7-92

1992

PRELIMINARY SERVICE MANUAL

NELLCOR® N-180 PULSE OXIMETER

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

Nellcor Incorporated
25495 Whitesell Street
Hayward, California 94545 U.S.A.
510 887-5858
1-800-NELLCOR

023219B-0292

TABLE OF CONTENTS

LIST OF FIGURES

The following are trademarks of Nellcor Incorporated: *NELLCOR* is a registered trademark in the United States and other countries; *DURASENSOR, OXIBAND, C-LOCK, OXINET,* and *TRI-GUARD* are registered trademarks in the United States; *OXISENSOR, DURAFORM, EASY CAP, N-CAT,* and the Nellcor knob are commercial trademarks.

Covered by one or more of the following patents: U.S. patent numbers 4,621,643; 4,653,498; 4,700,708; 4,770,179; 4,869,254;; and corresponding patents in other countries.

Section 1
Introduction

1.1 INTRODUCTION

This manual contains information for servicing the *NELLCOR* N-180 pulse oximeter. This manual is intended for use by individuals who have a technical background in analog and digital electronics. Service of this product must be done by qualified service personnel.

Before servicing the N-180, read the operator's manual carefully for a thorough understanding of operation.

1.2 OVERVIEW

The N-180 pulse oximeter measures functional oxygen saturation of arterial hemoglobin (SpO_2), and pulse rate. The N-180 monitors SpO_2 and pulse rate continuously and noninvasively, with measurements updated at each pulse beat. An internal AC power supply provides isolated power for operating the monitor and charging its internal batteries. In addition, the N-180 provides a digital output for external data recording devices.

1.3 FEATURES

The N-180 provides immediate use after power-up, without need for operator calibration or configuration. It offers:

- Automatic self-test and error messages.
- Automatic oximetry calibration.
- Visible and audible oximetry displays.
- An early warning system that provides an audible indicator for both SpO_2 and pulse rate: a tone signals each pulse and its pitch varies with changes in SpO_2.
- Operator-configured audible oximetry alarms, with default alarm limits preset for adults or neonates. Pulse rate and oxygen saturation displays change from green to red during an alarm condition.
- Battery operation up to 6 hours.

The N-180 provides the operator with the capability to tailor the system for specific clinical applications. Capabilities include:

- Audible alarms that can be silenced temporarily or disabled; the alarm tone has adjustable volume.
- Three oximetry operating modes that change measurement averaging time to suit varied clinical applications.

1.4 NOTES, CAUTIONS, AND WARNINGS

This manual uses three terms that are important for proper operation of the monitor:

1.4.1 *Warning*

A warning precedes an action that may result in injury to, or death of, the patient or user. Warnings are highlighted in boldface type, with a border.

1.4.2 *Caution*

A caution precedes an action that may result in damage to, or malfunction of, the monitor. Cautions are highlighted in boldface type.

1.4.3 *Note*

A note gives information that requires special attention by the reader.

Section 2
Principles of Operation

2.1 INTRODUCTION

The N-180 is based on the principles of spectrophotometry and plethysmography. It includes an electro-optical sensor and a microprocessor-based monitor. The sensor has two low-voltage light-emitting diodes (LEDs) as light sources and one photodiode as a photodetector. One LED emits red light (nominal 660 nm wavelength) and the other emits infrared (nominal 920 nm). When the light from the LEDs passes through the sensor site, part of the light is absorbed. The photodetector measures the light that passes through, which is a measure of red and infrared absorption.

With each heartbeat, a pulse of oxygenated arterial blood flows to the sensor site. Oxygenated hemoglobin differs from deoxygenated hemoglobin in its relative red and infrared absorption, and the N-180 measures red and infrared absorption to determine the percentage of functional hemoglobin that is saturated with oxygen.

Light absorption that is measured when pulsatile blood is not present reflects absorption by tissue and nonpulsatile blood—absorption that does not change substantially during the pulse. This is analogous to the reference measurement of a spectrophotometer. Absorption is also measured when pulsatile, arterial blood is in the tissue. The N-180 then corrects this measurement for absorption when the pulsatile blood is not present. The ratio of the corrected absorption at each wavelength determines SpO_2.

2.2 AUTOMATIC CALIBRATION

The oximetry subsystem incorporates automatic calibration mechanisms. It is automatically calibrated each time it is turned on, at periodic intervals thereafter, and whenever a new sensor is connected. Also, the intensity of the sensor's LEDs is adjusted automatically to compensate for differences in tissue thickness.

Each sensor is calibrated when manufactured: the effective mean wavelength of the red LED is determined and encoded by a calibration resistor in the sensor plug. The instrument's software reads this calibration resistor to determine the appropriate calibration coefficients for the measurements obtained by that sensor.

2.3 FUNCTIONAL VERSUS FRACTIONAL SATURATION

Because the N-180 measures functional SpO_2, it may produce measurements that differ from those of instruments that measure fractional SpO_2. Functional SpO_2 is oxygenated hemoglobin expressed as a percentage of the hemoglobin that is capable of transporting oxygen. Because the N-180 uses two wavelengths, it measures oxygenated and deoxygenated hemoglobin, yielding functional SpO_2. It does not detect dysfunctional hemoglobin, such as carboxyhemoglobin or methemoglobin.

In contrast, some laboratory instruments such as the Instrumentation Laboratory 282 CO-Oximeter report fractional SpO_2—oxygenated hemoglobin expressed as a percentage of all measured hemoglobin, whether or not that hemoglobin is available for oxygen transport. Measured dysfunctional hemoglobins are included.

Consequently, to compare N-180 measurements directly with those of another instrument, that other instrument must measure functional SpO_2. If it measures fractional SpO_2, those measurements can be converted using the following equation:

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

2.4 Measured versus Calculated Saturation

When SpO_2 is calculated from a blood gas measurement of the partial pressure of arterial oxygen (PaO_2), the calculated value may differ from the N-180 SpO_2 measurement. This is because the calculated SpO_2 may not have been corrected for the effects of variables that shift the relationship between PaO_2 and SpO_2 (see Figure 2-1): temperature, pH, the partial pressure of carbon dioxide ($PaCO_2$), and the concentrations of 2,3-DPG and fetal hemoglobin.

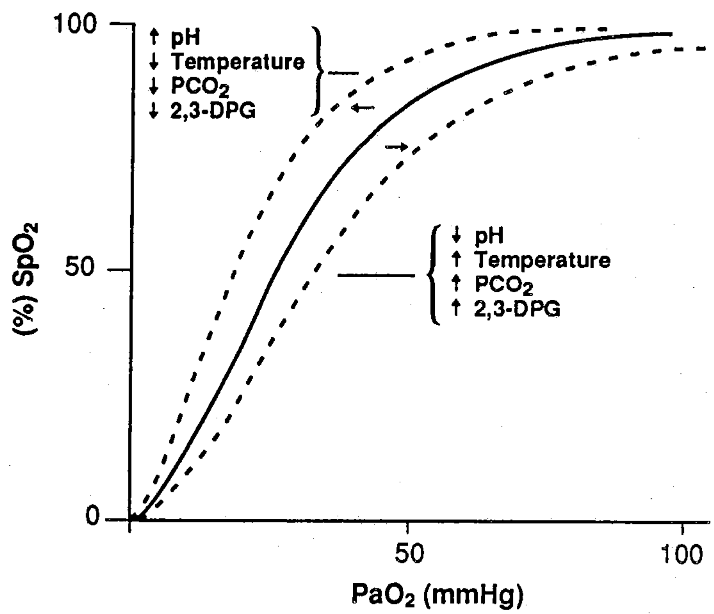


Figure 2-1: Oxyhemoglobin Dissociation Curve

Section 3
Circuit Analysis

3.1 INTRODUCTION

This section provides qualified service personnel with a detailed explanation of circuit operation for the *NELLCOR* N-180 pulse oximeter, hereinafter called the monitor. The text includes illustrations supporting discussions of circuit operation. Section 8, "Schematic Diagrams," contains circuit diagrams providing greater detail. The section is divided into two major parts:

3.2 Block Diagram Analysis
3.3 Detailed Circuit Analysis

Note: Active low logic signals are designated by a forward slash after the signal name (e.g., SIGNAL/).

3.2 BLOCK DIAGRAM ANALYSIS

The following discussion is an overview of the N-180 and identifies major assembly blocks. A detailed discussion of major functional blocks is given in paragraph 3.3 The N-180's circuits are divided into the following subassemblies:

3.2.1 Oximetry Module
3.2.2 Front Panel Assembly
3.2.3 CPU PCB
3.2.4 AC Power and Control
3.2.5 Battery Pack

Refer to Figure 3-1, "N-180 Block Diagram," for the physical relationship of these circuit blocks.

3.2.1 *Oximetry Module*

The oximetry module drives the oxygen transducer and conditions the signal derived from the patient. This signal, referred to as the "SAT" signal, is conditioned and used to derive saturation percentage and pulse rate values presented on the monitor. This information is serially coupled to the processing circuits on the CPU PCB for display and external output conditioning.

The following discussion is given as an overview of the oximetry module and identifies major circuit blocks. A more detailed discussion of each block is given in paragraph 3.3. The circuits of the oximetry module can be divided into the following major functional blocks:

3.2.1.1 LED Driver
3.2.1.2 Sensor Assembly
3.2.1.3 Input Amplifier and Synchronous Detector
3.2.1.4 Filters/Amplifiers
3.2.1.5 A:D Conversion
3.2.1.6 Support Circuits

Refer to Figure 3-2, "Oximetry Module Block Diagram," for the logical relationship of these circuit blocks.

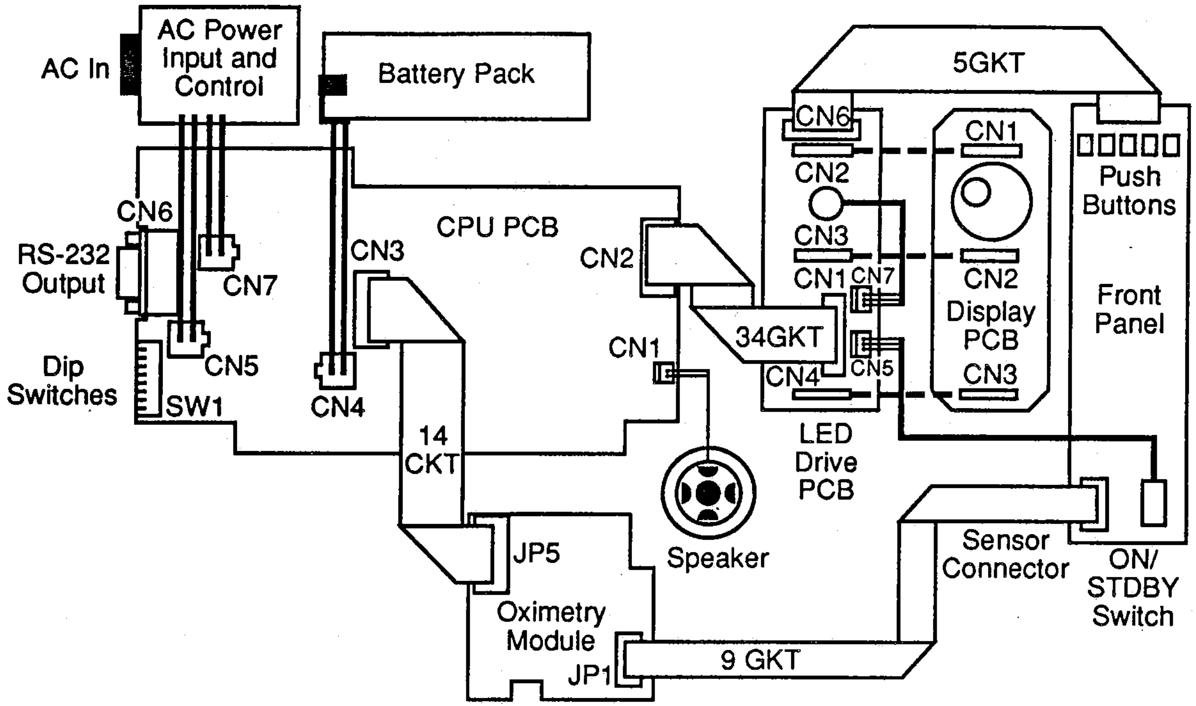


Figure 3-1: N-180 Block Diagram

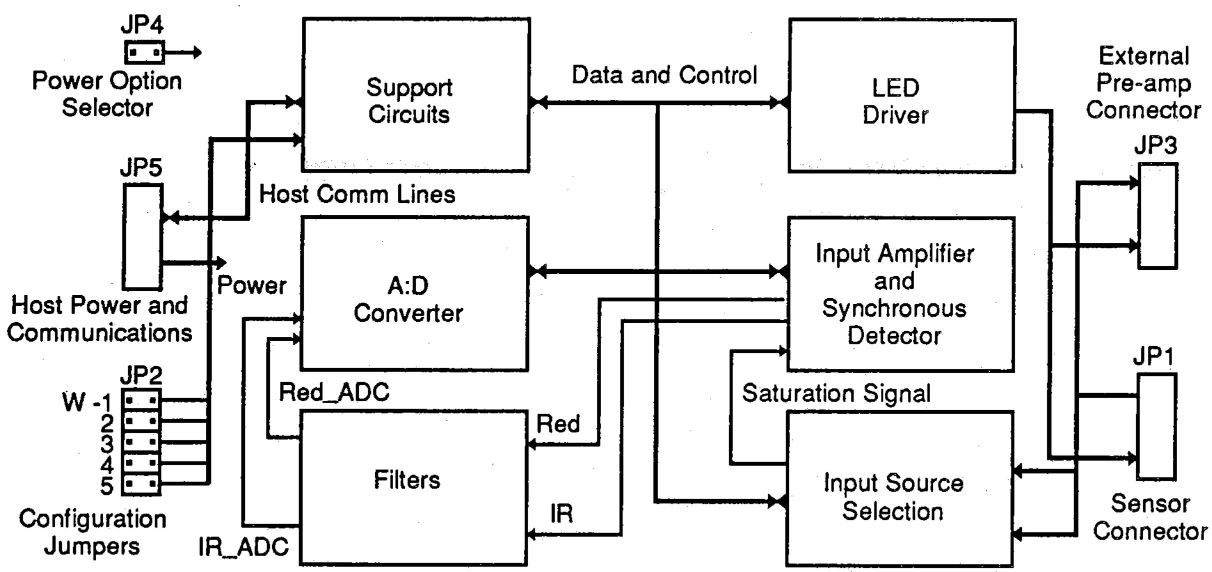


Figure 3-2: Oximetry Module Block Diagram

3.2.1.1 LED Driver

Circuits in this block develop LED drive signals as well as control current switching to ensure the necessary LED sequences to develop an oxygen saturation signal at the measurement site.

3.2.1.2 Sensor Assembly

Refer to Section 2, "Principles of Operation," for additional details about Nellcor sensor operation.

Oxygen saturation data signal is developed using a *NELLCOR* oxygen transducer at the selected patient site. Sensor LEDs generate alternate infrared and red light pulses at the measurement site. A photodiode in the transducer responds to the physiologically modulated emergent light energy from the site. The photodiode SAT signal is coupled into the module via the monitor's front-panel sensor connector.

3.2.1.3 Input Amplifier and Synchronous Detector

The SAT signal is conditioned by the input amplifier and the synchronous detector to provide signal gain and reduce or eliminate the effects of ambient interference (such things as motion artifacts, ambient light, and spurious electrical noise). The final analog conditioning of the SAT signal is accomplished by circuits in the filter block.

3.2.1.4 Filters/Amplifiers

The module includes two separate active filter channels, IR and red. These low-pass filter/amplifier circuits and associated gating circuits recover the patient's pulse waveform from the multiplexed SAT signal. The next step is to digitize these pulse waveforms in the A:D converter circuit block.

3.2.1.5 A:D Conversion

The A:D conversion block digitizes the two pulse waveforms obtained from examining the measurement site with IR and red light. Sensor calibration information is also digitized for use in the saturation calculation algorithms.

3.2.1.6 Support Circuits

Support circuits include the following:

- Processor Circuits
- Power

- **Processor Circuits**

Oximetry module operations are controlled by an 80C552 microcontroller with supporting hardware and software. The software also provides a diagnostic program to assist in determining module status.

- **Power**

Module power is supplied by the CPU PCB. See paragraph 3.3, "Detailed Circuit Analysis," for more information about module power requirements.

3.2.2 *Front Panel Assembly*

The front panel assembly includes the LED Driver PCB, LED Display PCB, front panel user interface points (push buttons, control knob, sensor input connector, and ON/STDBY switch).

3.2.3 *CPU PCB*

The CPU PCB includes the monitor processor, power supply, battery charger, audio generator, and the necessary interfaces to interconnect and power all system subassemblies.

3.2.4 *AC Power Input and Control*

The AC power input and control assembly includes the AC input receptacle, AC mains switch, fuses, interference filter, and power transformer.

3.2.5 *Battery Pack*

The battery pack is self-contained and connects directly to the CPU PCB via a special connector.

3.3 DETAILED CIRCUIT ANALYSIS

This section discusses the major functional circuit blocks of the N-180 in detail. The purpose is to provide qualified service personnel with the necessary information to understand monitor operation sufficiently to locate and repair malfunctions. The discussions address circuits in the order of logical troubleshooting methods using signal flow analysis where possible. Support circuits and components such as the microprocessor and power circuits are addressed last, or as they apply as support functions.

The following index assists in locating a specific area of interest:

Functional circuit block diagrams may employ a technique whereby some components are either absent from the circuit or grouped into functional sub-blocks. This is intended to give the reader a quick understanding of overall circuit operation. These simplified diagrams are similar in layout to the detailed schematics. This approach facilitates signal tracing to the component level when necessary.

Note: Depending on the manufacture date of any particular N-180 there may be differences in the circuits. If there are questions regarding differences, call Nellcor's Technical Services Department or your Nellcor representative.

3.3.1 *Oximetry Module*

The oximetry module is a self-contained assembly that provides oxygen transducer power, conditions the resulting SAT signal, and calculates the patient's oxygen saturation and pulse rate from the measured data. The saturation percentage, pulse rate, and other pertinent information are transmitted to the N-180 CPU PCB for display, alarm, and interface processing.

The following index assists in locating a specific area of interest:

Refer to the Oximetry Module schematic diagram (sheet 1 of 7) for details on the electronic relationship of these blocks.

3.3.1.1 LED Driver

Refer to Figure 3-3 "Oximetry Module LED Driver Circuit," and the Oximetry Module schematic diagram (sheet 2 of 7) for additional detail during the following discussion.

SAT signal development requires the measurement site to be illuminated with specific light wavelengths. The Nellcor system uses two light sources, IR and red. These LED sources are an integral part of each *NELLCOR* oxygen transducer. The LEDs are alternately pulsed on and off under control of the system microprocessor. The LED control circuit is discussed below.

The LED drive voltages are developed by dual DAC U1. Initially, both DACs in U1 are instructed via the DACBUS to develop approximately 0.5 VDC on their respective outputs (pins 4 and 18) coincident with the time period each LED is selected. The microprocessor alternately closes FET switches U4A/U4B via control lines IRLED/ (U4 pin 16) and REDLED/ (U4 pin 1). This results in samples of the DAC outputs being ORed or multiplexed at U4 pins 3 and 15.

The frequency of each control signal (IRLED/ and REDLED/) is 1355.3 Hz, with a 25% duty cycle. When both DAC outputs are multiplexed at U4 (pins 3 and 15) a four-phase LED drive signal with a frequency of 2710.6 Hz is created. The LED drive signal is summed with a negative 5 V coupled though voltage divider R2, R3, and R4. This results in the LED drive having a negative voltage. This negative voltage ensures that LED Driver U3A's output is zero during the times when no LED is being selected by either control line. This is necessary to counter any normal offsets that may be present in U3A.

Typically, the LED drive signal has a peak-to-peak value of 0.5 V with the lower boundary at 0 V.

Initially, both LED drive levels are maximum (0.5 V), but may be reduced as the processor adjusts each of the individual LED intensities to compensate for measurement site lighting variables. High background ambient light/energy and/or translucent measurement sites (such found in neonates) may cause a reduction in overall LED intensity.

As mentioned previously, the LEDs operate in a four-phase sequence. Each phase has a time period of 182 µs.

Phase 1	IR LED on
Phase 2	Both LEDs off
Phase 3	Red LED on
Phase 4	Both LEDs off

LED drive current switching is accomplished by Q1 through Q6 and the control lines, IRLED and REDLED. Figure 3-3 illustrates the relationship of these components and their association with the red (R) and IR (I) LEDs in the sensor (the LEDs are shown as they appear electrically in the circuit without the interconnection diagram). The numbers 2 and 3 on either side of the back-to-back LEDs indicate pin numbers in the sensor connector.

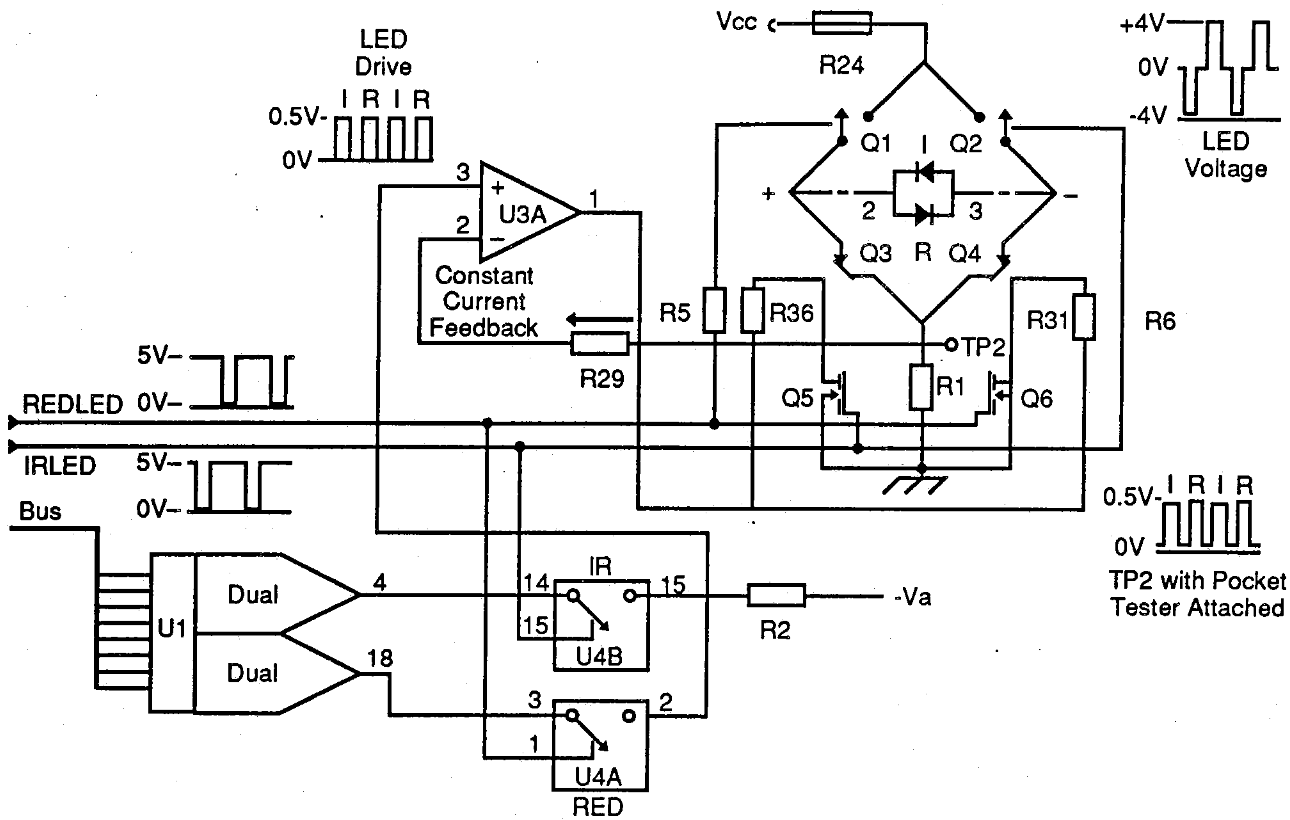


Figure 3-3: Oximetry Module LED Driver Circuit

The four-phase LED drive signal is presented to U3A. The resulting drive potential is coupled equally to both sides of the bridge circuit via R31 to Q4 and R36 to Q3. Control inputs IRLED and REDLED are pulsed low to cause their respective LEDs to light. When both lines are a logic high, all bridge transducers are turned off. Q1 and Q2 are reverse-biased directly by the control inputs via R5 and R6. Q3 and Q4 are reverse-biased by conduction of Q5 and Q6, which are being forward-biased by the control lines.

The IR LED (I) is lighted when control signal IRLED/ is pulsed low. Q5 turns off, allowing Q3 to respond to the drive level from U3A, and Q2 is turned on. The resulting current flow is from ground through R1, Q3, IR LED, Q2, and to Vcc. The red LED (R) is lighted when control signal REDLED/ is pulsed low. Q6 turns off, allowing Q4 to respond to the drive level from U3A, and Q6 is turned on. The resulting current flow is from ground through R1, Q4, red LED, Q1 Vcc. The LED back-to-back configuration ensures that the proper LED lights.

LED intensity is critical. Intensity variations during LED on time caused by any source other than blood oxygen levels can distort the SAT signal. The LED driver is a current regulator. Its purpose is to keep the voltage at TP2 exactly the same as the input voltage to the circuit (U3A, pin 3). This is accomplished by using the voltage voltage developed across R1 as a constant current feedback to driver U3A. This circuit has a very high rejection of power supply changes that could cause intensity changes.

3.3.1.2 Input Source Selection Circuits

Refer to Figure 3-4, "Oximetry Module Input Source Selection Circuits" and the Oximetry Module schematic diagram (sheet 3 of 7) for additional detail during the following discussion.

The SAT signal is developed by the photodiode in the *NELLCOR* sensor, responding to the emergent red and IR light at the measurement site. The emergent light intensity is a direct result of the four-phase controlled LED cycling, the patient's oxygen saturation, and the pulse changes occurring at the site.

The time-multiplexed, intensity-modulated photodiode current is coupled into the oximetry module via JP1 (pins 1 and 4) to the high-impedance input of U8, which performs current-to-voltage conversion for the photodiode current. The non-inverting input of U8 is biased by R38/R44 to 8.57 V. This results in the output of U8 having an 8.57 V maximum positive offset in the absence of any light or energy on the photodiode. This bias prevents a no-light condition from clamping U8 at +15 V. The presence of light or energy from any source causes U8's output to move in a negative direction.

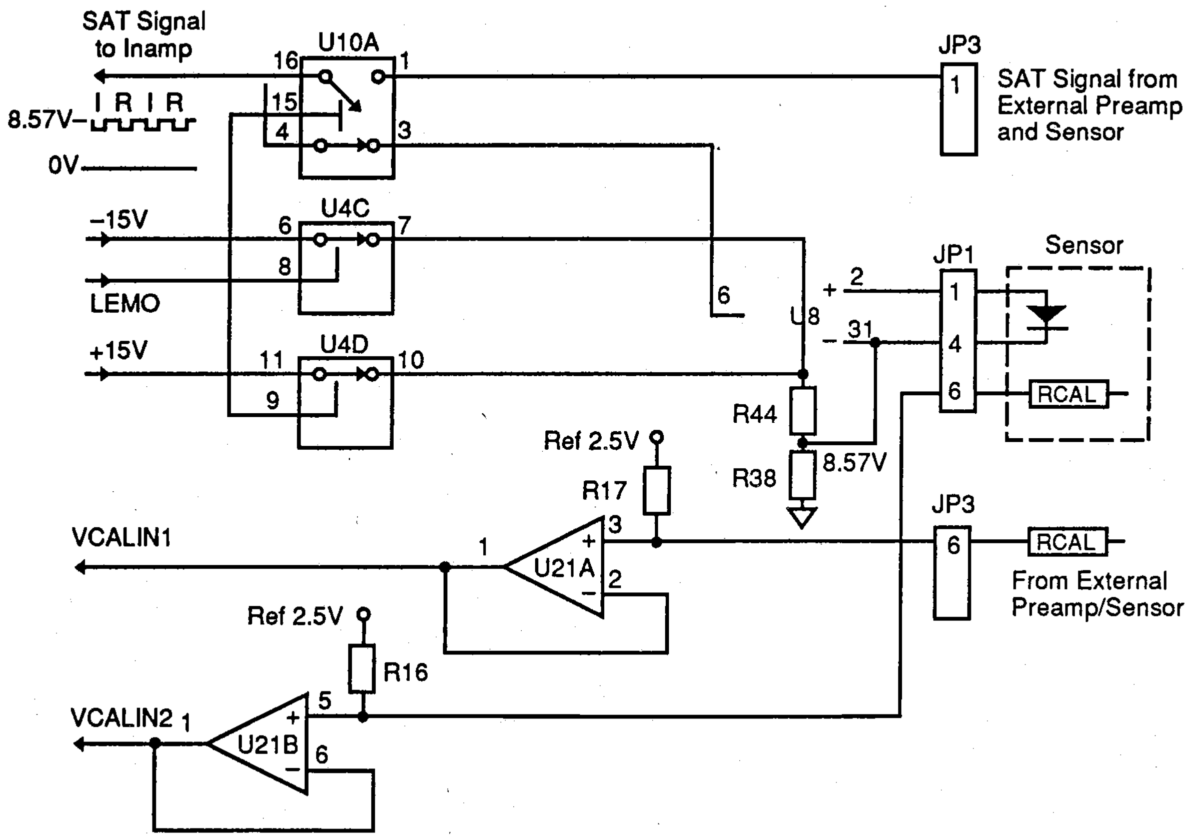


Figure 3-4: Oximetry Module Input Source Selection Circuits

An undistorted saturation signal at the input amplifier is essentially a square wave (the actual amplitudes may vary between the IR and red phases) with a frequency of 2710.6 Hz. The square wave peak-to-peak amplitude is proportional to LED emergent light intensity, plus any artifact with a frequency above DC. The DC offset (negative from the +8.57 V bias point) is dependent on steady-state background light or energy. Peak-to-peak amplitude changes in the signal are dependent on the measurement site oxygen saturation, pulse amplitude, and non-steady-state artifact energy.

The remainder of this discussion assumes that a *NELLCOR* PT-2500 pulse oximeter module tester (pocket tester) is connected to the module input in place of a normal patient sensor. This establishes a consistent set of values for discussion and comparison. The PT-2500 conditions the LED drive voltage and simulates the sensor photodiode output for an average adult with an oxygen saturation percentage of 81% ±1 digit (80% to 82%) and a pulse rate of 40 ±1 bpm (39 to 41 bpm). Note that pocket tester pulse rate is dependent on LED switching rate and will be different on other Nellcor pulse oximeter models.

The simulated SAT signal from the pocket tester is coupled to the monitor SAT conditioning circuits via the sensor input to JP1 (pins 1 and 4) on the oximetry module circuit board. After conditioning by current-to-voltage converter U8, the signal has the following characteristics:

DC offset:	approximately +8.5 V
Frequency:	2710.6 Hz
Modulation:	maximum peak-to-peak amplitude, approximately 0.02 V frequency, 0.666 Hz (40 cycles/minute)

Simply stated, a SAT signal produced by the PT-2500 is a low-amplitude, multiplexed carrier at 2710.6 Hz, modulated by an extremely low-amplitude 0.666 Hz square wave, changing amplitude approximately 20 mV.

The only additional oxygen saturation input requirement is the wavelength of the red LED. This number is derived from the RCAL resistor value located in the sensor or PT-2500. When a sensor is connected to the monitor, the RCAL resistor connects between JP1 pin 6 and ground to become part of a voltage divider with R16 on the PCB. Power for this divider is a 2.5 V reference developed in the module. This calibration voltage (VCALIN2) is communicated to the oximetry module microprocessor via buffer U21B.

Returning to the analysis of the oximetry module where U8 is used as the preamplifier, note that the SAT signal is coupled through U10A to the next conditioning stage, input amplifier, and synchronous detector.

3.3.1.3 Input Amplifier and Synchronous Detector

Refer to Figure 3-5, "Oximetry Module Input Amplifier, Synchronous Detector, and Filter/Amplifiers," and the Oximetry Module schematic diagram (sheet 4 of 7) for additional detail during the following discussion.

The SAT signal must be monitored continuously and controlled to prevent excessively high LED intensities or the combination of LED intensity and/or background light/energy from overloading the photodiode in the sensor. However, LED intensity must be kept as high as possible to ensure optimal signal-to-noise figures. The task of compensating for excessive light is accomplished by U7 and associated components, which monitor the SAT signal while it is still DC-coupled.

Initially LED intensity is set at maximum safe level (50 mA) upon monitor power-up. If the total of the LED energy and/or external light energy is excessive, the DC offset at the output of U8 could be enough to drive the SAT signal amplitude envelope into the negative region of U8's operating range. To prevent the amplitude from exceeding U8's negative supply voltage, U7 is employed to monitor the negative excursion of the SAT signal.

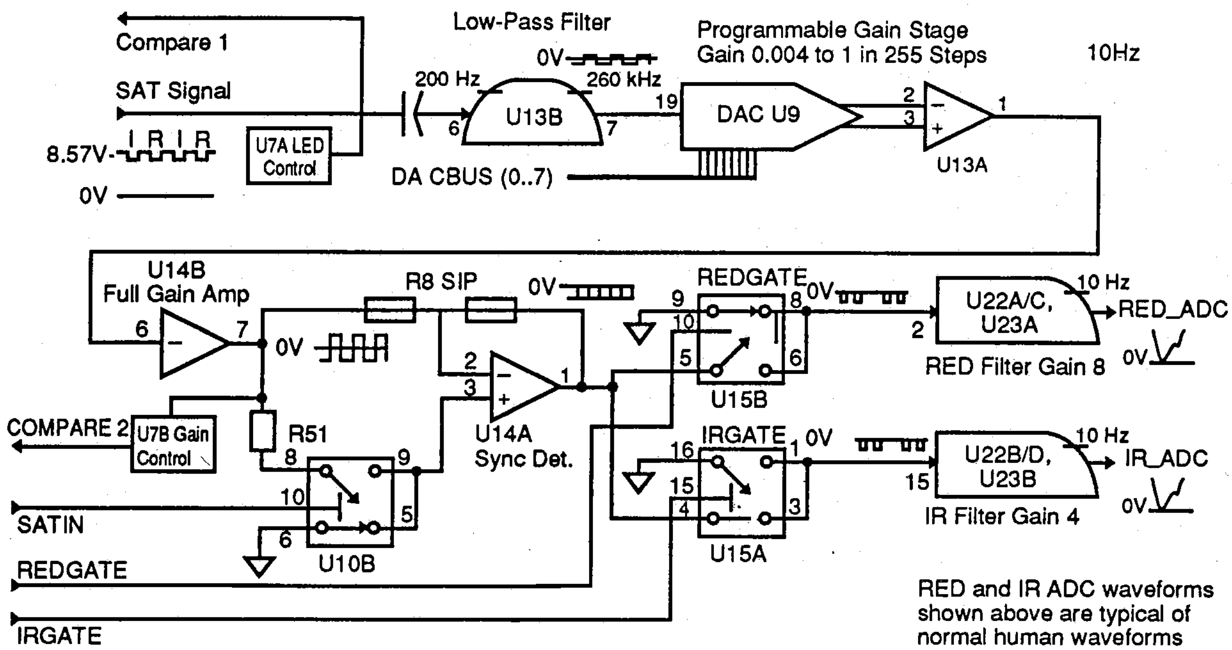


Figure 3-5: Oximetry Module Input Amplifier, Synchronous Detector, and Filter/Amplifiers

U7A is a negative peak detector that produces a DC output proportional to the maximum negative excursion of the SAT signal pulses. If negative excursions of the saturation signal exceeds –10 V (indicating that the patient module current-to-voltage converter stage output is approaching its negative supply voltage of –15 V), the microprocessor that is monitoring the output of U7A (COMPARE1) initiates action to reduce the output of the dual DAC that controls LED intensity. The microprocessor may reduce current through only one of the LEDs if necessary.

The result of the above-mentioned microprocessor action is that the pulse amplitude of the 2710.6 Hz saturation signal, during the time periods of the offending LED, will be reduced.

After the LED intensity control requirements are accomplished, the SAT signal is coupled through C55. This coupling removes the offset effect of DC or steady-state ambient energy artifact. The signal is then coupled to U13B, a bandpass filter with a gain of one, low-frequency roll-off at 200 Hz, and high-frequency roll-off at 260 kHz. The filter passes the SAT signal (2710.6 Hz) and effectively removes noise on either side of the SAT signal frequency.

The signal is then introduced to a programmable gain circuit, which consists of 8-bit DAC U9 and operational amplifier U13A. The DAC is configured so that its internal impedance ladder is in series with the operational amplifier feedback loop. Amplifier gain is controlled by microprocessor adjustment of the DAC impedance over 255 discrete steps. The maximum gain of the circuit is one. The minimum gain is 1/255 or 0.004.

The signal is then coupled to full-gain amplifier U14B, which has a gain of 51. The output of U14B is used by the microprocessor as the sense point to determine input channel gain requirements. U7B is employed to monitor the amplified SAT signal at the output of the input amplifier.

U7B is a positive peak detector that produces a DC output proportional to the positive excursion of the amplified SAT signal pulses. If the positive excursions of the saturation signal exceed +10 V (indicating excessive amplifier gain), the microprocessor, which is monitoring the output of U7B (COMPARE2) initiates action to reduce the programmable stage's gain. The microprocessor may reduce current through only one of the LEDs if necessary.

The SAT signal is then coupled to the synchronous detector. The signal is still in its original multiplexed format and essentially a square wave at 2710.6 Hz. The peak-to-peak amplitude of alternate voltage excursions represents the emergent light from one of the LEDs (IR or red). Amplitude changes or modulation of this signal represent the effect of the patient's saturation and pulse activity at the measurement site.

Synchronous detection conditions the SAT signal in a manner such that subsequent filtering can reclaim the patient's pulse waveform component relatively free of artifact and interference. U10B, U14A, and associated resistors comprise the synchronous detector. The detector is an operational amplifier configured so that it can operate as two different circuits: an inverting amplifier, and a voltage follower. When the positive input of U14A is grounded by U10B, the device is an inverting amplifier with a gain of one. When this input is not grounded, the device becomes a voltage follower with a gain of one.

The microprocessor controls U10B via the SATIN line, and closes the switch during phases 1 and 3 of the four-phase clock mentioned in the LED drive discussion. The result is that the voltage values represented by the IR and red LED on times are inverted by the detector. The voltage values represented by the LED off times (phases 2 and 4) are permitted to pass through the detector at their original voltage level and polarity. The output of the synchronous detector is applied to a bus coupled to the inputs of the IR and red filter/amplifier channels.

3.3.1.4 Filters/Amplifiers

There are three circuits in the demodulation (filtering) block:

- Gating
- IR Filter/amplifier
- Red Filter/amplifier

- **Gating**

Refer to Figure 3-5 and the Oximetry Module schematic diagram (sheets 4 and 5 of 7) for additional details during this discussion.

FET switches U15A/B are employed to separate the IR information in the SAT signal from the red information. Phases 1 and 3 constitute the IR and red on time segments, and phases 2 and 4, the IR and red off time segments. The gate control inputs (IRGATE and REDGATE) to U15A/B are processor-controlled and operate in time sequence with the four-phase LED drive control. The switch pairs in each gate operate exclusively so that the filter/amplifier input does not see an open circuit when switches to the signal input bus are open.

During the time period that phases 1 and 2 of the 2710.6 Hz saturation signal (IR ON and IR OFF) follow one another on the bus, the processor strobes U15A twice. The first strobe pulse comes 112 µs after the beginning of phase 1 and continues for 70 µs, or to the end of phase 1. This gates the last 70 µs of IR ON signal level into the IR filter/amplifier. The next gate strobe pulse comes 112 µs after the beginning of phase 2 and continues for 70 µs, or to the end of phase 2. This gates the last 70 µs of IR OFF signal level into the IR filter/amplifier.

During the time that phases 3 and 4 of the 2710.6 Hz saturation signal follow one another on the bus, the microprocessor strobes U15B twice. The first strobe pulse comes 112 µs after the beginning of phase 3 and continues for 70 µs, or to the end of phase 3. This gates the last 70 µs of RED ON signal level into the red filter/amplifier. The second gate control pulse comes 112 µs after the beginning of phase 4 and continues for 70 µs or to the end of phase 4. This gates the last 70 µs of RED OFF signal level into the red filter/amplifier.

The reason for gating only the last 70 µs of each phase into the filter/amplifier is to eliminate possible artifacts occurring during the first 112 µs of the phase due to sensor photodiode settling time. Photodiodes exhibit an exponential change when the energy from a sudden LED state change is experienced. Using only the last 70 µs of the photodiode output, after the diode has settled, excludes this potential error from the measurement.

- **IR Filter/Amplifier**

Refer to Figure 3-5 and the Oximetry Module schematic diagram (sheet 5 of 7) for additional details during this discussion.

The IR filter/amplifier circuit is an active low-pass type with a 3 dB roll-off point at approximately 10 Hz and a total gain of four. The filter cannot track the high-frequency LED pulse input, but does respond to the low-frequency patient pulse modulation, reproducing the patient's pulse waveform at the filter/amplifier output. The IR filter/amplifier pulse waveform output is coupled to the A:D Converter.

The input signal to the IR filter/amplifier, as explained above, is two 70 µs pulses separated by a 112 µs space (phases 1 and 2). The next two phases (3 and 4) are gated into the red filter/amplifier in the same manner. This leaves a 476 µs period until the next pair of IR pulses is gated into the IR filter/amplifier. The overall pulse amplitudes are proportional to the emergent light at the measurement site. The individual pulse pair amplitudes are a function of the low-frequency patient pulse modulation and artifacts at the measurement site.

These pulse pairs are coupled to the first of two identical filter/amplifier stages, each having a gain of approximately two. The signal is then coupled to the last stage, which has a gain of one. The DC offset of the resulting low-frequency patient pulse waveform is proportional due to the average LED intensity at the measurement site. The peak-to-peak amplitude of the patient's pulse waveform is a result of the factors expressed in the Beers-Lambert Law, which is used to calculate oxygen saturation (density, dimension, and color).

The patient's pulse waveform at the IR filter/amplifier output, labeled IR, must always be at a positive voltage level, because the next step is to digitize the waveform in the A:D circuits. To ensure that the waveform does not move to a negative level, the final amplifier stage input has a + 2.5 mV input, which guarantees a minimum positive offset of 0.05 V at the output.

- **Red Filter/Amplifier**

Refer to Figure 3-5 and the Oximetry Module schematic diagram (sheet 5 of 7) for additional details during this discussion.

The red filter/amplifier circuit is an active low-pass type with a –3 dB roll-off point at approximately 10 Hz and a total gain of four. The filter cannot track the high frequency LED pulse input, but does respond to the low frequency patient pulse modulation, reproducing the patient's pulse waveform at the filter/amplifier output. The red filter/amplifier pulse waveform output is coupled to the A:D Converter. The input signal to the red filter/amplifier, as explained previously, is two 70 µs pulses separated by a 112 µs space (phases 3 and 4). The next two phases (1 and 2) are gated into the IR filter/amplifier in the same manner. This leaves a 476 µs time space until the next pair of red pulses are gated into the red filter/amplifier. The overall pulse amplitudes are proportional to the emergent light at the measurement site. The individual pulse pair amplitudes are a function of the low frequency patient pulse modulation and artifact at the measurement site.

These pulse pairs are coupled to the first of two identical filter/amplifier stages, each having a gain of approximately two. The signal is then coupled to the last stage having a gain of two. The DC offset of the resulting low frequency patient pulse waveform is proportional due to the LED intensity at the measurement site. The peak-to-peak amplitude of the patient's pulse waveform is a result of the factors expressed in the Beers-Lambert Law is used to calculate oxygen saturation.

The pulse waveform at the red filter/amplifier output, labeled RED, must be at a positive voltage level, because the next step is to digitize the waveform in the measurement system. To ensure that the waveform does not move into a negative voltage region, the final amplifier stage input has a +2.5 mV input, which guarantees a minimum positive offset of 0.50 V at the output.

3.3.1.5 Control Signals

Refer to Figure 3-5 and the Oximetry Module schematic diagram (sheets 4 and 7 of 7) for additional details during the following discussion.

The SpO2 measurement process is controlled by several logic lines from microcontroller U5. The various control signals are listed and defined below:

IRGATE/	is a result of microcontroller output PWM1/ ANDed with output CMT1. IRGATE/ controls the transmission of the IR on and off levels into the IR Filter/amplifier.
IRLED/	from microcontroller output CMSR4. IRLED/ controls the selection of the LED drive level at U4B and the direction of current applied to the sensor LEDs.
REDGATE/	is a result of microcontroller output PWM1/ ANDed with output CMT0. REDGATE/ controls the transmission of the red on and off levels into the red filter/amplifier.
REDLED/	from microcontroller output CMSR5. REDLED/controls the selection of the LED drive level at U4A and the current direction applied to the sensor LEDs.
SATIN	from microcontroller output CMSR3. SATIN controls synchronous detector action through U10B.

3.3.1.6 A:D Conversion

Refer to Figure 3-6, "Oximetry Module A:D Conversion Circuits," and the Oximetry Module schematic diagram (sheet 6 of 7) for additional details during this discussion.

A:D conversion is accomplished by a dual-channel device (U20) that produces a multiplexed serial output. Channel 1 (AIN1) accommodates either VCAL1 voltage or the analog pulse waveform from the red filter/amplifier channel. Channel 2 (AIN2) accommodates either VCAL2 voltage or the analog pulse waveform from the IR Filter/amplifier channel. These selections are determined by the configuration of quad FET switch U24A,B,C,D. FET switching is controlled by logic signal RESISTORS.

U20's output bit stream multiplexing is determined by logic signal ADCCHN, which determines the channel present on the ADCDATA line. The ADCDATA line is coupled directly to microcontroller U5 for conditioning prior to transmission to the instrument display processing circuits.

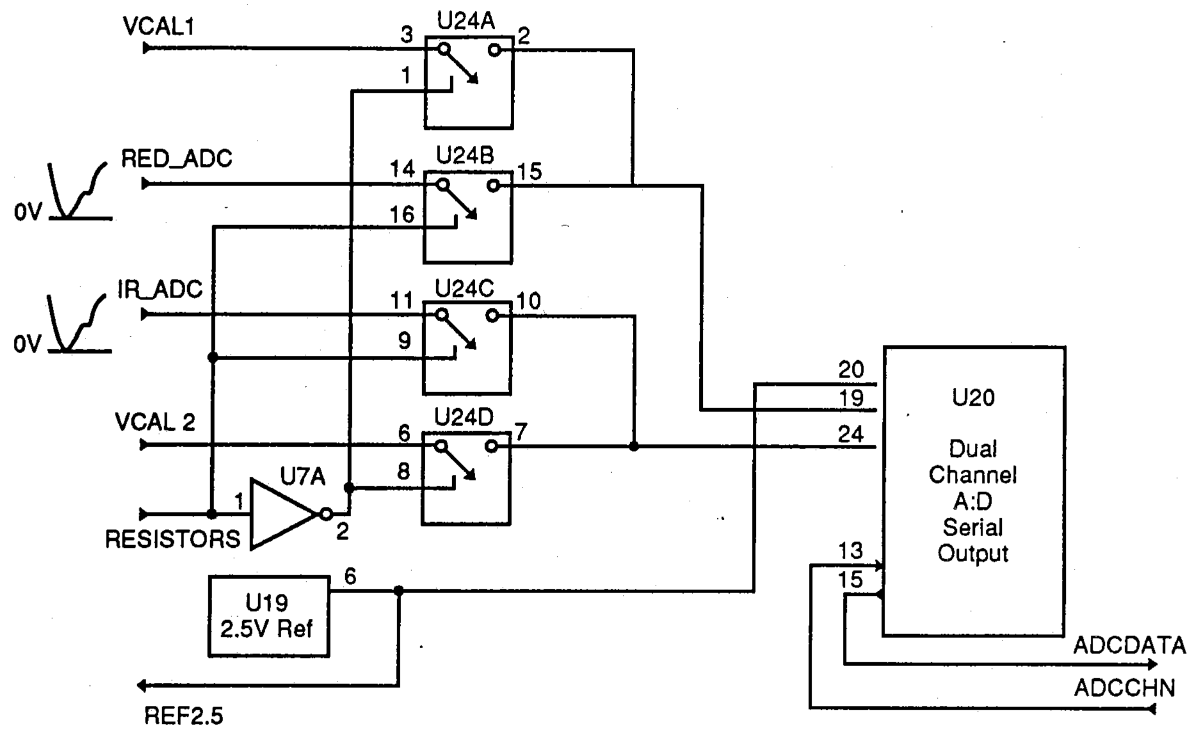


Figure 3-6: Oximetry Module A:D Conversion Circuits

3.3.1.7 Support Circuits

Support circuits include the following:

- Communications
- Processor Circuits
- Power

- **Communications**

Refer to Figure 3-7, "Oximetry Module Support Circuits," and the Oximetry Module schematic diagram (sheet 7 of 7) for additional details during the following discussion.

Other than supply voltages provided to the oximetry module from the power supply, there are five data signals present at the module connection to the instrument. These signals are:

CTS clear to send is a logic signal (active low) transmitted to the oximetry module by the instrument to suspend data transmission from the module.

RESET is an input (active low) from the processor to effect a reset in the saturation module.

RXD is the receive data line to the saturation module.

TXD is the transmitted data line from the saturation module.

The communication data link is bidirectional-asynchronous serial. Transmissions are checked for errors and the presence of an error is considered to be evidence of a hardware problem. No transmission retry capability is included.

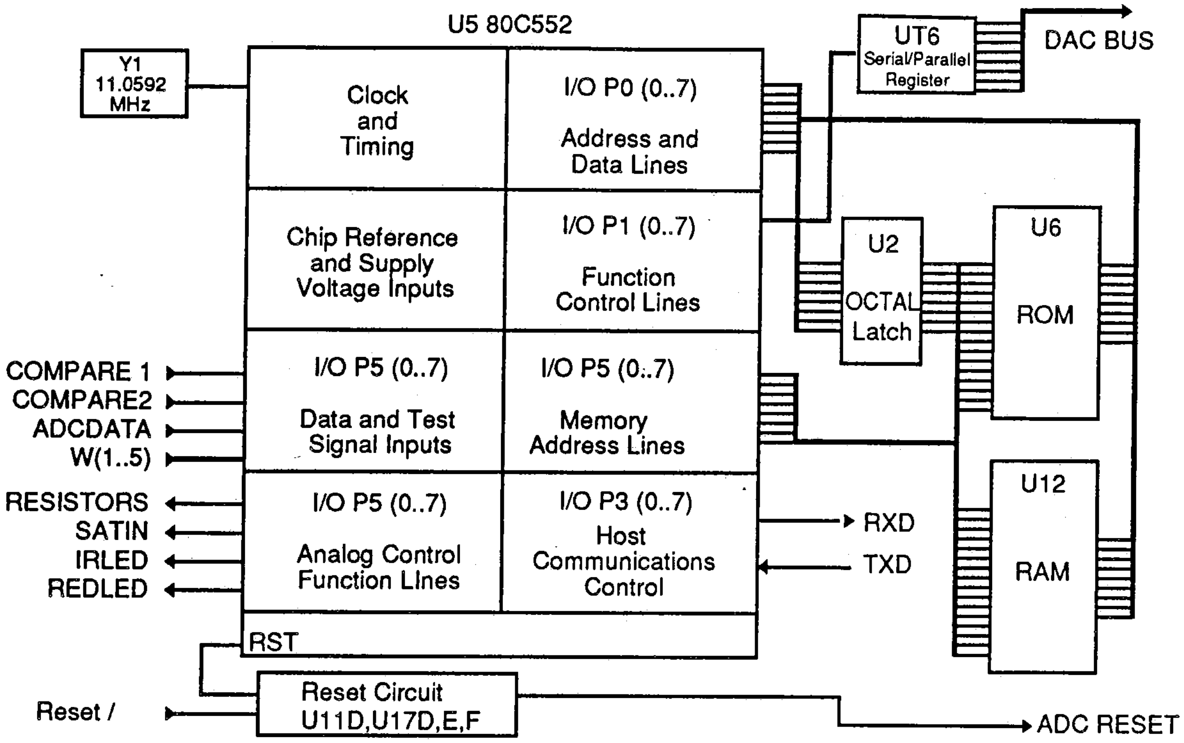


Figure 3-7: Oximetry Module Support Circuits

3.3.1.8 Processor Circuits

Refer to Figure 3-7 and the CPU PCB schematic diagram (sheet 1 of 4) for additional details during the following discussion.

Module support circuits consist of 80C522 microcontroller U5, ROM U6, and RAM U12, all served by octal latch U2. U16, a serial-to-parallel shift register, converts serial data to parallel data for the DACBUS.

The system operates using an 11 MHz crystal-controlled oscillator. Sections U11 and U17 perform reset and buffer functions for the communication link.

3.3.2 *Oximetry Module Communication Circuit*

Refer to Figure 3-8 "Oximetry Module Communication Circuit," and the CPU PCB schematic diagram (sheets 1 and 3 of 4) for additional information during the following discussion.

The oximetry module communication interface is in the form of a bidirectional, TTL level data link operating at 9600 baud. Processor U9 controls this data link via its I/O "A." Output signals TXA1, RTS1/, and RESET/ are buffered and sent to the oximetry module by gates U7A, C, and D. Connector CN3, on the CPU PCB, provides a power and data connection interface for the module.

3.3.3 *User Interface Circuits*

User interface circuits include the front-panel display circuits, front- and rear-panel input devices (push buttons, switches, control knob, etc.), and the rear panel external RS-232 output port. This subsection discusses the following circuit blocks:

3.3.3.1	Display Circuits
3.3.3.2	User Input Circuits
3.3.3.3	External Output Port

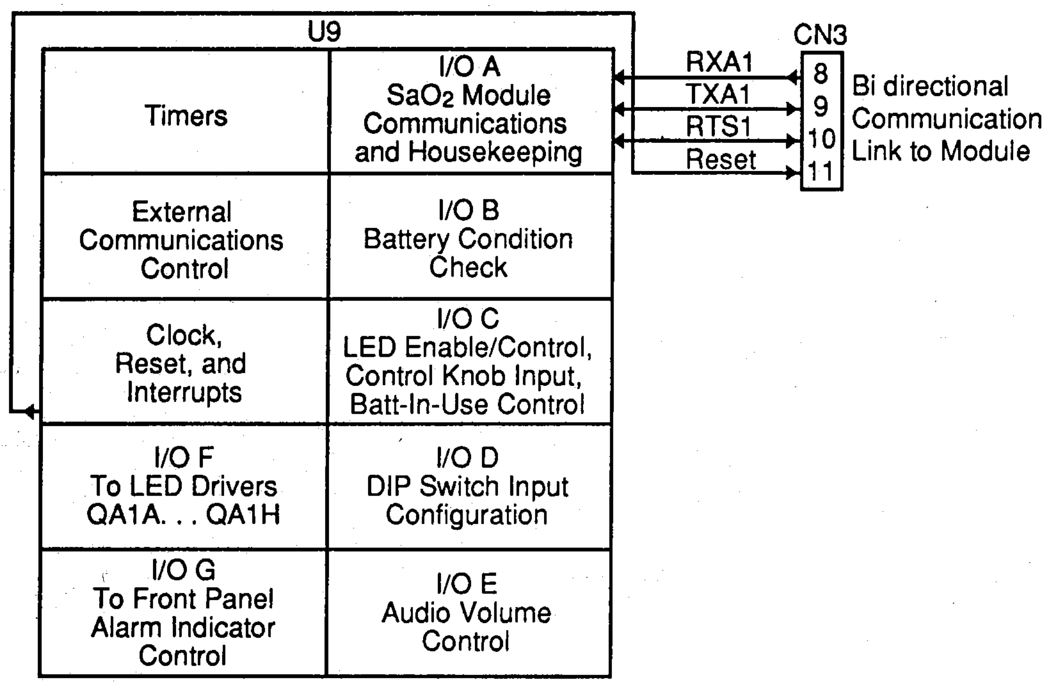


Figure 3-8: Oximetry Module Communication Circuit

3.3.3.1 Display Circuits

Refer to Figure 3-9 "N-180 Display Circuits," and the CPU PCB schematic diagram (sheets 1, 2, and 4 of 4) for additional information during the following discussion.

N-180 display data and control originate at processor U9 I/Os. Drive levels are sourced by I/O "F," buffered by QA1 on the CPU PCB, and coupled to the Display Driver PCB via CN2/CN1. LED enable and address information is sourced from I/O "C" and coupled to the Display Driver PCB in the same manner.

Address data is decoded by U1A and U2A on the Display Driver PCB and coupled with the drive information to the LED Display PCB via connectors CN1, CN2, and CN3.

The LED Display PCB consists of LED modules placed so that they provide the necessary display information.

3.3.3.2 User Input Circuits

User input circuits serve user interfaces on both the front and rear panels of the N-180. Circuits are found on both the CPU PCB, the Display Driver PCB, and the front panel mask. The following discussion addresses the following interfaces:

- Alarm push button assembly
- Control knob
- ON/STDBY switch

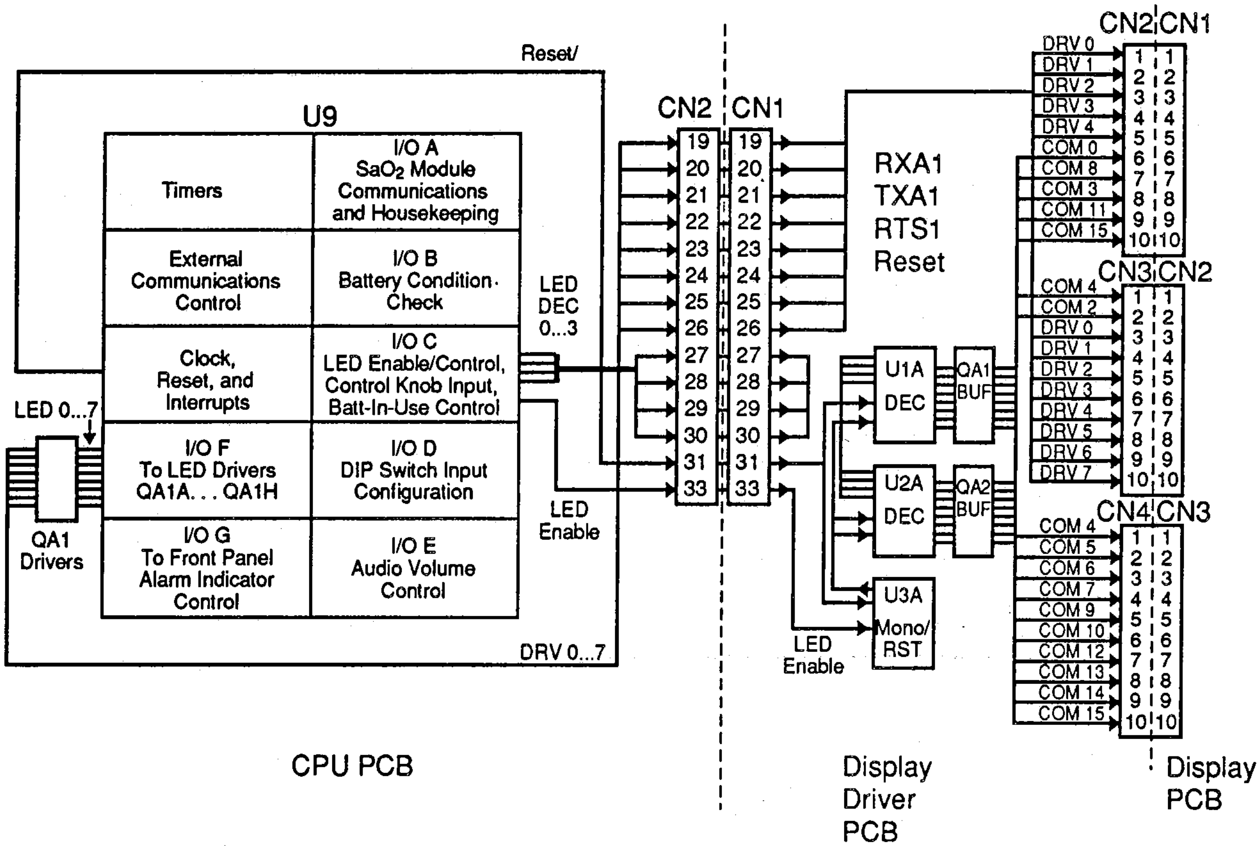


Figure 3-9: N-180 Display Circuits

- **Alarm Push Button Assembly**

Refer to Figure 3-10 "Front-Panel User Interface Circuits" and the CPU PCB schematic diagram (sheet 1 of 4) and LED Driver PCB schematic diagram for additional details during the following discussion.

The alarm push button assembly is composed of five membrane switches and a flat cable. The membrane switches and connecting cable are an integral part of the N-180 front-panel mask.

The six-circuit flat cable fits into connector CN6 on the LED Driver PCB, which couples these circuits to connector CN1 and then to the CPU PCB via a 34-circuit cable to CN2 on the CPU PCB. In this manner, push button inputs are coupled to processor U9 via the I/O "G" inputs.

- **Control Knob**

Refer to Figure 3-10, CPU PCB schematic diagram (sheet 1 of 4), and LED Driver PCB schematic diagram for additional details during the following discussion.

The control knob assembly is a sealed, two-phase rotary encoder mounted behind the front panel and connected directly to CN7 on the LED Driver PCB. Phase A and B out of the encoder are coupled to connector CN1 and then to the CPU PCB via a 34-circuit cable to CN2 on the CPU PCB.

The PHASE_A and PHASE_B signals are buffered onto the CPU PCB via U5C/D. The buffered signals (now labeled ROTSW_A and ROTSW_B are coupled directly to Processor U9 using I/O "C" inputs.

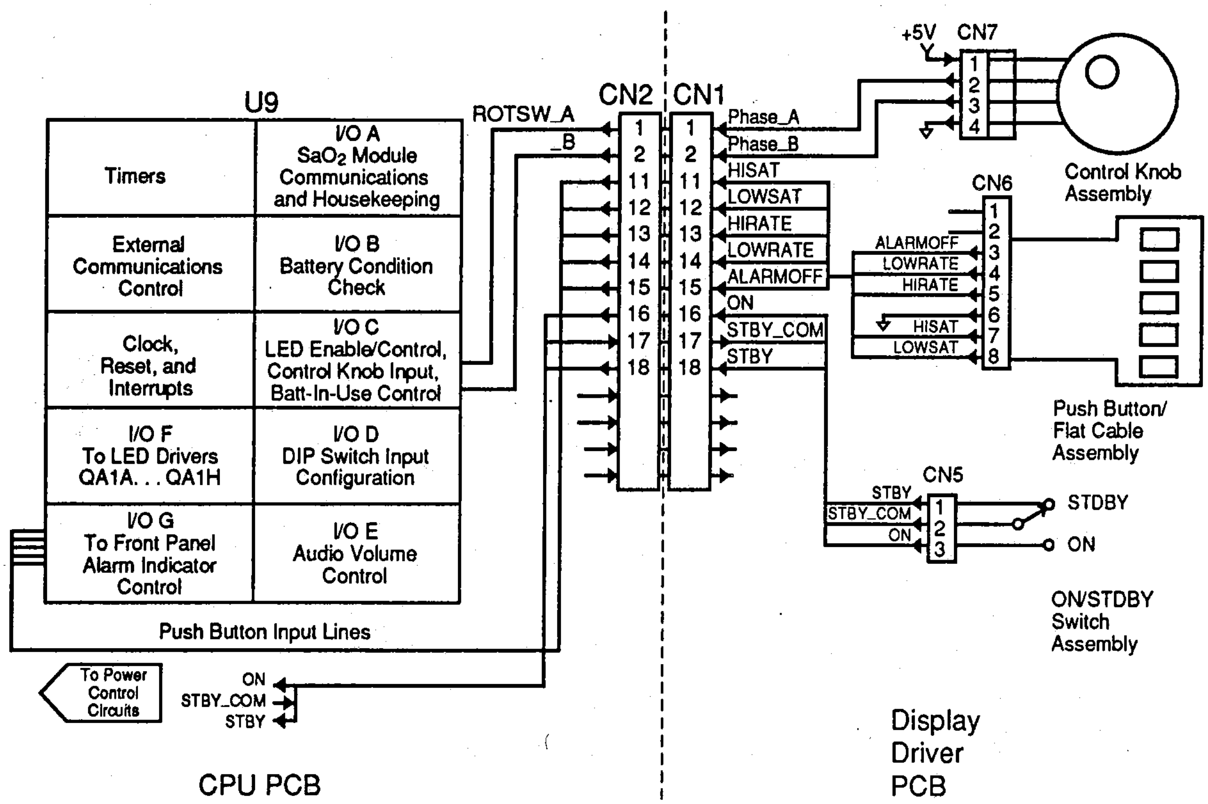


Figure 3-10: Front-Panel User Interface Circuits

- **ON/STD BY Switch**

Refer to Figure 3-10, the CPU PCB schematic diagram (sheet 1 of 4), and LED Driver PCB schematic diagram for additional details during the following discussion.

The ON/STDBY switch is mounted on the front panel. The three switch contact leads are connected to CN5 on the LED Driver PCB. The switch leads are coupled to connector CN1 and then to the CPU PCB via, a 34-circuit cable, to CN2 on the CPU PCB. The leads are then coupled to the DC power control circuits. The DC power control circuits monitor the switch position and control monitor operation.

3.3.3.3 External Output Port

Refer to Figure 3-11, "Rear-Panel User Interface Circuits," the CPU PCB schematic diagram (sheets 1 and 4 of 4), and the N-180 operator's manual, Section VI, "Connecting to Other Instruments," for additional details during the following discussion.

The rear-panel user interface circuits serve external RS-232 requirements. Processor U9, using its "0" internal modem, accommodates the four necessary RS-232 signals to support bidirectional communications. These signals are isolated by optical isolators PH1A/B (output) and PH2A/B (input). The optical isolators are coupled to the RS-232 port CN5 via RS-232 level adjuster U10 and inductors U18 A through H to reduce electromagnetic interference. The RS-232 signals are defined below.

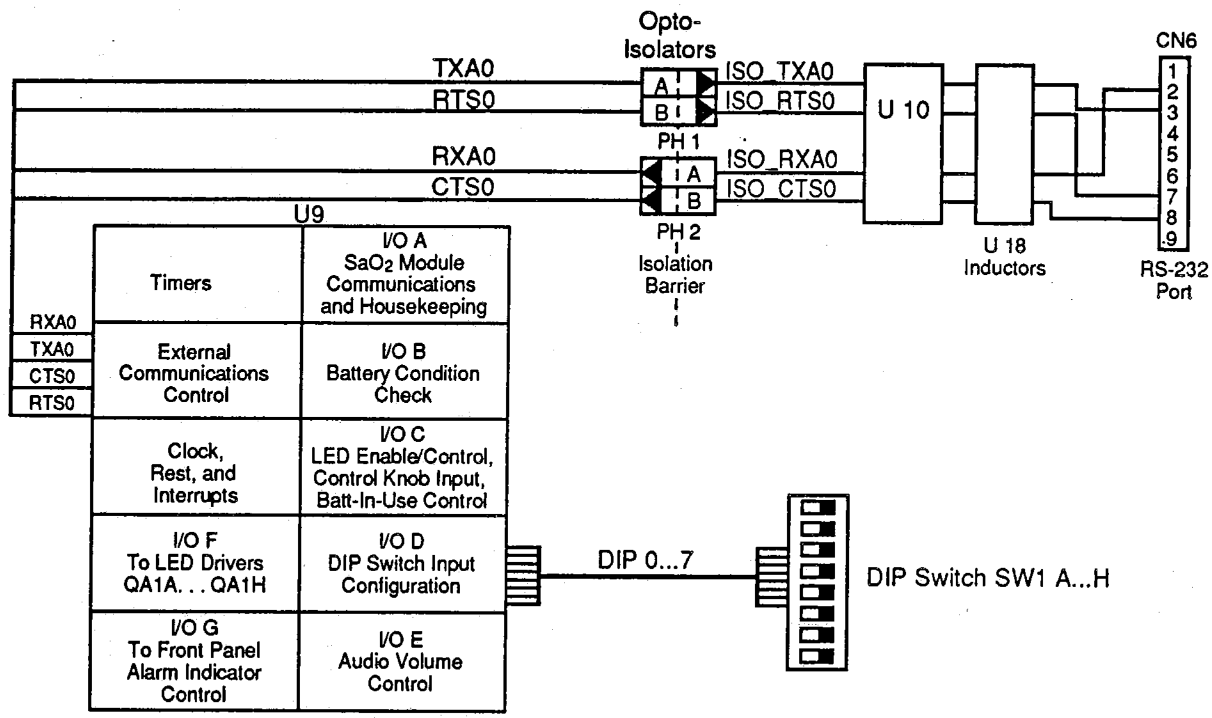


Figure 3-11: Rear-Panel User Interface Circuits

RXA0 Data received from the external source.

TXA0 Date transmitted to the external source.

CTS0/ Clear-To-Send level from the external source.

RTS0/ Ready-To-Send level from the monitor.

ISO_ Prefix to all signals on the output side of the optical isolators.

The RS-232 communication format and transmission speed (baud rate) is controlled by switch SW1. Switch configuration is given in the operator's manual.

3.3.4 *Support Circuits*

N-180 support circuits consist of the following functional blocks:

3.3.4.1 Speaker Drive Circuit
3.3.4.2 LED Current Check Circuit
3.3.4.3 Battery Condition Monitor
3.3.4.4 Power Control Circuits
3.3.4.5 Power Supply Circuits

3.3.4.1 Speaker Drive Circuit

Refer to the CPU PCB schematic diagram (sheet 1 of 4) for additional detail during the following discussion.

The speaker drive circuit is composed of transistor Q1 and FET Q2, in series with speaker and waveform conditioning components D1 and C3. The audio pulse tone (beep) is determined by the output frequency of processor U9 I/O, "A" CXS/PA5. This signal is buffered by U7B, which controls FET Q2. The beep frequency is proportional to the patient's oxygen saturation percentage, increasing in frequency with increasing saturation percentage.

Speaker volume is determined by the DC value of VOLUME, which controls Q1's conduction. The DC value of VOLUME is determined by the output of DAC U3. Processor U9 sets the default value initially, but the user can change the level by rotating the front-panel control knob.

3.3.4.2 LED Current Check Circuit

Refer to Figure 3-12, "LED Current Check Circuit," and the CPU PCB schematic diagram (sheet 2 of 4) for additional details during the following discussion.

The N-180's housekeeping diagnostics monitor the current flowing to the LEDs to check for any malfunction that may effect the credibility of the LED presentation. R34 is placed in series with the current for LED driver QA1. The voltage drop across R34 is amplified by U17A, which compares this value with processor-controlled reference from VOLUME DAC U3/U4A. By driving select segments while checking the current value at LED_CHECK the processor can determine if a segment is drawing too little or too much current.

Current values that are out of tolerance cause the processor to display Err 3 on the monitor display. An Err 3 condition can be overridden by pressing any front-panel button.

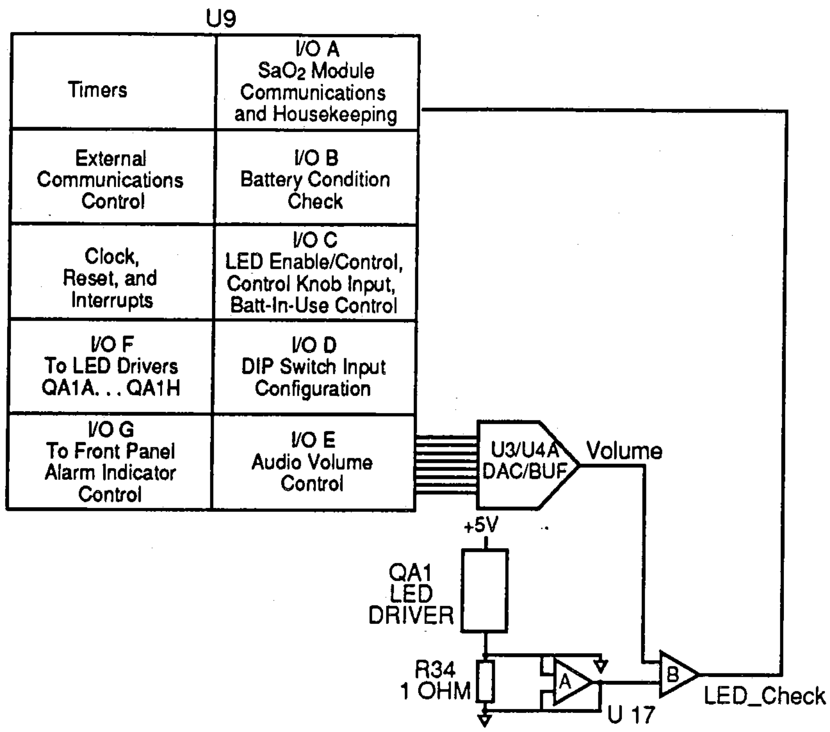


Figure 3-12: LED Current Check Circuit

3.3.4.3 Battery Condition Monitor

Refer to Figure 3-13, "N-180 Power Supply Circuits," and the CPU PCB schematic diagram (sheet 4 of 4) for additional details during the following discussion.

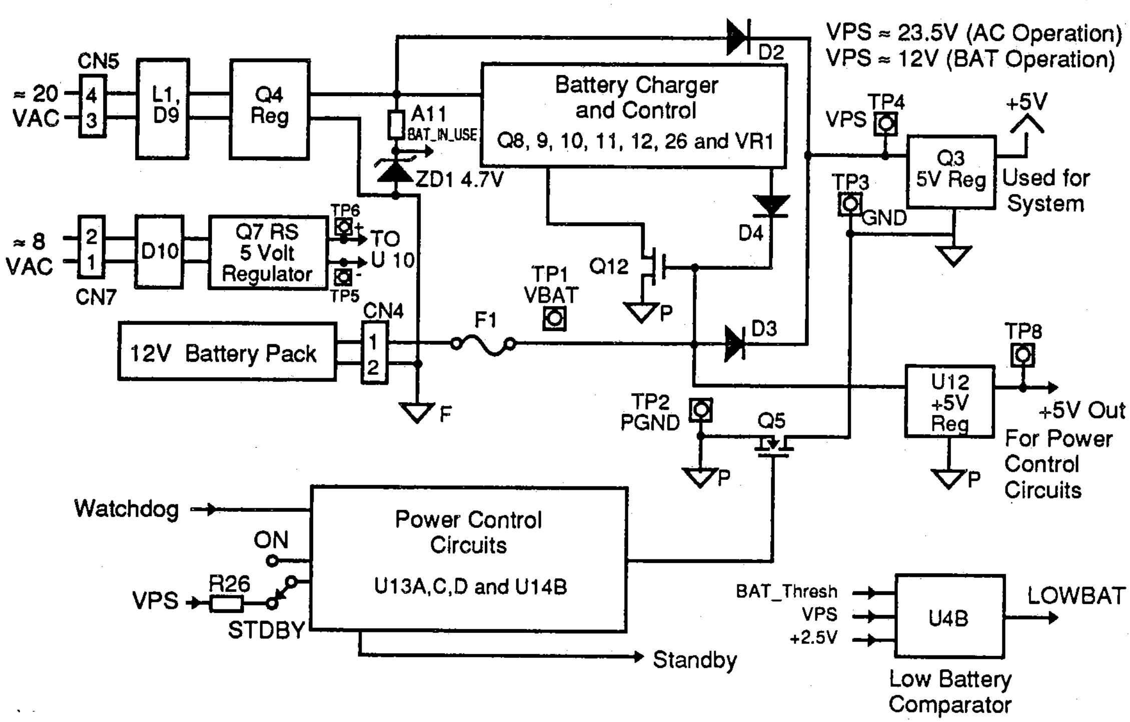


Figure 3-13: N-180 Power Supply Circuits

Battery condition monitor/low battery comparator U4B performs two functions: battery in use determination, and low battery notification. The circuit is a comparator with a logic input from processor U9 (BAT_THRESH). The comparator normally monitors VPS, which reflects the value of the monitor's DC operating voltage. When AC-powered, the value of VPS is typically 16 VDC.
When battery-operated, VPS is typically less than 13.2 V (actual value depends on battery charge level).

- **AC Operation**

The circuit performs as follows when the monitor is operating on AC power. VPS is equal to 16 V. BAT_THRESH is a logic high (+5 V) most of the time, and drops to a logic low for 200 µs every 100 ms.

When the processor brings BAT_THRESH to 0 V if the voltage at U4B pin 6 is 0.182 times VPS. If VPS is more than 13.2 V, the voltage at U4 pin 6 will be more than 2.5 V. This results in LOWBAT remaining at a logic low. The processor responds by *not* turning on the BATT IN USE light.

- **Battery Operation**

When the monitor is operating on battery, VPS drops to approximately 12 V, which is less than 13.2 V. . When BAT_THRESH is brought to logic low, the resulting voltage at U4B, pin 6 is below the 2.5 V reference (typically 2.2 V) and the comparator output (LOWBAT) rises to a logic high during the time that BAT_THRESH is low. This change in LOWBAT only during the BAT_THRESH low time period causes U9 to recognize battery operation and turns on the BATT IN USE light.

Resumption of AC power brings VPS above 13.2 V. This causes LOWBAT to stay at a logic low regardless of the state of BAT_THRESH. The processor responds by switching off the BATT IN USE indicator.

- **Low Battery Warning**

Refer to circuit operation during battery power. VPS is 13.2 V or less; this causes U4B's output to switch to a logic high during the BAT_THRESH strobe.

VPS now drops from its initial value as the battery discharges. When VPS drops below 10 V, this drives U4B pin 6 permanently below the 2.5 V reference, regardless of the state of BAT_THRESH. At this time U4B output LOWBAT remains at a logic high. The processor, noting that LOWBAT is high regardless of the level of BAT_THRESH, determines a low battery condition and starts flashing the LOW BATT light.

- **Low Battery Shutdown**

To protect the battery from excessive discharge, the processor starts a 5-minute timer after turning on the LOW BATT light. At the end of five minutes, if AC operation hasn't resumed, the processor initiates a normal shut-down procedure through the WATCHDOG line (see paragraph 3.3.4.4, "Power Control Circuits," for WATCHDOG action).

3.3.4.4 Power Control Circuits

Refer to Figure 3-13 and the CPU PCB schematic diagram (sheet 4 of 4) for additional details during the following discussion.

Monitor operation is controlled by the ON/STDBY switch on the front panel. The switch is connected to the power control circuits on the CPU PCB via connectors CN5/CN1 on the LED Display PCB.

The monitor is powered on by connecting the source and drain of FET Q5, which connects the system ground (TP3) to the power ground (TP-2). Flip-flop U14B controls the gate of Q5. In turn, U14B is controlled by gates U13A, C, D, and associated components. The various states of this circuit are discussed below.

- **STANDBY Condition**

Q5 is not conducting. U14B is RESET (logic low at Q). The ON/STDBY switch is in the STDBY position, which connects the STBY_COM pole to the STDBY pole of the switch (VPS). C13 will be charged to VPS (16 or 13 VDC depending on whether AC is connected to the monitor). C14 is charged to +5 V from regulator U12. The inputs to U13A (pin 1, +5 V, pin 2, 0 V) set the output, pin 3, to a logic high. The WATCHDOG input to the circuit (U13C) will be VPS (measured with reference to PGND TP2). The ON input to the circuit (U13D) will be 0 V. The line STANDBY, which will be polled by the processor, is at the VPS level.

Because the system ground is floating, most circuits are not functioning. The only functioning circuits are those operating on the PGND plane.

- **STANDBY to ON**

When the ON/STDBY switch is placed in the ON position, the STBY_COM and ON poles of the switch are connected. C13 discharges through R22, producing a positive spike into gate U13D. U13D inverts the spike that sets FF U14B and discharges C14 through D7. The ON input then remains at 0 V.

When U14B is set, the Q output (logic high) causes Q5 to conduct, connecting the PGND and system grounds. The processor starts operating and places a continuous stream of 0's and 1's on the WATCHDOG line. These transitions are differentiated by C16 and R20. The positive spikes are inverted by U13C and keep C14 discharged through D6.

The inputs to U13A (pin 1 0 V, pin 2 +5 V) set the output, pin 3, to a logic high. Line STANDBY, which reflects the charge on capacitor C13, will now be 0 V. The processor is now monitoring STANDBY.

- **ON to STANDBY**

A user request to place the instrument in standby results in the STBY_COM and STDBY poles of the switch being connected again. This action quickly charges C13 to VPS, causing the same value (logic high) to be present on line STANDBY.

Processor U9 notes the status change and removes the pulses from the WATCHDOG input to the control circuit. The cessation of negative pulses through D6 allows C14 to quickly charge to +5 V. This places two logic highs at the input on U13A, whose output goes to a logic low, resetting U14B. The logic low on the Q output of U14B then stops conduction in Q5, powering off the monitor. The circuit conditions are now as they were in the standby condition.

Processor U9 also uses this sequence to turn off the monitor in the event of low battery. In this case the trigger is not the STANDBY line, but information from the battery condition circuits.

3.3.4.5 Power Supply Circuits

The power supply circuits consist of the following:

- AC Power and Control
- DC Power Supplies/Battery Charger

Refer to Figure 3-13 and the CPU PCB schematic diagram (sheet 4 of 4) for additional details during the following discussion.

- **AC Power and Control**

AC power and control components consist of the AC input connector assembly (which includes the input receptacle, mains switch, fuses, and EMI filter) and the power transformer. Each component is self-contained, and with the exception of fuse replacement, is not repairable.

- **DC Power Supplies/Battery Charger**

The DC power supplies consist of two unregulated DC sources derived from two individually isolated secondary windings of the power transformer. These supplies are used for the battery charger and various regulators used for system operation. The following circuits will be discussed:

Main Power Supply
RS-232 Supply
Battery Charger Circuit

- **Main Power Supply**

Unregulated power for the main power supply comes from a 20 VAC isolated secondary. The AC is coupled onto the CPU PCB via connector CN5, filtered by inductor L1, and rectified by bridge D9. The resulting DC is from 15 to 25 V depending on the line voltage value. Three-terminal device Q4 regulates the DC at a maximum of 24 V. This voltage is passed through D2 and becomes VPS (TP4), which is used to power regulator Q3, providing a highly regulated +5 V for processor circuit power. The 24 VDC output from Q4 is also used by the battery charger circuits. Diode D3 isolates the battery from VPS when AC power is used.

In the absence of AC power, the 12-volt battery potential is coupled through D3 to supply regulator Q3. In this case D2 isolates the main power supply from the battery potential, reducing unnecessary current drain.

- **RS-232 Supply**

AC voltage for the RS-232 power supply comes from an 8 VAC isolated secondary. The AC is coupled onto the CPU PCB via connector CN7 and rectified by bridge D10. The resulting DC will be from 7 to 9 V depending on the line voltage value. Three-terminal device Q7 regulates the DC at 5 V. This voltage is isolated from all other grounds and powers only optical isolators PH1/PH2 and RS-232 device U10.

- **Battery Charger Circuit**

The battery charger circuit consisting of Q8, Q9, Q10, Q11, Q12, and associated components, operates as a charging voltage source having a maximum current of 160 mA. The circuit keeps the battery charged to a maximum of 13.8 V.

When the battery voltage is below 13.8 V the circuit charges the battery until it reaches 13.8 V. When the battery attains 13.8 V the charger switches to constant voltage operation to maintain the battery charge at 13.8 V.

Resistors R52, R53, and regulator VR1 drop the battery charge value (less D4's forward voltage drop). The common point of R52 and R53 is the battery charge sense point. Regulator Q10 monitors the voltage at this point and controls transistor Q8 to maintain this point at a voltage that represents a battery charge value of 13.8 V. VR1 adjusts the voltage at this point facilitate that particular charge value.

The circuit composed of transistor Q11 and associated resistors constitutes a current-limiting circuit with foldback characteristics.

Battery charge current flows through R54. The voltage drop across R54 is proportional to charge current. Q11 is normally turned off by reverse bias generated by the R49/R50 divider. If the charge current increases so that the drop across R54 exceeds the drop across R49 Q11 turns on. This allows additional current to flow through VR1/R53 raising the voltage at the sense point. Q10 reacts by reducing the drive to Q8, which in turn reduces the charging voltage.

In the event of a short across the battery or battery input circuit, the sense point at R53/R54 would drop, causing Q10 to attempt to increase the charge current. To prevent this and resultant overheating, short circuit protection circuit is employed. Q12, normally held in conduction by the battery voltage value, shuts off. This results in Q9 turning Q8 off.

Section 4
Routine Maintenance

4.1 INTRODUCTION

The N-180 requires no routine service other than that mandated by the service technician's institution. Section 5, "Troubleshooting," discusses potential difficulties, their possible causes, and suggestions for resolving them.

4.2 CLEANING INSTRUCTIONS

Caution: Do not immerse the N-180 in liquid or use caustic or abrasive cleaners.

To clean the N-180's surfaces, dampen a cloth with a commercial, nonabrasive cleaner and wipe the top, bottom, and front surfaces lightly. Do not spray or pour any liquid directly on the N-180 or its accessories. Do not allow any liquid to come in contact with power connector, fuse holder, or switches. Do not allow any liquid to penetrate connectors or openings in the chassis.

4.3 DETERMINING SOFTWARE VERSION

To determine the N-180 software version, press the HIGH SAT and AUDIO ALARM OFF buttons at the same time. Turn the control knob until a "0" appears in the OXYGEN SATURATION display. The units digit of the software version appears in the PULSE RATE display. Turn the control knob until a "1" appears in the OXYGEN SATURATION display. The tenths digit of the software version appears in PULSE RATE display. For example, version 1.0 should show as a "1" in the PULSE RATE display with "0" showing in the OXYGEN SATURATION display and "0" showing in the PULSE RATE display with "1" showing in the OXYGEN SATURATION display

4.4 TECHNICAL ASSISTANCE

For technical information and assistance, contact Nellcor's Technical Services Department or Nellcor's local representative. To order parts, contact Nellcor's Customer Service Department or Nellcor's local representative.

Section 5
Troubleshooting

5.1 OVERVIEW

This section lists status messages, along with the actions that the operator should take. If the recommended actions do not cause the message to disappear, contact Nellcor's Technical Services Department or Nellcor's representative. The service manual describes additional suggested actions for use by qualified service personnel.

5.2 N-180 STATUS MESSAGES

The following messages are displayed in the N-180's OXYGEN SATURATION and PULSE RATE displays. Note that if Err 4, Err 5, or Err 6 appear, this indicates an internal data error. Contact Nellcor's Technical Services Department or Nellcor's representative for assistance.

Err 1

Defective data memory. Contact Nellcor's Technical Services Department or Nellcor's representative.

Err 2

Defective program memory. Contact Nellcor's Technical Services Department or Nellcor's representative.

Err 3

WARNING: Continue to use the N-180 only in an urgent situation with an "Err 3" message and only if the defective segment(s) has been identified. If a defective segment cannot be identified, do not continue to use the N-180.

Defective display or indicator, or possibly a circuit malfunction. Contact Nellcor's Technical Services Department or Nellcor's representative.

Note: The N-180 may operate if any button is pressed while "Err 3" is showing. However, if any numeric display segment or indicator is missing, the display or warning indicators may be incorrect.

5.3 TROUBLESHOOTING

This section discusses potential difficulties and suggestions for resolving them. If the difficulty persists, contact Nellcor's representative.

This section is divided into two troubleshooting categories:

- Items 1 and 2 describe general system problems.
- Items 3 through 8 describe general oximetry subsystem problems.

1. N-180 does not turn on.

- Check AC connections. Check that monitor is connected properly to the AC supply.

- Check battery operation. If battery is discharged, connect N-180 to an appropriate AC outlet and turn on the power on/off switch. The N-180 requires a minimum of 14 hours to recharge the battery completely.
- Check AC fuses.

2. **N-180 operates on AC power but not on battery.**

- The battery may be discharged. To recharge the battery, connect the N-180 to an appropriate AC power outlet. Turn on the power on/off switch and confirm that the BATT IN USE indicator is off. A minimum of 14 hours is required to recharge the battery completely.
- The battery pack or battery charger circuit may be defective, or the battery fuse may be open.

3. **PULSE SEARCH indicator is on; SpO_2 and pulse rate not displayed.**

- *Check the patient.* The patient may be experiencing shock, hypotension, severe vasoconstriction, severe anemia, hypothermia, arterial occlusion proximal to the sensor, or cardiac arrest.
- The sensor may be improperly applied (e.g., too tight) or it may not be plugged in.
- There may be excessive ambient light; cover the sensor site with opaque material.
- The sensor may be placed on an extremity with a blood pressure cuff, arterial catheter, or intravascular line.
- The patient's perfusion may be too low for the N-180 to detect an acceptable pulse.
- Test the N-180 on someone else; try another sensor site; or try another sensor.
- The sensor may be damaged; replace it.
- Evaluate performance using a *NELLCOR* PT-2500 pocket tester, and if incorrect readings result, contact Nellcor's representative.

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

- *Check the patient.*
- Excessive patient motion may be making it impossible for the N-180 to find a pulse pattern. If possible, keep the patient still; check whether the sensor is applied securely and properly and replace if necessary; move the sensor to a new site; use a sensor that tolerates more motion; or set the N-180 for Mode 3.
- The sensor may be damaged; replace it.
- The patient's perfusion may be too low to allow the N-180 to measure saturation and pulse rate.

5. **SpO_2 or pulse rate change rapidly; pulse amplitude indicator is erratic.**

- *Check the patient.*
- Excessive patient motion may be making it impossible for the N-180 to find a pulse pattern. If possible, keep the patient still; check whether the sensor is applied securely and properly, and replace it if necessary; move the sensor to a new site; use a sensor that tolerates more motion; or set the N-180 for Mode 3.

- An electrosurgical unit (ESU) may be interfering with performance:
  - Move the N-180 and the cables as far from the ESU as possible.
  - Plug the N-180 and the ESU into different AC circuits.
  - Move the ESU ground pad as close to the surgical site as possible.
  - The sensor may be damp or may have been reused too often. Replace it.
  - If using a sensor extension cable, remove it and connect the sensor directly to the N-180.
  - If the patient weighs less than 3 kg or more than 40 kg, apply an *OXISENSOR* N-25 oxygen transducer to an appropriate site. This sensor has added insulation against electrosurgical interference.

6. Displayed pulse rate does not correlate with that of ECG monitor.

- Excessive patient motion may be making it impossible for the N-180 to find a pulse pattern. If possible, keep the patient still; check whether the sensor is applied securely and properly and replace if necessary; move the sensor to a new site; use a sensor that tolerates more motion; or set the N-180 for Mode 3.
- The patient may have a pronounced dicrotic notch, which causes the pulse rate measurement to double. Try another sensor site.
- An ESU may be interfering. Refer to discussion under item 5.

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

- The SpO_2 calculation may not have correctly adjusted for the effects of pH, temperature, $PaCO_2$, 2,3-DPG, or fetal hemoglobin. Check whether calculations have been corrected appropriately for relevant variables. (See Section II, "Principles of Operation," for more information.) In general, calculated saturation values are not as 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's directions for use.
- Evaluate performance using a *NELLCOR* PT-2500 pocket tester, and if incorrect readings result, contact Nellcor's representative.

8. Oxygen saturation does not correlate with laboratory CO-Oximeter.

- Fractional measurements may not have been converted to functional measurements before the comparison was made. The N-180, as well as other two-wavelength oximeters, measure functional saturation. Multi-wavelength oximeters, such as the Instrumentation Laboratory 282 CO-Oximeter and Corning CO-oximeters, measure fractional saturation. Fractional measurements must be converted to functional measurements for comparison. Refer to the equation for this conversion in Section II, "Principles of Operation."
- Close correlation requires simultaneous blood sampling and pulse oximeter measurements from the same arterial supply.

- Evaluate performance using a *NELLCOR* PT-2500 pocket tester, and if incorrect readings result, contact Nellcor's representative.

Section 6
Testing and Calibration

6.1 INTRODUCTION

This section details testing and calibration procedures for the N-180. The section is divided into subsections that support a top down approach to testing at three levels.

Paragraph 6.2, "Required Test Equipment," lists necessary test equipment.

Paragraph 6.3, "Safety Tests," describes high-potential and leakage testing.

Paragraph 6.4, "Functional Tests," lists tests that can be performed without removing the instrument cover. These tests are designed for an overall assessment of instrument safety and performance.

System-level tests are recommended for acceptance testing and periodic routine testing.

6.2 REQUIRED TEST EQUIPMENT

The following test equipment is required to perform the system-level test procedures described in this section.

6.2.1 *System-Level Testing*

System-level testing requires specific types of support equipment:

6.2.1.1 Commercially Available Test Instruments

6.2.1.2 Unique Test Equipment

6.2.1.1 Commercially Available Test Instruments

Specific devices in the following list are known to provide the necessary features to perform the tests in this section. Equivalent devices may be used if the technician has verified their compliance to test requirements.

1.	Safety analyzer	Biotek 370, Dynatech-Nevada 232D, or equivalent
2.	High-potential analyzer	0-5000 VAC, with timer, ROD-L Model M100AVS5, or equivalent.
3.	Autotransformer	0-140 VAC, 12 A (0-240 VAC, 6 A) Staco Type L1010 or equivalent.

6.2.1.2 Unique Test Equipment

The device listed below is a Nellcor product required to facilitate tests.

- *NELLCOR* PT-2500 pocket tester

6.3 SAFETY TESTS

The following tests should be performed to ensure the integrity of grounding and isolation:

6.3.1 Ground Integrity
6.3.2 High Potential
6.3.3 Electrical Leakage

6.3.1 *Ground Integrity*

This test verifies the integrity of the power cord ground wire from the AC plug to its connection with the N-180's chassis ground.

1. Configure the safety analyzer as follows:

Function:	Ground resistance test
Range:	Milliohms

2. Connect the AC plug to the analyzer as recommended by the analyzer operating instructions.

3. Connect the analyzer resistance lead to the ground (equipotential) point on the N-180 rear panel and verify that the analyzer indicates 0.150 (150 milliohms) or less.

6.3.2 *High Potential*

The high potential test is designed to test circuit component insulation from both the AC power line (primary) and chassis ground. There are two tests applicable:

- Primary-to-Chassis

WARNING: These tests involve the use of test equipment that generates high voltages (more than 5,000 V). Use extreme care when handling, connecting the equipment and performing the test to ensure personal safety and prevent accidental damage to the N-180. When performing high potential testing, the following limits must be observed:

Power Transformer Primary to Chassis Ground	**Maximum AC volts; 500**
Power Transformer Primary to Electronics	**Maximum AC volts; 1500**

Both tests are conducted with the N-180 disconnected from AC power or any other device except the high-potential analyzer.

6.3.2.1 **Primary-to-Chassis Input**

1. Configure the high-potential analyzer as follows:

Mode:	AC Volts
Amplitude:	1500 V
Timer:	1 Second
Output:	OFF

2. Connect the high-potential analyzer high output lead to either of the power blades of the N-180 AC plug.

3. Connect the high-potential analyzer low output lead to the N-180 ground point.

4. Place the N-180 mains switch in the ON position.

5. Turn the high-potential analyzer output on (if the analyzer does not have a timed output the technician must control the time) for 1 second.

6. Verify that the analyzer does not indicate any leakage during the 1-second period.

6.3.3 *Electrical Leakage*

This test verifies the electrical leakage specification of the N-180. There are two tests included under electrical leakage:

- Chassis-to-AC Power Line Leakage Current
- Electronics-to-AC Power Line Leakage Current

6.3.3.1 **Chassis-to-AC Power Line Leakage Current**

1. Configure the electrical safety analyzer as follows:

Function:	Leakage
Range:	Microamps

2. Connect the AC plug to the safety analyzer as recommended by the operating instructions.

3. Connect the safety analyzer leakage input lead to the ground point on the rear of the N-180 and verify that the analyzer indicates 50 μA or less for all of the following AC power configurations.

AC POLARITY	GROUND WIRE
Normal	Normal
Reverse	Normal
Reverse	Open
Normal	Open

6.4 FUNCTIONAL TESTS

The following functions are checked with the N-180 alone or with the pocket tester:

- AC line operation
- Battery operation indicator
- Adult/neonate alarm limit
- Operation with the pocket tester
- Adjustment of alarm limits
- Temporary audio alarm silence
- Audio alarm disable

6.4.1 *Battery Operation Test*

Leave the N-180 connected to the AC line for 14 hours with the mains switch on to charge the battery. After that, remove the N-180 from the AC line power source and let it operate on battery power. If the monitor stops operating within 4 hours, the battery needs replacement.

6.4.2 *AC Line Operation*

Connect the power cord to the N-180 and the AC line. Turn on the main switch located on the rear panel, and set the ON/STDBY switch to the ON position. The N-180 is checked for normal operation as follows:

- A beep sounds on setting the ON/STDBY switch to the ON position.
- All LEDs on the front panel are illuminated and then go off. The oxygen saturation and heart rate display windows change color from red to green.
- After a short period the display segments appear to rotate.
- Finally, the PULSE SEARCH indicator begins to flash.

6.4.3 *Battery Operation Indicator*

This test should be started with the N-180 operating on the AC line.

1. Turn off the mains switch on the rear panel and check that the BATT IN USE indicator is lighted.
2. Next, return the main switch to on and check that BATT IN USE indicator goes off.

6.4.4 *Adult/Neonate Alarm Limit*

Check alarm limits as outlined below.

1. Set switch section 1 of the rear-panel switch up to set the alarm limit for adults. Press the HI SAT button and check that "100" is displayed in the oxygen saturation display window.
2. Press the HI RATE button and check that "140" is displayed in the pulse rate display window.
3. Set switch section 1 down to set the alarm limit for neonates.
4. Press the HI SAT button and check that "95" is displayed in the oxygen saturation display window.
5. Press the HI RATE button and check that "200" is displayed in the heart rate display window.

* PT-2500 per Don 8-10-92 81 ± 1 Sat % 40 ± 1 Pulse (BPM)

6. Set switch section 1 to the up position.

6.4.5 *Operation with the Pocket Tester*

1. Connect a *NELLCOR* PT-2500 pocket tester to the N-180.

2. Set the ON/STDBY switch to the ON position. The N-180 begins to display the pulse rate and oxygen saturation values generated by the pocket tester. The values displayed should be within the limits of the values shown on the pocket tester label.

3. The "LOW SAT" and "LOW RATE" alarms occur as follows. The values shown in the OXYGEN SATURATION display and the PULSE RATE display window flash red. The indicator LEDs located next to the LOW SAT button and the LOW RATE button also flash and the audio alarm sounds.

   Note: The audio alarm can be disabled during the test by pressing the AUDIO ALARM OFF button.

4. Press the HI SAT button and the AUDIO ALARM OFF button simultaneously, and rotate the knob to display "24" (memory position) in the OXYGEN SATURATION display. Check that in this state that a number between 32 and 44 is displayed in the PULSE RATE display. This number indicates the gain of the input amplifier.

   omit per Don 8-10-92

   Note: In this test these numbers are shown in the displays for 3 seconds after the knob has been rotated. To prolong the period of display, rotate the knob or continue to press the two buttons simultaneously.

5. If all these tests prove that the instrument operates normally, proceed to the next section. Otherwise, the instrument needs repair.

6.4.6 *Alarm Limit Adjustment*

Follow the procedure below to check alarm limit adjustment.

1. Record the value of oxygen saturation shown in the appropriate display window. Press the LOW SAT button and rotate the knob counterclockwise slowly. Check that the LOW SAT indicator goes off when the value shown in the oxygen saturation display window has reached the value recorded. This test should be continued until the value in the oxygen saturation display window falls below 75.

2. Record the value of heart rate shown in the appropriate display window. Press the LOW RATE button and rotate the knob slowly counterclockwise. Check that the LOW RATE indicator goes off when the value shown in the heart rate display window has reached the value recorded. This test should be continued until the value in the heart rate display window falls below 40.

3. Press the HI SAT button and rotate the knob slowly counterclockwise. Check that the HI SAT indicator flashes and the audible alarm sounds when the value shown in the oxygen saturation display window falls below the value recorded in step 1 above. After the test, press the HI SAT button and rotate the knob clockwise to prevent an alarm from sounding.

4. Press the HI RATE button and rotate the knob slowly counterclockwise. Check that the HI RATE indicator flashes and the audible alarm sounds when the value shown in the display window falls below the value recorded in step 2 above.

5. Set the ON/STDBY switch to the STDBY position.

6.4.7 *Silencing the Audio Alarm Temporarily*

1. Connect the pocket tester to the N-180.

2. Set the ON/STDBY switch to the ON position. The N-180 begins to display the heart rate and oxygen saturation values generated by the pocket tester.

3. The LOW SAT and LOW RATE alarms occur as follows. The values in the oxygen saturation display window and the heart rate display window flash red. The indicator LEDs located next to the LOW SAT button and the LOW RATE button also flash and the audible alarm sounds.

4. Press the audible alarm off button.

5. Check that the red audible alarm off indicator and the audible alarm go off for 60 ±2.0 seconds.

6.4.8 *Audible Alarm Disable*

1. Press the audible alarm off button and rotate the knob clockwise, so that "OFF" is shown in the oxygen saturation display window.

2. Check that the audible alarm off indicator flashes, the LOW SAT and the LOW RATE indicators continue to flash, and the audio alarm goes off.

3. Press the audible alarm off button once again to enable the audio alarm. Check that the audible alarm indicator goes off and the audible alarm sounds.

4. Set the ON/STDBY switch to the STDBY position and remove the pocket tester.

Section 7
Specifications

7.1 CONFIGURATION

Components

Oximeter unit, hospital-grade power cord, and *NELLCOR* EC-8 eight-foot sensor extension cable.

Readout

Two three-digit green and red displays for oxygen saturation and pulse rate. Sixteen-segment display for pulse amplitude indicator (pulse amplitude). Annunciators for LOW BATT, PULSE SEARCH, HIGH SAT, LOW SAT, HIGH RATE, and LOW RATE alarms, and AUDIO ALARM OFF. Annunciators for LOW BATT, BATT IN USE and NEONATAL alarm limits.

Controls

Control knob to adjust volume and set alarm limits, and five buttons to select alarm limits and disable audio alarm.

Rear-panel switches for adult/neonatal alarm settings, RS-232 format, and baud rate.

7.2 PERFORMANCE

Range

Saturation: 0-100%

Pulse Rate: 20-250 bpm (beats per minute)

Accuracy

Saturation (%SpO_2±1 standard deviation)

SpO_2		Accuracy*
Adults	70-100 %	±2 digits
	50-69 %	±3 digits
	0-49 %	unspecified
Neonates:	70-95 %	±3 digits

Pulse Rate	Accuracy
20-250 bpm	±3 bpm

Note: The N-180 pulse oximeter is calibrated to read oxyhemoglobin saturation (%SpO_2) of functional hemoglobin as compared to an Instrumentation Laboratory 282 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.

*Accuracy is based on testing with an *OXISENSOR* D-25; 68% of the measurements across the population will be within ±1 standard deviation.

Accuracy (continued)

Testing to verify specifications is done against *NELLCOR* N-100 pulse oximeters with D-25 sensors previously validated for accuracy against an Instrumentation Laboratory CO-Oximeter. For specification of accuracy with other *NELLCOR* sensors, refer to the sensor's directions for use.

Sensors

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

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

Heating: Sensor power dissipation; less than 50 mW total heat dissipation by LEDs (typically less than 1°C temperature rise).

Patient Size: Nellcor provides a range of oxygen transducers. Each sensor has a recommended weight range.

Sensor	Model	Patient Size
OXISENSOR	N-25	< 3 or > 40 kg
	I-20	1-20 kg
	D-20	10-50 kg
	D-25, D-25L	> 30 kg
	R-15	> 50 kg
OXIBAND	OXI-A/N	< 3 or > 50 kg
	OXI-P/I	3-40 kg
DURASENSOR	DS-100A	> 40 kg
DURAFORM	DF-A	> 40 kg
Reflectance	RS-10	> 40 kg

Alarms

Audio and visual alarms for high and low oxygen saturation, high and low pulse rate, and loss of pulse. 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 a visual warning to alert the user that the audible alarm is disabled.

Alarms (continued)

The initial default alarm settings that are in effect when the N-180 leaves Nellcor are as follows. High and low alarm limits cannot overlap.

Adult Mode:

High Sat:	100%	(adjustable 20-100)
Low Sat:	85%	(adjustable 20-100)
High Rate:	140 bpm	(adjustable 20-250)
Low Rate:	55 bpm	(adjustable 20-250)

Neonatal Mode:

High Sat:	95%	(adjustable 20-100)
Low Sat:	80%	(adjustable 20-100)
High Rate:	200 bpm	(adjustable 20-250)
Low Rate:	100 bpm	(adjustable 20-250)

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.

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 not displayed, no pulse tone)

Switches

Eight for digital output, adult/neonatal alarm limits.

Switch Section	Function
1	Adult/neonatal alarm settings
2	RS-232 format
3, 4, 5, 6	not used
7, 8	Baud rate select

Data Output

Digital:

- **Type:** RS-232
- **Connector:** 9-pin D-type, sub-miniature, female
- **Baud Rate:** Switch-selectable, 2400, 4800, 9600, and 19,200
- **Formats:** Conversation and computer

7.3 ENVIRONMENTAL REQUIREMENTS

Temperature	**N-180:**	50-104°F (10-40°C) operating 32-122°F (0-50°C) storage
	Sensor:	Within physiologic range 82.4-107.6°F (28-42°C) for accurate measurement.

Humidity

Any humidity/temperature combination without condensation.

Altitude

0-10,000 ft (3,048 m)

7.4 ELECTRICAL CHARACTERISTICS

Protective Class

Class I: mains-supplied unit using a protective ground

Degree of Protection

Type BF: patient electrically isolated

Voltage

100-120 VAC ±10%, 50-60 Hz

Power Consumption

Maximum rating: 25 VA

Leakage Current

50 µA maximum, power line to ground
10 µA maximum, patient connector to ground
10 µA maximum, patient connector to power line

Battery

Type:	Lead-acid battery pack, 1.9 AH
Battery Life:	6 hours minimum on full charge
Recharge Period:	14 hours minimum

7.4 PHYSICAL CHARACTERISTICS

Dimensions

2.875 in. high x 8.5 in. wide x 7 in. deep (73 x 216 x 178 mm)

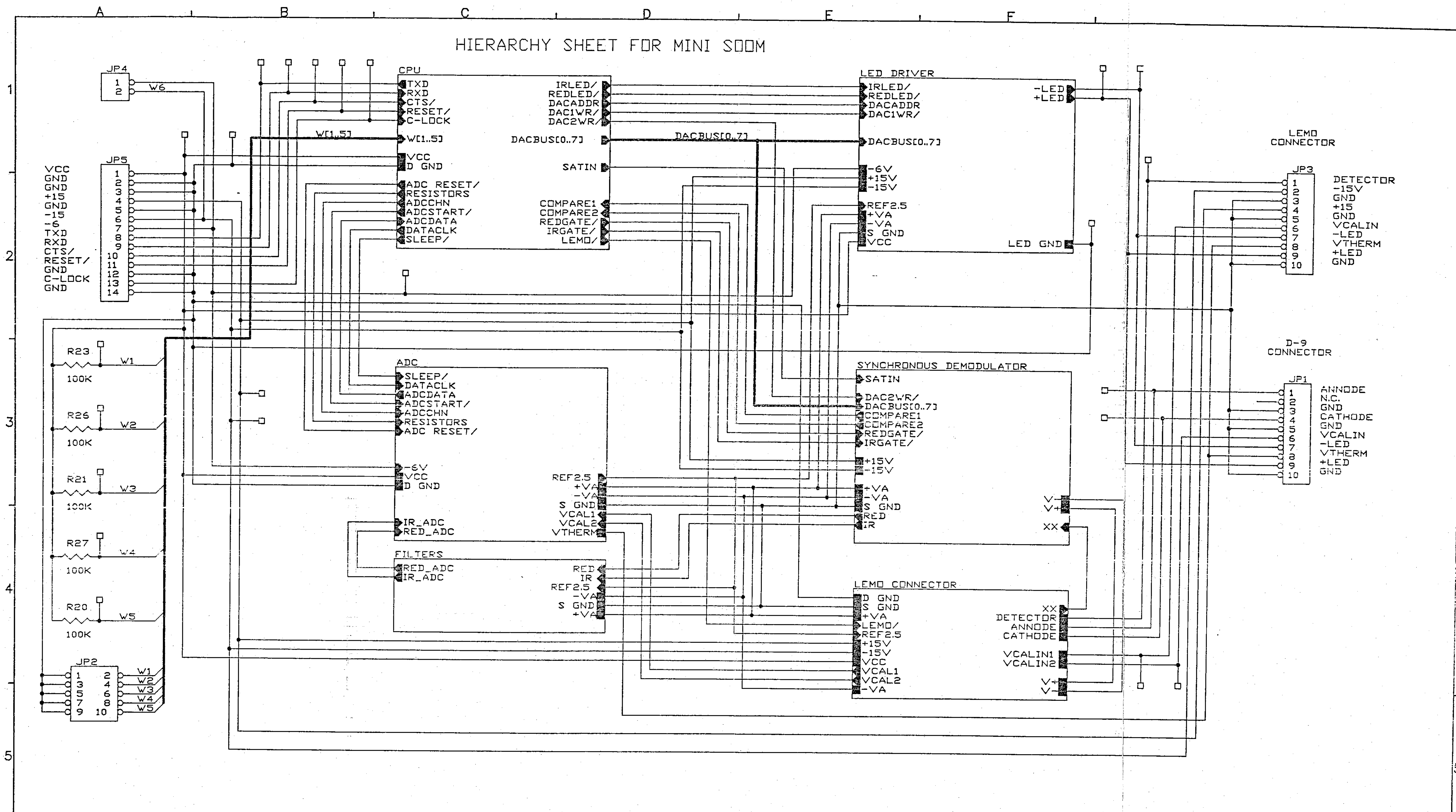
Weight

6.6 lb (3 kg)

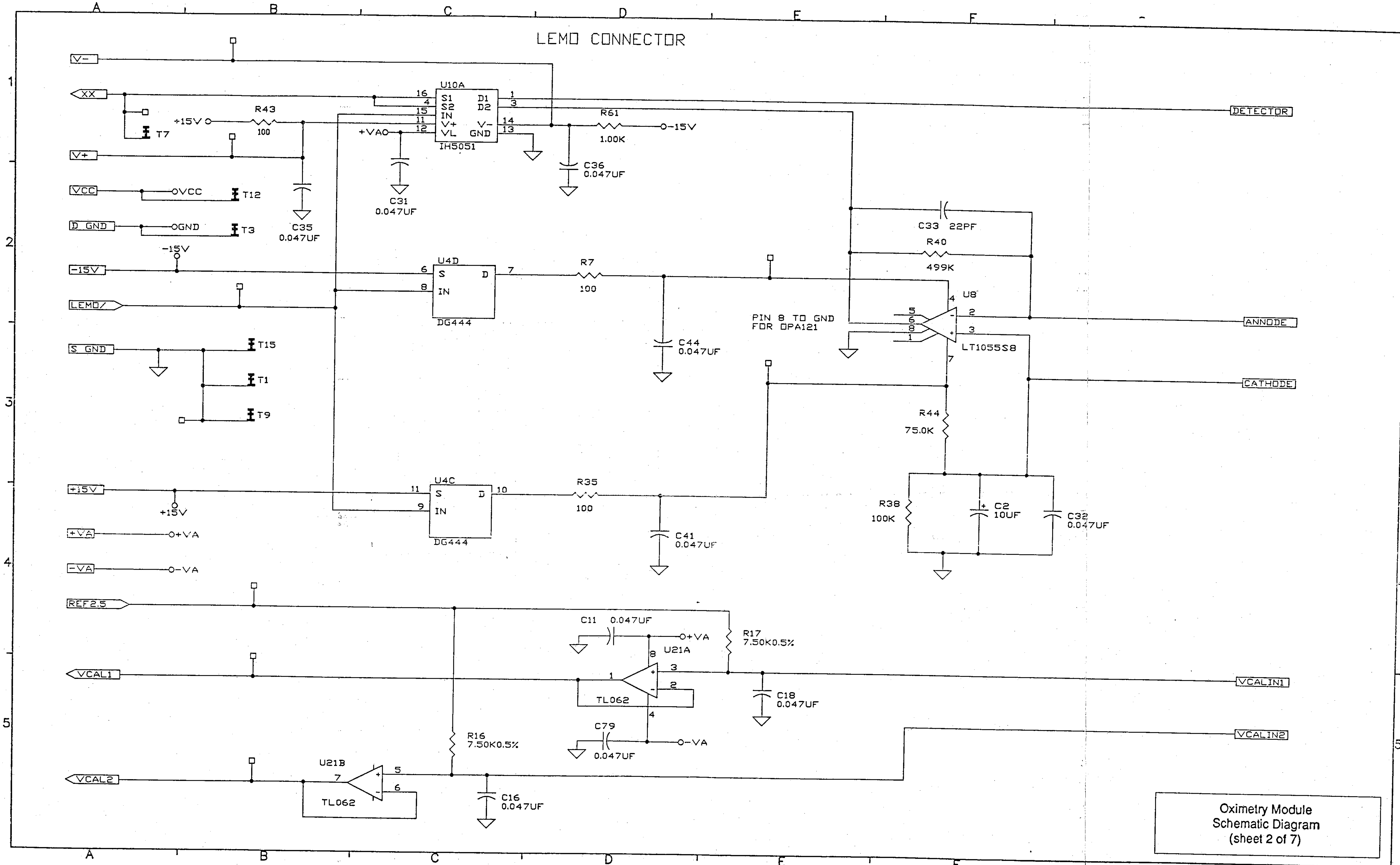
Section 8
Schematic Diagrams

This section includes schematic diagrams for the N-180. The following schematic diagrams are included:

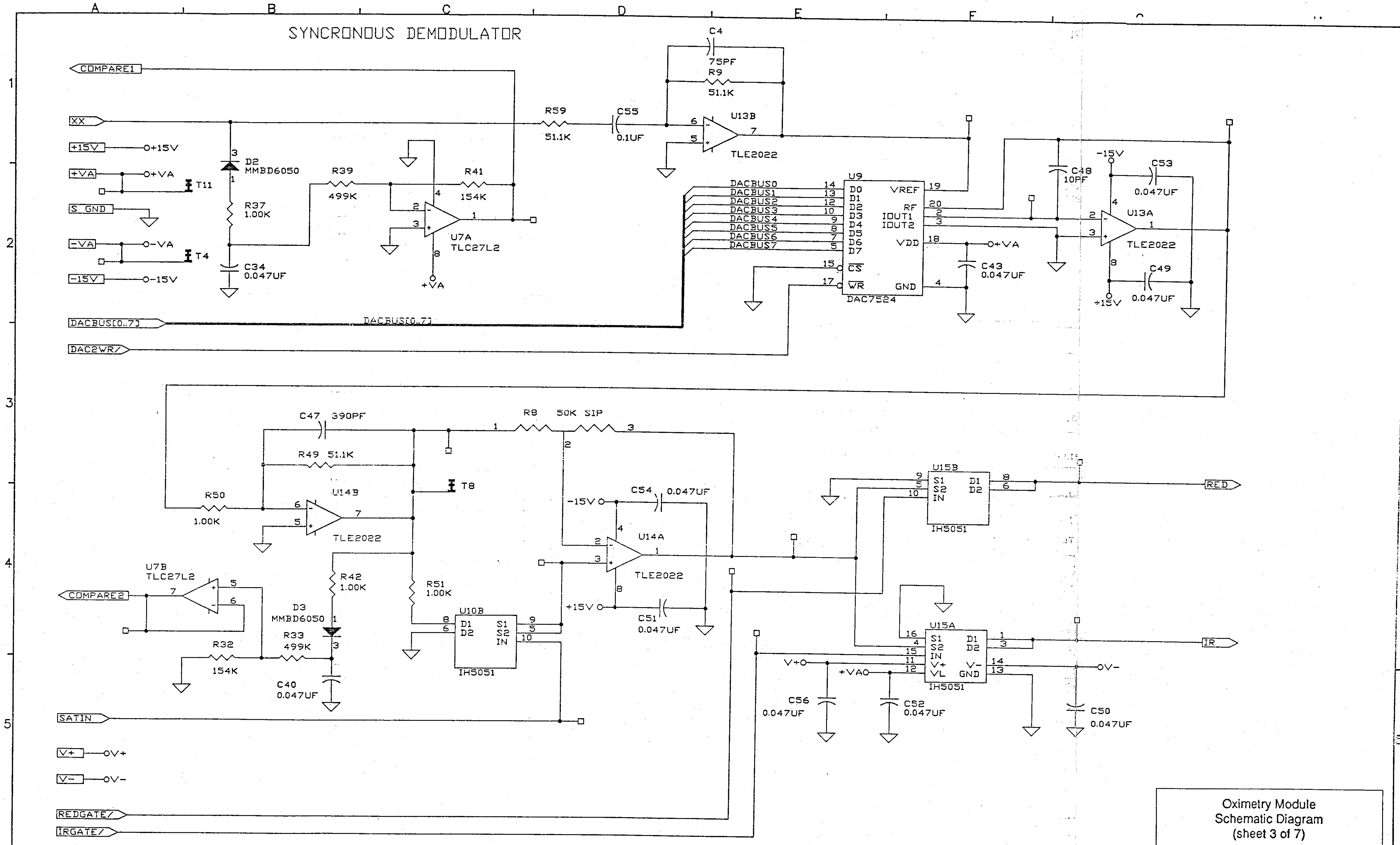
Drawing **Page**



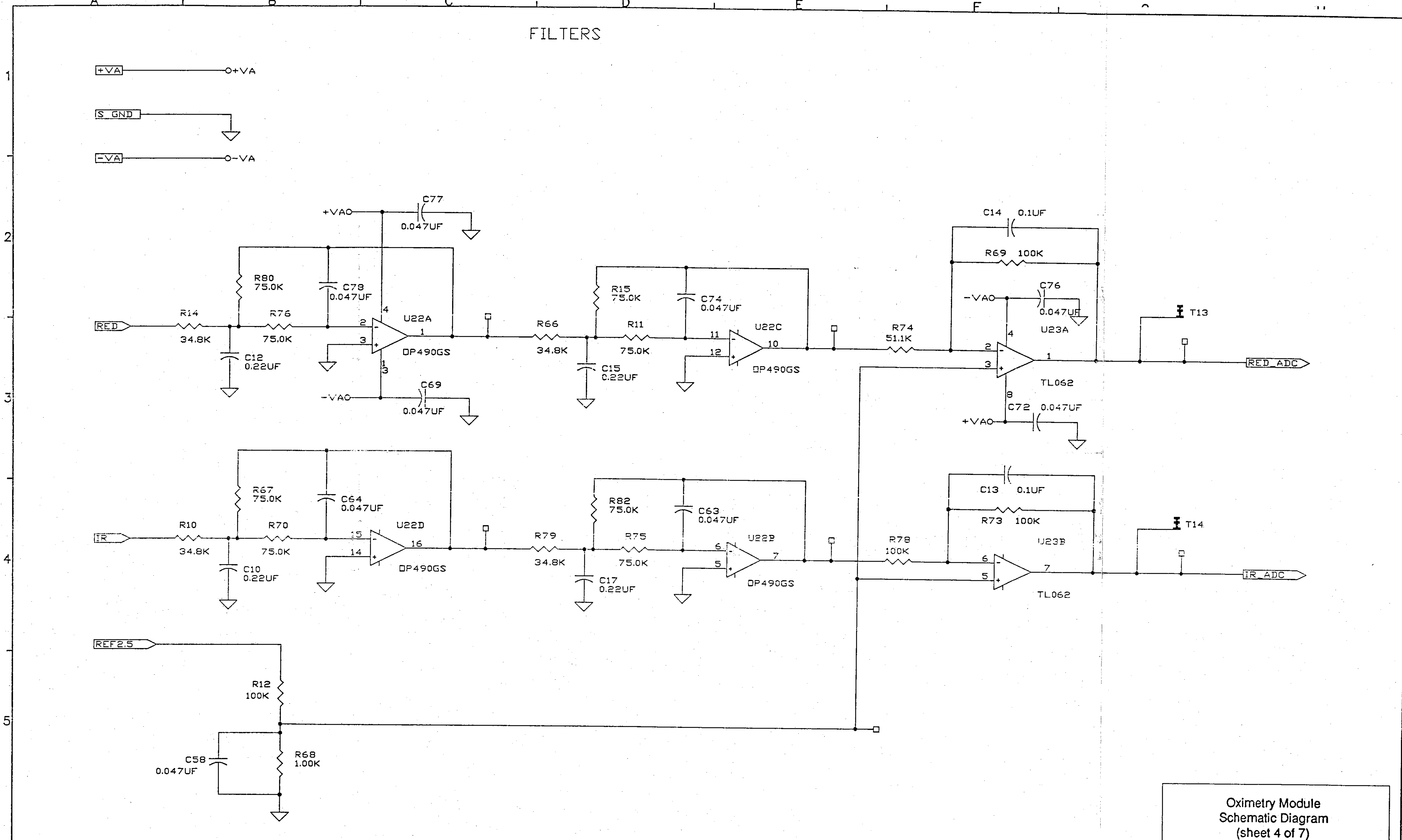
Oximetry Module
Schematic Diagram
(sheet 1 of 7)



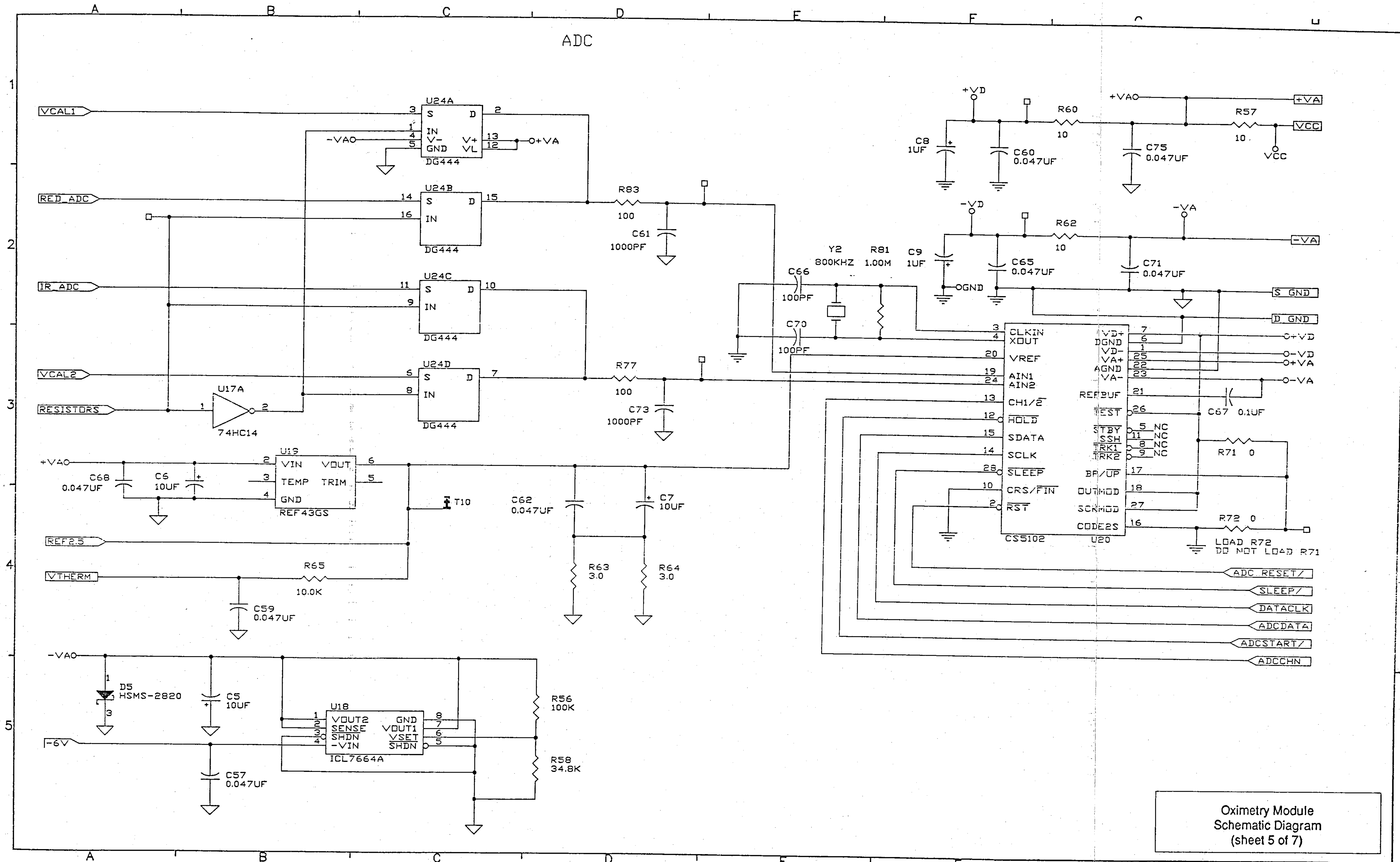
Oximetry Module
Schematic Diagram
(sheet 2 of 7)



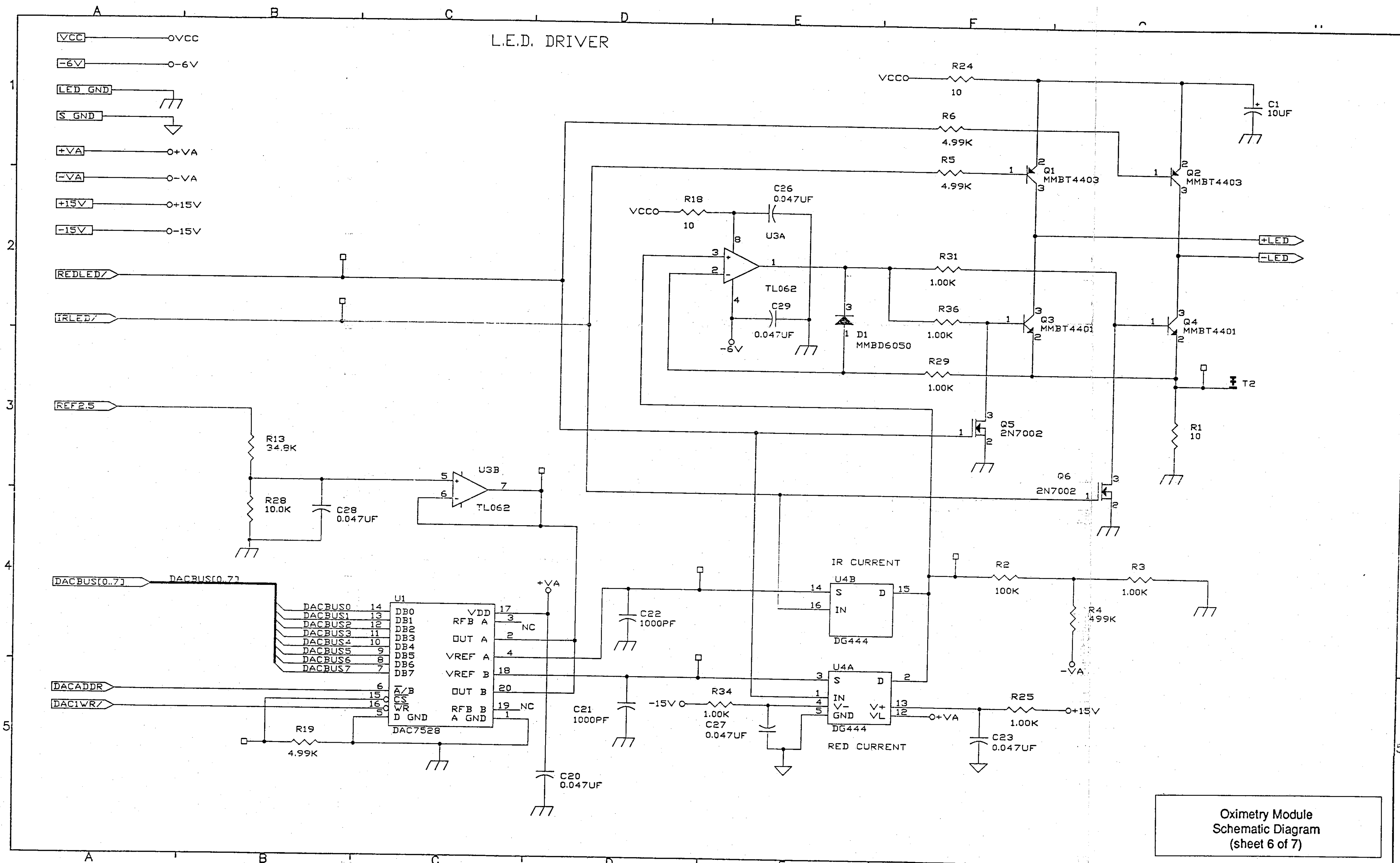
Oximetry Module
Schematic Diagram
(sheet 3 of 7)



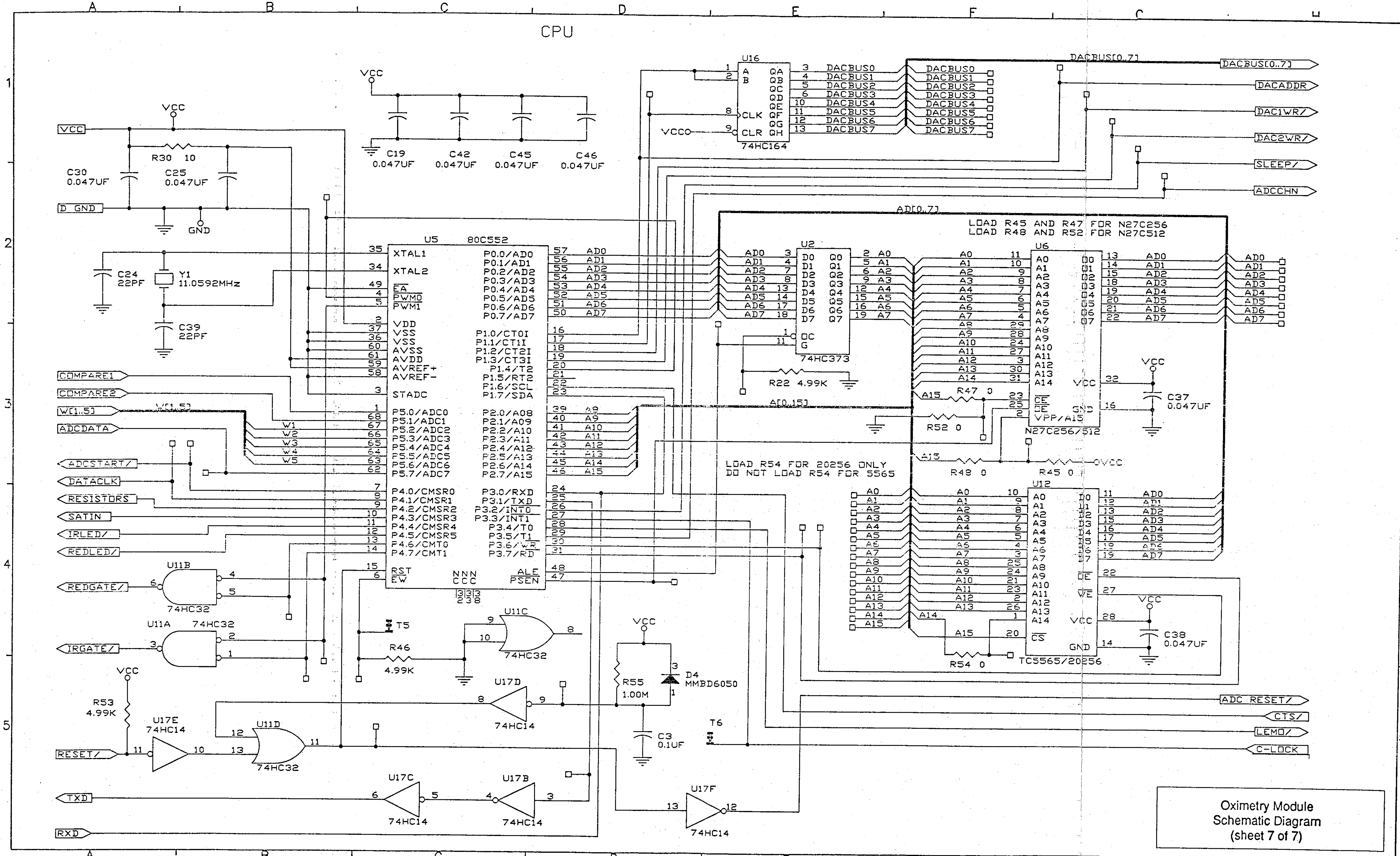
Oximetry Module
Schematic Diagram
(sheet 4 of 7)



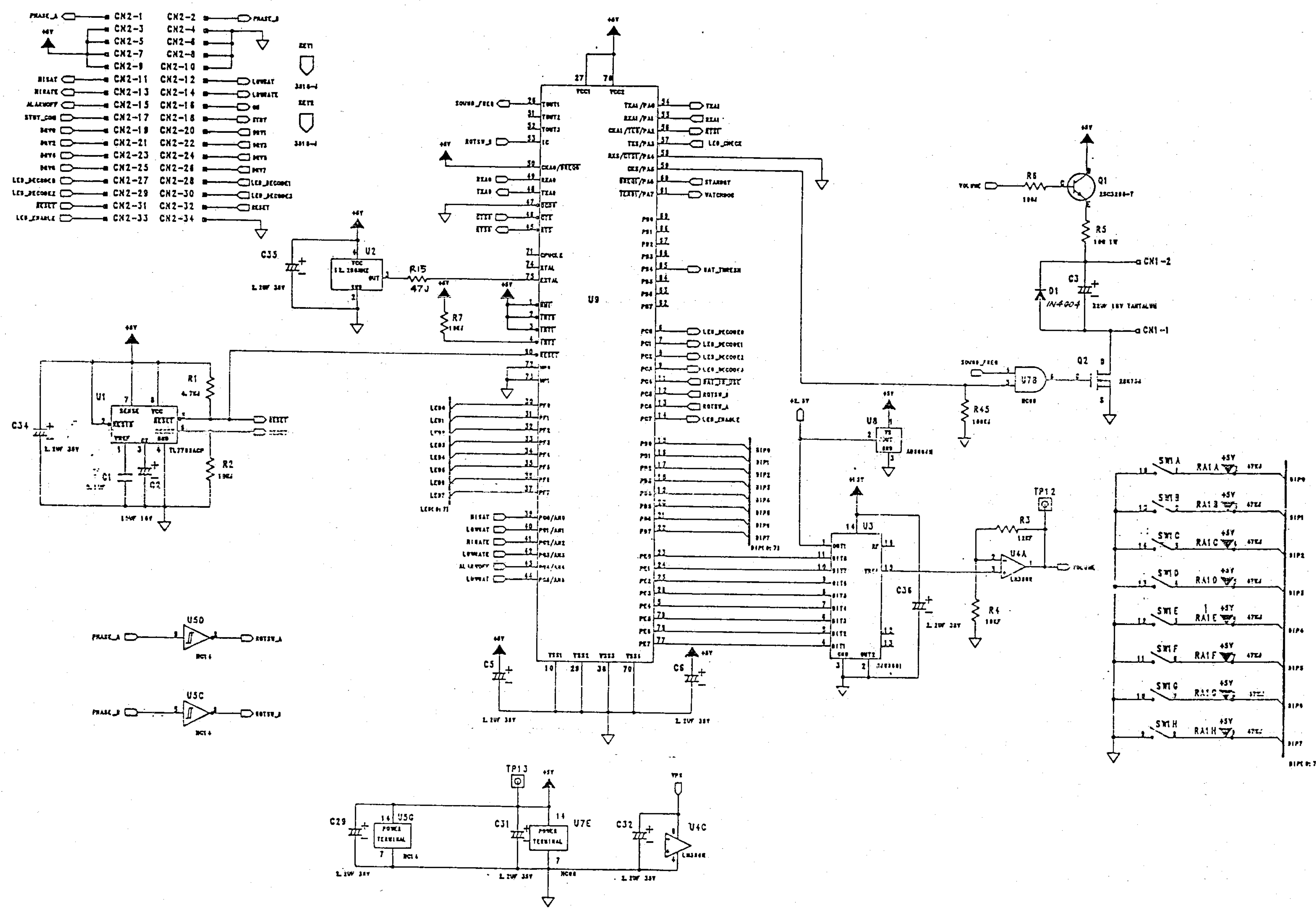
Oximetry Module
Schematic Diagram
(sheet 5 of 7)



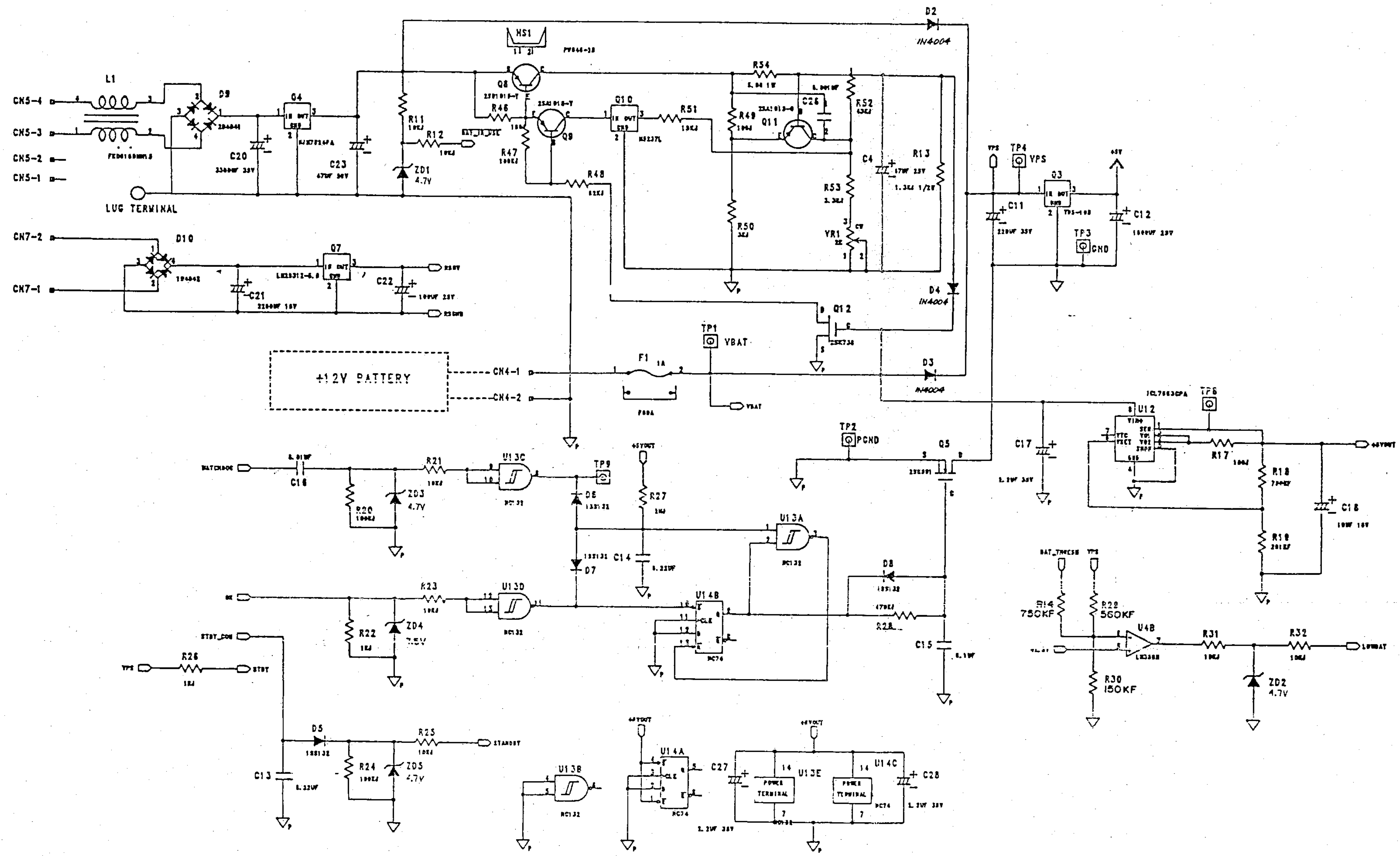
Oximetry Module
Schematic Diagram
(sheet 6 of 7)



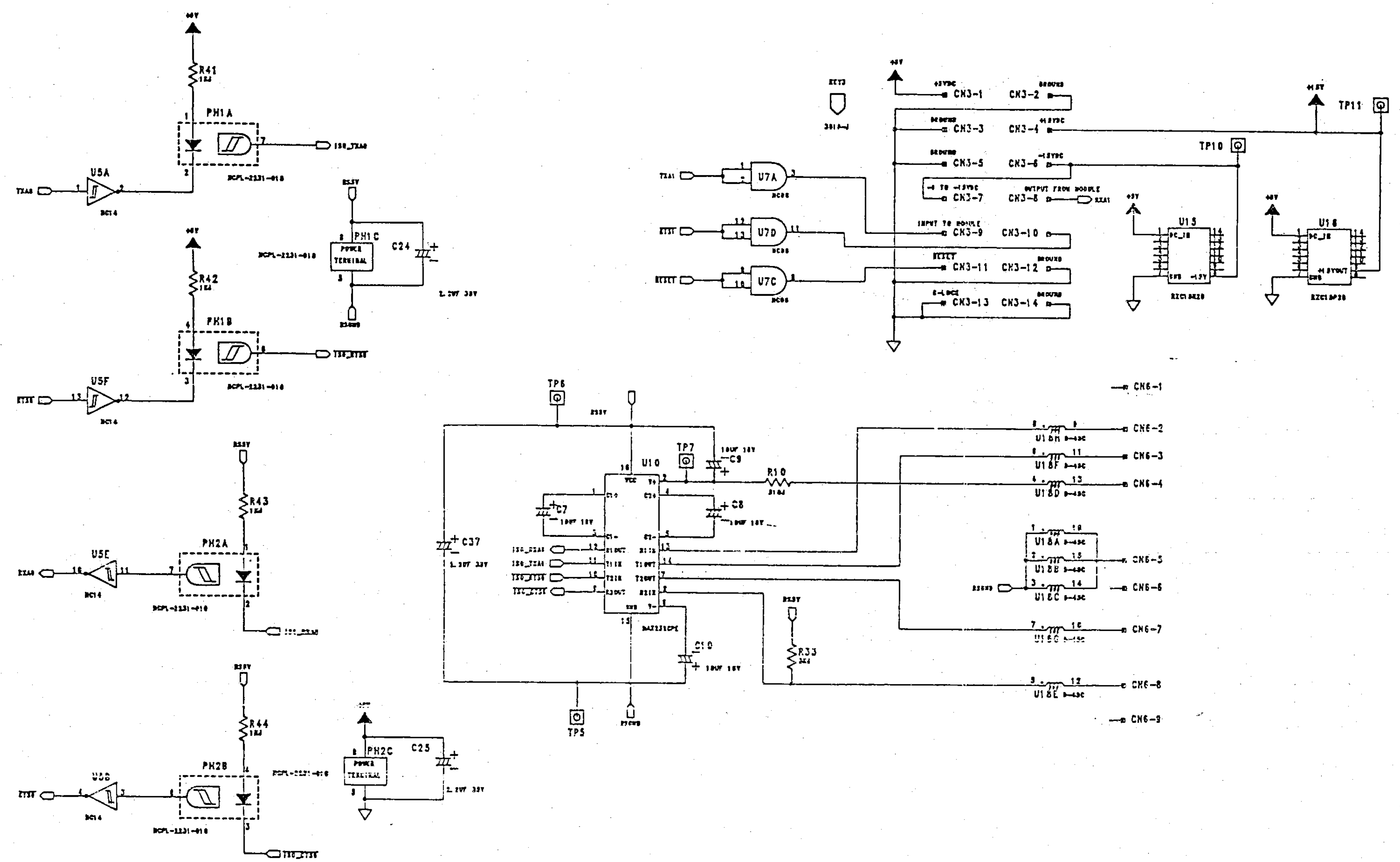
Oximetry Module
Schematic Diagram
(sheet 7 of 7)



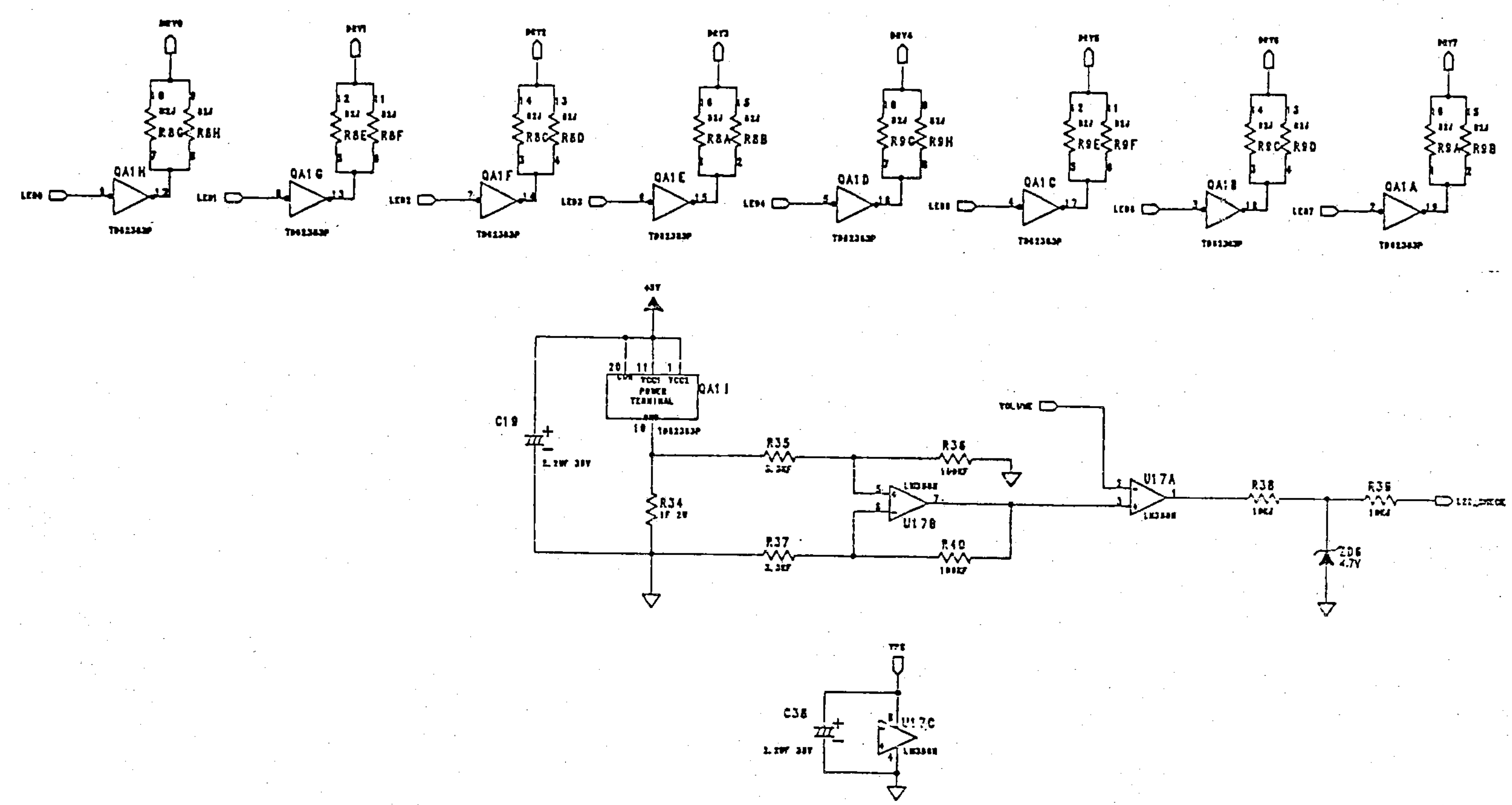
CPU PCB
Schematic Diagram
(sheet 1 of 4)



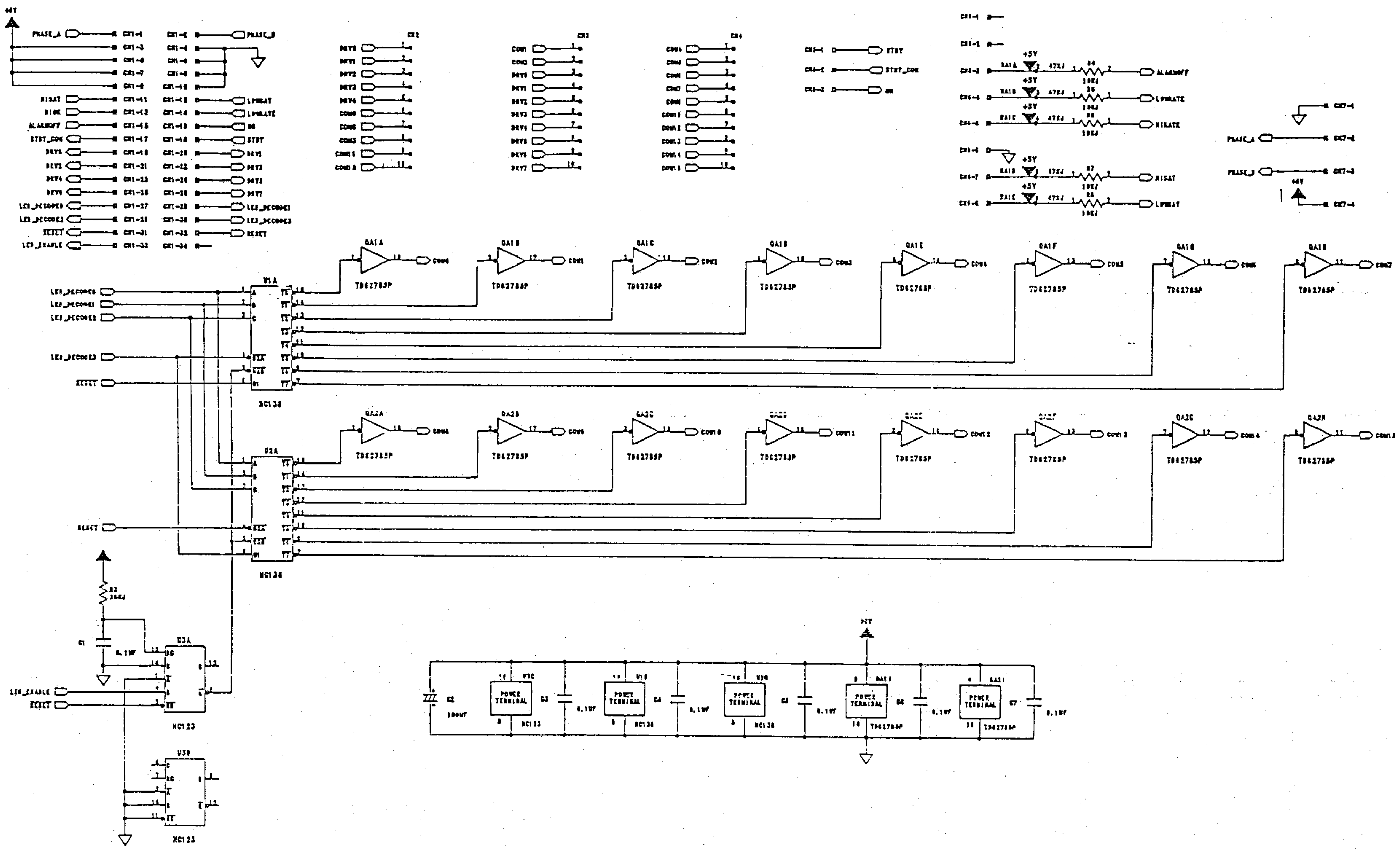
CPU PCB
Schematic Diagram
(sheet 2 of 4)



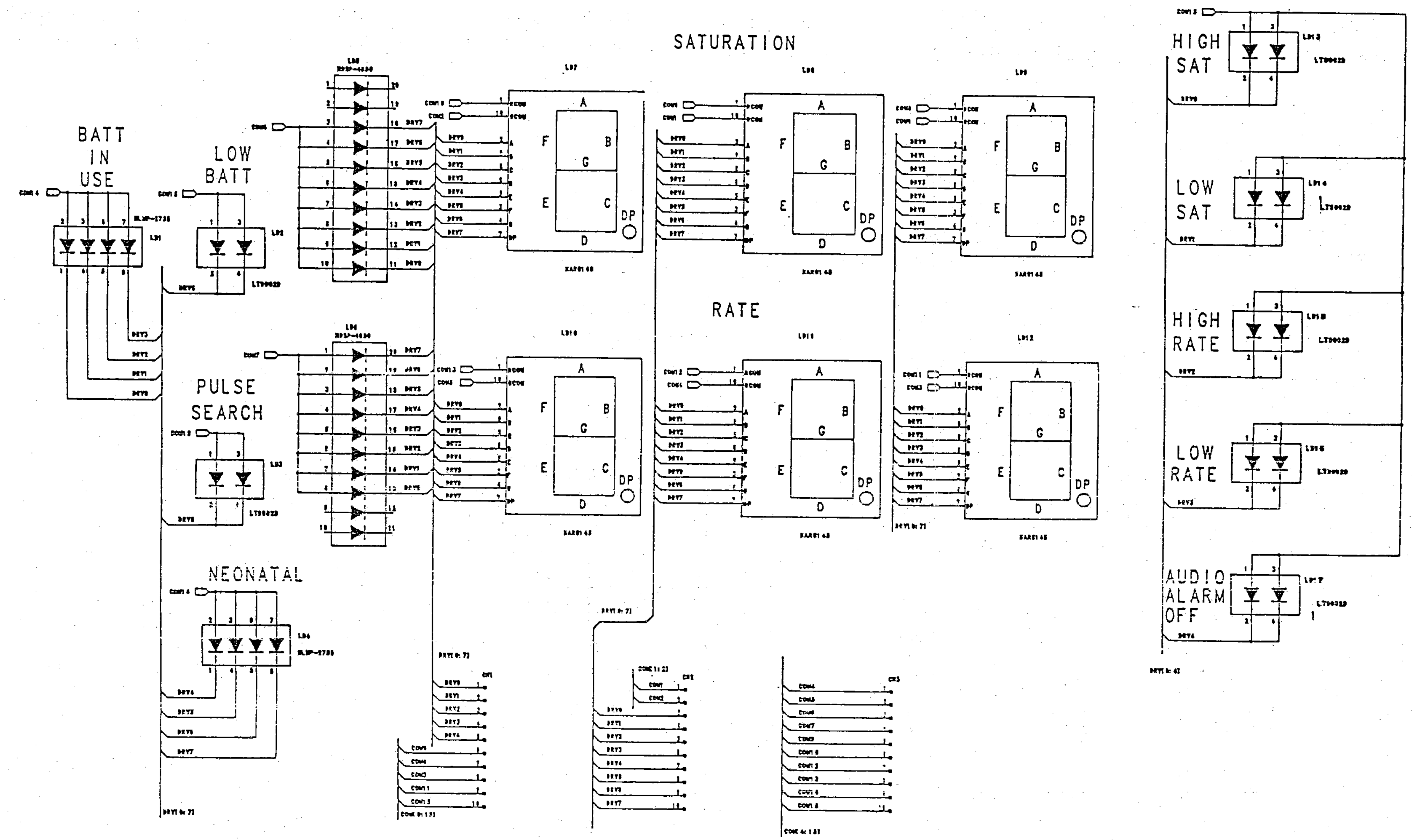
CPU PCB
Schematic Diagram
(sheet 3 of 4)



CPU PCB
Schematic Diagram
(sheet 4 of 4)



Display Driver PCB
Schematic Diagram



LED Display PCB
Schematic Diagram

NELLCOR®

NELLCOR® N-180 Spare Part Switch Assembly Installation Instructions

Parts Provided: Switch Assembly
Installation Instructions
Business reply card

Tools Required: Number 1 and number 2 Phillips-head screwdriver
PT-2500 Pocket Tester
Anti-static equipment

Note: Before you start, read these instructions and assemble all needed materials. Observe the instructions in the caution and warning. These instructions apply to the *NELLCOR* N-180 pulse oximeter (the monitor) and are only for qualified service personnel. After installation, perform the test procedures specified before using the instrument in a clinical setting.

DISASSEMBLY

WARNING: **To prevent injury from electrical shock, unplug the N-180 from the AC outlet before servicing.**

CAUTION: **Use anti-static precautions including the use of an anti-static wrist strap and mat. Follow all instructions carefully.**

1. Place the monitor, bottom side up, on a flat, stable surface. Remove the four Phillips-head screws located in the bottom cover. Carefully turn the monitor over, then lift the top cover assembly off; position top cover assembly out of the way being careful not to place stress on cables.

2. Release ribbon cable retainer clip and disconnect ribbon cable assembly from CN2 of CPU PCB.

3. Remove front panel ground wire from the chassis by removing the Phillips head screw located at the front-left battery hold-down bracket.

4. Release 10-pin retainer clip holding the sensor cable assembly connector (to male connector of oximetry module) and disconnect sensor connector.

5. Grasp front panel at top edge and lift free of bottom cover.

REPLACING THE SWITCH ASSEMBLY

The ON/STDBY switch is held in place by springy retainers (on either side) that are part of the switch housing.

1. To remove the ON/STDBY switch and cable assembly (Figure 1):

a. Disconnect the 3-wire connector from CN5 on the LED Drive PCB.

b. Working from the inside of the front panel, position the blade of a small flat-blade screwdriver between the electrical connectors on the switch and gently press outwards; the switch drops out of the front of the assembly.

2. Replace the switch and cable assembly with the new assembly by reversing the removal procedure

Note: When viewed from the front, the red wire should face left (toward STDBY) and the black wire should face right (toward ON).

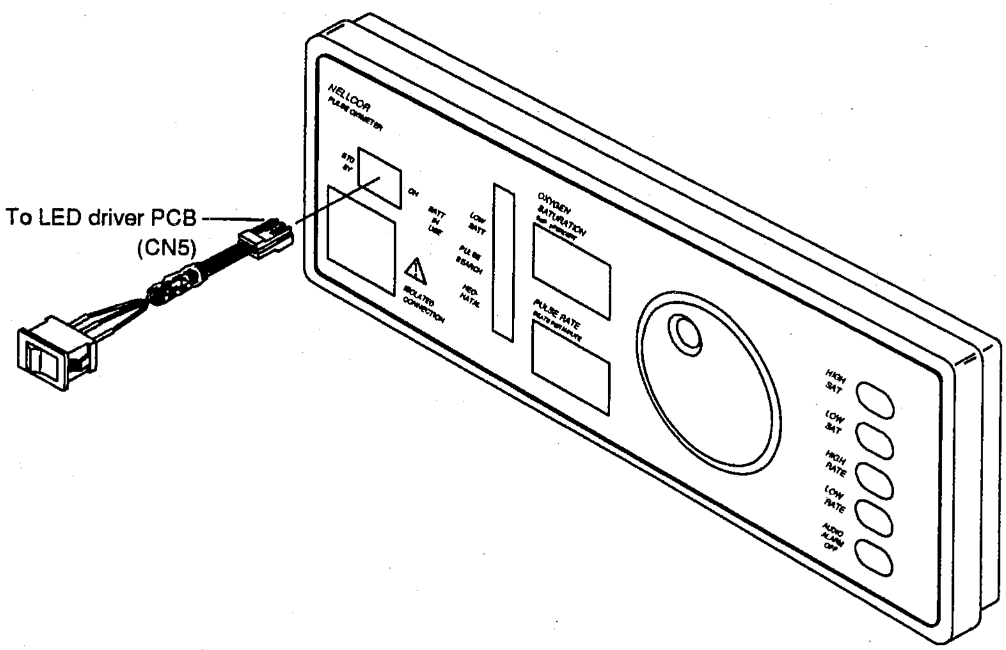


Figure 1. Switch and Cable Assembly

RE-ASSEMBLY

Reassemble the monitor by reversing the disassembly procedures, ensuring that the right hand flex cable and the left hand front-panel ground wire are routed to the inside of the respective plastic bosses.

TEST PROCEDURE

1. With AC power cord disconnected, set the monitor ON/STDBY switch to ON; ensure that the monitor operates according to the description in the operators manual. Repeat this procedure with the monitor connected to and running on AC line power.

Note: Ensure the AC power switch on the back of the monitor is ON.

2. With the monitor power on, connect a pocket tester and ensure that the SaO_2 (SAT) readings are 81% ± 1. The pulse rate should equal 40 bpm ± 1.

3. Perform any routine preventative maintenance procedures, such as electrical safety testing, as prescribed by your institution.

If you encounter any problems following these instructions or have any questions, contact Nellcor Technical Services at 1-800-NELLCOR (inside the U.S.A.), Nellcor Corporate Offices at 1-510-887-5858, or Nellcor BV at 31.73.426565.

Nellcor Incorporated 25495 Whitesell Street, Hayward, CA 94545 USA
Telephone 510 887-5858, Toll free 1-800-NELLCOR
Telex 172 428, Fax 510 293-4420

NELLCOR®

April 21, 1993

Re: *NELLCOR*® N-180 pulse oximeters

Dear Nellcor Customer:

Recently, and after thorough investigation, Nellcor has determined that there is the possibility of intermittent operation of the On/Standby switch of the *NELLCOR* N-180 pulse oximeter, which may require users of the device to toggle the switch more than once before the device will power on. Nellcor has also determined that there is a very small possibility of an "Error 3" message being displayed when the monitor powers on, which may occur if rough handling of the N-180 loosens the monitor display board. There have been no reports of injury as a result of either of these possible occurrences, and neither condition presents a safety hazard to patients or users of the device.

In our commitment to provide our customers with the finest quality medical equipment and to support your efforts in replacing the switch, Nellcor is offering a kit, at no charge, with all the necessary parts and instructions to address these potential concerns. After completing the kit installation and returning the kit documentation to Nellcor, we will reimburse your institution $25.00 for each monitor updated.

Enclosed is a list of *NELLCOR* N-180 monitors that our records show were shipped to your institution that could potentially experience either of the above conditions. Please review this list and identify those monitors that still reside at your institution. Contact Nellcor's Technical Service Department at 1-800-NELLCOR (1-800-635-5267, press 2) to arrange for shipment of kits or to discuss other alternatives for installing this kit in your N-180 monitors.

Should you wish to test a monitor for either of these conditions, you may perform the following steps. Plug the monitor into AC power and make sure that the AC switch on the rear panel is in the "On" position. Then toggle the front On/Standby switch 4 to 5 times at varying speeds, waiting at least 5 seconds between each toggle. The monitor should power on appropriately each time. If the unit does not turn on then it may indicate a switch problem. The intermittent operation of the switch may be influenced by factors such as AC line current and the speed with which the switch is depressed. Nellcor also recommends that the N-180 display PCBs be inspected for proper seating as part of your institution's routine service program.

Please accept out sincerest apologies for any inconvenience caused by this matter. We look forward to your prompt response to this letter so that we can make arrangements to provide your kits.

Sincerely,

Joice White

Joice White
Technical Services Manager

Nellcor Incorporated
25495 Whitesell Street
Hayward, CA 94545
Telephone 510 887-5858
Fax 510 293-4420