NELLCOR

Service Manual

N-20/N-20P Portable Pulse Oximeter

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

To contact Nellcor's representative: In the United States, call 1.800.635.5267 or 314.654.2000; outside the United States, call your local Nellcor representative.

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To obtain information about a warranty, if any, for this product, contact Nellcor's Technical Services Department, or your local representative.

Purchase of this instrument confers no expressed or implied license under any Nellcor Puritan Bennett patent to use the instrument with any sensor that is not manufactured or licensed by Nellcor Puritan Bennett.

Covered by one or more of the following U.S. Patents and foreign equivalents: 4,621,643; 4,700,708; and 4,770,179.

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1 INTRODUCTION

1.1 Manual Overview

This manual contains service information for the Nellcor® portable pulse oximeter, models N-20/N-20P, that is necessary to maintain and repair the N-20/N-20P by qualified service personnel. Note that models designated for sale in Europe differ from models designated for sale in the USA only in that the user control buttons and display use icons rather than alphabetical characters, and that the product labels reflect the appropriate European certifications and company addresses.

1.2 Warnings and Cautions

"WARNING" is used to call attention to procedures that could result in an error in calibration or performance, and/or precautions that are important to ensure the safety of both service personnel and patients.

"CAUTION" is used to call attention to procedures that should be carefully followed to prevent damage to the instrument.

1.3 Description of N-20 Portable Pulse Oximeter

The Nellcor portable pulse oximeters model N-20 (without printer) and N-20P (with printer) provide noninvasive and continuous information about the percent of oxygen that is combined with hemoglobin (SpO_2) and pulse rate. A pulse amplitude indicator provides a qualitative indication of pulse activity and patient perfusion. These instruments can be operated in either spot-check mode (single-measurement), or extended-measurement mode (30 minutes of data). Patients are connected to the instrument by a Nellcor oximeter sensor. The sensor LEDs are driven by the SpO_2 analog section, which also conditions the incoming signals, and provides CPU adjustable gains stages. The CPU measures the sensor's analog outputs, continually controls the gain stages, and calculates SpO_2.

The N-20/N-20P is automatically calibrated each time it is switched on, and whenever a new sensor is connected; it sets sensor-specific calibration coefficients by reading a calibration resistor in the sensor. Also, the intensity of the sensor's light sources is adjusted automatically to compensate for differences in tissue thickness and skin color.

Standard user controls consist of a Measure button and a Check-Battery button. The Measure button signals the power control circuit to switch on the power supply. The power supply then provides regulated power to the unit. Once power is on, the CPU reads both the Measure and Check-Battery buttons for user commands.

The N-20P printer provides a hard copy of acquired patient measurements. The printer circuit includes three user control buttons: ON (on/off), ADV (advance), and D/D (day/date). In addition, an ambient temperature sensor is used with the battery voltage input to control printout quality.

2 ROUTINE MAINTENANCE

2.1 Overview

The N-20/N-20P requires no routine maintenance, routine service, or calibration. If service is necessary, contact qualified service personnel or Nellcor's representative. Use only Nellcor-approved test equipment when running a performance test on the N-20/N-20P. The user's institution and/or local or national agencies may require testing.

2.2 Cleaning

Dampen a cloth with a commercial, nonabrasive cleaner, and lightly wipe the surfaces of the N-20/N-20P. Do not spray or pour liquid on the instrument or accessories. Do not allow liquid to contact connectors, switches, or openings in the chassis.

2.3 Periodic Safety and Functional Checks

The following checks should be performed at least every 2 years by a qualified service technician.

Inspect the exterior of the N-20/N-20P for damage.

Inspect safety labels for legibility. If the labels are not legible, contact Nellcor Technical Services Department or your local Nellcor representative.

2.4 Battery

When the N-20/N-20P is going to be stored for 3 months or more, remove the battery prior to storage. To replace or remove the battery, refer to Section 5, *Disassembly Guide.*

3 PERFORMANCE VERIFICATION

Caution: Adhere to all testing instructions; failure to do so may damage the N-20/N-20P.

3.1 Introduction

This section describes performance verification for the N-20 and N-20P pulse oximeters (hereafter called the “monitor”), following repairs. The N-20/N-20P are powered by alkaline batteries. The N-20/N-20P design includes built-in electrical insulation; no ground resistance or electromagnetic leakage testing is required.

The tests can be performed without removing the monitor cover. If the monitor fails to perform as specified in any test, repairs must correct the discrepancy before the monitor is returned to the user.

3.2 Required Materials

Durasensor	Nellcor DS-100A
Tester, Pulse Oximeter	Nellcor SRC-2

3.3 Performance Tests

The N-20/N-20P will operate in conjunction with the Nellcor® pulse oximetry tester, model SRC-2, to test instrument performance. The SRC-2 plugs into the DB-9 sensor connector and uses the instrument's power supply and diagnostic software to test the display and the operation of the instrument. Refer to the operator's manuals for the SRC-2 for details on performance testing with the SRC-2.

Other tests, which are outlined below, include the display backlight test, the low battery indicator test, the power-up self-test, and the thermal printer test (printer test applies only to N-20P).

3.3.1 Backlight Test

The electroluminescent backlight illuminates the display in three sections: (1) the main section, i.e., the Oxygen Saturation and Pulse Rate display fields, and the 14-segment pulse rate amplitude indicator; (2) the Low Battery indicator, and (3) Pulse Search indicators each have their own backlight. All backlights flash once during Power-On Self-Test.

The ambient light detector is located underneath a small circular window in the top right corner of the N-20/N-20P display. Under low light conditions, the main section backlight is switched on. If a Low Battery and Pulse Search indicator are lit, the monitor’s backlight is also lit.

To test for proper operation of the display backlight, observe the N-20/N-20P in a darkened room. If any backlight section is not working correctly, contact Nellcor's Technical Services Department or Nellcor's local representative for assistance.

3.3.2 Battery Performance

This test is provided to verify that the monitor will operate for the period specified.

The monitor is specified to operate on battery power as follows:

N-20 (no printer)	37 hours with Alkaline batteries.
N-20/P (with printer)	32 hours with Alkaline batteries.

This test requires a new set of batteries. The new batteries must be installed after the test.

Connect the Nellcor SRC-2 pulse oximeter tester to the monitor.
Set the switches on the SRC-2 as follows:

Switch	**Setting**
RATE	38
LIGHT	LOW
MODULATION	LOW
RCAL/MODE	RCAL 63/LOCAL

Momentarily press the MEASURE button, and verify the following power-up sequence:
All indicators—OXYGEN SATURATION, PULSE RATE, PULSE SEARCH, LOW BATTERY, and the PULSE BARS—light for a few seconds. Verify the OXYGEN SATURATION, and PULSE RATE displays indicate "888."
The OXYGEN SATURATION display momentarily indicates the monitor 3-digit software version. The other displays are not lit.
Software versions may vary depending on the type of monitor and the date of manufacture.

The N-20P will display printer status immediately after displaying the software version. The OXYGEN SATURATION display will indicate “Pr”and the PULSE RATE display will indicate either “On” or “OFF.”

The OXYGEN SATURATION display momentarily indicates the letters ”tSt” and the monitor sounds a single tone. The other displays are not lit. “tSt” verifies that the monitor recognizes that a tester is connected.

The OXYGEN SATURATION and PULSE RATE displays indicate “0,” the PULSE SEARCH indicator is flashing, and the PULSE BAR will start to register the simulated pulse.

After a few beats a pulse tone will be heard, and the PULSE SEARCH indicator will turn off. The OXYGEN SATURATION display indicates between 79 and 83, and the PULSE RATE display indicates between 37 and 39.

The monitor must operate for at least 37 hours if the printer is not turned on.

Verify that the LOW BATTERY indicator lights steadily sometime after 30 hours of operation.

Verify that the monitor turns off approximately 1 hour after the LOW BATTERY indicator starts flashing.

Allow the monitor to continue operation until power-down due to low battery.

3.3.3 Power-Up Performance

Monitors with the same software must demonstrate identical startup routines. The power-up tests verify the self-test function.

When an N-20/N-20P is switched on, a sequence of diagnostic tests is run that examines the instrument electronics and display functions. This power-on self-test consists of the following events:

Immediately after power is switched on, the instrument simultaneously:

- Displays the number "8" in all six Oxygen Saturation and Pulse Rate display field segments;
- Illuminates all 14 pulse rate amplitude indicator segments;
- Illuminates the Pulse Search and Low Battery indicators; and
- Illuminates the display backlight.

During the next few seconds, the instrument:

- Switches off the display backlight;
- Displays three digits in the Oxygen Saturation display field representing the software version (for example, 123 is software version 1.2.3).
- Only the N-20P displays the printer status in the display fields; that is, either "Pr On" or "Pr OFF."

If a sensor is attached to the instrument, a zero ("0") appears in first position of the display fields. The **Pulse Search** indicator flashes; if no sensor is attached to the instrument, horizontal dashes appear in all six **Oxygen Saturation** and **Pulse Rate** display fields, and the **Pulse Search** indicator flashes.

After approximately 1 minute, a short beep occurs and the instrument automatically switches off.

If at any time during the test sequence "Err" followed by a code number is displayed, make a note of the error code and refer to Section 4.7, Error Codes, for a description.

3.3.3.1 How To Run the Self-Test

Place a new set of batteries in the monitor.

Do not connect a sensor or SRC-2 to the monitor.

Momentarily press the MEASURE button, verify the following power-up sequence:

All indicators—OXYGEN SATURATION, PULSE RATE, PULSE SEARCH, LOW BATTERY, and the PULSE BARS—light for a few seconds. Verify that the OXYGEN SATURATION and PULSE RATE displays indicate "888."

The OXYGEN SATURATION display momentarily indicates the monitor 3-digit software version. The other displays are not lit.

Software versions may vary depending on the type of monitor and the date of manufacture.

The N-20P will display printer status immediately after it displays software version. The OXYGEN SATURATION display will indicate “Pr” and the PULSE RATE display will indicate either “On”or “OFF.”

OXYGEN SATURATION and PULSE RATE display dashes (– – –) in each window, the monitor sounds a single tone, and the PULSE SEARCH indicator is flashing. The other displays are not lit.

Verify that the monitor automatically turns off after 60 seconds.

If the **Measure** button was held down for more than 3 seconds (extended mode), the monitor will not turn off after 60 seconds but will operate for approximately 3 minutes before automatically turning off.

3.3.4 Printer Test

The following procedure applies to the N-20P only.

The SRC-2 must be used to test the operation of the N-20P printer and the printer's user-control buttons. When an SRC-2 is plugged into the DB-9 connector, the N-20P does not respond to button presses during Power-On Self-Test; however, it does acknowledge any button press after the self-test with an immediate beep and the following display codes:

Button Press	Display
Measure	9O
battery check	bAt
ON	On

ADV	Ad
D/D	dd
combinations	Err

1. Press the **Measure** button: "9O" appears in the **Oxygen Saturation** display.
2. Press the **Battery-Check** button: "bAt" appears in the **Oxygen Saturation** display.
3. Press the printer **ON** button: "On" appears in the **Oxygen Saturation** display. A printer test pattern prints out; the following is an approximate example of the test pattern:

Examine the test pattern to verify that all dots print with a uniform darkness. Overall printout darkness can be adjusted; to adjust printer darkness, see paragraph 4.6.7. If printout darkness is either irregular or dots are missing, contact Nellcor's Technical Services Department or Nellcor's local representative for assistance.

1. Press the printer ADV button. “Ad” appears in the Oxygen Saturation display. Paper advances one line for each button press.
2. Press the printer ***D/D*** button: "dd" appears in the **Oxygen Saturation** display.
3. End SRC-2 printer test.

3.3.5 Hardware and Software Tests

Hardware and software tests include the following:

Operation with a Pulse Oximeter Tester

Normal Operation

3.3.5.1 Pulse Oximeter Tester

1. Connect the Nellcor SRC-2 pulse oximeter tester to the monitor.
2. Set the switches on the SRC-2 as follows:

Switch	Setting
RATE	38
LIGHT	LOW
MODULATION	LOW
RCAL/MODE	RCAL 63/LOCAL

3. Momentarily press the MEASURE button, and verify the following power-up sequence:

4. All indicators—OXYGEN SATURATION, PULSE RATE, PULSE SEARCH, LOW BATTERY, and the PULSE BARS—light for a few seconds. Verify that the OXYGEN SATURATION and PULSE RATE displays indicate "888."”
5. The OXYGEN SATURATION display momentarily indicates the monitor 3 digit software version. The other displays are not lit.
6. Software versions may vary depending on the type of monitor and the date of manufacture.

The N-20P will display printer status immediately after software version display. The OXYGEN SATURATION display will indicate “Pr,” and the PULSE RATE display will indicate either “On” or “OFF.”

The OXYGEN SATURATION display momentarily indicates the letters ”tSt” and the monitor sounds a single tone. The other displays are not lit. “tSt” verifies that the monitor recognizes that a tester is connected.

The OXYGEN SATURATION and PULSE RATE displays indicate “0,” the PULSE SEARCH indicator is flashing, and the PULSE BAR will start to register the simulated pulse.

After a few beats a pulse tone will be heard, and the PULSE SEARCH indicator will turn off. The OXYGEN SATURATION display indicates between 79 and 83 and the PULSE RATE display indicates between 37 and 39.

3.3.6.2 Normal Operation

These tests are an overall qualitative check of the system and require connecting a live subject to the monitor:

Connect a DS-100A Sensor to monitor.
Place the DS-100A Sensor on the subject as recommended in the monitor Operator's Manual.
Press the Measure button for at least 5 seconds to turn on the monitor.
The monitor should stabilize on the subject's physiological signal in about 10 to 15 seconds. Verify that the saturation value and pulse rate are acceptable.

TEST RESULTS

Model:______N-20________ Serial:______________________________

Date:____________Customer Name:_________________________________

Description	Pass	Fail
Performance Tests	_____	____
Backlight Test	_____	____
Battery Performance	_____	____
Testing the Low Battery Indicator	_____	____
Power-Up Performance	_____	____
How to Run the Self-Test	_____	____
Printer Test	_____	____
Pulse Oximeter Test	_____	____
Normal Operation	_____	____

I certify that the monitor listed in this form has successfully passed all of these tests.

Technician:____Date:____________

I certify that the above signed technician has performed the tests listed on this form and the monitor performs satisfactorily.

Support Center Manager:____Date:____________

4 TROUBLESHOOTING

WARNING: Disassembly of the instrument exposes hazardous voltages. To avoid injury or instrument damage, disassembly or maintenance must be attempted only by qualified service personnel.

4.1 How to Use this Section

This section explains how to identify and correct monitor difficulties and provides procedures for common service-related activities, such as battery replacement, clearing paper jams, and adjusting printer darkness.

Use this section in conjunction with Section 3, *Performance Verification,* and Section 6, *Spare Parts*. To remove and replace a part you suspect is defective, follow the instructions in Section 5, *Disassembly Guide*. The functional circuit analysis, located in the Technical Supplement at the end of this manual, offers information on how the device functions, as well as part locator diagrams and detailed schematic diagrams.

4.2 Who Should Perform Repairs

Only qualified service personnel should open the device housing, remove and replace components, or make adjustments. If your medical facility does not have qualified service personnel, contact Nellcor Technical Services.

4.3 Replacement Level Supported

The replacement level supported for this product is to the printed circuit board (PCB) and major subassembly level. Once you isolate a suspected PCB, replace the PCB with a known good PCB. Check to see that the trouble symptom disappears and the device passes all performance tests. If the trouble symptom persists, swap the replacement PCB and the suspected malfunctioning PCB (the original PCB that was installed when you started troubleshooting) and continue troubleshooting as directed.

4.4 Obtaining Replacement Parts

Nellcor Technical Services provides technical assistance information and replacement parts. To obtain replacement parts, contact Nellcor. Refer to parts by the part names and part numbers listed in Section 6, *Spare Parts*.

4.5 Troubleshooting Guide

This section discusses potential symptoms, possible causes, and actions for their resolution. Should this troubleshooting guide fail to address the symptoms evident in a particular N-20/N-20P, please contact Nellcor's Technical Services Department or a local Nellcor representative for assistance.

If the N-20/N-20P does not perform as expected:

- Check for proper sensor placement.
- Depending on concentration, indocyanine green, methylene blue, and other intravascular dyes may affect the accuracy of a measurement.
- These instruments are calibrated to read oxygen saturation of functional arterial hemoglobin (saturation of hemoglobin functionally capable of transporting oxygen in the arteries), and significant levels of dysfunctional hemoglobins such as carboxyhemoglobin or methemoglobin may affect the accuracy of a measurement.

If the electronics and/or display functions require testing, refer to Section 3, *Performance Verification*.

Symptom 1: No response to Measure button.

Cause	Action
Battery access door may not be properly latched.	Check access door and ensure it is properly latched.
Batteries may be discharged.	Exchange them for a new set.
Batteries may be incorrectly installed.	Ensure that batteries are oriented according to the polarity indicator.
Batteries may not be making proper electrical contact.	Inspect contacts for deformity; clean contacts to remove oxidization.
Fuse F1 on the auxiliary PCB may be open.	See paragraph 4.6.5, Fuse Replacement.
Dust may have accumulated under Measure button causing loss of electrical contact.	Clean contact points under Measure button (see Section 5.3, *N-20 Disassembly Guide).*

Symptom 2: Pulse Search indicator appears for more than 5-10 seconds.

Cause	Action
Sensor may be improperly positioned.	Ensure the sensor is correctly applied (see sensor directions for use).
Incorrect sensor may be in use.	See sensor directions for use to ensure that the patient's weight and sensor application is correct. Test the sensor on another person to verify proper operation.
Perfusion may be too low.	Check patient status. Test the instrument on someone else, or try another type of sensor. The N-20/N-20P will not make a measurement if perfusion is inadequate.
Foreign material on the sensor LEDs or photodetector may be affecting performance.	Clean the test area and ensure that nothing blocks the sensor site.
Patient motion may be interfering with the instrument's ability to find a pulse pattern.	If possible, ask the patient to remain still. Verify that the sensor is securely applied and replace it if necessary, move it to a new site, or use a sensor that tolerates patient movement, such as an appropriate adhesive sensor.
Environmental motion may be interfering with the instrument's ability to track a pulse	
The sensor may be too tight, there may be excessive illumination (e.g., a surgical or bilirubin lamp or direct sunlight), or the sensor may be placed on an extremity with a blood pressure cuff, arterial catheter, or intravascular line.	
The DB-9 sensor connector on the N-20/N-20P may be broken.	Replace the DB-9 connector (Section 4.6.6).

Symptom 3: Pulse Search indicator appears after successful measurements have been made.

Cause	Action
Patient perfusion may be too low.	Check patient status. Test the instrument on someone else, or try another type of sensor. The N-20/N-20P will not make a measurement if perfusion is inadequate.
Patient motion may be interfering with the instrument's ability to find a pulse pattern.	If possible, ask the patient to remain still. Verify that the sensor is securely applied and replace it if necessary, move it to a new site, or use a sensor that tolerates patient movement, such as an appropriate adhesive sensor.
Environmental motion may be interfering with the instrument's ability to track a pulse.	
The sensor may be too tight, there may be excessive illumination (e.g., a surgical or bilirubin lamp or direct sunlight), or the sensor may be placed on an extremity with a blood pressure cuff, arterial catheter, or intravascular line.	

Symptom 4: Dashes (– – –) appear in the display.

Cause	Action
The sensor is not connected to the instrument.	Check all sensor connections; try substituting another sensor. Check all extension cables. If an extension cable is in use, remove it and plug the sensor directly into the instrument.

Symptom 5: Pr Err is displayed during the Power-On Self-Test (N-20P only).

Cause	Action
The printer is not operational, but the N-20P continues to obtain patient measurements.	Check to see if the paper is jammed. Examine the print head and ensure that it has returned to the home position.

Symptom 6: Err followed by a number appears on the display.

Cause	Action
See Section 4.7 for error codes.	Record the number that is displayed.

Symptom 7: Time or date is incorrect (N-20P only).

Cause	Action
The real-time clock (RTC) battery may be exhausted.	Replace the RTC battery (see Section 4.6.4). Reset the time and date (see Section 4.6.3).

Symptom 8: Printer fails to operate (N-20P only).

Cause	Action
Fuse F2 on the auxiliary PCB may be open.	See paragraph 4.6.5 for information about fuses.

Symptom 9: Printer paper advances but instrument does not print (N-20P only).

Cause	Action
The thermal paper may be improperly loaded; characters can be printed on only one side of the thermal paper roll.	Ensure that the thermal paper is properly loaded; if needed, remove the roll of printer paper and reload the printer paper.

Symptom 10: Paper mechanism jams (N-20P only).

Cause	Action
Note: If a printer paper jam is detected during Power-On Self-Test, Pr Err may appear on the display.	
	Switch off the N-20P. Then check to see if the print head is at the home position; if so, attempt to pull the paper out by pulling gently—do not force it.
	If the print head is not at the home position, and the paper cannot be easily pulled out from the printer, then the printer may need to be disassembled to remove the paper jam (see Sections 5.3, *N-20 Disassembly Procedure,* and 4.6.2, *Loading/Clearing Printer Paper).*

4.6 Service Procedures

The following service procedures are most likely to be encountered by the service technician. The PCB designation for a component appears in parentheses, for example, (BT1) or (U15).

4.6.1 Installing Batteries

1. Remove the battery cover access door by pressing the battery compartment access door latch.
2. Install four alkaline "C" cell batteries. Be sure to observe the polarity indicator sticker.
3. Replace the battery cover access door.

4.6.2 Loading/Clearing Printer Paper

The N-20P uses a thermal paper that can show printed characters on one side only. Make sure that the paper roll is correctly installed; always refer to the graphical instruction label found on the paper roll.

1. Press down and outward on the top of the paper compartment door to remove it.
2. Feed the paper into the paper compartment slot; refer to the graphic label for orientation.
3. Press and hold the ADV button until the end of the paper appears at the paper exit slot.
4. Replace the paper compartment door.

If the paper jams either during the loading process or during printing, proceed as follows:

1. Remove both the paper door and the printer-head access cover.
2. Firmly grab and pull the paper roll backward—out and away from the print head—observe the access to the print head to determine whether or not the paper escaped from the jammed position.
3. If paper remains jammed between the print head and printer, press the ADV button; the jammed paper may work its way out. If the paper remains jammed, and the printer drive does not advance the paper, manually advance the drive gear on the side of the printer to free the paper.
4. If these attempts fail to free the jammed paper, remove the printer from the unit to gain full access (see paragraph 5.3, *N-20 Disassembly Procedure).*

4.6.3 Setting Date and Time

The following procedure applies to the N-20P only.

The following code letters and numbers appear in both Oxygen Saturation and Pulse Rate display fields. The symbol "xx" represents information in the Oxygen Saturation display field and "yy" represents information in the Pulse Rate display field.

Begin this procedure by first removing any sensor from the instrument.

1. Turn on the monitor without the sensor connected. Switch on the N-20P and allow the unit to run the Power-On Self-Test.
2. When dashes appear in the Oxygen Saturation and Pulse Rate displays, press the D/D (day/date) button once. At this point, the Oxygen Saturation display field shows "txx", with "t" representing time; "xx" representing hours, and "yy" representing minutes. Note that "xx" (hours) is flashing.
3. Press the ADV (advance) button repeatedly until the correct hour is displayed.
4. Press the D/D button once. Note that "yy" (minutes) is now flashing.
5. Press the ADV button repeatedly until the correct minute is displayed.
6. At this point, the Oxygen Saturation display field shows "dxx", with "d" representing date; "xx" representing the month, and "yy" representing the date. Note that "xx" (month) is flashing.
7. Press the ADV button repeatedly until the correct month is displayed.
8. Press the D/D button once. Note that "yy" (date) is flashing.
9. Press the ADV button repeatedly until the correct date is displayed.
10. Press the D/D button. At this point, the Oxygen Saturation display field shows "Yxx", with "Y" representing "year." Note that "xx" (year number) is flashing.
11. Press the ADV button repeatedly until the correct year number is displayed.
12. Press the D/D button once. The N-20P turns itself off within 5 seconds.

13. Date and time are now correct. Check by switching on the N-20P with the printer enabled. After the N-20P executes its Power-On Self-Test, the printer prints the spot check mode header with the correct date and time.

4.6.4 Replacing the Real-Time Clock (RTC) Battery

The socket for the RTC battery (BT1) is located on the auxiliary PCB at grid location 5D. Typical life of the clock battery is 5 years.

1. Disassemble the N-20 (see Section 5.3, *N-20, Disassembly Procedure).*
2. Using a thin flathead screwdriver, gently pry the RTC battery from its socket.
3. Insert a new battery into the socket, observing the polarity indication (socket's clip and battery's flat side are positive).
4. Reassemble the unit.
5. Reset the clock (see paragraph 4.6.3, Setting Date and Time).

4.6.5 Replacing Fuses

Two fuses (F1 and F2) are located on the auxiliary PCB. Fuse F1 may open to protect the CPU and its associated components from damage if the power supply malfunctions. Fuse F2 may open to protect the printer from damage due to excessive voltage if the printer head jams or has been physically damaged. Refer to the auxiliary PCB schematic for the locations of F1 and F2.

4.6.6 Replacing the DB-9 Connector

1. Disassemble the N-20 (see Section 5.2); the connector is on the main PCB at grid location 3A.
2. Using a low-power soldering iron, unsolder the connector from the PCB and remove it. Save all Teflon tubing, ferrite blocks, and insulating materials for the replacement connector.
3. Install ferrite blocks between plastic lead spacer on the connector and the PCB.
4. Insulate connector pin numbers 2, 3, and 5 with Teflon tubing, and insert inside ferrite block.
5. Add insulating material between each end of ferrite block and PCB, and secure with Loctite glue.
6. Solder new connector to PCB and visually check PCB for stray drops of solder before reassembling.
7. Switch on the N-20/N-20P and test the connector with a patient sensor.

4.6.7 Adjusting Printer Darkness

Caution: Adjust the printer darkness setting until the lightest legible print is visible.

Setting the print darker than this could reduce the life of the printer-head. Although the N-20P is designed to automatically compensate for conditions that might influence the quality of the printout, the user may want to adjust the print darkness. The normal darkness setting is set at the factory; this setting maximizes both readability and life of the printer-head.

1. Switch on the N-20P in spot check mode. (Depressing the instrument Measure button once starts Spot-check mode.)
2. Simultaneously press and hold the *ADV* and *ON* buttons for 2 seconds. If these buttons are not pressed at the same time, two audible beeps will sound and the N-20P either advances the paper or switches off, depending on which button press is first sensed. If the buttons are pressed at the same time, a single audible beep will sound, Pr SEt is displayed, and the printer prints one of the following 6 lines:

PRINTING LIGHTER	**(10% lighter than normal darkness)**
PRINTING LIGHT	**(5% lighter than normal)**
PRINTING NORMAL	**(normal darkness)**
PRINTING DARK	**(5% darker than normal)**
PRINTING DARKER	**(10% darker than normal)**
PRINTING DARKEST	**(15% darker than normal)**

Note: The parenthetic line description is not printed, and button presses are ignored whenever the printer is printing.

1. Press the ADV button to change the darkness setting. The printer prints a line with each button press, and the setting increments from lighter to darkest and then wraps back to lighter.
2. Allow the N-20P to switch off (about 30 seconds). The last print darkness setting is remembered when the N-20P is switched back on. Test this by repeating the procedure and skipping step 3.

4.7 Error Codes

If a failure is detected during the Power-On Self-Test or during any performance test, the error message (Err) appears in the Oxygen Saturation display and a 3-digit error code number appears in the Pulse Rate display.

If an error message appears, find its category (the first digit of the error code represents the category) and record the error code number. Match the number to the description in the following table, and contact Nellcor's Technical Services Department or Nellcor's local representative for assistance.

Internal tests are performed in the order of the table listing. The first error condition encountered is the one displayed.

4.7.1 Category 1 — Microprocessor Errors

Table 4-1: Microprocessor Error Codes

Errors in the CPU (main PCB). Likely action is replacement of the CPU.	
101	Error in internal RAM registers test
102	Error in zero register test
103	Error in register contents clearing test
104	Error in register contents increment test
105	Error in register contents decrement test
106–109	Errors in logical operations test
110	Error in exchange test
111	Error in timer tests
112	Error in window select register test
113, 114	Errors in stack manipulation test
115–117	Errors in CPU flags test
118	Error in interrupt pending register test
119	Error in program counter test
120	Error in CPU serial port test
121	Error in pulse width modulation register test
122	Error in A/D register test
123	Error in addressing modes test
124	Error in high speed input register test
125	Error in content addressable memory test
126–129	Errors in arithmetic operations test

4.7.2 Category 2 — RAM Memory Errors

Errors in RAM memory (main PCB). Likely action is replacement of the main PCB.

201–203 Errors in external RAM test

4.7.3 Category 3 — PROM Errors

Errors in PROM memory (main PCB). Likely action is replacement of the PROM.

301	Error in PROM test

4.7.4 Category 4 — I/O Port Errors

Errors in the CPU's internal I/O port (main PCB). Likely action is replacement of either the CPU or the main PCB.

401–409	Errors in I/O port test

4.7.5 Category 5 — Reserved

4.7.6 Category 6 — Clock Errors

Failure of the real-time clock (auxiliary PCB), or timing differences between the CPU's clock and the real-time clock. Likely action is replacement of the main or auxiliary PCB.

601	Failure of real-time clock
602, 603	Errors in real-time clock

4.7.7 Category 7 — Watchdog-Timer Errors

Error in the watchdog-timer circuit of the CPU (main PCB). Likely action is replacement of the CPU.

701, 702	Errors in watchdog-timer

4.7.8 Category 8 — Printer Errors

Error in the printer (see Section 5.1, Troubleshooting).

If a printer error condition occurs, no error code number will display, rather the display reads Pr Err.

5 DISASSEMBLY GUIDE

WARNING: Only qualified service personnel must perform repair and testing. Improper repair and/or adjustment may compromise patient safety or the accuracy of the instrument.

5.1 Introduction

The N-20/N-20P can be disassembled down to all major component parts, including:

- PCBs
- battery
- cables
- chassis enclosures

WARNING: Before attempting to open or disassemble the N-20/N-20P, disconnect the power cord.

Caution: Observe ESD (electrostatic discharge) precautions when working within the unit.

Note: Some spare parts have a business reply card attached. When you receive these spare parts, please fill out and return the card.

5.2 Required Equipment/Tools

- Screwdriver, Phillips-head, small
- Screwdriver, Phillips-head, medium
- Pliers, long nose
- Screwdriver, small flathead
- Soldering iron, low-power
- Screwdriver, small blade
- Needle-nose pliers

5.2.1 N-20 Disassembly Procedure

Whenever repair or disassembly is required, always wear a ground strap connected to active ground. Before any disassembly or service procedure, switch instrument power off.

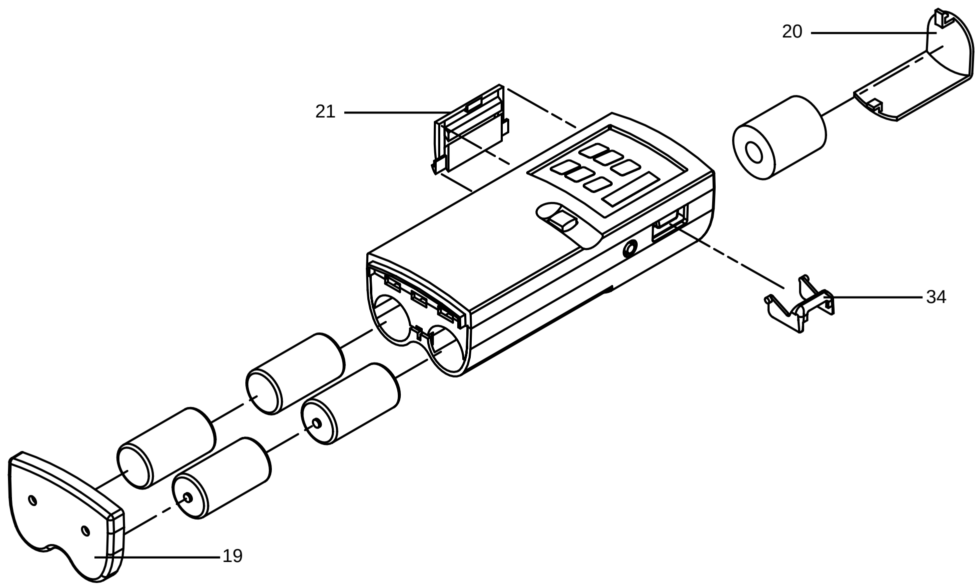


Figure 5-1: Sensor Lock, and Printer, Paper, and Battery Access Doors

1. Remove the battery door (19) and batteries.
2. Remove the sensor lock (34) by lightly pressing in on its ears and pulling out from the sensor shroud.
3. Remove the paper door (20) and paper roll, and the printer door (21).

5.2.2 Removing the Covers

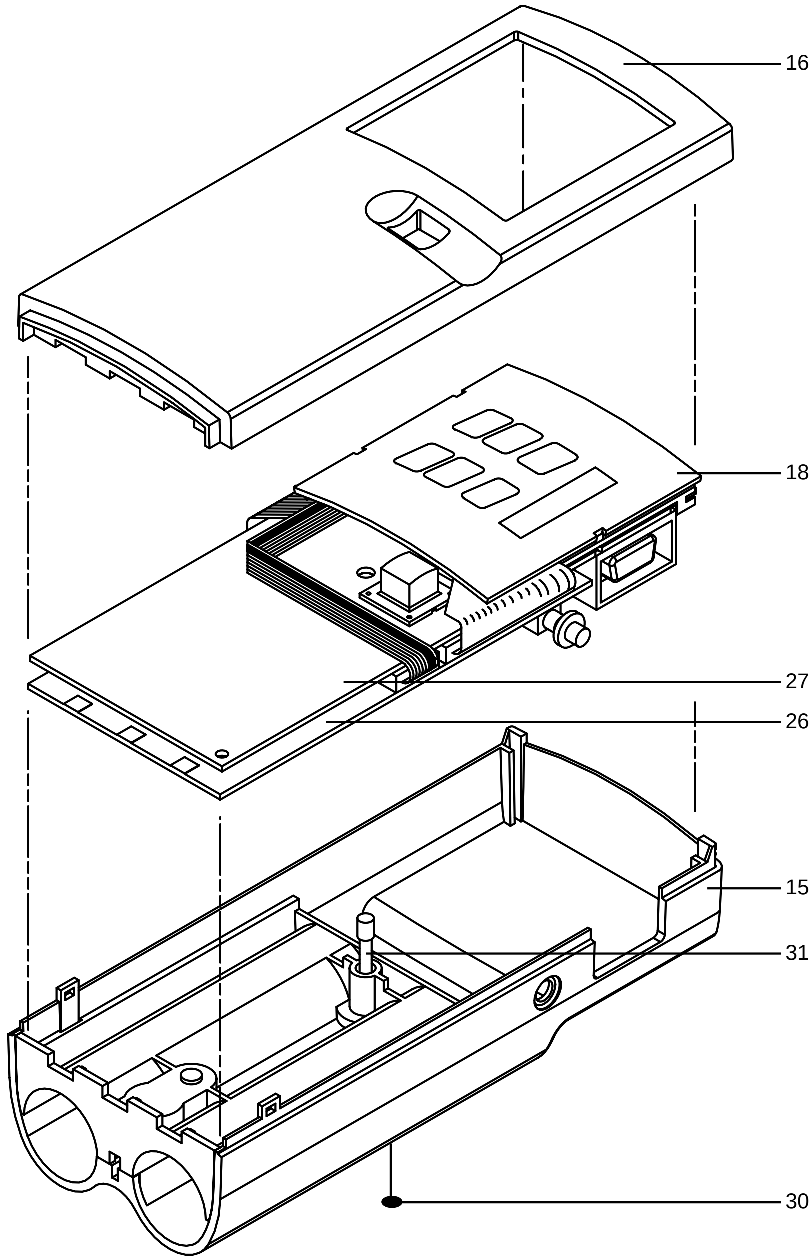


Figure 5-2: N-20 Covers with the PCB and Display Assembly

1. Remove screw cap (30), and loosen the captive screw (31), which secures the rear cover (15).
2. Separate the front cover (16) from the rear cover by wedging a thin flathead screw driver between the covers at the base of the instrument and slowly prying them apart.

   Note: The covers are hinged at the top end in a different way; do not attempt to separate the covers using this technique at the top of the instrument. Once the covers are separated at the bottom end, lift away the bottom end of the front cover first, allowing the tabs at the top end to act as a hinge.

5.2.3 Removing the PCBs and Display Assembly

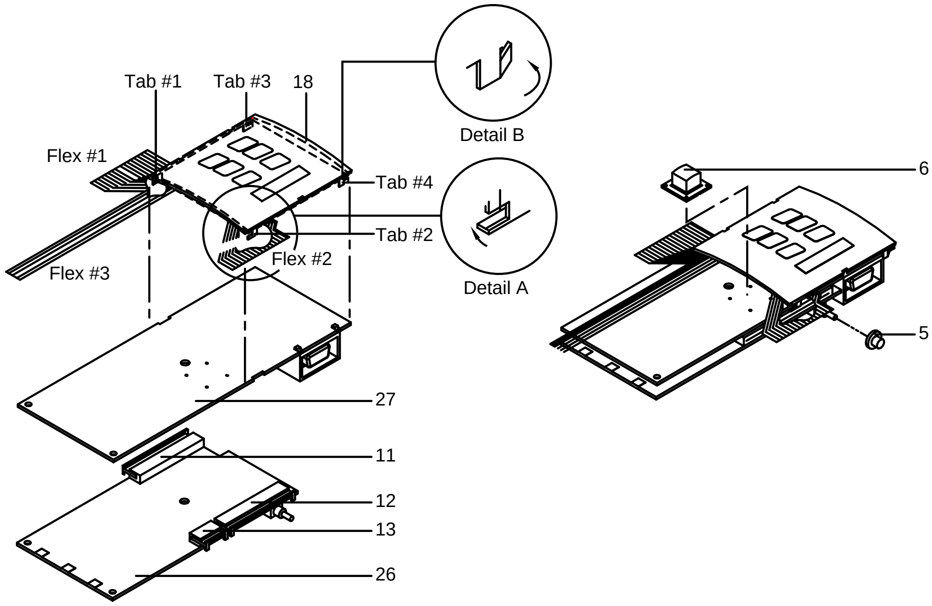


Figure 5-3: Main, Auxiliary, and Display PCB Assembly

1. Remove the Measure button (6) from the main PCB.
2. Remove the entire PCB/Taliq display assembly from the rear cover by tilting opposite the Battery-Check button (5).
3. Raise the locking tabs on the connectors (11, 12, and 13) to release the cable, on the auxiliary PCB (26), and remove the three flex display circuits.
4. Separate the auxiliary PCB from the main PCB (27) by pulling the PCB headers apart at the base.
5. Remove the display assembly (18) from the main PCB by unsoldering the four tabs that are physically bent around the main PCB. These tabs are bent to ensure contact with the ground plane of the main PCB.
6. Using a long-nose plier, remove the display assembly by untwisting the four tabs (see Detail A and B).

5.2.4 N-20P Disassembly Procedure

1. Remove the paper door (20) and any printer paper by firmly grasping the paper roll, and pulling the roll outward from the printer.
2. See paragraphs 5.2.1 and 5.2.2, *N-20 Disassembly Procedure,* for removal of covers, PCBs, and the display assembly.

5.2.5 Disassembling the Printer/Flex Circuit Assembly

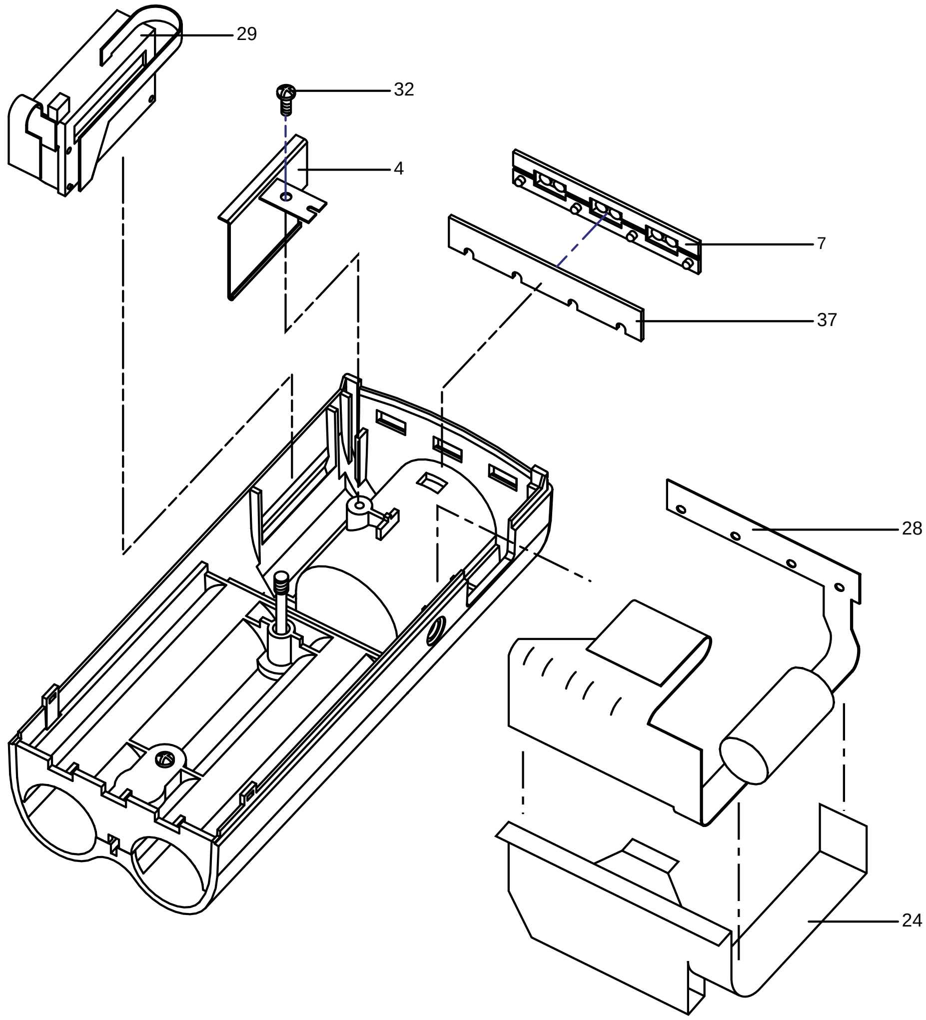


Figure 5-4: Printer and Flex Circuit Installation

1. Remove the printer button retaining plate (37) by sliding it away from the case assembly.
2. Disconnect the two flex-circuit headers of the printer (29) from the connectors on the printer flex circuit (28) by slowly pulling outward from side to side at alternating ends of the connectors.
3. Remove the printer button strip (7) from the printer flex-circuit.
4. Remove the printer flex-circuit insulator (24).
5. Remove printer hold-down bracket (4) from the back cover by removing the Phillips screw (32).
6. Press the printer hold-down bracket into the back cover and remove the printer.

6.1 N-20/N-20P Spare Parts

To order replacement parts, contact Nellcor's Technical Services Department and order by part number. Item numbers correspond to the callout numbers in the figures.

Item	Designator	Description	P/N
1	SW1	Battery switch (auxiliary PCB)	630106
2	BT1	Battery holder (auxiliary PCB)	901582
3	BT1	Battery, lithium (auxiliary PCB)	640112
4		Bracket, printer, hold-down	023133
5		Button, battery-check	023301
6	S2	Button, measure	022948
		Button, measure (European version)	026386
7		Buttons, printer, strip	022947
		Buttons, printer, strip (European version)	026387
9		Connector shield, DB-9	023467
10	P1	Connector, DB-9	463103
11	JP17, JP18	Connector, pin header 10x2, low profile (auxiliary PCB)	491244
12	JP5	Connector, ZIF, flex, 7-pin (auxiliary PCB)	491242
13	JP9	Connector, ZIF, flex, 22-pin (auxiliary PCB)	491250
14	JP2,3	Connector, ZIF, flex, 32-pin (auxiliary PCB)	491243
15		Cover, rear (non-printer model)	022929
		Cover, rear (printer model)	026339
16		Cover, front, with gasket assembly	022921
17	D8	Diode, photo, 8440 (main PCB)	591017
18		Display, Taliq, analog shield assembly	024466
		Display, Taliq, analog shield assembly (European version)	026765
19		Door, battery	022924
20		Door, paper.	022938
21		Door, printer	026338
22	F2	Fuse, micro, 1 amp (auxiliary PCB)	691236
23	F1	Fuse, micro, 1.5 amp (auxiliary PCB)	691239
24		Insulator, printer	026139
25		Nut, keps,SS, 4-40	851101
26		PCB, auxiliary	024472
27		PCB, main	024468
28		Printer flex circuit	024464
29		Printer	024462
30		Screw cap	023451

Item	Designator	Description	P/N
31		Screw, captive	891324
32		Screw, Phillips, 4-40 ×1/4	801025
33		Screw, plastite	871031
34		Sensor lock	022943
35		Sensor shroud	022944
36		Spacer	023452
37		Stiffener, printer button	023131
38		Tape, foam (.88" ×.38")	023300
39	BZ1	Transducer, audio, piezo ceramic	691230

7 PACKING FOR SHIPMENT

Should you need to ship the N-20/N-20P monitor for any reason, follow the instructions in this section.

7.1 General Instructions

Pack the monitor or printer carefully. Failure to follow the instructions in this section may result in loss or damage not covered by the Nellcor warranty. If the original shipping carton is not available, use another suitable carton or call Nellcor Technical Services to obtain a shipping carton.

Prior to shipping the device, contact Nellcor Technical Services for a returned goods authorization (RGA) number. Mark the shipping carton and any shipping forms with the RGA number.

7.2 Repacking in Original Carton

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

Place the monitor, or printer, and, if necessary, accessory items in original packaging.
Place in shipping carton and seal carton with packing tape.
Label carton with shipping address, return address, and RGA number.

7.3 Repacking in a Different Carton

If the original carton is not available:

1. Place the monitor or printer in plastic bag.
2. Locate a corrugated cardboard shipping carton with at least 200 pounds per square inch (psi) bursting strength.
3. Fill the bottom of the carton with at least 2 inches of packing material.
4. Place the bagged unit on the layer of packing material and fill the box completely with packing material.
5. Seal the carton with packing tape.
6. Label carton with shipping address, return address, and RGA number.

8 SPECIFICATIONS

8.1 Readout

Display shows SpO_2 (saturation of arterial hemoglobin oxygen), pulse rate, and pulse amplitude; also included are a Pulse Search and Low Battery indicator, and an electroluminescent backlight.

8.2 Controls

8.2.1 N-20

The **Measure** button switches the instrument on and off, and initiates the measurement cycle.

The **Battery-Check** button is used to check battery condition and switches beeper on and off.

8.2.2 N-20P

The Measure button switches the instrument on, initiates the measurement cycle, and switches instrument off.

The Battery-Check button is used to check battery condition and switches beeper on and off.

ON button switches the printer on and off.

D/D sets display date and time.

ADV advances paper and increments time and date.

8.3 Operating Modes

8.3.1 Spot Check Mode

Pressing the instrument Measure button once for less than 2 seconds starts the spot check mode. Spot check mode computes SpO_2 averaged over five valid pulses and displays SpO_2 and pulse rate at the end of the measurement interval. If the printer is activated, the printout shows the displayed SpO_2 and pulse rate.

8.3.2 Extended Mode

Extended mode is started by holding down the instrument Measure button for approximately 3 seconds, plus any time required to complete the power-on self-test. The N-20/N-20P displays updated SpO_2 and pulse rate with every pulse (after five valid pulses have been detected). The N-20/N-20P remains active until 3 minutes after the sensor is removed, or until the instrument is turned off.

For the N-20, a 2% or greater decrease in SpO_2 is indicated by two brief, low-pitched tones.

The N-20P printout shows SpO_2 and pulse rate at 30-second intervals. For the N-20P, a 2% or greater decrease in SpO_2 is indicated by two brief, low-pitched tones and an asterisk (*) on the printout. At the end of the measurement period, a header and statistical summary values (minimum, maximum, and mean of both pulse rate and oxygen saturation) are printed.

8.4 Printer Output

When activated by the printer *ON* button, the N-20P output shows date, time, SpO_2, and pulse rate (in spot check mode), with space provided for writing in patient identification. The thermal paper printout measures roughly 40 mm (1.6 in.) by 100 mm (4.0 in.) in size.

If the N-20P is in spot check mode and the printer is turned on any time during a measurement or after a measurement is taken and before the N-20P powers down, the printer will catch up and print a complete record of the measurements recorded up to the current moment.

8.5 N-20/N-20P Performance

8.5.1 Range

Saturation:	0–100%
Pulse Rate:	20–250 beats per minute (bpm) ± 1 standard deviation

8.5.2 SpO_2 Accuracy [1]

Adults:	70–100%	± 2 digits [2]
Neonates:	70–100%	± 3 digits [2]
Pulse Rate:	20 –250 bpm	± 3 digits [2]

8.5.3 Response

In spot check mode, the measurement cycle (from button press to display of data) is five valid pulses.

In extended mode, the instrument measures for a period of up to 30 minutes and continuously displays updated SpO_2 and pulse rate.

[1] Accuracies are expressed as plus or minus “X” digits (saturation percentage points) between saturations of 70-100%. This variation equals plus or minus one standard deviation (1SD), which encompasses 68% of the population. All accuracy specifications are based on testing the subject monitor on healthy adult volunteers in induced hypoxia studies across the specified range. Adult accuracy is determined with *Oxisensor II* D-25 sensor. Neonatal accuracy is determined with *Oxisensor II* N-25 sensor.

[2] This variation equals one SD.

8.6 Sensor Types

Table 8-1: Sensors

Sensor	Model	Patient Size
Oxisensor II oxygen transducers (sterile, single-use only)	N-25/N-25LF I-20/I-20LF D-20 D-25/D-25L R-15	<3 or >40 kg 3 to 20 kg 10 to 50 kg >30 kg >50 kg
Oxiband oxygen transducer (reusable with disposable nonsterile adhesive)	OXI-A/N OXI-P/I	<3 or >40 kg 3 to 40 kg
Durasensor oxygen transducer (reusable, nonsterile)	DS-100A	>40 kg
Nellcor reflectance oxygen transducer (reusable, nonsterile)	RS-10	>40 kg
Dura-Y multisite oxygen transducer (reusable, nonsterile) For use with the Dura-Y sensor: Ear clip (Reusable, nonsterile) Pedi-Check™ pediatric spot-check clip (reusable, nonsterile)	D-YS D-YSE D-YSPD	>1 kg >30 kg 3 to 40 kg
OxiCliq oxygen transducers (sterile, single-use only)	P N I A	10 to 50 kg <3 or >40 kg 3 to 20 kg >30 kg

8.7 Electrical Specifications

8.7.1 Battery

Type: four 1.5-V alkaline "C" cell batteries

Battery Capacity: typically 37 hours for N-20

typically 32 hours for N-20P

8.7.2 Instrument

Power Requirements: 4–6 VDC, supplied by battery only

Leakage Current: Meets applicable IEC- 601 and AAMI/ANSI standards;

the N-20/N-20P has no power or ground connections

Patient Isolation: No electrical connection to patient (inherently insulated)

8.8 Environmental Specifications

8.8.1 Operating Temperature

Instrument: 0 to 40 °C (32 to 104 °F)

8.8.2 Storage Temperature

-20 to 50 °C (4 to 122 °F)

Humidity: Any humidity/temperature combination without condensation

Altitude: 0 to 6200 meters (0 to 20,000 ft)

8.9 Physical Specifications

Physical specifications are based on product without the protective boot.

8.9.1 Weight (with batteries installed)

N-20: 0.6 kg (1.3 lb)

N-20P: 0.62 kg (1.4 lb)

8.9.2 Dimensions

N-20: 19.0 cm high × 7.6 cm wide × 5.08 cm deep
(7.5 in. × 3.0 in. × 2.0 in.)

N-20P: 19.0 cm high × 7.6 cm wide × 6.35 cm deep
(7.5 in. × 3.0 in. × 2.5 in.)

8.10 Qualifying Information

The Nellcor N-20/N-20P is calibrated to measure arterial hemoglobin oxygen saturation of functional hemoglobin. The specified accuracy of this measurement is based on statistical analysis of arterial blood samples as measured on an IL282 CO-Oximeter.

Indocyanine green, methylene blue, and other intravascular dyes, depending on concentration, may interfere with the accuracy of data obtained from the instrument. Carboxyhemoglobin or other dyshemoglobins may also interfere with the accuracy of the data if present in significant concentration.

9 TECHNICAL SUPPLEMENT

9.1 Overview

The N-20/N-20P is based on the principles of spectrophotometry and optical plethysmography. Optical plethysmography uses light absorption technology to reproduce wave forms produced by pulsatile blood. The changes that occur in the absorption of light due to vascular bed changes are reproduced by the pulse oximeter as plethysmographic wave form.

Spectrophotometry uses various wavelengths of light to qualitatively measure light absorption through given substances. Many times each second, the N-20/N-20P passes red and infrared light into the sensor site and determines absorption. The measurements, which are taken during the arterial pulse, reflect absorption by arterial blood, nonpulsatile blood, and tissue. The measurements that are obtained between arterial pulses reflect absorption by nonpulsatile blood and tissue.

By correcting "during pulse" absorption for "between pulse" absorption, the N-20/N-20P determines red and infrared absorption by pulsatile arterial blood. Because oxyhemoglobin and deoxyhemoglobin differ in red and infrared absorption, this corrected measurement can be used to determine the percent of oxyhemoglobin in arterial blood: SpO_2 is the ratio of corrected absorption at each wavelength.

9.2 Functional versus Fractional Saturation

The N-20/N-20P measures functional saturation, that is, oxygenated hemoglobin expressed as a percentage of the hemoglobin that is capable of transporting oxygen. It does not detect significant levels of dyshemoglobins. In contrast, some instruments such as the IL282 Co-oximeter measure fractional saturation, that is, oxygenated hemoglobin expressed as a percentage of all measured hemoglobin, including dyshemoglobins.

Consequently, before comparing N-20/N-20P measurements with those obtained by an instrument that measures fractional saturation, measurements must be converted as follows:

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

9.3 Measured versus Calculated Saturation

When saturation is calculated from a blood gas measurement of the partial pressure of arterial oxygen (PaO_2), the calculated value may differ from the N-20/N-20P SpO_2 measurement. This is because the calculated saturation may not have been corrected for the effects of variables that can shift the relationship between PaO_2 and saturation.

Figure 9-1 illustrates the effect that variations in pH, temperature, partial pressure of carbon dioxide (PCO_2), and concentrations of 2,3-DPG and fetal hemoglobin may have on the oxyhemoglobin dissociation curve.

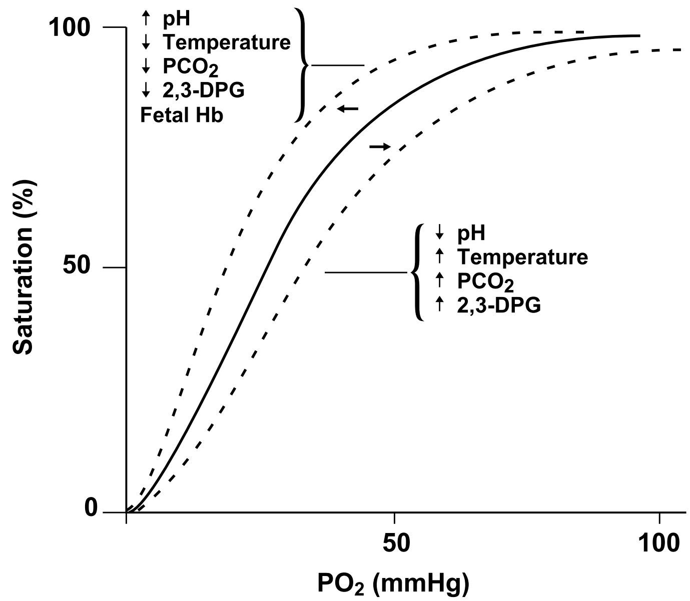


Figure 9-1: Oxyhemoglobin Dissociation Curve

9.4 Circuit Analysis

The following paragraphs discuss the circuits of the N-20/N-20P.

9.5 Functional Overview

This section provides a detailed explanation of N-20/N-20P operation using block diagrams and circuit schematics.

The relationship between these components and their interconnection is illustrated in the overall block diagram (Figure 9-2). The main component circuitry has been divided into the following subsections:

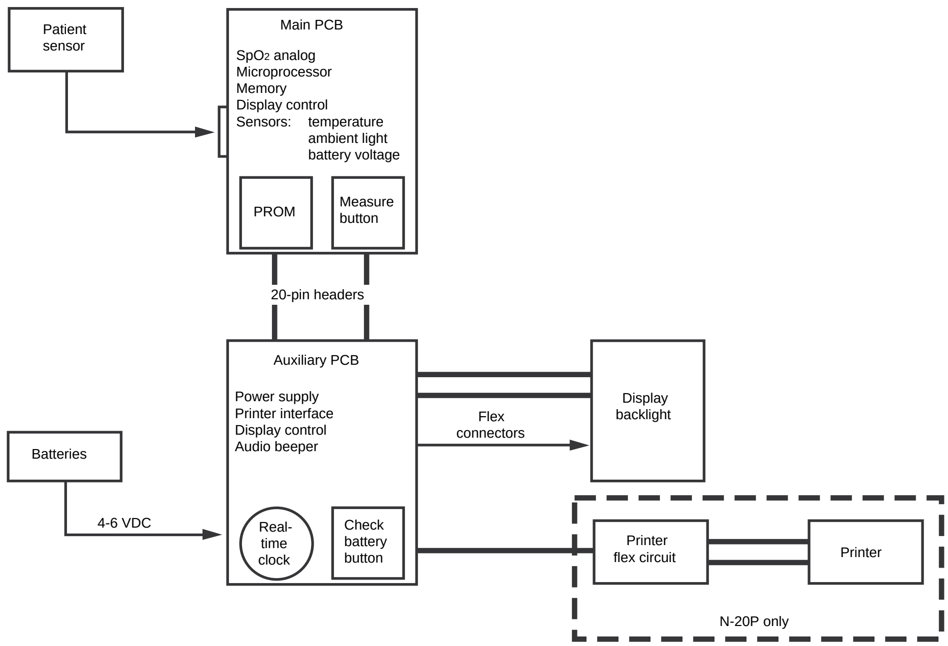


Figure 9-2: Overall Block Diagram

9.6 SpO_2 Analog Circuitry Block Diagram (Figure 9-3)

Analog circuitry has high signal sensitivity and reduced susceptibility to noise. Its design allows for a wide range of input signal levels and a broad range of pulsatile modulation. The SpO_2 analog circuit (Figure 9-3) consists of four subsections:

1. Sensor output/LED control, where the CPU controls the gain of both LEDs so that signals received at the input amplifier are in its acceptable dynamic range
2. Input signal conditioning, where sensor output current is converted to voltage
3. Signal gain, where the separated LED signals are amplified so their current levels are within the A/D converter's acceptable range; and
4. AC ranging, where DC offset is eliminated from each LED signal.

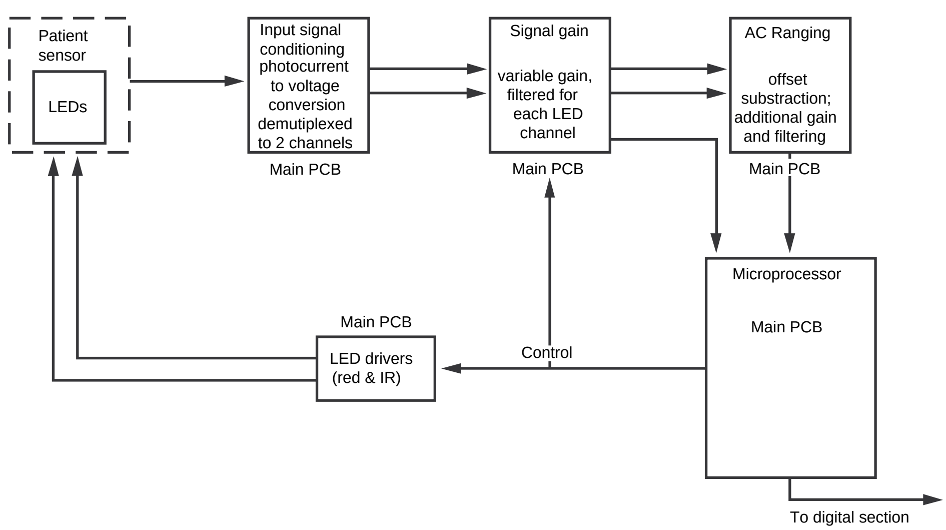


Figure 9-3: SpO_2 Analog Circuitry Block Diagram

9.6.1 Digital Circuitry Block Diagram (Figure 9-4)

Figure 9-4 shows the N-20/N-20P hardware and circuits, which include the CPU and system memory, the power supply and power control circuitry, user controls, display and ambient light sensors, audio output, thermal printer (N-20P only) and ambient temperature sensor, and the real-time clock.

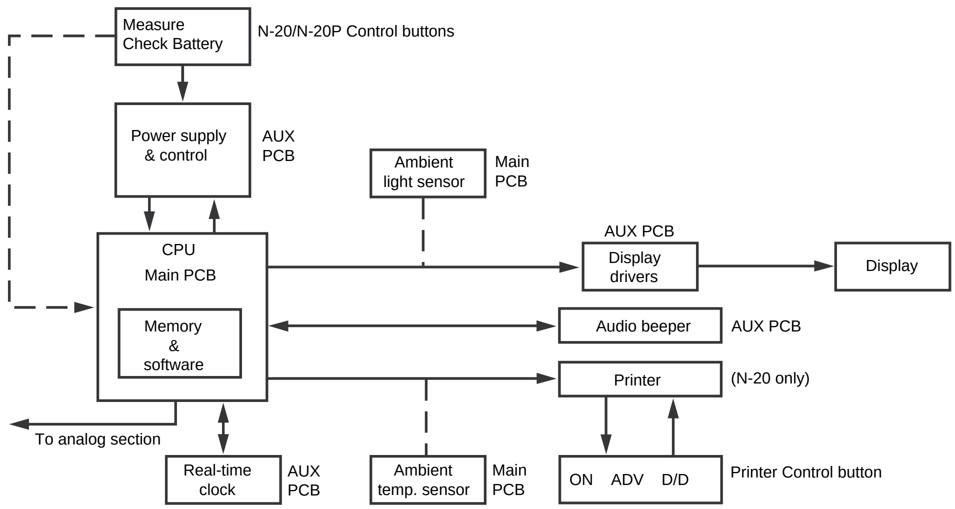


Figure 9-4: Digital Circuitry Block Diagram

9.6.2 Power Supply Block Diagram (Figure 9-5)

Power supply circuitry (Figure 9-5) is located on the auxiliary PCB and consists of four subsections:

1. Four "C" size batteries that provide 4-6 VDC
2. Power control circuitry that senses a press of the Measure button and switches power on
3. Power shutoff circuit that controls power to all circuits except the power control circuit
4. Power supply circuits include a regulated power supply at 5 VDC, unregulated power supplies of -5 VDC, 10 VDC, and 12 VDC, and a high voltage power supply of 70 VDC.

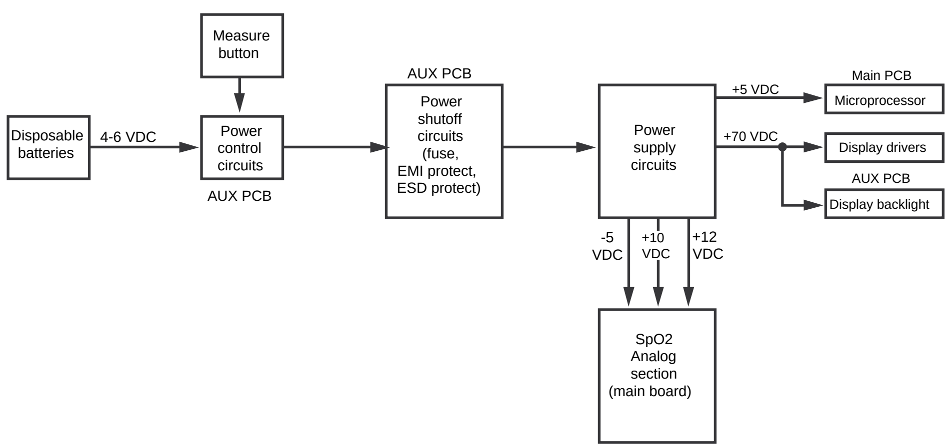


Figure 9-5: Power Supply Block Diagram

9.6.3 Display Control Block Diagram (Figure 9-6)

The N-20/N-20P display is controlled by the display control circuitry (see Figure 9-6). A sensor is used to measure ambient light. During low light conditions, the display backlight, an electroluminescent device, is automatically switched on.

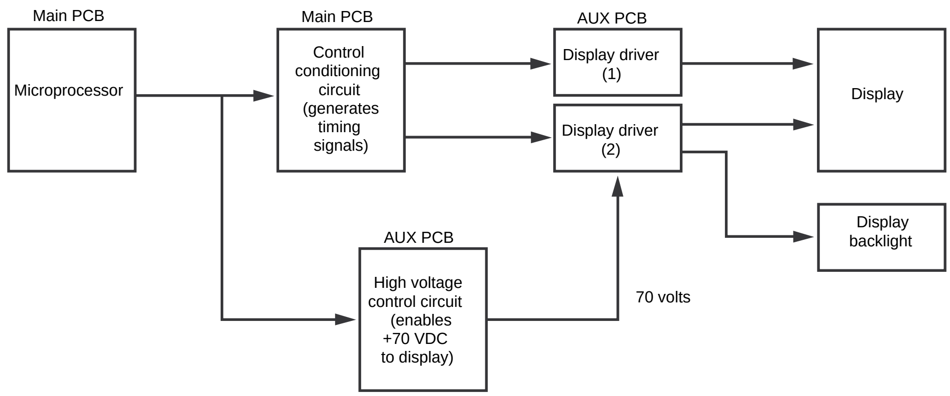


Figure 9-6: Display Control Block Diagram

9.6.4 Printer Control Block Diagram (Figure 9-7)

Printer circuitry (Figure 9-7) is divided into two subsections: the printer interface and the printer flex circuit. The printer interface circuitry is present on all models, but is disabled by software in the N-20. The printer flex circuit is added when a printer is present.

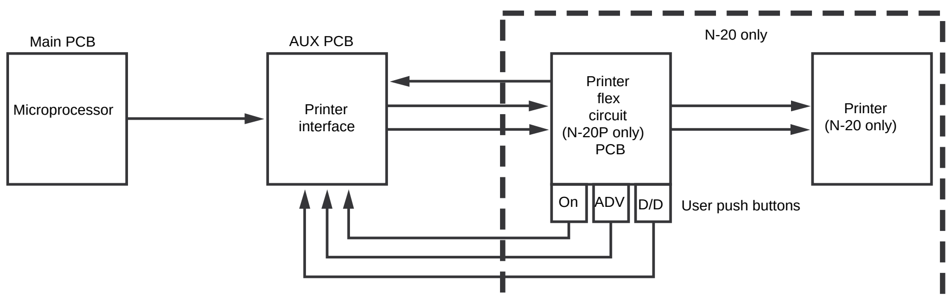


Figure 9-7: Printer Control Block Diagram

9.7 Definition of Terms

9.7.1 Analog to Digital (A/D) converter

The CPU has a 10-bit A/D converter on board. Up to eight different analog inputs can be provided to the A/D for measurement.

9.7.2 Central Processing Unit (CPU)

An Intel 80C196KC 16-bit microcontroller. The CPU sends and receives control signals to the SpO_2 analog section, display, and optional printer.

9.7.3 Content Addressable Memory (CAM)

The CPU controls the HSO lines with the CAM. CAM is software controlled and programmed with events scheduled relative to one of two internal timers.

9.7.4 High Speed Outputs (HSO)

The 6 HSO lines control most of the timing of the LED signal pulse and the demodulation of the received signal.

9.7.5 Input and Output (I/O)

Input and Output (I/O) are digital lines that are used by the CPU to read in data and output data.

9.7.6 Light-Emitting Diodes (LEDs)

Two LEDs are used in Nellcor oximetry sensors. Light is transmitted through body tissue and received by a photodetector circuit that converts it to photocurrent. The two wavelengths, which are used for calculation of pulse rate and oxygen saturation in blood, are transmitted at the following frequencies:

- infrared (IR) light at approximately 915 microns
- red light at approximately 660 microns

9.7.7 Pulse Width Modulation (PWM)

The three 8-bit PWM outputs can be software controlled; their duty cycle can be changed from 0-255/256 of the total pulse duration. PWM frequency is the crystal frequency of the CPU, which is 10 MHz divided by 1024. The PWMs control the gains within the analog circuit.

9.7.8 RCal

Sensor RCal value is a resistance value specific to an individual sensor. This value is used by the software during oxygen saturation computations to maximize accuracy.

9.7.9 Real-Time Clock (RTC)

The RTC is used with the optional printer to track time and date for printouts.

9.8 Overall Block Diagram

Exclusive of covers, buttons, and external connectors, the N-20/N-20P consists of three main components: the main PCB, the auxiliary PCB, and the display assembly and analog shield.

9.8.1 Main PCB

Contains the SpO_2 analog circuitry; the CPU; support memory circuits; sensor circuits for ambient light, temperature, and battery voltage; the check battery circuit; a serial data port; and some display control circuits.

9.8.2 Auxiliary PCB

Contains the power supply circuitry; the display driver circuits; the real-time clock; the interface circuitry for the printer flex circuit board (which is not used unless a printer is present); and audio output hardware.

9.8.3 Display and Analog Shield Assembly

This assembly connects to the main PCB by flex circuits. A metal shield shrouds the SpO_2 analog circuits on the main PCB to protect them from EMI. An integrated electroluminescent backlight illuminates the display under low light conditions.

The N-20P has an additional printer control board (printer flex circuit) and printer hardware. The following block diagram shows the relationship between these components.

9.9 SpO_2 Analog Circuitry

This subsection describes the SpO_2 analog hardware. The analog circuitry has high signal sensitivity and reduced susceptibility to noise. Its design allows for a wide range of input signal levels and a broad range of pulsatile modulation. The SpO_2 analog block diagram (Figure 9-3) consists of four subsections:

9.9.1 Sensor Output/LED Control

The CPU controls the gain of both LEDs so that signals received at the input amplifier are within an acceptable dynamic range. Signal channel gain may also need to be increased. The CPU uses PWM lines to control LED current level or to amplify the signal channel.

9.9.2 Input Conditioning

Sensor output current is converted to voltage. A demodulation circuit minimizes the effects of other light sources and stray frequency inputs. Because the IR and RED signals are at different current levels, the two LED signals are demultiplexed and separately amplified, so they can be compared with each other. Two circuits handle the demultiplexing by alternately selecting LED signals using switches. Filters then remove noise and smooth the signals before sending them to the amplifiers.

9.9.3 Signal Gain

The separated LED signals are amplified so that their current levels are within the A/D converter's acceptable range. The signals are filtered to improve the signal-to-noise ratio, and clamped to a reference voltage.

9.9.4 AC Ranging

DC offset is eliminated from each LED signal. An analog switch sets the mean signal value to the mean of the A/D converter range, and the AC modulation is superimposed on that DC level. Then, each AC signal is amplified and filtered to eliminate residual effects of the PWM modulations. Finally, these two signals are input to the CPU A/D converter.

The relationship between these subsections is shown in the following block diagram.

9.9.5 Sensor Output/LED Control

The SpO_2 analog circuitry provides control of the red and IR LEDs such that the received signals are within the dynamic range of the input amplifier. Because excessive current to the LEDs will induce changes in their spectral output, it is sometimes necessary to increase the received signal channel gain. To that point, the CPU controls both the current to the LEDs, and the amplification in the signal channel.

At initialization of transmission, the LEDs' intensity level is based on previous running conditions, and the transmission intensity is adjusted until the received signals match the range of the A/D converter. If the LEDs reach maximum output without the necessary signal strength, the PWMs will increase the channel gain. The PWM lines will select either a change in the LED current or signal gain, but will not do both simultaneously.

The LED circuit switches between red and IR transmission and disables both for a time between transmissions in order to provide a no-transmission reference. To prevent excessive heat build-up and prolong battery life, each LED is on for only a small portion of the duty cycle. Also, the frequency of switching is well above that of motion artifact and not a harmonic of known AC transmissions. The LED switching frequency is 1.485 kHz. The IR transmission alone, and the red transmission alone will each be on for about one-fifth of the duty cycle; this cycle is controlled by the HSOs of the CPU.

9.9.5.1 LED Drive Circuit

The LED drive circuit is illustrated in Figure 9-8 (at the end of this section).

The IR and red LEDs are separately controlled with their drives' currents multiplexed over two shared wires. Current to the IR LED is in the range of 4.3-50.0 mA; and, current to the red LED is in the range of 6.5-75.0 mA. Currents are limited to less than 100 mA for two reasons: (1) slight excess current can potentially change the emission characteristics of the LEDs, and (2) large excess current could create excessive heat at the sensor site.

The IR/red LED transmission signal (HSO1 of the CPU) is fed into the select inputs of the triple single-pole-double-throw (SPDT) analog multiplexing switch U10, causing either the IR or the red LED transmission to be enabled.

PWM1, which is filtered by the network of R44, C37, R52, and C38, is input to the LED drive circuit switch U10, and controls the magnitude of the IR LED current supply.

PWM2, which is filtered by the network of R43, C36, R53, and C39, is also input to U10, and controls the red LED current magnitude.

Two NPN transistors (Q1 and Q2) act as current sources for the IR and red LED outputs. Two PNP transistors (Q3 and Q4) act as switches between the IR and red LED output lines. Transistor Q5 acts as an LED drive current limiter; it clamps output of the current regulator circuit to the required level. If any resistor in the LED drive circuit fails, current to the LED will still be limited to a safe level.

The RSENS line senses the RCal value and enables the CPU to make the proper calculations based on the type of sensor being used.

9.9.6 Input Conditioning

Input to the SpO2 analog circuit is the current output of the sensor photodiode. In order to condition the signal current, it is necessary to convert the current to voltage.

A differential synchronous demodulation circuit is used to reduce the effects of other light sources and stray frequency inputs to the system. Because the IR and red signals are absorbed differently by body tissue, their received signal intensities are at different levels. Therefore, the IR and red signals must be demodulated and then amplified separately in order to compare them to each other. Demultiplexing is accomplished by means of two circuits that alternately select the IR and red signal. Two switches that are coordinated with the IR and red transmissions control selection of the circuits. A filter with a large time constant follows to smooth the signal and remove noise before amplification.

9.9.6.1 Differential Synchronous Demodulation Circuit

The differential synchronous demodulation circuit is illustrated in Figure 9-9 (at the end of this section).

Before the current from the photodetector is converted to voltage, any high frequency noise is filtered by C40 and R17. The op-amp U1A is used in parallel with the current-to-voltage converter U1D to cancel any DC voltage, effectively AC coupling the output of U1D. The average value of the SpO_2 analog reference voltage (VREF) of U1D, 5 V, is measured at pin 14 of test point 49.

The same line that controls the on/off pulsing of the LEDs controls U6D, a single-pole-single-throw (SPST) analog switch. When either of the LEDs are on (the line is low and the switch is closed), U35 is used as a non-inverting amplifier. When the LEDs are both off, U35 is used as an inverting amplifier. The signal at the output of amplifier U35 is then demultiplexed.

The CPU HSO lines SAMPRED and SAMPIR, which are both active low, control SPST analog switches U6A and U6B, respectively. Switch U6A is closed to sample the red signal; switch U6B is closed to sample the IR signal. The sampling rate for both switches is 10 kHz. Switching is coordinated with the LED transmission so that the IR and red signals are each sampled twice per cycle; that is, once when the LED is off (signal inverted), and once when the LED is on (signal not inverted). The filtering circuit that follows has a long time constant, thereby acting as an averaging circuit.

A simplified N-20 HSO timing diagram is illustrated in Figure 9-10 (at the end of this section).

If the instantaneous average photocurrent (DC offset) is excessive and U1D cannot bring it to VREF, the PHOTOI line to the CPU (HSI0) is activated. This action is an indication of excess ambient light into the photosensor, or the occurrence of excess noise in the input circuit. It also serves as a warning to the instrument that the sensor signal may be contaminated and causes the software to send an error message. After about 3 seconds of continuous photocurrent signal, pulse search annunciation will begin. After about 10 seconds of continuous photocurrent signal, zeros will be displayed.

9.9.7 Signal Gain

The separated IR and red signals are amplified so that their DC values are within the range of the A/D converter. Because the received IR and red signals are typically at different current levels, the signal gain circuits provide independent amplification for each signal as needed. The gain in these circuits is adjusted by means of the PWM lines.

After the IR and red signals are amplified, they are filtered to improve the signal-to-noise ratio and clamped to a reference voltage to prevent the combined AC and DC signal from exceeding an acceptable input voltage from the A/D converter.

9.9.7.1 Variable Gain Circuits

The variable gain circuits are illustrated in Figure 9-11.

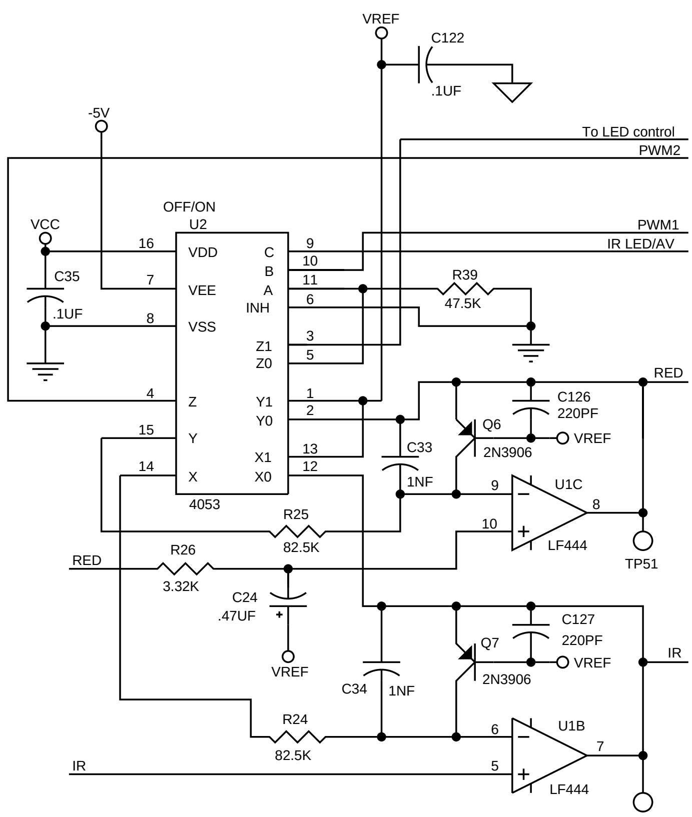


Figure 9-11: Variable Gain Circuit

The two variable gain circuits are functionally equivalent. The gain of each circuit is contingent upon the signals received level and is controlled to bring each signal to approximately 3.5 V. Each circuit uses an amplifier and one switch in the triple SPDT analog multiplexing unit U2.

The gain in each of the circuits is accomplished by means of a feedback loop, which includes one of the SPDT switches in U2. The PWMs control whether the feedback loop is connected to ground or to the amplifier output. The feedback is then averaged by C33/R25 (red), and C34/R24 (IR). The higher the value of PWM2, the greater the IR gain; the higher the value of PWM1, the greater the red gain.

9.9.7.2 Filtering Circuits

The filtering circuits are illustrated in Figure 9-12.

These circuits consist of two cascaded second-order filters with a break frequency of 10 Hz. Pairs of diodes (D1/D3 and D2/D4), that are located between VREF and ground at the positive inputs of the second amplifiers, maintain the voltage output within the range of the A/D converter.

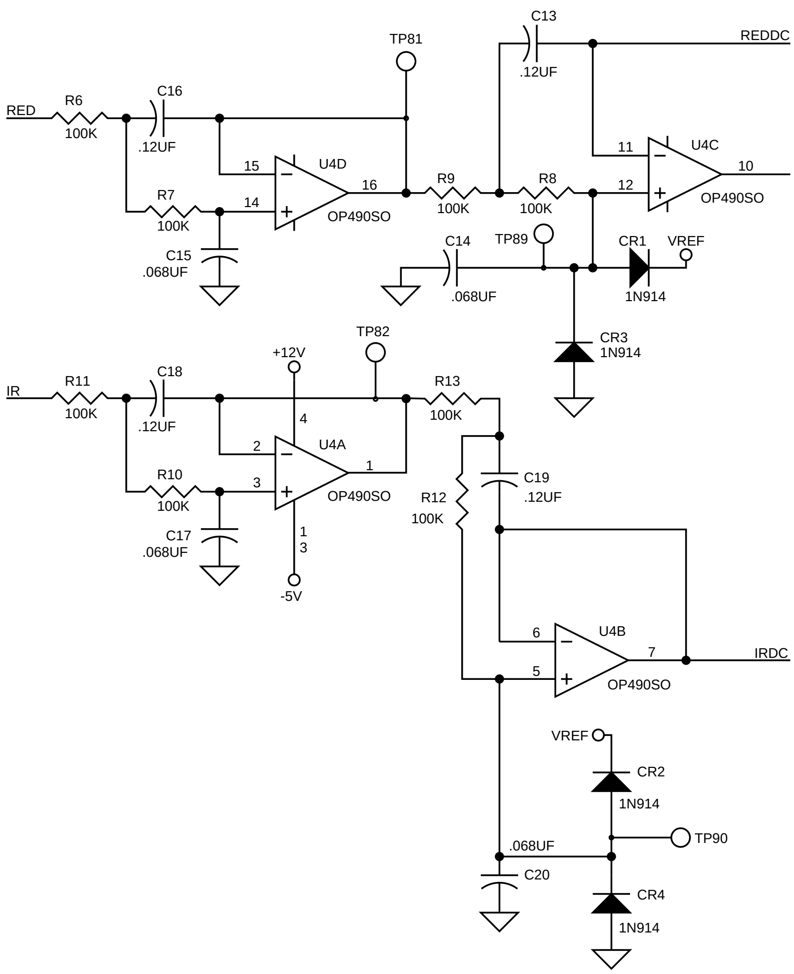


Figure 9-12: Filtering Circuit

9.9.8 AC Ranging

In order to measure a specified level of oxygen saturation and to still use a standard-type combined CPU and A/D converter, the DC offset is subtracted from each signal. Because the DC portion of the signal can be on the order of one thousand times the AC modulation, 16 bits of A/D conversion would otherwise be required to accurately compare the IR and red modulations between the combined AC and DC signals. The DC offsets are subtracted by using an analog switch to set the mean signal value to the mean of the range of the A/D converter whenever necessary. The AC modulation is then superimposed upon that DC level. This is also known as AC ranging.

Each AC signal is subsequently amplified such that its peak-to-peak values span one-fifth of the range of the A/D converter. The amplified AC signals are then filtered to remove the residual effects of the PWM modulations and, finally, are input to the CPU. The combined AC and DC signals for both IR and red signals are separately input to the A/D converter.

9.9.8.1 Offset Subtraction Circuits

The AC variable gain control circuit is illustrated in Figure 9-13 (at the end of this section). Voltage dividers R22 and R41 (red), and R31 and R5 (IR), which are located between VREF and ground, establish a baseline voltage of 2.75 V at the input of the unity gain amplifiers U7C (red) and U7D (IR).

Whenever SPST analog switches U11A and U11D are closed by HSO0 (active low), the DC portions of the IR and red signals create a charge, which is stored on C29 and C89, respectively. These capacitors hold this charge even after the switches are opened and the resulting voltage is subtracted from the combined signal— leaving only the AC modulation output. This AC signal is superimposed on the baseline voltage output by U7C and U7D. The IRDC and REDDC are then filtered and input to the CPU, and can be measured at TP58 and TP54, respectively.

9.9.8.2 AC Variable Gain Control Circuits

The AC variable gain control circuit is illustrated in Figure 9-13 (at the end of this section).

The AC modulations are amplified by U7A (red) and U7B (IR) and superimposed on the baseline voltages present at the output of U7D (IR) and U7C (red). The amplification is handled by means of the SPDT analog multiplexing switch U3 within the feedback loop, which increases gain as PWM0 is increased. The IRAC and REDAC are then filtered and input to the CPU, and can be measured at TP55 and TP59, respectively.

9.10 Digital Circuitry

The digital hardware and related circuitry, which is illustrated in the following block diagram (Figure 9-4), includes the following subsystems:

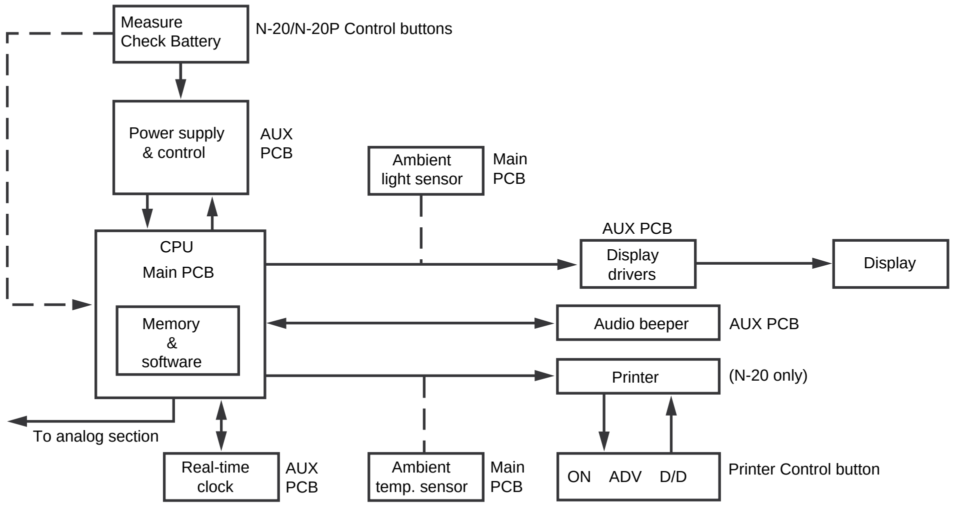


Figure 9-4: Digital Circuitry Block Diagram

9.10.1 CPU

A 16-bit microcontroller that includes a serial port, watchdog timer, A/D converter with an 8-input analog multiplexer, 3-pulse width modulators, and a high-speed I/O subsystem.

9.10.2 System Memory

External to the CPU and consists of an 8K ×8 static RAM and a 64K ×16 EPROM.

9.10.3 Real-Time Clock (RTC)

The RTC keeps track of date and time, which is printed on each printout. The RTC is powered by a lithium battery designed to last up to 5 years before needing replacement.

9.10.4 Audio Output

A piezoelectric ceramic beeper is used for audio output.

9.10.5 Display Control

A high-visibility display provides oxygen saturation and pulse rate values. An ambient light sensor responds to low-light conditions and turns on the display backlight.

9.10.6 User Controls

A **Measure** button and a **Battery-Check** button. The **Measure** button signals the power control circuit to switch on the power supply. Press and hold the **Battery-Check** button to display a percentage of useful life remaining in the batteries.

9.10.7 Power Supply/Power Control Circuitry

The N-20/N-20P receives power from 4 "C" cell batteries. The power control circuitry discontinues power to the unit when the batteries are no longer reliable.

9.10.8 Thermal Printer (N-20P only)

Generates a hard copy of oxygen saturation and pulse rate values. A sensor monitors ambient temperature and adjusts printer output to ensure consistent print quality.

9.10.9 CPU

The CPU circuit is illustrated in Figure 9-14.

The Intel 80C196KC CPU is a 16-bit microcontroller with built-in peripherals including: a serial port, watchdog timer, A/D converter with an 8-input analog multiplexer, three pulse width modulators, two 16-bit counter/timers, up to 48 I/O lines, and a high-speed I/O subsystem.

The CPU is capable of running up to 16 MHz, but it is run at 10 MHz for decreased power consumption. All unused inputs are tied to either Vcc or ground through resistors—this prevents unused inputs floating to any voltage and causing excess power drain. The READY input pin is tied high, thereby disabling wait-state generation; all bus accesses are zero-wait state. The EA pin is tied low to enable addressing of the external EPROM.

When the power supply is first switched on by the power control circuit, the reset generation circuit holds the CPU RESET pin low for at least 20 ms, then allows the internal pull-up resistor to bring it high; this assures a good CPU reset.

An internal watchdog timer is enabled and runs continuously. The watchdog timer provides a means of recovering from a software upset caused by ESD, EMI, etc. If the software does not clear the timer at least every 64K state-times (13.1 ms), the CPU will drive RESET low, resetting the entire unit. The reset output by the CPU is only 16 state-times long (3.2 µs). Q22 provides isolation from C65 so the CPU can drive a good reset to the display control circuit.

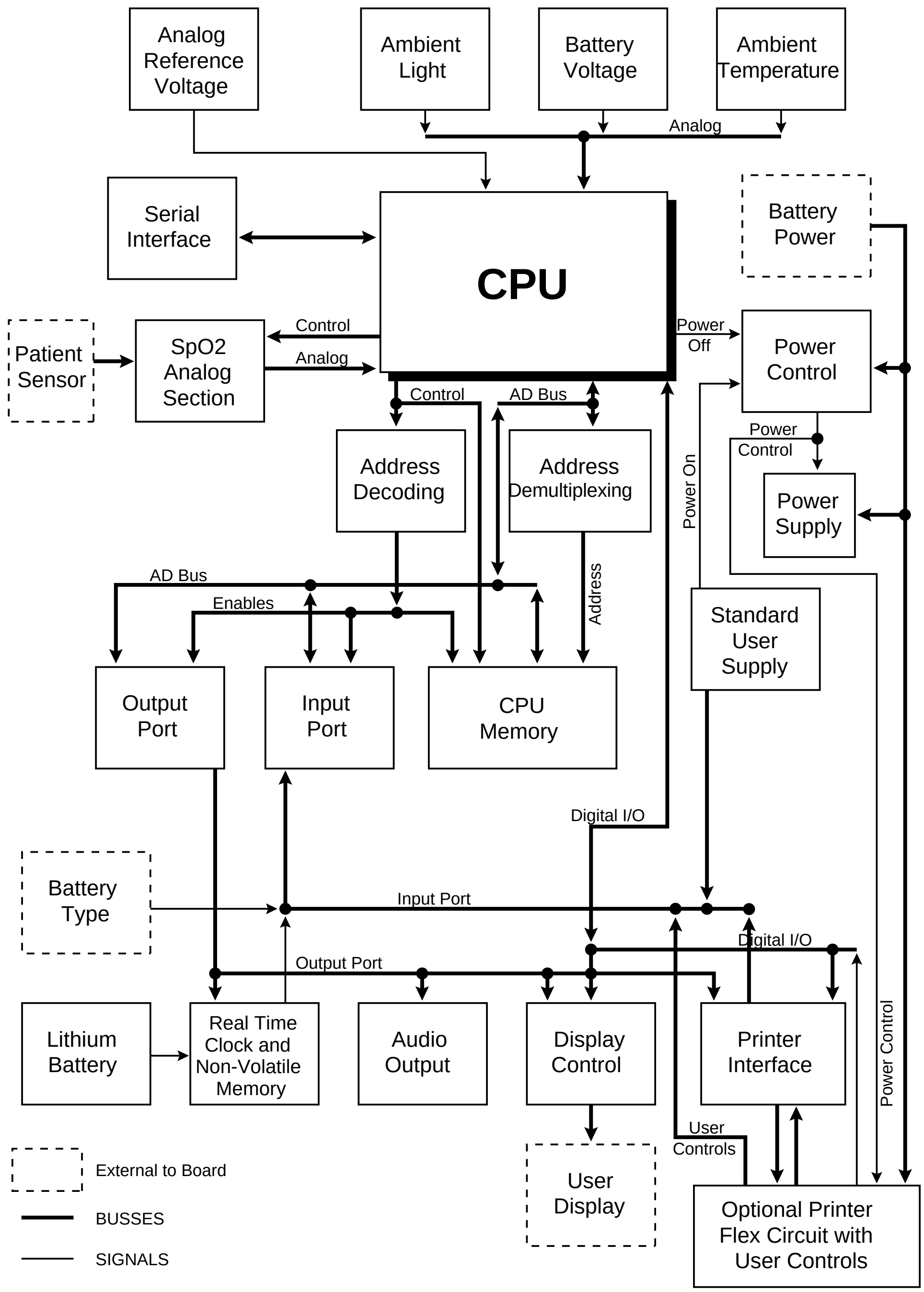


Figure 9-14: N-20 Hardware Block Diagram

The CPU has the ability to dynamically switch the data bus width—based on the BUSWIDTH input pin. A low on BUSWIDTH tells the CPU to access memory only 8 bits at a time. When accessing the static RAM, BUSWIDTH is low, automatically reading the 8-bit wide RAM. Since BUSWIDTH is connected to the active low RAM enable line (RAMEN), all other memory and mapped I/O are read or written 16 bits at a time.

The CPU measures eight analog inputs. Input from the SpO_2 analog section includes AC and DC signals for the oximeter sensor red and infrared channels, and the sensor calibration resistor RSENS. Light, temperature, and battery voltage are also measured.

The N-20 CPU is configured as follows:

- Decoded AD0 and BHE generate separate WR write strobes for the low and high bytes of a word. The signal WR (pin WRL) is the low-byte write strobe.
- A standard address latch enable (ALE) is generated and used.
- HSO pins 4 and 5 are configured as outputs. The HSO is used to generate stable timing control signals to the SpO_2 analog section, display, and printer.
- The timer-2 external control pins T2CLK, T2RST, T2U-D, and T2CAPT are disabled via software and used as standard I/O.
- The HOLD, HLDA, and BREQ bus accessing is disabled via software and the pins are used as standard I/O.
- Pins HSI0 and EXTINT are configured for interrupt input. The CPU receives 2 external interrupts (signals PR_TACH and PHOTOI).
- RXD and TXD are configured as a standard asynchronous serial transmitter and receiver for the serial interface.
- PWM0, PWM1, and PWM2 pins are configured as pulse width modulator outputs. They are used to control gains within the SpO_2 analog section.

9.10.9.1 Address Demultiplexing

The address demultiplexing circuit is illustrated in Figure 9-15.

U13 and U33 are transparent latches that latch the address portion of the AD bus data on the falling edge of ALE; the outputs are always enabled. The outputs of U13 and U33 are always the address portion of the AD bus.

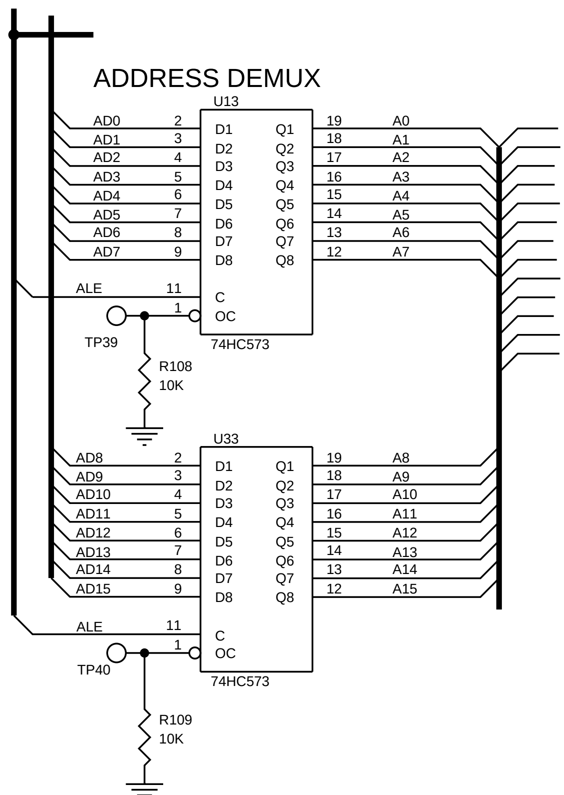


Figure 9-15: Address Demultiplexing Circuit

9.10.9.2 Address Decoding

The address decoding circuit is illustrated in Figure 9-16.

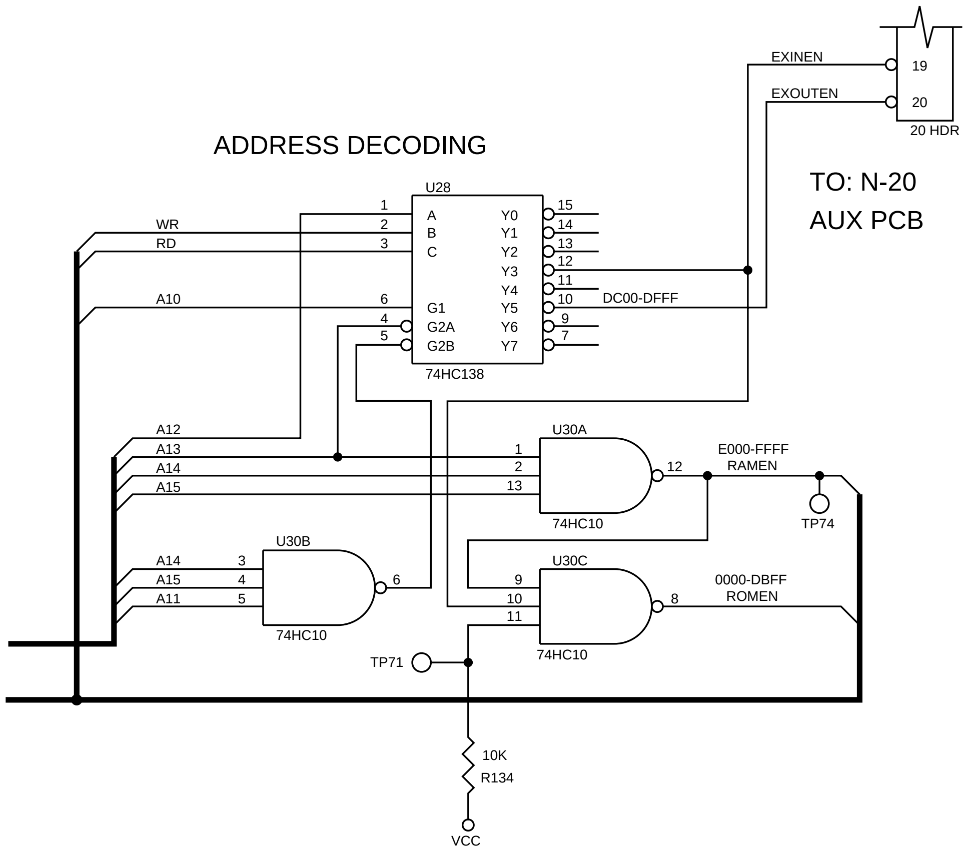


Figure 9-16: Address Decoding Circuit

The CPU has a 64 Kbyte address range of 0-FFFF. RAM, EPROM, and I/O ports share this space. The address decoding circuit splits up this space and output enable lines to the RAM, EPROM, and I/O ports.

U30A generates the static RAMs active low enable signal, RAMEN. When address lines A13, A14, A15 are all high, U30As output goes low, enabling the RAM. This occurs for the 8K address range of E000-FFFF.

U30B and U28 are used to generate the input port and output port active low enable signals EXINEN and EXOUTEN. When address lines A15, A14, A11, and A10 are high, and A13 is low, U28 becomes enabled. With U28 enabled, one of the 8 outputs is set low. The output to go low is selected by pins A, B, and C. They form a 3-bit binary number with pin C being the most significant bit. So when address line A12 is high, WR active (low), and RD inactive (high), a binary 5 is produced on pins A, B, and C, forcing output Y5 (EXOUTEN) low. This enables the output port for writing. When address line A12 is high, WR inactive, and RD active, a binary 3 is produced on pins A, B, and C, forcing output Y3 (EXINEN) low. Note that in both previous conditions, A15, A14, A12, A11, and A10 are high and A13 is low.

The input port and the output port both share the same 1 Kbyte address space of DC00-DFFF. When data are written to that address, the output port enable signal EXOUTEN is activated. But when data are read from the same address, EXINEN is activated. Because the CPU is configured to use a 16-bit bus, except for RAM, any even address in the DC00-DFF range could be used for external port access. In other words, reading or writing address DC00, DC02, DC04, etc., will all produce the same results. Due to the CPU configuration, the write strobe WR (WRL pin) is only active for low-byte writes; therefore, both bytes of the external output port must be written to at the same time. The upper byte of the output port cannot be written to alone, no write strobe and, therefore, no EXOUTEN signal will be generated.

U30C generates the EPROMs active low enable signal, ROMEN. The active low signals RAMEN and EXINEN are basically used as EPROM disable signals. When RAMEN or EXINEN or test point TP71 are low, the output of U30C, ROMEN, is forced high, disabling the ROM. Therefore, the EPROM is disabled for the range DC00-FFFF and enabled for the 55 Kbyte address range of 0h-DBFF. TP71 is used during board testing to disable the EPROM.

9.10.10 CPU Memory

The CPU memory circuit is illustrated in Figure 9-17.

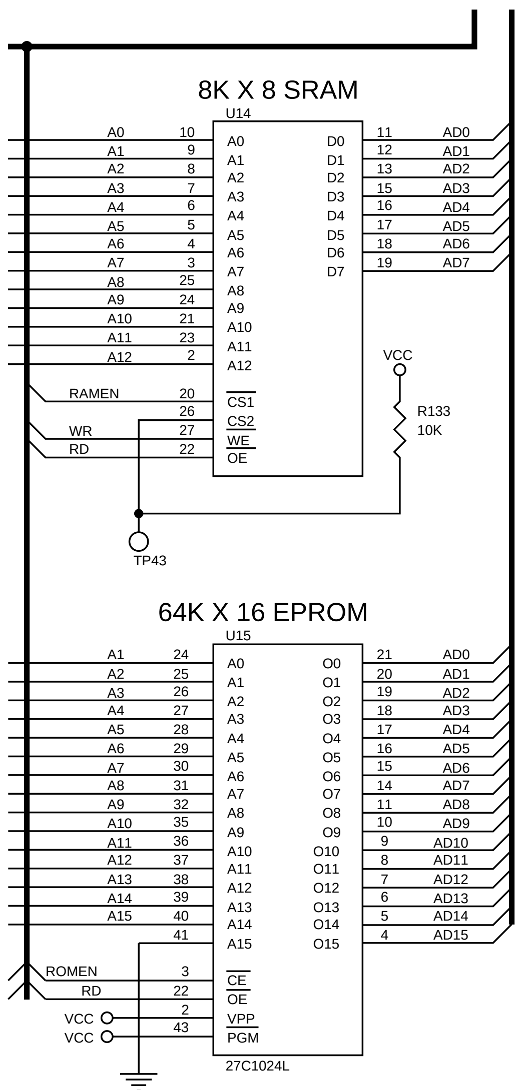


Figure 9-17: CPU Memory Circuit

The memory system external to the CPU consists of an 8 K ×8 static RAM (U14) and a 64 K ×16 EPROM (U15). The EPROM is 16 bits wide to enhance CPU performance. Because RAM is infrequently accessed, it is only 8 bits wide.

U14 is a standard 8K ×8 static RAM. Test point TP 43 is used during testing to disable the output.

The program that the CPU runs is stored in U15. U15 is a 16-bit wide output, one-time programmable (OTP) EPROM. During 16-bit wide bus accesses, the CPU uses address line A0 for low/high byte selection, and address line A0 is not used as a normal address line. The CPU can address only 64K ×8 bytes or 32K ×16 bytes. Pin A15 of U15 is tied low, always selecting the lower half of the EPROM. Signal ROMEN is then used to enable the EPROM for the proper memory area.

9.10.10.1 Input Port

The input port circuit is illustrated in Figure 9-18.

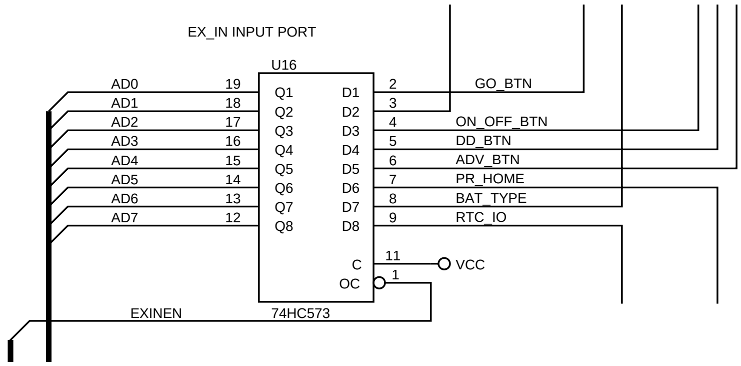


Figure 9-18: Input Port Circuit

U16 is the input port external to the CPU. The logic levels on the inputs (pins D1-D8) are output to the CPU via the AD bus while EXINEN is strobed low. All of the user control buttons are input via U16. Also, the battery type is sensed via U16; a high on signal BAT_TYPE signifies to the CPU that rechargeable batteries are being used. If the optional printer head is in the home position, PR_HOME will be a logic high.

Pin D8 (RTC_IO) and an output bit of the external output port are connected. They work as a pair to create a bidirectional bit for communicating with the RTC (see Section 3.5.3, Real-Time Clock and Non-Volatile Memory).

9.10.10.2 Output Port

The output port circuit is illustrated in Figure 9-19 (at the end of this section).

The output port external to the CPU consists of 2 octal D latches , U18 and U17; they function as a single 16-bit output port. U18 is the lower byte (LSB) and U17 is the upper byte (MSB). The output of U18 is always enabled. The output bits of U18 control: audio output, optional printer, RTC, and display.

The signal PR_STROBE controls U17s output drivers. Under normal operation, the outputs are tristated and resistors R148-R154 pull the outputs low. PR_STROBE is driven low to turn on the output drivers of U17. Signals PR_DOT0-PR_DOT6 (pins Q1-Q7) drive the 7 print dots of the optional printer. PR_STROBE pulses all 7 of the dot lines for a specific time period (see also "Printer Interface"). When the CPU is first powered on, PR_STROBE is in a tristate condition. R123 assures that U17 does not accidentally turn on the printer head dots until required to. Pin Q8 (RTC_IO) and an input bit of the external input port are connected. They work as a pair to create a bidirectional bit for communicating with the RTC (see also "Real-Time Clock and Non-Volatile Memory").

Both bytes of external output port (i.e., U18 and U17) must be written to at the same time. The upper byte of the output port (U17) cannot be written to independently (see also "Address Decoding").

9.10.11 Real-Time Clock (RTC) and Non-Volatile Memory

The real-time clock circuit is illustrated in Figure 9-20.

The RTC has two functions: (1) it provides non-volatile memory that is used to remember whether the printer should be enabled at power on, and (2) to keep track of time and date for the N-20P printer. The N-20 does not require or use the RTC; it is disabled via software.

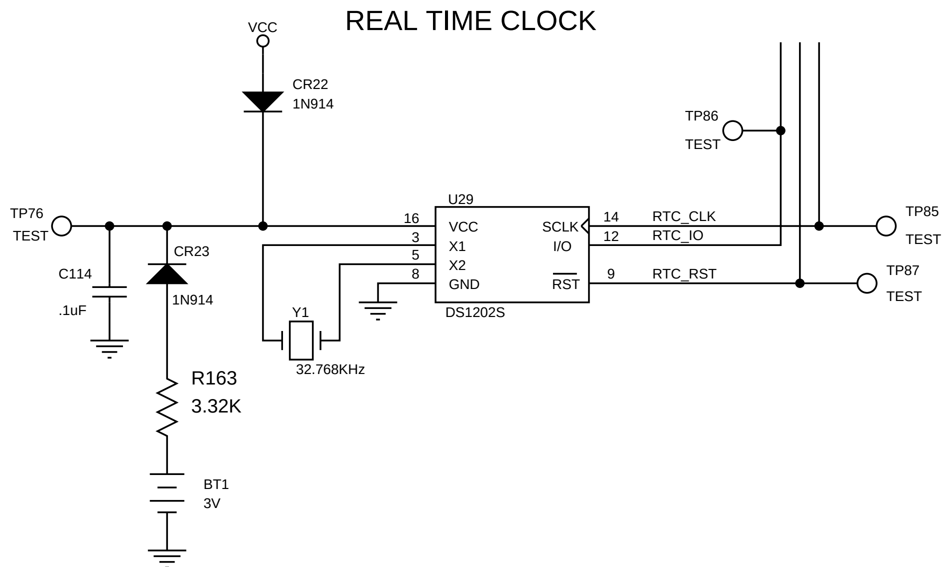


Figure 9-20: Real-Time Clock Circuit

The RTC chip U29 uses a 3-wire synchronous serial interface to communicate with the CPU. The CPU brings signal RTC_RST high to activate communication with the RTC. RTC_CLK clocks data into and out of the RTC chip. RTC_IO is the bidirectional communication data bit. The CPU drives RTC_IO when writing data and commands to the RTC. The CPU tristates RTC_IO and then reads data back on it from the RTC.

Crystal Y1 provides an accurate 32.768 KHz clock input whenever the time keeping circuitry of U29 is activated. The CPU enables the timekeeping function only when an optional printer is installed. If no printer is installed, the CPU switches off timekeeping, thereby extending battery life. Also, with no printer installed, the RTC clock is used only during diagnostic testing to verify the CPU clock timing.

The lithium battery BT1 and diodes CR22 and CR23 provide the power switch over and constant power needed to keep the time and RAM data while the unit is not in use. Whenever the unit is powered on, Vcc is at 5 V and U29 is powered via CR22. CR 23 is reverse biased because BT1 at 3 V is at a lower potential than Vcc. Whenever the unit is powered off, the potential between Vcc and switched ground is 0 V, CR23 is forward biased, and U29 is powered by BT1. CR22 is reverse biased, isolating BT1 from Vcc. This circuit design allows BT1 life of up to 5 years, typically, without the unit being powered on.

U29 holds 24 bytes of RAM, which is used for non-volatile storage of CPU data.

9.10.12 Audio Output

The audio output circuit is illustrated in Figure 9-21.

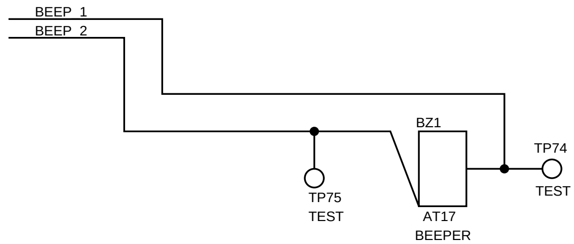


Figure 9-21: Audio Output Circuit

BZ1, a piezo ceramic sounder, is the audio output device. Due to its low drive current of 2 mA maximum, no drive circuitry is needed, and the audio output device is driven directly from the external output port. It is differentially driven with 2 square waves 180 degrees out of phase. The drive frequency is approximately 1480 Hz or 740 Hz and is generated by the CPU. BZ1 is differentially driven to obtain maximum audible volume.

9.10.13 Display Control Circuitry

The display control circuit is illustrated in Figure 9-22, at the end of this section.

The Taliq display is controlled by the display control circuitry. A photosensor measures ambient light and automatically switches on the electroluminescent display backlight during low light conditions. The display control circuitry is divided into the following subsections:

9.10.13.1 Control Conditioning Circuit

The control conditioning circuit, located on the main PCB (Figure 9-6), processes signals generated by the CPU to produce timing signals for the display drivers.

9.10.13.2 Display Driver ICs

The display driver ICs are located on the auxiliary PCB (Figure 9-6). Each of the two display driver ICs have 32 high-voltage outputs that enable individual segments of the display to be turned on or off.

9.10.13.3 High Voltage Control Circuit

The high voltage control circuit is located on the auxiliary PCB (Figure 9-6). The high voltage control circuit allows the CPU to switch on or off the display's high voltage input.

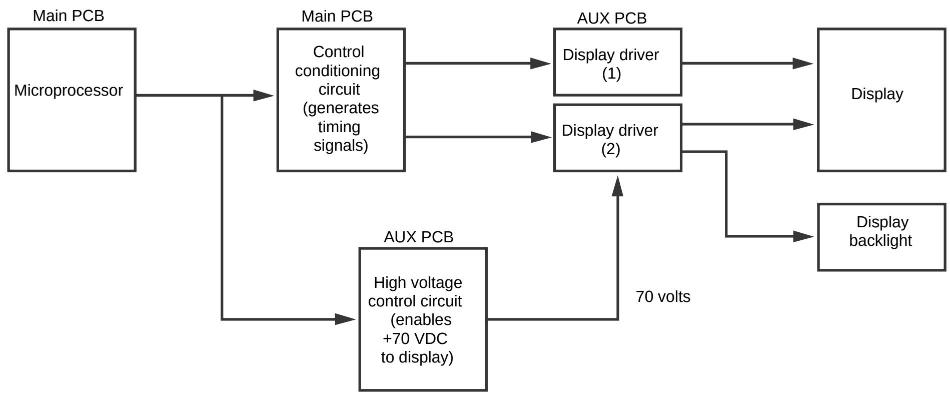


Figure 9-6: Display Control Block Diagram

9.10.13.4 Control Conditioning Circuit

The CPU generates a 400-µs low-pulse train at a 160 Hz rate on signal DISP_PHASE. Half of U34 takes DISP_PHASE as an input and creates DISP_POL as an 80 Hz 50% duty cycle square wave. A CPU reset initializes DISP_POL low when any CPU reset occurs so the software knows the initial state. The other half of U34 is used to synchronize the rising edge of the DISP_DL with the rising edge of DISP_POL. The CPU brings DISP_LATCH signal high before the rising edge of DISP_PHASE; this allows the high to be clocked out to DISP_DL on the rising edge of DISP_PHASE. About 100 µs after the rising edge of DISP_PHASE, the CPU brings DISP_LATCH low, asynchronously resetting DISP_DL low.

9.10.13.5 Display Driver Control Circuits

U19 and U20 are the display segment driver chips. Each chip has 32 high-voltage outputs and a display common marked BP (backplane). The display data are input to U19 and U20 by the CPU via a serial shift register input. U19 and U20 are daisy-chained together, forming a 64-bit serial shift register. Display data are loaded and shifted down via the DISP_DATA and DISP_CLK signals. When all 64 bits of the shift register are loaded, a high pulse on DISP_DL updates the display, all 64 bits at the same time. The display is clocked with an 80 Hz 50% duty cycle waveform by signal DISP_POL. The display cannot be driven by DC voltages or display damage will result. Display segments are illuminated by creating a 180-degree phase shift between the segment pin and the BP common pin. Segments are left dark by making the waveform on the segment pin be in phase with the BP pin. The display has an electroluminescent (EL) backlight, and is driven the same as the display segments. Connectors JP2, JP3, and JP5 connect the display and EL backlight to the drive electronics.

9.10.13.6 High Voltage Control Circuit

The cold switch circuit performs two basic functions: (1) it allows the CPU to enable and disable the display high voltage VDISP, and (2) it slows the edge slew rate of the segment drivers as it switches the high voltage. When the signal DISP_PHASE is low, Q14 is disabled, pulling VDISP low. Whenever the CPU is powered on, DISP_PHASE is tristated. The base emitter junction of Q12 pulls DISP_PHASE low, disabling the high voltage. This assures that the high voltage is only enabled to the display when controlled by the CPU.

The Taliq display is similar to an LCD in that the load of a segment is mainly capacitive. A cold switch circuit provides a current-limited 70 V to VDISP. R93, R95, Q21, and Q14 do the on/off switching and current limiting. As the driver chips' output waveforms and DISP_PHASE change states, the capacitive loads of the display cause VDISP to current limit until the capacitance is fully charged. This constant output current is integrated into the display capacitive loads, causing a highly linear rising and falling voltage ramp on VDISP. Because the high voltage to the drive chips (VDISP) is ramped, the outputs of the driver chips U19 and U20 are also ramped at the same controlled rate. This design is used to reduce current spikes on the 70 V power supply, and, in addition, reduces the EMI generated by the display due to the lower slew rates of the high voltage switching signals.

9.10.14 Standard User Controls

The user controls circuit is illustrated in Figure 9-23.

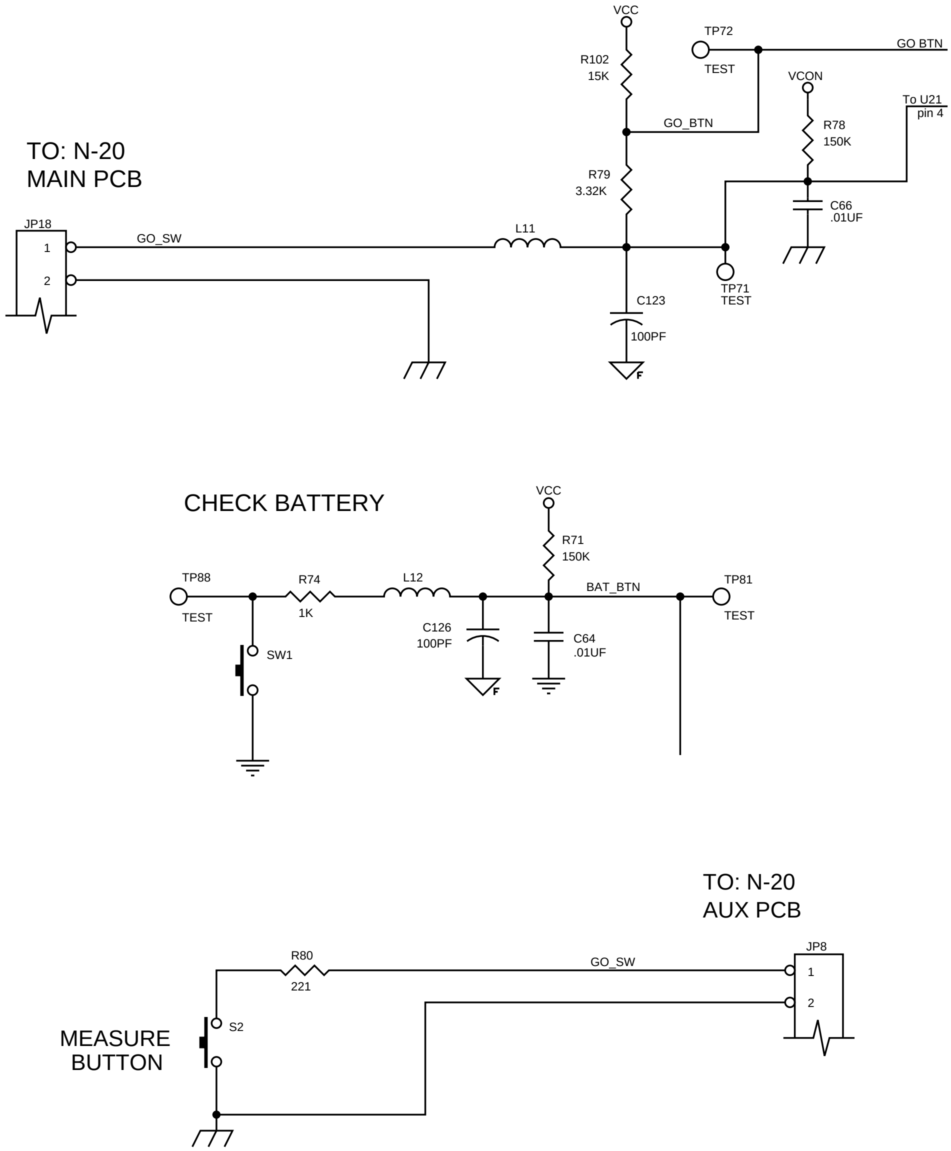


Figure 9-23: User Controls Circuit

The standard user controls consist of two momentary push-button switches (measure and check-battery). The Measure button is an elastomeric contact switch, and the Check-Battery button is a mechanical momentary switch.

The CPU input lines BAT_BTN and GO_BTN are normally pulled to the high state by R71 and R78. Whenever a button is depressed, the CPU input line is pulled low through R74 and R80. The switch contacts are debounced with C64 and C66. L11, L12, C126, and C123 provide a current path for ESD protection.

In addition to being read by the CPU, the Measure button also activates the power supply via the power control circuit. Note that the Measure button has circuitry on both the main PCB as well as the auxiliary PCB.

9.10.15 Power Supply/Power Control Circuitry

Power supply circuitry is located on the auxiliary PCB and consists of the following subsections:

- **Batteries**—Four 1.5-V alkaline "C" size batteries provide 4-6 VDC power.
- **Power control circuitry**—Power control circuitry is connected to the batteries. It senses any press of the Measure button and switches on the power supplies. Reverse current limiting protects the N-20/N-20P from damage if batteries are inserted incorrectly.
- **Power shutoff** circuit—This circuit controls power to all circuits except the power control circuit. In addition, a fuse protects the power supply from excessive current draw. The power supply is also protected against electrostatic discharge and electromagnetic interference.
- Power supply circuits consists of the following power supplies:

  Regulated power supply: Power supplied by the batteries is regulated at 5 VDC. All of the digital circuitry and some of the SpO2 analog circuitry use this supply.

  Unregulated power supplies: 5 VDC is converted by a switched capacitor network into unregulated power supplies of –5 VDC, 10 VDC, and 12 VDC, all of which are used in the SpO_2 analog circuits.

  High voltage power supply: A voltage regulator/doubler converts battery power to 70 VDC; the display drivers as well as the display backlight need this increase in power.

The power supply circuit is illustrated in Figure 9-24, at the end of this section.

9.10.15.1 Power Control Circuitry

The power control circuit is illustrated in Figure 9-25, at the end of this section.

The power control circuit consists of U21 and its associated components. U21 is a D flip/flop with asynchronous preset and clear; only the preset and clear are used.

Power is applied to U21 via CR11 whenever batteries are installed. CR11 provides protection for U21 if the batteries are installed with reverse polarity. This error condition will reverse bias CR11, thereby disabling current flow to U21.

The much larger RC time constant of R110, C67 compared to R78, C66 guarantees that the unit will not be accidentally powered on when batteries are first installed.

Whenever the **Measure** button is pressed, a low on GO_SW sets the output signal PWR_ON high. This condition connects switched and battery grounds, enables the power supplies, and switches on the unit. Whenever the CPU determines that the power should be switched off, it forces PWR_DOWN low. This action clears output PWR_ON to a logic low, disconnecting ground, and switching off the power supplies (see also Power Supply).

R79 and R81 provide current limit protection to U21 inputs. They also limit the current that will flow through U21 inputs to the CPU when the batteries are installed backwards. In the reverse battery error condition, massive current can flow from the inputs of U21 through the input protection diodes and/or substrate inside the CPUs integrated circuit. These resistors limit that current path to safe levels.

9.10.15.2 Power Shutoff Circuit

Refer to Figure 9-24, "Power Supply Circuit" (at the end of this section).

Fuse F1 protects the unit from excessive current draw. CR24 protects against large voltage transients caused by ESD, EMI, etc.

Q15 is a dual-channel FET; the drain of Q15 part 2 (pin D2) is connected to battery ground; the gate (G2) is connected to battery plus; and R155 applies a bias to the source (S2) so it will switch on when a positive voltage is applied to G2. When batteries are correctly installed, Q15 part 2 is switched on and conducts. If batteries are installed backward, Q15 part 2 switches off and disables current flow. This protects the units power supply circuitry from an accidental reversal of battery potential.

Q15 part 1 controls the power supplies. When a logic high is placed on the gate (pin G1) signal, PWR_ON battery ground is connected to the circuit and switched to ground via Q15 parts 1 and 2. When the power control circuitry pulls PWR_ON low, switched ground switches to a high impedance state. This action switches off the power supply and, therefore the unit, except for the power control circuit.

9.10.15.3 Vcc Power Supply

Refer to Figure 9-24, "Power Supply Circuit," at the end of this section.

The Vcc power supply is a switched inductor voltage regulator operating in boost mode (U22). The power input is provided by the batteries (VBAT). NFET (Q17) operates as a linear post regulator. The 1 M resistor (R77) operates as a static bleed device across the switched regulator when the regulator is switched down. The regulated output is Vcc (5 V ± 5%).

9.10.15.4 Raw Power Supplies

Refer to Figure 9-24, "Power Supply Circuit," at the end of this section.

The input to the raw power supplies is Vcc, which is a switched-capacitor voltage converter operating in separate multiply and invert modes in conjunction with supporting circuitry. U23 inverts Vcc and outputs raw –5 V. Raw 10 V is derived by voltage doubling Vcc with CR14, CR19, CR20, and CR78. Raw 12 V is derived by voltage tripling Vcc with CR15, Q8, Q9, C96, C81, R119, and R120.

The raw power supplies are used as bias supplies for the SpO2 analog section and are not tightly regulated. The normal operating range of the raw power supplies are:

raw –5.0 V	=	–6.0 V	to	–4.0 V
raw 10.0 V	=	7.5 V	to	11.0 V
raw 12.0 V	=	12.0 V	to	15.0 V

9.10.15.5 High Voltage Supply

Refer to Figure 9-24, "Power Supply Circuit," at the end of this section.

The input power for the high voltage supply is provided by the batteries (VBAT). The high voltage supply is a switched-inductor voltage regulator (U26) that operates in conjunction with a capacitive voltage doubler to output 72 VDC ± 5%. To protect against a runaway voltage condition, CR25 clamps U26's output to a safe level.

9.10.16 Analog Reference Voltage

The analog reference voltage circuit is illustrated in Figure 9-26.

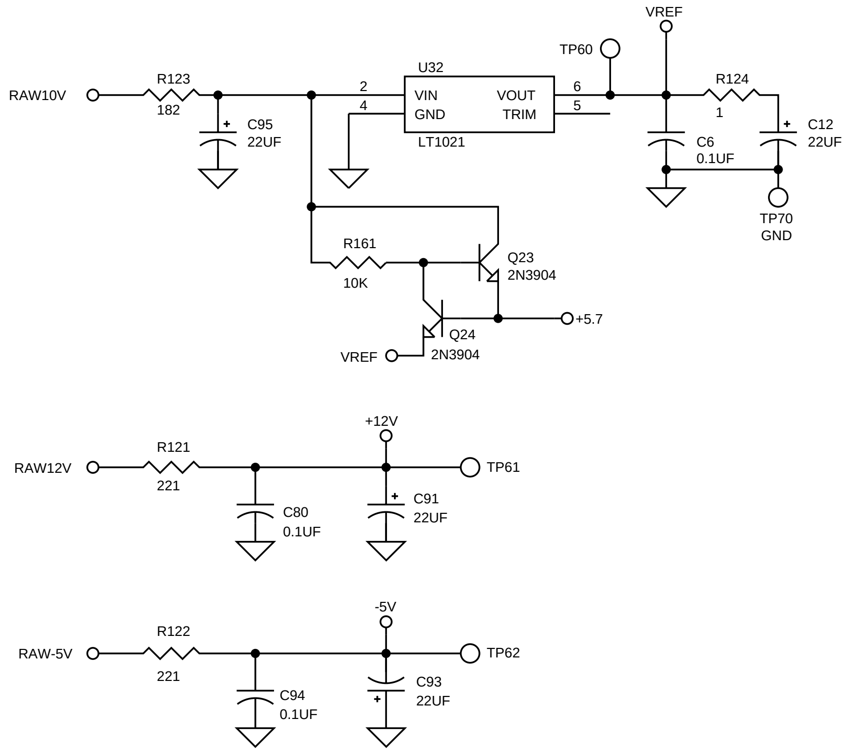


Figure 9-26: Analog Reference Voltage Circuit

U32 provides an accurate, regulated voltage that is used as the reference voltage for the A/D inside the CPU. Filtering is provided by C6, C12, and R124. The voltage output VREF is 5 V.

9.10.17 Ambient Light

The ambient light circuit is illustrated in Figure 9-27.

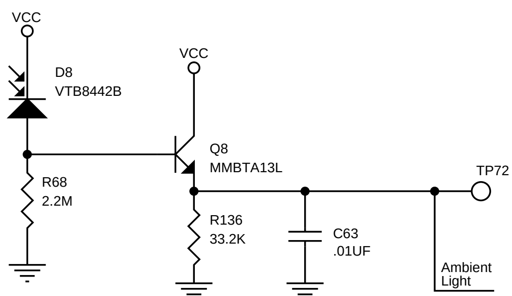


Figure 9-27: Ambient Light Circuit

Diode D8 is a photodiode that is used to measure ambient light. Q8, R68, and R136 provide current gain for D8 photocurrent. The amplified photocurrent flowing through R136 creates a voltage drop, which is measured by the CPU. The CPU continually monitors the light source output at AMB_LIGHT (TP72). Under low ambient light conditions, the CPU automatically switches on the display backlight.

9.10.18 Ambient Temperature

The ambient temperature circuit is illustrated in Figure 9-28.

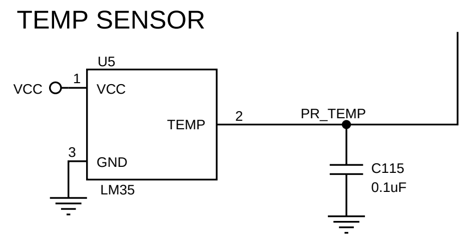


Figure 9-28: Ambient Temperature Circuit

U5 is a precision-temperature sensor. It outputs (PR_TEMP) a voltage proportional to the ambient temperature, which is 10 mV per degree centigrade. For example, at a room temperature of 25 °C, the U5 output would be 250 mV. U5 is used whenever an optional printer is installed. Because the printer is a thermal printer, ambient temperature must be compensated for.

9.10.19 Battery Voltage

The battery voltage circuit is illustrated in Figure 9-29.

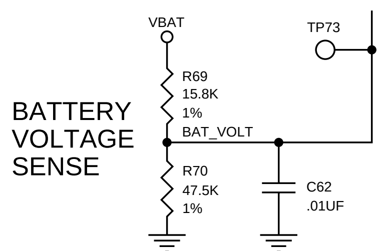


Figure 9-29: Battery Voltage Circuit

The analog input voltage range of the CPU is 0-5 VDC. Because the battery voltage may be as high as 6.2 V, R69 and R70 form a voltage divider to decrease the measured battery voltage to a usable level. The gain is 0.75; thus, if the battery voltage was 6 V, then the voltage of BAT_VOLT would be 6×0.75 which equals 4.5 V.

The software has the ability to determine when battery power is too low. If the software determines that the battery voltage is too low to provide accurate information, the software generates an audible signal and automatically switches the unit off. If an optional printer is installed, the battery voltage data are used to compensate for battery voltage changes that can affect printout quality.

9.10.20 Battery Type

The battery type circuit is illustrated in Figure 9-30.

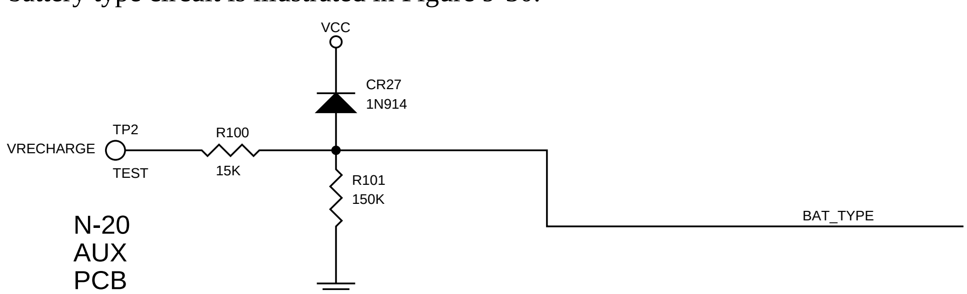


Figure 9-30: Battery Type Circuit

The unit can operate with either disposable or rechargeable batteries. Battery type input is digital; a high input informs the CPU that rechargeable batteries are in use. If rechargeable batteries are used, the battery and the VRECHARGE terminals are mechanically connected. This applies the battery voltage to VRECHARGE, pulling BAT_TYPE high. R100 and CR27 are a current-limiting resistor and a voltage-clamping diode that are used to protect the input port from excessive battery voltage. If disposable batteries are used, VRECHARGE is electrically isolated, which allows R101 to pull BAT_TYPE input low.

The nominal voltages and voltage discharge curves are significantly different between rechargeable and disposable batteries. In order for the CPU to predict how much "battery life" remains, the nominal voltage and discharge curves must be known; the BAT_TYPE signal provides that information.

9.10.21 Printer Control

Printer circuitry is divided into two subsections: the printer interface and the printer flex circuit. Printer interface circuitry is present on both models, but is disabled by software in the N-20.

- **Printer interface circuit** (auxiliary PCB)—This circuit detects the presence of the flex circuit, and supplies power to the print heads and paper-advance motor. Noise generated by the printer motor is filtered. The circuitry is protected from excessive battery currents by a fuse. The printer interface circuit is illustrated in Figure 9-31 (at the end of this section).
- **Printer flex circuit** (N-20P only)—The printer flex circuit is added when the printer is present. The printer generates a timing signal that is read by the CPU and sent to the flex circuit. This circuit signals the CPU that a printer is present by connecting one CPU input to ground. Power and power control signals from the auxiliary PCB generate an output load for a resistor array; heat from this process produces a dot matrix pattern on thermal paper. The printer flex circuit is illustrated in Figure 9-32.

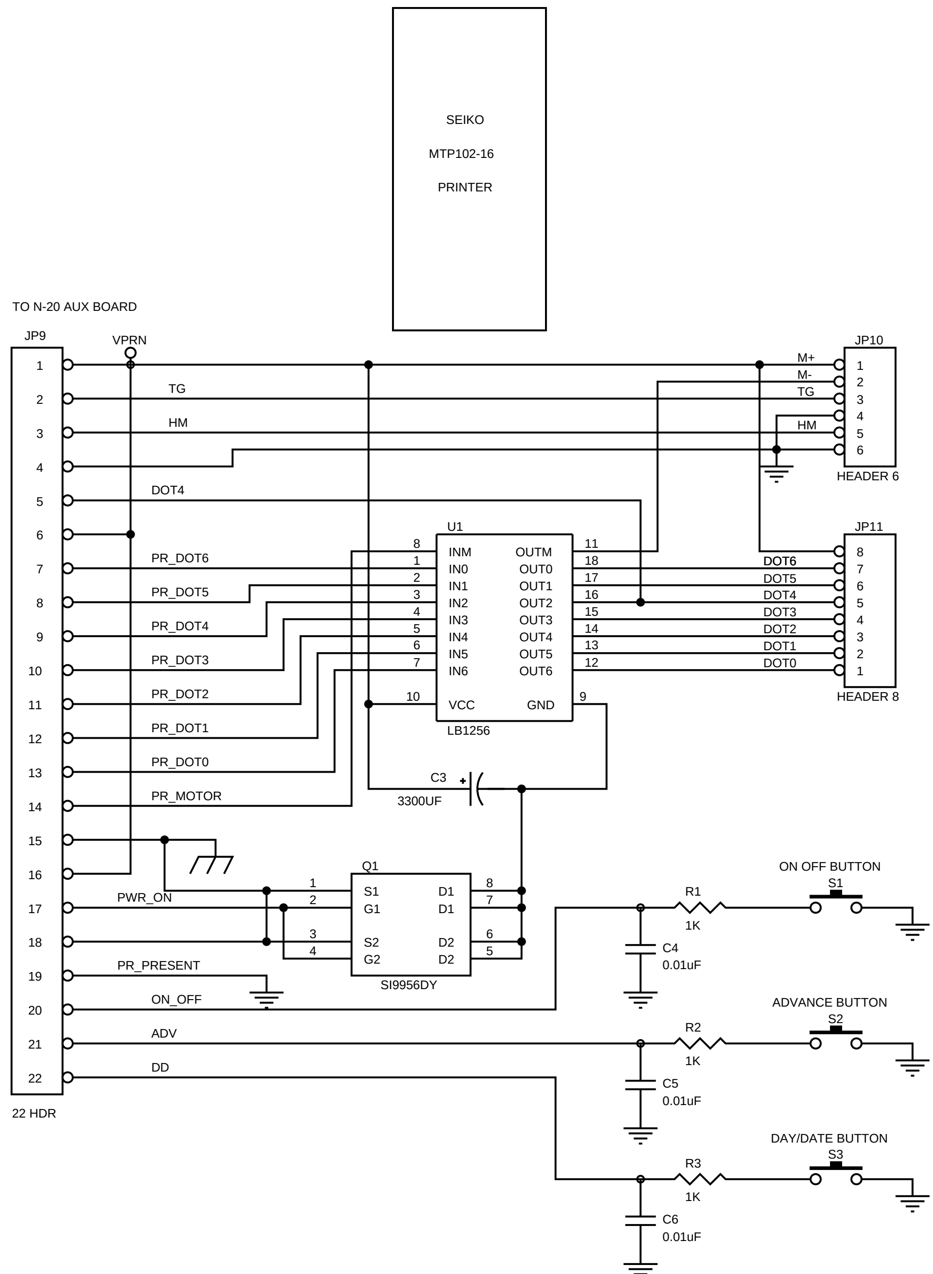


Figure 9-32: Printer Flex Circuit

User control is provided by momentary push buttons: *ON* (on/off), *ADV* (advance), and *D/D* (day/date). *ON* enables or disables the printer, *ADV* controls the advance of printer paper, and *D/D* sets date, time, and other clock parameters.

When a low battery voltage condition is present, the N-20 adjusts power to the printer's head; however, a weak battery voltage condition causes the printer to shut off, thereby allowing the N-20P to continue to display oxygen saturation and pulse rate readings until the batteries are exhausted. An ambient temperature sensor adjusts printout quality to compensate for environmental conditions.

9.10.22 Printer Interface Circuit

The printer interface circuit is illustrated in Figure 9-31, at the end of this section.

The N-20 is configured in two ways, with printer and without printer. The following is a description of the printer interface circuitry found on all N-20 auxiliary PCBs. The printer interface circuitry is there regardless of the unit configuration; however, if the optional printer is not installed, this circuitry serves no function.

The CPU reads the PR_PRESENT signal to determine if a printer is installed. With PR_PRESENT left floating, it is pulled high by the weak pull-up resistor inside the CPU. If a printer is installed, PR_PRESENT is connected to switched ground, which causes a low input to the CPU. The optional printer circuit is protected from excessive battery currents by fuse F2. CR28 is used to block noise generated by the printer motor being injected onto the batteries.

The N-20 printer is a 16-character–wide thermal dot matrix printer, which generates a CPU interrupt for every dot column. The thermal energy given to the print head is controlled by the pulse width of the active high signals PR_DOTx. In order to provide consistent print quality, the ambient temperature, print drive voltage, and print head resistance must be measured and accounted for.

Inside the print head are seven resistors that heat up when power is applied, and in turn create dark dots on the thermal paper. One lead of the print-head resistors is connected to the printer supply voltage VPRN; the other lead is connected to the driver chip (see Optional Printer Flex Circuit with User Controls). One of the print dot resistor leads (DOT4) is also fed back to the printer interface circuitry. The DOT4 signal is a print dot resistor with a range of 11–16 ohms, which is connected to VPRN.

The print head resistance is measured by U36. A two-level resistor bridge is formed by R143, R144, R145, R146, and head resistor DOT4. The resistor bridge is switched on when PR_MEAS is pulled high, pulling TP77 low and biasing the resistor bridge. The logic outputs of PR_HEAD1 and PR_HEAD2 are read in by the CPU to determine which of the three head resistance categories this particular head is R156, ensuring that Q20 does not switch on when the batteries are installed backward. Due to the large current draw of the resistor bridge and the fact that the head resistance does not change significantly over time, the head resistance is measured only once at every power-on.

The CPU starts the printer motor running by setting PR_MOTOR high. A single motor drives both the print head and paper-advance mechanisms. The printer provides a printer timing generator (TG) signal, which is an AC waveform of about 4 Vpp. Q19, R106, R142, and CR29 convert the AC waveform to a CMOS level square wave; this signal (PR_TACH) is then used as a CPU interrupt line. An interrupt routine services the printer, thereby producing the required dot patterns to create the characters. C127 is used to filter noise.

The position of the print head is sensed by the signal PR_HOME. Whenever the print head is not in the home position, a switch in the printer closes, shorting PR_HOME to switched ground. Whenever the print head is in the home position, the switch opens, allowing R118 to pull PR_HOME high.

The print head dot pattern and pulse width are controlled by the CPU. The proper printer dot values are loaded into the output port, then the proper pulse width is loaded into the CPU CAM for PR_STROBE. The signal PR_STROBE enables the outputs for the specified pulse width. When the PR_DOTX lines are high, a dot will be printed.

9.10.23 Printer Flex Circuit and User Controls

The printer flex circuit is illustrated in Figure 9-32.

The thermal printer is plugged in via connectors JP10 and JP11. The PR_PRESENT signal is connected to switched ground to tell the CPU that a printer is installed. U1 is a Darlington pair driver chip that is used to drive the printer dots and motor. When an input is high, the output is shorted to ground, driving the output load.

Constant power (VPRN) and a power control line (PWR_ON) are provided by the auxiliary PCB. Q1 is used as a power control FET. Both halves are used in parallel to reduce the on resistance. When

PWR_ON is high, the sources (S1, S2) short to the drains (D1, D2), connecting ground to U1 and C3. PWR_ON also controls the regulated power supplies; thus, Q1 and the power supplies are both enabled and disabled at the same time.

The large bulk capacitor C3 is required due to the large current spikes that are required by the printer and the large internal series resistance of disposable batteries. Bulk capacitance is required to lessen the drop in battery voltage caused by the current spikes.

The N-20P has three additional user-control buttons. L8, L9, L10, C120, C121, and C122 provide ESD protection. R103, R104, and R105 provide pull-ups when the user buttons are open. These pull-up resistors are in the printer interface circuit to ensure that the buttons (*ON*, *ADV*, and *D/D*) are never left floating, regardless of whether an optional printer flex circuit is installed or not.

The optional user controls consist of three momentary push-button elastomeric contact switches. Pull-up resistors are provided by the printer interface circuitry. R1, R2, and R3 help protect the input port by providing some current-limiting capability. C4, C5, and C6 debounce the switch contacts.

9.11 Support Illustrations

These illustrations, at the end of this section, support the descriptions within this manual.

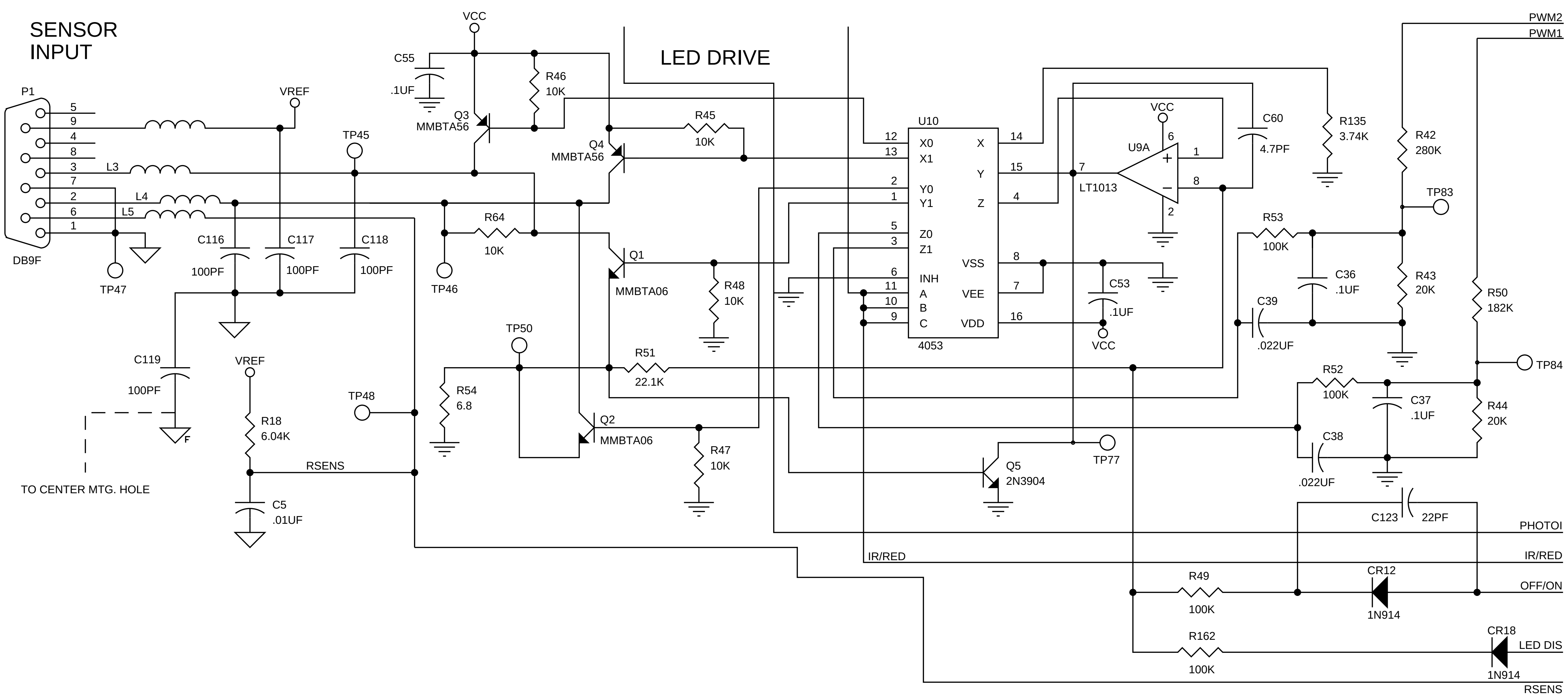


Figure 9-8
LED Drive Circuit

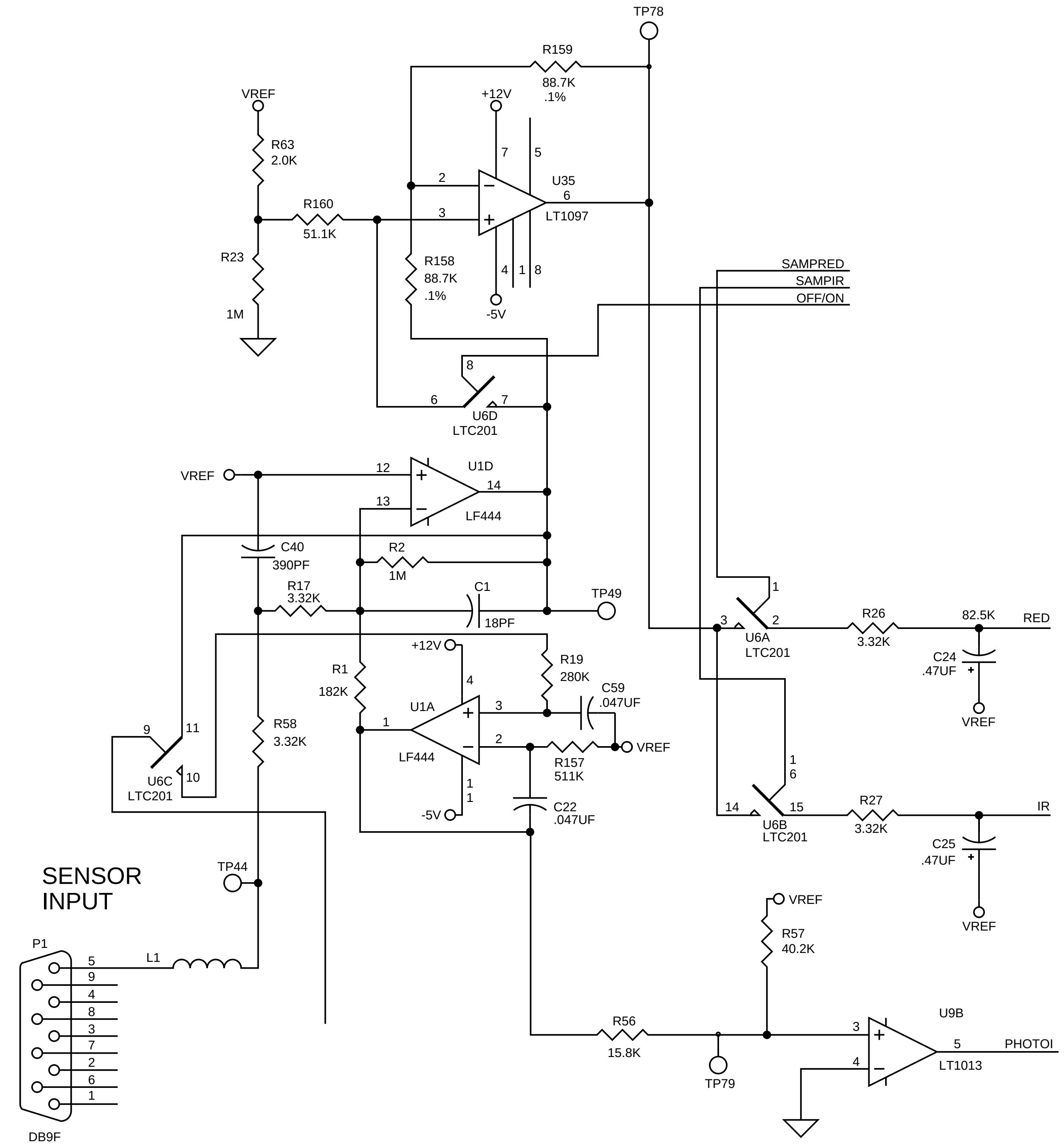


Figure 9-9
Differential Synchronous Demodulation Circuit

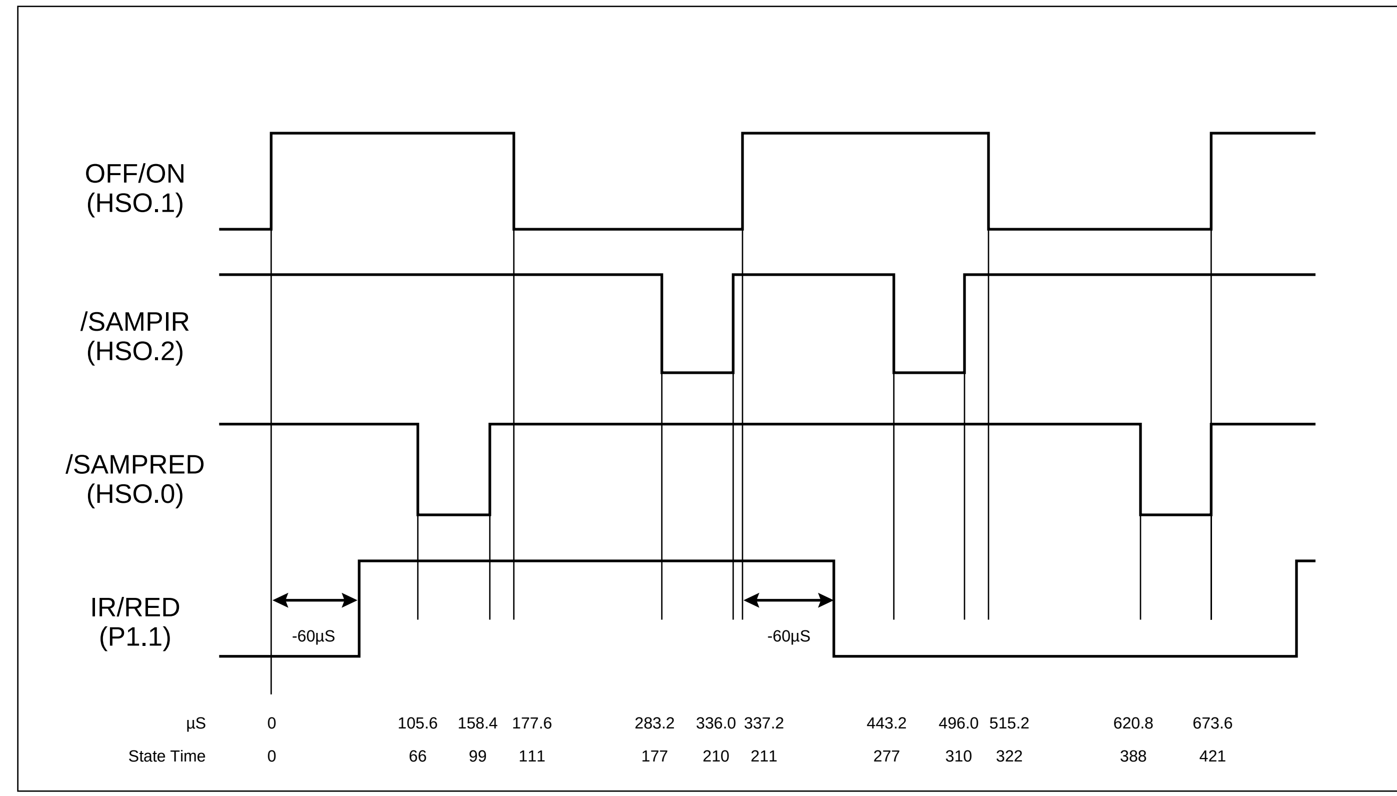


Figure 9-10
N-20 HSO Timing Diagram

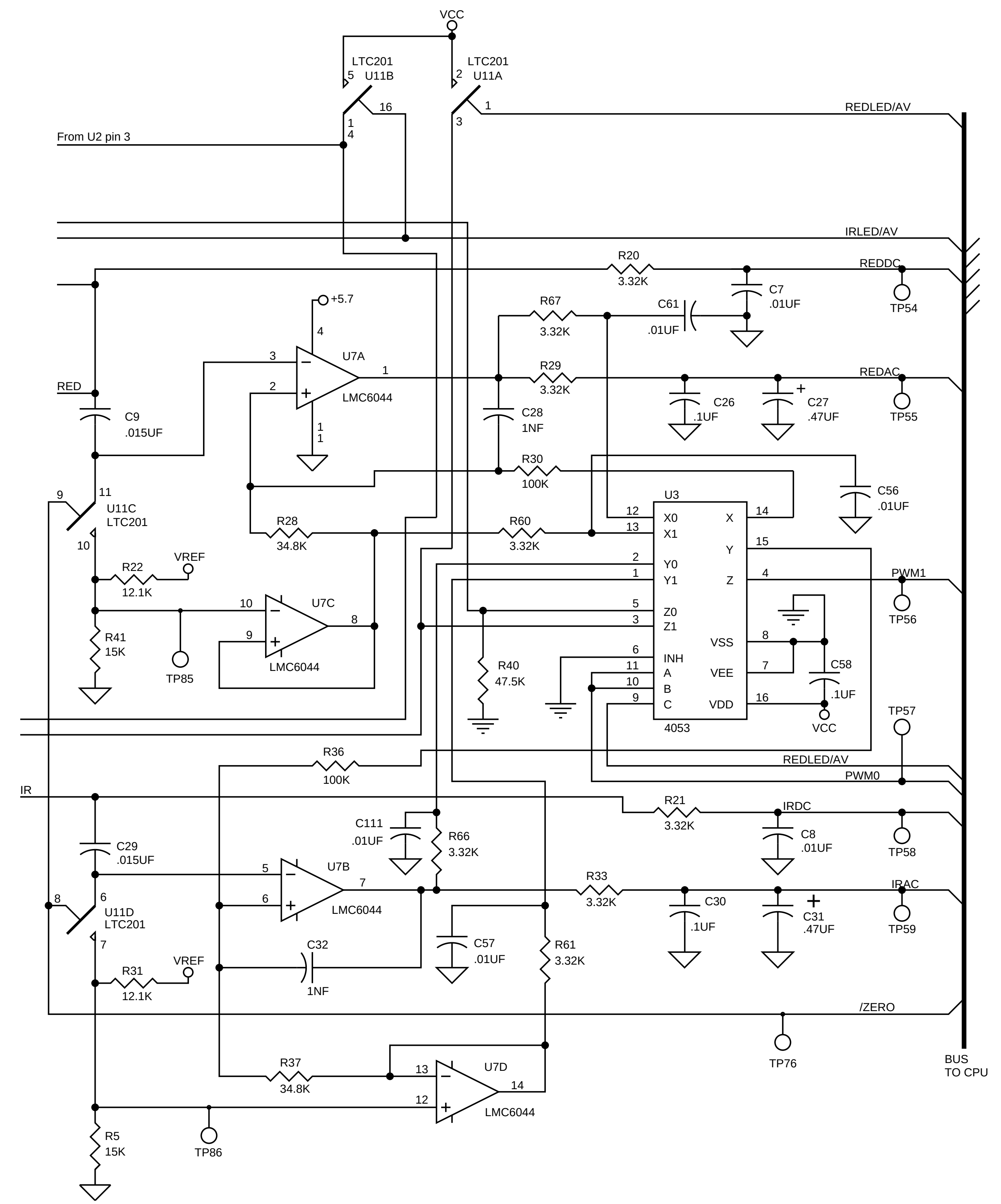


Figure 9-13
AC Variable Gain Control Circuit

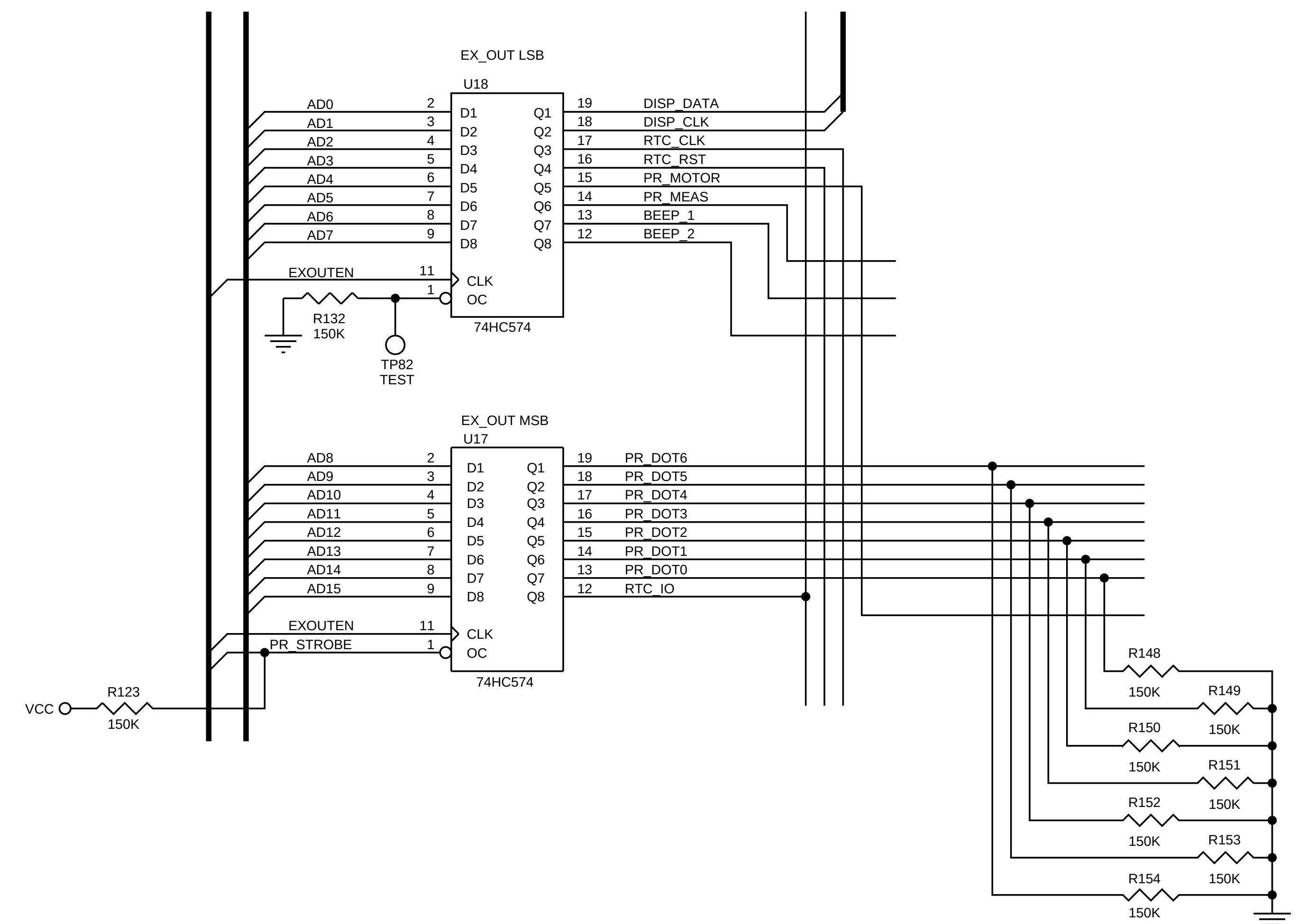


Figure 9-19
Output Port Circuit

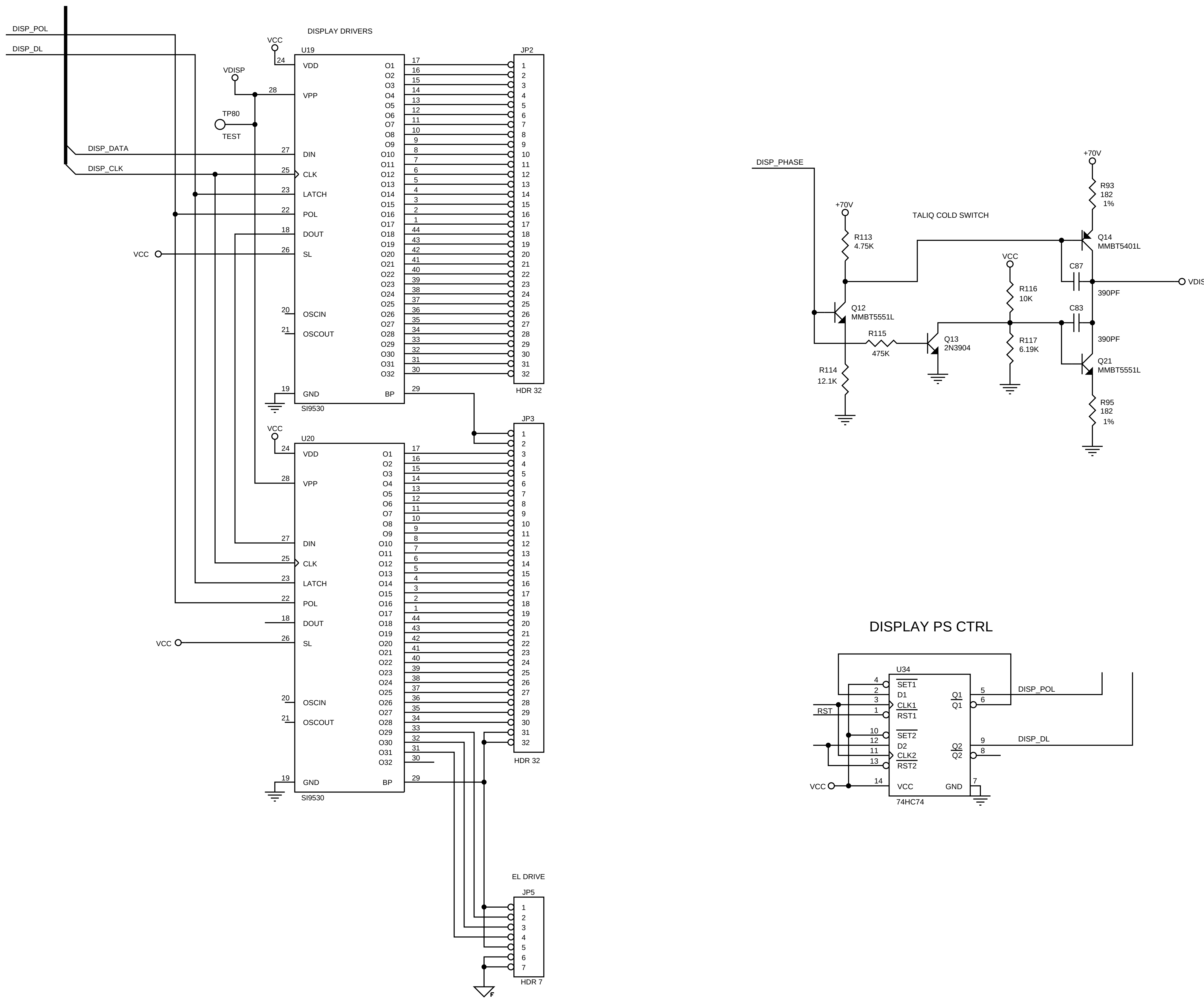


Figure 9-22
Display Control Circuit

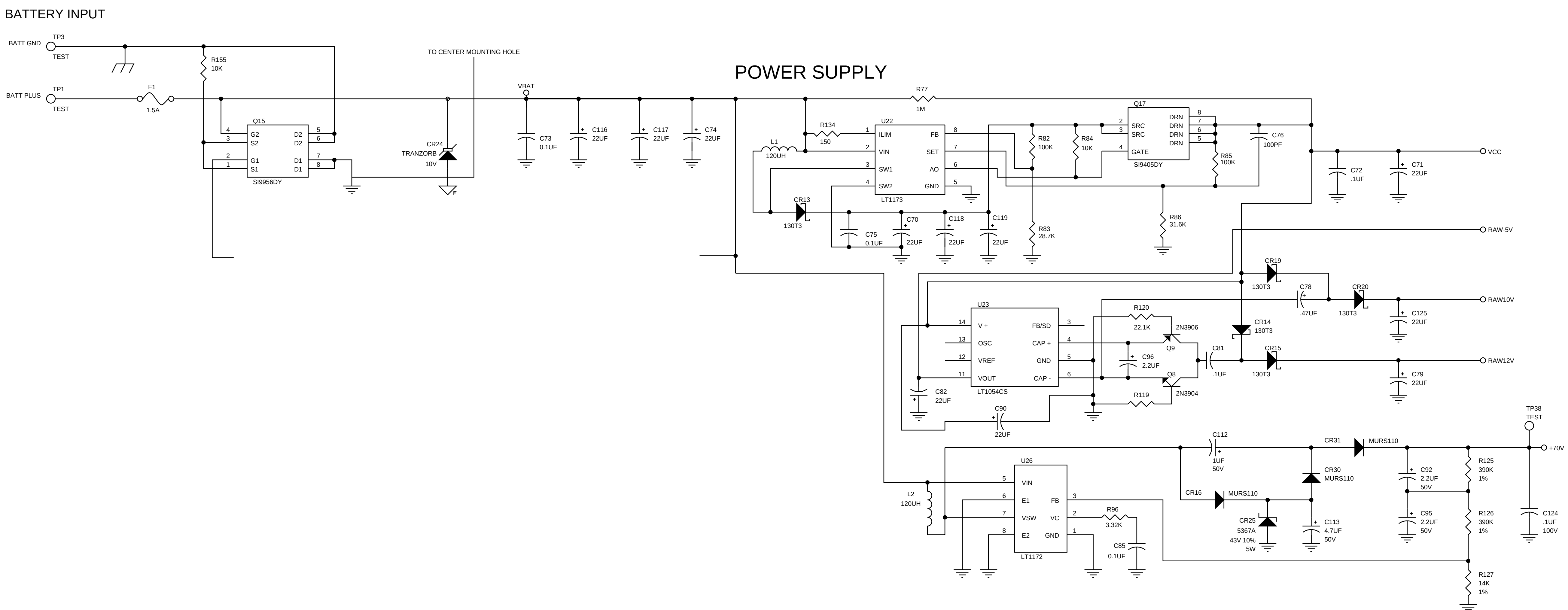


Figure 9-24
Power Supply Circuit

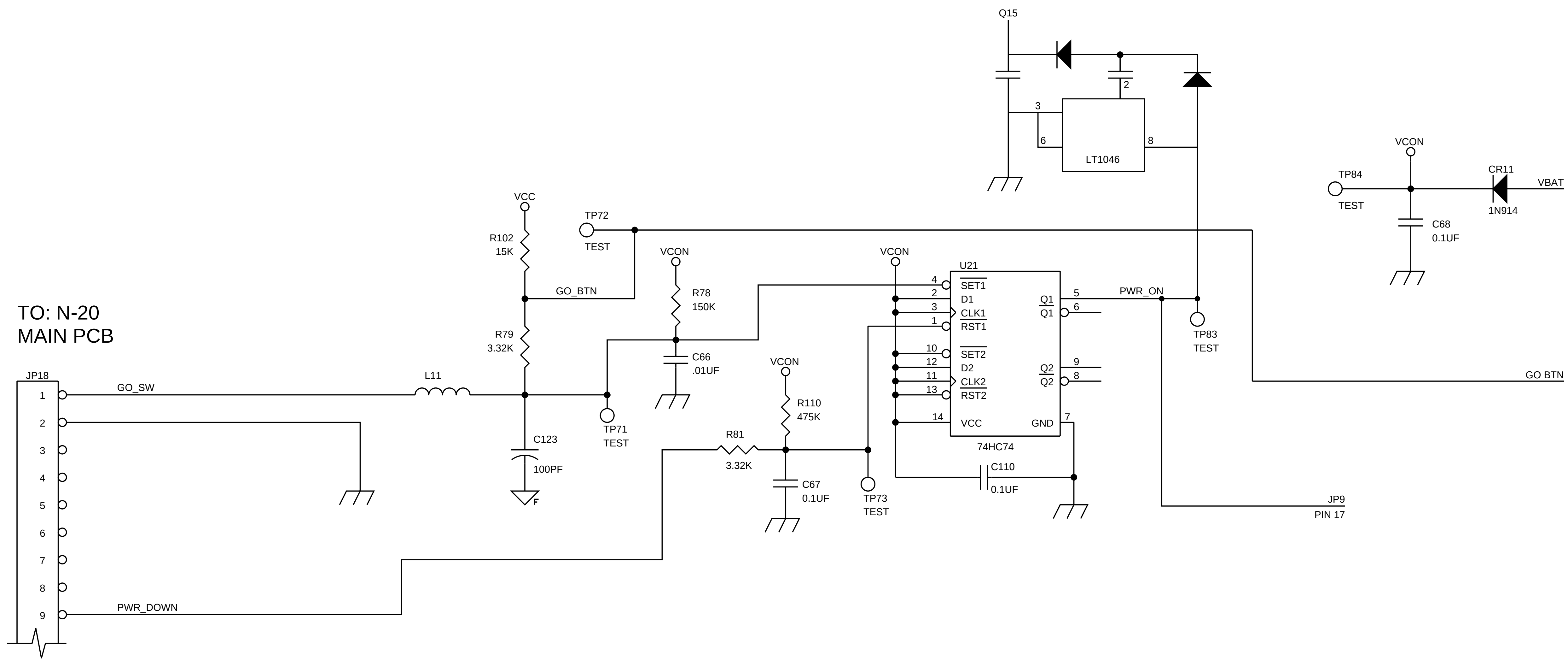


Figure 9-25
Power Control Circuit

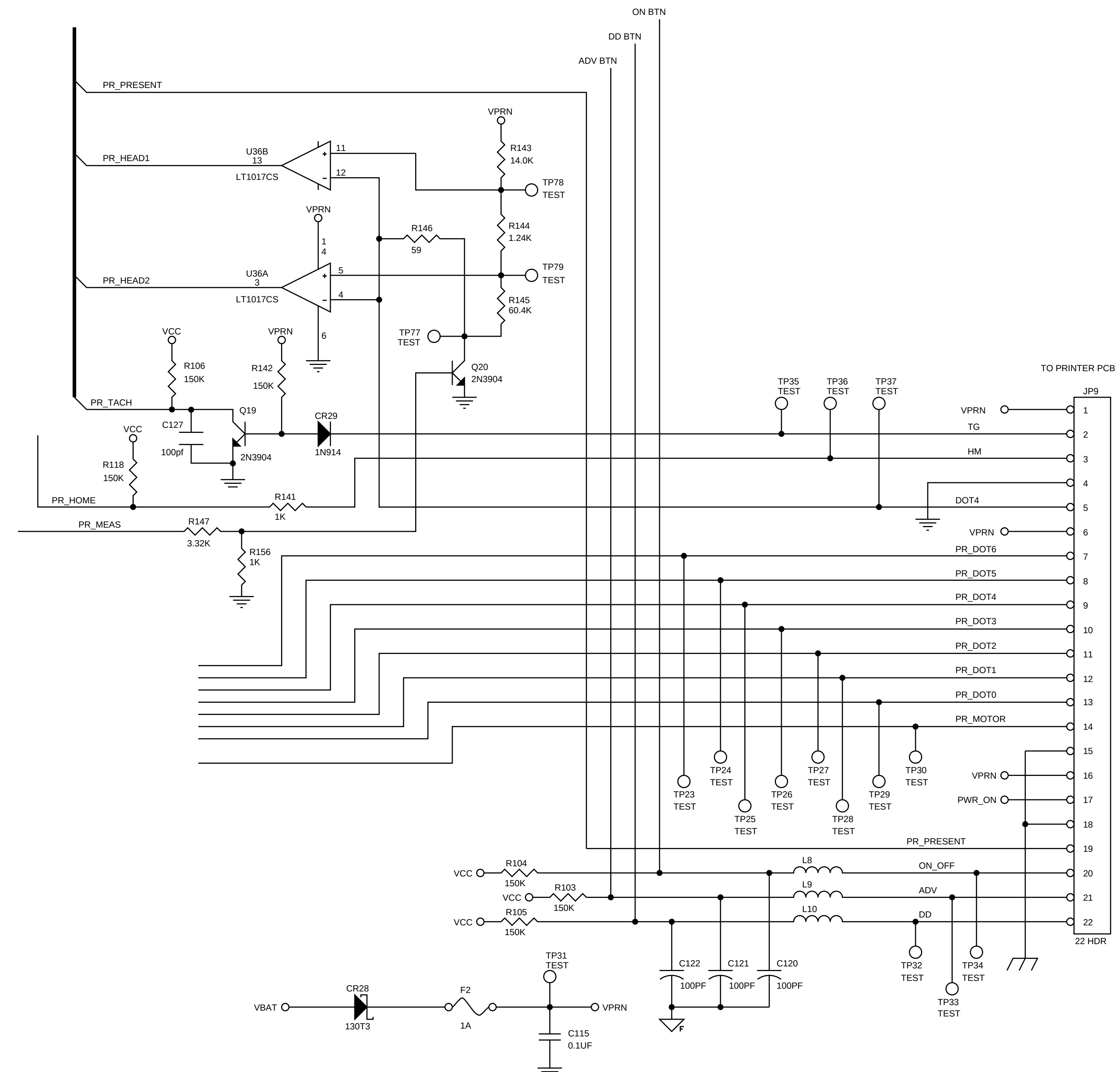


Figure 9-31
Printer Interface Circuit

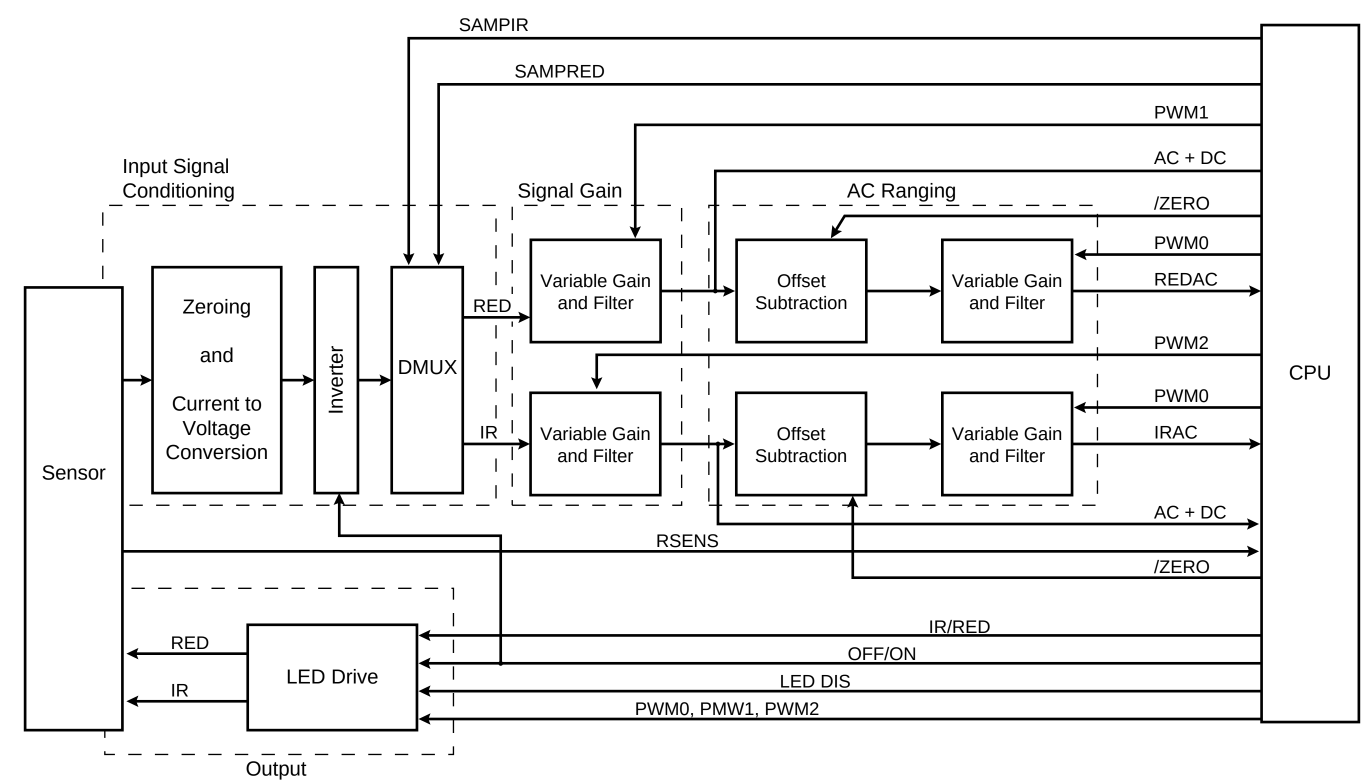


Figure 9-33
N-20 SpO_2 Analog Block Diagram

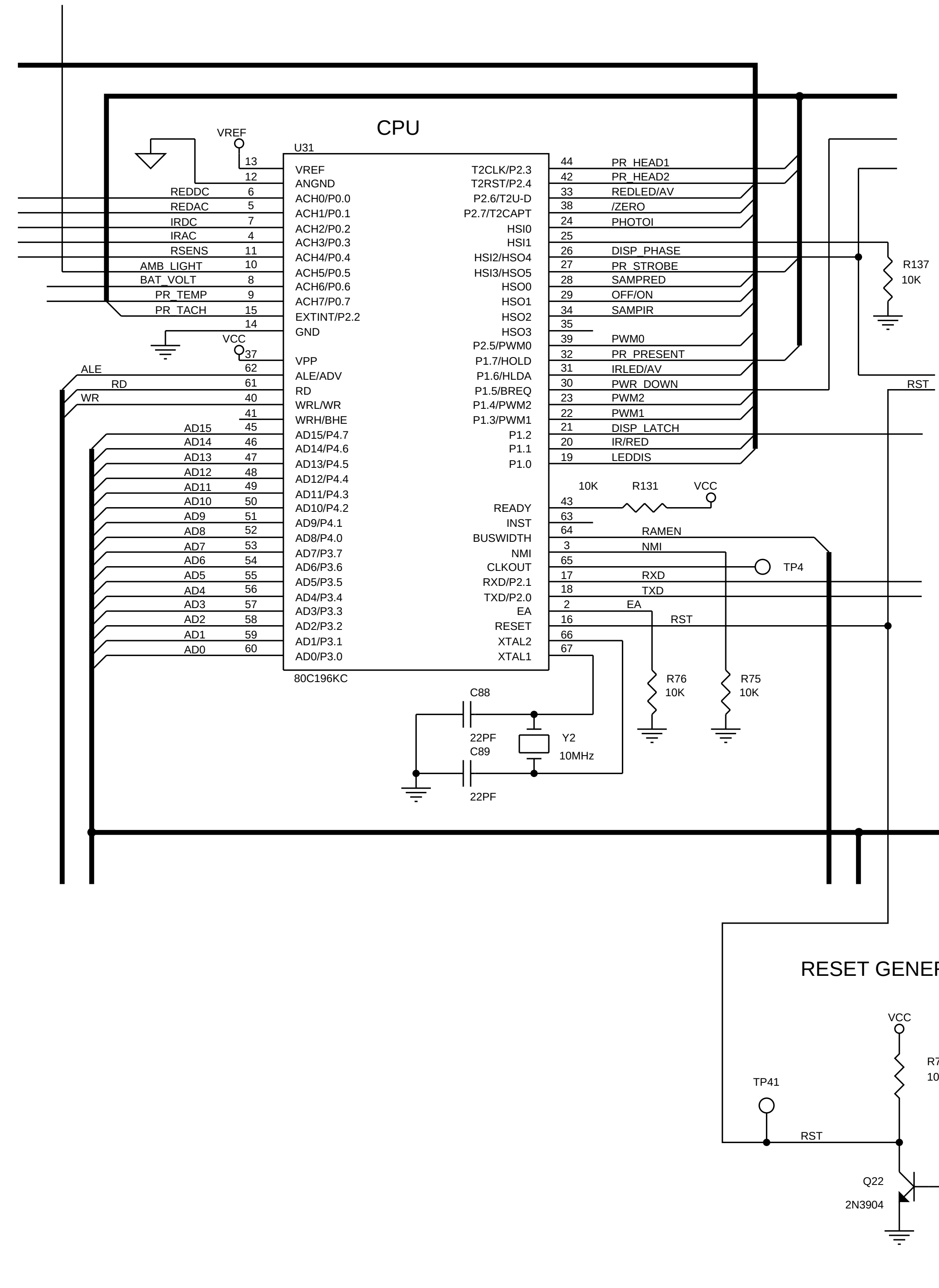
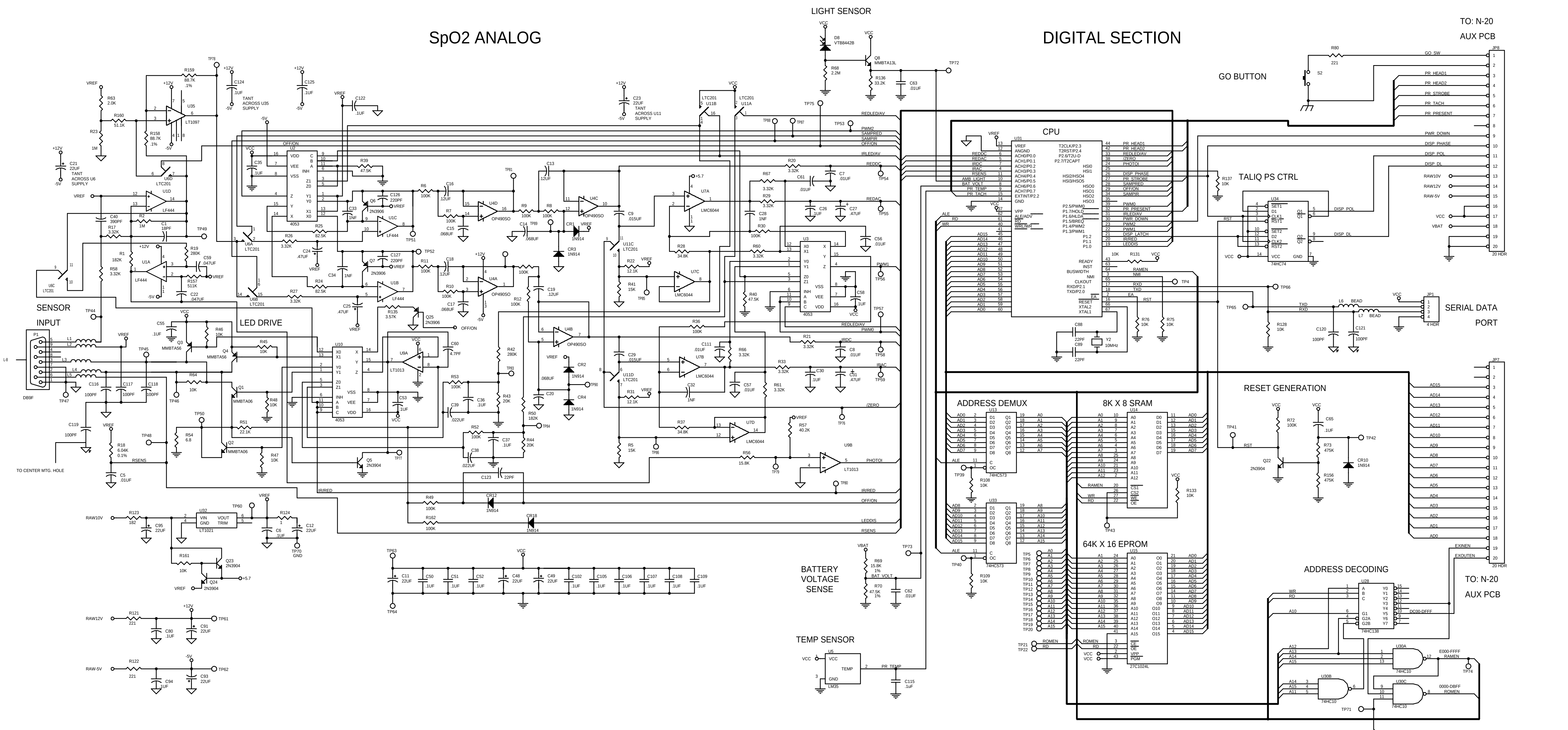


Figure 9-34
CPU Circuit



NOTES:
1. ALL RESISTORS 1/8W 1% UNLESS OTHERWISE SPECIFIED.

Figure 9-35
Main PCB Schematic Diagram

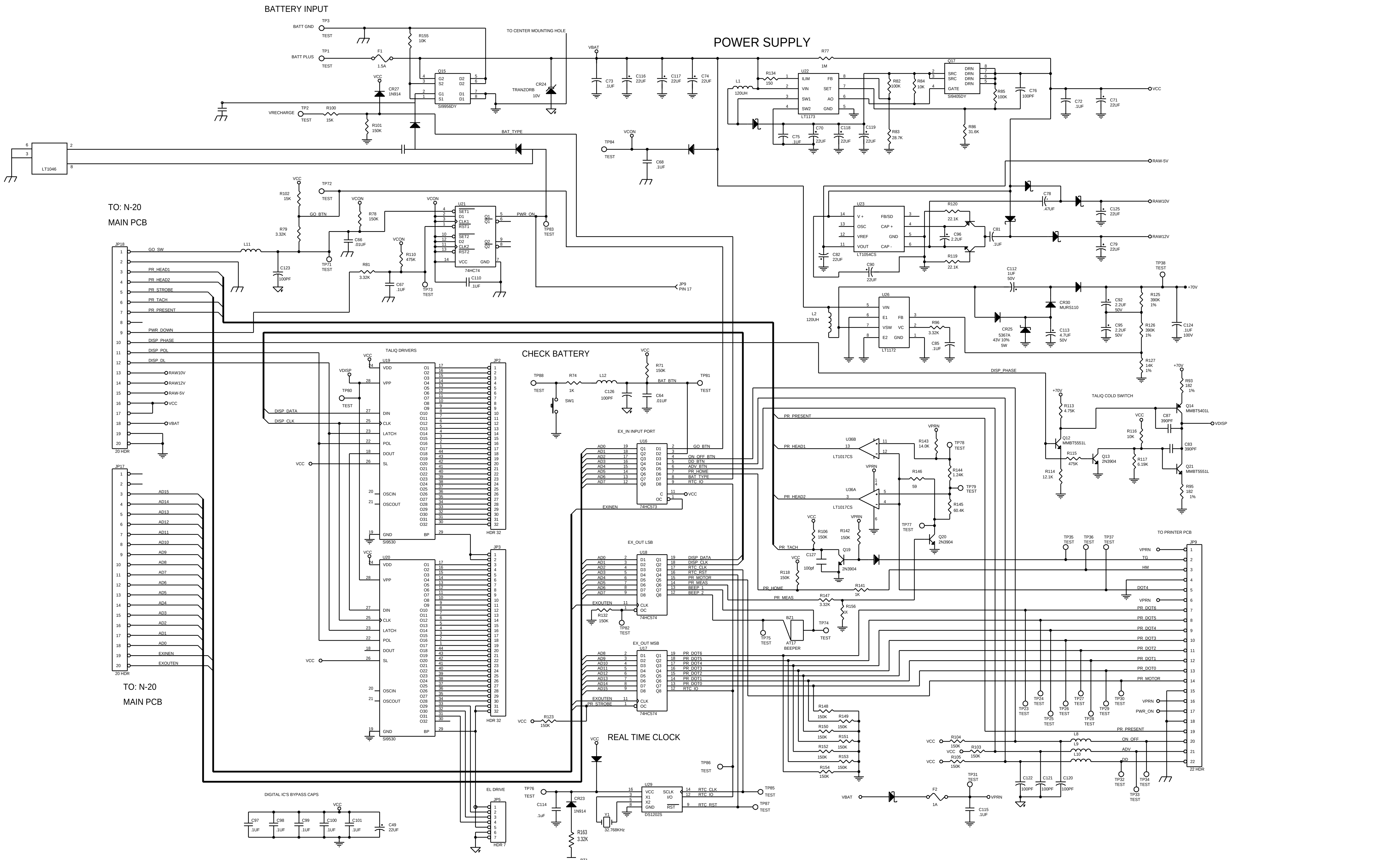


Figure 9-36
Auxiliary PCB Schematic Diagram

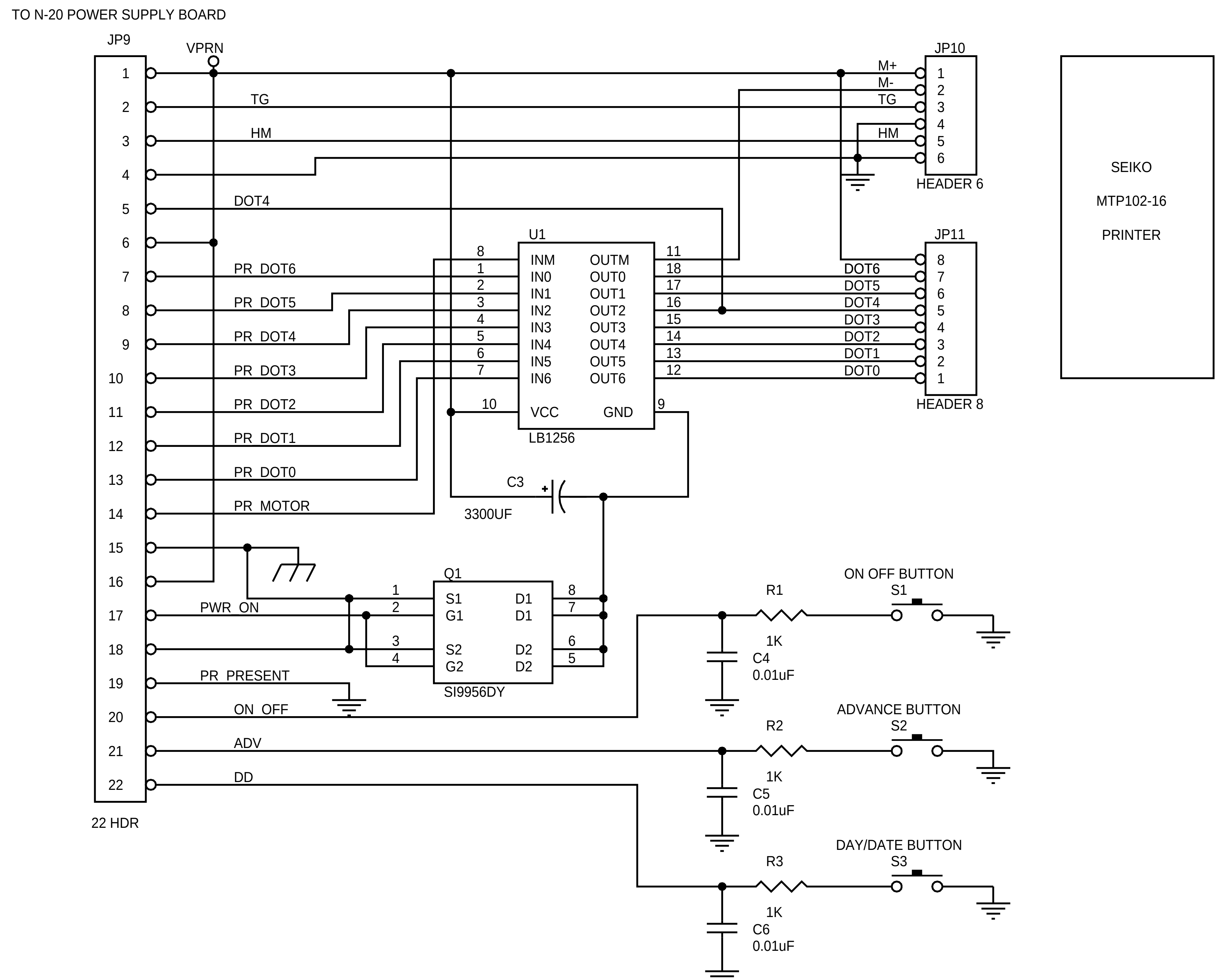


Figure 9-37
N-20 Flex Circuit Schematic Diagram