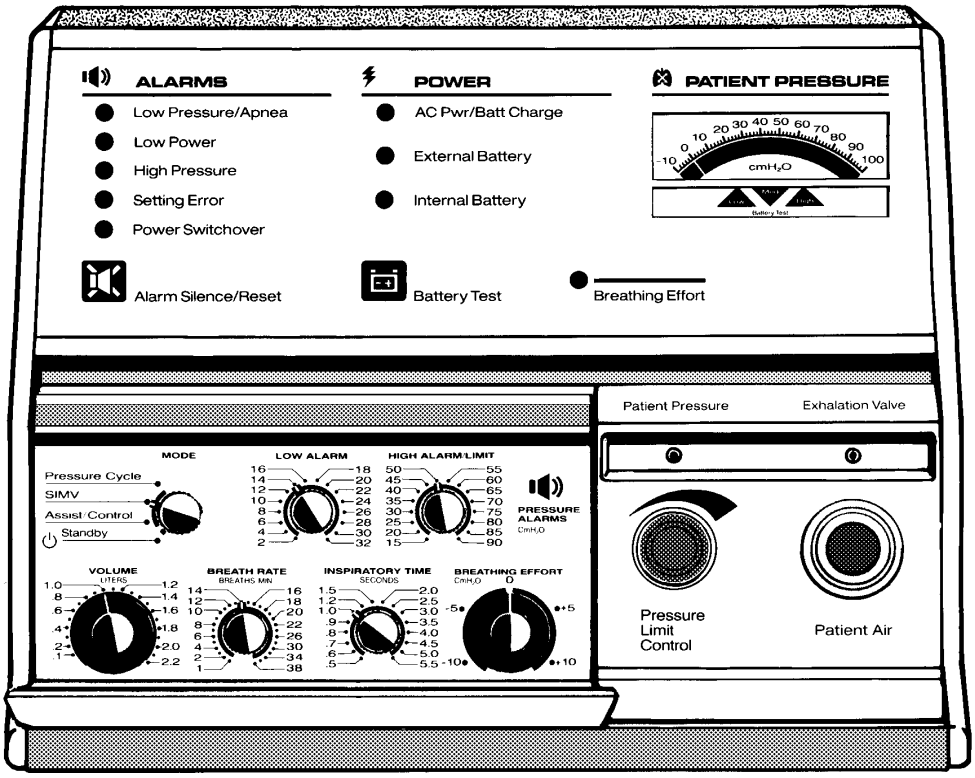
LP6 Plus, LP10, and LP20 Volume Ventilators
Technical Manual



NELLCOR PURITAN BENNETT

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For more information: For information on our full line of medical equipment and related services, contact Nellcor Puritan Bennett directly. General: (800) 497-4979. Customer Service: (800) 497-4968. Technical Service: (800) 497-3787.

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1 Introduction

This Technical Manual provides procedures to verify and maintain the LP6 Plus, LP10, and LP20 Volume Ventilators. It is not intended to be a complete maintenance document and therefore contains no disassembly, repair, or reassembly instructions.

Refer any adjustments or procedures that exceed the scope of this manual to a Nellcor Puritan Bennett Technical Service Representative by calling:

800-497-3787

Chapters

This manual consists of the following chapters:

Description Identifies all features and functions of the ventilators.

Testing Provides procedures for verifying unit operation.

Theory of Operation A detailed overview of the ventilators, with a block diagram to supplement the text.

Maintenance Outlines preventive maintenance procedures and troubleshooting.

What's New in this Revision

Chapter 3 Testing **Patient Circuit Leak** has been updated.

Chapter 4 Theory of Operation Surface-mount logic and power/motor boards are being used in addition to through-hole boards. Details are given for all board types.

Newer production units have an internal battery charge voltage of 14.4V.

Chapter 5 Maintenance New procedure has been added for inspecting and replacing the Flatpak inlet filter.

Chapter 7 Schematics Part descriptions added to drawings.

New surface-mount board drawings added.

Back panel drawing updated with new grounding scheme.

Conventions

The following differentiation is made in this manual between Notes, **Cautions,** and **Warnings:**

Note Directions that make it easier to use or service the product.

Caution Directions that help avoid damaging the ventilators.

Warning **Directions that warn of conditions or actions that put the patient, the technician, or other people at risk of injury.**

2 Description

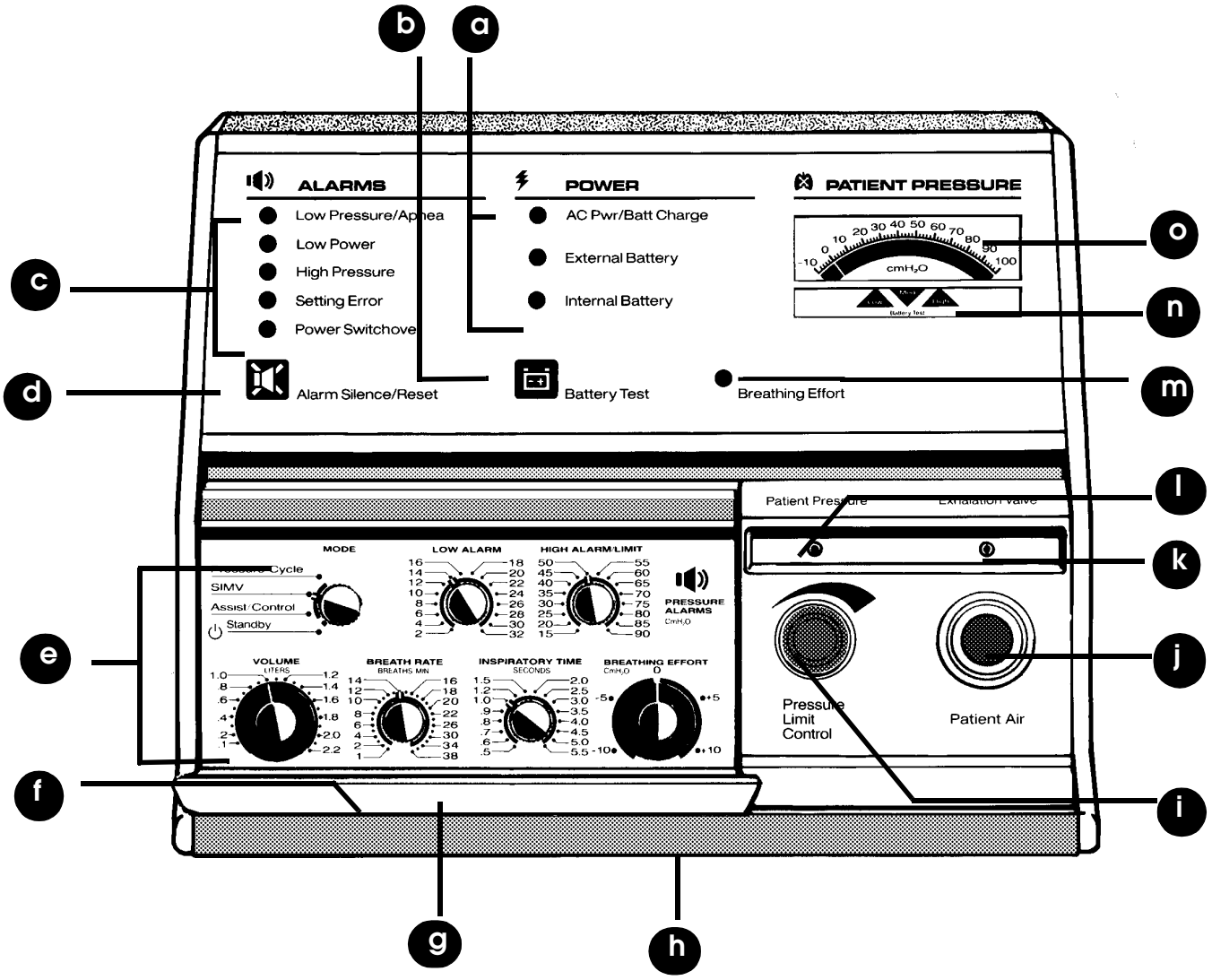
The Nellcor Puritan Bennett LP6 Plus, LP10, and LP20 are microprocessor-controlled Volume Ventilators. They provide continuous respiratory support for patients encountering ventilatory insufficiencies in home or hospital settings, or in transport.

The ventilators offer a range of delivery volumes, inspiratory times, and breathing rates. The control knobs in the recessed front panel allow the physician or respiratory therapist to set the parameters that will provide appropriate ventilation. The door panel and knobs are designed to prevent tampering and accidental setting changes.

The ventilators provide both audible and visual alarms. See the *Troubleshooting* section for a complete list of alarms, indications, and possible causes.

Components

Front Panel (LP20 shown)



a **Power Source Indicators** Green Light is on when AC power is in use and either battery is charging. Solid Amber Light is on when an external battery is providing power. Flashing Amber Light is on and audio signal every five minutes when internal battery is in use.

b **Battery Test** Press this button for a test of external/internal battery charge level (the ventilator must be operating on the battery being tested). Read results on Battery Condition scale of the **PATIENT PRESSURE** meter. Press in combination with **ALARM SILENCE/RESET** for operating hours on machine. Read results on **PATIENT PRESSURE** meter and multiply the number indicated on the meter by 200.

c **Visual Alarm Indicators** These LEDs identify alarm conditions or alarm pre-silence.

d **ALARM SILENCE/RESET** Button Push to test alarms (on the LP20, hold for 3 seconds). Push to pre-silence alarms for 60 seconds (LP20 only). Push to silence any audible alarm (except setting error or apnea alarms) for 60 seconds. A silenced alarm will automatically reset when the condition is corrected.

e **Ventilator Control Knobs** See "Operating Controls" on page 2-5 for details. **VOLUME** and **BREATHING EFFORT** controls are locking, skirted knobs; push in and turn to change setting.

f **Alarm Reference Guide** Summary of alarm functions with suggestions for corrective action.

g **Control Panel Door** Magnetically latched to protect controls.

h **Front Carrying Handle**

i **Pressure Limit Control (LP10, LP20)** This control limits the patient pressure during an assisted or controlled breath. The pressure limit control knob has a locking outer ring; push the outer ring in and turn the small center knob to change settings.

j **PATIENT AIR Port** Standard 22 mm connection for patient air tube.

k **EXHALATION VALVE Port** A connection for the exhalation valve tubing of the patient circuit.

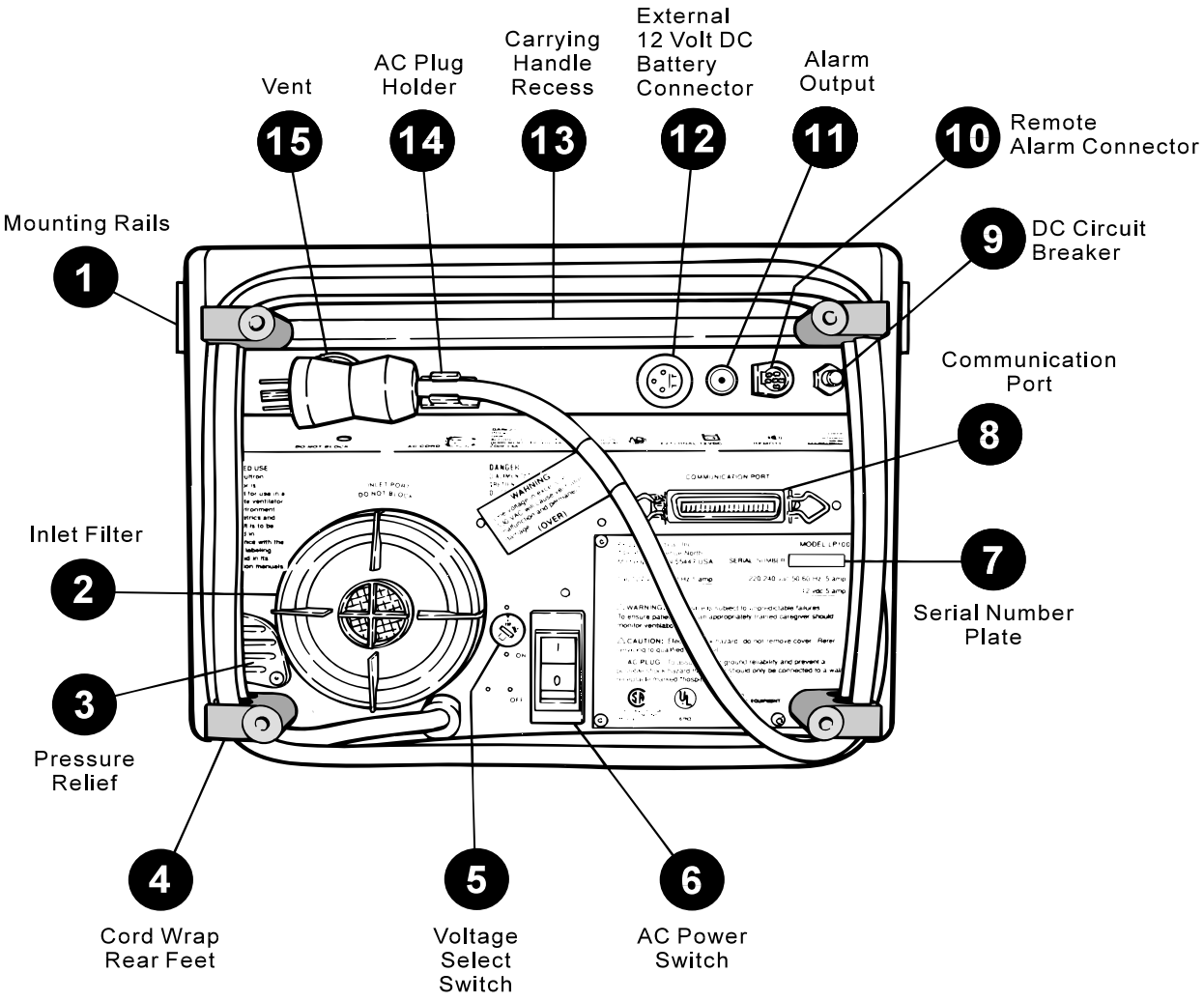
l **PATIENT PRESSURE Port** A connection for the proximal pressure line of the patient circuit. Connection and line are color coded with black stripe.

m **BREATHING EFFORT** Green light is activated by patient breathing effort. Breathing effort sensitivity is set by the **BREATHING EFFORT** control knob.

n **Battery Condition Scale** While pressing the **BATTERY TEST** button, read the battery condition here.

o **PATIENT PRESSURE** Meter Displays proximal pressure. Also displays battery charge level and machine hours of operation when appropriate buttons are pressed.

Back Panel (LP20 shown)



1 Mounting Rails Connection for accessories.

2 INLET FILTER with Screw Off Cap Patient air is drawn through this filter. Protects airflow and allows for easy filter change. *Do not block.*

3 Pressure Relief

4 Cord Wrap and Rear Feet

5 Voltage Select Switch

6 AC Power Switch/Circuit Breaker

7 Serial Number Plate

8 COMMUNICATIONS PORT Connector for optional printer.

9 DC Circuit Breaker

10 REMOTE ALARM Connection

11 ALARM OUTPUT (LP20 only) 1/4" phone jack for connecting the ventilator to a nurse call station.

12 EXTERNAL 12VDC BATTERY Connector

13 Rear Carrying Handle Recess

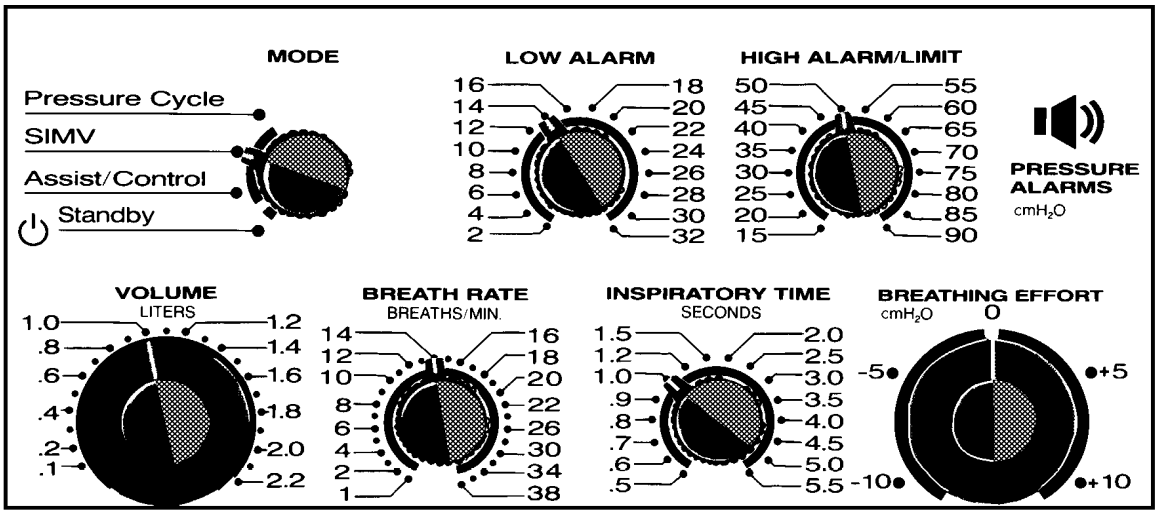
14 AC Plug Holder

15 Vent *Do not block.*

Operating Controls

Warning

Periodically check the control panel to be sure that the controls are on the prescribed settings. The settings should not be changed without the order of a physician.



MODE Control: Selects modes of operation. See page 2-6.

VOLUME Control: Sets the breath volume. Push in, then turn the knob to change the setting. When adjusted, the volume changes in 100 ml steps during each breath until the new volume is reached.

BREATH RATE Control: Adjusts the number of breaths per minute.

INSPIRATORY TIME Control: Adjusts delivery time for the breath.

BREATHING EFFORT Control: Adjusts the patient effort needed to trigger a machine delivered breath. Push in, then turn to change the setting. When a breath is sensed, the **BREATHING EFFORT** indicator lights.

LOW ALARM: Sets the low pressure limit. The low pressure alarm sounds if this limit is not reached for two consecutive breaths.

HIGH ALARM/LIMIT: Sets the high pressure alarm or high pressure limit. The high pressure alarm sounds when the setting is exceeded (except in Pressure Limited mode). The alarm stops when the pressure drops to a lower level. Inspiration ends when the set point is reached.

Modes of Operation

Modes are set by a 4-position **MODE** switch. The modes are as follows:

- Standby
- Assist/Control
- SIMV
- Pressure Cycle

Standby In this mode, the ventilator is placed in a Standby mode, while both the external or internal batteries are being recharged. AC power must be on. Patient assisted ventilation cannot occur in this mode, but spontaneous breathing through the machine can occur.

Note Batteries charge equally well in all **MODE** switch positions.

Assist/Control The ventilator functions as an assistant or controller, depending upon the patient inspiratory efforts. The Assist mode permits the patient to receive patient-initiated breaths, delivered when the patients inspiratory effort creates a negative pressure that equals or exceeds that set on the **BREATHING EFFORT** control.

If the patient fails to breathe spontaneously or to achieve the required negative pressure, the ventilator takes control and delivers a breath to the patient. The ventilator continues to function as a controller until the patient resumes spontaneous inspiratory efforts at an acceptable rate and depth (negative pressure).

If the breathing rate is set at less than 6 BPM and the patient makes no spontaneous effort, the apnea alarm sounds within 10 seconds; the ventilator then delivers 10 BPM at the preset volume.

SIMV The SIMV (Synchronized Intermittent Mandatory Ventilation) mode permits patients to breathe spontaneously between mandatory machine-delivered breaths. This mode is frequently used where sleep apnea may occur, to assist patients with advanced COPD, or to wean patients from mechanical ventilation.

Under normal SIMV operation, the ventilator delivers mandatory breaths at a rate set on the **BREATH RATE** control. The ventilator monitors the patients spontaneous breathing and synchronizes these mandatory breaths to improve patient comfort.

If the patients inspiratory efforts stop, the following occurs:

- For preset SIMV rates between 1 and 5 BPM, an apnea alarm sounds after 20 seconds, and the ventilator delivers 10 BPM at the set volume.
- At rates of 6 BPM or greater, the ventilator will continue to deliver mandatory breaths at the set rate and volume; the apnea alarm will not sound.

Pressure Cycle

This mode is similar to the Assist/Control mode with the exception that the **HIGH ALARM/LIMIT** (pressure) control determines inspiratory cutoff. Therefore, if the pressure limit set on the **HIGH ALARM/LIMIT** control is reached before the set inspiratory volume is delivered, this pressure limit terminates inspiration, regardless of volume delivered, and no alarm sounds. The high pressure limit may be selected from 15 to 90 cmH_2O above atmospheric pressure. If the termination is ineffective, causing the pressure to exceed the high pressure limit setting by more than 10 cmH_2O, the **HIGH PRESSURE** light and audio alarm activate.

If the patient makes no effort to breathe, the ventilator will take control and deliver air. Exactly how this occurs depends on the **BREATH RATE** setting:

With **BREATH RATE** set at 1-5 BPM: If the patient does not start a breath for 10 seconds, an apnea alarm signals the caregiver; the ventilator delivers 10 breaths per minute at the set volume, or until it reaches the set pressure limit.

With **BREATH RATE** set at 6 BPM or greater: The ventilator will continue to deliver breaths at the set rate. The apnea alarm will not sound unless the ventilator cannot deliver a breath.

Ventilator Parameters

Volume The delivered volume, or tidal volume, is set using the front panel **VOLUME** control. This push-to-turn control sets piston excursion, with continuous settings ranging from 100 to 2200 ml.

Breath Rate Breathing rates (breaths per minute) are adjustable using the **BREATH RATE** control. The control permits rates of 1 to 20 BPM (in increments of 1 BPM), and 22 to 38 BPM (in increments of 2 BPM).

Inspiratory or I-Time The **INSPIRATORY TIME** control adjusts the rate of air flow being delivered into the patients lungs, thereby varying the amount of time that is required to deliver the set volume. Inspiratory time settings range from 0.5 to 1.0 sec. (in increments of 0.1 sec.), and 1.5 to 5.5 seconds (in increments of 0.5 sec.). Expiratory time and the I/E ratio are determined by the **INSPIRATORY TIME** and **BREATH RATE** settings; flow rate is determined by the **VOLUME** and **INSPIRATORY TIME** settings.

Note **BREATH RATE** and **INSPIRATORY TIME** settings that would result in inspiratory time longer than expiratory time will cause a **SETTING ERROR** alarm. The ventilator will deliver at the set inspiratory time at an I/E ratio of 1:1.

Breathing Effort The **BREATHING EFFORT** control allows the operator to set the patient effort necessary for triggering a machine-delivered breath, or to reset the apnea alarm (at breathing rates of 1 - 5 BPM). Settings are continuous from -10 to +10 cmH_2O, with zero being atmospheric pressure. When a sufficient breathing effort is sensed, the green **BREATHING EFFORT** indicator lights. Control settings above zero (+) are used to compensate for Positive End Expiratory Pressure (PEEP).

Warning

BREATHING EFFORT settings above zero without the use of PEEP may cause the ventilator to autocycle (come on and off repeatedly without patient effort).

Pressure Alarms

A front panel **LOW ALARM** control sets the low pressure limit. Available alarm limits are 2 to 32 cmH_2O (increments of 2 cmH_2O). The alarm sounds only after the low pressure setting has not been achieved for two consecutive breaths.

Note On the LP20, the audible alarm is double-pulsed for Low Pressure alarm events.

A separate **HIGH ALARM/LIMIT** control permits the operator to set the high pressure limit point. In Assist/Control or SIMV ventilation, the alarm will sound whenever the high alarm setting is exceeded, but the alarm automatically stops when the pressure drops to a level below the limit. This control also sets the high pressure limit for pressure limited ventilation. In this mode, inhalation is terminated when the high pressure alarm set point is exceeded. The high pressure alarm does not sound in the PRESSURE LIMITED mode unless the pressure limit is exceeded by 10 cmH_2O or more. Available settings are 15 to 90 cmH_2O in increments of 5 cmH_2O.

Supplemental Oxygen

The ventilator includes provisions for the addition of prescribed supplemental oxygen. The ventilator delivers up to 40% oxygen concentration when the oxygen elbow and fitting is used. Concentrations up to 100% are attainable when oxygen is delivered through the inlet filter port (located on the rear panel), using the Oxygen Enrichment Kit. Instructions for delivering supplemental oxygen are included with these accessories.

PEEP

PEEP (Positive End Expiratory Pressure) is accomplished with the ventilator by connecting an accessory valve to the patient circuit. The ventilator is PEEP-compensated for up to +10 cmH_2O. Complete PEEP instructions are included with these accessories.

Humidification

When humidification is prescribed, several humidification devices are compatible with the ventilator. Under normal extended use, an active humidifier is often recommended. Nellcor Puritan Bennett can supply a mounting bracket that is especially designed for the most popular humidifiers. Connection information is supplied with the mounting bracket.

A passive, in-line regenerative humidifier such as an artificial nose is commonly used to conserve humidification during patient transport or wheelchair use. It is intended for short-term use only. The regenerative humidifier retains portions of the exhaled heat and humidity, to aid in conditioning subsequent inhalations.

12-Volt External Battery Capability

The ventilator can operate from a mobile power source by connecting the ventilator to a 12 V battery and disconnecting the AC power. A **POWER SWITCHOVER** alarm signals the change from an AC power source to an external battery. A deep-cycle battery, 74 amp-hour in good condition, can operate the ventilator without recharging for approximately 24 hours. A gel-cell type battery (34 amp-hour) can operate for approximately 10 hours between recharges. The ventilator is capable of recharging an external battery, but it is less efficient than using a standard battery charger. Approximately three hours recharge time is required for each hour of use.

Caution

An external battery must be recharged immediately after use. A standard battery charger is strongly recommended.

Internal Battery

The ventilator switches to its internal battery should the AC power source fail or the unit become disconnected from the power source. The internal battery also takes over automatically when power from an external battery becomes inadequate. A **POWER SWITCHOVER** alarm signals the change to internal power. The ventilator can operate from 30 to 60 minutes on the internal battery, depending on the charge level and on the control settings. Therefore, the internal battery should be used only for emergency power backup.

The amber **INTERNAL BATTERY** light flashes continuously, and a single-tone audio alarm sounds every five minutes when the internal battery is in use. The ventilator charges the internal battery in three hours when the ventilator is connected to AC power and the **MODE** switch is in any position. A discharged internal battery must be recharged for at least three hours prior to turning off the ventilator to prevent shortening internal battery life.

Caution

The internal battery must be recharged for three hours immediately after use. An external battery cannot recharge the internal battery.

Warning

If the patient's health or safety would be jeopardized by long-term power failure, a reliable backup power source is mandatory. The caregiver and patient are cautioned not to regard the internal battery as long-term power backup.

Accessories

A number of accessories are available for the ventilator, including a printer. For details, see your Nellcor Puritan Bennett Representative.

Specifications

LP6 Plus, LP10, and LP20 Volume Ventilators

Power Line

110 VAC range (100-127 VAC) or 220 VAC range (220-240 VAC), 50/60 Hz, external voltage selector switch.

Power Usage

Maximum: 630 kW per year

Nominal: 315 kW per year

Extension Cord Gauge: Use three-conductor cord only; up to 49', use 18 gauge cord; up to 99', use 16 gauge cord; up to 200', use 14 gauge cord

External Battery: Approximately 20 hrs operation with 75-80 amp-hour 12 VDC deep-cycle, gel-cell battery. Approximately 10 hrs operation with 35-40 amp-hour 12 VDC deep-cycle, gel-cell battery

Internal Battery: Approximately one hour operation

Type

Volume ventilator

Motor: Brushless induction

Pump: Piston, 100-2200 ml tidal volume capability

Front Panel Controls

Alarm Silence/Reset: Push-button to pre-silence alarms before events (LP20 only), silence alarms during events, or reset alarms after events; used with Battery Test button to read machine operating hours on Patient Pressure meter

Battery Test: Push-button to show battery charge level on the lower window of Patient Pressure meter (unit must be operating on battery)

Mode: Rotary switch to set ventilator operating mode: Standby, Assist/Control, SIMV, or Pressure Cycle

Low Alarm: Rotary switch to set limit for Low Pressure alarm: 2-32 cmH_2O in increments of 2 cmH_2O

High Alarm/Limit: Rotary switch to set limit for High Pressure alarm (Assist/Control, SIMV modes), or limit for Pressure Cycle mode: 15-90 cmH_2O in increments of 5 cmH_2O

Volume: Push-to-turn knob to set volume: continuously adjustable from 100 to 220 ml

Breath Rate: Rotary switch to set breathing rate: 1-20 BPM in increments of one BPM, and 22-38 BPM in increments of two BPM

Inspiratory Time Rotary switch to set time for delivery of set volume: 0.5-1.0 sec. in increments of 0.1 sec.; 1.2 sec.; and 1.5-5.5 sec. in increments of 0.5 sec.

Breathing Effort: Push-to-turn knob to set pressure level for detecting breathing effort: continuously adjustable from -10 to +10 cmH_2O

Pressure Limit (LP10, LP20): Locking knob sets pressure limit level from 15-50 cmH_2O or Closes off the pressure limit feature

Input

Patient Pressure: Port for connection to the proximal pressure line of the patient circuit

Outputs

Patient Air: 22 mm tube for connection to the bacteria filter

Exhalation Valve: Port for connection to the exhalation valve of the patient circuit

Indicators

Normal Events
Patient Pressure Meter: Displays patient pressure -10 to +100 cmH_2O; also displays battery charge and machine hours of operation when appropriate buttons are pressed.
Breathing Effort: Green LED activated by adequate patient breathing effort.
Power: LEDs to indicate operating power source: green AC Pwr/Batt Charge, amber External Battery, flashing amber Internal Battery.

Alarms: **Flashing Red LEDs:** Low Pressure/Apnea, Low Power, High Pressure, Setting Error, Power Switchover

Audible Alarms:
Double-Pulsed Tone: Low Pressure/Apnea (LP20 only)
Pulsating Tone: Low Pressure/Apnea (LP6 Plus, LP10), Low Power, High Pressure, Setting Error, Power Switchover
Steady Tone: Loss of microprocessor control, depleted internal battery
Reminder Tone: Every five min. when powered by internal battery, and each time accessory printer generates a report

Rear Panel Controls

AC Circuit Breaker: Internal to the AC power switch (1 for on, 0 for off)

Inputs

Inlet Filter: Intake for patient air, screw-off cap for filter change

External Battery: Connection for 12 VDC battery

Communication Port Calibration information during service procedure

Outputs

Vent: Cooling vent for internal ventilator components

Communications Port: Connection for optional printer or display

Alarm: Connection for Remote Alarm accessory

Alarm Output: (LP20 only) Factory default is normally open relay, 1.67 Hz 50% duty cycle open/closed for Low Pressure alarms; closed for all other alarm conditions and when mode is set to Standby. Can be changed to normally closed; call Technical Service (800 497-3787) for details. 32 VDC @ 0.5 A

Environment

Do not use or store in the presence of strong electromagnetic fields.

Operating: 5°-40°C (41°-104° F), 10-90%RH

Storage: -15°-50°C (5°-122°F), 10-90% RH; when moving from a non-operating to an operating environment, allow a minimum of one hour temperature stabilization before use

Maintenance

Preventive maintenance must be performed by qualified personnel every 6000 hours or recertification every 12 months, whichever occurs first

Dimensions

9.75" x 14.5" x 13.25" (24.6 x 36.8 x 33.6 cm)

Weight

~34 pounds (15.5 kg)

Ventilatory Factors

Resistance Factor: <0.05 cmH_2O/LPM

Emergency Pressure Relief: Approximately 100 cmH_2O

Flow: 20-100 LPM

3 Testing

This section provides instructions for verifying the general operation of the ventilator on a routine basis. Use this procedure to verify operation of a new ventilator before use with a patient.

Operational verification should be performed on a monthly basis by a qualified operator, or by a trained hospital or home care service technician, to ensure that the ventilator is operating as intended by the manufacturer.

An operational checklist, located at the end of this section, should be reproduced and used each time a verification is performed. A copy of the completed checklist should be maintained in the health care provider's file.

Simple procedures, such as the Daily Safety Check (listed in the User's Manual), and oxygen percentage verification (when required), should be performed at least once daily when the ventilator is in 24 hour use.

The Monthly Safety Check (listed in the User's Manual) provides an additional test which the caregiver must perform.

Note

This procedure was designed to minimize the need for special test equipment, and to eliminate the need for disassembly of the ventilator. These restrictions limit the accuracy of tests involving time and rate; such tests are marked with an asterisk. Before accepting or rejecting a unit based on these tests, ensure that the results are not due to procedural error.

Scope

These procedures verify operation without use of special calibration equipment, and without disassembling the ventilator.

Note Calibration and testing beyond the scope of this manual should be preferred to an authorized service technician.

The checkout procedure in this section includes:

- Visual inspection of controls, attachments, accessory items, and external surfaces.
- Power functions, including battery recharging.
- Control modes: Assist/Control, SIMV, Pressure Cycle.
- Key Operational Parameters, including volume delivered, breathing rate, inspiratory time, pressure limiting, and trigger sensitivity (breathing effort).
- All alarms and indicator functions.
- Patient circuit functions and possible leaks.

Warning

Do not use the ventilator if it does not pass all of the verification procedures. Refer the ventilator to a Nellcor Puritan Bennett Service Technician for repair and calibration.

Note Time and rate tests marked with an asterisk have limited accuracy. Before accepting or rejecting a unit based on these tests, ensure that the results are not due to procedural error.

Equipment

In addition to the ventilator, the following Nellcor Puritan Bennett equipment is required for a complete operational verification test:

- Patient Circuit with test lung
- Exhalation Manifold Valve
- Bacteria Filter
- DC Power Cable Assembly
- 12 VDC Battery

Refer to the table below for a listing of required test equipment and recommended supplier.

Equipment	Recommended Supplier
Respirometer (hand held)	Wright
	Fraser-Harlake
	Ferrairs Medical
Stop Watch	Any
Syringe (10cc or larger)	Any
Tubing (1/8" I.D.)	Any

Test Equipment Accuracy

Ascertain the accuracy of any test equipment being used for operational verification. Make certain that the calibration procedures and date comply with the test instrumentation requirements adopted by the testing organization.

Supplies

- ❒ Isopropyl Alcohol (a cleaner)
- ❒ Absorbent wipes or clean towels or cloths

Procedure

Operational verification should be performed by a qualified operator or service technician familiar with the function, setup, and operation of the ventilator. For basic operational information, refer to the LP6 Plus and LP10 User's Manual or the LP20 Clinician's Manual.

Warning

Do not use the ventilator if it does not pass all of the verification procedures. Refer the ventilator to a Nellcor Puritan Bennett Service Technician for repair and calibration.

Visual Inspection

Cleaning

Prior to inspecting and testing the ventilator, clean the exterior with a bactericidal or germicidal agent. Use isopropyl alcohol on the display panel. Do not allow liquid cleaning agents to penetrate the inside of the ventilator.

Warning

Any liquid leaking into the ventilator or its connections may damage the unit or result in an electrical shock hazard.

Cabinet

Examine the cabinet for scratches, dents, or deformities. Screw seals on the side panel covers should be intact. Side mounting brackets should be securely attached. Rubber feet should be in place and not broken or cracked.

Display Panel

Check the display panel for cracks or breaks. Check the meter window for scratches and debris. The meter needle should be within one division of -10.

Control Panel

Open the magnetically secured control panel door. Inspect each control knob to ensure it is not chipped, broken or loose on its shaft. Make certain the press-to-turn knobs (**VOLUME** and **BREATHING EFFORT**) operate correctly. Check the indexing of the knobs. Turn them to their left and right limits to insure proper alignment at both limits and to assure they have not slipped on their respective shafts. If misalignment is detected, calibration should be verified by an authorized Nellcor Puritan Bennett Service Technician.

Front Panel Connection

Check the front panel connection ports for cracks, dents or bent tubes. Ensure that they are free of foreign matter. LP10 or LP20: Inspect the **PRESSURE LIMIT** knob to ensure that it is not chipped, broken, or loose on its shaft. Make sure that the outer ring locks the small, inner knob.

Rear Panel

Check the rear panel for dirt, or damage. Examine the power cord for damaged insulation. Check the plug for bent pins or breaks. Examine the **EXTERNAL BATTERY,** and **COMMUNICATIONS PORT** for secure attachment and unbent connector pins.

Inlet Air Filter

Unscrew the cap to the inlet air filter, and check the air filter for cleanliness. Replace the air filter when it becomes discolored. Insert a clean filter so any printing is towards the front of the ventilator.

Caution

This filter should be checked weekly (or daily if the ventilator is being used for transport or in an outdoor environment). A blocked filter may cause setting error alarms as well as serious damage to the ventilator.

Caution

Correct any problems found during the visual inspection before proceeding to unit checkout.

Control Settings

Unless otherwise stated, set the controls to the standard settings listed in the table below.

Control	Setting
MODE	Standby
LOW ALARM	2 cmH_2O
HIGH ALARM/LIMIT	90 cmH_2O
VOLUME	2.2 Liter
BREATH RATE	6 BPM
INSPIRATORY TIME	1.5 seconds
BREATHING EFFORT	-5 cmH_2O
PRESSURE LIMIT (LP10 and LP 20 ONLY)	Fully clockwise
AC POWER SWITCH	OFF

Connections

Unless otherwise specified, make the following external connections to the ventilator:

- Power Plug to 110 VAC (three prong, grounded)
- Patient hose (with exhalation manifold) to **PATIENT AIR** port (front panel)
- 500 ml Test Lung to exhalation manifold
- Proximal Pressure tube to **PATIENT PRESSURE** port (front panel)
- Exhalation valve tube to **EXHALATION VALVE** port (front panel)
- Connect to a fully charged external battery.
- (Optional) Calibrator to communication port (back panel)

Patient Circuit Leak Test

The following procedure tests the patient circuit for leaks. Ensure that no leaks are present before continuing with subsequent verification procedures. Note that this test is not intended to replace the self-test function of the ventilator. The self-test function performs several additional inspection steps to verify correct operation of the ventilator.

1. Turn the ventilator's power switch to ON.
2. Set the **MODE** switch from Standby to Assist/Control. Allow the unit to run for a minute to stabilize peak pressure readings (can be monitored by pushing the PEAK button on the calibrator).
3. Obtain a syringe (10 cc or larger) and attach a short length of 1/8" I.D. to the tip. Pull the plunger out as far as possible.
4. Immediately after a breath is completed and all air has been released through the exhalation manifold, remove the clear tubing from the top of the exhalation manifold. Quickly attach the syringe to the top of the exhalation manifold. Supply a slight amount of air with the syringe (approximately 3 cc).
5. Allow the ventilator to give one breath, then turn the Mode switch from Assist/Control to Standby.
6. Monitor the patient circuit pressure on the front panel meter or the calibrator (by pushing the PRESS button). The time required for the pressure to drop by 10 cmH_2O/hPa must be greater than 10 seconds in order to pass. Supply an extra cc of air from the syringe every several seconds if necessary to prevent the exhalation manifold from opening.
7. If the loss of pressure is too high, make sure that the Pressure Limit Control is fully clockwise (LP10 and LP20 only). Check the patient circuit. Make sure all hose fittings are tight. Check the exhalation valve and make sure that it seats properly in the manifold. Check the test lung for a secure fit or leaks.

Caution

Do not overtighten the Pressure Limit Control. Overtightening can cause system leaks.

8. Repeat the leak test procedure following any component modifications. If leaks persist, refer the unit to an authorized Nellcor Puritan Bennett Service Technician.
9. Disconnect the syringe and reconnect the exhalation valve tubing to the exhalation manifold.

Power Checkout

The following procedure verifies that the ventilator is properly powered by both AC and DC power sources, that power switchover occurs upon source power failure, and that the proper alarm and indicators activate.

Prior to beginning the checkout procedure, place all operating controls in the position identified under Control Settings on page 3-6 in this section. Record results on a copy of the Operational Checklist, located at the end of this chapter.

Switch/Action	From	To	Desired Response
AC Power Switch	OFF	ON	Indicator lights flash; AC PWR/BATT CHARGE light on; ventilator cycles once; pressure gauge at ± 1 division.
MODE	Standby	Assist/ Control	Alarm sounds and all indicators light for 2.0 ± 0.5 seconds; AC PWR remains on; ventilator cycles at 10 ± 1 BPM; gauge indicates pressure excursion.
AC Power Switch	ON	OFF	POWER SWITCHOVER light on; alarm sounds; EXTERNAL BATTERY light on; ventilator continues cycles.
Alarm silence	Press		Alarm and indicator OFF
Disconnect External Battery			POWER SWITCHOVER light on; alarm sounds; INTERNAL BATTERY light on; ventilator continues cycling.
Alarm silence	Press		Audible and visual alarms OFF
BATTERY TEST	PRESS & hold		Gauge indicates Internal Battery condition; INTERNAL BATTERY light flashes
AC Power Switch	OFF	ON	Internal Power LIGHT OFF; AC PWR light on
BATTERY TEST ALARM SILENCE	Press & hold at same time		Patient pressure meter reads ventilator operating time (i.e., a reading of 30 = 6000 operating hours).
MODE	Assist/ Control	Standby	Completes Power Checkout

Assist/Control Mode Checkout

Verify all operational functions with the ventilator in the Assist/ Control Mode Checkoutmode by performing the following. Record the results on a copy of the Operational Checklist located at the end of this chapter.

Prior to beginning the checkout procedure, place all operating controls in the position identified under Control Settings on page 3-6.

Note Volume variation will be a function of the respirometer accuracy, which is flow rate dependent. See the respirometer manual. Ventilator volume change occurs at a rate of 100 ml/breath cycle.

Switch/Action	From	To	Desired Response
MODE	Standby	Assist/ Control	Alarms/lights test; AC PWR LED on; gauge registers pressure
Time breaths			Rate equals 10 ± 1 BPM
BREATHING EFFORT	-5	1 line width (-) from zero	Set Breathing rate continues; BREATHING EFFORT LED off
Squeeze or extend test lung between controlled breaths		Negative pressure (slightly under zero)	Gauge registers (-) pressure effort; BREATHING EFFORT LED lights; ventilator delivers assisted breath
BREATHING EFFORT	Near 0	+1	Ventilator auto cycles
BREATHING EFFORT	+ 1	-5	Completes Breathing Effort check
Replace test lung and patient hose with respirometer; Block exhalation port			Volume reads 0.5 ± 100 ml
VOLUME	0.5	1.0	Volume reads 1.0L ± 120 ml
VOLUME	1.0	2.0	Volume reads 2.0L ± 200 ml
VOLUME Replace test lung and patient hose	2.0	0.5	Completes Volume check
Measure I-time			Should be 1.5 seconds ± 10%
VOLUME	0.5	1.0	
INSPIRATORY TIME	1.5	3.0	Should be 3.0 seconds ± 10%
INSPIRATORY TIME	3.0	4.5	SETTING ERROR alarm

Switch/Action	From	To	Desired Response
Reset INSPIRATORY TIME	4.5	1.5	Alarm, LED off; completes I-Time and Setting Error check
HIGH ALARM/LIMIT	90	25	Pressure increase on meter stops at HIGH LIMIT; HIGH PRESSURE LED flashes; alarm sounds
ALARM SILENCE	Press		Alarm off; HIGH PRESSURE LED flashes. In one minute alarm reactivates.
VOLUME	1.0 L	0.5 L	HIGH PRESSURE LED and audio alarm continue until pressure is below HIGH ALARM setting, then alarm off; LED remains on.
ALARM SILENCE/RESET	Press		LED extinguishes
HIGH ALARM/LIMIT	25	90	Completes HIGH PRESSURE check
Remove test lung			At second breath, alarm on (double-pulsed on LP20), LOW PRESSURE LED flashes
ALARM SILENCE	Press		Alarms off; LED flashes. After one minute alarm reactivates.
Replace test lung			Alarm off (LP20 only)
ALARM SILENCE	Press		LED and alarm off. Completes LOW PRESSURE check
BREATHING EFFORT	-5	1 line width (-) from zero	
BREATH RATE simulate breaths by extending test lung between breaths	10	4	BREATHING EFFORT LED light; ventilation occurs, synchronized to patient effort.
Cease spontaneous breaths			In 10 ± 0.5 seconds, alarm on, APNEA LED on; ventilator delivers 10 ± 1 BPM
ALARM SILENCE	Press		Light & alarm off; 10 BPM delivery stops; in 10 ± 0.5 seconds alarm reactivates
BREATH RATE	4	10	Completes APNEA test and Assist/Control verification
BREATHING EFFORT	Near 0	-5	
MODE	Assist/ Control	Standby	

SIMV Mode Checkout

This procedure verifies those operational functions unique to the SIMV mode. Those functions which are verified in the Assist/Control mode, are not repeated. Therefore, conduct Assist/Control operational verification in addition to SIMV.

Prior to beginning the checkout procedure, listed on the following page, place all operating controls in the position identified under Control Settings on page 3-6. Record results on a copy of the Operational Checklist located at the end of this section.

Note In SIMV mode, the ventilator coordinates assisted breaths with the patient's inspiratory effort; therefore, measured breath rates will vary somewhat from the rate set on the **BREATH RATE** control.

Switch/Action	From	To	Desired Response
AC POWER SWITCH	OFF	ON	Indicator light flash; AC PWR/BATT CHARGE light on; ventilator cycles once; pressure gauge at 0 ± 1 1 division
MODE	Standby	SIMV	Alarms and indicators test
BREATH RATE	10	6	
BREATHING EFFORT	-5	-1	
Squeeze test lung to stimulate 2 or 3 spontaneous breaths at about 6 second intervals			BREATHING EFFORT LED flashes; pressure gauge dips negative; ventilation occurs synchronized to simulated effort
Cease spontaneous effort			A mandatory breath will occur within 20 seconds after spontaneous breaths cease and will continue at the 6 ± 1 BPM rate; no alarms activate.
BREATH RATE Within 20 seconds after switching to 4, simulate breaths	6	4	BREATHING EFFORT LED lights; ventilation occurs, synchronized to effort.
Cease spontaneous effort			In 20 ± 0.5 seconds after last spontaneous breath, alarm on, Apnea LED on; ventilator delivers 10 ± 1 BPM
Alarm Silence	Press		Light and alarm off; 10 BPM delivery stops in 20 ± 0.5 seconds; alarm reactivates
ALARM SILENCE	Press		Light & alarm deactivate; 10 BPM delivery stops.
Within 20 seconds, simulate breaths			BREATHING EFFORT LED flashes; breaths delivered; light and alarm off
MODE	SIMV	Standby	This completes SIMV check.

Pressure Cycle Mode Checkout

The following procedure only verifies those operational functions unique to the Pressure Cycle mode of the ventilator. Those functions which are verified in the Assist/Control mode are not repeated here. Therefore, conduct Assist/Control operational verification in addition to pressure limit mode checkout.

Prior to beginning the checkout procedure, place all operating controls in the position identified under Control Settings on page 3-6 in this section. Record results on a copy of the Operational Checklist located at the end of this section.

Switch/Action	From	To	Desired Response
AC POWER SWITCH	OFF	ON	Indicator lights flash; AC PWR/ BATT CHARGE light on; ventilator cycles once; pressure gauge at 0 ± 1 division
MODE	Standby	Pressure Cycle	Alarms and indicators test; ventilator commences cycling at 10 ± 1 BPM
VOLUME	0.5	1.0	
HIGH ALARM/LIMIT Observe gauge	90	25	Pressure increase on meter stops when HIGH LIMIT is achieved; HIGH PRESSURE alarm does not activate.
BREATHING EFFORT Simulate spontaneous breathing by extending test lung between breaths	-5	1 line width (-) from zero	BREATHING EFFORT LED flashes; ventilator cycles with each simulated breath; each inhalation ends when HIGH LIMIT is achieved.
HIGH ALARM LIMIT	25	90	This completes Pressure Limited mode check
MODE	Pressure Cycle	Standby	

Pressure Limit Checkout (LP10, LP20)

The following procedure only verifies those operational functions unique to the Pressure Limit function of the LP10 ventilator. Those functions which are verified in the Assist/Control mode are not repeated here. Therefore, conduct Assist/Control operational verification in addition to Pressure Limit Checkout.

Prior to beginning the checkout procedure, place all operating controls in the position identified under Control Settings on page 3-6. Record results on a copy of the Operational Checklist located at the end of this chapter.

Switch/Action	From	To	Desired Response
AC POWER SWITCH	OFF	ON	Indicator light flash; AC PWR/BATT CHARGE light on; ventilator cycles once; pressure gauge at 0 ± 1 division
MODE	Standby	Assist/Control	Alarms and indicators test; ventilator cycles at 10 q1 1 BPM
VOLUME	0.5 liter	0.8 liter	Patient pressure reaches ~40 cmH_2O
PRESSURE LIMIT CONTROL	Full clockwise rotation	Push in the outside locking ring and turn the small knob counterclockwise until the patient pressure reads a peak of 20 cmH_2O	The patient pressure consistently reads peaks of 20 ± 4 cmH20 over five minutes.
Hold the test lung for several cycles to prevent it from inflating			The patient pressure peaks at 22 ± 6 cmH_2O. Increased exhaust occurs near the Pressure Limit Control. The Patient Pressure returns to 20 ± 4 cmH_2O after the test lung is released.
MODE	Assist/Control	Standby	Completes pressure limit control checkout
VOLUME	0.8 liter	0.5 liters	
Pressure Limit Control	Previous setting	Full clockwise rotation (do not overtighten)	

Operational Checklist

The operational checklist at the end of this chapter should be reproduced and used each time a verification is performed. A copy of the completed checklist should be kept in the health care provider's file.

Warning

Do not use the ventilator if it does not pass all of the verification procedures. Refer the ventilator to a Nellcor Puritan Bennett Service Technician for repair and calibration.

Ventilator Operational Checklist

Owned by:	Serial #	Hour Meter Reading:	Date:	
User:		Serviced by:		
Address:		Address:		
City:		City:		
State:		State, Zip		
Zip		Service Representative:		
User Phone:				
Test	**Operation**	**Test Results**	**Pass**	**Fail**
Visual	Inspect	As specified	❒	❒
Control Settings	Procedure	Not applicable		
Connections	Procedure	Not applicable		
Patient Circuit Leak Test	Perform Test	As specified	❒	❒
Power	Perform Tests	As specified	❒	❒
Assist/Control Mode	Perform Tests	As specified	❒	❒
SIMV	Perform Tests	As specified	❒	❒
Pressure Cycle Mode	Perform Tests	As specified	❒	❒
Pressure Limit (LP10, LP20)	Perform Tests	As specified	❒	❒
Comments**:**				
Signature:			Date:	

4 Theory of Operation

This section provides an overview of the functions of the ventilator to a level necessary to supplement the intended level of maintenance. A set of schematic diagrams is located at the end of this section.

General Description

The ventilator is a compact, microprocessor-controlled volume ventilator delivering tidal volumes from 100 to 2200 ml, inspiratory times ranging from 0.5 to 5.5 seconds, and breathing rates from 1 to 38 BPM. The system functions in Assist/Control, SIMV, or Pressure Cycle modes. It permits PEEP ventilation with a PEEP-compensated assist sensitivity control. A pressure Limit control (LP10 and LP20) is provided primarily for use with patients with uncuffed tracheostomy tubes.

The ventilator uses an electronically controlled piston pump that operates independently from a high pressure gas source or compressor. Intended for 110 VAC or 220 VAC primary power, the ventilator also operates for extended periods from 12 VDC power without compromising operational specifications. An internal DC source provides emergency power for up to one hour (when properly charged) should all external power sources fail.

A brushless motor increases reliability by eliminating components such as brushes, belts, and armatures. It also decreases periodic maintenance, plus provides a more controllable system.

Volume is adjusted by a computer chip that controls the length of the return stroke.

An integral molded manifold eliminates the need for extensive internal tubing, and greatly improves the parallel IMV breathing path. A 62 micron gross particulate filter enhances air filtration. All inlet passages and check valves are sized to minimize airflow resistance.

An elapsed time clock monitors operating hours. The clock is tied to existing controls and to the PATIENT PRESSURE gauge to provide a rapid and accurate time check without disassembly. The ventilator can provide operating parameters and waveforms to an optional printer.

Pneumatic System Overview

Refer to Functional Block Diagram at the end of this section. Numbers in parentheses refer to component identification numbers on the diagram.

Air is entrained into the ventilator through a 0.3 micron inlet filter (1). Negative pressure for entrainment is accomplished by the withdraw stroke of the piston in the mechanical piston pump assembly (5). Passing through an inlet check valve (4), the air enters the cylinder and becomes pressurized by the forward piston stroke. Air exits through a pump outlet check valve (10) and through a 62 micron, stainless steel gross particulate filter (11). Before exiting to the patient through the PATIENT AIR outlet tube, the air passes through one additional 40 mesh gross particle screen (13). A mechanical pressure limit system (LP10 and LP20) uses an adjustable spring to close an opening between the patient air path and atmosphere. As the pressure in the patient air path increases beyond the force of the spring, air escapes and the pressure is regulated.

Intermittent Mandatory Ventilation (IMV) is accomplished by use of a parallel path incorporated into the manifold. This path bypasses the pump and allows air to move directly to the PATIENT AIR outlet tube after passing through the inlet filter (1) and an inlet check valve (3).

On the forward pumping stroke, a small segment of air delivered to the patient outlet tube is routed through a three-way electrical exhalation solenoid valve (14). This portion of air exits through the exhalation valve port and is delivered to the patient manifold to expand the exhalation mushroom valve and allow ventilation of the patient's lungs.

During the exhalation phase of the ventilatory cycle, the exhalation solenoid valve de-energizes, relieving pressure on the exhalation mushroom valve, permitting patient air to exhaust to atmosphere. The air in the exhalation mushroom is routed back through the valve and dumped to atmosphere inside the ventilator.

A patient pressure sensing tube passes from the proximal pressure line to a pressure transducer (51). This transducer is a solid state, sealed chamber, strain gauge device. The pressure transducer functions from -10 cmH_2O to + 100 cmH_2O, allowing both negative and positive exhalation pressures, using the appropriate patient air lines and accessories.

Pumped air is delivered through a 22 mm tapered outlet tube with locking ribs. Many of the standard patient hoses that are commercially available can be used. Pressure is indicated on a front panel PATIENT PRESSURE gauge (52). The gauge reading is generated by the microprocessor from signals sensed by the pressure transducer (51). The gauge also identifies the condition of connected batteries when the BATTERY TEST button is pressed. Pressing the BATTERY TEST and the ALARM SILENCE buttons simultaneously registers elapsed time from 0-20,000 hours for the scale 0-100.

A mechanical relief valve (2) prevents excessive pressure (greater than 100 cmH_2O) by providing a release to atmosphere. This valve is a mechanically actuated, spring return, one-way leaf valve (2).

Mechanical System Overview

Refer to the Functional Block Diagram at the end of this section. Numbers in parentheses refer to the component numbers on the diagram.

The major mechanical elements of the ventilator are the motor/gearbox (8 and 9), the piston pump (5), the pressure relief valve (2), and the exhalation solenoid valve (14).

The basic mechanical drive is a brushless DC motor driving a 100 to 1 gearbox. The gearbox drives the crank arm, which in turn drives a piston within a seven-inch diameter cylinder. An "end-of-stroke" sensor (7) determines when the machine is to commence counting the return stroke for positioning of the next volume stroke.

The pump piston retracts a selected number of Hall Effect sensor codes (24 per motor revolution) until it reaches the correct piston position for the next stroke. At the end of the air delivery stroke, the piston reverses direction, passing over bottom dead center with each breath. This creates a pendulum action which allows shorter inspiratory times with low volumes. The microprocessor stops the motor drive once the piston retracts to its correct starting position.

If the patient pressure reaches the high alarm/limit, the crank arm reverses the piston without passing over bottom dead center.

An over pressure relief valve (2) ensures a dump to atmosphere when excess pressure is created. This valve is mechanically actuated and preset to release at a pressure between 90 and 100 cmH_2O, using a spring return.

The electrically controlled exhalation solenoid valve (14) mechanically provides a path to inflate the mushroom exhalation valve in the patient manifold assembly to permit inflation of the patient's lungs.

Electrical System Overview

Refer to the Functional Block Diagram at the end of this section. Numbers in parentheses refer to component identification numbers on the diagram.

Power for the ventilator may originate from one of three sources:

- AC Power
- External Battery
- Internal Battery

AC power (110 or 220V), 50-60 Hz is automatically selected by the ventilator, if connected. Choice of 110V or 220V is selected by a switch located on the back panel.

Caution

Connecting to 220V power when the switch is set for 110 will damage the unit.

The AC power path is from the line cord (20) through the two-pole power switch (18), which incorporates a two-pole, 1 Amp circuit breaker. The AC path continues through an RFI filter (17) to the 110V-220V switch, and then to the transformer, to a full wave rectifier (21), and finally to the system power bus on the power/motor board. With AC power disconnected, the power bus is supplied by an external battery (via connector 23), or by the internal 12 VDC source (22). Battery power from the bus only operates the ventilator if the **MODE** switch is in Assist/Control, SIMV, or Pressure Cycle position.

The power bus supplies three current-limited switching power supplies: 5V, 12V, and battery charge (13.8V on older models, 14.4V on newer models).

Switchover from AC power to external or internal battery is completely automatic. The ventilator operates from the external battery until that voltage is no longer adequate. When a switch from either AC power or external battery to internal battery occurs, an audio switchover alarm (32) sounds. The switchover occurs at an external battery voltage of approximately 11.6 VDC. If a printer is connected, a printout records this and any other alarm events, provided printer

AC power is available.

The AC power switch provides the disconnect of AC power, and the mode switch on the ventilator front panel controls the operating mode. With the AC power switch ON, the ventilator will operate on AC power and will charge the batteries in all mode settings. With the AC power switch OFF, the ventilator will operate on DC power and will not charge the battery.

Power for the ventilator piston pump comes from six drive transistors functioning as the motor commutator. The drive transistors' current produces a magnetic field in the motor. This, in turn, causes the motor to rotate under microprocessor control. Hall Effect sensors detect the position of the rotor. The drive transistors then cause the stator's magnetic field to fluctuate, causing the 8-pole permanent magnet rotor to follow that magnetic field. The fan (35) helps dissipate motor generated heat.

Note Schematic diagrams of the power/motor board, logic board, and LED board are included in the back of this section.

Operating Modes

Standby

The MODE switch in the Standby position applies AC power to the unit, and provides battery charge voltage (13.8V on older models, 14.4V on newer models) to either the external battery or the internal battery through the motor board. The battery charge mode is slower than a standard charger, thereby an external charger is recommended for the external battery. The battery charger has no preference for either the internal or external battery. It simply chooses the one having the lowest charge. When switching to a ventilation mode, battery charge continues, functioning equally effectively in all modes, whether the machine is running or not.

Assist/Control

The system's microprocessor reads the MODE and other switches 10 times a second and controls ventilator operation in accordance with what it reads. With the MODE switch in Assist/Control, the microprocessor initiates appropriate action only when it reads the switch position and the interrelated controls, i.e., VOLUME, BREATHING RATE, INSPIRATORY TIME, BREATHING EFFORT. The patient's breathing efforts control rate as an assister. Flow is actually set by volume and I-time. Exhalation time is a function of rate and I-time.

When the adequate level of negative pressure, caused by patient inhalation effort and determined by the **BREATHING EFFORT** control, is sensed by the microprocessor, appropriate signals are sent to initiate the breath. If spontaneous breathing rates fail to reach the preset rate, the microprocessor circuitry initiates a controlled breath, and continues controlled breaths at the preset rate until spontaneous breaths resume.

If spontaneous breathing or a controlled breath is not sensed once every 10 seconds, (breath rate less than 6 BPM) the apnea alarm sounds and the ventilator delivers the set volume at 10 BPM at the set inspiratory time.

Should control settings in this or any other mode demand breathing rates or flows beyond the capability of the ventilator, the setting error alarm sounds. Regardless of settings, the machine prevents I/E ratios greater than 1:1.

During operation in this or any other mode, ventilation data, including waveforms of flow, volume, and pressure, are obtainable using the optional printer module.

SIMV

In this mode, intermittent mandatory breaths are synchronized with the patient's breathing effort near the rate set on the **BREATH RATE** control. Stacking, i.e., a mandatory breath immediately following a spontaneous breath without adequate exhalation time, is eliminated.

The ventilator delivers a mandatory breath when the **SIMV** mode is entered. It then establishes a time period during which patient effort is monitored, and readies itself to deliver a breath. If the patient makes sufficient effort to trigger a breath during the time period (determined by the BPM setting), then the ventilator synchronizes a delivered breath to the effort. Any additional breaths taken by the patient during the same time interval are not assisted by the ventilator. If the patient does not make sufficient effort to trigger a breath by the end of the time period, the ventilator delivers a mandatory breath.

At the end of each time period, the ventilator starts a new time period and monitors for the first patient effort sufficient to trigger a breath.

At settings of 1-5 BPM, the ventilator will enter the apnea mode if there is not sufficient patient effort for 20 seconds. At that time the apnea alarm sounds and 10 breaths per minutes are delivered. If the patient resumes breathing spontaneously, the ventilator automatically shifts from apnea to the SIMV mode.

At **BREATH RATE** settings of 6 BPM or above, the ventilator delivers mandatory breaths at the preset breath rate and will not sound an apnea alarm.

Pressure Cycle

In the Pressure Cycle mode, the ventilator functions identically as in the Assist/Control mode with the following exception. The ventilator delivers gas flow from the piston until the high pressure limit is reached. If the high pressure limit is achieved prior to end of stroke, motor rotation reverses to retract the piston, and the exhalation valve is depressurized. The volume set on the **VOLUME** control is therefore not delivered to the patient.

In Pressure Cycle mode, the high pressure alarm is activated only if the peak pressure achieved exceeds the **HIGH PRESSURE** limit setting by more that 10 cmH_2O. The maximum setting of the limit control is 90 cmH_2O.

Boards and Major Components

Logic Board

The logic board contains the microprocessor, the ROM, the EEPROM, and a real timeclock. The real time clock/calendar provides date and time data for the remote printer.

Power/Motor Board

The power/motor board contains the voltage regulators, battery charge circuit, and the drive circuit for motor control.

LED Board

This board contains the connections for the alarm and power indicator LEDs as well as the **ALARM SILENCE/RESET** and **BATTERY TEST** buttons. The LED board is connected by a ribbon cable to the logic board.

Exhalation Solenoid Valve

This valve allows for inflation and deflation of the Patient Manifold mushroom. A 12V source activates the normally closed valve, allowing air to inflate the mushroom and thereby preventing patient exhalation during the inspiratory cycle.

Pressure Transducer

This transducer indicates the patient pressure as a reading on the pressure gauge. The output voltage ranges from 0 to 5 V. At atmospheric pressure, the output voltage is 0.8 V, to allow for negative patient pressure. The logic board monitors the signal from the transducer, comparing the signal with set values.

Fan

On units with the older through-hole power/motor board, the unit's fan operates on 12V and blows across the heat sink to help dissipate heat. The newer surface-mount power/motor does not have a heat sink, so the fan is not needed.

Audio Alarm

The alarm, located on the side panel, functions as a single tone alarm. The alarm is pulsed on and off.

Magnetic Position Sensor

This magnetic sensor detects the crank to determine position. Operated on 12 V, the sensor signal goes high when no metal is present and low with metal present.

Motor and Gearbox

The motor is a custom made, brushless DC motor driving a 100 to 1 gearbox. The armature is stationary with a spinning 8 pole, permanent magnet rotor. The three Hall Sensors located in the stator determine motor rotation speed and position. The aluminum gearbox attaches directly to the motor.

Transformer

The power transformer has a dual primary, for two separate supply voltage ranges. The transformer is protected by a thermal cutout that opens if temperature limits are exceeded.

RFI Filter

The filter meets the requirements of U.L. 544 and U.L. 1283.

AC Power Switch/Circuit Breaker

The AC Power switch controls both mains lines. The power switch contains a one-amp AC circuit breaker. Normal AC type equipment in the United States only requires that the hot line be breaker protected, however when operating on 220V outside the U.S., either line could be hot.

Rectifier

This is a standard 25A Bridge Rectifier.

AC Power Cord

This cord consists of a hospital grade plug and U.L. #544 and U.L. 817 approved cord with less than 0.1 ohm impedance from the ground conductor to chassis ground.

Internal Battery

The sealed, lead/acid battery is rated at 12 VDC.

DC Circuit Breaker

The DC circuit breaker provides protection in addition to the fuse in the external battery cable. This circuit breaker is for the external battery only.

Nurse Call Board (LP20 only)

The remote alarm signal controls a FET, which de-energizes the relay during alarm conditions.

Accessories

Printer

The optional printer operates on 110 VAC/60 Hz and is connected to the ventilator by the COMMUNICATIONS PORT. The printer creates a permanent record of patient information and ventilator parameters. The printer automatically generates a print-out:

- Every four hours.
- Each time there is an alarm condition.
- Each time a setting is changed.
- Each time the battery test button is pressed.

The printer also generates a waveform diagram showing the flow, volume, and pressure characteristics of air being delivered by the ventilator. Graphs are obtained by pressing the BATTERY TEST button three times in rapid succession.

Note This printer has been modified to meet hospital standards for leakage current. This modification may cause radio frequency or television interference. The printer is exempt under section 15.801 (c) (5) of the non-interference regulation adopted by the FCC.

External Battery

The recommended battery is a sealed jellied electrolyte type with a rating of 12V, 34 amp-hour, designed as a deep cycle battery. The ventilator should run approximately 10 hours using standard settings. The battery plugs into the ventilator on the back panel using a three pin connector. Charging the battery after use requires approximately three hours of charge for every hour of use.

The battery should be spill-proof in any position. It may be transported aboard commercial aircraft according to the following regulations:

- F.A.A. - Title 49 C.F.R.
- C.A.B. - Air Transport Restricted Articles #1924
- I.A.T.A. - Restricted Articles Regulations #1924

System Control

All functions of the ventilator are controlled by a microprocessor. A single Z80A microprocessor, running at 4 MHz, controls the motor, alarm circuitry, battery charging system, meter drive, and solenoid valve, along with interfacing with the printer.

The microprocessor reads the switches 10 times a second and controls ventilator operation in accordance with what it finds.

The **VOLUME** and **BREATHING EFFORT** controls are potentiometers. Their value is an analog value, a voltage produced on the pot, which is converted to a digital value by U19 on the logic board. All the remaining controls, **INSPIRATORY TIME, BREATH RATE, LOW ALARM, HIGH ALARM/ LIMIT** and **MODE,** are switches which set digital codes and require no conversion to be read by the microprocessor.

Microprocessor

Note: There are two types of logic and power/motor boards that have been used with LP6+ and LP10: an older through-hole board and a newer surface-mount board. These can be distinguished by checking the types of components on the circuit boards, plus the absence of a power/motor board heat sink and fan assembly on surface-mount units.

Refer to the Logic Board schematic in the Schematics Chapter. The microprocessor, U28, is the heart of the system. The program is contained in two memory ICS. An EEPROM (U24 used on older through-hole board or U26 on the newer surface-mount board) stores the calibration data and becomes accessible through the use of the external calibrator. Two EPROMs (U25 and U26 used on older through-hole board or U24 and U25 on the newer surface-mount board) contain the program. The general structure of the program is that every 10 ms (100 Hz) certain high priority tasks (i.e., pressure read, printer output) are performed, then one of ten sub-programs is performed (i.e., read and compute switch setting). Thus, each sub-program is performed ten times per second. When the sub-program is complete, the microprocessor waits for another 100 Hz interrupt. In addition, the program is interrupted at 2400 Hz to perform certain high speed motor control functions.

The microprocessor sends an analog level to the motor controller, causing the motor to rotate at a speed proportional to the level. When a new volume/inspiratory time combination is set on the controls, an initial speed control level is computed and sent to the motor controller. After each stroke the actual inspiratory time is computed and compared to the set value. The speed control level is

adjusted as necessary for the patient compliance/resistance. The controller limits motor drive power to an amount that will not produce excessive patient pressures or damage to the drive electronics.

Anytime the microprocessor fails to complete its program cycle, motor movement stops, all front-panel LEDs light, and a continuous alarm sounds. During internal battery-powered operation, if the system voltage drops too low, the ventilator is turned off and the remainder of the internal battery power is used for an alarm.

The RAM (U1 used on older through-hole board or U23 on the newer surface-mount board) contains 2 kB of memory. About 800 bytes are used for temporary storage. The remainder is used to store pressure and position data during piston stroke. It is from here that the data are obtained for printout.

EEPROM (U24 used on older through-hole board or U26 on the newer surface-mount board) retains memory without power, so it stores data such as calibration, machine hours, etc. The Time-of-Day Chip (U10 used on older through-hole board or U17 on the newer surface-mount board) uses its own battery to maintain the date/time function while power is off.

Analog to Digital Converter

An eight-channel analog-to-digital converter (U19 used on older through-hole board or U15 on the newer surface-mount board) converts the following signals:

- Patient Pressure, for meter display, low and high pressure alarm sensing and printout
- Amplified Patient Pressure, for patient effort triggering
- Volume Control Setting
- Patient Effort Control Setting
- Internal Battery Voltage
- Internal Battery Current
- External Battery Voltage
- External Battery Current

Digital to Analog Converter

A D/A converter is required to convert data to an analog format. Components U16 and U17 on older through-hole board, or U16 and U21 on the newer surface-mount board, serve this function. U17 or U21 converts a digital value to make it applicable for motor speed control. U16 supplies the front panel meter. The data from the pressure transducer is converted to a digital value for use by the microprocessor and must be reconverted as an input to the meter.

Chip Identification

The following identifies the functions of the logic board chips:

Chip Number		Function
U3		Reads BPM switch and MODE switch
U4		Reads inspiratory-time switch and push button switches
U5		Eight lines out to parallel printer port
U6		Reads low limit and high limit pressure switches
U9		Timer, timed interrupts to Z80
U10		Real time clock
Older through-hole board	**Newer surface-mount board**	
U12	U9	Output to remote alarm, internal alarm battery select, battery charge
U13	U10	Reads Hall sensors, mag sensor, printer busy
U15	U11	Output to motor control, backup mode, and printer port
U21	U27	I/O read decoder
U22	U29	I/O output decoder
U23	U13	Memory decoder
U27	U30	Microprocessor clock, 4 MHz

High/Low Pressure Alarms

High pressure data is obtained from the binary data available from the **HIGH PRESSURE** switch. The pressure transducer provides pressure information via the A/D converter.

Pressure calibration constants are stored in EEPROM U24 on the older through-hole board, or U26 on the newer surface-mount board. Here the transducer digital code is compared to the constant to arrive at the pressure level. Knowing this, determination of pressure level relative to preset limits occurs. If an alarm condition is appropriate, the program initiates the alarm functions.

The program for the low pressure alarm is similar. Pressure signals are monitored 100 times per second; high and low pressure switch positions are monitored 10 times per second.

Alarm Lights; Front Panel Push Buttons

Alarm light signals are sent from the microprocessor to the LED display board by way of U2 on the older through-hole board, or U19 on the newer surface-mount board. The ALARM SILENCE and BATTERY TEST push button switches also come off of the display board and feed into U4 on the older through-hole board, or U12 on the newer surface-mount board. The microprocessor detects if these switches are pressed individually, simultaneously, or in the case of BATTERY TEST, three times to initiate a graphic printout.

Error Detection

Normally, the circuit through resistor R12 on the older through-hole board, or R41 on the newer surface-mount board, has a constant high/low excursion. Should this excursion cease for a time period in excess of 1/10th of a second, a microprocessor error has been detected. If this occurs, motor movement will cease, all front-panel LEDs will light, and a continuous tone alarm will sound.

Power/Motor Board

Refer to the Power/Motor Board schematic at the end of this manual. The basic function of the power/motor board is to control the motor speed and position, and to provide power to the rest of the ventilator.

All components outside the dotted line are external to the board. This includes the power sources and associated circuitry, as well as the motor end stroke sensor, exhale solenoid valve, and the fan assembly.

The magnetic sensor senses the position of the piston and compares it to constants stored in the EEPROM on the logic board. This allows the microprocessor to know the location of the crank arm that drives the piston. From there it counts the Hall Codes per revolution.

The circuitry on page 2 of the schematic is motor control circuitry. Power transistors Q8 - Q13 on the older through-hole board, or Q6, Q7, Q8, Q10, Q12, and Q14 on the newer surface-mount board, supply power to the motor. These outputs are controlled by U10 on the older through-hole board, or U4 on the newer surface-mount board. Various address lines control the output, some from Hall sensors and some from the microprocessor.

The microprocessor sends three signals:

- Motor on or off
- Motor forward, motor reverse
- Solenoid

Another important U10/U4 input (A3) originates from the motor control chip, U9 on the older through-hole board, or U12 on the newer surface-mount board. It:

- controls how much power is supplied to the motor. It turns the motor power on and off at a 16 kHz rate and acts as a speed control. A speed input signal (J4 on the older through-hole board or J2 on the newer surface-mount board, pin 1) comes from the microprocessor, through an analog switch, U6 on the older through-hole board or R13 on the newer surface-mount board, and enters a control input of U9 or U12. The other U9 or U12 control input comes from U7 on the older through-hole board, or U2 on the newer surface-mount board, a tachometer generator. This is a speed feedback signal to U9 or U12.

- Two other inputs to U9 or U12 (pins 15 and 16) provide current limiting to the motor so that it cannot be driven harder than it is intended, particularly if it is stalled. The U9 or U12, pin 16 circuitry sets the motor drive power to approximately the same level regardless of source (a 12V battery, or from the AC line). This puts about 22V output on the drive circuitry (from AC power); 12V (from DC power sources).

A8 on U10 on the older through-hole board, or U4 on the newer surface-mount board, is the backup line (the line on the logic board that monitors whether the microprocessor is functioning properly). If this line goes high, the three CPU lines, A4, A5, and A6 are ignored by U10 or U4. The exhalation solenoid will be de-energized and all six motor-drive transistors will be off. No air will be delivered.

Three nearly identical power supplies provide: 1) 5V for much of the system circuitry, particularly on the boards; 2) 12V for several IC's on the logic board, for the solenoid, for the fan, and for the magnetic sensor; 3) 13.8V or 14.4V for charging the battery.

The external power system is also shown on this schematic, with AC power passing through the power switch/circuit breaker, through the transformer and full wave rectifier, and onto the motor board where it is filtered and becomes system power.

The internal and external batteries also connect directly to the motor board through the two parts of CR13 on the older through-hole board, or D32 on the newer surface-mount board, (dual diode) to the system power common. If AC power is connected, its voltage is much higher than that of the batteries and therefore overrides the batteries in supplying power to the system. AC operation is supplying approximately 22V, where the battery is supplying around 12V. Therefore, no current flows from the battery during AC operation.

The charge path for the external battery is through diode CR8 on the older through-hole board, or D37 on the newer surface-mount board, and in the case of the internal battery, through CR7 on the older through-hole board, or D36 on the newer surface-mount board, and the relay contact.

The external battery is always on line. The internal battery is on line for powering the system through a diode, and a relay contact (normally closed). The relay is powered on its positive side by the external battery. If no external battery is connected, and if the charger is not on, this relay cannot operate, so the internal battery will be on line by default. The relay is also controlled on the negative side by the microprocessor.

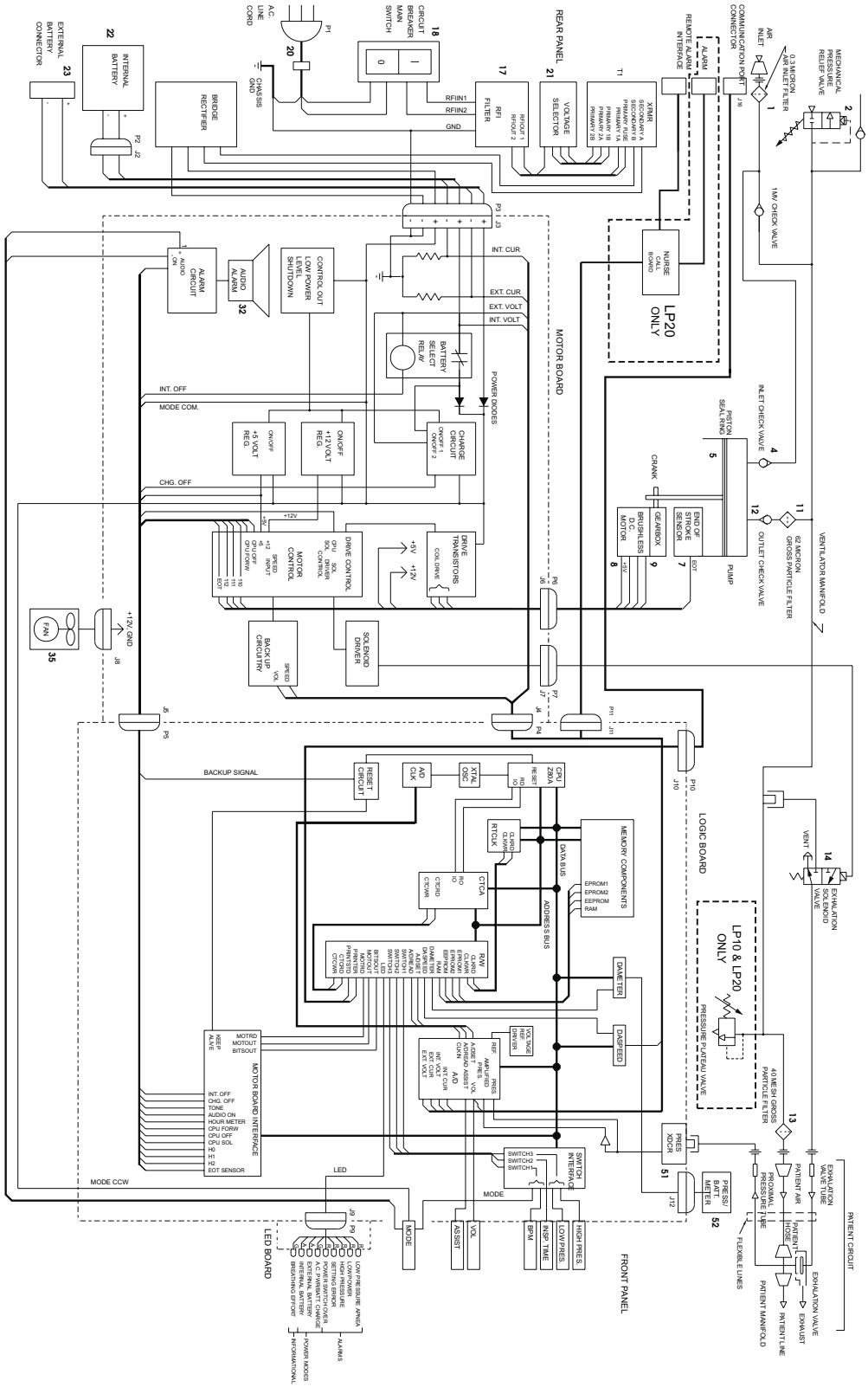
Because the system cannot differentiate between a fully charged battery (internal and external) and no battery, the battery charge circuitry is interrupted for three seconds every five minutes to allow this check to be completed.

U4 on the older through-hole board, or U13 on the newer surface-mount board, detects when system voltage has fallen below approximately 8V. At that point everything is cut off except the alarm. The ventilator will not function with power this low, so the remaining power is used to alert the caregiver of the conditions via the audible and visible alarm system.

LED Board

The LED Board contains eight LEDs that are digitally powered by the microprocessor. A ninth LED is powered by AC power but is read by the microprocessor to determine the presence of the AC power source. Two push button switches, **ALARM SILENCE/RESET** and **BATTERY TEST,** send inputs to the microprocessor when activated.

Functional Block Diagram



5 Maintenance

The maintenance section provides the information necessary to maintain the ventilator in optimal operating condition. It outlines those procedures necessary to schedule and perform preventive maintenance including cleaning and sterilization, troubleshooting, and to make minor adjustments or repairs that require no special training or instrumentation.

For repair assistance beyond the scope of this manual, contact a Nellcor Puritan Bennett Customer Service Representative.

Warning

Those procedures outlined in this section can be performed by the operator without invalidating the warranty. Nellcor Puritan Bennett, Inc. assumes no responsibility or liability for the results of any servicing attempted, beyond that listed, by personnel not factory-trained by Nellcor Puritan Bennett, Inc.

Maintenance Schedule

Task	Frequency
Visual Check	As required
Clean Exterior	As required
Replace Inlet Filter	Weekly; daily if used in transit or outdoors
Replace Bacteria Filter	As required
Clean Patient Circuit	Daily; minimum three times a week
Clean Exhalation Manifold Assembly	Daily; minimum three times a week
Clean Humidifier	Twice weekly
Test External and Internal Batteries	Monthly
Clean Printer Module	As required

Preventive Maintenance

Visual Check

Frequency - As required

Procedure (with unit turned off)

1. Check the PATIENT PRESSURE meter. The needle should be within one division of -10.
2. Check for cracks on the case or meter face. Check for legible control and indicator identification markings and front panel Alarm Reference Guide instructions (located on control panel door).
3. Check all connections including power, EXTERNAL BATTERY, and COMMUNICATIONS PORT. Examine the cables and connections on the printer module, if used.

Exterior cleaning

Frequency - As required

Supplies

- ❒ liquid detergent
- ❒ cold disinfectant
- ❒ cloth

Procedure

1. Clean the exterior with soap and water or with a bactericidal or germicidal agent.
2. Clean the display panel with isopropyl alcohol. Do not allow liquid cleaning agents to penetrate the inside of the ventilator.

Warning

Any liquid leaking into the ventilator or its connections may damage the unit or result in an electrical shock hazard.

Inlet Filter

Caution Failure to change the filter may result in serious damage to the ventilator, and can invalidate the warranty.

Standard Inlet Filter

Frequency Weekly; daily if used in transit or outdoors

Supplies

- ❒ replacement filter

Procedure

1. Twist the threaded plastic cap counterclockwise.
2. Remove the screens and the old filter.
3. Wash the screens with soap and water; rinse and dry thoroughly before reinserting.
4. Check the filter for dust, dirt or discoloration.

Note: Filters cannot be cleaned. Replace, if necessary. Any printing on the replacement filter should face towards the front of the ventilator.

5. Reassemble in reverse order and secure the plastic filter cap.

Flatpak Inlet Filter

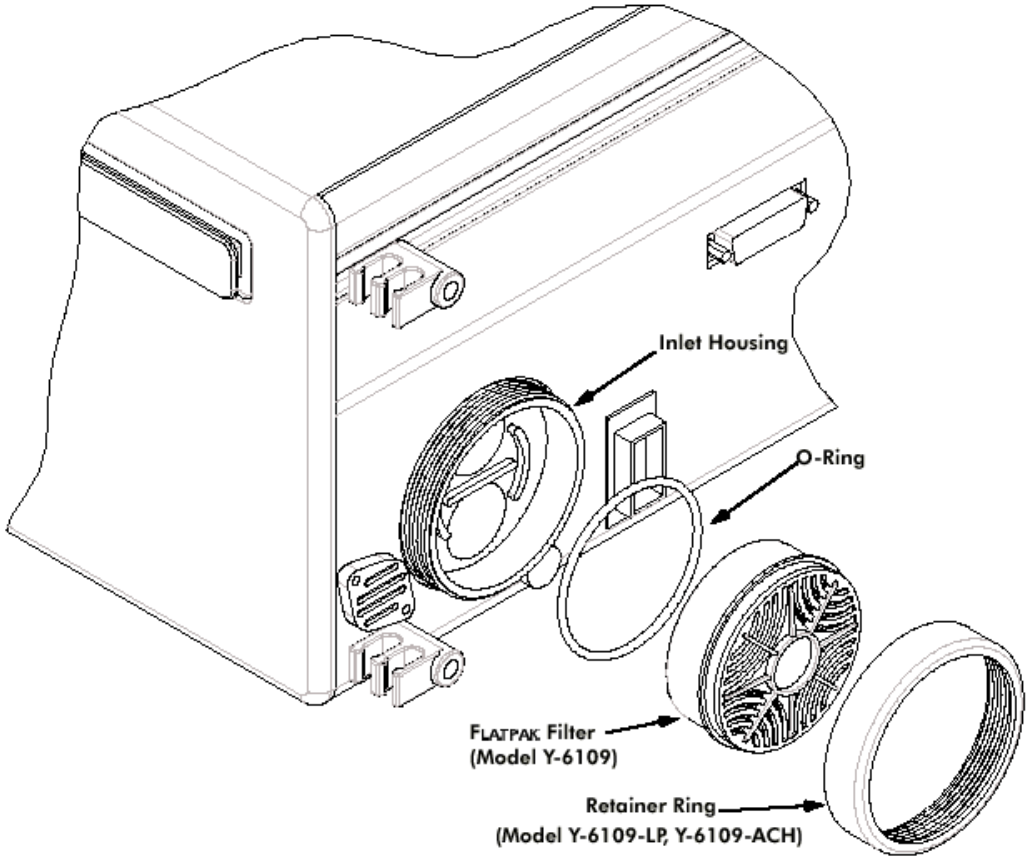
Frequency Monthly; weekly if used in transit, outdoors, or dusty conditions

Supplies

- ❒ replacement Flatpak filter

Procedure

1. Twist the retainer ring counterclockwise. See figure on the next page.
2. Remove and inspect the Flatpak filter for dust, dirt, or discoloration. Filters cannot be cleaned. Replace, if necessary.
3. Reassemble in reverse order, making sure that the retainer ring is tight.



Flatpak Filter Replacement

Bacteria Filter

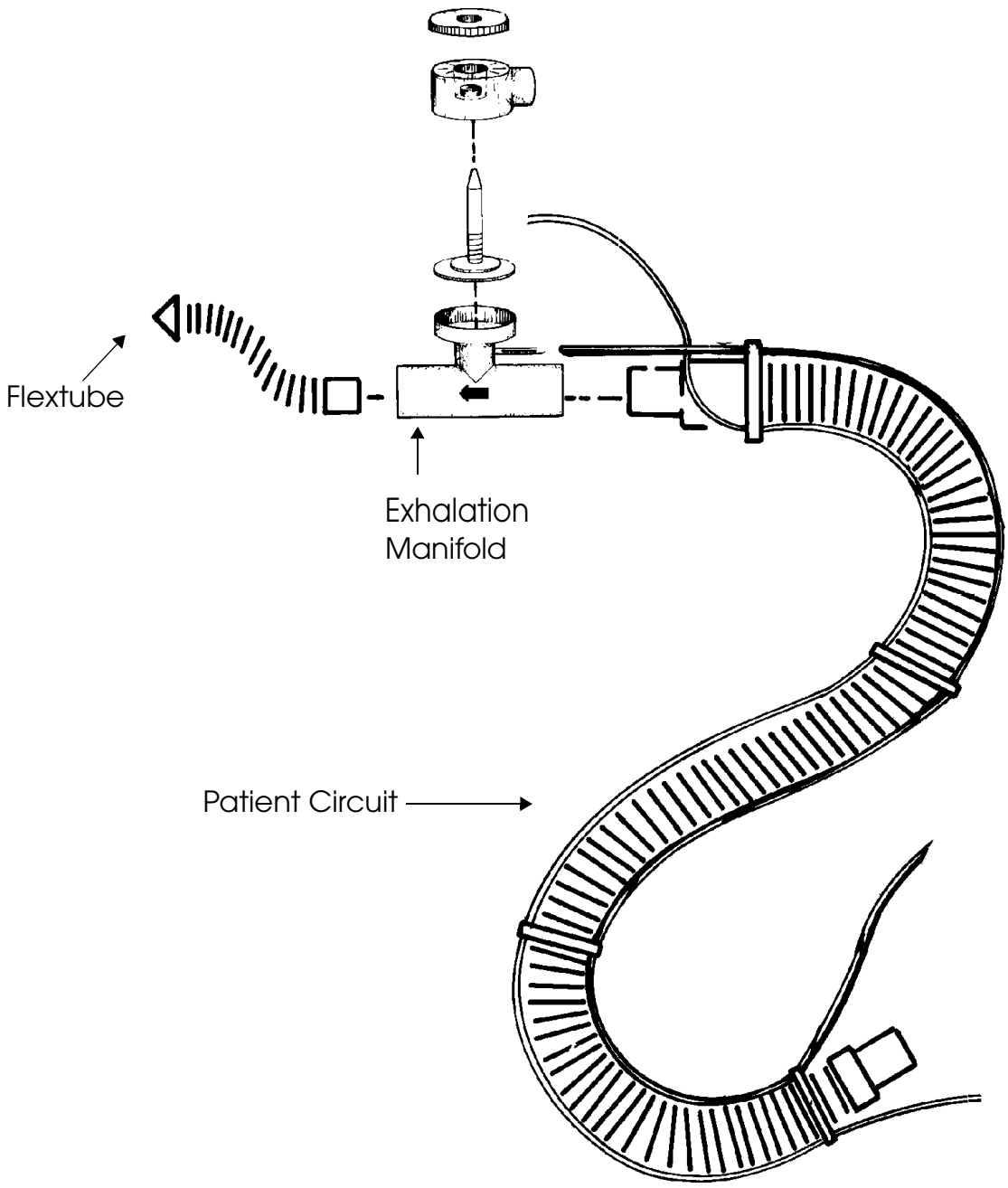
Frequency As required

Supplies

- ❒ replacement filter

Procedure

1. Remove the bacteria filter and check for discoloration of the internal filter material.
2. Replace if needed, or if a new patient is placed on the ventilator, or if four weeks have passed since the last filter change.


Flextube
Exhalation
Manifold
Patient Circuit

Patient Circuit

Warning

Patients requiring ventilation assistance are often highly susceptible to respiratory infections. Because of dormant moisture, a patient circuit is an ideal source of infection. Failure to properly clean and disinfect patient circuit components may result in added pulmonary complications.

Frequency Daily, minimum three times a week

Supplies

- ❒ manual resuscitator or backup ventilator
- ❒ liquid detergent
- ❒ white vinegar or recommended disinfectants
- ❒ long bristle and bottle brushes

Procedure

1. Disassemble as shown on the opposite page.
2. Scrub all parts of the patient circuit using brushes and warm soapy water. Make certain the brush enters each convolution to remove medication, secretions or other foreign matter.
3. Rinse all parts under tap water; make certain all residue is removed.
4. Disinfect the patient circuit using one of the following methods:
   a. Soak for 30 minutes in a solution of one part white vinegar to two parts water. Rinse thoroughly.
   b. Soak in an approved chemical disinfectant, following the manufacturer's instructions.
3. Shake excess moisture from all parts and place on a clean towel to air dry. Do not wipe or dry with a towel. Do not use a blow dryer. Tubing must be completely dry before reattaching to the ventilator.

Exhalation Manifold Assembly

Frequency Daily, minimum three times a week

Supplies

- ❒ manual resuscitator or backup ventilator
- ❒ liquid detergent
- ❒ white vinegar or recommended disinfectants
- ❒ long bristle and bottle brushes

Procedure

1. Unsnap the body and cap.
2. Unscrew the mushroom valve as shown.
3. Clean and disinfect using the procedure given for the patient circuit. Make certain no water or cleaning solution remains in the mushroom or other valve parts.
4. When completely dry, screw the mushroom securely into the locking nut and snap the body back into the cap.

Warning

Ensure proper reassembly of the exhalation manifold. Failure of the manifold to function as intended could present a hazard to the patient.

Humidifier

Frequency Twice weekly

Supplies

- ❒ liquid detergent
- ❒ scouring powder or steel wool (fine)
- ❒ autoclave, gas or cold sterilization

Procedure Refer to the manufacturer's manual.

External Battery

Frequency Monthly

Supplies

- ❒ External Battery Charger (optional)

Procedure

1. With the external battery connected and operating the ventilator, press the **BATTERY TEST** button on the front panel and observe the **BATTERY CONDITION** indicator on the meter. The needle should be in the **NORMAL** to **HIGH** range.

2. Check the external battery hookup. Make certain the cable connections are correct and the terminals are not corroded.

   The external battery will be charged by the ventilator in any **MODE** position. The ventilator will fully charge a 12 V deep cycle battery, in good condition, in approximately three hours of charge time for each hour of use.

   For faster charging time, disconnect the battery from the ventilator and attach it to an appropriate external charging device.

Internal Battery

Frequency Monthly

Supplies None required

Procedure

1. With the internal battery operating, disconnect AC power and the external battery from the ventilator.

2. Press the **BATTERY TEST** button on the front panel and observe the **BATTERY CONDITION** indicator on the meter. The needle should be in the **NORMAL** to **HIGH** range.

Printer Module

The following routine procedure is listed here for your convenience. For more detailed instructions, refer to the instructions which accompanied the unit.

Caution

Do not operate the Printer Module without paper. This can cause permanent damage to the unit.

Procedure

1. Disconnect AC power.
2. Clean the Printer Module using a damp sponge and a mild household detergent. Keep liquid from entering the unit.
3. Check the power and ribbon cables for physical damage.
4. Connect to an operating ventilator. Press the ventilator's **BATTERY TEST** switch three times within two seconds; verify that a printout is produced.

6 Troubleshooting

This table provides procedures for identifying and correcting operator problems. This list includes only those problems correctable without special equipment. Refer problems beyond the scope of this section to an authorized Nellcor Puritan Bennett Service Representative.

Troubleshooting Chart

Symptom	Cause	Solution
Green AC power light is out with unit connected to AC power	AC Power Switch	Move switch to ON
	No AC power at outlet	Check for 110 VAC at outlet
	Open Circuit Breaker	Reset by moving AC switch to ON
	Defective cord or connector	Check cord and connector for possible loose connections.
	Defective LED	Contact Nellcor Puritan Bennett
Power light ON, but ventilator fails to cycle	Mode switch in Standby position	Move MODE switch to an active position
Alarms activate when unit is turned on	Normal test of audible and visual indicators	Not applicable; Alarms automatically reset
Low Pressure alarm sounds frequently	Incorrect alarm settings	Check alarm control setting
	Improper patient connections	Check patient connection (trach) for a secure, leakproof fit
	Leaks in components or connections	Check all connections, especially the humidifier and exhalation valve
	Water in small tubing	Remove water
	No patient circuit is connected to unit; no pressure is registered	Connect circuit with test lung to achieve proper pressure according to alarm set point
	Pressure Limit control is overtightened (LP10, LP20)	Do not overtighten the Pressure Limit control

Symptom	Cause	Solution
Low pressure alarm sounds, is reset, but alarm light remains on and alarm triggers again in approximately one minute	The initial cause of the alarm has not been corrected	Check for leaks
		Check for proper control setting
		Check Volume setting
		Possible change in patient compliance
High Pressure alarm sounds frequently	Incorrect alarm setting	Check alarm control setting
	Moisture in large tubing	Drain tubing
	Crimped tubing	Make certain tubing is unbent and open
	Trach or airway restriction	Check trach; suction patient
	Exhalation Manifold occluded	Ensure manifold operates properly
	Incorrect Pressure Limit Setting (LP10 and LP20)	Check Pressure Limit control
Patient unable to receive assisted breath	BREATHING EFFORT set to negative	Check setting
	Moisture in small tubing	Drain tubing
Unit cycles continually in 1:1 I/E ratio in Assist/Control mode	Improper BREATHING EFFORT control setting	Check BRATHING EFFORT control setting
Patient seems inadequately ventilated; no alarms sound	Incorrect VOLUME setting	Check VOLUME control setting
	Low ventilator output	Check exhaled volume
	Leaks, not sufficient to trip LOW PRESSURE alarm	Check potential leak locations
	High Pressure Limit set too low in Pressure Cycle mode	Contact health care provider for prescription change
	Incorrect Pressure Limit Setting (LP10 and LP20)	Check Pressure Limit Control

Symptom	Cause	Solution
Ventilator connected to external battery but INTERNAL BATTERY power light flashing	Unit not switching to external battery	Check DC power cord; check for blown fuse in DC power circuit; check DC circuit breaker
	Low charge on external battery	Connect to AC power; recharge external battery
	Loose or broken connections	Check all connectors for broken or missing pins, or loose connections.
Audible alarm sounds, LOW POWER light illuminates, AC power off	Internal battery low	Change to adequate external battery or to AC power; Recharge internal battery by connecting to AC power
All alarm lights on steady; continuous alarm	Unit has detected a microprocessor error	Turn unit OFF; wait 10 seconds, then turn the unit back ON. If the alarm situation still exists, do not use the ventilator. Turn it OFF and contact your Service Representative
	Internal battery depleted	Charge Internal battery

Alarm Condition Chart

Alarm	LED	Audio Alarm	Alarm Silence Reset	Self Cancel Visual/ Audible	Resulting calibrator & printer test	Resulting effect on machine operation
Alarm Test	All LEDs	Alarm for 1 second	n/a	both	none	none
Start-up	All LEDs	Alarm for 2 seconds	n/a	both	n/a	n/a
Microproces-sor Error	All LEDs	Continuous alarm	n/a	n/a	n/a	No ventilation
High Pressure	High Pressure	Pulsing alarm	60 second silence	audible	HIGH PRESS	Piston retracts and mushroom deflates
Excess Pres-sure	High Pressure	Pulsing alarm	60 second silence	audible	EXCESS PRESS	Piston retracts and mushroom deflates
Low Power	Low Power	Pulsing alarm	60 second silence	none	LOW POWER	none
Charger Fault	Low Power	Pulsing alarm	60 second silence	none	CHARGER FAULT	none
Low Pressure	Low Pres-sure/apnea	Pulsing alarm	60 second silence	none (audible on LP20)	LOW PRESS	none
Valley Pres-sure	Low Pres-sure/Apnea	Pulsing alarm	60 second silence	none (audible on LP20)	VALLEY ALARM	none
Exhale Fail-ure	Low Pres-sure/Apnea	Pulsing alarm	60 second silence	none (audible on LP20)	EXHALE FAIL	No delivery until pressure decreases

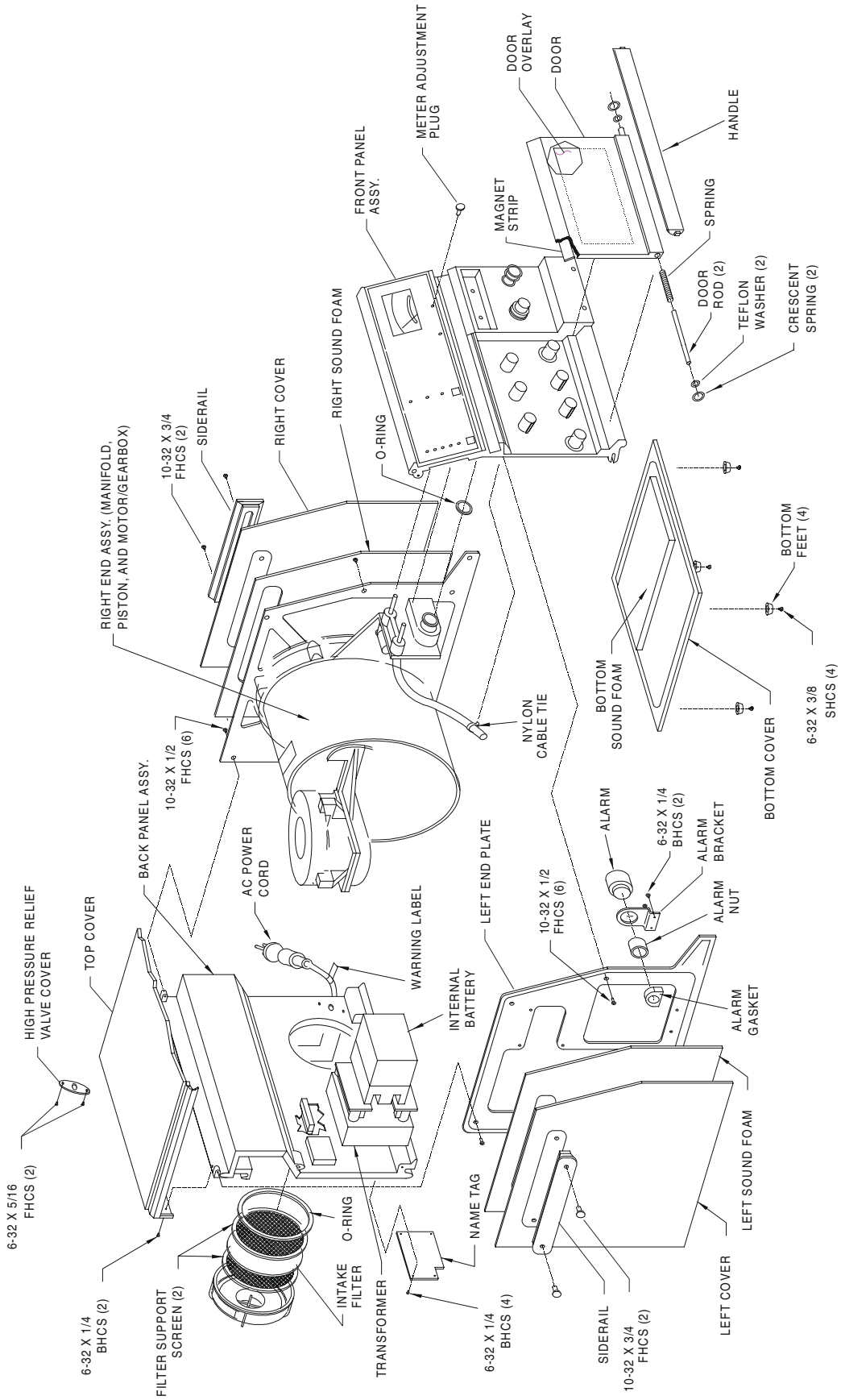
Alarm	LED	Audio Alarm	Alarm Silence Reset	Self Cancel Visual/ Audible	Resulting calibrator & printer test	Resulting effect on machine operation
Stall	Low Pressure/Apnea	Pulsing alarm	60 second silence	none	STALL	No delivery
Apnea	Low Pressure/Apnea	Pulsing alarm	Reset	none	APNEA	Apnea mode of ventilation
Power Switchover	Power Switchover	Pulsing alarm	Reset	none	POWER SWITCHOVER	none
Inverse I/E setting	Setting Error	Pulsing alarm	Test	both	INVERSE I:E	Delivers at set inspiratory at 1:1 I:E
BPM Error	Setting Error	Pulsing alarm	60 second silence	audible	RATE ERROR	none
Volume Error	Setting Error	Pulsing alarm	60 second silence	audible	VOL ERROR	none
Inspiratory Effort	Setting Error	Pulsing alarm	60 second silence	audible	INS ERROR	none, except to maintain max I:E of 1:1
Mode Switch	Setting Error	Pulsing alarm	60 second silence	audible	MODE SWITCH ERROR	may default to ventilating mode
Self test Over Pressure Valve Fail	High Pressure	Pulsing alarm	60 second silence	both	OVP VALVE FAILURE	Perform self test then function as in standby mode
Selftest Leak Test Fail	Low Pressure	Pulsing alarm	60 second silence	both	LEAK TEST FAILURE	Perform self test then function as in standby mode

Alarm	LED	Audio Alarm	Alarm Silence Reset	Self Cancel Visual/ Audible	Resulting calibrator & printer test	Resulting effect on machine operation
No EOT Sensor	Setting Error	Pulsing alarm	60 second silence	audible	EOT SENSOR FAILURE	Ventilator resynchronizes with a seek cycle
Wrong EOT sensor	Setting error	Pulsing alarm	60 second silence	audible	EOT/HALL ERROR	Ventilator resynchronizes with a seek cycle
Hall Code Error	Setting Error	Pulsing alarm	60 second silence	audible	HALL ERROR	none
CTC Error	Setting Error	Pulsing alarm	Reset	n/a	TIMER ERROR	none
EEPROM Error	Setting Error	Pulsing alarm	60 second silence	audible	EEPROM WRONG	Machine runs on calibration constants
Pressure Setting Error	Setting Error	Pulsing alarm	Test	both	PRESURE SETTINGS	System uses and displays set limits
Dynamic RAM Test Error	All LEDs	Continuous alarm	n/a	n/a	n/a	No ventilation
Dynamic ROM Test Error	All LEDs	Continuous alarm	n/a	n/a	n/a	No ventilation
10 Hz Task Ending	All LEDs	Continuous alarm	n/a	n/a	n/a	No ventilation.

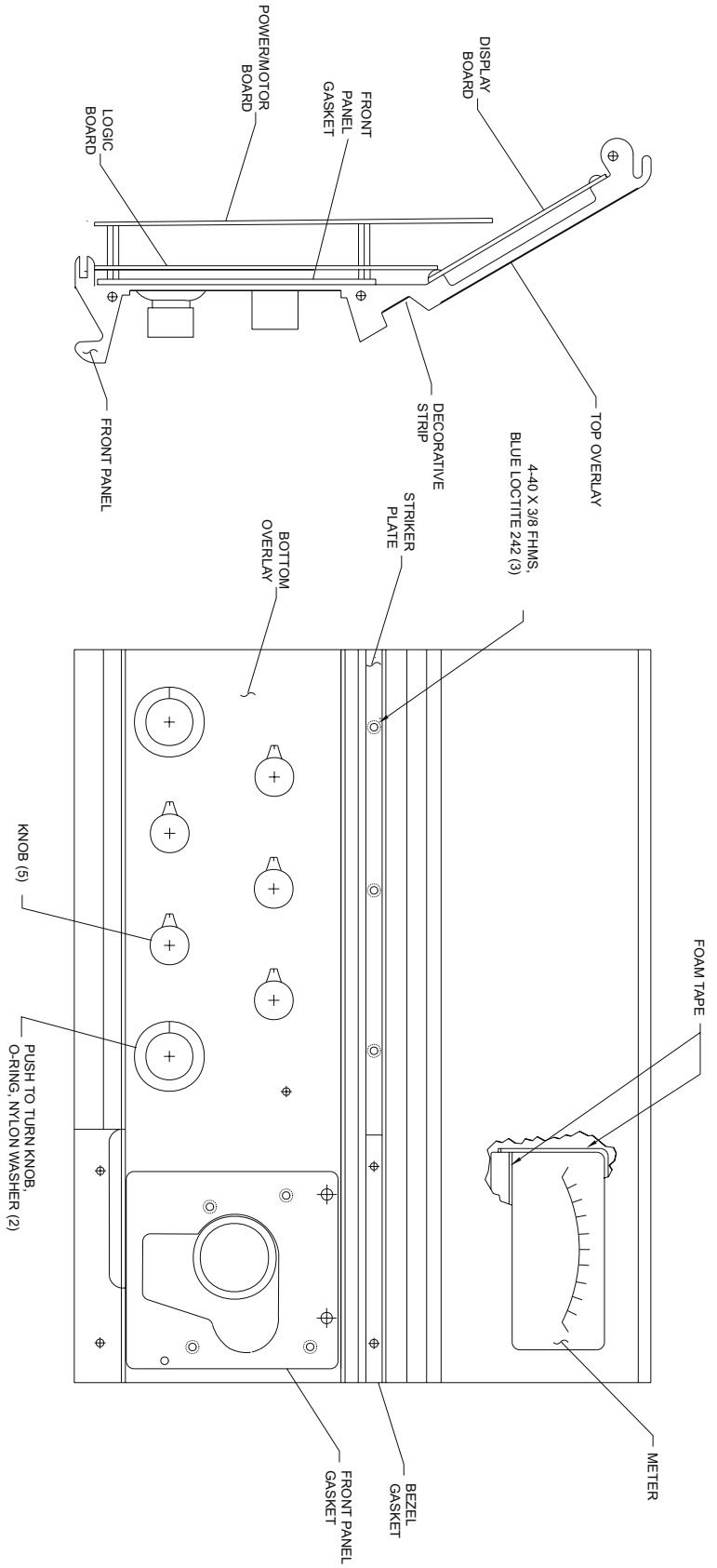
7 Schematics

This chapter contains the schematics and mechanical drawings for Nellcor Puritan Bennett's LP6 Plus, LP10, and LP20 Volume Ventilators. This chapter contains proprietary information. It is intended for use only by qualified individuals in the installation and maintenance of the ventilator. Receipt, purchase, or possession of this document in no way confers or transfers any other rights for the use of this information. Disclosure or reproduction of the enclosed, without the written permission of Nellcor Puritan Bennett, Inc., is prohibited.

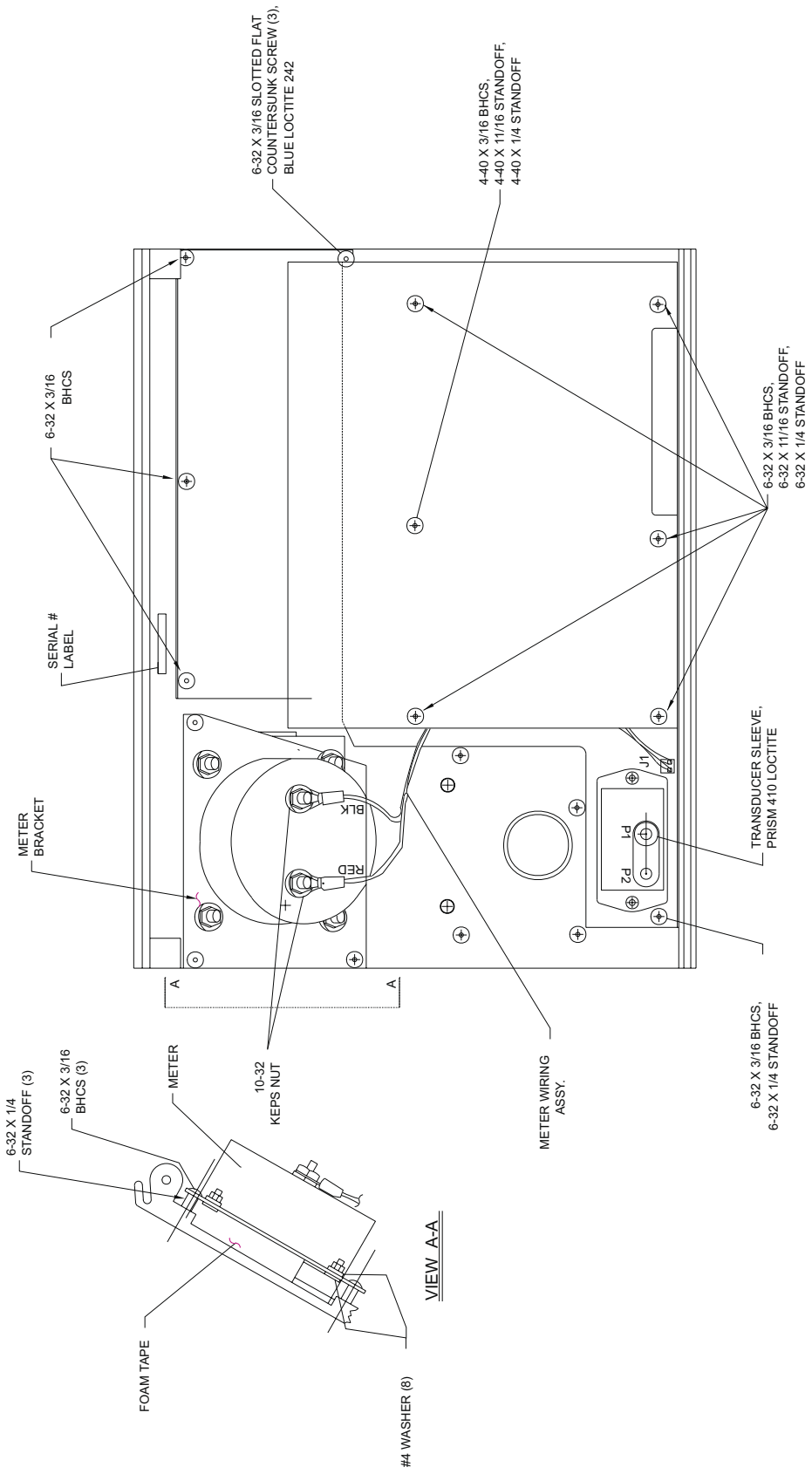
Final Assembly



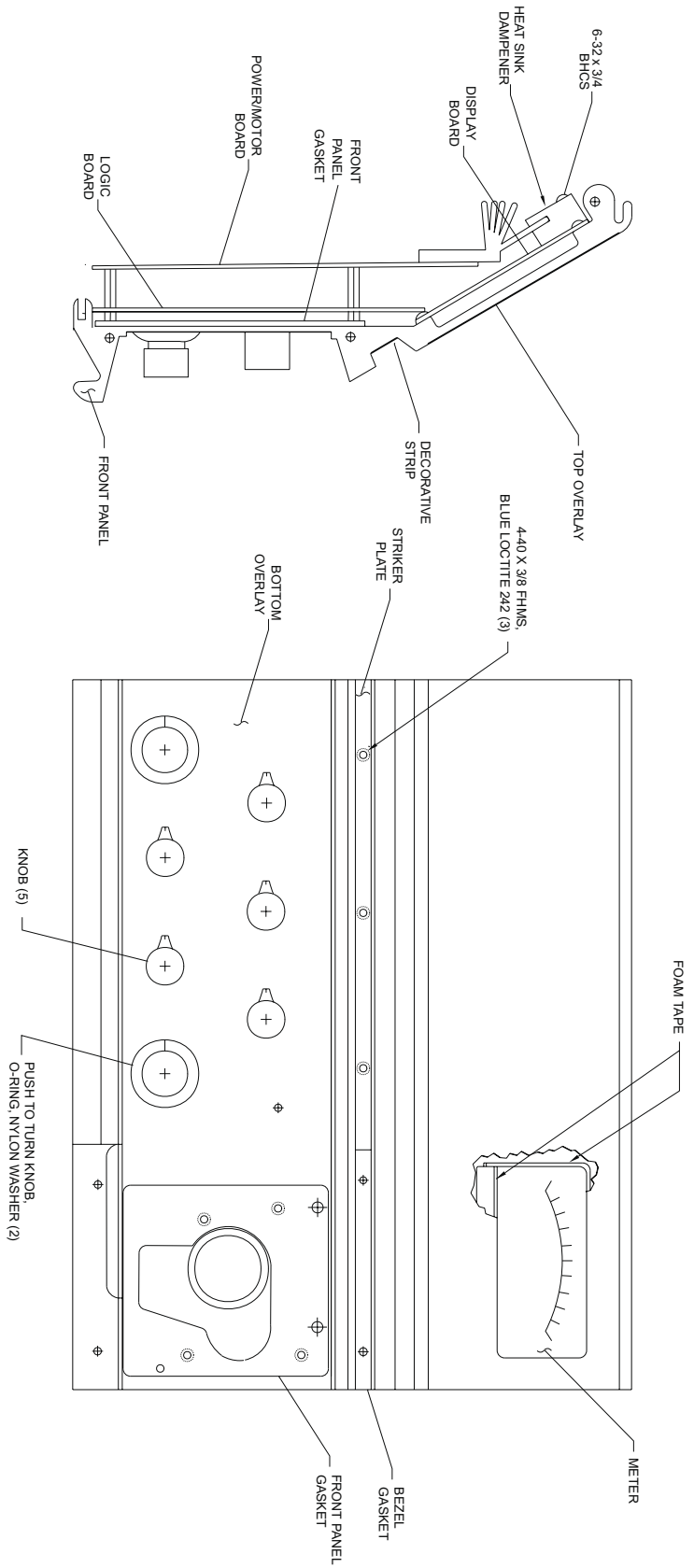
Front Panel (LP6 Plus, LP10)



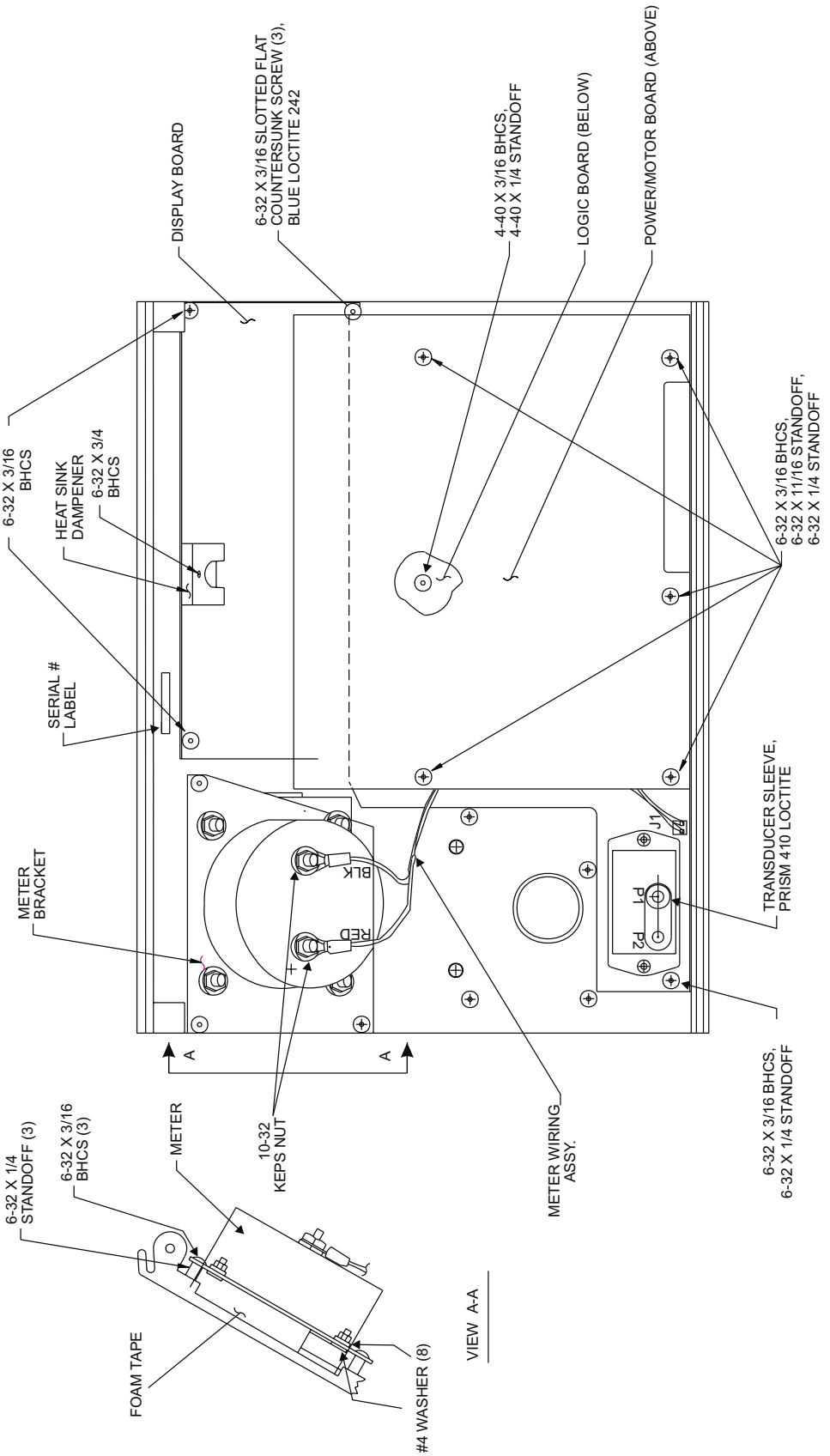
Front Panel (LP6 Plus/LP10)



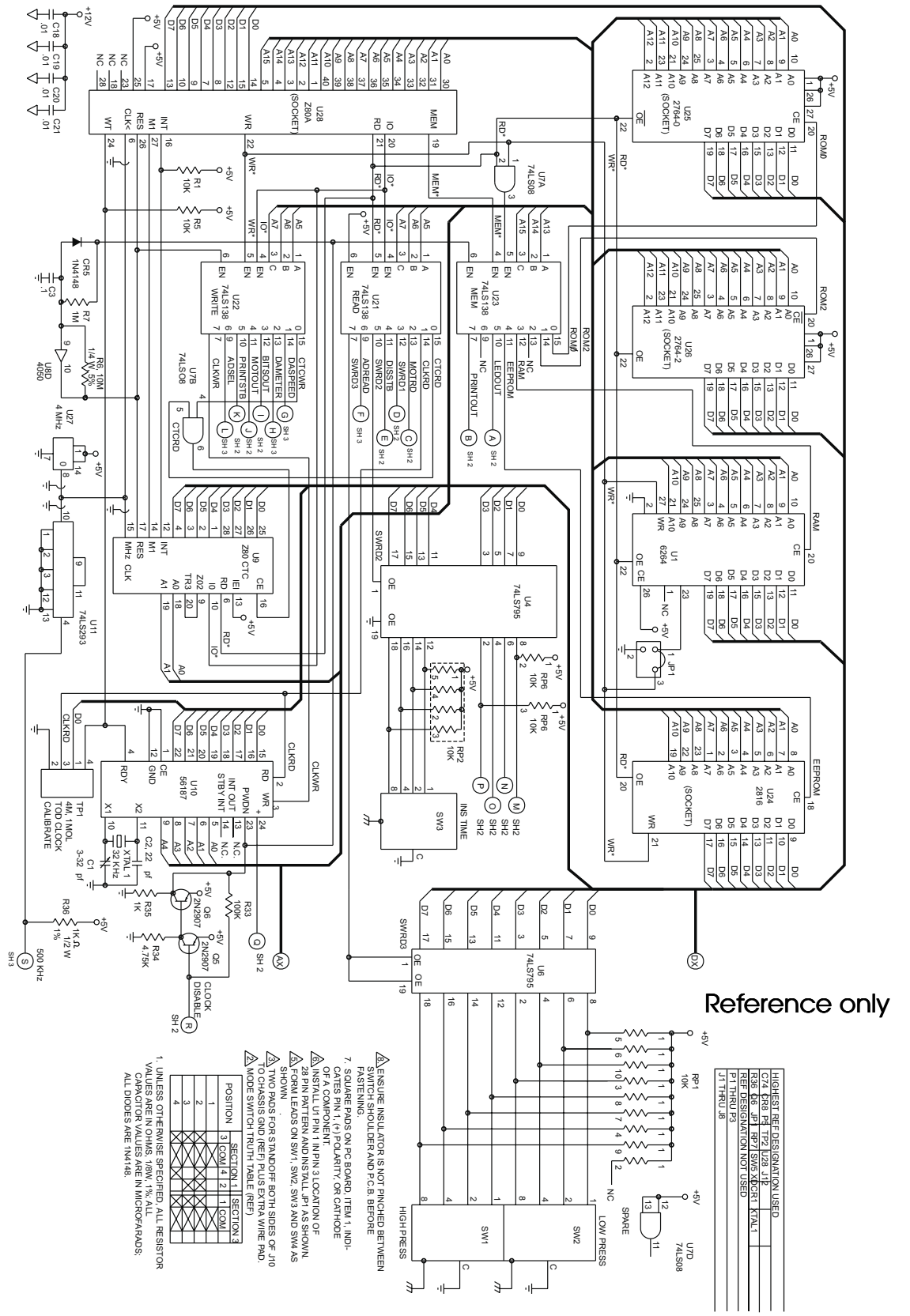
Front Panel (LP20)



Front Panel (LP20)

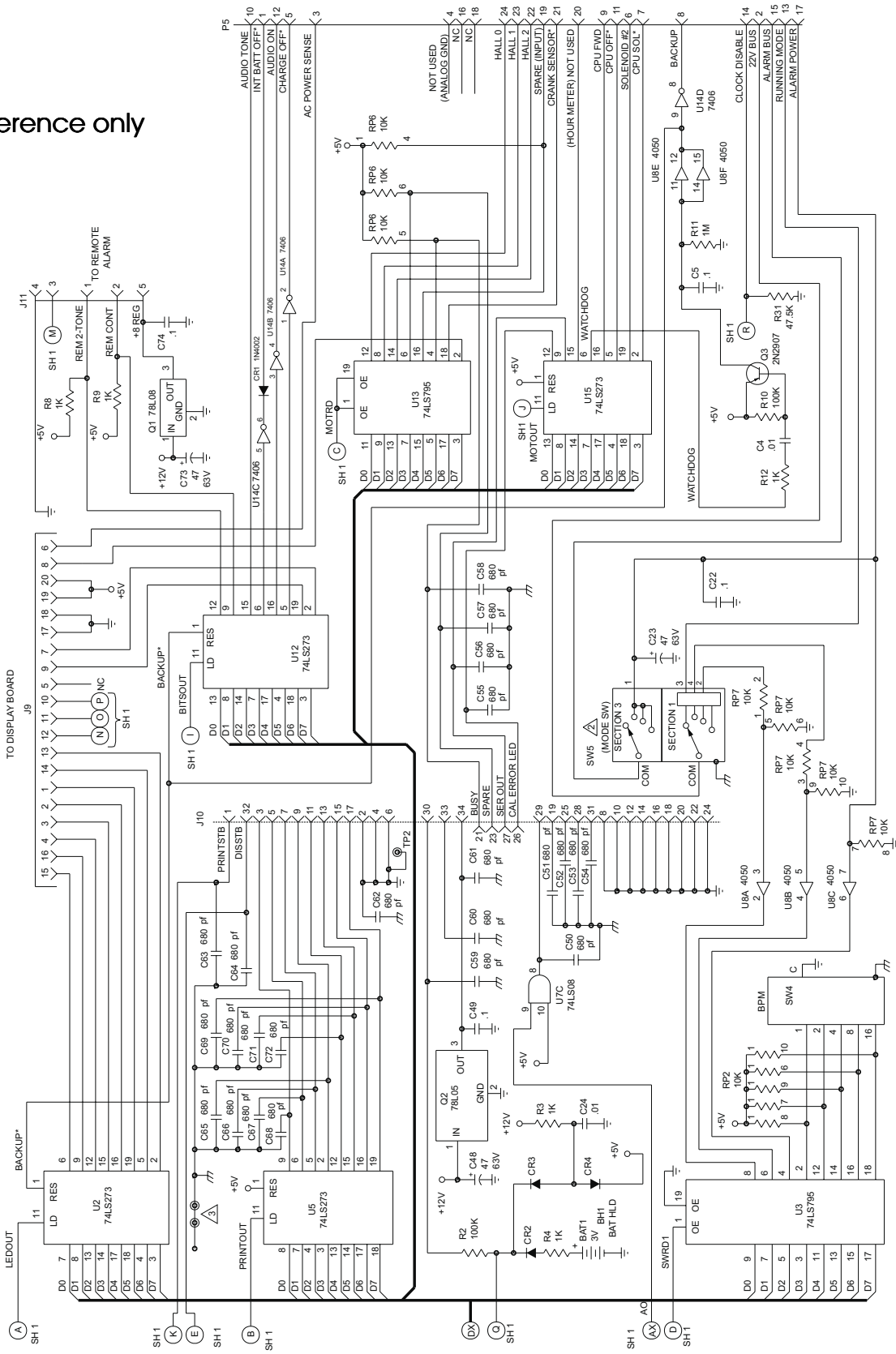


Through-Hole Logic Board

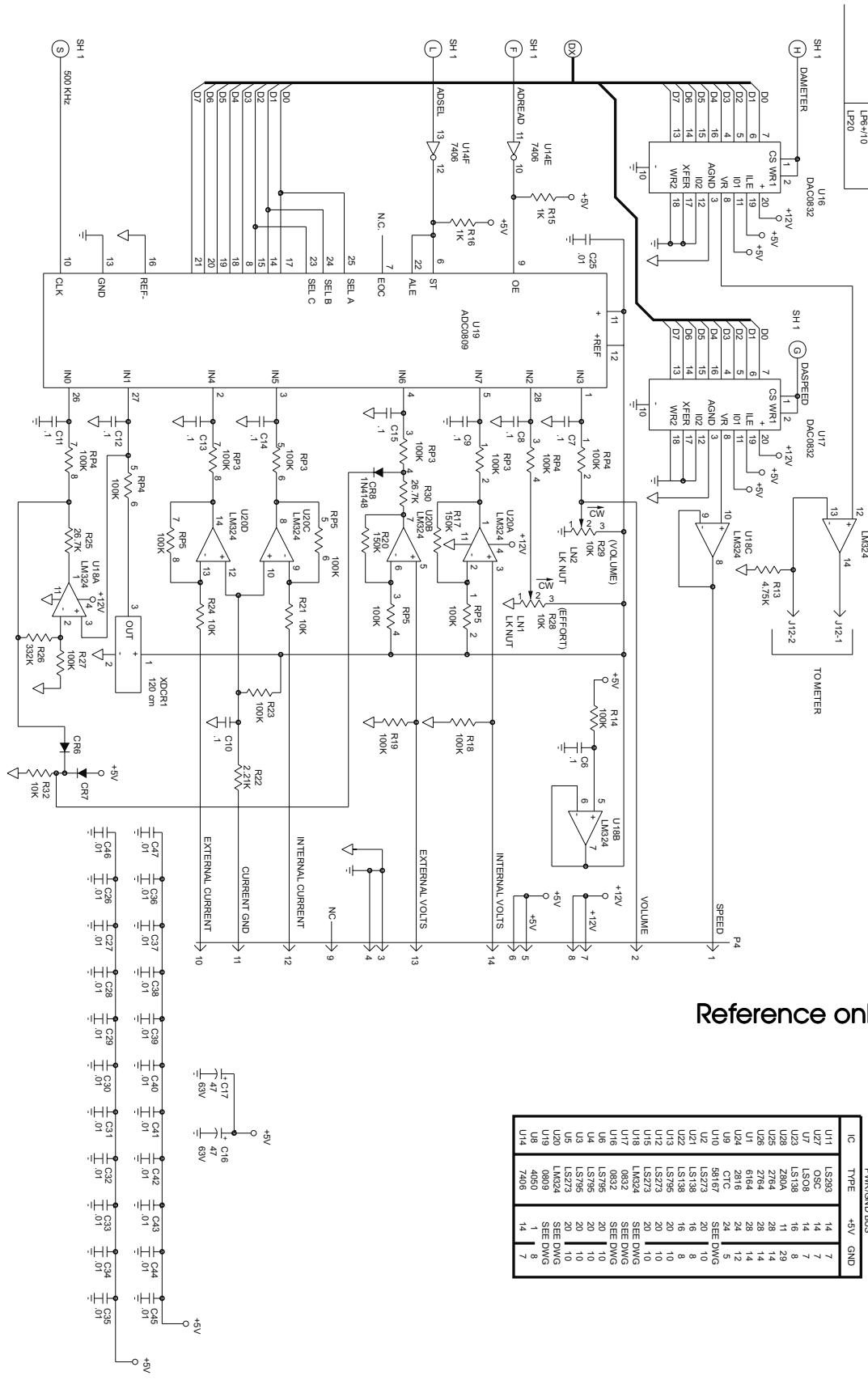


Through-Hole Logic Board

Reference only



Through-Hole Logic Board

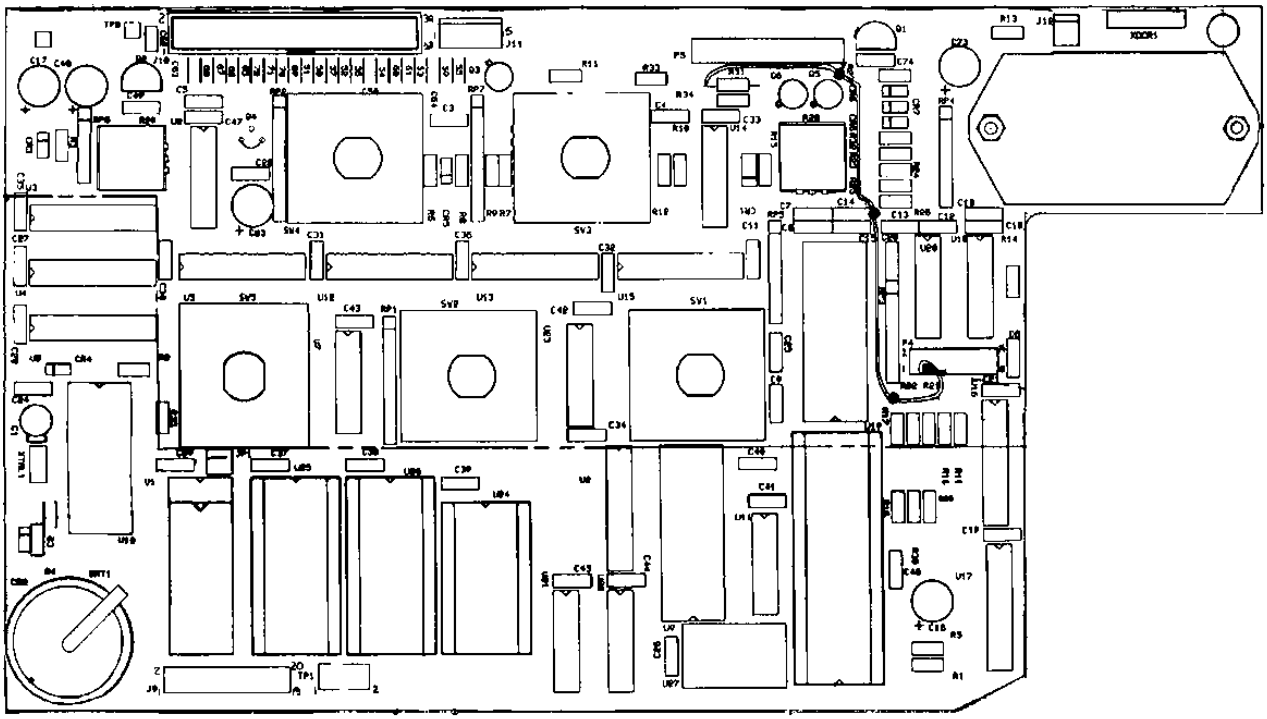


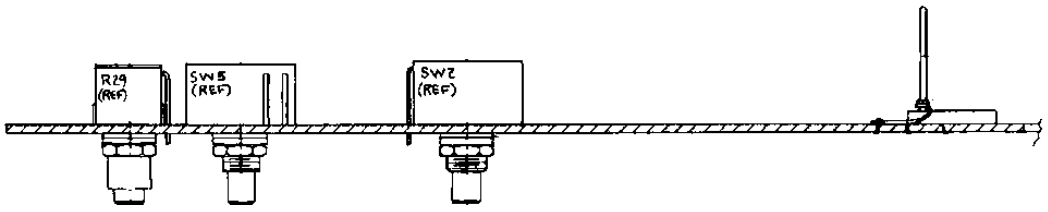
Reference only

IC	TYPE	PWR/GND BUS +5V	GND
U11	LS283	14	7
U27	OSC	14	7
U7	LS08	14	7
U23	LS138	16	8
U28	Z80A	11	29
U26	2764	28	14
U1	6164	28	14
U24	2816	24	12
U9	CTC	24	5
U10	58167	SEE DWG	
U2	LS273	20	10
U21	LS138	16	8
U22	LS138	16	8
U13	LS795	20	10
U12	LS273	20	10
U15	LS273	20	10
U18	LM324	SEE DWG	
U17	0832	SEE DWG	
U16	0832	SEE DWG	
U6	LS795	20	10
U4	LS795	20	10
U3	LS795	20	10
U5	LS273	20	10
U20	LM324	SEE DWG	
U19	0809	SEE DWG	
U8	4050	1	8
U14	7406	14	7

Through-Hole Logic Board

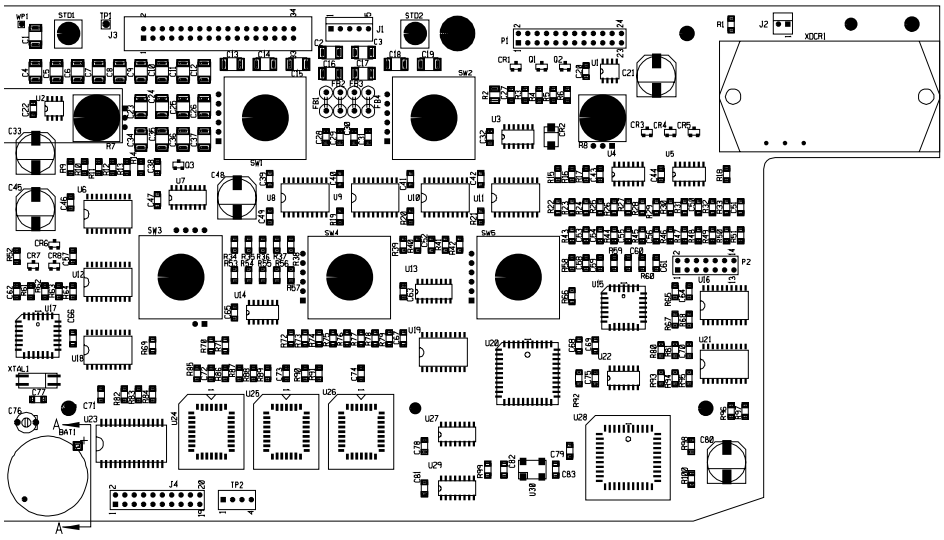
Reference only

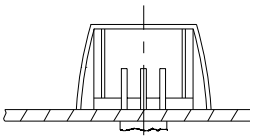


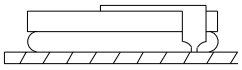


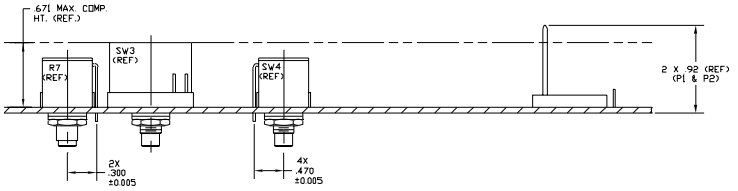
Surface-Mount Logic Board

Reference only



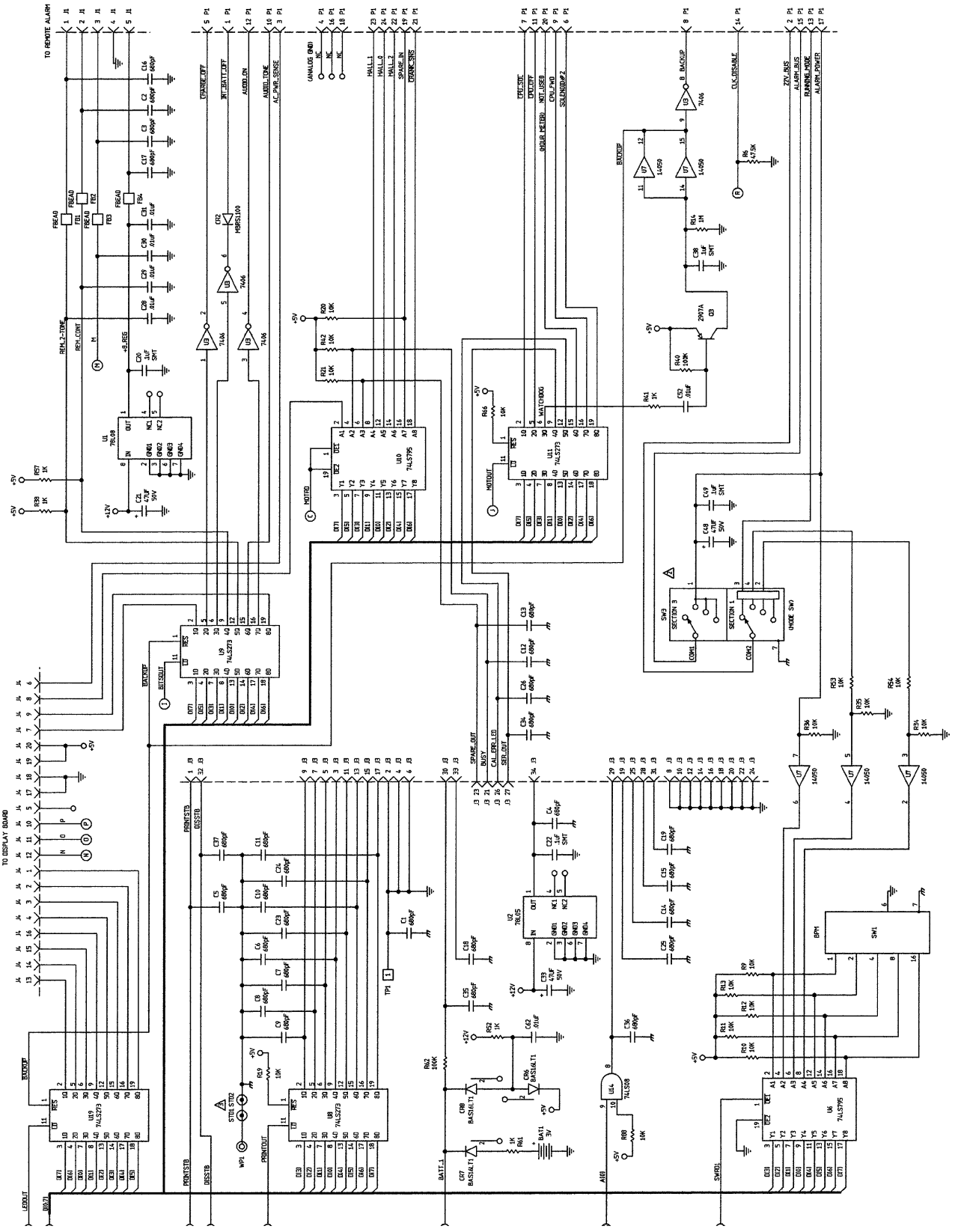






Surface-Mount Logic Board

Reference only



Surface-Mount Logic Board

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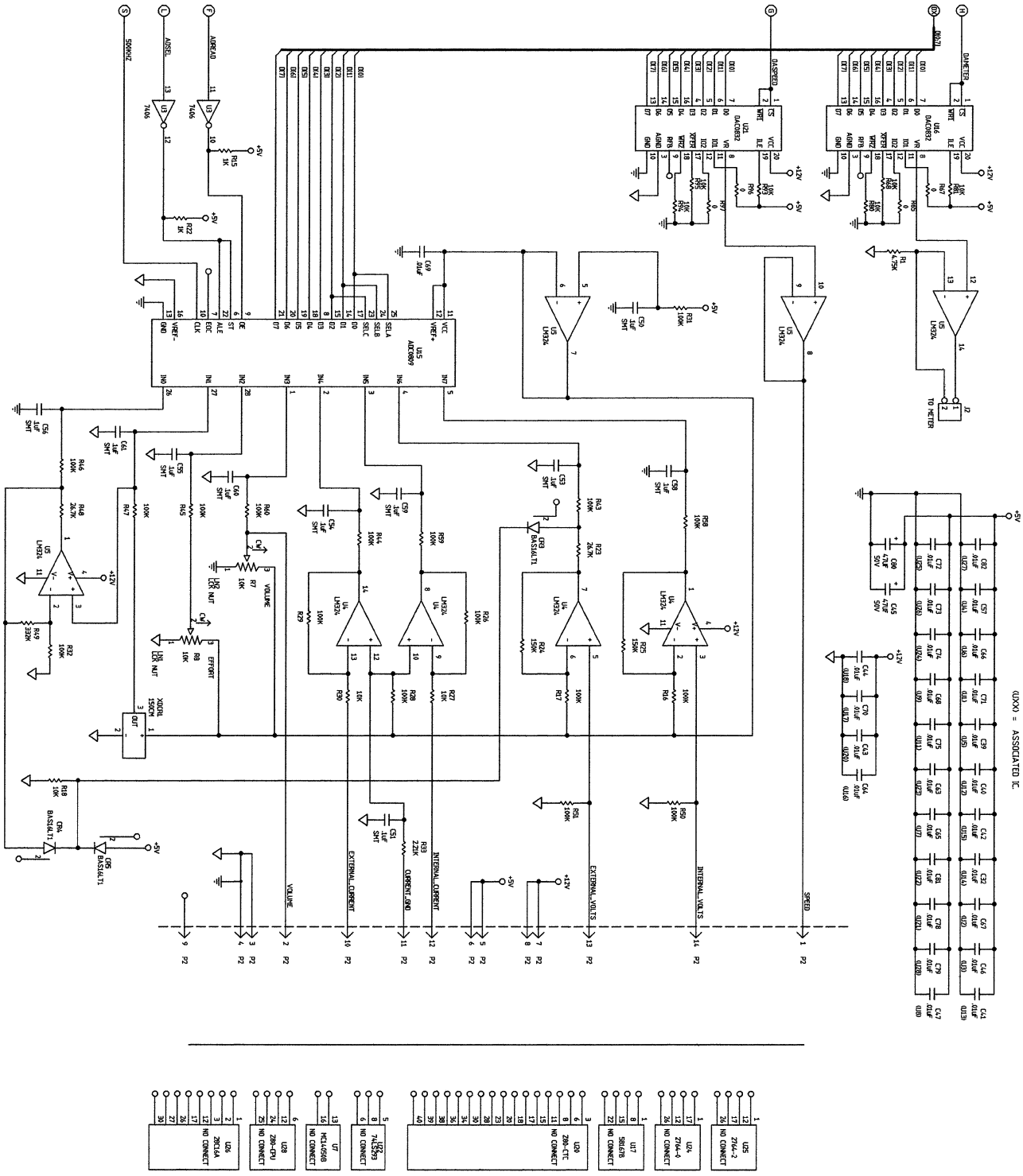
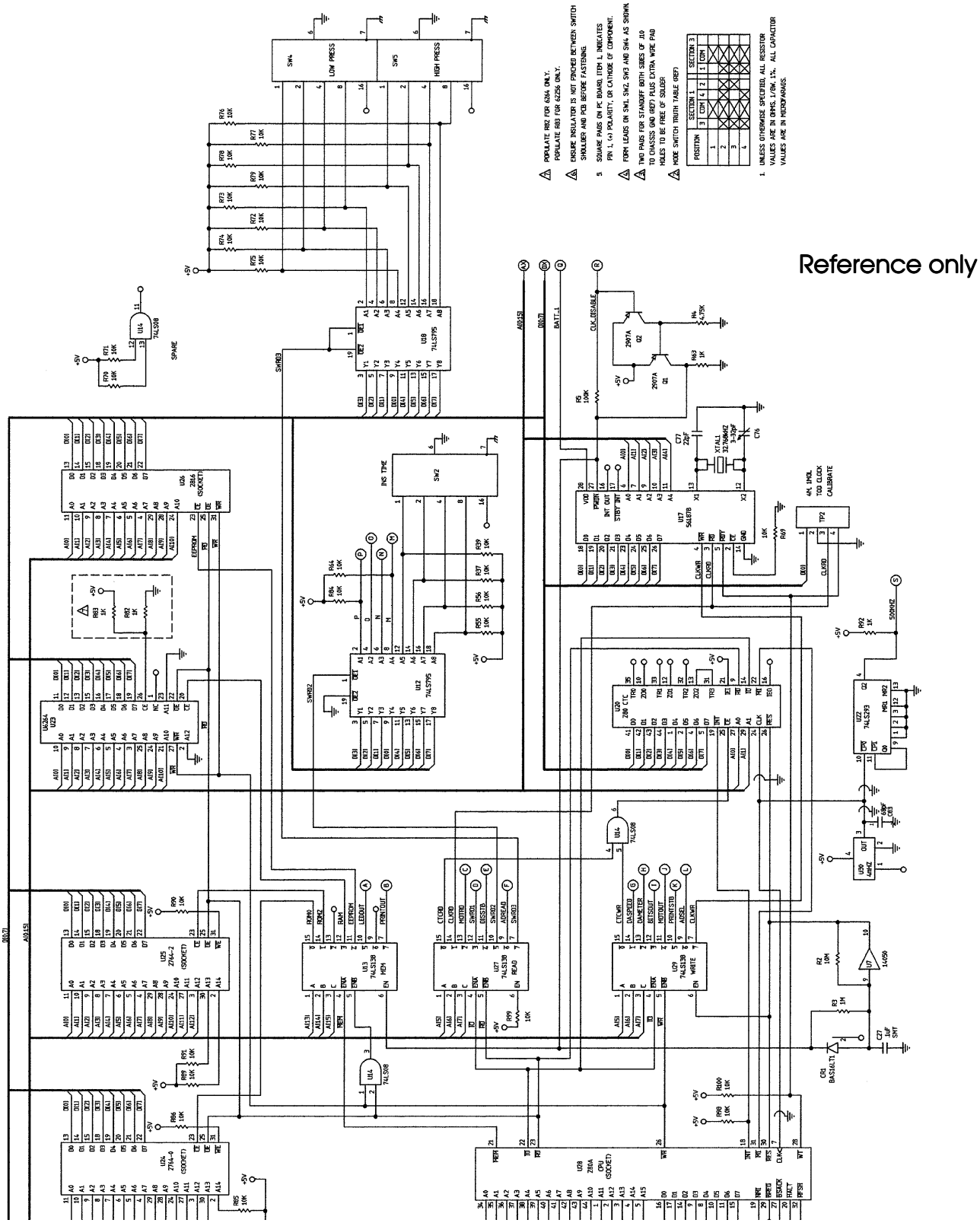
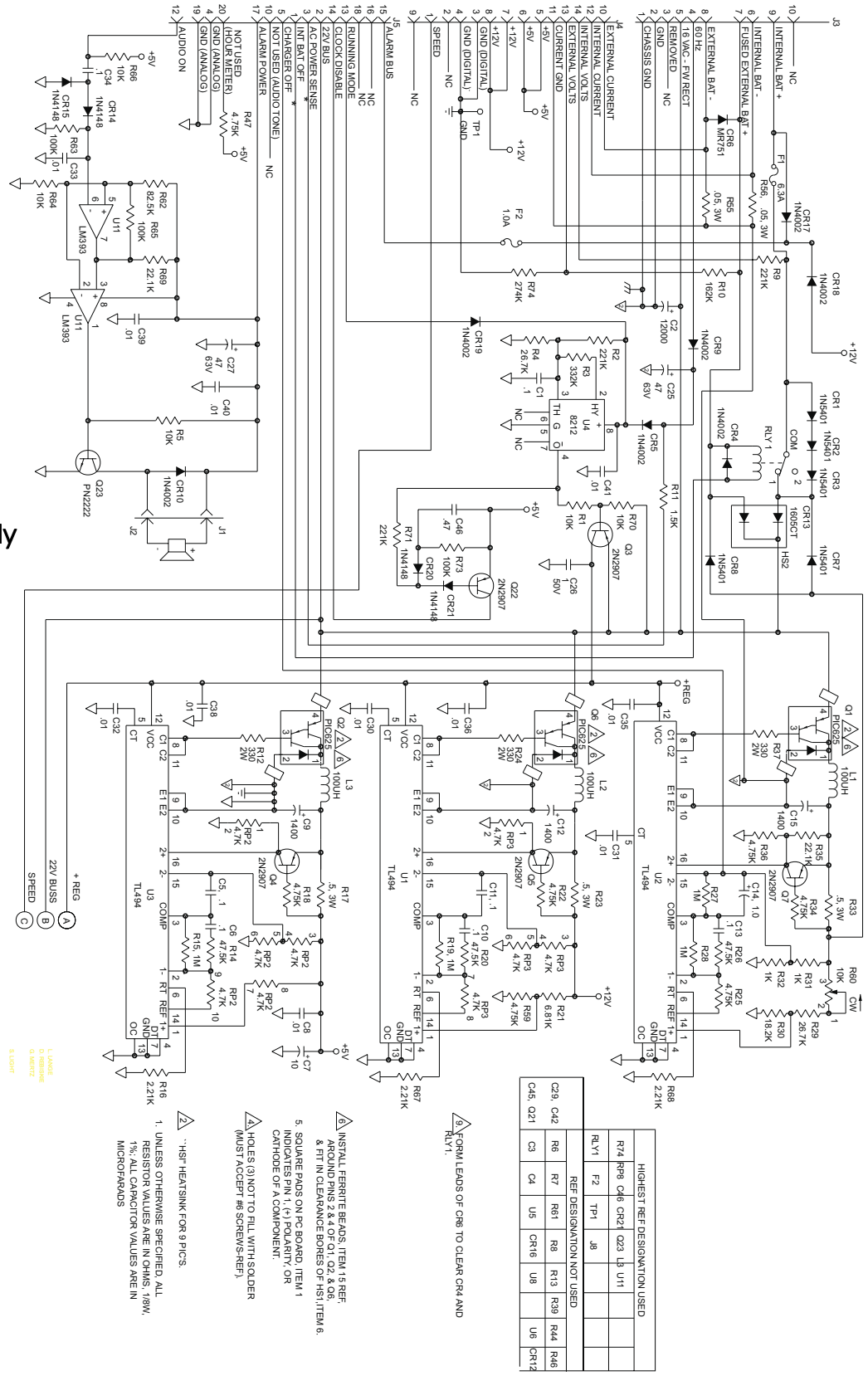


Surface-Mount Logic Board

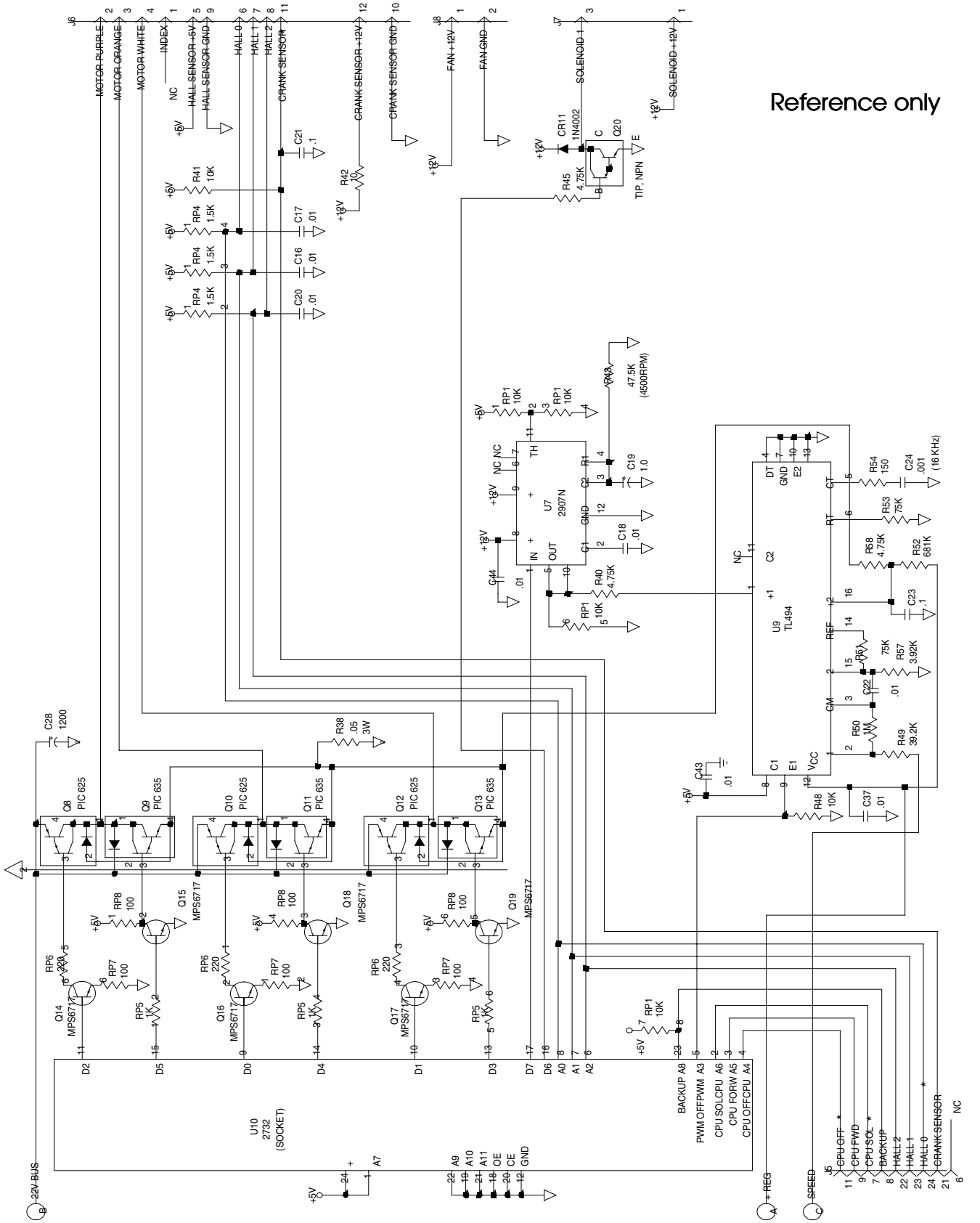


Through-Hole Power-Motor Board

Reference only



Through-Hole Power/Motor Board



Through-Hole Power/Motor Board

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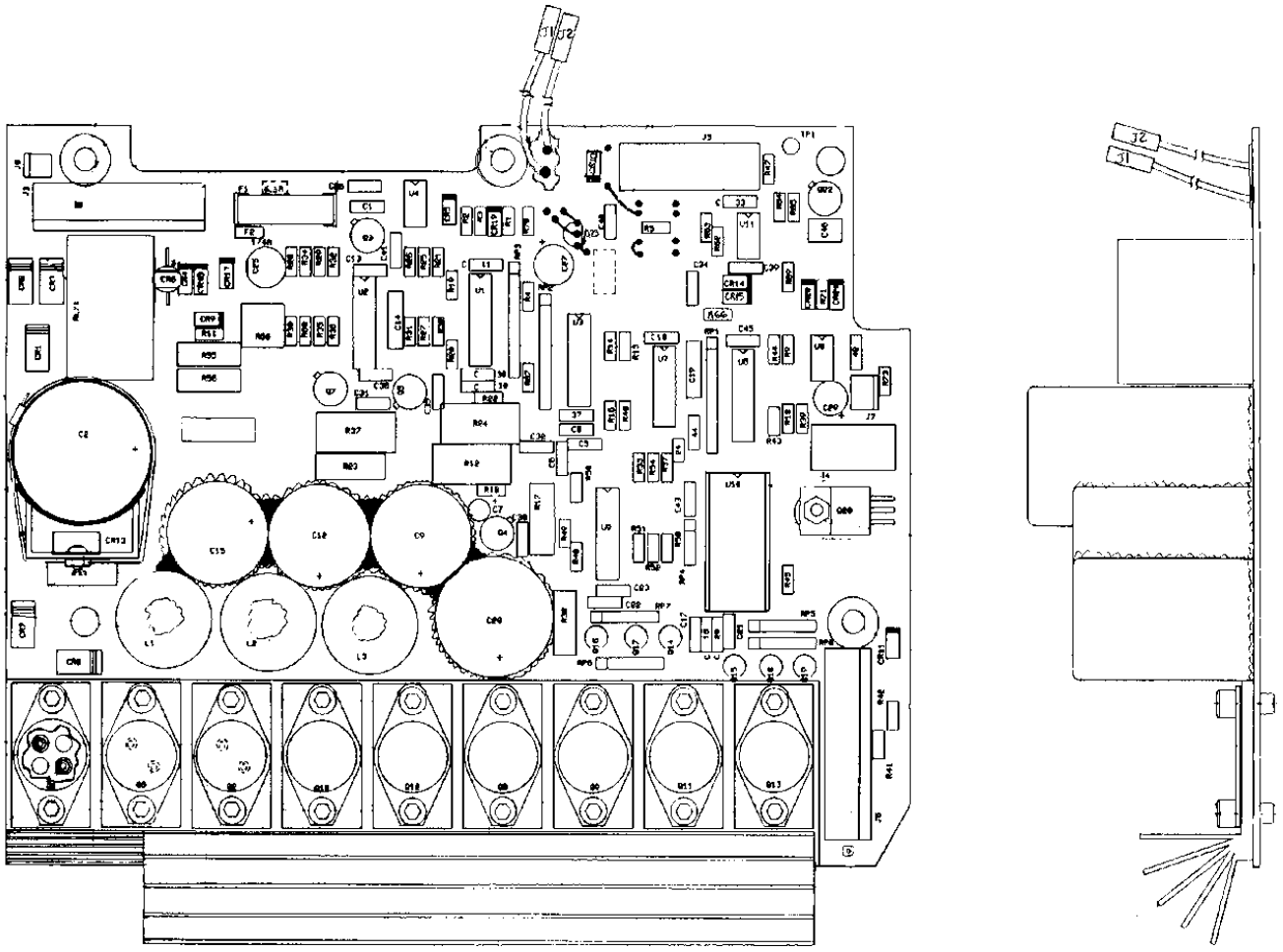
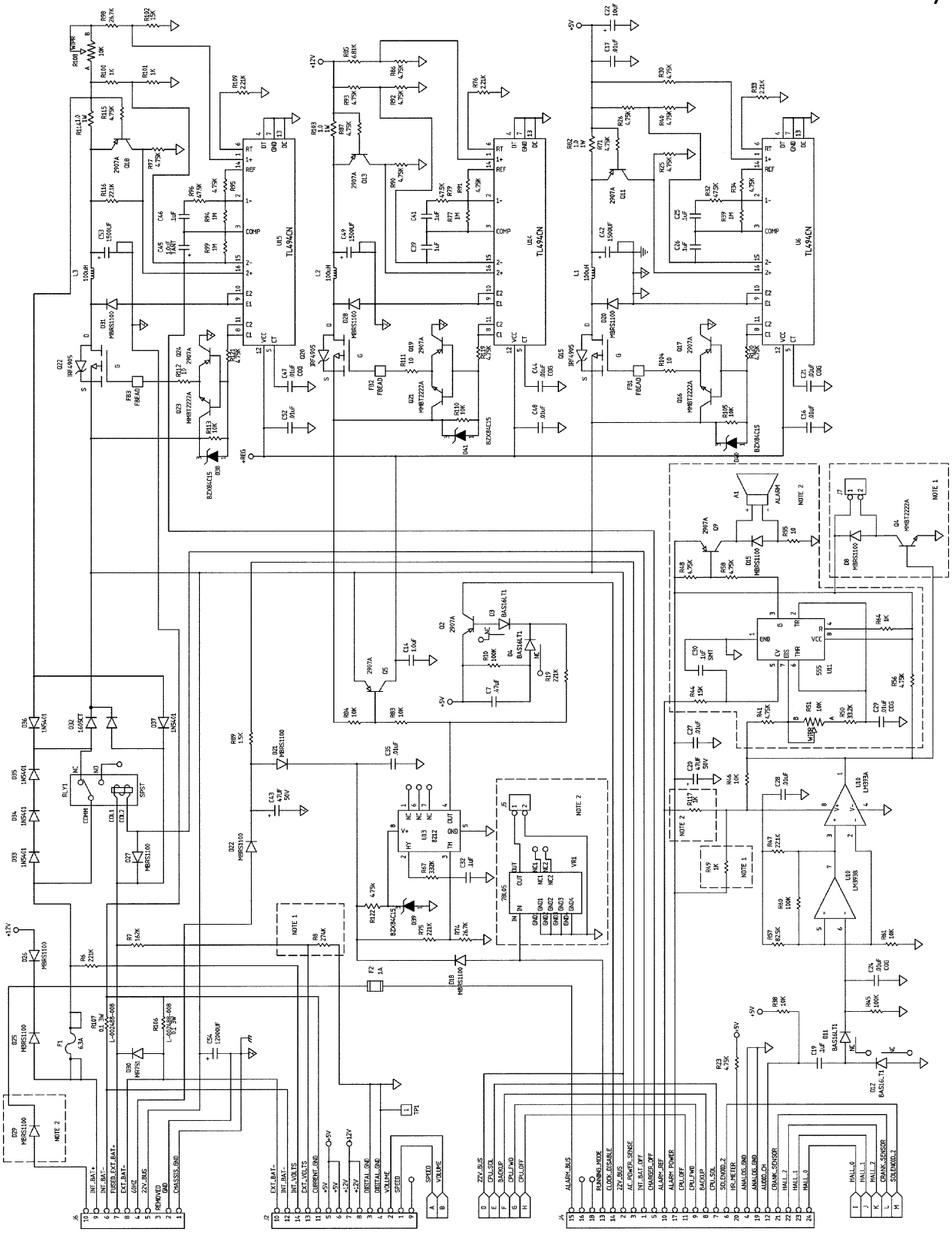


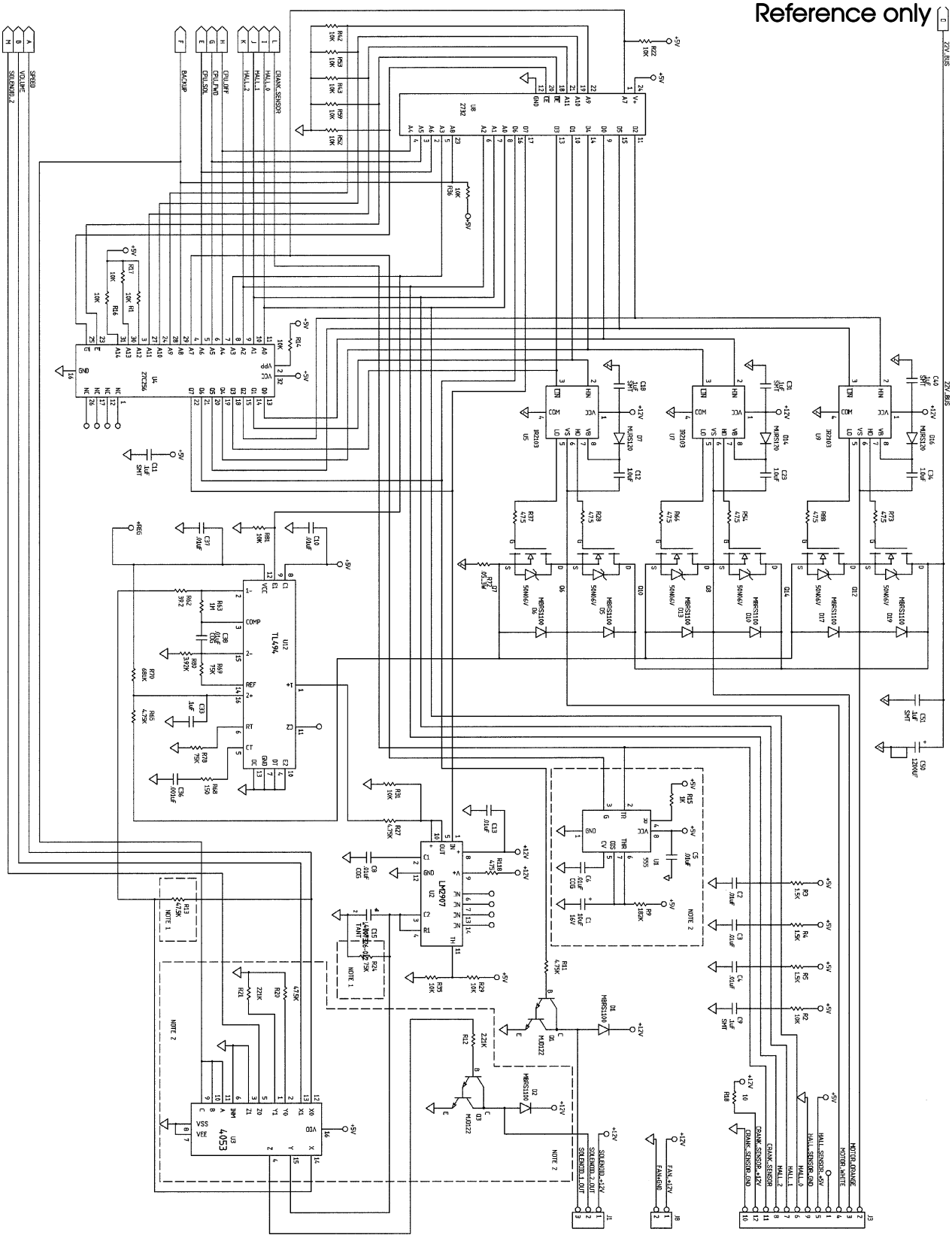
Surface-Mount Power/Motor Board

Reference only



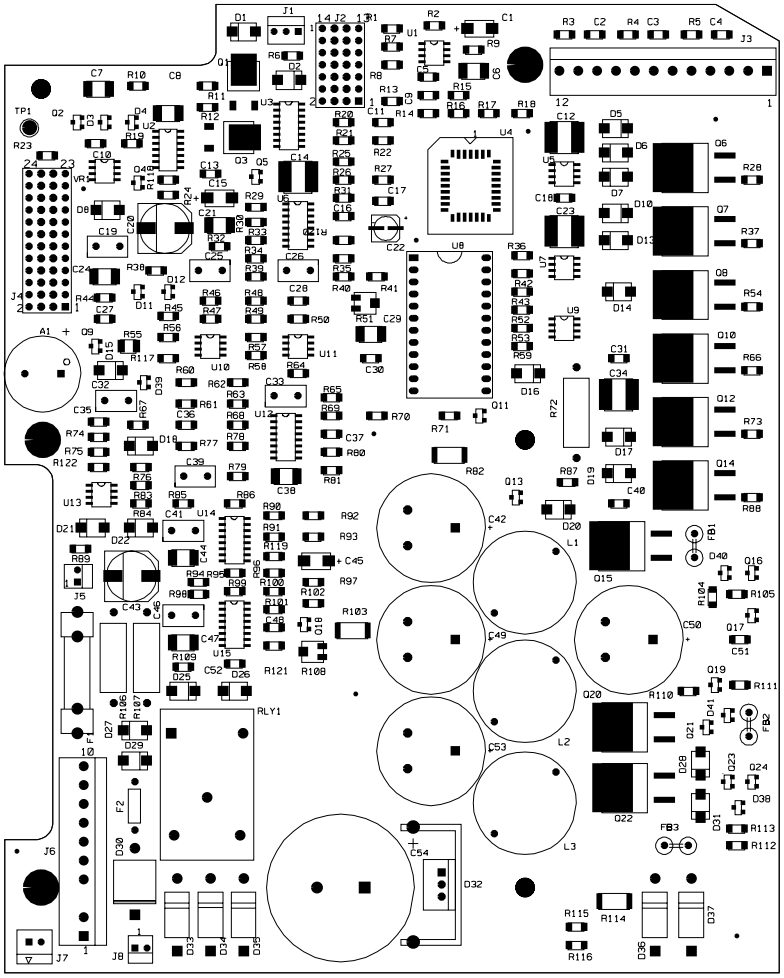
Surface-Mount Power/Motor Board

Reference only

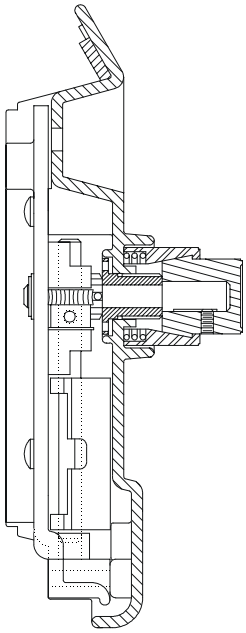


Surface-Mount Power/Motor Board

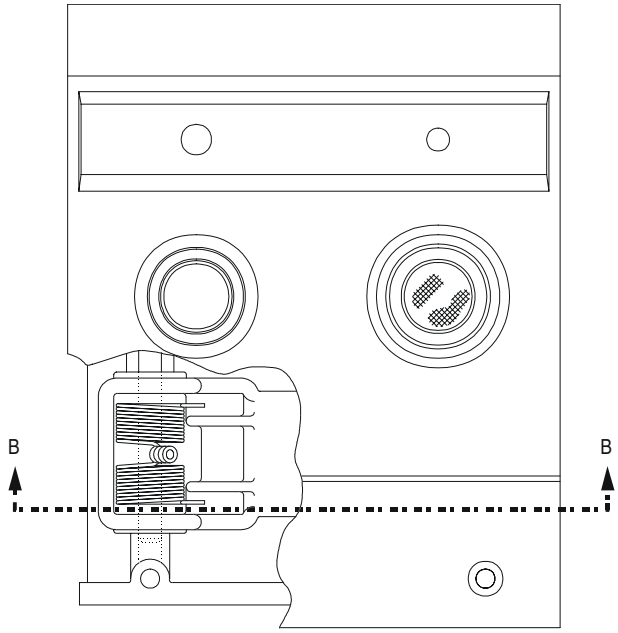
Reference only

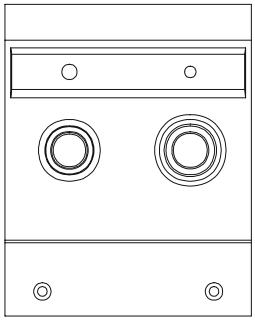


Pressure Limit Assembly (LP10, LP20)

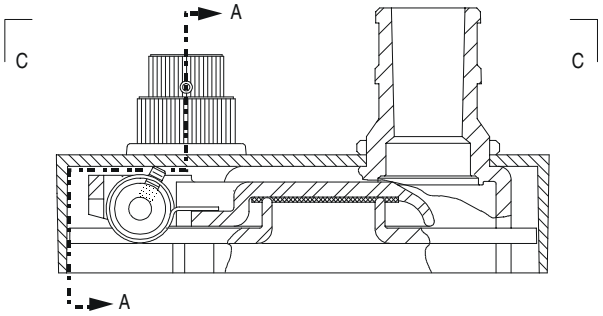


SECTION A-A



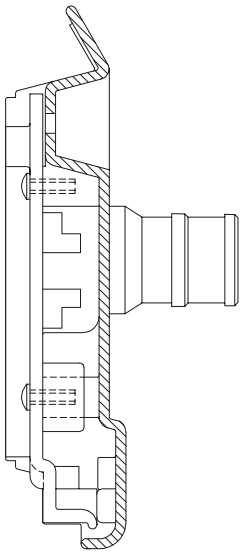


DETAIL C-C

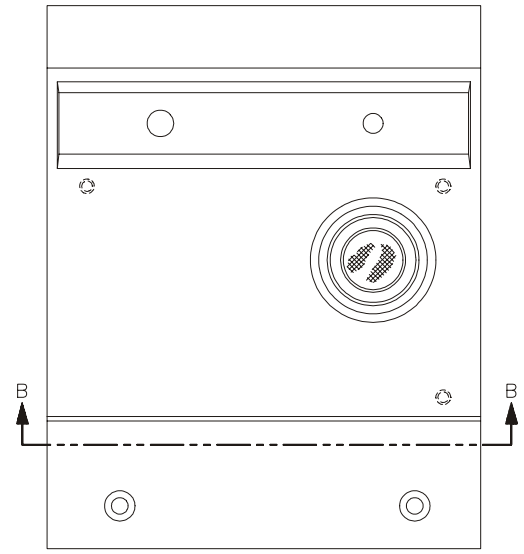


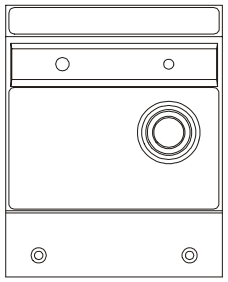
Reference only

Front Bezel (LP6 Plus only)

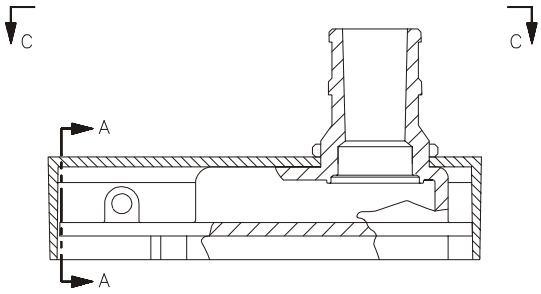


SECTION A–A





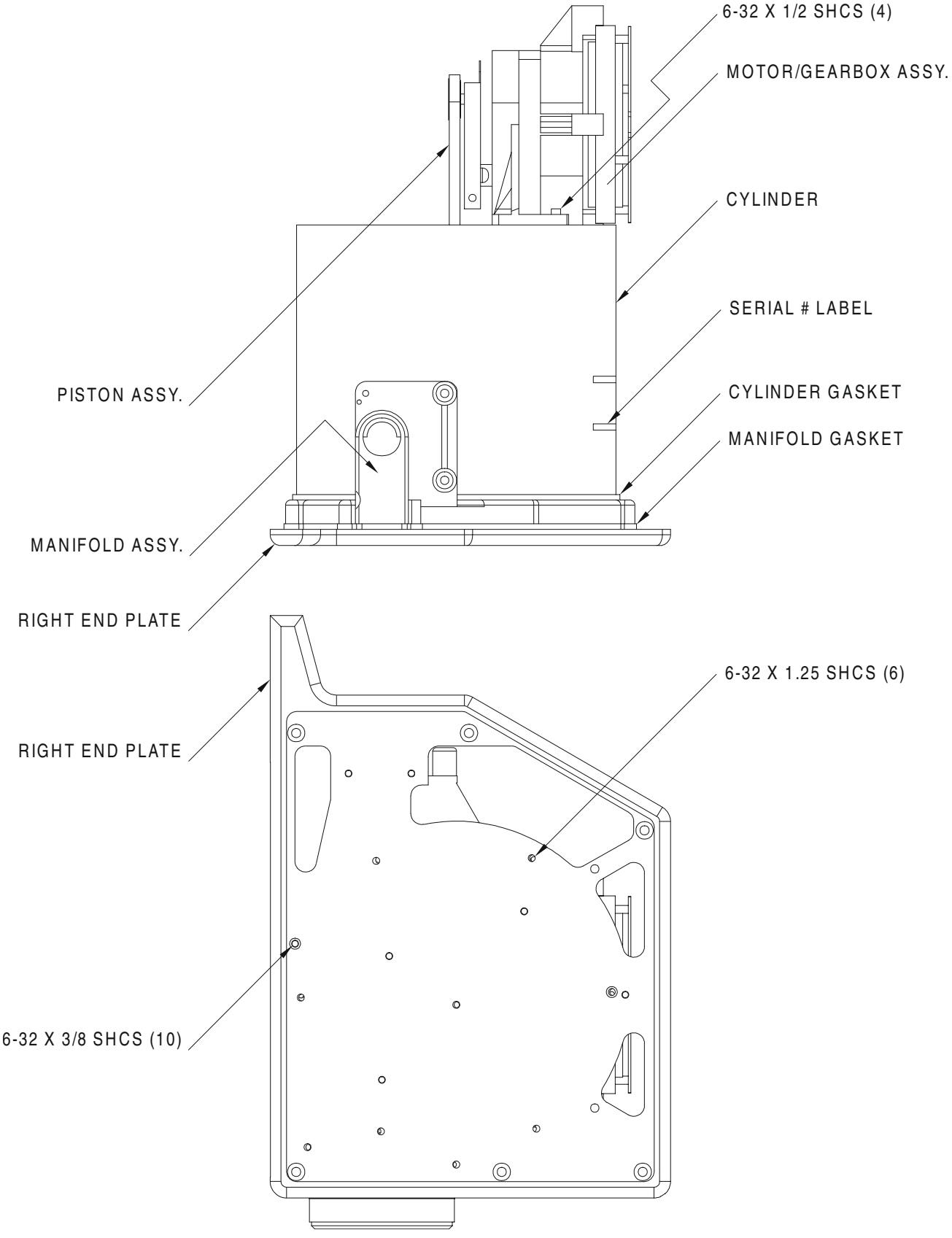
DETAIL C–C



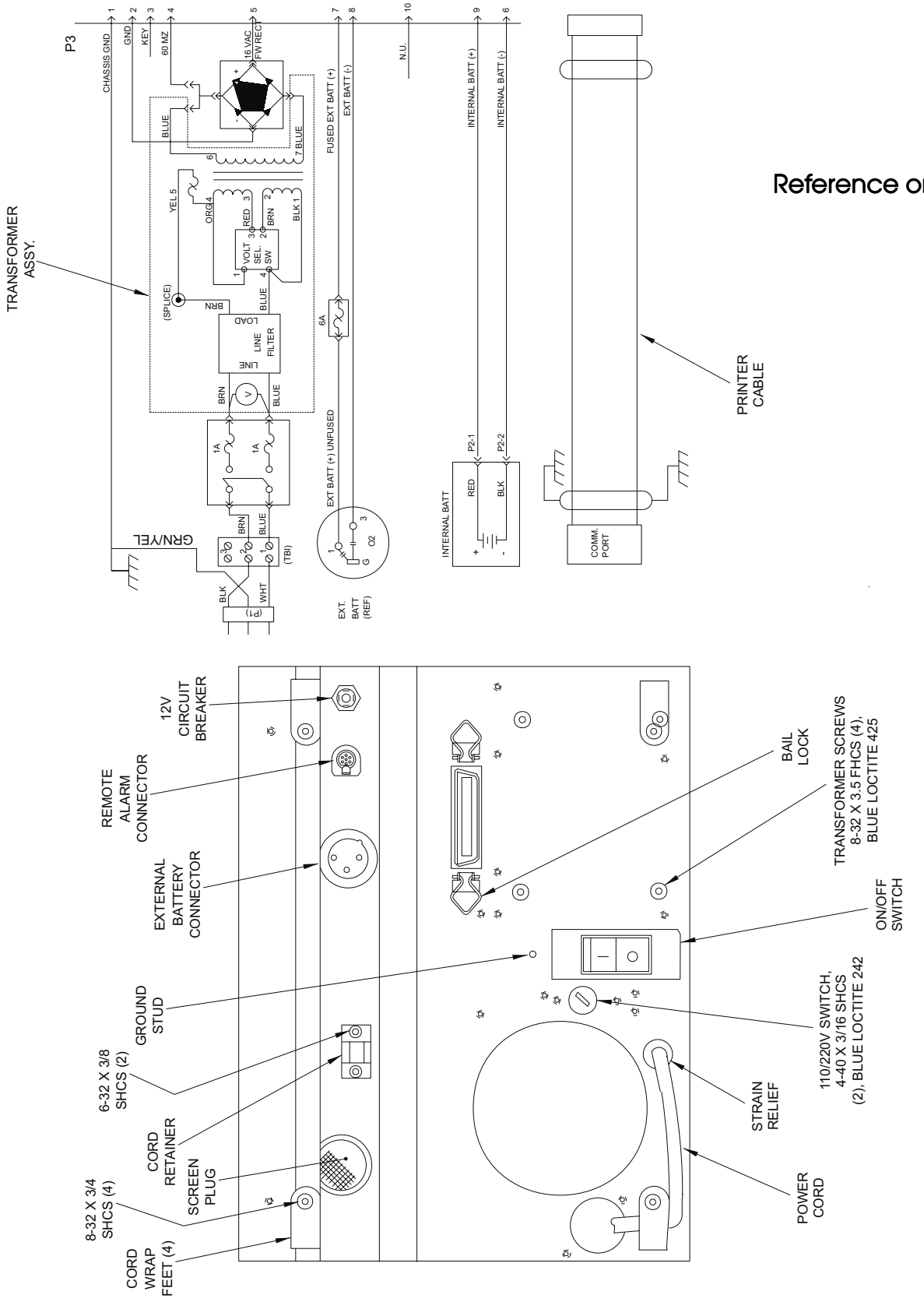
SECTION B–B

Reference only

Right End Assembly

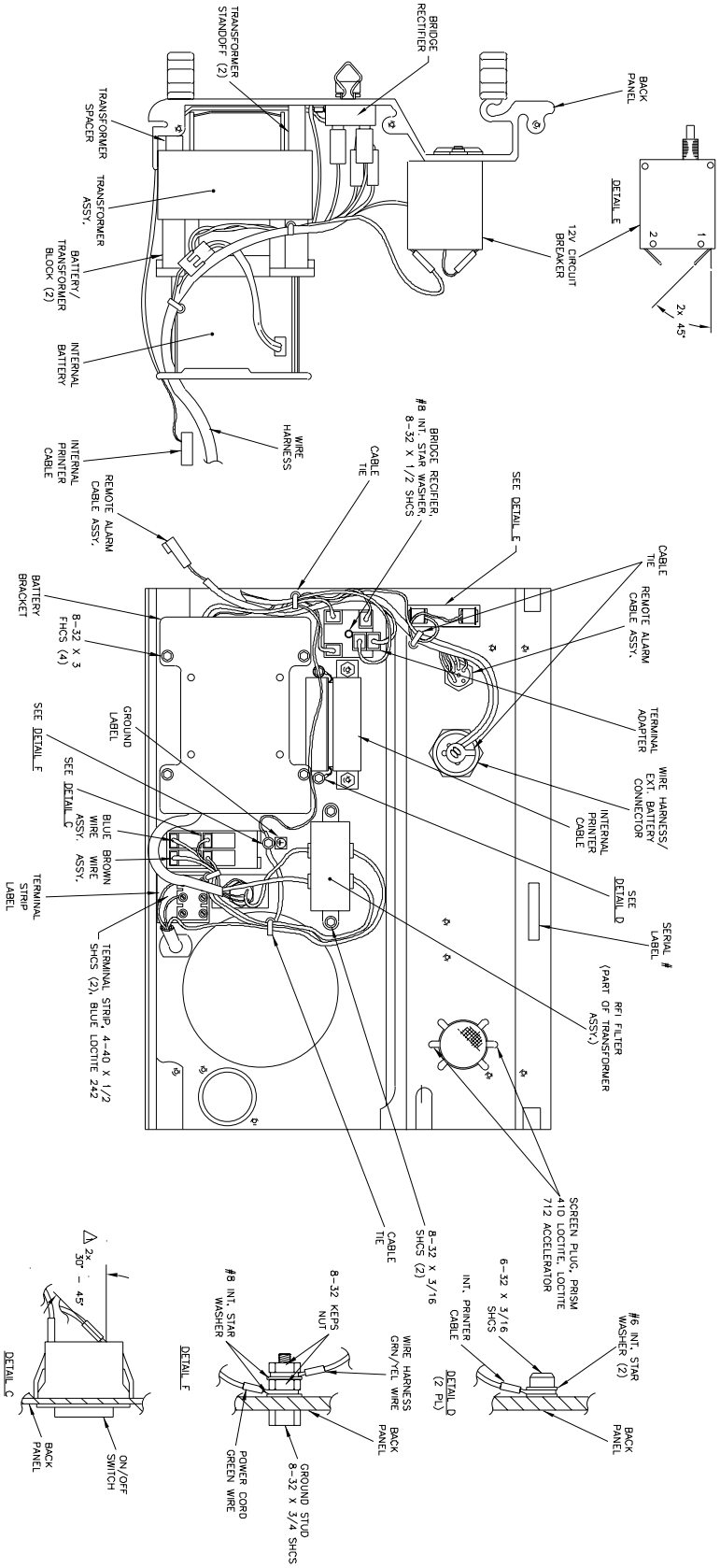


Back Panel (LP6 Plus, LP10)

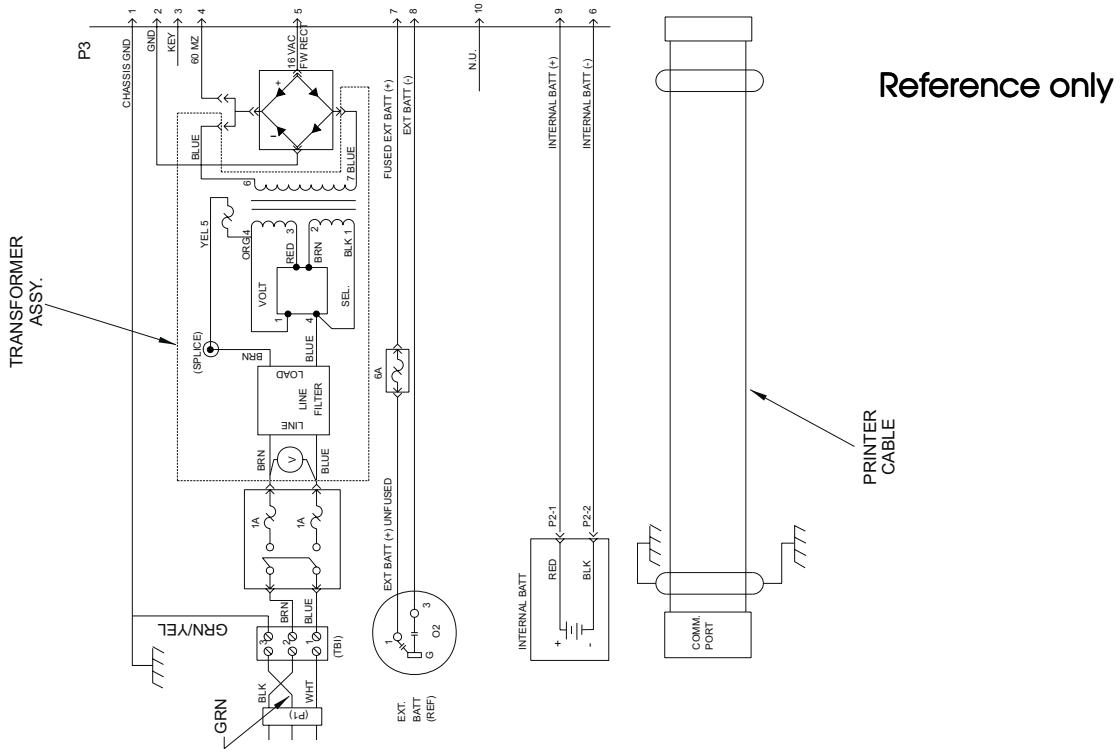


Back Panel (LP6 Plus, LP10)

Reference only

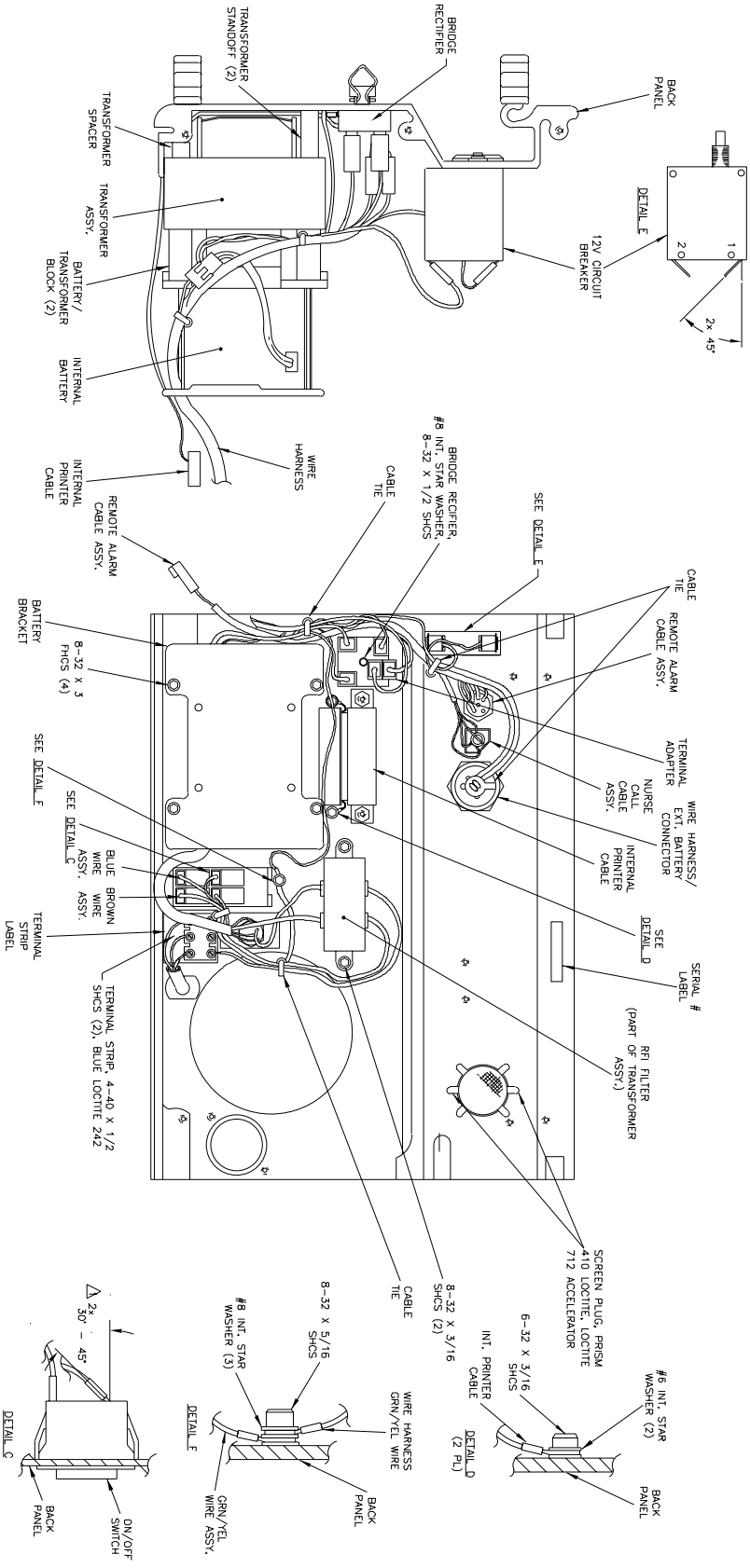


Back Panel (LP20)

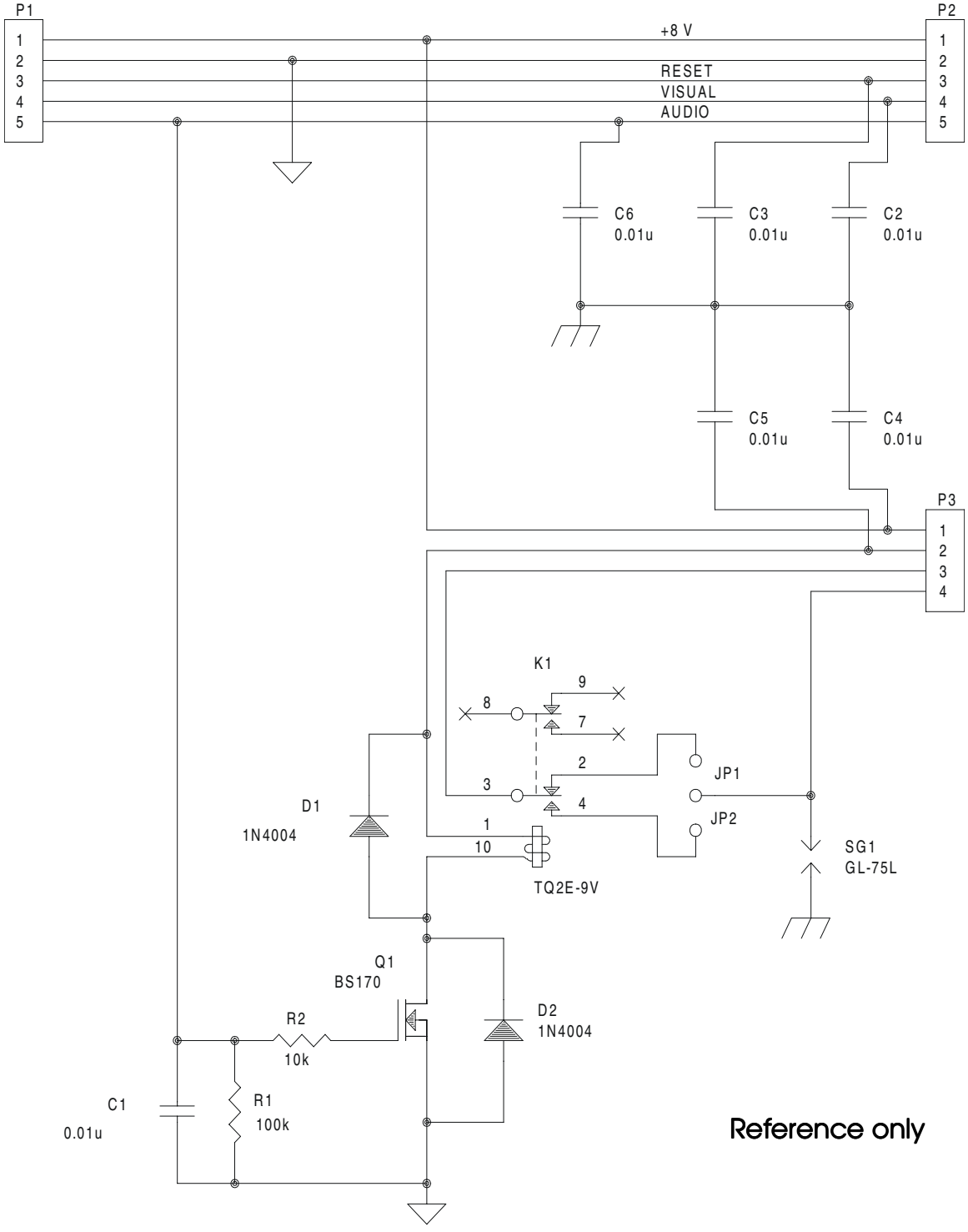


Back Panel (LP20)

Reference only



Nurse Call Board



8 Service Policy

The LP6 Plus, LP10, and LP20 Volume Ventilators are warranted against defects in workmanship and materials. The full warranty on the next page provides details. Do not make any service repairs on this equipment. Any unauthorized work immediately voids the warranty. If you need information or assistance, or the information in this manual is insufficient, contact Nellcor Puritan Bennett, Inc., at:

(800) 497-3787

Ask for a Technical Service Representative.

Nellcor Puritan Bennett does not recognize the owner of a Volume Ventilator as an authorized service representative. Nellcor Puritan Bennett will not be liable for any repairs attempted by the owner. Any such attempted repairs, other than specified non-warranty repairs, voids the warranty. Parts and labor costs incurred by the owner will not be reimbursed by Nellcor Puritan Bennett, Inc.

Before returning any device to Nellcor Puritan Bennett, you must get a Return Authorization Number by calling Nellcor Puritan Bennett at the number given above.

To ensure the best possible service, we need all the information from a completed Ventilation Data Sheet. There is a sample of this sheet in the back of the Clinician's Manual.

Limited Warranty

Nellcor Puritan Bennett® Inc. warrants to the owner that the LP6 Plus, LP10, and LP20 Volume Ventilators, exclusive of expendable parts and other accessories, shall be free from defects in material and workmanship for twenty-four (24) months from the original date of sale. Nellcor Puritan Bennett's sole obligation, with respect to any such defect, is limited to the repair or, at Nellcor Puritan Bennett's option, replacement of the Volume Ventilator. Purchaser pays return freight charges.

This warranty is made on the condition that prompt notification of a defect is given to Nellcor Puritan Bennett within the warranty period, and that Nellcor Puritan Bennett has the sole right to determine whether a defect exists.

This warranty is conditional on performance of Preventive Maintenance at a minimum of once every 6,000 hours of operation or recertification every twelve (12) months (whichever occurs first), by personnel qualified by Nellcor Puritan Bennett. The warranty does not apply to Volume Ventilators that have been partially or completely disassembled; altered; subjected to misuse, negligence, or accident; or operated other than in accordance with the instructions provided by Nellcor Puritan Bennett. This includes repair by unauthorized personnel.

This warranty represents the exclusive obligation of Nellcor Puritan Bennett and the exclusive remedy of the purchaser regarding defects in a Volume Ventilator.

"THIS WARRANTY IS GIVEN IN LIEU OF ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE."

No person is authorized to modify, in any manner, Nellcor Puritan Bennett's obligation as described above.

Nellcor Puritan Bennett, Inc., Minneapolis, MN 55441-2625 U.S.A.
(General) 800.497.4979 (Customer Service)800.497.4968 (Technical Service)800.497.3787