SERVICE MANUAL

NELLCOR® ULTRA CAP™

PULSE OXIMETER AND CAPNOGRAPH,

MODEL N-6000

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

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

028065A-0193

Corporate Headquarters

Nellcor Incorporated
25495 Whitesell Street
Hayward, California 94545
USA
Tel 510-887-5858

European Office

Nellcor BV
Hambakenwetering 1
5231 DD 's-Hertogenbosch
The Netherlands
Tel. +31.73.426565

European Regional Offices

Northwest Europe
Nellcor Europe BV
Hambakenwetering 1
5231 DD 's-Hertogenbosch
The Netherlands
Tel. +31.73.426565

Middle and Central Europe
Nellcor GmbH
Black-&-Decker-Strasse 28
W-6270 Idstein
Germany
Tel. +49 6126.5930

Southern Europe
Nellcor Sarl
3, rue du Petit Robinson
78353 Jouy-en-Josas Cedex
France
Tel. +33.1.39.46.96.58

European Local Offices

Nellcor (UK) Limited
University of Warwick
Science Park
Coventry CV4 7EZ
United Kingdom
Tel. +44.203.690220

Nellcor (Belgium) NV/SA
Interleuvenlann 62/8
B-3001 Leuven
Belgium
Tel. +32.16.400467

Asia/Pacific Headquarters

Nellcor Limited
Suite 1204C
Admiralty Centre, Tower 1
18 Harcourt Road
Hong Kong
Tel. +852.529.0363

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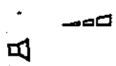
SYMBOLS

FRONT PANEL

	On/Standby		Freeze
	Pulse tone volume	*MENU*	Menu
	Audible alarm off		Audible alarm on
	*C-LOCK* signal lost		*C-LOCK* in use
	Low battery		Battery in use
	Battery charging		

220/240V~ INSTRUMENT ONLY FRONT PANEL

	Attention: Refer to operator's manual!		Type BF equipment, (patient electrically isolated)

SYMBOLS

BACK PANEL

Battery fuse

Fuse replacement

ECG input

Equipotential ground

I/O

On/Off

RS-232 input/output port

Type BF equipment,
(patient electrically isolated)

110/120 VOLT INSTRUMENTS ONLY BACK PANEL

Instrument not anesthetic proof

Attention: Refer to operator's manual!

WARNINGS

The N-6000 contains no user-serviceable parts. For protection against electrical hazard, all service must be performed by qualified personnel.

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

The N-6000 is a patient-connected medical device. Isolated patient connectors protect the patient from potentially dangerous electrical potentials or ground paths. To protect the integrity of this connection, the procedures and part specifications contained in this manual must be adhered to.

SECTION I
Introduction

1.1 INTRODUCTION

This manual contains information for servicing the *NELLCOR® ULTRA CAP™* pulse oximeter and capnograph, model N-6000. Service of this product must be done by qualified service personnel, who have a technical background in analog and digital electronics.

Note: This manual is written for an N-6000 configured for English-language displays and service screens. If the unit is configured for French or German, the technician must change the language option to English. To reach the language selection menu from the main monitoring screen, press the Freeze button on the front panel while the main monitoring screen is displayed, and then press the second and fourth soft keys from the left at the same time. The legend "LANGUAGE" (LANGUE in French and SPRACHE in German) appears above the fourth soft key from the left. Press this key to gain access to the language selection menu and select "ANGLAIS" or "ENGLISCH."

- The N-6000 is a compact, microprocessor-controlled instrument used for continuous real-time monitoring of oxygen saturation (SpO_2), pulse rate (PR), inspired CO_2 (ins.), end-tidal carbon dioxide ($ETCO_2$), and respiratory rate (RR).
- SpO_2 is noninvasively and continuously measured using Nellcor's reusable or adhesive SpO_2 sensors which are available for a variety of patient sites. SpO_2 values are displayed numerically, while the plethysmograph is displayed as a waveform. A bar graph indicator shows the patient's relative pulse strength as measured by the pulse oximetry circuits.
- $ETCO_2$ is determined by positioning an infrared mainstream CO_2 sensor across an intubated patient's airway (15 mm diameter). The amount of CO_2 present at the end of exhalation is displayed numerically, while CO_2 is displayed as a waveform.

This manual is intended for use by authorized service personnel, trained in servicing analog and digital patient monitoring equipment. Service personnel must have read and understood the N-6000 operator's manual and be familiar with instrument operation before attempting maintenance or repair.

1.2 WARNINGS, CAUTIONS, AND NOTES

Before you read the N-6000 service manual, it is important to understand the following terms. These terms identify information that pertains to technician and patient safety, and indicates proper operation of this instrument.

WARNING: A warning describes a condition that may result in injury to the patient, operator or service technician. WARNINGS are always in boldface type and boxed.

Caution: Cautions describes a condition that may result in damage to the instrument. Cautions are always in boldface type.

Note: A note gives information that warrants special attention.

1.3 DESCRIPTION

The following paragraphs describe the N-6000 and list important features.

1.3.1 *Visible and Audible Indicators*

The N-6000 features numeric displays of SpO_2, PR, RR, and $ETCO_2$:

- CO_2 and plethysmographic waveform displays: and a pulse amplitude bar graph, which provides a qualitative indication of pulse strength at the oximetry sensor.
- Trends are acquired for all parameters, and the following five trend screens can be displayed: SpO_2 trend alone; CO_2 trend alone; SpO_2 and CO_2 trends; pulse rate and respiratory rate trends; SpO_2, CO_2, pulse rate, and respiratory rate trends.
- When the operator connects the monitor to AC power and turns on the rear-panel on/off switch, a battery charging indicator lights.

1.3.2 *Audible Indicator*

Pulse rate and oxygen saturation are indicated audibly with a tone that signals each pulse. The pitch of this tone changes with variation in SpO_2, rising as saturation increases and falling as it decreases. This early warning system encourages prompt corrective action since the clinician can watch the patient and listen for SpO_2 changes simultaneously.

1.3.3 *Visible and Audible Alarms*

The monitor has both visible and audible alarms. These alarms are activated when a variable moves outside an adjustable limit (operator-defined), when the monitor detects loss of pulse or apnea, or when a sensor gets disconnected. The tone and pattern of the audible alarm depend on the priority of the alarm state. Pressing the ALARM SILENCE button turns off the audible portion of the alarm temporarily. A flashing ALARM SILENCE indicator adjacent to the ALARM SILENCE button alerts the operator that the alarm tone has been silenced temporarily. A steady ON of the ALARM SILENCE indicator warns that one or more parameters have had their audible alarm function disabled. Visible alarms appear on the monitor screen, and unlike audible alarms, they are always operational.

Note: The SpO_2 and $ETCO_2$ numeric indicators change from green to red when an alarm occurs.

Note: When the French language is chosen and one or more of the parameters have had the error audible alarm function disabled, a single tone occurs every three minutes.

1.3.4 *Status Messages*

A status message is displayed in case an error condition occurs. An error condition will be identified by a module identifier and an error code number that assists service personnel in troubleshooting the problem. (See section VIII for more information.)

1.3.5 *Automatic Self-Test and Warm-Up Time*

The monitor automatically performs a series of diagnostic tests when turned on. The system self-test takes approximately 15 seconds after the operator turns on the monitor. These tests confirm that the program memory, data memory, and internal circuitry are functioning properly, while allowing the mainstream CO_2 sensor to warm. The CO_2 sensor warm-up time is approximately 45 seconds. If an error is detected, a status message appears. (Refer to Section 8, "Troubleshooting," for more information.)

1.3.6 *On-Screen Menus*

The on-screen menu guides the operator through all system functions. Menu items are displayed at the bottom of the screen just above the four function keys that are used to select an item. When a function key is pressed, the screen displays a new menu with additional functions. Press the MENU button to display the top level menu, or to return to the main monitoring screen.

1.3.7 *N-6000 Default and Custom Default Set-Up*

The N-6000 power-on default settings can be customized according to institutional requirements. Once configured, the custom alarm limits will always be in place, even after power-down.

1.3.8 *Trend Memory*

The N-6000 stores up to 24 hours of trend data for CO_2, SpO_2, pulse rate, and respiratory rate. Trend memory can be viewed in 30-minute, 2-hour, 4-hour, 8-hour, 12-hour, or 24-hour segments. When the memory is full, the oldest data are automatically erased as new data are stored. Data stored in memory can be viewed on the screen and can be printed with a printer. Patient monitoring continues while the trend data are being printed.

1.3.9 *Automatic Calibration*

The SpO_2 subsystem of the N-6000 is fully self-calibrating. It is calibrated automatically whenever the system is turned on and periodically thereafter. Additionally, it is recalibrated automatically whenever a new oximetry sensor is connected. The capnography subsystem of the N-6000 is factory calibrated.

1.3.10 *Battery Operation*

If external power is lost or transportable operation is necessary, the N-6000 can operate up to 90 minutes on its rechargeable internal battery. This operating time can be extended up to 180 minutes by using the GRAPHICS w/BATTERY power saver option.

- By choosing GRAPHICS w/BATTERY ON in the SYSTEM menu, the display graphics (including all waveforms, messages, etc.) will continue to operate. By choosing GRAPHICS w/BATTERY OFF, the display remains blank during battery operation. The N-6000 displays only the numerical values of SpO_2 and $ETCO_2$. This allows up to 180 minutes of battery life.

- When the GRAPHICS w/BATTERY option is selected to be OFF and the unit is operating on AC MAINS power, the display will only blank when the unit transfers to battery power. Press the MENU button to turn the GRAPHIC w/BATTERY option ON. The display returns when the operator reapplies AC power to the monitor.

1.3.11 *Noninvasive Oximetry Sensors*

Noninvasive *NELLCOR* oximetry sensors obtain measurements by optical means alone, using two light-emitting diodes (LEDs) as light sources. The N-6000 adjusts automatically for differences in tissue thickness or skin pigmentation. Specific sensors are available for neonates, infants, children, and adults. Refer to specific sensor directions for use for complete information.

1.3.12 *C-LOCK™ ECG Synchronization for Pulse Oximetry*

If a patient is moving or has poor perfusion, *C-LOCK* ECG synchronization can enhance signal quality for measurements of oxygen saturation. When this feature is used, the N-6000 receives two separate signals that reflect cardiac activity: an optical signal from the sensor and an electrical signal from the ECG. The N-6000 uses the ECG QRS complex to help identify the pulse and synchronize the SpO_2 measurements.

When *C-LOCK* ECG synchronization is used, the *C-LOCK* IN USE symbol appears on the display. If the ECG signal is lost or deteriorates to the point that it can no longer be used, the *C-LOCK* SIGNAL LOST symbol appears on the display. No symbol is displayed if the *C-LOCK* feature of the N-6000 is not being used.

SECTION II
Principles of Operation

2.1 OVERVIEW

This section describes, in general terms, operating principles for the N-6000.

2.2 PULSE OXIMETRY SUBSYSTEM

The N-6000 oximetry subsystem is based on the principles of spectrophotometry and plethysmography. It includes an electro-optical sensor and a microprocessor-based module. 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) 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 indicates 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. The N-6000 measures red and infrared absorption to determine the percentage of functional hemoglobin that is saturated with oxygen.

In principle, a pulse oximeter measures the light absorption by tissues and nonpulsatile blood. Absorption is also measured when pulsatile arterial blood is in the tissue. The ratio of absorption at both wavelengths results in a value for the arterial oxygen saturation (SpO_2).

2.2.1 *C-LOCK ECG Synchronization*

Through *C-LOCK* ECG synchronization, the N-6000 uses an ECG signal as a reference point for identifying the pulse and synchronizing SpO_2 measurements. This enhances signal quality during patient movement and when the patient's perfusion is poor.

When provided with an ECG signal, the N-6000 receives two signals that reflect cardiac activity: an optical signal from the sensor and an electrical signal from the ECG. A short time after a QRS complex is detected, an optical pulse is detected at the sensor site. The length of this delay varies with the patient's physiology and with the location of the sensor. However, for a given patient, the length of the delay is relatively stable. Through *C-LOCK* ECG synchronization, that time relationship is used to identify "good" pulses and reject nonsynchronized artifacts such as random motion.

If an ECG signal is not provided, or if that signal deteriorates so that it can no longer be used, the optical pulse alone is used to determine the pulse rate and to initiate saturation measurements. *C-LOCK* ECG synchronization resumes when an adequate ECG signal is available.

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 and pigmentation.

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

2.2.3 *Functional versus Fractional Saturation*

Because the N-6000 measures functional SaO_2, it may produce measurements that differ from those of instruments that measure fractional SaO_2. Functional SaO_2 is oxygenated hemoglobin expressed as a percentage of the hemoglobin that is capable of transporting oxygen. Because the N-6000 uses two wavelengths, it measures oxygenated and deoxygenated hemoglobin, yielding functional SaO_2. It does not detect significant amounts of dysfunctional hemoglobin, such as carboxyhemoglobin or methemoglobin.

In contrast, some laboratory instruments such as the Instrumentation Laboratory 282 CO-Oximeter report fractional SaO_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 directly compare N-6000 measurements with those of another instrument, that other instrument must measure functional SaO_2. If it measures fractional SaO_2, those measurements can be converted using the following equation:

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

2.2.4 *Measured versus Calculated Saturation*

When saturation is calculated from a blood gas measurement of the partial pressure of arterial oxygen (PaO_2), the calculated value may differ from the N-6000 SpO_2 measurement. This is because the calculated saturation may not have been corrected for the effects of variables that shift the relationship between PO_2 and saturation (Figure 2-1): temperature, pH, the partial pressure of carbon dioxide ($PaCO_2$), the concentrations of 2,3-DPG and fetal hemoglobin.

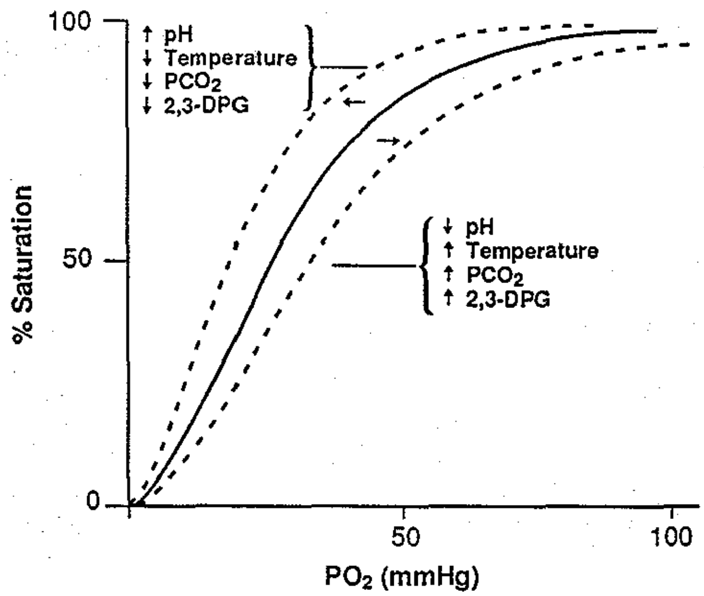


Figure 2-1: Oxyhemoglobin Dissociation Curve

2.3 CAPNOGRAPHY SUBSYSTEM

The N-6000 uses nondispersive infrared spectroscopy to quantitatively measure the amount of CO_2 present at the end of exhalation ($ETCO_2$). It features a small lightweight "mainstream" CO_2 sensor that attaches to a disposable airway adapter. The airway adapter is inserted into the ventilator circuit either between the endotracheal tube and the ventilator circuit or between the elbow and the patient wye. The CO_2 mainstream sensor fits on top of the adapter and does not come into contact with the respired gases.

Infrared spectroscopy can be used to measure the concentration of any molecule that absorbs infrared light. Of the normally respired gases, only CO_2, N_2O, and water vapor selectively absorb specific wavelengths of infrared light (i.e., have an infrared spectrum). This absorption pattern, the infrared spectrum of a molecule (usually displayed as a graph of light absorbed by a molecule versus the wavelength of light), is unique to that molecule. However, different molecules may have similar spectra that have overlapping absorption peaks. Because the absorption of light is proportional to the concentration of the absorbing molecule, an unknown concentration can be determined by comparing the absorbance to that of a known standard.

The CO_2 detection mechanism used in the N-6000 (commonly referred to as the CO_2 sensor or "optical bench"), has an infrared source that is optically filtered to provide a narrow band of wavelengths corresponding to an absorption peak of the CO_2 spectrum (see Figure 2-2).

During monitoring, light first passes through the respiratory gas in the airway adapter. Next it reaches the narrow-band infrared filter, which was selected because it passes wavelengths that are selectively absorbed by CO_2. It then encounters the chopper wheel, which rotates many times each second. Three measurements are obtained during each rotation:

- A sample measurement is made when the light passes through the open area of the chopper wheel and then reaches the detector (i.e., light passes through the respiratory gas).

- A reference+sample measurement is obtained when light passes through a reference gas cell containing a known CO_2 concentration and then reaches the detector (i.e., light passes through respiratory gas and gas in the reference cell).

- A dark measurement is made when light strikes a solid area of the wheel (i.e., no light reaches the detector).

The ratio, "reference+sample/sample", is then used in the sensor-specific calibration equation to determine the CO_2 concentration in respiratory gas. Respiratory rate is determined by the N-6000 from the analysis of the CO_2 waveform (capnograph).

The N-6000 measures the partial airway pressure of CO_2 in the patient airway adapter at normal assumed conditions of 33° C and fully saturated. Barometric pressure is measured directly by the N-6000. When units of % (by volume) are displayed on the front panel LEDs, the measured value is expressed as % dry gas. By convention, all readings of CO_2 posted on the front-panel LED display are assumed to be measured from a patient and corrected to body temperature (37° C). When PCO_2 is being displayed on the front panel LED in units of mmHg or kPa, the values are also converted to fully saturated conditions (BTPS) before being displayed.

The N-6000 detects and counts breaths when the CO_2 level crosses a threshold, which is set dynamically from maximum and minimum CO_2 values. Hence, when a ventilated patient has several spontaneous breaths with low $ETCO_2$ values followed by a mechanical breath with a higher $ETCO_2$ value, the N-6000 accurately detects and counts all breaths.

The value of $ETCO_2$ that best estimates the true alveolar CO_2 value is the maximum value obtainable from the patient during forced exhalations. Unlike conventional capnometers that simply average all breaths together to display the $ETCO_2$ value, the N-6000 looks for the maximum value of $ETCO_2$ seen within the last 8 seconds and displays that maximum value for the true $ETCO_2$. This results in a stable $ETCO_2$ value that best approximates the arterial $PaCO_2$ value in the patient.

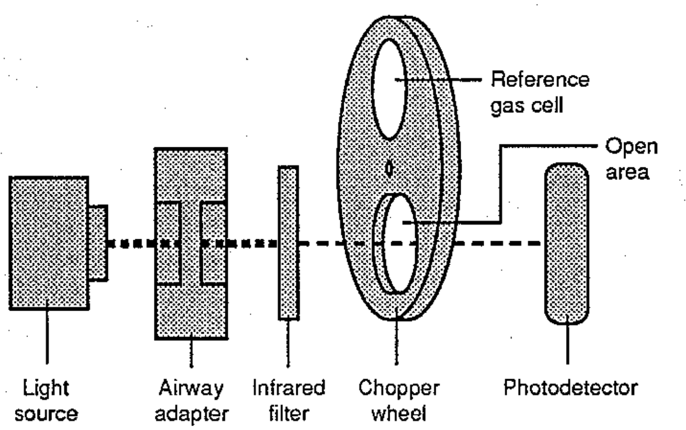


Figure 2-2: Nondispersive Infrared CO_2 Analyzer

2.4 N_2O/O_2 COMPENSATION

Unless compensated for, elevated levels of oxygen (O_2) and nitrous oxide (N_2O) in the airway affect the measurement of the concentration of CO_2 by a collision broadening effect.

To ensure accurate measurements, the N-6000 provides two levels of compensation: (1) nitrous oxide with oxygen; and (2) high oxygen. Compensation levels are user selectable via display screen menu selections.

The N-6000 is calibrated for low O_2 compensation, which assumes the reference state of 0% nitrous oxide and 20% oxygen. This is the default mode where COMP. = OFF. In the N-6000, an increase in O_2 beyond the reference state decreases the displayed CO_2 value by 1.5% of reading for every 20% of increase in O_2. An increase in N_2O increases the displayed CO_2 value by 1.6% of reading for every 20% increase in N_2O.

The first compensation level assumes 50% nitrous oxide and 50% oxygen. Selecting COMP. = N2O provides the necessary correction factor for high levels of N_2O. When this correction is applied, there is zero error under these assumed conditions.

The second compensation level assumes 0% nitrous oxide and 60% oxygen. Selecting COMP. = O_2 provides the correction factor for high levels of O_2. Once again, when this correction is applied, there is zero error under these assumed conditions.

Finally, barometric pressure changes also affect measured CO_2 values. However, changes in barometric pressure require no user intervention; the N-6000 automatically adjusts for these changes.

The following paragraphs contain further in-depth discussion of compensation and standard conditions, as pertains to N-6000 operation.

2.4.1 *Standard Gas Conditions*

The accuracy specifications for the N-6000 refer to the following standard conditions: test gas is CO_2 in balance air (21% O_2), at airway conditions of 33 °C, fully saturated (water vapor pressure of 38 mmHg), and a barometric pressure of 760 mmHg. Additional corrections and/or residual errors are required for barometric pressure (altitude), N_2O, O_2, and water vapor.

2.4.2 *Pressure Broadening Compensation*

Ambient barometric pressure affects measured CO_2 by a "pressure broadening" effect, in which energy exchanged in molecular collisions alters the absorption spectrum of CO_2. In the N-6000, barometric pressure is automatically measured and a compensation is automatically applied to CO_2 values reported on both the main monitoring screen and the service screen. However, additional residual errors may be observed when testing reference gases at pressures different from the standard reference state of 760 mmHg (sea level). These amount to approximately ±0.5 mmHg for every 5000-foot change in altitude.

2.4.3 *N_2O Collision Broadening*

Nitrous Oxide (N_2O) can affect the CO_2 measurement by both direct absorption of infrared and by a "collision broadening" effect in which energy exchanged in molecular collisions alters the absorption spectrum of CO_2. The infrared narrow bandpass filter used in the N-6000 is chosen to eliminate any direct absorption of infrared energy by N_2O. However, N_2O collision broadening causes an increase in measured CO_2 of approximately +0.8% per 10% increase in N_2O from standard conditions. A software-selected (user-selectable) N_2O compensation option is provided to correct for high N_2O, assuming a gas composition of 50% N_2O and 50% O_2. CO_2 values reported on both the N-6000 main monitoring screen and on the service screen are compensated for this gas mixture if the O_2 compensation option is selected.

2.4.4 *O_2 Collision Broadening*

Oxygen (O_2) can affect the CO_2 measurement by a "collision broadening" effect in which energy exchanged in molecular collisions alters the absorption spectrum of CO_2. O_2 collision broadening causes a decrease in measured CO_2 of approximately -0.75% per 10% increase in O_2 from standard conditions. A software-selected (user-selectable) O_2 compensation option is provided to correct for high O_2, assuming a gas composition of 60% O_2 (0% N_2O). CO_2 values reported on both the N-6000 main monitoring screen and the service screen are compensated for this gas mixture if the O_2 compensation option is selected.

2.4.5 *Water Vapor Effect*

Water vapor also has an effect on CO_2 measurements. In normal use, it is assumed that respiratory gas is at standard airway conditions of 33°C, fully saturated. Under these conditions, water vapor (with a vapor pressure of 38 mmHg) causes an increase in measured CO_2 of 6%. The N-6000 is calibrated to include this effect, and CO_2 values reported on the main monitoring screen are automatically compensated, while those on the service screen are not. If applying a dry test gas to verify calibration, CO_2 values reported on the service screen should be used for comparison.

2.4.6 *BTPS/ATPS Compensation*

The N-6000 assumes that measured respiratory gases are at standard airway conditions of airway temperature and pressure fully saturated (ATPS). That is, it is assumed that the gas in the airway adapter is measured at 33 °C, fully saturated with a water vapor pressure of 38 mmHg, at ambient barometric pressure. By convention, CO_2 values are reported on the main monitoring screen after conversion to deep lung conditions of body temperature and pressure fully saturated (BTPS): 37 °C, fully saturated with a water vapor pressure of 47 mmHg, at ambient barometric pressure. Service screen values do not have these corrections applied.

2.4.7 *Summary: Reported CO_2 Values on the Main Monitoring and Service Screens*

CO_2 values reported on the service screen are uncorrected for BTPS/ATPS conditions (including water vapor correction). That is, CO_2 values reported on the service screen are accurate assuming a dry test gas is present in the airway adapter (at 25 °C). Corrections for N_2O and O_2, if selected, are also applied to the service screen values.

CO_2 values reported on the main monitoring screen have all corrections applied: BTPS/ATPS, water vapor, and, if selected, N_2O and O_2.

2.5 FACTORY CALIBRATED SENSOR

Each CO_2 sensor is individually factory-calibrated over multiple gas concentrations and multiple temperatures. The N-6000 sensor is temperature-regulated to 42 °C, which keeps the sensor optical components and electronics at a known constant temperature. Additionally, the sensor is factory-calibrated over multiple temperatures, so that any deviation from the 42 °C set-point is automatically compensated by temperature calibration coefficients stored with each sensor unit.

SECTION III
Circuit Analysis

3.1 INTRODUCTION

This section provides details of circuit operation. Refer to Figure 3-1, the overall block diagram.

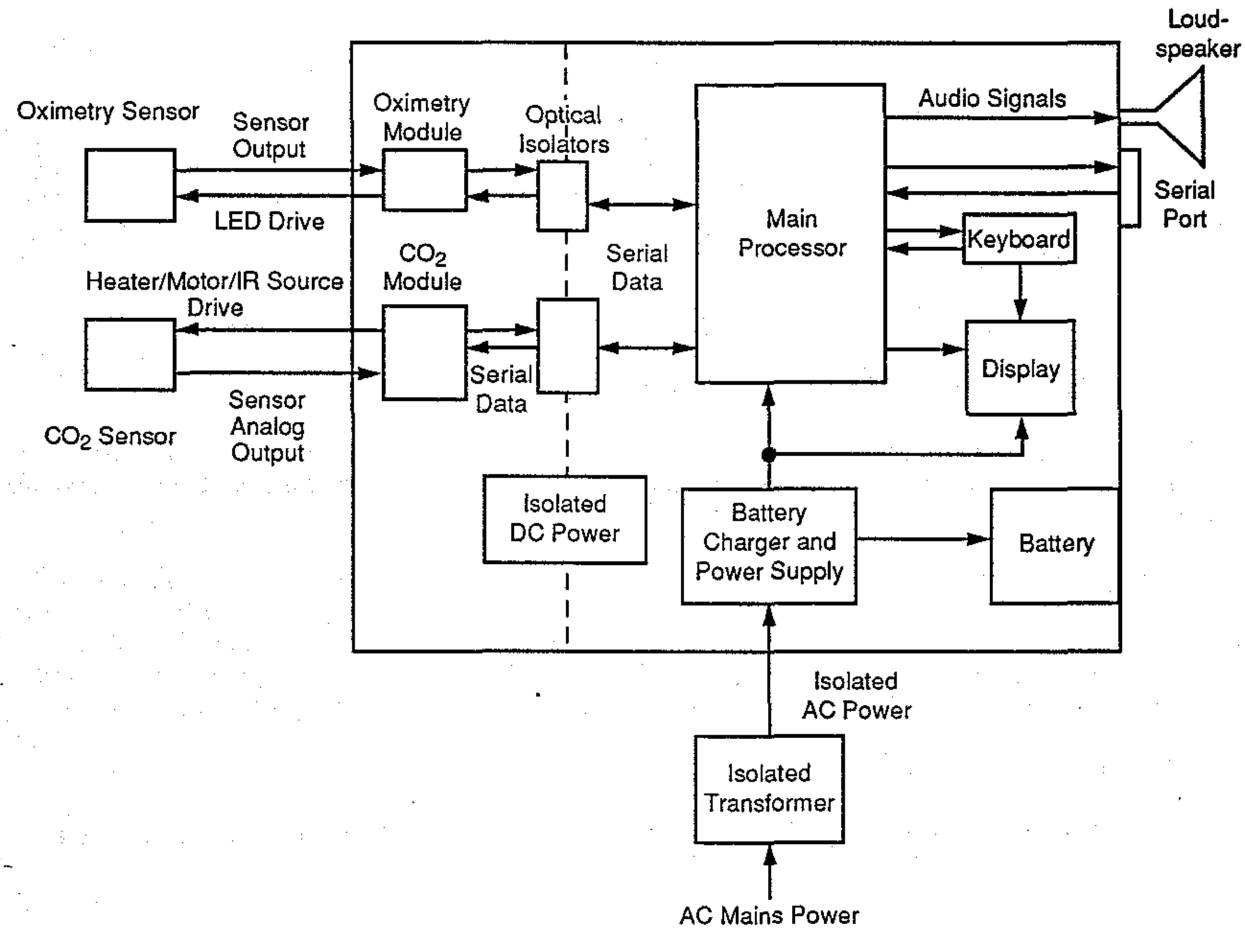


Figure 3-1: Overall Block Diagram

3.2 CO_2 MODULE CIRCUIT DETAILS

The CO_2 module acquires CO_2 data from the mainstream CO_2 sensor and communicates the information to the main processor. The module accepts commands from the processor to change modes and send sensor information/status.

The mainstream sensor has six basic components: an IR source, detector, chopper motor, heater, thermistor, and non-volatile memory.

3.2.1 *Sensor Operation*

The IR source emits energy that is directed toward the detector. The detector generates a voltage based on the amount of energy it receives. In the light path between the source and detector are three components: a filter, the airway gas sample, and a chopper wheel.

The filter allows only energy of a wavelength within the CO_2 absorption band to pass. At this frequency, the attenuation effects due to the presence of CO_2 molecules are much greater than for other molecules normally present in respired gas.

The airway gas sample is a disposable airway adapter that is inserted between the endotracheal tube and the ventilator circuit. The sensor clips to the airway adapter, putting the respired gas within the sensor's light path.

The chopper wheel is split into three sections or phases that are presented sequentially to the light path as the wheel rotates. The first phase has a reference cell filled with a known amount of CO_2. The second phase is an opening providing no attenuation. The third phase is dark, allowing no energy to pass to the detector.

The detector output is sampled during each phase. The amount of CO_2 present in the gas sample can be determined by comparing the change in detector output from phase one to phase two. The third (dark) phase provides a zero reference for recalibrating the detector.

The CO_2 sensor temperature is elevated to 42° C. There are two reasons for doing this: to keep condensation from forming on the airway windows, and to maintain a stable detector temperature because the sensor's output is affected by temperature.

The sensor power-up sequence is optimized to keep power supply loading to a minimum. The maximum available heater output can be varied in software to match the power available. As the sensor reaches temperature, the heater is temporarily disabled, and the motor is started. This requires some current; by disabling the heater, the demands on the power supply are minimized. As the motor reaches speed, the heater is re-enabled, followed by activation of the IR source.

3.2.2 *CO_2 Module Hardware*

The CO_2 module has six main sections: digital, motor control, signal amplifier, heater, source and barometric pressure transducer/amplifier.

3.2.3 *Digital*

The module is controlled by U602, an 80C552 microprocessor, running at 11 MHz. The program is stored in U600. The microprocessor uses its on-board serial port to communicate asynchronously with the main processor. The microprocessor communicates serially to A/D converter U605, EEPROM U603, and the sensor EEPROM. The external A/D converter is used to digitize the sensor waveform. EEPROM U603 stores calibration constants for the module. The microprocessor uses its internal A/D converter to determine sensor temperature, barometric pressure, and fault determination in other sections of the hardware.

3.2.4 *Motor Control*

The sensor's chopper motor consists of two fixed coils on the stator and three magnets on the rotor. The sense coil is amplified to generate a synchronized drive voltage, and to generate a motor clock signal. This signal is used by the processor for synchronizing processor activity to the chopper motor. The motor control hybrid controls the amplitude of the drive signal derived from the sense signal to regulate the speed to the equivalent of a 30 ms period. The motor can be disabled by the processor via the MTRGATE signal.

3.2.5 *Signal Amplifier*

The "bench" hybrid circuit U607 contains the necessary circuitry to amplify the sensor detector output and bias the detector properly, so that its output is zero-referenced and in the range for the A/D converter. A positive bias voltage is applied to the sensor using a filtered PWM output from the microprocessor to set the operating point of the photodetector. A negative bias voltage is also applied to the sensor which servos the sensor signal to be referenced to zero volts.

3.2.6 *Heater*

The heater output consists of a PWM signal from the processor switching a FET power transistor. The FET signal is filtered by L600 and C614 before being applied to the heater. The temperature in the sensor is converted to a proportional voltage by the bench hybrid. This voltage is translated to a temperature by the microprocessor. The software regulates the power applied to the sensor to regulate it to 42° C. As a safety precaution, the PWM output feeding the heater output can be inhibited by a comparator circuit monitoring the temperature voltage, this override will become active as the sensor temperature reaches 48° C. The heater output voltage is available to the processor's internal A/D converter for fault determination.

3.2.7 *Source*

A current regulator formed by U615 and R645 provides constant current of 83.3 mA to the IR source located in the sensor. The source is controlled by the microprocessor via Q608 and Q606. The source voltage is brought back to the microprocessor's internal A/D converter for fault determination.

3.2.8 *Barometer*

The barometer circuit generates a voltage proportional to the atmospheric pressure. This is achieved by sensing voltage variations at the pressure transducer with a constant current applied. The transducers differential voltage is amplified and zero-referenced before being presented to the processor's internal A/D converter for translation to a barometric pressure reading.

3.2.9 *Status LEDs*

On power-up, the green LED flashes five times momentarily, indicating that the processor has reset and the initialization sequence is taking place. After the green LED flashes, the red LED turns on, indicating a sensor warm-up condition. The light remains on until the sensor reaches temperature, allowing the sensor to start measuring. When the sensor is ready to measure, the red LED is turned off, and the green LED is turned on.

If the CO_2 module is not receiving commands from the main processor, or a sensor fault condition exists, the RED LED will flash at a rate of 2 Hz.

If the CO_2 module has no sensor connected to it, the red LED flashes at 1 Hz.

If the CO_2 module finds an internal fault during initialization, the green LED is on, and the red LED flashes at 2 Hz.

3.2.10 *LED Status Summary*

Green LED flash	Reset, Initialization
Red LED on	Sensor Warming Condition
Green LED on	Sensor Active (Measuring CO_2)
Red LED flash 1 Hz	Sensor Disconnect Condition
Red LED flash 2 Hz	No Communications or Sensor Fault Condition
Red LED flash, Green on	System Fault Condition

3.3 OXIMETRY MODULE BLOCK DIAGRAM ANALYSIS

The following discussion is an overview of the oximetry module and identifies major circuit blocks. A detailed discussion of major functional circuit blocks is given in paragraph 3.4.

3.3.1 *Oximetry Module*

The 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 processing circuits in the host system for display and for external output conditioning.

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

- LED Driver
- Sensor Assembly
- Input Source Selection
- Input Amplifier and Synchronous Detector
- Filters
- A:D Conversion
- Support Circuits

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

Functional circuit block diagrams may employ a technique where some components are either absent from the circuit or grouped into functional sub blocks. This is intended to give service personnel quick understanding of overall circuit operation. These simplified diagrams are similar in layout to the schematic diagrams to facilitate tracing signals to the component level when necessary.

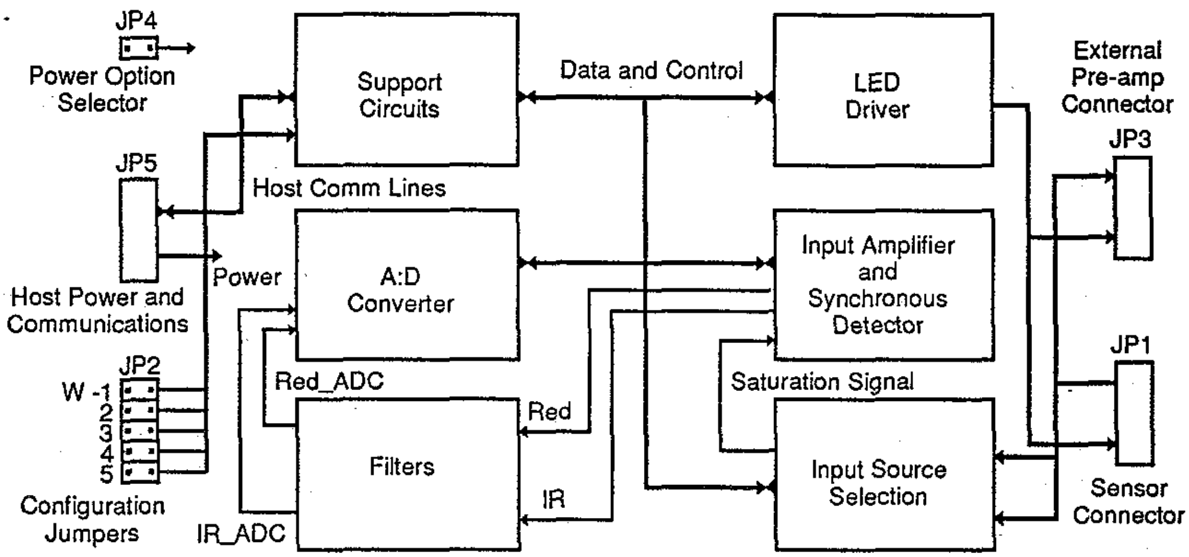


Figure 3-2: Oximetry Module Overall Circuit Block Diagram

3.3.1.1 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.

3.3.1.2 Sensor Assembly

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

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

Sensors are not provided with the module. The module is designed to operate with all currently available *NELLCOR* oxygen transducers. Preamplifier circuits serving connector JP1 are configured to accommodate oxygen transducers directly.

3.3.1.3 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). Final analog conditioning of the SAT signal is accomplished by circuits in the filter block.

3.3.1.4 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.

3.3.1.5 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.

3.3.1.6 Support Circuits

Module operations are controlled by an 80C552 microprocessor with supporting hardware and software. The software also provides diagnostics to assist in determining module status.

3.4 DETAILED OXIMETRY MODULE CIRCUIT ANALYSIS

This section discusses the major functional circuit blocks of the module in detail. The purpose is to provide qualified service personnel with the necessary information to understand module 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.

3.4.1 *Oximetry Module*

The 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 is transmitted to the host system for display, alarm, and interface processing.

The following list assists in locating a specific area of interest.

- LED Driver
- Input Signal Processing
- Input Amplifier and Synchronous Detector
- Filters/Amplifiers
- Control Signals
- A:D Conversion
- Support Circuits

Refer to the oximetry module schematic diagram (sheet 1 of 7) for details on the relationship of these blocks.

3.4.1.1 LED Driver

Refer to Figure 3-3 "LED Driver Circuit," and the 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's 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 2 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 control lines IRLED and REDLED. Figure 3-2 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.

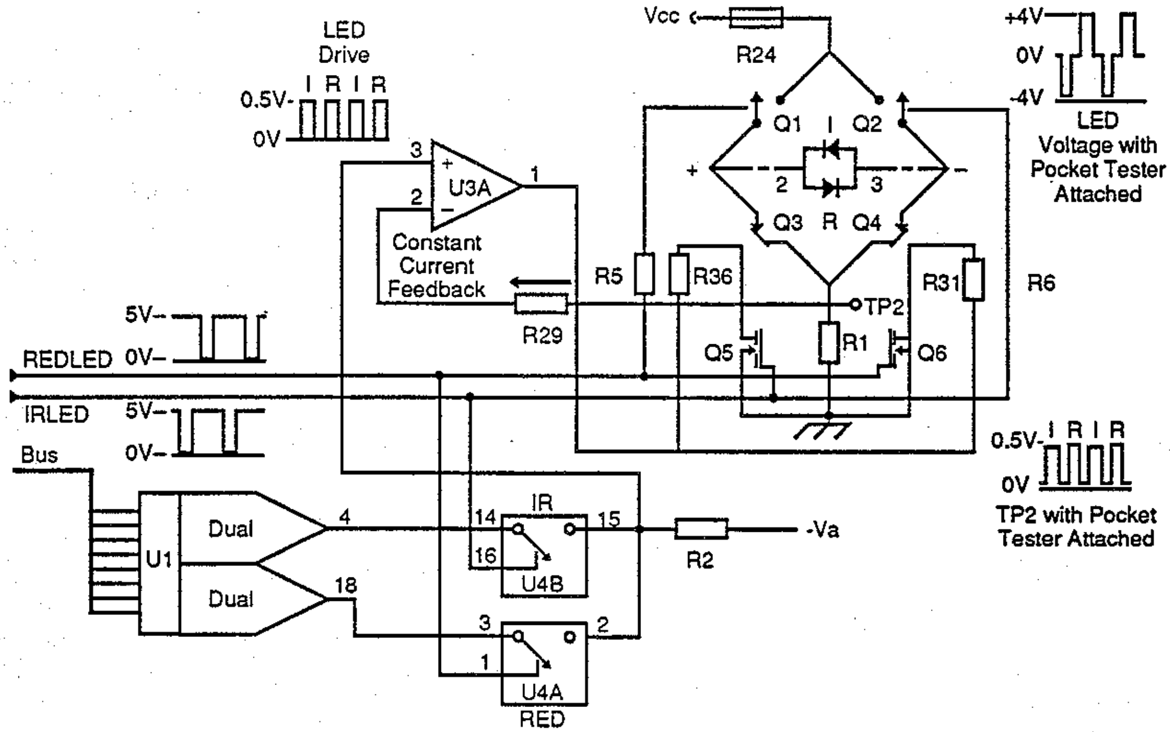


Figure 3-3: LED Driver Circuit

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 at 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 forward-biased by the control lines.

The IR LED (I) lights 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) lights 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 back-to-back LED 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 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.

3.4.1.2 Input Signal Processing

Refer to Figure 3-4 and the oximetry module schematic diagram(sheet 3 of 7) while reading this discussion.

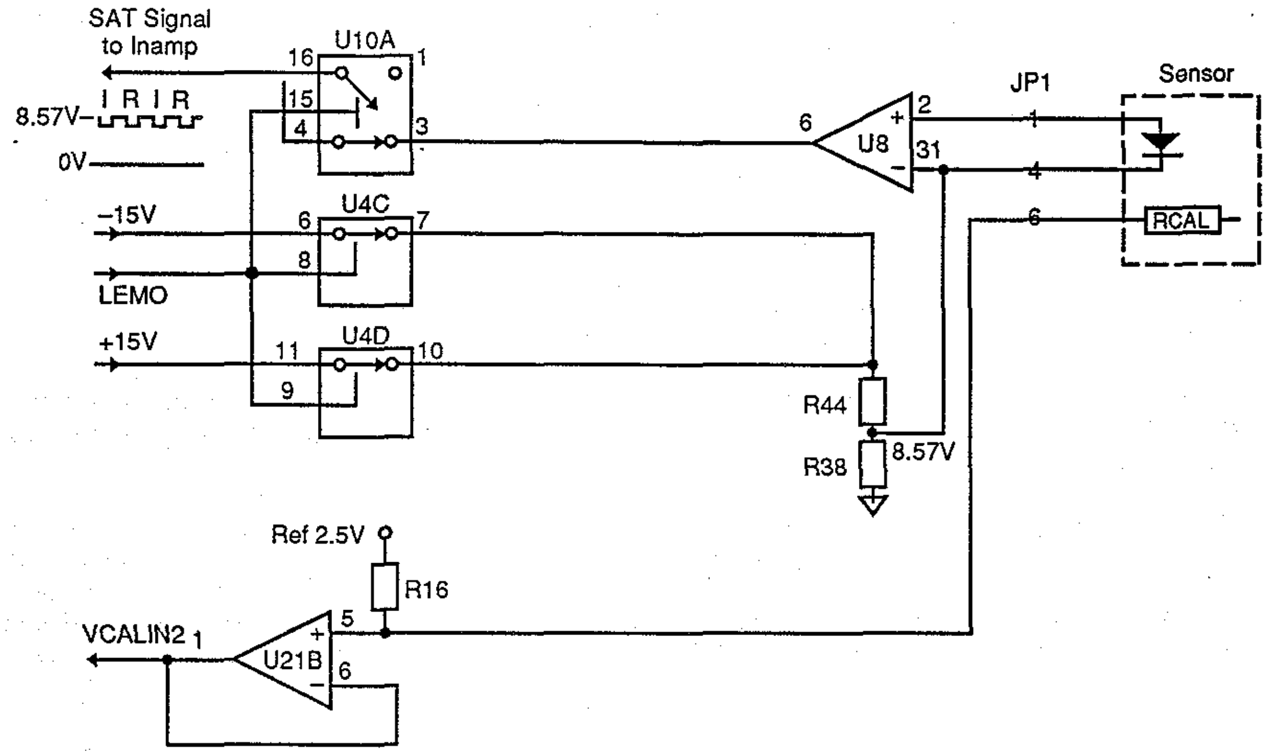


Figure 3-4: Input Signal Processing

The SAT signal is developed by the photodiode in the oximetry 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 sensor site.

The time-multiplexed, intensity-modulated photodiode current is coupled into the 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 noninverting input of U8 is biased to 8.57 V by R38 and R44. 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.

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 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 remaining 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 microprocessor via buffer U21B.

Returning to the analysis of the 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.

3.4.1.3 Input Amplifier and Synchronous Detector

Refer to Figure 3-5, "Input Amplifier, Synchronous Detector, and Filter/Amplifiers," and the 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.

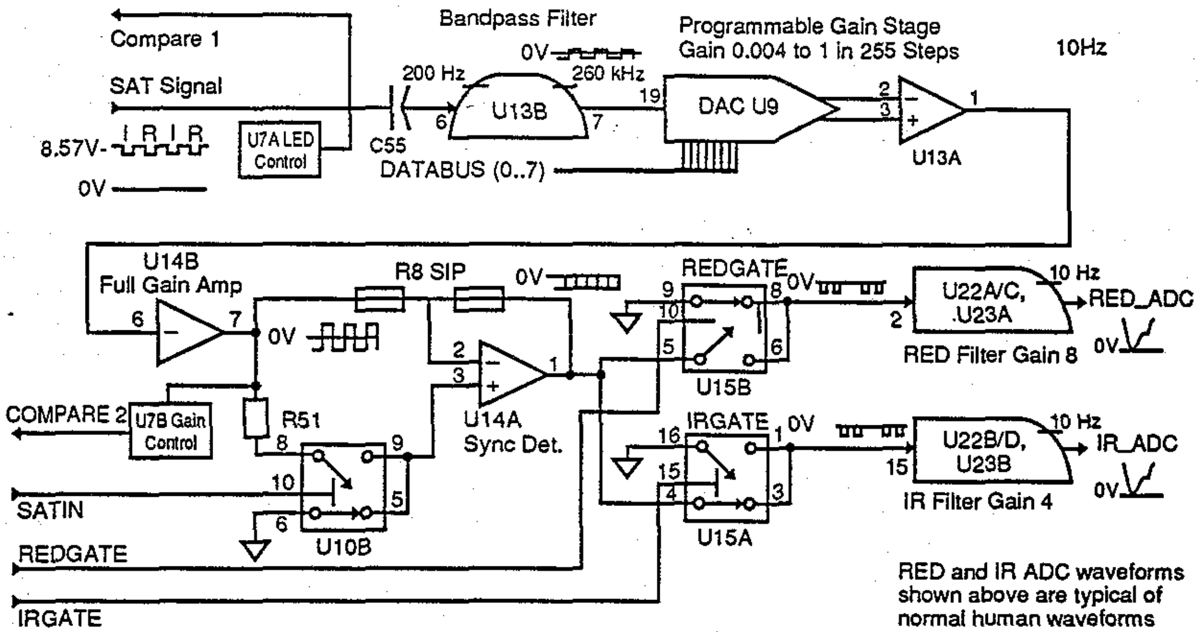


Figure 3-5: Input Amplifier, Synchronous Detector, and Filter/Amplifiers

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 exceed –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 this 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 met, 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. Amplifier gain is controlled by microprocessor adjustment of the DAC impedance over 255 discrete steps. The maximum gain of the circuit is 1. 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. If necessary, the microprocessor may reduce gain of only one of the channels.

The SAT signal is then coupled to the synchronous detector. The signal is still in its original multiplexed format and is 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 1. When this input is not grounded, the device becomes a voltage follower with a gain of 1.

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. A comparison of Figures 8-8 and 8-9 illustrates the resulting effect on the signal. The output of the synchronous detector is applied to the inputs of the IR and red filter/amplifier channels.

3.4.1.4 Filters/Amplifiers

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

a. Gating
b. IR Filter/amplifier
c. Red Filter/amplifier

a. Gating

Refer to Figure 3-5 and the 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.

b. IR Filter/Amplifier

Refer to Figure 3-5 and the 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 4. 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 2. The signal is then coupled to the last stage, which has a gain of 1. 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.

c. Red Filter/Amplifier

Refer to Figure 3-5 and the 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 8. 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 2. The signal is then coupled to the last stage having a gain of 2. 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 and 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.

3.4.1.5 Control Signals

Refer to Figures 3-3, 3-4, 3-5, and the 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:

C-LOCK Is a hard-wired timing pulse (active high) transmitted to the saturation module, via the host instrument, from an external ECG monitor. The rising edge of this pulse is used by the module to satisfy the software requirements necessary to perform pulse recognition using ECG as a timing reference.

The occurrence of an ECG timing pulse can also be transmitted to the module using the real-time (fast data) message input over the bi-directional communication link. To prevent confusion regarding the source of ECG synchronization, the module will not accept hard-wired logic inputs for two seconds after a real-time message input is received.

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.

3.4.1.6 A:D Conversion

Refer to Figure 3-6, "A:D Conversion Circuits," and the 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 accommodates either VCAL1 voltage or the analog pulse waveform from the red filter/amplifier channel. Channel 2 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 host system's display processing circuits.

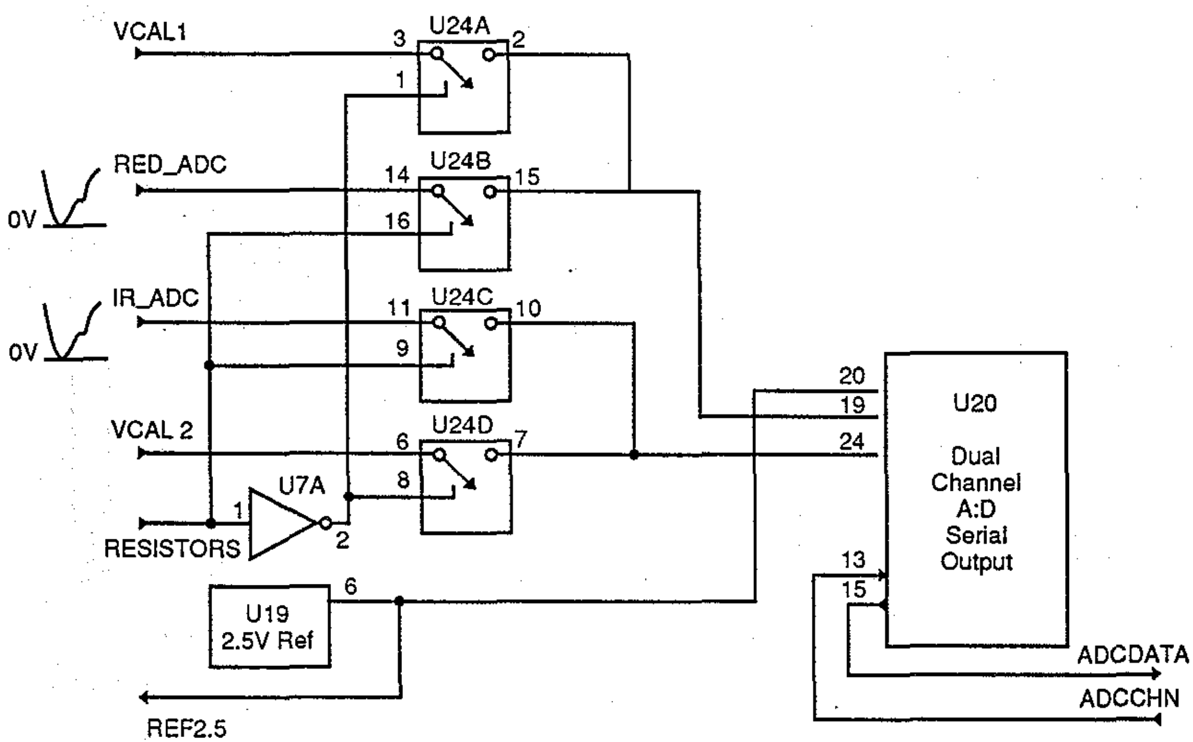


Figure 3-6: A:D Conversion Circuits

3.4.1.7 Support Circuits

Support circuits include the following:

a. Communications
b. Processor Circuits

a. Communications

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

In addition to the supply voltages provided to the module from the power supply, there are four data signals present at the module connection to the instrument. These signals are as follows:

CTS clear to send is a logic signal (active low) transmitted to the 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 bi-directional-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.

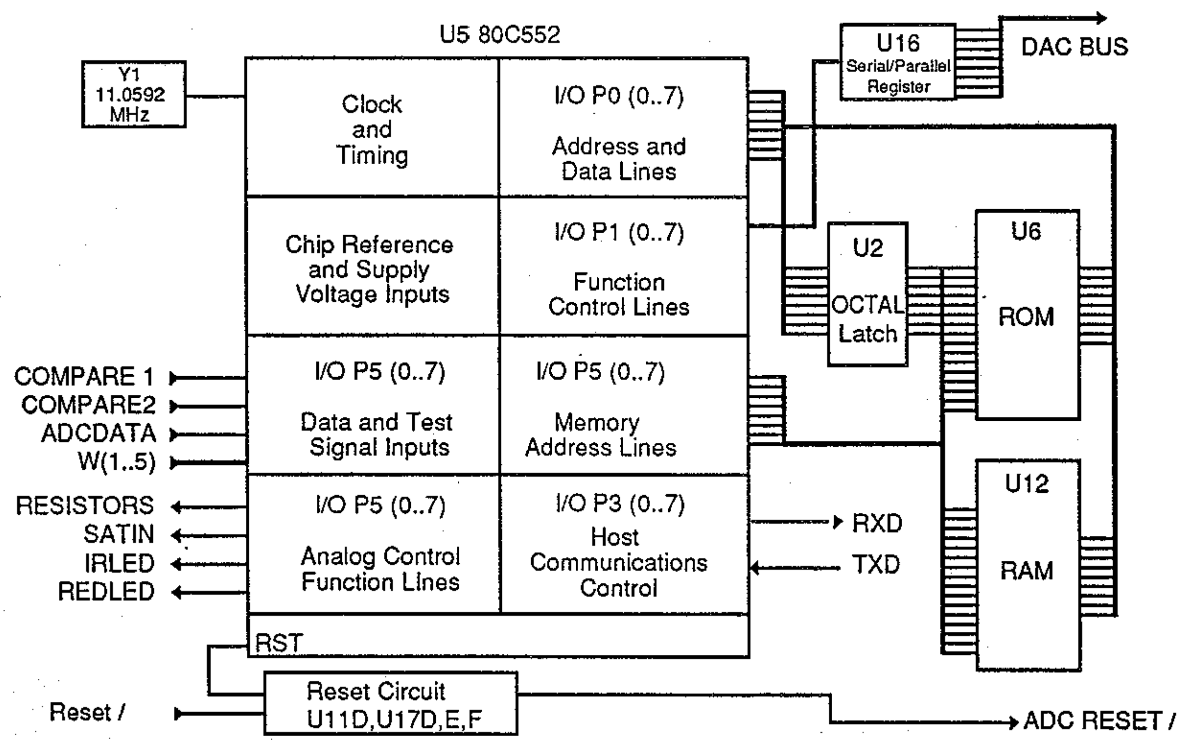


Figure 3-7: Support Circuits

b. **Processor Circuits**

Refer to Figure 3-7 for additional details during the following discussion.

Module support circuits consist of 80C552 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.

3.5 MAIN PROCESSOR PCB CIRCUIT DETAILS

Refer to the block diagram (Figure 3-1) and schematic diagrams in Section 12 while reading this section.

3.5.1 *Microprocessor Section*

Microprocessor U200 is an 80C188. The main program is stored in FLASH (electrically reprogrammable memory) U201 and U203. Temporary and semi-nonvolatile information is stored in U204, which is a 128K x 8 S-RAM. U204 remains powered from the system storage battery while the unit is off. U205 and U210B latch the multiplexed address/data bus from U200 and create A16 and the lower 8 address lines. U206 acts as a buffer/driver for the data bus between U200 and all peripherals.

3.5.2 *Power Control*

Pressing the front-panel power switch biases Q301 into conduction via R314 and D203, causing RY1 to pull in. RY1 enables power from either the internal storage battery or the rectified AC mains power to be applied to secondary regulators U302 and U303.

U208A, R200, and C202 form a Power-On Reset (POR) pulse of approximately 600 ms. This pulse is applied to U207A's preset pin to guarantee that this flip-flop will be set on power-up. Through D204 and R203, Q200 is forward-biased, providing hold-in bias to Q301 to maintain system power.

Power may be removed from the unit in three ways. First, the user may press the front-panel power switch. This causes C203 to be discharged through R201 and D203. If the button is held long enough to decrease the voltage on C203 below the input threshold on U208C, a clock pulse will be generated for U207A, causing it to be reset.

Power may also be removed from the unit if the microprocessor requests it when a low battery condition occurs. U200 may remove power by taking PCSOFF low; this clears U207A through D211.

The battery voltage is also monitored by the system via an A/D converter on U102. Switched system power is divided down by R275 and R276 and limited by D215 to a 0-5 V signal that is routed to the display controller via P205.

The third way to power-down the monitor is through U220. This device detects if the battery voltage drops below 9.5 volts. Pin 2 of U220 is set to approximately 3.9 volts from voltage reference U221. When the battery voltage drops to approximately 9.5 volts, the voltage divider formed by R225 and R226 presents U220 pin 3 with approximately 3.9V. Once the battery is low enough, pin 6 of U220 goes low, and via D211 clears U207A. The software cutout set point is 10 volts, plus or minus 0.5 volts.

Resetting U207A causes U207A pin 6 to go high, initiating an NMI (nonmaskable interrupt) to U200, informing it that power-down is imminent. Resetting U207A also causes U207A pin 5 to go low. At this point, C204 is the only remaining base drive for Q200. After about 1 second, C204 discharges through R203 and R204, removing bias from Q200 causing the relay to drop out.

3.5.3 *Reset and Watchdog*

On power-up, C209 is initially discharged by D210, which initially puts U200 into a reset condition by holding RES low. U200 takes RESET high while its RES input is LOW. This signal is inverted by U208F and is used to reset both watchdog circuits via D205 and D208. After power-up R207 charges C209, after approximately 100 ms RES is high enough to satisfy U200. This in turn takes RESET low. With RESET low, C207 and C208 are free to start charging through R206 and R209. If neither of the watchdog systems is satisfied before either C207 or C208 reach the threshold value of U209 approximately 1 second later, RES is driven low via D206, which discharges C209. This action again causes RESET to go low and discharge C207 and C208, effectively resetting the watch dog timers again. With this done, C209 is once again free to charge through R207. Unless there is some intervention this cycle will repeat continuously.

Watchdog trips are counted by U212B. This device is reset on power-up via the POR signal generated for the power control section described above. During power-up, POR is held active for approximately 600 ms. Since the reset pulse to the microprocessor is only about 100 ms wide, the first reset pulse is not counted by U212B. Each reset transition after power-up is counted, and if U212B ever reaches the eighth count, U210A is clocked, latching the FAILED signal. When the FAILED signal goes high, this removes the clear condition from U212A, which is configured as a divide-by-two divider. This device, when allowed to run, divides a 3,906 Hz clock down to 1953 Hz. This FAILTONE signal is routed to the main speaker amplifier and informs the user that the microprocessor has encountered a system failure.

The two independent watchdog timers are satisfied by positive-going edges applied to C205 and C206. The first watchdog timer is connected to U200 via U207B, which forms a single-bit output port. The second watchdog timer is connected to U102, which controls the front-panel numeric displays and key PCB. U200 and U102 are in constant communications, and should U200 fail to communicate properly to U102, or should U102 fail, the system will be reset.

If P209 is shorted, the first watchdog timer will be disabled. If P210 is shorted, the second watchdog timer will be disabled. If P211 is shorted, this will keep pulses from satisfying the first watchdog timer to allow testing the watchdog pulse counter.

3.5.4 *Battery Backup and Memory Retention*

The battery voltage is applied to U222, a micro-power shunt regulator, via R228. U222 regulates a battery backup voltage for U204 and U219 (Real-Time Clock) to 3 volts as set by R229 and R230. Power to U204 (S-RAM) is supplied via D213 and D214, which are low-voltage drop Schottky diodes. If system power is applied, D213 is forward-biased and D214 is reverse biased, causing U204 to draw its power from the +5 volt supply. As the system power falls off, D213 reverse-biases and D214 forward-biases, providing backup power from the storage battery.

With system power applied, Q204 is forward-biased by U221, which is set to approximately 3.9 volts. On power-down Q204 loses drive when the 5 volt supply has dropped to approximately 4.5 volts. This causes the voltage on Q204's collector to fall off sharply and takes the PFAIL input to U219 (RTC) low.

PFAIL is also connected to U204's CE2 line; when this line goes low, further accesses are inhibited to the RAM, maintaining data integrity. During reset, Q205 conducts to effectively hold Q204 in the off state, keeping PFAIL low until the reset cycle is complete. This further enhances data integrity during system reset conditions.

3.5.5 *Internal and External Serial Communications*

U213 is a quad UART (Universal Asynchronous Receiver Transmitter). It provides communications between U200 and the front-panel numeric display and key PCB processor, the CO2 And SpO2 circuit PCBs, and the rear panel RS-232 connector. The RS-232 port is buffered by U217. U217 generates + and –10 Volt supplies needed to generate the bipolar signals needed by the RS-232 port from the system +5 volt supply via an internal charge pump that uses C212, C213, and C215. The remainder of U217 provides the necessary level translations and current limiting needed to meet RS-232 input/output specifications.

Serial communications to the CO_2 and SpO_2 PCBs, which are patient-connected isolated circuit PCBs, is accomplished through four identical optocoupler circuits. The LED in the optocoupler lights when the input data line is low. This in turn causes the optocoupler's transistor to turn on, which applies drive current to the buffer transistor. The 68-ohm pull-down resistor in the emitter circuit of the optocoupler provides a faster turn off response. When the buffer transistor is saturated, the data output line, which is normally held high through the 4.7K pull-up resistor, is pulled low.

Communications with the numeric display and key PCB processor is buffered with U216B, U208D, and U208E.

The quad UART also provides additional I/O capability for such things as the graphic display power control, FLASH memory program voltage enable, power source sensing, and control of U214 (EEPROM). Each of these circuits is discussed below.

3.5.6 *Graphical Display*

The front-panel graphic display connects to the system's bus via U215 and U216, which are tri-state buffers. This is needed because the power to the graphic display may be removed to conserve power during battery operation. The buffers are enabled by taking U232A's input high; this in turn enables U216's outputs and allows U232B to control the enable line of U215 when the display is accessed by PCSDISP going low.

Power is applied to the graphic display by driving Q202 into saturation, which pulls the NTKEPWR line low. This activates a FET switch located on the Power Supply-Charger PCB to apply 5 volts to the graphic display.

3.5.7 *EEPROM*

U214 is an electrically erasable programmable ROM that stores the user's default settings. The device is accessed serially from port pins on U213 and stores such data as user default settings, serial number (if original board), and total hours in operation.

3.5.8 *FLASH Memory*

The firmware is stored in U201 and U203. These devices are electrically reprogrammable devices that do not need to be removed from the circuit to accept a new program. U201 allows a partial erase to be performed, which enables a small portion of software to remain resident. This software is responsible for accepting completely new software via the rear panel RS-232 connector. During programming, U218 supplies the 12 volts needed for reprogramming. U218 receives its primary power from unregulated supply VSW via Q203, which is driven into saturation via Q201, which is turn driven from U213.

3.5.9 *Real-Time Clock*

System time is provided by U219. When the unit is powered-down, U219 receives its power from the primary storage battery. The battery is regulated down to 3 volts by the micropower shunt regulator U222, which also regulates power to the system SRAM for backup. When the power is applied, U219 then internally switches over to the system +5 volt supply. U219 derives its timebase from XTAL202, which is a 32.768 kHz crystal. The crystal may be trimmed for timing accuracy via C218 while observing the buffered 32.768 kHz signal at TP1.

3.5.10 *Audio Generation*

Timer 1 of U200 is used to generate a selected frequency square wave that is provided to U230's output enable input. U230 is a tri-state 8-bit latch that holds a value written by U200 when PCSVOL goes low. The outputs of U230 are connected to an R-2R ladder network that serves as a D/A converter for the value latched into U230. As the square wave from U200 gates U230, the resultant voltage output from the ladder network varies between zero volts and the programmed D/A value. This signal is then AC-coupled via C225 to U231 via a low-pass filter formed by R263, R264 and C271. The low pass filter serves only to slow the square wave's leading and trailing edges. U231 is a bridge amplifier that drives the rear-panel mounted speaker directly.

3.5.11 *Charging Indicator*

The front panel charging LED is driven by Q212, which receives base drive via D201 when Q300 is turned on. Q300 detects whether mains power is applied to the unit by looking for AC from the mains transformer. This signal is also available to U200 via U213 and D201.

3.5.12 *Patient Isolation Power Supply*

Isolated power is supplied to the CO2 and SpO2 subsystems via a power supply located on the main circuit PCB. U233 is a current mode switched power supply controller that drives T200 via Q211 in a flyback configuration. Transistor Q211 is a sense-FET that provides a mirrored current output signal back to U233, which sets the current switching point of T200. Voltage regulation of the secondary +8 volt supply is accomplished by current modulating optocoupler U239. R291 is used to set the operating voltage of the secondary +8 volt supply. The switching frequency is set at 62.5 kHz by coupling a divided system clock supplied by U211 via C230 to R-C timing components R277 and C228 for U233. This reset synchronization pulse resets the R-C timer and forces it to lock to the 62.5K Hz signal. The isolated power supply may be disabled by saturating Q210, which is driven by U213.

Secondary regulation is supplied by conventional linear regulators. The +5 volt logic supply is regulated down from the +8 volt supply via U235. The –5 volt supply is regulated by U238 from the unregulated
–8 volt supply. U236 and U237 provide + and –15 volt supplies for the SpO_2 PCB. An unregulated –42 volt supply for the CO_2 PCB is filtered by C243.

3.5.13 *Front Panel Display Controller*

U102 is a programmable single-chip microprocessor programmed to provide the multiplexing for the front-panel dual-color LED displays and to scan the key PCB for key presses. Segment drive is provided by U103 which is a seven section open collector Darlington transistor array. The eighth segment is driven by Q112. Segment current limiting is provided by R115-R122. U100 and U101 decode which display should be selected during the multiplex cycle and drive the appropriate output low, which in turn drives one of the transistors Q100-Q109 into saturation. This connects the selected display to the +5 volt supply. The display drive signals also connect the key switches. When a key is pressed and the associated display is selected, a common line is driven back to U102 which senses the key switch depress and informs the main microprocessor of the event.

As mentioned previously, U102 also contains an on PCB 8-bit A/D converter. This converter is used to read the battery voltage via a voltage divider on the main circuit PCB. Additionally, it is used to detect if any of the display segments fail to light. On power-up each segment is illuminated briefly, all LED current returns through R102 causing a slight voltage drop. This voltage is read by U102 to determine if the segment lit.

As a participant in the watchdog system U102 provides a watchdog healthy signal to the main watchdog control system. If U102 should ever fail, or should it fail to communicate with the main computer for an extended period of time it will shut down and cause the system to reset via a watchdog trip. The system reset signal is routed to U102 so that the entire system resets together in an orderly fashion.

D100 provides isolation of the power switch signal so that it can be monitored by U102 to detect for power-down.

3.6 POWER SUPPLY-CHARGER PCB CIRCUIT DETAILS

3.6.1 *Power Supply-Charger Theory of Operation*

The Power Supply-Charger PCB contains these three basic circuit blocks: AC rectifier and +12 volt battery charger, +5 volt logic and display power supply, and the analog portion of *C-LOCK* ECG synchronization input circuitry. The schematics of these circuits are shown on the 2704S, Power Supply-Charger schematic diagram.

3.6.2 *AC Rectifier and +12 volt Battery Charger*

The power transformer's AC secondary voltage (20 VAC) is input via P303 to 8 ampere full-wave bridge rectifier D303, and 6800 µF filter capacitor C303. The nominal +25 volts DC unregulated output is fed directly to battery charging switching regulator U301. This device has a built-in NPN driver and is configured as a buck converter with a 330 µH (L300) output inductor. The switching frequency is set at 66 k HZ (nominal) via C305. The output is set at +14.25 volts at the cathode of reverse blocking diode D307 (and + term of the battery) via potentiometer R312. This voltage is labeled VBAT on schematics.

The output current is limited at a nominal 500 mA to control maximum charge current to the battery via R326, (0.2 Ω, 1%, 3 W), current limit set resistor. VBAT is fed from the PCB via P304 pin 1, which connects the 2.5A rear-panel fuse to the + terminal of the battery. It is also connected through blocking diode D308 to the common of power switching relay RY1.

Unregulated DC, during AC operation is also diode coupled to RY1 common via D309. RY1 supplies switched voltage VSW (either VBAT or unregulated DC) to the rest of the power circuits on Power Supply charger PCB and via P300 to the Main Processor PCB. RY1's coil is energized from VBAT through PNP switching transistor Q301.

Base current, for Q301 turn-on, is provided through R314 when PWRON control line is switched LOW by MAIN PCB control pin P300 pin 9. AC on/off power recognition is provided by turning on NPN transistor Q300. Q300 is turned on, pulling AC P300 pin 7 low when AC transformer secondary voltage is present. That AC is rectified via D304 and D305, filtered by RC R308 and C304, and coupled to base of Q300.

3.6.3 *+5 Volt Logic and Display Power Supply*

Energizing RY1 applies input voltage to the +5 volt switcher circuit. The basic circuit is the same as the battery charger. The differences are: the operating frequency is higher, at 95 k Hz, maximum output current is much higher, at 2.5 amperes continuous, and the nominal current limit value is about 4.5 amperes.

The operating frequency is set by C311 and current limit by R316 (0.25 Ω, 1%, 3 W). Output voltage is fixed by divider R318 and R319. Vacuum fluorescent display power is switched by N-channel FET Q303, fed by the +5.0 V supply. Q303 gate voltage is controlled by NPN Q302. When Q302 is on, its gate voltage is low and the FET is off. When NTKE PWR, P300 pin 10, is brought low (via Main Processor PCB control), Q302 is turned off and gate voltage is allowed to rise to D313's zener value of +10 V (derived from VSW).

The turn-on time of approximately 90 ms is determined by R327 and C314. This timing acts to keep the heavy load demanded by the display during its turn-on to less than 4.0 amperes, which is less than the +5.0 V supply's current limit value. This heavy load lasts for about 20 to 30 ms during the display power-up cycle.

3.6.4 *C-LOCK QRS Sync Input Circuit*

Power for quad operational amplifier U300 is developed by U302, a three-terminal +8.0 volt regulator. U302's input voltage comes from P302, a rear-panel miniature phone jack, through R300 to divider R301. The input is then AC-coupled through C300 to two parallel circuits, U300A unity gain buffer and U300B peak follower. The divided input is clamped to 4 volts by back-to-back zener diodes D300 and D301. The + inputs of U300A, B, and D are biased to +4.0 V by dividers R302, R303 for A and B sections and R325, R310 for section D. These dividers set the amplifiers' operating point so that a negative voltage supply for U300 is not needed. The peak follower circuit (composed of U300B, D302, R304, C301, R305, and U300C) stores the peak value of the *C-LOCK* input from one peak to the next. This sets the threshold for comparator U300D. The comparator's output produces a positive-going pulse, CINT, when the input signal exceeds the threshold set by the previous peak value. CINT is connected to the Main Processor PCB, via P300 pin 8, for further processing.

SECTION IV
Routine Maintenance

4.1 INTRODUCTION

The N-6000 requires no routine service other than that which is mandated by the operator's institution. Nellcor, however, recommends replacing the monitor's battery every 2 years. Section 8, "Troubleshooting," discusses potential difficulties, their possible causes, and suggestions for resolving them.

4.2 CLEANING INSTRUCTIONS

Caution: Do not immerse the N-6000 in liquid or use caustic or abrasive cleaners.

To clean the N-6000'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-6000 or its accessories. Do not allow any liquid to penetrate switches, connectors, or openings in the chassis.

4.3 CHANGING MAINS VOLTAGE INPUT

The N-6000 operating voltage must match the local mains AC power ratings. The voltage setting is indicated by a white marker located near the AC mains power cord receptacle. To change the voltage setting:

1. Turn the Mains AC ON/OFF switch to the OFF position and then disconnect the power cord.
2. Open the power entry module cover (located next to the power cord connector) using a small blade screwdriver or similar tool.
3. Set aside the cover/fuse block assembly and pull the voltage selector card straight out of the housing.
4. Orient the selector card so that the desired voltage is readable at the bottom.
5. Orient the indicator pin so that it points up when the desired voltage is readable at the bottom.
6. Insert the voltage selector card back into the housing, printed side of the card facing toward the power cord connector, and the edge containing the desired voltage first.
7. Verify that the proper fuse is installed. If the fuse needs to be replaced, refer to "Replacing or Changing the Fuse," in this section.
8. Replace the power entry module cover, then verify that the indicator pin shows the desired voltage.

4.4 REPLACING OR CHANGING THE FUSE

To replace or change the fuse arrangement from North American to European Fusing:

1. Disconnect the AC power cord.
2. Open the power entry module cover by using a small blade screw driver or any similar tool.
3. Loosen the screw by two turns counterclockwise.
4. Remove the fuse block by sliding up, then away from screw and lifting up from the pedestal.
5. Change the fuse or fuse arrangement as shown in Figures 4-1 and 4-2. Note that two European fuses are required. Replace the "dummy" fuse in the neutral (lower) holder when operating on 220 V~.
6. Insert fuse block and slide back onto screw and pedestal.
7. Tighten screw and replace the cover.

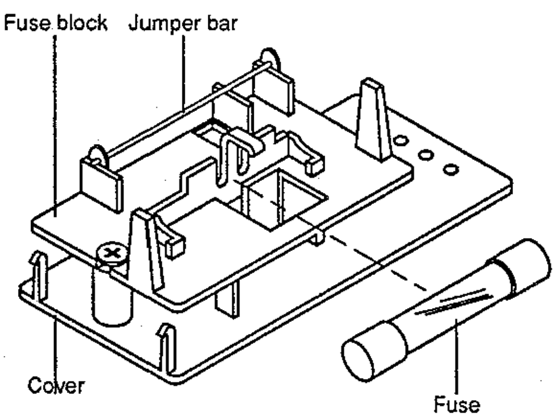


Figure 4-1: North American Fuse Arrangement

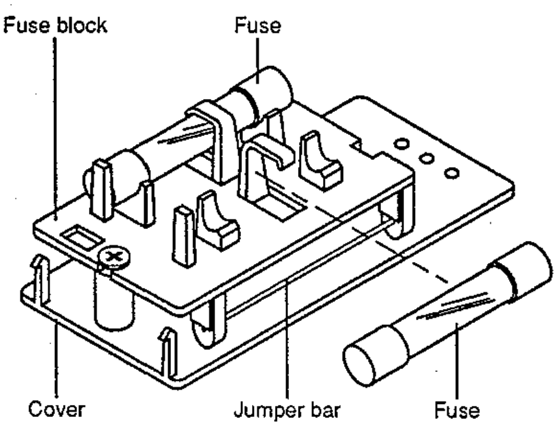


Figure 4-2: European Fuse Arrangement

SECTION V
Packing and Shipping Instructions

5.1 OVERVIEW

This section contains instructions for returning the N-6000 for repair or replacement. The instrument should be packed carefully; failure to follow the instructions in this section may result in loss or damage not covered by the Nellcor warranty. If the original shipping carton is not available, a suitable carton should be used. Additional packing materials may be purchased through Nellcor's Technical Services Department.

To facilitate the repair or replacement process, a returned goods authorization (RGA) number must be issued before the instrument is returned. Contact Nellcor's Technical Services Department for an RGA number. Be sure to mark the shipping carton and any shipping forms with the RGA number.

5.2 REPACKING IN ORIGINAL CARTON

If available, use the original carton and packing materials. Pack the monitor as follows:

1. Place monitor in original plastic foam packaging and place in shipping carton. Seal carton with packaging tape.

2. Label carton with shipping and return addresses and RGA number.

5.3 REPACKING IN NEW CARTON

If the original carton is not available, use the following procedure:

1. Place the monitor and accessories in plastic bags.

2. Locate a corrugated cardboard shipping carton with at least 200 psi bursting strength.

3. Fill the bottom of the carton with at least 2 inches of packing material.

4. Place the unit on the layer of packing material and fill the box completely.

5. Seal the carton with packing tape.

6. Label carton with shipping and return addresses and RGA number.

SECTION VI
Disassembly Guide

6.1 INTRODUCTION

This section includes procedures for disassembling the N-6000 when required for testing or troubleshooting. Refer to Figure 6-1 when reading this procedure.

6.2 DISASSEMBLY PROCEDURE

Tools Required:
- Small cross-head screwdriver with magnetic tip
- Medium cross-head screwdriver with magnetic tip
- Small flat-blade screwdriver
- 1/4-inch nut driver
- 5/16-inch nut driver
- 5/16 open end wrench

Note: This procedure is listed in order of disassembly, but some assemblies may be removed without removing the assembly listed in the prior step. The cover must be removed first, the battery next, and then the Oximetry and CO_2 subassembly. Other assemblies may then be removed if accessible. The AC power input assembly must be removed from the rear panel and lifted out of the way to remove the Power Supply–Charger PCB. The transformer must be removed last and replaced first when reassembling the instrument.

6.2.1 *Removing Instrument Cover*

1. Disconnect power cord, sensors, and other external connections from instrument.

2. Place instrument upside down on bench top.

3. Remove screws from instrument cover.

4. Turn instrument over, pull handle side of cover away from chassis, and slide cover off to the rear.

6.2.2 *Removing Battery*

Note: Removing the battery causes all trend information and custom defaults to be lost and resets the real-time clock. To prevent data loss, operate the N-6000 on AC power while removing and replacing the battery.

WARNING: Use extreme caution when removing or replacing the battery with AC power applied. Dangerous voltages are present inside the cabinet in this operating condition.

1. Release tie-wraps holding battery to chassis.

2. Disconnect battery leads.

3. Pull battery straight up and out of chassis.

6.2.3 *Removing Oximetry and CO_2 Subassembly*

1. Disconnect ribbon cables from Main Processor PCB.
2. Remove screw from right chassis side.
3. Pull assembly out of slots on side panel.
4. Pull subassembly away from chassis side.
5. Disconnect cable from front-panel oximetry input connector.
6. Pull the subassembly up and out of the chassis

Note: When replacing subassembly, be sure to place the flexible plastic insulation *inside* the subassembly's enclosure. Snap the vertical tab in the side panel first, and then snap the two horizontal tabs in place. Secure the assembly with the screw.

6.2.4 *Removing Main Processor PCB*

1. Disconnect all cable connectors from Main Processor PCB.
2. Remove screws from four corners of Main Processor PCB and two screws from center of PCB.
3. Lift Main Processor PCB up and away from chassis.

6.2.5 *Removing Front-Panel Assembly*

1. Remove screws holding the front panel to the chassis at the top and on the bottom.
2. Pull panel away from the chassis about an inch.
3. Disconnect the three ribbon cable connectors.
4. Pull panel away and out of the chassis.

6.2.6 *Removing Pull-Out Card Tray*

Note: The front panel must be moved away from chassis before removing tray.

1. Turn instrument upside down.
2. Remove screws holding tray to chassis bottom.
3. Pull tray away from chassis.

6.2.7 *Removing Speaker*

1. Using a 5/16-inch nut driver, remove nuts holding speaker to rear panel.
2. Pull speaker away from panel.

6.2.8 *Removing Power Supply-Charger PCB*

1. Using a 1/4-inch nut driver, remove nuts holding AC input power assembly to rear panel.
2. Pull assembly away from rear panel and clear of the Power Supply-Charger PCB.
3. Disconnect cable connector from fuse holder and battery leads.
4. Remove screws holding Power Supply-Charger PCB to chassis bottom.
5. Lift Power Supply-Charger PCB up and out of chassis.

6.2.9 *Removing Transformer*

1. Using a 5/16-inch nut driver and 5/16 open end wrench, remove nuts holding transformer to chassis bottom.
2. Pull transformer and AC input assembly up and out of chassis.

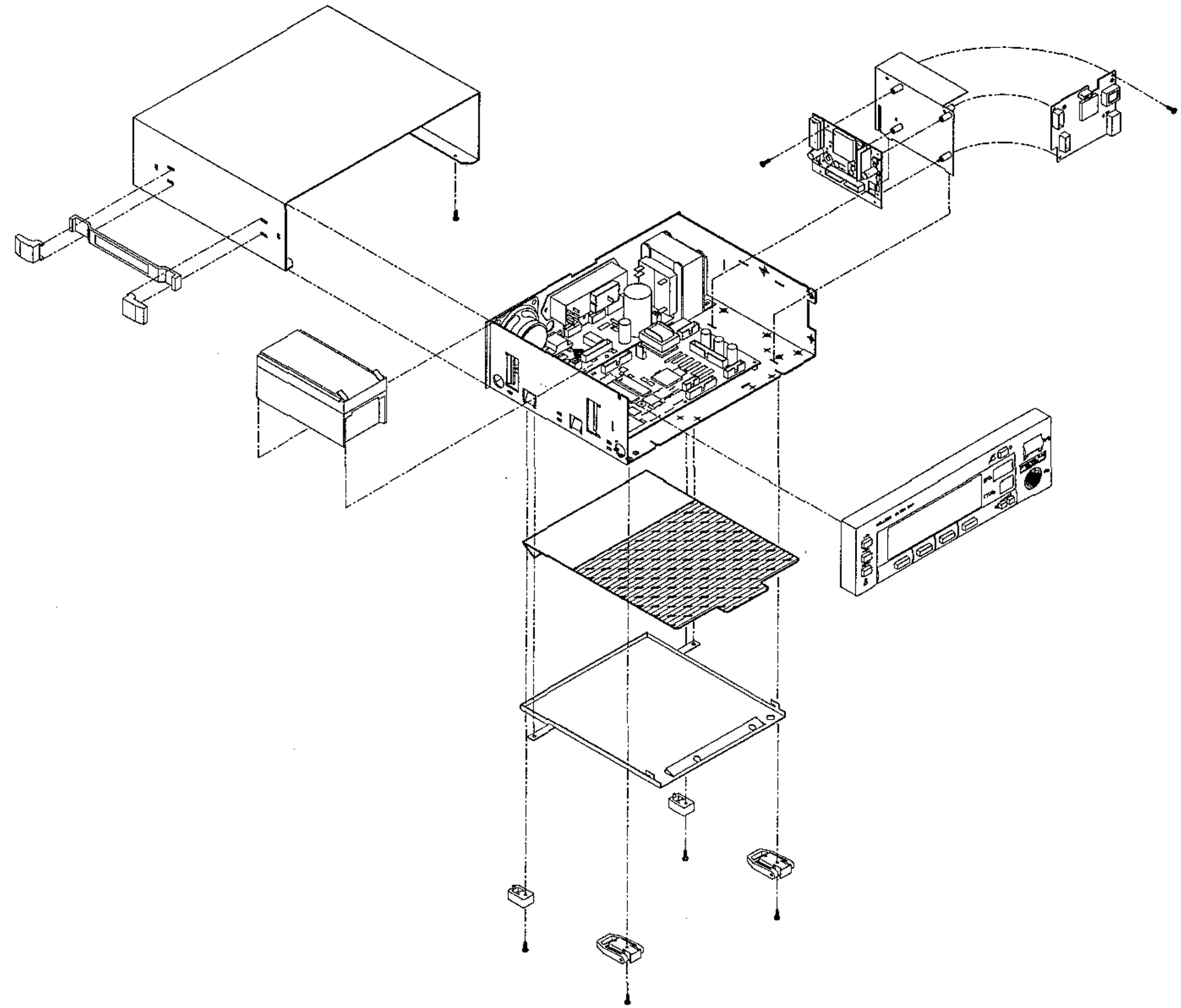


Figure 6-1
N-6000 Disassembly Diagram

SECTION VII
Testing and Calibration

7.1 DESCRIPTION

This section describes testing and calibration procedures for the N-6000. Instructions for troubleshooting and repair are found in Section 8, "Troubleshooting." Also refer to Section 6, "Disassembly Guide," for cover removal instructions.

Table 7-1 describes service screens, reached from the main monitoring screen by pressing the Freeze button, then pressing the second and fourth soft keys (counting the far left key as first), and pressing the SERVICE soft key. To return to the main monitoring screen, press the MENU key. Note that the service screens are not available until the CO_2 sensor has warmed up.

7.2 CO_2 DISPLAY CONVENTIONS

7.2.1 *Service Screen and Display Conventions*

The N-6000 measures the partial pressure of CO_2 (PCO_2) in the patient airway adapter at normal assumed patient conditions of 37° C body temperature and exhaled breath fully saturated with water vapor. The N-6000 measures barometric pressure directly. By convention, all readings of CO_2 expressed on the front-panel numeric display are assumed to be measured from a patient and corrected to 37° C body temperature and ambient pressure. When PCO_2 is being displayed on the numeric display in units of mmHg or kPa, the values are also converted to fully saturated breath conditions (Body Temperature, Pressure, Saturated, or BTPS) before being displayed. When units of % (by volume) are displayed on the front-panel display, the measured value is expressed as % dry gas. Thus, the front-panel numeric display always refers to conditions within the patient's body.

For service screen displays, however, the assumption is always made that dry gas at room temperature is being applied to the N-6000. No correction to BTPS is made. Thus, the service screen display always refers to laboratory test conditions.

These conventions, although correct and appropriate for the different monitoring and test conditions described, may cause confusion.

For example, if a patient at sea level (barometric pressure equal to 760 mmHg) is exhaling fully saturated gas with a true deep lung end-tidal PCO_2 of 38 mmHg into the patient airway adapter, the front-panel display will read 38 mmHg, 5.1 kPa, and 5.3 % (% equals the pressure of CO_2 divided by barometric pressure minus water vapor partial pressure). The service screen will read approximately 1% lower values for mmHg and kPa due to the service screen assumption that the gas is being read at conditions of room temperature and is dry. The service screen reading in % will be approximately 8% lower because the gas source (the patient) is actually fully saturated but the service screen assumes dry gas input.

On the other hand, if dry gas with 5.0% CO_2 from a tank is being applied to the patient airway adapter at the same barometric pressure of 760 mmHg, the service screen displays will be 5.0%, 38 mmHg (5% times 760), and 5.1 kPa. The front-panel display will read approximately 1% higher in mmHg and kPa, and 8% higher in % for the same reasons.

Although the above conventions may seem confusing, they allow accurate readings during both patient monitoring and laboratory testing. A good rule of thumb is that the front-panel display values are used for patient monitoring, and the service screen is used for bench testing. When monitoring a patient, ignore the service screen. When testing dry gas in a test setup, ignore the front-panel numeric display.

7.2.2 Breath Detection and Display of End-Tidal CO_2 Values

The N-6000 detects and counts breaths when the CO_2 level crosses a threshold set dynamically from maximum and minimum values of CO_2. When a patient on a ventilator has several spontaneous breaths with low $ETCO_2$ values followed by a mechanical breath with a higher value of $ETCO_2$, the N-6000 detects and counts all breaths accurately.

The value of $ETCO_2$ that best estimates the true alveolar CO_2 value is the maximum value obtainable from the patient during forced exhalation. Unlike conventional capnometers that simply average all breaths together to display the $ETCO_2$ value, the N-6000 looks for the maximum value of $ETCO_2$ seen within the last 8 seconds and displays that maximum value for the true $ETCO_2$. The result is a stable $ETCO_2$ value that best approximates the arterial $PaCO_2$ value in the patient.

Table 7-1: Service Screen Indications

Parameter	Function	Normal Range and Tolerance
Software Version Screen (press SERVICE soft key)		
BOOT ROM	FLASH memory bootstrap loader version	
EEPROM	FLASH software version: Main product operating software	
CO2 BOARD ROM	CO_2 subsystem software EPROM version	
DISPLAY BOARD ROM	LED display/keyboard controller microcontroller software version	
SPO2 BOARD ROM	SpO_2 subsystem software EPROM version	
CO_2 Service Screens (press CO2 soft key)		
BOARD STATUS	CO_2 board status	0300 with sensor connected and normal operation.

Table 7-1: Service Screen Indications
(continued)

RAW RATIO	Calculated ratio of bench peaks used to determine amount of CO_2 present.	Varies sensor to sensor; typically 0.5 to 0.9. Depends on bench characteristics and reading.
BENCH TEMP	Sensor temperature	This is microprocessor-regulated to 42.0° C. This should not vary once the bench is up to temperature and the monitor detects a breath. An error is generated once the bench temperature exceeds 46.0° C. Otherwise, the temperature drops to 39° C after 7 minutes as a safety precaution.
BARO. PRESSURE IN MMHG	Current barometric pressure	Displays current barometric pressure in mmHg that is used for correcting percentage readings and for calibration.
CO_2 IN (operator-selected units)	Uncompensated detected CO_2 in current display units	Displays CO_2 value in operator-selected units (mmHg, kPa, or %). This value is not compensated for Body Temperature, Pressure, Saturated and assumes that the temperature is 25° C. The service screen reading may be different from the $ETCO_2$ value displayed by the monitor.
Press CO_2 and then MORE CO_2 VALUES		
HIGH PEAK	Bench signal	One of two bench waveform peaks. Typically 3.5 V with no CO_2 present, and will vary with temperature.
DETECTOR	A bias voltage	Will vary sensor to sensor and is used to compensate for sensor gains. typical readings are 1 to 2 V.
HEATER	Heater voltage	This is the voltage applied to the heater in the sensor head. It varies with room temperature; at 25° C ambient it is typically 2 V.
MOTOR SPEED	Bench motor speed	This is the period of rotation of the bench motor in milliseconds. It is typically 30.0 ms; ±5 ms.

Table 7-1: Service Screen Indications
(continued)

BIAS	Bias control number	Used to set the desired detector bias voltage.
LOW PEAK	Bench Signal	One of two bench waveform peak voltages. It is typically 2 V and varies with the amount of CO_2 present and with temperature.
SOURCE	IR source voltage	The voltage applied to the source; this will vary slightly because the source is current-regulated, not voltage-regulated. A typical reading is 2.5 V.
HEAT CONT.	Heater control term	Used in regulating the temperature and varies based on ambient temperature.
MOTOR POT	Setting of electronic potentiometer for motor control	Setting will vary 0–255; there is no definitive typical setting.
Press CO_2 and then SENSOR VALUES		
SENSOR REV.	Indicates revision level of sensor EEPROM data format	Used to determine how to interpret data in the Sensor Memory screen.
SENSOR TIME	Sensor run time	Indicates total accumulated sensor run time; units are in hours.
SERIAL NUMBER	Sensor serial number	Electronic sensor serial number.
LAST CAL DATE	Last calibration date	Used as an indication of last date of sensor calibration.
Press DISPLAY		
SEGMENT FAIL DATA	Indicates failed LED	Should normally be all zeros; any non-zero number indicates a failed LED digit. Figure 7-1 shows how to determine the failed LED digit.
DISPLAY CURRENT	Relative current draw of LED displays	Used to indicate relative current draw for each LED display digit. Number varies with what's currently on the display.

Table 7-1: Service Screen Indications
(continued)

Press SPO2		
CALIB. INDEX	Sensor Calibration Index	Shows the value of the calibration resistor in the SpO2 sensor.
INAMP GAIN	Input Amplifier Gain	Shows current setting of the SpO2 input amplifier. Range is 0 to 255.
RED LED DRIVE	Red LED Drive	Relative amount of power being applied to the red LED. Range is 0 to 255.
IR LED DRIVE	Infrared LED Drive	Relative amount of power being applied to the infrared LED. Range is 0 to 255
Press MORE and then MAIN BOARD		
SERIAL NUMBER	N-6000 serial number	Electronic serial number of the N-6000; this number is stored in an EEPROM on the original main processor circuit board.
HOURS IN OPERATION	N-6000 run time	Indicates total hours in operation of the main board.
Press POWER SUPPLY		
DC	Unregulated DC supply voltage	When running on AC mains, indicates unregulated voltage supplied to the various system regulators.
BATTERY VOLTAGE	Battery voltage	Indicates present voltage of rechargeable battery. A freshly-charged battery indicates a little over 13 V; the system shuts down at about 10 V. Present only when AC power is off.
AC MAINS	Shows power source	Shows either ON or OFF.

0000000000000000000000 — Service display screen

1 2 3 4 5 6 7 8 9 10 11 — Pairs

1. Left SpO2, red
2. Middle SpO2, red
3. Right SpO2, red
4. Left CO2, red
5. Right CO2, red
6. Left SpO2, green
7. Middle SpO2, green
8. Right SpO2, green
9. Left CO2, green
10. Right CO2, green
11. Alarm silence

(7–11: Failed digits)

Figure 7-1: Failed LED Digits
Non-zero numbers indicate failure.

7.3 CALIBRATION AND ACCURACY CHECK

Check the mainstream CO_2 sensor of the N-6000 at least once a year to ensure its accuracy. Section VIII, "Troubleshooting," discusses potential difficulties, their possible causes, and suggestions for resolving them.

To check the mainstream sensor, follow these steps:

1. In a well-ventilated room, connect the mainstream CO_2 sensor to an airway adapter and plug the sensor into the N-6000.

2. Turn the monitor ON and let the device warm up (approximately 45 seconds) until the monitoring screen is displayed. Use the MENU button to disable all audible alarms: press the MENU button, the ALARMS function key, the DISABLE function key, followed by the DSABLE ALL function key. Press the MENU to return to the monitoring screen.
Note: The DISABLE key may not be available, depending upon custom default settings.

3. Let the mainstream CO_2 sensor run in this condition for 15 minutes.

4. Using the MENU button, change the units of measurement of CO_2 to "% CO_2": press the MENU button, the SYSTEM function key, then the SYSTEM VARIABLES function key. Press the CO_2 UNITS function key until the selector is on "%", then press MENU button to get back to the monitoring screen.

5. To view CO_2 values, enter the service screen: (1) press FREEZE, then press the second and fourth soft keys simultaneously; (2) press SERVICE; (3) press CO_2 The CO_2 BOARD SERVICE SCREEN should now be displayed.

6. Wait 15 minutes, then observe the reading of CO_2 IN %. CO_2 should be at 0% to 0.3% with room air. Check the sensor temperature; it should be +42 ±0.25° C. Breathe through the airway adapter or simulate a few breaths to deactivate the sensor cool-down safety feature.

7. Introduce a 10% quantity of CO_2 of a known concentration (preferably from a *NELLCOR* GSTK-6000 calibration gas kit) into the airway adapter. Note the reading on the N-6000.
Note: The CO_2 values displayed on the service screen are not compensated for water vapor or temperature. The $ETCO_2$ value is compensated. The user must identify the proper value displayed.

In room air, the ETCO2 reading must be 0.0% to 0.3%. With 5% CO2 introduced, the reading must be 5.0 ±0.3%. With 10% CO2 introduced under the same barometric pressure conditions, the reading should be 10.0 ±0.4%.
If desired, this screen can be printed by pushing the FREEZE button, then the PRINT SCRN key. If the mainstream CO_2 sensor is not within specifications, call the Nellcor Technical Services Department for assistance.

There are three factors that occur during this test that can result in unfavorable situations:

1. The first factor is conducting the test in a room containing significant background CO_2 levels (*room air is not 0% CO_2.*). The test room must be well-ventilated.

2. The second factor is use of a source of CO_2 that does not match its label (example: gas canister label says 5.0% but contains 4.6%). One way to check this is to sample the canister with additional mainstream CO_2 sensors. If they all are consistently high or consistently low, then the gas source's accuracy is suspect and another gas source should be tried.
To avoid these difficulties, the following precautions must be observed:

   - Use calibration gas from a known source, preferably NBS traceable and assayed by a gravimetrics method.
   - Make sure all connections are secure. Leaks of room air will decrease measured CO_2 concentration.

   Note: Gas-sampling test kit GSTK-6000 is available from Nellcor. This gas-sampling system provides calibrated gases for use in verifying calibration. Gases are sampled continuously, at a low nominal flow rate of 35 cc/minute.

3. The third factor is that the CO_2 sensor is not operating at 42° C. Ensure that the sensor has seen a breath by breathing through the airway adapter a few times. The sensor's temperature should rise to 42° C. Repeat tests.

SECTION VIII
Troubleshooting

8.1 INTRODUCTION

This section describes potential trouble symptoms, probable causes, and suggestions for resolving them. There are two kinds of malfunctions: those that cause the instrument not to operate at all, and those that cause erratic behavior. The first kind is a result of internal component failures; the second can be caused by external factors such as improper sensor use or external electrical interference, such as that from an electrosurgical unit.

If the following table does not describe the problem, refer to the service screens description in Section 7, "Test and Calibration," for additional indications.

Table 8-1: Troubleshooting Guide

Symptom	Probable Cause
Instrument cannot be turned on.	• Connect to AC power and verify that the front-panel battery charging indicator is on. If the indicator is off and the problem persists, check the AC fuse(s). If this does not resolve the problem, contact Nellcor's Technical Services Department.
Instrument operates on AC power but not on the battery.	• The battery may be discharged. A minimum of 12 hours is required to completely recharge the battery. • The battery fuse may be open. Check it. • The battery or the battery charger may be defective. Contact Nellcor's Technical Services Department.
SpO_2 pulse amplitude indicator is not tracking the pulse: no values are displayed.	Check the sensor and sensor extension cable: • Sensor or sensor extension cable may not be plugged in. Check them. • The sensor or extension cable may be damaged. Replace them.

Table 8-1: Troubleshooting Guide
(continued)

SpO_2 pulse amplitude indicator is not tracking the pulse: no values are displayed (continued).	Check SpO_2 module operation: • Connect a *NELLCOR* PT-2500 pocket tester to the SpO_2 sensor input connector. Pulse rate should be 40±1 and the saturation reading should be 81±1. • Connect a *NELLCOR* sensor to the SpO_2 sensor input connector. Move the LEDs and optical sensor away from and toward each other. LED intensity should change. • Connect an oscilloscope probe to pin 1 of U229 on the Main Processor PCB. 5V logic-level pulses should appear on the oscilloscope trace. If they do not, the oximetry module is probably defective; replace it.
SpO_2 pulse amplitude indicator is not tracking the pulse: zero display for oxygen saturation and pulse rate.	• The sensor may be improperly applied to the patient. Check application. • The patient's perfusion may be too poor for the instrument to detect an acceptable pulse. Check the condition of the patient; use *C-LOCK* ECG synchronization; test the instrument on yourself or on another patient; try another sensor site; or try the *OXISENSOR* R-15. • Check SpO_2 module operation as listed above.

Table 8-1: Troubleshooting Guide
(continued)

Pulse amplitude indicator tracks a pulse, but there is no oxygen saturation or pulse rate.	• The patient's perfusion may be too low to allow the instrument to measure saturation and pulse rate (fewer than two to three bars on the pulse bar). Check the condition of the patient; use *C-LOCK* ECG synchronization; test the instrument on someone else; or try the *OXISENSOR* R-15. • Excessive patient motion may be making it impossible for the instrument to find the pulse pattern. If possible, keep the patient still; check whether the sensor is securely and properly applied, and replace it if necessary; use *C-LOCK* ECG synchronization; move the sensor to a new site; use a sensor that tolerates more motion; or set the SpO2 averaging mode to 10–15 seconds (Mode 3).
SpO2 and/or pulse rate display changes rapidly; pulse amplitude indicator erratic.	• Excessive patient motion may be making it impossible for the instrument to find the pulse pattern. If possible, keep the patient still; check whether the sensor is securely and properly applied, and replace it if necessary; use *C-LOCK* ECG synchronization; move the sensor to a new site; use a sensor that tolerates more motion; or set the SpO2 averaging mode to 10–15 seconds (Mode 3)
Displayed pulse rate does not correlate with that of ECG monitor.	• Excessive patient motion may be making it impossible for the instrument to find the pulse pattern. If possible, keep the patient still; check whether the sensor is securely and properly applied, and replace it if necessary; use *C-LOCK* ECG synchronization; move the sensor to a new site; use a sensor that tolerates more motion; or set the SpO2 averaging mode to 10–15 seconds (Mode 3). • The patient may have a pronounced dicrotic notch, which causes the pulse rate measurement to double. Try another sensor site. • If *C-LOCK* ECG synchronization is in use, an artifact or poor quality signal may be present on the ECG monitor. Adjust ECG leads to improve quality of ECG signal. Refer to the manual for that monitor.

Table 8-1: Troubleshooting Guide
(continued)

SpO_2 measurement does not correlate with the value calculated from a blood gas determination.	• The calculation may not have been correctly adjusted for the effects of pH, temperature-relevant $PaCO_2$, 2,3-DPG, or fetal hemoglobin. Check whether calculations have been appropriately corrected for relevant variables. 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, the operator's manual, and in the SpO_2 sensor directions for use.
SpO_2 does not correlate with laboratory CO-Oximeter.	• Fractional measurements may not have been converted to functional measurements before the comparison was made. The N-6000, as well as two-wavelength oximeters, measure functional saturation. Multi-wavelength oximeters, such as the Instrumentation Laboratory 282 CO-Oximeter and Corning multi-wavelength oximeters, measure fractional saturation. Fractional measurements must be converted to functional measurements for comparison. The equation used to make this conversion is found in the "Principles of Operation" in Section II of this manual. Close correlation requires that the blood sampling and pulse oximeter measurement be obtained simultaneously from the same arterial supply.

Table 8-1: Troubleshooting Guide
(continued)

$ETCO_2$ value does not match pCO_2 values obtained from blood gas sample.	• Ventilation/perfusion mismatching may be clinically present; consider patient's physiologic situation. • Check for leaks in the patient ventilation circuit at the airway adapter. • N_2O may be present; use N_2O compensation mode. • Elevated levels of O_2 may be in use; use O_2 compensation mode. • The N-6000 system may have an error; check the display for status messages. • Sensor may be out of calibration; verify with the GSTK-6000.
$ETCO_2$ display window is not showing a CO_2 waveform or value.	• Monitor may be in the SpO_2 mode; change to the CO_2/SpO_2 monitoring mode. • N-6000 may not be connected correctly to the patient airway; verify secure and proper connections. • CO_2 module may have an internal error; check the display for status messages. • Water condensation or patient secretions may occlude sapphire windows; clean or replace ADAP-UC, as required.

8.2 ADVISORY MESSAGES

Advisory messages are displayed by the system to provide information to the operator. Advisory messages are displayed on the display screen and will disappear when the underlying reason for the message no longer exists.

AIRWAY ADAPTER OCCLUDED

- The message indicates that the CO_2 bench signal is reduced due to an obstruction of the airway adapter. Other causes include obstructions on the sapphire windows or internal electromechanical faults.

CO_2/SpO_2 SENSOR NOT CONNECTED

- If the sensor is removed, the SENSOR NOT CONNECTED message is displayed. If a physiological signal has been detected and the sensor is removed, an audio alarm sounds. To clear this alarm, press the ALARM SILENCE button twice.

CO_2 SENSOR WARMING UP

- The CO_2 sensor may be at a temperature that is below the specified operating range and requires a short time period to warm up to the desired operating temperature. The CO_2 SENSOR WARMING UP message is displayed during this time period.

PULSE SEARCH

- Indicates that the SpO_2 sensor is connected but no pulse is being detected. When a sensor is initially connected to the monitor and not to the patient, a pulse search message is displayed without a tone. If a valid physiological pulse is detected and then the pulse is lost, an alarming pulse search condition is activated. To clear this alarm, press the ALARM SILENCE button twice.

TREND DATA LOST, ERROR 125

- This message is displayed at power-up if stored trend data have been lost. This may have occurred if the battery was disconnected. If the battery has not been replaced, contact Nellcor's Technical Services Department or Nellcor's representative. Press any function key to clear the message and continue.

CUSTOM DEFAULTS LOST, ERROR 126

- This message is displayed at power-up if the custom default settings have been lost; the factory default settings will be used. Press any function key to clear the message and continue. Contact Nellcor's Technical Services Department or Nellcor's representative for further information.

8.3 STATUS MESSAGES

A status message is displayed when an error condition occurs. An error condition will be identified by a module identifier and an error code number that will assist service personnel in troubleshooting the problem. Most error messages can be cleared by pressing any function key. In the case of a defective submodule, the submodule will be automatically disabled.

8.3.1 *Main System Errors*

Error Code	Meaning	Recommended Corrective Action
101	RAM error	Turn the N-6000 off by pressing the ON/STANDBY button. Wait at least 20 seconds, then turn it back on. If the message persists, contact qualified service personnel or Nellcor's representative. For error conditions 125 and 126, press any function key to continue.
102	ROM error	
103	LED segment out	
104	Noritake RAM error	
122	EEPROM error	
125	TREND data error	
126	Custom defaults error	

8.3.2 *CO_2 Subsystem Errors*

Error Code	Meaning	Recommended Corrective Action
201	CO_2 RAM error	The capnography subsystem is automatically halted and is not operational. Cycle mains power on and off, then retry. Contact qualified service personnel or Nellcor's representative regarding the capnography subsystem.
202	CO_2 ROM error	
205	CO_2 analog error	
206	CO_2 general hardware failure	
210	CO_2/host communications error	

8.3.3 *CO_2 Sensor Errors*

Error Code	Meaning	Recommended Corrective Action
250	CO_2 Sensor General Failure.	The capnography subsystem is not operational because of a problem with the CO_2 sensor. Disconnect, then reconnect the CO_2 sensor. Try another CO_2 sensor. Clean the airway adapter. Check for excessive heat or cold being applied to the sensor from an external source. Contact qualified service personnel or Nellcor's representative to have the CO_2 sensor repaired.
252	CO_2 Sensor EEPROM Error.	
260	CO_2 Sensor Temperature Failure.	
261	CO_2 Sensor Temperature Too Low. This message appears while monitoring if sensor temperature drops below 36° C for 30 seconds or more.	
262	CO_2 Sensor Temperature Too High. This message appears while monitoring if sensor temperature rises above 46° C for 30 seconds or more.	Retry sensor (see procedure above). If the error continues to persist, contact Nellcor's Technical Services Department.

8.3.3 CO_2 *Sensor Errors (continued)*

Error Code	Meaning	Recommended Corrective Action
270	CO_2 Sensor Motor Speed Out of Range. This message appears when the sensor chopper motor is running too fast or too slow.	The capnography subsystem is not operational because of a problem with the CO_2 sensor. Disconnect, then reconnect the CO_2 sensor. Try another CO_2 sensor. Clean the airway adapter. Check that the IR source is illuminated. Check the optical path for an obstruction. Contact qualified service personnel or Nellcor's representative to have the CO_2 sensor repaired.
280	CO_2 Sensor Manufacturer ID Mismatch. This message appears when the sensor ID stored in the monitor's EEPROM does not match the Nellcor ID. It also may be an indication of a fault in the sensor's EEPROM.	Retry sensor (see procedure above). If the error continues to persist, contact Nellcor's Technical Services Department.
290	Sensor low signal fault.	

8.3.4 SpO_2 *Subsystem Errors*

Error Code	Meaning	Recommended Corrective Action
301	SpO_2 RAM error	The oximetry subsystem is not operational. Contact qualified service personnel or Nellcor's representative regarding the oximetry subsystem.
302	SpO_2 ROM error	
310	SpO_2/host communications error	

SECTION IX
Spare Parts

9.1 INTRODUCTION

This section lists N-6000 spare parts, both electrical and mechanical.

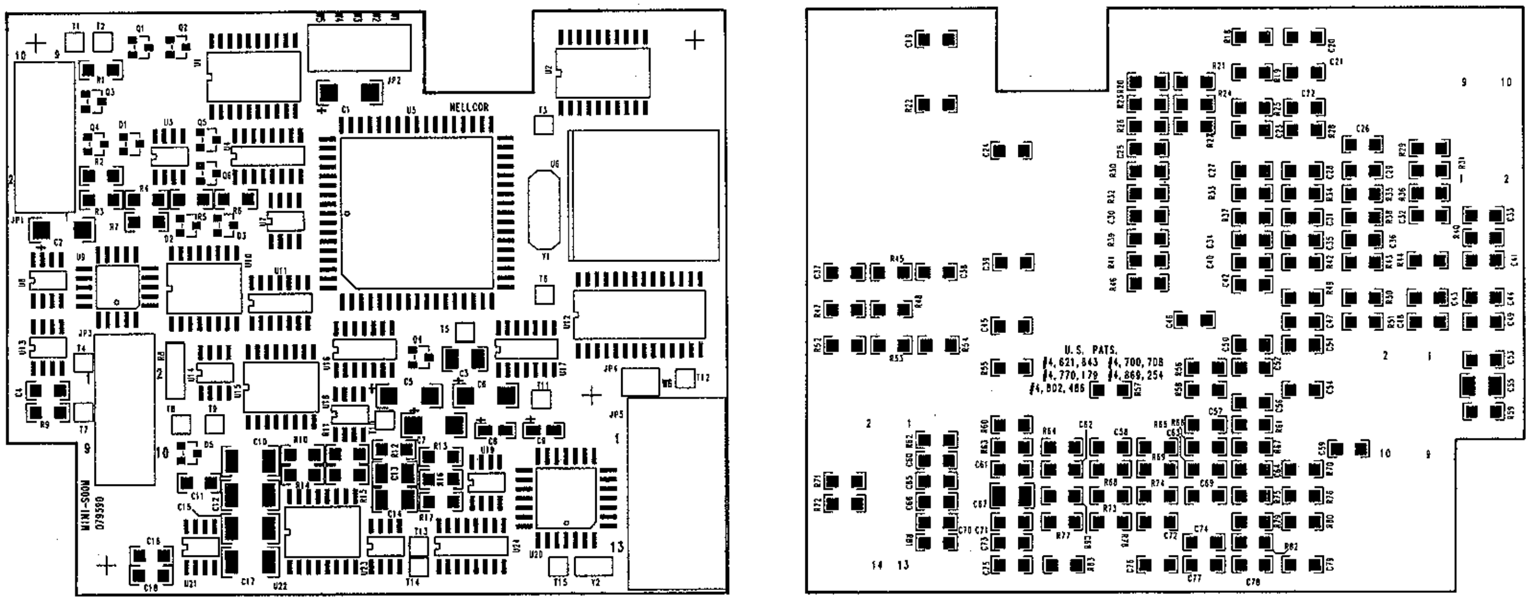
Description	Nellcor Part Number
Main Processor PCB	026414
Power Supply-Charger PCB	026413
Display Controller PCB	026419
CO_2 Module	026418
Oximetry Module	MP-203
Display	026420
Battery	026417
Transformer Assembly	026416
Bezel Assembly	026415
Speaker Assembly	026421
Bezel Keypad	024612
Upper Bracket	024613
Lower Bracket	024614
Chassis	024615
Pull-Out Card Tray	024616
Rear Panel lug with hardware	024617
Rubber Foot Holder	025409
Cover/Handle Assembly	024620
Handle Mounting Clips	024622
Handle	024623
Power Entry Module	026422
Sensor Door	024646
Harness Assembly	024630
Ribbon Cable, 10-Conductor	024635
Ribbon Cable, 14-Conductor	024636
Ribbon Cable, 26-Conductor, 5-1/2 inch	024637
Ribbon Cable, 26-Conductor, 1-3/4 inch	024638
Ribbon Cable, 34-Conductor	024639
Front Bezel	024640
Display Shield	024642
Fuse holder	024626
Filter	024676
Filter Bezel Assembly	024677
Tilt Stand Foot	025398

SECTION X
Component Location

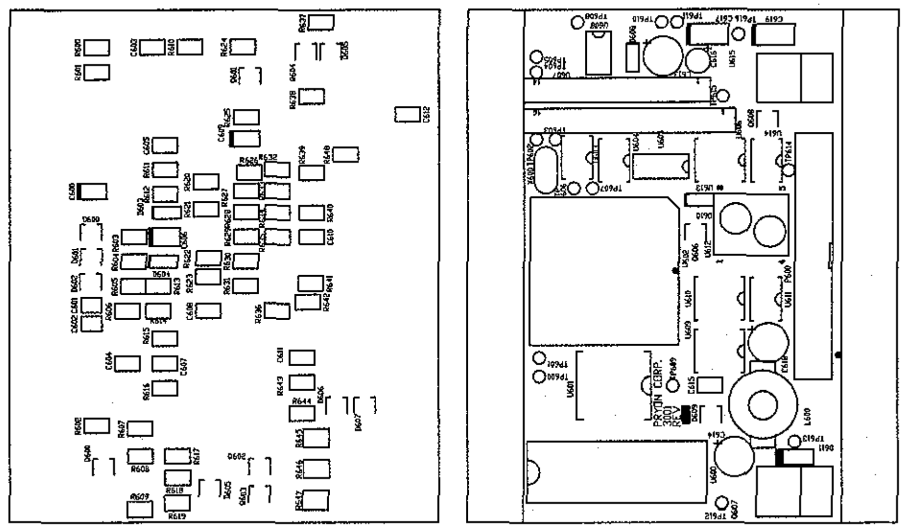
10.1 OVERVIEW

This section contains PCB drawings, showing component location.

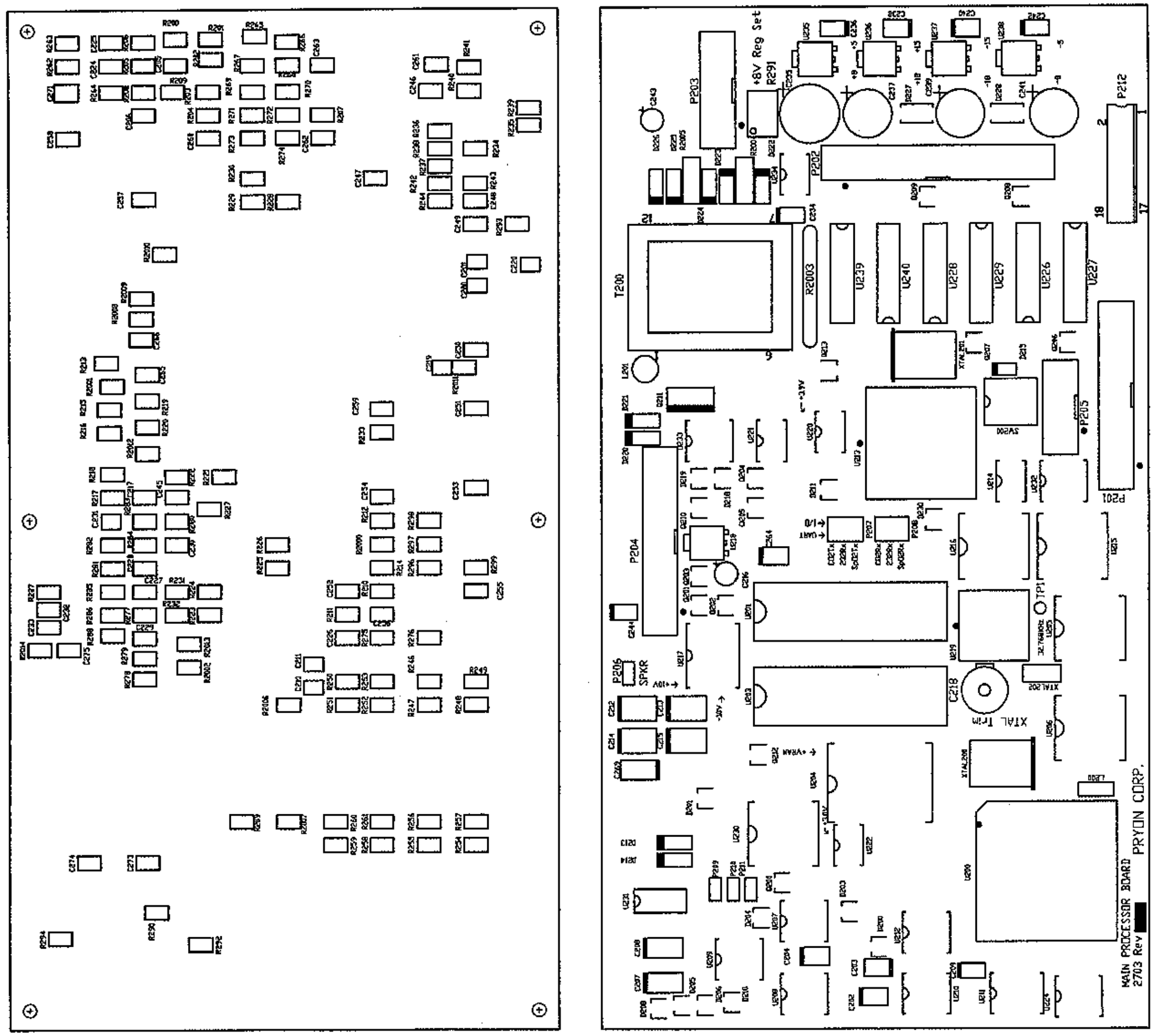
Drawing **Page**



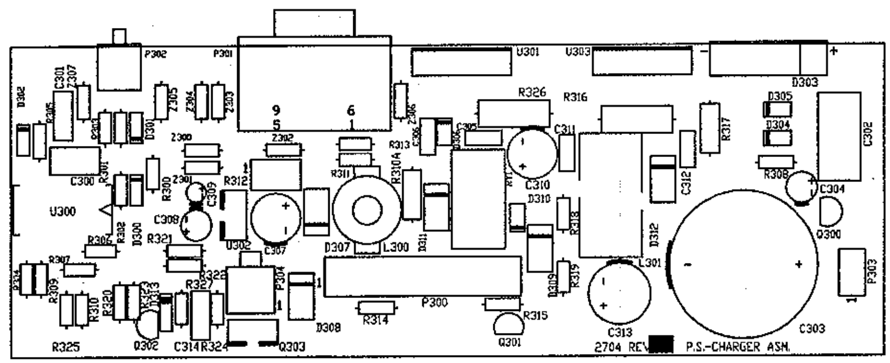
Oximetry Module PCB



CO$_2$ Module PCB



Main Processor PCB



Power Supply-Charger PCB