NELLCOR

N-200
Pulse Oximeter

Operator's Manual
1988

NEL-15

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QUICK GUIDE TO OPERATION

Basic Operation

1. If desired, plug one end of the power cord to the *NELLCOR*® N-200 pulse oximeter. Plug the other end into a properly grounded 100 to 120 volt AC outlet marked "Hospital Only" or "Hospital Grade" (see page 7). Alternatively, operate on internal battery for up to two hours.

2. Align the red dot on the connector at the end of the patient module with the red dot on the CONNECTION socket of the monitor, and push the connector straight in until it locks (see page 7). Do NOT twist.

3. If *C-LOCK*™ ECG synchronization is to be used, connect an appropriate ECG signal (see page 7).

4. Select an appropriate *NELLCOR* sensor and apply it to the patient, following the instructions in the sensor directions for use. Plug the sensor into the patient module (see pages 7 and 24).

5. Press the ON/STDBY switch to the ON position (see page 7).

6. Check the alarm limits. If necessary, adjust them to suit the needs of the patient (see page 8).

For a quick guide to using the special features of the N-200, refer to the next page.

Warning: This "Quick Guide to Operation" is intended only as a checklist for operating the *NELLCOR* N-200 pulse oximeter. Carefully read this operator's manual before attempting clinical use of the instrument.

Warning: Carefully read the directions for use provided with each *NELLCOR* sensor for complete description, instructions, warnings, cautions, and specifications.

QUICK GUIDE TO OPERATION

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Use of Special Features

Pulse Tone	Operator's Actions	Display
adjust volume of "beep" (see page 9)	turn control knob	none
Alarm Functions		
check alarm limits (see page 8)	press appropriate alarm button (HIGH SAT, LOW SAT, HIGH RATE, or LOW RATE)	current setting appears
adjust alarm limits (see page 8)	press appropriate alarm button (HIGH SAT, LOW SAT, HIGH RATE, or LOW RATE), and turn control knob until the new setting appears	new setting appears
adjust audio alarm volume (see page 10)	press LOW SAT and HIGH SAT buttons, and turn control knob until desired setting appears (10-100)	new setting appears
temporarily silence audio alarm (see page 10)	press AUDIO ALARM OFF button	AUDIO ALARM OFF indicator lights steadily
adjust period during which the audio alarm is temporarily silenced (see page 10)	press AUDIO ALARM OFF button, and turn control knob until desired setting appears (30-120 seconds)	new setting appears
disable audio alarm (see page 11)	press AUDIO ALARM OFF button, and turn control knob until "OFF" appears	"OFF" appears; AUDIO ALARM OFF indicator flashes
Operating Mode		
set operating mode (see page 14)	press HIGH RATE and LOW RATE buttons, and turn control knob	number of new mode appears
Memory Functions		
set clock (see page 15)	press LOW SAT and HIGH RATE buttons (flashing number is current year setting), and turn control knob to change setting (repeat sequentially to set month, day, hour, and minute)	last two digits of year appear (or month, day, hour, or minute)

Memory Functions (cont'd)	Operator's Actions	Display
print trend memory on ThinkJet or strip-chart recorder (see pages 15 and 16)	press TREND button (to pause when data are being printed by a strip-chart recorder, press TREND button again)	none
print entire event memory on ThinkJet printer (see page 18)	press EVENT button	none
print entire event memory on strip-chart recorder (see page 18)	press EVENT button (to pause, press EVENT button again)	none
set event limits that differ from alarm limits (see page 22)	press applicable alarm limit button and the EVENT button, and turn control knob until desired setting appears (to again make event limits equal alarm limits, press buttons and turn control knob until "= AL" appears)	new setting appears
initiate user-defined event (see page 21)	press HIGH RATE and AUDIO ALARM OFF buttons ("UdE 0" appears), and turn control knob until desired duration appears (1-60 minutes); release buttons to start the event	"UdE n" appears, where "n" represents duration in minutes
change duration of ongoing user-defined event (see page 21)	press HIGH RATE and AUDIO ALARM OFF buttons ("UdE n" appears, where "n" represents the number of minutes remaining); turn control knob until desired duration appears	"UdE n" appears, where "n" represents duration in minutes
end user-defined event prematurely (see page 21)	press HIGH RATE and AUDIO ALARM OFF buttons, and turn control knob until "UdE OFF" appears	"UdE OFF" appears
determine number of events in memory (see page 19)	press LOW SAT and LOW RATE buttons	"no E" appears if there are no events; "nnn E" indicates the number of events

Memory Functions (cont'd)	Operator's Actions	Display
print specific event on ThinkJet printer (see page 19)	press LOW SAT and LOW RATE buttons, and turn control knob until appropriate event identifier appears; **or** press EVENT button for at least 3 seconds, and turn control knob until appropriate event identifier appears	event identifier appears (i.e., "L" to designate an alarm-limit event or "E" to designate a user-defined event, as well as the hour and minute that the event started)
cancel trend and event output (see page 22)	simultaneously press TREND and EVENT buttons ("End Prt" appears), and turn control knob to the right until "Prt End" flashes; then release the buttons, at which time "Prt End" lights steadily and the output is canceled (to avoid canceling output, turn control knob to left until "Prt" appears)	"Prt End" stops flashing and lights steadily
erase trend and event memories (see page 22)	press HIGH SAT and HIGH RATE buttons ("CLr t E" appears), and turn control knob until "ALL clr" appears (to preserve the data after starting, before releasing buttons, turn control knob back until "not clr" appears)	"ALL clr" appears
determine whether trend and event memories are disabled (see page 22)	press HIGH SAT, HIGH RATE, and AUDIO ALARM OFF buttons	"t E diS" appears if memories are disabled; "t E On" appears if memories are enabled
disable trend and event memories (see page 22)	press HIGH SAT, HIGH RATE, and AUDIO ALARM OFF buttons, and turn control knob until "t E diS" appears (to reactivate, press buttons and turn control knob until "t E On" appears	"t E diS" appears
Software Version Codes		
determine monitor software version code (see page 42)	press HIGH SAT and AUDIO ALARM OFF buttons, and turn control knob until "0" appears in OXYGEN SATURATION display	version code appears in PULSE RATE display
determine powerbase software version code (see page 42)	press HIGH SAT and AUDIO ALARM OFF buttons, and turn control knob to the left until "Pb" appears in OXYGEN SATURATION display	version code appears in PULSE RATE display

I. INTRODUCING THE *NELLCOR* N-200 PULSE OXIMETER

The *NELLCOR®* N-200 pulse oximeter accurately, non-invasively, and continuously measures functional oxygen saturation of arterial hemoglobin and pulse rate.

Measurements are displayed both visibly and audibly. Oxygen saturation and pulse rate measurements are displayed digitally and are updated with each pulse beat. Pulse amplitude is displayed qualitatively. Additionally, the tone that signals each pulse beat varies in pitch to reflect changes in saturation, rising as saturation increases and falling when it decreases. This patented early warning system allows the operator to monitor saturation changes while watching the patient, notifying the operator of changes in the patient's status and allowing early initiation of corrective actions. If either the oxygen saturation level or pulse rate falls outside adjustable upper or lower limits, both visible and audible alarms activate.

Because measurements are made from the pulsatile arteriolar component of blood, the instrument's accuracy is not affected by tissue or bone. The N-200 does not provide a measurement unless perfusion is sufficient to supply the data necessary for accuracy.

NELLCOR sensors, which are available in various sizes and configurations, allow the instrument to be used on patients ranging from neonates to adults in a variety of clinical settings. These sensors are lightweight and completely non-invasive, with no heat source that could burn a patient.

A number of patient-safety and performance-enhancing features are incorporated into the N-200:

- *C-LOCK™* ECG synchronization enhances performance in motion environments such as the ICU, and in patients with poor peripheral perfusion.
- Three operating modes provide different averaging times, adapting the N-200 for use in various clinical settings. In all three operating modes, the N-200 updates the measurements with every pulse beat.
- The N-200 is equipped with two sets of default alarm limits, one for use in monitoring adults and one for neonates.
- Non-invasive *NELLCOR* sensors obtain measurements by optical means alone, using two light emitting diodes as light sources. Specific sensors are available for use on neonates, infants, children, and adults.
- The N-200 provides patented automatic calibration mechanisms. The instrument automatically calibrates itself each time it is turned on, at periodic intervals thereafter, and whenever a new sensor is connected. The instrument's sensitivity changes automatically to accommodate a wide range of tissue thicknesses and skin pigmentations.
- Saturation, pulse rate, and pulse waveform data are available in both analog and digital formats for output to other devices. When the ECG signal is provided through the patient module connector, an analog output of the ECG signal is available.

- Twelve hours of oxygen saturation and pulse rate data may be stored in the trend memory; one hour of saturation, pulse rate, and pulse perfusion data may be stored in the event memory. These data may be provided to a variety of analog and digital output devices.

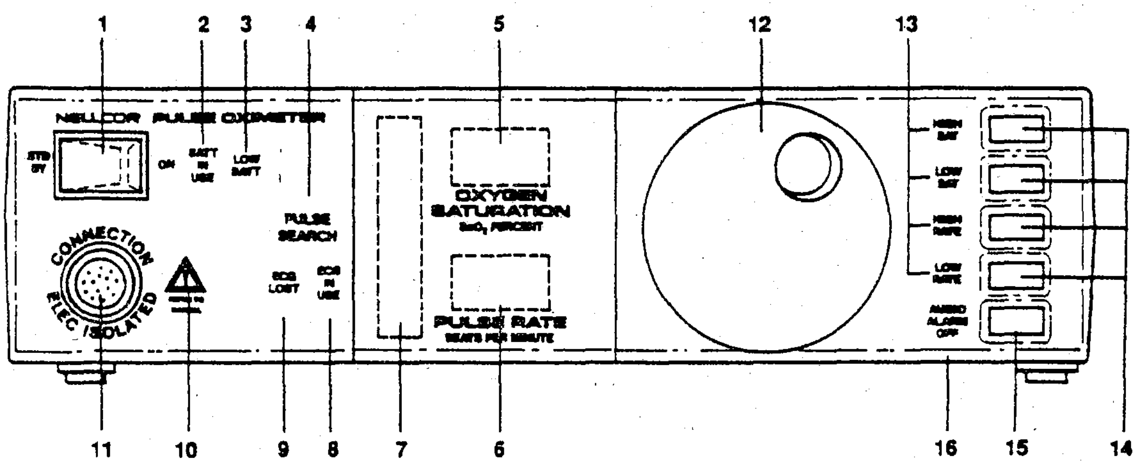
- The N-200 is completely portable and can operate for up to two hours on its internal battery, even when the monitor is detached from the powerbase.

II. OPERATING THE N-200

Controls, Displays, and Connectors

The *NELLCOR* N-200 pulse oximeter consists of three primary components: the monitor (with the front-panel controls and displays), the detachable powerbase (with the rear-panel controls and connectors), and the patient module (which has connectors for the sensor and the ECG cable).

Front Panel (Monitor)



1. ON/STDBY switch
2. BATT IN USE indicator
3. LOW BATT indicator
4. PULSE SEARCH indicator
5. OXYGEN SATURATION display
6. PULSE RATE display
7. Pulse amplitude indicator
8. ECG IN USE indicator
9. ECG LOST indicator
10. Caution symbol
11. CONNECTION socket
12. Control knob
13. HIGH SAT, LOW SAT, HIGH RATE, LOW RATE indicators
14. HIGH SAT, LOW SAT, HIGH RATE, LOW RATE buttons
15. AUDIO ALARM OFF button
16. AUDIO ALARM OFF indicator

1. **ON/STDBY switch:** turns the instrument on and off

2. **BATT IN USE indicator:** yellow indicator that lights when the instrument is operating on its internal battery

3. **LOW BATT indicator:** red indicator that flashes when five or fewer minutes of battery power remain

4. **PULSE SEARCH indicator:** red indicator that flashes when the N-200 is attempting to locate the patient's pulse

5. **OXYGEN SATURATION display:** digital display that shows arterial hemoglobin oxygen saturation as a percentage of functional hemoglobin; when the HIGH SAT or LOW SAT button is pressed, the display shows the upper or lower saturation alarm limit

6. **PULSE RATE display:** digital display that shows the pulse rate in beats per minute; when the HIGH RATE or LOW RATE button is pressed, the display shows the upper or lower pulse rate alarm limit

7. **Pulse amplitude indicator:** unlabeled vertical column of light bars that qualitatively indicates pulse amplitude

8. **ECG IN USE indicator:** yellow indicator that flashes when the N-200 locates an ECG signal; lights steadily when the N-200 locks onto the signal

9. **ECG LOST indicator:** red indicator that flashes if the ECG signal is lost or if it deteriorates to the extent that the N-200 can no longer track it

10. ⚠ **Caution:** Before connecting, refer to Operator's Manual

11. **CONNECTION socket:** connector into which the patient module is plugged

12. **Control knob:** adjusts the volume of the "beep"; when used in conjunction with specific buttons, the control knob modifies various alarm functions, sets alarm and event limits, modifies various functions of the trend and event memories, and sets the operating mode

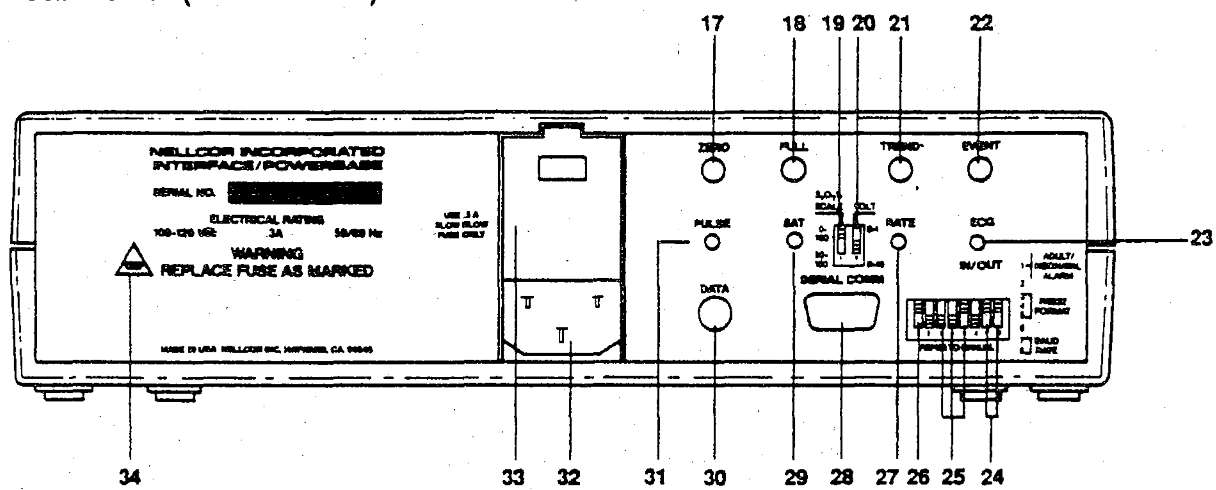
13. **HIGH SAT, LOW SAT, HIGH RATE, LOW RATE indicators:** flashes during the alarm state to indicate which parameter is beyond the established alarm limit (e.g., the HIGH RATE indicator flashes when the upper pulse rate alarm limit is exceeded)

14. **HIGH SAT, LOW SAT, HIGH RATE, LOW RATE buttons:** when pressed, cause the current alarm limits to be displayed; when used in conjunction with the control knob, these buttons modify various alarm functions, set alarm and event limits, modify various functions of the trend and event memories, and set the operating mode

15. **AUDIO ALARM OFF button:** temporarily silences the audio alarm; when used in conjunction with the control knob, changes the period during which the audio alarm is temporarily silenced or disables the audio alarm; when used in conjunction with the control knob and other buttons, sets the clock, disables and activates the trend and event memories, and initiates and modifies user-defined events

16. **AUDIO ALARM OFF indicator:** lights steadily when the audio alarm has been temporarily silenced; flashes when the audio alarm has been disabled

Rear Panel (Powerbase)



17. ZERO button
18. FULL button
19. SaO2% SCALE switch
20. VOLT switch
21. TREND button
22. EVENT button
23. ECG IN/OUT connector
24. BAUD RATE switches
25. RS-232 FORMAT switches
26. ADULT/NEONATAL ALARM switch
27. RATE connector
28. SERIAL COMM connector
29. SAT connector
30. DATA connector
31. PULSE connector
32. AC power inlet
33. Fuse compartment
34. Warning symbol

17. **ZERO button:** provides a zero volt signal on all analog outputs except ECG IN/OUT

18. **FULL button:** provides a full-scale signal on all analog outputs except ECG IN/OUT (voltage depends on VOLT switch setting)

19. **SaO2% SCALE switch:** sets the analog output scale for oxygen saturation at 0-100% or 50%-100%

20. **VOLT switch:** sets the voltage output range for the analog outputs at 0-1 volt or 0-10 volts (Note: This does not affect ECG input)

21. **TREND button:** initiates a trend memory output sequence

22. **EVENT button:** initiates an event memory output sequence

23. **ECG IN/OUT connector:** provides an analog ECG output signal (when the ECG signal is provided via the patient module) or an ECG input connector for an external ECG waveform or a DEFIB SYNC signal (when the ECG signal is provided from a bedside ECG monitor) (3/32" subminiature phone plug)

    Warning: The N-200 ECG signal output must NOT be used as the input signal for defibrillator synchronization.

24. **BAUD RATE switches:** set the baud rate for serial communications (DIP switches 7 and 8)

25. **RS-232 FORMAT switches:** set the RS-232 format (DIP switches 3, 4, and 5)

26. **ADULT/NEONATAL ALARM switch**: sets the default alarm limits for adults or neonates (DIP switch 1)

27. **RATE connector:** provides analog output of pulse rate in beats per minute, with a range of 0-250 bpm (3/32" subminiature phone plug)

28. **SERIAL COMM connector:** provides RS-232 digital interface via a nine-pin "D"-type connector

29. **SAT connector:** provides analog output of oxygen saturation data (%SaO2), with a range of 0-100% or 50%-100% (3/32" subminiature phone plug)

30. **DATA connector:** provides fiber optic output for connection to a *NELLCOR* N-9000 recorder/ interface or a *NELLCOR* N-8000 interface

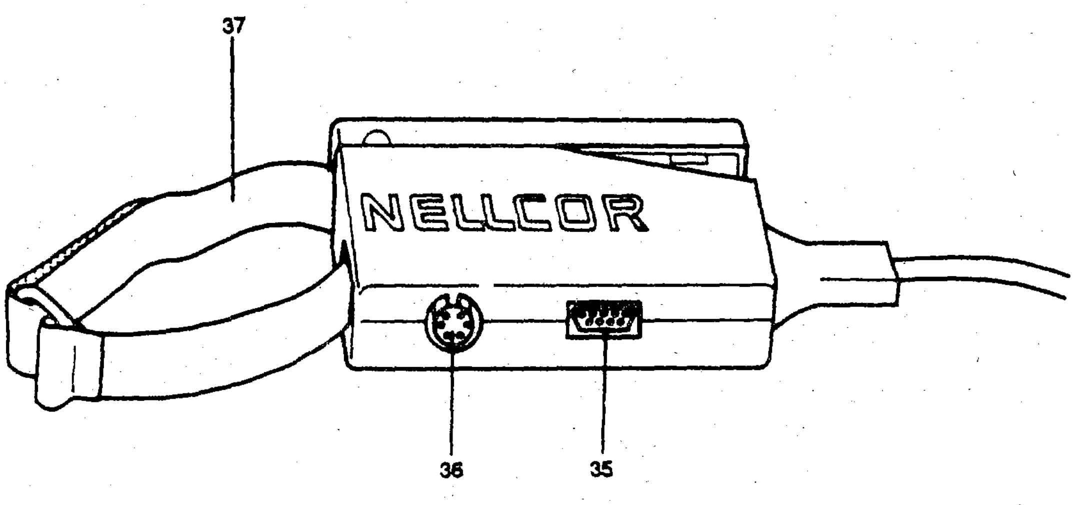
31. **PULSE connector:** provides analog output of pulse waveform (3/32" subminiature phone plug)

32. **AC power inlet**

33. **Fuse compartment**

34. ⚠ **Warning:** Risk of fire. Replace fuse as marked.

Patient Module



35. Sensor connector 36. ECG connector 37. Velcro strap

35. ***NELLCOR* sensor connector**: connector for the plug on the end of *NELLCOR* sensors

36. **ECG connector:** AAMI-specified socket for attaching an ECG cable

37. **Velcro® strap:** used for fastening the patient module to a bedside support

Basic Operation

Warning: Improper use of the N-200 could present a hazard to the patient. Carefully read the "Warnings" section of this manual before clinical use of the instrument.

1. If desired, plug one end of the power cord into the AC power inlet on the back of the *NELLCOR* N-200. Plug the other end into a properly grounded 100 to 120 volt AC outlet marked "Hospital Only" or "Hospital Grade." Alternatively, operate the N-200 for up to two hours on its internal battery.

   Never use an outlet that does not have a grounding connection. Use only the original hospital-grade AC power plug and cord or an equivalent hospital-grade plug.

2. If the patient module is disconnected, align the red dot on the patient module connector with the red dot on the CONNECTION socket on the front of the N-200. Push the connector straight in until it locks. Do NOT twist the connector while attaching it.

   Use the *NELLCOR* C-200-13 patient module, which is supplied with the N-200, or the C-200-20 patient module. (If the ECG connector on the patient module is not necessary, a *NELLCOR* C-13 C/D or C-20 C/D patient module may be used instead.)

3. If *C-LOCK* ECG synchronization is to be used, provide an ECG signal as follows: apply ECG electrodes to the patient in standard limb lead configuration, attach lead wires to the electrodes, plug the lead wires into the ECG cable (observing correct limb connections), and plug the ECG cable into the patient module; alternatively, connect the DEFIB SYNC pulse output or the ECG OUT waveform (high-level output) from an ECG monitor to the N-200 ECG IN/OUT connector. *C-LOCK* ECG synchronization enhances stability in high-motion or low-perfusion environments.

   See the "Use of Special Features" section of this manual for full instructions.

4. Select an appropriate *NELLCOR* sensor and apply it to the patient, following the directions for use provided with the sensor. Plug the sensor into the patient module.

5. Turn the instrument on by moving the ON/STDBY switch to the ON position.

   The instrument emits a "beep" and all displays light momentarily while the N-200 tests its circuitry. Then the PULSE SEARCH indicator begins to flash, and the OXYGEN SATURATION and PULSE RATE displays show a non-flashing zero. The ECG IN USE display illuminates if ECG synchronization is being used and an ECG signal is detected.

   After four to six pulses, the digital OXYGEN SATURATION and PULSE RATE displays begin to show beat-to-beat information. The instrument emits a "beep" with each pulse, and the pitch of the "beep" rises as oxygen saturation increases and falls as it decreases. The pulse amplitude indicator begins to follow the pulse. At this time, the alarms are operational, with the default alarm limits in effect (see page 9 for the default limits).

Normally, for adults the pulse amplitude indicator reaches at least mid-scale, while it is typically lower for neonates. If the pulse amplitude indicator shows less than two to three light bars, perfusion is inadequate to enable the N-200 to track the pulse and the PULSE SEARCH indicator will begin to flash. (See the "Troubleshooting Guide" in this manual for a discussion of actions to take in this situation.)

When the instrument is receiving a signal from the ECG electrodes but not from a *NELLCOR* sensor, with each pulse beat the instrument emits a high-pitched tone that has a slight warble. Be sure to familiarize yourself with the different pulse tones before clinical use of the instrument.

6. Check the alarm limits each time the N-200 is used, by sequentially pressing the HIGH SAT, LOW SAT, HIGH RATE, and LOW RATE buttons. Each limit will be displayed.

   To adjust the alarm limits to meet the needs of a specific patient, press and hold the appropriate button (HIGH SAT, LOW SAT, HIGH RATE, or LOW RATE), and turn the control knob until the desired value is displayed. Oxygen saturation alarm limits may be set for any value from 50% to 100%, and the pulse rate alarm limits may be set for any value from 35 to 250 beats per minute. The upper limit must be higher than the lower limit.

   When the instrument is turned off and back on again, the alarm limits return to the default values.

7. To turn the N-200 off, move the ON/STDBY switch to the STDBY position.

   If it is necessary to disconnect the patient module, grasp the textured metal surface of the connector and pull straight out. Do NOT twist the connector while unplugging it.

Use of Special Features

Pulse Tone

When a *NELLCOR* sensor is connected to the N-200 and a patient, the pulse beat is signaled by a "beep" that varies in pitch to reflect changes in oxygen saturation, rising as saturation increases and falling as it decreases. This patented early warning system allows the operator to monitor saturation changes while watching the patient, notifying the operator of changes in the patient's status and allowing prompt initiation of corrective actions (U.S. Patent 4,653,498).

When the N-200 is receiving only an ECG-derived signal (no sensor-derived signal), each pulse beat is signaled by a high-pitched tone that has a slight warble. This tone is distinct from any "beep" heard when a sensor-derived signal is present. The pitch of the warbling tone that accompanies an ECG-derived signal is NOT related to oxygen saturation. The pitch of the warbling tone also is significantly higher than any "beep" that reflects oxygen saturation. Before using the instrument, be sure to familiarize yourself with the difference between the ECG warbling tone and the "beep" that changes pitch with oxygen saturation.

To adjust the volume of the pulse tone, turn the control knob. When the N-200 is turned off and back on again, the pulse tone returns to its default volume.

Alarm Functions

The N-200 has both visible and audible alarms that activate as described below.

If the alarms activate because the oxygen saturation level or pulse rate moves beyond the alarm limits, the corresponding alarm indicator will flash, the appropriate display will flash, and an audio alarm will sound (unless or until it has been turned off).

If the alarms activate because the pulse signal is lost, the OXYGEN SATURATION and PULSE RATE displays will flash zero, the PULSE SEARCH indicator will flash, and an audio alarm will sound (unless or until it has been turned off).

If the alarms activate because the sensor or patient module is disconnected, the displays will become blank, the PULSE SEARCH indicator will flash, and an audio alarm will sound (unless or until it has been turned off).

If the alarm activates because the ECG signal is lost, the red ECG LOST indicator will flash.

The audio alarm function can be altered in several ways: it can be temporarily silenced, it can be disabled, and its volume can be adjusted. The visible alarm cannot be modified.

Default Alarm Limits: Default alarm limits are in effect when the N-200 is turned on. There are two sets of default alarm limits, one for monitoring adults and one for monitoring neonates.

Alarm Limit	Adult Setting	Neonatal Setting
high oxygen saturation	100%	95%
low oxygen saturation	85%	80%
high pulse rate	140 beats/minute	200 beats/minute
low pulse rate	55 beats/minute	100 beats/minute

To determine whether the default alarm limits are set for an adult or a neonate, press the HIGH SAT button immediately after turning on the N-200. If the instrument is set for an adult, "100" appears in the OXYGEN SATURATION display; if it is set for a neonate, "95" appears.

To change the adult/neonatal setting, move the ADULT/NEONATAL ALARM switch on the back of the powerbase (DIP switch 1), using a slender, nonmetallic object. Note: The N-200 must be operating on AC power when the setting is changed for that change to be implemented.

Adjusting the Audio Alarm Volume: To adjust the audio alarm volume, press and hold both the HIGH SAT and LOW SAT buttons, and turn the control knob to the right to increase the volume or to the left to decrease it.

When the N-200 is turned off and back on again, the audio alarm returns to the default volume.

Warning: Do not set the alarm volume too low to be heard.

Temporarily Silencing the Audio Alarm: To silence the audio alarm for 60 seconds, press the AUDIO ALARM OFF button once. The red AUDIO ALARM OFF indicator lights steadily to show that the audio alarm has been temporarily silenced. After 60 seconds, the alarm will again sound if the alarm state continues.

To change the period during which the audio alarm is temporarily silenced, hold the AUDIO ALARM OFF button down, and turn the control knob until the desired period appears in the OXYGEN SATURATION display. Then release the button. This period can be set for any value between 30 and 120 seconds.

When the N-200 is turned off and back on again, this period returns to 60 seconds.

Disabling the Audio Alarm: Warning—In normal operation, the AUDIO ALARM OFF button temporarily silences the audio alarm. While it is possible to disable the audio alarm by following the instructions below, this should not be done if patient safety could be compromised.

To disable the audio alarm, hold the AUDIO ALARM OFF button down, and turn the control knob to the right until "OFF" appears on the OXYGEN SATURATION display. The AUDIO ALARM OFF indicator then begins flashing. The audio alarm can be reactivated by pressing the AUDIO ALARM OFF button again (and the AUDIO ALARM OFF indicator then goes out). Then it can be disabled again by pressing the AUDIO ALARM OFF button (and the AUDIO ALARM OFF indicator begins flashing again).

When the instrument is turned off and back on again, the audio alarm returns to its normal function.

Warning: When the AUDIO ALARM OFF button has been pressed and the red AUDIO ALARM OFF indicator is illuminated, no audio alarm will sound in the event of adverse patient condition. The AUDIO ALARM OFF button should not be used in situations in which patient safety could be compromised.

C-LOCK ECG Synchronization

To provide more reliable saturation measurements in a high-motion environment or when a patient has poor perfusion, the N-200 can use an ECG (R-wave) signal as a time reference to identify the pulse and synchronize the saturation measurements. This feature, known as *C-LOCK* ECG synchronization, enhances performance while maintaining rapid response time and an accurate heart rate display.

Connecting the ECG Signal: As described on the following pages, the N-200 can receive an ECG signal from two sources: directly from the patient via a conventional three-lead ECG cable, or alternatively, from a bedside ECG monitor via an interconnection cable.

If the ECG signal is lost or deteriorates to the extent that the N-200 can no longer track it, the red ECG LOST indicator flashes. IF THIS HAPPENS, FIRST CHECK THE STATUS OF THE PATIENT. If that is not the source of the problem, follow the suggestions outlined in the "Troubleshooting Guide" in this manual. When the ECG signal is lost, if a *NELLCOR* sensor is connected to the patient, oximeter measurements derive from the optical signal alone. During this time the N-200 continues to search for an ECG signal, and, when it tracks an adequate signal, *C-LOCK* ECG synchronization again becomes active. To cancel the ECG LOST indicator, press the AUDIO ALARM OFF button.

When using *C-LOCK* ECG synchronization, an electrocautery unit or significant upper-body muscular activity may disrupt the ECG signal and cause the N-200 to begin using the optical signal alone for obtaining measurements. When an adequate ECG signal is again available, *C-LOCK* ECG synchronization automatically begins functioning.

Default Alarm Limits: Default alarm limits are in effect when the N-200 is turned on. There are two sets of default alarm limits, one for monitoring adults and one for monitoring neonates.

Alarm Limit	Adult Setting	Neonatal Setting
high oxygen saturation	100%	95%
low oxygen saturation	85%	80%
high pulse rate	140 beats/minute	200 beats/minute
low pulse rate	55 beats/minute	100 beats/minute

To determine whether the default alarm limits are set for an adult or a neonate, press the HIGH SAT button immediately after turning on the N-200. If the instrument is set for an adult, "100" appears in the OXYGEN SATURATION display; if it is set for a neonate, "95" appears.

To change the adult/neonatal setting, move the ADULT/NEONATAL ALARM switch on the back of the powerbase (DIP switch 1), using a slender, nonmetallic object. Note: The N-200 must be operating on AC power when the setting is changed for that change to be implemented.

Adjusting the Audio Alarm Volume: To adjust the audio alarm volume, press and hold both the HIGH SAT and LOW SAT buttons, and turn the control knob to the right to increase the volume or to the left to decrease it.

When the N-200 is turned off and back on again, the audio alarm returns to the default volume.

Warning: Do not set the alarm volume too low to be heard.

Temporarily Silencing the Audio Alarm: To silence the audio alarm for 60 seconds, press the AUDIO ALARM OFF button once. The red AUDIO ALARM OFF indicator lights steadily to show that the audio alarm has been temporarily silenced. After 60 seconds, the alarm will again sound if the alarm state continues.

To change the period during which the audio alarm is temporarily silenced, hold the AUDIO ALARM OFF button down, and turn the control knob until the desired period appears in the OXYGEN SATURATION display. Then release the button. This period can be set for any value between 30 and 120 seconds.

When the N-200 is turned off and back on again, this period returns to 60 seconds.

Disabling the Audio Alarm: Warning—In normal operation, the AUDIO ALARM OFF button temporarily silences the audio alarm. While it is possible to disable the audio alarm by following the instructions below, this should not be done if patient safety could be compromised.

To disable the audio alarm, hold the AUDIO ALARM OFF button down, and turn the control knob to the right until "OFF" appears on the OXYGEN SATURATION display. The AUDIO ALARM OFF indicator then begins flashing. The audio alarm can be reactivated by pressing the AUDIO ALARM OFF button again (and the AUDIO ALARM OFF indicator then goes out). Then it can be disabled again by pressing the AUDIO ALARM OFF button (and the AUDIO ALARM OFF indicator begins flashing again).

When the instrument is turned off and back on again, the audio alarm returns to its normal function.

Warning: When the AUDIO ALARM OFF button has been pressed and the red AUDIO ALARM OFF indicator is illuminated, no audio alarm will sound in the event of adverse patient condition. The AUDIO ALARM OFF button should not be used in situations in which patient safety could be compromised.

C-LOCK ECG Synchronization

To provide more reliable saturation measurements in a high-motion environment or when a patient has poor perfusion, the N-200 can use an ECG (R-wave) signal as a time reference to identify the pulse and synchronize the saturation measurements. This feature, known as *C-LOCK* ECG synchronization, enhances performance while maintaining rapid response time and an accurate heart rate display.

Connecting the ECG Signal: As described on the following pages, the N-200 can receive an ECG signal from two sources: directly from the patient via a conventional three-lead ECG cable, or alternatively, from a bedside ECG monitor via an interconnection cable.

If the ECG signal is lost or deteriorates to the extent that the N-200 can no longer track it, the red ECG LOST indicator flashes. IF THIS HAPPENS, FIRST CHECK THE STATUS OF THE PATIENT. If that is not the source of the problem, follow the suggestions outlined in the "Troubleshooting Guide" in this manual. When the ECG signal is lost, if a *NELLCOR* sensor is connected to the patient, oximeter measurements derive from the optical signal alone. During this time the N-200 continues to search for an ECG signal, and, when it tracks an adequate signal, *C-LOCK* ECG synchronization again becomes active. To cancel the ECG LOST indicator, press the AUDIO ALARM OFF button.

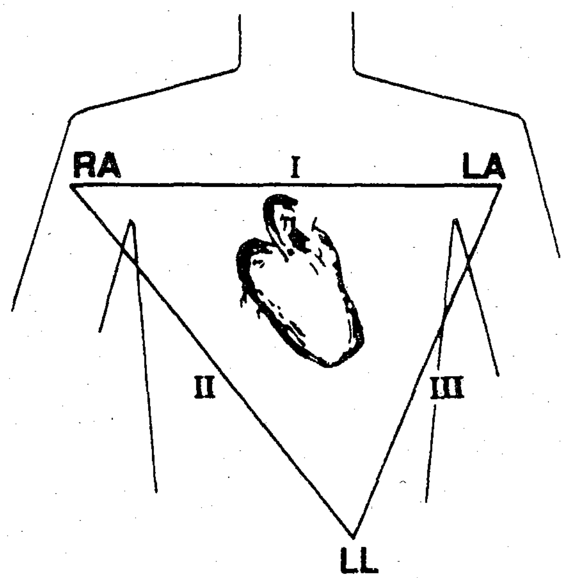
When using *C-LOCK* ECG synchronization, an electrocautery unit or significant upper-body muscular activity may disrupt the ECG signal and cause the N-200 to begin using the optical signal alone for obtaining measurements. When an adequate ECG signal is again available, *C-LOCK* ECG synchronization automatically begins functioning.

Warning: N-200 ECG signal output (from the ECG IN/OUT connector) must NOT be used as the input signal for defibrillator synchronization.

Warning: Only direct three-lead ECG cable input from the monitored patient should be connected to the patient module ECG connector. Do not connect any other signal to that connector, such as the output from an ECG monitor.

To utilize direct ECG input, position three conventional disposable electrodes in the standard limb lead configuration (LA, RA, LL), as illustrated on the following page. When applying the electrodes, follow all instructions in their package insert and observe institutional standards. For optimal performance, position the RA and LA electrodes below the lateral aspect of each clavicle. Position the LL electrode at the left costo-phrenic margin in the mid-axillary line. Attach the lead wires to the electrodes, connect the lead wires to the ECG cable (observe correct limb connections), and plug the cable into the ECG connector on the patient module. This is a standard AAMI-specified three-lead ECG connector; an AAMI-specified three-lead ECG cable should be used.

When the ECG signal is directly provided to the N-200 via the patient module ECG connector, artifact rejection and pacemaker spike rejection are enhanced.



To utilize the signal from a bedside ECG monitor, connect either the DEFIB SYNC pulse output or the ECG OUT waveform analog output (high-level output) to the N-200 ECG IN/OUT connector using a Nellcor supplied or specified ECG patch cord, as described in the patch cord's directions for use.

The peak of the ECG monitor signal must be between 0.5 volts and 15 volts. The QRS complex must be at least 10 milliseconds wide at 50% of peak amplitude. This output signal should be delayed by no more than 20 milliseconds from the actual QRS complex. The oximeter is designed to optimally respond to a QRS complex with a positive deflection rather than a negative deflection. Therefore, oximeter performance may be improved by selecting a lead configuration that results in a positive QRS complex.

Refer to the operator's manual for the ECG monitor before attempting any connection. When using the signal from an ECG monitor, the N-200 powerbase must be connected to the monitor and the N-200 must be operating on AC power.

Warning: Before use, confirm that the ECG patch cord connector is compatible with your ECG monitor, and test the patch cord as described below and in the patch cord's directions for use.

Before clinical use, test each ECG patch cord, as described below. If the patch cord is fabricated at your institution, also perform a continuity test before clinical use. Should problems arise during the following test procedures, first check all connections. If that does not resolve the problem, contact Nellcor's Technical Service Department at 1-800-NELLCOR.

1. For each configuration of clinical ECG monitor to be used with the *NELLCOR* oximeter, test instrument and patch cord function on yourself or another person as follows. Position conventional disposable ECG electrodes in the configuration that will be used clinically. (The ECG output signal must have the characteristics previously described.) Use the ECG patch cord to connect the appropriate output port on the ECG monitor ("ECG OUT" or "DEFIB SYNC") to the oximeter's "ECG IN/OUT" port. Turn on both instruments. Verify that a normal tracing is displayed on the ECG monitor, and verify that the pulse rate displayed by the oximeter is accurate and that its "ECG IN USE" indicator is steadily illuminated. Next, apply a *NELLCOR* oxygen transducer to that same person, following the instructions in its directions for use. Connect the oxygen transducer to the *NELLCOR* patient module, and verify that a saturation value is displayed by the oximeter and that the "ECG IN USE" indicator remains steadily illuminated.

2. Test all instrument functions under both normal and alarm conditions (e.g., "ECG leads off") to ensure appropriate operation before clinical use (see the Operator's and Service Manuals of the N-200 and the ECG monitor).

Warning: An ECG monitor output that is delayed by more than 20 milliseconds from the actual QRS complex may prevent the oximeter from calculating and displaying saturation. If this is observed, disconnect the patch cord and use the N-200 without *C-LOCK* ECG synchronization, substitute a different ECG monitor, or connect the patient ECG leads directly to the connector on the *NELLCOR* patient module.

Operation with an ECG Signal: The yellow ECG IN USE indicator flashes when the N-200 locates an ECG signal. When it locks onto an adequate signal, the ECG IN USE indicator lights steadily. The ECG R-wave is then being used to identify the pulse and synchronize the saturation measurements, as described in the "Principles of Operation" section of this manual.

Operating Modes

Selecting an Operating Mode: The N-200 has three operating modes, which enable it to make accurate measurements despite differing levels of patient activity. Each operating mode uses a different averaging time.

Mode 1 is the standard operating mode. It uses a 5 to 7 second averaging time and is useful in most clinical situations in which the patient is relatively inactive.

Mode 2 uses a 2 to 3 second averaging time and therefore is more affected by patient motion. It is useful for special studies in which an extremely fast response is desired (e.g., sleep studies).

Mode 3 uses a 10 to 15 second averaging time and consequently is least affected by patient motion. When the patient is unavoidably active and *C-LOCK* ECG synchronization is not being used, set the N-200 for Mode 3. The pulse rate is NOT displayed when the instrument is operating in Mode 3.

In all three operating modes, the N-200 updates the measurements with every pulse beat. At each beat, the instrument recalculates the saturation and pulse rate measurements: data from the most recent beat replace data from the earliest beat, and new averages are determined and displayed.

Setting the Operating Mode: When the N-200 is turned on, it is set for Mode 1. If another operating mode is better suited to the specific clinical setting, press and hold the HIGH RATE and LOW RATE buttons, and turn the control knob to the right until the desired number appears in the PULSE RATE display.

When the N-200 is turned off and back on again, it returns to Mode 1.

Trend and Event Memories

The N-200 has two memories. The trend memory stores up to 12 hours of oxygen saturation and pulse rate data, sampled once a second and averaged every five seconds. The higher resolution event memory stores up to one hour of oxygen saturation, pulse rate, and pulse perfusion data, sampled once a second. This event sampling is either associated with an alarm state or it occurs when the operator initiates an "event." Both memories also record the time of data acquisition.

Data are automatically acquired and stored unless the operator has disabled the memories. The N-200 memories accumulate data even when the powerbase is detached and the monitor is operating on battery power. Data are retained in the memories while the instrument is turned off.

The N-200 adds new data to that which is already stored, and identifies the beginning of the new data with a time marker. When a memory has been completely filled, the oldest data are automatically erased as new data are stored.

Trend and event data are available in both analog and digital formats for output to printers or other devices. During output, the N-200 monitor must be connected to the powerbase.

Setting the Clock: Before initially storing data in the memories, set the internal clock, as described below.

1. Year: Simultaneously press the LOW SAT and HIGH RATE buttons. The flashing numbers in the OXYGEN SATURATION display are the last two digits of the existing year setting. While holding thebuttons in, turn the control knob until the correct year is displayed. Then release the buttons.

2. Month: Press the same buttons again. The flashing number in the OXYGEN SATURATION display is the existing month setting. While holding the buttons in, turn the control knob until the correct month is displayed. Then release the buttons.

3. Day: Press the same buttons again. The flashing number in the PULSE RATE display is the existing day setting. While holding the buttons in, turn the control knob until the correct day is displayed. Then release the buttons.

4. Hour: Repeat Step 2 to set the hour (OXYGEN SATURATION display). The clock uses 24-hour "military" time (i.e., 1:00 PM is 13:00 hours; midnight is 00:00 hours).

5. Minute: Repeat Step 3 to set the minutes (PULSE RATE display).

6. Allow at least five seconds to elapse, and then check the settings by simultaneously pressing the LOW SAT and HIGH RATE buttons five times.

The N-200 sequentially sets the year, month, day, hour, and minute. If more than five seconds elapse between any of the steps listed above, then the existing changes are stored and the N-200 starts the sequence again (beginning with "year").

Trends: The oxygen saturation and pulse rate measurements are sampled every second and the average of the sampled values is computed every five seconds. That average is then stored in the trend memory. Up to 12 hours of these data can be stored.

- **Printing Trend Data:** Data in the trend memory may be printed on a Hewlett-Packard ThinkJet™ printer with an RS-232 serial interface (model 2225D) or on an analog strip-chart recorder, as described below. To print the contents of the trend memory, the N-200 must be connected to AC power. The instrument continues to function as a monitor while the trend data are being printed. The data are retained in memory after printing, unless they are erased, as described at the end of this section.

  Using a ThinkJet Printer: Set up the printer and connect it to the N-200 rear-panel SERIAL COMM connector according to the instructions in "Connecting the N-200 to Other Instruments." To print only trend data, set the N-200 RS-232 FORMAT switches to "Graphics Only," as described in the same section. Then press the TREND button on the back of the N-200 to begin printing.

When trend data are printed on a ThinkJet printer, 12 hours of data are printed on one 8-1/2" x 11" page, with the earliest data in the top left portion of the page. Each point on the printout represents 50 seconds. The oxygen saturation scale is automatically selected, based on the range of the data: the maximum value is always 100%; the minimum value is 50%, 25%, or 0. The pulse rate scale is 0 to 250 beats per minute; a narrower range is automatically selected if the data are suited to it. Time (date, hour, minute) is presented along the horizontal axis.

The following automatic markers appear on ThinkJet trend graphs:

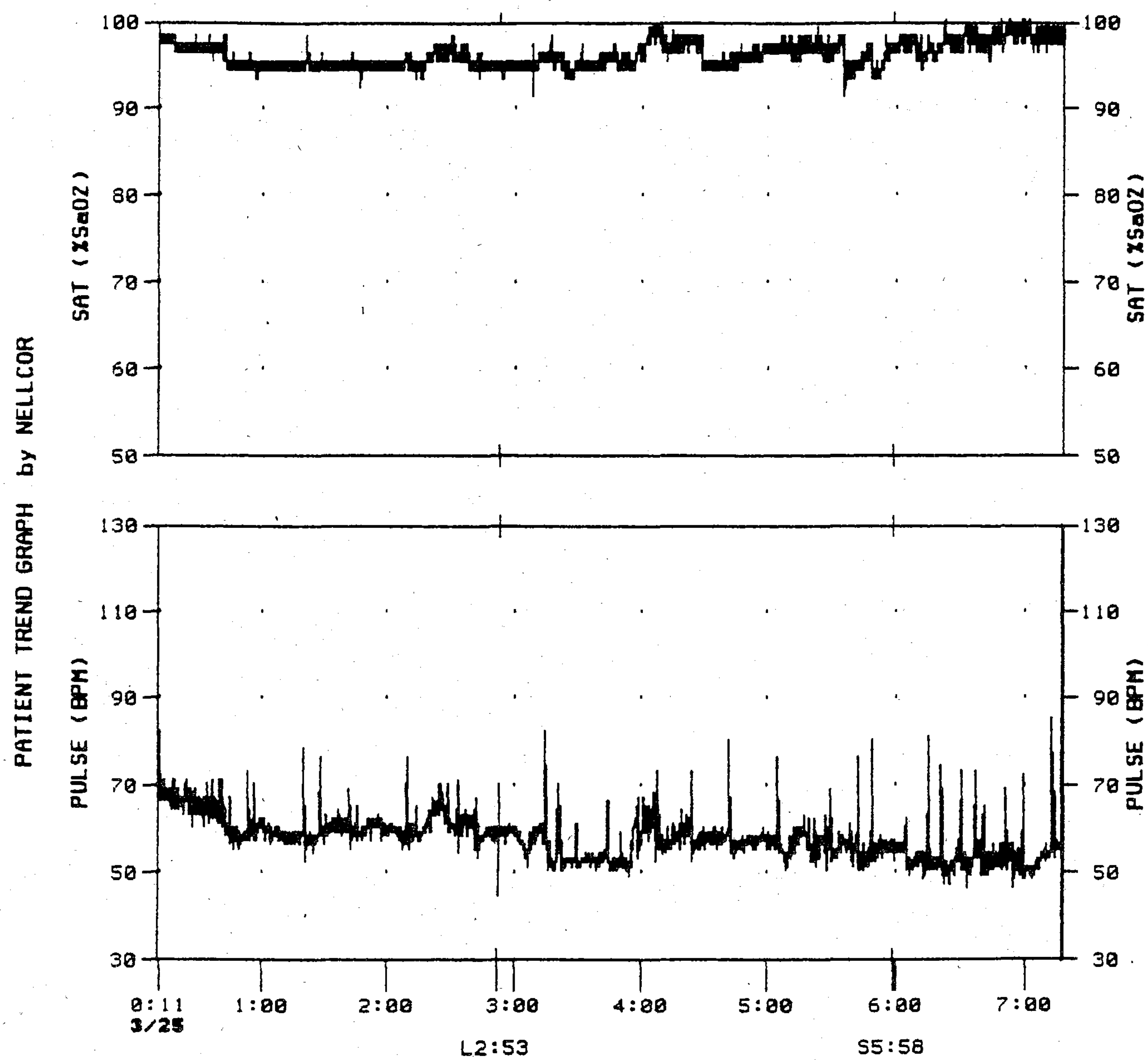
Occurrence	Marker
Alarm-limit event	L
User-defined event	E
Power turned off	P
Pulse signal is lost	S
Clock is reset	C
Signal is acquired	A

Whenever an "A" marker appears, the trend graph ends and a new one begins. (If less than five minutes elapse, no "A" marker is printed; instead the period during which the power was off or the signal was lost is represented on the trend graph by missing data points.) Each marker consists of a tick mark on the horizontal axis, along with the letter that indicates the type of occurrence and the time of onset (e.g., "L3:47" indicates an alarm-limit event that began at 3:47 AM). If more than six markers occur in close succession, each is identified by a tick mark on the horizontal axis, but only the first six are identified by type of event and time of occurrence. If more than 60 events are stored in memory, only the last 60 will be identified by type of event and time of occurrence. The remaining events are identified only by tick marks on the horizontal axis. The example on the next page illustrates the trend output from a ThinkJet printer.

Using an Analog Strip-Chart Recorder: Connect the strip-chart recorder to the N-200, as described in "Connecting the N-200 to Other Instruments." Calibrate the recorder, adjust the settings as necessary, and confirm proper operation. If the N-200 is also connected to a graphics printer, that printer must be turned off. Otherwise, the trend memory will be printed by the graphics printer rather than the strip-chart recorder. Do not attempt to print trend data on the N-9000 recorder/interface.

To print the trend memory, press the TREND button. Data are printed at the rate of approximately one hour of data per minute. If, prior to printing the trend memory, the strip-chart recorder was printing real-time data, the beginning and end of the trend data are identified by zero-voltage outputs.

The trend output can be stopped at any time by again pressing the TREND button. To restart it, push the TREND button again—if less than 30 seconds have elapsed, the output continues from the point at which it was stopped; if more than 30 seconds have elapsed, the output starts again at the beginning.



Sample ThinkJet trend graph with an alarm-limit event at 2:53 AM on 3/25 ("L2:53")
and the signal lost at 5:58 AM on 3/25 ("S5:58")

The following automatic markers appear on the trend graphs printed by an analog strip-chart recorder:

Occurrence	Marker
Beginning of the trend output	A one-second, zero-voltage output followed by two full-scale deflections
End of the trend output	A two-second, zero-voltage output
Time when the signal is acquired	A full-scale to current-value deflection
Time when the pulse signal is lost	A full-scale to current-value deflection
Time when the N-200 is turned off	A full-scale to current-value deflection
Alarm-limit or user-defined event	A full-scale to zero-voltage deflection

If more than 60 events are stored in memory, only the last 60 will be identified.

Events: The event memory stores a "snapshot" of concurrent oxygen saturation, pulse rate, and pulse perfusion measurements. During the snapshot, measurements are obtained once every second, resulting in a data display that has higher resolution than the trend memory. Up to one hour of event data may be stored.

There are two types of events: alarm-limit events which occur each time the saturation or pulse rate moves beyond the established limits, and user-defined events which the operator initiates.

For an alarm-limit event, the snapshot starts 30 seconds before the beginning of the alarm state and ends 30 seconds after the end of the alarm state. For a user-defined event, the snapshot starts 30 seconds before the event is initiated and lasts from one to 60 minutes (the operator selects the duration).

- **Printing Event Data:** Data in the event memory may be printed on a ThinkJet printer with an RS-232 serial interface (model 2225D) or a strip-chart recorder, as described below. To print the contents of the event memory, the N-200 must be operating on AC power. The N-200 continues to function as a monitor while the event data are being printed. The data are retained in memory after printing, unless they are erased as described at the end of this section.

  Using a ThinkJet Printer: Set up the printer and connect it to the N-200 rear-panel SERIAL COMM connector according to the instructions in "Connecting the N-200 to Other Instruments." To print only event data, set the N-200 RS-232 FORMAT switches to "Graphics Only," as described in "Connecting the N-200 to Other Instruments."

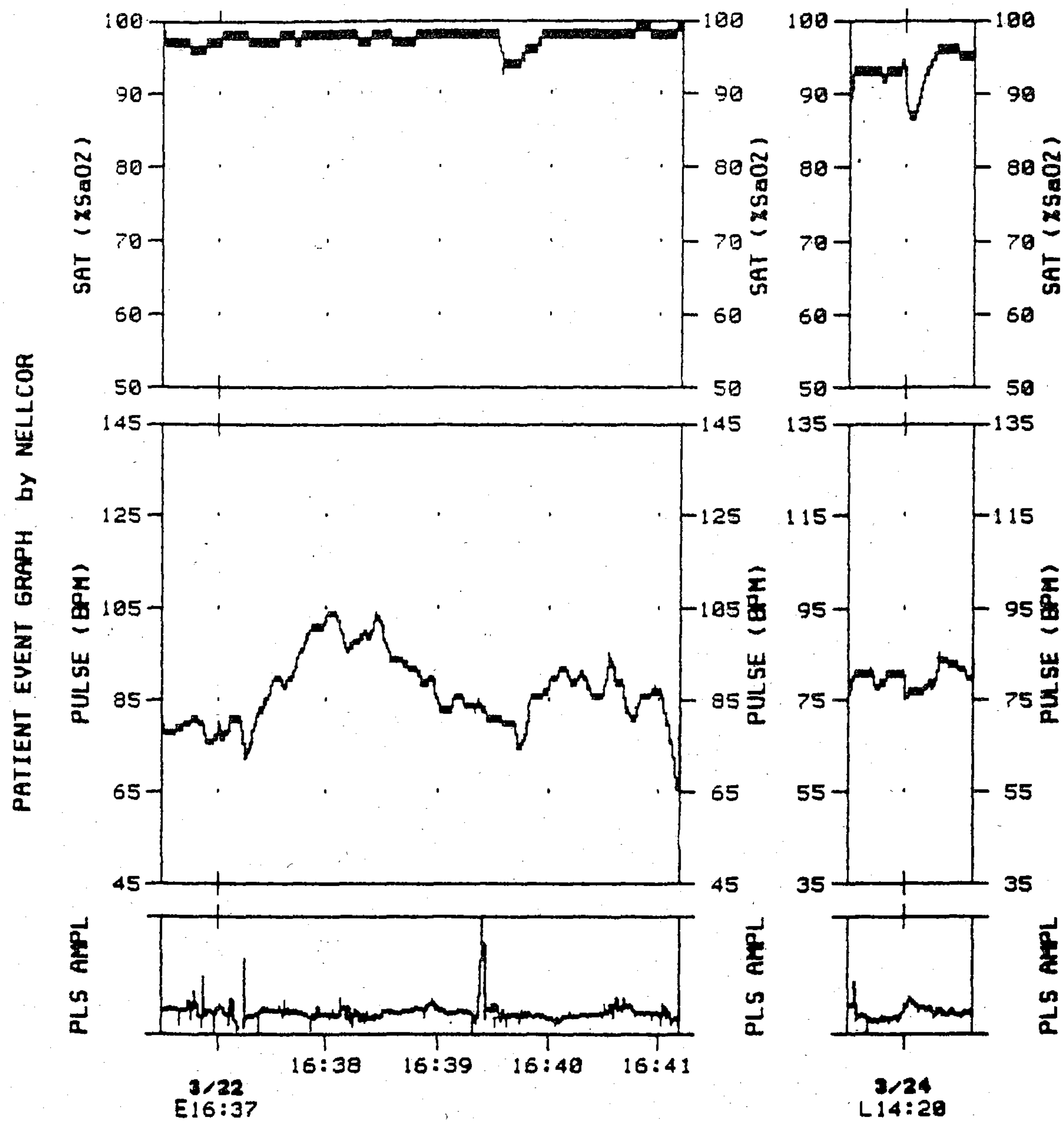
  To print all events that are stored in memory, press the EVENT button on the back of the N-200. The events are printed when the button is released.

  When event data are output on a ThinkJet printer, the earliest data are in the top left portion of the page. The graph begins 30 seconds before the beginning of each event, and an automatic marker identifies the type of event (alarm limit [L] or user-defined [E]). Each marker consists of a tick mark on the horizontal axis, along with a letter that indicates the type of event and the time of onset (e.g., "E15:10" identifies a user-defined event that began at 3:10 PM). New scales are printed for each event. The oxygen saturation scale is automatically selected, based on the range of the data:

the maximum value is always 100%; the minimum value is 50%, 25%, or 0. The pulse rate scale is selected based on the range of the measurements. The example on the next page illustrates event output on a ThinkJet printer.

To determine the number of events in memory, press and hold the LOW SAT and LOW RATE buttons. "no E" is displayed if no events are stored in memory, or "nnn E" is displayed to indicate the number of stored events (up to 60 events). If more than 60 events are stored, only the last 60 are available.

After determining the number of events, a specific event may be printed as follows. While still pressing the LOW SAT and LOW RATE buttons, turn the control knob until the identifier for the desired event appears in the display. Then release the buttons and within 10 seconds press the EVENT button. The event is then printed. (Also, pressing the EVENT button for at least three seconds and then turning the control knob until the identifier for the desired event appears causes that event to be printed.) The identifiers for events are the same as those printed on the ThinkJet output: a letter that indicates the type of event, and the hour and minute at which the event started.



Sample ThinkJet event graphs: a user-defined event that started at 4:37 PM on 3/22 ("E16:37") and an alarm-limit event that started at 2:20 PM on 3/24 ("L14:20")

Using an Analog Strip-Chart Recorder: Connect the strip-chart recorder to the N-200, as described in "Connecting the N-200 to Other Instruments." Calibrate the recorder, adjust the settings as necessary, and confirm proper operation. If a graphics printer is also attached to the N-200, it must be turned off. Otherwise, the event data will be printed by the graphics printer rather than by the strip-chart recorder.

To print the event memory, press the EVENT button on the back of the N-200. Approximately 10 minutes of data are printed each minute. Events are separated by a zero-voltage output on each channel. The earliest event and earliest data are presented first. The following automatic markers appear on the event graphs printed by an analog strip-chart recorder:

Occurrence	Marker
Beginning of the event output (which is 30 seconds before the beginning of the event)	A one-second, zero-voltage output followed by one full-scale deflection and another one-second, zero-voltage output
Beginning of the event	A full-scale to zero-voltage deflection
End of the event is acquired	A two-second, zero-voltage output
Time when the signal is acquired	A full-scale to current-value deflection
Time when the pulse signal is lost	A full-scale to current-value deflection
Time when the N-200 is turned off	A full-scale to current-value deflection

The event output can be stopped at any time by again pressing the EVENT button. To restart the output, push the EVENT button again—if less than 30 seconds have elapsed, the output continues from the point at which it was stopped; if more than 30 seconds have elapsed, the output starts again at the beginning. While the event output is stopped, there is a zero-voltage output signal.

Do not attempt to print event data on the N-9000 recorder/interface.

- **Initiating a User-Defined Event:** To initiate a user-defined event, press and hold the HIGH RATE and AUDIO ALARM OFF buttons ("UdE 0" appears). Turn the control knob until the "0" is replaced by the desired event duration (1 to 60 minutes). Then release the buttons. The data stored in the event memory begin 30 seconds before the buttons are released.

  To change the duration of an ongoing user-defined event, press and hold the HIGH RATE and AUDIO ALARM OFF buttons. "Ude n" appears, with "n" representing the number of minutes that remain in the ongoing event. Turn the control knob until the desired number of minutes appears. Then release the buttons.

  To end a user-defined event prematurely, press and hold the HIGH RATE and AUDIO ALARM OFF buttons, and turn the control knob to the left until "UdE OFF" appears. Then release the buttons.

- **Setting the Limits that Trigger an Alarm-Limit Event:** Normally, the established alarm limits determine when an alarm-limit event occurs (i.e., data are stored in the event memory whenever the saturation or pulse rate falls outside the alarm limits).

To set event limits that differ from the alarm limits, the N-200 must be operating on AC power. Press the applicable alarm button (HIGH SAT, LOW SAT, HIGH RATE, or LOW RATE) and the rear-panel EVENT button; while holding them in, turn the control knob until the desired setting appears in the display. The saturation event limits may be set for any value from 50% to 100%, and the pulse rate event limits may be set for any value from 35 to 250 beats per minute.

To again make an event limit equal to the alarm limit, while the N-200 is operating on AC power, press the applicable alarm button and the EVENT button; while holding them in, turn the control knob to the right until "= AL" appears in the display.

When the N-200 is turned off and back on again, the event limits are reset to the alarm-limit values.

Canceling Trend or Event Output: To stop an ongoing output of the trend or event memories, press both the TREND and EVENT buttons ("End Prt" appears); while holding them in, turn the control knob to the right until "Prt End" flashes. Then release the buttons, at which time "Prt End" lights steadily and the output is canceled.

To avoid canceling the output after starting to do so, before releasing the buttons turn the control knob to the left until "Prt" appears.

Erasing the Trend and Event Memories: To erase the stored trend and event data, press the HIGH SAT and HIGH RATE buttons ("CLr t E" appears in the display); while holding them in, turn the control knob to the right until "ALL clr" appears in the display. Then release the buttons, at which time the contents of both memories will be erased.

To preserve the data after starting to erase the memories, while still holding the buttons in, turn the control knob to the left until "not clr" appears. Then release the buttons.

Disabling the Trend and Event Memories: To disable both memories, simultaneously press the HIGH SAT, HIGH RATE, and AUDIO ALARM OFF buttons. "t E On" is displayed if the memories are active. To disable them, while holding the buttons in, turn the control knob until a flashing "t E diS" appears. If the memories are disabled, to reactivate them hold the buttons in and turn the control knob until a flashing "t E On" appears.

When the memories are disabled, the operator can still trigger a user-defined event, as previously described. When the N-200 is turned off and back on again, the memories are made active again.

Powerbase

The powerbase is the detachable AC power supply and external interface for the N-200. It provides isolated power for operating the monitor and for recharging the internal batteries. In addition, the powerbase contains the circuitry required to communicate with the monitor.

The powerbase provides analog outputs of pulse waveform, oxygen saturation, and pulse rate data, ECG waveform, and a digital output connector (RS-232 serial interface). In addition, it also provides a fiber optic output connector for use with the *NELLCOR* N-9000 recorder/ interface or the *NELLCOR* N-8000 interface via the fiber optic cable.

Because the N-200 is patient isolated, the monitor and powerbase communicate through a bi-directional optical link that is established whenever the monitor and powerbase are connected. Saturation, pulse rate, pulse waveform, and ECG waveform data are transmitted from the monitor to the powerbase where they are translated into analog or digital outputs. Status information is transmitted from the powerbase to the monitor to initiate output of the trend and event memories.

Disconnecting the Powerbase from the Monitor: The monitor can be disconnected from the powerbase for portable use. To do so, place the instrument on a secure flat surface and firmly push the latches on each side of the monitor, which allows the units to be separated. The analog, digital, and fiber optic outputs, and ECG/defib sync inputs (from the external monitor) are not available when the powerbase is detached from the monitor.

To reconnect the units, place them on a flat, stable surface, and position them so that the groove on the powerbase is aligned with the rib on the monitor. Push the powerbase straight in until the latches on the monitor engage.

Battery Operation/Portable Use

If external power is lost or disconnected, an internal battery automatically operates the N-200 for up to two hours. The yellow BATT IN USE light illuminates to indicate battery operation. The red LOW BATT indicator flashes when only about five minutes of battery power remain. It continues to flash until the device is plugged into an AC power source or the battery level is too low to power the instrument reliably. At that time an internal switch automatically turns off the N-200.

The battery recharges whenever the instrument is plugged into AC power. Fourteen hours are required to fully recharge it.

If *C-LOCK* ECG synchronization is used when the N-200 is operating on battery power, the ECG signal must be supplied directly from the patient through a cable attached to the patient module. A signal from a bedside ECG monitor cannot be used.

Warnings

Carefully read this operator's manual before attempting clinical use of the N-200.

In the event of an adverse patient condition, the audio alarm will not sound if it has been temporarily silenced or disabled.

Tissue damage can be caused by incorrect application or use of a sensor (e.g., wrapping the sensor too tightly, applying supplemental tape, failing to periodically inspect the sensor site). Refer to the directions for use provided with each sensor for specific instructions on application and use, and for description, warnings, cautions, and specifications.

The N-200 ECG signal output (from the ECG IN/OUT connector) must NOT be used as the input signal for defibrillator synchronization.

Only direct three-lead ECG cable input from the monitored patient should be connected to the patient module ECG connector. Do not connect any other signal to that connector, such as the output from an ECG monitor.

Loss of pulse signal can occur if

- the sensor is too tight;
- there is excessive illumination (e.g., a surgical or bilirubin lamp or direct sunlight);
- the sensor is placed on an extremity with a blood pressure cuff, arterial catheter, or intravascular line;
- the patient experiences shock, hypotension, severe vasoconstriction, severe anemia, hypothermia, arterial occlusion proximal to the sensor, or cardiac arrest.

Inaccurate measurements may be caused by

- incorrect application or use of a sensor;
- significant levels of dysfunctional hemoglobins, such as carboxyhemoglobin or methemoglobin;
- significant levels of indocyanine green, methylene blue or other intravascular dyes;
- exposure to excessive illumination, such as surgical lamps, especially ones with a xenon light source; bilirubin lamps; fluorescent lights; infrared heating lamps; or direct sunlight;
- excessive patient movement;
- venous pulsations;
- electrosurgical interference;
- placement of the sensor on an extremity that has a blood pressure cuff, arterial catheter, or intravascular line.

Refer to the "Troubleshooting Guide" in this manual and the sensor directions for use for complete information and suggested actions.

Do not use a damaged sensor or one with exposed electrical contacts; do not immerse a sensor; do not irradiate it; and do not steam autoclave it.

Explosion hazard. Do not use the N-200 in the presence of flammable anesthetics.

III. *NELLCOR* SENSORS

Warning: Use only *NELLCOR* oxygen transducers. Use of oxygen transducers produced by other manufacturers with *NELLCOR* pulse oximeters may result in improper oximeter performance.

Warning: Incorrect application or use of a sensor may cause tissue damage or improper operation of the N-200. Carefully read the "Warnings" section of this manual and the directions for use provided with the sensor.

Nellcor provides a family of sensors that are suitable for a variety of clinical settings and for patients of various sizes. Specific *NELLCOR* sensors have been developed for use on neonates (<3 kg), infants (3-15 kg), children and small adults (15-50 kg), and adults (>40 kg).

Nellcor's *DURASENSOR®* oxygen transducer is a reusable sensor supplied in a nonsterile package; its optical components are mounted in a plastic casing. The *OXIBAND™* oxygen transducer is a reusable sensor. An *OXIBAND* disposable adhesive wrap is used to apply it to the patient and maintain appropriate positioning of the optical components. *OXISENSOR™* oxygen transducers are sterile adhesive sensors; their optical components are mounted in medical-grade adhesive tape.

Among the available *NELLCOR* sensors are the *DURASENSOR* DS-100A adult digit oxygen transducer, the *OXIBAND* OXI-200N neonatal oxygen transducer, the *OXISENSOR* D-25 adult digit oxygen transducer, the *OXISENSOR* R-15 adult nasal oxygen transducer, the *OXISENSOR* D-20 pediatric digit oxygen transducer, the *OXISENSOR* I-20 infant digit oxygen transducer, and the *OXISENSOR* N-25 neonatal oxygen transducer.

Each sensor is designed for application to a specific site(s) on patients within a certain size range. To select the appropriate sensor, consider the patient's weight and which sensor application sites are available, as well as the adequacy of the patient's perfusion, the level of patient activity, whether sterility is required, and the anticipated duration of monitoring.

To ensure optimal performance, use an appropriate sensor, apply it as described in the directions for use, keep the sensor site at the level of the patient's heart, and observe all warnings and cautions noted in the sensor directions for use.

If excessive ambient light is present, cover the sensor site with opaque material. Failure to do so may result in inaccurate measurements. Light sources that can affect performance include surgical lights, especially those with a xenon light source; bilirubin lamps; fluorescent lights; infrared heating lamps; and direct sunlight.

If poor patient perfusion is affecting instrument performance and the patient weighs more than 50 kg, consider using the *OXISENSOR* R-15 adult nasal oxygen transducer. Because the R-15 obtains its measurements from an artery supplied by the internal carotid, the nasal septal anterior ethmoid artery, this sensor can obtain measurements when peripheral perfusion is relatively poor.

If patient movement is presenting a problem, evaluate the following possible solutions:

- check whether the sensor is securely and properly applied;
- use *C-LOCK* ECG synchronization;

- use a new sensor with fresh adhesive backing;
- move the sensor to a less active site;
- use a type of sensor that tolerates some patient motion, such as the D-25, D-20, N-25, or I-20;
- set the N-200 for Mode 3.

Finally, although the N-200 is designed to minimize any effects of electrosurgical interference, should such interference ever present a problem, evaluate the following possible solutions:
- move the cables of the N-200 and the electrocautery unit as far apart as possible;
- move the ground pad closer to the surgical site;
- plug the N-200 and the electrocautery unit into different AC circuits or consider operating the N-200 on battery power;
- move the sensor as far away from the electrocautery site and ground pad as possible;
- check whether the sensor is dry and firmly attached;
- if a *NELLCOR* sensor extension cable is being used, remove the extension cable and connect the sensor directly to the patient module;
- if appropriate, use an *OXISENSOR* D-25 oxygen transducer, which has added insulation against electrosurgical interference.

When using *C-LOCK* ECG synchronization, an electrocautery unit may disrupt the ECG signal and cause the N-200 to begin using the optical signal alone for obtaining measurements. When an adequate ECG signal is again available, *C-LOCK* ECG synchronization automatically begins functioning.

IV. CONNECTING THE N-200 TO OTHER INSTRUMENTS

The *NELLCOR* N-200 pulse oximeter may be connected to a variety of other instruments that enhance and expand its capabilities. These include the *NELLCOR* N-9000 recorder/interface, the *NELLCOR* N-8000 interface, other analog recorders, and digital devices including printers.

Caution: When connecting the *NELLCOR* N-200 to any other instrument, verify proper operation before clinical use. Refer to the instrument manual for the other device for complete instructions.

Connecting the *NELLCOR* N-9000 Recorder/Interface

When connected to the N-200, the *NELLCOR* N-9000 recorder/ interface provides an ongoing record of oxygen saturation, pulse rate, and pulse waveform data. The readings are printed on a strip chart, and all recordings include timing marks.

Connect the N-9000 to the N-200 as follows.

1. Set the N-200 baud rate to 2400 using the BAUD RATE switches (DIP switch 7 down, DIP switch 8 up).
2. Set the N-200 RS-232 format to the N-9000 Recorder format (DIP switches 3-5 down).
3. Connect the gray end of the fiber optic cable provided with the N-9000 to the DATA connector on the powerbase. Connect the blue end to the N-9000 connector labeled DATA INPUT. Push each connector in until it snaps into place. Route the fiber optic cable without bends; poor transmission may occur if the cable is kinked.

The N-200 may also be connected to the *NELLCOR* N-8000 interface to provide additional analog and digital output connectors. Refer to the N-8000 operator's manual for full instructions.

Connecting Other Strip-Chart Recorders

A general-purpose strip-chart recorder may be connected to the N-200 to provide a permanent record of oxygen saturation, pulse rate, pulse waveform, ECG data, and/or data in the trend and event memories.

The N-200 analog output connectors are standard 3/32" subminiature phone plugs. The output voltage range required by the recorder (0 to 1 volt or 0 to 10 volts) is set with the N-200 VOLTAGE switch. The oxygen saturation output can be set for a 0 to 100% display or an expanded 50% to 100% display using the N-200 SaO2% SCALE switch.

To print oxygen saturation and heart rate, use the SAT and RATE connectors. Use the ZERO and FULL buttons to generate zero and full-scale voltage signals in order to adjust the recorder controls.

To print the pulse (plethysmographic) waveform, use the PULSE connector; to print the ECG waveform, use the ECG IN/OUT connector. Use the ZERO and FULL buttons to generate zero and full-scale voltage signals at the PULSE connector in order to adjust the recorder controls.

To print trend data on a strip-chart recorder, use the SAT and RATE connectors; to print event data, use the SAT, RATE, and PULSE connectors.

Note: Connect only a high impedance device (1 M ohm or higher) to the analog output connectors. Improper loading distorts the correspondence between the measured voltage and the intended output voltage.

Connecting the Hewlett-Packard ThinkJet Printer

The ThinkJet printer with an RS-232 serial interface (model 2225D) may be used to print the contents of the trend and event memories, as well as to record ongoing saturation, pulse rate, pulse perfusion, and monitor status.

The ThinkJet printer and necessary accessories may be ordered directly from Nellcor's Customer Service Department.

It may be connected to the N-200 as follows.

1. Set the N-200's baud rate to 19.2 K using the BAUD RATE switches (DIP switches 7 and 8 up).
2. Set the N-200 format using the RS-232 FORMAT switches ("Graphics Only": DIP switches 3-4 up, DIP switch 5 down; or to another desired format).
3. Set the printer's MODE SELECTION switches: DIP switches 1-5 down, DIP switch 6 up, DIP switches 7-8 down.
4. Set the printer's RS-232C switches: DIP switch 1 up, DIP switches 2-4 down, DIP switch 5 up.
5. Connect the printer to the N-200 using the interface cable provided by Nellcor with the ThinkJet printer. (Additional cables are available from Nellcor.)
6. Provide isolated power (if appropriate), turn on the printer, verify proper operation, and position the paper to start printing near the top of the page.

Note: If the printer's switch settings are changed while it is turned on, it must be turned off and back on again to implement those changes.

Caution: Provide the ThinkJet printer with isolated power, according to institutional standards. A stand-alone isolation transformer is available from Nellcor (model P-ISO).

Connecting Other Digital Devices

Serial Communication Format

The RS-232 serial communication format of the N-200 is eight data bits, no parity bit, and one stop bit.

Setting the Baud Rate

Identify the baud rate required by the device that is to be connected, and set the N-200 baud rate using the rear-panel BAUD RATE switches (DIP switches 7 and 8).

Baud Rate	Switch Position 7	Switch Position 8
1200	Down	Down
2400	Down	Up
9600	Up	Down
19200	Up	Up

RS-232 Pin Assignments

The following table defines the pin assignments on the rear-panel SERIAL COMM connector and the corresponding pin assignments for a standard 25-pin RS-232 connector.

N-200 9-Pin Connector	Powerbase Signal	Direction	Output Device 25-Pin Connector	Output Device Signal
1	Not Used	None	None	None
2	Rx Data	<--	2	Tx Data
3	Tx Data	-->	3	Rx Data
4	DTR	-->	6	DSR (Ignored by ThinkJet)
5	Sig Ground	<->	7	Signal Ground
6	DSR	<--	4	RTS
7	RTS	-->	5	CTS (Ignored by ThinkJet)
8	CTS	<--	20	DTR
9	Alarm Out	-->	25	Not Used

Pin 8 (CTS) may be used to control the transmission of data. When "TRUE" (positive voltage or not connected), data transmission takes place. When "FALSE" (negative voltage), data transmission is temporarily suspended.

Pin 9 may be used to connect the N-200 to a remote alarm. The output is "FALSE" (less than 0.3 volts) when there is no alarm state and "TRUE" (greater than 4.0 volts) when there is an alarm state. This pin should be connected to a high-impedance circuit (greater than1 K ohm) and protected against transient voltages.

Setting the RS-232 Communication Port Format

The RS-232 FORMAT switches are used to set the communication port format, as follows.

Format Name	Description	DIP Switch Position 3	4	5
Full	Full readable strings for CRT or printer	Down	Down	Up
Computer	Single identifier character plus values	Down	Up	Down
Conversation	Request for parameter	Down	Up	Up
N-9000 Recorder	Used to communicate with *NELLCOR* N-9000 recorder/interface	Down	Down	Down
Beat to Beat	Outputs rate and saturation once per beat	Up	Down	Up
No Real-Time Output	Supresses real-time data output; trend and event data will be output if connected	Up	Down	Down
Graphics Only	Supresses sign-on message and real-time data output; trend and event data will be output if connected	Up	Up	Down

Full Format: This format is designed for printer or CRT output. Once a minute, one of the following lines appears:

HH:MM:SS: MONITOR: RATE = nnn %SAT = nnn PULSE AMPL. %FS=nnn
or
HH:MM:SS: MONITOR: NO PULSE DATA

Additionally, if alarm status, monitor status, or limits change, one of the preceding lines will appear again, along with the following (also, an asterisk [*] is printed in front of the line to identify which variable has changed):

MONITOR STATUS:	NORMAL or (SEARCH, OXISENSOR OFF, ECG LEADS OFF, AUDIO ALARM DISABLED)
ALARMS ACTIVE:	NONE or (LOW SATURATION, HIGH SATURATION, LOW RATE, HIGH RATE)
LIMITS:	LOW RATE= nnn HIGH RATE= nnn LOW SAT= nnn HIGH SAT= nnn

For MONITOR STATUS or ALARMS ACTIVE, only abnormal indications are given.

If the N-200 is turned off or the powerbase is detached from the monitor, the following sequence is transmitted immediately and again once each minute:

HH:MM:SS: COMMUNICATIONS WITH MONITOR LOST

Computer Format: Once every ten seconds, and when the status or limits change, the following data are transmitted:

(02) (03)
STXRnnnSnnnPnnnLnnnHnnnOnnnAnnnMnnnTnnnnnnQnnnCRLFCHKSMETX

S = Saturation %
T = Time hhmmss
R = Heart Rate
n = ASCII character, normally a number
P = Pulse Amplitude (current sample)
L = Low Rate Alarm Limit
H = High Rate Alarm Limit
O = Low Saturation Alarm Limit
Q = High Saturation Alarm Limit
A = Alarm Status in Bits 1 = in alarm condition
- Bit 0 = High Rate
- Bit 1 = Low Rate
- Bit 2 = Low Sat
- Bit 3 = High Sat

  i.e., ASCII 005 = 0101B = low sat and high rate alarms

M = Monitor Status

Bit 0 = Pulse Search Status	1 = Locked	0 = Search
Bit 1 = Sensor Status	1 = Attached	0 = Off
Bit 2 = Audio Alarm Status	1 = Enabled	0 = Disabled
Bit 3 = ECG Status	1 = Off	0 = On
Bit 7 = Communications with Monitor Lost	1 = Lost	0 = Intact

i.e., ASCII 015 = 00001111B = Locked on pulse, sensor attached, audio alarms enabled, and ECG off

CRLF = Carriage Return and Line Feed
CHKSM = 1 Byte Checksum

Conversation Format: This mode uses the same character definitions as Computer format, but the output is a single parameter, by request only. For example, the computer requests the current heart rate by sending an "R." The interface responds with "Rnnn" (nnn is the heart rate).

The Conversation format is available for all parameters listed in the Computer format.

N-9000 Recorder Format: This mode is used to communicate with the *NELLCOR* N-9000 recorder/interface.

Beat to Beat Format: This mode transmits saturation and pulse rate data once per beat in the following format:

RnnnSnnnCRLF

No Real-Time Output Format: In this mode there is no output of real-time saturation and pulse rate data. Trend and event data are transmitted to an output device, if one is connected. The sign-on message from the powerbase is printed when AC power is first connected.

Graphics Only Format: In this mode the sign-on message is supressed and there is no output of real-time saturation and pulse rate data. Trend and event data are transmitted to an output device, if one is connected.

V. TROUBLESHOOTING GUIDE

This section discusses some potential difficulties, their possible causes, and suggestions for resolving them. If the difficulty persists after following these suggestions, contact qualified service personnel or call Nellcor's Technical Service Department at 800 433-1244 (U.S.) or 800 351-9754 (CA).

Warning: Shock hazard. Do not remove cover. There are no user-serviceable parts inside. Contact qualified service personnel.

1. The instrument cannot be turned on.

   - AC power is not connected and the battery is discharged. Connect to AC power. If the problem persists, check the AC fuse. If this does not resolve the problem, contact qualified service personnel or Nellcor's Technical Service Department.

2. The instrument operates on AC power but not on the battery.

   - The battery may be discharged. Fourteen hours are required to completely recharge the battery.
   - The battery pack may be defective or the battery fuse may be open. Contact qualified service personnel or Nellcor's Technical Service Department.
   - The battery charger circuit may be defective. Contact qualified service personnel or Nellcor's Technical Services Department.

3. The instrument operates on AC power but the BATT IN USE indicator is always on.

   - The powerbase may be disconnected from the monitor.
   - The instrument may not be receiving AC power because the power cord is defective, it is not connected, or it is connected to a defective AC outlet. Replace the power cord, check the connections, or try another AC outlet.
   - The AC fuse on the rear panel may be defective. Replace the fuse with one of the same type and rating.

4. The instrument displays an error message and then turns itself off after five minutes.

   - "Err 1" indicates a damaged RAM (data memory). Contact qualified service personnel or Nellcor's Technical Service Department.
   - "Err 2" indicates a damaged ROM (program memory). Contact qualified service personnel or Nellcor's Technical Service Department.
   - "Err 3" indicates a damaged display or indicator, or possibly a malfunction of an analog-to-digital converter. Contact qualified service personnel or Nellcor's Technical Service Dept.

Note: The instrument will operate if any button is pressed while "Err 3" is showing. However, because at least one numeric display segment or indicator may be missing, the display or warning indicators may be incorrect.

Caution: Continue to use the instrument only in an urgent situation and only if the defective segment(s) has been identified. If a defective segment cannot be identified, do not continue to use the N-200.

- "Err 4" indicates that the N-200 lost power without going through the normal shut-down procedure. Turn the ON/STDBY switch to STDBY and back to ON.

- "Err 5" indicates jumpers W1 and W4 were not installed properly. Contact qualified service personnel or Nellcor's Technical Service Department.

  Note: The instrument will operate if any button is pressed while "Err 5" is displayed.

- "Err 6" indicates that battery-backed memory contents have been lost, and the trend and event memories were erased and reinitialized. The trend and event memories will operate normally as long as the N-200 is turned on, but when the ON/STDBY switch is set to STDBY, the trend and event memories will be erased. This message may indicate that the RAM socket assembly U15 needs to be replaced. Contact qualified service personnel or Nellcor's Technical Service Department.

  Note: This message may also appear briefly when the N-200 is first turned on after the monitor EPROM has been replaced with a different version. No action is required.

- "ALL clr" indicates that the trend and event memories were erased and reinitialized. The N-200 erases and reinitializes the memories if the data have been corrupted. The memories can also be manually cleared and reinitialized. In both cases, the "ALL clr" appears. No further action is necessary. (When "ALL clr" appears because the memory data were corrupted and erased, a simultaneous 5-second alarm sounds.)

  Note: If the N-200 erases the trend and event memories, a message header appears on the trend graph indicating that the oldest portion of the memory was erased.

- "Err Pb" indicates that the powerbase is not communicating with the monitor. Check that the powerbase is plugged in and the monitor is correctly installed on the powerbase. If the message does not disappear, contact qualified service personnel or Nellcor's Technical Service Department.

  Note: The instrument will operate if any button is pressed while "Err Pb" is displayed.

5. The perfusion indicator is not tracking the pulse (PULSE SEARCH indicator is on), and oxygen saturation and pulse rate are not displayed.

   - The sensor may be improperly applied to the patient or it may not be plugged in. Check and correct if necessary.

   - The patient's perfusion may be too poor for the instrument to detect an acceptable pulse. Check the condition of the patient; use *C-LOCK* ECG synchronization; test the instrument on yourself or another patient; try another sensor site; or try the *OXISENSOR* R-15.

   - The sensor may be damaged. Replace it with another sensor.

   - The patient module may be damaged. If possible, try another patient module. If that is not possible or it does not resolve the problem, contact qualified service personnel or Nellcor's Technical Service Department. Note: A model C-13 C/D or C-20 C/D patient module from a *NELLCOR* N-100 pulse oximeter may be used if *C-LOCK* ECG synchronization is not being used or if the ECG signal is being provided via the rear-panel connector.

6. The pulse amplitude indicator tracks a pulse, but there is no oxygen saturation or pulse rate display.

   - The sensor may be damaged. Replace it with another sensor.

   - The patient's perfusion may be too low to allow the instrument to measure saturation and pulse rate (fewer than two to three bars on the perfusion display). Check the condition of the patient; use *C-LOCK* ECG synchronization; test the instrument on yourself or another patient; or try the *OXISENSOR* R-15.

   - Excessive patient motion may be making it impossible for the instrument to find the actual pulse pattern. Use *C-LOCK* ECG synchronization. If that is not possible, set the N-200 for Mode 3.

7. The patient module cannot be connected to the instrument.

   - The incorrect type of patient module may be in use. Use a *NELLCOR* C-200-13 patient module or a C-200-20 patient module (or a C-13 C/D or C-20 C/D patient module if ECG input is not required or if it is being provided via the rear-panel connector).

- The connector pins may be bent. Straighten them carefully or replace the patient module. (The plug is internally sealed. Do not attempt to disassemble it.)

8. The saturation and/or pulse rate displays are changing rapidly and the pulse amplitude indicator is erratic.

   - Excessive patient motion may be making it impossible for the instrument to find a pulse pattern. If possible, ask the patient to remain still. Alternatively, check whether the sensor is securely and properly applied, and replace it if necessary; use *C-LOCK* ECG synchronization; move the sensor to a new site; use a type of sensor that tolerates more patient motion; or set the N-200 for Mode 3.

   - An electrocautery unit (ECU) may be interfering with performance. Check whether

     — the ECU cable and N-200 patient module are too close to each other; move them as far apart as possible;

     — the ECU ground pad is positioned far away from the surgical site; move it as close as possible;

     — the sensor is too close to the ground pad or electrocautery site; move the sensor to a different site if possible;

     — the ECU and N-200 are plugged into a common power source; operate the N-200 on battery if possible, or plug them into different circuits;

     — the sensor is damp or has been reused too often; replace it with a new sensor;

     — a *NELLCOR* sensor extension cable is being used; remove it and connect the sensor directly to the patient module;

     — an *OXISENSOR* D-25 adult digit oxygen transducer may improve performance because it has added insulation against ECU interference.

   - Ambient light may be interfering. Shield the sensor from bright ambient light with opaque material.

9. The ECG LOST indicator is displayed.

   - Check the condition of the patient.

   - There may be a loose or unplugged ECG electrode or electrode cable. Check the connections.

   - If appropriate, reposition the ECG electrodes to increase the amplitude of the R-wave.

   - If the ECG signal is provided via the rear-panel connector,

- the input signal from the ECG monitor may be incorrect; use 60 dB ECG analog output or defib sync pulse wave;

- AC power to the monitor may have been interrupted;

- increase the gain of the ECG monitor.

• The patient module may be defective. Try another patient module. If that is not possible, contact qualified service personnel or Nellcor's Technical Service Department.

10. When ECG is connected, the pulse rate is displayed but saturation is not.

• Check whether the sensor is properly applied and connected.

• The patient's perfusion may be inadequate. Check the status of the patient; test the instrument on yourself or another patient; try an *OXISENSOR* R-15.

11. The pulse rate that is displayed by the N-200 does not correlate with that of an ECG monitor.

• Excessive patient motion may be making it impossible for the instrument to find a pulse pattern. If possible, ask the patient to remain still. Alternatively, check whether the sensor is securely applied and replace it if necessary; use *C-LOCK* ECG synchronization; move the sensor to a new site; use a type of sensor that tolerates more patient motion; or set the N-200 for Mode 3.

• The patient may have a pronounced dicrotic notch, which causes the pulse rate measurement to double. Try another sensor site.

• If *C-LOCK* ECG synchronization is in use, an artifact or poor quality signal may be present on the ECG monitor. Adjust ECG leads to improve quality of ECG signal. Refer to the manual for that monitor.

• An electrocautery unit may be interfering. Refer to the discussion under Item 8.

12. The N-200 oxygen saturation measurement does not correlate with the value calculated from a blood gas determination.

• The calculation may not have been correctly adjusted for the effects of pH, temperature, $PaCO_2$, 2,3-DPG, or fetal hemoglobin. Check whether calculations have been appropriately corrected for relevant variables. (For more information, see the discussion in the "Principles of Operation" section of this manual.) In general, calculated saturation values are not reliable as direct CO-Oximeter measurements.

- Accuracy can be affected by incorrect sensor application or use, significant levels of dysfunctional hemoglobins, intravascular dyes, bright light, excessive patient movement, venous pulsations, electrosurgical interference, and placement of a sensor on an extremity that has a blood pressure cuff, arterial catheter, or intravascular line. Observe all instructions, warnings, and cautions in this manual and in the sensor directions for use.

13. The N-200 oxygen saturation measurement does not correlate with a value measured by a laboratory CO-Oximeter.

    - Fractional measurements may not have been converted to functional measurements before the comparison was made. The *NELLCOR* N-200, as well as other two-wavelength oximeters, meters, measure functional saturation. Multi-wavelength oximeters, such as the IL282 CO-Oximeter and Corning oximeters, measure fractional saturation. Fractional measurements must be converted to functional measurements for comparison. The equation used to make this conversion may be found in the "Principles of Operation" section of this manual.

    - Close correlation requires that the blood sampling and pulse oximeter measurement be obtained simultaneously from the same arterial supply.

14. The OXYGEN SATURATION display is erratic and the ECG LOST display is flashing.

    - Excessive patient motion may have caused the ECG electrodes to become displaced, dislodged, or disconnected from the ECG cable. Check the electrodes and check the connections.

    - The ECG cable may have come loose from the patient module connector. Check the connection.

    - If the ECG signal is coming from an ECG monitor, the input cable may have become dislodged from the ECG IN/OUT connector on the back of the N-200. Check the connection.

15. Trend and event data are not available.

    - The memory battery may be discharged. Contact qualified service personnel or Nellcor's Technical Service Department.

    - The data in the trend and event memories may have been erased.

16. Trend or event data cannot be printed.

    - The N-200 BAUD RATE switch settings or the printer MODE SELECTION or RS-232C switch settings may be incorrect. Check them.

    - The cables may be improperly connected. Check them.

17. The *NELLCOR* N-9000 recorder/interface or *NELLCOR* N-8000 interface cannot be used.

    - The N-200 BAUD RATE or RS-232 FORMAT switch settings may be incorrect. Check them.

VI. PRINCIPLES OF OPERATION

The *NELLCOR* N-200 provides continuous, non-invasive, automatically calibrated measurements of both oxygen saturation of functional hemoglobin and pulse rate.

The instrument combines the principles of spectrophotometric oximetry and plethysmography. It consists of an electro-optical sensor that is applied to the patient and a microprocessor-based monitor that processes and displays the measurements. The electro-optical sensor contains two low-voltage, low-intensity light emitting diodes (LEDs) as light sources and one photodiode as a light receiver. One LED emits red light (approximately 660 nm) and the other emits infrared light (approximately 920 nm).

When the light from the LEDs is transmitted through the blood and tissue components, a portion of both the red and infrared light is absorbed by the blood and by each tissue component. The photodiode in the sensor measures the light that passes through without being absorbed, and this measurement is used to determine how much red light and infrared light was absorbed.

With each heart beat, a pulse of oxygenated arterial blood flows to the sensor site. This oxygenated hemoglobin differs from deoxygenated hemoglobin in the relative amount of red and infrared light that it absorbs. The N-200 measures absorption of both red and infrared light and uses those measurements to determine the percentage of functional hemoglobin that is saturated with oxygen.

Initially, light absorption is determined when the pulsatile blood is not present. This measurement indicates the amount of light absorbed by tissue and nonpulsatile blood, absorption that normally does not change substantially during the pulse. This is analogous to the reference measurement of a spectrophotometer. Absorption is then measured following the next heartbeat, when the pulsatile blood enters the tissue. In that measurement, the light absorption at both wavelengths is changed by the presence of the pulse of arterial blood.

The *NELLCOR* N-200 then corrects the measurements during the pulsatile flow for the amount of light absorbed during the initial measurements. The ratio of the corrected absorption at each wavelength is then used to determine functional oxygen saturation.

***C-LOCK* ECG Synchronization:** *C-LOCK* ECG synchronization enables the N-200 to use an ECG signal as a reference point for identifying the pulse and synchronizing saturation measurements. This enhances the performance of the instrument in the presence of patient movement and when the patient's perfusion is poor, as discussed below.

When the N-200 is provided with ECG input, it is receiving two separate signals that reflect cardiac activity: an optical signal from the sensor and an electrical signal from the ECG. When an ECG R-wave is detected, an optical pulse will be detected at the sensor site a short time later. The length of this delay varies with the patient's physiology, the heart rate, and the location of the sensor. However, for a given patient, the length of the delay is relatively stable. Through *C-LOCK* ECG synchronization, the N-200 uses that time relationship to identify "good" pulses and reject nonsynchronized artifacts (e.g., random motion).

If the N-200 is not provided with an ECG signal, or if that electrical signal deteriorates to such an extent that it can no longer be used by the instrument, then the optical pulse alone is used to determine pulse rate and initiate saturation measurements, if that optical signal is available. *C-LOCK* ECG synchronization resumes when an adequate ECG signal again is being tracked.

Automatic Calibration: Patented automatic calibration mechanisms are incorporated into the N-200 pulse oximetry system (U.S. Patent 4,621,643). Each sensor is calibrated when it is manufactured: the effective mean wavelength of the LED is determined, coded into a calibration resistor, and then checked. That calibration resistor is read by the N-200 software to determine the calibration coefficients that should be used for the measurements obtained by that sensor.

The N-200 is automatically calibrated each time it is turned on, at periodic intervals thereafter, and when a new sensor is connected. Also, the intensity of the LEDs in the sensor are adjusted automatically to compensate for differences in tissue thickness.

Functional vs. Fractional Saturation: Because the N-200 measures functional oxygen saturation, it may produce measurements that differ from those of instruments that measure fractional oxygen saturation.

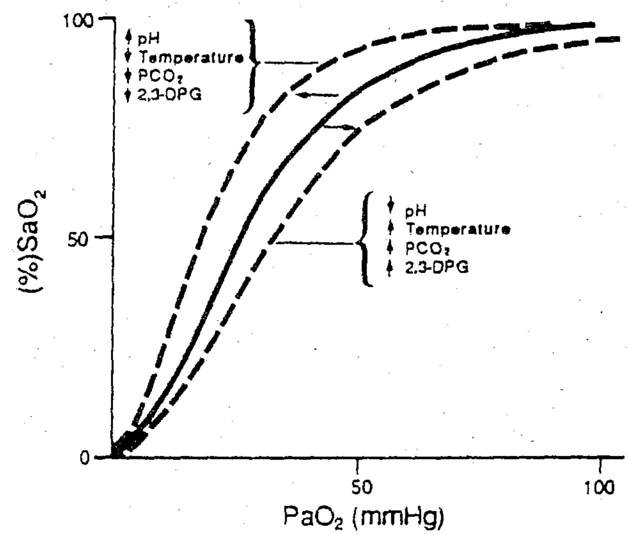
Functional oxygen saturation is defined as oxygenated hemoglobin expressed as a percentage of the hemoglobin that is capable of transporting oxygen. Because the N-200 uses two wavelengths to measure saturation, it measures only oxygenated and deoxygenated (i.e., functional) hemoglobin.

In contrast, some other laboratory instruments, such as the IL282 CO-Oximeter, report fractional oxygen saturation values. Fractional saturation is defined as oxygenated hemoglobin expressed as a percentage of all hemoglobin that is measured, whether or not that hemoglobin is available for oxygen transport. Measured dysfunctional hemoglobins are included in this calculation.

Consequently, when measurements from the N-200 are compared with those from another instrument, it is important to consider whether that other instrument is measuring functional or fractional saturation. If the other instrument measures fractional saturation, those measurements may be converted to functional saturation, using the following equation:

$$\text{functional saturation} = \text{fractional saturation} \times \frac{100}{100 - (\%\ \text{carboxyhemoglobin} + \%\ \text{methemoglobin})}$$

Measured vs. Calculated Saturation: When oxygen saturation is calculated from blood gas PaO2, the calculated value may differ from the oxygen saturation measurement of the N-200. This is because an oxygen saturation value that has been calculated from blood gas PaO2 has not necessarily been correctly adjusted for the effects of variables that shift the relationship between PaO2 and saturation. These variables include temperature, pH, PaCO2, 2,3-DPG, and the concentration of fetal hemoglobin. The effects of these variables are indicated below.



VII. UNPACKING AND CHECKING THE N-200

Notify the carrier immediately if the N-200 shipping carton is damaged. Carefully unpack the instrument and its accessories. Confirm that the following are included:

1 *NELLCOR* N-200 pulse oximeter, including monitor and powerbase (120 volts)

1 patient module (model C-200-13; 4 meters/13 feet)

1 power cord, 120 VAC U-ground hospital plug

1 ECG patch cord (optional)

1 three-lead ECG cable

1 ECG lead wire set

3 ECG electrodes

2 Operator's Manuals

1 assortment pack of *OXISENSOR* oxygen transducers

Inspect each component. If any component is missing or damaged, contact Nellcor's Customer Service Department at 800 433-1244 (U.S.) or 800 351-9754 (CA).

Test all functions of the N-200 as described in the "Operating the N-200" section of this manual. If a difficulty occurs, refer to the "Troubleshooting Guide." If that does not resolve the difficulty, contact qualified service personnel or Nellcor's Technical Service Department.

If it is necessary to repack and ship the N-200, disconnect the patient module, unplug the sensor, and wrap each separately. Pack the instrument and its accessories in the original shipping carton.

VIII. SERVICE AND MAINTENANCE

The *NELLCOR* N-200 pulse oximeter requires no routine service other than that which is mandated by the operator's institution. The "Troubleshooting Guide" in this manual discusses potential difficulties, their possible causes, and suggestions for resolving them. Complete service instructions, including preventative maintenance checks, are contained in the *NELLCOR* N-200 pulse oximeter service manual.

If necessary, Nellcor's Technical Service Department may be reached at 800 433-1244 (U.S.) or 800 351-9754 (CA).

To respond to questions, the Technical Service Department may need the version code of the monitor and powerbase software. To find the monitor version code, press the HIGH SAT and AUDIO ALARM OFF buttons, and turn the control knob until "0" appears in the OXYGEN SATURATION display; the code will appear in the PULSE RATE display. To find the powerbase version code, when the power-base is connected to the monitor, again press the HIGH SAT and AUDIO ALARM OFF buttons, and turn the control knob to the left until "Pb" appears in the OXYGEN SATURATION display; the version code will appear in the PULSE RATE display.

Warning: The N-200 contains no user-serviceable parts. Removing the covers or disassembly will expose hazardous voltages. To avoid injury or instrument damage, do not attempt to disassemble or service the instrument unless you are qualified to do so.

Caution: To reduce the risk of electric shock, do not remove cover. Refer servicing to qualified personnel.

Warning: For continued protection against fire, replace the fuse only with one of the same type and rating.

To clean the surfaces of the N-200 and its accessories, use 70% isopropyl alcohol or a commercial cleaning solution such as Fantastic® or Formula 409®

Do not immerse the instrument or its accessories. Do not use caustic or abrasive cleaners that will damage the housing.

If it is necessary to return the N-200 to Nellcor, disconnect the patient module, unplug the sensor, and wrap each separately. Pack the N-200 and its accessories in the original carton.

IX. SPECIFICATIONS

Configuration

Components: Monitor unit with detachable powerbase, patient module, hospital-grade power cord.

Readout: Two three-digit red LED displays for oxygen saturation and pulse rate.
Red 16-segment LED display for pulse amplitude indicator (pulse amplitude).
Red LED annunciators for LOW BATT, PULSE SEARCH, HIGH SAT, LOW SAT, HIGH RATE, and LOW RATE alarms, ECG LOST, and AUDIO ALARM OFF.
Yellow LED annunciators for BATT IN USE and ECG IN USE.

Controls: Control knob to adjust volume and set alarms, and five buttons to select alarms and disable audio alarm.

Rear-panel switches for adult/neonatal alarm settings, analog voltage output range (0-1 V or 0-10 V), analog saturation output scale (0-100% or 50%-100%, RS-232 format, baud rate; rear-panel buttons for printing trend data, printing event data, analog full scale output, and analog zero output.

Performance

Range:

Saturation Range = 0-100%
Pulse Rate Range = 20-250 beats per minute

Accuracy:

Saturation:	70%-100%:	± 2 digits
(%SaO2, ±1SD)	50%-70%:	± 3 digits
	0-50%:	unspecified
Neonates:	70%-95%:	± 3 digits
Heart Rate:	± 2 bpm:	± 1 digit

(See the "Qualifying Information" section of these specifications.)

Sensor:

Type: Compatible with *NELLCOR* sensors including *OXISENSOR* , *OXIBAND*, and *DURASENSOR* oxygen transducers

Wavelengths: 660 nm (red, nominal), 920 nm (infrared, nominal)

Heating: Power dissipation sensor; less than 50 milliwatts total heat dissipation by LEDs (typically less than 1°C temperature rise)

Tissue Range: *OXISENSOR* oxygen transducers: typical tissue thickness between LED and detector is approximately 5-20 mm for the D-25 and N-25, and approximately 3-12 mm for the D-20 and I-20 sensors.

OXIBAND oxygen transducer, model OXI-200N: typical tissue thickness between LED and detector is approximately 5-20 mm.

DURASENSOR oxygen transducer, model DS-100A: typical tissue thickness between LED and.detector is approximately 8-13 mm.

Alarms: Audio and visual alarms for high and low oxygen saturation, high and low pulse rate, loss of pulse, visual alarm for loss of ECG. Audio alarms are interrupted briefly for detected pulses and the volume is adjustable. Audio alarms can be disabled for a 60-second period with the AUDIO ALARM OFF button; disable period can be changed to 30-120 seconds, or the disable timer can be turned off (for permanent disable) with associated visual warning.

The initial default alarm settings that are in effect when the N-200 leaves Nellcor are,

Adult Mode:

High Sat:	100%	(adjustable 50-100)
Low Sat:	85%	(adjustable 50-100)
High Rate:	140 bpm	(adjustable 35-250)
Low Rate:	55 bpm	(adjustable 35-250)

Neonatal Mode:

High Sat:	95%	(adjustable 50-100)
Low Sat:	80%	(adjustable 50-100)
High Rate:	200 bpm	(adjustable 35-250)
Low Rate:	100 bpm	(adjustable 35-250)

To select different default alarm limits refer to the N-200 Service Manual.

High and low alarm limits cannot overlap.

Audio Pulse: When a sensor-derived signal is present, an audio beep sounds with each detected pulse; volume is adjustable with control knob; pitch is proportional to oxygen saturation.

When ONLY an ECG-derived signal is present, a higher-pitched beep sounds with each detected pulse; volume is adjustable with the control knob; pitch is NOT proportional to oxygen saturation.

Modes: Three response modes, selected by the control knob and LOW RATE/HIGH RATE buttons.

Mode 1: normal response (5-7 seconds)
Mode 2: fast response (2-3 seconds)
Mode 3: slow response (10-15 seconds, pulse rate is not indicated)

ECG: **Direct: Via patient module**

Input:	Defibrillator protected, differential, standard Lead II limb configuration
Bandwidth:	0.5 - 40 Hz
Input Range:	0.5 - 2.0 mV for QRS detection
Input Impedance:	>10 M ohms

Indirect: Via ECG in/out analog jack

Input:	Defib Sync or ECG out waveform from bedside ECG monitor. For optimum performance, waveform with positive deflection recommended.
Input Range:	0.5 – 15.0 V Minimum of 10 milliseconds wide at 50% of peak amplitude

CMRR: >100 dB at 60 Hz with 5 k ohm source imbalance

Data Output:

Optical: Fiber optic transmitter
Baud rate: 2400
Data format: compatible with *NELLCOR* N-9000 recorder/interface and *NELLCOR* N-8000 interface

Analog: 4 each; 3/32" phone jacks

Outputs:	SaO2 Pulse Rate Pulse Wave ECG wave out or ECG wave/defib sync in
Voltage:	0-1 V or 0-10 V (switch selectable)
Scale Set:	pushbuttons provided for 0 volts and full scale voltage
Range Set:	SaO2 0-100% SaO2 50%-100% (DIP switch selectable)
Accuracy:	± 20 mV at zero, ± 0.5% (F.S.), referred to front-panel display

Digital:

Type:	RS-232C
Connector:	9-pin "D"-type sub-mini (female)
Baud Rate:	DIP switch selectable from 1200, 2400, 9600, 19.2 K
Formats:	1. N-9000 Recorder 2. Full 3. Computer 4. Conversation 5. Beat to Beat 6. No Real-Time Output 7. Graphics Only Waveform data are available in N-9000 mode

Input/Output:

1) DIP switches
8 each for digital output/alarm set
2 each for analog scale/analog output voltage range

2) Pushbuttons - 4 each (momentary action)
- analog ZERO
- analog FULL scale
- TREND
- EVENT

DIP Switch	Function
7,8	Baud rate select
3,4,5	RS-232 format
1	Adult or neonatal alarm settings
2,6	Unused

DIP Switch	Function
1	0-100% or 50%-100% SaO_2 output scale
2	0-1 volt or 0-10 volt range

Environmental Requirements

Temperature:

Instrument: 0-40°C operating
0-50°C storage

Sensor: Within physiologic range (28-42°C) for accurate measurement

Humidity:	Any humidity/temperature combination without condensation
Altitude:	0-10,000 ft

Electrical Characteristics

Voltage:	100-120 VAC, ± 10%, 50/60 Hz
Power Consumption:	25 watts maximum 22 watts - monitor electronics 3 watts - powerbase electronics
Leakage Current:	50 uA maximum, power mains to ground 10 uA maximum, patient connector to ground 10 uA maximum, patient connector to mains

Battery:

Type:	Starved-electrolyte lead acid battery pack 3 each 2 Volt @ 2.5 AH - "D" cells
Battery Life:	2 hours minimum on full charge
Recharge Period:	14 hours minimum; (80% charge after 8 hours)
Charger Type:	Float voltage, 250 mA current limit

Physical Characteristics

Dimensions:	2.5" x 10" x 10" overall 2.5" x 10" x 7" (monitor) 2.5" x 10" x 3" (powerbase)
Weight:	8 lb overall 5 lb (monitor) 3 lb (powerbase)
Patient Module:	4 m (13 ft) long LEMO B-series 12 pin front panel of monitor

Qualifying Information

The *NELLCOR* N-200 pulse oximeter is calibrated to read oxyhemoglobin saturation (%SaO_2) of functional hemoglobin as compared to an IL282 CO-Oximeter. Significant levels of dysfunctional hemoglobins (e.g., carboxyhemoglobin, methemoglobin) may affect the accuracy of the instrument. Indocyanine green, methylene blue, and other intravascular dyes, depending upon their concentrations, may interfere with the accuracy of the instrument. Instrument performance may also be compromised by excessive patient movement, electrosurgical interference, or intense environmental illumination.

X. GLOSSARY

2,3-DPG:	2,3-diphosphoglycerate; a plentiful intermediate compound in the glycolytic energy production of red cells; 2,3-DPG binds to the beta chain of adult hemoglobin and thus shifts the oxyhemoglobin dissociation curve to the right; fetal hemoglobin does not contain beta chains and therefore is not shifted to the right
Alarm Limits:	Upper and lower settings for oxygen saturation and pulse rate; when the measurement exceeds the upper limit or falls below the lower limit, the alarms of the N-200 activate
Averaging Time:	The span of time during which an instrument averages incoming signals to obtain a mean measurement; the N-200 offers three averaging times, which correspond to Modes 1, 2, and 3
Carboxy-hemoglobin:	A species of dysfunctional hemoglobin; hemoglobin that has combined with carbon monoxide, which occupies the sites on the hemoglobin molecule that normally bind oxygen
Default Settings:	Pre-established settings that are in effect when an instrument is turned on and that remain effective until they are changed; the N-200 has different default alarm-limit settings for adults and neonates
Deoxygenated Hemoglobin:	Functional hemoglobin that is not combined with oxygen; also known as deoxyhemoglobin or reduced hemoglobin
Dysfunctional Hemoglobin:	Hemoglobin that is not capable of reversibly binding oxygen (e.g., carboxyhemoglobin or methemoglobin); also known as dyshemoglobin
ECG Synchronization:	*C-LOCK* ECG synchronization, by linking pulse detection to the preceding R-wave, enhances performance of the N-200 in a high-motion environment and when the patient's perfusion is poor; for additional information, refer to the discussion in the "Principles of Operation" section of this manual
Electrocardiogram:	ECG; a graphic tracing of the change in electrical potentials associated with activity of the heart muscle, as detected at the body skin surface
Event:	The event memory of the N-200 stores a "snapshot" of saturation, pulse rate, and pulse waveform data (sampled once each second); there are two types of events: alarm-limit events, which occur each time the saturation or pulse rate alarm activates, and user-defined events, which the operator initiates; for alarm-limit events, the snapshot starts 30 seconds before the beginning of the alarm state and ends 30 seconds after the end of the alarm state; for user-defined events, the snapshot starts 30 seconds before the beginning the event, it can last up to 60 minutes, and it can be ended prematurely; one hour of event data can be stored by the N-200

Event Limits: Upper and lower settings for oxygen saturation and pulse rate; when the measurement exceeds the upper limit or falls below the lower limit, data are stored in the event memory of the N-200

Fractional Oxygen Saturation: Oxygenated hemoglobin expressed as a percentage of all measured hemoglobin, including those dysfunctional hemoglobins that are measured

Functional Oxygen Saturation: Oxygenated hemoglobin expressed as a percentage of only the hemoglobin capable of transporting oxygen (oxyhemoglobin and reduced hemoglobin); dysfunctional hemoglobin is excluded from this calculation

Hemoglobin: The oxygen-carrying, iron-containing pigment of the erythrocytes; hemoglobin consists of identical half-molecules, each containing two polypeptide chains that differ in amino acid sequence; adult hemoglobin (HbA) contains alpha and beta chains; fetal hemoglobin (HbF) contains alpha and gamma chains

Hypoxemia: Insufficient oxygenation of the blood

Methemoglobin: A species of dysfunctional hemoglobin; the iron in methemoglobin is oxidized from the ferrous to the ferric state, which prevents it from functioning as a reversible oxygen carrier

Oximeter: A photoelectric instrument that measures the oxygen saturation of blood

Plethysmograph: An instrument that measures variations in the volume of an organ, part, or limb caused by pulsatile variations in the amount of blood present or passing through it

R-wave: An electrical spike in the ECG, which is caused by depolarization of the ventricles; a component of the QRS-complex (also, a pacemaker spike can be detected by the N-200 as an "R-wave," particularly when the ECG signal is provided through the rear-panel ECG IN/OUT connector; however, this normally does not affect performance adversely)

Sensor Site: The place on a patient's body to which the sensor is applied; each *NELLCOR* sensor has a recommended sensor site, and most also have an alternate sensor site(s)

Spectrophotometer: An instrument that estimates the quantity of colored material in a light path by determining the amount of light that is absorbed

Trend: The trend memory of the N-200 records oxygen saturation and pulse rate once each second and computes averages every five seconds; those averages are stored in the trend memory; up to 12 hours of trend data can be stored by the N-200

XI. WARRANTY

Nellcor Incorporated warrants to the initial Purchaser that each new pulse oximeter, interface, recorder/ interface, and *DURASENSOR* oxygen transducer (the "Warranted Products") purchased from Nellcor or a Nellcor-authorized distributor will be free from defects in workmanship and materials during its Warranty Period. The Warranty Period is one year from initial shipment of the Warranted Product to the Purchaser for all Warranted Products except *DURASENSOR* oxygen transducers and six months after initial shipment for *DURASENSOR* oxygen transducers.

Nellcor's only obligations under this warranty are (1) to repair or replace any Warranted Product (or part thereof) that Nellcor reasonably determines to be covered by this warranty and to be defective in workmanship or materials; and (2) to provide loaner equipment with respect to any such Warranted Product (or part) other than *DURASENSOR* oxygen transducers. All rights and obligations under this warranty are governed by the provisions set forth below.

To request repair or replacement under this warranty, Purchaser should contact Nellcor at 25495 Whitesell Street, Hayward, California 94545, 800 433-1244 or 800 351-9754 in California. If on the basis of the information provided by Purchaser, Nellcor reasonably believes that the defect is covered by this warranty, Nellcor will authorize Purchaser to return the Warranted Product (or part thereof) to Nellcor and, if the Warranted Product is other than a *DURASENSOR* oxygen transducer, will promptly ship a comparable loaner product for use by Purchaser during the period that the Warranted Product or part is at Nellcor's facility for service. Nellcor shall repair or replace Products, or parts thereof, reasonably determined by Nellcor to be covered by this warranty. Nellcor shall determine whether to repair or replace Products and parts, and all Products or parts replaced shall become Nellcor's property. In the course of warranty service, Nellcor may but shall not be required to make engineering improvements to the Warranted Product or part thereof.

Loaner Policy

Purchaser is responsible for any damage to or loss of any loaner equipment while it is at Purchaser's location. Purchaser must return loaner equipment within10 days after receiving the repaired or replacement Product, and agrees to pay Nellcor any charges imposed for failure to return the loaner equipment in accordance with Nellcor's standard loaner policy then in effect, provided that Nellcor has notified Purchaser of the terms of that policy.

Shipping Procedures

If Nellcor reasonably determines that a repair or replacement is covered by the warranty, Nellcor shall bear the costs of shipping the loaner Product and the repaired or replacement Product to Purchaser. All other shipping costs shall be paid by Purchaser. Risk of loss or damage during shipments under this warranty shall be borne by the party shipping the product.

Exclusions

This warranty does not extend to any Warranted Products or parts thereof that have been subject to misuse, neglect or accident; that have been damaged by causes external to the Warranted Products, including but not limited to failure of or faulty electrical power; that have been used in violation of Nellcor's instructions; that have been affixed to any nonstandard accessory attachment; or that have been modified or improperly disassembled, serviced or reassembled by anyone other than Nellcor.

Nellcor makes no warranty with respect to *OXISENSOR* oxygen transducers, any other disposable products or any other products that are not warranted products under an express written warranty issued by Nellcor, with respect to any products purchased from a person other than Nellcor or a Nellcor-authorized distributor or with respect to any product sold under a brand name other than that of Nellcor.

THIS WARRANTY, TOGETHER WITH ANY OTHER EXPRESS WRITTEN WARRANTY THAT MAY BE ISSUED BY NELLCOR, IS THE SOLE AND EXCLUSIVE WARRANTY AS TO NELLCOR'S PRODUCTS. THIS WARRANTY EXTENDS ONLY TO THE PURCHASER AND IS EXPRESSLY IN LIEU OF ANY ORAL OR IMPLIED WARRANTIES, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR AGAINST INFRINGEMENT. NELLCOR SHALL NOT BE LIABLE FOR ANY INCIDENTAL, SPECIAL OR CONSEQUENTIAL LOSS, DAMAGE OR EXPENSE DIRECTLY OR INDIRECTLY

SERVICE MANUAL

NELLCOR® N-200 PULSE OXIMETER

NOTICE:

This manual is provided for the purpose of servicing the *NELLCOR* N-200 pulse oximeter. It is provided without charge by Nellcor Incorporated. This manual contains unpublished proprietary information and is not to be copied, transmitted, or used for any other purpose. Additional copies are available upon request by writing the Company at the address below.

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

Nellcor Incorporated
25495 Whitesell Street
Hayward, California 94545 U.S.A.
1–800–NELLCOR

5380A-1287

S/N:

F8812039

WARNING: The *NELLCOR* N-200 pulse oximeter contains no user-servicable parts. For protection against electrical hazard, refer all servicing to qualified personnel.

WARNING: For continued protection against fire hazard, replace fuses only with the same type and rating.

WARNING: The *NELLCOR* N-200 pulse oximeter is a patient-connected medical device. An isolated patient connector is provided to protect the patient from potentially dangerous electrical potentials or ground paths. To protect the integrity of this connection, the procedures and part specifications contained in this manual must be adhered to.

TABLE OF CONTENTS

Introduction

SECTION 1

INTRODUCTION

This manual covers test and repair of the *NELLCOR®* N-200 pulse oximeter. The N-200 is identified by its two-piece construction. The front part of the N-200 is the monitor; the back part of the N-200 is the powerbase. The monitor receives, processes, and stores patient pulse data; the powerbase provides AC power to the monitor and drives peripheral display and recording devices. Communication between monitor and powerbase is provided by a bi-directional optical link.

This manual is provided to qualified service personnel for the purpose of maintaining and repairing the *NELLCOR* N-200 pulse oximeter. Dangerous voltages are exposed when the cover is removed, certain components are critical to maintain patient isolation, and improper repair procedures can adversely affect the instrument's calibration. For the protection of service personnel and patients, the procedures described in this manual are only to be performed by qualified service personnel.

Repair and testing of the instrument exposes service personnel to potentially hazardous voltages, and improper repair or adjustment may affect the accuracy or patient protection associated with the instrument. Where appropriate, warnings or cautions have been included in the text of this manual. The term **"WARNING"** is used to bring attention to a procedure or precaution that is important to ensure the safety of the service personnel or possibly the patient. The word **"CAUTION"** brings attention to a procedure that should be carefully followed in order to prevent damage to the instrument or an error in calibration or performance. It is important that these warnings and cautions be read carefully and followed.

Description of
Instrument

SECTION 2

DESCRIPTION OF THE INSTRUMENT

The *NELLCOR* N-200 pulse oximeter is intended for continuously monitoring arterial oxygen saturation and pulse rate. The measurement is made non-invasively by applying a reusable clip-on or disposable adhesive-attached sensor to a finger or other site on the patient to be monitored.

The instrument is a portable unit, weighing about 8 pounds total, with a self-contained battery intended for operation for periods of up to 2 hours during power failures or transport. The battery is recharged whenever the unit is connected to AC power, and is fully recharged in 14 hours.

Front panel controls allow adjustment of the beeper volume, alarm volumes, alarm disabling, and adjustment of alarm limits for high and low oxygen saturation, and high and low pulse rate. A connector is located on the front panel for connection of the patient module assembly. The standard patient cable is 4 meters in length and is terminated by a module containing a preamplifier and sensor and ECG connectors. The entire patient module assembly is isolated from ground with a maximum leakage current of 10 microamperes. This provides safety for the patient from currents generated by faulty equipment, e.g., defibrillators or electrosurgical units.

WARNING: To assure continued patient safety, the patient module or sensors must not be replaced with any parts other than those designated or manufactured by Nellcor Incorporated.

A number of patient safety and labor-saving features are incorporated into the N-200:

- *C-LOCK*™ ECG synchronization enhances performance in high-motion environments, such as the ICU or the NICU.
- Three operating modes provide different averaging times, adapting the N-200 for use in the presence of varying levels of patient activity.
- The N-200 is equipped with two sets of default alarm limits, one for use in monitoring adults and one for neonates.
- Twelve hours of oxygen saturation and pulse rate data are stored in the trend memory, and one hour of saturation, pulse rate, and pulse perfusion data are stored in the event memory. These data can be provided to a variety of analog or digital output devices.
- Non-invasive *NELLCOR* sensors obtain measurements by optical means alone, using two light-emitting diodes as light sources. Specific sensors are available for use on neonates, infants, children, and adults.
- Patented automatic calibration mechanisms are incorporated in the N-200 (U.S. Patent 4,621,643 and others pending). The N-200 automatically calibrates itself each time it is turned on, at periodic intervals thereafter, and whenever a new sensor is connected. Instrument sensitivity changes automatically to accommodate a wide range of tissue thicknesses and skin pigmentations.

Internally, the monitor contains five printed circuit boards (PCBs), the battery, and a speaker. The largest circuit board (mounted on the top cover of the monitor) is the processor PCB, which contains the analog processing circuitry and the microprocessor with its associated circuitry. The power supply PCB is located on the back of the monitor. The battery charger PCB is located along the left side of the instrument chassis when viewed from the front. The display and driver PCBs are located immediately behind the front panel and contain the LED displays and front panel switches.

The powerbase contains a power supply transformer, a mother PCB and three daughter PCBs. The mother PCB is mounted vertically at the front of the powerbase (facing the monitor); the daughter PCBs are mounted horizontally and mate to the mother PCB. Details of instrument assembly and disassembly are found in Section 4.

Theory of Operation

SECTION 3

THEORY OF OPERATION

Theory of operation is presented in two parts. First, a general overview of the N-200's capabilities and the physical principles of its operation is presented. Next, the details of circuit operation are discussed.

3.1. GENERAL THEORY

The *NELLCOR* N-200 provides continuous, non-invasive, self-calibrated measurements of both functional oxygen saturation and pulse rate.

The instrument combines the principles of spectrophotometric oximetry and plethysmography. It consists of an electro-optical sensor that is applied to the patient and a microprocessor-based monitor that processes and displays the measurements. The electro-optical sensor contains two low-voltage, low-intensity light emitting diodes (LEDs) as light sources and one photodiode as a light receiver. One LED emits red light (approximately 660 nm) and the other emits infrared light (approximately 920 nm).

When the light from the LEDs is transmitted through the tissue at the sensor site, a portion of the light is absorbed by skin, tissue, bone, and blood. The photodiode in the sensor measures the light that passes through, and this information is used to determine how much light was absorbed. The amount of absorption remains essentially constant during the diastolic (nonpulsatile) phase and is analogous to the reference measurement of a spectrophotometer.

With each heart beat, a pulse of oxygenated arterial blood flows to the sensor site. This oxygenated hemoglobin differs from deoxygenated hemoglobin in the amount of red and infrared light that it absorbs. The N-200 continuously measures absorption of both red and infrared light and uses those measurements to determine the percentage of functional hemoglobin that is saturated with oxygen.

When the pulsatile blood is present, the light absorption at both wavelengths is changed by the presence of that blood. The *NELLCOR* N-200 then corrects the measurements during the pulsatile flow for the amount of light absorbed at the initial measurements. The ratio of the corrected absorption at each wavelength is then used to calculate functional oxygen saturation.

3.1.1. *C-LOCK* ECG Synchronization

When the N-200 is provided with ECG input, it is receiving two signals that independently reflect cardiac activity: one from the sensor and the other from the ECG. This enhances the performance of the instrument in the presence of patient movement, as discussed below.

There is a time delay between the electrical and mechanical activity of the heart. When an ECG QRS-complex is detected, a pulse will be detected at the sensor site a short time later. The length of this delay varies with the heart rate, the patient's physiology, and the location of the sensor. The N-200 measures this time delay, and, after a few pulse beats, calculates the average delay between the occurrence of the R-wave and the detection of the optical pulse by the sensor. This average delay is used to establish a "time window" during which the optical pulse is expected at the sensor site.

A pulse that is received within this time window is considered a real pulse and is processed. A pulse that is received outside the time window is considered an artifact and is rejected. Both the average delay and the time window are recalculated with each pulse beat to adjust for changes in the patient's physiology. If the ECG signal is irregular or noisy, then the optical pulse alone is used to determine pulse rate and initiate saturation calculations. Since artifacts often appear independently in the ECG and pulse signals, this method provides the most stable measurement of pulse rate and saturation.

If either the optical pulse or the ECG signal is markedly degraded or lost, the appropriate alarm activates and *C-LOCK* ECG synchronization is suspended. It will resume once both inputs have been re-established.

3.1.2. Automatic Calibration

Patented automatic calibration mechanisms are incorporated into the N-200 pulse oximetry system (U.S. Patent 4,621,643 and others pending). Each sensor is calibrated when it is manufactured: the effective mean wavelength of the red LED is determined, coded into a calibration resistor, and then checked. That calibration resistor is read by the N-200 software to determine the calibration coefficients that are used for the measurements obtained by that sensor.

The N-200 is automatically calibrated each time it is turned on, at periodic intervals thereafter, and when a new sensor is connected. Also, the intensity of each LED in the sensor is adjusted automatically to compensate for differences in tissue thickness.

3.1.3. Functional vs. Fractional Saturation

Because the N-200 measures functional oxygen saturation, it may produce measurements that differ from those of instruments that measure fractional oxygen saturation.

Functional oxygen saturation is defined as oxygenated hemoglobin expressed as a percentage of the hemoglobin that is capable of transporting oxygen. Because the N-200 uses two wavelengths to measure saturation, it measures only oxygenated and deoxygenated (i.e., functional) hemoglobin. It does not detect the presence of significant amounts of dysfunctional hemoglobin, such as carboxyhemoglobin or methemoglobin.

In contrast, some other laboratory instruments, such as the IL-282 CO-Oximeter, report fractional oxygen saturation values. Fractional saturation is defined as oxygenated hemoglobin expressed as a percentage of total hemoglobin, whether or not that hemoglobin is available for oxygen transport. Dysfunctional hemoglobin species are included in this calculation. Consequently, when measurements from the N-200 are compared with those from another instrument, it is important to consider whether the other instrument is measuring functional or fractional saturation.

3.1.4. Measured vs. Calculated Saturation

When oxygen saturation is calculated from blood gas PaO2, the calculated value may differ from the oxygen saturation measurement of the N-200. This is because an oxygen saturation value that has been calculated from blood gas PaO2 has not necessarily been correctly adjusted for the effect of variables that shift the relationship between PaO2 and saturation. These variables include temperature, pH, PaCO2, 2,3-DPG, and the concentration of fetal hemoglobin. Refer to the Operator's Manual for additional information.

3.2. CIRCUIT-LEVEL DESCRIPTION

Refer to Section 9 for the instrument schematic and block diagrams. The major circuit sections consist of:

- the patient module
- the analog processing circuitry and microprocessor circuitry
- the front panel display logic
- the battery charger and power supply
- the instrument powerbase, which contains the data communications interface circuitry.

Since the measurement of oxygen saturation requires light of two different wavelengths, two LEDs (one IR and one red) are used to generate light which is passed through the tissue at the sensor site into a single photodiode. The LEDs are illuminated alternately with a four-state clock. The photodiode signal, representing light from both LEDs in sequence, is amplified and then separated by a two-channel synchronous detector, one channel sensitive to the infrared light waveform and the other sensitive to the red light waveform. These signals are then filtered to remove the LED switching frequency as well as electrical or ambient noise, and then digitized by an analog to digital (A:D) converter. This digital signal is then processed by the microprocessor in order to identify individual pulses and compute the oxygen saturation from the ratio of the pulse seen by the red wavelength compared to the pulse seen by the IR wavelength.

Throughout this section and on the schematics, active low logic signals are designated by an overbar above the signal name (for example, "$\overline{\text{SIGNAL}}$").

3.3. PATIENT MODULE

The patient module contains preamplifiers for the saturation (SAT) and electrocardiogram (ECG) signals (refer to SCHEMATIC PATIENT MODULE PCB). Power for the circuitry is ± 15 V generated by the processor board.

The drive current for the pair of sensor LEDs is supplied from the instrument, generated on the processor board (VIR and VRED on SCHEMATIC PROCESSOR PCB, SHEET 4). This waveform is a bipolar current drive which is passed through the patient module to the back-to-back sensor LEDs. A positive current pulse drives the IR LED and a negative current pulse drives the red LED. The drive current is controlled by a feedback loop on the processor board in response to photodetector response.

The detector photodiode generates a current proportional to the amount of light received. SAT preamplifier U2 is a current to voltage (I:V) converter in an inverting configuration that converts the DETECTOR current to a SAT voltage signal. The conversion ratio is 250 mV/µA. Voltage regulator VR1 biases the preamplifier to approximately +8.5 V output for 0 current input. This bias increases the swing of the I:V converter to an effective output swing of +8.5 V to -10 V. The additional voltage headroom is necessary for high ambient light conditions.

Instrumentation amplifier U1 preamplifies the ECG signal. Gain of the amplifier is set for approximately 30. Neon lamps DS1, DS2, and DS3 are used to protect U1 from potentially damaging high-energy pulses which may result from defibrillation procedures. Series resistors R1 and R2 provide further isolation from high transient currents. Diodes CR1 through CR4 shunt high-voltage transients to the low-impedance power supplies. Resistors R3 and R4 pull the input signal lines to the power supply voltage levels when an ECG signal lead has become detached.

Common mode signals A1 and A2 from U1 are summed through R9 and R10, amplified, and inverted through operational amplifier U2. The output of U2 is fed back to the patient to maintain the patient at a constant potential and eliminate common mode signals from the input sensing leads. The ECG signal from U1 goes directly to the processor board.

The sensor contains a calibration resistor that codes the wavelength of the red LED mounted in the sensor. Because the wavelength of the red LED varies from one sensor to another, an error would result in the computation for oxygen saturation if not corrected for by the calibration resistor. This calibration resistor is connected directly through the instrument cable assembly to the processor board. Since the patient module assembly is used close to the patient environment, it is potted in epoxy to prevent any damage from moisture and is not repairable. In the event of failure or damage to the sensor contacts or to the cable or connector itself, the entire assembly must be replaced.

3.4. PROCESSOR PCB

The processor PCB contains most of the active circuitry in the N- 200, both analog and digital. Refer to SCHEMATIC PROCESSOR PCB, SHEETS 1 through 4, in the following discussion.

3.4.1. Digital Section

The digital section of the N-200 processor PCB is shown on SCHEMATIC PROCESSOR PCB, SHEET 1.

3.4.1.1. Microprocessor Subsection

The processing power of the N-200 pulse oximeter is contained within a standard 8088 minimum mode microprocessor RAM/ROM configuration. Program memory is contained in one 64K x 8 EPROM (U21) while the 32K x 8 system RAM (U15) provides a data buffer, stack, scratchpad, diagnostic, trend and event data memory functions. The RAM is mated to a "Smartwatch" socket, which provides time and date information used during trend and event recording, as well as battery back-up to prevent data loss when the instrument is in standby.

Processor (U8) pins 9 through 16, designated AD0-AD7, are multiplexed to alternately present the low-order address byte and a data byte. On the first clock cycle of an instruction, an address is present on these lines. The ALE signal (U8, pin 25) pulses high to latch the lower byte of the address in transparent octal latch U33. In the following clock cycles, data can flow bidirectionally on these lines.

The upper 4 address lines of U8 (A16 through A19) are also multiplexed, alternately carrying address and status information. Only the uppermost bit (A19) is used in the N-200 for address decoding. This pin (U8, pin 35) is at logic high when the system is addressing ROM space, and low when it is addressing RAM or performing input/output (I/O) functions. The processor's ALE signal latches this bit in flip-flop U3.

3.4.1.2. Memory Map

The entire processor system is memory mapped. That is, all devices on the 8088 data bus are accessed (read from or written to) at specific memory locations in the 1 Mbyte memory range. The upper 512 kbytes of memory are considered ROM space; the lower 512 kbytes are considered RAM and I/O space. ROM resides in the top 64 kbytes of memory, with the program starting at hex FFFF0 after reset. Since only 64 kbytes of the ROM space are actually used, images of the 64 kbyte ROM are repeated up to the 512 kbyte limit because memory is not uniquely decoded.

RAM begins at address 0 and extends for 32 kbytes. I/O functions reside directly above RAM, starting at address hex 8000. The I/O select lines coming from U17 and U23 are 16 addresses apart, ranging from hex 8000 to hex 80F0.

3.4.1.3. Wait State Generator

Two D-type flip-flops in U1 form a wait-state generator. A wait state of one clock cycle is generated whenever I/O is addressed (that is, whenever a peripheral device is accessed). Accessing RAM (addresses between 0 and 32k) generates no wait state.

3.4.1.4. Clock Generator

U2 produces a processor clock with the correct duty cycle, as well as a peripheral clock which drives UART U16 and the two timer chips U34 and U38. Because the 8088 processor U8 requires a 33% duty cycle clock, the crystal oscillator runs at 22.1184 MHz, three times the desired frequency. U2 divides the 22.1184 MHz signal by three and provides the correct duty cycle to U8.

A reset circuit composed of R1, CR1, and C19 ensure that U2, pin 11, is held low immediately following power-up. This maintains the logic at a known state while the power supplies and crystal oscillator stabilize.

3.4.1.5. Timer Circuits and UART

Additional peripheral devices include two 82C53 triple counter/timer chips U34 and U38 and UART device U16. The 82C53 sections control:

1. Display update interrupts to the 8088 at a 2.5 ms rate (also provides for real time references within the system program).
2. Baud rate for the 8251 UART (U16), which drives an optical data link for communication between the monitor and powerbase. The baud rate is set at 19.2 kbaud.
3. Audio frequency generation for the alarm beeper (TONE).
4. Clock frequency for the ECG switched-capacitor notch filter (NCLK).
5. Pattern generator clock frequency (the pattern generator is composed of U39, U35, and U28), which controls synchronous circuit operations.

3.4.1.6. Pattern Generator

The pattern generator (U39, U35, and U28) provides software selectable timing patterns used to control sync detector gating, LED control, and power supply synchronization triggers.

In operation, a preprogrammed bit pattern in EPROM U35 is continuously cycled through by counter U39, clocked by the divided down processor clock output. One of eight patterns can be selected through address lines A8-A10 on U35 through octal latch U40. Additional latch U28 serves to "de-glitch" the EPROM outputs by holding the last output byte while the counter steps to the next address. Various patterns within the EPROM are used to select LED/sync detector sampling speeds along with real time calibration patterns and diagnostic timing.

3.4.2. Analog Front End and LED Current Drive

The analog circuitry and LED drive circuitry is shown on SCHEMATIC PROCESSOR PCB SHEET 2.

3.4.2.1. Main Analog Signal Flow

The SAT signal from the patient module passes through a 50 kHz low-pass filter (one quarter of quad operational amplifier U27 in a 2-pole Butterworth configuration). The signal is then AC coupled to another U27 op amp, configured as a gain stage with unity gain. A variable attenuator composed of Digital-to-Analog Converter (DAC) U44 and amplifier U32 is followed by a noninverting amplifier (U32) with gain of 51. Together, the two circuits provide a programmable variable-gain function that can vary between 0 and 51. This gain is called INAMP (input amplifier) gain. In operation, the composite signal is always maximized by the operating software such that the largest possible signal is fed into the next stage of synchronous demodulation; this helps optimize the signal/noise (S/N) ratio.

Voltage regulator VR3 provides a low-noise 5 V DC supply for U44.

3.4.2.2. Sync Detector

The INAMP stage drives sync detector U32. If the $\overline{\text{SATINVERT}}$ signal is at logic low, U32, pin 10, is pulled to ground potential, and the stage becomes an inverting amplifier with unity gain. When $\overline{\text{SATINVERT}}$ is high, the stage becomes a noninverting voltage follower. Trimpot R123 is used to equalize the magnitudes of the inverting and noninverting gains.

3.4.2.3. Demultiplexer

The output of the sync detector drives both halves of U14. U14 demultiplexes the signal synchronously with the IRGATE and REDGATE steering pulses. Low-pass filters (R47 and C14; R52 and C30) suppress switching transients. The signal in each channel is then buffered by a unity-gain amplifier and low-pass filtered by two active-filter stages (each with two poles at approximately 20 Hz). The filters are slightly overdamped to improve step response.

The last stage in each channel is an offset amplifier with gain, which offsets the signals by a small positive voltage (approximately 0.25 V). This voltage is derived from VREF (set at 10 V) and the voltage dividers R50 and R46 (R80 and R74). Since the Analog-to-Digital Converter can only process 0 to 10 V signals, the positive bias provides a reference floor for analog-to-digital conversion stages that follow to ensure that the total chain offset errors of the op amps can never drive the outputs negative. Because the RED channel has twice the gain of the IR channel, the offset seen at TP10 is twice that seen at TP9 when no signal input is present.

3.4.2.4. Logic Flags

Several flags are produced in the analog section of the processor PCB that instruct the processor to vary circuit parameters (gain and LED drive currents) so that signal levels are kept safely below those which would saturate on-board electronics.

LEDHI — The SAT signal coming from the patient module can range from +8.5 V to -10 V without saturating the patient module's analog amplifiers. Comparator U20 compares the filtered (and halved) SAT signal to a -5 V reference. When the signal drops too low (SAT less than -10 V), the signal is too close to the patient module's negative power rail. This condition sets the LEDHI flag, which interrupts the processor. The processor then reduces the LED drive currents to avoid signal saturation.

INAMPHI — Following the INAMP programmable gain section, another comparator (U20) generates the INAMPHI interrupt. This circuit compares the signal to a 10 V reference. When the INAMP gain is set too high, the signal level exceeds 10 V, and the INAMPHI flag is set. The processor then reduces the gain of the INAMP stage to lower the signal level.

LEDLOW — If a sensor is exposed to bright light, the output of the patient module is driven negative an amount proportional to the ambient light exposure. This condition occurs because the ambient light causes an increase in the photodetector current from the sensor. The I:V converter in the patient module converts the increased current to a negative voltage.

When comparator U20 senses negative-going voltage signals more positive than its -5 V reference, it sets LEDLOW high. The processor polls the LEDLOW flag and increases drive current to the LEDs when LEDLOW is high for improved S/N ratio. This condition occurs when the patient removes the sensor from high ambient light exposure. A delay of up to 30 seconds is provided to prevent the LED current from changing in frequently changing ambient light conditions. The delay is implemented by passing the SAT signal through a fast-attack/slow-decay circuit formed by R95, R96, C74, CR8, and U27 before it reaches comparator U20. The orientation of diode CR8 causes the circuit to be sensitive only to negative-going signals.

3.4.2.5. LED Drive Circuitry

The analog switches in U19 allow the gating of separate drive voltages (VRED and VIR) for the red and IR LEDs so that the two LEDs can be run at different intensities. VRED and VIR are determined by the SAT signal level from the photodetector/patient module and set by the sample/hold subsection (SCHEMATIC PROCESSOR PCB SHEET 4, U18 and U11) on the processor board. Control signals $\overline{\text{RED}}$ and $\overline{\text{IR}}$ come from the pattern generator (SCHEMATIC PROCESSOR PCB SHEET 1, U28). Drive circuitry converts the VRED and VIR voltages to drive currents.

The voltage level at TP8 is translated to current for LED drive via a bridge driver circuit consisting of error amplifier U32 and the six signal transistors Q2 through Q7. The bridge output (J3 pins 7 and 9) goes to the back-to-back IR/red LEDs of the sensor assembly. In operation, the signals $\overline{\text{RED}}$ and $\overline{\text{IR}}$ select IR or red LED drive, determining the half of the bridge circuit that is active and forward biasing either the red or IR LED; Q3 and Q6 act as current boosters for U32, while Q2, Q4, Q5, and Q7 steer the current flow. The current through the LEDs is sensed by resistor R12 and fed back to pin 13 of error amp U32, thus maintaining a constant current proportional to voltage at TP8 and independent of the +5 V supply that powers the bridge. Maximum LED current is approximately 50 mA.

3.4.3. ECG Front End

Refer to SCHEMATIC PROCESSOR PCB SHEET 3 in the following discussion.

3.4.3.1. Active Filters

The ECG signal from the patient module is conditioned by 5 stages of active filtering. The total gain of the chain of active filters is approximately 32.

The ECG is first low-pass filtered by U12 and associated circuitry. The two filter poles are set at 40 Hz and the gain is equal to 1.

U6 is a switched-capacitor notch filter with a gain of 0.32. Capacitor switching frequency (NCLK) is derived from timer IC U34 (PROCESSOR PCB SHEET 1), and is set by the processor to remove AC power line interference. (See Section 3.4.3.4., Power Line Frequency Sensing.)

A second 2-pole, 40-Hz low-pass filter follows the notch filter. This filter removes the switching transients inherent in switched capacitor filter U6.

A high-pass filter (U12) with gain of 101 and cutoff frequency 0.5 Hz follows the second low-pass stage. Because this filter stage has a long time constant, a processor control input ($\overline{ECGZERO}$) resets the filter by discharging the filter capacitors. Reset occurs under the following conditions: if a lead comes loose from the patient (or the ECG signal is contaminated by patient muscle contractions), the ECG signal baseline can be driven into a railed condition. This occurs because of the high (approximately 1000) combined gain of the patient module and ECG front end filters. When the ECG baseline rises too much, the processor temporarily brings $\overline{ECGZERO}$ low to reset the filter.

3.4.3.2. Offset Amplifier

An offset amplifier (U12) biases the filtered ECG signal by +5 V so that the A:D converter can digitize the entire waveform (the A:D converter can only process positive analog signals). The output of the offset amplifier (ECG') is digitized by the A:D converter and provided as a data output by the powerbase.

3.4.3.3. Detached Lead Indicator

A 3-stage circuit composed of absolute-value amplifier U5, voltage comparator U4, and D-type flip-flop U3 generates the LEADOFF flag. The circuit examines the condition of the ECG signal at the input to the switched-capacitor notch filter U6, after it has undergone one stage of lowpass filtering.

A detached lead is sensed as follows: within the patient module, a biasing resistor network drives the ECG signal to one of the supply rails (±15 V) if one or both ECG signal leads becomes detached from the patient. If the signal is driven to the negative supply rail, it is converted to a positive voltage by absolute value amplifier U5. The output of this circuit is compared to a 10 V reference by comparator U4. A voltage in excess of 10 V drives the output of U4 low, setting and latching flip-flop U3 through NAND gate U10. When the flip-flop has latched, the LEADOFF logic signal is set high, notifying the processor that a lead has come loose. When the processor polls LEADOFF and discovers that it is at a logic high, it stops using the ECG R-wave as a gating mechanism and lights an LED on the instrument front panel to notify the user that the ECG signal has been lost.

The processor clears the flip-flop with $\overline{\text{CLRLO}}$ after a high LEADOFF signal has been recognized. NAND gate U10 is provided to latch the flip-flop during brief (intermittent) lead-off conditions.

3.4.3.4. Power Line Frequency Sensing

The mains power AC signal going into the power supply board is transformed to 9.2 VRMS and sensed by one-volt-crossing comparator U20. The one-volt-crossing detector produces the logic signal AC, which interrupts the processor at the frequency of the AC power line. This signal is used to set notch filter U6 to the line frequency, automatically adjusting for 60 Hz or 50 Hz power.

3.4.4. A:D/D:A Subsection

The A:D/D:A subsection is shown on SCHEMATIC PROCESSOR PCB SHEET 4.

The A:D/D:A subsection performs both analog to digital and digital to analog conversions. A unique feature of the design is the ability to subtract variable DC offsets and post-amplify signals prior to A:D conversion. This allows for accurate measurements of small modulation levels on large DC levels without slow-response AC coupling.

3.4.4.1. A:D Conversion

The sequence of a typical A:D conversion routine is as follows:

A) The 8088 processor selects an analog channel for conversion by writing to 8-to-1 analog multiplexer U24. Signals available for conversion are:

IR'	the demultiplexed and filtered IR detector channel signal
RED'	the demultiplexed and filtered RED detector channel signal
ECG'	the filtered ECG waveform
VCAL'	the filtered voltage from the calibration resistor within the sensor
VPS	the power supply voltage, used to determine whether the system is running on AC power or batteries and to check the battery voltage when the instrument is operating on battery power
ISEG	a voltage level from the display driver board, used to detect bad segments or light bars on the display during power-up test
VREF	approximately 10 V reference voltage used for board alignment
GROUND	analog ground potential used for board alignment.

B) Set programmable amplifier U30 gain by writing to latch U42.

C) Set desired analog offset value to be subtracted at U25, pin 2, by writing two bytes (low byte, high nybble) to 12-bit bus-compatible DAC U43 (12 bits, 0-10 V).

D) Now a scaled analog value is present at the output of programmable gain amplifier stage U37, pin 1, (TP3). The offset voltage has been subtracted by differential amplifier U25 and amplified by programmable amplifier U30 and U37. The total range of programmable gain is 1/8 to 16.

E) Triggering the sample and hold line (S/H) causes U36 to hold the scaled voltage for A:D conversion.

F) The 8088 processor begins executing a successive approximation routine (SAR).

G) The SAR performs a binary search sequence by setting up a voltage on the D:A converter U43 which is compared to the held signal voltage via comparator U29. The result of this comparison is polled by the processor via buffer U41.

H) The SAR continues until the least significant bit has been set. Each 12-bit conversion is accomplished in approximately 100 µs.

3.4.4.2. D:A Conversion

The analog sample/hold circuits formed by analog demultiplexer U18 and quad operational amplifier U11 are used to update and store the following four analog signals:

- VIR, which controls the IR LED brightness
- VRED, which controls the red LED brightness
- VOLUME, which controls the speaker volume.
- RWTHRESHOLD, not used.

In operation, the processor sets up an analog voltage on analog demultiplexer U18, pin 9, by writing to DAC U43. U18 is enabled through U18, pin 3, and the processor selects which output is written with address lines A0 through A2. When U18 is enabled, the voltage at U18, pin 9, is routed to one of the four outputs S1 through S4, charging storage capacitor C39, C41, C42, or C43. When U18 is disabled, the capacitor voltage is held by the very low leakage follower op amp U11 until the next update.

3.4.5. Timing and Control

Most processor timing and control flags are generated in circuits shown on SCHEMATIC PROCESSOR PCB SHEET 2 and 3. Processor timing is affected by two types of logic flags:

- Polled processor I/O signals
- Processor interrupts, which may occur asynchronously.

Many of these flags are discussed elsewhere in this section and all are summarized below.

3.4.5.1. Polled Processor Flags

Buffer U41 allows the 8088 processor to poll the following logic flags:

SWITCH indicates the state of the front panel switch (logic low indicates ON position)

LEADOFF indicates that an ECG lead has become detached, and that the ECG signal from the patient module was near saturation level as a result

LEDLOW indicates that LED drive currents should be increased to increase SAT S/N ratio

DACMP the output of voltage comparator U29, used in SAR A:D conversion

Four jumpers W2, W3, W4, W5, which are selectively installed to place the processor in various diagnostic modes.

3.4.5.2. Interrupt Processor Flags

AC interrupts the processor at the frequency of the AC power line

LEDHI instructs the processor to decrease the LED drive currents in the presence of ambient light to avoid SAT signal saturation

INAMPHI indicates that the INAMP gain is set too high. The processor then reduces the gain of the INAMP stage to lower the signal level to avoid saturation

TxRDY signals that UART U16 is ready to transmit another character

RxRDY signals that UART U16 has received a new character

INT real-time interrupt from interrupt controller U22

3.5. FRONT PANEL DISPLAY

Front panel display is accomplished by two circuit boards:

- Driver PCB, which contains drive circuitry for the display LEDs
- Display PCB, which contains the display LEDs and pushbuttons.

3.5.1. Driver PCB

The driver circuit board is shown on SCHEMATIC DRIVER PCB. Refer to this schematic in the following discussion.

During power-up, CR2, R10, and C11 provide a short-duration reset pulse to all latches on the driver board. This reset pulse clears all front-panel display elements.

Two different mechanisms are used to drive the display:

- digit and bargraph drivers
- drivers for the lightbars used with other front-panel indicators such as "PULSE SEARCH" and "AUDIO ALARM OFF."

The phase relationship between the two channels provides an UP or DOWN count command to the counter, depending on which way the knob is turned (clockwise rotation results in count-up commands).

To detect a change in the U/D counter, the processor reads the twos-complement value of the counter's output and adds it to its accumulated turns count. After it accumulates the counter value, the processor generates a signal into the LOAD line of U5 to clear it for the next count value.

3.5.1.4. Power-Up Display Element Test

Differential amplifier U7 senses the power return line of driver ICs U8, U9, and U11 by monitoring the voltage across resistor R9. The sensed voltage is proportional to the current flowing through the driver ICs. The voltage is amplified with a gain of 10 and is provided to the A:D converter as signal ISEG (PROCESSOR PCB SHEET 4, U24). The processor digitizes ISEG and uses it during the power-up display test to determine whether any display element has a shorted or open LED segment.

3.5.1.5. Speaker Driver Circuit

The sample/hold VOLUME signal from the processor (SCHEMATIC PROCESSOR PCB SHEET 4, U11) controls the amount of current going into the speaker's SPEAKER(+) lead. The TONE signal (SCHEMATIC PROCESSOR PCB SHEET 1, U38 and U9) switches FET Q2 to alternately connect or disconnect the SPEAKER(-) lead from ground. The frequency of the TONE signal determines the pitch of the sound produced. The harsh-sounding square wave of TONE is softened by filter capacitor C6. Diode CR1 suppresses transients from the inductive speaker load. Transistor Q1 supplies a current boost for the U7 operational amplifier.

3.5.2. Display PCB

The display circuit board is located immediately behind the front panel and contains the numeric LEDs, the LED indicator lamps, the control buttons and the control knob, as well as associated current limiting and pull-up resistors.

3.6. POWER SUPPLY PCB

The power supply circuitry is shown on the SCHEMATIC POWER SUPPLY PCB drawing.

The power supply board contains two switching power supplies in flyback converter configuration. The supplies are capable of providing 2 A at +5 V, 100 mA at +18 V, and 100 mA at -18 V.

Pulse width modulator (PWM) U2 controls the +5 V supply; PWM U4 controls the +18/-18 V supply. The PWMs sense the DC output voltages through their INV (pin 1) inputs and control the pulse width at the gates of switching FETs Q2/Q4 and Q3. Voltage regulator VR1 provides 5 V power and a 5 V reference to the two PWMs. Schmitt inverters U3 provide low impedance active current drive to the somewhat capacitive gates of the FET switching transistors, minimizing drain rise and fall times.

Also resident on the power supply board is one half (monitor side) of the powerbase-monitor optical link, formed by diode DS1 and phototransistor Q1.

3.7. BATTERY CHARGER PCB

The battery charger PCB is shown on the SCHEMATIC BATTERY CHARGER PCB drawing. The battery charger PCB contains two major circuits:

- ON/STDBY control circuitry
- Battery charger circuitry

3.7.1. ON/STDBY Control Circuit

The ON/STDBY control circuit is shown on the bottom portion of the schematic.

The ON/STDBY switch J1 is shown in the ON position. It does not switch power. Rather, it provides a logic control signal (SWITCH) that is polled by the main processor through a tri-state buffer (U41 on SCHEMATIC PROCESSOR PCB SHEET 4). When the processor senses a change in switch position from ON to STDBY through this signal, it executes a shutdown procedure. The ON mode is activated by bringing the gate of FET switch Q1 high, which provides a low impedance connection between power supply ground (labeled "P") and signal ground. STDBY mode is activated by cutting off Q1. Power supply voltage, VPS, may be either the battery voltage or the rectified and filtered AC voltage from the powerbase, depending on the mode of operation.

In the following sections, the circuit is examined as the ON/STDBY switch is moved first from ON to STDBY, and then as the instrument is returned to the ON state.

3.7.1.1. ON State

In the ON state, capacitor C2 is discharged. The combination of R5 and C2 forms a watchdog timer that ensures processor control over instrument power. If C2 is allowed to recharge, pin 8 of U1 will go low, flip-flop U2 will be cleared, the gate of Q1 will go low, and the connection between power and signal grounds will be broken.

The processor keeps C2 from recharging by placing a negative pulse on the power supply enable line (PSEN) at least once every 150 ms. The pulse is AC-coupled through capacitor C1, its rising edge producing a narrow positive-going pulse on U1, pins 1 and 2. The resulting low pulse on U1, pin 3 periodically discharges C2 through diode CR4. Capacitor C1 ensures that only active transitions on PSEN, not static highs or lows, have an affect on the watchdog timer. The N-200 is thus placed in the STDBY state if an abnormal condition "hangs" the processor.

3.7.1.2. ON to STDBY

The ON to STDBY transition can occur either by placing switch J1 in position 1 (STDBY), or in response to a decline in battery voltage below approximately 5.6 V.

Placing J1 in the STDBY position causes the voltage on the polled SWITCH signal to rise. If this occurs, or if battery voltage falls below 5.6 V, the processor blanks the front-panel displays and executes an infinite loop routine that does not involve pulsing PSEN. As a result, watchdog timer capacitor C2 is not discharged, U1, pin 9, voltage rises, U1, pin 8, voltage falls, and flip-flop U2 is cleared. The resulting logic low at U2, pin 5, shuts off FET Q1, placing the instrument in the STDBY state.

3.5.1.1. Digit and Bargraph Drivers

A total of 8 components comprise the digit and bargraph displays (DIGIT 0 through DIGIT 5, BARGRAPH 0 and BARGRAPH 1). The drive signals for these displays are multiplexed.

Latch U12 and decoder U13 are used to select which digit or bargraph to update. Latch U10 and driver U11 determine which segments within the selected digit or bargraph are illuminated.

3.5.1.2. Lightbar Drivers

The lightbars are driven by latch circuitry and are not multiplexed. U3 and U8 drive lightbars with the following signals:

DP	lights decimal point in the 7-segment digital displays
ALMINH	lights AUDIO ALARM OFF lightbar
N/C	not connected
PLSSRCHLO	with PLSSRCHHI, lights PULSE SEARCH lightbar
PLSSRCHHI	with PLSSRCHLO, lights PULSE SEARCH lightbar
LOWSAT	lights LOW SAT lightbar.

U2 and U9 drive the remaining lightbars with the following signals:

HISAT	lights HIGH SAT lightbar
LOWRATE	lights LOW RATE lightbar
HIRATE	lights HIGH RATE lightbar
BATLO	lights LOW BATT lightbar
BATON	lights BATT IN USE lightbar
ECGLOST	lights ECG LOST lightbar
ECGON	lights ECG IN USE lightbar

Decoder U6 takes the select line from the processor ($\overline{\text{DISPLAY}}$) and the three low address lines from the processor (A0, A1, and A2) and uses them to select a latch for display updating.

3.5.1.3. Front Panel Controls

Decoder U6 also lets the processor select octal buffer U1, which reads the state of inputs BUTTON 0 through BUTTON 4 and control knob rotation information relayed through UP/DOWN (U/D) counter U5.

The control knob consists of a two channel optical chopper, with the two channels mechanically 90 degrees out of phase to each other, and a dual channel optical slot detector. Schmitt trigger inverters U4 are used to clean up the signals from the knob, one inverter per channel. Channel A provides the clocking pulse for U/D counter U5; Channel B provides the direction (U/D) signal.

3.7.1.3. STDBY State

With the front panel switch in the STDBY state, VPS charges capacitor C5, and the SWITCH signal is maintained at logic high. SWITCH voltage is clamped to logic levels by protection zener diode CR8. Zeners CR1 and CR3 perform similar functions elsewhere in the circuit.

In STDBY, capacitor C2 is charged to 5 V through resistor R5.

3.7.1.4. STDBY to ON State

When the switch is moved to the ON position, C5 discharges through R7 and provides a momentary positive voltage pulse to Schmitt NAND gate U1, pins 4 and 5. In response, U1, pin 6, falls to logic low, discharging capacitor C2 through diode CR5, and setting D-type flip-flop U2. When the flip-flop is set, U2, pin 5, goes to logic high, placing positive voltage on the gate of FET switch Q1. Positive gate voltage on Q1 creates a low-resistance path between signal ground and power ground. As the switched voltage pulse from C5 discharges through R7, U1, pin 6, returns to a logic high, and C2 (the watchdog timer) begins recharging. The processor again begins to periodically discharge C2 to maintain the instrument in the ON state.

3.7.1.5. Voltage Regulator

Micropower voltage regulator U3 provides 5 V power to the battery charger PCB. Battery charger and ON/STDBY sensing circuitry is always on as long as the battery maintains sufficient voltage. Total current drain for the circuits on this board is approximately 40 µA.

3.7.1.6. Power-On Time Delay

A time delay provided by CR2, R6, and C3 at the gate of Q1 allows the power supplies to return to ground potential on occasions when the switch is cycled rapidly. Without this time delay, cycling the switch from ON to STDBY and back to ON might not allow the power supply voltage to fall far enough to generate a reliable power-up reset pulse to the processor (SCHEMATIC PROCESSOR PCB, SHEET 1, power-up reset circuit R1, CR1, and C19).

3.7.2. Battery Charger Circuit

Battery charger circuitry is shown in the upper part of the schematic.

AC power VCB+ and VCB- (12.5 VRMS) is taken from one of the power supply transformer secondary windings. It is rectified through diode bridge CR6 and filtered by C7 to provide a positive voltage for voltage regulator VR1. Current sensing resistor R15 provides current limiting through Q2 and Q3, cutting output voltage when current draw increases above 250 mA. Trimmer potentiometer R12 adjusts the nominal battery charging voltage to 7.2 V at TP5.

Diode CR9 prevents back-discharge through the regulating circuit when AC power is removed. With AC power disconnected, battery voltage can vary between 6.6 V and 5.6 V.

3.8. POWERBASE

The powerbase contains electronics for data communications for the N-200. It is composed of a mother PCB and three daughter PCBs.

3.8.1. Mother PCB

The mother board is shown in the SCHEMATIC MOTHER PCB POWERBASE.

The mother board provides power for the rest of the powerbase electronics. Bridge rectifier U2 charges filter capacitor C1. The AC voltage supplied at AC(±) is typically 7.5 V RMS. Voltage regulator U3 and current booster Q1 form a linear regulator that lowers the rectified AC voltage to +5 V.

Portions of the powerbase analog circuitry require ±15 V power. DC:DC converter U1 derives these voltages from the +5 V supply. U4 and U5 regulate these voltages down to ±12 V for use in the RS232 serial port.

Diode CR1 and phototransistor Q2 form one half (powerbase side) of the powerbase-monitor optical link.

3.8.2. Upper and Lower Daughter PCBs

The upper and lower daughter PCBs comprise the digital portion of the powerbase electronics.

3.8.2.1. Upper Daughter PCB

In the upper daughter PCB, 8085 processor U5 is driven by a 6.144 MHz crystal. A watchdog timer comprised of U6, C7, CR1, R5, Q1, R6, and C8 monitors the Serial Output Data (SOD) signal from U5, pin 4. If SOD does not produce a positive pulse within any 100 ms period, the watchdog timer sets the trap pin (U5, pin 6) which causes the 8085 to reset to address 0. Delay circuit CR2, R9, and C10 provides reset on power up.

Addresses presented on the multiplexed address/data bus of U5 are held by latch U2 when ALE (U5, pin 30) pulses high. 16-kbyte EPROM U4 is mapped starting at address 0, and 8-kbyte RAM U3 is mapped starting at HEX 4000. I/O for the upper daughter PCB is memory-mapped. Addresses are decoded on the lower daughter PCB.

Buffer U1 reads several digital signals:

- Four switches S1 through S4:

  —S1 and S2 (ZERO and FULL) set zero and full-scale on all analog outputs

  —S3 (TREND) initiates a TREND printout

  —S4 (EVENT) initiates an EVENT printout

- Jumpers W1 and W2, which, when installed, place the system in various diagnostic modes

- SCALE, which is the output of switch SW1 (SCHEMATIC MIDDLE DAUGHTER PCB POWERBASE), sets the SAT analog output range (0-100% or 50-100%)

- ECGTRIG, which is generated with every R-wave when an external ECG monitor is used (SCHEMATIC MIDDLE DAUGHTER PCB POWERBASE, U7, pin 7).

3.8.2.2. Lower Daughter PCB

U6 and U7 provide address decoding for all devices in the powerbase. I/O functions begin at HEX 8000.

Timer circuit U4 generates the real-time interrupt RST7.5 (U4, pin 10). U4 also produces the baud rates for UARTs U2 and U5. U5 drives the powerbase side of the monitor-powerbase optical link at 19.2 kbaud. Circuit elements associated with U5 provide signal conditioning for transmitting and receiving on the optical communication link. The link's LED and phototransistor are shown on the SCHEMATIC MOTHER PCB POWERBASE drawing.

U5, pin 23 ($\overline{\text{RTS}}$) is set low in software when the instrument is in an alarm condition, producing a logic high on U8, pin 11 (ALMOUT).

UART U2 drives the external RS232 interface and the fiber-optic output CR1. Level translator U3 performs the voltage level shift required for the TTL-RS232 interface. RxRDY (U2, pin 14) is returned to the main processor as RST5.5. Baud rates for both UARTs are derived from timer U4 (pins 13 and 17).

Buffer U1 reads 8-bit DIP switch S1, which is used to select the baud rate and data transmission format.

Connector J8 is a 9-pin miniature D type for the RS232 data link.

3.8.3. Middle Daughter PCB

The middle daughter board (shown on SCHEMATIC MIDDLE DAUGHTER PCB POWERBASE) contains all of the analog circuitry for the powerbase. For purposes of discussion, the board can be divided into two portions:

- the sample/hold circuit, with its associated DAC and analog demultiplexer
- the ECG input circuit with self-adjusting threshold. This circuit triggers processor U5 on the upper daughter board whenever an external ECG signal appears

3.8.3.1. Sample/Hold Circuit

Bus-compatible 8-bit DAC U5 is provided with a reference voltage of approximately -10 V by negative voltage regulator U6. Potentiometer R11 trims the output voltage of U1, pin 6, to +10.00 ± 0.02 V when DAC gain is set to maximum (the U1-U5 combination inverts the reference voltage). Switch SW1 selects a full scale analog output voltage of 1 V or 10 V by switching in the voltage divider formed by R2, R5, and R6.

U4 is a 1-to-8 bus-compatible analog demultiplexer. DAC output at U4, pin 9, feeds through to the selected output: U4 pin 5, 6, 7, or 8. Each output drives a separate sample/hold circuit made up of storage capacitors C4 through C7 and FET-input operational amplifiers U2 and U3. Zener diodes at the outputs of the sample/hold amplifiers protect against external short-lived transients. The 1 kohm output resistors quell oscillations which may occur when driving highly capacitive loads.

3.8.3.2. ECG Output

The ECG sample/hold channel is bidirectional. It differs from the other three channels in that the output signal is AC coupled (at a corner frequency of 0.5 Hz) to unity-gain buffer U2. Resistor R12 buffers the output of the unity-gain buffer when signals enter the ECG bidirectional port (J3). Incoming ECG signals are AC coupled through C16 and R25 to two parallel circuits:

- unity-gain buffer U3
- a peak follower circuit (composed of U2, CR9, C17, R27, and U3) with slow decay that stores the peak value of the R-wave from one peak to the next.

The peak follower circuit provides an adjustable threshold for sensing each ECG R-wave peak. Voltage comparator U7 produces a positive voltage pulse (ECGTRIG) when the ECG input signal exceeds the adjustable threshold determined by previous peak R-wave values.

Troubleshooting
and Assembly Guide

SECTION 4

TROUBLESHOOTING AND ASSEMBLY GUIDE

This section first discusses some potential difficulties, their possible causes, and suggestions for resolving them that do not require disassembly of the instrument. If the difficulty persists after following these suggestions, proceed to the subsections on detailed troubleshooting and disassembly. Refer if necessary to Section 5, Testing and Calibration. If qualified service personnel are not available, contact Nellcor's Technical Service Department at 1–800–NELLCOR.

NOTE: Instrument must be operating on AC power for the powerbase to be functional.

NOTE: To reset the powerbase microprocessor, disconnect and reconnect AC power.

4.1. INITIAL TROUBLESHOOTING PROCEDURES

1. The instrument does not turn on.

   - The AC power is not connected and the battery is discharged. Connect to AC power. If the problem persists, check the AC fuse. If this does not resolve the problem, contact qualified service personnel or Nellcor's Technical Service Department.

2. The instrument operates on AC power but not on the battery.

   - The battery is discharged. Fourteen hours are required to completely recharge the battery.
   - The battery pack is defective or the battery fuse is open. Contact qualified service personnel or Nellcor's Technical Service Department.
   - The battery charger is defective. Contact qualified service personnel or Nellcor's Technical Services Department.

3. The instrument operates on AC power, but the BATT IN USE indicator is always on.

   - The powerbase is disconnected from the monitor.
   - The instrument is not receiving AC power because the power cord is defective, is not connected, or is connected to a defective AC outlet. Replace the power cord, connect to AC power, or try another AC outlet.
   - The AC fuse on the rear panel is defective. Replace the fuse (see Section 4.4.1.).

4. The instrument displays an error message.

   - "Err 1" indicates defective RAM (data memory). See Section 3.4.1.1.
   - "Err 2" indicates defective ROM (program memory). See Section 3.4.1.1.
   - "Err 3" indicates a damaged display or indicator. See Sections 4.3.4. and 3.5.1.4.

WARNING: The instrument will operate if any button is pressed while "Err 3" is showing. However, because at least one segment or indicator is missing, the display or warning indicators may be incorrect. Continue to use the instrument only in an urgent situation and only if the defective segment(s) has been identified.

5. Perfusion indicator is not tracking pulse (PULSE SEARCH indicator is on) and saturation and pulse rate are not displayed.

   - The sensor is improperly applied to the patient or it is not plugged in. Check and correct if necessary.

   - The patient's perfusion is too poor for the instrument to detect an acceptable pulse.

     —check the condition of the patient.

     —use *C-LOCK* ECG synchronization.

     —test the instrument on yourself or another patient.

     —try the nasal *OXISENSOR*™ R-15.

   - The sensor is damaged. Replace with another sensor.

   - The patient module is damaged. Try another patient module. If no spare patient module is available, or replacement does not resolve the problem, refer to Sections 3.3 (Patient Module), 3.4.2 (Analog Front End and LED Current Drive), and 5.4 (Processor PCB Tests).

     NOTE: The patient module from a *NELLCOR* N-100 pulse oximeter (model C-13C/D or C-20C/D) may be used if R-wave synchronization is not being used or if the ECG signal is being provided via the rear panel connector.

6. Perfusion amplitude indicator tracks a pulse but there is no oxygen saturation or pulse rate display.

   - The sensor is damaged (red LED). Replace with another sensor.

   - The patient's perfusion is too low to allow the instrument to measure saturation and pulse rate (fewer than three or four bars on the perfusion display).

     —check the condition of the patient.

     —use *C-LOCK* ECG synchronization.

     —test the instrument on yourself or another patient.

     —try the nasal *OXISENSOR* R-15.

   - Excessive patient motion is making it difficult for the instrument to find the actual pulse pattern.

     —use *C-LOCK* ECG synchronization.

     —set the N-200 for Mode 3 (refer to Operator's Manual).

7. Patient module cannot be connected to the instrument.

   - Incorrect type of patient module is being used. Use a *NELLCOR* C-200-13 or C-200-20 patient module (or a C-13 C/D or C-20 C/D patient module if ECG input is not required or if it is being provided via the rear panel connector).

   - The connector pins are bent. Straighten them carefully or replace the patient module (the plug is internally sealed and should not be disassembled).

8. Saturation and/or pulse rate display are changing rapidly and pulse amplitude indicator is erratic.

   - Excessive patient motion is making it difficult for the instrument to find a pulse pattern.

     —use *C-LOCK* ECG synchronization, or

     —if possible, ask the patient to remain still, or

     —check whether the sensor is securely applied and replace it if necessary, or

     —use a type of sensor that tolerates more patient motion, or

     —move the sensor to a site with less movement, or

     —use Mode 3 if appropriate. (Refer to the N-200 operator's manual.)

   - An electrocautery unit (ECU) is interfering with performance.

     —the ECU cable and N-200 patient module are too close to each other. Move them as far apart as possible.

     —the sensor is too close to the ground pad or electrocautery site. Move sensor to a different site if possible.

     —the ECU and N-200 are plugged into a common power source. Operate the N-200 on battery, or plug it into a different AC outlet.

     —the sensor is damp or has been reused too often. Replace it with a new sensor.

     —use an *OXISENSOR* D-25, which has added insulation against electrosurgical interference.

   - Ambient light may be interfering with the sensor. Shield the sensor from bright ambient light with opaque material.

9. The ECG LOST indicator is displayed.

   - Check the condition of the patient.

   - The ECG electrode or electrode cable is loose or unplugged. Check connections.

   - If the ECG signal is supplied via the patient module, the patient module may be defective. Try another patient module. If that is not possible, see Sections 3.3., 3.4.3., and 5.4.

- If the ECG signal is provided via the rear panel connector, the input signal from the ECG monitor may be incorrect. Use 1 V/mV ECG analog output or defib sync pulse wave.

- AC power to the powerbase may have been interrupted (this applies only if the ECG signal is being supplied via the rear panel connector).

10. When ECG is connected, pulse rate is displayed but saturation is not.

    - The patient's perfusion may be inadequate.

      —check the condition of the patient.

      —test the instrument on yourself or another patient.

      —try the nasal *OXISENSOR* R-15.

11. The pulse rate displayed by the N-200 does not correlate with that of the ECG monitor.

    - Excessive patient motion is making it difficult for the instrument to find a pulse pattern.

      —use *C-LOCK* ECG synchronization, or

      —if possible, ask the patient to remain still, or

      —check whether the sensor is securely applied and replace it if necessary, or

      —use a type of sensor that tolerates more patient motion, or

      —move the sensor to a site with less movement, or

      —use Mode 3 if appropriate (refer to the N-200 Operator's Manual).

    - The patient has a pronounced dicrotic notch, which causes the pulse rate to double. Try another sensor site.

    - An artifact is present on the ECG monitor. Refer to the manual for that monitor.

    - An electrocautery unit is interfering (refer to item number 8).

12. Oxygen saturation measurement does not correlate with the value calculated from a blood gas determination.

    - The calculation has not been correctly adjusted for the effects of pH, temperature $PaCO_2$, 2,3-DPG, or fetal hemoglobin. In general, calculated saturation values are not reliable as correlative measurements.

      —check to see that the calculations have been corrected for relevant variables. For more information, see Section 3.1.4.

- Accuracy can be affected by incorrect sensor application or use, significant levels of dysfunctional hemoglobins, intravascular dyes, bright light, excessive patient movement, venous pulsations, electrosurgical interference, and placement of a sensor on an extremity that has a blood pressure cuff, arterial catheter, or intravascular line. Observe all instructions, warnings, and cautions in the N-200 Operator's Manual and in the directions for sensor use.

13. The oxygen saturation measurement of the N-200 does not correlate with a value measured by a laboratory CO-Oximeter.

    - Fractional measurements have not been converted to functional measurements before the comparison was made. The *NELLCOR* N-200, like other two-wavelength oximeters, measures functional saturation. Multi-wavelength oximeters, such as the IL282 CO-Oximeter and Corning oximeters, measure fractional saturation. Fractional measurements must be converted to functional measurements for comparison. The equation used to make this conversion can be found in Section VI of the N-200 Operator's Manual.

14. The OXYGEN SATURATION display is erratic and the ECG LOST display is flashing.

    - Excessive patient motion has caused the ECG electrodes to become displaced, dislodged, or disconnected from the ECG cable.

      —check the position of the electrodes and check the connections.

    - The ECG cable has come loose from the patient module connector.

      —check the connection.

    - If the ECG signal is coming from a bedside ECG monitor, the ECG input cable may have become dislodged from the ECG IN/OUT connector on the rear of the N-200, or from the bedside monitor.

      —check the connection.

15. Trend and event data are not available.

    - The memory back-up battery has been discharged.

    - The trend and event memory has been erased.

16. Trend or event data cannot be printed.

    - Switch settings are incorrect.

      —check the switch settings (see N-200 Operator's Manual).

    - Cables are improperly connected.

      —check the cable connections.

17. The *NELLCOR* N-9000 recorder/interface cannot be used.

- The switch settings are incorrect.

  —check the switch settings (see N-200 Operator's Manual).

4.2. DETAILED TROUBLESHOOTING PROCEDURES

4.2.1. Failure Modes

Instrument failures can be broadly divided into two classes.

- An outright failure of a component in one of the instrument modules will cause consistently incorrect operation or no operation at all. Use the Troubleshooting Summary below as a guide to diagnosing these failures. Subsequent sections dealing with repairs to each specific module can then be used to correct the diagnosed problem.

- The second, more difficult, problem deals with intermittent, noisy, or out-of-spec performance of the instrument. While these problems may also be related to a component failure, they can also be caused in some cases by noise in the environment (such as electrocautery or "Bovie" interference), an improperly functioning sensor or misapplication of the sensor by the user. If an instrument is suspected of having substandard performance, the procedures outlined in Section 5, Testing and Calibration, should be followed to help diagnose the problem.

WARNING: The procedures in this section require tests and adjustments made with the power applied and the cover removed. These tests should only be made by qualified service personnel and adequate precaution must be taken against electrical shock.

WARNING: Adjustment procedures described in this section could affect the measurement accuracy of the instrument. To insure continued accuracy, the procedures must be performed as described using only test equipment specified in this section.

4.2.2. Troubleshooting Summary

4.2.2.1. Monitor

Symptom	Probable Diagnosis
1. INSTRUMENT COMPLETELY INOPERATIVE (AC or battery).	A. Blown AC fuse and battery discharged. Refer to Section 4.4.1. B. Blown AC and battery fuses. Refer to Sections 4.4.1 and 4.3.5. C. Failure of the switching circuitry on the charger board. Refer to Sections 5.3.4 and 3.7. D. Power supply failure. Refer to Sections 5.3.1 and 3.6. E. Logic failure on the processor board. Refer to Sections 5.4 and 3.4.

Symptom	Probable Diagnosis
2. INSTRUMENT INOPERATIVE ON BATTERY (functional on AC).	A. Failure of battery charger circuit on the charger board. Refer to Sections 5.3.3 and 3.7.2. B. Battery failure. Refer to Sections 5.3 and 4.3.5. C. Blown battery fuse. Refer to Section 4.3.5.
3. INSTRUMENT FUNCTIONS CORRECTLY ON BATTERY, "BATT IN USE" LIGHT STAYS ON FOR AC. **NOTE**: This symptom may turn into Symptom #1 once the battery discharges.	A. Blown AC fuse. Refer to Section 4.4.1. B. AC rectifier failure on the charger board. Refer to Sections 5.3.3 and 3.7. C. AC rectifier/filter failure on power supply. Refer to Sections 5.3.1 and 3.6. D. ±18 V power supplies out of spec. Refer to Section 5.3.1.1.
4. INSTRUMENT INOPERATIVE, RANDOM STEADY DISPLAY SEGMENTS AND/OR CONTINUOUS BEEP.	A. Failure of microprocessor logic on the processor board (including the microprocessor, ROM, RAM, and associated circuitry). Refer to Sections 5.4 and 3.4. B. +5 V power supply out of spec. Refer to Sections 5.3.1 and 3.6. C. Failure of switching circuit on charger board. Refer to Sections 5.3.4 and 3.7.
5. INSTRUMENT OPERATES, DISPLAY SHOWS "Err 1".	A. Failure of RAM memory on the processor board diagnosed during power up test. Refer to Sections 5.4 and 3.4.1.
6. INSTRUMENT OPERATES, DISPLAY SHOWS "Err 2".	A. Failure of ROM memory on the processor board diagnosed during power up test. Refer to Section 5.4 and 3.4.1.
7. INSTRUMENT OPERATES, DISPLAY SHOWS "Err 3".	A. Failure of an LED segment or lamp diagnosed during power up test. Refer to Section 3.5.1.4. B. ±18 V power supplies out of spec. Refer to Sections 5.3.1 and 3.6. C. Failure of D/A conversion circuitry on the processor board. Refer to Sections 5.4.6 and 3.4.4.

Symptom	Probable Diagnosis
8. INSTRUMENT OPERATES, NO PULSE INDICATION, PULSE RATE, OR SATURATION.	A. Sensor disconnected or inoperative. Refer to Section 3.3. B. Patient module or its cable defective. Refer to Section 3.3. C. ±18 V power supplies out of spec. Refer to Sections 5.3.1 and 3.6. D. Circuit failure of the analog signal processing circuitry on the processor board. Refer to Sections 5.4 and 3.4.2. E. A/D converter circuitry failure on the processor board. Refer to Sections 5.4.6 and 3.4.4. F. Defective LED drive or amplifier on processor board. Refer to Sections 5.4 and 3.4.2.
9. INSTRUMENT OPERATES, PULSE INDICATION, NO SATURATION OR PULSE RATE DISPLAY.	A. Defective red LED on the sensor. Refer to Section 3.3. B. Defective red LED driver circuit on processor board. Refer to Section 3.4.2.5. C. Circuit failure in the RED channel of the analog processing circuitry on the processor board. Refer to Sections 5.4.5 and 3.4.2.
10. INSTRUMENT OPERATES, PULSE WAVEFORM AND SATURATION/RATE VALUES "NOISY".	A. Defective sensor or tester. Refer to Section 3.3. B. Noisy +5 or ±18 VDC power supply. Refer to Sections 5.3.1 and 3.6. C. Partial failure of the A/D conversion circuitry on the processor board. Refer to Sections 5.4.6 and 3.4.4.
11. INSTRUMENT OPERATES, BEEPER "RASPY".	A. Noisy +5 V power supply. Refer to Sections 5.3.1.2 and 3.6.
12. INSTRUMENT OPERATES, DOES NOT TURN OFF WITH SWITCH IN "STDBY".	A. Failure of switching circuitry in charger board. Refer to Sections 5.3.4 and 3.7.1.

4.2.2.2. Powerbase

Symptom	Probable Diagnosis
1. NO ANALOG OR DIGITAL OUTPUTS.	A. AC power disconnected. B. Picofuse blown on mother PCB. Refer to Section 3.8.1. C. Faulty transformer. Refer to Section 3.8. D. Digital circuitry on upper or lower daughter boards. Refer to Section 3.8.2.

Symptom	Probable Diagnosis
2. FULL SCALE AND ZERO SWITCHES WORK, BUT NO ANALOG OUTPUTS. MONITOR INFORMATION DOES NOT APPEAR ON DIGITAL OUTPUTS.	A. Phototransistor on mother PCB defective. Refer to Section 3.8.1. B. LED on monitor power supply board defective. Refer to Section 3.6.
3. TREND/EVENT FUNCTIONS INOPERATIVE, EXTERNAL ECG INOPERATIVE, ADULT/ NEONATE ALARM SWITCH INOPERATIVE.	A. AC power disconnected. B. LED on mother PCB defective. Refer to Section 3.8.1. C. Phototransistor on power supply PCB defective. Refer to Section 3.6.
4. NO OR INCORRECT DIGITAL OUTPUT.	A. Baud rate mismatch between powerbase and output device. Refer to N-200 Operator's Manual.

4.3. MONITOR DISASSEMBLY AND REASSEMBLY

Unless otherwise noted, the method used for reassembly of the instrument or one of its subassemblies is the reverse of that used for disassembly.

4.3.1. Top Cover Removal

Remove AC power cord from the instrument. Disconnect the powerbase. Place the instrument top-down on a flat work surface. Remove the four Phillips-head screws from the bottom of the instrument, taking care not to lose washers. Turn the instrument over with the front panel facing you. Lift off the top cover and place it on your left as shown in Figure 4–1, leaving all internal connecting cables in place. Hold the spring-loaded latches located at the back of the monitor securely in the bottom cover while the top cover is being removed. If the latches come out, reassemble them in the bottom cover.

In its opened condition, with all cables connected, the instrument may be operated normally for calibration and troubleshooting.

Figure 4-1 shows the placement of PCBs within the top and bottom covers.

- The processor PCB is on the top cover, held with two screws. There are two washers under each screw.
- The power supply PCB is on the back edge of the instrument
- The battery charger PCB is on the left side.

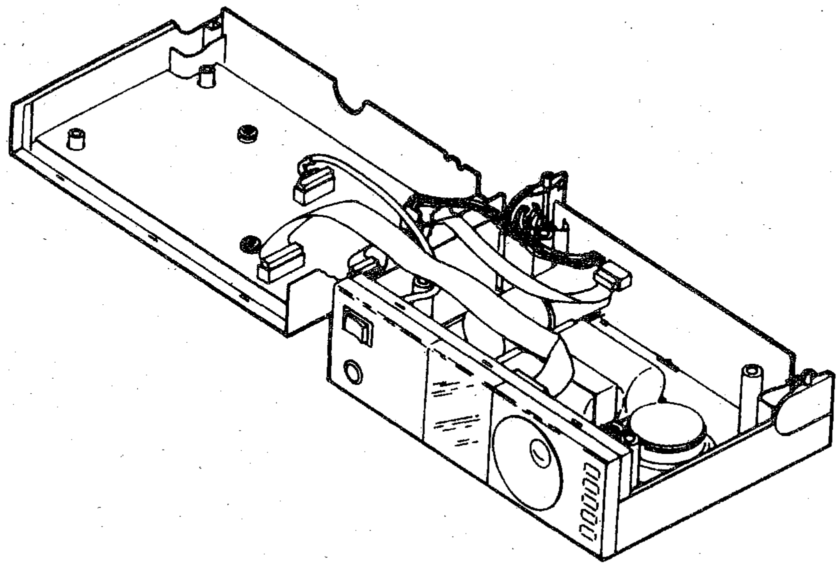


Fig. 4-1: Monitor PCB locations

4.3.2. Power Supply PCB and Battery Charger PCB Removal

The power supply PCB and battery charger PCB can be removed after the instrument top cover has been removed. Remove the two PCBs as a set by performing the following steps:

1. Disconnect all cables on the processor PCB (some connectors have retaining clips which must be removed first).
2. Cut the tie-wrap holding the large electrolytic capacitor on the power supply PCB.
3. Disconnect the 2-conductor power cable from the display driver PCB. For reassembly, verify that the red lead is on top.
4. Disconnect the battery leads and switch connector from the battery charger PCB. For reassembly, verify that the red battery lead connects to the "BATT +" terminal, the black battery lead connects to the "BATT -" terminal, and the switch connector is oriented with brown lead on top.
5. Remove the power supply PCB and battery charger PCB as one unit.

The PCBs can now be separated if necessary by disconnecting the 18-conductor flex circuit cable from the battery charger PCB.

4.3.3. Front Panel Removal

The front panel can be removed after the instrument top cover has been removed. Remove the front panel from the top cover by performing the following steps:

1. Turn the bottom cover upside-down and remove the two Phillips-head screws securing the front panel to the bottom cover.
2. Disconnect the ON/STDBY switch cable from the battery charger PCB. For reassembly, the switch connector is oriented with the brown lead on top.
3. With the bottom cover right-side up on the workbench, locate the four latches on the front panel that secure the front panel to the bottom cover.
4. Use a small blade screwdriver to disengage the front panel latches and pry them free one at a time. See Figure 4-2.
5. Pull the front panel away from the bottom cover and disconnect all cables from the driver PCB. For reassembly, verify that the 2 conductor power cable is installed with the red lead on top, the speaker cable is installed with the orange lead on top, and the ribbon cable is installed with pin 1 designators aligned.

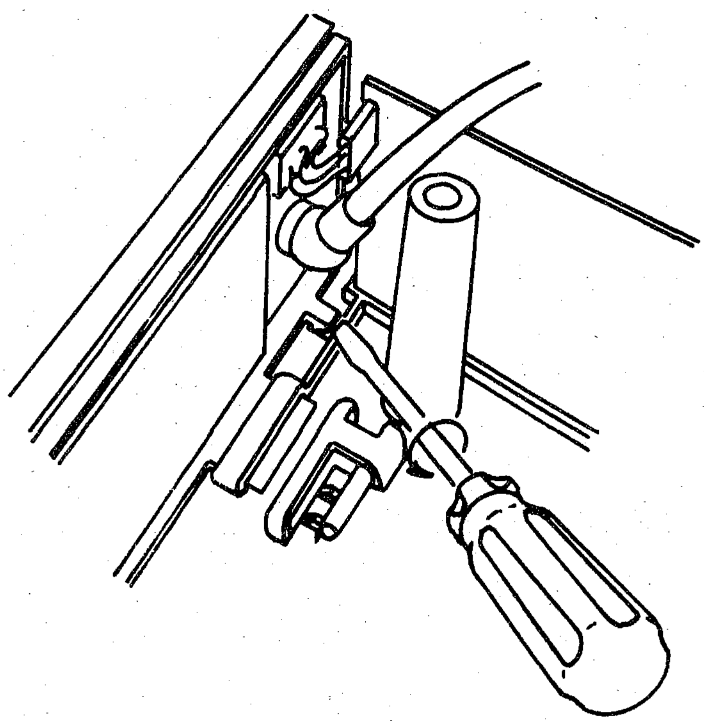


Fig. 4-2: Monitor front panel latch locations.

4.3.4. Display PCB and Driver PCB Removal

The display PCB and driver PCB are attached to the front panel; the driver PCB is nearest the instrument interior. Remove the two PCBs as a single unit by performing the following steps:

1. If not already removed, remove all connectors from the two PCBs at this time.

2. Insert a small screwdriver through the two holes above the encoder assembly and push off the encoder knob from the encoder shaft.

3. With a deep 7/16 inch hex socket, remove the encoder shaft retaining nut. Remove the encoder assembly. When replacing the encoder assembly, be sure to replace the toothed lock washer between the retaining nut and the front panel for proper knob clearance (torque on retaining nut not to exceed 15 in-lb). Verify that the encoder cable is installed with the red/white lead on top.

4. Unscrew the six Phillips-head screws securing the front panel to the display and driver PCBs. Remove the screws in two steps: first, loosen each screw part way, then go back and remove each screw completely. Note that the screws may remain in their holes, held by the plastic standoffs between the PCBs.

5. Remove the display and driver PCBs as one unit. The PCBs are assembled with component sides exposed for easy troubleshooting access. It is recommended that they not be separated unless replacement of one of the PCBs is required. If necessary, separate the two PCBs by decoupling connectors J6 and J4, then separate the PCBs by carefully prying the two snap-in standoffs apart, beginning at one end of the two-board assembly.

4.3.5. Battery Pack Removal/Fuse Replacement

The battery pack can be removed with the instrument front panel in place.

1. The in-line fuse holder and negative lead from the battery pack are secured to a clip by a tie-wrap. Cut this tie-wrap to free the battery cables. For fuse replacement, untwist halves of in-line fuse holder and replace fuse with one of same type and rating.

2. Remove the two screws from the battery retaining clip and lift out the battery pack.

4.3.6. Speaker Removal

To remove the speaker, detach the speaker connector and remove the four speaker mounting screws.

4.3.7. Top Cover Replacement

Refold the connector cables to their original contours so that the top cover fits securely without being forced. Take care that cables do not interfere with bosses or other obstructions on the cover. In particular, make sure that the shroud of processor PCB connector J4 (a five-pin header) clears the flex cable connecting the processor PCB and the battery charger PCB.

If cables have been disconnected during servicing, refer to Figure 4-1 for the order of cable replacement. Cables at the back of the unit should be connected first so that they lie below those toward the front of the unit. The order is:

1. Connect 5-conductor power cable from power supply PCB to processor PCB.

2. Connect 10-conductor ribbon cable from processor PCB to power supply PCB, noting polarity.

3. Connect patient cable from front panel LEMO connector to processor PCB, noting polarity.

4. Connect 20-conductor ribbon cable from processor PCB to driver PCB, noting polarity.

5. Replace retaining clips on all ribbon cable connectors.

NOTE: See cable interconnect diagrams, Section 9.

When refitting the top cover, note the following details:

1. Be sure that all PCBs fit properly into the alignment slots and features provided in the case. In particular, note that the power supply PCB fits into a guide on the top cover and that the charger PCB is fully seated in the slot in the bottom cover. Do not force the top cover down onto misaligned PCBs.

2. Three tabs on the top cover mate with slots on the front panel.

3. Pivot points on the side latches fit into holes in the top and bottom covers.

After the top cover has been fitted properly, turn the instrument over and replace the four screws into the bottom cover in the following manner:

1. Make sure that the washers are in place under each screw head.

2. Before tightening the screws securely, check the top cover to see that its front edge mates properly with the front panel. Press the top cover down into place if necessary.

3. When tightening the screws, be careful not to strip the threads in the plastic case by over-tightening. Recommended screw tightening torque is 16 to 18 in-lb.

4.4. POWERBASE DISASSEMBLY AND REASSEMBLY

Disconnect AC power cord before attempting disassembly. Unless otherwise noted, the method used for reassembly of the instrument or one of its subassemblies is the reverse of that used for disassembly.

4.4.1. AC Fuse Replacement

Fuses are contained inside a door above the AC power inlet on the back of the powerbase. To gain access, unplug the AC cord from the back of the powerbase and open the door by prying the top edge with a small flat-blade screwdriver.

Pull out the fuse holder on the right side to gain access to the fuse. The holder contains a 230 V, 0.5 A slo-blow fuse. Replace the fuse only with the same type and rating.

Replace the fuse holder by first making sure that the arrow on the holder points to the right, and then pressing it into place.

A removable barrel can be set to either 115 V or 230 V positions. If the barrel comes out of its holder, be sure that it is replaced so that one of the 115 V settings (United States units) is exposed to view.

Close the fuse door by exerting firm pressure against the door.

4.4.2. Powerbase Disassembly

The powerbase is disassembled by removing the four Phillips-head screws from the bottom of the unit. With the unit upright on the bench, lift off the top cover. All electronics are contained in the bottom portion of the powerbase. The solder side of the upper daughter PCB is exposed.

4.4.3. PCB Removal

The mother PCB is mounted vertically at the front of the unit. The upper, middle and lower daughter PCBs are mounted horizontally and mated to the mother PCB. The entire 4-PCB assembly can be removed as a unit by lifting the assembly out. If necessary, disconnect slip-on connectors and the 4-conductor DIN connector from mother board.

To disassemble the daughter PCBs from the mother PCB, hold the mother PCB and apply demating pressure between the bottom daughter PCB and the mother PCB. The upper and middle daughter PCBs can now be easily disconnected from the mother PCB.

4.4.4. Powerbase Reassembly

During reassembly, make sure that all pins on connector J3 on the bottom daughter PCB mate properly with the corresponding connector on the mother PCB. Also, make sure that the PCBs are seated fully in the slots and ribs provided on the backplate and on the bottom case of the powerbase.

Testing and
Calibration

SECTION 5

TESTING AND CALIBRATION

5.1. DESCRIPTION

This section details procedures for routine test and calibration checks for the *NELLCOR* N-200 pulse oximeter. Instructions for troubleshooting and repair of oximeter defects are detailed in Section 4. Refer also to Section 4 for instructions on cover removal and other access procedures. Note that certain component-level repairs require comprehensive tests of the analog section of the processor board to verify correct repair. If such repairs are necessary, read the appropriate parts of Section 3 that relate to the theory of operation. After the repair, verify that the circuits perform as described in Section 3, then perform the tests described in this section to verify overall instrument performance.

WARNING: The procedures in this section require tests and adjustments made with the power applied and the cover removed. These tests should only be made by qualified service personnel and adequate precautions must be taken against electrical shock.

WARNING: Adjustment procedures described in this section could affect the measurement accuracy of the instrument. To insure continued accuracy the procedures must be performed as described using only test equipment specified in this section. It is particularly important that a *NELLCOR* oximeter pocket tester be available to verify accuracy before adjustment or service is attempted. (See list of required test equipment.)

5.2. REQUIRED TEST EQUIPMENT

The following test equipment is required to perform the procedures described in this section:

1. Oscilloscope, 50 MHz dual channel, 10:1 probes with 20 pF maximum input capacitance (Tektronix 465 or equivalent).

2. Digital voltmeter, 3 1/2 digits, 0.1% accuracy, DC volts, AC volts and ohmmeter functions.

3. Variable voltage DC power supply, 0-15 V, 0-3 A.

4. *NELLCOR* model 2500 or model 2000 pocket tester.

   NOTE: The model 2500 and model 2000 pocket testers are functionally identical. The model 2500 has added label information for use with the N-200.

5. Power resistor, 20 ohms, 3 watts.

6. Waveform generator 1 Hz to 1 kHz with square, sine, and triangle waveforms and DC level offset adjustment.

5.3. BATTERY CHARGER AND POWER SUPPLY TESTS

The power supply PCB is located at the back of the monitor chassis. The battery charger PCB is located on the left side of the monitor chassis. The tests described in this section can be accomplished with the PCBs in place. If troubleshooting and repair is required, refer to Section 4 for instructions on removing and troubleshooting these PCBs.

5.3.1. Power Supply Checkout

The power supply generates +5 V, used by the processor board, and ±18 V used by the analog circuitry on the processor board. These voltages are generated by two independent power supply sections on the board, both consisting of pulse width modulation control chips and associated circuitry. All three outputs should be carefully checked for voltage and noise. Since the power supply is of a switching type DC to DC converter, it is quite possible that a component failure may not cause supply failure, but may introduce unacceptable noise levels on the output.

5.3.1.1. Output Voltages

Check the power supply output voltages by performing the following steps.

1. Connect the ground lead of a digital voltmeter to pin 2 or 4 of the 5-pin power supply connector (black wires). Set the meter to an appropriate scale.
2. Pin 1 (red) should read +5.00 V (± 0.15 V).
3. Pin 3 (orange) should read +18 V (+1.8 V -0.5 V).
4. Pin 5 (violet) should read -18 V (-1.8 V +0.5 V).
5. No adjustment is possible; an out-of-spec voltage indicates a defective control chip or other component.

5.3.1.2. Noise

Power supply output noise must be checked with an oscilloscope.

1. Set the horizontal deflection to 50 μs/div, 200 mV/div vertical deflection, AC coupled.
2. Measure the peak-to-peak noise of each voltage output. Peak-to-peak noise measured at the power supply connector should not exceed 100 mV for any of the three output voltages.

A very fine "grass" may be observed at the 50 kHz switching speed, depending on measurement technique. The major part of this grass is often stray pick up by the oscilloscope probe.

Noise of concern will be observed at much lower frequencies of 100 to 1,000 Hz. Some load variation with LED current is also observable and is acceptable as long as it lies within the same 100 mV peak-to-peak limit.

If a noise problem is suspected, but not identified by the above tests, repeat the tests at an elevated temperature since occasionally an unstable component will be temperature sensitive. The instrument may be warmed in a controlled oven to a maximum temperature of 40°C with the cover in place, or 50°C without the cover.

5.3.2. Unregulated Supply Voltage

Test the unregulated power supply voltage by performing the following steps on the power supply PCB (see SCHEMATIC POWER SUPPLY PCB).

1. Connect the oscilloscope probe to the cathode (BAR) side of diode CR2.

2. Connect probe ground lead to AGND point on processor PCB.

3. With the N-200 ON/STDBY switch in the STDBY position, the oscilloscope trace should indicate 0 V.

4. With the ON/STDBY switch in the ON position, read the following voltages on the oscilloscope trace:

   - With the instrument operating on batteries only (AC power disconnected), read 5.2 V to 6.4 V.

   - With the instrument operating on AC power, read 10.0 V to 15.0 V.

5.3.3. Battery Charging Voltage

Test the battery charging voltage by performing the following steps.

1. Disconnect the red and black battery leads from the charger board.

2. Connect the positive lead of a digital voltmeter to battery charger board TP5; connect the negative voltmeter lead to TP4. Alternatively, connect the negative voltmeter lead to the "BATT-" terminal and the positive lead to the "BATT+" terminal.

3. Connect a 30K to 50K ohm resistor across the voltmeter leads for this step, to improve the stability of the open circuit charge voltage reading. With AC power applied, verify an open circuit charging voltage of 7.20 V ± 0.02 V. Adjust R12 on the charger board (near the center of the board) if necessary to correct the charge voltage.

4. After adjustment, monitor the voltage at TP5 while connecting a 20 ohm, 3 W resistor across the battery charger board battery terminals. Verify that the voltage at TP5 (LM317 output voltage) drops to 5 V ± 0.5 V when the resistor is connected.

   If the voltage drop is not observed, the current limit circuit is defective.

5.3.4. Instrument Shutoff Test

Test the instrument's "Battery Low" indicator and shutoff voltage by performing the following steps.

1. Disconnect AC power, and connect a variable voltage power supply (initially set to 0 V output) to the charger board battery terminals. Connect the positive power supply lead to the "BATT +" terminal.

2. Connect a digital voltmeter between variable power supply ground and the cathode of diode CR2 (SCHEMATIC POWER SUPPLY PCB).

3. Raise the power supply voltage until the voltmeter reads 6.0 V.

4. Place the N-200 ON/STDBY switch in the ON position. Verify correct instrument operation ("BATT IN USE" light should be on).

5. Decrease the power supply voltage until the N-200 "Battery Low" indicator light just comes on. The voltmeter reading should be 5.2 V ± 50 mV.

6. Further decrease the power supply voltage until the instrument just shuts off. This turnoff voltage should be 5.0 V ± 50 mV.

7. Reconnect the battery leads to the battery charger PCB (black lead to "BATT-" terminal, red lead to "BATT+" terminal).

5.3.5. Battery Operation

With the battery leads connected to the battery charger PCB, test the battery's ability to hold a charge by performing the following steps.

1. Connect AC power for a minimum of 14 hours to charge the battery.

2. Disconnect AC power and verify that the instrument operates for a minimum of two hours on battery power with a pocket tester attached and the audio alarm disabled.

3. If the instrument fails to operate for two hours, then the battery should be replaced (see Section 4).

5.3.6. ON/STDBY Switch Test

Test the operation of the ON/STDBY switch and the watchdog timer circuit by performing the following steps.

1. Disconnect connector J2 from the processor PCB (10 conductor cable).

2. Connect an oscilloscope probe to IC U2, pin 5, on the battery charger PCB. Connect probe ground to TP4 or the "BATT-" terminal. Set the oscilloscope trace for

   - 5 V/div vertical deflection
   - 100 ms/div horizontal deflection
   - internal trigger on rising voltage edge

3. Place the N-200 ON/STDBY switch in the STDBY position. The oscilloscope trace should show pin U2, pin 5, at logic low (near 0 V).

4. Place the N-200 ON/STDBY switch in the ON position. The oscilloscope trace should show U2, pin 5, going to logic high (near 5 V) for 200 ms ± 50 ms, then low again.

5. If the observed oscilloscope traces are not as described in Steps 3 and 4, the ON/STDBY switch or the watchdog timer circuit is defective and must be repaired.

6. Reconnect connector J2 on the processor PCB.

5.4. PROCESSOR BOARD TESTS

The following tests of the processor board should be made as part of a routine test of the instrument. Additionally, the tests described in this section are required if components are changed on the processor board, or if the instrument measures out of calibration.

5.4.1. Test Setup

In order to begin processor board testing and calibration, configure the equipment as described in the following steps.

1. Disconnect the patient cable connector, J3, coming from the front panel to the processor board.

2. Connect the signal generator positive lead to TP6 and the negative lead to AGND.

3. Enable diagnostic software access by placing a wire jumper in location W3 on the processor board (near the lower right side PCB hold-down screw).

   The instrument software can be used to set various memory locations and invoke diagnostic subroutines via the front panel as follows:

   - With the power switch on, hold down the HIGH SAT and AUDIO ALARM OFF front panel buttons and dial up a particular memory location (0-255) by rotating the control knob. Location appears in SaO2 display; value appears in RATE display.

   - Then, by simultaneously holding the LOW SAT and AUDIO ALARM OFF buttons, alter the location's value via the control knob.

   The following nomenclature is used throughout this section to describe the setting of memory locations: xxx-yyy refers to setting memory location xxx to value yyy by the above procedure.

NOTE: Following processor board tests and calibration operations, be sure to remove jumper W3 before replacing the top cover.

5.4.2. INAMP Gain Verification

With the preceding setup in place, test INAMP gain by performing the following steps. (Refer to SCHEMATIC PROCESSOR PCB SHEET 2.)

1. Set the signal generator to 10 Hz sine wave, 2 V p-p, 0 V offset.

2. Place the N-200 ON/STDBY switch in the ON position.

3. Invoke diagnostic loop at 190-1 (that is, set location 190 to value 1).

4. Connect the oscilloscope probe to TP7. Ground the probe at the AGND test point.

5. Observe wave form at test point TP7 while varying the value of memory location 193 from 0 to 255.

   - The 10 Hz sine wave should vary in amplitude from <1 V p-p to the op amp rail of ±15 V.

6. With the second oscilloscope channel monitoring U20, pin 2, increase TP7 sine wave level to ± 24 V p-p. The state of U20, pin 2, should switch from 0 V to +5 V whenever the TP7 sine wave exceeds an approximately +10 V peak, i.e., 20 V p-p.

5.4.3. Sync Detector Alignment

NOTE: After verifying INAMP gain (above), allow at least 5 minutes of instrument warm up before proceeding with calibration.

1. Set the 10 Hz amplitude at TP7 to 10 V p-p by adjusting the value at location 193.

2. Attach Channel 1 scope probe to TP10 with scope settings at 0.5 µs, 50 mV/div, AC coupled.

3. Adjust trimpot R123 such that less than 10 mV of 10 Hz sine wave is present at TP10 (i.e., set at null point minimum).

4. Verify that TP9 is less than 10 mV after the trimpot is nulled.

5.4.4. IR Channel Gain Verification

1. Adjust signal generator amplitude to 0.5 V p-p, 10 Hz, zero offset. Connect signal generator lead to U7, pin 12; ground to the AGND test point.

2. With oscilloscope, verify that the signal level at TP9 measures 5 V to 7 V p-p.

5.4.5. RED Channel Gain Verification

1. Adjust signal generator amplitude to 0.5 V p-p, 10 Hz, zero offset. Connect signal generator lead to U13, pin 12; ground to the AGND test point.

2. With oscilloscope, verify that the signal level at TP10 measures 10 V to 14 V p-p.

5.4.6. A:D/D:A Alignment

The following steps perform A:D/D:A alignment. See SCHEMATIC PROCESSOR PCB, SHEET 4 for device references.

1. Set up the following memory locations:

   190-1
   195-7
   196-8
   197-0
   198-0

2. With a four digit DVM on 1 V or 2 V scale, adjust R117 to read 0.000 V at TP2 (DVM ground at AGND)

3. Read and record the offset voltage at TP3, if not equal to 0.000. Note the polarity of this voltage.

4. Set location 195-6.

5. Read and record the voltage at TP1.

6. Add or subtract the voltage recorded at TP3 in Step 3 to the TP1 value recorded in Step 5 (add if it was positive, subtract if negative).

7. Monitor the value at TP3 and adjust R116 to read the value calculated in Step 6.

   Example:
   1. TP3 voltage in Step 3 = -.0172 V
   2. TP1 voltage in Step 5 = 9.997 V
   3. In Step 7, set R116 so TP3 reads 9.997 - .0172 V or 9.980 V.

8. Set Locations 197-255, 198-15. Connect DVM to TP5 on 10 V or 20 V scale. Adjust R130 to read 9.997 V to 9.998 V.

9. Place N-200 ON/STDBY switch in STDBY, then to ON, to clear diagnostic operation.

5.4.7. Operation Verification

Secure processor PCB calibration and verify operation by performing the following steps.

1. GLPT all trimpots to prevent vibrational calibration shifts.

2. Remove jumper W3.

3. Reinstall patient cable J3, verifying pin 1 designators are aligned.

4. Connect the *NELLCOR* model 2500 or model 2000 pocket tester to the patient module.

5. Turn on the instrument. After a few seconds delay, the instrument should start to follow the artificial pulse and display a rate of 46 ± 1 and saturation of 81 ± 1.

6. If the alarm limits are set to default values, then both the LOW SAT and LOW RATE alarms will be active. Both displays and the lights next to the LOW SAT/LOW RATE buttons will be blinking and the audio alarm will sound if not disabled.

5.5. POWERBASE ALIGNMENT

Perform the powerbase 0 V, 1 V, and 10 V scale alignments with the following steps.

1. Disconnect the AC power cord from the powerbase and remove cover as instructed in Section 4.4.

2. Reconnect the AC power cord.

WARNING: ELECTRICAL SHOCK HAZARD. When the powerbase cover is removed, AC power voltages are exposed. Do not place fingers or metal tools in contact with AC power sources.

3. Press instrument ZERO button while monitoring the voltage at the SAT output jack (J5 on SCHEMATIC MIDDLE DAUGHTER PCB POWERBASE). Voltage should be 0.000 V ± 10 mV.

4. If necessary, adjust 0 V level with a small screwdriver through the small access hole marked "0 V" in upper daughter PCB (this hole provides access to trimpot R3 on middle daughter PCB).

5. On the powerbase back panel, push the FULL button with the SCALE switch placed in the 0-10 V position.

6. With the DVM, again monitor the SAT voltage while the FULL button is depressed. Voltage should be 10.000 V ± 10 mV.

7. If necessary, adjust 10 V level with small screwdriver through small access hole marked "10 V" in upper daughter PCB (this hole provides access to trimpot R11 on middle daughter PCB).

8. Place instrument scale switch in 0-1 V position. Push FULL button while again monitoring the SAT voltage with the DVM. Voltage should be 1.000 V ± 10 mV.

9. If necessary, adjust 1 V level with small screwdriver through small access hole marked "1 V" in upper daughter PCB (this hole provides access to trimpot R2 on middle daughter PCB).

10. Replace the top cover.

Additional Service
Information

Packing for
Shipment

SECTION 6

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SECTION 7

PACKING FOR SHIPMENT

7.1. REPACKING IN ORIGINAL CARTON

The best package to use when packing the instrument for shipping is the original packing carton. If the original packing carton is available, pack the instrument as described in the following steps:

1. Snap the monitor and its powerbase together and place it in its plastic bag. The plastic bag is necessary to prevent abrading the instrument's front panel during shipment.
2. Place the instrument in the bottom piece of supporting foam, making sure that the ON/ STNDBY switch on the bottom of the instrument fits into the recess made for it in the foam.
3. Place the upper foam pad on top of the instrument.
4. Place the instrument accessories (patient module, power cord, etc.) in the original accessories box and place the accessories box on top of the upper foam pad.
5. Securely seal the carton with packing tape.

7.2. PACKING IN DIFFERENT CARTON

If the instrument's original packing carton is not available, pack the instrument as described in the following steps:

1. Snap the monitor and its powerbase together and place it in a plastic bag.
2. Find a sturdy cardboard carton large enough to provide at least 2 inches of clearance on all sides of the instrument.
3. Fill the bottom of the carton with 2 inches of loose styrofoam packing material.
4. Place the instrument on the packing material and place the accessories on top of the instrument.
5. Fill the box completely with loose styrofoam packing material and securely seal the carton with packing tape.

Spare Parts

SECTION 8

SPARE PARTS

8.1. EXTERNAL PARTS

Item *	Description	Part No.
—	ASSY, Power Cord	071505
—	Patient Module, 13'	072752
—	Patient Module, 20'	073145
1.4	Fuse, 1/2 Amp Slo-blow (100-120 V)	691011
1.5	Fuse, 1/4 Amp Slo-blow (220-240 V)	691098
1.6	Fuse, 4 Amp (Battery Pack)	691014

8.2. ELECTRICAL ASSEMBLIES

8.2.1. Monitor

Item *	Description	Part No.
2.1	ASSY, Power Supply PCB	072268
2.2	ASSY, Battery Charger PCB	072270
2.3	ASSY, Speaker	072487
2.4	ASSY, Processor PCB	072700
2.5	ASSY, Patient Cable	072756
2.6	ASSY, Encoder, Front Panel	072757
2.7	ASSY, Front Panel PCB Set	072758
2.8	ASSY, Battery Pack	073136
2.9	ASSY, On/Standby Switch	073217
2.10	Cable, Proc. PCB/Pwr. Sply PCB	053138
2.11	Cable, Processor PCB/Display PCB	053142

8.2.2. Powerbase

Item *	Description	Part No.
3.1	ASSY, Motherboard PCB	072120
3.2	ASSY, Upper Daughter PCB	072140
3.3	ASSY, Middle Daughter PCB	072150
3.4	ASSY, Lower Daughter PCB	072160
3.5	ASSY, AC Inlet/Transformer	073820

* Item numbers are keyed to the chassis-level assembly views in Section 8.4.

8.3. MECHANICAL PARTS

8.3.1 Monitor

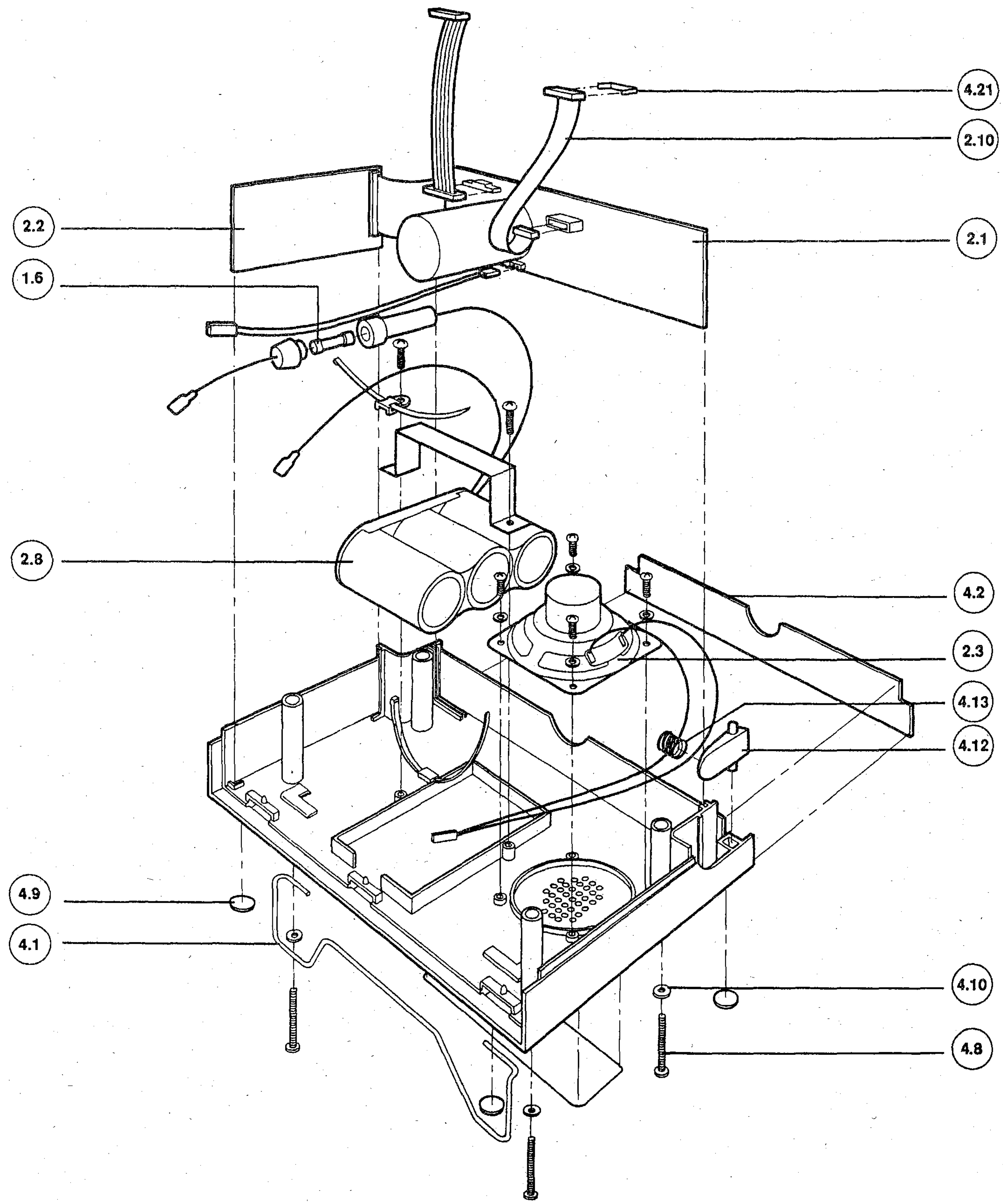
Item *	Description	Part No.
4.1	Wire Bail, Bottom Cover	052248
4.2	Gasket, Bottom Cover	052258
4.3	Gasket, Top Cover	053567
4.4	Keypad, Front Panel	052577
4.5	Top Cover	053724
4.6	Front Panel Window, Red	052719
4.7	Front Panel	053374
4.8	Screw, Top Cover	872063
4.9	Rubber Bumper, Bottom	759110
4.10	Washer, Top Cover	860202
4.11	Screw, Proc. PCB hold-down	871031
4.12	Latch	052262
4.13	Spring, Latch Compression	891064
4.14	Washer, Proc. PCB hold-down	891074
—	Patient Module Velcro Strap	052283
4.16	Knob, Front Panel	054235
4.17	Retaining Ring for Knob	891050
4.19	Clip, 20 Pin Connector	491100
4.20	Clip, 14 Pin Connector	491099
4.21	Clip, 10 Pin Connector	491098
4.22	Washer, LEMO Connector	491005
4.23	Nut, LEMO Connector	491006
4.24	Screw, Display Panel Assy.	871056

8.3.2 Powerbase

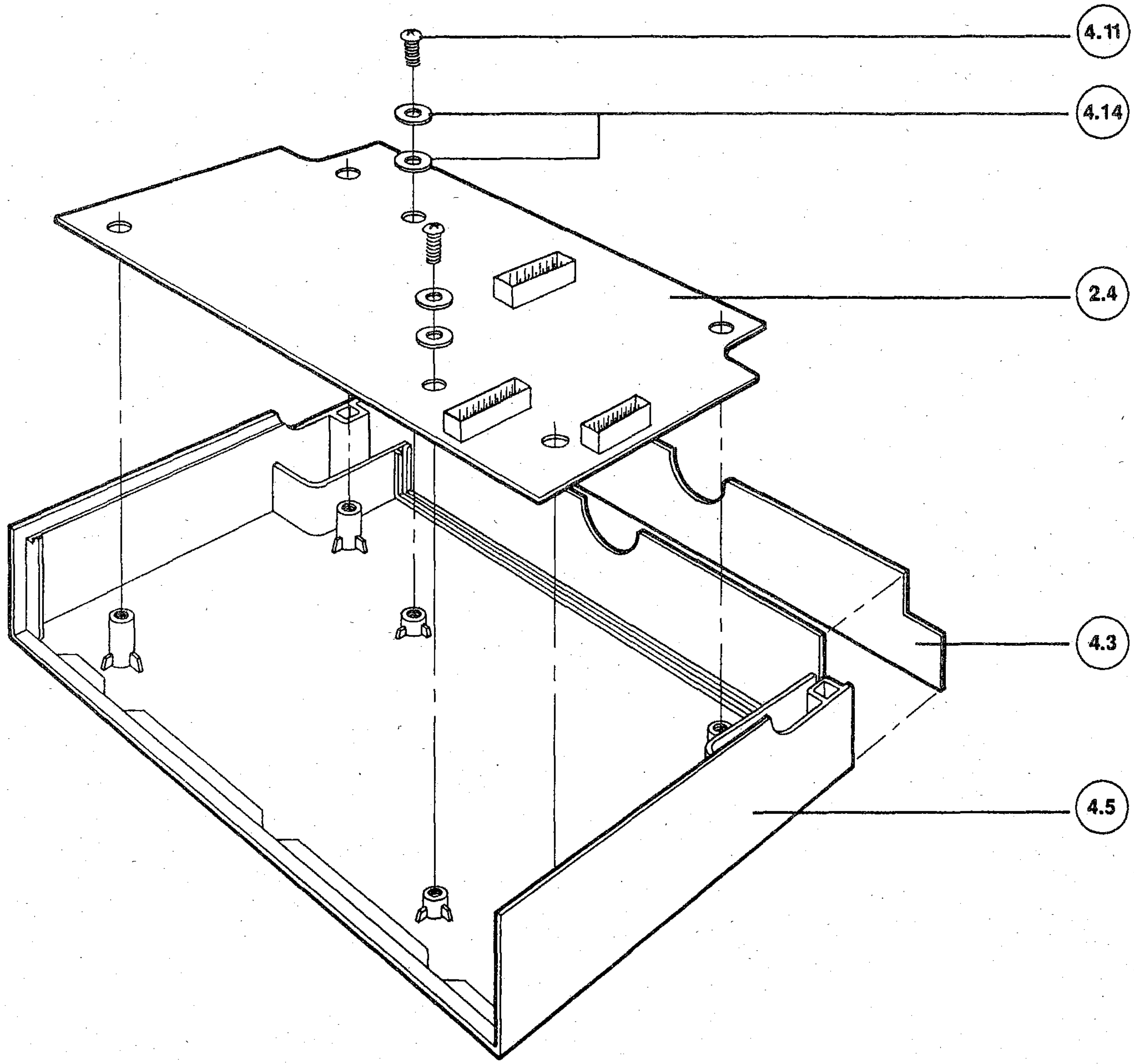
Item *	Description	Part No.
5.1	Top Cover	053897
5.2	Bottom Cover	052141
5.3	Backplate	052174
5.4	Pushbutton Cap	639101
5.5	Screw, Powerbase Covers	872163
5.6	Screw, Transformer Attachment	873100

* Item numbers are keyed to the chassis-level assembly views in Section 8.4.

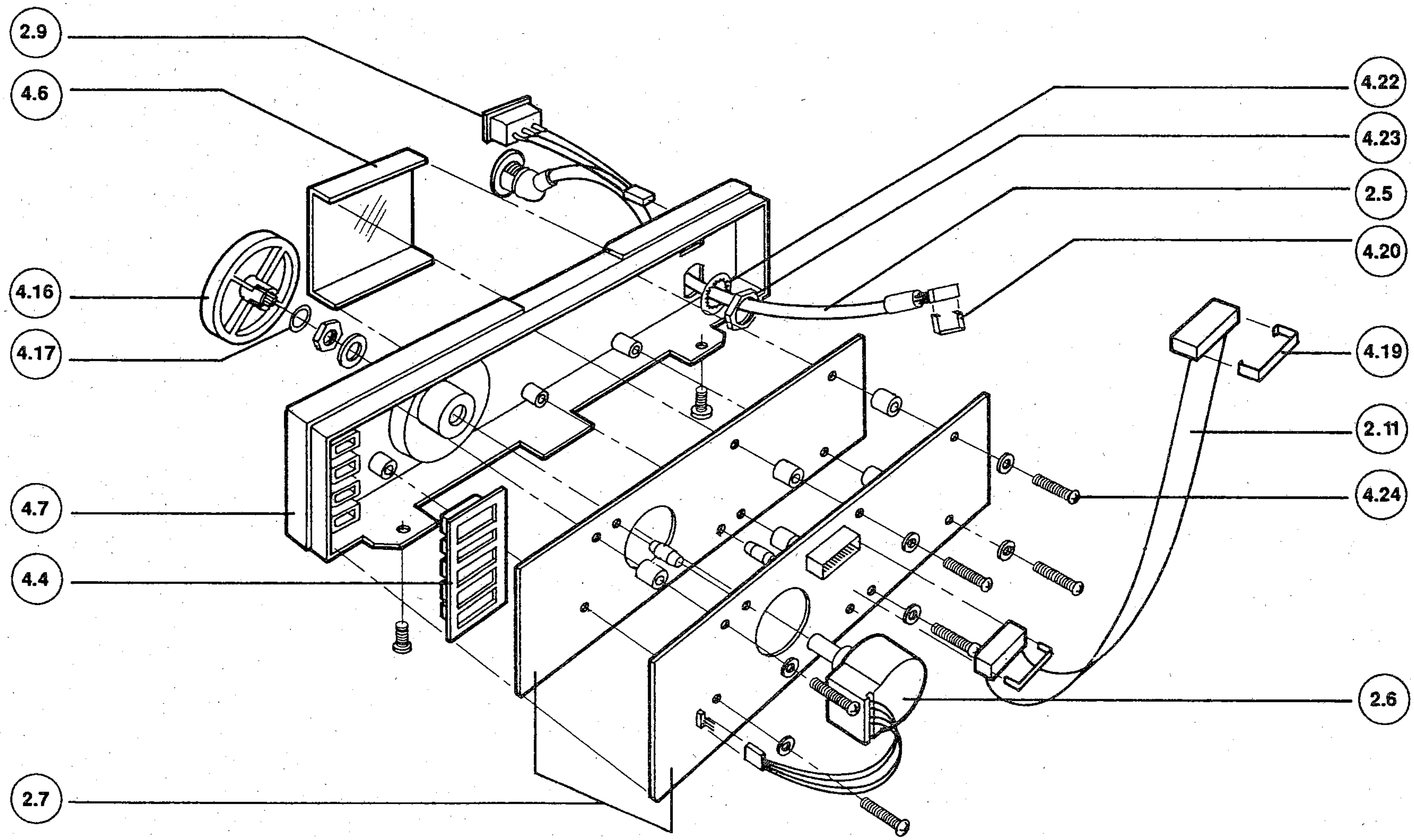
8.4. CHASSIS-LEVEL ASSEMBLY VIEWS



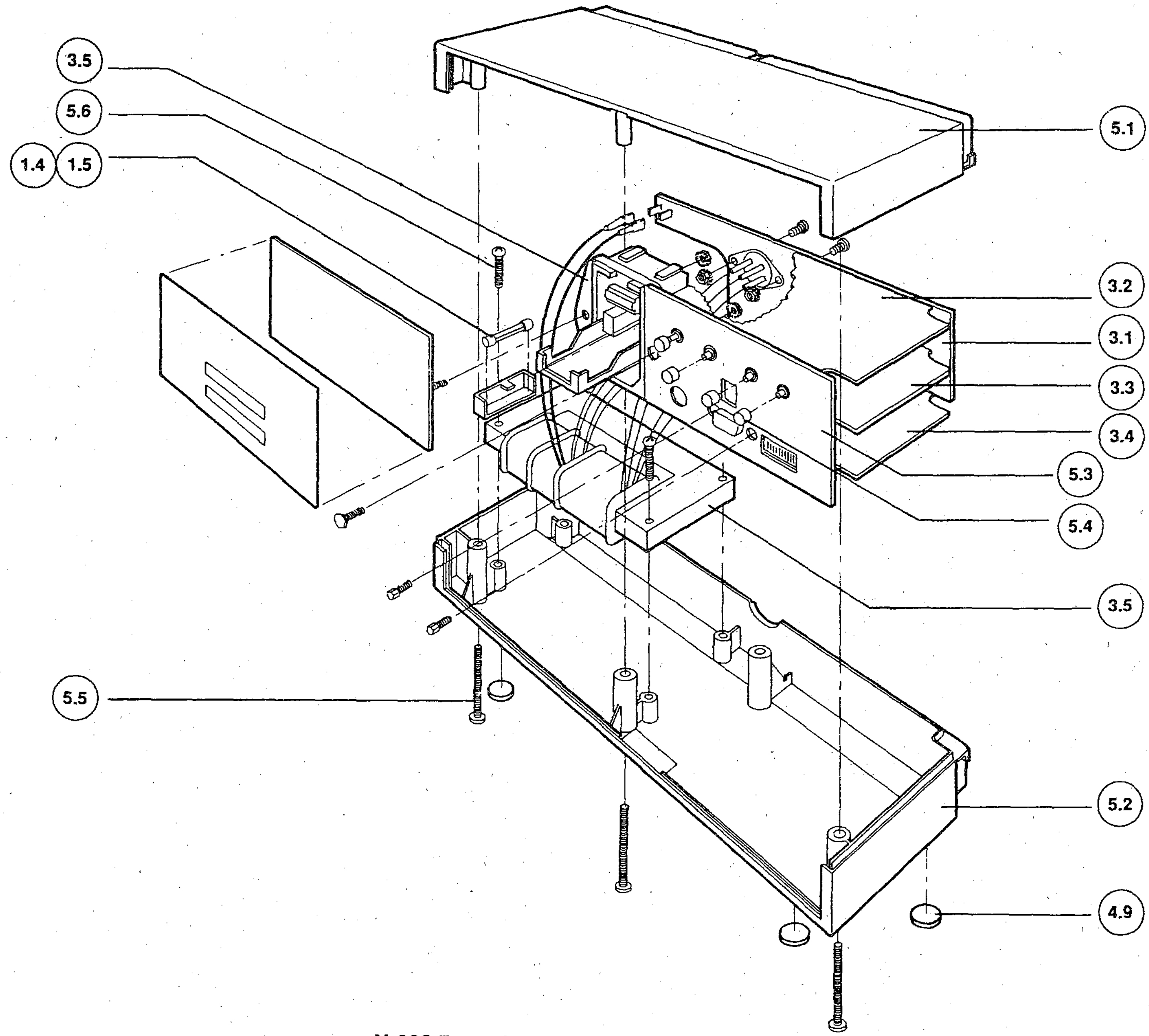
N-200 Monitor Chassis



N-200 Monitor Top Cover



N-200 Mc r Front Panel

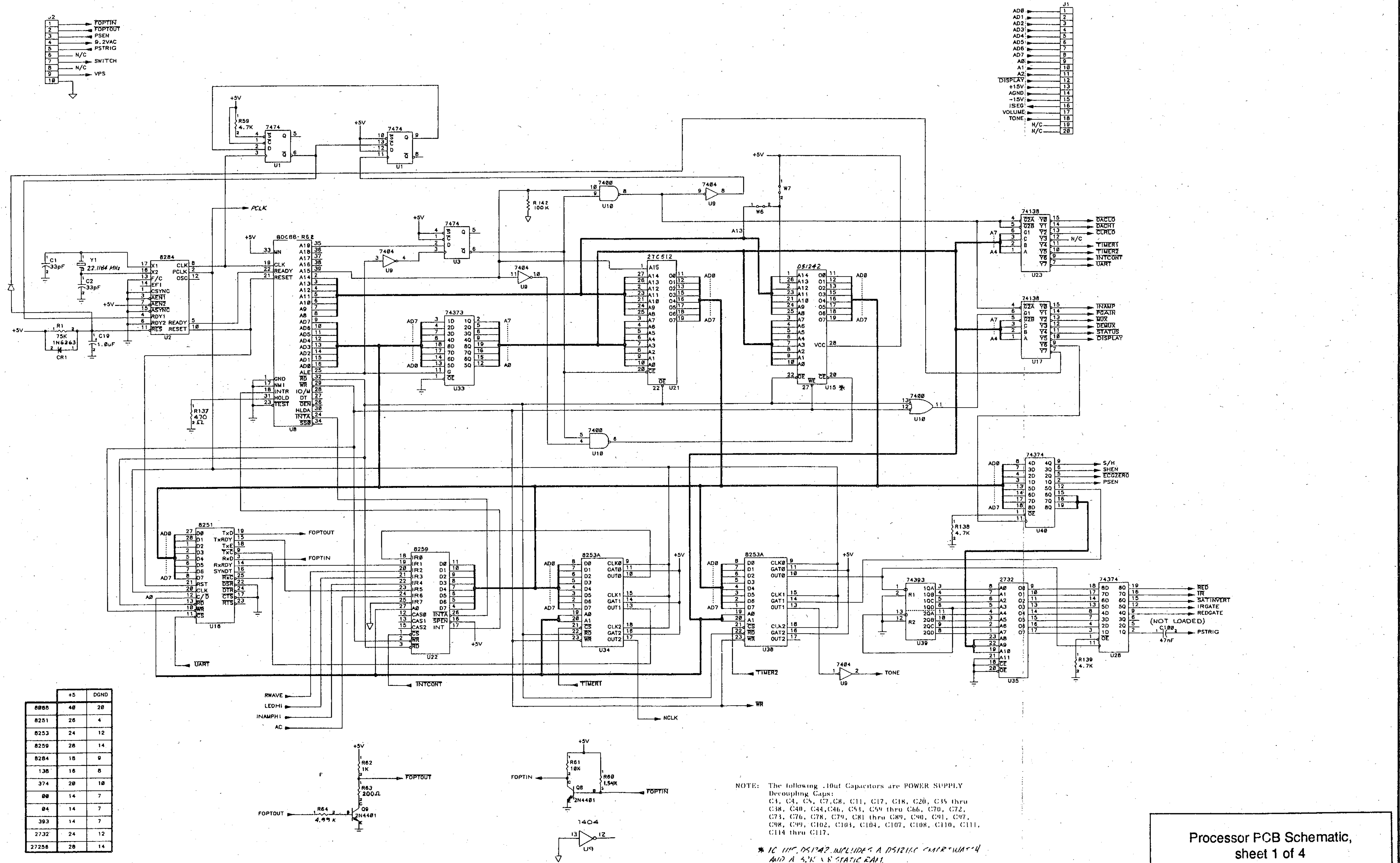


N-200 Powerbase

Schematics
Diagrams

SECTION 9

SCHEMATIC DIAGRAMS

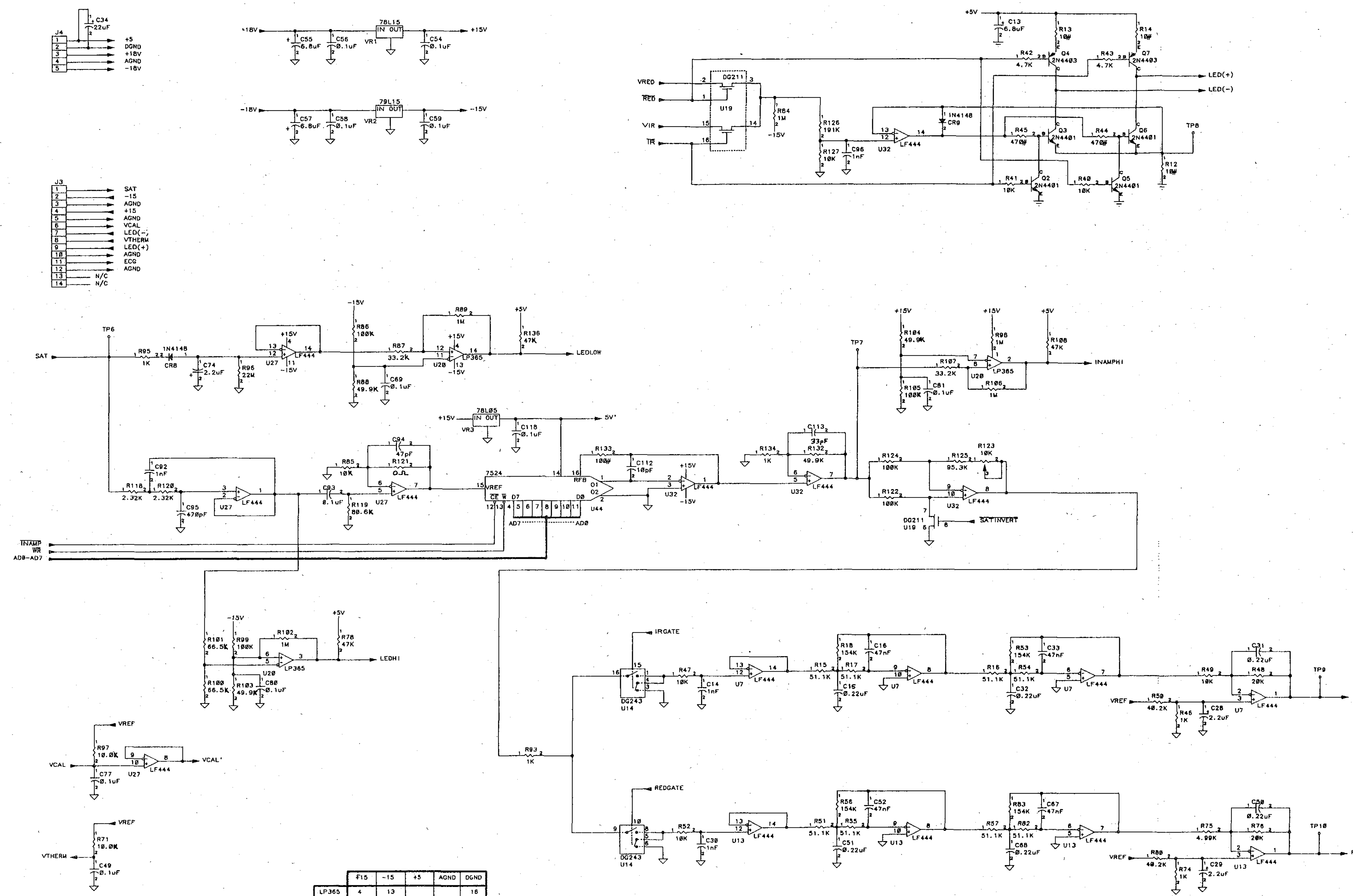


	+5	DGND
8088	40	20
8251	26	4
8253	24	12
8259	28	14
8284	18	9
138	16	8
374	20	10
00	14	7
04	14	7
393	14	7
2732	24	12
27256	28	14

NOTE: The following .10uf Capacitors are POWER SUPPLY Decoupling Caps: C3, C4, C5, C7,C8, C11, C17, C18, C20, C35 thru C38, C40, C44,C46, C53, C59 thru C66, C70, C72, C73, C76, C78, C79, C81 thru C89, C90, C91, C97, C98, C99, C102, C103, C104, C107, C108, C110, C111, C114 thru C117.

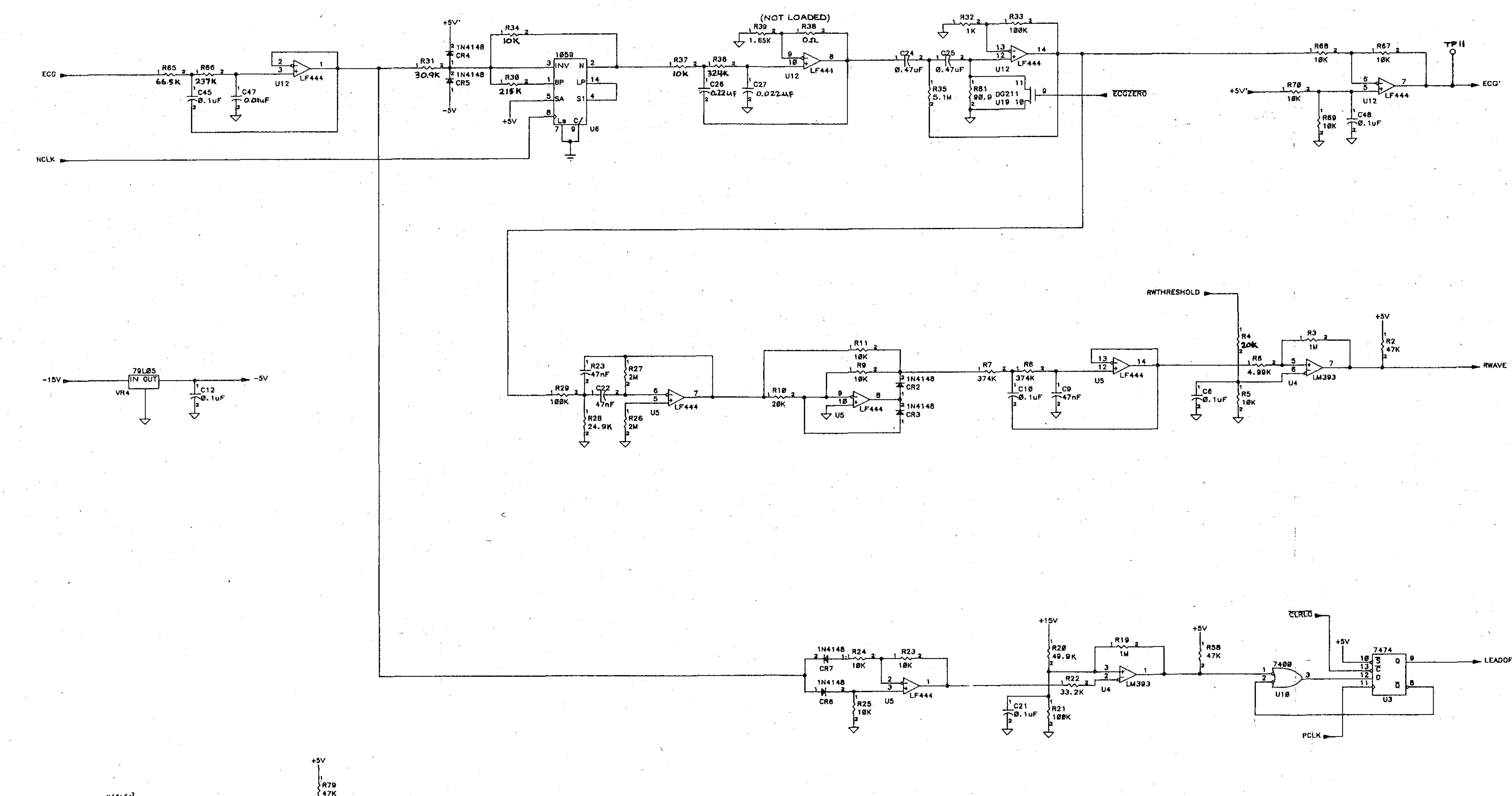
* IC U15, DS1242 INCLUDES A DS1216C SMARTWATCH AND A 32K X 8 STATIC RAM.

Processor PCB Schematic, sheet 1 of 4



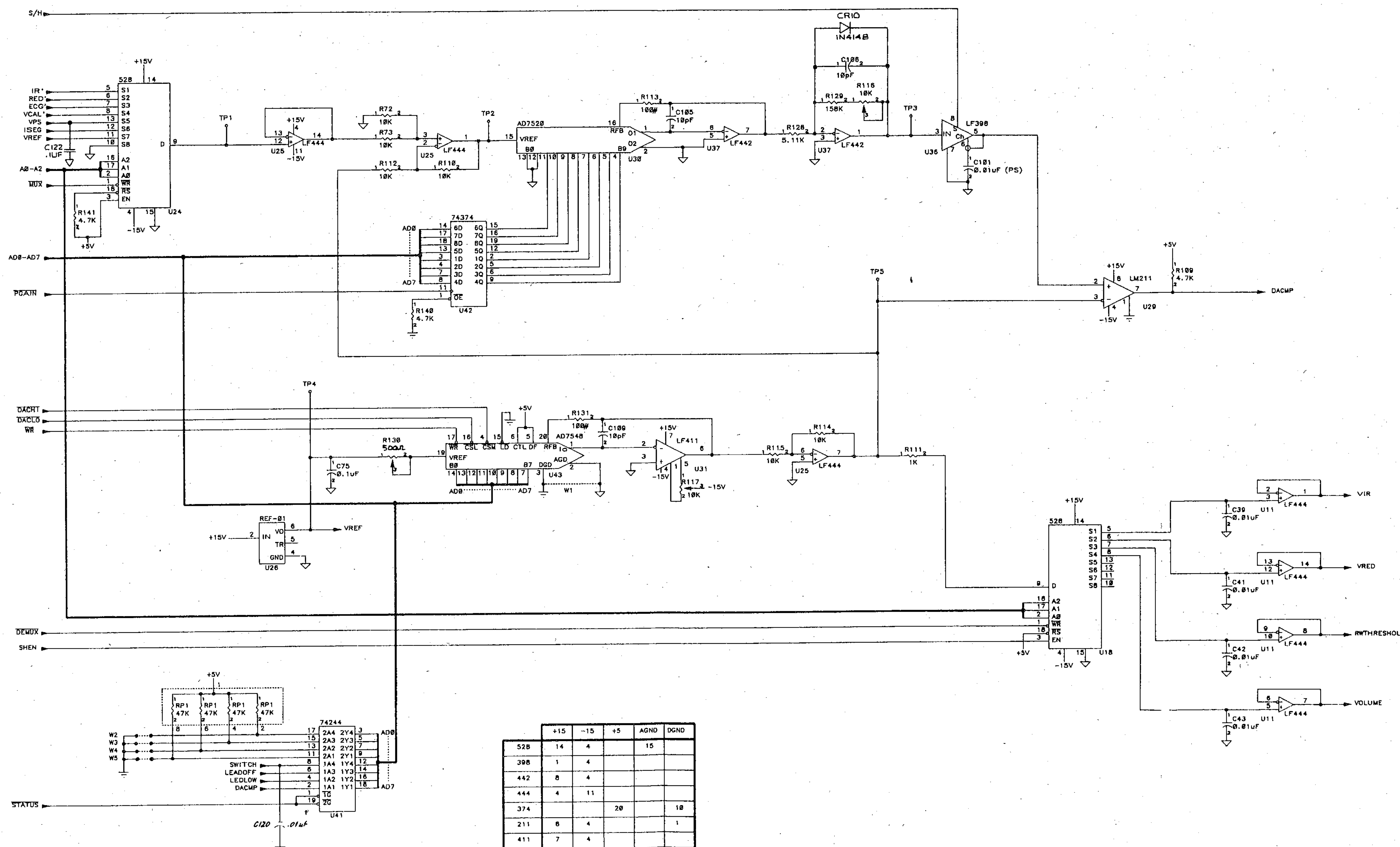
	+15	-15	+5	AGND	DGND
LP365	4	13			16
LF444	4	11			
DG211	13	4	12	5	
DG243	11	14	12	13	
7524				3	

Processor PCB Schematic,
sheet 2 of 4



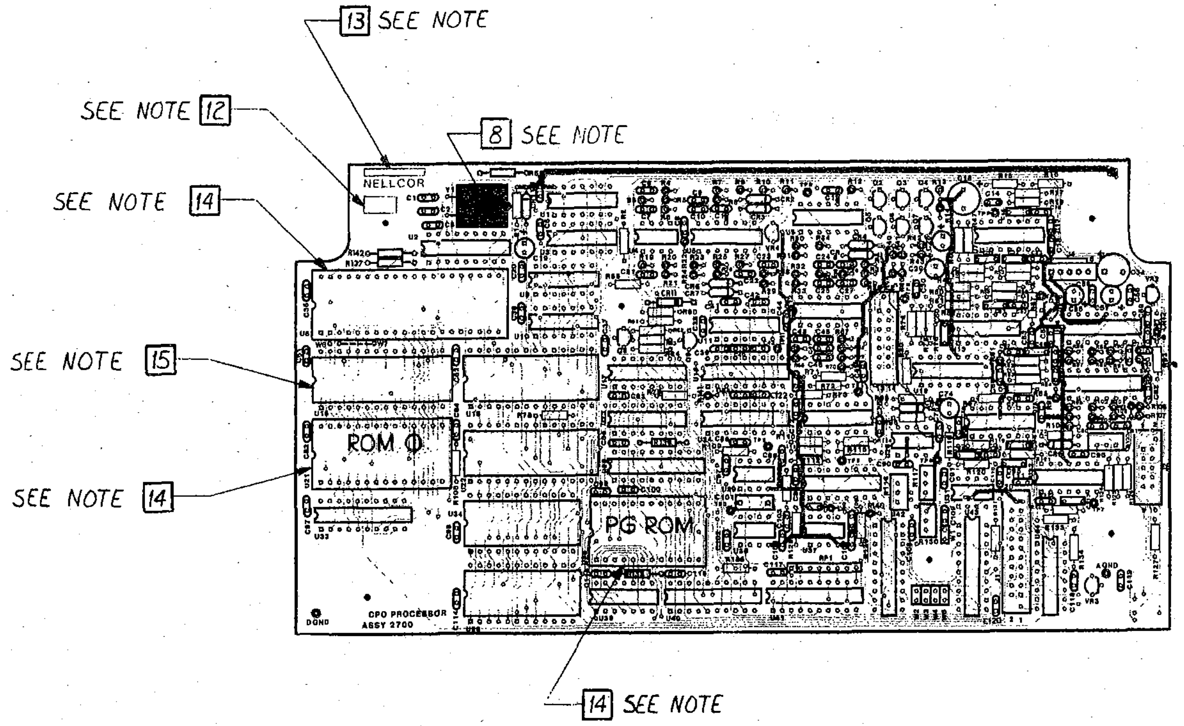
	+15	-15	+5V'	-5	+5	AGND	DGND
444	4	11					
211	13	4			12	5	
393	8						4
365	4	13				16	
74					14		7
00					14		7
1059			6	10		11	

Processor PCB Schematic,
sheet 3 of 4



	+15	-15	+5	AGND	DGND
528	14	4		15	
398	1	4			
442	8	4			
444	4	11			
374			20		10
211	8	4			1
411	7	4			
244			20		10
7548	18			2	3
7520	14			3	

Processor PCB Schematic, sheet 4 of 4



DETAIL A
PROGRAM ASSY. 3565 PLACEMENT
ROM Φ ASSY. - U21
PG ROM ASSY. - U35

16. PCB'S PASSING "IN CIRCUIT TEST," MUST BE STAMPED BY OV SOLDER SIDE.

NOTES:

1. Designations for Resistor, 10.0K, P/N 211002 (27 ea):

   R5, R9, R11, R23, R24, R25, R34, R37, R40, R41, R47, R49, R52, R61, R67, R68, R69, R70, R71, R85, R90, R92, R94, R97, R114, R115, R127.

2. Designations for Capacitor, .10uf, P/N 304104, (77 ea):

   C3 thru C8, C10, C11, C12, C17, C18, C20, C21, C35 thru C38, C40, C44, C45, C46, C48, C49, C53, C54, C56, C58 thru C66, C69 thru C73, C75 thru C78, C80 thru C90, C91, C93, C97, C98, C99, C102, C103, C104, C107, C108, C110, C111, C114 thru C119, C121, C122.

3. Orient I.C.'s with Pin 1 to Square Pad.

4. Polarized Capacitors to be mounted with Positive (+) side to Square Pad.

5. Color Coded Resistors to be LEFT or UP as appropriate.

6. All Capacitors and Precision Resistors to be mounted with value visible.

7. Diodes to be mounted with Banded (Cathode) side to Square Pad.

[8] Crystal, Y1, may be secured by 22 ga. buss wire, hot melt glue, foam tape (P/N 753121), or by pin inserted into board and bent over crystal.

9. Note: This board contains static sensitive components and should be handled accordingly.

10. RESISTOR LOCATIONS R38 AND R121 ARE JUMPERED WITH 22 GA BUSS WIRE ACROSS PADS OR WITH ZERO OHM RESISTOR (P/N 200000)

11. The following designations are NOT loaded: R39, C100.

[12] Apply three (3) digit 'Year Week' date code in the area indicated on component side per procedure MI-019235.

[13] Apply assembly revision, vendor code, and the serial number in the area indicated on component side per procedure MI-019235.

[14] Add tape (106) to I.C. sockets U8, U21, & U35 (cut as required) before loading I.C. 80C88RS (7) & ROM Assy (18 & 28)

[15] I.C. DS1242, U15, may not be processed thru automatic flow solder or cleaning operations. HAND CLEAN WITH FREON OR ALCOHOL ONLY.

REFERENCE NOTES:

1. Reference "MADIC" Bill of Materials 982700 or 992700 for outside vendor processing of PCB Assembly.

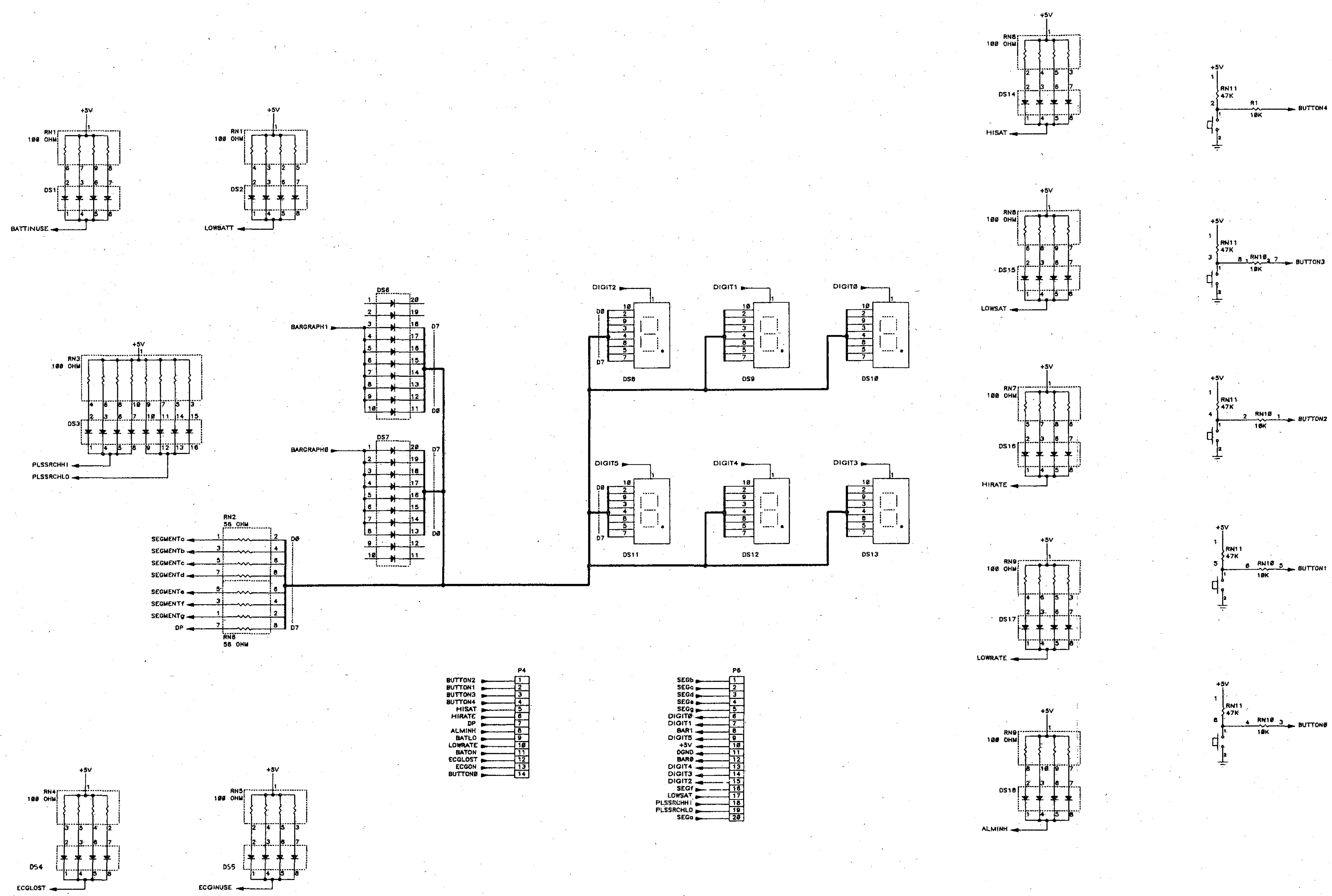
2. The following parts are not loaded by outside vendor:

   a) For 992700: 1) 073565, Program Assembly
      2) 199135, I.C. 80C88RS-2
      3) 753121, TAPE AT LOCATIONS U21, U35 AND U8

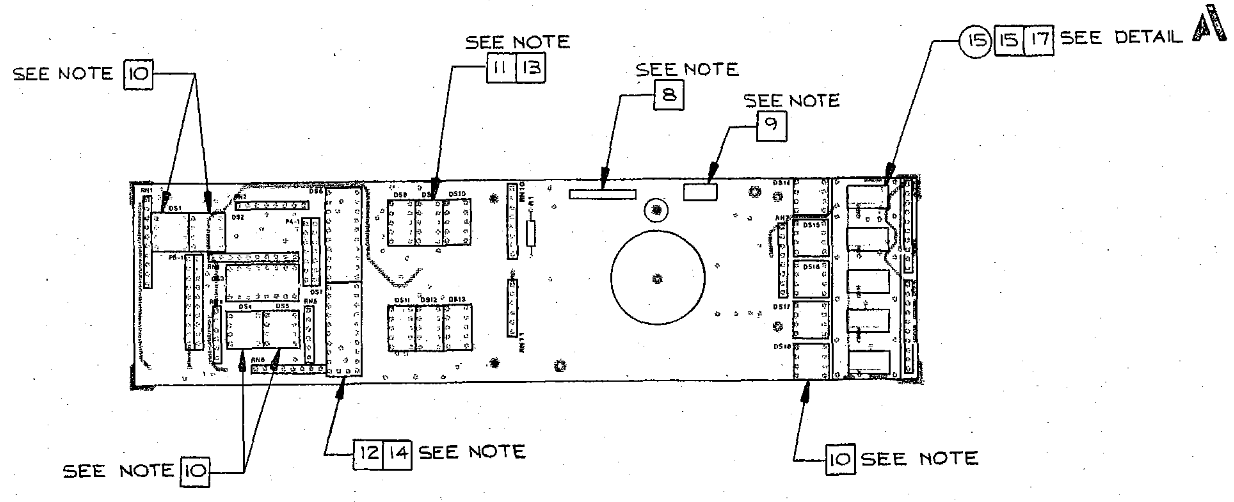
   b) For 982700: 1) 073565, Program Assembly
      2) 753121, TAPE AT LOCATIONS U21 AND U35

ITEM	P/N:	DESCRIPTION:	QTY	DESIGNATION
108.	052699	PCB Processor, N-200, Rev. B	1	-
107.	073565	Assy., Monitor Program	1	See Detail A
106.	753121	Tape, Foam 1/16" thick	A/R	See Note 14
105.	481015	Terminal Test Points	13	TP1 thru TP11, D GND, A GND
104.	491131	Connector, Socket Strip, 8 Pin	1	W2 through W5
103.	491086	Connector, Hdr, Str, 5 Pin Locking	1	J4
102.	401114	Connector, Hdr, Str, 14 Pin	1	J3
101.	401110	Connector, Hdr, Str, 10 Pin	1	J2
100.	401120	Connector, Hdr, Str, 20 Pin	1	J1
99.	691075	Crystal, 22.1184 MHz	1	Y1
98.	611005	Regulator, -5V, 79L05A	1	VR4
97.	610005	Regulator, +5V, 78L05	1	VR3
96.	611015	Regulator, -15V, 79L15	1	VR2
95.	610015	Regulator, +15V, 78L15	1	VR1
94.	604403	Transistor, 2N4403	2	Q4, Q7
93.	604401	Transistor, 2N4401	6	Q2, Q3, Q5, Q6, Q8, Q9
92.	584148	Diode, 1N4148	10	CR2 thru CR10, CR12
91.	591003	Diode, 1N6263	2	CR1, CR11
90.	304100	Capacitor, M.S. 10pf	4	C105, C106, C109, C112
89.	390103	Capacitor, Polyprop. .01uf	1	C101
88.	304471	Capacitor, M.S. 470pf	1	C95
87.	304470	Capacitor, M.S. 47pf	1	C94
86.	304103	Capacitor, M.S. .01uf	6	C39, C41, C42, C43, C47, C120
85.	344226	Capacitor, Dipped Tant, 35V 22uf	1	C34
84.	344225	Capacitor, Dipped Tant, 25V 2.2uf	3	C28, C29, C74
83.	304223	Capacitor, M.S. .022uf	1	C27
82.	304474	Capacitor, M.S. .47uf	2	C24, C25
81.	344105	Capacitor, Dipped Tant, 35V 1uf	1	C19
80.	304224	Capacitor, M.S. .22uf	7	C15, C26, C31, C32, C50, C51, C68
79.	304102	Capacitor, M.S. .001uf	4	C14, C30, C92 C96
78.	344685	Capacitor, Dipped Tant, 35V 6.8uf	3	C13, C55, C57
77.	304473	Capacitor, M.S. .047uf	7	C9, C16, C22, C23, C33, C52, C67
76.	304104	Capacitor, M.S. .10uf	75	See Note 2
75.	304330	Capacitor, M.S. 33pf	3	C1, C2, C113
74.	291016	Potentiometer, 18T Top Adj. 500 Ohm	1	R130
73.	211583	Resistor, 1% M.F. 158K	1	R129
72.	215111	Resistor, " " 5.11K	1	R128
71.	211913	Resistor, " " 191K	1	R126
70.	219532	Resistor, " " 95.3K	1	R125
69.	218062	Resistor, " " 80.6K	1	R119
68.	212321	Resistor, " " 2.32K	2	R118, R120
67.	291008	Potientiometer, 18T Top Adj. 10K	3	R116, R117, R123
66.	211000	Resistor, 1% M.F. 100 Ohm	3	R113, R131, R133
65.	200226	Resistor, 1/4W 5% CC 22 Meg	1	R96
64.	219092	Resistor, 1% M.F. 90.9K	1	R81
63.	291009	Resistor, .1% M.F. 10.0K	4	R72, R73, R110, R112
62.	212373	Resistor, 1% M.F. 237K	1	R66
61.	216652	Resistor, 1% M.F. 66.5K	3	R65, R100, R101
60.	212000	Resistor, 1% M.F. 200 Ohm	1	R63
59.	211541	Resistor, " " 1.54K	1	R60
58.	214022	Resistor, " " 40.2K	2	R50, R80
57.	200471	Resistor, 1/4W 5% CC 470 Ohm	3	R44, R45, R137
56.	200472	Resistor, 1/4W 5% CC 4.7K	8	R42, R43, R59, R109, R138 thru R141
55.	213243	Resistor, " " 324K	1	R36
54.	215114	Resistor, " " 5.11 Meg	1	R35
53.	211001	Resistor, " " 1.00K	8	R32, R46, R62, R74, R93, R95, R111, R134
52.	213092	Resistor, " " 30.9K	1	R31
51.	212153	Resistor, " " 215K	1	R30
50.	212492	Resistor, " " 24.9K	1	R28
49.	212004	Resistor, " " 2 Meg	2	R26, R27
48.	213322	Resistor, " " 33.2K	3	R22, R87, R107
47.	211003	Resistor, " " 100K	9	R21, R29, R33, R86, R99, R105 R122, R124, R142
46.	214992	Resistor, " " 49.9K	5	R20, R88, R103, R104, R132
45.	211543	Resistor, " " 154K	4	R18, R53, R56, R83
44.	215112	Resistor, " " 51.1K	8	R15, R16, R17, R51, R54, R55, R57, R82
43.	210100	Resistor, " " 10 Ohm	3	R12, R13, R14,
42.	212002	Resistor, " " 20.0K	4	R4, R10, R48, R76
41.	213743	Resistor, " " 374K	2	R7, R8
40.	214991	Resistor, " " 4.99K	3	R6, R64, R75
39.	211002	Resistor, " " 10.0K	27	See Note 1
38.	211004	Resistor, " " 1 Meg	8	R3, R19, R84, R89, R91, R98, R102, R106
37.	200473	Resistor, 1/4W 5% CC 47K	7	R2, R58, R78, R79, R108, R136, R143
36.	217502	Resistor, 1% M.F. 75.0K	1	R1
35.	230473	Resistor Pkg., 8 Pin SIP 47K	1	RP1
34.	197524	I.C. 7524LN, 8 Bit DAC	1	U44
33.	197548	I.C. 7548KN	1	U43
32.	130244	I.C. 74HC244	1	U41
31.	130393	I.C. 74HC393	1	U39
30.	120442	I.C. LF442N	1	U37
29.	120398	I.C. LF398	1	U36
28.	170032	I.C. P2732A	REF	U35
27.	752024	I.C. Socket, 24 Pin	1	U35
26.	198253	I.C. 82C53-5	2	U34, U38
25.	130373	I.C. 74HC373	1	U33
24.	199120	I.C. LF411A	1	U31
23.	191020	I.C. DAC1020L	1	U30
22.	120211	I.C. LM211	1	U29
21.	130374	I.C. 74HC374	3	U28, U40, U42
20.	190001	I.C. REF01, 10 Volt	1	U26
19.	198259	I.C 82C59-2RS	1	U22
18.	171512	I.C. 27C512, EPROM	REF	U21
17.	752028	I.C. Socket, 28 Pin	1	U21
16.	120365	I.C. LP365N	1	I20
15.	190211	I.C. DG211CJ	1	U19
14.	190528	I.C. DG528C	2	U18, U24
13.	130138	I.C. 74HC138	2	U17, U23
12.	199121	I.C. 82C51	1	U16
11.	199137	I.C. DS1242	1	U15-See Note 15
10.	190243	I.C. DG243C	1	U14
9.	130000	I.C. 74HC00	1	U10
8.	130004	I.C. 74HC04	1	U9
7.	199135	I.C. 80C88RS-2/UPD70108C-8	1	U8
6.	752040	I.C. Socket, 40 Pin	1	U8
5.	191059	I.C. LTC1059	1	U6
4.	120444	I.C. LF444	8	U5, U7, U11, U12, U13, U25, U27, U32
3.	120393	I.C. LM393	1	U4
2.	199136	I.C. 82C84A-2/UPD71084C	1	U2
1.	130074	I.C. 74HC74	2	U1, U3

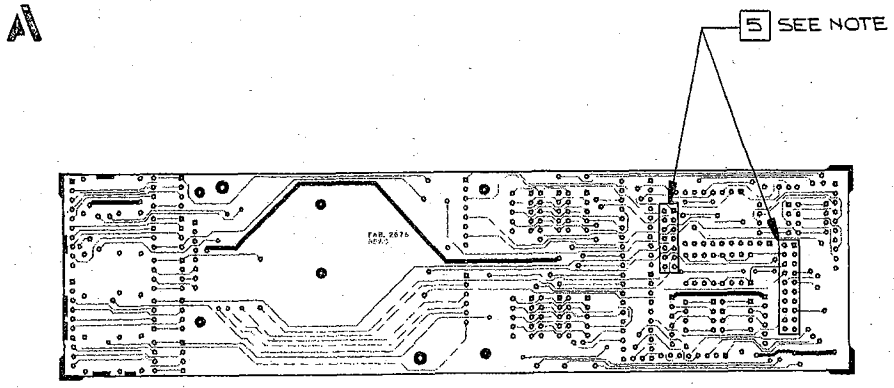
Processor PCB Assembly



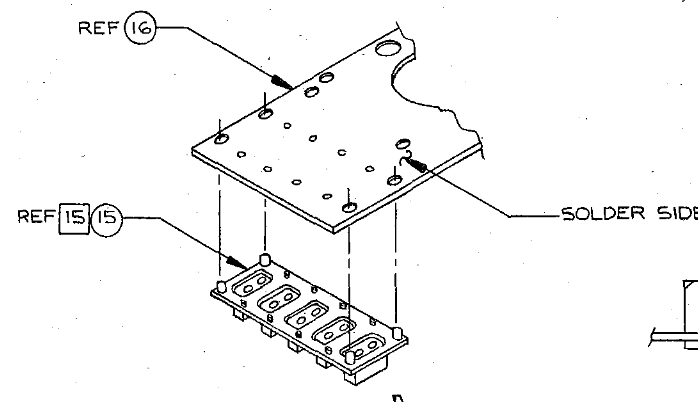
Display PCB Schematic



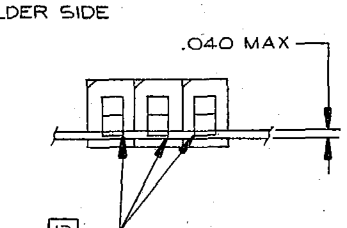
COMPONENT SIDE



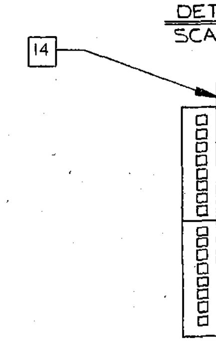
SOLDER SIDE



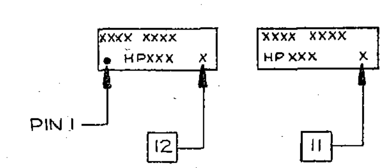
DETAIL A
SCALE: NONE



DETAIL B
SCALE : NONE



DETAIL C
SCALE: NONE



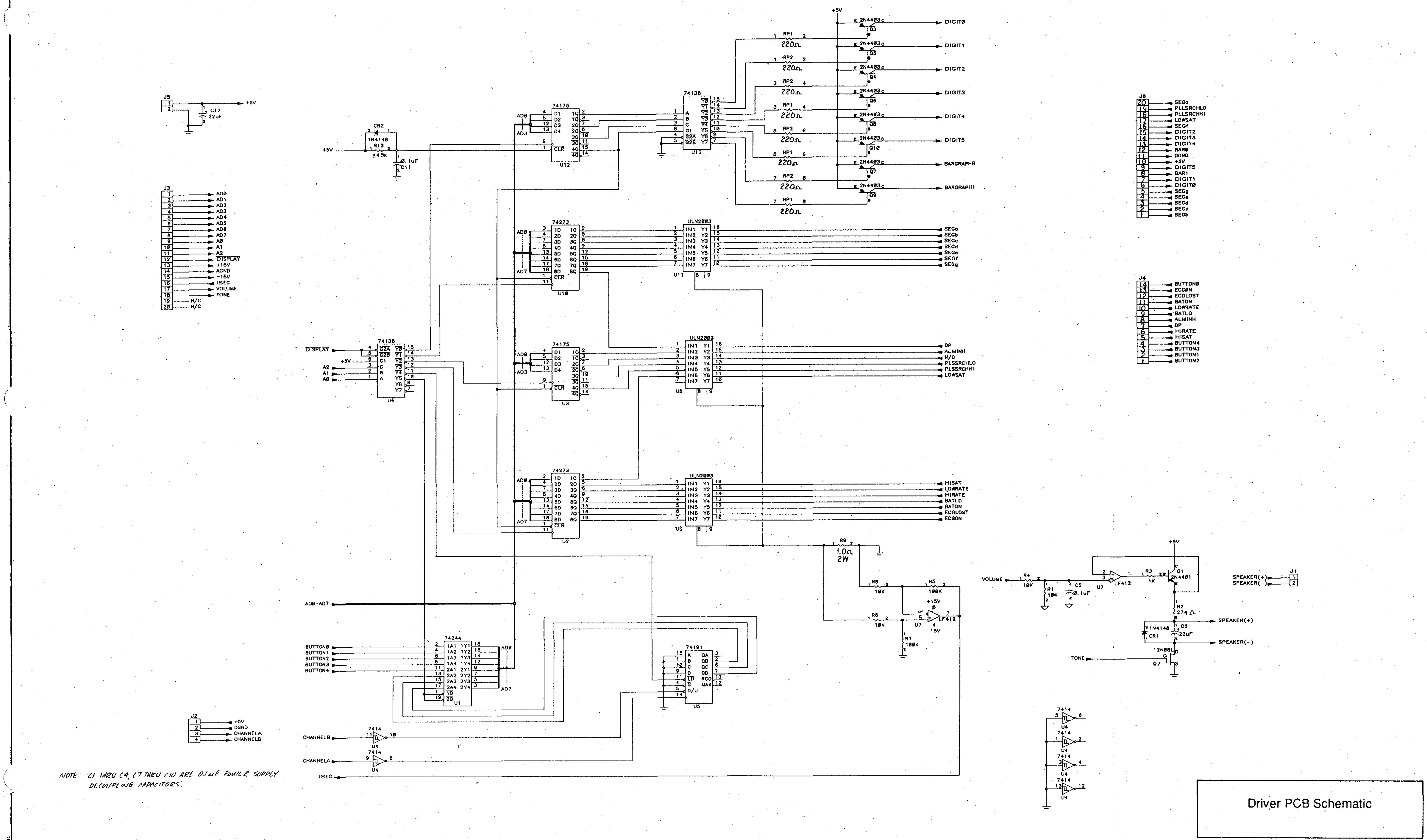
DETAIL D
SIDE VIEW
SCALE: NONE

NOTES:

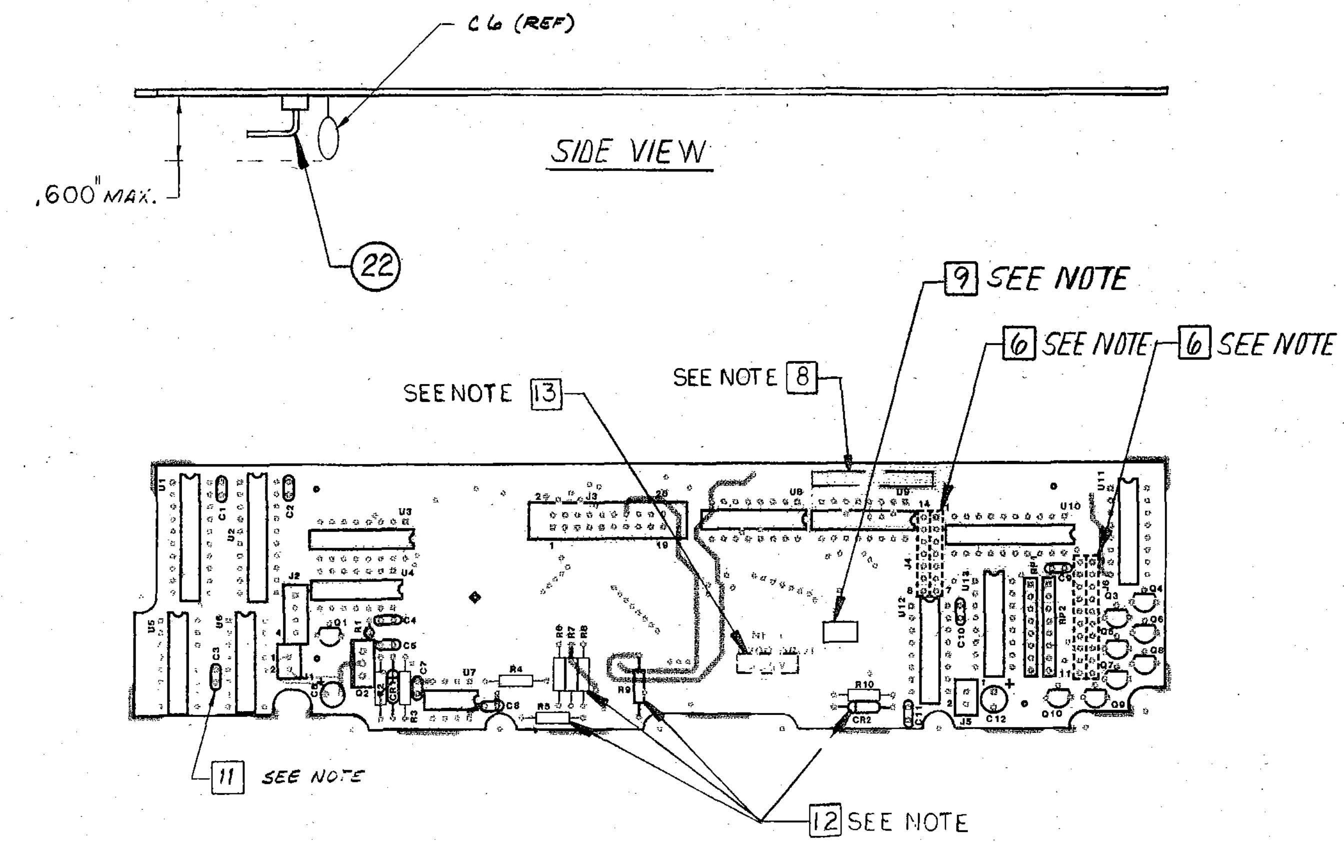
1. Orient I.C.'s with Pin 1 to Square Pad.
2. Color Coded (Banded) Resistors to be LEFT or UP as appropriate.
3. All Precision Resistors to be mounted with value visible.
4. Diodes to be mounted with Banded (Cathode) Side to Square Pad.
5. LOAD SOLDER SIDE: P6 and P4.
6. This Board contains static sensitive components and should be handled accordingly. After assembly, place in antistatic plastic bag.
7. Resistor packages, RN1 thru RN11, mounted with Pin 1 to Square Pad.
8. Apply assembly revision, vendor code, and the serial number in the area indicated on component side per procedure MI-019235.
9. Apply three (3) digit 'year week' date code in the area indicated on component side per procedure MI-019235.
10. LED light bars (Red), DS2 thru DS4, DS14 thru DS18 must have brightness codes of "E" or "F". LED light bars (Yellow), DS1 and DS5, must have brightness codes of "D" or "E". Do not mix brightness codes.
11. LED 7 segment displays, DS8 thru DS13 must have brightness codes of "C" or "D". Do not mix brightness codes. See Detail "D".
12. LED Bar Graph, DS6 and DS7 must have brightness codes of "G" or "H". Do not mix brightness codes. See Detail "D".
13. Align each set of three LEDs (DS8, 9, 10) & (DS11, 12, 13) such that the lower segments are between two parallel lines .040" apart per Detail "B".
14. Align both bargraphs, DS6 & DS7, such that bars are vertically aligned per Detail "C".
15. Install keypad (15) in-house using keypad insertion tool #3629. See Detail "A".
16. All LEDs to be installed with Pin 1 to Square Pad.
17. Clean gold contact area with alcohol before installing keypad. Solder not allowed on gold contact area.
18. All component leads not to exceed 1/16" max.
19. LED 7 segment display, P/N 510102, (White background), may be used if P/N 691090, (Black background), not available. LED Bar Graph, P/N 520102, (White background), may be used if P/N 691091, (Black background), not available. Color backgrounds may not be mixed, i.e., the entire assembly must be built with either all white or all black background parts for items 11 and 12.

ITEM	P/N	DESCRIPTION:	QTY	DESIGNATION
16.	052675	PCB, Display, Rev C	1	-
15.	052577	Keypad	1	See Notes 15,17
14.	491055	Conn Skt Strip, DR, 20 Pin	1	P6 SEE NOTE 5
13.	491057	Conn Skt Strip, DR, 14 Pin	1	P4 SEE NOTE 5
12.	691090	LED 7 Segment Display, High Eff.	6	DS8 thru DS13 } SEE NOTE 19
11.	691091	LED Bar Graph, High Eff., Red	2	DS7, DS6 } SEE NOTE 19
10.	542101	LED Light Bar, Yellow, Small	2	DS5, DS1, (HLMP-2755)
9.	540102	LED Light Bar, High Eff., Red, Large	1	DS3
8.	540101	LED Light Bar, High Eff., Red, Small	7	DS2, DS4 (HLMP-2655) DS14-DS18
7.	291059	Resistor, 47K, 6 Pin	1	RN11 } SEE NOTE 7
6.	291049	Resistor, 10K, 8 Pin	1	RN10 } SEE NOTE 7
5.	220101	Resistor Pkg, 100 Ohm, 10 Pin	4	RN9, RN8, RN3, RN1 } SEE NOTE 7
4.	230101	Resistor Pkg, 100 Ohm, 8 Pin	1	RN7 } SEE NOTE 7
3.	291043	Resistor Pkg, 56 Ohm, 8 Pin	2	RN6, RN2 } SEE NOTE 7
2.	291042	Resistor Pkg, 100 Ohm, 6 Pin	2	RN5, RN4 } SEE NOTE 7
1.	211002	Resistor, 1%, M.F., 10K	1	R1

Display PCB Assembly



Driver PCB Schematic



28.	053799	PCB, DRIVER II, BARE, REV A	1	
27.	491056	Conn Interconnect, DR, 20 Pin	1	J6 - SEE NOTE 6
26.	401002	Conn Header, Str, 2 Pin (Amp)	1	J5
25.	491058	Conn Interconnect, DR, 14 Pin	1	J4 - SEE NOTE 6
24.	401120	Conn Header, STR, 20 Pin	1	J3
23.	401004	Conn Header, Str, 4 Pin (Amp)	1	J2
22.	491104	Conn Header, R/A, 2 Pin	1	J1 - SEE SIDE VIEW
21.	604403	Transistor, 2N4403	8	Q3 thru Q10
20.	601208	Transistor, 12N08L	1	Q2
19.	604401	Transistor, 2N4401	1	Q1
18.	584148	Diode, 1N4148	2	CR1, CR2
17.	344226	Capacitor, Dipped Tant, 22uf, 35V	2	C6, C12
16.	304104	Capacitor, M.S., .10uf	10	C1, C2, C3, C4, C5, C7, C8, C9, C10, C11
15.	212493	Resistor, 1% M.F., 249K	1	R10
14.	291073	Resistor, 1% W/W, 2W, 1.0 Ohm	1	R9
13.	211003	Resistor, 1% M.F., 100K	2	R5, R7
12.	211001	Resistor, 1% M.F., 1K	1	R3
11.	210270	Resistor, 1% M.F., 27.4 Ohm	1	R2
10.	211002	Resistor, 1% M.F., 10.0K	4	R1, R4, R6, R8
9.	291074	Resistor Pkg, 8 Pin SIP, 220 Ohm	2	RP1, RP2
8.	192003	I.C., ULN2003	3	U8, U9, U11
7.	120412	I.C., LF412	1	U7
6.	130138	I.C., 74HC138	2	U6, U13
5.	130191	I.C., 74HC191	1	U5
4.	130014	I.C., 74HC14	1	U4
3.	130175	I.C., 74HC175	2	U3, U12
2.	130273	I.C., 74HC273	2	U2, U10
1.	130244	I. C., 74HC244	1	U1
ITEM	P/N	DESCRIPTION	QTY	DESIGNATION

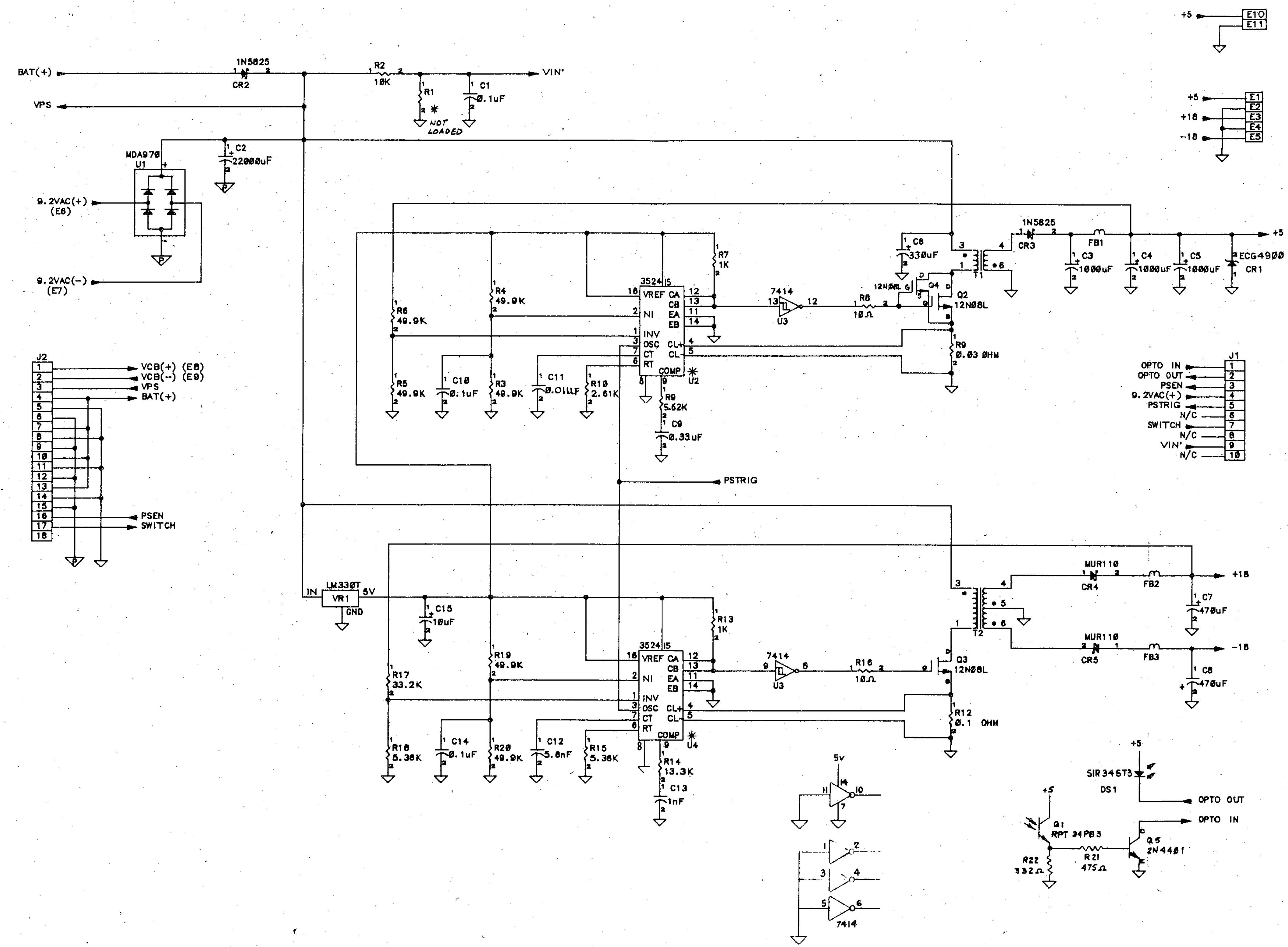
NOTES:

1. Orient I.C.'s with Pin 1 to Square Pad.
2. Polarized Capacitors to be mounted with Positive Side to Square Pad.
3. Color Coded (Banded) Resistors to be LEFT or UP as appropriate.
4. All Capacitors and Precision Resistors to be mounted with value visible.
5. Diodes to be mounted with Banded (Cathode) Side to Square Pad.
6. LOAD SOLDER SIDE: J6 and J4.
7. This Board contains static sensitive components and should be handled accordingly. After assembly, place in anti-static plastic bag.
8. Apply Assembly Revision, Vendor Code, and the Serial Number in the area indicated on COMPONENT SIDE per procedure MI-019235.
9. Apply three (3) digit "Year Week" date code in the area indicated on COMPONENT SIDE per procedure MI-019235.
10. ALL COMPONENT LEADS NOT TO EXCEED 1/16" MAX.
11. CAPACITOR C3 HEIGHT NOT TO EXCEED TOP OF IC. U6.
12. **DIODE CR2 AND RESISTORS R5 THRU R10 TO BE MOUNTED MAX OF .010" OFF PCB.**
13. PCB'S PASSING "IN CIRCUIT TEST" MUST BE STAMPED BY VENDOR ON SOLDER SIDE.

REFERENCE NOTES

1. REFERENCE "MADIC" BILL OF MATERIALS, 993800, FOR OUTSIDE VENDOR PROCESSING OF PCB ASSEMBLY.

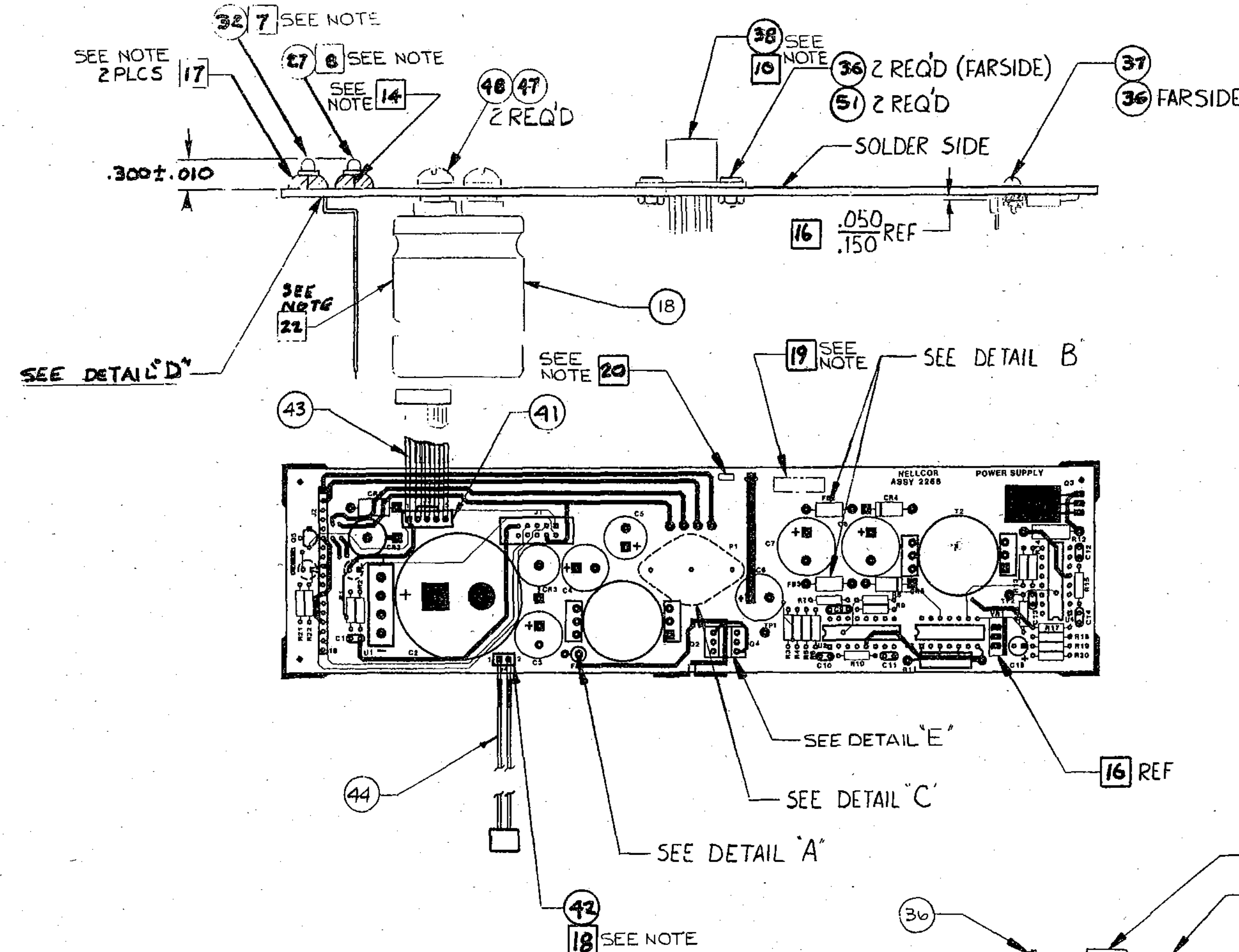
Driver PCB Assembly

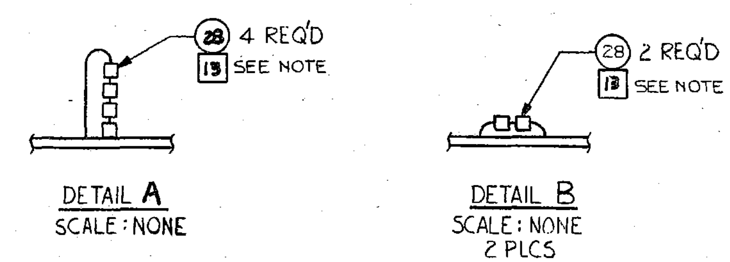


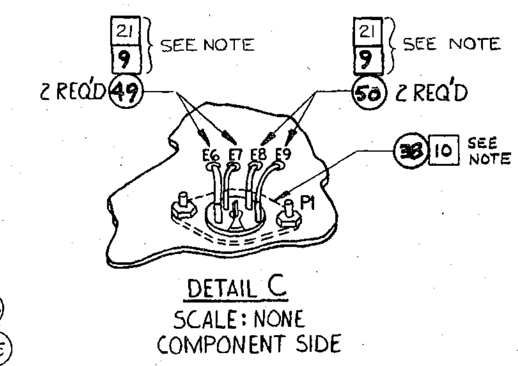
NOTES:
1. ALL RESISTORS 1% METAL FILM UNLESS SPECIFIED OTHERWISE
2. ALL RESISTORS IN KOHMS UNLESS SPECIFIED OTHERWISE
3. ALL RESISTANCES FOLLOWED BY ASTERISK IN OHMS
✱ USE ONLY NATIONAL LM3524.

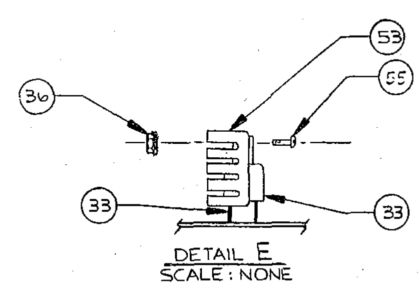
Power Supply PCB Schematic

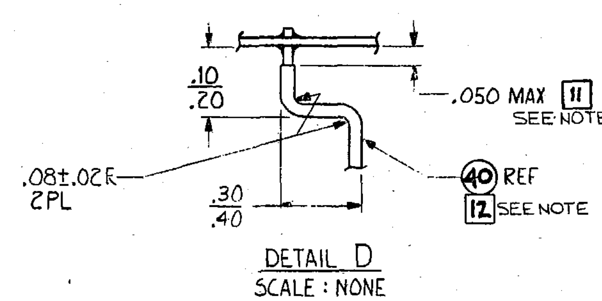
PRINTED ON DIEPO NO. 1000H CLEARPRINT











NOTES:

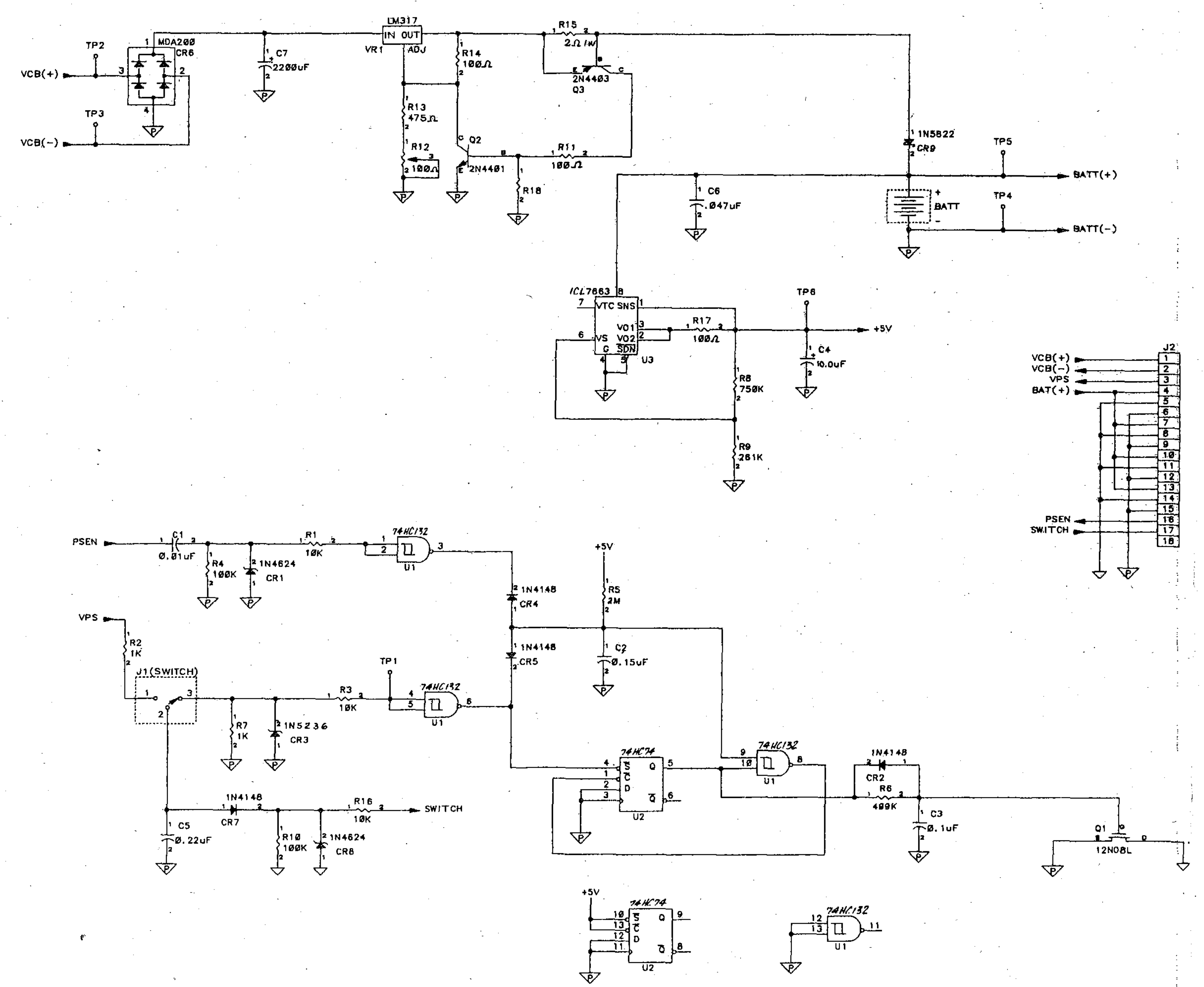
1. Orient I.C.'s with Pin 1 to Square Pad.
2. Polarized Capacitors to be mounted with Plus (+) side to Square Pad.
3. Color coded Resistors to be mounted with color code LEFT or UP as appropriate.
4. ALL Capacitors and Precision Resistors to be mounted with value visible.
5. Diodes to be mounted with banded (Cathode) side to Square Pad.
6. This board contains static sensitive components and must be handled accordingly. After assembly, place in anti-static bag.
7. Mount Q1 with long lead in Square Pad.
8. Mount DS1 with short lead in Square Pad.
9. Strip gap not to exceed .100" above the PCB. Solder joints to be clearly visible (both sides). Tin stripped wires before soldering.
10. Connector (38) to be installed flush to PCB. INSTALL FROM SOLDER SIDE.
11. Solder flex jumper (40) with a max. gap of .050" to the insulation. Solder joints must be clearly visible. Non-conductive spacers may be used at Pins 1 & 18.
12. Pre-bend flex jumper (40) as shown in Detail 'D'. Bends to have radius as shown (do not make complete fold).
13. Use 20ga Buss Wire to load Ferrite Beads (28).
14. Apply heatsink to DS1 & Q1 leads close to the component body during soldering. Soldering tip temperature to be a max. of 600° F for max. of 5 seconds. USE 30 WATT SOLDERING IRON. SOLDER FROM PCB COMPONENT SIDE ONLY. WAIT MIN. OF 10 MINUTES AFTER SOLDERING BEFORE CUTTING THE LEADS.
15. All component leads not to exceed 1/16" max.
16. Solder VR1 (35) .050" - .150" above the PCB.
17. Apply hot melt glue (52) to the base of phototransistor Q1 (32) & LED DS1 (27) as shown. Hot melt glue not to exceed 1/3 height of the bulbs. Items (27),(32), & (52) to be installed in-house.
18. Orient Cable Assy (44) with Black wire to Pin 1 (Square Pad).
19. Apply assembly revision, vendor code, and the serial number in area indicated on Component Side per procedure MI-019235.
20. Apply three (3) digit 'Year Week' date code in the area indicated on Component Side per procedure MI-019235.
21. All wire connections from P1 to E6, 7, 8, and 9 to be 1.50 inches long.
22. BEFORE INSTALLING, MARK CAPACITOR C2 (WITH PERMANENT INK) WITH "+" SIGN ON POSITIVE SIDE OF COMPONENT
23. RESISTOR R1 NOT LOADED.

REFERENCE NOTE:

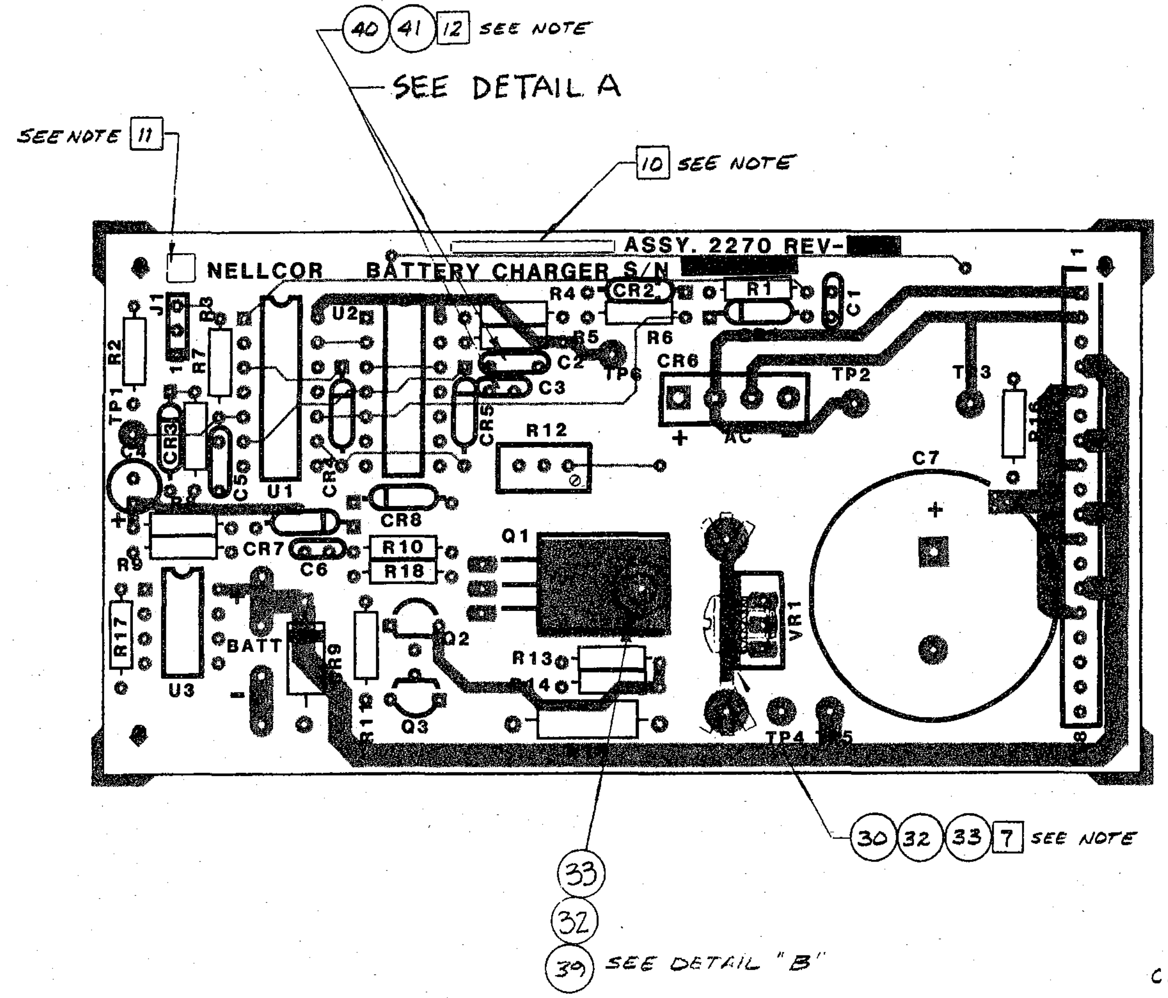
1) REFERENCE "MAGIC" BILL OF MATERIAL 982268 OR 992268 FOR OUTSIDE VENDOR PROCESSING OF PCB ASSEMBLY.

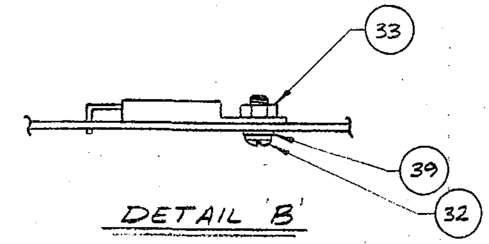
ITEM	P/N	DESCRIPTION:	QTY	DESIGNATION
55.	801038	SCREW, PAN HEAD, 4-40 x 3/8"	1	Q2, Q4
54.	052267	PCB, Power Supply, Bare, Rev C	1	-
53.	891141	Heat Sink, TO-220 Trans. Pkg	1	Q2/Q4
52.	901091	Hot melt glue	A/R	-
51.	891111	Screw, Flathead, 82° #4-40 x 3/8"	2	P1
50.	721430	Wire, 22 GA, Orange, UL1007	3"	P1,E8,E9
49.	721470	Wire, 22 GA, Violet, UL1007	3"	P1,E6,E7
48.	866401	Washer, Lock Internal #10	2	C2
47.	804031	Screw, 10-32 x 5/16	2	C2
46.	051167	ASSY, Transformer P.S.	1	T2
45.	053409	ASSY, 5 Volt Transformer	1	T1
44.	074343	ASSY, Cable, Display/Power Supply PCBs	1	J4
43.	074342	ASSY, Cable, Power Supply/Prcssr PCBs	1	J3
42.	401002	Connector, Hdr, 2 Pin, Str.	1	J4
41.	491086	Connector, Hdr, 5 Pin, Str., Locking	1	J3
40.	491096	Connector, Flex Jumper, 18 Pin 2" long	1	J2 - See Detail D
39.	401110	Connector, Hdr, Str, 10 Pin	1	J1
38.	491084	Connector, DIN, 4 Pin (Male)	1	P1
37.	801025	Screw, Pan Head, 4-40 x 1/4"		Q3
36.	851101	Kepnut, 4-40	4	P1, Q2/Q4,Q3
35.	616005	Regulator, +5V, LM330T	1	VR1
34.	604401	Transistor, 2N4401	1	Q5
33.	601208	Transistor, 12N08L, 12 Amp	3	Q2, Q3, Q4
32.	691035	Transistor, Photo	1	Q1
31.	591004	Diode, MUR110, 100V	2	CR4, CR5
30.	585825	Diode, 1N5825	2	CR2, CR3
29.	584900	Diode, 1N5908 (ECG4900)	1	CR1
28.	691010	Ferrite Beads	8	FB3 (2ea) FB2 (2ea) SEE DETAIL B; FB1 (4 ea) See Detail A
27.	501001	LED, IR Lamp	1	DS1
26.	344106	Capacitor, Dipped Tant, 25V, 10uf	1	C15
25.	304102	Capacitor, M.S. .001uf	1	C13
24.	304562	Capacitor, M.S. .0056uf	1	C12
23.	304103	Capacitor, M.S. .01uf	1	C11
22.	304334	Capacitor, M.S. 0.33uf	1	C9
21.	399114	Capacitor, Electrolytic, 25V 470uf	2	C7, C8
20.	399115	Capacitor, " 25V 330uf	1	C6
19.	399116	Capacitor, " 10V 1000uf	3	C3, C4, C5
18.	399117	Capacitor, Electrolytic, 25V 22,000uf	1	C2
17.	304104	Capacitor, M.S. .10uf	3	C1,C10, C14
16.	213320	Resistor, 1% M.F. 332 Ohm	1	R22
15.	214750	Resistor, 1% M.F. 475 Ohm	1	R21
14.	213322	Resistor, 1% M.F. 33.2K	1	R17
13.	215361	Resistor, " " 5.36K	2	R15, R18
12.	211332	Resistor, " " 13.3K	1	R14
11.	291001	Resistor, 1%, 1W WW .1 Ohm	1	R12
10.	291052	Resistor, 1%, 3W WW .03 Ohm	1	R11
9.	212611	Resistor, 1% M.F. 2.61K	1	R10
8.	215621	Resistor, " " 5.62K	1	R9
7.	210100	Resistor, " " 10 Ohm	2	R8, R16
6.	211001	Resistor, " " 1.00K	2	R7, R13
5.	214992	Resistor, " " 49.9K	6	R3, R4, R5 R6,R19,R20
4.	211002	Resistor, " " 10.0K	1	R2
3.	130014	I.C. 74HC14	1	U3
2.	199139	I.C. LM3524N	2	U2, U4
1.	691004	Bridge Rectifier, MDA 970A2 (IBU8B)	1	U1

Power Supply PCB Assembly

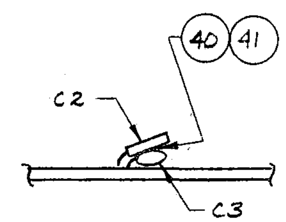


Battery Charger PCB Schematic





DETAIL 'B'



DETAIL A
SIDE VIEW

ITEM	P/N:	DESCRIPTION:	QTY	DESIGNATION:
42.	585236	DIODE, IN5236, 7.5 V ZENER	1	CR 3
41.	901077	LOCTITE ACCELERATOR	A/R	C2, C3
40.	901009	LOCTITE ADHESIVE	A/R	C2, C3
39.	891026	WASHER, NYLON # 4	1	Q1
38.	052269	PCB, Battery Charger, Rev B	1	-
37.	491097	Connector Socket, Flex 18 Pin	1	J2
36.	401003	Connector Header, STR, 3 Pin	1	J1
35.	481015	Terminal, Test Point	6	TP1 thru TP6
34.	481014	Terminal, Disconnect Tab, .250	2	BATT+, BATT-
33.	851101	Kepnut, 4-40	2	VR1, Q1
32.	801038	Screw, Pan Hd, 4-40 x 3/8"	2	VR1, Q1
31.	891089	Heat Sink, Power Transistor	1	VR1,
30.	901097	Adhesive, Thermal Conductive	A/R	VR1
29.	691048	Voltage Regulator, Adj, LM317	1	VR1
28.	604403	Transistor, 2N4403	1	Q3
27.	604401	Transistor, 2N4401	1	Q2
26.	601208	Transistor, 12N08L	1	Q1
25.	585818	Diode, 1N5818	1	CR9
24.	691034	Bridge Rectifier, MDA200	1	CR6
23.	584148	Diode, 1N4148	4	CR2, CR4, CR5, CR7
22.	584624	Diode, 1N4624	2	CR1, CR8
21.	399113	Capacitor, Alum Elec. 2200uf	1	C7
20.	304473	Capacitor, M.S. .047uf	1	C6
19.	304224	Capacitor, M.S. .22uf	1	C5
18.	344106	Capacitor, Dip. Tant, 25V, 10 uf	1	C4
17.	304104	Capacitor, M.S. .10uf	1	C3 SEE DETAIL A
16.	304154	Capacitor, M.S. .15uf	1	C2 SEE DETAIL A
15.	304103	Capacitor, M.S. .01uf	1	C1
14.	291053	Resistor, 1% 1W WW 2 Ohm	1	R15
13.	214750	Resistor, 1% M.F. 475 Ohm	1	R13
12.	291012	Potentiometer, 18 Turn 100 Ohm	1	R12
11.	211000	Resistor, 1% M.F. 100 Ohm	3	R11, R14, R17
10.	212613	Resistor, 1% M.F. 261K	1	R9
9.	217503	Resistor, 1% M.F. 750K	1	R8
8.	214993	Resistor, 1% M.F. 499K	1	R6
7.	212004	Resistor, 1% M.F. 2 Meg Ohm	1	R5
6.	211003	Resistor, 1% M.F. 100K	2	R4, R10
5.	211001	Resistor, 1% M.F. 1.00K	2	R2, R7
4.	211002	Resistor, 1% M.F. 10.0K	3	R1, R3, R16
3.	197663	I.C. ICL7663	1	U3
2.	130074	I.C. 74HC74	1	U2
1.	130132	I.C. 74HC132	1	U1

NOTES:

1. Orient I.C.'s with Pin 1 to Square Pad.
2. Color Code Resistors to be LEFT or UP as appropriate.
3. All Capacitors and Precision Resistors to be mounted with value visible.
4. Polarized Capacitors mounted with positive (+) side to Square Pad.
5. Diodes mounted with banded (Cathode) side to Square Pad.
6. Resistor R18 is NOT loaded.
7. Apply Thermal Conductive Adhesive (30) to Heat Sink surface before mounting VR1.
8. All component leads not to exceed 1/16" maximum.
9. This PCB ASSY contains static-sensitive components. Please Handle With Care.
10. Apply assembly revision, vendor code, and the serial number in the area indicated on component side per procedure MI-019235.
11. Apply three (3) digit "year Week" date code in the area indicated on the component side per procedure MI-019235.
12. INSTALL CAPACITOR C3 FLUSH TO PCB PER DETAIL 'A'. INSTALL CAPACITOR C2 AND SECURE TO CAPACITOR C3 USING ADHESIVE (40 & 41) PER DETAIL 'A'.

REFERENCE NOTE:

1. Reference Madic Bill of Material 992270 for outside vendor processing of PCB Assy.

Battery Charger PCB Assembly

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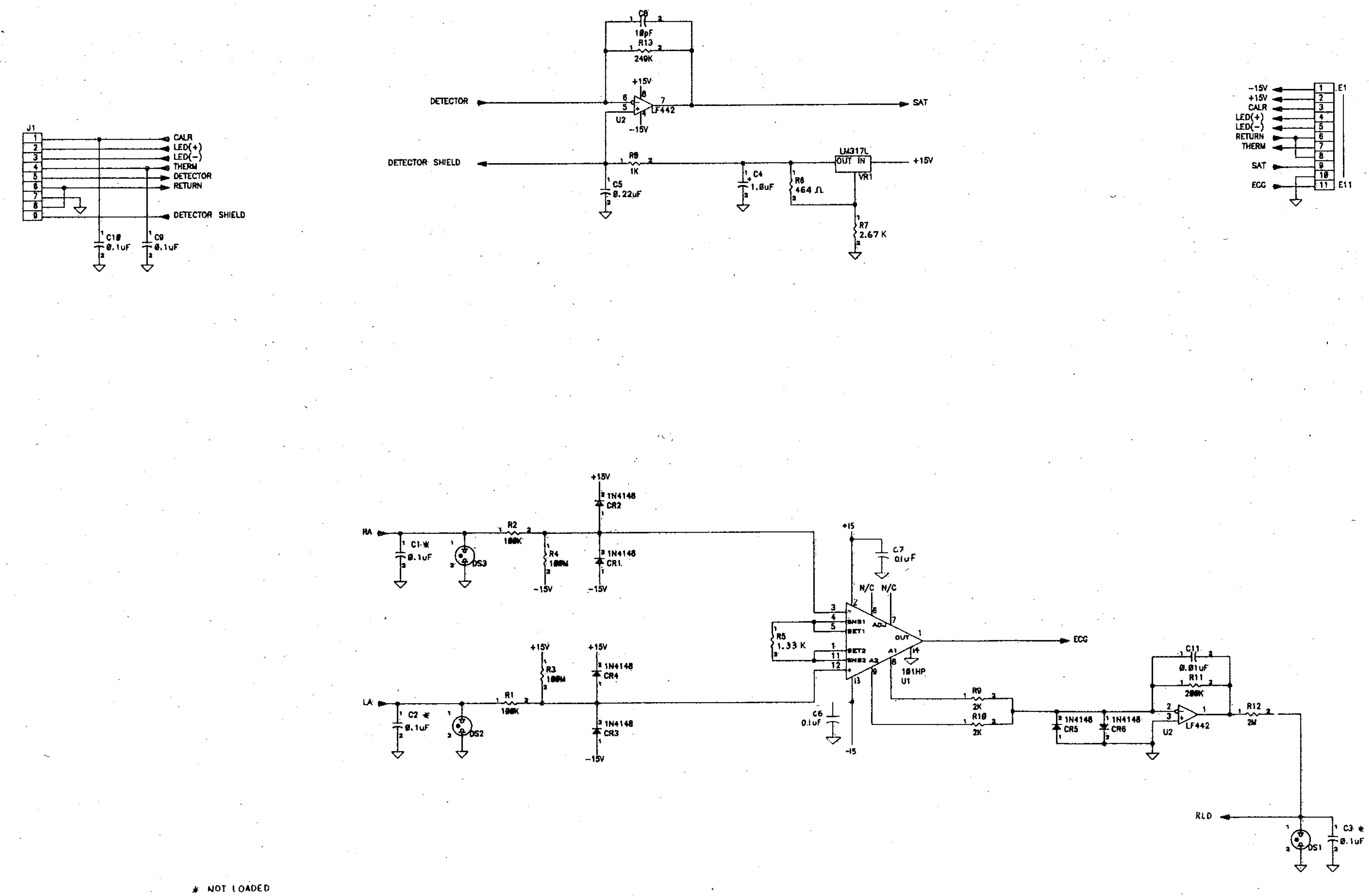
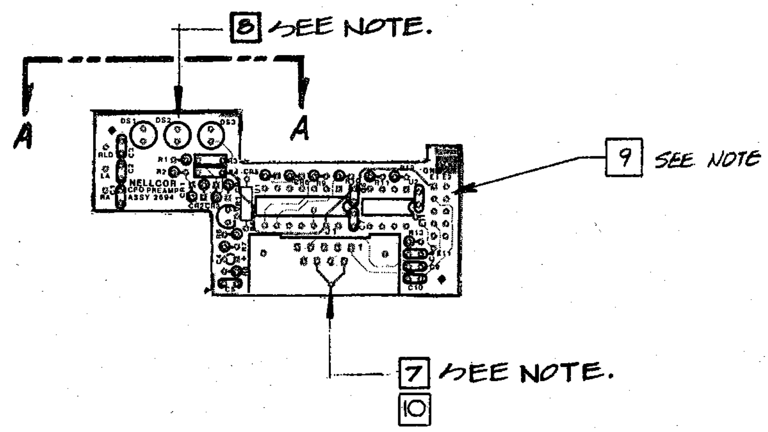
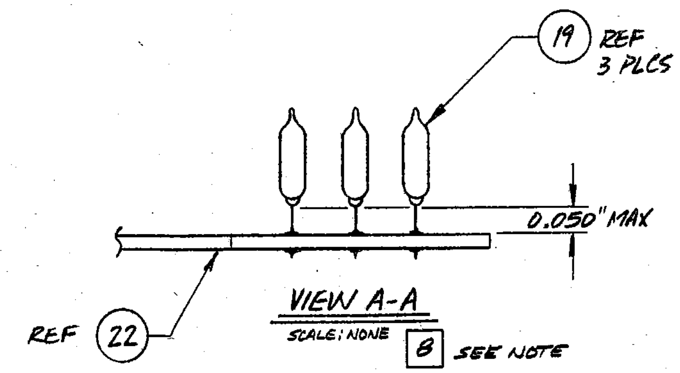


Patient Module PCB Schematic





NOTES:

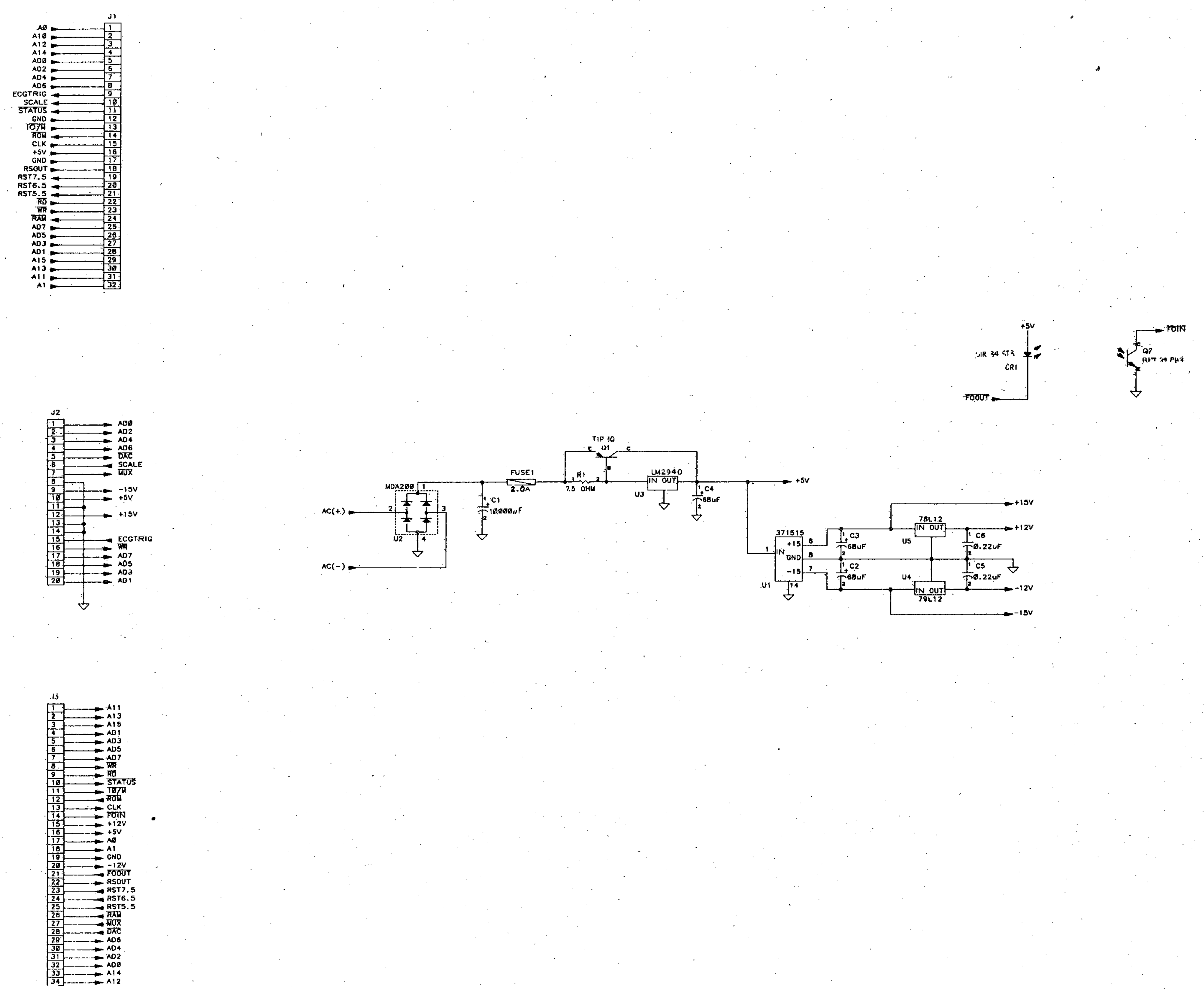
1. Orient I.C.'s with Pin 1 to Square Pad.
2. Color Coded Resistors to be LEFT or UP as appropriate.
3. Mount all Capacitors and Precision Resistors with value visible.
4. Polarized Capacitors to be mounted with positive (+) side to Square Pad.
5. Diodes to be mounted with banded (Cathode) side to Square Pad.
6. Capacitors C1, C2, C3 are NOT Loaded.
7. REMOVE BRACKET FROM CONNECTOR, J1, AFTER SOLDERING IN PLACE, IF REQUIRED.
8. LAMPS, DS1, DS2 AND DS3 TO BE MOUNTED WITH MAX LEAD LENGTH OF 0.050" ABOVE THE PCB AND THE SOLDER JOINT CLEARLY VISIBLE (BOTH SIDES) PER VIEW A-A.
9. SOLDER MASK HOLES E1 THRU E11 BEFORE WAVESOLDERING.

NOTE: THIS BOARD CONTAINS STATIC SENSITIVE COMPONENTS AND SHOULD BE HANDLED ACCORDINGLY.

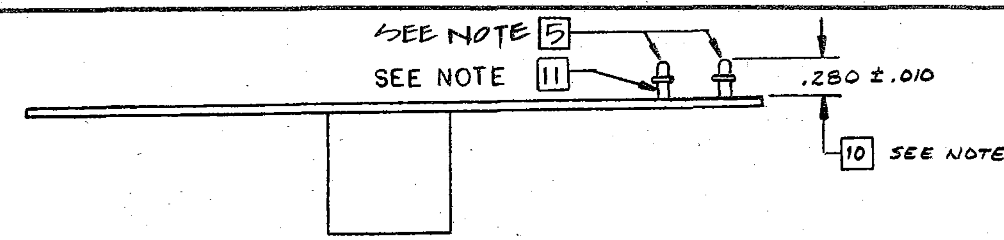
10. CONNECTOR, (20), TO BE SEALED IN THE GAP BETWEEN PINS AND PLASTIC INSULATOR, AND BETWEEN METAL SHELL AND PLASTIC INSULATOR USING ADHESIVES (23) & (24).

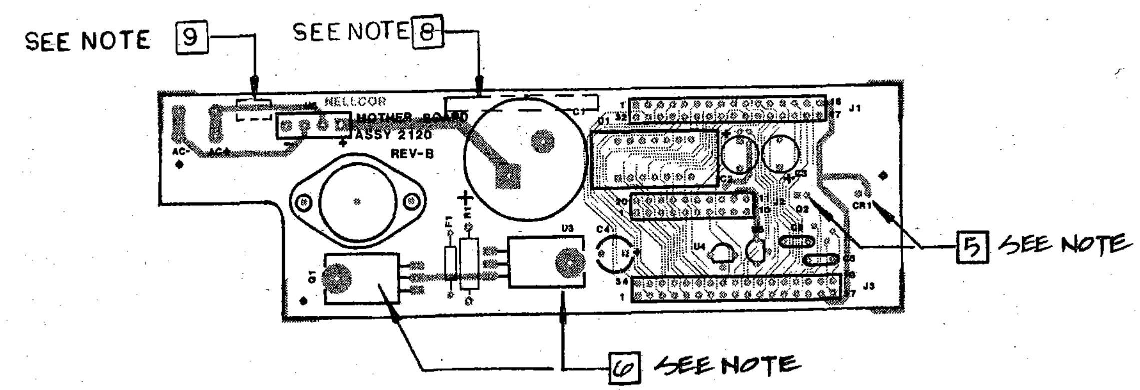
#	P/N	DESCRIPTION:		QTY	REFERENCE
24.	901117	ADHESIVE, LOCTITE #460		A/R	J1 } SEE NOTE 10
23.	901009	ADHESIVE, ACCELERATOR		A/R	J1 } SEE NOTE 10
22	052493	PCB, PREAMP, BARE		1	–
21.	212493	RESISTOR 1% M.F.	249K	1	R13
20.	491122	Connector, 9 Pin D, FEMALE, GREEN		1	J1 – SEE NOTE 7, 10
19.	691066	Lamp, Neon		3	DS1, DS2, DS3 – SEE NOTE 8
18.	691052	Voltage Regulator, Adjustable, LM317 (TO-92)		1	VR1
17.	584148	Diode, 1N4148		6	CR1 thru CR6
16.	304103	Capacitor, M.S.	.01uf	1	C11
15.	304100	Capacitor, "	10pf	1	C8
14.	304104	Capacitor, "	.10uf	4	C6, C7, C9, C10
13.	304224	Capacitor, "	.22uf	1	C5
12.	344105	Capacitor, Dipped Tant, 35V	1uf	1	C4
11.	212004	Resistor, 1% M.F.	2 Meg	1	R12
10.	212003	Resistor, " "	200K	1	R11
9.	212001	Resistor, " "	2.00K	2	R9, R10
8.	211001	Resistor, " "	1.00K	1	R8
7.	212671	Resistor, " "	2.67K	1	R7
6.	214640	Resistor, " "	464 Ohm	1	R6
5.	211331	Resistor, " "	1.33K	1	R5
4.	291045	Resistor, 100 Meg Ohm Precision Film		2	R3, R4
3.	211003	Resistor, 1% M.F.	100K	2	R1, R2
2.	120442	ICS LF442N		1	U2
1.	199125	ICS INA101HP		1	U1

Patient Module PCB Assembly



Mother PCB Powerbase Schematic





NOTES:

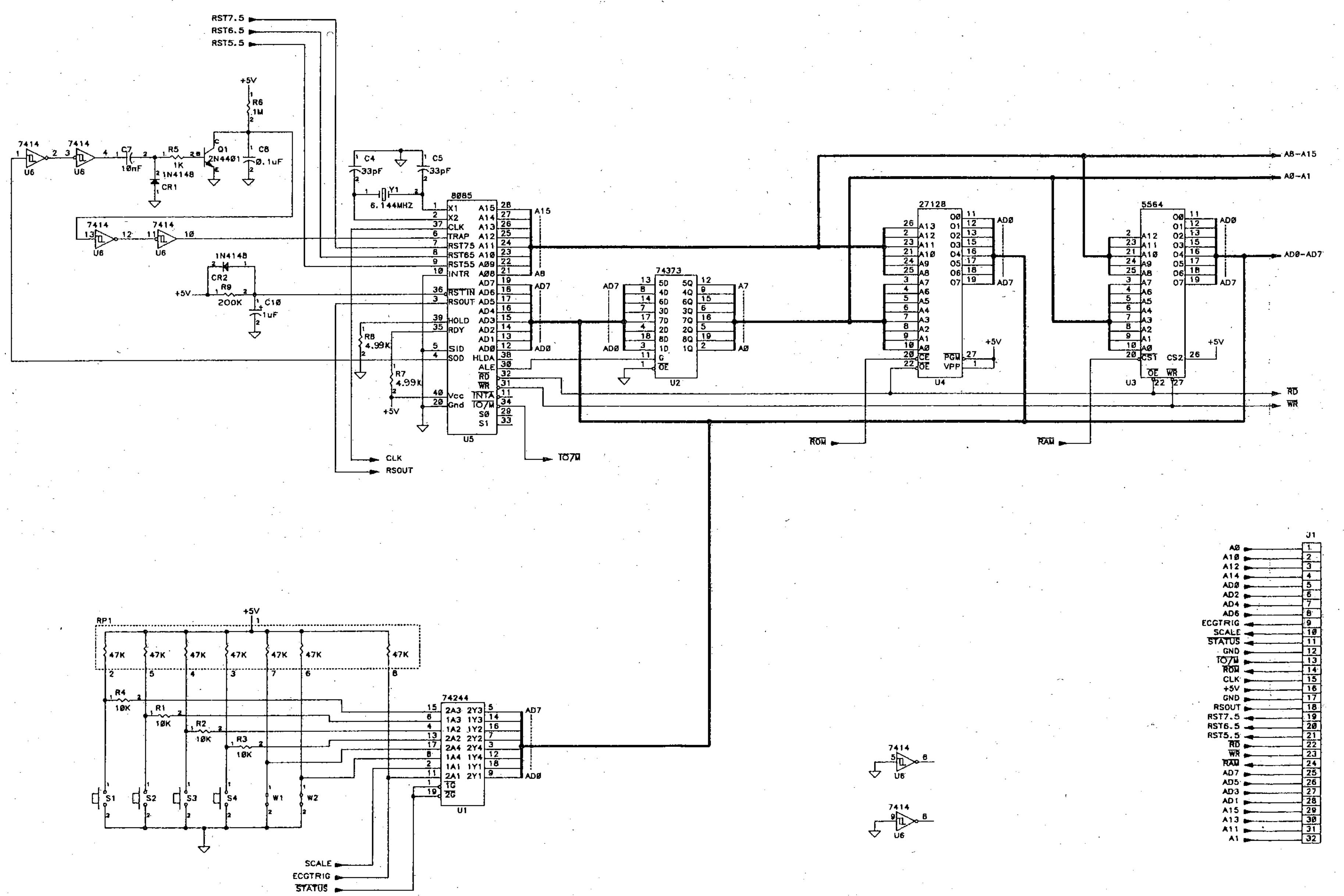
1. Orient I.C.'s with Pin 1 to Square Pad.
2. Polarized Capacitors to be mounted with positive (+) side to Square Pad.
3. Color coded Resistors to be LEFT or UP as appropriate.
4. Mount all Capacitors and Precision Resistors with value visible.
5. IR LED Lamp, CR1, and Photo Transistor, Q2, to be mounted on SOLDER SIDE, with CR1 short lead to Square Pad, and Q2 long lead to Square Pad.
6. Mount Voltage Regulator, U3, and Transistor, Q1, with Screw and Kepnut, Items 12 & 11; Kepnut to COMPONENT SIDE of PCB.
7. NOTE: This Board contains static sensitive components and should be handled accordingly.
8. Apply Assembly Revision, Vendor Code, and the Serial Number in the area indicated on SOLDER SIDE per procedure MI-019235.
9. Apply three (3) digit "Year Week" date code in the area indicated on SOLDER SIDE per procedure MI-019235.
10. DIMENSION SHOWN IS FROM TOP OF THE PCB TO THE TOP OF THE LED'S.
11. LEADS OF PHOTO TRANSISTOR,Q2,(13) AND LED LAMP CR1,(14) TO BE HEATSINKED CLOSE TO COMPONENT BODY DURING SOLDERING, SOLDERING TIP TEMPERATURE TO BE MAX. OF 700°F FOR MAX OF 5 SECONDS.
12. ALL COMPONENT LEADS NOT TO EXCEED 1/16" MAX.

REFERENCE NOTES:

1. Reference "MADIC" Bill of Materials, 992120, for outside Vendor Processing of PCB Assembly.

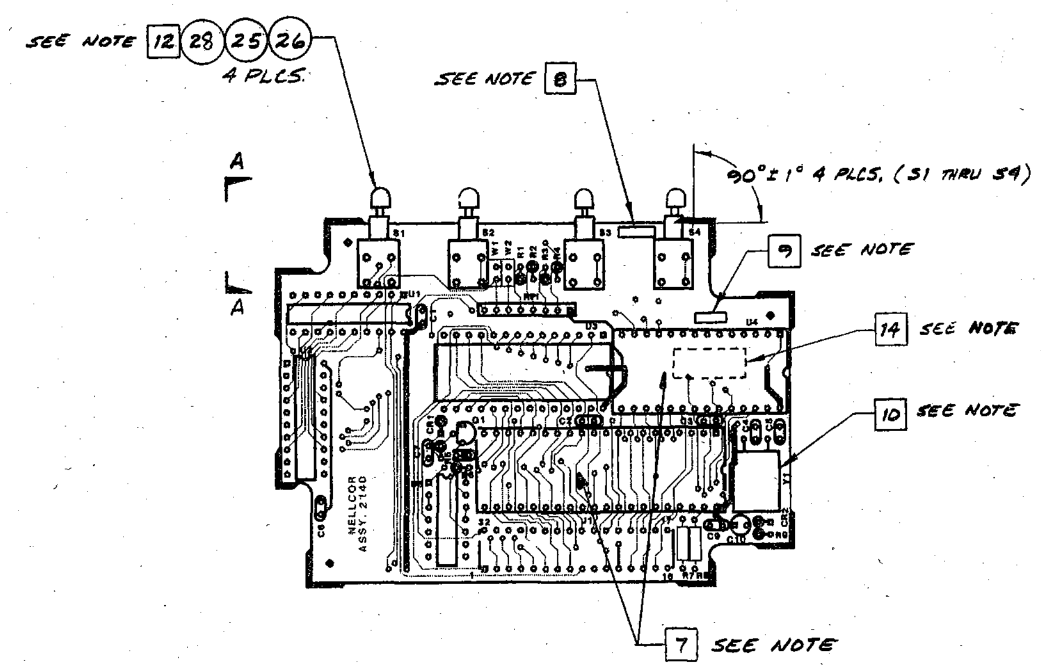
ITEM	P/N	DESCRIPTION	QTY	DESIGNATION
20.	052119	PCB, Mother, Bare, Rev B	1	-
19.	491101	Connector, Hdr, Str, 34 Pin	1	J3
18.	491103	Connector, Hdr, Str, 20 Pin	1	J2
17.	491102	Connector, Hdr, Str, 32 Pin	1	J1
16.	481014	Terminal, Disconnect Tab, .250"	2	AC+, AC-
15.	691024	Picofuse, 2.0 Amp	1	F1
14.	501001	LED Lamp, I.R.	1	CR1 - See Note 5
13.	691035	Photo Transistor,	1	Q2 - See Note 5
12.	801025	Screw, Pan Hd, 4-40 x 1/4"	2	Q1, U3
11.	851101	Kepnut, 4-40	2	Q1, U3
10.	600030	Transistor, TIP30	1	Q1
9.	304224	Capacitor, MS. .22uf	2	C5, C6
8.	344686	Capacitor, Dipped Tant. 25V 68uf	3	C2, C3, C4
7.	399111	Capacitor, Alum. Elect. 25V 10,000 uf	1	C1
6.	250070	Resistor, 1/2W, 5% CC 7.5 Ohm	1	R1
5.	610012	Voltage Regulator, +12V, 78L12	1	U5
4.	611012	Voltage Regulator, -12V, 79L12	1	U4
3.	691049	Voltage Regulator, +5V, LM2940	1	U3 - See Note 6
2.	691034	Bridge Rectifier, MDA200	1	U2
1.	191515	I.C. DIP371515DB	1	U1

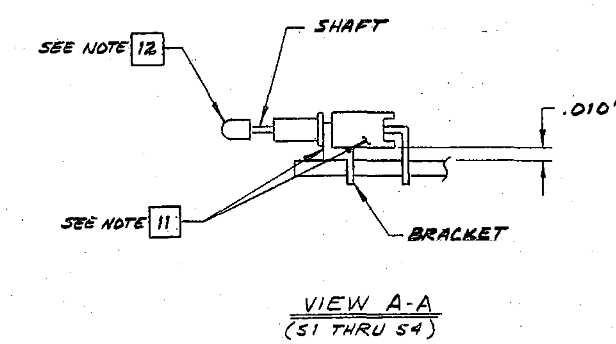
Mother PCB Powerbase Assembly



NOTE: C1,C2,C3,C6,C9 ARE 0.1uF POWER SUPPLY DECOUPLING CAPACITORS.

Upper Daughter PCB Powerbase Schematic





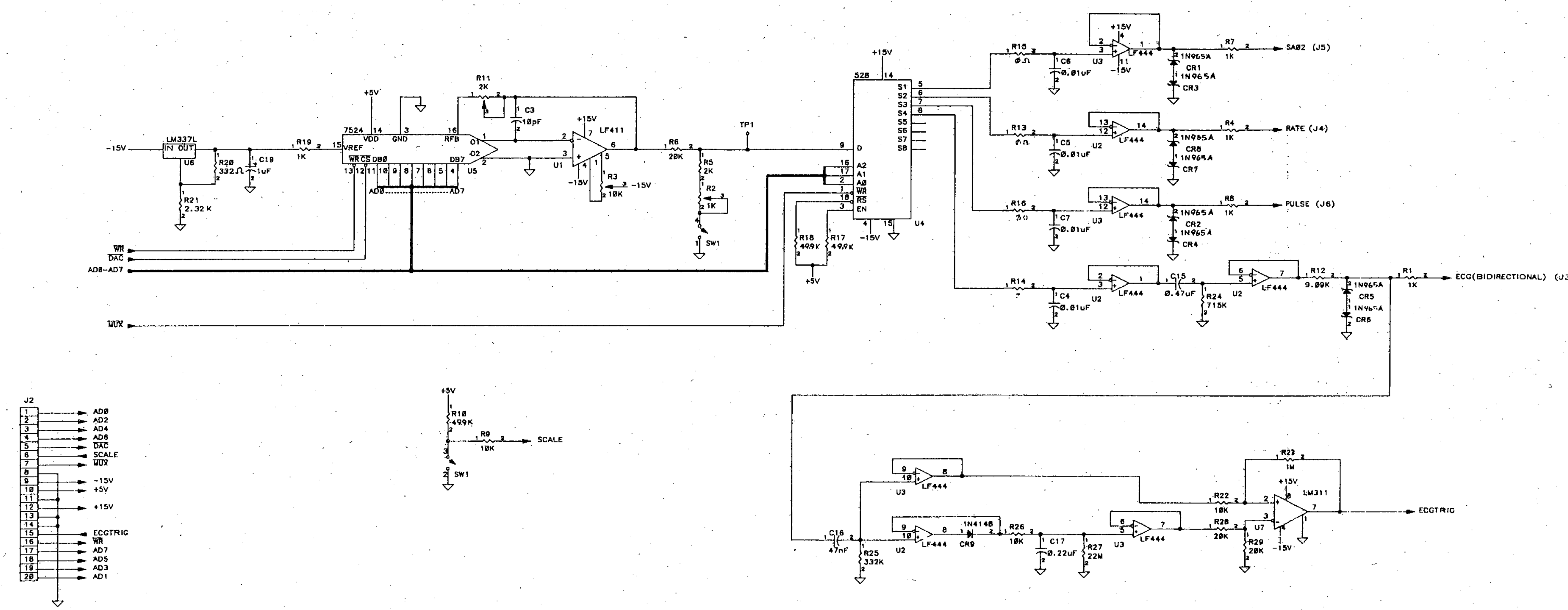
VIEW A-A
(S1 THRU S4)

NOTES:

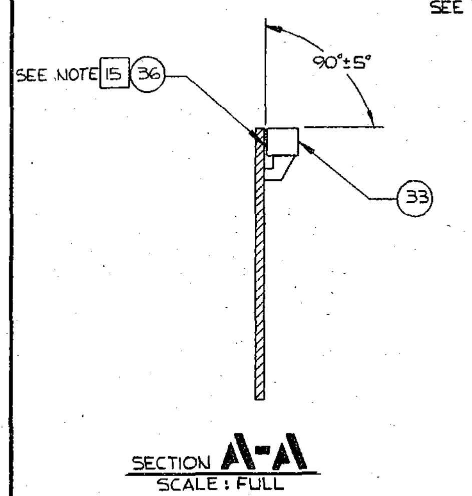
1. Capacitor, C3, is NOT loaded.
2. Orient I.C.'s with Pin 1 to Square Pad.
3. Polarized Capacitors to be mounted with Positive (+) side to Square Pad.
4. Color Coded Resistors to be LEFT or UP as appropriate.
5. Diodes to be mounted with banded (Cathode) side to Square Pad.
6. NOTE: This board contains static sensitive components and should be handled accordingly.
7. Add tape (24) to I.C. Sockets U4 and U5 (cut to length of Socket) before loading ROM Ø assembly (5) and IC 80C85A (7).
8. Apply assembly revision, vendor code, and the serial number in the area indicated on Solder side per procedure MI-019235.
9. Apply three (3) digit 'Year Week' date code in the area indicated on Solder side per procedure MI-019235.
10. Crystal, Y1, (22) to be secured with foam tape (24), or hot melt glue, P/N 901091. Keep Y1 body within its silkscreened outline.
11. Switches S1-S4 to be mounted flush to PCB. Max gap of .010" allowed between PCB and bracket per view A-A.
12. Caps (25) must be completely seated and properly aligned on S1-S4 shaft.
13. All component leads to be 1/16" max.
14. PCB's passing "In Circuit Test" must be stamped by vendor on Solder Side.

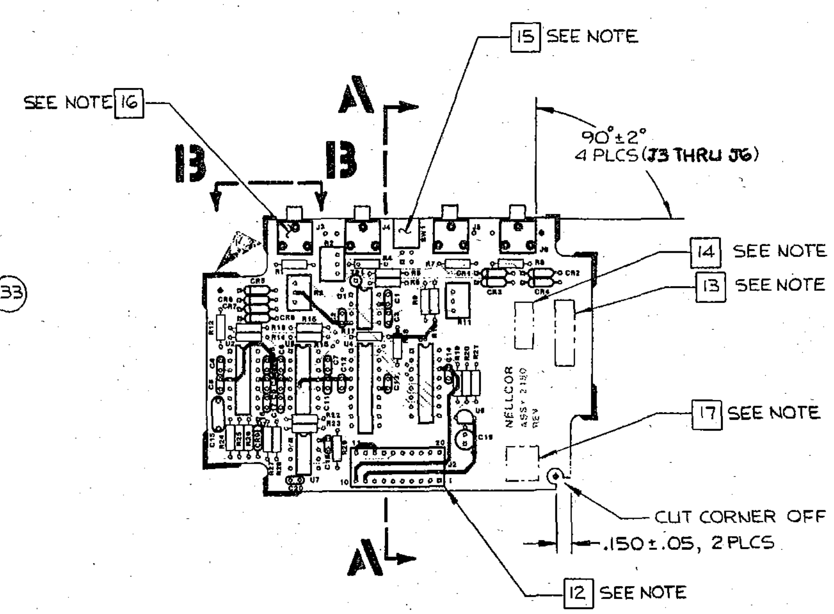
ITEM	P/N:	DESCRIPTION:	QTY	DESIGNATION:
29.	052139	PCB, Upper Daughter Rev B	1	—
28.	901009-2	Accelerator Tak-Pak Liquid	A/R	S1 THRU S4
27.	171128	I.C., 27C128, EPROM	REF	U4
26.	901117	Adhesive, Loctite #460	A/R	S1 thru S4
25.	639101	Cap, Black (Switch)	4	S1 thru S4
24.	753121	Tape, Foam, 1/16" Thk	A/R	See Note 7
23.	491091	Connector, Socket, R/A, 32 Pin	1	J1
22.	691001	Crystal, 6.144MHz	1	Y1
21.	630103	Switch, Momentary Pushbutton	4	S1 thru S4
20.	604401	Transistor, 2N4401	1	Q1
19.	584148	Diode, 1N4148	2	CR1, CR2
18.	344105	Capacitor, Dipped Tant. 35V 1uf	1	C10
17.	304103	Capacitor, M.S. .01uf	1	C7
16.	304330	Capacitor, M.S. 33pf	2	C4, C5
15.	304104	Capacitor, M.S. .10uf	5	C1, C2, C6, C8 & C9
14.	230473	Resistor Pkg, 8 Pin SIP 47K	1	RP1
13.	212003	Resistor, 1% M.F. 200K	1	R9
12.	214991	Resistor, " " 4.99K	2	R7, R8
11.	211004	Resistor, " " 1 Meg	1	R6
10.	211001	Resistor, " " 1.00K	1	R5
9.	211002	Resistor, " " 10.0K	4	R1 thru R4
8.	130014	I.C. 74HC14	1	U6
~~7.~~	~~151085~~	~~I.C. 80C85A~~	1	U5
6.	752040	I.C. Socket, 40 Pin	1	U5 - See Note 7
5.	073916	Assy, Interface/Powerbase Program	1	U4
4.	752028	I.C. Socket, 28 Pin	1	U4 - See Note 7
3.	161064	I.C. TC5564PL-15	1	U3
2.	130373	I.C. 74HC373	1	U2
1.	130244	I.C. 74HC244	1	U1

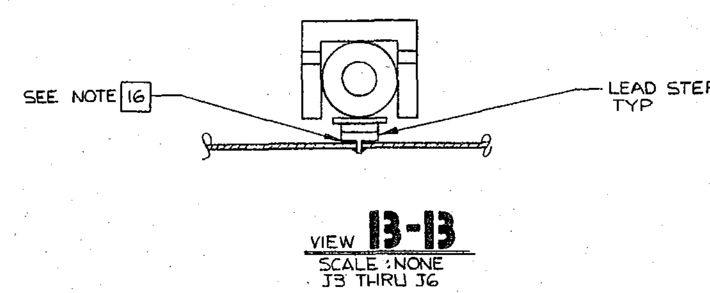
Upper Daughter PCB Powerbase Assembly



Middle Daughter PCB Powerbase
Schematic





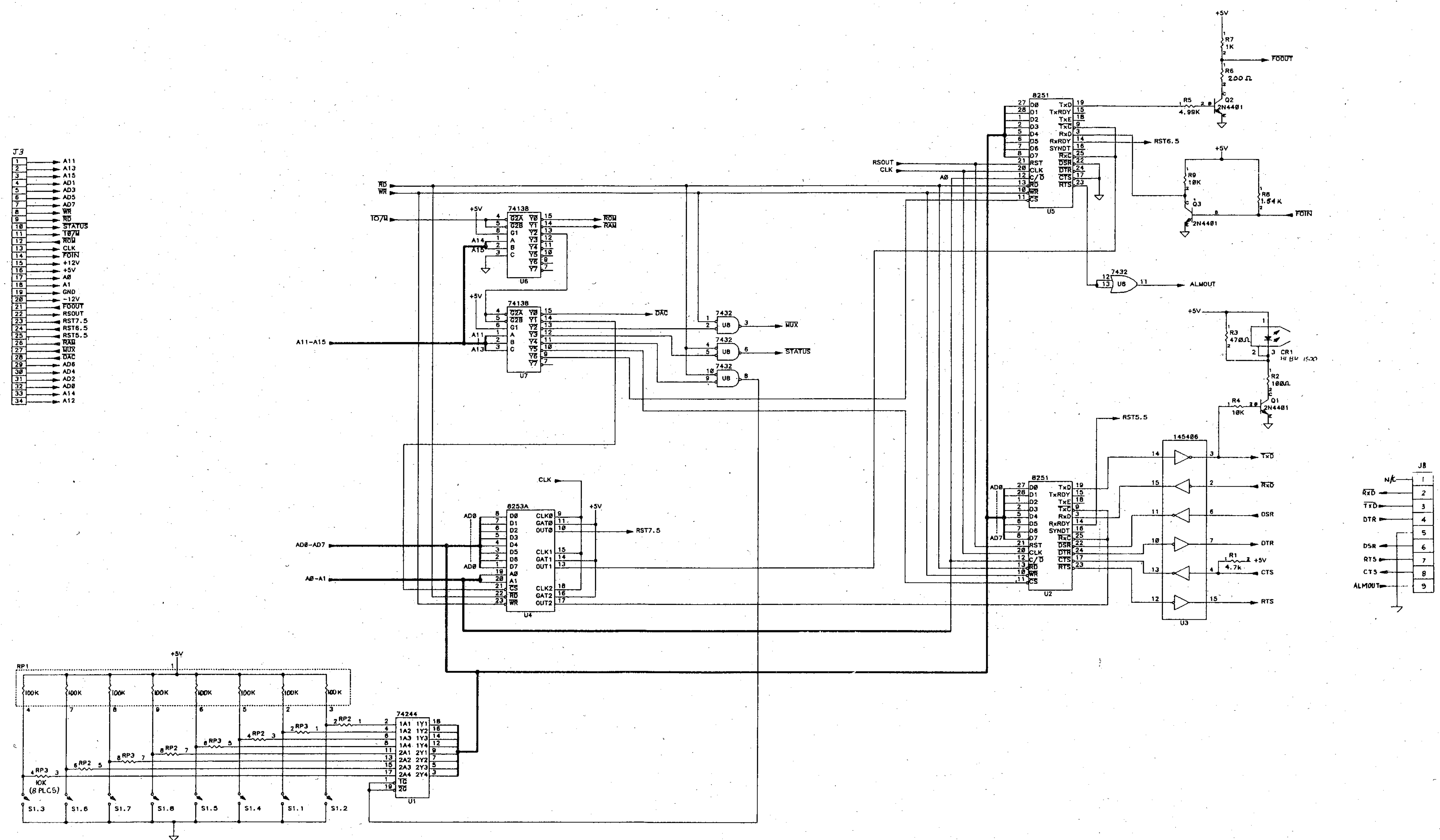


NOTES:

1. Orient I.C.'s with Pin 1 to Square Pad.
2. Polarized Capacitors to be mounted with positive (+) side to Square Pad.
3. Color coded Resistors to be LEFT or UP as appropriate.
4. Mount Capacitors and Precision Resistors with value visible.
5. Diodes to be mounted with banded (Cathode) side to Square Pad.
6. Resistors R13 through R16 are jumpered with 22 ga Buss wire across pads or with a zero ohm resistor.
7. Load Potentiometer, R3 with Pin 1 nearest Connector J3.
8. Load Potentiometer, R2 with Pin 1 nearest Test Point TP1.
9. Load Potentiometer, R11 with Pin 1 nearest Connector J5.
10. Test Point, TP1, is not loaded.
11. NOTE: This Board contains static sensitive components and should be handled accordingly.
12. Trim leads of Connector J2 as close as possible to PCB after soldering. All other component leads to be 1/16" Max.
13. Apply Assembly Revision, Vendor Code, and the serial number in the area indicated on component side per procedure MI-019235.
14. Apply three (3) digit "year week" date code in the area indicated on component side per procedure MI-019235.
15. Use Adhesive (36) to secure Switch, SW1, to the PCB per Detail "A". Switch, SW1, may not be processed through automatic flow solder or cleaning operations. Do not allow flux remover or solvents in switch.
16. Analog jacks (35) to be mounted with lead steps flush to PCB. Max. gap of .010" allowed between lead step and PCB per View B-B.
17. PCB's passing "In Cicuit Test" must be stamped by vendor on solder side.

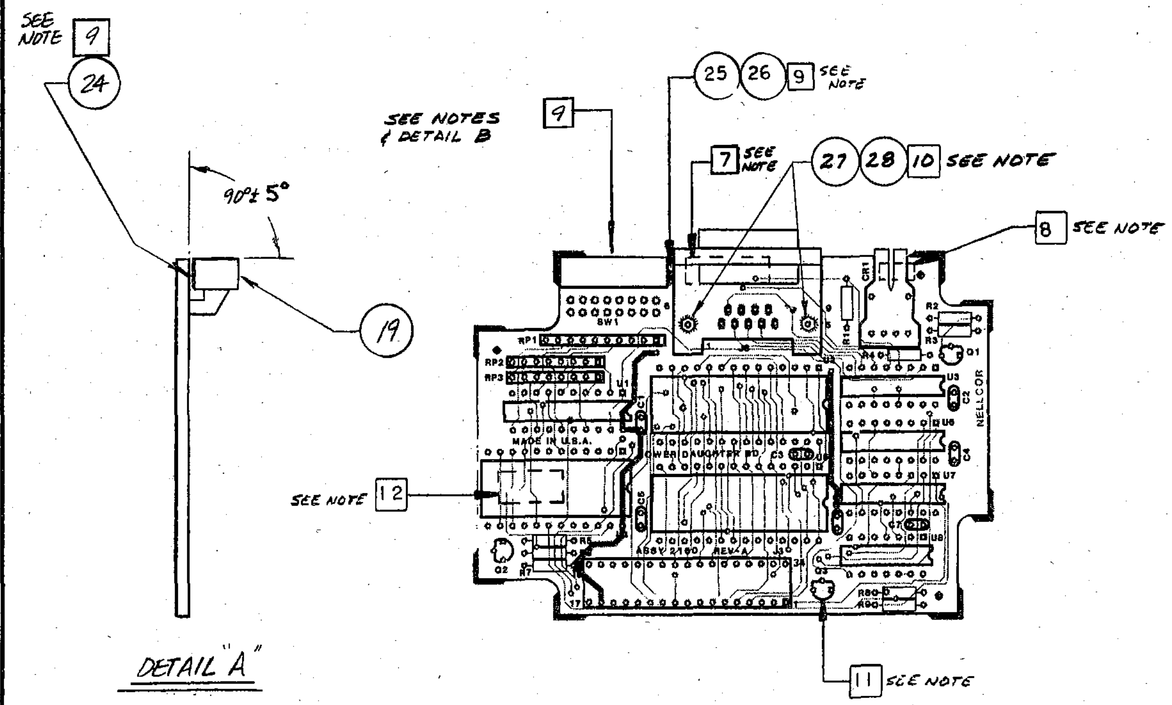
ITEM	P/N:	DESCRIPTION:		QTY	DESIGNATION
37.	052149	PCB, Middle Daughter, REV B		1	-
36.	901104	Adhesive, Loctite #422		A/R	SW1
35.	491024	Connector, Analog Jacks		4	J3, J4, J5, J6
34.	491090	Connector, Socket, R/A, 20 Pin		1	J2-See Note 12
33.	632106	Switch, DIP, R/A. 2- POSITION		1	SW1
32.	481015	Terminal, Test Point		1	TP1-See Note 10
31.	584148	Diode, 1N4148		1	CR9
30.	580965	Diode, 1N965A, Zener, 15V		8	CR1 thru CR8
29.	344105	Capacitor, Dipped Tant, 35V	1uf	1	C19
28.	304224	Capacitor, M.S.	.22uf	1	C17
27.	304473	Capacitor, M.S.	.047uf	1	C16
26.	304474	Capacitor, M.S.	.47uf	1	C15
25.	304103	Capacitor, M.S.	.01uf	4	C4 thru C7
24.	304100	Capacitor, M.S.	10pf	1	C3
23.	304104	Capacitor, M.S.	.10uf	11	C1, C2, C8 thru C14, C18, C20
22.	200226	Resistor, 1/4W, 5% CC	22 Meg	1	R27
21.	213323	Resistor, 1% M.F.	332K	1	R25
20.	217153	Resistor, " "	715K	1	R24
19.	211004	Resistor, " "	1 Meg	1	R23
18.	212321	Resistor, " "	2.32K	1	R21
17.	213320	Resistor, " "	332 Ohm	1	R20
16.	214991	Resistor, " "	4.99K	2	R17, R18
15.	219091	Resistor, " "	9.09K	1	R12
14.	214992	Resistor, " "	49.9K	1	R10
13.	211002	Resistor, " "	10.0K	3	R9, R22, R26
12.	212002	Resistor, " "	20.0K	3	R6, R28, R29
11.	212001	Resistor, " "	2.00K	1	R5
10.	211001	Resistor, " "	1.00K	5	R1, R4, R7, R8, R19
9.	291056	Potentiometer, 18 Turn Top	2K	1	R11
8.	291008	Potentiometer, 18 Turn Top	10K	1	R3
7.	291006	Potentiometer, 18 Turn Top	1K	1	R2
6.	120311	I.C. LM311, Voltage Comparator		1	U7
5.	691063	Voltage Regulator, Adjustable, LM337L		1	U6
4.	197524	I.C. 7524LN, 8 Bit DAC		1	U5
3.	190528	I.C. DG528, Analog Switch		1	U4
2.	120444	I.C. LF444		2	U2, U3
1.	120441	I.C. LF441A		1	U1

Middle Daughter PCB Powerbase Assembly

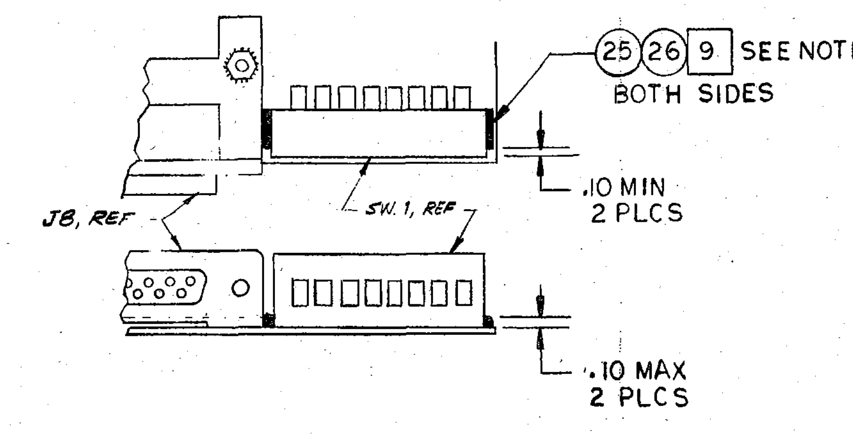


NOTE:
C1 THRU C7 ARE 0.1µF POWER SUPPLY DECOUPLING CAPS.

Lower Daughter PCB Powerbase Schematic



DETAIL "A"



DETAIL "B"

ITEM	P/N:	DESCRIPTION		QTY	DESIGNATION:
28.	851101	KEPNUT # 4-40		2	J8
27.	801038	SCREW, PAN HD., # 4-40 x 3/8"		2	J8
26.	901009-2	ACCELERATOR, TAK-PAK, LIQUID		A/R	SW1
25.	901136	ADHESIVE, LOCTITE, QUICK GEL # 409		A/R	SW1
24.	901104	ADHESIVE, LOCTITE # 422		A/R	SW1
23.	130244	IC 74HC244		1	U1
22.	052159	PCB, Lower Daughter, Rev A		1	-
21.	463109	Connector, DB, 9 Pin		1	J8
20.	491092	Connector, Socket, R/A, 34 Pin		1	J3
19.	632105	Switch, DIP, R/A, 8 Position		1	SW1
18.	621001	Fiber Optics Transmitter		1	CR1
17.	604401	Transistor, 2N4401		3	Q1, Q2, Q3
16.	304104	Capacitor, M.S.	.10uf	7	C1 thru C7
15.	291049	Resistor Pkg, 8 pin SIP	10K	2	RP2, RP3
14.	220104	Resistor Pkg, 10 Pin SIP	100K	1	RP1
13.	211541	Resistor, 1% M.F.	1.54K	1	R8
12.	211001	Resistor, " "	1.00K	1	R7
11.	212000	RESISTOR, " "	200 OHM	1	R6
10.	214991	Resistor, 1% M.F.	4.99K	1	R5
9.	211002	Resistor, " "	10.0K	2	R4, R9
8.	200471	Resistor, 1/4W 5% CC	470 Ohm	1	R3
7.	200101	Resistor, " " "	100 Ohm	1	R2
6.	200472	Resistor, " " "	4.7K	1	R1
5.	130032	I.C. 74HC32		1	U8
4.	130138	I.C. 74HC138		2	U6, U7
3.	198253	I.C. 82C53-5		1	U4
2.	199119	I.C. MC145406		1	U3
1.	199121	I.C. 82C51		2	U2, U5

NOTES:

1. Orient I.C's with Pin 1 to Square Pad.
2. Polarized Capacitors to be mounted with positive (+) side to Square Pad.
3. Color Coded Resistors to be LEFT or UP as appropriate.
4. Mount all Capacitors and Precision Resistors with value visible.
5. Diodes to be mounted with banded (Cathode) side to Square Pad.
6. NOTE: This board contains static sensitive components and should be handled accordingly.

[7] APPLY ASSEMBLY REVISION, VENDOR CODE, AND THE SERIAL NUMBER IN THE AREA INDICATED ON SOLDER SIDE PER PROCEDURE MI-019235.

[8] APPLY THREE (3) DIGIT 'YEAR WEEK' DATE CODE IN THE AREA INDICATED ON SOLDER SIDE PER PROCEDURE MI-019235.

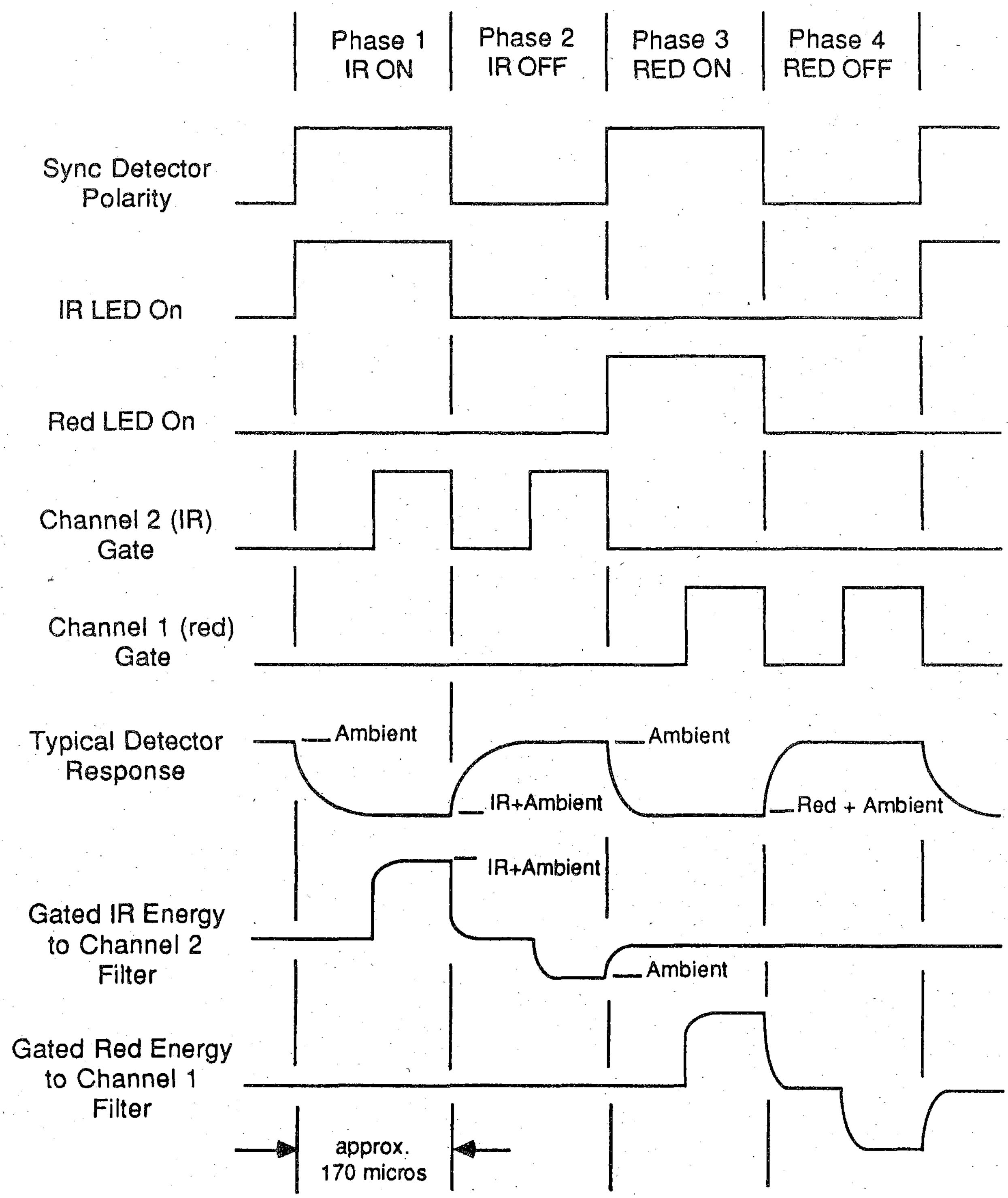
[9] USE ADHESIVE (24) TO SECURE BOTTOM OF SWITCH SW1, TO THE PCB PER DETAIL 'A'. SECURE SIDES OF SW1, WITH ADHESIVE (25) AND (26) PER DETAIL 'B'. SWITCH, SW1, (19) MAY NOT BE PROCESSED THRU AUTOMATIC FLOW SOLDER OR CLEANING OPERATIONS. DO NOT ALLOW FLUX REMOVER OR SOLVENTS IN SWITCH.

[10] INSTALL SCREW (27) FROM SOLDER SIDE.

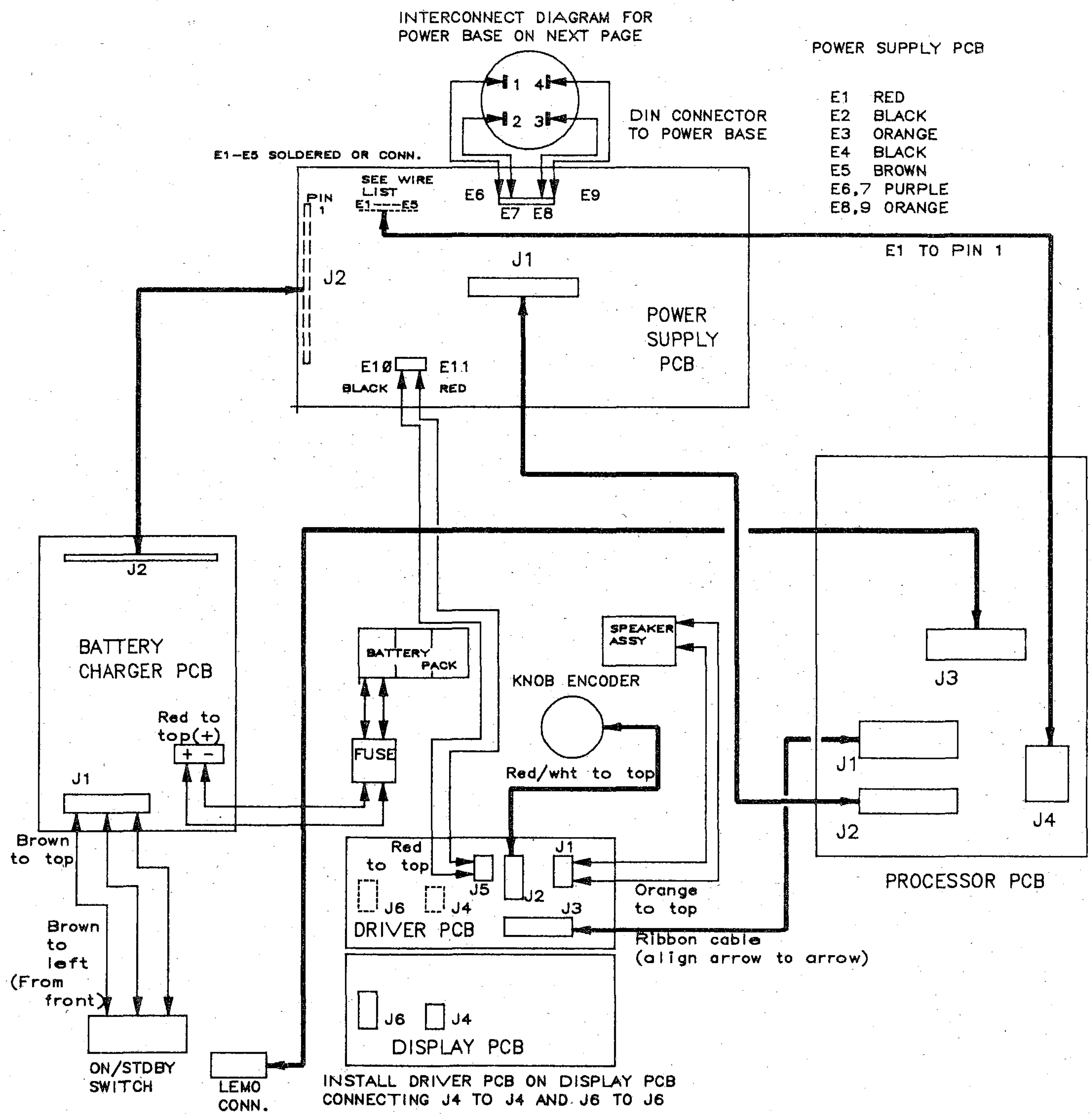
[11] HEIGHT OF TRANSISTOR Q3 NOT TO EXCEED HEIGHT OF CONNECTOR, J3

[12] PCB'S PASSING "IN CIRCUIT TEST" MUST BE STAMPED BY VENDOR ON SOLDER SIDE.

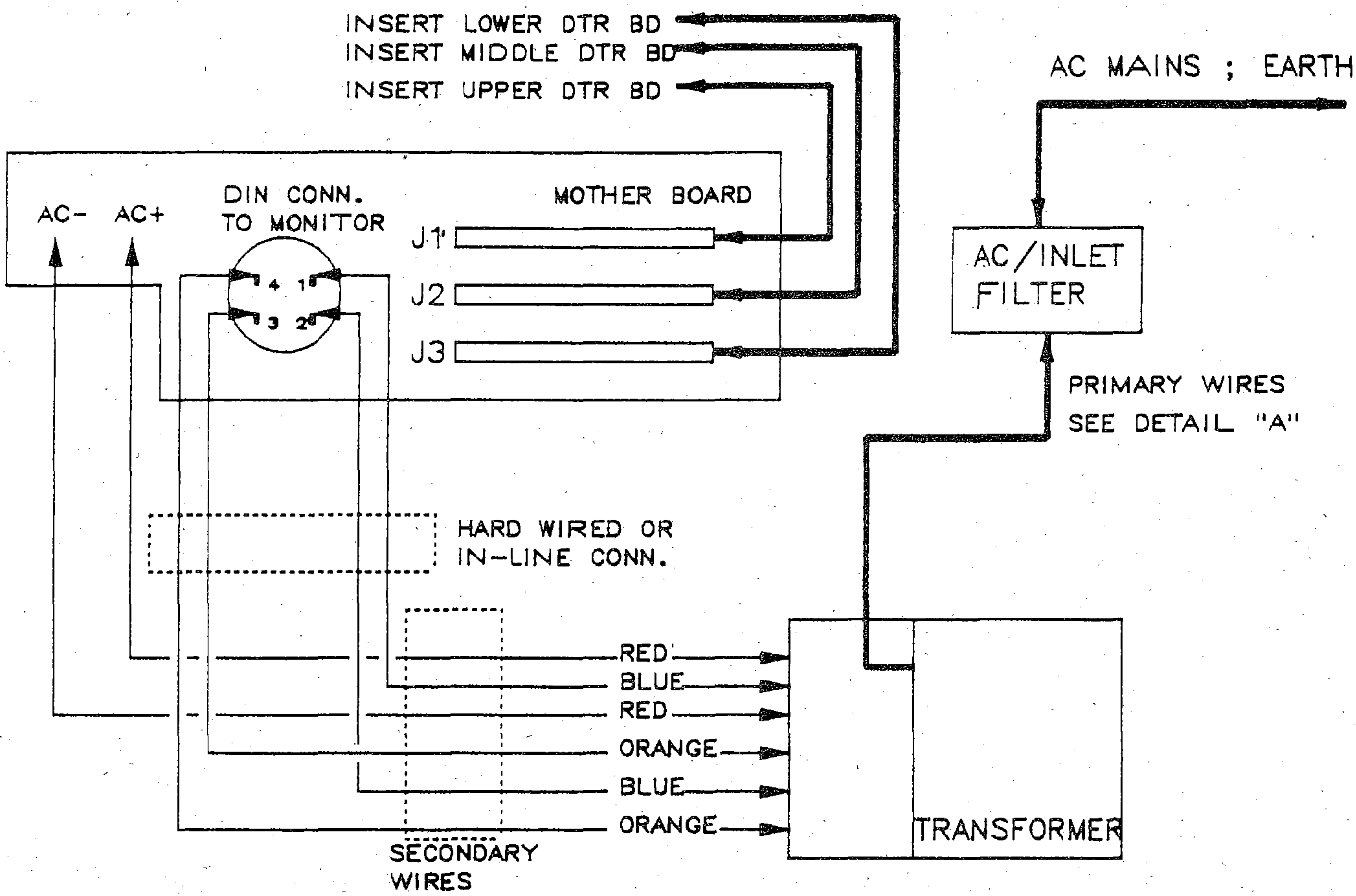
Lower Daughter PCB Powerbase Assembly



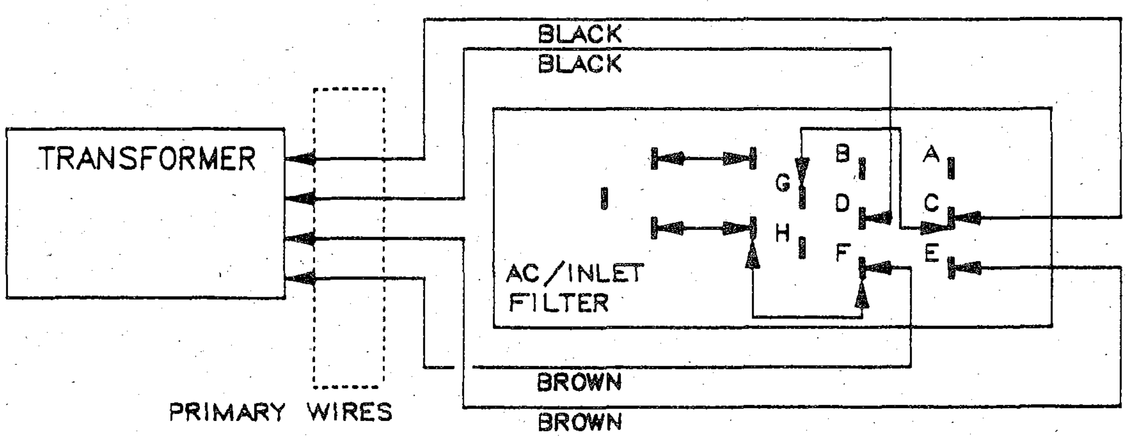
Timing Diagram, Oximeter



Cable Interconnect Diagram, Monitor



INTERCONNECT DIAGRAM-N2ØØ POWER BASE



DETAIL "A"

Cable Interconnect Diagram,
Powerbase

SECTION 10

INDEX

OPERATOR'S MANUAL

NELLCOR® N-200 PULSE OXIMETER

Two COMPUTER FORMAT Digital Output Formats Available

This notice is to provide you with additional information on computer formats described on page 30 of this manual. Two COMPUTER FORMAT digital-output formats are now available. Format is selected using the rear-panel eight-position DIP switch. First, select COMPUTER FORMAT by setting DIP switch 3 down, 4 up, and 5 down. Then, select the digital output format by setting DIP switch 2.

When the N-200 is transmitting data to a Spacelabs 90600-series ECG monitor, set DIP switch 2 up. The digital output format is

STXRnnnSnnnPnnnLnnnHnnnOnnnAnnnMnnnTnnnnnnQnnnCRLFETXCHKSUMETX

When DIP switch 2 is down, the digital output format is

STXRnnnSnnnPnnnLnnnHnnnOnnnAnnnMnnnTnnnnnnQnnnCRLFCHKSUMETX

In both formats, data are transmitted every 10 seconds and each time the status or limits change.

05 7606A-1288

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

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6962A-1088