NELLCOR

SERVICE MANUAL

N-20PA Portable Pulse Oximeter

MALLINCKRODT

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

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

CE 0123

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

Covered by one or more of the following U.S. Patents and corresponding foreign patents: 4,621,643; 4,685,464; 4,700,708; and 4,770,179

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SECTION 1: INTRODUCTION

1.1 Manual Overview

1.2 Warnings, Cautions, and Notes

1.3 Description of the N-20PA Portable Pulse Oximeter

1.1 MANUAL OVERVIEW

This manual contains information for servicing the N-20PA portable pulse oximeter. Only qualified service personnel should service this product. Before servicing the device, read the operator's manual carefully for a thorough understanding of its operation.

1.2 WARNINGS, CAUTIONS, AND NOTES

This manual uses three terms that are important for proper operation of the device: Warning, Caution, and Note.

1.2.1 Warning

A warning precedes an action that may result in injury or death to the patient or user. Warnings are boxed and highlighted in boldface type.

1.2.2 Caution

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

1.2.3 Note

A note gives information that requires special attention.

1.3 DESCRIPTION OF THE N-20PA PORTABLE PULSE OXIMETER

The Nellcor® N-20PA portable pulse oximeter provides noninvasive measurement of, and continuous information about, the percent of oxygenated hemoglobin compared with total hemoglobin and pulse rate. A pulse amplitude indicator provides a qualitative indication of pulse activity and patient perfusion. Patients are connected to the instrument by a Nellcor sensor. The sensor LEDs are driven by the SpO_2 analog section, which also conditions the incoming signals, and provides CPU-adjustable gain stages. The N-20PA CPU measures the sensor's analog outputs, continually controls the signal gain, and calculates SpO_2 and pulse rate.

The N-20PA 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 are adjusted automatically to compensate for differences in tissue thickness and darkness.

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, both the measure and check battery buttons are read by the CPU for user commands.

The N-20PA 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.

SECTION 2: ROUTINE MAINTENANCE

2.1 Overview

2.2 Cleaning

2.3 Periodic Safety and Functional Checks

2.4 Batteries

2.1 OVERVIEW

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

2.2 CLEANING

Dampen a cloth with a commercial, nonabrasive cleaner, and lightly wipe the surfaces of the N-20PA. 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-20PA for damage.

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

2.4 BATTERY

When the N-20PA 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*.

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SECTION 3: PERFORMANCE VERIFICATION

3.1 Introduction

3.2 Required Tools and Equipment

3.3 Performance Tests

3.1 INTRODUCTION

This section describes performance verification and safety testing for the Nellcor N-20PA pulse oximeter (monitor) and all options, following troubleshooting and repairs.

The tests can be performed without removing the monitor cover. All tests except Battery Operation must be performed before the monitor is returned to the user.

If the monitor fails to perform as specified in any test, repairs must correct the discrepancy before the monitor is returned to the user.

The N-20PA is powered by alkaline batteries. The N-20PA design includes built-in electrical isolation; no ground resistance or current leakage testing is required. In addition, the N-20PA requires no calibration.

3.2 REQUIRED TOOLS AND EQUIPMENT

Durasensor	Nellcor DS-100A
Oxisensor II	Nellcor D-25
Tester, Pulse Oximeter	Nellcor SRC-2 or SRC-1

Variable DC power supply; 1 amp supply, voltage range 0-6 VDC

3.3 PERFORMANCE TESTS

The procedures required to verify correct monitor performance are listed below:

3.3.1 Battery Performance

3.3.2 Power-Up Performance

3.3.3 Hardware and Software Tests

3.3.4 Backlight Test

3.3.5 Low Battery Test

3.3.6 Printer Test

The N-20PA will operate in diagnostic mode in conjunction with the Nellcor pulse oximetry tester, model SRC-2 or SRC-1, 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. Mallinckrodt recommends routine performance testing at 1-year intervals. Refer to the SRC-2 operator’s manual for details on performance testing with the SRC-2.

To enter the diagnostic mode, connect the SRC-2 to the N-20PA while the oximeter is off; then, turn the oximeter on. While in the diagnostic mode, a “d” is displayed in the leftmost segment of the display. Note: No alarms sound while in the diagnostic mode. Note also that, if the SRC-2 is disconnected while the N-20PA is in diagnostic mode, the N-20PA shuts off automatically.

3.3.1 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/PA (with printer) 32 hours with Alkaline batteries.

This test requires a new set of batteries. Note that the batteries must be replaced after the test.

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 then verify the following power-up sequence:
   a. 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."

   b. 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 date of manufacture.

      The N-20PA will display the letters “PA” in the PULSE RATE display while the software version is being displayed in the OXYGEN SATURATION display.

   c. 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.

   d. 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.

   e. 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 N-20PA will indicate a “d” in the most significant digit (MSD) of the OXYGEN SATURATION display when the SRC-2 is connected.

4. The monitor must operate for at least 37 hours with no printer activity.
5. Verify that the LOW BATTERY indicator lights sometime after 35 hours of operation.
6. Verify that the LOW BATTERY indicator starts flashing after 36 hours of operation.
7. Verify that the monitor turns off approximately 1 hour after the LOW BATTERY indicator starts flashing.
8. Allow the monitor to continue operation until power-down due to low battery.

3.3.2 Power-up Performance

Monitors with the same software must demonstrate identical startup routines.

The power-up tests verify the following monitor functions:

3.3.2.1 Power-On Self-Test

3.3.2.2 Adult Defaults and Alarm Limit Ranges

3.3.2.3 Neonate Defaults and Alarm Limit Ranges

3.3.2.1 Power-On Self-Test

1. Place a new set of batteries in the monitor.
2. Do not connect a sensor or SRC-2 to the monitor.
3. Momentarily press the MEASURE button, and verify the following power-up sequence:
    a. 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."
    b. The OXYGEN SATURATION display momentarily indicates the monitor 3 -digit software version. The other displays are not lit.

Note: Software versions may vary depending on the manufacture date.

Note: The N-20PA will display the letters “PA” in the PULSE RATE display while the software version is being dispalyed in the OXYGEN SATURATION display.

    c. The 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.

4. Verify that the monitor automatically turns off after 60 seconds.

Change the SRC-2 to the switch configurations shown below, and verify monitor operation using the chart shown below.

SRC-2 Settings			Monitor Indications	
RATE	**LIGHT**	**MODULATION**	**SpO_2**	**PR**
112	HIGH1	HIGH	81± 2	112± 2% (110 - 114)
201	LOW	LOW	81± 2	201± 3% (195 - 207)
201	LOW	HIGH	81± 2	201± 3% (195 - 207)

3.3.2.2 Adult Defaults and Alarm Limit Ranges

The following procedure will allow verification of the monitor's adult factory defaults, adjusting those defaults, and automatic reset to factory defaults.

1. Place a new set of batteries in the monitor.
2. Connect the DS-100A sensor to the monitor and place the sensor on a live subject.
3. Press the MEASURE button, and verify the following power-up sequence:
   a. 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."

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

Note: Software versions may vary depending on the date of manufacture.

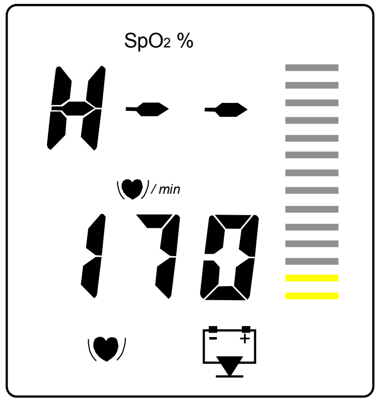
Note: The monitor will display the letters "PA" in the PULSE RATE display while the software version is being displayed in the OXYGEN SATURATION display.

   c. The OXYGEN SATURATION and PULSE RATE display "0" in each window, the monitor sounds a single tone, and the PULSE SEARCH indicator is lit. The other displays are not lit.

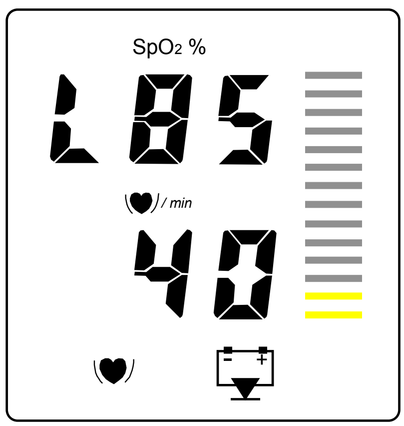
   d. The monitor will begin to track the pulse and after a few beats will display the subject's Oxygen Saturation and Pulse Rate.

   If the subject's OXYGEN SATURATION is below 91, select another subject to facilitate the test procedure as written.

4. Press and hold the BATTERY CHECK button and then momentarily press the DAY/DATE (D/D) button on the top of the monitor. Verify that the following display is shown and that the "dashes" are flashing. The "H" indicates that the High Alarm Limits can be set. The "dashes" in the SpO2 display indicate that the present setting is the Adult Default of 100% and cannot be increased.



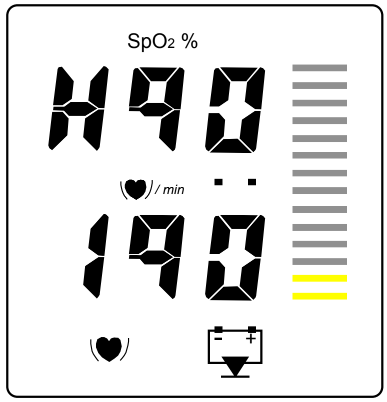
5. Press the PRINTER ON button and reduce the High Saturation Alarm limit below the live subject's value; typically 90 will be sufficient.
6. Momentarily press the DAY/DATE button and verify that the "90" in the SpO_2 display stops flashing and the "170" starts flashing.
7. Press the PRINTER PAPER ADVANCE button and increase the High Rate Alarm limit to 190.
8. Momentarily press the DAY/DATE button; then verify that the following display is shown and that the "85" is flashing.



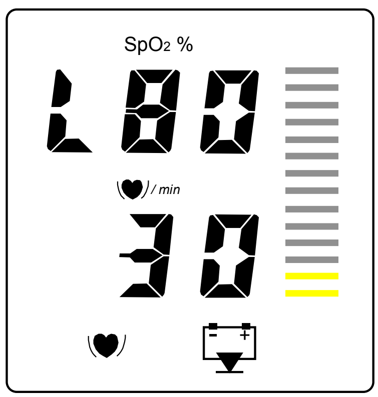
9. Press the PRINTER ON button, and reduce the Low Saturation Alarm limit to 80.
10. Momentarily press the DAY/DATA button, and verify that the "80" in the SpO_2 display stops flashing and the "40" starts flashing.
11. Press the PRINTER ON button, and reduce the Low Rate Alarm limit to 30.
12. Momentarily press the DAY/DATE button and verify that the monitor returns to the normal monitoring display and indicates the subject's saturation and pulse rate.
13. Verify that the monitor begins to alarm and that the SpO_2 reading begins to flash.
14. Momentarily press the BATTERY TEST button, and verify that the alarm remains silent for 2 minutes and that the SpO_2 reading continues to flash.

Note: The alarm may be silenced as necessary for remainder of the test.

15. Press and hold the BATTERY CHECK button and then momentarily press the DAY/DATE (D/D) button on the top of the monitor. Verify that the following display is shown and that the "90" is flashing.



16. Momentarily press the DAY/DATE button and verify that the "90" in the SpO_2 display stops flashing and that the "190" Rate Default starts flashing.
17. Momentarily press the DAY/DATE button and verify that the following display is shown and that the "80 " is flashing.



18. Momentarily press the DAY/DATE button and verify that the "80" in the SpO_2 display stops flashing and that the "30" in the Rate Display starts flashing.
19. Momentarily press the DAY/DATE button and verify that the monitor returns to the normal monitoring display and indicates the live subject's saturation and pulse rate.
20. Press the MEASURE button until the monitor turns off.

21. Press the MEASURE button, and verify the following power-up sequence:

    a. 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."

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

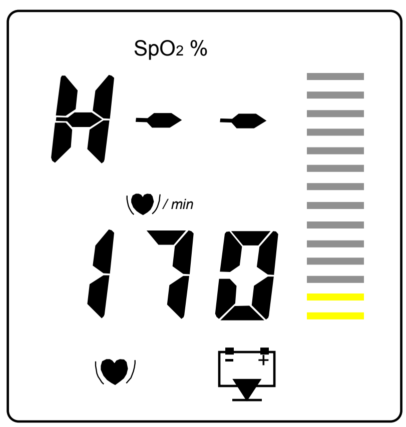
Note: Software versions may vary depending on the type of monitor and the date of manufacture.

The monitor will display the letters PA in the PULSE RATE display while the software version is being displayed in the OXYGEN SATURATION display.

    c. The OXYGEN SATURATION and PULSE RATE displays “0” in each window, the monitor sounds a single tone and the PULSE SEARCH indicator is flashing. The other displays are not lit.

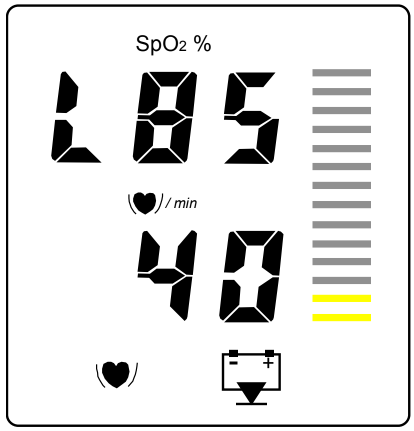
    d. The monitor will begin to track the pulse and after a few beats will display the subject’s Oxygen Saturation and Pulse Rate.

22. Press and hold the BATTERY CHECK button and then momentarily press the DAY/DATE (D/D) button on the top of the monitor. Verify that the following display is shown and that the dashes (“-“) are flashing. This indicates the monitor has returned to the factory default settings.



23. Momentarily press the DAY/DATE button and verify that the dashes (“-“) in the SpO_2 display stop flashing and that the “170” Rate Default starts flashing.

24. Momentarily press the DAY/DATE button and verify that the following display is shown and that the “85” is flashing.



25. Momentarily press the DAY/DATA button and verify that the “85” in the SpO_2 display stops flashing and that the “40” Rate Default starts flashing.
26. Momentarily press the DAY/DATE button and verify that the monitor returns to the normal monitoring display and indicates the live subject’s saturation and pulse rate.
27. Press the MEASURE button until the monitor turns off.

3.3.2.3 Neonate Defaults and Alarm Limit Ranges

The following procedure will allow verification of the monitor NEONATAL factory defaults, adjusting those defaults, and automatic reset to factory Adult defaults.

1. Place a set of batteries in the monitor. Verify that batteries are new.
2. Connect the DS-100A sensor to the monitor and place the sensor on a live subject (adult subject is OK for this procedure).
3. Press and hold the BATTERY TEST button and press the MEASURE button for at least 5 seconds, and then verify the following power-up sequence:
   a. 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."
   b. The OXYGEN SATURATION display momentarily indicates the monitor 3-digit software version. The other displays are not lit.

   Note: Software versions may vary depending on the date of manufacture.

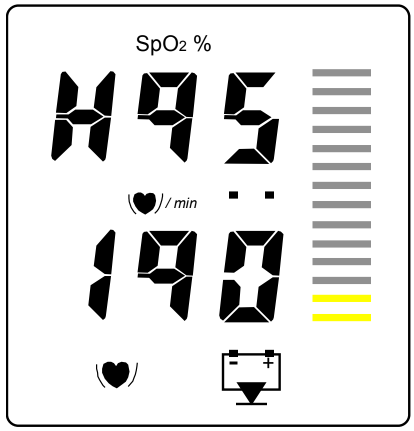
   The monitor will display the letters PA in the PULSE RATE display while the software version is being displayed in the OXYGEN SATURATION display.

   c. The OXYGEN SATURATION and PULSE RATE displays “0” in each window, the monitor sounds a single tone, and the PULSE SEARCH indicator is lit. The other displays are not lit.

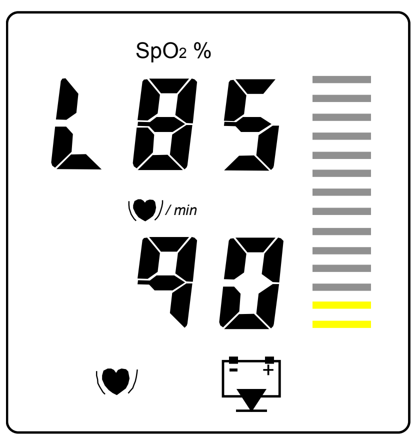
   An “n” will be displayed in the Most Significant Digit (MSD) of the SpO_2 display, indicating the Neonatal mode.

d. The monitor will begin to track the pulse and after a few beats will display the subject's Oxygen Saturation and Pulse Rate.

4. Press and hold the BATTERY CHECK button and then momentarily press the DAY/DATE (D/D) button on the top of the monitor. Verify that the following display is shown and that the "95" is flashing. The "H" indicates that the High Saturation Alarm Limit can be set.

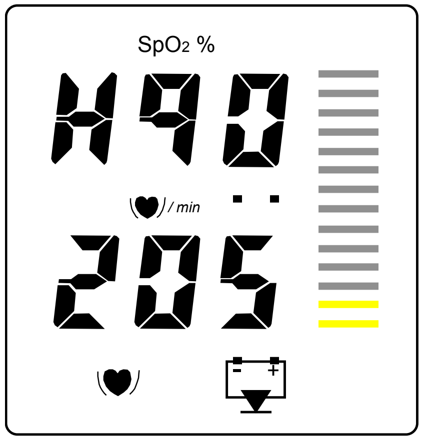


5. Press the PRINTER ON button and reduce the High Saturation Alarm limit to 90.
6. Momentarily press the DAY/DATE button and verify that the "90" in the SpO_2 display stops flashing and that the "190" starts flashing.
7. Press the PRINTER PAPER ADVANCE button and increase the High Rate Alarm limit to 205.
8. Momentarily press the DAY/DATE button to verify that the following display is shown and that the "80" is flashing.

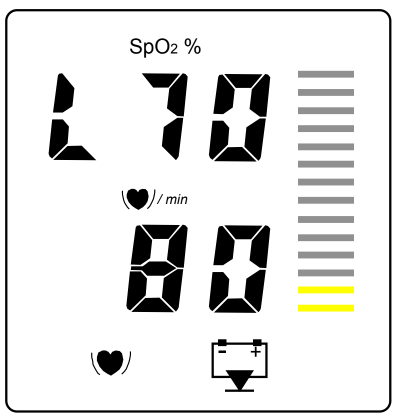


9. Press the PRINTER ON button and reduce the Low Saturation Alarm limit to 70.
10. Momentarily press the DAY/DATE button and verify that the "70" in the SpO_2 display stops flashing and that the "90" starts flashing.
11. Press the PRINTER ON button and reduce the Low Rate Alarm limit to 80.

12. Momentarily press the DAY/DATE button and verify that the monitor returns to the normal monitoring display and indicates the live subject's saturation and pulse rate.
13. Press and hold the BATTERY CHECK button and then momentarily press the DAY/DATE (D/D) button on the top of the monitor. Verify that the following display is shown and that the "90" is flashing.



14. Momentarily press the DAY/DATE button and verify that the "90" in the SpO2 display stops flashing and that the "205" Rate Default starts flashing.
15. Momentarily press the DAY/DATE button and verify that the following display is shown and that the "70 " is flashing.



16. Momentarily press the DAY/DATE button and verify that the "70" in the SpO_2 display stops flashing and that the "80" in the Rate Display starts flashing.
17. Momentarily press the DAY/DATE button and verify that the monitor returns to the normal monitoring display and indicates the live subject's saturation and pulse rate.
18. Verify that the monitor begins to alarm and that the number representing the live subject's saturation and pulse rate begins to flash.

19. Momentarily press the BATTERY TEST button and verify that the alarm remains silent for 2 minutes and that the number representing the live subject's saturation and pulse rate continues to flash.

The alarm may be silenced as necessary for remainder of the test.

20. Press the MEASURE button until the monitor turns off.
21. Press the MEASURE button, and verify the following power-up sequence:
    a. 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."

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

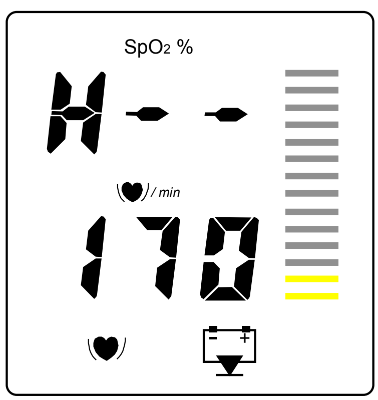
    Note: Software versions may vary depending on the date of manufacture.

    The monitor will display the letters PA in the PULSE RATE display while the software version is being displayed in the OXYGEN SATURATION display.

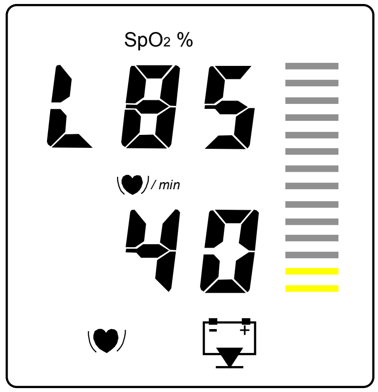
    c. The OXYGEN SATURATION and PULSE RATE display dashes "0" in each window, the monitor sounds a single tone, and the PULSE SEARCH indicator is lit. The other displays are not lit.

    d. The monitor will begin to track the pulse and after a few beats will display the subject's Oxygen Saturation and Pulse Rate.

22. Press and hold the BATTERY CHECK button and then momentarily press the DAY/DATE (D/D) button on the top of the monitor. Verify that the following display is shown and that the "dashes" are flashing. This indicates the monitor has returned to the factory default settings.



23. Momentarily press the DAY/DATE button and verify that the "dashes" in the SpO_2 display stop flashing and that the "170" Rate Default starts flashing.
24. Momentarily press the DAY/DATE button, and verify that the following display is shown and that the "85" is flashing.



25. Momentarily press the DAY/DATA button and verify that the "85" in the SpO_2 display stops flashing and that the "40" Rate Default starts flashing.
26. Momentarily press the DAY/DATE button and verify that the monitor returns to the normal monitoring display and indicates the live subject's saturation and pulse rate.
27. Press the MEASURE button until the monitor turns off.

3.3.3 Hardware and Software Tests

Hardware and software tests include the following:

3.3.3.1 Operation with a Pulse Oximeter Tester

3.3.3.2 Normal Operation

3.3.3.1 Operation with a 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:
   a. 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."

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

Note: Software versions may vary depending on the date of manufacture.

The N-20PA will display the letters “PA” in the PULSE RATE display while the software version is being displayed in the OXYGEN SATURATION display.

c. 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.

d. 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.

e. 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 N-20PA will indicate a “d” in the most significant digit (MSD) of the OXYGEN SATURATION display when the SRC-2 is connected.

3.3.3.2 Normal Operation

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

1. Connect a DS-100A Sensor to monitor.
2. Place the DS-100A Sensor on the subject as recommended in the N-20PA Operator's Manual.
3. Press the MEASUREMENT button to turn on the monitor.
4. The monitor should stabilize on the subject's physiological signal in about 10 to 15 seconds. Verify that the saturation value and pulse rates are acceptable

3.3.4 Backlight Test

The electroluminescent backlight illuminates the display in three sections:

1. The main section, that is, 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. Each backlight flashes 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-20PA display. Under low light conditions, the main section backlight is switched on. If a Low Battery and Pulse Search indicator is lit, those individual backlights are also lit.

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

3.3.5 Low Battery Test

The N-20PA CPU monitors the battery voltage level and alerts the user via the Low Battery indicator when voltage is getting low. To test the proper function of the Low Battery indicator, connect the N-20PA to an external variable DC power supply.

Battery voltage levels described in this section are accurate; however, slight variations may exist due to differences between batteries of different manufacturers. To that point, the N-20PA operates normally at voltages above 4.0 VDC.

When the battery voltage drops below 4.05 VDC, the Low Battery indicator is lit, and the two lowest segments of the battery level meter are lit (number of segments lit is dependent upon battery strength) when the battery-check button is pressed. When the voltage level drops below 4 VDC, the N-20PA continues to display Oxygen Saturation and Pulse Rate values, but the printer no longer operates; otherwise, the N-20PA operates normally.

Battery voltage levels below 3.5 VDC cause the Low Battery indicator to begin flashing. When the battery-check button is pressed only the lowest segment of the Low Battery indicator will illuminate.

When the battery voltage level drops below 3.3 VDC, the N-20PA turns itself off.

Caution: If a sensor is attached, remove it prior to running the following test.

To test for proper function of the Low Battery indicator:

1. Switch off the N-20PA; open the battery door and remove the batteries.
2. Set the power supply voltage to 5 VDC, and connect the supply to the battery contacts of the N-20PA.

Note: Ensure that polarity is correct.

3. Switch on the N-20PA; verify complete Power-On Self Test (the N-20PA should operate normally).
4. Decrease the power supply voltage to 4.0 VDC or slightly below. The Low Battery indicator should illuminate and the lowest two segments of the battery level meter should illuminate and printer operation should cease.
5. Decrease the power supply voltage to 3.5 VDC or slightly below. Then press the battery-check button; the Low Battery indicator should begin to flash and only the lowest segment of the battery level meter should illuminate.
6. Decrease the power supply voltage to below 3.2 VDC. The N-20PA should turn itself off immediately. Pressing the measure button should not turn the unit back on.

The Low Battery indicator test is now complete.

3.3.6 Printer Test

The SRC-2 tester can be used to test the operation of the N-20PA printer and the printer's user-control buttons. When an SRC-2 is plugged into the DB-9 connector, the N-20PA acknowledges any button press with an immediate beep and the following display codes:

Button Press	Display
On/Off	9O
battery check	bAt
ON	On
ADV	Ad
D/D	dd
combinations	Err

1. Momentarily click the On/Off button: "9O" appears in (or shuts off) 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 0. If printout darkness is either irregular or dots are missing, contact Mallinckrodt's Technical Services Department or your local Mallinckrodt representative for assistance.

4. Press the printer *ADV* button: "Ad" appears in the Oxygen Saturation display. The paper advances one line for each button press.
5. Press the printer *D/D* button: "dd" appears in the Oxygen Saturation display.

The SRC-2 printer test is now completed.

TEST RESULTS

Model:______N-20PA________ Serial:_____________________________

Date:___________Customer Name:________________________________

Test #	Description	Pass	Fail
3.3.1	Battery Performance	____	____
3.3.2	Power-Up Performance	____	____
3.3.2.1	Power-Up Self-Test	____	____
3.3.2.2	Adult Defaults and Alarm Limit Ranges	____	____
3.3.2.3	Neonate Defaults and Alarm Limit Ranges	____	____
3.3.3	Hardware and Software Tests	____	____
3.3.3.1	Operation with a Pulse Oximeter Tester	____	____
3.3.3.2	Normal Operation	____	____
3.3.4	Backlight Test	____	____
3.3.5	Low Battery Test	____	____
3.3.6	Printer Test	____	____

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:____________

SECTION 4: TROUBLESHOOTING

4.1 Introduction
4.2 How to Use This Section
4.3 Who Should Perform Repairs
4.4 Replacement Level Supported
4.5 Obtaining Replacement Parts
4.6 Troubleshooting Guide

4.1 INTRODUCTION

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.

4.2 HOW TO USE THIS SECTION

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.

4.3 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 Mallinckrodt Technical Services.

4.4 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.

4.5 OBTAINING REPLACEMENT PARTS

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

4.6 TROUBLESHOOTING GUIDE

Table 4-1 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-20PA, please contact Mallinckrodt Technical Services or your local Mallinckrodt representative for assistance.

If the N-20PA does not perform as expected, the problem may be related to the following:

- Incorrect 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). Significant levels of dysfunctional hemoglobins such as carboxyhemoglobin or methemoglobin may affect the accuracy of a measurement.

If the electronics or display functions, or both, require testing, refer to the *Performance Verification* section.

Table 4-1 : Troubleshooting the N-20PA

Symptom	Possible Cause	Recommended Action
No response to On/Off button.	1. Battery access door may not be properly latched.	1. Check access door and ensure that it is properly latched.
	2. Batteries may be discharged.	2. Exchange batteries for a new set.
	3. Batteries may be incorrectly installed.	3. Ensure that batteries are oriented according to the polarity indicator.
	4. Batteries may not be making proper electrical contact.	4. Inspect battery contacts for deformity; clean contacts to remove oxidization.
	5. Fuse F1 on the auxiliary PCB may be open.	5. See Section 4.7.5, Replacing Fuses.
	6. Dust may have accumulated under On/Off button causing loss of electrical contact.	6. Clean contact points under On/Off button (see Section 5.2.1, N-20PA Disassembly Procedures).
Pulse Search indicator appears for more than 5-10 seconds.	1. Sensor may be improperly positioned.	1. Ensure that the sensor is correctly applied (see sensor Directions for Use).
	2. Incorrect sensor may be in use.	2. See sensor Directions for Use to ensure that the patient's weight and sensor application are correct. Test the sensor on another person to verify proper operation.
	3. Perfusion may be too low.	3. Check patient status. Test the instrument on someone else, or try another type of sensor. The N-20PA will not make a measurement if perfusion is inadequate.
	4. Foreign material on the	4. Clean the test area and ensure

	sensor LEDs or photodetector may be affecting performance. 5. Patient motion may be interfering with the instrument's ability to find a pulse pattern. 6. Environmental motion may be interfering with the instrument's ability to track a pulse. 7. The sensor may be too tight, there may be excessive illumination (for example, 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; Mallinckrodt does not recommend using a sensor on the same limb as these three devices.	that nothing blocks the sensor site. 5-7. 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.
	8. The DB-9 sensor connector on the N-20PA may be broken.	8. Replace the DB-9 connector.
Pulse Search indicator appears after successful measurements have been made.	1. Patient perfusion may be too low.	1. Check patient status. Test the instrument on someone else, or try another type of sensor. The N-20PA will not make a measurement if perfusion is inadequate.
	2. Patient motion may be interfering with the instrument's ability to find a pulse pattern. 3. Environmental motion may be interfering with the instrument's ability to track a pulse. 4. The sensor may be too tight, there may be excessive illumination (for example, 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; do not use the sensor on the same limb as these three devices.	2-4.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.

Dashes (- - -) appear in the display.	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.
Pr Err is displayed during the POST.	The printer is not operational (however, the N-20PA continues to obtain patient measurements) due to paper jam or print head not in the home position.	Check to see if the paper is jammed. Examine the print head and ensure that it has returned to the home position. Turn the printer off, then on again.
Err followed by a number appears on the display.	See Section 4.7.8 for error codes.	Record the number that is displayed.
Time or date is incorrect.	The real-time clock (RTC) battery may be exhausted.	Replace the RTC battery (see Section 4.7.4). Resent the time and date (see Section 4.7.3).
Printer fails to operate.	Fuse F2 on the auxiliary PCB may be open. Batteries may be low.	1. See Section 4.7.5 for information about fuses. 2. Replace old batteries with fresh batteries.
Printer paper advances but instrument does not print.	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.
Paper mechanism jams. Note: If a printer paper jam is detected when the printer is turned on, Pr Err may appear on the display.	Switch off the N-20PA. 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-20PA Disassembly Procedure, and 4.7.2, Loading/Clearing Printer Paper).

4.7 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).

4.7.1 Installing Batteries

The N-20PA operates on four 1.5-V alkaline “C” cell batteries. Do not use off-the-shelf rechargeable batteries; this type of battery can cause the Low Battery indicator to be inaccurate. To install the batteries:

1. Remove the battery 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.

4.7.2 Loading/Clearing Printer Paper

The N-20PA 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. To load the paper:

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—and observe the print head access to determine whether or not the paper escaped from the jammed position.
3. If paper remains jammed between the printer 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.

If these attempts fail to free the jammed paper, remove the printer from the unit to gain full access (see Section 5.3, *N-20PA Disassembly Procedure).*

4.7.3 Setting Date and Time

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.

1. To set the date and time: Remove any sensor from the instrument.
2. Switch on the N-20PA and allow the unit to run POST.

3. 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 shows "txx", with "t" representing time; "xx" representing hours, and "yy" representing minutes. Note that "xx" (hours) is flashing.
4. Press the *ADV* (advance) button repeatedly until the correct hour is displayed.
5. Press the *D/D* button once. Note that "yy" (minutes) is now flashing.
6. Press the *ADV* button repeatedly until the correct minute is displayed.
7. Press the *D/D* button. At this point, the Oxygen Saturation display shows "dxx", with "d" representing date; "xx" representing the day and "yy" representing the month. Note that "xx" (day) is flashing.
8. Press the *ADV* button repeatedly until the correct date is displayed.
9. Press the *D/D* button once. Note that "yy" (month) is flashing.
10. Press the *ADV* button repeatedly until the correct month is displayed.
11. Press the *D/D* button. At this point, the Oxygen Saturation display shows "Yxx," with "Y" representing "year". Note that "xx" (year number) is flashing.
12. Press the *ADV* button repeatedly until the correct year number is displayed.
13. Press the *D/D* button once. The N-20PA turns itself off immediately.
14. Verify that date and time are now correct by switching on the N-20PA and then enabling the printer. After the N-20PA executes its POST, the printer prints the header with the correct date and time.

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

Note: If in the D/D mode and there is no user interaction (no buttons are being pressed) for 60 seconds, the N-20PA turns off and any changes made are not saved.

4.7.4 Replacing the Real-Time Clock (RTC) Battery

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

Caution: After replacing an RTC battery, switch the instrument on, then immediately switch it off; this action will prevent possible damage to the RTC voltage circuit.

To replace the real-time clock/battery:

1. Disassemble the N-20PA (see Section 4.3, Disassembly Guide).
2. Using a thin flat-head 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. Switch on the instrument, then immediately switch it off (the RTC voltage circuit requires this step to prevent possible damage to the unit). The instrument is now ready for normal operation.

6. Reset the clock (see paragraph 4.7.3, Setting Date and Time).

4.7.5 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 if it has been physically damaged. Refer to the auxiliary PCB schematic for the locations of F1 and F2.

4.7.6 Replacing the DB-9 Connector

To replace the DB-9 connector:

1. Disassemble the N-20PA (see Section 5); the connector is on the main PCB.
3. Using a low-power soldering iron, unsolder the connector from the PCB and remove it.

Note: Save all Teflon tubing, ferrite blocks, and insulating materials for the replacement connector.

3. Install ferrite blocks between the 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 the PCB, and secure with Loctite glue.
6. Solder new connector to the PCB and visually check the PCB for stray drops of solder before reassembling.
7. Switch on the N-20PA and test the connector with a patient sensor.

4.7.7 Adjusting Printer Darkness

Caution: Adjust the printer darkness setting until the lightest legible print is visible. Setting the print darker than this could reduce printer-head life.

Although the N-20PA 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 printer head life.

Note: This procedure cannot be performed after a valid pulse is received following power-on. Hence, perform this procedure with no sensor attached to the monitor.

To adjust the printer darkness:

1. Switch on the N-20PA.

2. Simultaneously press and hold the *ADV* and printer *ON* buttons for 4 seconds. If these buttons are not pressed at the same time, two audible beeps will sound and the N-20PA either advances the paper or turns on (or off) the printer, 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)
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. 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-20PA to switch off (about 30 seconds). The last printer darkness setting is remembered when the N-20PA is switched back on. Test this by repeating the procedure and skipping step 3.

4.7.8 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, record the error code number. Match the number to the description in the following table, and contact Mallinckrodt's Technical Services Department or your local Mallinckrodt representative for assistance. The first digit of the error code is the category.

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

Category 1 — Microprocessor Errors

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

101	Error in internal RAM register 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

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

Category 3 — PROM Errors

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

301	Error in PROM test

Category 4 — I/O Port Errors

Errors in the CPU 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

Category 5 — Reserved

Category 6 — Clock Errors

Failure of the real-time clock (auxiliary PCB), or timing differences between the CPU 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

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

Category 8 — Printer Errors

Error in the printer. If a printer error condition occurs, the display reads Pr Err. See the *Troubleshooting* section for further information on this error.

SECTION 5: DISASSEMBLY GUIDE

5.1 Introduction
5.2 Beginning Disassembly
5.3 N-20PA Disassembly Procedure

5.1 INTRODUCTION

The device can be disassembled down to all major component parts, including:

- PCBs
- batteries
- cables
- chassis enclosures

Tools required:

- small, Philips-head screwdriver
- small flat-head screwdriver
- needle-nose pliers
- low-power soldering iron

WARNING: Before attempting to open or disassemble the device, turn it off.

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

5.2 BEGINNING DISASSEMBLY

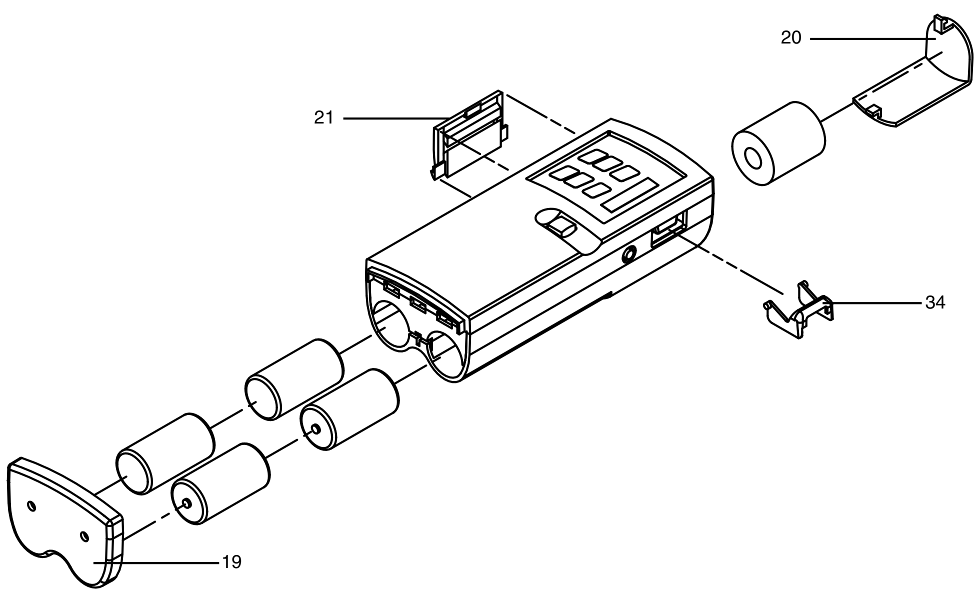


Figure 5-1: Sensor Lock, Printer, Paper, and Battery Access Doors

Figure 5-1 shows the how to start the N-20PA disassembly.

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), paper roll, and the printer door (21).

5.2.1 Removing the Covers

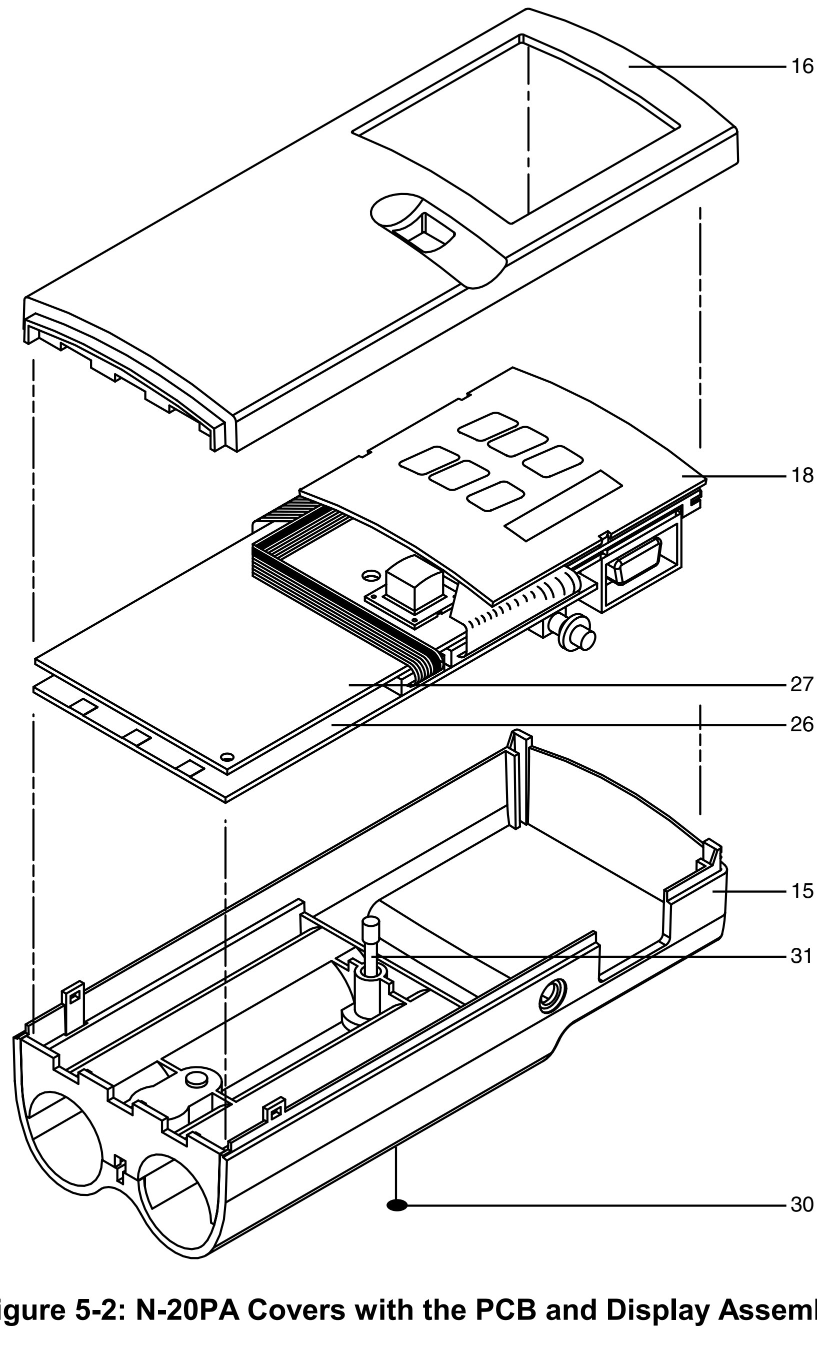


Figure 5-2: N-20PA Covers with the PCB and Display Assembly

Figure 5-2 shows how to remove the N-20PA cover and display assembly.

1. Remove screw cap (30) and loosen the captive screw (31) that secures the rear battery cover (15).

2. Separate the front cover (16) from the rear battery cover by wedging a thin flat-head 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.

5.2.2 Removing the PCBs and Display Assembly

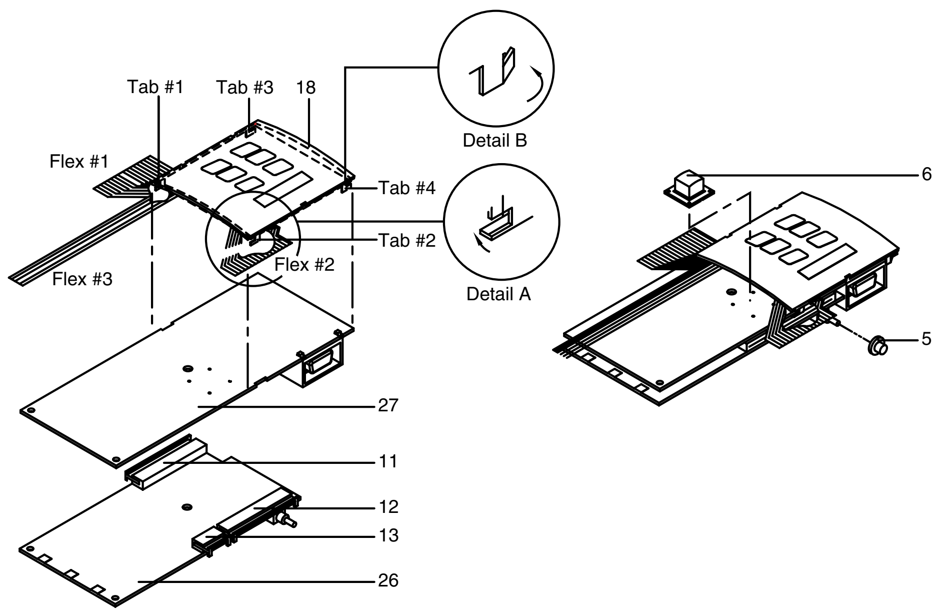


Figure 5-3: Main, Auxiliary, and Display PCB Assembly

Figure 5-3 shows how to remove the PCB assemblies.

1. Remove the On/Off button (6) from the main PCB.
2. Remove the entire PCB/Taliq display assembly from the rear battery cover by tilting opposite the battery-check button (5).
3. Release connectors (11, 12, and 13) 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 long-nose pliers, remove the metal shroud by untwisting the four tabs (see Detail A and B).

5.3 DISASSEMBLYING THE PRINTER/FLEX CIRCUIT ASSEMBLY

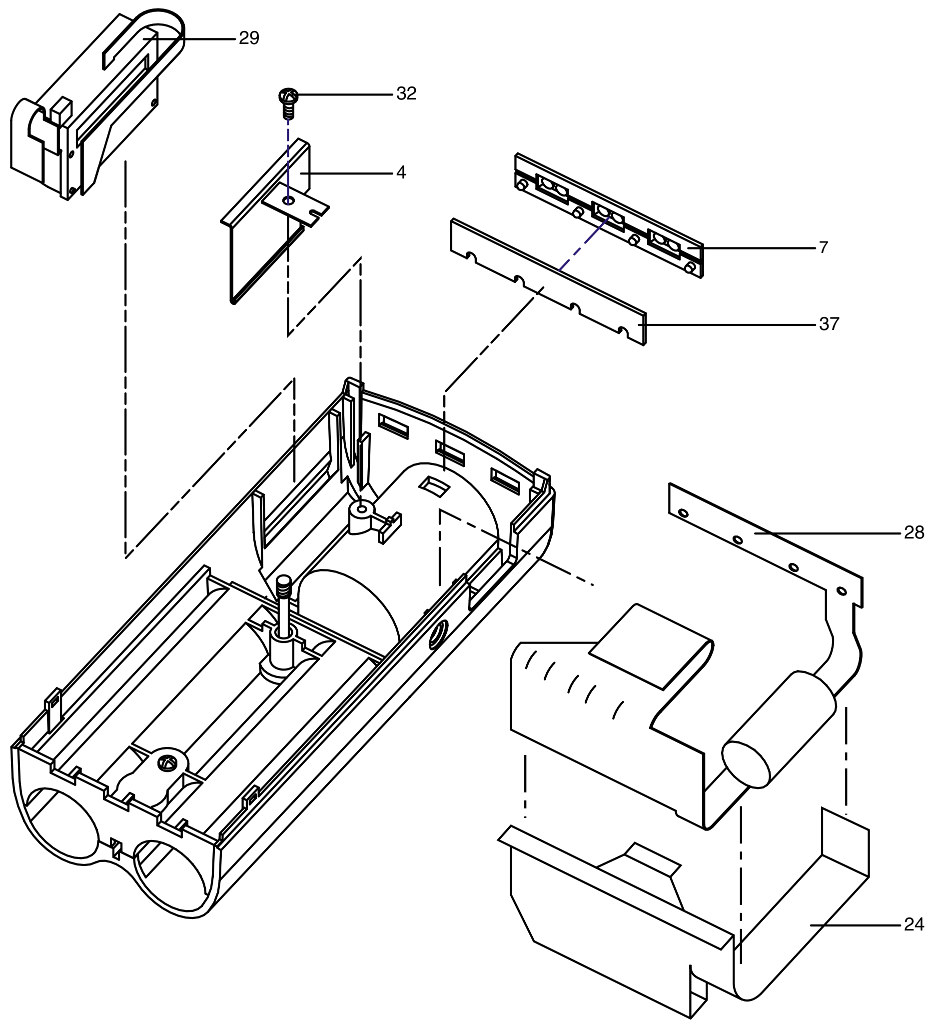


Figure 5-4: Printer and Flex Circuit Assembly

Figure 5-4 shows how to disassemble the printer and flex circuitry.

1. Remove the printer button stiffener (37).
2. Disconnect the two flex-circuit headers of the printer (29) from the connectors on the printer flex circuit (28) by slowly pulling them 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 the 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.

SECTION 6: SPARE PARTS

6.1 Introduction
6.2 Spare Parts List

6.1 INTRODUCTION

Spare parts, along with corresponding part numbers, are shown below. To order replacement parts, contact Mallinckrodt's Technical Services Department and order by part number.

6.2 SPARE PARTS LIST

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
8	L1, L2	Coil, 120 µH SMT (auxiliary PCB)	691238
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, JP3	Connector, ZIF, flex, 32-pin (auxiliary PCB)	491243
15		Cover, battery, rear (non-printer model)	022929
		Cover, battery, 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

Item	Designator	Description	P/N
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
Item	**Designator**	**Description**	**P/N**
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
31		Screw, captive	891324
32		Screw, Phillips, 4-40 x 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” x .38”)	023300
39	BZ1	Transducer, audio, piezo ceramic	691230

SECTION 7: PACKING FOR SHIPMENT

7.1 General Instructions
7.2 Repacking in Original Carton
7.3 Repacking in a Different Carton

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

7.1 GENERAL INSTRUCTIONS

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

Prior to shipping the device, contact Mallinckrodt 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 as follows:

1. Place the monitor and, if necessary, accessory items in original packaging.
2. Place in shipping carton and seal carton with packaging tape.
3. 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 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 two 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.

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SECTION 8: SPECIFICATIONS

8.1 Performance
8.2 Alarms
8.3 Electrical
8.4 Environmental
8.5 Physical

8.1 PERFORMANCE

8.1.1 Range

Saturation

0–100%

Pulse Rate
20–250 beats per minute (bpm)

8.1.2 Accuracy

SpO_2[1]

Adults	70–100% ± 2 digits[2]
	0–69% unspecified
Neonates	70–95% ± 2 digits[2]
	0–69% unspecified

Pulse rate

20–250 bpm	± 3 bpm[2]

8.2 ALARMS

8.2.1 Alarm Limit Range

Saturation
20–100%

Pulse Rate
30–250 bpm

[1] The reference for accuracy testing is an N-200 oximeter and D-25 sensors that have been validated in human blood studies against an Instrumentation Laboratories CO-Oximeter. Adult accuracy specification is based on testing with D-25 sensors; neonatal accuracy specification is based on testing with N-25 sensors. For specifications with other *NELLCOR* sensors, see the sensor Directions for Use.

[2] This variation equals one standard deviation (SD). Plus or minus one SD encompasses 68% of the population.

8.2.2 Factory Default Alarm Settings

	Adult	Neonate
SpO_2 Upper Limit:	100%	95%
SpO_2 Lower Limit:	85%	80%
PR Upper Limit:	170 bpm	190 bpm
PR Lower Limit:	40 bpm	90 bpm

8.3 ELECTRICAL

8.3.1 Battery

Type
Four alkaline "C" size batteries

Battery Capacity
Typically 32 hours with four alkaline "C" size batteries[1]

8.3.2 Instrument

Power Requirements
4–6 V, supplied by battery only

Patient Isolation
No electrical connection to patient (inherently isolated)

8.4 ENVIRONMENTAL

8.4.1 Operating Temperature

Instrument
0 to 40°C

Sensor
Within physiologic range for specified accuracy

8.4.2 Storage Temperature

–20 to 50°C

8.4.3 Humidity

Any humidity/temperature combination without condensation

8.4.4 Altitude

0–6200 m (0–20,000 ft)

[1] Not all brands of off-the-shelf alkaline batteries provide the same battery life.

8.5 PHYSICAL

8.5.1 Weight (with batteries installed)

0.6 kg (1.3 lb)

8.5.2 Size

19.0 cm high × 7.6 cm wide × 6.35 cm deep
(7.5 in. × 3.0 in. × 2.5 in.)

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SECTION 9: TECHNICAL SUPPLEMENT

9-1 Introduction
9-2 Functional Overview
9-3 Definition of Terms
9-4 Overall Block Diagram
9-5 SpO2 Analog Circuitry
9-6 Digital Circuitry
9-7 Circuitry Illustrations

9.1 INTRODUCTION

This Technical Supplement provides the reader with a discussion of the N-20PA circuits. This discussion is supported with applicable illustrations, including graphics that have been placed on reverse-fold pages so they can be easily referenced while reading the text. The foldout graphics and schematics are located at the end of this supplement.

9.2 FUNCTIONAL OVERVIEW

The N-20PA consists of three main components:

- The N-20PA main printed circuit board (PCB)
- The N-20PA auxiliary PCB
- The N-20PA flex circuit

The relationship between these components and their interconnection is illustrated in the overall block diagram (Figure 9-1). The main component circuitry has been divided into the following subsections:

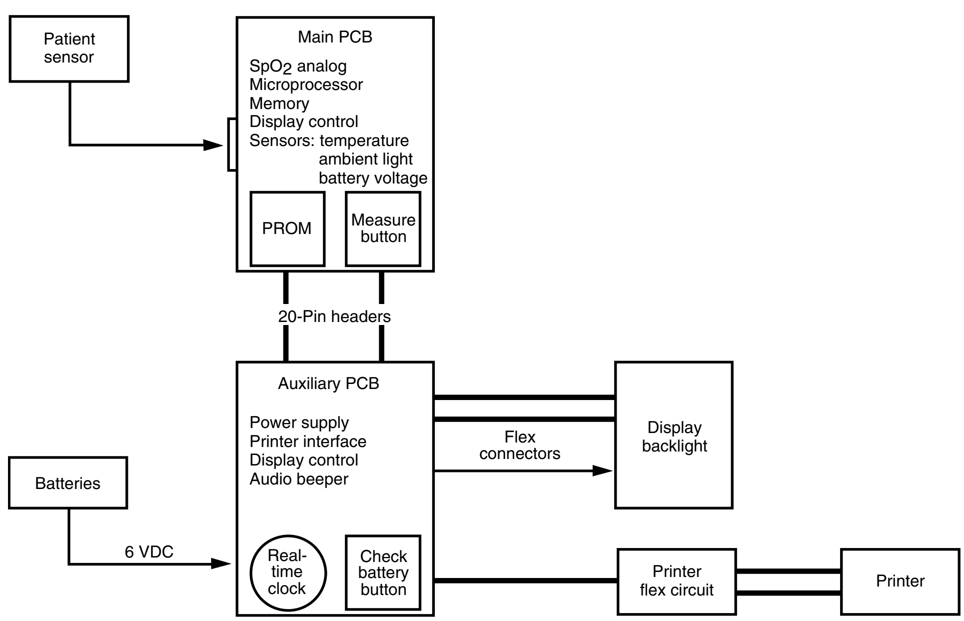


Figure 9-1: Overall Block Diagram

- SpO_2 Analog Block Diagram (Figure 9-2) — 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 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

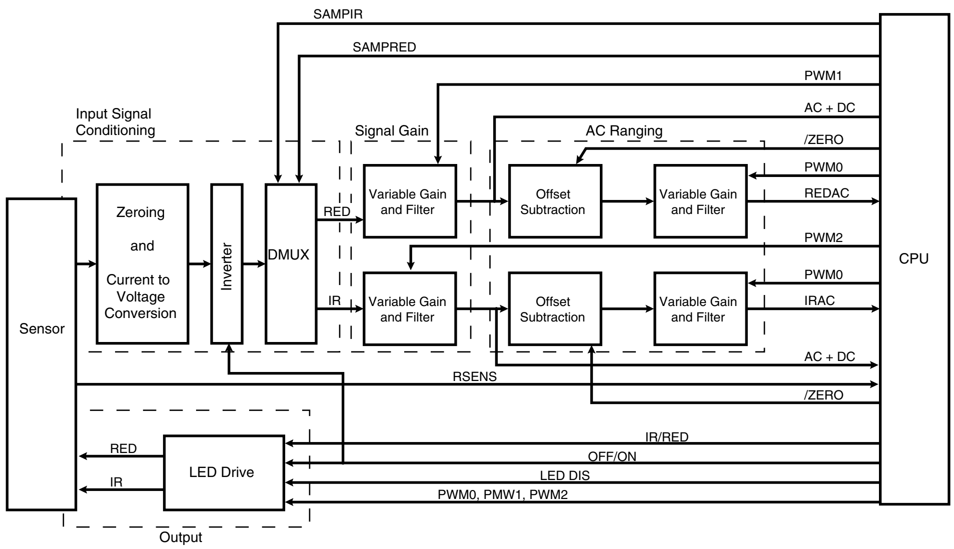


Figure 9-2: SpO2 Analog Block Diagram

4. AC ranging, where DC offset is eliminated from each LED signal

- Hardware Block Diagram (Figure 9-3) — This diagram shows the N-20PA 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 and ambient temperature sensor, and the real-time clock.
- Power Supply Block Diagram (Figure 9-4) — Power supply circuitry 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 On/Off 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

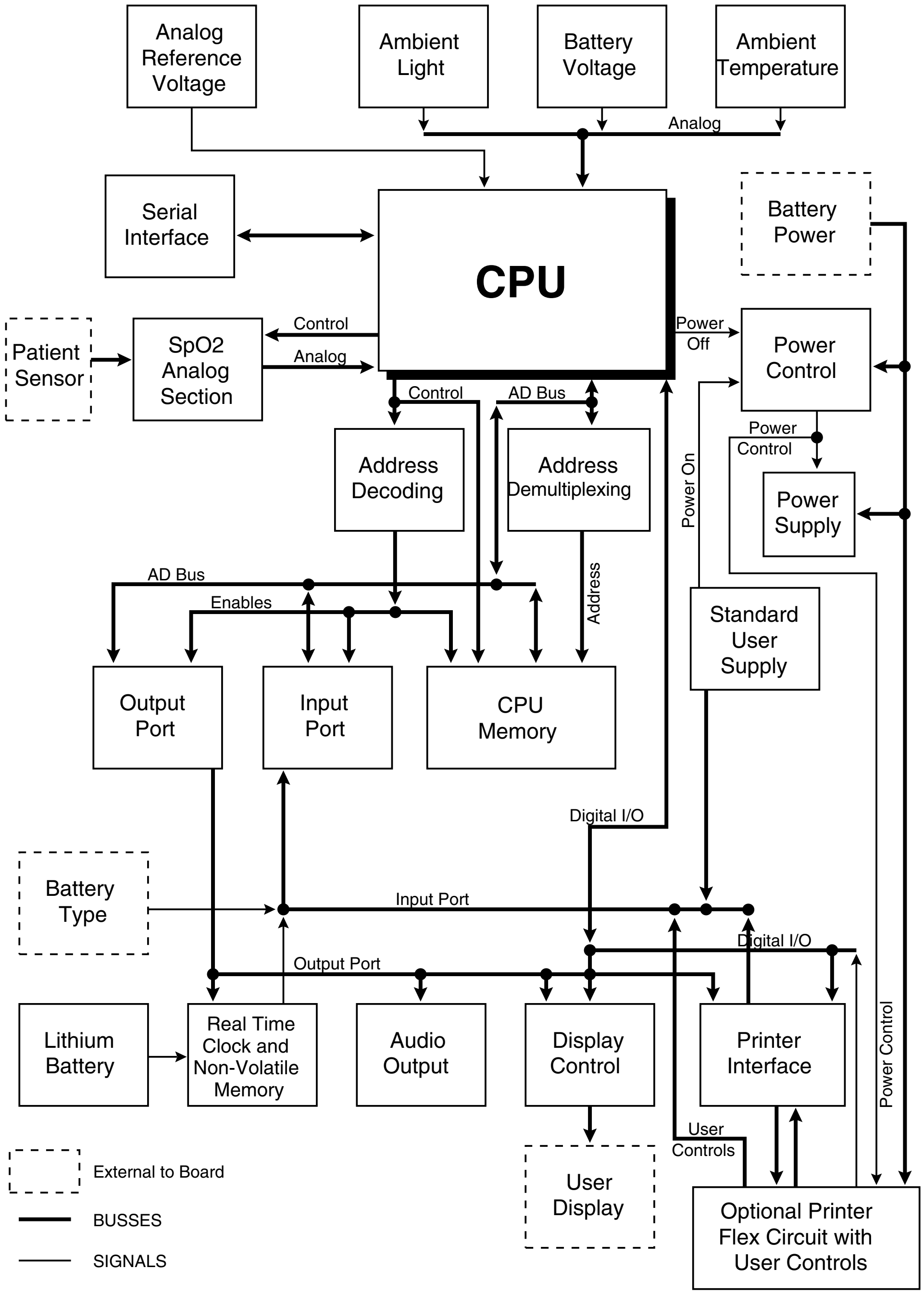


Figure 9-3: N-20PA Hardware Block Diagram

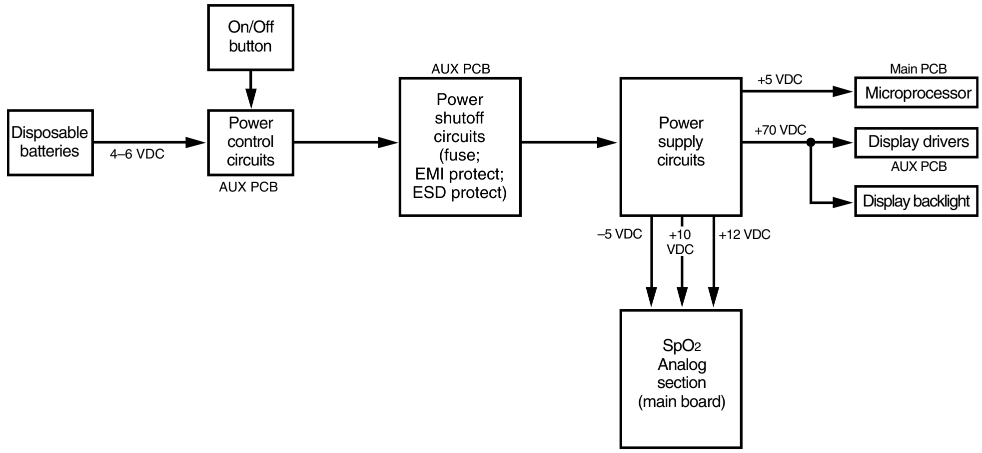


Figure 9-4: Power Supply Block Diagram

- **Display Control Block Diagram (**Figure 9-5**)** — The N-20PA display is controlled by the display control circuitry. A sensor is used to measure ambient light. During low-light conditions, the display backlight, an electroluminescent device, is automatically switched on.

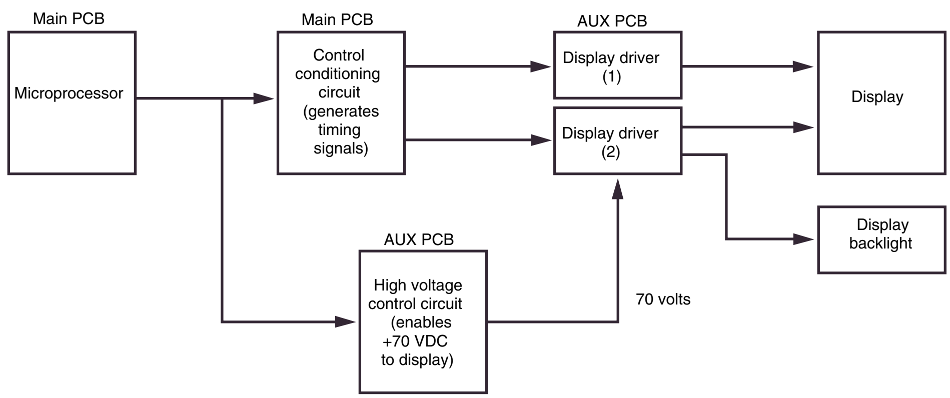


Figure 9-5: Display Control Block Diagram

- **Printer Control Block Diagram (**Figure 9-6**)** —Printer circuitry is divided into two subsections: the printer interface and the printer flex circuit.

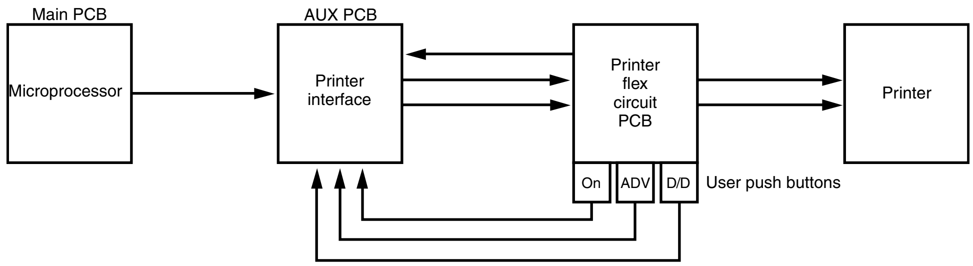


Figure 9-6: Printer Control Block Diagram

9.3 DEFINITION OF TERMS

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 converter for measurement.

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.

Content Addressable Memory (CAM). The CPU controls the HSO lines with the CAM. CAM is controlled by software and programmed with events scheduled relative to one of two internal timers.

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.

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

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

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.

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.

Real-Time Clock (RTC). The RTC is used with the optional printer to track time and date for printouts.

9.4 OVERALL BLOCK DIAGRAM

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

- **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.
- **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.
- **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-20PA has an additional printer control board (printer flex circuit), and printer hardware. Figure 9-1 shows the relationship of these components.

9.5 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 9-2) consists of four subsections:

- **Sensor output/LED control —** The CPU controls the drive level 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 the LED current level or to amplify the signal channel.
- **Input conditioning —** Sensor detector current is converted to voltage. A demodulation circuit minimizes the effects of other light sources and stray frequency inputs. Because the infrared (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.
- **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.
- **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 of these subsections is shown in Figure 9-7.

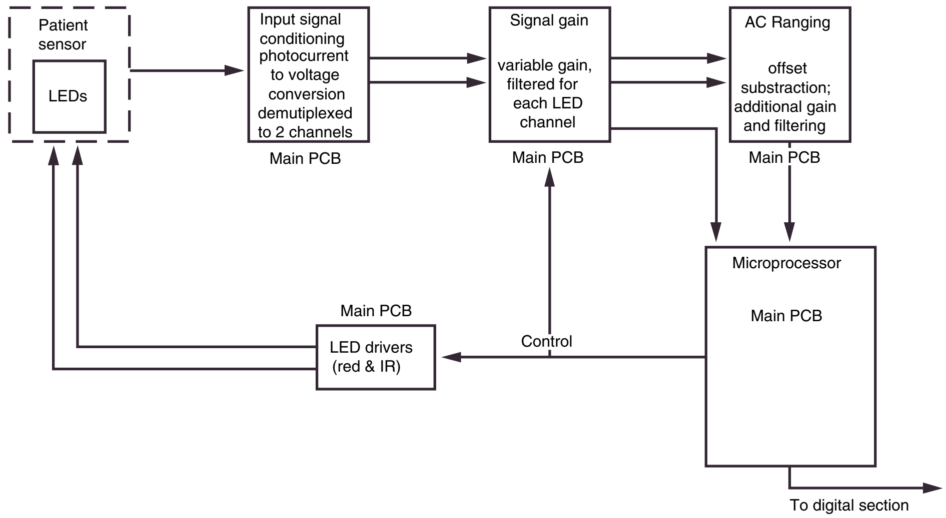


Figure 9-7: SpO_2 Analog Circuitry Block Diagram

9.5.1 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, intensity level of the LEDs 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 buildup 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.

9.5.1.1 LED Drive Circuit

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

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 regulators for the IR and red LED return lines. 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.

9.5.2 Input Conditioning

Input to the SpO_2 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 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 signals. Selection of the circuits is controlled by two switches that are coordinated with the IR and red transmissions. A filter with a large time constant follows to smooth the signal and remove noise before amplification.

9.5.1.2 Differential Synchronous Demodulation Circuit

The differential synchronous demodulation circuit is illustrated in Figure 9-9.

Before the current from the photodetector is converted to voltage, C40 and R17 filter any high frequency noise. 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 test point 49.

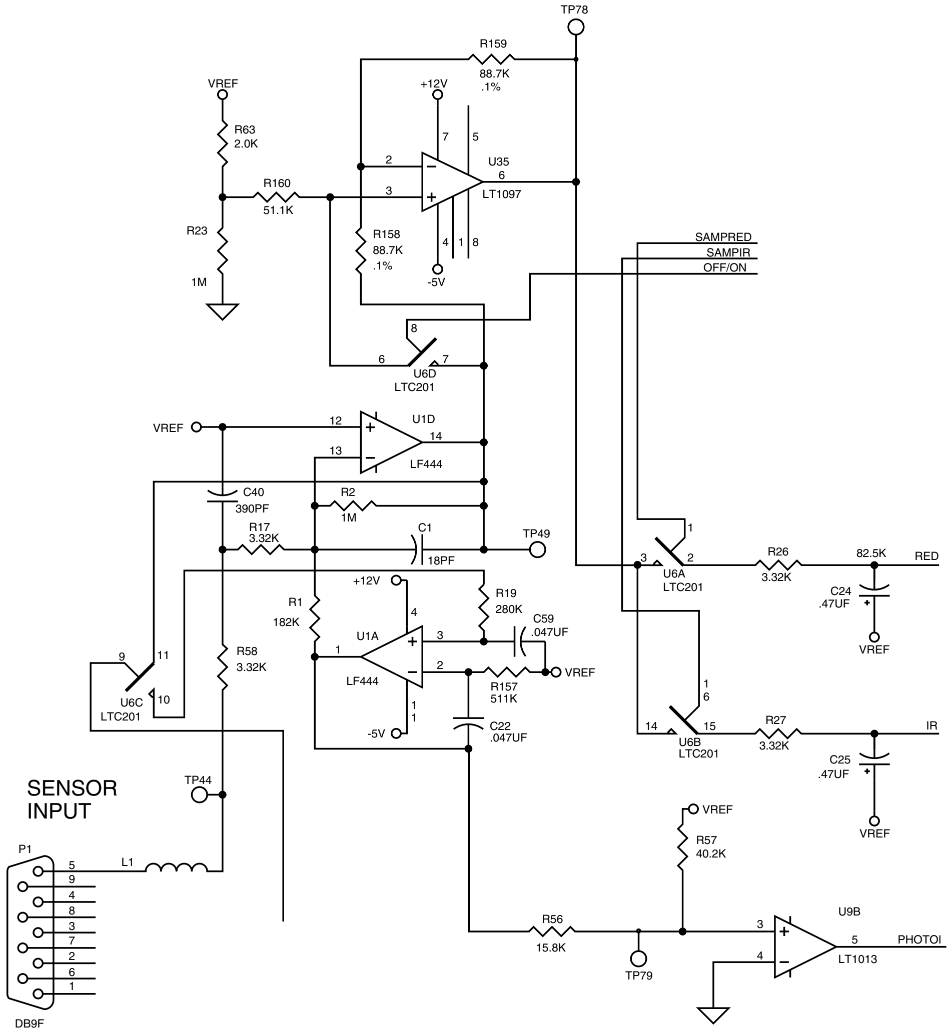


Figure 9-9: Differential Synchronous Demodulation Circuit

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 is on (the line is low and the switch is closed), U35 is used as a noninverting 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-20PA HSO timing diagram is illustrated in Figure 9-10, at the end of Section 9.

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.

9.5.3 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 signals from exceeding an acceptable input voltage from the A/D converter.

9.5.3.1 Variable Gain Circuit

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

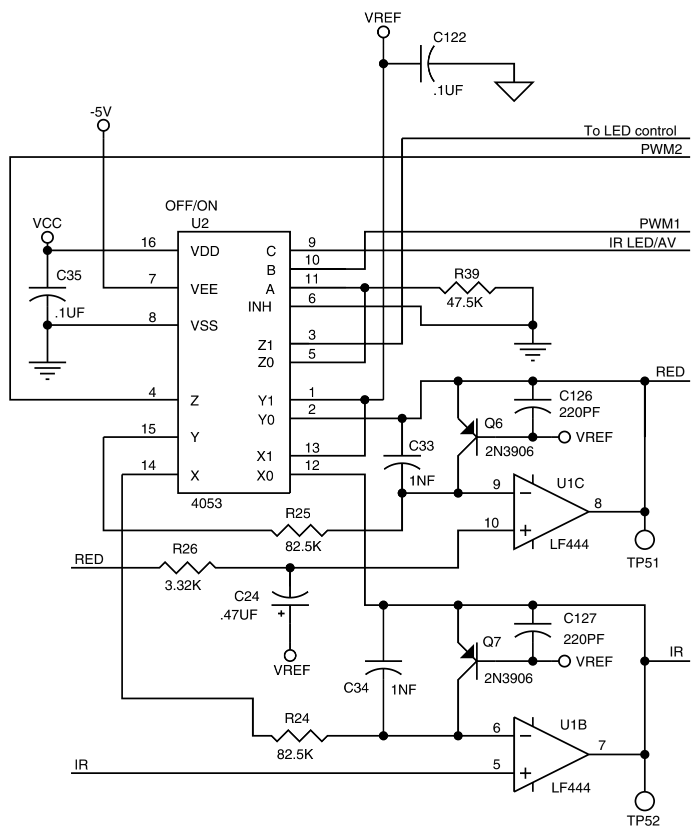


Figure 9-11: Variable Gain Circuit

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.

9.5.3.2 Filtering Circuit

The filtering circuits are illustrated in Figure 9-12.

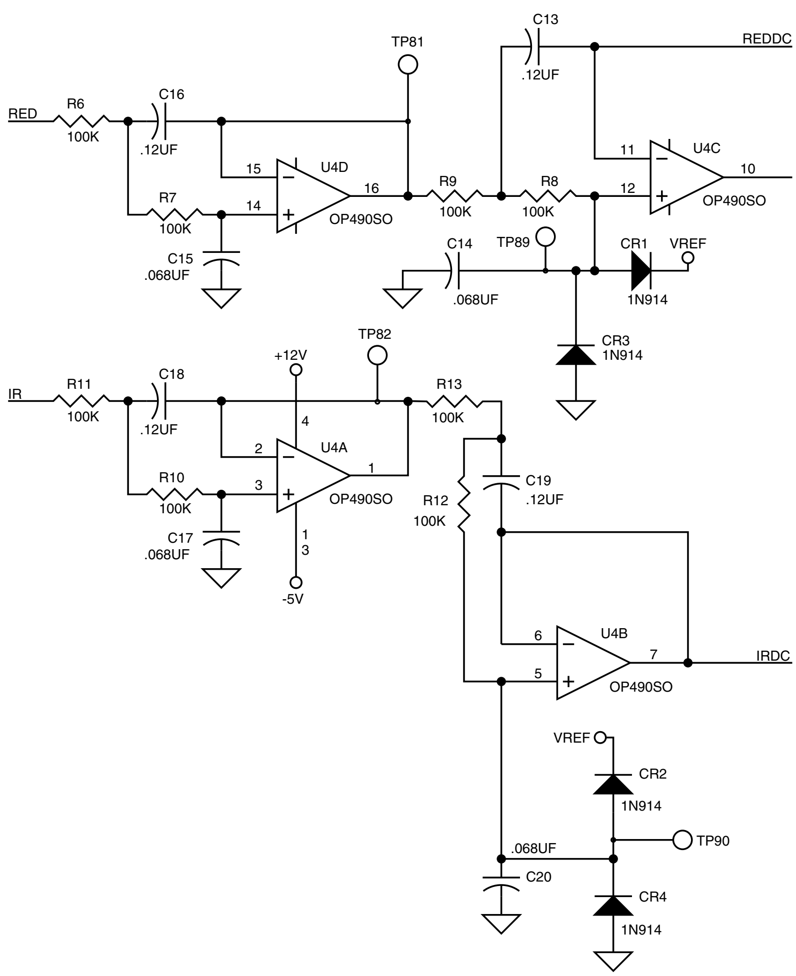


Figure 9-12: Filtering Circuit

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.

9.5.4 AC Ranging

In order to achieve a specified level of oxygen saturation measurement 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 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.

9.5.4.1 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.

9.5.4.1 AC Variable Gain Control Circuits

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

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.

9.6 DIGITAL CIRCUITRY

The digital hardware and related circuitry, which is illustrated in Figure 9-14, includes the following subsystems:

- **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.

- **System memory** — System memory is external to the CPU and consists of an 8K × 8 static RAM and a 64K × 16 EPROM.
- **Real-Time Clock (RTC)** — The RTC keeps track of date and time, which is printed on each printout. A lithium battery designed to last up to 5 years before needing replacement powers the RTC.
- **Audio output** — A piezoelectric ceramic beeper is used for audio output.
- **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.
- **User controls** — A On/Off button and a battery-check button. The On/Off 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.
- **Power supply/Power control circuitry** — The N-20PA receives power from 4 “C” cell batteries. The power control circuitry discontinues power to the unit when the batteries are no longer reliable.
- **Thermal printer** — 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.

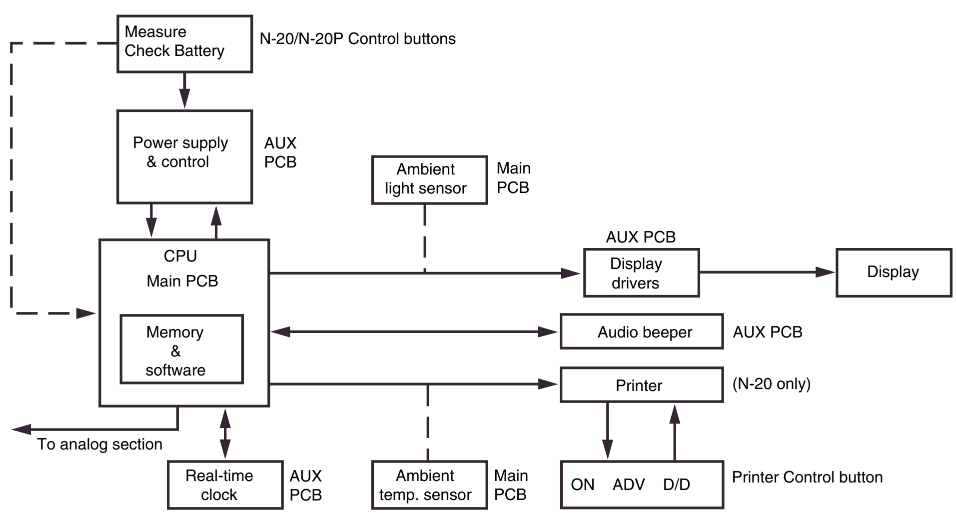


Figure 9-14: Digital Circuitry Block Diagram

9.6.1 CPU

The CPU circuit is illustrated in Figure 9-15, at the end of this section.

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; however, 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 glitch caused by ESD, EMI, and so forth. 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.

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-20PA 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.

9.6.1.1 Address Demultiplexing

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

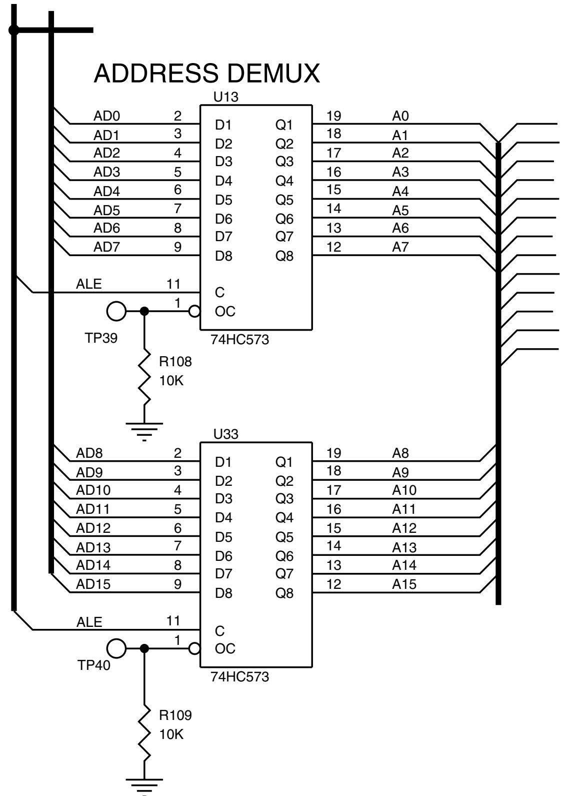


Figure 9-16: Address Demultiplexing Circuit

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.

9.6.1.2 Address Decoding

The address decoding circuit is illustrated in Figure 9-17.

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, U30A's output goes low, enabling the RAM. This occurs for the 8K address range of E000-FFFF.

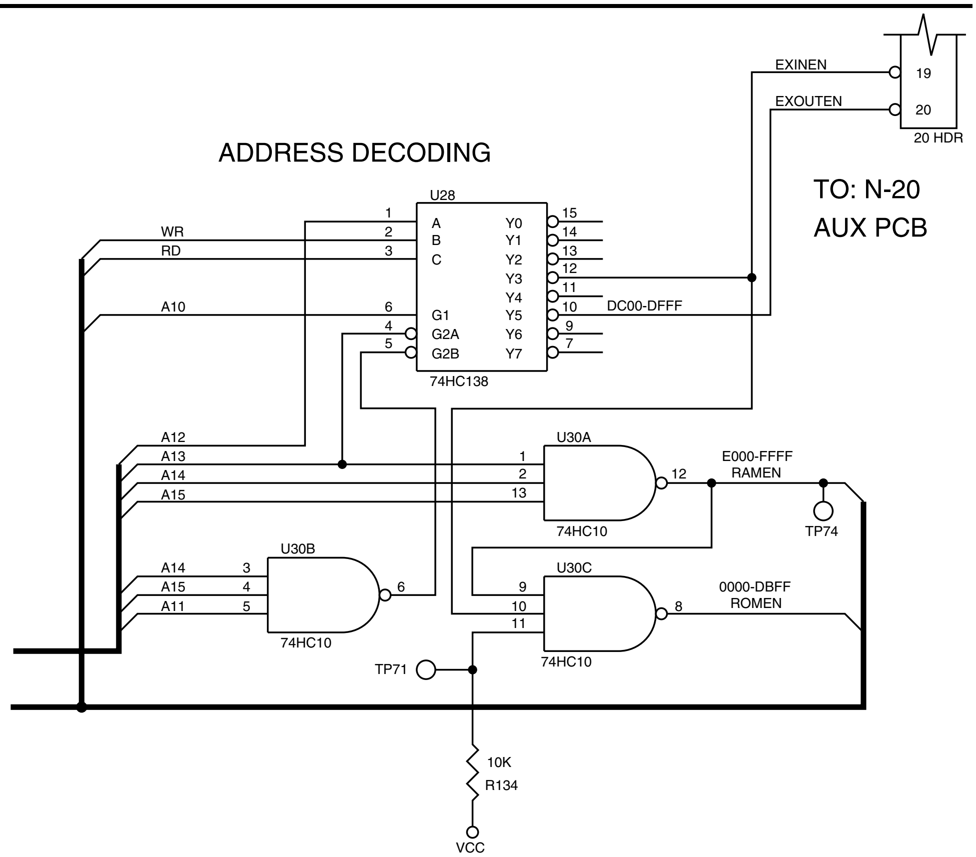


Figure 9-17: Address Decoding Circuit

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, and so on, 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. Because, 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.

9.6.2 CPU Memory

The CPU memory circuit is illustrated in Figure 9-18.

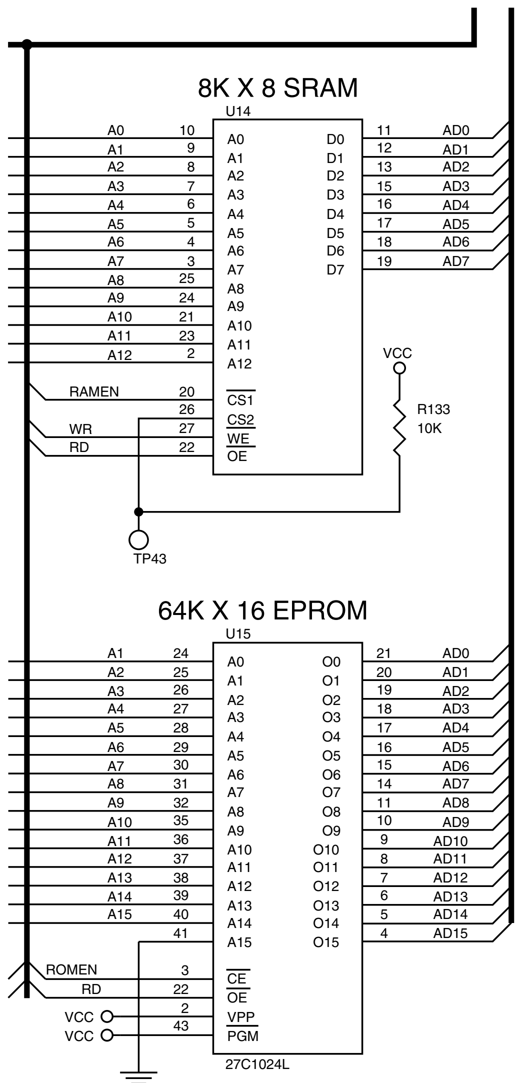


Figure 9-18: CPU Memory Circuit

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. A0 is not used as a normal address line. The CPU can only address 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.

9.6.2.1 Input Port

The input port circuit is illustrated in Figure 9-19.

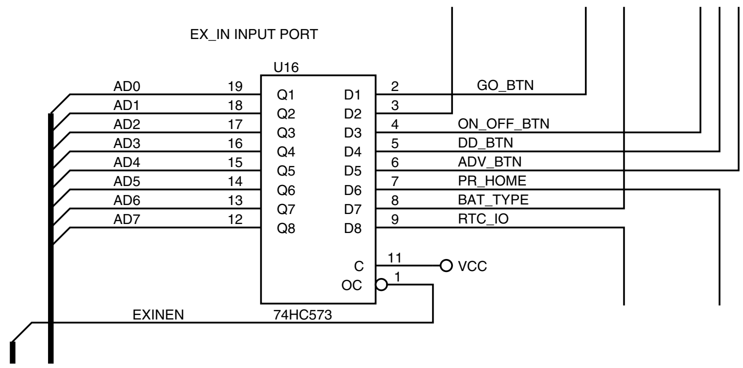


Figure 9-19: Input Port Circuit

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 senses 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 6.3, Real-Time Clock and Non-Volatile Memory).

9.6.2.2 Output Port

The output port circuit is illustrated in Figure 9-20, at the end of Section 9.

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 U17's 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, Section 6.14). 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 Nonvolatile Memory").

Both bytes of external output port (that is, 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").

9.6.3 Real-Time Clock (RTC) and Nonvolatile Memory

The Real-Time Clock Circuit is illustrated in Figure 9-21.

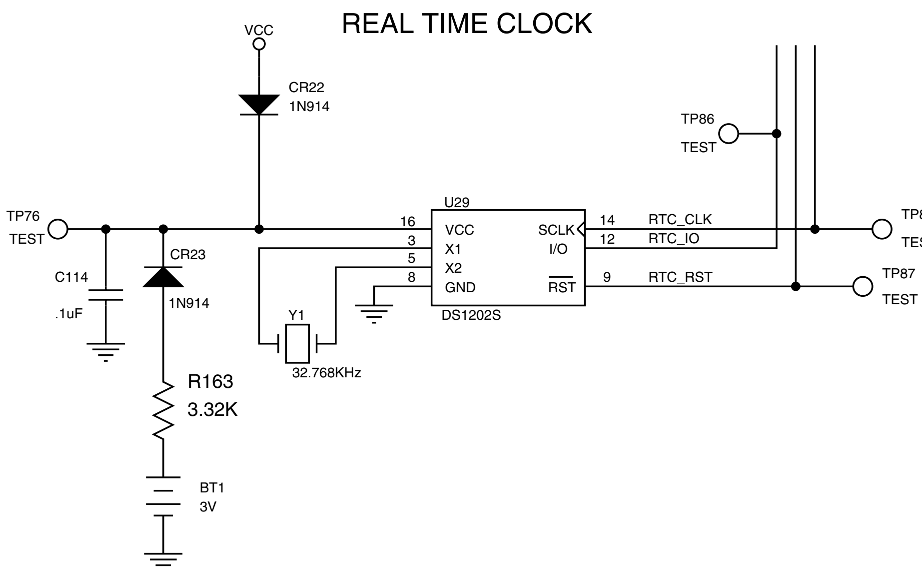


Figure 9-21: Real-Time Clock Circuit

The RTC has two functions: (1) it provides nonvolatile 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-20PA printer. The N-20PA does not require or use the RTC; it is disabled via software.

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 onto it from the RTC.

Crystal Y1 provides an accurate 32.768 KHz clock input whenever the timekeeping circuitry of U29 is activated. The CPU only enables the timekeeping function 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 only used 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 typical, without the unit being powered on.

U29 holds 24 bytes of RAM, which is used for nonvolatile storage of CPU data.

9.6.4 Audio Output

The audio output circuit is illustrated in Figure 9-22.

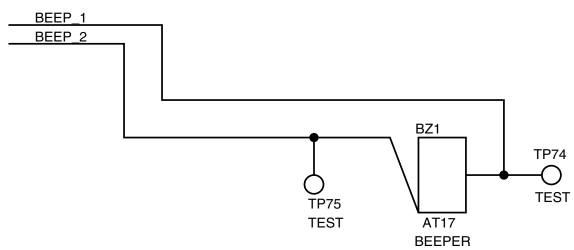


Figure 9-22: Audio Output Circuit

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 is driven directly from the external output port. The audio output device 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.

9.6.5 Display Control Circuitry

The display control circuit is illustrated in Figure 9-23, at the end of Section 9. Figure 9-5 shows the display control block diagram.

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

- **Control Conditioning Circuit** (main PCB) — The control conditioning circuit processes signals generated by the CPU to produce timing signals for the display drivers.
- **Display Driver ICs** (auxiliary PCB) — 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.

- **High Voltage Control Circuit** (auxiliary PCB) — The high-voltage control circuit allows the CPU to switch on or off the display's high-voltage input.

9.6.5.1 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.

9.6.5.2 Display Driver Control Circuits

U19 and U20 are the display segment driver chips. Each chip has 32 high-voltage outputs and a common display marked BP (backplane). The CPU via a serial shift register input inputs the display data to U19 and U20. 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. DC voltages cannot drive the display or display damage will result. Creating a 180-degree phase shift between the segment pin and the BP common pin illuminates display segments. 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.

9.6.5.3 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 limit current 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, to reduce the EMI generated by the display due to the lower slew rates of the high-voltage switching signals.

9.6.6 Standard User Controls

The user-controls circuit is illustrated in Figure 9-24.

The standard user controls consist of two momentary push-button switches (On/Off and battery-check). The Of/Off button is an elastomeric contact switch, and the battery-check 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 pressed, 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 On/Off button also activates the power supply via the power control circuit. Note that the On/Off button has circuitry on both the main PCB as well as the auxiliary PCB.

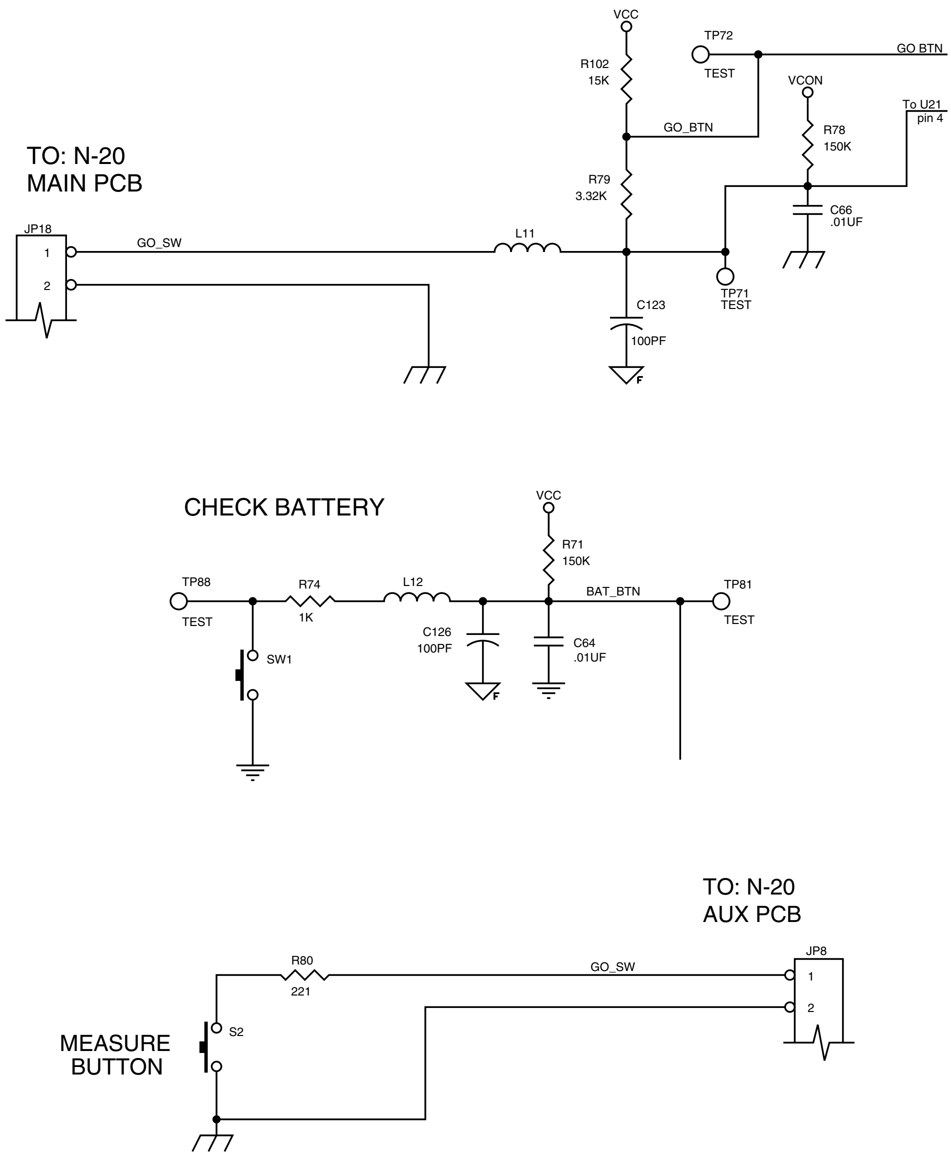


Figure 9-24: User Controls Circuit

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 On/Off button and switches on the power supplies. Reverse current limiting protects the N-20PA 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 consist of the following power supplies:

  Regulated power supply: Power supplied by the batteries is regulated at 5 VDC. This supply is used by all of the digital circuitry and some of the SpO_2 analog circuitry.

  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; this increase in power is needed by the display drivers as well as the display backlight.

The power supply circuit is illustrated in Figure 9-25, at the end of Section 9. Figure 9-4 shows the power supply block diagram.

9.6.7.1 Power Control Circuitry

The power control circuit is illustrated in Figure 9-26, at the end of Section 9.

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 backward. In the reverse battery error condition, excessive current can flow from the inputs of U21 through the input protection diodes or substrate inside the CPUs integrated circuit or through both. These resistors limit that current path to safe levels.

9.6.7.2 Power Shutoff Circuit

This circuit is illustrated in Figure 9-25, Power Supply Circuit.

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

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 current. If batteries are installed backward, Q15 part 2 switches off and disables current flow. This protects the unit's 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.

9.6.7.3 Vcc Power Supply

This circuit is illustrated in Figure 9-25, Power Supply Circuit.

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%).

9.6.7.4 Raw Power Supplies

This circuit is illustrated in Figure 9-25, Power Supply Circuit.

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 SpO_2 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

9.6.7.5 High Voltage Supply

This circuit is illustrated in Figure 9-25, Power Supply Circuit.

The batteries (VBAT) provide the input power for the high-voltage supply. 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 output to a safe level.

9.6.8 Analog Reference Voltage

The analog reference voltage circuit is illustrated in Figure 9-27.

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

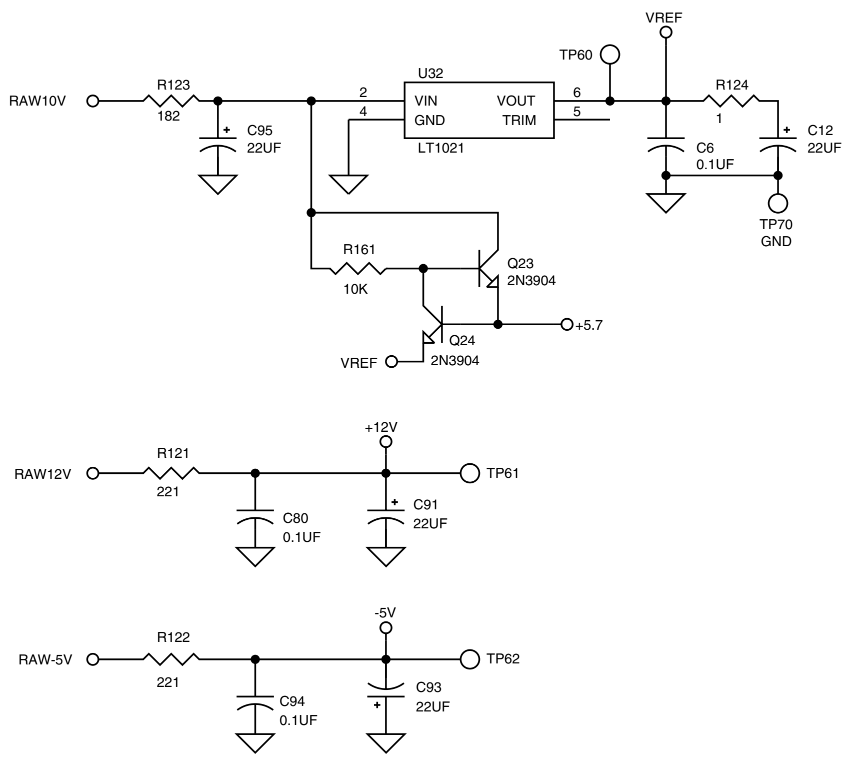


Figure 9-27: Analog Reference Voltage Circuit

9.6.9 Ambient Light

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

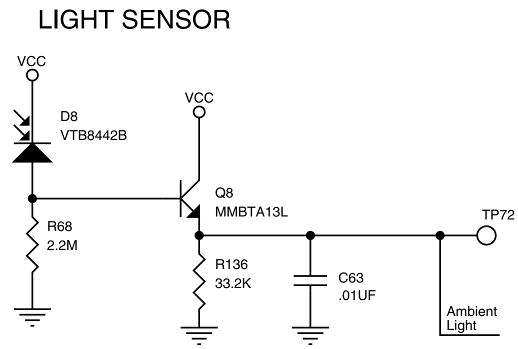


Figure 9-28: Ambient Light Circuit

Diode D8 is a photodiode that is used to measure ambient light. Q8, R68, and R136 provide current gain for D8's 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.

9.6.10 Ambient Temperature

The ambient temperature circuit is illustrated in Figure 9-29.

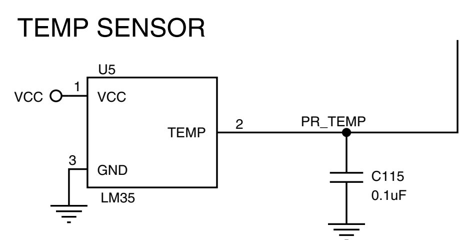


Figure 9-29: Ambient Temperature Circuit

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 to compensate for ambient temperatures associated with thermal printers.

9.6.11 Battery Voltage

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

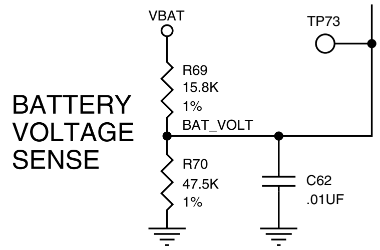


Figure 9-30: Battery Voltage Circuit

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. The battery voltage data are also used to compensate for battery voltage changes that can affect printout quality.

9.6.12 Battery Type

The battery type circuit is illustrated in Figure 9-31.

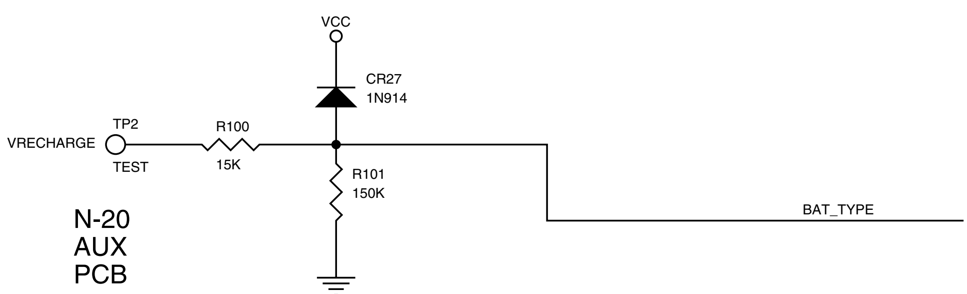


Figure 9-31: Battery Type Circuit

The unit operates on disposable 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

9.6.13 Printer Control

Printer circuitry is divided into two subsections: the printer interface and the printer flex circuit.

- **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 9-32, at the end of Section 9.

- **Printer flex circuit** — 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 9-33, at the end of Section 9. The printer control block diagram is shown in Figure 9-6.

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-20PA adjusts power to the printer’s head; however, a weak battery voltage condition causes the printer to shut off, thereby allowing the N-20PA 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.

9.6.13.1 Printer Interface Circuit

The printer interface circuit is illustrated in Figure 9-32, at the end of section 9.

The following is a description of the printer interface circuitry found on all N-20PA auxiliary PCBs.

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-20PA 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. R143, R144, R145, R146, and head resistor DOT4 form a two-level resistor bridge. 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 the head-resistance category of this particular head. R156 ensures 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 only measured 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.

9.6.13.2 Printer Flex Circuit and User Controls

The printer flex circuit is illustrated in Figure 9-33, at the end of section 9.

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.

The auxiliary PCB provides constant power (VPRN) and a power control line (PWR_ON). 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 battery voltage drop caused by the current spikes.

The N-20PA 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.

9.7 CIRCUIT ILLUSTRATIONS

The foldout graphics referenced throughout the Technical Supplement text are as follows:

Figure 9-8: LED Drive Circuit

Figure 9-10: N-20PA HSO Timing Diagram

Figure 9-13: AC Variable Gain Control Circuit

Figure 9-15: CPU Circuit

Figure 9-20: Output Port Circuit

Figure 9-23: Display Control Circuit

Figure 9-25: Power Supply Circuit

Figure 9-26: Power Control Circuit

Figure 9-32: Printer Interface Circuit

Figure 9-33: Printer Flex Circuit

Figure 9-34: N-20PA Main PCB Schematic Diagram

Figure 9-35: N-20PA Auxiliary PCB Schematic Diagram

Figure 9-36: N-20PA Flex Circuit Schematic Diagram

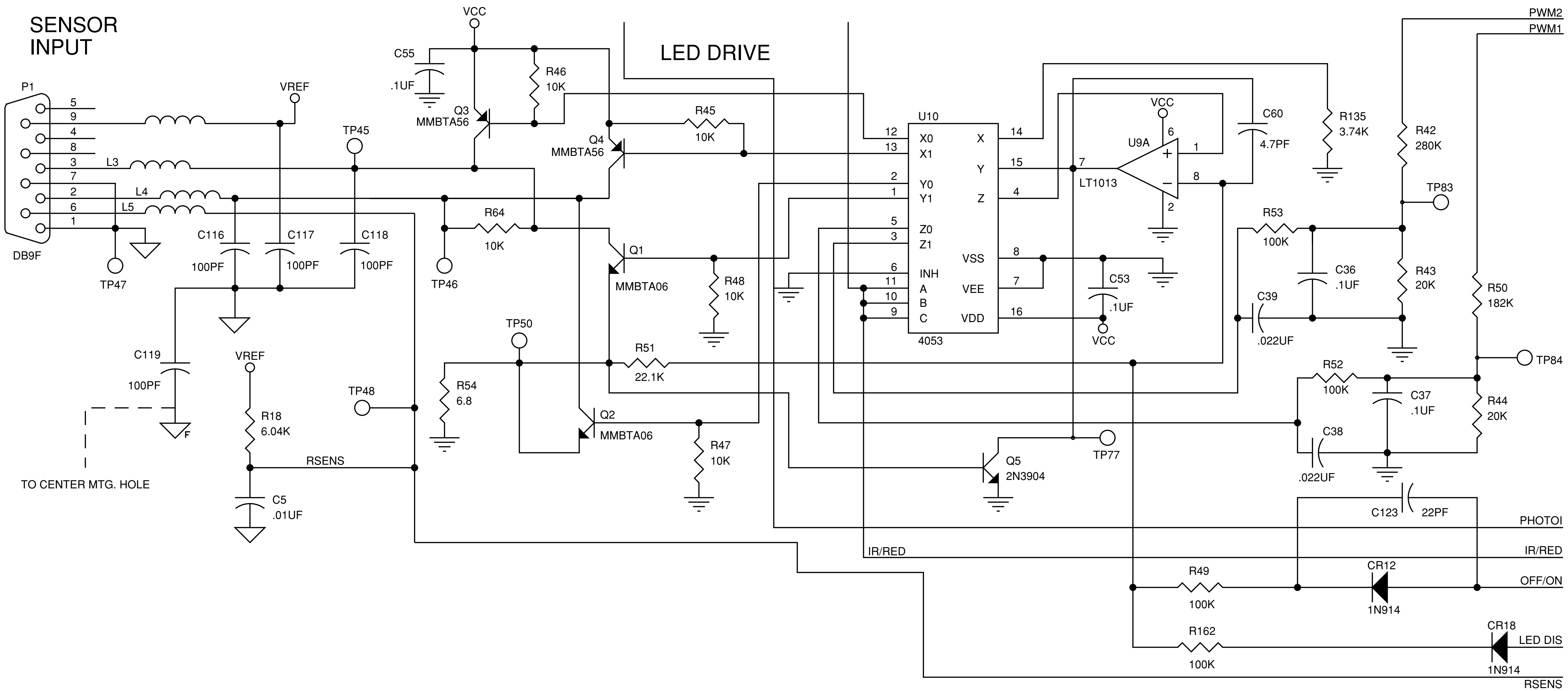


Figure 9-8
LED Drive Circuit

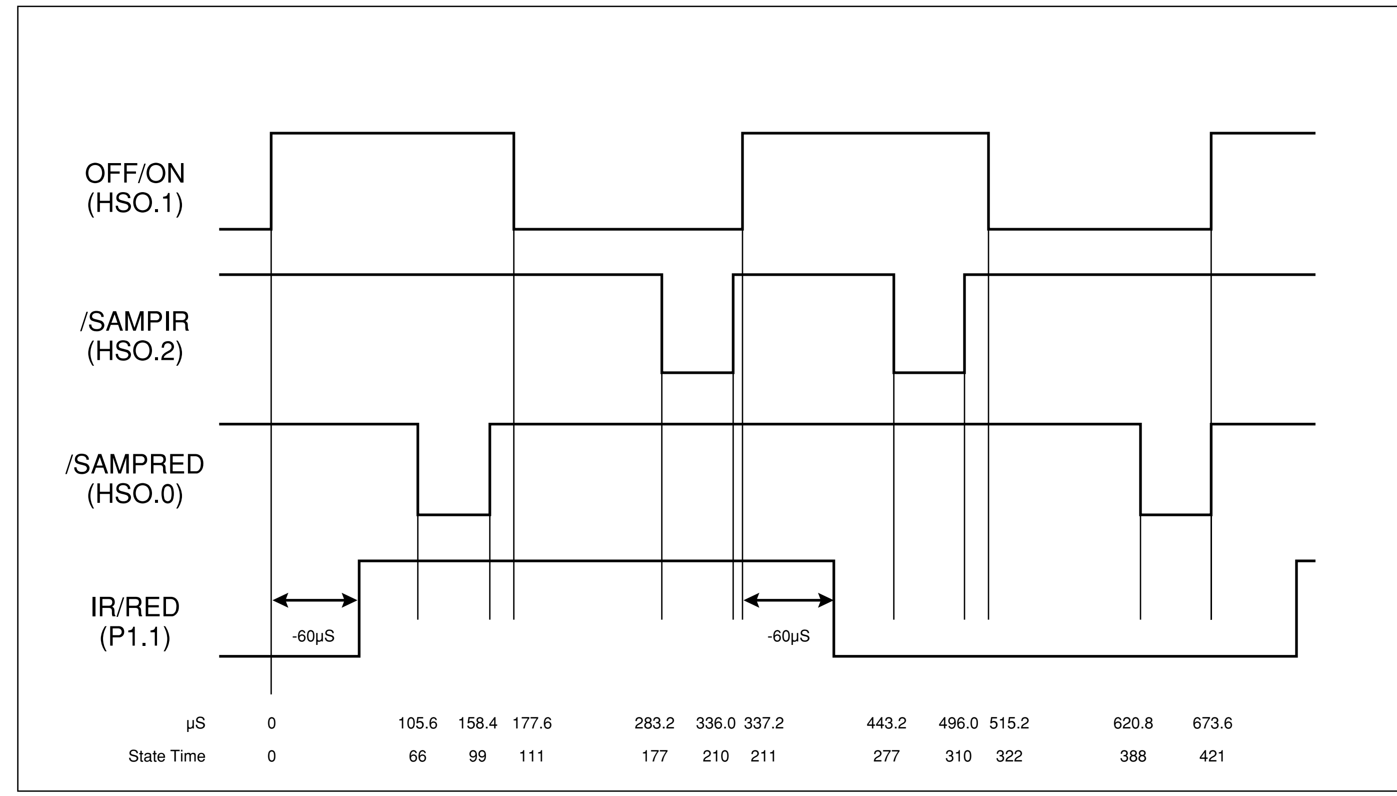


Figure 9-10
N-20PA HSO Timing Diagram

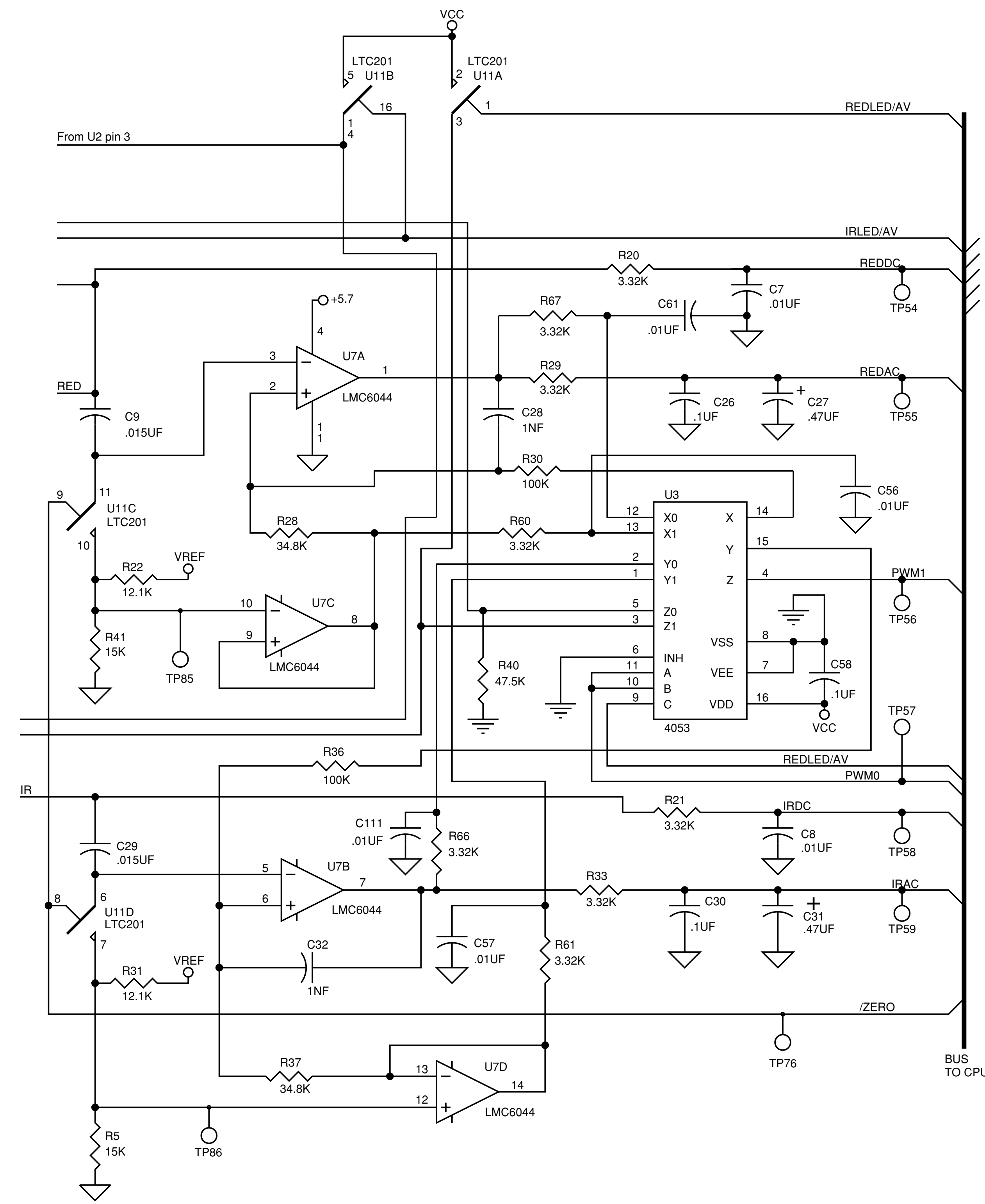


Figure 9-13
AC Variable Gain Control Circuit

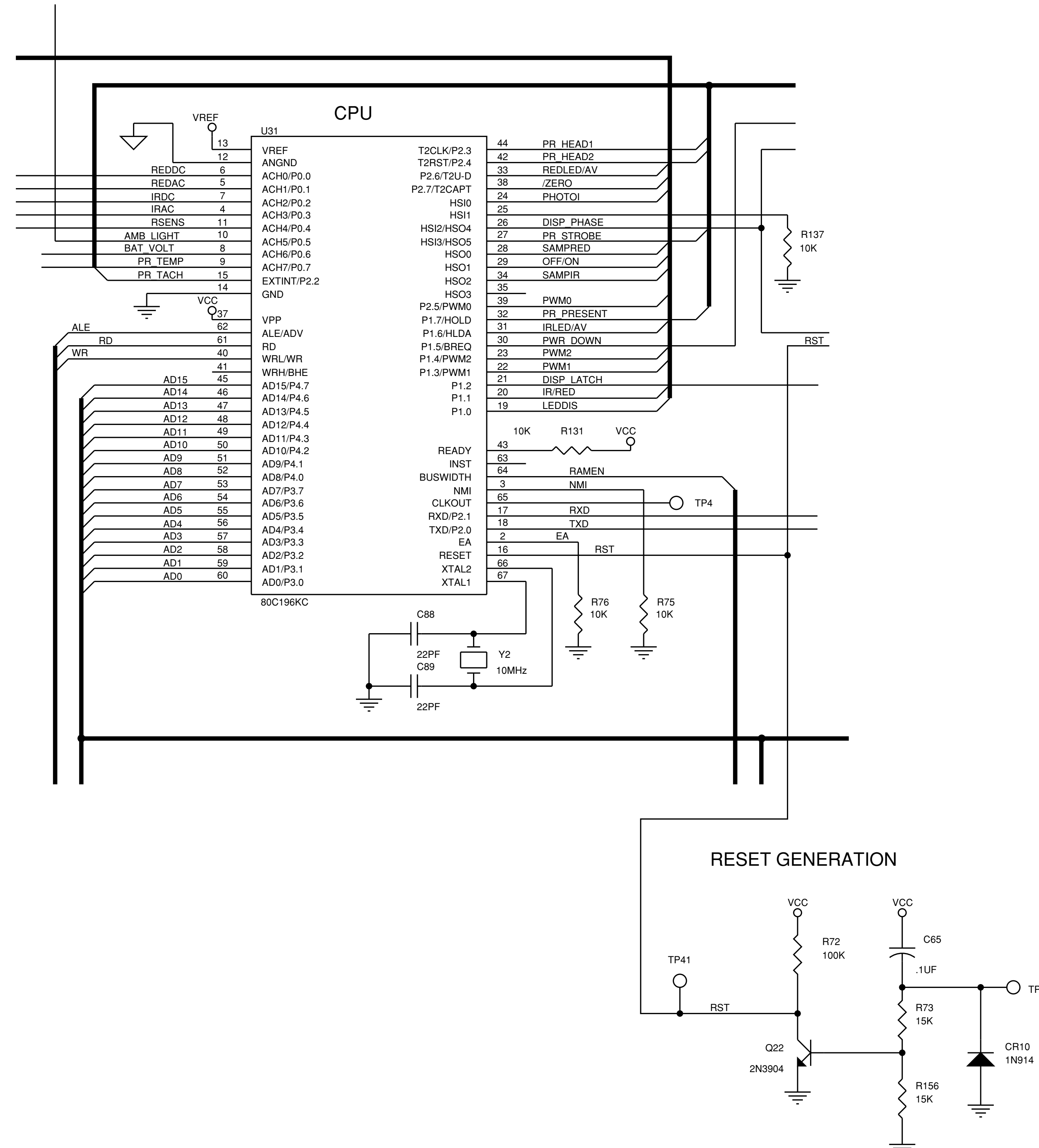


Figure 9-15
CPU Circuit

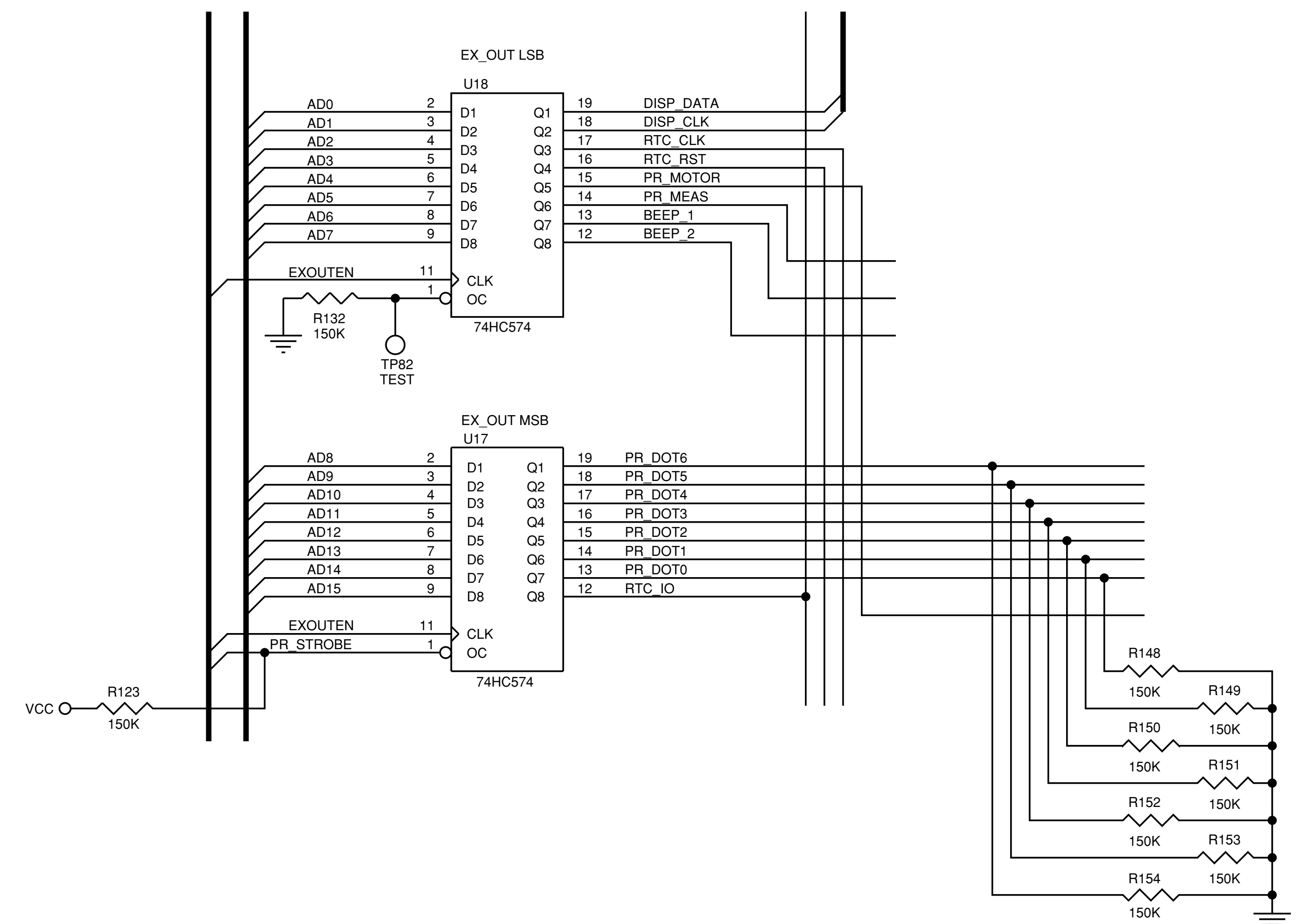


Figure 9-20
Output Port Circuit

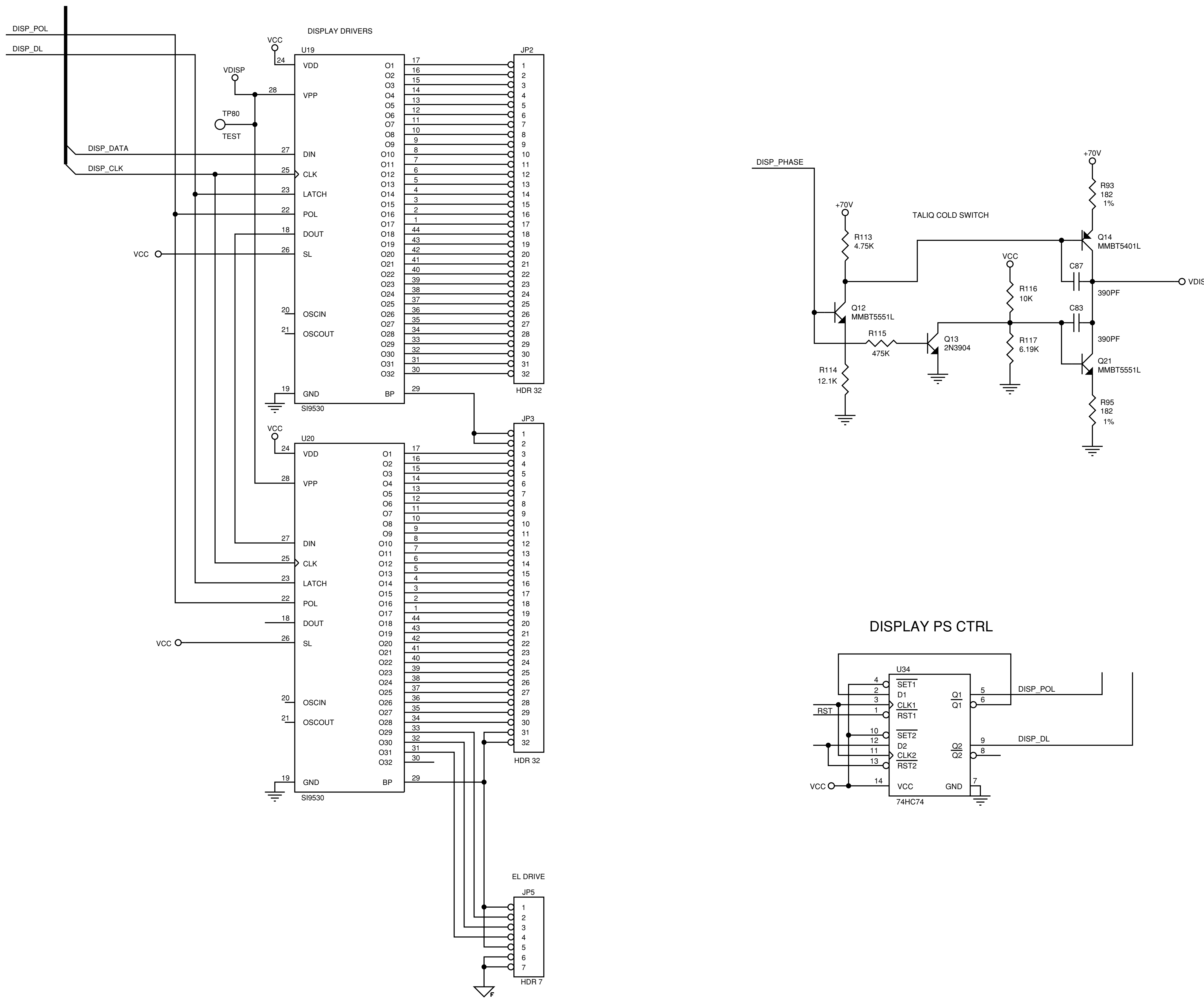


Figure 9-23
Display Control Circuit

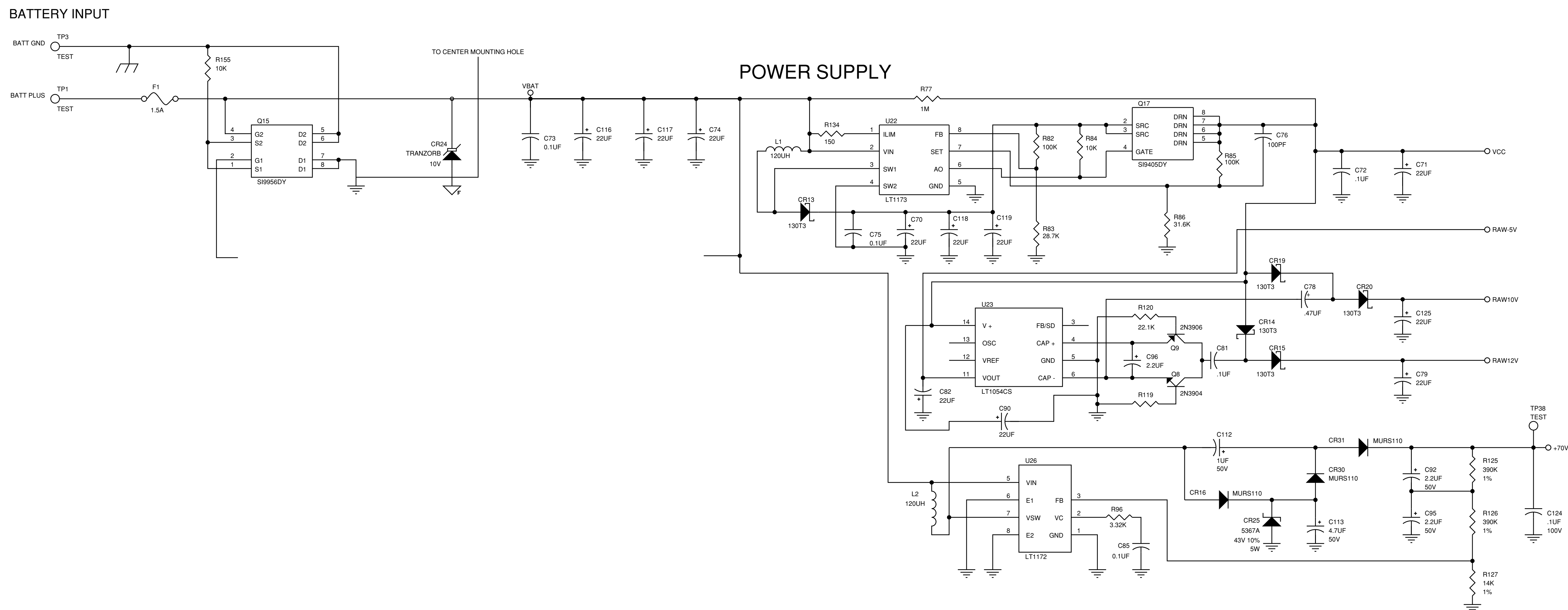


Figure 9-25
Power Supply Circuit

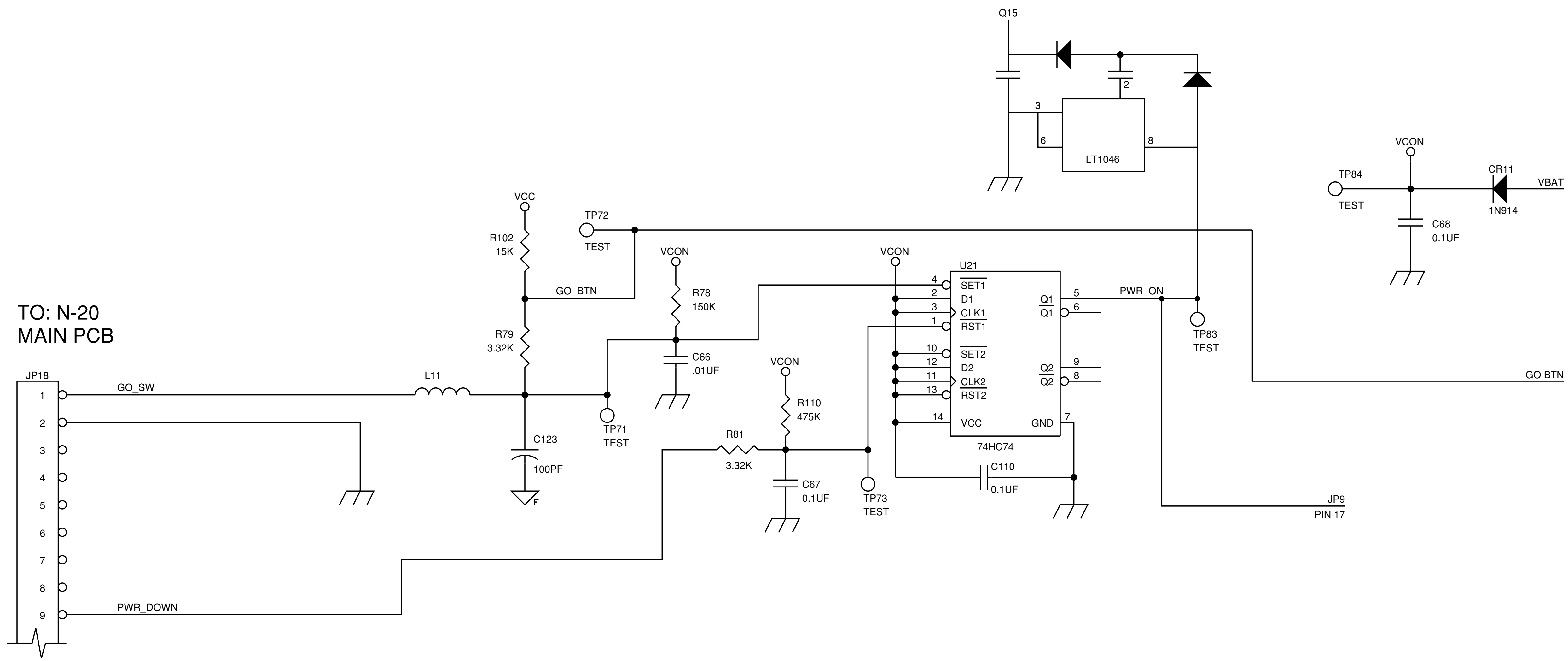


Figure 9-26
Power Control Circuit

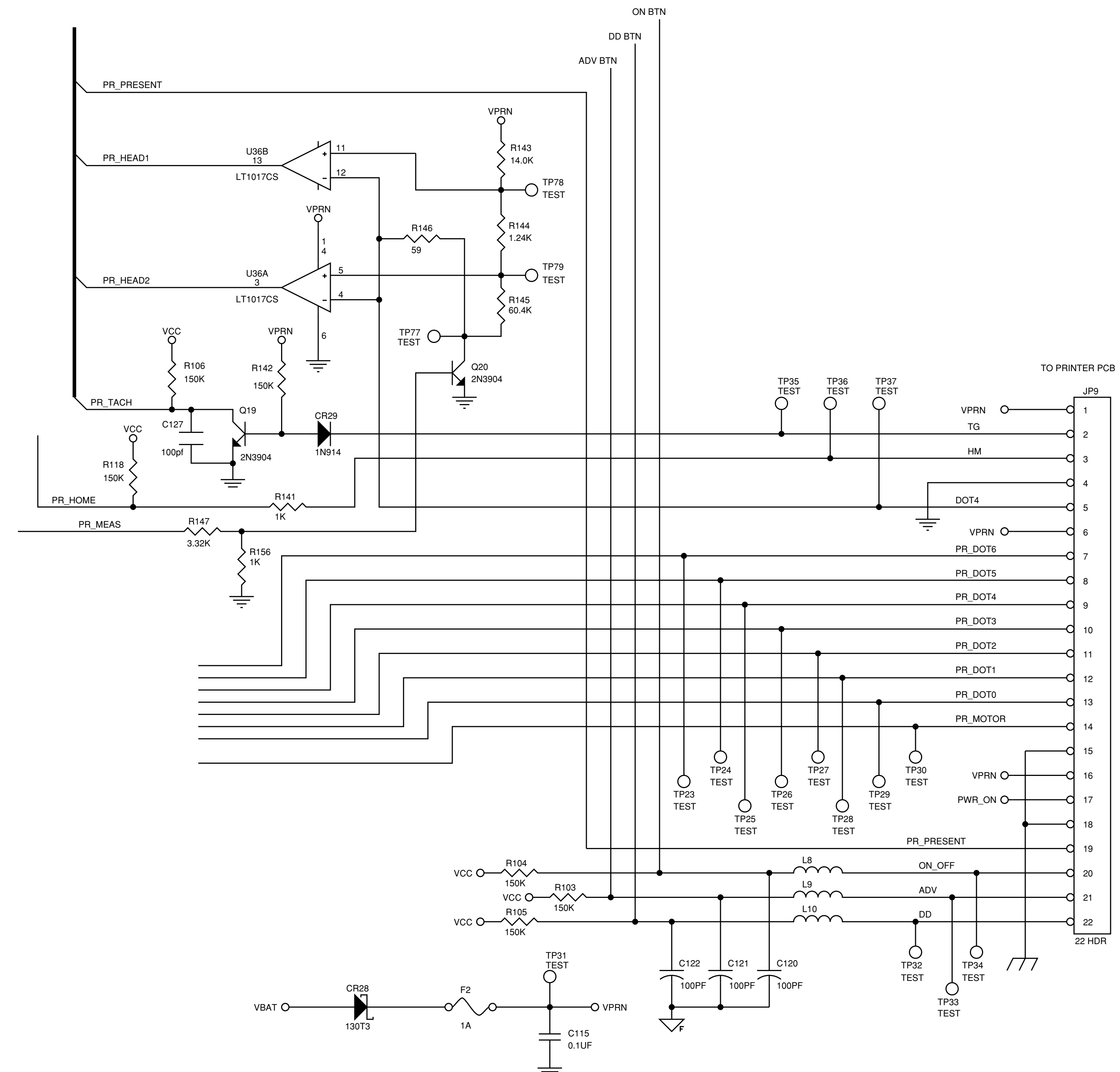


Figure 9-32
Printer Interface Circuit

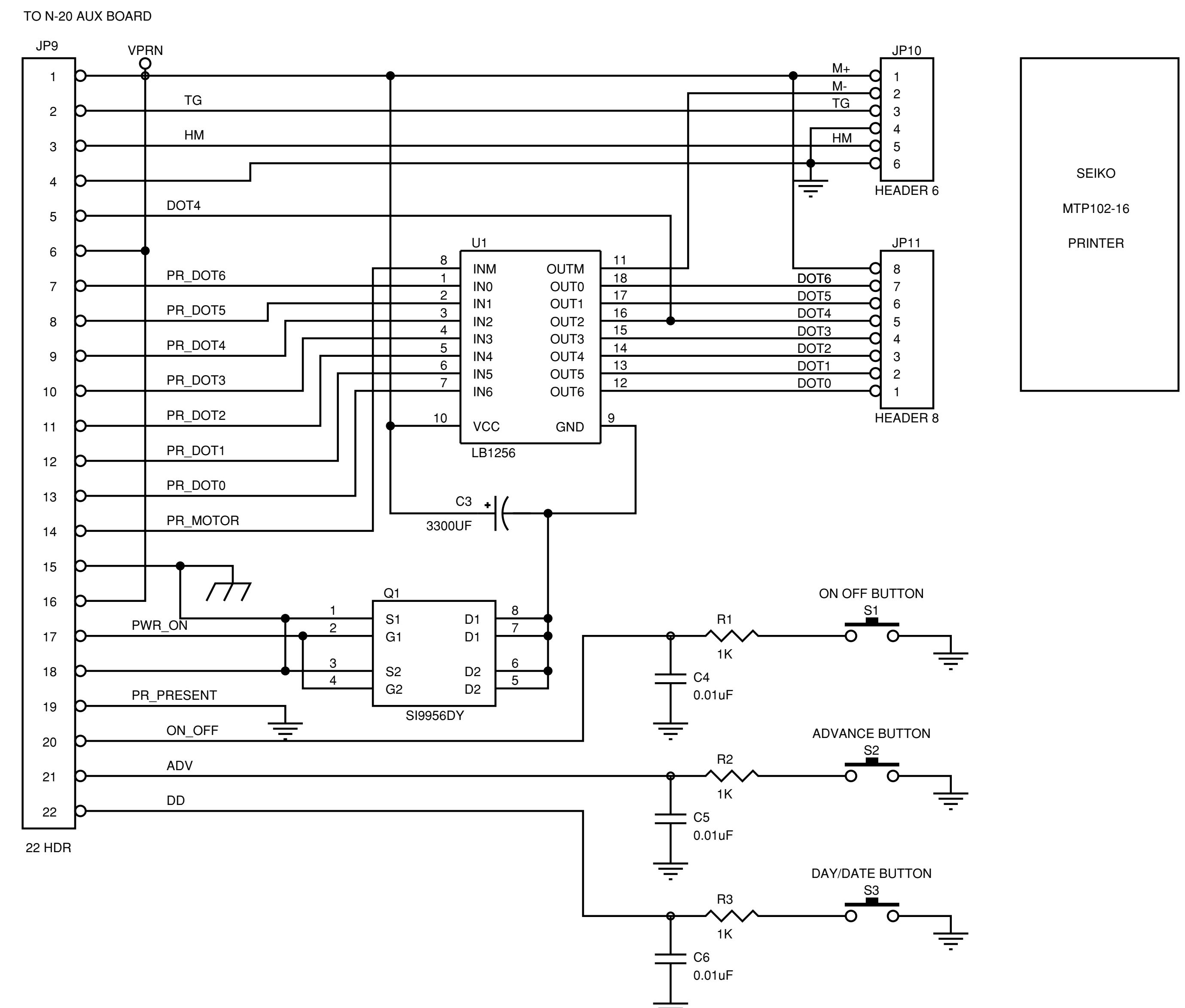


Figure 9-33
Printer Flex circuit

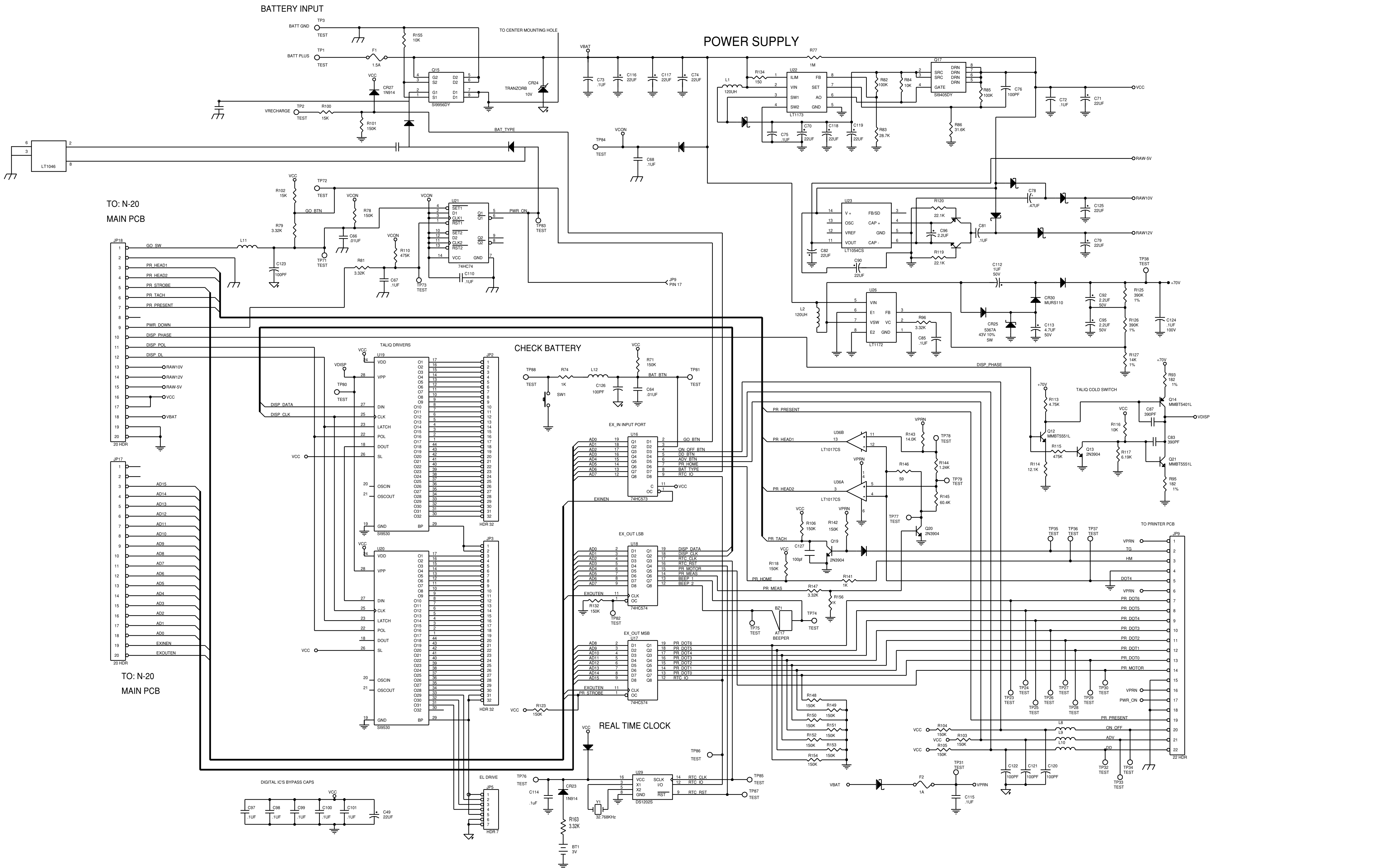


Figure 9-34
N-20PA Auxiliary PCB Schematic Diagram

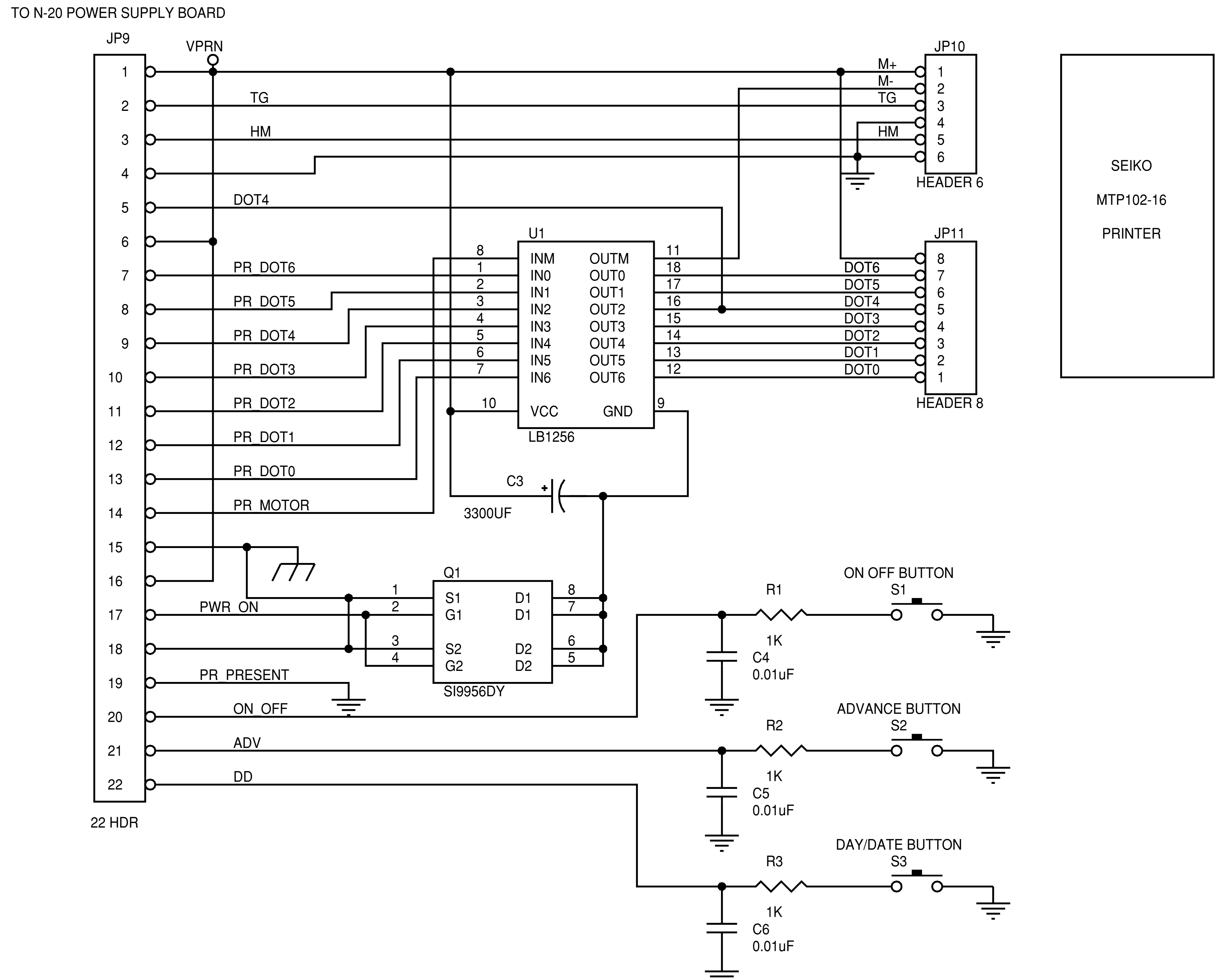
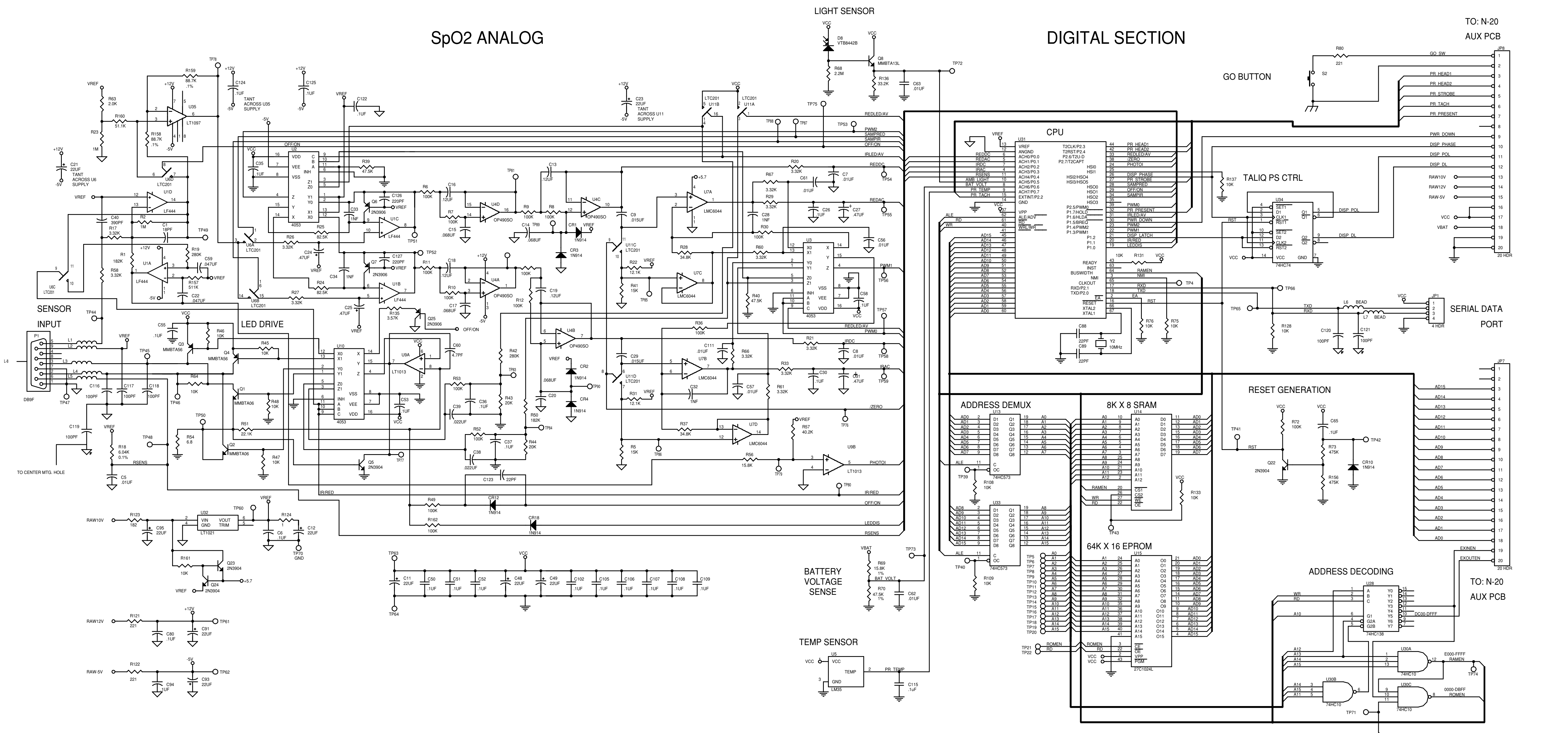


Figure 9-35
N-20PA Flex Circuit Schematic Diagram



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

Figure 9-36
N-20PA Main PCB Schematic Diagram