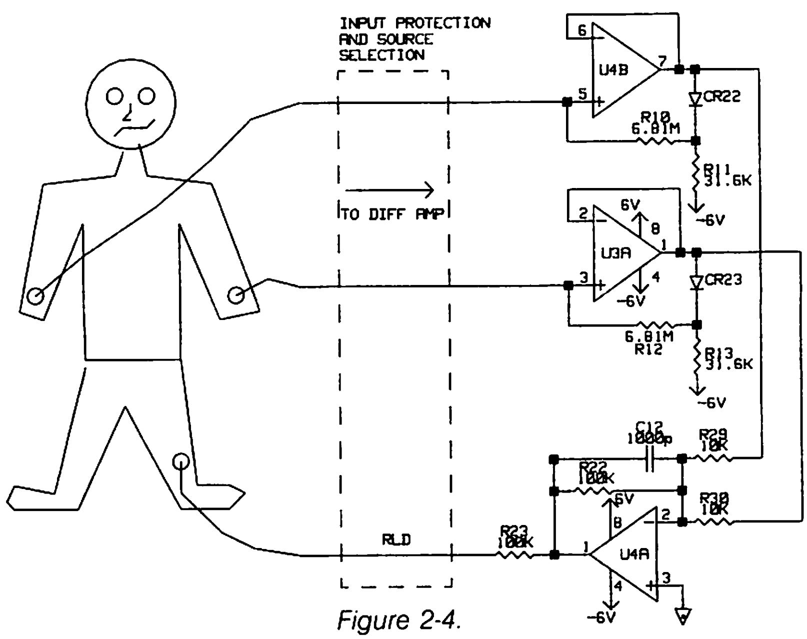


Figure 2-4.

2-8. LEADS OFF INDICATOR.

The Leads Off indicator is only operable in Leads mode (I, II, or III). Opamps U3A and U4B, with associated resistors and diodes, form the central part of the leads off circuit. R11 and R13 forward bias CR22 and CR23 causing 80 nA of DC current to flow through both R10 and R12. This current is supplied, via the patient, by the Right Leg Drive amplifier. If one or more of the three electrodes falls off, the RLD amplifier will saturate high. This condition will be detected by op-amp U6B (used as a comparator) and its output will go high. The high state of U6B causes chopper U5 to switch to transmitting a large (1.8V) DC offset across isolation transformer T1. This large DC potential is demodulated in the grounded circuitry and forces successive gain stages to saturate. In the grounded section, U102A saturates high and turns on Q105, pulling the INOP LEADS OFF signal (P30-12) low. Main control processor U61 (on the contrlo board 43100-6010X) detects this low, activates the "LEADS OFF" message and generates an artificial baseline until the condition is cleared. Note: large DC offsets (O 3 V at the leads inputs may also initiate this chain of events, although the leads are connected. This will typically occur after a defibrillator discharge or when very high electrode impedance occurs (greater then 30 megohms).

2-9. FLOATING POWER SUPPLY CIRCUIT.

A 31250 Hz combined timing and power signal is coupled to the floating section by isolation transformer T2. The signal from T2 is divided down by R31 and R32 to provide the clock signal for the chopper modulator. It is also full wave rectified by CR 15-CR18 to generate the +/− 6.0 V dc supplies. See Figure 2-5.

2-10. CHOPPER MODULATOR CIRCUIT.

The ECG signal from the first stage differential amplifier is chopper modulated with the 31250 Hz timing signal by analog multiplexer U5. By modulating the signal with a high frequency clock, the ECG signal can be transferred to the grounded section via isolation transformer T1. The 1.8 V dc signal is used in signalling Leads Off. (See Leads Off Indicator Section 2-8.) See Figure 2-5.

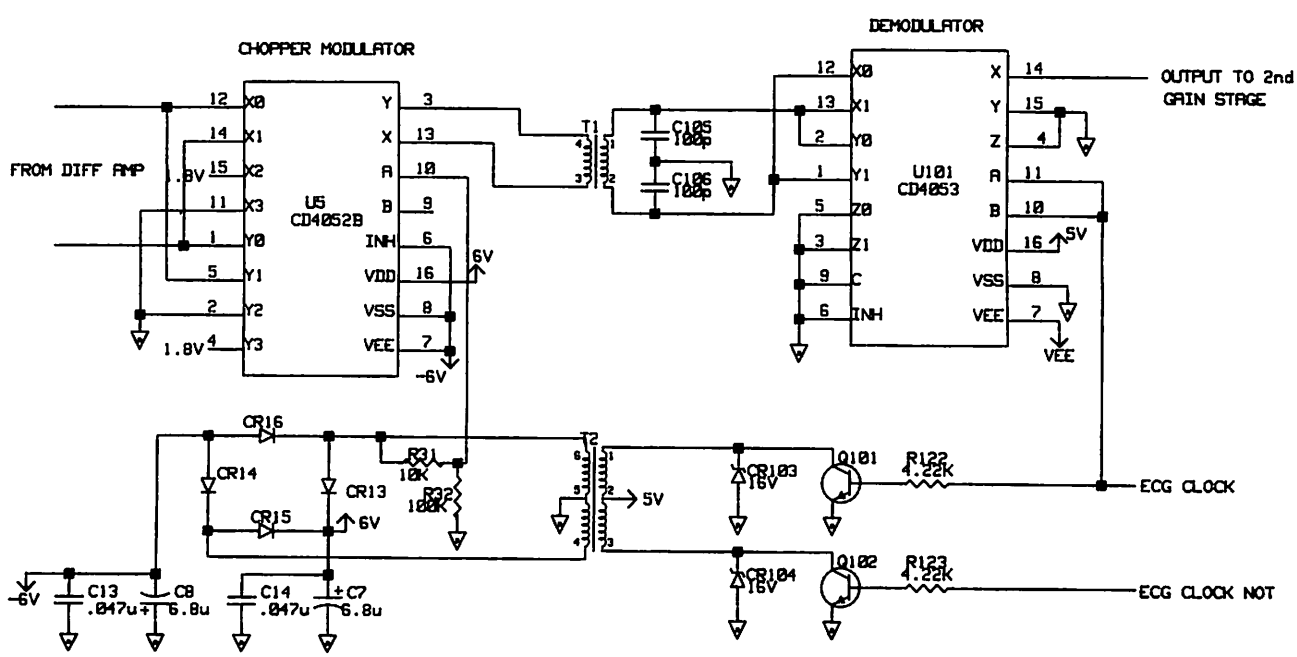


Figure 2-5.

2-11. POWER SUPPLY TIMING AND DRIVE CIRCUIT.

Two 31250 Hz signals of opposite phase are supplied by the control board (43100-6010X) and labeled ECG CLOCK and ECG CLOCK NOT (P30-4 and P30-6). These two signals are used to alternately turn on and off transistors Q101 and Q102 which drive the power isolation transformer T2. This is a driven push pull converter configuration. CR103 and CR104 protect the drive transistors from voltage transients associated with switching the inductive load. See Figure 2-5.

2-12. CHOPPER DEMODULATOR CIRCUIT.

The demodulator circuit consists of analog multiplexer U101 which is controlled by ECG Clock and reconstructs the chopped ECG signal from isolation transformer T1. C105 and C106 are used to reduce switching transients. See Figure 2-5.

2-13. SECOND GAIN STAGE.

Op-amp U102C, with associated resistors and capacitors, forms a non-inverting amplifier and third order low pass filter with a gain of 4.2 and cutoff frequency of 45 Hz.

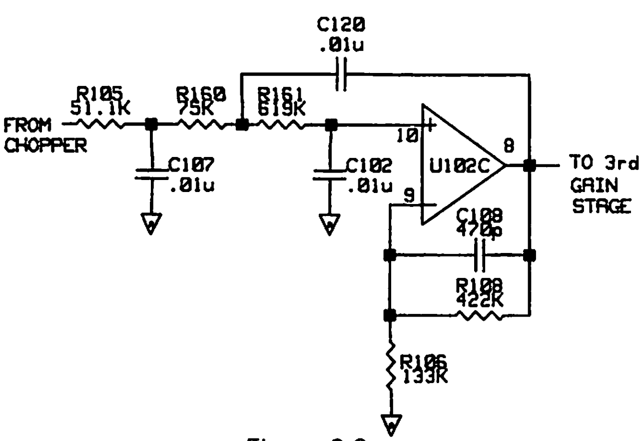


Figure 2-6.

2-14. THIRD GAIN STAGE.

Op-amps U102A and U102B, form a bandpass amplifier. The gain is approximately 3.85 at mid frequencies and exhibits a rolloff characteristic at .1 Hz and 800 Hz. U102B combined with R107 and C103 form an integrator in the feedback path to establish the low frequency cutoff. This integrator will saturate if the DC magnitude of the input signal from U102C is too large. This is normal during a Leads Off condition.

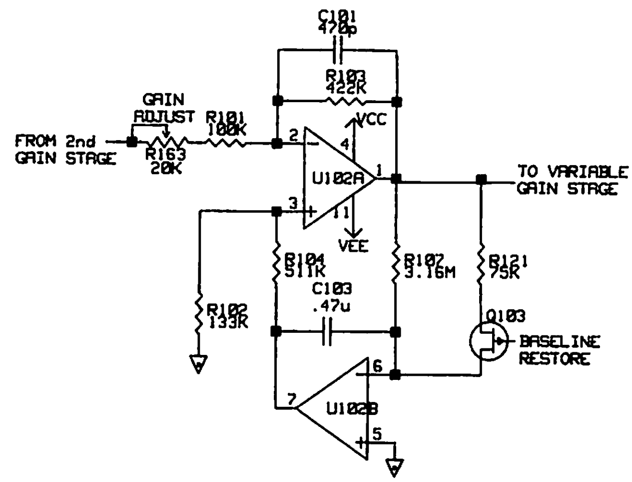


Figure 2-7.

2-15. BASELINE RESTORE.

Large offsets or a drifting baseline, which typically accompany a defibrillator discharge or Leads Off condition, are sensed by software in the main control microprocessor. The processor will then turn on JFET Q103 and charge the low frequency cutoff in the third gain stage from 0.1Hz to approximately 5 Hz by switching R121 in parallel with R107. This allows C103 to quickly charge and center the baseline on the CRT. BASELINE RESTORE is also activated for two seconds whenever the input source is changed, (i.e. between Paddles and Leads or between the various Leads; I, II, and III).

2-16. VARIABLE GAIN STAGE.

Op-amp U104A and analog multiplexer U103, form a variable gain, microprocessor-controlled amplifier. The minimum gain is .5, the maximum gain 8. This provides eight total gain steps of 250, 400, 650, 1000, 1300, 2000, 3000, and 4000 when combined with other fixed-again stages. The gain choice of this amplifier is determined by the combination of resistors R109-R116 with R120 and R158 as selected by U103. The gain maybe caculated as the ratio of the sum of the feedback resistance divided by the sum of the input resistance to the feedback point. In manual gain operation, the main control processor echoes the user-selected gain choice to the analog multiplexer.

The output of this stage is ANALOG ECG (P30-17) and is sent to the control board (43100-6010X) for additional low pass filtering, a level shift, and analog-to-digital conversion.

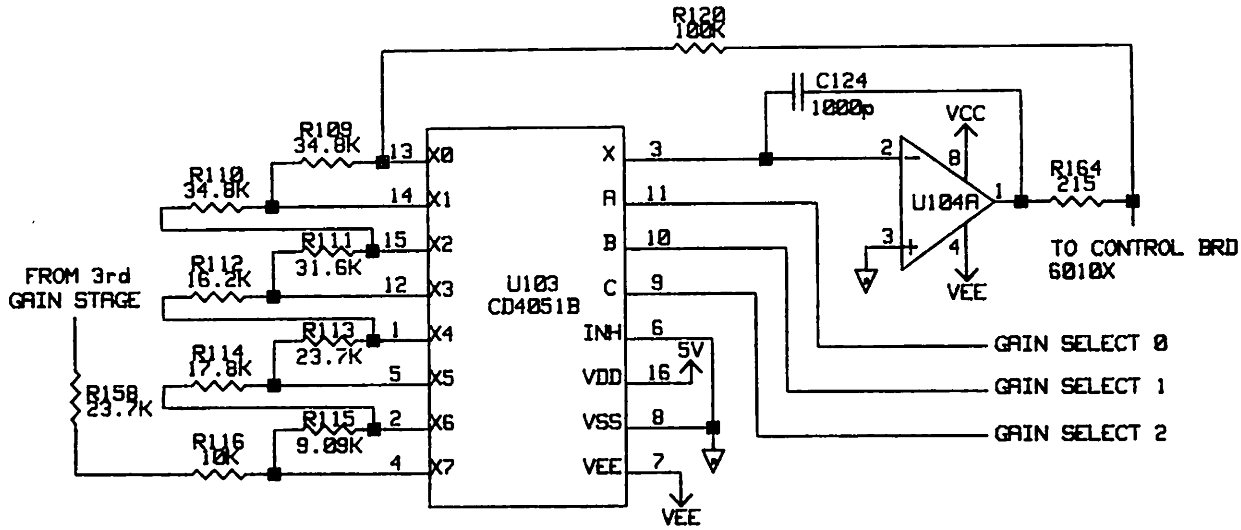


Figure 2-8.

2-17. ECG OUT AND INSTRUMENT STATUS OUT.

Op-amp U102D supplies an analog ECG signal to the mini phone jack located in the lower left front of the defibrillator. The gain is fixed at 1000 (nominally 1 V out). R119, CR107, and CR108 protect this output from external transients.

2-18. Paddle Contact Indicator.

The Paddle Contact Indicator (43100A, 43120A) is a ten segment bar graph located on the Sternum paddle. It indicates the impedance measured between the Apex and Sternum paddles. The more LED's lit, the lower the measured impedance.

The PCI AND TEST SIGNAL (P30-24) is a 5V 31,250 Hz 50% duty cycle square wave. It is divided by R127 and R126 to produce a 25mVp-p square wave which is applied to isolation transformer T3. The patient impedance between the Apex and Sternum paddles is reflected across T3 (turns ratio 1:1). Capacitor C10 compensates for transformer T3's leakage inductance. Op-amps U105B and U105D, form a composite amplifier with high loop gain. The gain is:

$$\text{Gain} = \frac{-R129}{R126 + R_{patient}}$$

Op-amp U105C, with associated resistors and capacitors, forms a bandpass filter with center frequency at 31250 Hz. This stage extracts and amplifies the fundamental frequency and yields a sine wave at the output whose amplitude is a function of the impedance between the paddles. Comparator U107A is a peak detector which stores the peak value of the sine wave on C113. Op-amp U105A is the final stage used to tailor the PCI display. PCI INTENSITY (P30-13) which is driven by an open collector output, modulates the dc output level with an RC ramp function at 250 Hz. This modulates the intensity of each individual segment of the bar graph display so that of the LED's which are on, the lowest will be dimmest, and the highest will be brightest. The PCI 1 HZ SQ WAVE (P30-11) flashes the lowest red LED at 1 Hz if the impedance between the paddles is very high, i.e. greater than 300 ohms. The output of U105A, PCI OUT TO PADDLES (J27-1), is sent to the Sternum paddle. In the sternum paddle a comparator/LED driver integrated circuit controls the bar graph.

2-19. I PEAK DETECTOR.

During a discharge the peak current delivered to the patient is monitored for printout with the other post discharge annotation. The discharge current flows through a 1:2500 current stepdown transformer T4 (43100-62701, mounted in the lower case). This proportional current is converted to a voltage by R150, integrated and held by the composite peak hold circuit consisting of open collector comparator U107B, op-amp U104B, resistor R152 and capacitor C117. The output of this peak hold circuit, I PEAK (P30-19), is sent to the analog-to-digital converter on the control board (43100-60100) for further processing. The peak hold circuit is reset by I PEAK RESET (P30-23), a control

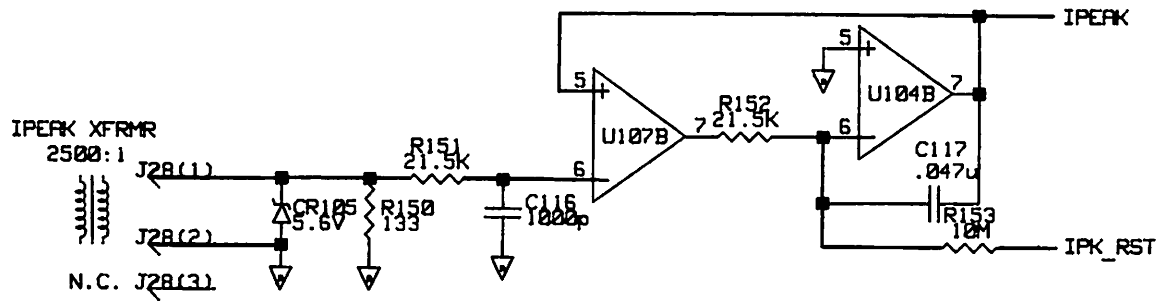


Figure 2-9.

microprocessor signal, via R153. R151 and C116 perform a low pass filtering function to prevent noise from disturbing the I peak reading.

2-20. CONTROL BOARD CIRCUIT ASSEMBLY

The Control board is divided into 3 major functional areas. These areas are the main control, recorder control, and display *control* circuits. Each of the control circuits is designed around a microprocessor; and the three processors communicate with each other over a serial interface.

The main controller circuit handles the primary instrument functions and provides overall system control. Control is accomplished with the help of a gate array. Functions include reading the operator control panel, processing of patient ECG, defibrillator charge and discharge control, and system diagnostics. The ECG processing includes filtering out line frequencies, determining heart rate, and controlling gain of the ECG signal. Processed ECG, status information, and operator messages are sent to the other control microprocessors over a serial interface. Calculation of discharge parameters is also performed.

The recorder control circuit performs all the control functions of the recorder. These functions include processing ECG and annotation data for printing, loading the recorder printhead, controlling motor speed, monitoring the paper supply, and keeping track of the time for annotating events. Operator information and patient ECG are received from the main control processor over the serial interface.

The display controller circuit generates the horizontal sweep, vertical deflection, and beam intensity signals for controlling the CRT deflection board. Patient ECG, status information, and operator messages are received by the display processor from the main control processor over the serial interface. The display processor stores the operator messages and status information internally, and ECG data in an external RAM. This information is processed and used in generating the vertical deflection signal. Vertical deflection is generated with a gate array and a digital to analog converter.

2-21. MAIN CONTROLLER

The main controller circuitry consists of the main control processor, the clock circuit, the control gate array, the analog- to-digital conversion circuitry, the speaker circuit, and the front panel switch matrix.

2-22. MAIN CONTROL PROCESSOR

U61, the main control processor, is an 8051 single-chip micro- controller. It is the heart of the main controller circuitry. System control is accomplished either directly, from the processor's own I/O ports; or indirectly, through the control gate array's I/O lines.

The main control software is executed once every 4.167ms on a cyclic basis. The 4.167 ms software cycle is generated by a timer internal to the processor. Software functions include servicing the A/D converter; serial transmission of data to the other control processors; reading the front panel switch matrix, energy select switch, and paddle switches; digital filtering of the patient ECG; QRS detection; heart rate calculation and alarms; HV capacitor charge and discharge control; and system diagnostics.

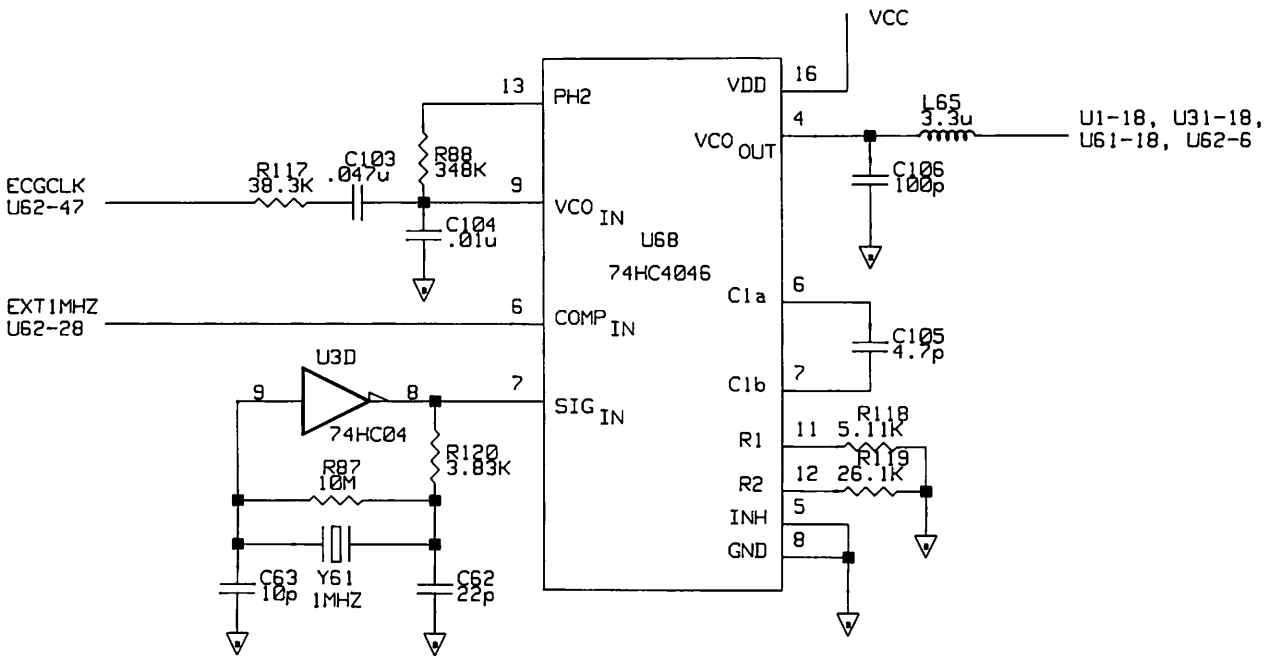


Figure 2-10.

2-23. CLOCK CIRCUIT

The clock circuit (see Figure 2-10.) drives the three control processors (U1, U31, and U61), and the control gate array (U62). It generates a signal that sweeps linearly in frequency from 11.8 to 12.2 Mhz; with a center frequency of 12 Mhz. The period of the frequency sweep (the time to sweep from 11.8 to 12.2, back to 11.8 Mhz) is 32 microseconds. The reason for sweeping the frequency, rather than just using the center frequency of 12 Mhz, is to reduce the radiated EMI of the instrument.

U68 is a phase lock loop IC, consisting of a voltage controlled oscillator (VCO), and phase comparator. The frequency range of the VCO output (pin 4 of U68) is approximately 10 to 14 Mhz; and is set by R118, R119, and C105. The actual frequency at the VCO output is determined by the voltage at the its input (pin 9 of U68). The output of the VCO is input to pin 6 of the control gate array, U61; where it is divided by 12, and then output at pin 28. This divided signal is approximately 1 Mhz; and is input to the phase comparator (pin 3 of U68) and compared to a 1 Mhz reference signal. The 1 Mhz reference signal is generated by the crystal oscillator circuit U3D. This reference signal is input to pin 14 of U68.

The output of the phase comparator (pin 13 of U68) drives the VCO input, through the lowpass filter consisting of R88, and C104. The phase comparator output signal will try and drive the VCO input to a voltage that will give a VCO output of 12 Mhz, so that the divided signal from pin 28 of U62 will match the 1Mhz reference signal. However, a 31.25 Khz signal from the control gate array (pin 47 of U62) is filtered through R117 and C103; and then summed with the phase comparator signal at the VCO input. This 31.25 Khz signal (which has a period of 32 microseconds) is also divided down from the VCO signal input to pin 6 of U62. The filtered 31.25 Khz signal is a small amplitude triangle wave; which causes the frequency sweep of the VCO output. Without the 31.25 Khz signal, U68 would act as a phase lock loop, and the VCO output would lock on 12 Mhz.

2-24. CONTROL GATE ARRAY

The control gate array, U62, is a collection of several smaller digital circuits. It generates many of the system timing signals, and provides I/O expansion for the main control processor. The major functional areas of the gate array are the system timing chain, memory map control logic, control registers, switch matrix control logic, tickle/reset circuit, PCI timing, speaker tones, and charge rate control.

2-25. MEMORY MAPPED I/O

The gate array control registers, switch matrix control logic; as well as, the A/D converter (U63) are configured as memory mapped I/O to the main control processor. Port P0 (pins 32 to 39) of the main control processor is used as the external address/data bus. The control gate array and A/D converter are connected to this bus as shown in Figure 2-11. The memory map control logic is located internal to the control gate array. It consists of an address latch and combinational logic to decode the address. The memory mapped devices are accessed by data memory read/write instructions from the main control processor.

2-26. GATE ARRAY CONTROL REGISTERS.

There are three registers internal to the control gate array, that are configured as external memory locations to the main control processor. They are used for internal control of the gate array, and also as direct outputs to other parts of the system. The contents of each register is updated once every 4.167 ms software cycle.

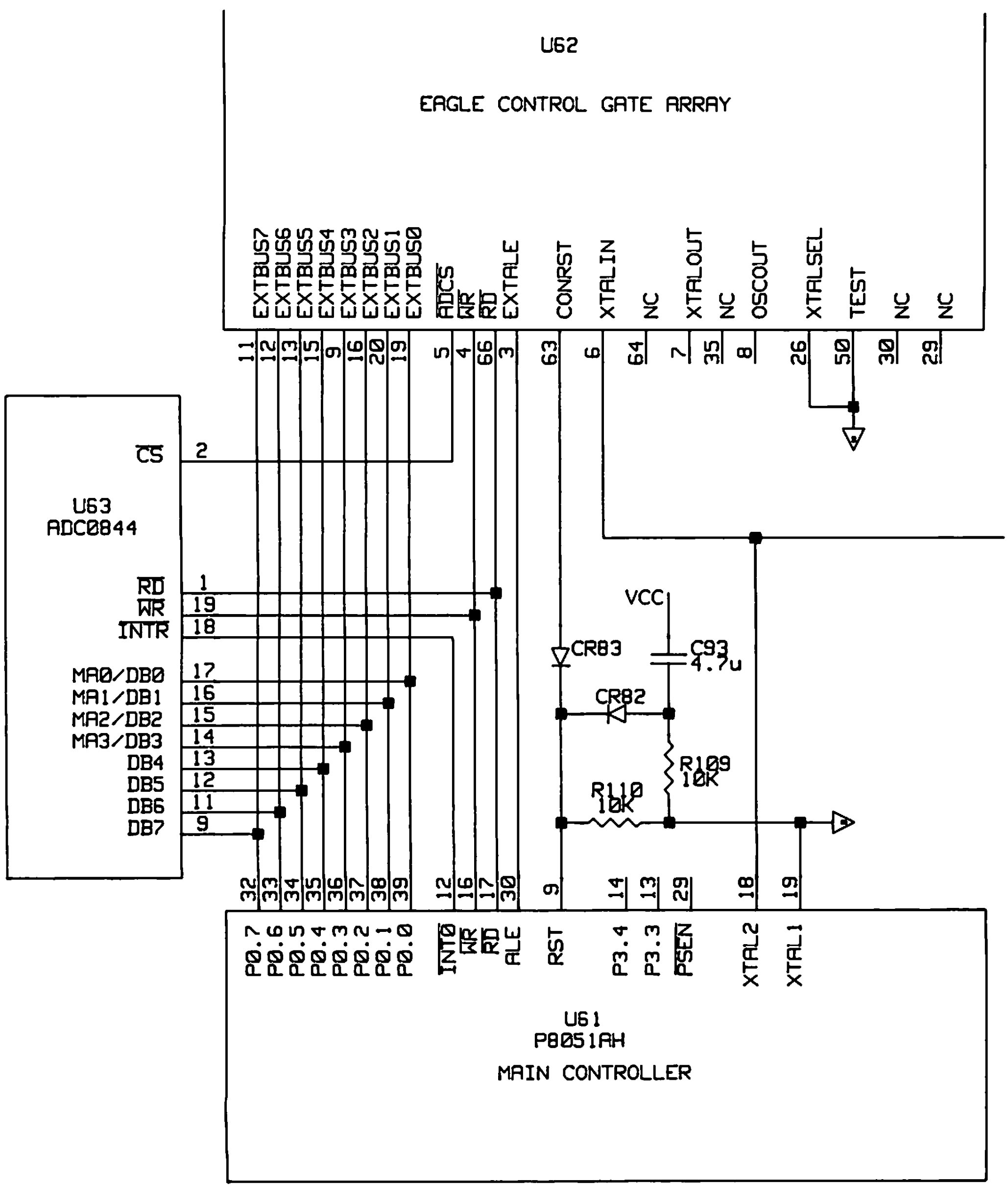


Figure 2-11.

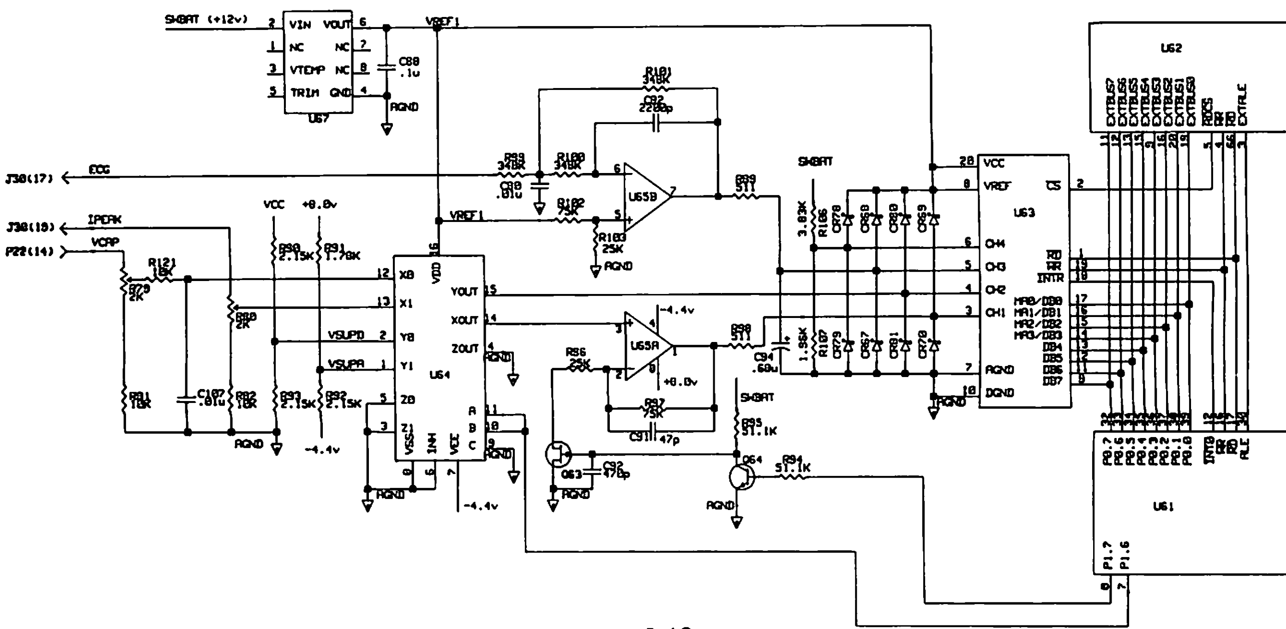


Figure 2-12.

2-27. ANALOG/DIGITAL CONVERSION

U63 is an 8-bit successive approximation A/D converter. The converter has an internal 4 channel analog multiplexer, and generates its own timing with an internal clock. Typical conversion times are 40 microseconds. A +5 volt 1% voltage reference, U67, is used as the reference input to pin U63-8.

An A/D conversion is initiated when the main control processor executes an external data memory write instruction to the address the A/D converter occupies in the memory map. See Figure 2-12. When this occurs, pin U62-5 from the control gate array goes low and selects the A/D converter, U63. The data written to the A/D converter is the multiplexer channel address of the signal intended for conversion. The actual conversion begins when the write signal, pin U63-19, returns high at the end of the external data memory write instruction from U61. After the conversion is completed, the A/D interrupt signal, pin U63-18, goes low and generates an interrupt at pin 12 of U61. The main control processor, U61, reads the conversion result with an external data memory read instruction, and then starts another conversion.

Five to six A/D conversions are performed each 4.167 ms software cycle. Conversions are done on the patient ECG signal (ECG), HV capacitor voltage signal (VCAP), battery voltage (SWBAT), and supply voltages (VSUPD and VSUPA). The order of conversions is ECG, VCAP (at unity gain), SWBAT, VCAP (at 4x gain), VSUPD, and VSUPA. The second conversion of VCAP (at 4x gain) is done only if the first conversion (at unity gain) is less than 1.2 volts. The second conversion of VCAP is done after the SWBAT conversion, to give the gain of U65A time to settle after being changed. An A/D conversion of the peak discharge current signal IPEAK is performed during the discharge sequence.

The patient ECG signal from the Analog ECG board is input to filter stage U65B. This filter stage is an inverting second order low pass filter with a corner frequency of 95 hz. It filters out high frequency noise, and shifts the signal offset to 2.5 volts. The filter's output signal, pin U65-7, is input to Channel 3 of the A/D converter (pin 5 of U63) through resistor R89. Resistor R89, and diodes CR67 and CR68 serve as input protection for U63.

The battery voltage SWBAT is divided down by resistors R106 and R107. The divided signal is input to Channel 4 of the A/D converter (pin 6 of U63). Diodes CR78 and CR79 are used as input protection for U63.

The HV capacitor voltage signal (from the Defibrillator Charger board) is divided down through potentiometer R79 and resistor R81. This divider is used to adjust out the component tolerance of the HV capacitor, and calibrate the delivered energy. The divided VCAP signal is input to X0 (pin 12) of U64. Similarly, the peak discharge current signal (from the Analog ECG board) is divided down through R80 and R82. The IPEAK divider is used to calibrate the test energy accuracy, and the post-discharge calculations printed on the recorder. The divided IPEAK signal is input to X1 (pin 13) of U64.

The digital +5 volt supply is divided down through resistors R90 and R93 to obtain the signal VSUPD. This signal is input to Y0 (pin 2) of U64. The analog +8 volt and −4.4 volt supplies are summed together through resistors R91 and R92 to obtain the signal VSUPA. This signal is then input to Y1 (pin 1) of U64.

U64 is a triple 2 to 1 analog multiplexer. The control inputs A (pin 11) and B (pin 10) for outputs XOUT (pin 14) and YOUT (pin 15) are both connected to P1.6 (pin U61-7) of the main control processor. When P1.6 is low, the signal's VCAP and VSUPD are output at XOUT and YOUT respectively. When P1.6 is high, the signal's IPEAK and VSUPA are output at XOUT and YOUT of U64. The signal XOUT is input to the gain stage U65A. The signal YOUT is input to Channel 2 (pin 4) of the A/D converter. Diodes CR80 and CR81 act as input protection for Channel 2.

U65A is configured as a programmable non-inverting gain stage, and the gain is determined by the state of transistor Q63. When Q63 is pinched-off, the gain is unity; and when Q63 is on, the gain is 4. The state of Q63 is controlled by the main control processor, through transistor Q64. When Q64 is on, the gate of Q63 is at ground, and Q63 is on; and when Q64 is off, the gate of Q63 is pulled to +12 volts and Q63 is pinchedoff. Resistors R96 and R97 set the gain when Q63 is on. Capacitors C91 and C92 are for noise suppression, when Q63 and Q64 are switching.

2-28. SWITCH MATRIX

A switch matrix is used to input the front panel switches and information from the main control processor. The matrix consists of 3 rows and 8 columns as shown in Figure 2.13. The columns are pulled high by resistor network R111, and the rows are held high when not selected. Diodes are used to decouple the rows from each other. Switch positions are determined by strobing the rows low, one at a time, and reading the columns. A closed switch will pull the corresponding column low, when the row goes low.

The row strobes are output from the control gate array, and the columns are input to the control gate array. The switch matrix control logic is internal to the control gate array. Each row of switches occupies an address location in the I/O memory map. A row is selected, and strobed low, when the main control processor executes an external data memory read instruction to the appropriate memory map address. The matrix columns are put on the address/data bus while pin 66 of U62 is low, and read into the main control processor. The switch positions are read by the processor once each 4.167 ms software cycle, and debounced in software.

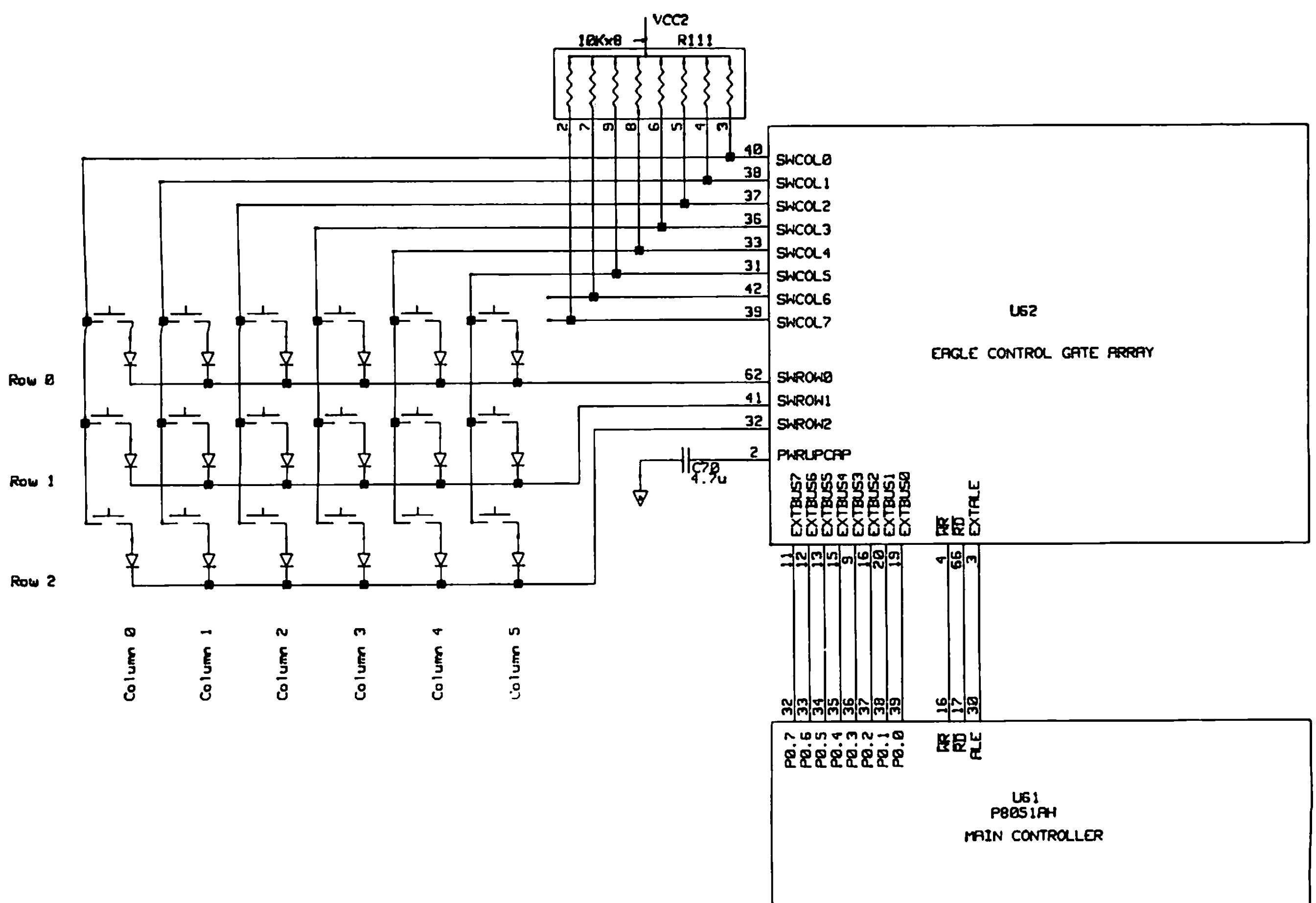


Figure 2-13.

The front panel switches are connected to rows 1 and 2 (pins 41 and 32 of U62) and dip switches S61 are connected to row 0 (pin 62 of U62). Columns 6 and 7 (pins 42 and 39 of U62) are not used.

Pin 2 of U62 serves a special function in the switch matrix. It is read into the main control processor in place of column 7 of row 2. Capacitor C70 is connected to pin 2 and charged through a pull-up transistor internal to U62. The main control processor checks the logic level of pin 2 (which effectively is the charge on C70) to determine if the unit has recently been turned on.

2-29. SPEAKER CIRCUITRY

The speaker circuit generates the power-up tone, charge done tone, heart rate limits alarm tone, the QRS beeper tone, and the triple beep that accompanies certain operator messages.

The tones are derived from the control gate array signals CHGTONE (pin U62-23), HRTONE (pin U62-14), and RWTONE (pin U62-10). The signals CHGTONE and HRTONE are 1953 Hz square waves, and RWTONE is a 1736 Hz square wave. The main control processor controls which of the 3 signals is enabled, through the gate array control registers.

The three signals are AC coupled to the summing amplifier U35B through capacitors C65, C66, and C67. Resistors R73, R75, and R76 in conjunction with R78, set the maximum volume of each tone. Resistor R116A and the beeper volume potentiometer provide volume adjustment for the signal RWTONE. The summing amplifier U35B drives the push-pull transistor pair Q61 and Q62 which in turn, drives the audio transducer DS61 through capacitor C71. Resistor divider R104 and R105 provides a 2.5 volt offset to the output of U35B. See Figure 2-14.

The power-up tone is generated by enabling HRTONE for a 1 second interval upon instrument turn on. The charge done tone is the result of enabling the signal CHGTONE; similarly, the heart rate limits alarm tone is the result of enabling the signal HRTONE. The QRS beeper tone is produced by enabling RWTONE for 180 ms after a QRS complex is detected. The triple beep is generated by alternately enabling and disabling HRTONE at 256 ms intervals.

2-30. TICKLE/RESET CIRCUIT

The tickle/reset circuit, inside the control gate array, provides a means of software recovery for the main control processor. This is a useful circuit when operating in an electrically noisy environment. The circuit is basically a ripple counter that is driven by the system timing chain internal to the gate array. If allowed to run freely, the counter output CONRST (pin U62-63) will generate a signal that is 6.4 ms high and 6.4 ms low. An additional circuit makes it possible to change this signal to 44.8 ms high and 6.4 ms low. The pulse duration is programmed through one of the gate array control registers. During normal operation the 6.4 ms pulse duration is selected. The 44.8 ms pulse duration is used during the discharge sequence.

The signal CONRST is connected to the reset input (pin 9) of the processor. Under normal operation, the main control processor "tickles" or resets the tickle/reset ripple counter once each 4.167 ms software cycle. This prevents CONRST from ever going high and resetting the main control processor. However, if the processor operation is upset by electrical noise and fails to "tickle", then CONRST will reset the processor within 6.4 ms. When reset the software will start over from program address location 0; and "tickle" *rapidly for 25 ms* before resuming normal operation. "Tickling" is accomplished by writing to one of the gate array control registers. The tickle signal from U61 is output as a test signal on pin 1 of U62.

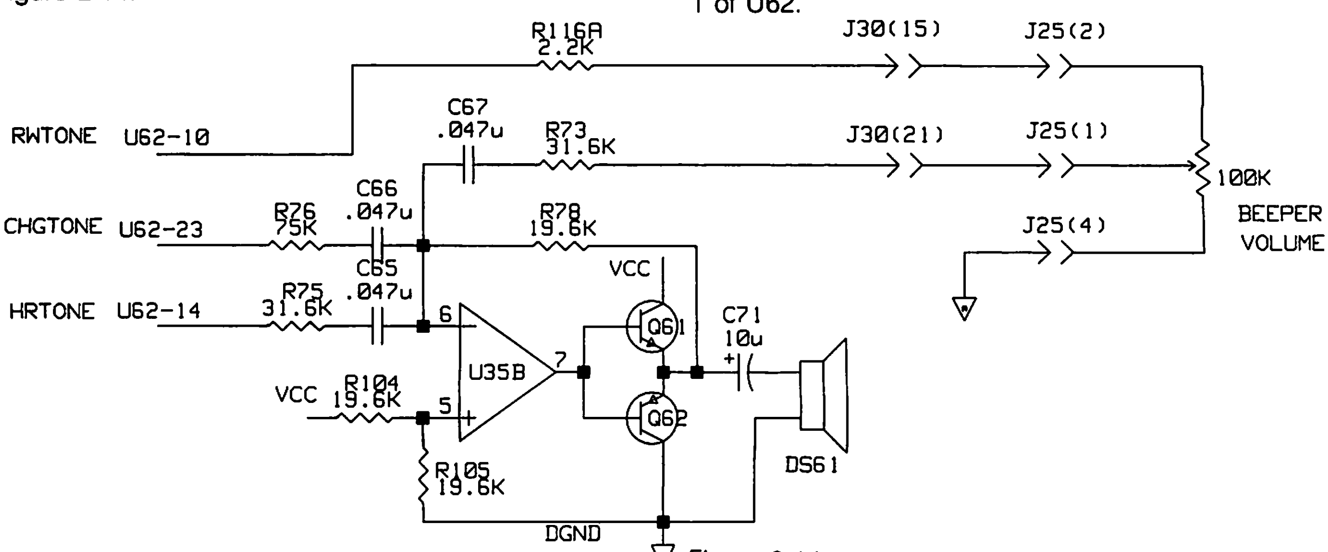


Figure 2-14.

During a discharge sequence, the main control processor turns on the patient relay control signal PATRLY (pin U62-61) to close the patient relay, then programs the tickle/reset circuit for a long (44.8 ms) reset pulse, and stops tickling. Because of the relay's mechanical delay, the processor goes into reset before the relay closes. The processor is held in reset, while the relay closes and the HV capacitor energy is discharged through the patient. This protects the processor's internal registers during the relay closure, which is a time of high electrical interference. Also, the processor is brought up in a known state after the discharge.

When the processor comes out of reset after the discharge, it tickles rapidly for 25 ms, and then performs an A/D conversion of the peak discharge current signal IPEAK. A second conversion of IPEAK is done (at 4x gain) if the signal at unity gain was less than 1.2 volts.

The post discharge calculations (delivered energy, peak current, patient impedance) are performed, and then the patient relay control signal PATRLY (pin U62-61), and the safety relay control signal SFTYRLY (pin U62-59) are turned off to open the patient relay and close the safety relay. The processor then waits for CONRST to go high again, and hold it in reset while the safety relay closes. This second long reset protects the processor from any electrical interference that might occur on the closing of the safety relay. This electrical interference can be significant if an open paddles discharge occurs.

After coming out of the second long reset, the processor tickles rapidly for 25 ms, and then resumes normal operation; and sends the post discharge calculation results to the recorder control processor over the serial interface. See Figure 2-15.

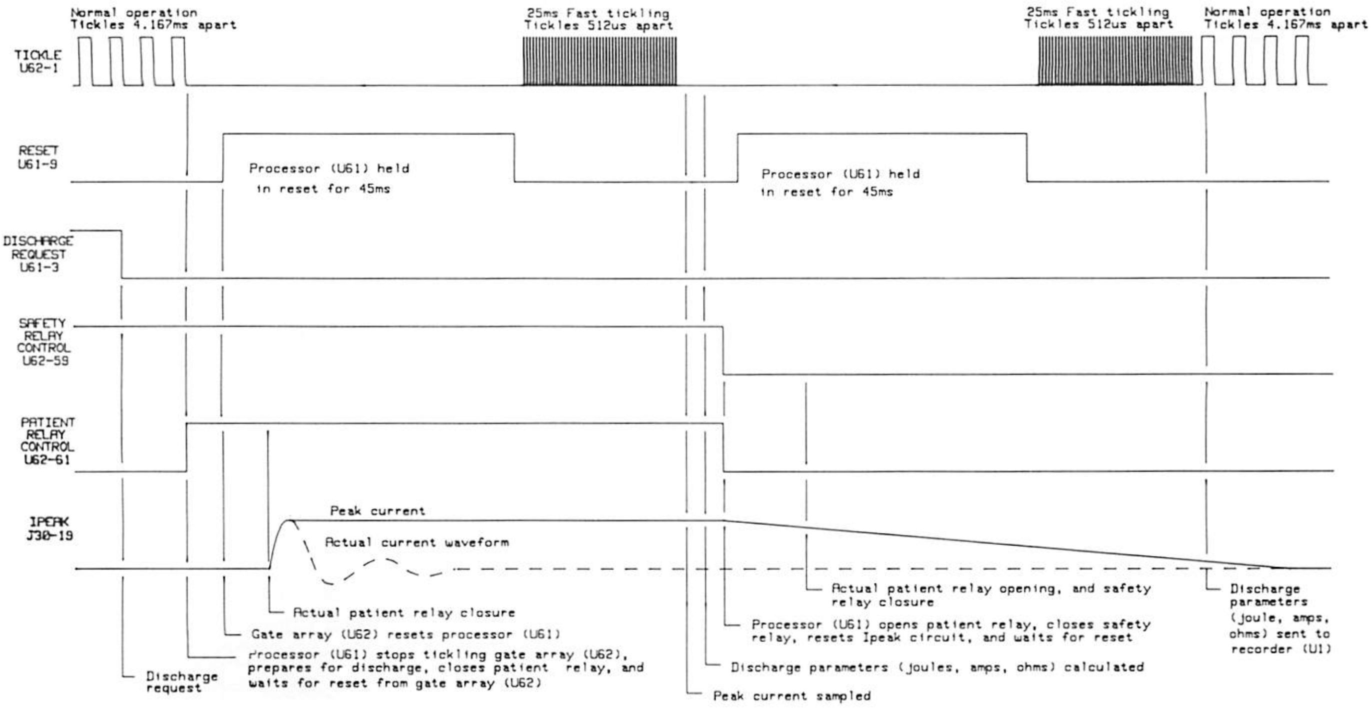


Figure 2-15.

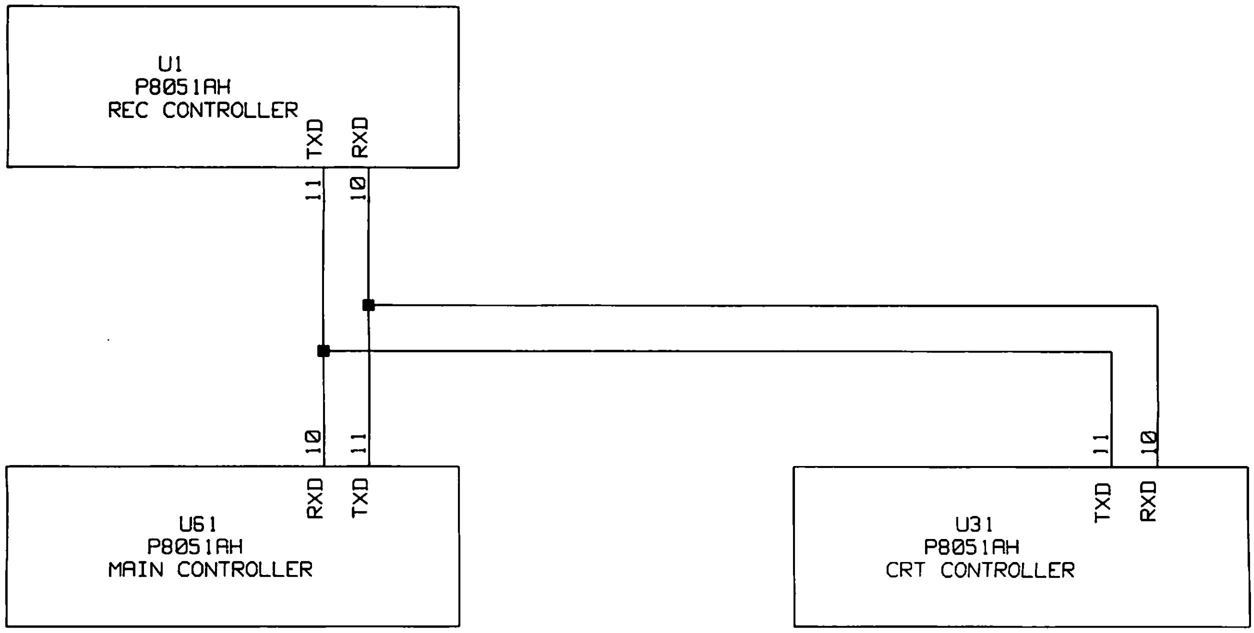


Figure 2-16.

2-31. SERIAL COMMUNICATION

All communication between the 3 control processors (U1, U31, and U61) on the Control board is accomplished through the serial ports of the 8051. Each processor has a transmit port TXD (pin 11) and a receive port RXD (pin 10). The transmit ports of U1 and U31 are connected to the receive port of U61; and the receive ports of U1 and U31 are connected to the transmit port of U61. This configuration allows the main control processor (U61) to talk to both the recorder (U1) and display (U31) control processors; but only allows these two processors to talk to the main control processor. See Figure 2-16.

The serial interface allows exchange of data and status information between the processors, and also provides the synchronizing signal for the software cycles of the recorder and display control processors. All information is exchanged in 11 bit words. The first bit being a start bit, the next 8 bits are data, followed by a flag bit, and then a stop bit. The flag bit indicates whether the information is to/from the recorder or display processor. If set, the information is to/from the display control processor; otherwise, information is to/from the recorder control processor.

The main control processor sends 1 word of ECG data to the recorder control processor at the beginning of each software cycle (every 4.167 ms), and sends an additional 1 to 4 words of status information every other software clcle (every 8.334 ms). On software cycles where the additional information is not sent to the recorder, the main control processor sends 1 word of status and 2 words of ECG information to the display control processor. Thus U61, and U31 communicate only every other software cycle (8.334 ms).

The recorder control processor sends 1 word of status information back to the main control processor, each 4.167 ms cycle, after receiving the ECG data word from U61. The display control processor sends 2 words of 4 second old ECG data to U61; one word after each of the new ECG data words are received from U61. See Figure 2-17.

If U61 detects that a paddles set is not connected, the "NO PADDLES" message is sent to the display processor at regular intervals. If U61 detects an internal paddles set is connected, the energy selection is software limited to 50 joules. Energy switch settings greater than 50 joules are interpreted as 50 joules and the "50J MAX" message is sent to the display processor.

The signal INT PADDLES is also used to light the charge done LED in the apex paddle. When the HV charge is done, P2.6 of the main control processor goes high and turns on Q65, which turns on Q65. With Q66, pulled to + 12 volts (SWBAT) and the charge done LED is turned on.

2-34. SYSTEM DIAGNOSTICS

The main control processor performs diagnostic checks of the instrument each 4.167 ms software cycle. These checks are to verify that the unit is operational and can be safely charged and discharged. If an unsafe condition is detected, the main control processor will disable the charge and discharge sequences, and send error messages to the other two control processors for printing on the recorder, and display on the CRT. Error conditions that are checked include the A/D converter malfunctioning; the supply voltages out of specification; the safety relay circuitry stuck open or closed; and the HV capacitor overcharged, leaking, or arcing.

The main control processor also monitors whether the other two control processors are functioning via the serial interface. If either the recorder or display control processor fails to transmit information back to the main control processor in a given number of 4.167 ms software cycles; the main control processor will reset the unresponsive processor to attempt a software recovery. The recorder control processor is given 4 software cycles (16.7 ms), and the display control processor is given 20 software cycles (83.3 ms) to transmit information back to U61, before being reset. The reset signals (U62 pins 22 and 65) are 16 micro-second wide pulses, generated by the control gate array. They are controlled by U61, through control the control register in U62.

2-35. OPERATOR MESSAGES

The main control processor generates a majority of the operator messages that are displayed on the CRT. These messages are transmitted, in code form, to the display control processor over the serial interface. The display control processor converts these codes to alphanumerics and displays the messages on the CRT.

Battery voltage is monitored as described earlier. If the battery drops below 11.8 volts for more than 2 seconds, the "LOW BATTERY" code is sent to U31 for display. This code continues to be sent at regular intervals to U31, until the battery voltage rises above 11.8 volts for more than 1 second.

Paddles status is determined by the main control processor as previously described. If the paddles are disconnected from the unit, The "NO PADDLES" code is sent to the display processor at regular intervals. If an internal paddles set is connected to the unit, the "50J MAX" code is sent to the display processor each time the energy switch position is changed to a setting greater than 50 joules. The "50J MAX" code is accompanied by a triple beep from the speaker circuit.

The INOP signal (pin U61-2) from the Analog ECG board indicates when the ECG leads have fallen off the patient. When this signal is low, the "LEADS OFF" code is sent to the display control processor.

The main control processor keeps track of the mode (Sync or Defib) and the source selection (Leads I, II, III, or Paddles) of the instrument. When Sync and Paddles are selected, the code for "USE LEADS" is sent to U31, accompanied by a triple beep from the speaker circuit.

The "NO PAPER" and "LOW PAPER" messages are generated by the recorder control processor, and transmitted to the main control processor. The main control processor transmits these messages to the display control processor, and generates a triple beep with the speaker circuitry.

2-36. RECORDER CONTROLLER

The recorder controller (U1) works on a 4.167 millisecond cycle that is synchronized with the serial communications from the control processor.

Reset of the recorder processor is by the main control gate array, U62 pin 22. The gate array will reset the recorder processor on command of the main control processor. Resets will occur on power up of the main unit and on failure of the recorder processor to transmit a message within 4 consecutive cycles to the control processor. On power up, pin 9 of the recorder processor will be held high for approximately 100 milliseconds. Pin 31 of the processor will determine if the processor executes code out of internal ROM or external ROM. If pin 31 is held high execution will be out of internal ROM, and if held low out of external ROM. Normal operating mode will be for execution to be from internal ROM.

2-37. REAL TIME CLOCK

The real time clock (U4) provides time keeping functions that allows the recorder processor to time date all annotation. The clock will keep time when the defibrillators is off by way of the main defibrillator battery. The real time clock is connected to the battery through the unswitched battery line from connector P22-5. The current is controlled by resistor R9. The voltage at Vcc of U4 must not drop below 2.2 volts or time keeping functions will stop with the time registers being corrupted. To regulate the voltage after R9, the voltage reference VR7 is used to keep the voltage at 2.5 volts. CR6 is used to negate the voltage drop of CR4. This circuit will insure the real time clock will keep time when the unit is off. Power will be supplied from switched battery when the defibrillator is on. This will be current limited by resistor R8. CR5 will set the voltage after R8 to 5.7 volts. CR3 is used to block the 2.5 volts from being put on the 5 volt bus when the defib is off. C13 is used to provide approximately six minutes of back up power to the clock, when the main battery is being changed. If the battery is left out longer then six minutes the time will be lost and have to be reset. In this case, wait 15 minutes before setting the clock. This is the time required for the battery to charge C13. See Figure 2-19.

To read or write to the clock the chip select line must first be pulled low. This is done through the open collector transistor Q4 and processor output pin 15. When pin U1-15 goes high the clock will be selected as soon as cap C6 and C15 are discharged. There are software traps to ensure that the clock will not be selected unless under proper software control. Transistor Q3 will make sure that the clock will not be selected when the processor is in reset. A reset will pull line P3.7 high also turning on Q3. When Q3 turns on it will pull the CLK ENABLE line low holding off Q4 ensuring that a inadvertent chip select will not occur. After reset the CLK ENABLE line will remain high until pulled low by software. C6 and C15 will provide enough storage capability to keep the chip disabled until ports are configured by software.

2-38. BUFFERING

Buffering chips U2, U3, and U66 perform two functions. They protect the processor from off board signals and provide sufficient drive current.

PRTHD STROBE line U1-28, will enable the printhead. C10 and R10 form a time constant that will shut off the printhead in case of a processor failure. NO PAPER SWITCH line U1-26 when high, will enable Q5 to sink current from connector J32-4. This will provide a path to ground for the no paper circuitry current (pin J32-4) enabling no paper detection. U3-10 is the motor control signal, when high, will turn on the motor. U3-6 buffers the NO PAPER detection line.

The printhead will be loaded with data from U2. Data is clocked in using port 0 (pins 32-39) and the write strobe (pin 16) of the recorder processor. A dummy address will be output on port 0, followed by the printhead data. The write strobe will go low after the printhead data has been output on port 0. Data will then be clocked into U2 on a low to high transition of the write strobe goes high. The printhead will be ready to print after 32 bytes have been loaded.

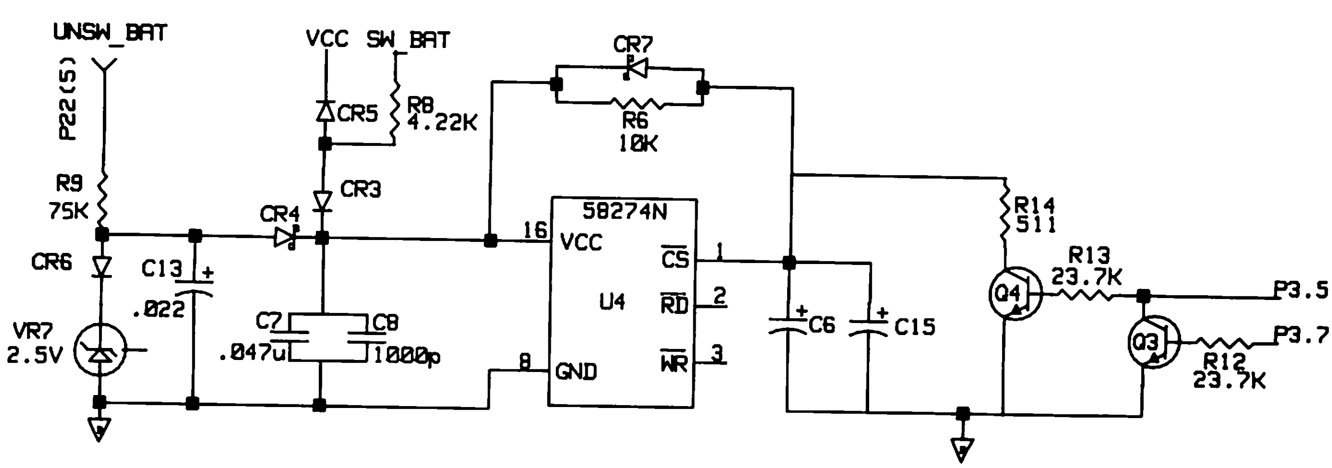


Figure 2-19.

2-39. DISPLAY CONTROLLER

The display processor functions are; accept ECG data and display messages from the main processor, store 4 seconds of ECG data in the RAM, send 4 second delayed ECG data back to the main control processor, and control the gate array to produce vertical, horizontal and beam intensity control signals for the CRT deflection board. Signals generated for the CRT deflection board are shown in Figure 2-20.

The messages are written on the CRT screen from left to right in eight milliseconds. The ECG trace is also written in eight milliseconds on the return sweep from right to left. Thus the entire screen is refreshed every 16 ms. Every 8 milliseconds two ECG data samples are received from the main control processor. The data is stored into the 2Kx8 static RAM by the display processor. To display the ECG waveform the memory cells are sequentially addressed by the display processor. This ECG data is converted to an analog signal which controls the vertical deflection on the CRT. Eight bits of digital stored sample data of each sample are converted into one of 256 possible vertical locations. Zero is at the bottom of the screen, 128 is the center and 256 is at the top. During the eight millisecond ECG display sweep all 1000 data samples are read from memory. Two data points are stored every eight milliseconds. Thus four seconds are required to store new data in all 1000 cells. Therefore the CRT refresh signal is 500 times the input frequency. As new ECG information is received, the oldest information is lost from memory. For a graphic desciption of the read write sequence see Figure 2-21.

The character and message data is stored in ROM in the display processor. The message data is accessed as directed by the message codes received from the main control processor. This data provides the CRT beam blanking control to create the dots in the 5x7 dot matrix letters. The "mini-raster" scan for the letters is produced by the gate array.

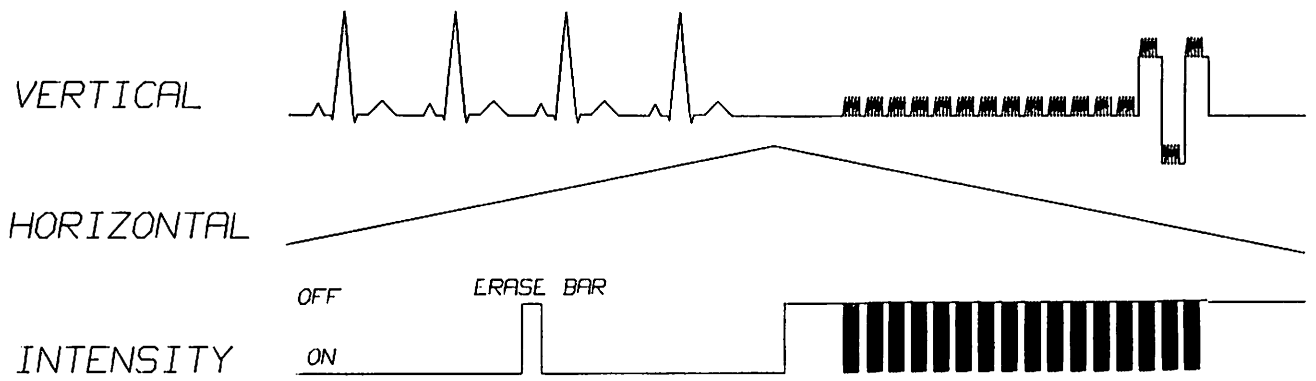


Figure 2-20.

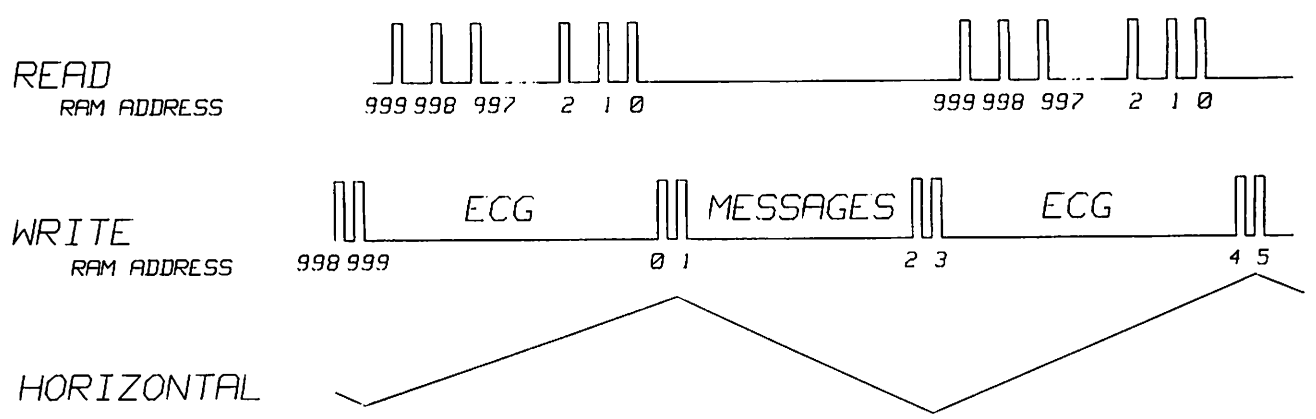


Figure 2-21.

2-40. THE DISPLAY PROCESSOR

The display processor (U31) is an 8051 microprocessor. The RXD (U31-10) line carries message codes and ECG data from the main control processor. ECG data delayed by four seconds returns to the main control processor via the TDX (U31-11) line. Data and control lines go to the CRT gate array and to the 2Kx8 static RAM. The erase bar and the horizontal sweep signal are also controlled by the display processor.

2-41. RAM

The memory (U32) is a 2Kx8 CMOS static RAM. The RAM receives addressing from both the display processor and the CRT gate array. The chip select and output enable signals are generated in the CRT gate array so that the data from the RAM will be valid as needed.

2-42. CRT GATE ARRAY

The CRT gate array (U33) contains the following circuits; Address/Data bus demultiplexing, data latch for the DAC, a counter to produce the letter "mini-raster" and RAM control, and sync marker detection circuitry. Resistors R37 and R35 set the intensity level for the ECG trace messages and the sync marker respectively.

2-43 DAC AND OPAMP

The DAC (U34) and opamp (U35A) convert the digital vertical deflection codes to an analog voltage signal.

2-44. DEFLECTION BOARD

This board provides the drive signals and supply voltages for the deflection yoke and CRT. It contains a triangle wave generator, a vertical amplifier, a horizontal amplifier, an intensity driver, a filament voltage control and a high voltage power supply module.

Vertical and horizontal control signals from the display processor are amplified in closed loop bridges which drive the CRT deflection yoke with current feedback control. The X-axis deflection circuit contains a triangle wave generator for the horizontal sweep. A constant current generator maintains intensity at a nominal setting which is turned off or intensified under control of the display processor. A relay reduces CRT filament voltage when the battery is being charged.

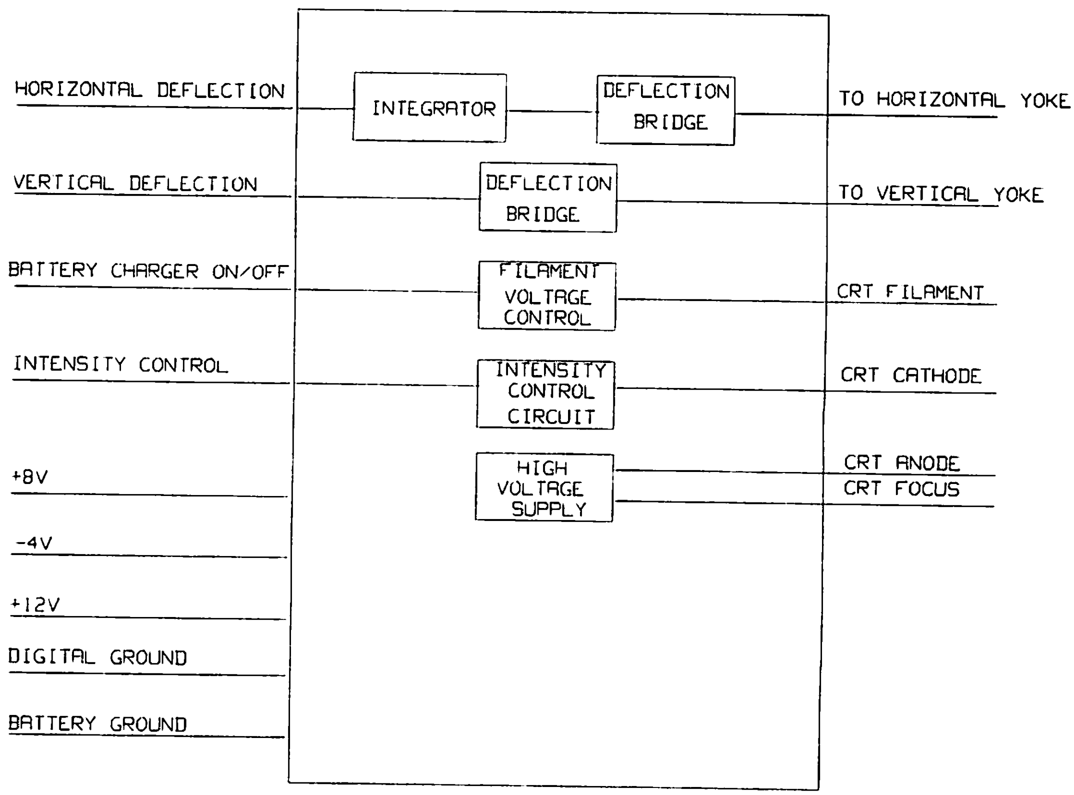


Figure 2-22.

2-45. TRIANGLE WAVE GENERATOR

The triangle wave generator receives a square wave from the display processor and produces a modified triangle wave with "S" correction for the horizontal deflection. The "S" correction provides a wave form which compensates for the larger writing velocities at the edges of the screen. Opamp U2A is the triangle wave generator which is switched by a square wave from the display processor. The signal from the display processor is AC coupled by C3. When the square wave is high C4 and C5 charge through R3 producing a rising voltage ramp. At the end of 8 milliseconds the square wave switches low discharging the capacitors producing a falling ramp. Resistors R33 and R34 determine the signal amplitude which in turn determines the width of the display. U2A is a CMOS opamp. The rails are −4.5 volts and +5 volts.

2-46. HORIZONTAL AMPLIFIER

This circuit is a high impedance, voltage controlled current source. The horizontal drive circuitry generates current ramps in the horizontal deflection coil of the CRT yoke. The increasing magnetic field generated by the increasing current passing through the yoke sweeps the electron beam across the screen.

The circuit is driven by the triangle wave generator. The voltages used by the circuit are the battery voltage and −4.5 volts. The outputs of the circuit are the two lines that carry current to the horizontal deflection yoke of the CRT.

The current through R4 caused by the triangle wave generator causes a voltage across R9. Since R9 is part of a loop that includes the horizontal deflection coil, the yoke current is virtually identical to the current through R9. Therefore the yoke current is proportional to the triangle voltage wave applied to R4.

Q1 and Q2 form the basis of a class B amplifier that buffers the output of the opamp to increase current through the yoke. R8 provides bias for Q1 through CR1 and also provides base current to Q26. CR1 reduces the voltage change required to switch between Q1 and Q2. This minimizes cross over distortion.

Opamp U1A inverts the voltage applied to the yoke. This enables the circuit to reverse the current in minimum time without requiring a high current negative supply voltage. The current to the yoke is buffered by a class B amplifier based on Q3 and Q4. CR2, like CR1 helps minimize cross over distortion. R15 in parallel with the yoke coil lowers the Q of the yoke inductance to prevent ringing and oscillation.

2-47. VERTICAL AMPLIFIER

The vertical voltage to current circuit is almost identical to the horizontal current source. The opamp U2B maintains the impedance to R16 regardless of the ratio of R35 and R36. These resistors control the vertical size of the display.

Heat sinks must be used on transistors Q5, Q6, Q7 and Q8 due to the high current levels.

2-48. CRT FILAMENT CONTROL

The CRT filament has an operating voltage range of 10.8 to 13.2 volts DC. During battery operation the filament is operated directly from the battery. However, during battery recharge from the AC charging circuit the battery voltage rises to 14.2 volts. To protect the cathode relay K1 switches a resistor (R32) in series with the filament whenever the battery is charging.

2-49. INTENSITY CONTROL

The intensity of the CRT trace is controlled by modulating the cathode current. Two distinct current levels are used to provide two brightness levels for normal ECG and the ECG sync marker (higher intensity). The display processor drives two buffers on the control board. Each buffer output is connected to the CRT intensity signal line via a fixed resistor. The intensity control to the deflection board is connected to the emitter of the common base circuit made up of Q9 and Q10. Thus different impedances as seen from the emitter (as controlled by the display processor) cause different cathode current levels. To minimize induced noise on the intensity signal (i.e. on the system ribbon cable), a current 40 times larger than the beam current is sent over the ribbon cable. A current divider is used (R26,R27,Q9,Q10) to divide the intensity signal by 40. The first transistor (Q9) controls the cathode current. The second transistor (Q10) provides some thermal compensation for the current divider and provides the CRT blanking feature. The blanking circuit is comprised of R29, CR5 and CR6. When the CRT trace is to be blanked, the intensity control is pulled high (+5V). Both Q9 and Q10 will be turned off and the collector of Q9 will go high. CR5 will be forward biased while the cathode capacitance is charged by R29. CR6 prevents the +38V supply from coupling into the +12V. A neon lamp (DS1) and a 68k ohm resistor protect the intensity circuit from CRT arcing.

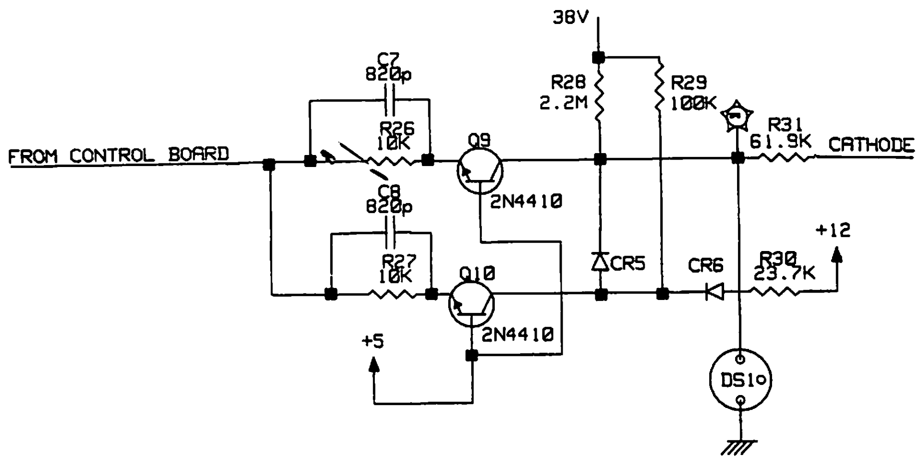


Figure 2-23.

2-50. POWER SUPPLY MODULE

The power supply module is supplied with 12 volts. The outputs are 38 volts for intensity control, 100 volts for CRT focus and 5.5KV anode voltage.

2-51. DEFIBRILLATOR CHARGER BOARD,

The interaction of the different blocks in Figure 2-24 will be described in this section. Then in following sections the circuitry in each block will be described in detail.

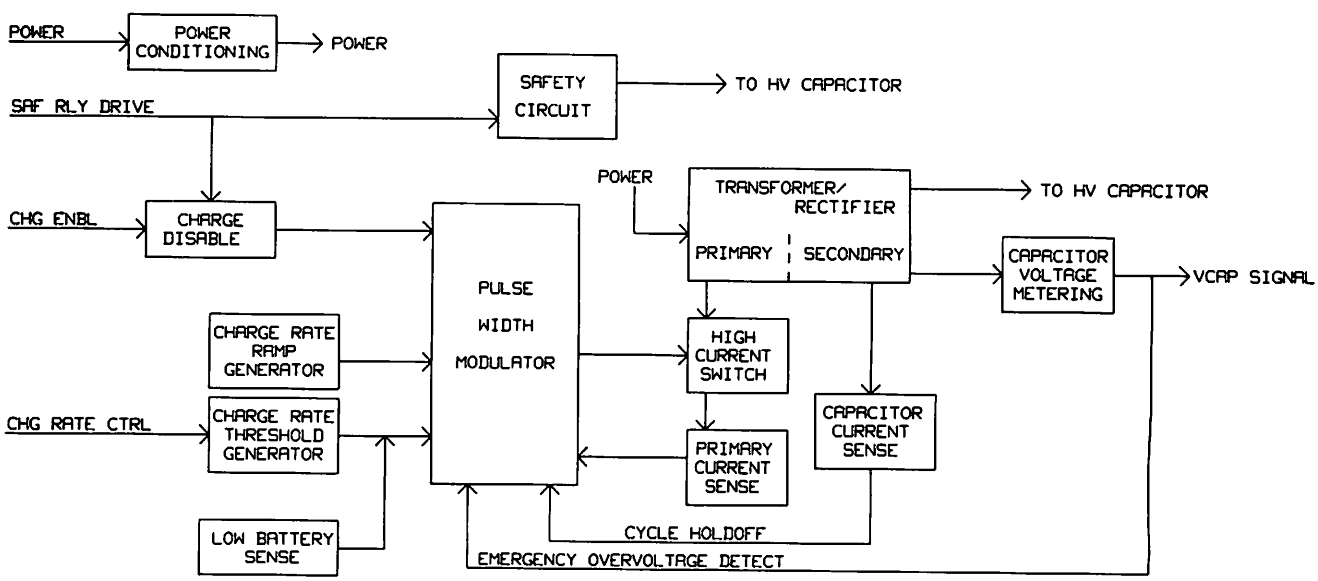


Figure 2-24.

The Defibrillator Charger Board operates as a variable frequency flyback DC- DC high voltage switching power supply for purposes of charging the HV Capacitor. Charging begins with reception of the proper SAF RLY DRIVE (safety relay drive, CHG ENBL (charge enable), and CHG RATE CNTL (charge rate control) signals from off-board. The Pulse Width Modulator, as the central controlling block, outputs a pulse the duration of which is dependent upon the time required for the Charge Rate Ramp to reach the Charge Rate Threshold. During this time the High Current Switch, a power MOSFET, is turned on; the result is a current ramp in the transformer primary. At the end of the Pulse Width Modulator output pulse duration the power MOSFET stops conducting, and the Transformer/Rectifier secondary conducts current onto the off-board Main Storage Capacitor. The Capacitor Current Sense circuit then detects current, which causes it to inhibit the restart of another Pulse Width Modulator output. When the capacitor current reaches zero, however, the Cycle Holdoff is released, and the entire cycle is repeated. Meanwhile the capacitor voltage is being scaled and buffered by the Capacitor Voltage Meter circuit for output to the Control Board. During all this time the Power Conditioning circuit provides bypassing for the Switched Battery input, and provides fusing and bypassing for the Raw Battery input; and the Safety Relay Drive input to the Safety Circuit operates to disconnect a shunt resistor from the HV Capacitor.

A number of signals and blocks serve as inputs to the Pulse Width Modulator block, to influence its output. The Charge Disable circuit uses the Safety Relay Drive input as well as the Charge Enable input to enable charging as appropriate. The Charge Rate Ramp Generator generates a voltage ramp which is slower when the battery voltage is lower, to partially compensate for otherwise slowed charging under low battery conditions. The charge rate is varied remotely by duty cycle modulation into the Charge Rate Control input which is received by the Charge Rate Threshold Generator circuit. This circuit also AC-couples the Charge Rate Control input to protect against an erroneous stuck-high condition. The Low Battery Sense circuit disables defibrillator charging if the battery voltage drops below 10 volts. The Primary Current Sense circuit monitors the Transformer/Rectifier primary current for a possible overcurrent condition, in which case the pulse width modulator would terminate its output pulse. Finally, the Pulse Width Modulator block receives the output from the Capacitor Voltage Metering circuit, to disable charging in the event of a runaway charge condition where the HV Capacitor reaches an unacceptably high voltage level.

2-52. POWER CONDITIONING CIRCUIT, Figure 2-25.

High-and low-current battery and ground lines enter the HV Charger Board on separate lines. The ground lines are connected on the Battery Charger Board. The high-current battery line enters the HV Charger Board unfused and unswitched, and is fused by F1, which is mounted in FH1. It is then filtered by C8, a low ESR capacitor needed to supply the high current surges required in the primary circuit. The low-current battery line enters the HV Charger Board having been through a circuit breaker and through a relay controlled by the front panel switch. It is bypassed by C2 and C9 to low-current ground. The low-current ground is also used as an analog ground for the capacitor voltage indication which is returned to the Control Board.

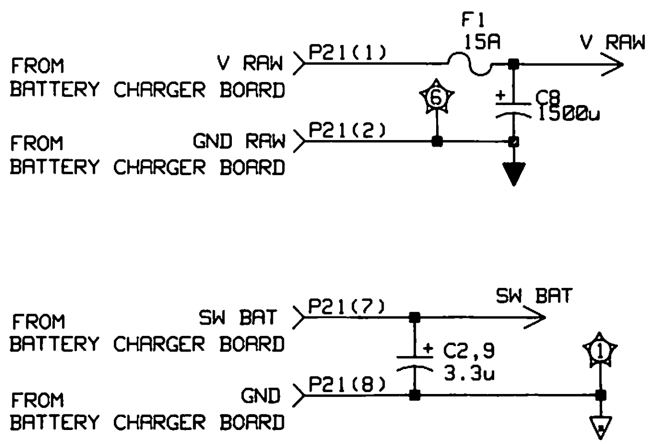


Figure 2-25.

2-53. SAFETY CIRCUIT, Figure 2-26.

The defibrillator safety circuit is composed of K1, R1, CR1, C11, and R19. The Safety Relay Drive line is brought low by a relay driver on the Battery Charger Board, in response to a command from the Control Board. The high voltage relay K1 will then open, which disconnects R1 from the negative HV capacitor terminal. Upon command from the Control Board the line will be released and the relay will again close, allowing R1 to discharge the capacitor to zero or to some other value selected by the Control Board. Disconnecting power will also release the relay contacts into their normally closed position, safely shunting the HV capacitor terminals. Upon release of the Safety Relay Drive line, CR1 serves

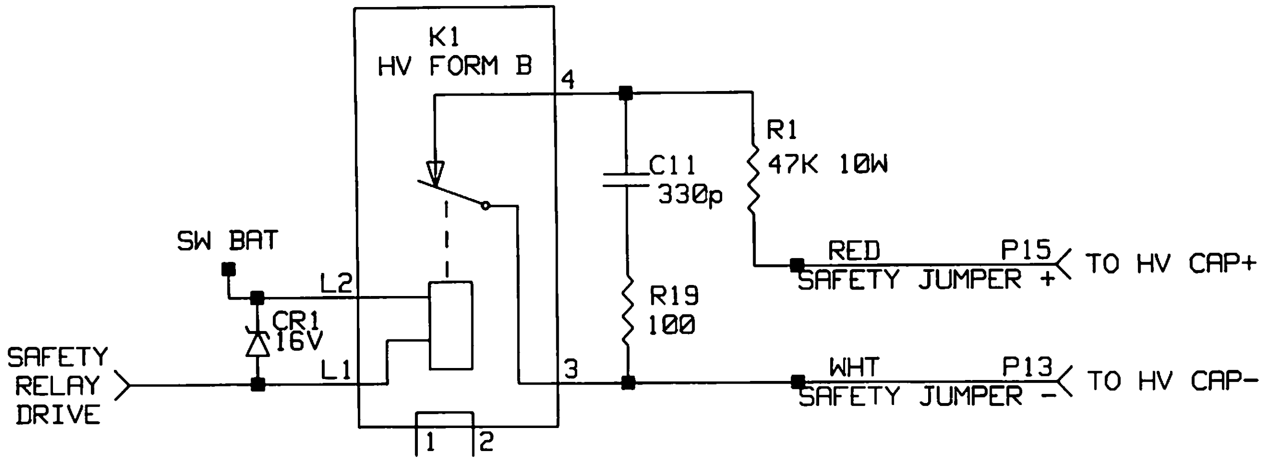


Figure 2-26.

to augment the Battery Charger Board's diode clamping as protection from the K1 coil inductive spike. In addition, CR1 helps protect the driver circuitry from spikes that may be capacitively coupled through the relay when the opening or closing relay contacts undergo rapid voltage swings. C11 and R19 are relay contact snubber components that help to reduce the rate of voltage change across the contacts during contact opening or bounce, thereby reducing radiated and conducted noise.

2-54. PULSE WIDTH MODULATOR, Figure 2-27A.

For this circuit implementation, the pulse width modulator can be seen in Figure 2-27B as: a voltage source the output of which can be disabled by any one five conditions; and a 5 volt reference. Figure 2-27A shows a more complete but less intuitive representation of the device; schematics of several of the internal functional blocks are available from the manufacturers' catalogs.

The output stage is an emitter follower; so the output voltage will be slightly less than switched battery when the output is turned on, and will be floating when the output is off or disabled. Resistors R11 and R12 provide the only current sinking on the output. The 5 volt reference output is bypassed with C1.

There are five conditions which can cause the output to turn off:

1. If current is sourced into pin 10,
2. If the voltage at pin 7 is greater than that at pin 9,
3. If the voltage at pin 1 is greater than that at pin 2,
4. If a voltage greater than 3 volts is placed on pin 3,
5. If the voltage at pin 4 exceeds the voltage at pin 5 by 200 millivolts or more.

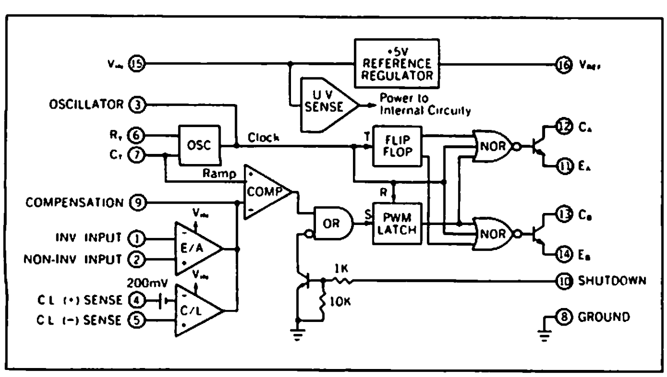


Figure 2-27A.

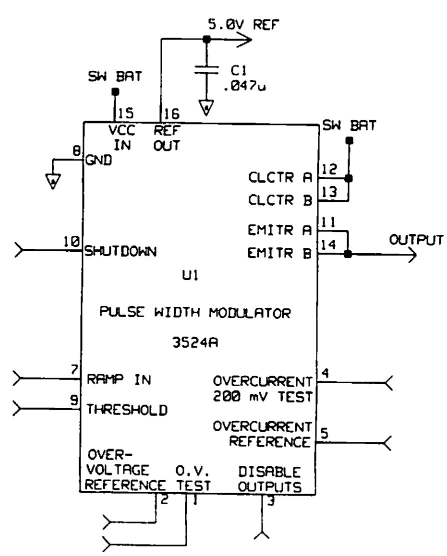


Figure 2-27B.

Any one of conditions 3 through 5 will also cause a Darlington *transistor (internal* to the Pulse Width Modulator) to pull the voltage at pin 7 down to about 0.8 volts above ground. It should also be mentioned that pin 9 is the output of a transconductance opamp in the Pulse Width Modulator, the inputs of which are pins 1 and 2. Pin 9 is a current source of about 100 microamps at essentially any time that the voltage at pin 2 is higher than that at pin 1 unless condition 5 is met as described above.

2-55. CHARGE DISABLE CIRCUIT, Figure 2-28.

R2, CR2 and CR3 form the charge disable circuit. In order for the charger to operate, the Charge Enable input must be brought low, and the safety relay must be driven. The diodes provide the OR function for disabling charge, as well as improving the logic zero voltage margin from the off-board signals.

2-56. RAMP GENERATOR CIRCUIT, Figure 2-29.

R3 and C3 form the Ramp Generator circuit. The exponential voltage rise is terminated after only a few volts excursion, when it reaches the voltage at pin 9 or when any of the other conditions described in the Pulse Width Modulator section are met; so the ramp is approximately linear. When the battery voltage is lowest, the ramp is the slowest, increasing the T1 primary on-time in partial compensation for decreased primary voltage.

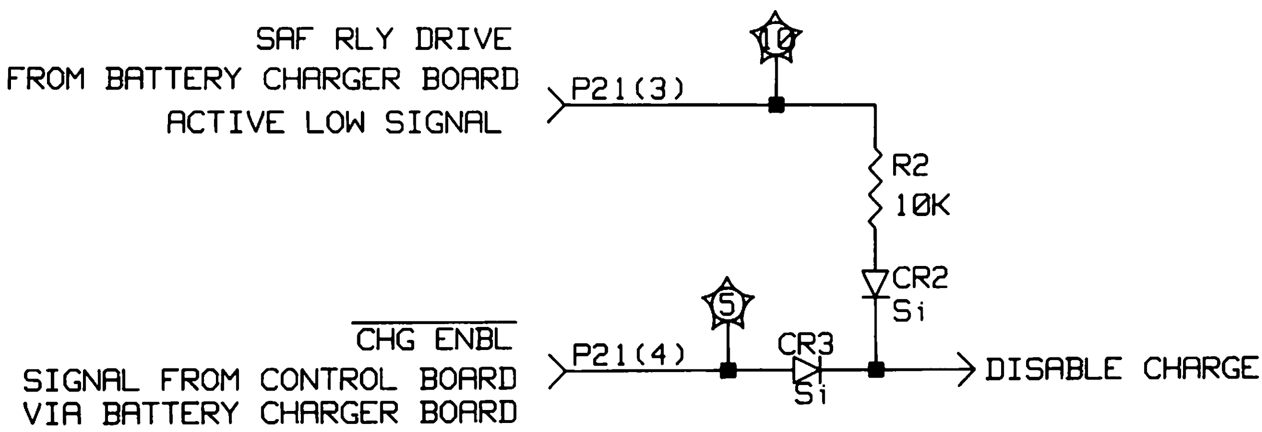


Figure 2-28.

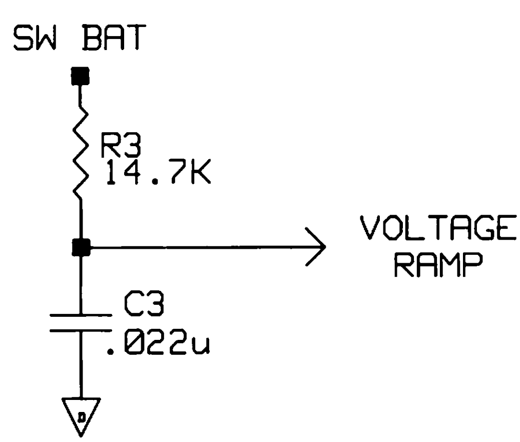


Figure 2-29.

2-57. CHARGE RATE THRESHOLD GENERATOR CIRCUIT, Figure 2-30.

The components that form the Charge Rate Threshold Generator are C4, CR4, R4, R5, C5, U2C, R6, and CR5. The Charge Rate Control signal from the Control Board is a 15.6 kHZ, variable duty cycle, logic level square wave. A higher duty cycle yields a higher charge rate threshold, which will cause a faster charge. C4 and CR4 AC-couple and rectify the Charge Rate Control signal so that if the incoming signal is erroneously stuck high, the charge rate threshold will go low. R4, R5, and C5 filter the AC component from the resulting signal. U2C buffers that averaged value, and R6 overcomes the high output impedance that may result from the op amp's operation near ground. CR5 assures that the output of U2C will only sink current from U1 pin 9, allowing either U1 or U2B to pull pin 9 low.

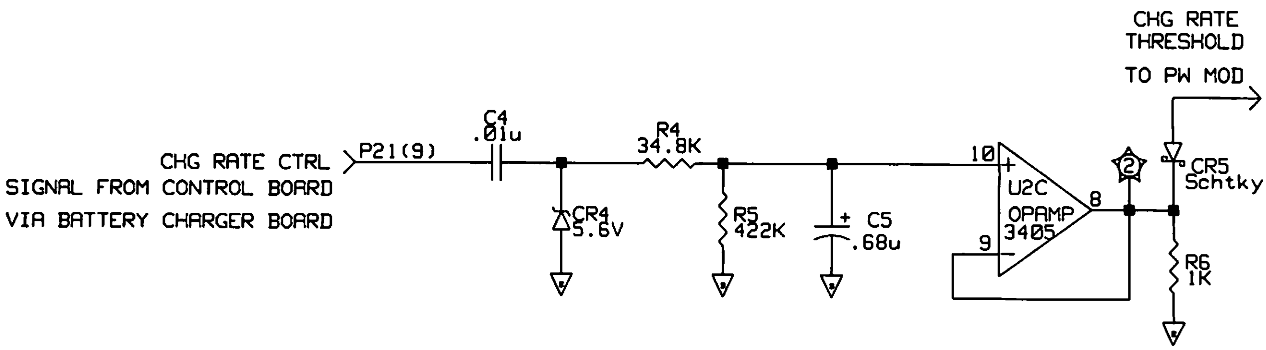


Figure 2-30.

2-58. LOW BATTERY SENSE CIRCUIT, Figure 2-31.

R7 and R8 divide the battery voltage in half; C6 filters the divided voltage. If the resulting voltage drops below 5 volts, i.e., if the battery voltage drops below 10 volts long enough, then the output of U2B will sink current and thus disable the output of U1 as described in the Pulse Width Modulator Section 2-54.

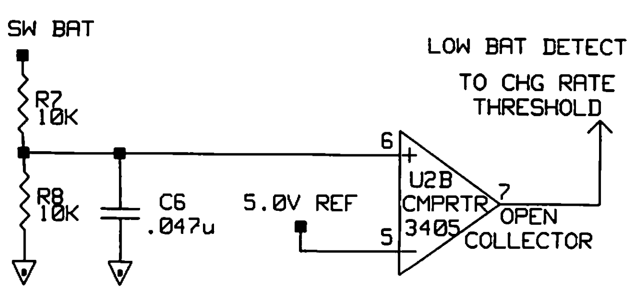


Figure 2-31.

2-59. HIGH CURRENT SWITCH CIRCUIT, Figure 2-32.

A high output from the pulse width modulator turns on the high current switch, Q1, which is a power MOSFET. Upon removal of the high output from the pulse width modulator, R11 and R12 will bleed off the gate charge, turning off the power MOSFET. If the drain voltage approaches an unsafe value for the device, CR6 will pull up on the gate voltage, so that the MOSFET will turn on and keep the drain voltage to a safe value. CR7 inhibits conduction of CR6 when the MOSFET switch is turned on. CR8 protects the device from spurious transients which could damage the gate-source junction. The MOSFET is mounted on a heatsink to keep it cool. The heatsink is electrically at the drain potential.

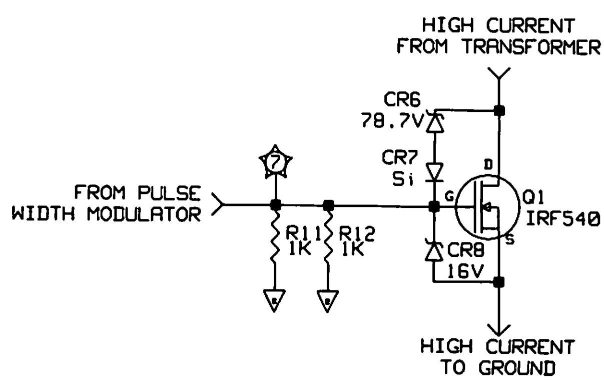


Figure 2-32.

2-60. PRIMARY CURRENT SENSE CIRCUIT, Figure 2-33.

R10, R9, and C7 form the Primary Current Sense circuit. The voltage across the current measuring resistor R10, a low inductance resistor, is directly related to the primary current. R9 and C7 filter from the signal high frequency components which are due to various primary and secondary circuit parasitic capacitances and stray inductances, including the secondary capacitance ringing reflected as mentioned in the Transformer/Rectifier description below. In addition, R9 and C7 attenuate the signal slightly in order to allow the primary current to ramp higher than would otherwise be possible with worst case component tolerances.

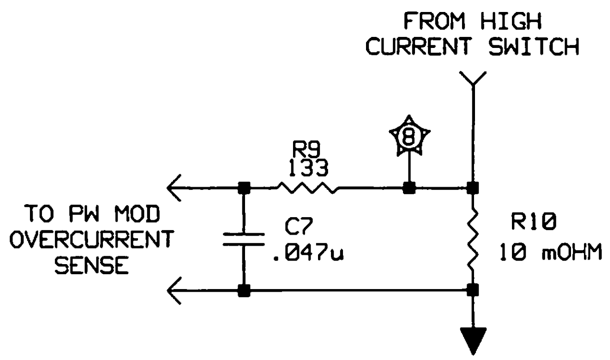


Figure 2-33.

2-61. TRANSFORMER/RECTIFIER CIRCUIT, Figure 2-34.

The Transformer/Rectifier circuit involves four of the five parts in T1: the primary winding, the secondary winding, the core, and the high voltage rectifier. The metering resistor, also part of T1, is discussed as part of the Capacitor Voltage Metering circuit.

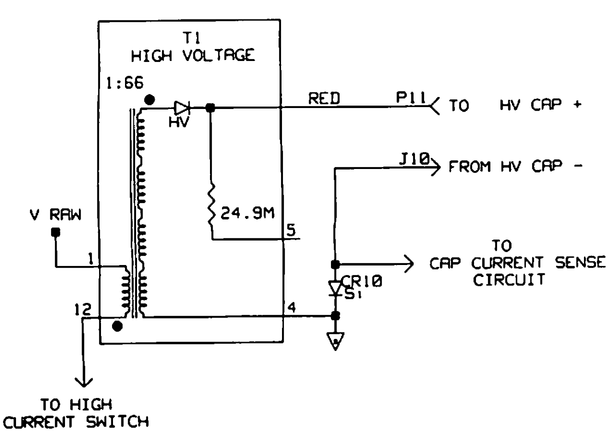


Figure 2-34.

When the high current switch Q1 turns on, approximately full battery voltage is applied across the primary winding. The high voltage rectifier is then reverse-biased; the rectifier anode is at a negative voltage approximately equal in magnitude to the battery voltage times the turns ratio (66). The constant voltage across the primary inductance, then, causes a constant slope current ramp in the primary circuit. When the high current switch Q1 turns off, the flux in the core of T1 causes current to flow in the secondary winding. The secondary voltage rises rapidly until the high voltage rectifier becomes forward-biased. At that time current is conducted into the HV capacitor positive terminal. The initial rectifier current is related to the ending primary current by the transformer turns ratio; and, because the secondary inductance is held at a near-constant voltage (approximately equal to the HV capacitor voltage), the current ramps down nearly linearly with time. Cessation of current is detected by the Capacitor Current Sense circuit, and the primary-secondary cycle is repeated. Note that when the HV Capacitor is at a high voltage, the secondary conduction time is less than when it is at a low voltage; hence the variable frequency capacitor charging.

It should be noted that a number of parasitic capacitances and stray or leakage inductances have an effect on the voltage and current waveforms. For example, when the power MOSFET switch turns off, the flux that is not coupled to the secondary winding will cause the MOSFET drain voltage to go higher than would be calculated by reflecting the secondary voltage back to the primary. The actual voltage depends on the amount of parasitic capacitance available for energy storage, and on the amount of energy that is dissipated by such resistive losses as the MOSFET during switching. Another parasitic capacitance that plays a significant role is the interwinding secondary capacitance. When the MOSFET stops conducting and the secondary starts conducting, the rise time of the secondary voltage is limited by the relatively constant secondary current that is charging secondary stray capacitances. Then at the end of the secondary conduction portion of the cycle, when the high voltage rectifier becomes reverse-biased, the secondary capacitances will ring with secondary stray and leakage inductances, and with reflected impedances from the primary. This ringing can continue during the entire primary conduction time. It will couple magnetically into the primary circuit; and will couple capacitively, via the capacitances of the high voltage rectifier's reverse-biased junctions, into the Capacitor Current Sense circuit.

2-62. CAPACITOR CURRENT SENSE CIRCUIT, Figure 2-35.

Current from the HV Capacitor negative terminal, which flows during the time the rectifier in transformer T1 is forward- biased, flows to the transformer secondary through diode CR10. At that time U1 pins 11 and 14 are low, so that R13 serves to reduce the voltage that would otherwise be produced by R14 and R15. The CR10 diode voltage is then greater than the resulting voltage on U2A pin 3, so the output of U2A is open. R16 and the emitter follower Q2 then drive U1 pin 3 high, inhibiting the pulse width modulator output from going high. When current in the capacitor ceases, the voltage across CR10 becomes less than that at U2A pin 3, and the cycle holdoff signal at U1 pin 3 goes low. At that time the pulse width modulator output, U3 pins 11 and 14, will go high, which raises the voltage on U2A pin 3 by way of R13. During this time, some current will flow alternately in CR9 and CR10 due to the high voltage rectifier's capacitive coupling of transformer secondary ringing as described in the transformer/rectifier section above. The output of U2A will not toggle, however, because of the increased threshold on pin 3 during primary conduction.

2-63. CAPACITOR VOLTAGE METERING CIRCUIT, Figure 2-36

Transformer T1 contains a resistor connected on one side to the high voltage rectifier cathode, which is at the HV capacitor voltage. The other side comes out of T1 on pin 5, and connects on the PC board to R17, which serves to divide the voltage down to a voltage under 5 volts. C10 filters any noise, and U2D buffers the voltage. CR11 protects U2D from any positive or negative spikes that may enter the board at that point, and R18 helps to maintain low impedance on the Vcap line. The capacitor voltage indication is sent to the Control Board for its use in determining the defibrillator's state of charge, and also to U1 pin 1, which will disable charging in the event that the capacitor voltage indication reaches an unacceptably high value of 5 volts.

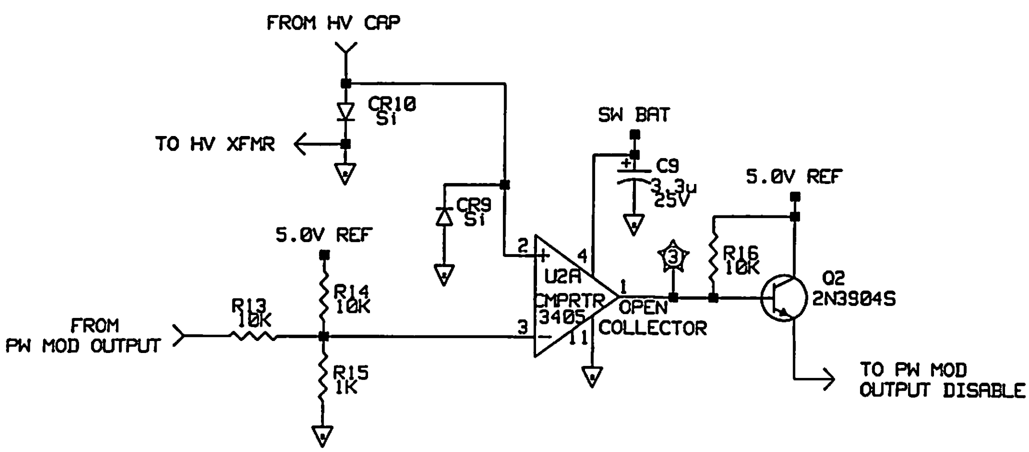


Figure 2-35.

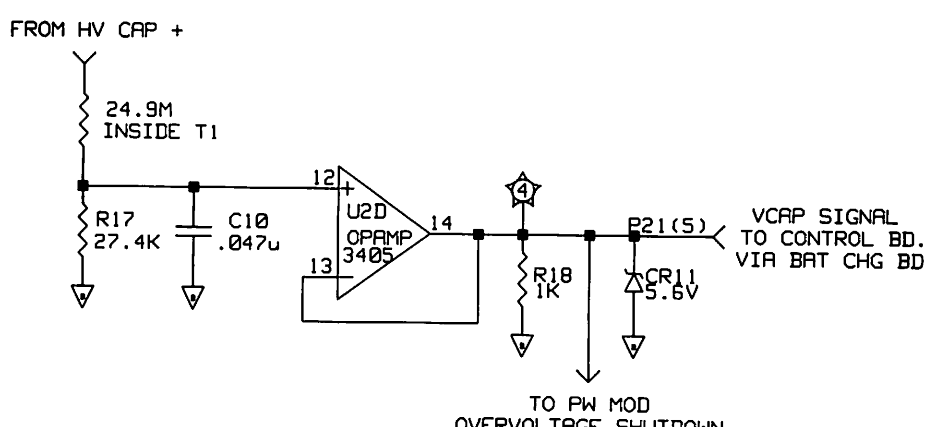


Figure 2-36.

2-64. HIGH VOLTAGE CIRCUITRY

High Voltage Circuitry functions to store energy during defibrillator charging; and to switch, waveshape, and measure energy during defibrillator discharging. The patient is isolated from the Defibrillator Charger Board and from the HV Capacitor at all times except during discharge; the charging circuit is isolated from the HV Capacitor and from the patient during discharge. A resistive load is provide for test discharges.

2-65. HV CAPACITOR CHARGE CIRCUIT, Figure 2-37.

The HV Capacitor Charge Circuit is composed of the Defibrillator Charger Board A5; the HV Capacitor A1C1; and the Patient Relay A1K1. The Defibrillator Charger Board supplies the energy needed to charge the HV Capacitor, and also supplies a shunt resistive load to dump charge when needed. The HV Capacitor includes a 24.9 megohm bleeder resistor as well, to preclude a buildup of charge when the Defibrillator Charger Board is disconnected from the circuit. The Patient Relay is a double-pole, double-throw, high voltage, high surge current relay. The relaxed position of the relay is shown.

2-66. HV CAPACITOR DISCHARGE CIRCUIT, FIGURE 2-37.

The HV Capacitor discharge circuit is composed of the HV Capacitor A1C1; the Patient Relay A1K1; the HV Inductor A1L1; the Current Transformer A1T1; and the Test Load Resistor A1R1.

When the 12 ohm coil of the Patient Relay is supplied with current by the Battery Charger Board A4, the relay contacts A1K1 will switch from the normally closed position to the normally open position. The RF chokes included in the relay assembly help to suppress EMI from high-energy arcing of the contacts. The HV inductor provides smoothing of the current waveform to meet specified parameters; in addition, its 11 ohms of winding resistance provides energy dissipation in the event that the defibrillator is discharged into a low external impedance. The Current Transformer divides the discharge current by a factor of 2500, for use by a peak detector on the Analog ECG Board A6. The Test Load Resistor is available between the paddles' pockets, for use in simulating a discharge into a 50 ohm patient. Note that the ECG signal from the paddles follows some of the same path as does defibrillator discharge current.

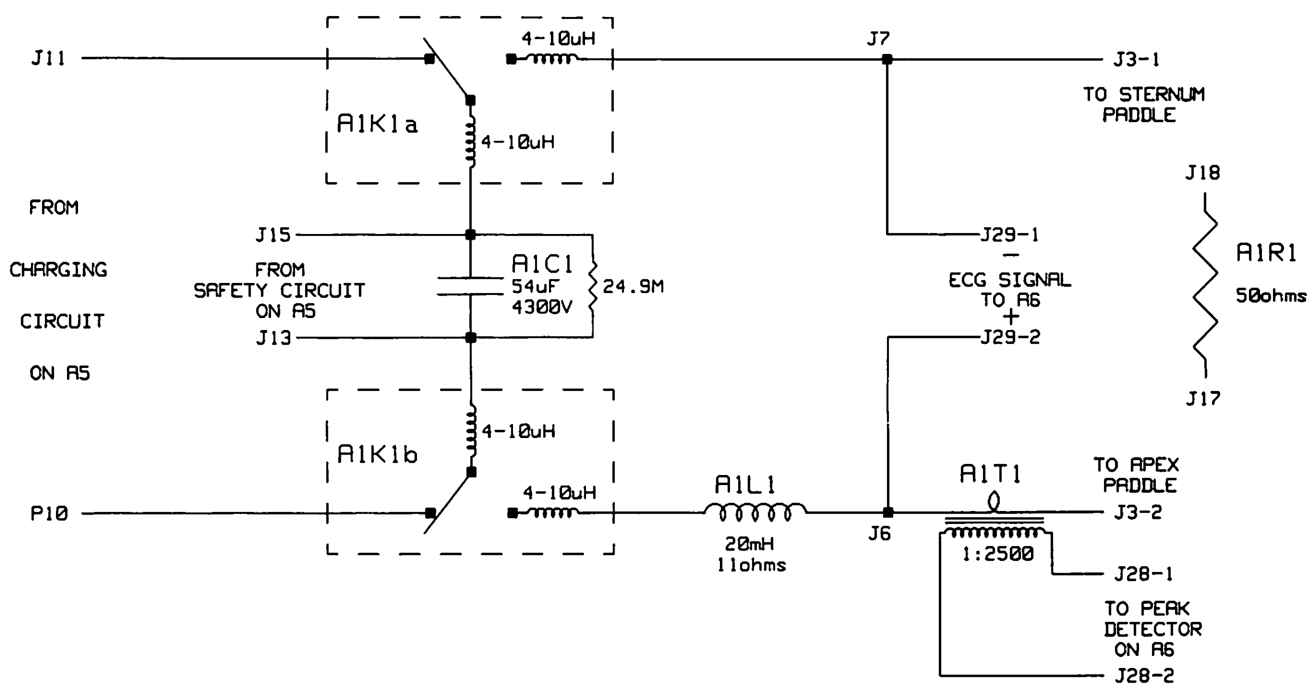


Figure 2-37.

2-67. BATTERY CHARGER AND LOW VOLTAGE POWER SUPPLIES

Line voltage is converted to a constant voltage charging source for the unit's battery with a forward-converter switching power supply. An input line filter isolates switching noise from the power cord. This supply is factory strapped for either 110 or 220 VAC.

Battery power is connected directly to the High Voltage Charger board and clock. It is connected through a circuit breaker and low battery shutdown circuit to the rest of the instrument.

A combination of linear and switching power supplies create the +5V, +8V, and −4.4V regulated outputs. Circuits on this board power the battery charge LED and drive the safety and patient relay coils.

Figure 2-38. is provided as a schematic flowchart, showing power flow and interconnects.

2-68. POWER INPUT/GROUND/PROTECT/LINE FILTER CIRCUIT (Figure 2-39.)

The power cord line and neutral connect to the Circuit Breaker Board, sending AC power through the circuit breakers and EMI suppression inductors L1 and L2: to the battery charger: (a) directly in the 110 VAC model, or (b) via the ON/OFF DPST power switch in the 220 VAC model. The power cord safety ground connects to the ground post, which then connects through EMI inductor L3 on the Circuit Breaker Board to the battery charger EMI filter ground and the DC power supply (secondary) ground, plus the green/yellow safety ground wire leading to the: (a)recorder frame, (b)ECG output jack and (c)volume adjust potentiometer frame.

A line filter attenuates conducted EMI/RFI from the switching power supplies and digital circuitry, to conform to FCC and VDE standards. L1, C1 and C2 form a common-mode filter, while C3 and C4 provide the differential-mode filtering. The capacity-to-ground of the power cord, C3 and C4 are limited to keep leakage current under the safety standard limit. R1 is a safety bleeder for C1 and C2. A metal enclosure surrounds the off-line switching power supply circuits and serves also in confining EMI/RFI.

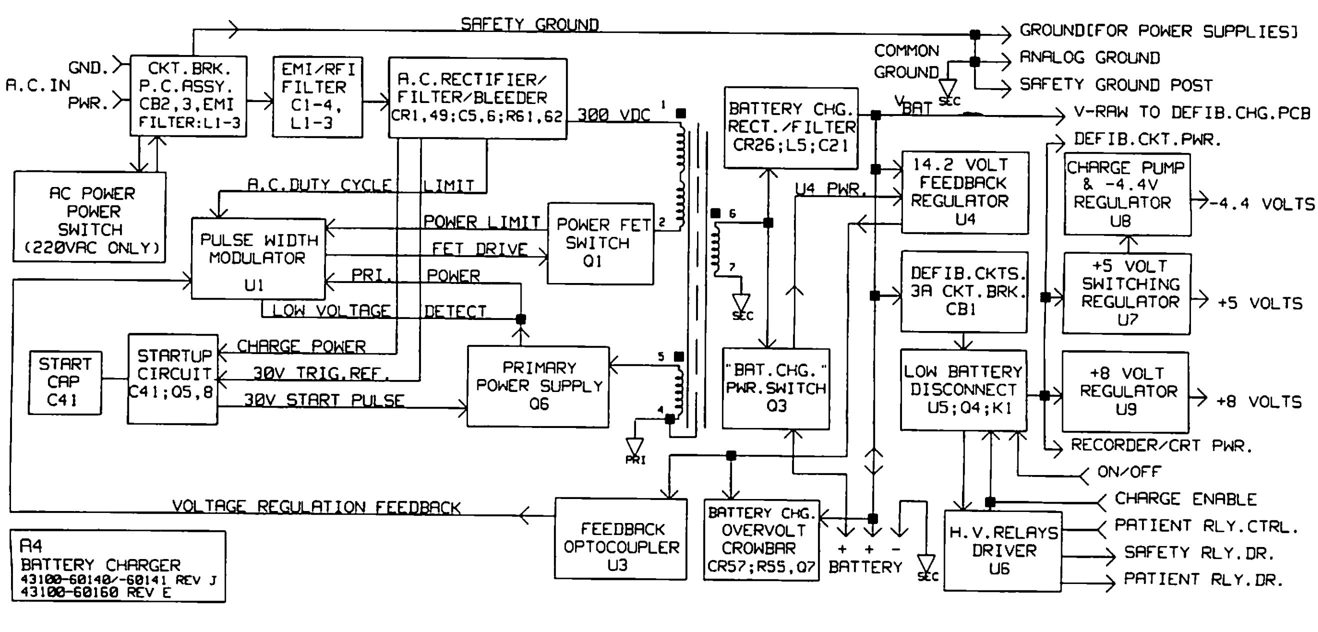


Figure 2-38.

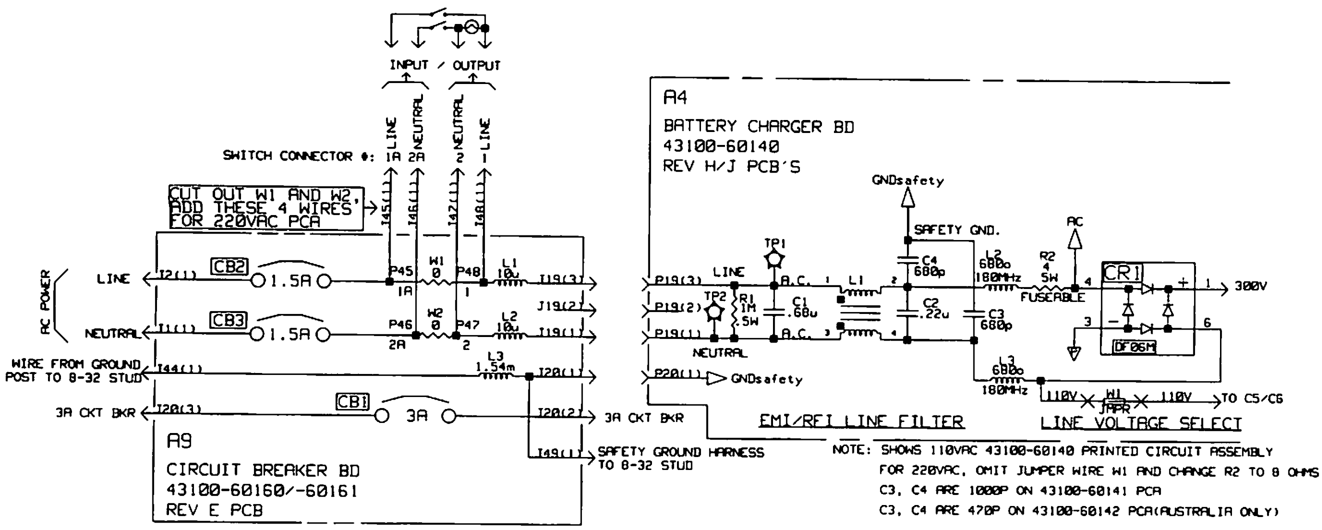


Figure 2-39.

2-69. AC RECTIFIER/FILTER CIRCUIT

This is a standard 110/220 VAC "off-line" circuit. For 110 VAC, jumper/inductor W1 utilizes rectifier CR1 and filter capacitors C5 and C6 as a voltage doubler. For 220 VAC, CR1 direct charges C5 and C6 in series, for the same nominal 300 VDC. R2 (4 ohms/110VAC or 8 ohms/220VAC) limits inrush current through CR1, C5 and C6 and is fuseable at currents well above normal circuit breaker trip ratings, but such that a short in CR1 or Q1 will blow R2 in a time short enough to limit damage to other circuit components.

Bleeder resistors R61 and R61 plus Zener CR49 set the midpoint voltage of C5 and C6 and provide the 30 volt START capacitor reference voltage to PROGRAMMABLE UNIJUNCTION TRANSISTOR (PUT) Q5.

2-70. PULSE-WIDTH MODULATOR CONTROL CIRCUIT

U1 is an off-line switcher Pulse-Width Modulator (PWM) I.C. The ERROR AMPLIFIERS give ON-OFF control: OFF if pin 1 is more positive than pin 2 or pin 14 more positive than pin 13. The duty cycle reduces from 100% to 0% with either pin 4 rechanging from nominal 0 to 2.8 VDC or pin 3 changes from nominal 0.7 to 3.5 VDC.

5Vref, CR15 and R22 turn U1 OFF if Vc-PRI drops below about 8.6 VDC, where inadequate drive could cause Q1 overheating.

Nominal U1 oscillator frequency is 42 kHz. This is set by C14, R16, R17 and R18. R17 and R18 sample the A.C. line voltage to modulate the 42 kHz by a nominal about +/− 1 kHz at the line frequency rate.

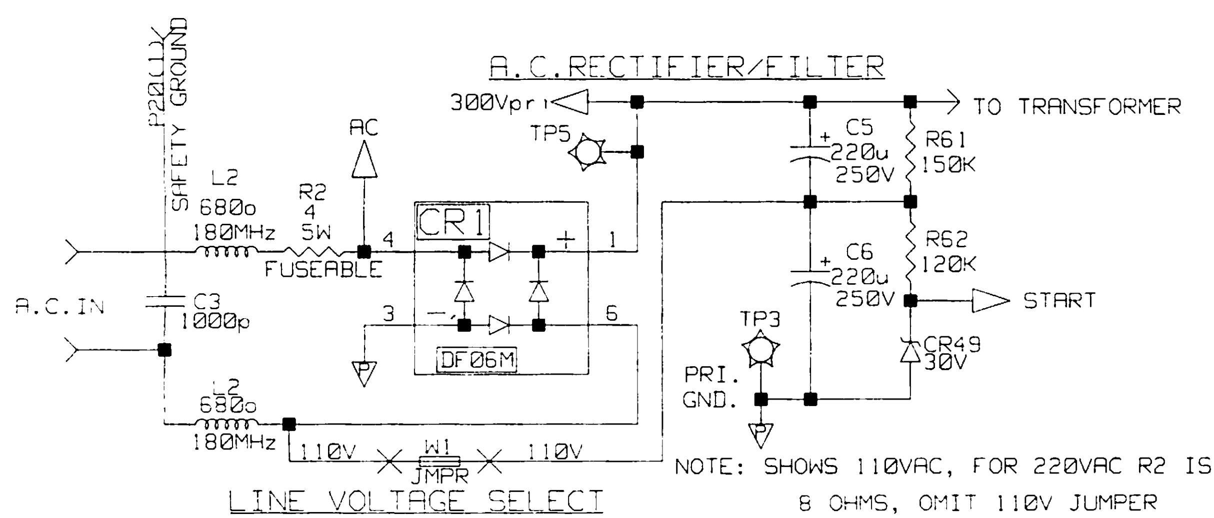


Figure 2-40.

POWER LIMIT is used to limit Battery Charger current to the battery, etc. R9 senses the current through Q1. Peak limit detector circuit CR69, R69, C9 and R8 gives a signal for comparison with the level set by R19 and R20. C15 and R21 provide feedback stabilization. In this mode, the secondary output is limited to a nominal 3 Amps.

FEEDBACK pin 3 is used for: (a)Startup, as C46 charges up, (b)safety turn-off (when Optocoupler U3 output transistor open circuits, V-REF pulls up pin 3 to 4.4 VDC) and (c)output voltage regulation, via U3 (unless Power Limit takes over.)

Q1 is the power switch in this forward-converter power supply, with T1 having one winding (pins 5-4) for added primary circuit power plus an isolated winding (pins 6-7) to give the required 14.3 VDC battery float charge voltage.

CR3, R68, CR57 and C7 form the primary snubber, reducing component stress and EMI generation when Q1 turns OFF.

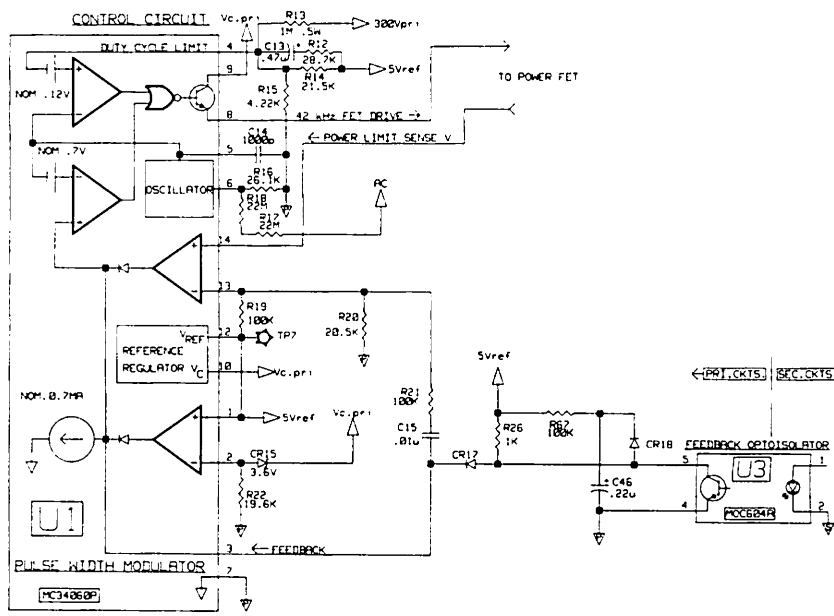


Figure 2-41.

The DUTY CYCLE is controlled dynamically via FEEDBACK, pin 3. Except for fault conditions, the DUTY CYCLE LIMIT, pin 4, normally operates below a controlling level. At pin 4 the DC set point combines a sample of the 5V reference and C5 plus C6 voltage (R14, R13 and R15). This permits higher duty cycles at low A.C. line voltage, since longer Q1 ON times are required to provide the same energy transfer. R12 and C13 momentarily raises this set point when AC is first applied.

2-71. POWER FET/TRANSFORMER SWITCHING CIRCUIT

PWM U1 output drive, pin 8, is adequate to directly drive power FET Q1 ON, but needs a pull-down circuit (Q2, and R7) for rapid turn OFF. CR8 provides gate and CR4-6 drain-source protection for Q1. R9 is a current-viewing resistor and C10 a high frequency clamp. Peak limit detector CR69, R69, C9 and R8 then transmit a signal to U1 for POWER LIMIT.

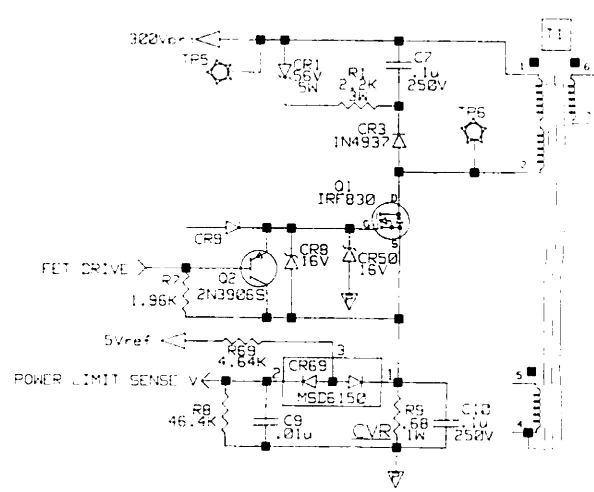


Figure 2-42.

2-72. STARTUP AND PRIMARY CIRCUIT POWER SUPPLY

It is necessary to provide power to U1 circuits at above 8.6 VDC to start up the battery charger switching operation. C41 is charged in about 5 seconds from the 300V primary DC supply, through R1 and Q1. PUT Q5 discharges C41 through Q6 when C41 reaches 30.7VDC, charging C44 and C43 high enough to initiate the U1 startup.

After startup, transformer T1 provides a steady flow of power via CR54. Vc-PRI is nominally 12-15VDC.

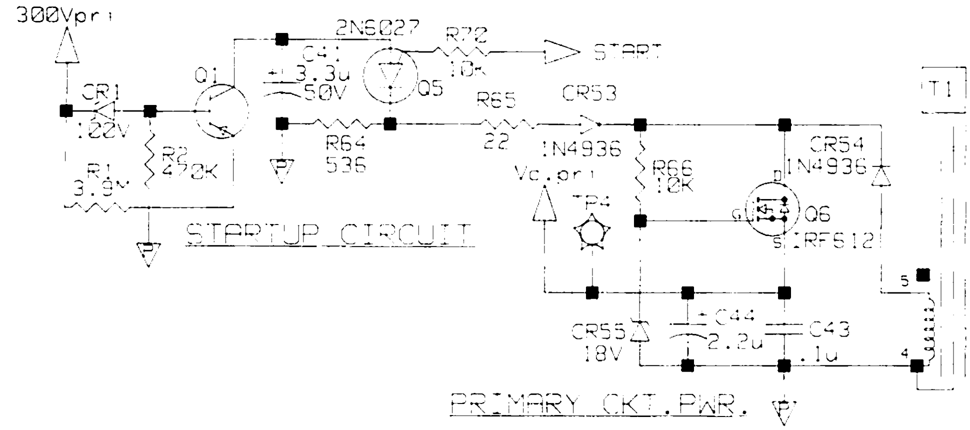


Figure 2-43.

2-73. SECONDARY RECTIFIER/FILTER CIRCUITS

The output of T1 is rectified by CR26, then filtered by L5 and C21. Snubbing is provided by C20, CR25, and R31. Overvoltage surges are snubbed by CR24.

Output voltage regulation (14.3 +/− 0.3V) uses a 3-terminal 2.5 volt programmable voltage reference, U4. When the voltage sample from R37 and R38 rises to 2.5V at pin 8 of U4, pin 1 is clamped to 2.5V. The additional voltage drop in CR56 results in turnoff of the LED in optocoupler U3. The U3 output transistor then turns off and R26 pulls up U1, pin3, reducing the output duty cycle.

During regulated output operation, U3 LED and transistor are partially conducting, with U4, pin 1, above its 2.5V pull-down limit. C25 and R36 the loop stability. R35 and CR30 will turn off U3 if excessive secondary loading drops the output voltage below nominal 9 volts.

Q3 serves to: (a)disconnect secondary regulation U3 and U4 loads when there is no output from T1, to conserve battery power, (b)send signal to the BAT CHG LED on the instrument panel and (c)turn on a relay in the CRT filament circuit to prevent overheating. Q3 turns on when output from the charge pump (C22, CR28,29, C23, R33,34) reaches 1.2V.

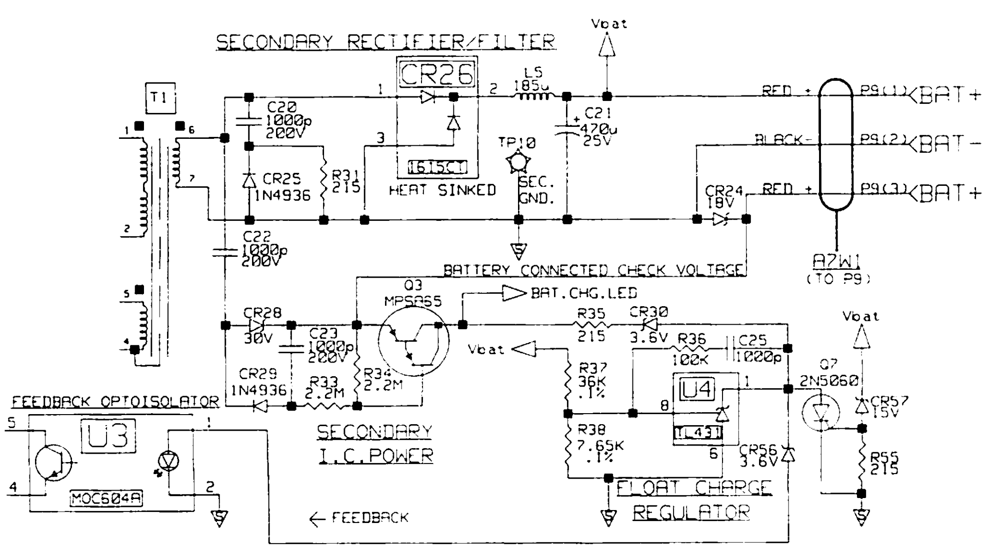


Figure 2-44.

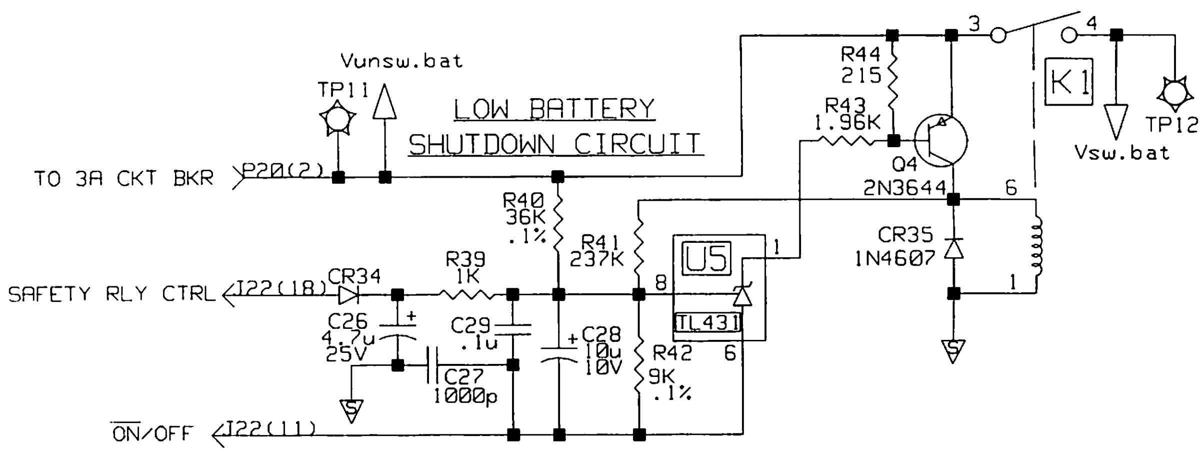


Figure 2-45.

2-74. LOW BATTERY SHUTDOWN CIRCUIT

The power supply output connects directly to the 12 volt battery and the Defibrillation Charger Board (J21, pin1), which has a protective fuse. It also connects to the clock (J22, pin 5), with R49 as a current limit. The standby load of these, plus metering resistors R37 and R38, is small, though ON at all times.

Power to other parts of the instrument must pass through CB1 and the low battery disconnect relay K1, powered by Q4 and U5. R40, R41 and R42 are selected to open K1 when battery voltage drops to 11.1V, while requiring 13.0V to restart, a point above the voltage to which the discharged battery will climb after the load is disconnected. The 11.1V point is selected to prevent excessive battery discharge, which would limit useful battery life.

The ON-OFF switch on the ENERGY SELECT knob connects U5, pin 6 and R42 to ground in the ON position, permitting normal operation.

At the moment of turn-on, C26 stored enough charge to initially charge C28,overcoming the 13.0V requirement. When OFF, these float up, opening K1 and ending power use by the instrument. This enables use of a low current ON-OFF switch, since K1 is used to switch power to the load.

Operation of this circuit is inhibited during HV Capacitor charge, since the high current momentarily drops the battery voltage. This is done by pulling up pin 8 of U5 with the safety relay drive via for the entire charge cycle duration. Additional time for battery recovery is provided by C26 and C28.

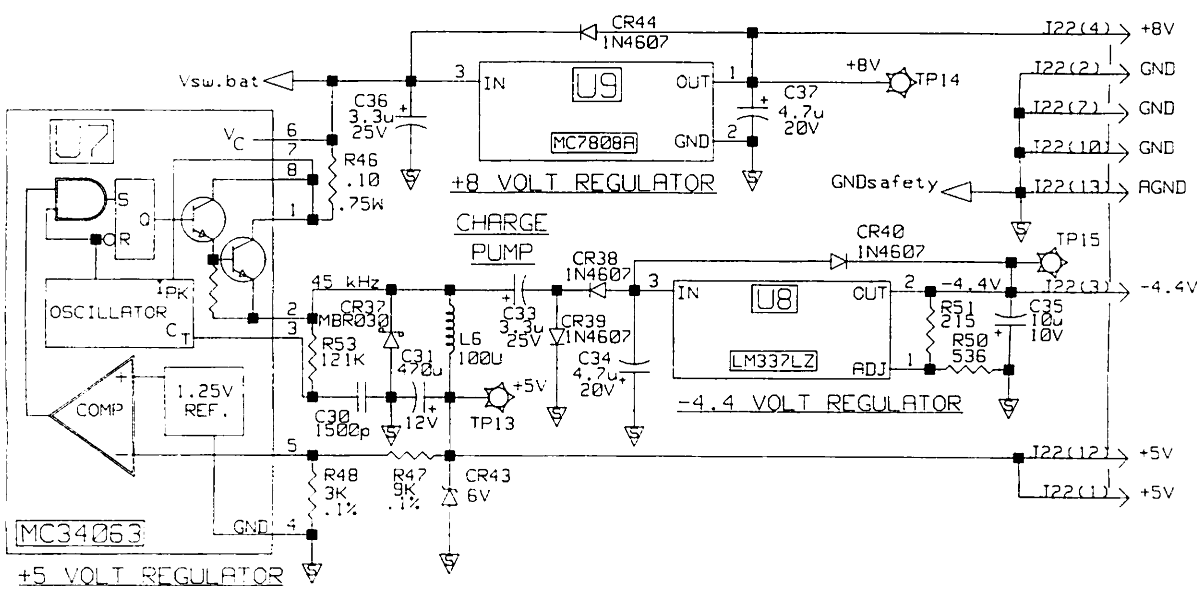


Figure 2-46.

2-75 REGULATED POWER SUPPLIES

The +8 volts is regulated by U9, a 5% linear regulator connected to the switched battery line.

A switching regulator provides the higher current needed for the +5 volt supply, since the high efficiency maximizes battery monitoring time. U9 is a 1.5 amp peak output switching I.C., with L6 and C31 the step-down components. U7 reference spec and precision divider resistors R47 and R48 maintain the 6% reference accuracy. R46 limits the output current to about one ampere maximum. Surges are limited by CR43.

C33, CR38, CR39 and C34 form a charge pump, giving a negative voltage. CR40, R50, R51 and U8 form a −4.4 volt linear regulator circuit with about 6% accuracy. Current limiting is inherent in both U8 and U9.

Nominal U7 oscillator frequency is 45kHz. This is set by C30 and R53.

2-76. PATIENT/SAFETY RELAY DRIVE CIRCUITS

U6 is a 1.5 amp., dual-Darlington driver with integral snubber diodes. Transistor pins 2, 3 and 4 drive the patient relay coil, while pins 5, 6 and 7 drive the safety relay coil.

There are three other signals between the control board and defibrillator charger board. The lines pass through the battery charger board but are not used or altered.

2-77. RECORDER

The recorder employs a thermal dot array printhead to produce both ECG waveform and annotation on thermally sensitive paper. A drive motor and capstan pull the paper across the printhead. Sensors are provided at the rear of the motor and behind the rotating paper spindle to measure both speed of the motor and paper roll. Knowledge of paper roll speed allows the recorder microprocessor to judge conditions of low and no paper.

The recorder board (A9) contains the motor drive circuitry and the no/low paper detection circuitry. The rest of the board takes signals from cables P32, P23 and P36 and routes them to the appropriate cables connecting the recorder board and the recorder mechanism. The electrical aspects of the printhead will also be detailed in this section.

2-78 NO/LOW PAPER

The no/low paper detection circuit consists of an optical emitter detector and an alternating reflective, nonreflective surface in 45 degree steps on the back of the paper spindle. The paper spindle will rotate as paper is drawn from the roll. As the diameter of the paper roll decreases, the angular velocity of the paper spindle will increase. This will cause the alternating reflective, nonreflective surfaces to pass in front of the optical sensor at a faster rate. Low paper will be detected when the paper spindle reaches a velocity that corresponds to approximately 2 minutes of paper left. No paper detection will occur when the state of the reflective surface, in front of the sensor,

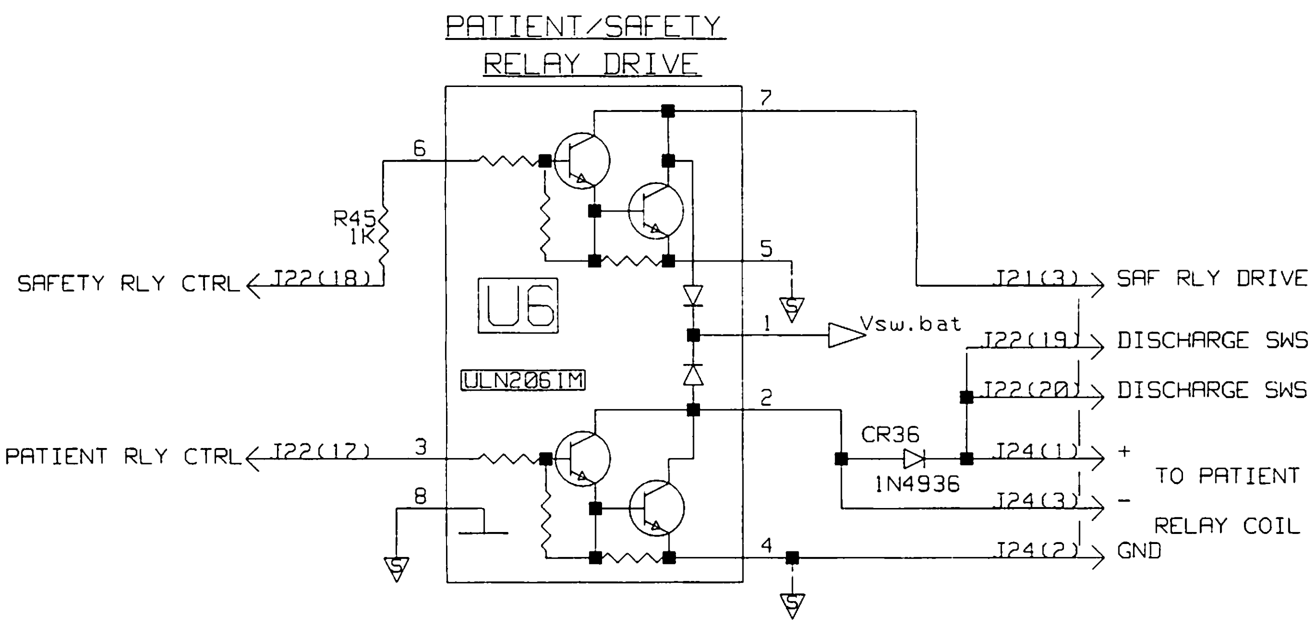


Figure 2-47.

does not change state for one second. This state will cause the motor and the printhead to be turned off and the processor reset. R1 is a current limiting resistor for the photo diode with R2 the pull up for the open collector of the photo transistor. NO PAPER DETECT (P32-15) will be pulled low with a reflective surface facing the sensor and high with a nonreflective surface. The circuitry will be turned on when NO PAPER switch (P32-2) is pulled low, allowing a path to ground for the current through R1 and R2. The sensor itself is located on the recorder housing.

2-79. MOTOR DRIVE

The motor control circuitry on the 43100-60150 board (A9) consists of a velocity feed back loop and motor drive circuitry. The feed back loop is comprised of an optical emitter and detector pair and a 12-slot interruptor attached to the extended shaft out the back of the motor. The shaft reflects the actual speed of the motor, not the geared down speed of the paper roll. The feed back loop works on a phase lock loop scheme. When the interruptor is spinning, the MOTOR TACH line (P32-14) is pulsed. The number of pulses in a given time period is compared against a constant. The difference gives a error figure that varies the duty cycle of the drive signal. R6 is the bias for CR3 and R3 biases Q2. The MOTOR TACH line will go high when the beam from CR3 is interrupted. When the beam is not interrupted, Q2 will pull down the MOTOR TACH line.

The motor drive circuitry consists of a FET switch that turns the motor off and on. The switch is driven by a pulse width modulated signal at 1000 Hz, the greater the duty cycle the harder the motor is driven, conversely a smaller duty cycle will slow the motor. C2 and R5 form a time constant that will shut off the motor if the MOTOR CON line (P32-3) stays high. CR1 is a snubber that will protect the FET switch (Q1) from the inductive spikes from the motor. The motor will use SWBATT (P32-1) for power.

2-80. PRINTHEAD

The printhead is a thick film thermal dot array printhead. Dot density is 4 dots/mm (101 dots/inch). The printhead has 20 interconnects from the recorder board. The printhead has seven 32-bit shift registers, with each register being loaded serially by it's corresponding data line. D0 through D5 are used for ECG data while D5 and D6 are used for annotation. The data is clocked in by the PRINTHEAD CLK line (P32-4). It takes 32 clock cycles to fully load the printhead. Once the printhead buffer is loaded the information can be printed by setting the PRINTHEAD STROBE (P32-8) high. The power to the printhead is supplied by SWBATT line which is taken off the battery. The print darkness will vary with the change in battery voltage and with quality of paper used.

A. INSTRUMENT MODES.

3-1. SERVICE MODE:

1. Press and hold the SYNC button.
2. Turn the ENERGY SELECT knob to the MONITOR position.
3. Release the SYNC button after about one second.
4. A test waveform should appear on the CRT.
5. To exit the service mode turn the unit off.

3-2 READ BATTERY VOLTAGE:

1. Place the unit into Service Mode
2. Press up and down arrows (gain adjustments) simultaneously.
3. In the Heart Rate location of the CRT three numbers will indicate battery voltage (i.e. 128 means 12.8 volts).

NOTE

Unit plugged in and battery charger working normally ~14.2V

Unit not plugged in and battery fully charged ~13V

Low battery warning message comes on ~11.8V

Low battery shutdown ~11.2V

3-3. SET CLOCK (If So Equipped)

1. Press and hold the SET ALARMS button.
2. Turn the unit on.
3. Release the SET ALARMS button after about one second.
4. The time will appear on the CRT (upper left) with Day flashing (Format : DD MMM YY HH:mm.)
5. Press up or down arrows to adjust the Day.
6. Press SET ALARMS to advance to Month adjustment.
7. Press up or down arrows to adjust the Month.
8. Repeat until all desired changes are made. TIME SET mode will be exited by pressing any button other than the up-down arrows or waiting 30 seconds (normal time out).
9. The time circuit has an energy retention function which will allow the clock to run for six minutes with the unit battery removed. If the clock is allowed to fully run down, the default time will be 1 Jan 85 00:00.
10. If extreme noise or circuit fault has caused the clock to hold an impossible time (i.e. 42 Jan) Error 10 or "set clock" will be printed on the recorder. If the above procedure to set the clock is not effective, refer to the troubleshooting section.

B. LEVEL II PERFORMANCE AND CHECKS.

These checks should be preformed every six months or after a major repair. For best results, use the equipment recommended. Record the defibrillator serial number and the date the checks were performed.

3-4. TEST EQUIPMENT.

Test equipment required for performing the level II performance, safety and maintenance checks is listed in Table 3-1. Table 3-2. lists the equipment necessary if the Dempsey model 431F safety analyzer is not used.

Test equipment characteristics and a recommended commercial model are included. If the recommended model is not available, select another with similar characteristics and capabilities.

> WARNING
>
> LETHAL VOLTAGES ARE PRESENT INSIDE THE DEFIBRILLATOR AND ARE EXPOSED WHEN THE DEFIBRILLATOR COVERS ARE REMOVED. DO NOT WORK INSIDE THE INSTRUMENT WHEN POWER IS APPLIED OR IF DEFIBRILLATOR IS CHARGED.

TABLE 3-1.

REQUIRED TEST EQUIPMENT FOR LEVEL II PERFORMANCE, SAFETY, and MAINTENANCE TESTS

DIGITAL VOLTMETER Recommend:	Capable of 5 to 15 V DC +/− 1% measurements
OHMMETER HP 3466A	Capable of 0.1 to 10 ohm +/− 2% measurements
ENERGY METER Recommend: Dempsey Model 429	Capable of 5 to 400 Joule, critically damped sinusoidal waveform measurements with +/− 2% of full scale accuracy. Load resistance 50 ohm +/− 0.5%.
STOPWATCH OR TIMER	Capable of measuring 2 to 12 second events with hand start/ stop actuation to 1/4 sec. accuracy
ECG SIMULATOR Recommend: Parke-Davis 3175	Output Level: 1mV Range: 60 and 120 BPM calibrated outputs
TEST LOAD HP 78620-60860	2Ω, 200 WATT 5%
PADDLE CONTACT INDICATOR Test Resistors	61.1 ohms, 64.9 ohms, 250.0 ohms, all 1%
TEST CABLES AND COMPONENTS	
(1) HP 14489A	Patient Cable
(1) HP 14151NA	Electrode Lead Set
(1) HP 14445A	ECG Electrodes
(1) HP 78660-67800	Test Load Adapter
SAFETY ANALYZER Recommend: Dempsey Model 431F	See Table 3-2 for substitute equipment

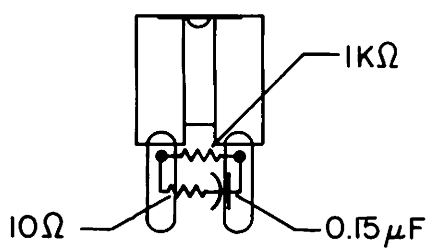
TABLE 3-2.

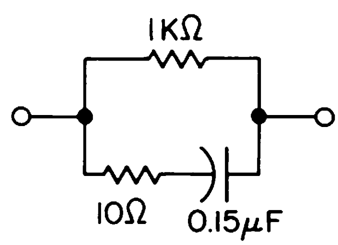
EQUIPMENT NECESSARY IF THE DEMPSEY MODEL 431F SAFETY ANALYZER IS NOT USED

REQUIREMENT	NECESSARY QUALIFICATIONS
DIGITAL VOLTMETER Recommend: HP 3466A	Capable of 10 μV DC +/− 0.5% measurements
2 to 3 WIRE AC PLUG ADAPTOR HP 1251-1852	Must have ground wire pig-tail
TEST PLUG FOR 120 VAC SOURCE HP 04655-60100	1 MΩ resistor in hot lead

CURRENT METERING NETWORK	HP 1251-1284 HP 0757-0159 HP 0757-0984 HP 0160-3238	Dual Banna Plug 1 KΩ 1% Reisitor 10KΩ 1 % Resistor 0.15 μF Capacitor

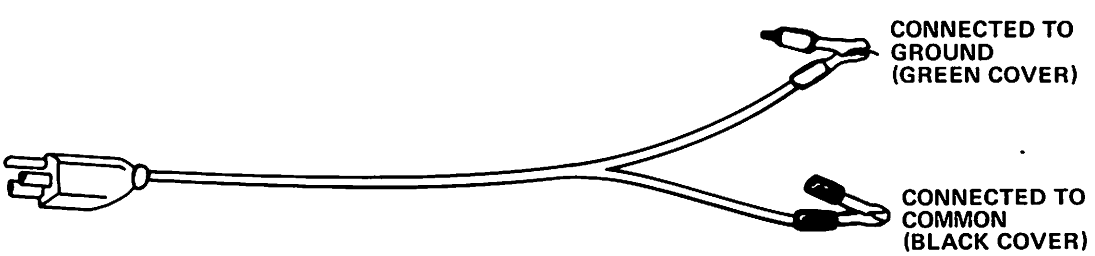
CONNECTED AS FOLLOWS:





Ground Test Cable	HP 1251-3133 HP 8120-0022 (2) H. H. Smith, 331	NEMA Male Plug Cable, 6 feet required Alligator Clip, 1 green, 1 black

CONNECTED AS FOLLOWS:



3-5. ENERGY ACCURACY.

Connect the Equipment as shown in Figure 3-1.

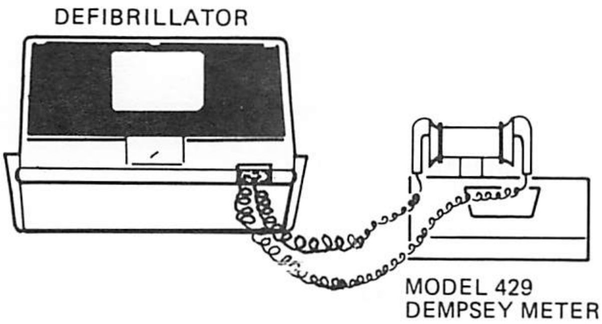


Figure 3-1. Energy Accuracy Test Setup.

With the instrument in service mode(see Section 3-1.), set the ENERGY SELECT knob to each of the positions indicated in the table below; press the CHARGE button and allow the unit to charge. The CHARGE DONE tone will sound and the CHARGE DONE indicator on the Apex paddle will light when the unit is ready to discharge. Firmly press the paddles to the energy meter and press both DISCHARGE buttons simultaneously. Record the energy levels measured and note the annotation on the recorder.

Compare the delivered energy levels indicated on the Dempsey with the information below.

Energy Selected	Delivered Energy (Joules)
2	1 - 3
3	2 - 4
5	4 - 6
7	5 - 9
10	8 - 12
20	16 - 24
30	26 - 34
50	43 - 57
70	60 - 80
100	85 - 115
150	127 - 172
200	170 - 230
300	255 - 345
360	306 - 414

3-6. SELF TESTING ACCURACY.

1. Make sure the paddles and the paddle contacts in the storage pockets are clean and free of contaminants. This is to assure good electrical contact and prevent paddle surface damage during discharge.
2. Place the paddles firmly in their storage positions, with Apex on the right side and Sternum on the left.
3. Turn the unit on in service mode (see Section 3-1.)
4. Select 100J with the ENERGY SELECT knob. Charge and discharge the unit.
5. The test energy should flash on the CRT (85-115 Joules) and the recorder should print the test results.
6. Repeat at 360J for results of 306-414 Joules.

3-7. DEFIBRILLATOR CAPACITOR CHARGE TIME.

Place the instrument in the service mode (see Section 3-1.) and unplug the unit from AC power. Read the battery voltage using the up-down arrows (see Section 3-2.). If the battery is above 12.3 volts proceed, otherwise allow it to charge fully by plugging into an AC outlet for 8 hours or more.

Set the energy to 360 Joules and press the CHARGE button. The CHARGE DONE tone should indicate charge completion in less than ten seconds.

3-8. SYNCHRONIZER.

1. Set the ENERGY SELECT switch to 20 Joules, and press the SYNC/DEFIB button to enter the Sync mode. SYNC should appear on the CRT.
2. Place the paddles in their storage pockets.
3. Press CHARGE on the Apex paddle to charge the unit. The charge is done when the CHARGE DONE tone turns on and the CHARGE DONE LED on the Apex paddle lights.
4. Press both DISCHARGE buttons simultaneously. The unit should not discharge.

5. Connect an ECG simulator/calibrator to the ECG input with a lead set. Make sure the unit is in the Sync mode. Adjust the ECG simulator output to give a moderately large signal on the CRT. The signal should be detected and be indicated by a marker on the CRT.

6. Charge the unit to 20 Joules.

7. Press and hold both DISCHARGE buttons. The unit should discharge in synchronization with the input signal from the ECG simulator. Verify on the recorder strip.

NOTE

The Synchronizer will ignore the first 250 ms of input signal occurring immediately after the Discharge buttons are pressed. The synchronizer will ignore the first 250 ms of input signal after a gain change (autogain or manual gain).

3-9. ECG AMPLIFIER NOISE.

1. Connect test equipment as shown in Figure 3-2.

2. Select Lead I

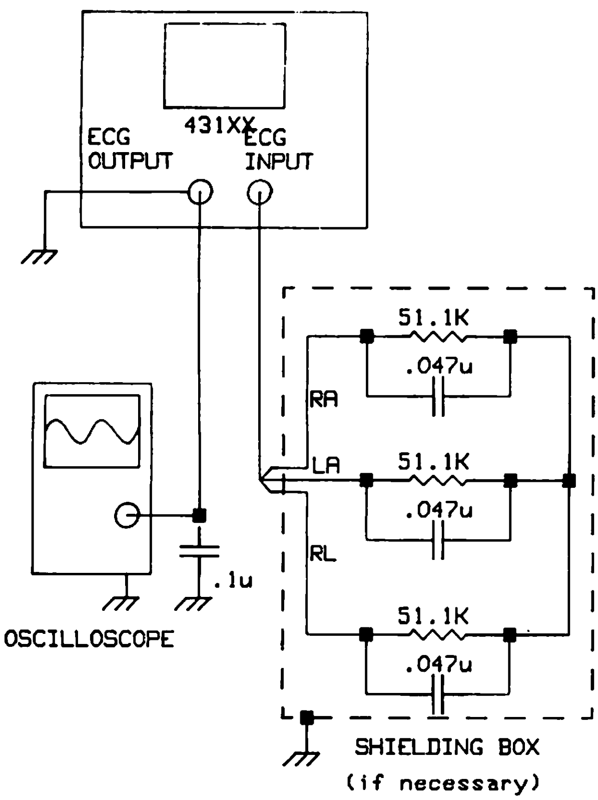
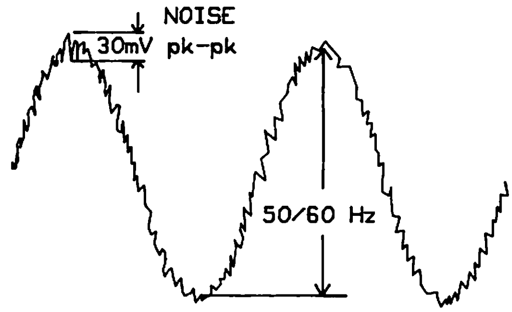


Figure 3-2. ECG Noise Test

3. Test limit: noise, excluding 50/60 Hz hum, should be $<30\mu V$ p-p. (referred to input)on external scope.



4. Adjust ECG to maximum gain (press up arrow seven or more times). Observe CRT and recorder traces for excessive noise. Each pixel on the CRT or dot on the recorder represents about 5 μV referred to input at max gain.

5. If excessive 50/60 Hz noise is present, use double shielded box technique recommended in ANSI/AAMI EC13.

3-10. ECG AMPLIFIER GAIN.

1. Connect test equipment as shown in Figure 3-4.

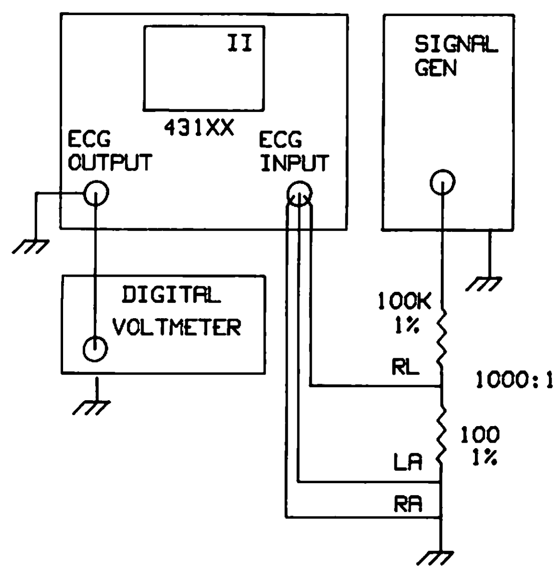


Figure 3-4. ECG Gain Test.

2. Select Lead II.

3. Adjust signal generator to output a 5 HZ sine wave 5V p-p.

4. Measure gain to ECG out jack. The output should be 5V ±2% for a gain of 1000. If not, adjust gain as described in Section 3-20.

5. Manually adjust gain to minimum setting by pressing the down arrow seven or more times. The gain should now be 250.

6. Measure amplitude at the CRT and strip chart recorder. Test limit : CRT 16 mm ±10%; Recorder 12.8 mm ±10%.

7. Increase gain one setting by pushing up arrow once.
8. Measure amplitude at the CRT and strip chart recorder.
9. Repeat this procedure until all the gain settings have been verified.

Input Voltage	Theoretical Gain	Measured Height (mm) ±10% CRT	Recorder
5mV	0250	16	12.8
5	0400	26	20.5
5	0650	43	33.3
2	1000	26	20.5
2	1300	34	26.6
1	2000	26	20.5
1	3000	40	30.7
1	4000	53	41.0

10. Apply input signal to the paddles. Repeat this procedure. Gain will be about 5% less at each setting.

C. SAFETY AND MAINTENANCE CHECKS.

These checks should normally be performed every six months or after a major repair. (Routine printhead cleaning is listed in the next section).

NOTE

Make these initial checks before performing the safety tests.

1. Check that paddle electrodes are in good condition, clean and not pitted. Remember to check pediatric electrodes as well as the adult adapters. Check for obvious cracks (small chips, gouges and scratches are acceptable and will not affect instrument performance). Check cable strain reliefs for cracks or other signs of deterioration at the paddles.

2. Check that the CHARGE button will initiate charge and DISCHARGE buttons function when the cables are stretched to their full length. Check that discharge only occurs when both buttons are simultaneously pressed.

3-11. POWER CORD TO CHASSIS GROUND RESISTANCE CHECK.

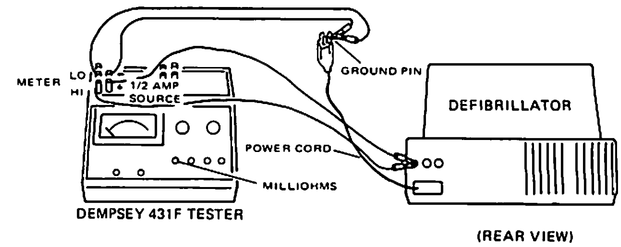


Figure 3-5. Power Cord to Chassis Ground Resistance Check.

1. Set the test equipment up for the test as shown in Figure 3-5. If the Dempsey 431F is not available, use a conventional ohmmeter.

2. Connect the dual banana plug of a Kelvin Kable between the LO meter terminal of the Dempsey and the – (negative) terminal of the ½ amp source on the Dempsey.

3. Connect the clip on the other end of the Kable to the ground pin of the male power connector.

4. Connect the dual banana plug of the second Kelvin Kable between HI terminal of the meter section and the + (positive) terminal of the ½ amp source.

5. Connect the clip on the other end to a banana/banana cable inserted in the external ground jack on the rear of the defibrillator.

6. Press MILLIOHMS and read the resistance on the current ranges. The test limit is less than or equal to 0.20 ohms.

3-12. PADDLE LEAKAGE CURRENT (SOURCE LEAKAGE) TO GROUND.

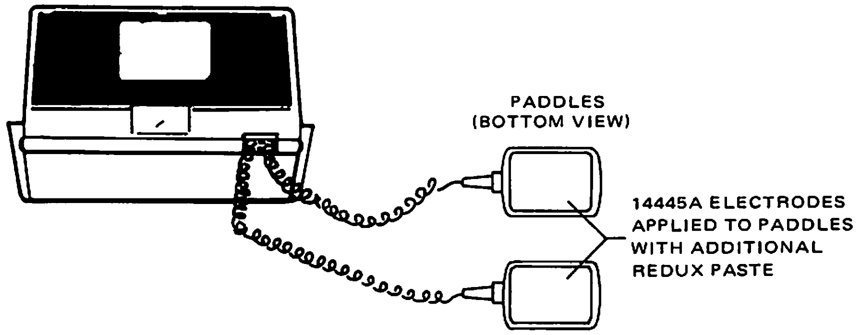
Perform the check as follows:

1. Connect the test equipment as shown in Figure 3-6.

2. Set the Dempsey FUNCTION switch to CURRENT. (Set the SELECTOR switch to either RA or LA to test either paddle. For paddle-to-paddle checks, ground either paddle and test the other.)

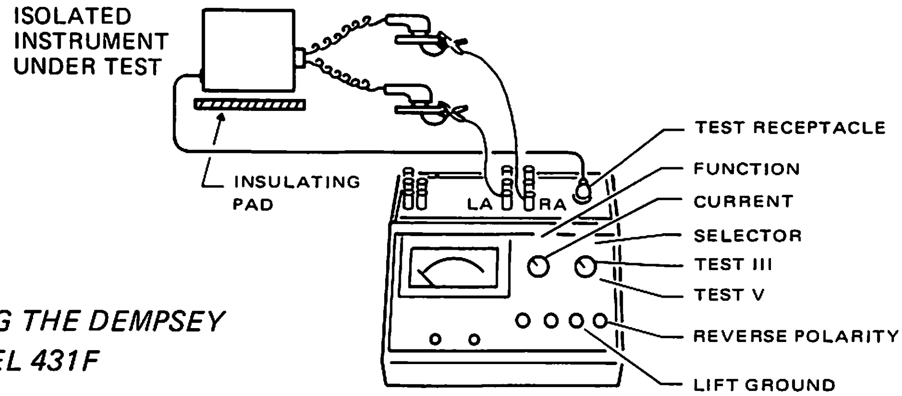
3. Measure paddle source leakage to ground for each paddle individually. Current should be no more than 20 μA paddle to ground with the ECG input switched to Leads I, II, III, or Paddles.

4. Perform the same test under each of the following conditions with the power ON and OFF.



ALLIGATOR-ALLIGATOR CLIP LEADS, LENGTH LESS THAN 6 INCHES, SHOULD BE USED TO CONNECT ELECTRODES TO TEST EQUIPMENT AS SHOWN IN THE STEP DIAGRAMS.

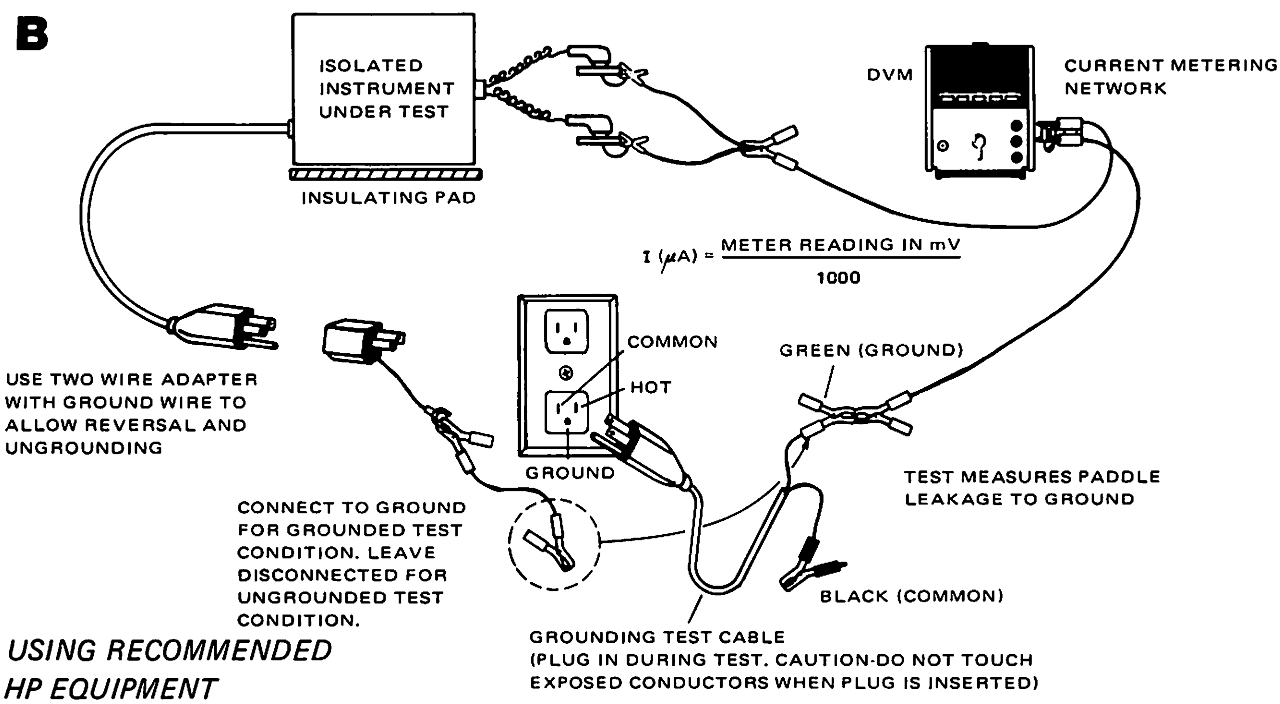
A



USING THE DEMPSEY MODEL 431F

NOTE: WHEN USING AN HP MULTIMETER, PERFORM BOTH AN AC AND A DC MEASUREMENT. THE DEMPSEY 431F RESPONDS TO BOTH AC AND DC SIMULTANEOUSLY.

B



USING RECOMMENDED HP EQUIPMENT

WARNING

MAKE ALL PADDLE TEST CONNECTIONS BEFORE PERFORMING FIFTH CHECK (LIVE PADDLES). KEEP PADDLES SEPARATED AND ON INSULATED PAD DURING TEST.

a. Chassis grounded, standard power polarity.
b. Chassis grounded, reverse power polarity.
c. Chassis ungrounded, standard power polarity.
d. Chassis ungrounded, reverse power polarity.
e. Defibrillator charged to 360J. (see warning above)
f. Defibrillator discharged by turning power switch off with energy control.

DO NOT PRESS DISCHARGE BUTTONS

3-13. PADDLE LEAKAGE CURRENT (SINK CURRENT) WITH 115 VOLTS APPLIED.

Perform the check as follows:

1. Connect the test equipment as shown in Figure 3-7A or B. If the Dempsey 431F is used, also follow the instructions included in that portion of the figure. Use clip leads to connect the right paddle to the RA output of the Dempsey and the left paddle to the LA output.

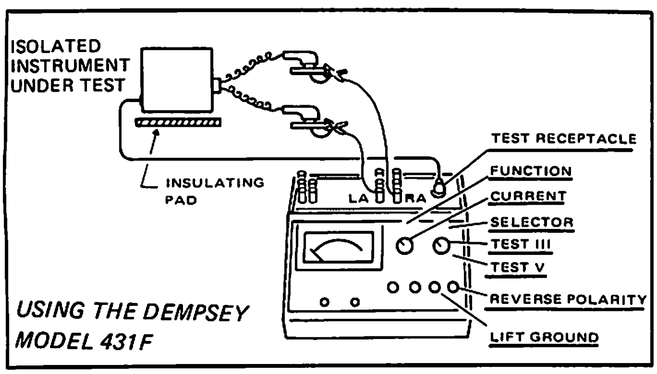


Figure 3-7A. Paddle Leakage Current (Sink Current) with 115 Volts applied.

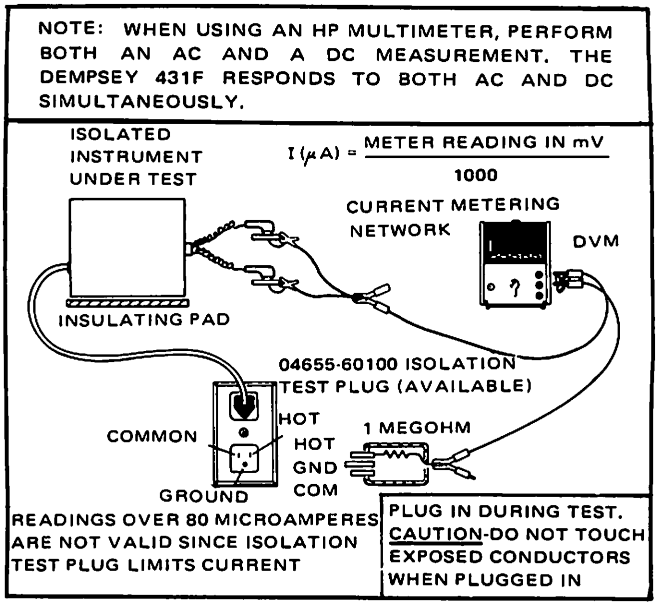


Figure 3-7B. Paddle Leakage Current (Sink Current) with 115 Volts Applied.

2. Set Dempsey FUNCTION switch to CURRENT.
3. Press the red 115V test button under each of the following conditions with the power ON and OFF. Current should be no more that 100μA.

CONDITIONS:

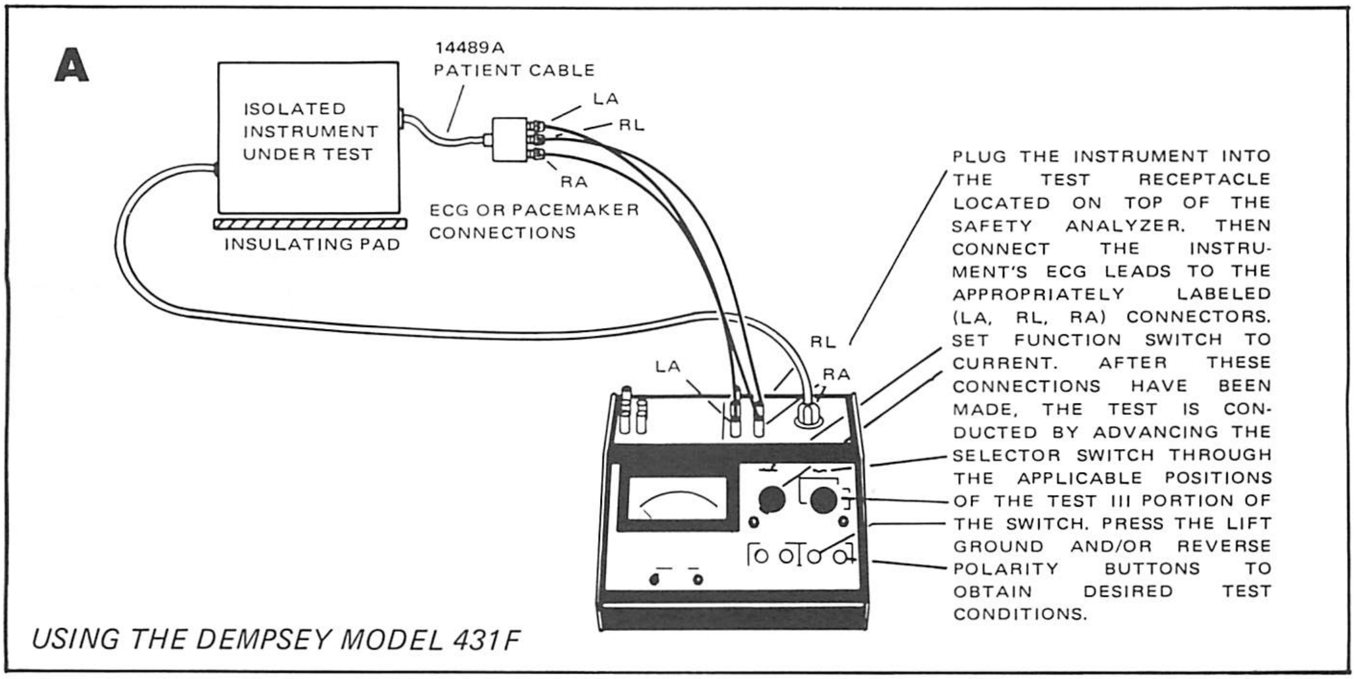
a. Chassis grounded, standard power polarity.
b. Chassis grounded, reverse power *supply.*

3-14. PATIENT LEAD LEAKAGE CURRENT (SOURCE LEAKAGE) TO GROUND.

Perform the check as follows:

1. Connect the test equipment as shown in Figure 3-8A or B. If the Dempsey 431F is used, follow only instructions included in that portion of the figure.

2. Perform the tests of Step C under each of the following power polarity and grounding conditions with the power ON and OFF.
   a. Chassis grounded, standard power polarity.
   b. Chassis grounded, reverse power polarity.
   c. Chassis ungrounded, standard power polarity.
   d. Chassis ungrounded, reverse power polarity.



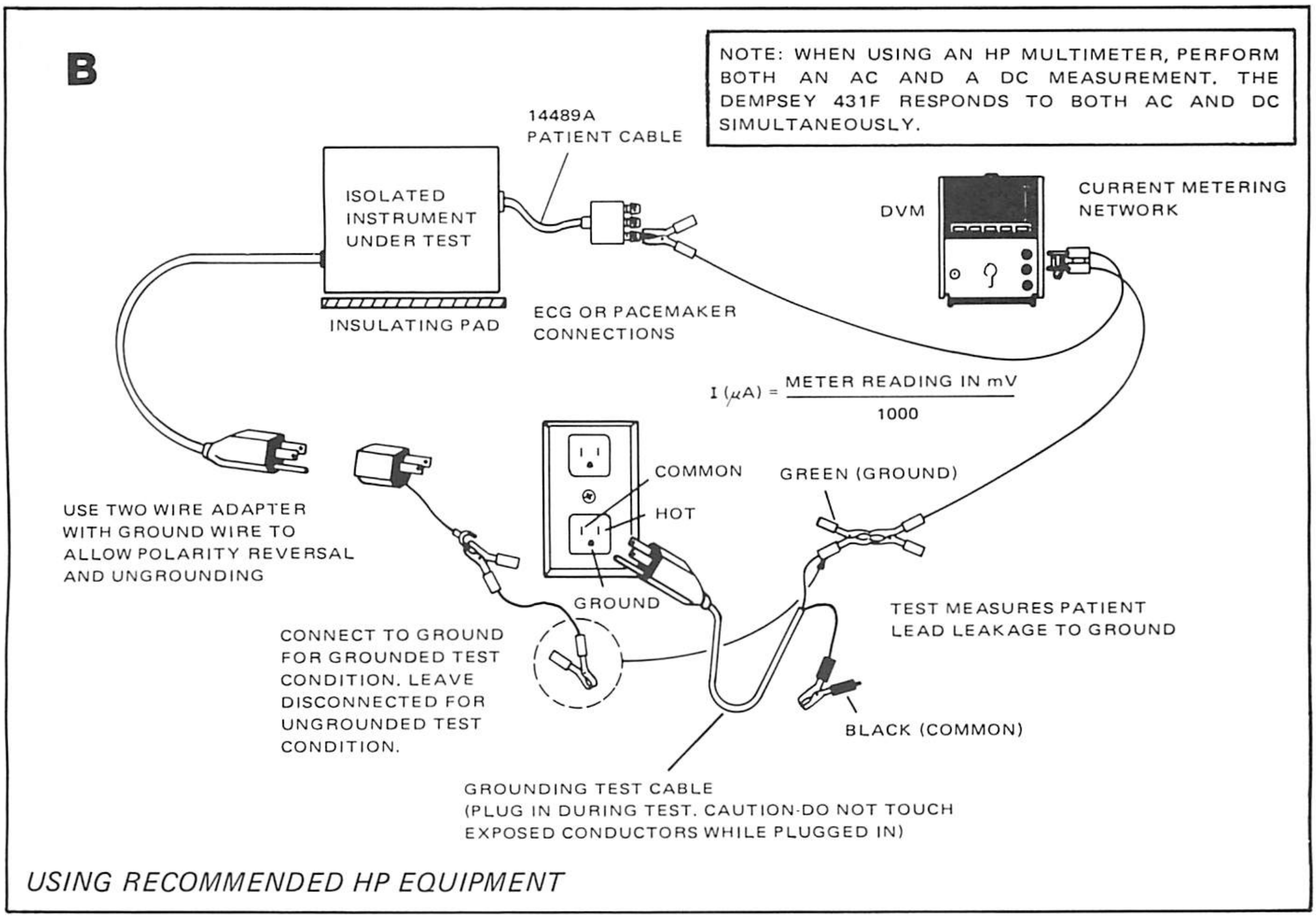


Figure 3-8. Patient Lead Leakage Current To Ground Test.

3. Using the patient cable in the test setup, measure each patient lead leakage current to ground. When a voltmeter is used to derive leakage current, divide the meter reading in millivolts by 1000. Result is current in microamperes. Current should be no more than 10 μA.

3-15. LEAKAGE CURRENT BETWEEN PATIENT LEADS CHECK.

Perform the check as follows:

1. Connect the test equipment as shown in Figure 3-9A or B. If the Dempsey is used, also follow the instruction included in the figure.

2. Perform the tests of Step C under each of the following power polarity and grounding conditions with the power ON and OFF.
   a. Chassis grounded, standard power polarity.
   b. Chassis grounded, reverse power polarity.
   c. Chassis ungrounded, standard power polarity.
   d. Chassis ungrounded, reverse power polarity.

3. Using a patient cable, measure the leakage current between individual patient input leads. When a voltmeter is used to derive leakage current, divide the meter reading in millivolts by 1000. (Result is current in microamperes). Current should be no more than 10 μA.

3-16. PATIENT LEAD LEAKAGE CURRENT (SINK CURRENT) WITH 115 VOLTS APPLIED.

Perform the check as follows:

1. Connect the test equipment as shown in Figure 3-10A or B. If the Dempsey 431F is used, also follow the instruction included in the figure.
2. Perform the tests of Step C under each of the following power polarity conditions with the chassis grounded and with the power ON and OFF.

   a. Chassis grounded, standard polarity
   b. Chassis grounded, reverse polarity

3. Using the exact test setup shown, measure the patient lead leakage current for all leads tied together while driving the leads with line voltage. When a voltmeter is used to derive the leakage current, divide the meter reading in millivolts by 1000. (Result is current in microamperes. Current should be no more than 10 μA). In addition, perform both and AC and DC measurement when using a voltmeter for the measurements. The Dempsey 431F responds to both AC and DC simultaneously.

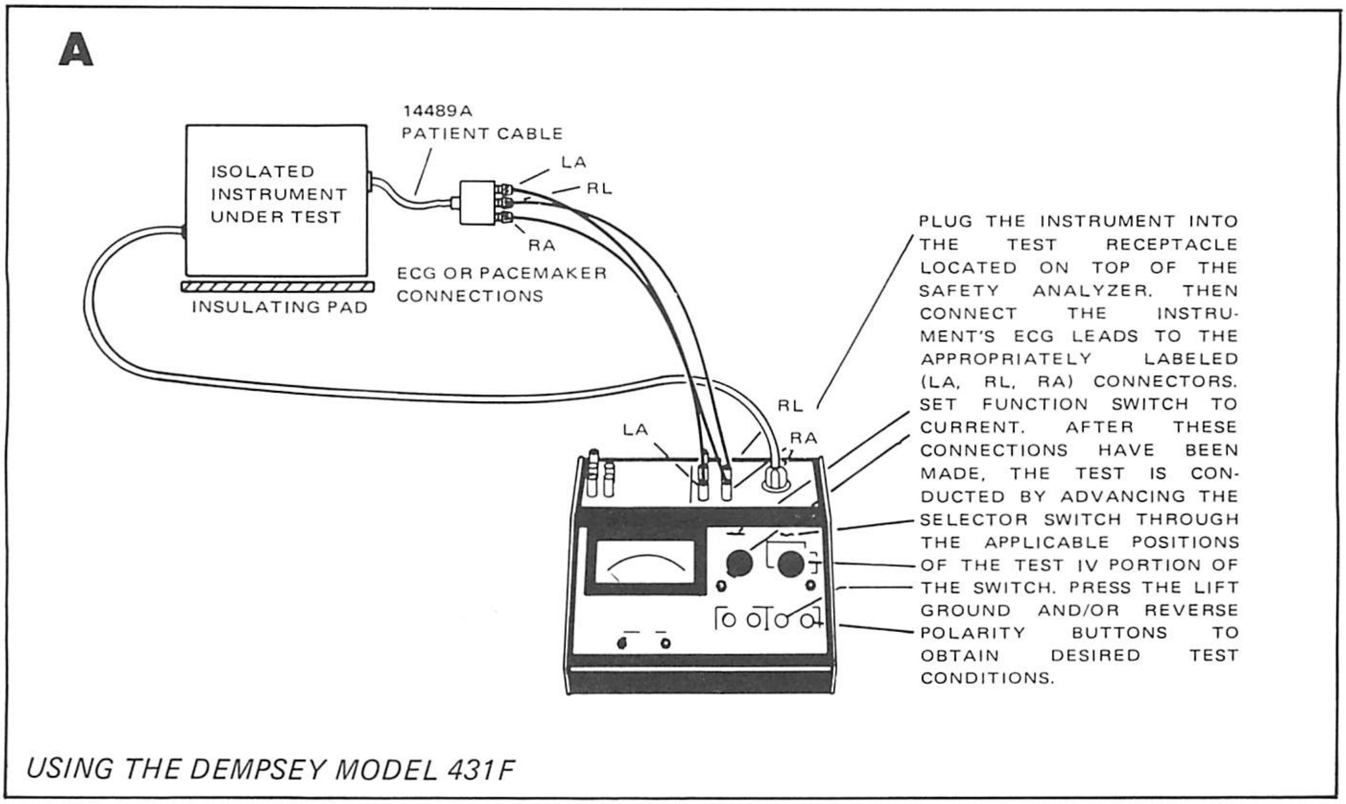


Figure 3-9. Leakage Current Between Patient Leads Test.

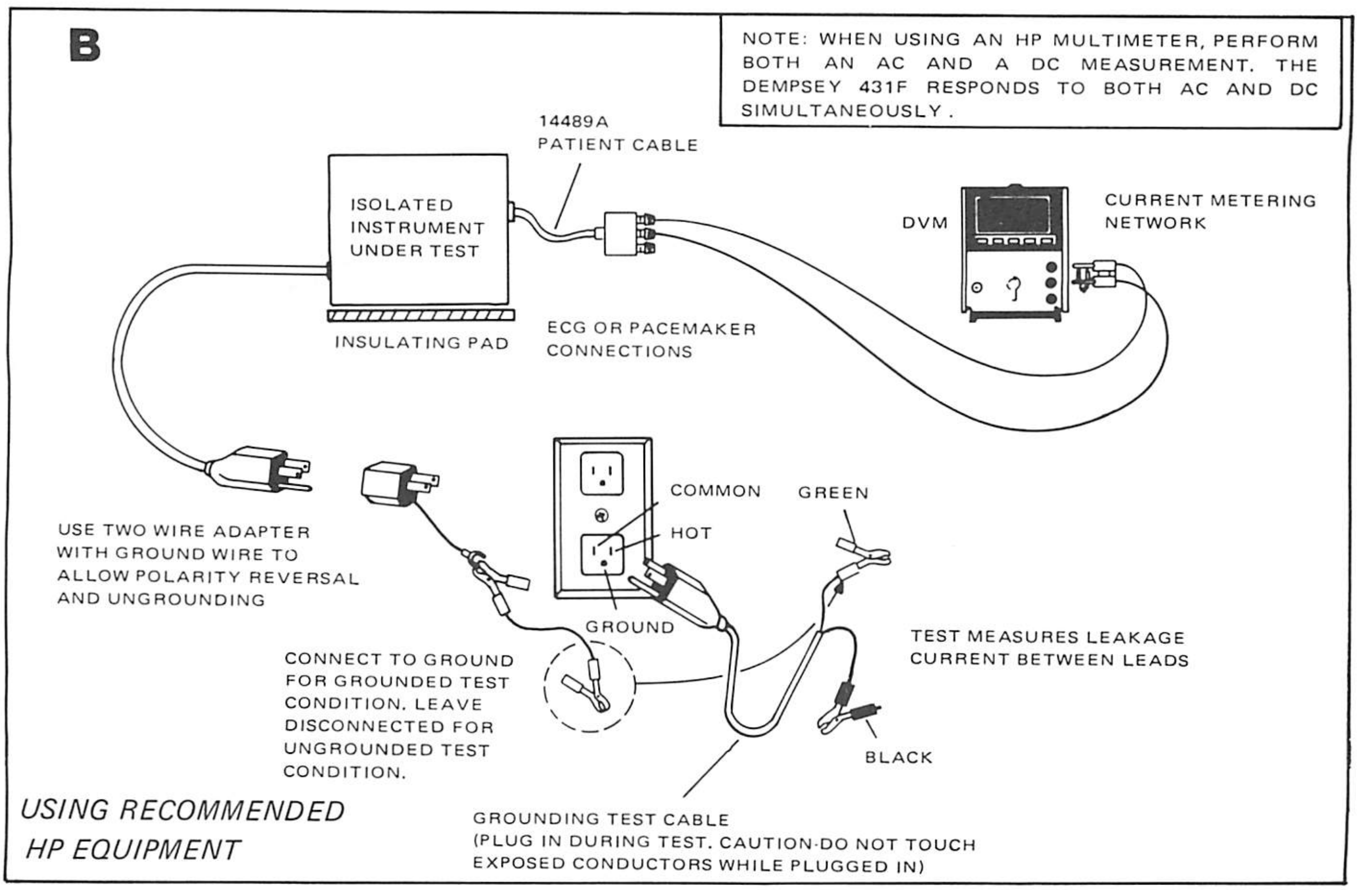
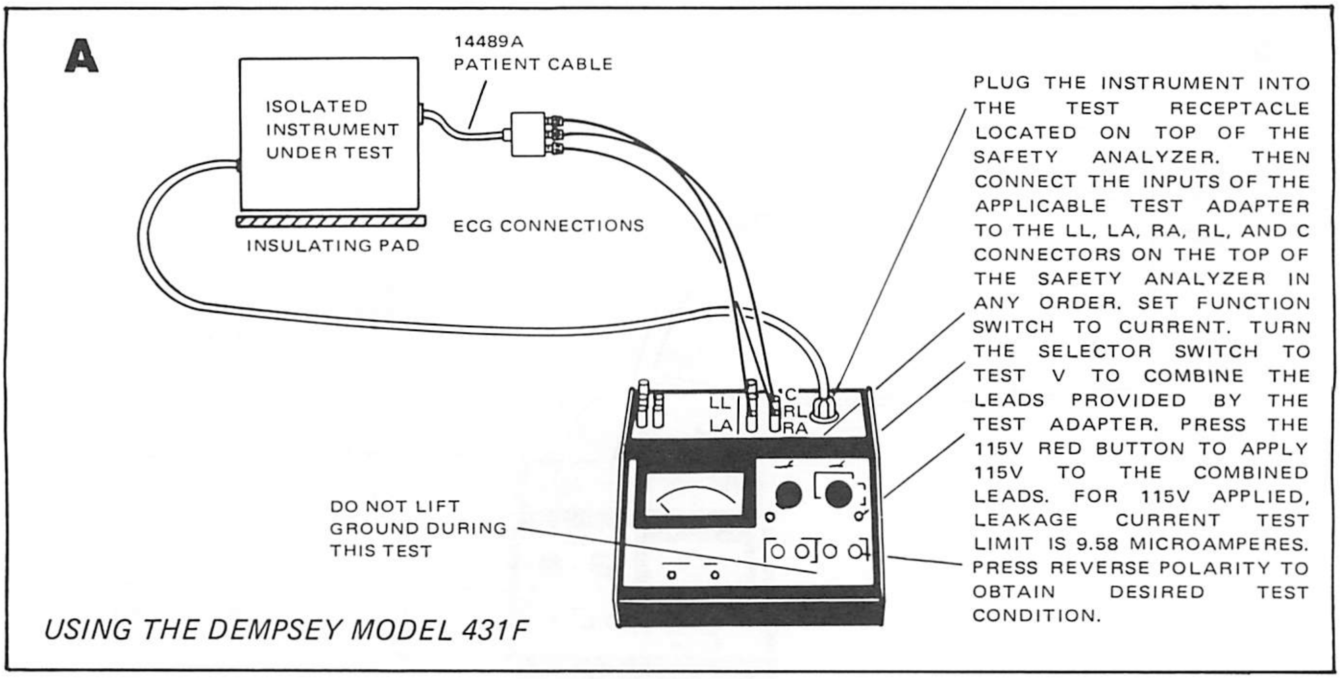


Figure 3-9B. Leakage Current Between Patient Leads Test.



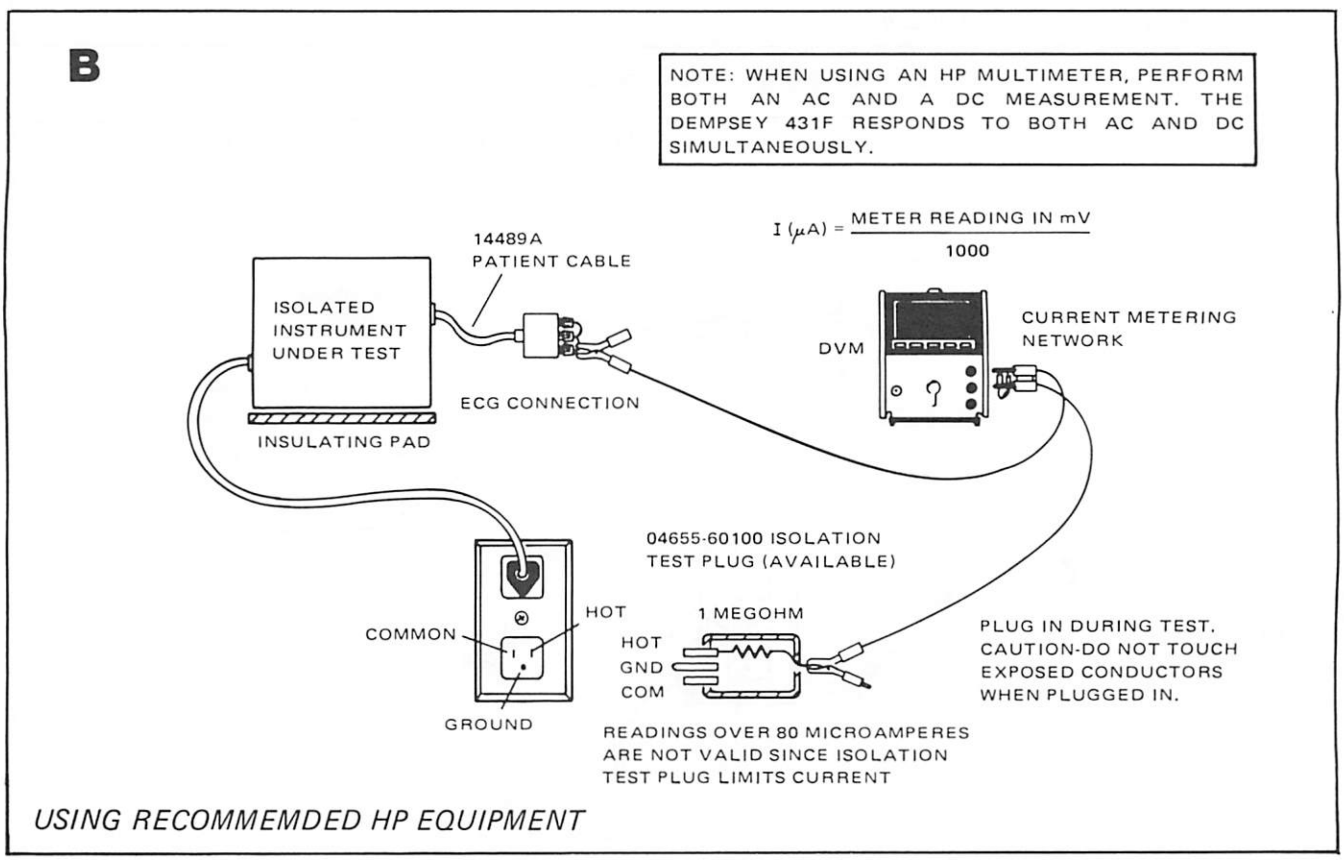


Figure 3-10. Patient Lead Leakage Current Test with 115V Applied.

D. ADJUSTMENTS.

Internal adjustments are made at the factory and normally do not require attention. If assemblies are repaired or replaced, however, check and adjust as necessary.

All test equipment necessary to make the adjustments is listed in each Adjustment Procedure.

To gain access to the adjustment controls, the instrument case must be opened. Refer to Section IV.

3-17. CRT DISPLAY ADJUSTMENTS.

The display adjustments include the CRT beam centering and the horizontal and vertical size adjustments on the CRT Deflection board 43100-60130 (A8) Adjust (A8) R38 (Marked "V") until distance from the top of the leads/paddles digit to the bottom of the alarm ON/OFF bells is 60 mm. Adjust the ring magnet tabs on the CRT yoke to center image on the screen. Adjust (A8) R37 (marked "H") until the leads 'III' is just on the screen, and the ends of the ECG trace are readily visible.

3-18. DEFIBRILLATOR OUTPUT ENERGY CALIBRATION. (A7 R79)

Adjustment of the output energy on discharge. Adjustment location is on the Control Board 43100-6010X (A7).

Equipment Required:

Energy Meter Recommend Dempsey 429	Capable of 2 to 400 Joule measurement with critically damped sinusoidal waveform. Accuracy ±2% of full scale Load resistance 50 ohms ±0.5%

Procedure:

1. Set the Energy switch to 100 Joules.
2. Place the paddles in contact with the energy meter contacts, press the CHARGE button, and after the CHARGE DONE LED on the Apex paddle lights, press both DISCHARGE buttons.
3. Adjust the HV capacitor voltage signal by adjusting R79 if necessary, to obtain proper delivered energy.
4. Set the Energy switch to 360 Joules.
5. Charge and discharge the defibrillator into the energy meter and again make adjustments of R79 until the energy delivered is equal to or slightly greater than the energy switch setting.
6. Check settings to confirm they are meeting specifications below:

2J ±1J	50J ±15%
3J ±1J	70J ±15%
5J ±1J	100J ±15%
7J ±2J	150J ±15%
10J ±2J	200J ±15%
20J ±4J	300J ±15%
30J ±15%	360J ±15%

7. If an adjustment has been required, the self-test accuracy should be tested and adjusted also (refer to 3-19.).

3-19. SELF TEST ENERGY ACCURACY ADJUSTMENT. (A7 R80).

Adjust of the peak current circuit output to calibrate the self test mode accuracy. This adjustment also determines the accuracy of the post-discharge calculation results annotated on the recorder after a discharge. Adjustment location is on the Control Board 43100-6010X (A7)

NOTE

The Defibrillator Output Energy Calibration must be performed before this adjustment (refer to 3-18.).

NOTE

To avoid overheating of the internal 50 ohm test load (with consequent inaccuracies of the derived information) do not exceed the equivalent of three 360J discharges per minute.

NOTE

If the unit is a 43100A, the post-discharge calculations results (delivered energy, peak current, and patient impedance) are annotated on the recorder strip.

Procedure:

1. Put the instrument in Service mode (see Section 3-1.). Place paddles in storage pockets.

2. Set the Energy switch to 360 Joules. Charge and discharge the defibrillator.

3. Adjust the I-peak potentiometer R80 to obtain a self test reading on the display of 360 Joules.

4. If the instrument is a 43100A, change the paddles to opposite storage pockets, adjust R80 until the patient impedance annotated on the recorder strip is 50 ohms.

5. Switch paddles back to the original storage pockets. Set the Energy switch to 100 Joules. Charge and discharge the defibrillator. Check that the Self-test reading, is between 90 and 110 Joules.

3-20. ECG GAIN ADJUSTMENT.

1. Connect a signal generator to the patient cable as shown in Figure 3-14.
2. Adjust the generator for an output of 5 Hz and 1 V rms. (Use the DVM).
3. Select Lead II.
4. Measure the voltage at the ECG Output jack.
5. Adjust (A6) R163 until the voltage is 1V.

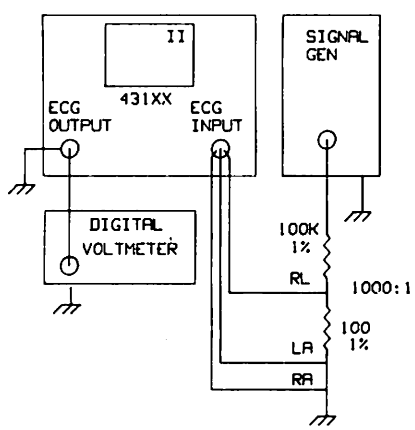


Figure 3-14. ECG Gain Adjust.

3-21. PATIENT CONTACT INDICATOR ADJUSTMENT.

1. Short across the paddles with a 61 ohm ±1% resistor.

2. Adjust (A6) R136 until the top two green LED'S on the Sternum paddle glow with approximately the same intensity. (A6) R136 is located next to the large black relay.

3-22. SWITCH SETTINGS.

SWITCH SETTINGS.

Six switches in a DIP package are located on the Control board A7. These switches personalize each model and should never need changing. Their function is listed here against the case of inadvertant changes or if the control board is changed and needs to be set. When viewed from the front of instrument the switches are numbered from 6 to 1.

SWITCH 6 - ANNOTATION.

Model 43100A will produce full annotation of patient parameters during discharge with the switch to the left. Turning the switch right limits the printed annotation to energy only.

SWITCH 5 - MODEL.

This switch must be to the left to read the front panel of the 43100A and right for the 43110A and 43120A.

SWITCH 4 - RECORDER DELAY.

When this switch is to the left the recorder will produce real time charts with the paddles out of the pockets and delay with the paddles in the pockets. Switch 4 in the right position will cause all recorder output to be delay mode.

SWITCH 3 - 50/60 HZ.

Switch 3 changes the notch filter for the ECG. Left position is 60 HZ and right is 50 HZ.

SWITCHES 2 AND 1.

These switches personalize the language used on the recorder and CRT. English (or French depending on ROM used) will be output with both switches either right or left together.

CHARGE DONE TONE OPTION.

The CHARGE DONE tone function can be permanently eliminated by removing R76 on the control board.

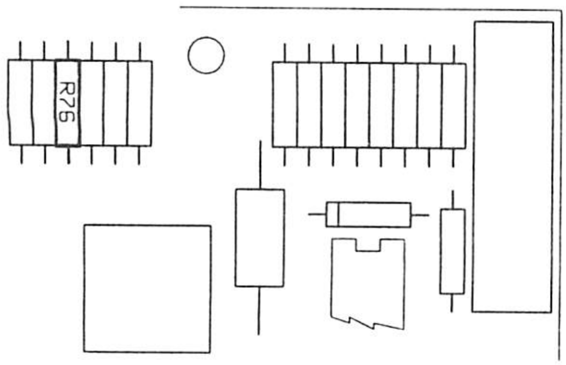


Figure 3-15. Location of R76.

3-23. PRINTHEAD ALIGNMENT.

The printhead needs alignment if the print is darker on one half of the paper than the other half (if a dirty printhead is not the cause of light printing).

1. The recorder can be adjusted without opening the case by removing the recorder lid to access the printhead adjustment screw. To remove the lid raise the recorder door by pushing the recorder release button, then using a posi-drive #1 screwdriver remove the two lid screws. The lid is attached at the rear; push back, then lift. The set screw is located underneath the flat ribbon cable on the printhead housing wall.

2. Place the instrument in the service mode (see Section 3-1.) so the test waveform is available.

3. With a #8 hex wrench adjust the adjustment screw on the recorder. (See Figure 3-16.).

The recorder must be physically held in its closed position inside the unit while making the adjustment. Turn the set screw until the bottom half of the paper is printing light, then back off the set screw until the bottom half darkens to the same intensity as the top half.

NOTE

Adjusting for greater darkening on the top half can cause paper tracking problems.

Reassemble by reversing the procedure and check print quality with the recorder lid in place.

3-24. CLEANING THE RECORDER PRINTHEAD.

The printhead should be cleaned every 3 months or when a buildup of residue becomes excessive and causes poor print quality.

1. Open the recorder by pushing the recorder release button. Raise the recorder fully to allow access to the printhead. The printhead will automatically lift off the pressure roller as the lid is raised.

2. Dampen a cotton swab in alcohol and gently wipe the area of the printhead just above the roller until the residue has been removed.

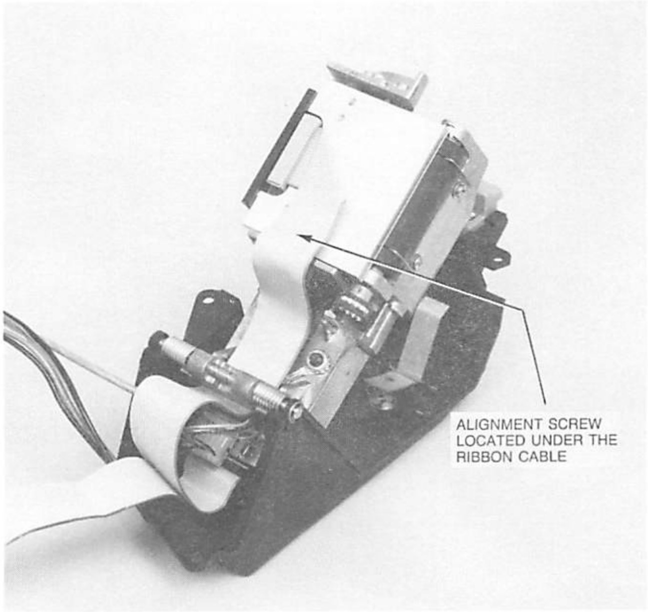


Figure 3-16. Location of alignment screw (under ribbon cable)

> WARNING
>
> DISCONNECT THE DEFIBRILLATOR FROM THE A.C. POWER SOURCE BEFORE PROCEEDING.

4-1. BATTERY REMOVAL.

1. Refer to Figure 4-1.
2. Rotate the battery cover latches 90 degrees.
3. Open the battery compartment.
4. Unplug the battery connector and remove the battery.

4-2. DISASSEMBLE.

1. Place the unit on its top on the workbench.
2. Remove the battery (see Section 4-1.).
3. Remove screws indicated by the arrows in Figure 4-1.
4. Hold the top and bottom case halves together and turn the unit over. (The screws will fall out.)
5. Lift the top half of the case from the bottom half. Place the top section on its side to the left of the bottom section. See Figure 4-2.
6. For many procedures, the top and bottom sections must be disconnected from each other. If this is necessary, disconnect J23, J31, J32 and J33 in Figure 4-3. The green/yellow ground wire must be disconnected from the grounding screw near the energy switch in the top section.

Re-Assembly

<u>CAUTION</u>

If the battery has been re-installed to operate the defibrillator, remove it before re-assembly. Re-assembly should present no problems. However, some positioning of the ribbon cables will be necessary. Be especially careful that no cables lie on the battery charger board shield.

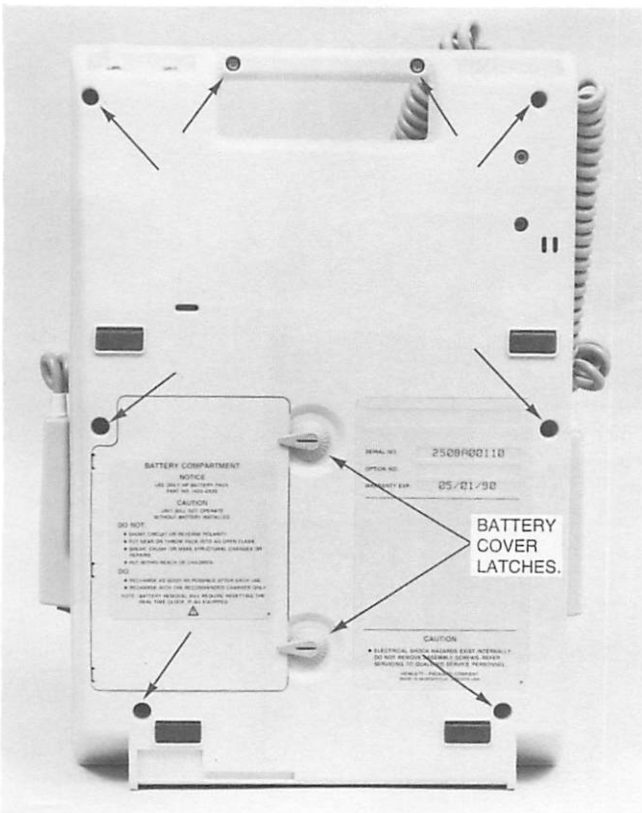


Figure 4-1.

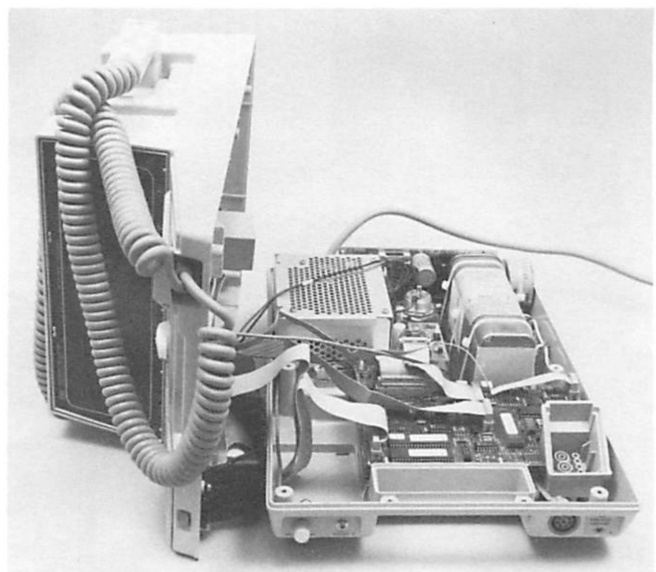


Figure 4-2.

4-3. LOW VOLTAGE POWER SUPPLY/BATTERY CHARGER BOARD (A4)

1. Open the instrument as outlined in Section 4-2, Paragraphs 1-5.

2. Remove the battery charger circuit board shield by removing the four screws indicated by the arrows in Figure 4-3.

3. Lift off the cover.

4. Disconnect J9, J21, J22, J23 and J24 (see Figure 4-3).

5. Remove the four aluminum spacers indicated by the arrows in Figure 4-4.

6. Compress the latch on the plastic spacer (Figure 4-4.) and lift the board until it clears the latch. Place a finger under the board at that point and near the circuit breaker connections and lift the board out.

7. When installing this board, be certain the circuit breaker connectors and the plastic spacer engage before pressing the board in place.

8. Reconnect the cables, install the four aluminum spacers and install the shield.

Figure 4-3.

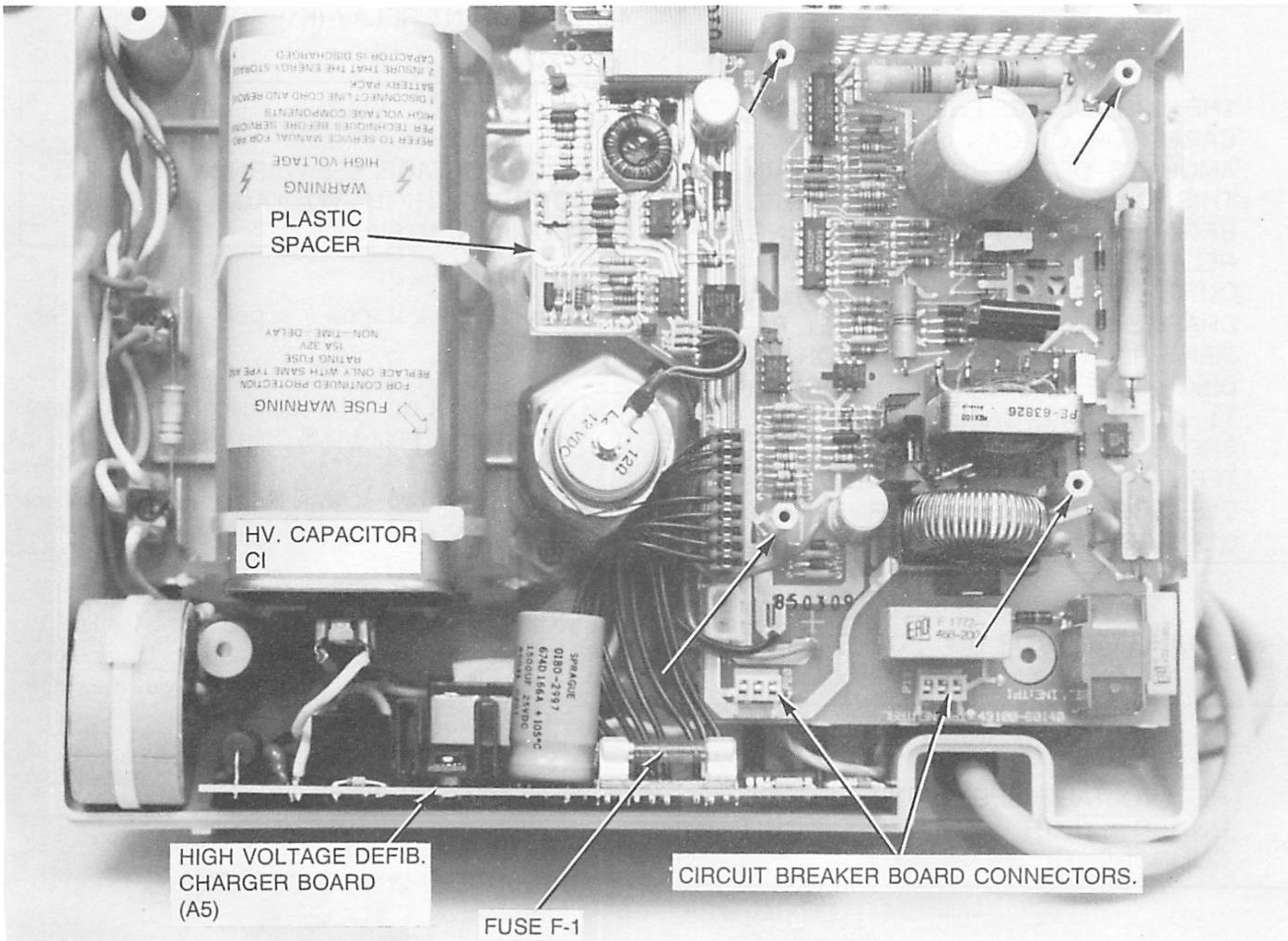


Figure 4-4.

4-4. CIRCUIT BREAKER BOARD (A3).

NOTE

A special knurled nut wrench, Part Number 8710-0983, is required to remove the nuts from the circuit breakers. These nuts are made of aluminum and the use of pliers will deface the nuts.

1. The circuit breaker board is located under the L.V. power supply board (A4). This board must be removed to allow access to the circuit breaker board. See Section 4-3. for instructions.

2. The circuit breakers are soldered to the circuit breaker board so the entire assembly must be removed.

3. After the low voltage power supply board is removed, disconnect the A.C. power line quick connect lugs from the circuit breaker board.

4. Remove the knurled circuit breaker nuts.

5. Lift the circuit breaker board assembly out of the case.

6. Refer to Section 4-3 Paragraphs 7 and 8 when re-installing the L.V. power supply board.

WARNING

THE HIGH VOLTAGE ENERGY STORAGE CAPACITOR C1 CAN STORE LETHAL AMOUNTS OF ENERGY. BE CERTAIN THIS CAPACITOR IS DISCHARGED BEFORE TOUCHING ANYTHING RELATED TO THE HIGH VOLTAGE CIRCUIT, I.E. DEFIBRILLATOR H.V. CHARGER BOARD, CAPACITOR C1, PATIENT RELAY K1, H.V. INDUCTOR L1, DISCHARGE ENERGY TRANSFORMER T1 OR PADDLE CABLE CONNECTOR. SHORT CIRCUIT THE H.V. CAPACITOR TERMINALS WITH AN INSULATED HANDLE SCREWDRIVER. WEAR SAFETY GLASSES.

4-5. DEFIBRILLATOR H.V. BOARD (A5).

WARNING

HIGH VOLTAGE. SEE WARNING NOTICE UNDER "HIGH VOLTAGE CIRCUIT COMPONENTS"

1. The defibrillator charger board (A5) is mounted vertically at the rear of the unit behind the H.V. capacitor. See Figure 4-4.

2. Refer to Figure 4-3. Disconnect J21. To remove the board, grasp the upper corners and lift. The board is a rather tight fit and it may be difficult to get it loose.

3. When the board is loose, disconnect two wires from the patient relay and two wires from the H.V. capacitor.

4. When installing the H.V. board, connect the patient relay and H.V. capacitor before pressing board in place.

4-6. PATIENT RELAY (K1).

WARNING

HIGH VOLTAGE. SEE WARNING NOTICE UNDER "HIGH VOLTAGE CIRCUIT COMPONENTS"

1. Remove the L.V. power supply board (A4). See Section 4-3.

2. Remove, but do not disconnect, the defibrillator H.V. charger board (A5). See Figure 4-5.

3. Remove the two screws that secure the patient relay.

4. Lift the relay out of the unit. Disconnect the H.V. wires (two to the H.V. circuit board, two to the H.V. capacitor C1, one to the H.V. inductor L1, and one to a H.V. terminal junction beside the H.V. capacitor.)

5. Reconnect and replace components in the reverse order.

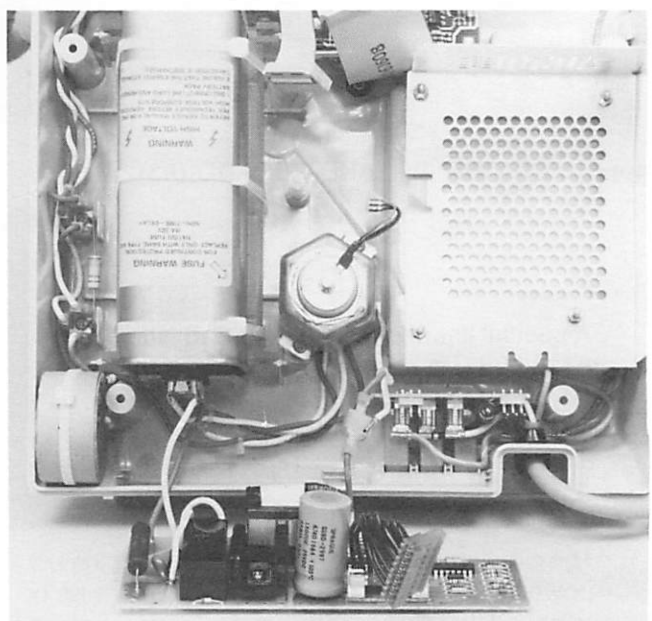


Figure 4-5.

4-7. H.V. CAPACITOR (C1).

> WARNING
>
> HIGH VOLTAGE. SEE WARNING NOTICE UNDER "HIGH VOLTAGE CIRCUIT COMPONENTS." BE CERTAIN THE CAPACITOR IS DISCHARGED.

1. Disconnect the four push-on lugs from the capacitor terminals.
2. Clip the three tie-wraps and remove the capacitor.
3. Install the new capacitor and secure with three tie wraps (P/N 1400-1318).

> WARNING
>
> DO NOT REMOVE THE RESISTOR FROM THE CAPACITOR TERMINALS.

4-8. SAFETY RELAY.

The safety relay is part of the H.V. defibrillator charger board assembly (A5). In case of safety relay failure, the entire assembly should be replaced. See Section 4-5.

4-9. CONTROL BOARD (A7).

1. Refer to Figure 4-3. Disconnect J22, J30, J31, J32 and J33.
2. The control board is located in front of the H.V. capacitor C1. It is mounted in notches in the case behind the handle and on three plastic spacers at the rear of the board. See Figure 4-6.
3. Compress the latches on the plastic spacers, one at a time and lift the board enough to keep the latch compressed. When the last latch is compressed place your fingers under the board near the spacers and lift the board out of the defibrillator.
4. When replacing the board, place the front board edge in the notches in the case. Line up the holes over the plastic spacers and press down evenly so the back of the board remains level as the spacer latches engage. Reconnect J22, J30, J31, J32 and J33.

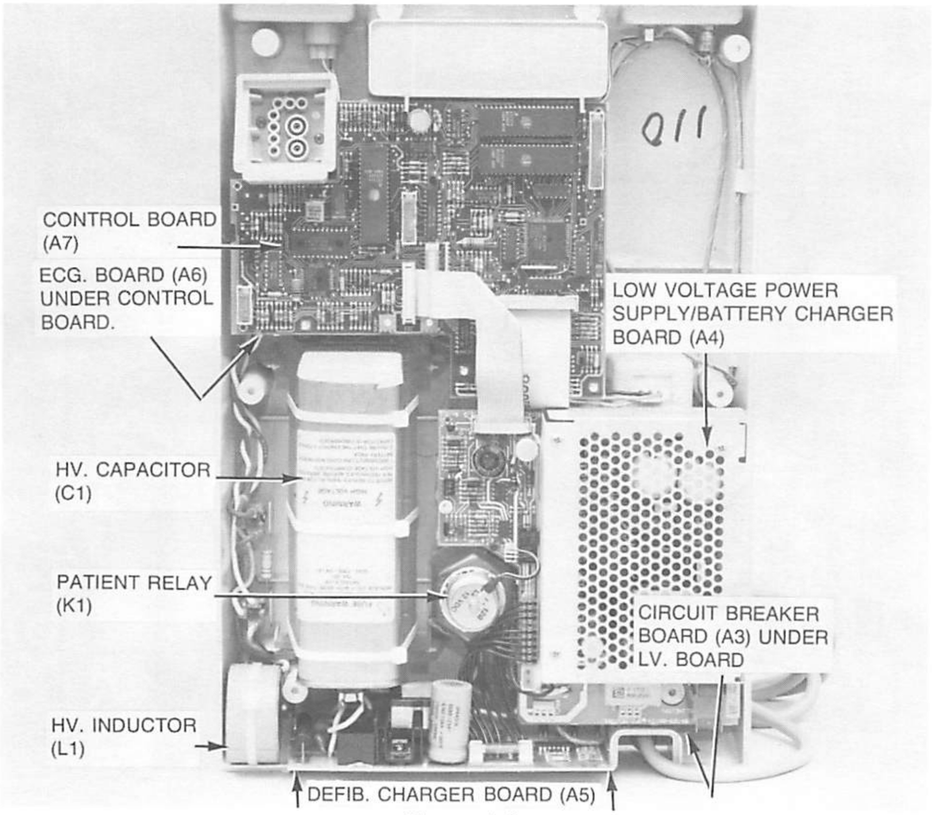


Figure 4-6.

4-10. ECG BOARD (A6).

The ECG board is located under the control board.

1. Remove control board as described in Section 4-9.
2. Disconnect J25, J26, J27 and J28. See Figure 4-7. Follow the red and white H.V. wires back to the junction connectors and disconnect these wires.
3. Unscrew the three plastic spacers along the rear edge of the board. The ECG board can now be removed.
4. When installing an ECG board, do not overtighten the plastic spacers.
5. Twist the red and white H.V. wires.

4-11. CRT OVERLAY PANEL.

This procedure varies slightly, depending on the defibrillator model. Some units have membrane switches and indicator lamps built into the panel and the cables must be unplugged before the panel can be removed. On those units the case must be opened and the cables unplugged.

1. Lift one of the clips at the top of the panel and slip a small flat-blade screwdriver between the clip and the panel. See Figure 4-8.
2. Pry the panel out far enough to allow the clip to drop behind the panel. Now repeat the procedure on the other clip.
3. If the unit is a 43110A or 43120A, simply lift the panel out. See Figure 4-9.

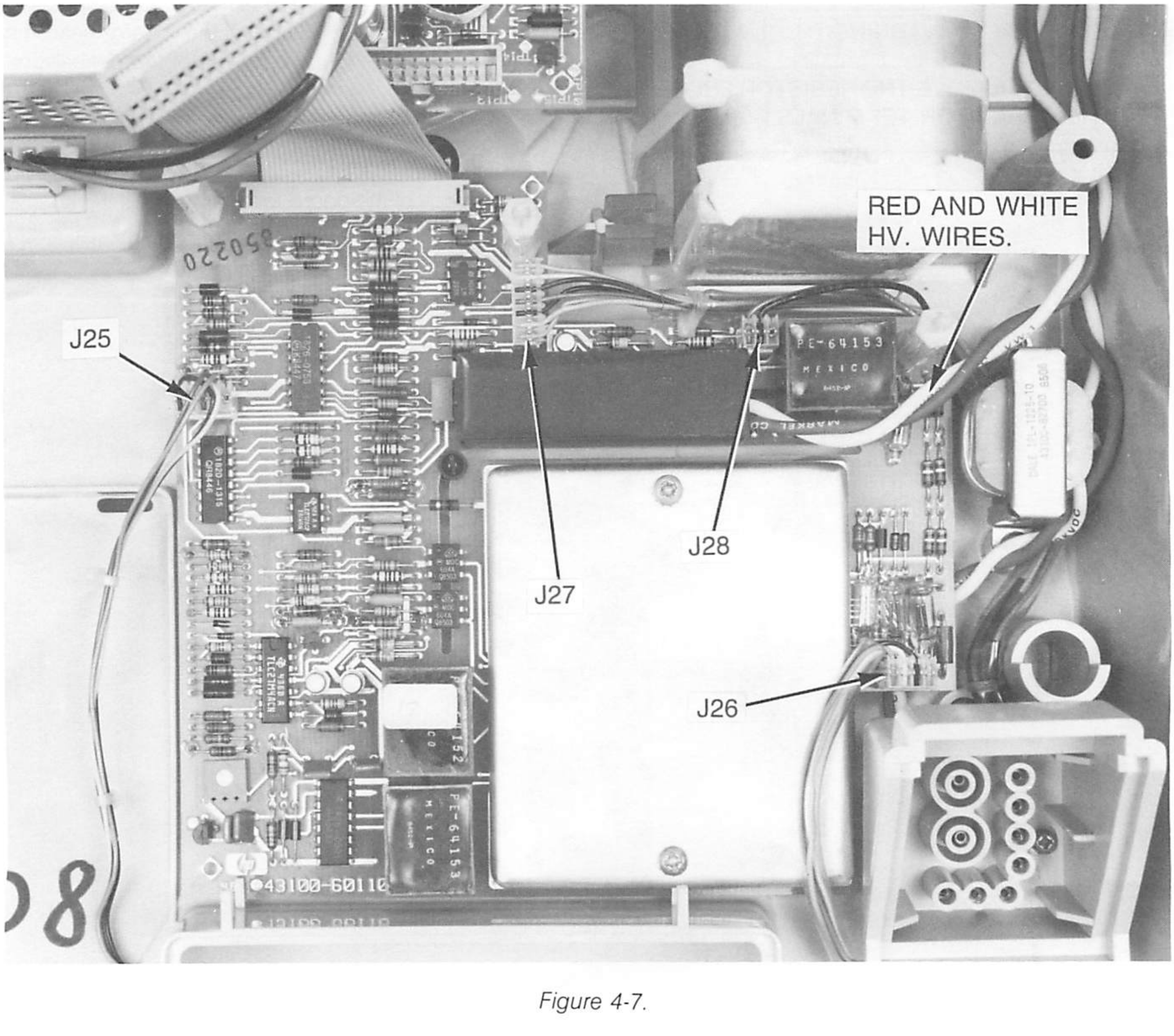


Figure 4-7.

4. If the unit is one with membrane switches in the panel, lift the panel clear of the defibrillator, then pull the cables free.

5. Replacement is a reversal of the procedures outlined above.

NOTE

When re-installing the panel, lift the clips at the top when you press the panel in place.

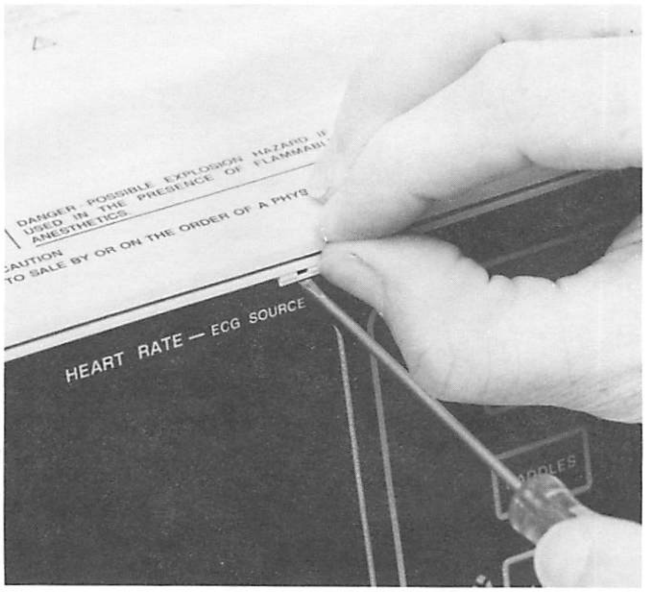


Figure 4-8.

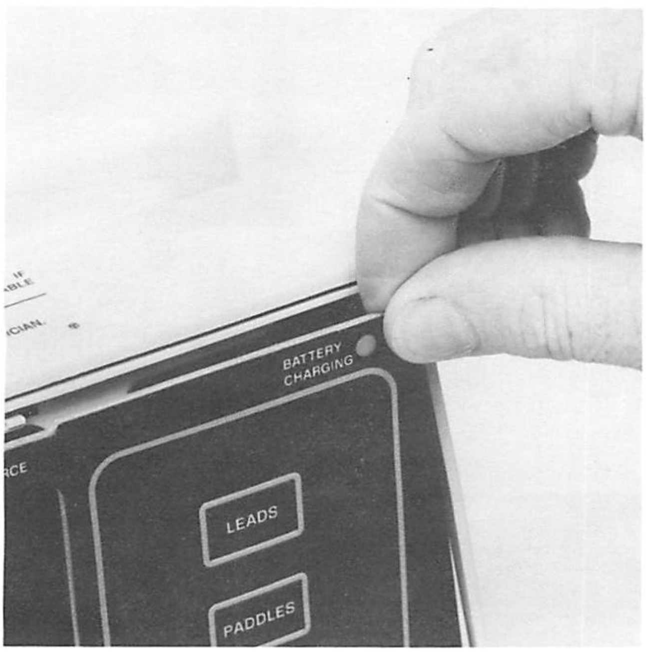


Figure 4-9.

4-12. CRT REMOVAL AND REPLACEMENT.

CAUTION

Wear Safety Glasses

1. Open the defibrillator case. Refer to Section 4-2.
2. Disconnect the cables so the case halves can be separated.
3. Remove the front panel as described in Section 4-11.
4. Refer to Figure 4-10. Disconnect the H.V. connector P37 from the side of the CRT. Disconnect the CRT socket J43 from the rear of the CRT.
5. Disconnect the CRT yoke cable connector J35 from the deflection board.
6. The CRT and shield are secured with four screws accessible from the front of the instrument after the front panel has been removed. These screws attach to two vertical straps on the rear of the panel. Remove the screws while holding the CRT with one hand.
7. Lift the CRT and shield from the case assembly.
8. If the yoke is to be removed, loosen the clamp screw and slide the yoke off the neck of the CRT.
9. CRT replacement is a reversal of the procedures just described. If the yoke has been removed, it may be necessary to rotate the yoke slightly to align the CRT trace.

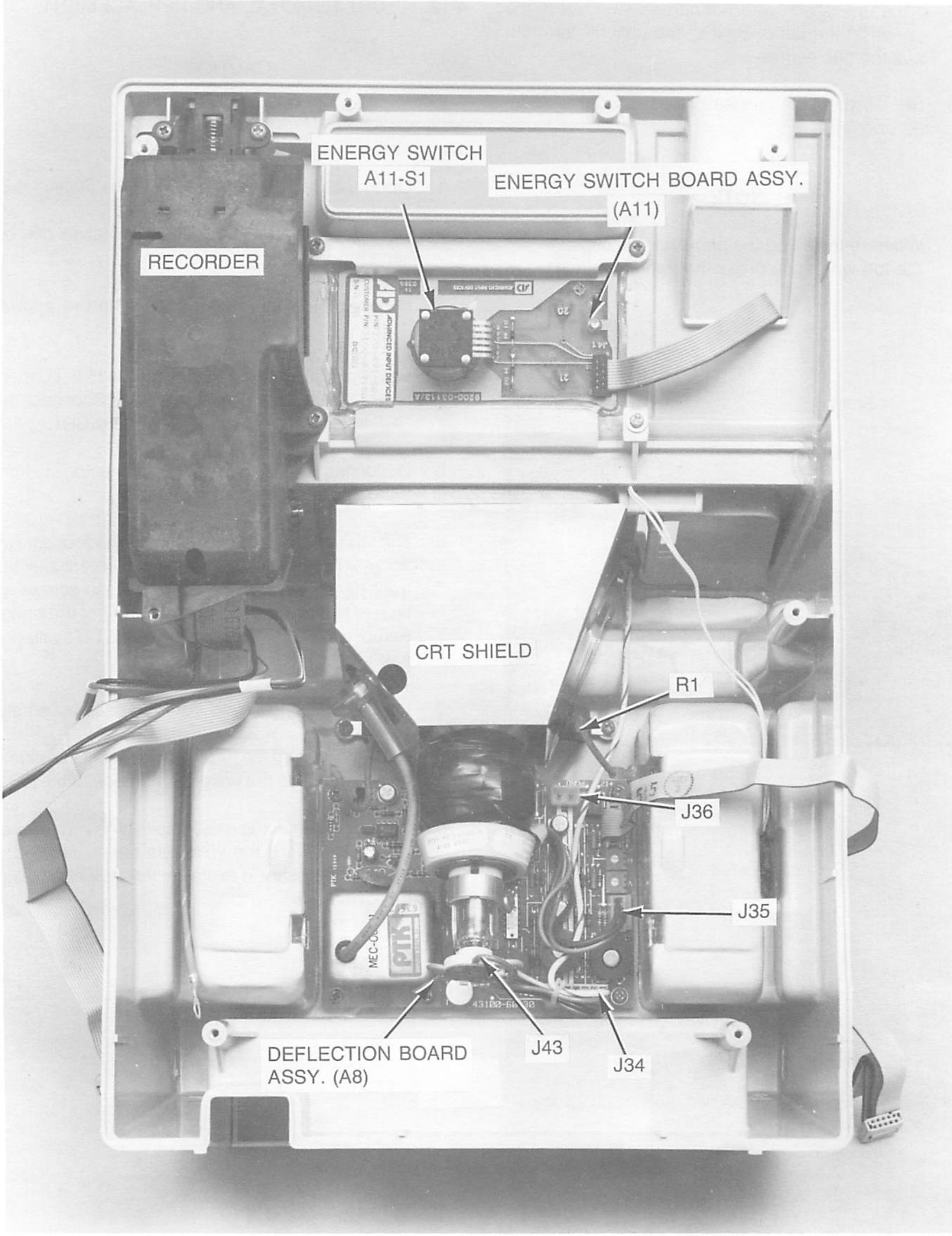

ENERGY SWITCH
A11-S1
ENERGY SWITCH BOARD ASSY.
(A11)
RECORDER
CRT SHIELD
R1
J36
J35
DEFLECTION BOARD
ASSY. (A8)
J43
J34

Figure 4-10.

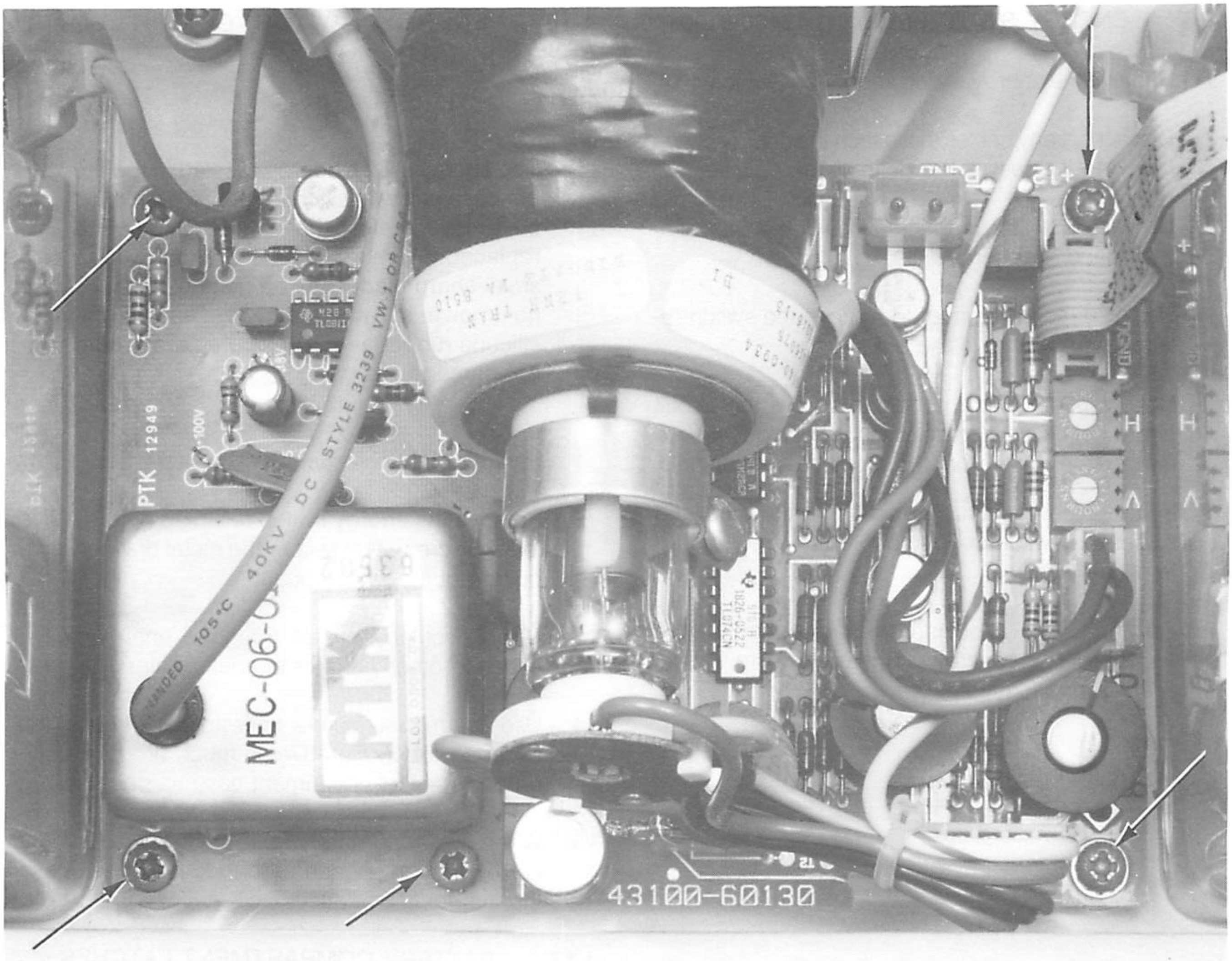


Figure 4-11.

4-13. DEFLECTION BOARD (A8).

1. The deflection board can be removed without removing the CRT. Refer to Figure 4-10.

2. Disconnect the high voltage connector P37 from the side of the CRT.

3. Disconnect the CRT socket J43 and the other end of this cable J34 from the deflection board.

4. Disconnect the CRT yoke cable connector J35 from the deflection board.

5. Remove the five screws indicated by the arrows. See Figure 4-11.

6. Lift the rear of the board and carefully slide it past the rear of the CRT. Be careful to not damage the CRT pins or seal.

4-14. ENERGY SWITCH KNOB REMOVAL.

1. The set screws that secure this knob are only accessible from inside the instrument. Open the instrument as outlined in Section 4-2. For convenience, disconnect the cables so the case halves can be separated.

2. Rotate the energy switch to the OFF position.

3. Insert a 1/16 inch allen wrench through the hole at the top of the switch (inside the instrument) and loosen the set screw. See Figure 4-12.

4. Rotate the energy switch to the 7 Joule position and loosen a second set screw. Both set screws should be loosened about two full turns.

5. It should be possible to remove the knob. If not, loosen the set screws another full turn.

4-15. ENERGY SWITCH (A11-S1) 43100-61901.

1. Remove the energy switch knob. See Section 4-14.
2. Disconnect any cables that attach the energy switch board to the rest of the defibrillator.
3. Clip the six switch conductors near the point where they bend. See Figure 4-12.
4. Use a ½ inch nut driver to remove the switch retaining nut. Remove the old switch.
5. Unsolder the switch conductors from the circuit board lugs. Use a solder sucker or solder wick to remove the solder from the circuit board terminals.
6. Install the new switch. Tighten the retaining nut and solder the switch conductors to the circuit board terminals.
7. Be certain the knob is correctly aligned before tightening the set screws. Tighten the screw at the 7 Joule position first.

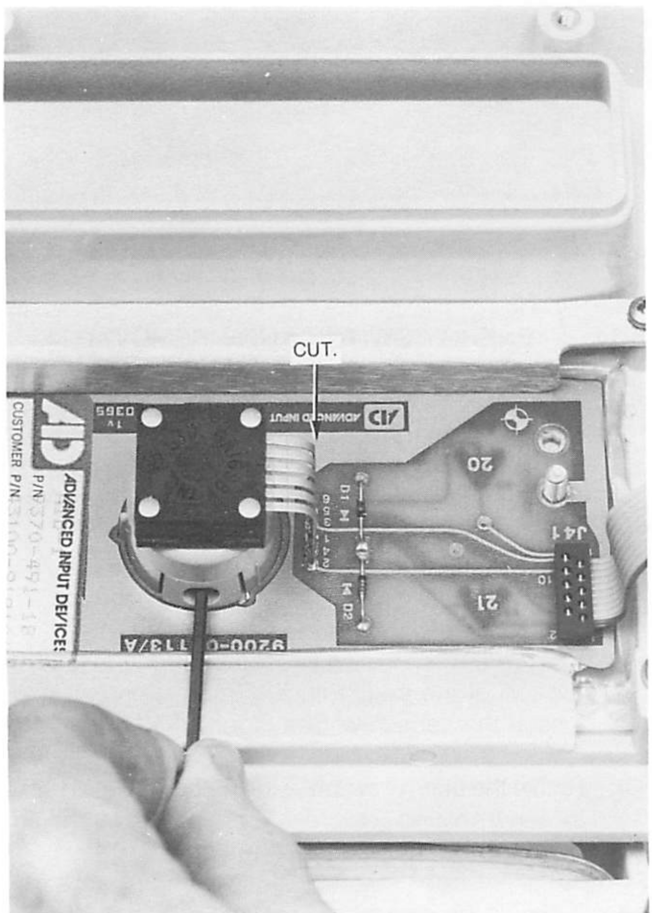


Figure 4-12.

4-16. ENERGY SWITCH CIRCUIT BOARD ASSEMBLY (A11).

NOTE

The energy switch board is sealed to the upper case half with silicone rubber. This must be removed before the circuit board can be replaced. A model-maker's knife with a small sharp blade may be helpful. There is no known solvent that will dissolve the silicone rubber after it has cured that would not damage the case.

1. Remove the knob. See Section 4-14.
2. Remove the energy switch retaining nut. Remove the two screws that secure the metal bracket at the bottom of the switch board.
3. Disconnect any cables from the energy switch board to other parts of the defibrillator.
4. Use the model-makers knife to cut through the silicone rubber. Remove as much of the silicone rubber from the instrument case as possible.
5. When installing the circuit board use a non-corrosive type silicone rubber. It should not have the acrid smell of acetic acid.

4-17. BATTERY COMPARTMENT LATCHES.

1. Remove the battery and battery comparment cover.
2. Open the case as described in Section 4-2.
3. Remove the low voltage power supply board. See Section 4-3.
4. Depending on which latch requires replacement, it may be necessary to remove the patient relay (K1). See Section 4-6.
5. The latch retainer ring may be pried off with a flat blade screwdriver or the ring may be cut with diagonal pliers.
6. Insert the new latch and install new mounting hardware on the shaft. Use long-nose pliers to press the retainer ring into place. Apply pressure on opposite sides of the ring at the same time. Do this at several points around the ring.

4-18. RECORDER REMOVAL.

1. Open the defibrillator case. See Section 4-2.

2. Press the recorder door release button to open the recorder.

3. Remove the paper roll and the two screws that secure the lid. See Figure 4-13. Lift the front of the cover up and slide it to the rear to remove.

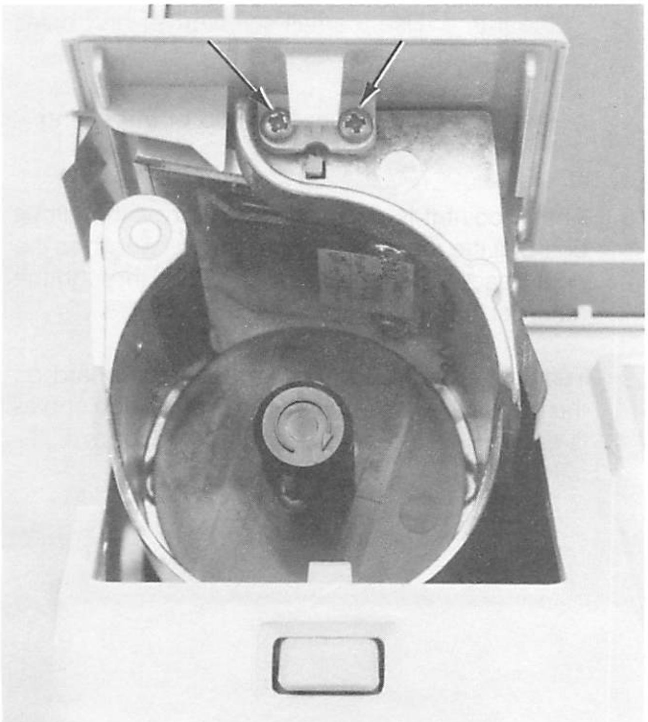


Figure 4-13.

4. Disconnect the recorder ground wire from the terminal located near the energy switch board.

5. Remove the three screws indicated in Figure 4-14. Lift the recorder assembly out of the case.

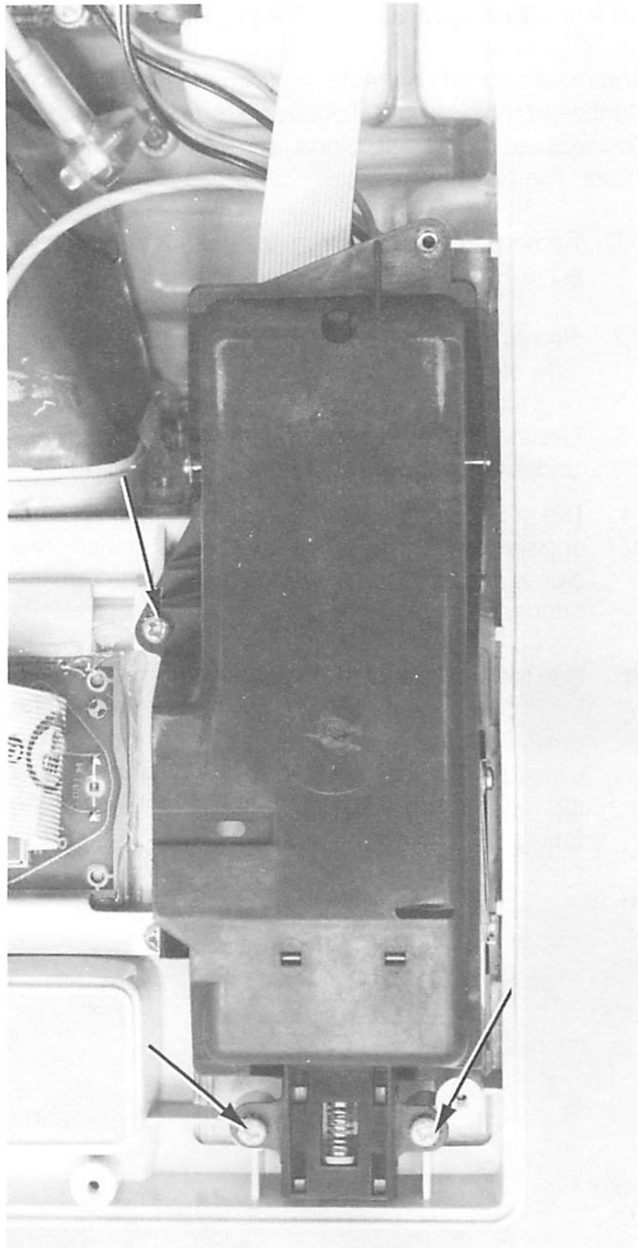


Figure 4-14.

4-19. REPLACING THE PRINT HEAD.

The recorder must be removed from the defibrillator for print head replacement. Tools required: Small posidrive screwdriver, small flat blade screwdriver, long-nose pliers, fine-point tweezers.

1. Remove the recorder from the defibrillator as outlined in Section 4-18.

2. Remove the plastic part attached to the right hand side of the print head.

3. Use the long-nose pliers to remove the two springs under the right hand side of the print head.

4. The print head is suspended at the center on what appears to be a square shaft. This is actually two pieces and does not extend all the way through the print head.

5. Use the small flat-blade screwdriver to press off the small E-ring located inside on the front half of the shaft. Turn the recorder on its back and insert the screwdriver from the bottom. It is helpful to place the recorder on a soft cloth to prevent loss of the E-ring.

6. Grasp the front shaft with long-nose pliers and pull it out of the print head. See assembly breakdown Figure 4-15.

7. Lift the front edge of the print head high enough to clear the frame and gently pull it loose. The rear shaft section should remain in the frame. If it came out with the print head it must be put back into the recorder frame.

   a. You will see a coil spring in the shaft hole in the frame. Use a small screwdriver and press the spring all the way down.

   b. Install the square shaft on top of the spring.

8. At this point it is necessary to remove the circuit board at the rear of the recorder mechanism so the print head cable connector can pass through the recorder frame.

9. Turn the recorder to expose the circuit board on the rear of the assembly. One of the ribbon cables is secured to the recorder with a tie wrap.

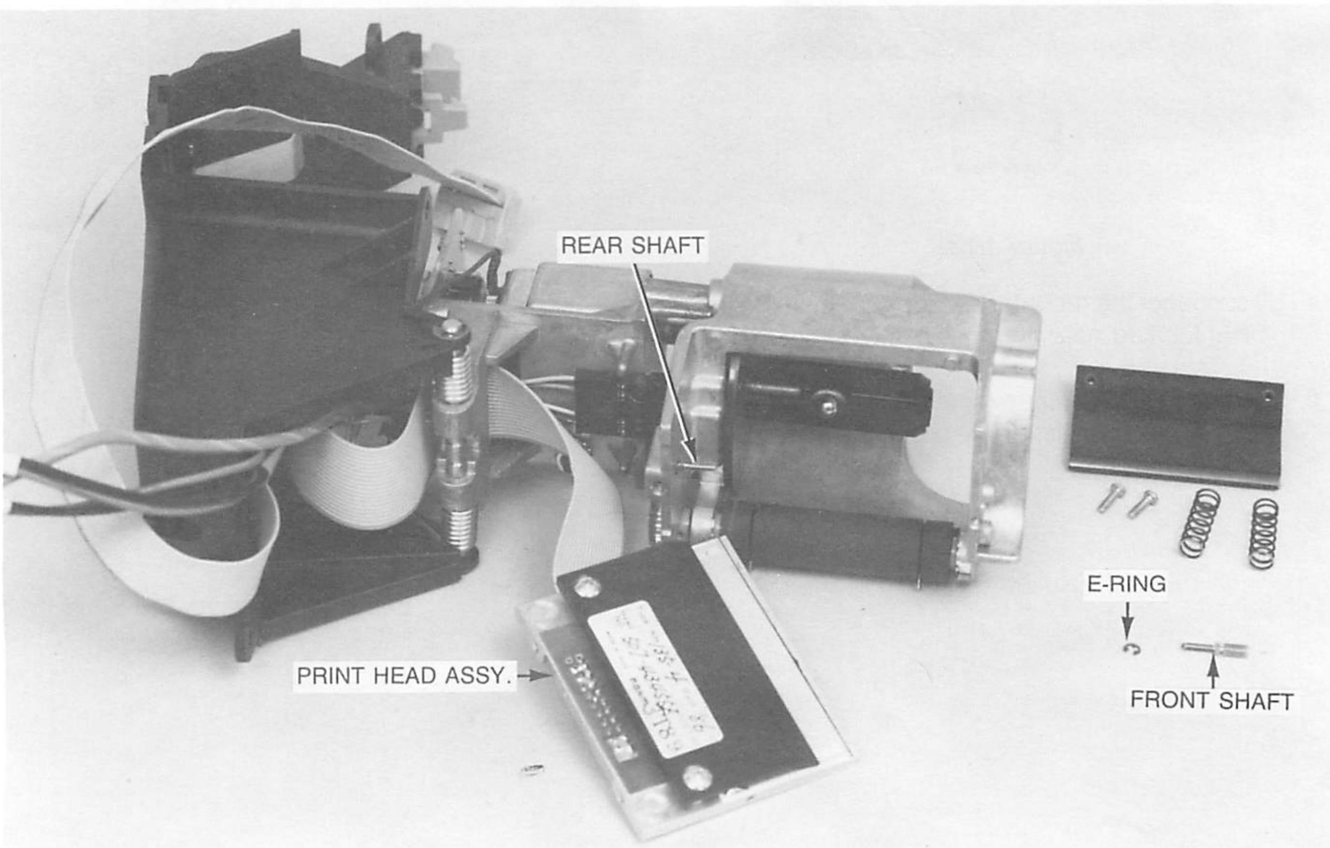


Figure 4-15.

10. Cut the tie wrap to free up the ribbon cables and unplug the printhead connector from the circuit board.

11. Remove the three screws that secure the board to the recorder assembly.

12. It should be possible to pull the ribbon cable through the opening in the recorder frame.

13. Reverse the procedure for installing the new print head.

14. When you are ready to install the little E-ring on the front print head shaft, press the shaft into the frame. Position the E-ring on the shaft inside the frame and press it onto the shaft with the screwdriver. You should hear a click when the E-ring snaps onto the shaft.

4-20. REPLACING THE PAPER SPINDLE

1. Remove the recorder mechanism from the defibrillator as outlined in Section 4-18.

2. Open the assembly to expose the recorder mechanism.

3. Remove the E-ring on the end of the spindle shaft near the motor drive chain gear.

4. Pull the spindle out of the recorder frame. See Figure 4-17.

5. When installing the E-ring on the shaft, apply pressure until you hear it click. Examine the E-ring to be certain it is installed correctly.

4-21. REPLACING THE DRIVE CHAIN

The print head roller is driven by a plastic chain. The chain is visible when the cover is removed (see Section 4-18.). The recorder mechanism must be removed from the defibrillator to replace the chain.

1. Remove the recorder assembly from the defibrillator as outlined in Section 4-18.

2. Remove the paper spindle as described in Section 4-20.

3. Remove the three screws behind the paper spindle. This separates the front part of the recorder from the motor section. See Figure 4-17 and 4-18.

4. Remove the old chain if it has not broken and fallen off. Place the new drive chain on the gears and replace the screws that secure the front and rear sections of the recorder.

5. Check the chain drive gear set screws. Tighten if necessary; the screw is retained by loc-tite. If screw is turned loc-tite (222) should be reapplied. Be sure the gears line up so there is no side force on the drive chain. Replace the paper spindle.

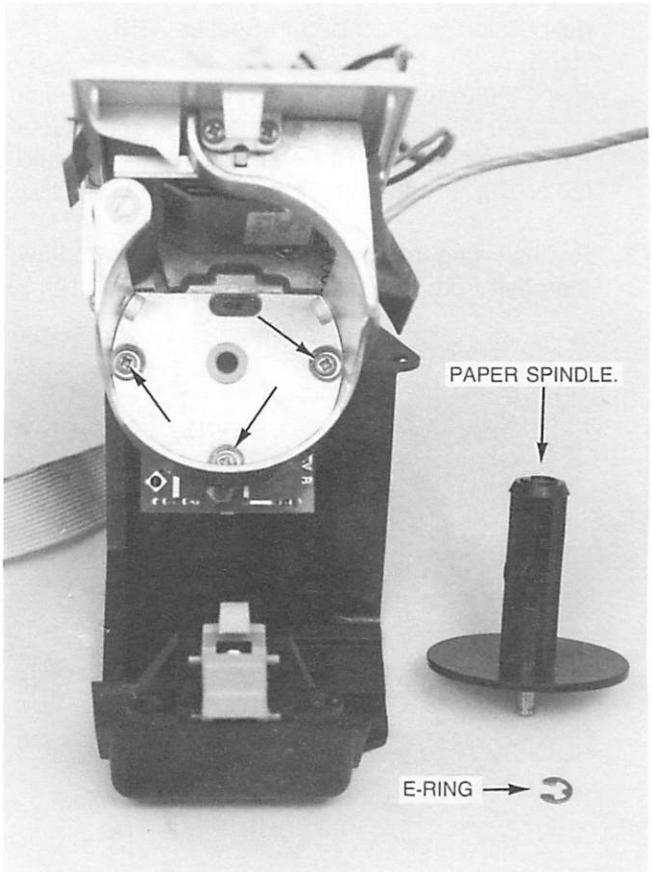


Figure 4-17.

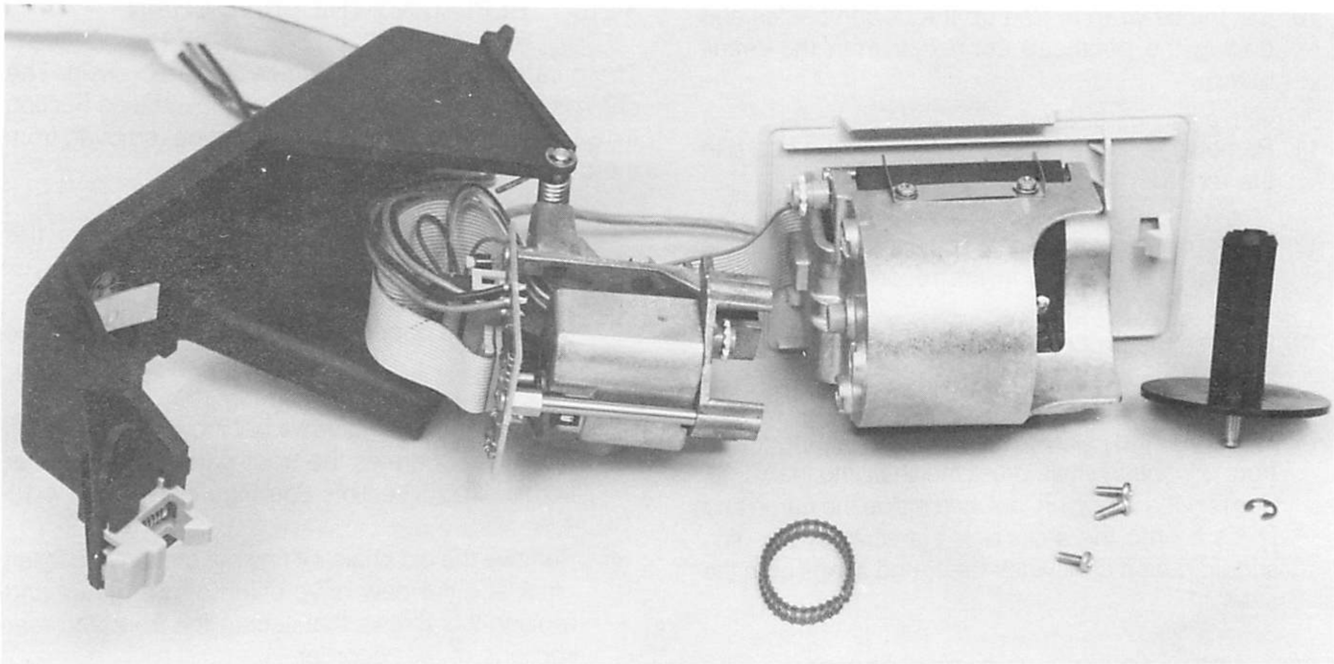


Figure 4-18.

4-22. PLASTIC RECORDER HOUSING REPLACEMENT

1. Remove the recorder assembly from the defibrillator as described in Section 4-18.

2. Place the assembly on the work surface and examine the torsion springs on the hinge shaft. Note the spring position on the shaft. There is a right and left spring and they must be replaced correctly.

3. Pry the E-ring from one end of the shaft. Withdraw the shaft from the assembly. See Figure 4-19.

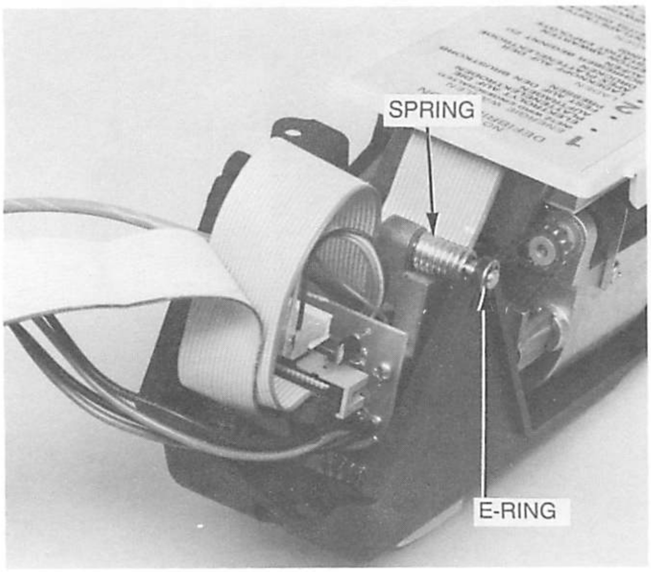


Figure 4-19.

4. Install the shaft and springs in the new housing.

5. Transfer latch and spring and the arm assembly from the bottom of the old housing. Refer to Section 4-23.

4-23. RECORDER LATCH REPLACEMENT

1. Remove the recorder assembly from the defibrillator. See Section 4-18.

2. Compress the spring and remove it from the latch.

3. Push the latch backward until the side lugs clear the guides in the housing, then lift up. See Figure 4-20.

4. Place the new latch in the housing then install the spring. Be sure the spring is properly centered. Spring installation is most easily accomplished working from the bottom of the housing.

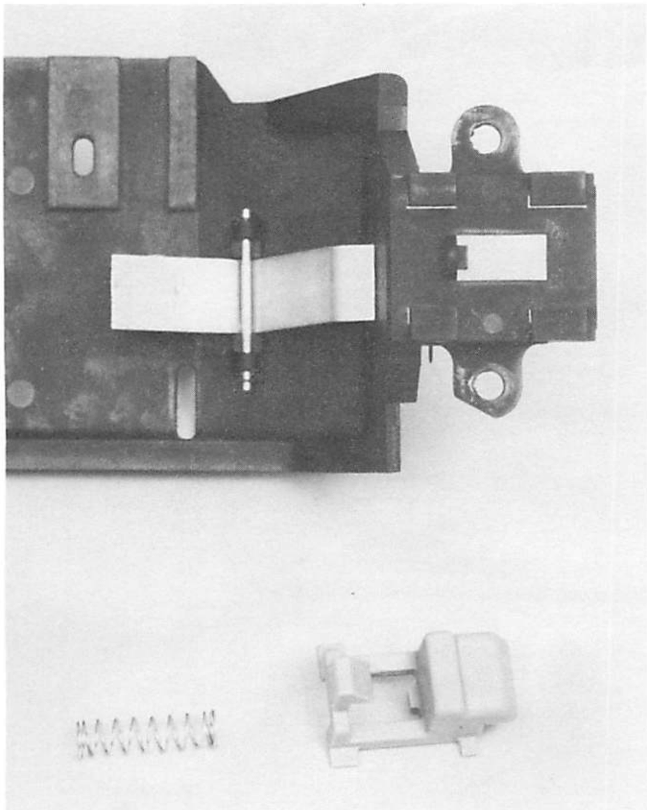


Figure 4-20.

4-24. REMOVING "NON-REMOVABLE" PADDLES

1. Remove the label from the paddle cable connector.
2. Remove the screw from the connector.
3. Slide the latch back and remove the connector from the defibrillator.

NOTE

These paddles could be replaced with standard anterior-anterior paddles. However, interior paddles cannot be used because there is no way to charge the defibrillator.

This instrument has no provision for paddles with the contact indicator.

4-25. PADDLE SWITCH REPLACEMENT

Paddle switch replacement, anterior-anterior paddles.

Switch replacement consists of replacing a small circuit board assembly. No soldering is necessary.

Paddle	Circuit Board	Label
Apex	43100-60125	43100-84513
Sternum	43100-60135	43100-84514
Sternum w/PCI	43100-60115	43100-84512

Tools required: Small posidrive screwdriver, long-nose or flat-nose pliers with very thin jaws.

1. Unplug the paddle from the defibrillator. If the paddles are not removable, disconnect the defibrillator from AC power line. Make certain the energy switch is in the off position.
2. Remove the label from the top of the paddle handle.
3. Remove the two screws that secure the cover.
4. Slide a knife blade or other very thin object between the rear edge of the cover and cable strain relief. Pry the cover loose.
5. Lift the cover then slide it forward to clear discharge switch button. Set the cover aside.

NOTE

On the APEX paddle, unplug the two-in LED connector on the side of the board opposite the CHARGE switch before removing board. See Figure 4-21.

6. Lift the circuit board out of the paddle. Unplug the connector at the rear of the board.
7. Remove the red DISCHARGE switch button and the small spring from the switch actuator. Note that one end of the spring is smaller in diameter.
8. When installing the DISCHARGE switch button, place a finger behind the bend in the actuator so it cannot slide back. The short side of the button goes up.
9. Force the small end of the spring over the rear of the actuator bar. It will be a snug fit. If the paddle is the APEX, be sure that the charge button and spring are in place before installing the circuitboard. If it is necessary to reinstall the spring in the base of the charge button, the end with the several closed coils goes in first.

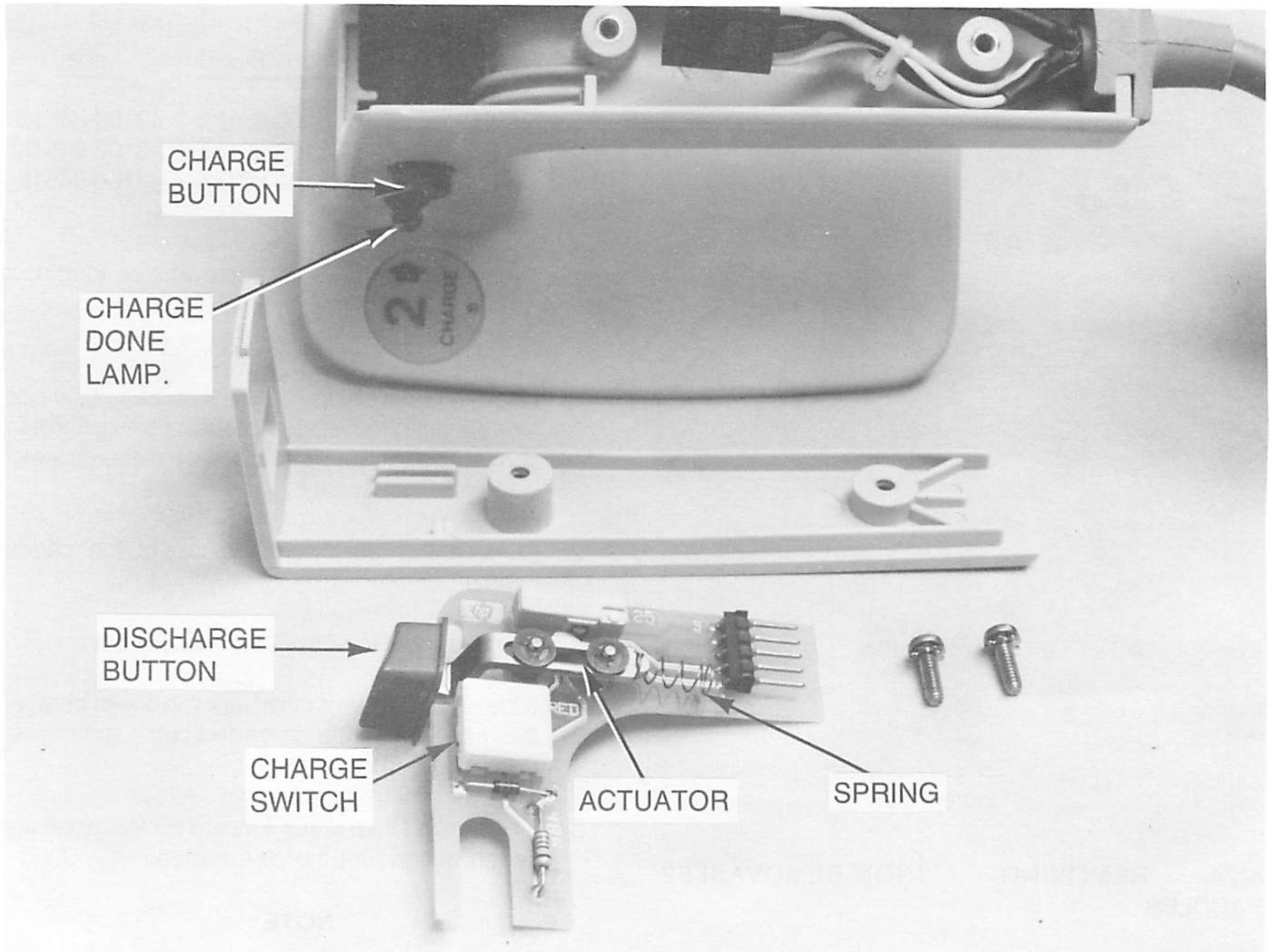


Figure 4-21.

10. Reconnect the wires to the circuit board.

11. Place the board in the grooves in the paddle and press it down. Use long-nose pliers to position the end of the spring over the small projection on the plastic piece behind the spring.

NOTE

If paddle is the APEX, route the LED wires away from H.V. lead to paddle.

12. Place the lower front edge of the cover in position at the front of the paddle handle. Rock the cover back so that the discharge button projects through the opening.

13. When everything is in place, install the screws and the label.

4-26. PADDLE SWITCH REPLACEMENT FOR PADDLE WITH CONTACT INDICATOR

1. Remove the label and the screws that secure the cover to the handle.

2. Place a finger under the DISCHARGE switch button and lift the cover straight up. Turn the cover on its side. Note that the circuit board is attached to the cover.

3. To remove the circuit board from the cover, first re move the spring from the actuator, using long-nosed pliers. Then remove the two screws that attach the circuit board to the cover.

4. Lift the backside of the circuit board and unplug the cable connector. Continue to lift the circuit board and slide it back until the discharge buttons is clear of the cover.

5. Hold the switch actuator when replacing the discharge button on the new circuit board. The short side of the button goes toward the side of the board the display is mounted on.

6. Reinstall the circuit board in the reverse order. Make sure the pin numbers on the cable connector and circuit board match.

7. Install the small end of the spring on the switch actuator. Slide the actuator forward. Using long-nosed pliers, place the aft end of the spring over the projection on the spring stop.

8. Before tightening the screws, completely actuate the discharge button and be certain it moves freely.

10. Turn the cover over and position the wires so they do not lie between the bosses in the handle and cover.

11. Beginning at the front, slide the cover assembly straight down. If the rear of the cover does not go all the way down, a wire may need re-positioning. Lift the rear of the cover and use a small screwdriver to move the wire.

12. When the cover fits flush full length, install and tighten the screws and install the label.

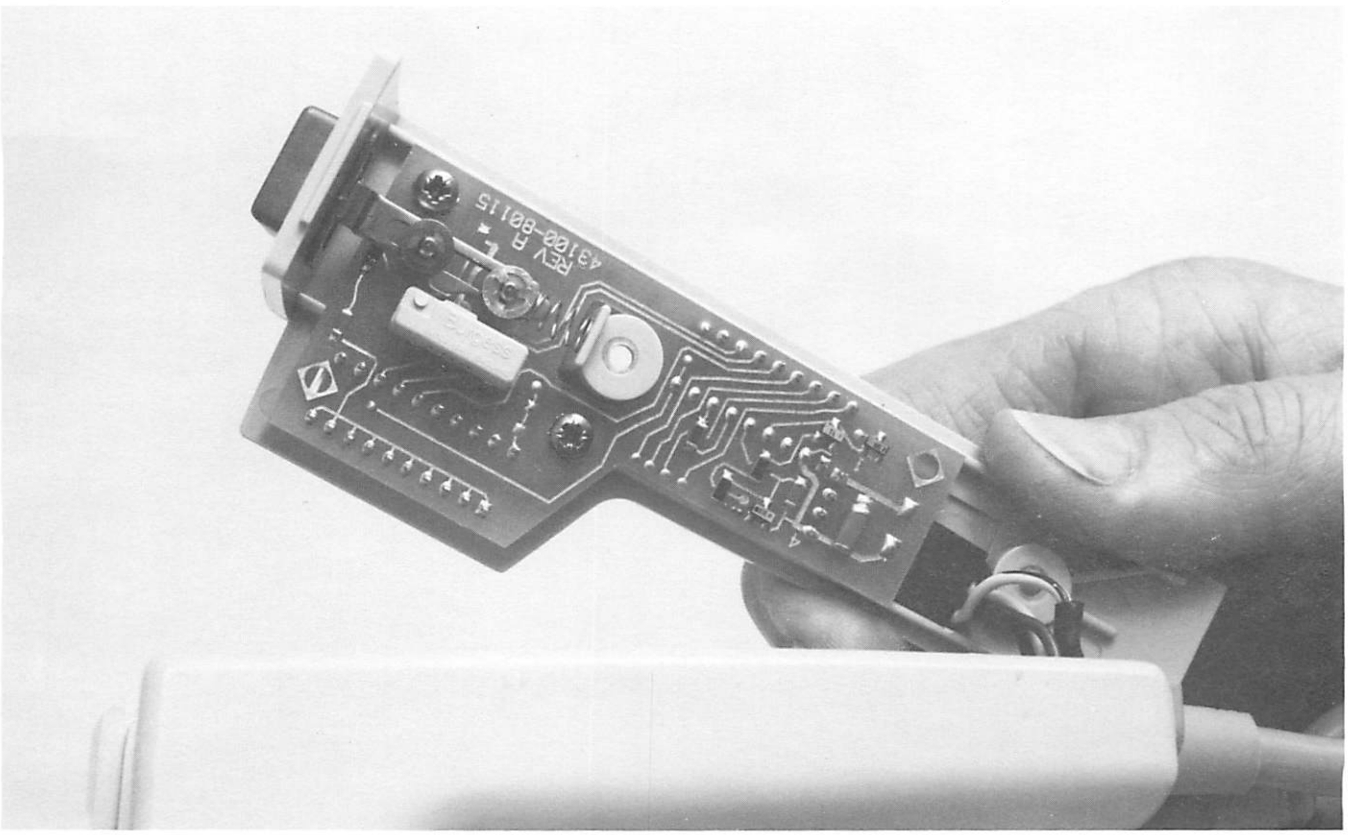


Figure 4-22.

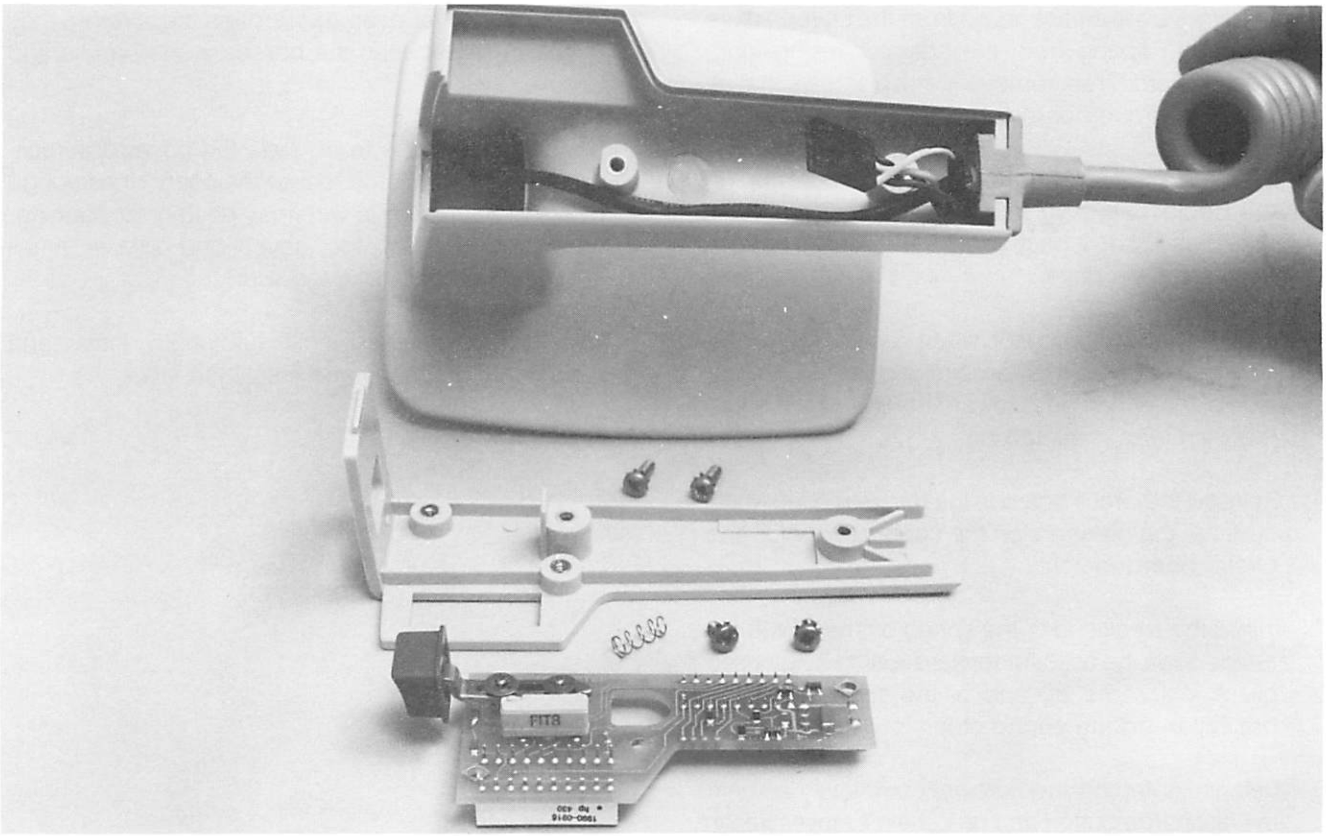


Figure 4-23.

Hint to locating trouble areas:

1. Almost all functions in these instruments are confined to two circuit areas, one of which is the control board.
2. Most problems in troubleshooting these instruments will be logical, i.e., if the recorder doesn't work the problem is likely on the recorder section of the control board or in the recorder itself.
3. However, in many cases signal lines pass through several boards. For example, the discharge switches pass through the lower case, the ECG board, the control board, and finally the battery charger board to the patient relay.
4. Therefore, although the failure rate is low on the control board, it does have a high opportunity for failure because of its complexity.
5. Remember all functions rely on proper power. Check voltages.

SYMPTOM	PAGE

ERROR MESSAGES

SYMPTOM	SUSPECT AREA	CHECKS
No CRT display or display is jittery and recorder print "ERROR 0"	CRT Processor dead	See display section
CRT displays or recorder prints "ERROR 1"	Control processor dead	See system section
CRT displays "ERROR 2"	Defib charging too slow	See defib section and See HV charger section
CRT displays "ERROR 3"	Defib cap arcing	See defib section and see HV charger section
CRT displays "ERROR 4"	Defib charged but shouldn't be	See defib section and See HV charger section
CRT displays "ERROR 5"	Defib overcharged	See defib section and see HV charger section
CRT displays "ERROR 6"	LV supply out of spec	See battery charger section
CRT displays "ERROR 7"	A/D won't respond	See system dead section
CRT displays "ERROR 8"	Recorder motor failure	See recorder section
CRT displays "ERROR 9"	Recorder	See recorder section
Recorder prints "ERROR 10" or "SET CLOCK"	Clock	Needs to be set (see checks and adjustments) or see real time clock section

SYSTEM DEAD

SYMPTOM	SUSPECT AREA	CHECKS
System Dead	Power	Check circuit breaker Check battery voltage
No low voltage	Energy switch A11	Check for continuity between J41 pin 10 and J41 pin 6, when energy switch in "Monitor On" position.
	Front panel switches	Check for continuity between J33 pin 16 and J33 pin 19 when energy switch in "Monitor On" position.
	Control PCA*A7	Check for continuity between J33 pin 16 and J22 pin 11.
	Battery charger PCA A4	See page 5-31
Unit does not turn on voltages OK. Audible relay click on turn on.	PLL clock A7 U68	Check U68 pin 4 for 12 MHz -1v to 6v signal Check U68 pin 14 for 1 MHz 0 to 5v sine wave.

* printed circuit assembly

SYSTEM DEAD

SYMPTOM	SUSPECT AREA	CHECKS
Continuous tone no CRT display.	Control processor U61	Check Vcc on U62 pins 34 and 68 for >4.3v. Check U61 pin 40 for 4.7 to 5.3v. Check U62 pin 20 for 4.9 to 5.1v. Check U62 pin 1 for 0 to 5v signal period of 4 ms and 30% duty cycle. Check U61 pin 9 for reset signal Check external address/ data bus pins U61-32 thru 39, U62 pins 9, 11 thru 16, 19, 20 and U63 pins 9, 11 thru 17 for activity. None should be stuck hi or low. Check ALE signal between processor and gate array U61 pin 30 and U62 pin 3. Should be 2 mHz square wave with 300 ns high pulse.
Unit turns on but no "READY" message and no power up tone	Control gate array U62	Check signal on C70 and U62 pin 2 during turn on. Should take several hundred-milliseconds to charge to Vcc.
Unit turns on, CRT display frozen with 'ERROR 0' may or may not have continuous tone	Control processor U61	Check "tickle" signal U62 pin 1, "reset" signal U61 pin 9.

DEFIBRILLATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Unit does not respond to Apex paddle charge switch	A7 U66-1,2 J30-33, J27-4	Check signal at J30-33, U66-1, and U66-2 while pressing and releasing charge switch.
	A7 R108	Check for connections to Vcc and J30-32
Unit does not respond to discharge switches	A7 U66 A7 CR65 (5.6V) A7 U61-3 A6 J27-6	Check J30-32 while pressing and releasing discharge switches
	Paddles	Check continuity between P3-3 and P3-5.
"NO PADDLES" message	Paddles	Check continuity between P3-8 and P3-9.
	A7 J30-31, J30-34 A7 U66-11 A7 U66-3 A7 U66-4,10, U61-4,5	Check for 4.2v. Check for 4.1v. Check for 4.3v. Check for 0v.
50J Interlock does not work with internal paddle set	A7 J30-31,34, U66-3,11 A7 U61-4, U61-5	Check for 0v. Check for >4v.
	Paddles	Check continuity between P3-7 and 8. Check for no continuity between P3-9 and all other pins.

DEFIBRILLATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
The defibrillator does not seem to charge. The CRT displays 0 joules, then in a few seconds displays Error 2 and aborts the charge.	A. The defibrillator is charging, but the Main Storage Capacitor voltage is not being recognized.	A. Listen for the high-pitched charging sound when charging is initiated. If it is heard, check A5TP4 and suspect A5U2D or a problem on the Vcap line to the A/D on the Control Board. Use caution in the high voltage area! area!
	B. Cables P21, P11, J10; power supplies; Fuse A5F1	B. 1. Check cables for proper connection 2. Check the voltage at P21 pin 7 (SW BAT) with respect to A5TP1 (GND). It should be greater than 10 volts. 3. Check the voltage at P21 pin 1 (V RAW) with respect to A5TP6 (GND RAW). It should be greater than 10 volts. 4. Check for fused V RAW voltage (on the right side of the fuse, looking at the component side of A5) with respect to A5TP6 (GND RAW). If it is less than V RAW, suspect Fuse F1. Remove the fuse and continue troubleshooting to find the cause of the failure. failure.

DEFIBRILLATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
	C. A5U1 is not receiving the correct input or delivering the correct output.	C. With fuse A5F1 removed, and during a charging attempt, ensure that: 1. A5U1 pin 10 is less than 700 millivolts. 2. A5U1 pin 7 has a sawtooth wave on it. 3. A5U1 pin 9 is above 1.5 volts. If not, and if CHG RATE CTRL is present, check A5TP2 and suspect A5U2C or A5 U2B circuit. 4. A5U1 pin 1 voltage is less than A5U1 pin 2 voltage. 5. A5U1 pin 4 is less than 200 millivolts. 6. A5U1 pin 3 is not stuck high. If it is, check A5TP3 and suspect A5U2A of A5Q2. 7. A5TP7 is toggling from about zero to >10 volts.

DEFIBRILLATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
	D. Power MOSFET A5Q1 or Transformer A5T1	D. With Fuse A5F1 removed, ensure that: 1. The resistance from A5TP9 to A5TP7 is >1megohm with A5TP9 the positvie ohmmeter lead. 2. The resistance from A5TP7 to A5TP8 is>400ohms with A5TP7 the positive ohmmeter lead. 3. The resistance from A5TP9 to A5TP8 is >1megohm with A5TP9 the positive ohmmeter lead. 4. The resistance from A5TP8 to A5TP9 is like a diode with A5TP8 the positive ohmmeter lead. Then with Fuse A5F1 in place, but when not attempting to charge, 1. Accurately measure the voltage from A5TP8 to A5TP6. If greater than 1 mV, suspect A5Q1. 2. Measure the voltage at A5TP9. If less than V RAW, suspect A5T1 (primary). Then with Fuse A5F1 in place, and during a charging attempt, verify that A5TP7 is toggling from about zero to greater than 10 volts. 1. If A5TP9 is not toggling, suspect A5Q1. 2. If A5TP9 is not toggling, suspect A5T1 (secondary).

DEFIBRILLATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Slow charging (greater than 10 seconds to 360 joules with fully charged battery; or charge aborted with Error 2 indication on the CRT).	A. J10 is disconnected.	A. Check J10 connection.
	B. Safety relay A5K1 not opening.	B. With the instrument turned on and all cables connected, verify that neither Error 4, nor 6, nor 7 is displayed on the CRT. Measure the voltage at A5TP4 and verify that it is less than 50 mV. Turn the instrument off and short the 2 terminals of the Main Storage Capacitor with an insulated-handle screwdriver; then connect an ohmmeter from A5C11 to A5R19 (neither connection at the junction of C11 and R19). Also connect a jumper from A5TP10 (A5CR1 anode) to A5TP1 (A5CR4 anode). Turn the instrument on. If the resistance indicates a short, suspect A5K1.
	C. A5CR9 or A5CR10 bad.	C. Disconnect P21, and measure the resistance across A5CR9. If a short is indicated, replace both A5CR9 and A5CR10.
	D. Charge rate control circuit problem.	D. During an attempt to charge, measure the voltage at TP2. If it is less than 1.5V, suspect A5U2C.

DEFIBRILLATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Charging begins, but then is aborted with Error 3 indication on the CRT.	A. Main Storage Capacitor arc	A. With the instrument turned on and all cables connected, verify that neither Error 4, nor 6, nor 7 is displayed on the CRT. Measure the voltage at A5TP4 with respect to A5TP1 and verify that it is less than 50 mV. Turn the instrument off and short the 2 terminals of the Main Storage Capacitor with an insulated-handle screwdriver; then connect an ohmmeter across the 2 terminals. If the resistance settles to less than 30K ohms, suspect the capacitor. Remove the ohmmeter.
	B. Main Storage Capacitor voltage measurement problem.	B. If it is verified that the capacitor is not shorted (see section A directly above), turn the instrument on and observe the voltage at A5U2 pin 12 during charge. After 800 mV is reached, if there is >10% change in voltage within 10 ms, suspect transformer A5T1. Otherwise measure the voltage at A5TP4. After 800 mV is reached, if there is >10% change in voltage within 10 ms, suspect A5U2D.

DEFIBRILLATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Error 4 displayed on the CRT.	A. Main Storage Capacitor voltage measurement problem.	A. Measure the voltage at A5U2 pin 12. If it is >50mV, go to section B directly below. Otherwise measure the voltage at A5TP4. If it is <50mV, suspect A5U2.
	B. Safety circuit problem.	B. After performing step A directly above, turn the instrument off to ensure that there is no safety relay drive. Wait at least 20 seconds. Then turn the instrument on. If the Error 4 indication does not reappear on the CRT within 10 seconds, perform the following steps: 1. Check the voltage at TP4 to verify that it is less than 50 mV; 2. Short the Main Storage Capacitor with an insulated-handle screwdriver; 3. Remove Fuse F1 for further troubleshooting; 4. Suspect the safety relay drive signal at TP10 and on the Battery Charger Board.

DEFIBRILLATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
		If the Error 4 indication does reappear on the CRT, perform the following steps: 1. Turn the instrument off. 2. With the paddles in pockets, quickly turn the instrument on, set the Energy Level to 360J, and depress the charge switch. 3. When the charge is done, depress the discharge buttons. 4. Verify that the Error 4 indication does not appear on the CRT. 5. Suspect A5K1 or A5R1.
I peak error	A6U104, A6U107, and associated components.	U104B, U107B, and other components form a peak hold circuit. Current that flows through the paddles during discharge is monitored by this circuit. U107B is an open collector output comparator and hence is only capable of ramping the output of U104B in a positive direction. R153 discharges the peak hold circuit whenever IPKRST P30-23 is held high IPKRST is held high except for an 80 msec period during discharge. U104-7 should normally be at zero volts. R150 performs the current to voltage conversion. Suspect U104 if pin 7 has a triangular ripple component during reset.

CRT DISPLAY PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Character dots jitter	Voltage reference A7 Vertical deflection A8	Check A7 U35-1 for waveform in if OK check A8 U2-5, 7 and U1-8, 14 for jitter on miniraster position of trace.
	Damping cap A7 C40	Check proper value of A7 C40 and Vref2 for stable 5V.
Display baseline no characters	Vertical deflection A7	Check A7 U35-1 for waveform if OK check U2-5, 7 and U1-8, 14.
	Deflection yoke	Check yoke resistance - approx 6 ohms vertical and approx 40 ohms horizontal.
	+8V supply Check Voltage reference A78	U35-8 for +8V. Check Vref2 for +5V.
Characters short	-4.5 volt supply	Check A8 P32-2, A7 U34-3 and A7 U35-4 for -4.5V.
	A7 Voltage reference	Check Vref2.
Display Blank	High voltage supply	Check A8 +38V and +100V test points. Check A7 U35-4 for -4.5V
	A7 U33 waveform shown in Fig CRT2.	Check A7 U33-15 for intensity
	A7 U31 from processor A7 U31-13,14. If either is stuck high or low suspect U31. If they are toggling suspect U33.	Check intensity control signal
	Intensity circuit, tube filament	Check test point 5 for waveform show in Fig. CRT2. Check for filament current by plugging instrument in and measuring 1.2V drop across R32.

CRT DISPLAY PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Too bright		See "Display blank"
Too dim		See "Display blank"
Intensity varies	High voltage supply	Check +38V and +100V on HV supply.
Asymetrical horizontal gain	A8 Q1-4,U1	Check base voltages on A8 Q1-4. If there is no signal suspect U1. Else suspect Q1 and Q4 for right side problems and Q2 and Q3 for left side problems.
Asymetrical vertical gain	A8 Q5-8, U1	Check base voltages on A8 Q-8. If there is no signal suspect U1. Else suspect Q5 and Q8 for upper half problems and Q6 and Q37 for bottom half problems.

CRT DISPLAY PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Vertical deflection shakes	A8 R25	Check test point 3. If not stable replace U2. If O.K. verify value of damping resistor R25.
No ECG	A7 U33 gate array A7 U31 If none, suspect processor U31.	Check solder connection of Check bus pins 32-39 for activity.
No ECG - letters ok	Gate array	U33 check all solder joints on gate array
	CRT processor	Check bus on U31 pin 32-39
Flat trace - no characters	+8 volt supply	Check U35 pin 8 for +8V Check U34 pin 13 for +8V
	Voltage reference	Check U ref 2 for +5V

CRT DISPLAY PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Characters short	+8 volt supply	See "Flat Trace"
	Voltage reference -4.5 volt supply	Check U34 pin 3 and U35 Pin 4 for -4.5V
Too bright or dim	Resistors R35 and R37	Check R37 and R35 for proper value and connection.
Display jumps	+5 volts	Check +5 volts for noise
	Horizontal sweep signal	Check V61 pin 8 for undistorted square wave.
No sync marker	Gate array	Check U33 pin 16 for sync pulse. Check R35 for proper value and connection

RECORDER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Recorder Problems		
Will not run	A7 U1-27, U3-10 A9 C2	1 kHz signal variable duty cycle present
	Motor	Interrupter on rear motor shaft turning freely
	Front panel switch	Signal not reaching U1, see control section
Erratic speed	A7 U3-2 A9-R3	3.974 kHz signal 50% duty cycle present
Runs for short period then shuts off (doesn't detect paper)	No Paper A7 Q5 A7 U3-5 A9 R1,R2 Optodetector U3-5, U3-6, Q5	Replace paper roll On every 32 ms for 4 ms Change when Q5 turns on Current when Q5 turns on Clean lens
No Automatic runs on charge and discharge or only prints Test	Paddles in pockets detect switch	Check for continuity at J40 with paddles in pockets and open when out.
Printing light or missing top or bottom half	Adjust printhead	
No printing	A7 U3-4 A9 P32-8	Alternating high-low signal every 250-1000 uSec
Light Printing	Printhead	Needs cleaning
	Battery low	Check voltage in service mode
	Improper paper	Use p/n 40453A
	Door	Door not closing completely

RECORDER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
False 'No Paper' message paper of spec	Paper rotating on spindle	Paper core inner dia too large (improper paper)
	A7 R15; A9 P32-2	4 ms low pulse every 32 ms
	A7 U3-5	Signal active every 32 ms
No paper shut off	A7 U3-5 A9 R1,R2	Signal level remains constant when Q5 turns on
Wrong language	A7 S61	Switch setting wrong

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ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
LEADS OFF circuit not working properly. (failure to detect leads off or detecting leads off when the leads are shorted together).	(1) Faulty patient electrode cable. Relay K1 Multiplexers U1, U2 Optoisolators U108, U109	Short out R159 (this ties floating and earth grounds together and allows single ended measurements in the floating section). Measure for continuity from RL(grn) to U3-5 approx 21k ohms LA(blk) to U4-1 approx 121k ohms RA(wht) to U3-3 approx 21k ohms Switch back and forth from leads and paddles, relay K1 should have an audible click. Optoisolators U108 and U109 transmit the ECG source selected with the front panel switch. They can be read as a two bit code at U109-5, U108-5 where 00 selects paddles; 01 selects lead I; 10 selects II, and 11 selects lead III.

ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
	(2) Opamps U3, U4, U6	During LEADS OFF U6-7 should be high (6v). If the leads are on (shorted) U6-7 should be low (-6v). During LEADS OFF (all leads open-circuited by removing patient cable from instrument) the following levels should be present. U3-1 = -3v, U3-7 = -3v, U4-1 = 5v U4-7 = -3v, U6-1 = -3v, U6-7 = 5v When the leads are shorted together, the following levels should be present U3-1 = 0v, U3-7 = 0v, U4-1 = 0v, U4-7 = 0v, U6-1 = 0v, U6-7 = -6v.
	(3) Modulator, transformer, demodulator, U5, T1 U101	If the floating circuitry is detecting LEADS OFF, i.e. U6-7 = 6v, then the voltage across C107 should be approximately -1.6v. Otherwise it should be less than +/− .25v.

ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
	(4) U102, Q103, Q105	During LEADS OFF, U102-8 should be saturated low (-4.4) and U102-1 high (7v) Otherwise U102-1 should be less than +/− 25 mV. During LEADS OFF, Q105 should be on, its collector near ground. This informs processor U61 (A7) that the leads are off. Otherwise Q105 should be off.
ECG baseline offset from center of CRT screen. (greater than .25 inch)	(5) Floating section circuitry. Multiplexer U101	Short across pins 1 and 2 of U101. If offset goes away then problem is with floating circuitry, refer to suspect areas (2) and (3). If U101-14 does not go to zero volts, suspect U101.
	(6) Opamp U102 FET Q103 Leakage in C103	Select Paddles or otherwise insure that a leads off condition is not present. Measure DC voltage at U102-1, should be less then +/− 25 mV.
	(7) Opamp U104 Multiplexer U103	Measure DC voltage level at P30-17 ANALOG ECG, should be less than +/−1-200 mV. If it is, suspect control board's (A7) analog circuitry and/or connector.

ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
GAIN ERROR (gain too low, too high, or less than 8 discrete steps)	ECG board	Apply a 1 mVp-p 5 Hz sine wave input to the leads using a 1000:1 100k:100 ohm divider. Adjust gain to maximum by pushing up arrow at least seven times. Measure the 5 Hz output at P30-17. It should be 4 Vp-p +/−10%. Otherwise suspect ECG board.
	(8) 1st differential gain stage consisting of U3, U6, and associated passive components.	The inputs to this stage are U3-3 and U3-5. The output is across C5. The theoretical gain is 37.
		Increase input amplitude to 10 mVp-p (to allow easier measurements).
		This stage is primarily responsible for the .5 Hz low frequency cutoff.
		If loss of gain is suspected in the input protection or lead selector circuitry, apply inputs directly to U3
	(9) Modulator/demodulator	Measure input across C5. Measure output across C107. The theoretical gain is 1.

ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
	(10) Gain stage consisting of U102C and associated passive components	Measure input across C107. Measure output at U102-8. The theoretical gain is 4.2 This stage is primarily responsible for setting the 40 Hz upper cutoff frequency. It has a three pole rolloff characteristic
	(11) Gain stage consisting of U102A, U102B, Q103, and associated passive components.	Measure input at U102-8. Measure output at U102-1. The theoretical gain is adjustable between 3.5 and 4.2 using R163 The low frequency cutoff for this stage is normally .1 Hz. If Q103 is on (logic low at the gate) the cutoff shifts to 4.6 Hz for quick baseline restore. The maximum DC input (from U102-8) that this stage can reject is +1.8 or -1.1 volt

ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
	(12) Gain stage consisting of U104A, U103, and associated passive components	Measure input at U102-1 Measure output at U104-1 The theoretical gains are: .5,.8,1.3,2,2.6,4,6,and 8
		The gains are selected by the logic levels present at U103-9, 10, 11. A 000 corresponds to a gain of .5 111 corresponds to a gain of 8 (total gain of 4000)
	(13) Gain stage consisting of U102D and associated passive components.	Measure input at U102-1. Measure output at U102-14. The theoretical gain is 2.
		The ECG gain pot R163 is adjusted by monitoring the output of this stage and setting total gain to 1000
50/60 Hz noise on the CRT, recorder, and/or ECG out jack.	(14) Electrically or magnetically noisy environment.	Isolate from noise sources, large motors, etc. Check for faulty 3rd wire grounds Shield where possible
	(15) High electrode impedance.	Faulty electrode patches Poor quality electrodes Old or dried out electrodes
	(16) Imbalance in paddles input impedance.	With power on Select Paddles mode input Measure resistance from Apex paddle to U3-5, should be approximately 205k ohms. Also measure from Sternum paddle to U3-3, should be approximately 205k ohms.

ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
	(17) Imbalance in leads input impedance.	Refer to measurement technique in (1)
Noisy ECG trace on CRT, recorder, and/or ECG out jack. NOT 50/60 HZ.	(18) Floating section circuitry.	Remove ECG shield Short across C5, if noise does not go away problem is in grounded circuitry. Then- short out successive gain stages until noise source is isolated. If noise does go away problem is in floating circuitry.
	(19) U3 U4 R41-46	Replace these parts if noisy in paddles mode but not in leads. However, could also be current noise in opamps. Try putting 185k ohms in series with leads as per paddles.
	Input protection components R1-7, CR1-6, C15-17	
		Short U3-3 to U3-5. Short out at appropriate pins of select multiplexers U1 and U2 Check for noisy supplies: -6v, -2.4v, 1.8v, 6v

ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
No ECG from Paddles, ECG from leads is OK	(20) Paddle set, wiring, relay K2	Check connectors J6 and J7 (three terminal quick dis connects located beside the high voltage capacitor) K2 is normally closed (only opens during defibrillator discharge) Measure continuity from Apex paddle to junction of R41 and R48, should be zero ohms. Also from Sternum to junction of R42 and R48 Turn power on. Short from the collector of Q104 to ground. This should open both contacts of K2
	(21) Relay K1 and associated drive components.	Switch back and forth from leads to paddles. Relay K1 should audibly click. Relay K1 is a latching type. Q1 and Q2 with associated parts apply appropriate pulses to K1 to set or reset the relay.
No ECG from LEADS, paddles ECG is OK.	(22) Relay K1, patient electrode cable, internal wiring.	Check K1 as per (21) Check connector J26 mating Measure continuity from patient connections (RL,LA, and RA) to input source select multiplexers U1 and U2, or all the way to U3 pins 3 and 5 and U4-1 with power on and appropriate source selected, i.e. LEAD II.

ECG PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Less the 40 Hz of bandwidth.	ECG board	Apply a 1 mV input using a 1000:1 divider. Measure high frequency cutoff at ECG out jack. Should be greater then 40 Hz. If so, suspect CRT deflection (A8)
	(23) Gain stage consisting of U102C and passive components.	This stage should be the primary stage setting the high frequency cutoff. It has a three pole rolloff characteristic. Test as per gain test (10) except vary the input wave frequency
	(24) Any other gain stage.	Test as per gain tests (8) thru (13) except vary the input wave frequency
Less than .5 Hz bandwidth (low frequency -3 db cutoff is above .5 hZ).	(25) 1st differential gain stage consisting of U3, U6, and passive components.	In an instrument that is working normally this stage is the primary factor affecting low frequency cutoff (however you cannot ignore the stage tested in (26) and it is even more likely to be at fault) Apply a 10 mV sine wave input to the leads, same method as used in (8), and measure frequency response across C5. particularly suspect C3,U6,R18,R20,R21
	(26) Gain stage consisting of U102A, U102B, Q103 and associated passive components.	This stage normally has a low frequency cutoff of .1 Hz. When Q103 is on the low frequency cutoff is 4.6 Hz. Q103 is on when the gate is near zero volts. Especially suspect Q103,U102A,B,C103

PATIENT CONTACT INDICATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
PCI not working. (Paddle Contact Indicator)		PCI is turned off to save power when the instrument senses paddles in pockets. With a 50 ohm load across the two paddles the highest green LED should be on. Roughly one LED should turn off for each 10 ohm increase impedance. The lowest red LED should flash when resistance exceeds approximately 300 ohms.
	ECG board.	Measure a 25 mV 31250 Hz square wave across R126. If not, suspect PCI clock from control board (A7). Measure the signal at the cathode of CR109. It should be greater than 6v with pulses to zero volts every 4 msec. If this signal is present but highest green LED is not on, suspect wiring, connector J27, and/or the paddle set.

PATIENT CONTACT INDICATOR PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
	(27) Paddle set, wiring,	Short across C128. If the LED bar lights all segments suspect these problems and test as per (20)
	(28) U105, U107, and passive components.	Short paddles through a 50 ohm load. Measure approximately 7vp-p 31250 Hz sine wave centered about 2.2v at U105-8. Measure approximately .4vp-p 31250 Hz distorted sine wave centered about -.5v at U105-14. Measure DC level at cathode of CR101 which corresponds to the AC peak of the sine wave at U105-8. (U105 is an open collector output and forms a peak hold circuit). Observe the 1.5 Hz square wave at P30-11 that causes the lowest LED to flash at high patient impedances. If there is no 1.5 Hz clock, suspect control board (A7). P30-13 gives a 16 usec pulse from an open drain output on the gate array U62 (A7) which occurs every 4.2 msec. It is used to shape the PCI wave out to the paddles. This shaping modulates the intensity of each segment so that the highest ones will be brightest.

REAL TIME CLOCK PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Real Time Clock Problems		
Time is 1 Jan 85 0000 after being set	A7 U4-2	Low pulse every 64 uSec in time set mode
	A7 U4-16	2.2V with defib off
	A7 VR7	2.5V
Time doesn't advance	A7 U4	32 kHz

SERVICE MODE PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Will not enter Service mode.	Control board (A7)	
	SYNC switch (Matrix Column O and Row Z)	Check for switch continuity on Front Panel (A10) and Energy Switch Panel (A11)
No service ramp-step waveform on CRT or recorder	Main processor U61 on Control board (A7)	
Ramp waveform is non-linear	Deflection board (A8)	

BATTERY CHARGER TROUBLESHOOTING

WARNING: HIGH CURRENT A.C. LINE VOLTAGE AND UP TO 300 V.D.C. ARE EXPOSED WHEN THE BATTERY CHARGER IS CONNECTED TO A.C. POWER, WITH POTENTIAL LETHAL SHOCK HAZARD!
FOR EXAMPLE, THE PRIMARY (A.C.CIRCUITS) GROUND IS SUCH A SHOCK HAZARD WITH RESPECT TO SAFETY/SECONDARY CIRCUITS GROUND.

SEVERAL OF THE COMPONENTS, ESPECIALLY THE HEAT SINKS AND POWER RESISTORS, MAY BE HOT ENOUGH TO CAUSE BURNS IF TOUCHED, EVEN FOR A WHILE AFTER POWER IS OFF!

CAUTION: SINCE THE PRIMARY (A.C.CIRCUITS) GROUND IS AT HIGH VOLTAGE AND CURRENT WITH RESPECT TO GROUND, IT MUST NEVER BE CONNECTED TO ANY INSTRUMENT OR A.C. SAFETY GROUND WHEN CONNECTED TO A.C. POWER! IF GROUNDED, SUCH A CONNECTION WILL CAUSE SERIOUS DAMAGE TO THE BATTERY CHARGER CIRCUITS OR IF NOT, YOU MAY EXPOSE INSTRUMENT FRAMES TO LETHAL VOLTAGES. ANY CONTACT BETWEEN PRIMARY (A.C.CIRCUITS) AND SECONDARY (BATTERY/POWER SUPPLIES) GROUNDS WILL CAUSE SERIOUS DAMAGE TO COMPONENTS AND/OR CIRCUIT BOARD TRACES!

WHEN MAKING ACTIVATED PRIMARY CIRCUIT MEASUREMENTS OTHER THAN WITH RESPECT TO SAFETY GROUND EITHER USE A DIGITAL MULTIMETER WITH FULL FLOATING, 1000 VOLT RATED INPUT, OR A DUAL PROBE OSCILLOSCOPE OPERATED IN A DIFFERENTIAL INPUT MODE!

ANY CONNECTION WHICH CAUSES POWER FET Q1 TO CONDUCT WITHOUT OPERATION OF U1 DUTY CYCLE OR CURRENT LIMIT PROTECT CIRCUITRY WILL CAUSE Q1 TO SHORT, POSSIBLY DAMAGING R2, Q2, CR8, CR50 AND PERHAPS OTHER COMPONENTS.

SERVICE TIPS: MANY COMPONENT CHECKS CAN BE PERFORMED WITH A DIGITAL MULTIMETER, WITH A.C. POWER AND BATTERY UNPLUGGED. OBSERVING THESE PRECAUTIONS ARE NECESSARY TO OBTAIN VALID READINGS AND THEY WILL MINIMIZE THE POSSIBILITY OF ELECTRIC SHOCK OR DAMAGE TO BOARD CIRCUITRY.

MOST DIODES WILL TEST A NOMINAL 0.6 V ON A DMM 2K OHMS SCALE,WHICH INJECTS 1 mA. CR37, A SCHOTTKY, WILL BE NOTICEABLY LOWER. PN JUNCTIONS IN BIPOLAR TRANSISTORS SUCH AS Q2 CAN BE TESTED IN THE SAME WAY. U3 LED TESTS ABOUT 1.0V.

CHECK HIGH CAPACITY ELECTROLYTICS FOR CHARGE ACCEPT ON HI OHMS SCALE, OBSERVING CHARGE TIME SIMILARITY.

BATTERY/BATTERY CHARGER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Battery Charging LED is off, battery runs down, unit operating	A.C. Power source	Check A.C. outlet voltage; is plug fully Inserted?
	A.C. power switch (Model 43120 only)	Check switch on back of the defibrillator: "0" not shown, green light illuminated?
	Circuit Breakers CB2, CB3	Reset breakers(s) & check (some shorts may blow the breaker heater open circuit, see A.C. on check below.)
Battery Charging LED is off, unit will not operate	Battery	Remove battery cover, check for tight connector fit. If problem persists, take out battery, use DMM to check both red wire volts to black wire: If either reads zero or intermittent, replace battery & recheck.

AT THIS POINT, FURTHER CHECKS REQUIRE DISCONNECTING A.C. POWER, OPENING DEFIBRILLATOR CASE, UNPLUGGING BATTERY CONNECTOR AND REMOVING TOP EMI SHIELD FROM BATTERY CHARGER PCB.

BATTERY/BATTERY CHARGER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Battery Charging LED is off, system O.K., battery charges	Charge LED Circuit	Check continuity of Circuit from Q3 collector through to LED on front panel.
Battery charging LED is off, battery runs down	Fuseable R2	If open circuit, also use DMM on 2K scale to check CR1, CR4, 5 & 6: replace if short or open circuit. Check across CR8: Replace CR8 CR50, Q1, and Q2 if shorted. Also test R9, CR 3, 8, 9 & 10 replace if short or open.
		Replace R2, connect battery & A.C. POWER, checking charge LED & battery voltage (14.2 V if battery is charged, lower if battery charge state is lower, but higher than if AC power is disconnected. Is the battery charger LED on now?
	Secondary circuits	Check CR26,CR28, CR29, CR30, CR56, CR57, Q3, Q7, and U3 with DMM.

BATTERY/BATTERY CHARGER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
THE FOLLOWING TESTS REQUIRE CONNECTING THE BATTERY: THIS CAN DESTROY COMPONENTS AND BOARD TRACES IF SHORTED!		
Battery Charging LED flashes every 1-3 sec.	U4	If VBAT > 14.5 V with AC connected and monitor off, replace U4.
Unit does not work, when switched "ON", battery charged	U5 circuit	Check for >12 VDC at TP 11 from the battery through breaker CB1. U5: pin 6 goes from >10 TO O VDC & pin 1 from >10 to 2.5 VDC; switch OFF to ON, or defective U5 or related circuit component. Q4: Collector from 0 to >10 VDC or replace Q4 or CR35. K1: Replace if coil does not close contacts

BATTERY/BATTERY CHARGER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Unit does not work or very abnormal, battery charged	Regulated voltage +5V low: < +4.7 VDC	If regulated -4.4 VDC +5 VDC <4.7 VDC, unplug J22, Jumper U5, pin 6, to SEC. GND & CHECK +5V. If O.K., reconnect J22, unplug each printed circuit board to locate shorting load (gate array, capacitor, Diode,etc.) If +5V low with unplugged J22 & jumper (Note: -4.4 V will be very low without load on +5V) check U7 circuit, including CR37-40, 43, C31, 33, 34, OR L6. Note the NO LOAD (J22 OFF) & monitor load waveforms in Figs. 3A & 3B. If signs of overheating in U7, etc., Check voltages carefully with reconnected load after repair for possible cause on other printed circuit board!
	Regulated -4.4V abnormal	Check with monitor on or or 10 ohm, 5 watt load on +5 V. If U8, pin 3 is >-7 VDC check C33-35, CR38-40. If U8, pin 3 is >-7 VDC and U8 output is abnormal, either U8 is bad or abnormal load conditions will be found on another board.
	Regulated +8V abnormal	Check U9, CR44, C37 or find problem on another board.

BATTERY/BATTERY CHARGER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
Unit does not turn off when battery is below 11 VDC.	U5/Q4/K1 circuit	Run above checks, replacing U5 if bad, Q4 if shorted, or K1 if stuck. Also replace battery if it was discharged below 11 VDC: low capacity!
Patient or Safety relay not operating	U6 circuit	Check drives to pin 6 or pin 3: If absent, trace back to point-of-origin.
If pin 7 does not GO LO, pin 6 Hi, Replace U6. Otherwise trace to relay.		Safety Relay
		Patient Relay: Check for >10 VDC @ J24, pin 1, when both paddle discharge switches closed--possible paddle circuit problem. Check U6, pin 2 LO, pin 3 HI, momentary, or replace U6. Otherwise CR36 or trace to relay.

BATTERY/BATTERY CHARGER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS

THE FOLLOWING TESTS REQUIRE CIRCUIT TESTS WITH A.C. POWER ON AND BATTERY: OBSERVE CAUTIONS NOTED PREVIOUSLY!

SYMPTOMS	COMPONENT	CHECKS
Still no charging LED and no increase in battery voltage with A.C. power	A.C. Rectifier/Filter	Use DMM, check for 300 VDC nom. @ TP5 with respect to primary ground @ TP3: much less, trace A.C. volts thru circuit breakers to P19, thru L1, R2, CR1. If fault is located, unplug A.C. and recheck fault area with DMM OHMS, and replace component or repair PCB trace as required. Replace repaired board & test again with A.C. power.

BATTERY/BATTERY CHARGER PROBLEMS

SYMPTOM	SUSPECT AREA	CHECKS
300 VDC @ TP5 O.K. but no charge	start circuit Q5, Q6	110 VAC passes through CR51, R63, and CR52 with normal operation, charging C41 in about 3 seconds to +30 VDC. then Q5, with trigger set at +30 VDC by CR49, discharges through Q6 to charge C44 to about 11 V, starting U1 and Q1 circuits. Check these circuits and voltages until fault is located.
		Observe cautions noted above, use two oscilloscope probes in differential mode for the start mode tests:
	Q3 circuit	Normal charging, voltage on CR24 is >12 VDC.
	U4 circuit	Normal charging, U4, pin 8, is 2.5 VDC, pin 1 is between 3 & 4 VDC.
	U3 Circuit	Normal charging, 1.0 VDC, pin 1 to pin 2; 3 to 4 VDC, pin 5 to pin 4.
CR4,5,6 burned and/or shorted	C7, R68, CR58 CKT.	Replace as per DMM tests.