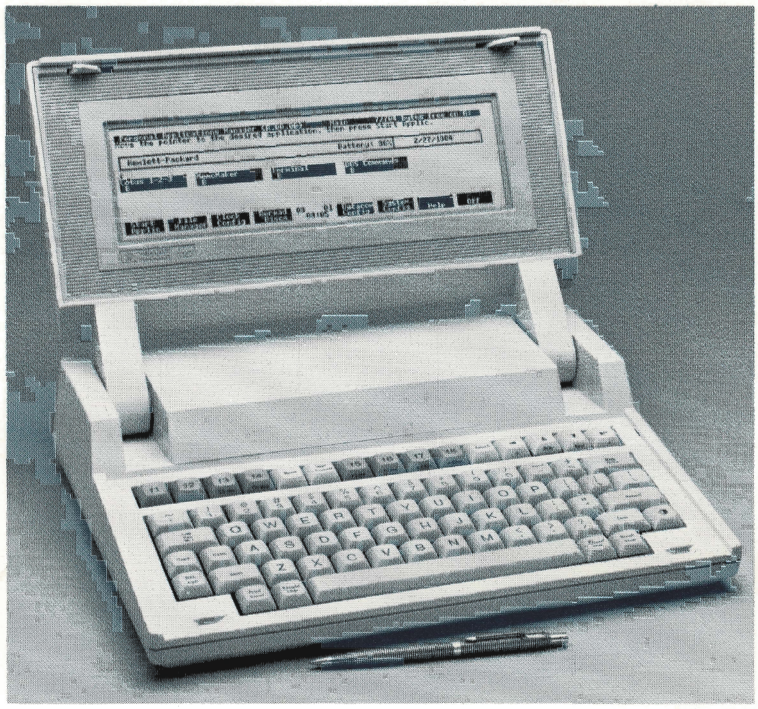
JIM HORN

HP 110

Portable Computer

Service Manual



HEWLETT PACKARD

HEWLETT PACKARD

HP 110 Portable Computer Service Manual

(Including Versions A, AL, BD, BF, BK, BU, and BZ)

For all units with serial numbers before 2440A17889, the service information in this manual must be revised according to chapter 8.

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Chapter 1
Product Information

1.1 Introduction

This manual contains information to help you troubleshoot and repair the HP 110 Portable Computer. Using the information in this manual, you can repair the HP 110 at the assembly level or at the component level.

The manual is divided into nine chapters:

- A description of the HP 110 (chapter 1).
- Installation information (chapter 2).
- An explanation of how the HP 110 works (chapter 3).
- Steps for troubleshooting and repair to assembly level and component level (chapter 4).
- Procedures for removing and replacing HP 110 assemblies (chapter 5).
- Lists of replaceable parts (chapter 6).
- Reference information (chapter 7).
- Product updating information (chapter 8).
- Diagrams (chapter 9).

Information about test equipment is included in section 1.6.

1.2 Description

The HP 110 Portable Computer is a battery-powered computer with a full-sized keyboard and a liquid-crystal display (LCD). The display shows 16 80-character lines of alpha information or 480-by-128 dots of graphic information. The display angle can be adjusted by tilting the hinged top case. The display contrast can be adjusted by pressing the contrast key.

Memory consists of 272K bytes of random-access memory (RAM) and 392K bytes of read-only memory (ROM). An "electronic disc" occupies 208K bytes of RAM (the mass storage RAM). (The user can configure the "electronic disc" to occupy more or less RAM.) An EPROM (erasable, programmable ROM) provides 8K bytes of ROM that contains specialized system information.

The HP 110 provides three external connections for input/output (I/O) operations: an HP-IL (Hewlett-Packard Interface Loop) interface, a serial interface (RS-232-C compatible), and a 300-baud direct-connect modem (except version B—see below).

The computer is powered by a sealed 6-volt lead-acid battery. The battery is recharged using an external ac recharger.

The HP 110 is available in several versions (refer to table 1-1). The "A" versions include a 300-baud direct-connect modem. The "B" versions have no modem.

Table 1-1. HP 110 Versions

Version	Order Number*	Keyboard†	Modem
A (U.S.)	45710A	U.S.	Yes
AL (Canada)	45710AL	U.S.	Yes
BK (International)	45710BK	U.S.	No
BD (Germany)	45710BD	German	No
BF (France)	45710BF	French	No
BZ (Italy)	45710BZ	Italian	No
BU (U.K.)	45710BU	U.K.	No

* The order number is shown on the bottom label of the HP 110 for versions A and AL. For all B versions, the bottom label shows "45710B"—press (Shift)/(CTRL)/(Break) simultaneously to momentarily display the version code (at the end of the serial number), which is used to form the order number.

† Keyboard layouts are shown in figures 9-13 through 9-17.

1.3 Specifications

The specifications for the HP 110 are listed in table 1-2.

Table 1-2. HP 110 Specifications

Physical Properties

- Dimensions: 33.0 × 25.4 × 7.3 cm (13.0 × 10.0 × 2.9 inches) closed.
- Weight: 4 kilograms (8½ pounds) with battery.

Power Requirements

- Battery type: 6-volt, sealed, three-cell, lead-acid battery.
- Battery voltage: 6.3 to 6.5 volts (fully charged).
- Battery capacity: 2½ ampere-hours.
- Recharging time: 95 percent charged in 12 hours if turned off, 20 hours if turned on.
- Consumption: 160 mA typical (power-up, running).
  280 μA typical (power-down).

Table 1-2. HP 110 Specifications (Continued)

Environmental Limits

- Operating temperature: 0 to 45°C (32 to 113°F).
- Storage temperature: −25 to 55°C (−13 to 131°F).
- Humidity: 5 to 95 percent relative humidity (noncondensing).
- Altitude (unpressurized conditions): 4600 meters (15,000 feet) power-up.
  15,000 meters (50,000 feet) power-down.

Display

- Type: liquid-crystal display.
- Area: 24 × 7 cm (9.5 × 2.8 inches).
- Refresh rate: 43.4 Hz.
- Contrast: adjustable via keyboard.
- Alpha formats: 16 lines by 80 characters.
- Graphic format: 480 by 128 dots.

Keyboard

- Design standard: Hewlett-Packard ITF (Integrated Terminal Family).
- Style: full-sized, low-profile keyboard.
- Keys: 76 short-stroke keys.
- Functionality: alphanumeric, display control, edit, special function, function control, and terminal control.

Memory

- ROM: 392K bytes.
- RAM: 272K bytes.
- Display RAM: 8K bytes.

HP-IL Interface

- HP 110 default status: controller.
- Cables: refer to paragraph 1.5.
- Uses: disc drive, printer, plotter, modem, etc.

Serial Interface

- Compatibility: RS-232-C standard.
- Selections: baud, parity, word size, handshake, echo.
- Baud rates: 50, 75, 110, 135, 150, 300, 600, 1200, 1800, 2400, 3600, 4800, 7200, 9600, 19200.
- Connector: Female 9-pin D-subminiature.
- Cables: refer to paragraph 1.5.
- Uses: printer, modem, etc.

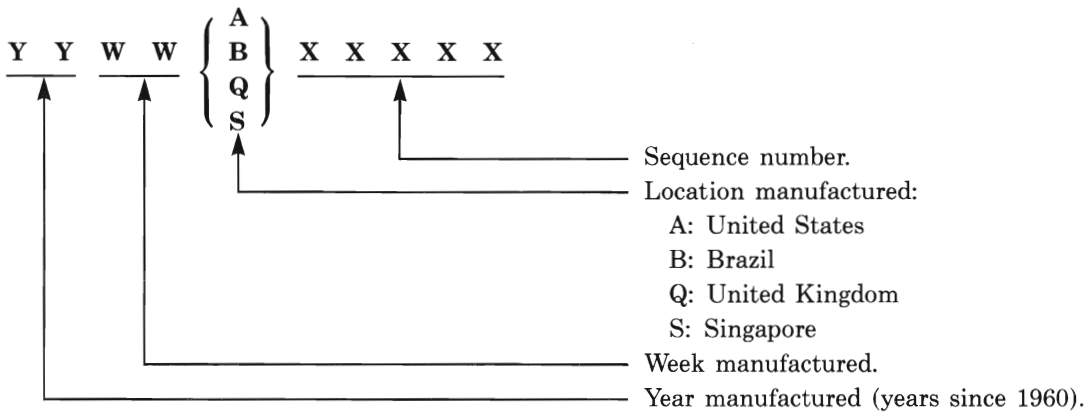
Table 1-2. HP 110 Specifications (Continued)

Modem ("A" versions only)

- Compatibility: Bell 103/113 protocol.
- Operation: full-duplex, asynchronous.
- Baud rate: 300.
- Modes: Originate or Answer.
- Dialing: pulse or tone.
- Answering: automatic or manual.
- Ringer equivalence: 1.3B.

1.4 Identification

The serial number of the HP 110 is used for identification and determination of warranty status. It's located on the bottom case. Its format is described below.



1.5 Accessories

The following accessories are available for the HP 110:

- HP-IL cables
  ½ meter (1½ feet)—model HP 82167A.
  1 meter (3 feet)—model HP 82167B.
  5 meters (16 feet)—model HP 82167D.
- Serial interface cables (with 25-pin D-subminiature connector)
  Modem (DCE) cable (male connector)—model HP 92221M.
  Printer (DTE) cable (male connector)—model HP 92221P.
- Serial interface adapters (25-pin D-subminiature connectors)
  Female adapter (for converting interface cable)—model HP 92222F.
  Custom wiring kit (male and female connectors for customizing interface cables)—model HP 92222W.
- Rechargers (refer to table 4-11).

1.6 Test Equipment

Table 1-3 lists tools and equipment needed to repair the HP 110. The list includes the tools you'll need for troubleshooting and for removing and replacing bad assemblies and components, as described in chapters 4 and 5.

Table 1-3. Recommended Tools and Equipment

HP Part/Model Number	Description
00090-60904*	Diagnostic module.
00090-60910*	Keyboard extension cable.
00090-60915*	Service battery assembly.
00090-60905‡	Service disc.
HP 9114	Disc drive.
00090-60914*	RS-232 test connector.
82167-60001*	HP-IL cable, ½ meter.
HP 6216B†	Power supply, 25 Vdc, 50 mA.
HP 5005A†	Signature analyzer—optional.
00090-90044‡	*HP 110 Signature Analysis Service Supplement.*
HP 180C/1801A/1820C†	Oscilloscope.
HP 10004†	Oscilloscope probe.
8710-1422	Torx® driver, T-8 bit.
8710-1418	Torx® driver, T-10 bit.
8710-1413	Handle for hex bits.
8710-1425	Extension for hex bits—optional.
8710-1220	Hex driver, 5.5 mm.
8710-1590	Hex driver, 10 mm.
8730-0008	Flat-blade screwdriver
8710-0948	Pozidriv® screwdriver
8690-0129	Soldering tool.
8690-0132	Soldering tool stand.
8690-0344	IC desoldering tool—optional.
8700-0003	X-acto® knife.
8700-0006	X-acto® knife blade.

* Included in expensed tool package (00090-67801).

† Or equivalent.

‡ Included in service documentation package (00090-60909).

Chapter 2
Installation

2.1 Preparation

The HP 110 is a truly portable computer. It can be used at a fixed work station, and it can be carried to virtually any location.

A typical work station might require space for peripheral devices, such as a disc drive and a printer. A power outlet would enable the recharger to recharge the battery in the HP 110 (and would provide power for recharging or plugging in any peripheral devices).

For portable use, the HP 110 can be used almost anywhere, since it carries its own battery power. (Refer to the environmental specifications in table 1-2.) Battery-powered peripheral devices might also be used. However, the HP 110 provides an internal "electronic disc" (mass storage memory), which reduces the need for a mass storage device during remote operation.

2.2 Installation

Installation isn't required in order to operate the HP 110. If the battery in the HP 110 is sufficiently charged, the HP 110 is immediately ready to operate as a stand-alone computer. If the battery isn't charged sufficiently, connect a recharger to the HP 110 (figure 2-1)—the computer can be used while the battery is recharging.

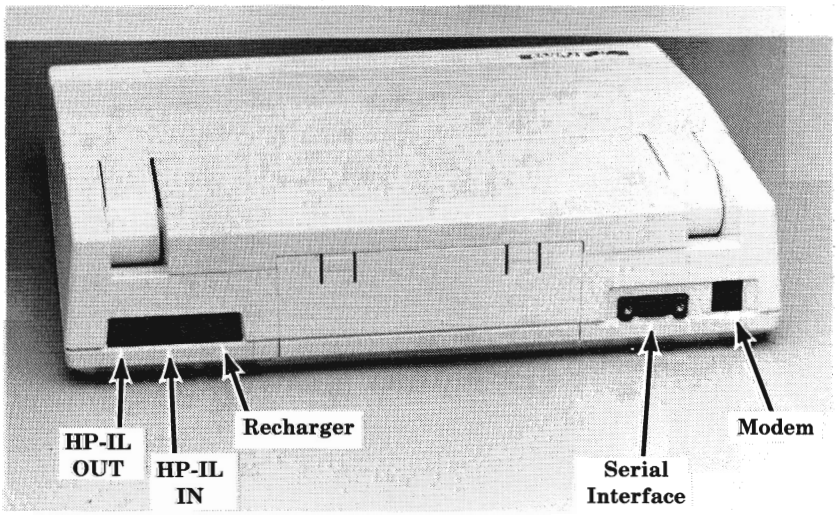


Figure 2-1. Recharger and I/O Receptacles

Peripheral devices are installed by connecting them to one of the three I/O receptacles at the back of the HP 110 (figure 2-1):

- HP-IL devices are connected in series between the computer's IN and OUT receptacles using HP-IL cables. Cables are keyed to ensure proper orientation. All devices must be turned on for the interface to operate.
- One serial device is connected to the serial interface receptacle using a serial interface cable.
- A phone line is connected to the direct-connect modem receptacle using a cable with a standard modular telephone plug. (The Federal Communications Commission requires specific procedures for installing and operating equipment that uses public communications lines. These procedures are described in the owner's manual for the HP 110.)

Cables that are used for connecting HP-IL and serial devices are listed in section 1.5.

2.3 Functional Verification

The built-in diagnostic tests verify that the basic functions in the HP 110 are operating properly. The tests do *not* clear mass storage RAM. You can perform these tests in this way:

1. Turn off the HP 110 (press (f8) in the main P.A.M. screen, if present; otherwise press and hold (◑) for at least 15 seconds).
2. Start the built-in diagnostic test by holding down (Shift) and (Extend char), and pressing (f8). (If the test menu doesn't appear within about 10 seconds, the system isn't operating properly.)
3. Perform all of the built-in tests by pressing the (f4) special-function key.

   The HP-IL test requires either that you connect a good HP-IL cable between the IN and OUT receptacles (for the "no devices" test) or that you connect the HP 110 and one or more devices (turned on) in a loop (the "devices" test). (Refer to section 2.2 for information about connecting HP-IL devices.)

For a good unit, all tests should indicate "ok". An error message or failure code indicates a test didn't pass and service is required.

The built-in diagnostic tests don't test the entire unit. Additional functions are tested by disc-based diagnostic tests that are available to the user on the "Utilities" disc, which comes with the HP 110. More extensive diagnostic tests are provided on the service disc, which is used during troubleshooting. (Refer to chapter 4 for additional information.)

2.4 Configuration

The HP 110 uses software for configuring its settings, rather than using hardware (such as switch settings).

To turn on the HP 110, press any key. The main P.A.M. (Personal Applications Manager) screen should appear in the display.

To adjust the contrast of the display, press (◑) to increase contrast, and press (Shift) (◑) to decrease contrast. Press several times to increase or decrease the contrast even more.

> **Note:** If you hold (◑) for more than about 5 seconds, the system is reset. This affects active operations; it doesn't affect stored files.

To change the clock configuration, press (f3) (Clock Config) in the main P.A.M. screen. From the clock configuration menu, use the tab or cursor keys to select the fields to edit, and use the "Next Choice" and "Previous Choice" function keys to select the desired choice. Use the "Exit Config" function key to return to the main P.A.M. screen.

The system configuration defines memory allocation, timeout operation, display options, and peripheral communications. To change the system configuration, press (f6) (System Config) in the main P.A.M. screen. From the system configuration menu, use the tab or cursor keys to select the fields to edit, and use the "Next Choice" and "Previous Choice" function keys to select the desired choice. Use the "Exit Config" function key to return to the main P.A.M. screen. (Choosing a serial peripheral may require changes in the datacom configuration, discussed next.)

The datacom configuration defines the interaction with serial devices: those connected to the serial interface, and those connected to the HP-IL interface via an HP-IL/RS-232 interface device (HP 82164A HP-IL/RS-232-C Interface). The datacom configuration defines whether the HP 110 uses the serial interface or the direct-connect modem, and defines the baud rate, word length, number or stop bits, and parity. To change the datacom configuration, press (f5) (Datacom Config) in the main P.A.M. screen. From the datacom configuration menu, use the tab or cursor keys to select the fields to edit, and use the "Next Choice" and "Previous Choice" function keys to select the desired choice. Use the "Exit Config" function key to return to the main P.A.M. screen.

Refer to the owner's manual for the HP 110 for more information about the configuration menus.

Chapter 3
Functional Description

3.1 Introduction

The HP 110 Computer consists of 15 basic circuits:

- CPU (central processor unit) circuit.
- System RAM/ROM.
- Mass storage RAM.
- Address/control circuit.
- Configuration EPROM.
- PPU (peripheral processor unit) circuit.
- Keyboard interface.
- Keyboard.
- LCD (liquid-crystal display) interface.
- Liquid-crystal display.
- Clock/ready circuit.
- HP-IL interface.
- Serial interface.
- Direct-connect modem ("A" version only).
- Power supply.

These circuits are connected according to the block diagram shown in figure 3-1. Each circuit is described in this chapter.

Note that "B" version units don't include the modem circuit, but they do include the other 14 circuits listed above.

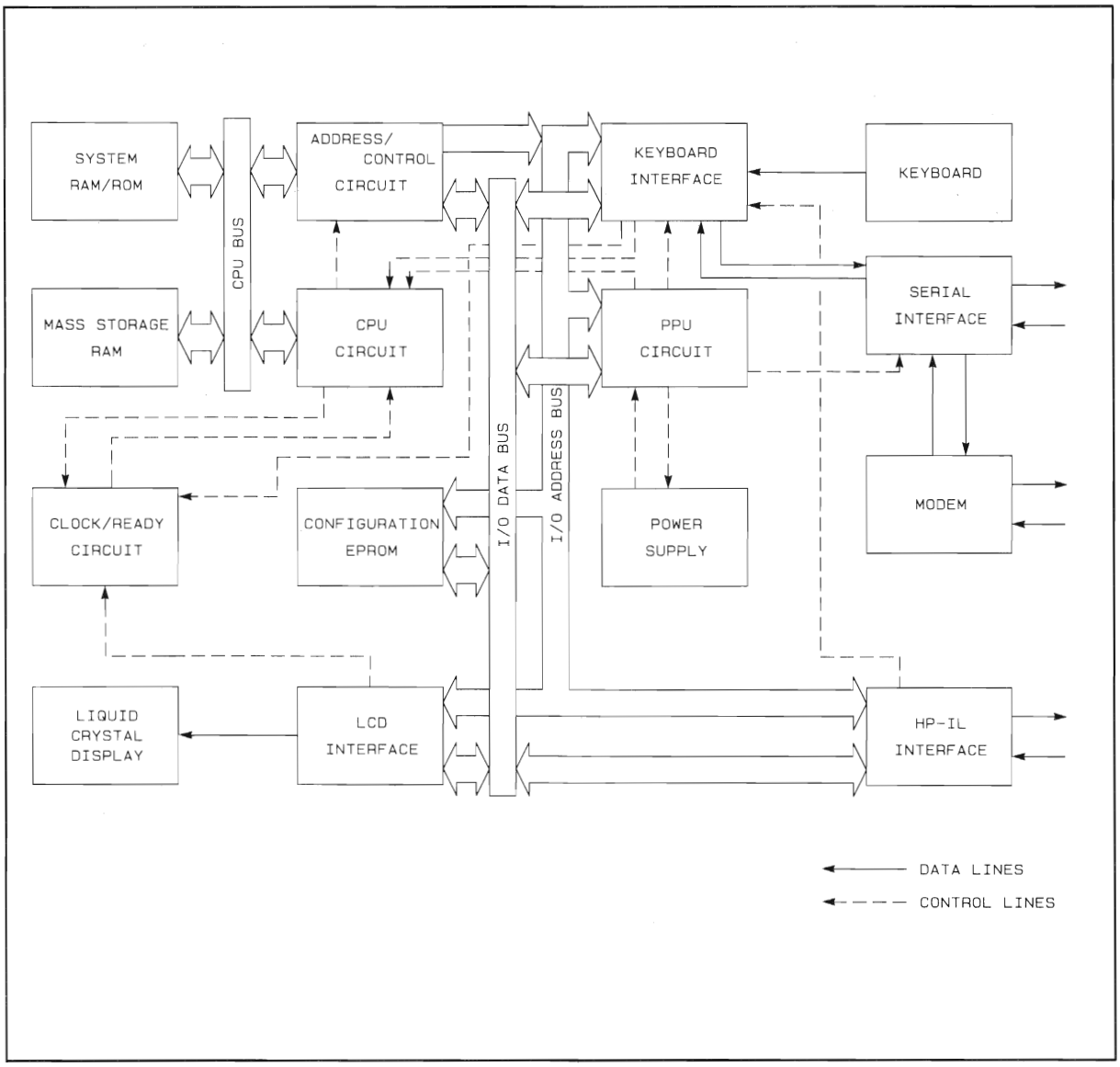


Figure 3-1. HP 110 Block Diagram

The system PCA (assembly A1) contains the CPU circuit, the system RAM/ROM, and the mass storage RAM. The I/O PCA (assembly A2) contains all of the remaining circuits except for part of the modem circuit, which is contained on the modem PCA (assembly A3). The reference designations for each individual component contains a prefix that indicates the PCA. For example, A2U6 indicates component U6 on assembly A2.

Refer to the schematic diagrams in chapter 9 for details about components within each circuit. Table 7-2 in chapter 7 lists the names and descriptions of internal signals used by the HP 110.

3.2 CPU Circuit

This circuit consists of the CPU and four auxiliary circuits that enable the CPU to interact with other main circuits in the HP 110.

3.2.1 CPU

The CPU (A1U1) (figure 9-2, upper left) is a CMOS 16-bit 80C86 microprocessor. It performs these primary functions:

- Controls the operation of circuits according to programs and data stored in system RAM/ROM, mass storage RAM, and the configuration EPROM.
- Directs the transfer of data on the CPU address/data bus and on the I/O data bus.
- Responds to interrupts from the PPU and keyboard interface circuits.

The CPU operates at 5.33 MHz using a clock signal (CLK) provided by the clock/ready circuit.

The CPU communicates using a multiplexed 16-line CPU address/data bus (AD0–AD15)—these lines carry address information and data during separate portions of the bus cycle. Four additional address lines (A16–A19) provide the CPU with 20 address lines in all. Output line M/$\overline{IO}$ selects either 20-bit addresses in main memory (1M-byte address space) or 16-bit addresses in I/O memory (64K-byte address space). Figure 3-2 is the memory map addressed by the CPU.

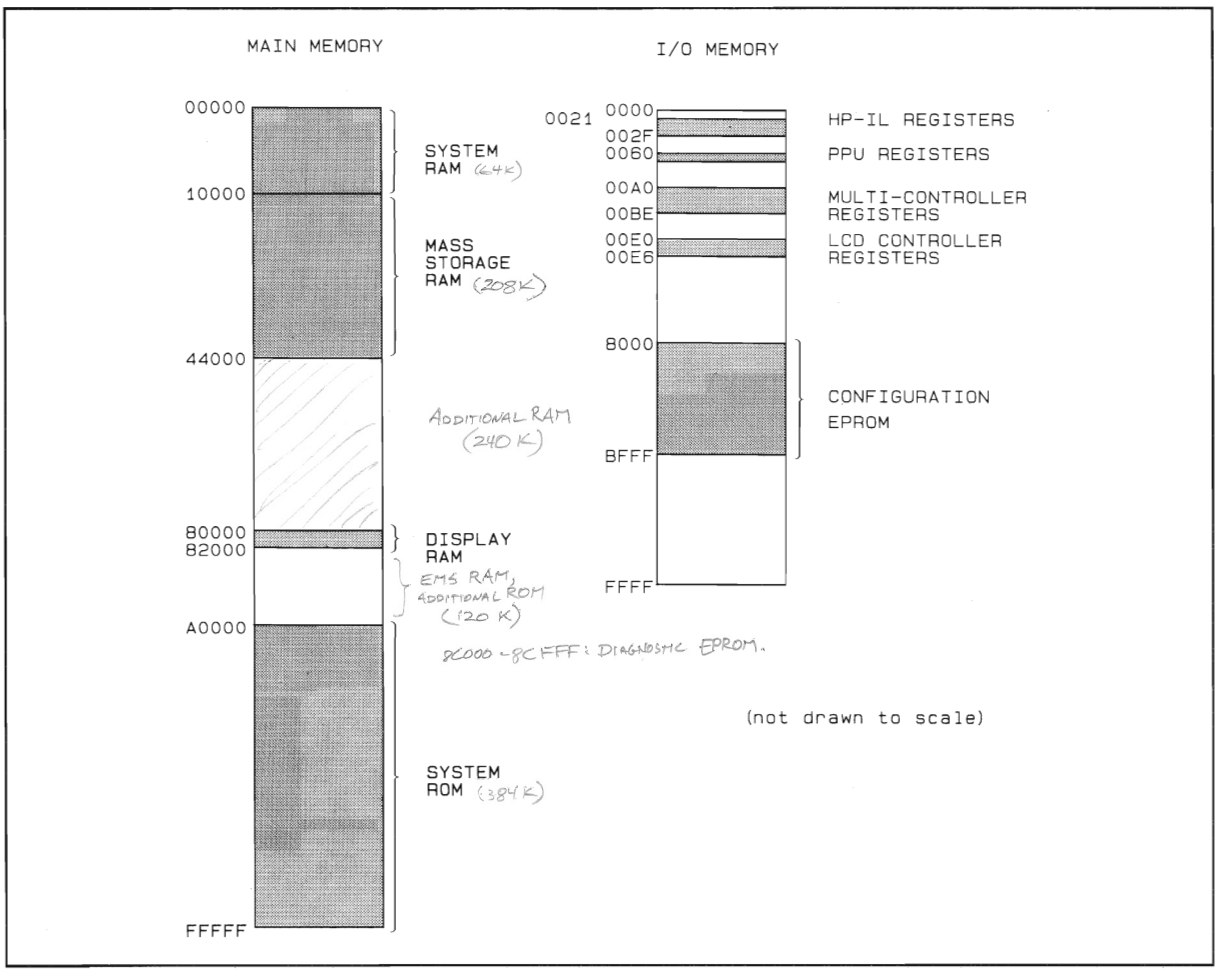


Figure 3-2. CPU Memory Map

During operation, the CPU simultaneously executes program instructions and accesses its data/address bus to fetch instructions and fetch and store data. The following paragraphs describe the basic operation of the multiplexed CPU address/data bus.

During a "read" operation, the CPU holds M/$\overline{IO}$ in the appropriate state for the entire bus cycle (which is at least four clock cycles long). The CPU also holds CDT low during the bus cycle, enabling transceivers to send data at the proper time. During the first step of the operation, the CPU sets CALE high and places an address on the address/data bus (and on the auxiliary address lines). Then CALE goes low, which latches the address at the CPU buffers. During the second step, the CPU removes the address from the bus. Then it sets $\overline{CDEN}$ low, enabling the proper circuit to access the data bus, and sets $\overline{CRD}$ low, signaling that data should be sent by the circuit that's been selected by the address. The CPU then waits for the READY input signal to go high, indicating that data is available on the bus. During the last step, the CPU reads the data, then sets $\overline{CRD}$ high, clearing the data from the bus.

During a "write" operation, the CPU holds M/$\overline{IO}$ in the appropriate state for the entire bus cycle (which is at least four clock cycles long). The CPU also holds CDT high during the bus cycle, enabling transceivers to receive data at the proper time. During the first step of the operation, the CPU sets CALE high and places an address on the address/data bus (and on the auxiliary address lines). Then CALE goes low, which latches the address at the CPU buffers. During the second step, the CPU places data on the bus. Then it sets $\overline{CDEN}$ low, enabling the proper circuit to access the data bus, and sets $\overline{CWR}$ low, signaling that data should be read by the circuit that's been selected by the address. The CPU then waits for the READY input signal to go high, indicating that the data has been read. During the last step, the CPU sets $\overline{CWR}$ high and clears its data from the bus.

Whenever the CPU puts an address on the address/data bus, it also sets the $\overline{BHE}$ line. When low, this signal selects ICs that send or receive data on the upper half of the bus (AD8 through AD15). This signal is used to enable "odd-address" ICs, such as for sending or receiving the higher-order byte of a two-byte (16-bit) word. (Signal AD0 performs the same function for the "even-address" ICs on the lower half of the bus.)

The CPU is interrupted by the keyboard interface circuit or the PPU circuit when either of them sets the INTR input signal high. During the next bus cycle, the CPU starts a "read" operation, but allows the bus to float during the address time, then sets $\overline{INTA}$ low instead of $\overline{CRD}$. It reads the interrupt byte from the low half of the bus during the read time of the bus cycle. (The interrupt byte is generated by A2U36 in the address/control circuit.)

The CRESET input line resets the CPU. While this line is high, the CPU stops operating and remains dormant. When the line drops low, the CPU performs an internal reset sequence, then starts operating according to reset instructions in system ROM.

Power is removed from the CPU during the power-down state. When power is applied at power-up, the CPU initializes itself internally. The high-to-low CRESET transition shouldn't occur until after the CPU is initialized.

3.2.2 CPU Buffers

Buffer A1U2 (figure 9-2, upper center) provides buffered control signals from the CPU. Signals $\overline{CRD}$ and $\overline{CWR}$ are fanned out to system ROM and RAM, mass storage RAM, the address/control circuit, and the LCD interface.

Latch A1U3 transfers address signals from the CPU to other CPU circuits. When CALE is high, the signals are transferred to the CPU circuits. When CALE goes low, the address signals are latched at the output.

3.2.3 Bus Select

This CPU circuit (figure 9-2, upper right) enables appropriate circuits according to the CPU's memory map. A low LM signal indicates that the CPU is using a 16-bit address in I/O memory. A high LM signal indicates a 20-bit address in main memory. Signals SA19 through SA16 represent the most significant bits of a 20-bit address. The enable signals are $\overline{\text{IOEN}}$ (I/O PCA), $\overline{\text{SYSEN}}$ (system RAM/ROM), and $\overline{\text{MSEN}}$ (mass storage RAM). Table 3-1 summarizes the effects of this circuit.

Table 3-1. Bus Select Operation

LM	SA19–SA16	Active Output	Memory Selected
0	0000	$\overline{\text{IOEN}}$	I/O Memory
1	0000	$\overline{\text{SYSEN}}$	System RAM
1	0001 through 0111*	$\overline{\text{MSEN}}$	Mass Storage RAM
1	1000	$\overline{\text{IOEN}}$	Display RAM
1	1001 through 1111*	$\overline{\text{SYSEN}}$	System ROM

* The CPU doesn't use the entire range of values.

This circuit also provides the $\overline{\text{MSSEL}}$ output signal (logically equivalent to $\overline{\text{MSEN}}$) and the $\overline{\text{WAIT}}$ output signal (used by the clock/ready circuit to cause a delay after CALE goes high).

3.2.4 RAM Select

This CPU circuit (figure 9-2, lower center) activates the appropriate select signals to the RAM ICs in response to address information from the CPU. A low A0 signal (from an even address) selects "even-address" ICs, which use the lower half of the bus (AD0 through AD7). A low $\overline{\text{LBHE}}$ signal selects "odd-address" ICs, which use the upper half of the bus (AD8 through AD15). For the transfer of a two-byte (16-bit) word, both AD0 and $\overline{\text{LBHE}}$ are low.

The circuit consists of five 3-to-8 decoders (A1U13 through A1U17) and one dual 2-to-4 decoder (A1U65). They operate on the lower half of the main address space, which contains system RAM and mass storage RAM. A1U17 separates RAM into two 128K-byte blocks and one 16K-byte block according to SA19 through SA17. The first 128K-byte block is split into 8K-byte segments by A1U13 (even CPU addresses) and A1U15 (odd CPU addresses). Similarly, A1U14 and A1U16 split the second 128K-byte block. A1U65 splits the 16K-byte block into two 8K-byte segments (even and odd addresses).

3.2.5 ROM/Display RAM Select

This CPU circuit (figure 9-2, lower right) activates the appropriate select signals to the ROM ICs in response to address information from the CPU. Alternatively, this circuit selects the display RAM when its CPU address is present. (System ROM and display RAM are adjacent in CPU address space.)

The circuit consists of one 3-to-8 decoder (A1U12). It separates the higher 512K-byte block of CPU address space into 64K-byte segments. Each segment in ROM consists of two ICs—one containing the upper bytes of 16-bit words, and one containing the lower bytes. The display RAM segment consists of one 8K-byte IC, which is used to store the upper and lower bytes of 16-bit words in separate registers.

3.3 System RAM/ROM

The system RAM/ROM (random-access memory/read-only memory) circuit (figure 9-3) consists of 8 RAM ICs (A1U20 through A1U27), 12 ROM ICs (A1U52 through A1U63), 2 address latch ICs (A1U4 and A1U5), and 2 data transceiver ICs (A1U8 and A1U9).

Each of the RAM ICs provides 8K bytes of static memory. The RAM ICs normally operate in pairs, with odd-numbered ICs containing the upper bytes of 16-bit words and even-numbered ICs containing the lower bytes. Signals $\overline{\text{U00}}$ through $\overline{\text{U0C}}$ select the upper IC; $\overline{\text{L00}}$ through $\overline{\text{L0C}}$ select the lower IC. Address lines BA1 through BA13 specify the RAM address. (Because the ICs are paired for 16-bit words, the BA0 line is used only to select the "even-address" ICs—refer to section 3.2.4.) Input signals $\overline{\text{WR1}}$ and $\overline{\text{RD1}}$ cause data to be stored in or retrieved from the selected RAM ICs.

Each ROM IC contains 32K bytes of memory. The ROM ICs operate in pairs also, with odd-numbered ICs containing the upper bytes of 16-bit words and even-numbered ICs containing the lower bytes. Signals $\overline{\text{SA}}$ through $\overline{\text{SF}}$ select ICs in pairs. Address lines BA1 through BA13, SA14, and SA15 specify the ROM address. Input signal $\overline{\text{RD1}}$ causes the selected ROM ICs to send data.

The two latches transfer address information from the CPU address/data bus to the RAM and ROM ICs. When CALE is high, the signals are transferred to the CPU circuits. When CALE goes low, the address signals are latched at the output.

The two transceivers buffer data between the CPU address/data bus and the RAM and ROM ICs. The direction of transfer is set by the DT signal from the CPU buffer (high indicates transfer from the CPU). A low $\overline{\text{SYSEN}}$ signal from the CPU bus select circuit enables the transceivers. Data is transferred when the $\overline{\text{WR1}}$ or $\overline{\text{RD1}}$ signal activates the RAM or ROM ICs.

3.4 Mass Storage RAM

The mass storage RAM circuit (figure 9-4) consists of 26 RAM ICs (A1U28 through A1U51, A1U66, and A1U67), 2 address latch ICs (A1U6 and A1U7), and 2 data transceiver ICs (A1U10 and A1U11).

Each RAM IC contains 8K bytes of static memory. The RAM ICs normally operate in pairs, with odd-numbered ICs containing the upper bytes of 16-bit words and even-numbered ICs containing the lower bytes. Signals $\overline{\text{U10}}$ through $\overline{\text{U40}}$ select the upper IC; $\overline{\text{L10}}$ through $\overline{\text{L40}}$ select the lower IC. Address lines MA1 through MA13 specify the RAM address. (Because the ICs are paired for 16-bit words, address line AD0 is used only to select the "even-address" ICs—refer to section 3.2.4) Input signals $\overline{\text{WR2}}$ and $\overline{\text{RD2}}$ cause data to be stored in or retrieved from the selected RAM ICs.

The two latches transfer address information from the CPU address/data bus to the RAM ICs. The latches are enabled by a low $\overline{\text{ADDEN}}$ signal, which is normally derived from address line SA19. When CALE is high, the signals are transferred to the CPU circuits. When CALE goes low, the address signals are latched at the output. A high $\overline{\text{ADDEN}}$ signal saves power by disabling the address latch when mass storage RAM isn't being used by the CPU.

The two transceivers buffer data between the CPU address/data bus and the RAM ICs. The direction of transfer is set by the DT signal from the CPU buffer (high indicates transfer from the CPU). A low $\overline{\text{MSEN}}$ signal from the CPU bus select circuit enables the transceivers. Data is transferred when the $\overline{\text{WR2}}$ or $\overline{\text{RD2}}$ signal activates the RAM ICs.

3.5 Address/Control Circuit

The address/control circuit (figure 9-6, upper right) connects the CPU to the circuits located on the I/O address and data buses. This circuit consists of latches A2U8 and A2U9, transceivers A2U6 and A2U7, decoders A2U21 and A2U22, and buffer A2U36.

The address/control circuit interfaces the multiplexed CPU address/data bus (AD0–AD15) with the I/O address bus (A0–A15) and the I/O data bus (D0–D15). The I/O buses are standard (non-multiplexed) buses. All addresses placed on the I/O address bus come from the CPU. All communication on the I/O data bus is between the CPU and ICs that it selects.

The two latches transfer address information from the CPU address/data bus to the I/O address bus. When CALE is high, the signals are transferred to the CPU circuits. When CALE goes low, the address signals are latched at the output.

The two transceivers buffer data between the CPU address/data bus and the I/O data bus. The direction of transfer is set by the DT signal from the CPU buffer (high indicates transfer from the CPU). A low $\overline{\text{IOEN}}$ signal from the CPU bus select circuit enables the transceivers. Data is transferred when a write or read signal activates the selected IC.

Decoder A2U22 selects individual circuits to transfer data on the I/O data bus. When incoming LM and A15 signals are low, this 3-to-8 decoder uses address lines A5, A6, and A7 to select the HP-IL interface ($\overline{\text{HPILCS}}$), the PPU circuit ($\overline{\text{SYS}}$), the keyboard interface ($\overline{\text{KEYCS}}$), or the LCD interface registers ($\overline{\text{LCDRCS}}$). When the PPU circuit is selected ($\overline{\text{SYS}}$ low), A2U21 provides "write" and "read" signals to that circuit: $\overline{\text{WR1}}$ low produces $\overline{\text{SYSWR}}$ low, $\overline{\text{RD3}}$ low produces $\overline{\text{SYSRD}}$ low.

When signal LM is low, dual decoder A2U21 uses address lines A14 and A15 to select the configuration EPROM ($\overline{\text{ROMCS}}$) to transfer data on the I/O data bus.

All of the circuits selected by the address/control circuit are in the CPU's I/O memory space.

Buffer A2U36 provides the interrupt byte to the CPU. When the CPU sets $\overline{\text{INTA}}$ low, the buffer pulls data bus lines D0 through D7 high. The CPU then reads the interrupt byte (and uses only the lower byte).

3.6 Configuration EPROM

The configuration EPROM (erasable/programmable read-only memory), A2U28 (figure 9-6, center), contains 8K bytes of data that defines certain operating characteristics of the HP 110. A different EPROM is used for each localized version of the HP 110. It normally contains the unit's unique serial number, the checksums for all ROM ICs, and information about keyboard mapping, display fonts, and hardware configuration. The CPU uses this information to determine system operation.

The EPROM is connected to the I/O address and data buses. A low $\overline{\text{ROMCS}}$ signal from the address/control circuit selects the EPROM. Input signal $\overline{\text{RD3}}$ causes the EPROM to send data.

3.7 PPU Circuit

The PPU circuit operates under the direction of the CPU, and controls the operation of several system functions. The primary ICs in this circuit are the PPU (A2U1) and three ICs (A2U16, A2U17, and A2U18B) that provide an interface between the PPU and the I/O data bus.

3.7.1 PPU

The PPU (figure 9-6, lower center) is a self-contained CMOS microcomputer that has 2106 bytes of internal ROM, 112 bytes of internal RAM, and an internal timer. It performs these primary functions according to its internal coding and in response to commands and data received from the CPU:

- Controls the power-down and power-up status of the system.
- Maintains a real-time clock.
- Interrupts the CPU at certain enabled events (interrupt received from keyboard interface during power-down state, contrast key pressed during power-down state, alarm time reached, low-battery condition reached, battery-shutdown condition reached, PPU performed power-up reset).
- Controls the negative LCD supply voltage, which determines the LCD contrast.
- Computes reserve battery power and controls battery recharging.
- Controls the operation of the serial interface and modem.
- Controls the beeper.

The PPU has one input register and one output register. It uses these registers when it communicates with the CPU. The input register accepts commands and data on the SDATIN serial line. The output register sends data on the SDATOUT serial line when directed by the CPU. The DATACLK line provides timing for the serial transfers. (The PPU interface translates between the serial PPU lines and the parallel I/O data bus.)

The CPU talks to the PPU only when the PPU isn't busy. (The PPU indicates its busy status by its BUSY line, which stores this status in a register in the multi-controller (A2U2); the CPU reads this multi-controller register to determine the PPU busy status.) If the CPU directs the PPU to send data of some type, the PPU sets BUSY low when the data is available.

The PPU interrupts the CPU by setting the $\overline{\text{KEYIRQ}}$ line low. Otherwise, the PPU lets this line float. ($\overline{\text{KEYIRQ}}$ is also tied to an output line of the multi-controller, so the PPU never pulls this line high.) The $\overline{\text{KEYIRQ}}$ signal causes a high INTR signal to the CPU. The CPU determines the cause of the interrupt by fetching the interrupt status from the PPU, then takes appropriate action. During a power-down condition, the PPU uses $\overline{\text{KEYIRQ}}$ as an input line that indicates an interrupt from the multi-controller.

The power supply is monitored and controlled by the PPU. The power supply indicates its condition using four signals that it provides to the PPU. The $\overline{\text{CHARGE}}$ signal is low whenever an ac recharger is connected. The LOBAT and SHUTDOWN signals go high as the battery voltage decreases below given levels. The PPU uses these signals to determine the condition of the battery. If LOBAT goes high, the PPU interrupts the CPU, which warns the user of a low-battery condition. If SHUTDOWN goes high, the PPU interrupts the CPU with this information, causing the system to go to its power-down condition. If a charger is connected ($\overline{\text{CHARGE}}$ low) and rapid charging is required ($\overline{\text{BATDOWN}}$ low), the PPU sets its FAST signal high to the power supply.

The PPU maintains a computed battery charge level based on power-up time and recharging time. It sends this data when requested by the CPU.

The PPU controls the system power status. The PPU interrupts the CPU if power-down is required (no CPU activity for a specified period, or a battery shutdown condition is indicated by the SHUTDOWN power supply signal). When directed by the CPU, the PPU sets its SLEEP output high, which turns off the switched voltage supply (VCC2) and the LCD voltage supply (LCDNEG), and reduces the unswitched voltage supply (VCC1) to 3 volts. This turns off the CPU, the LCD controller, the HP-IL controller, and the clock/ready circuit, and places the multi-controller in an active, low-power state (for keyboard input). Note that the PPU itself is always on.

If the system is in its power-down condition, any of three events causes the PPU to power-up the system: the multi-controller indicates a keyboard interrupt by setting $\overline{\text{KEYIRQ}}$ low, the contrast key is pressed (bringing line C13 low), or the PPU clock reaches a preset alarm time. When an event occurs, the PPU sets its SLEEP output low, which restores VCC2 and LCDNEG to system circuits. It holds $\overline{\text{RESET}}$ low to initialize circuits, then sets LCDEN high (to enable the display circuit) and BEEP high. (Refer to section 3.17.)

While the system is in its power-up condition, the PPU monitors the C13 and C10 lines (from the contrast and Shift keys). It uses this information to determine the desired display contrast and sets four output lines (STEP8, STEP4, STEP2, STEP1) in the appropriate pattern so that the power supply generates the proper LCD voltage.

The serial interface and modem are controlled by the PPU (even though data sent and received by these circuits is handled by the multi-controller in the keyboard interface circuit). The modem uses part of the serial interface circuit, and therefore only one of these I/O circuits can be active at a time. Three PPU output lines (TRANSEN/$\overline{\text{RTS}}$, SELFTEST/$\overline{\text{DTR}}$, and ORIG/RS232PWR) have dual labels—the first part indicates the modem function, the second part indicates the serial function.

The PPU selects the serial interface by setting the $\overline{\text{MODEMON}}$ line high. The RS232PWR signal from the PPU turns on the positive- and negative-voltage supplies for the serial drivers. Under the direction of the CPU, the PPU controls output lines $\overline{\text{DTR}}$ and $\overline{\text{RTS}}$ to the serial interface.

The PPU selects the modem circuit by setting the $\overline{\text{MODEMON}}$ line low. It also sets MODEMEN high, which establishes the 1-MHz modem clock. The PPU sets OFFHOOK high to prepare the modem circuits for sending and receiving signals. OFFHOOK is also toggled (switched) to generate pulse-dialing signals. When directed by the CPU to send dial tones, the PPU indicates the appropriate telephone-button row-column combinations using the row lines ($\overline{\text{MR1}}$ through $\overline{\text{MR4}}$) and column lines ($\overline{\text{MC1}}$ through $\overline{\text{MC3}}$). The ORIG output signal from the PPU sets the modem to originate mode (low-band transmit carrier) or answer mode (high-band transmit carrier). The TRANSEN output enables the modem to send data. The SELFTEST output causes the modem to enter its self-test mode, in which it routes output data from the keyboard interface back to the keyboard interface, testing part of the modem circuit.

When directed by the CPU, the PPU toggles its BEEP output at 240 Hz. This signal drives the piezoelectric transducer (beeper) located in the top case. This produces an audible tone.

The PPU has its own 1-MHz crystal oscillator, which enables the PPU to run while the clock/ready circuit is powered down.

A low signal on the PWO input line resets the PPU. When power is first applied to the system and VCC1 is established, capacitor A2C5 holds PWO low long enough to reset the PPU. This enables the PPU to begin operating from a known condition. If PPU operation becomes disrupted for any reason (or if it doesn't reset properly when power is applied), a button on the battery terminal block PCA grounds the PWO line, resetting the PPU (and multi-controller).

3.7.2 PPU-Bus Interface

Three ICs (A2U16, A2U17, and A2U18B) (figure 9-6, lower center) provide a serial-parallel interface between the serial PPU data lines (SDATIN and SDATOUT) and the lower half of the I/O data bus (D0 through D7).

The CPU views this circuit as one eight-bit read/write register in I/O memory. The address/control circuit enables either shift register A2U17 for a "write" operation, or shift register A2U16 for a "read" operation. During a "read" operation, the CPU must wait for PPUBUSY to go low before attempting to read data. (The multi-controller causes an interrupt when PPUBUSY goes low.)

The PPU views this circuit as a 17-bit shift register. When the CPU sends data to the PPU, the address/control circuit sets $\overline{\text{SYSWR}}$ low. This signal causes shift register A2U17 to load the data. The $\overline{\text{SYSWR}}$ signal also causes flip-flop A2U18B to set SDATIN high to the PPU and also sets PPUBUSY high to the multi-controller (via A2U23D). The PPU observes the SDATIN signal and sets BUSY high, which keeps PPUBUSY high. The PPU then shifts in 17 bits using its DATACLK clock signal, causing the CPU data to shift from A2U17 to the PPU SDATIN line (via A2U16 and A2U18B).

The PPU sends data to the CPU in response to receiving a command to do so from the CPU. The PPU shifts out 17 bits on its SDATOUT line using the DATACLK clock signal. The second through ninth bits shift into shift register A2U16 (via A2U17). The PPU then sets its BUSY line low, causing PPUBUSY to go low and causing an interrupt at the multi-controller. The CPU then addresses the PPU and reads the data (the address/control circuit sets $\overline{\text{SYSRD}}$ low, causing A2U16 to place the data on the data bus).

3.8 Keyboard Interface

The keyboard interface (figure 9-6, upper right) is basically the multi-controller (A2U2), which performs several functions:

- Buffers row and column information from the keyboard.
- Interrupts the CPU when certain enabled events occur (interrupts PPU when in power-down condition).
- Sends and receives serial data from the serial interface (and modem).
- Stores the busy status of the PPU for access by the CPU.
- Provides interval timing for keyboard operations.

The CPU controls the multi-controller by reading and writing data in 16 registers in the multi-controller, usually in response to an interrupt from the multi-controller. The CPU selects the multi-controller by setting the $\overline{\text{KEYCS}}$ line low. The CPU addresses a register using the I/O address bus (lines A1 through A4). Input lines $\overline{\text{RD3}}$ and $\overline{\text{WR1}}$ indicate whether an output or input register is selected. Data is sent or received by the multi-controller on the I/O data bus (lines D0 through D7). When the multi-controller has completed its task, it sets its KEYRDY line high to the clock/ready circuit, which provides the READY signal to the CPU.

Several interrupt events can be enabled by the CPU, causing the multi-controller to interrupt the CPU when an event occurs: any key line changes state, PPU sets PPUBUSY high, HP-IL controller sets $\overline{\text{HPILIRQ}}$ low, serial interface sets $\overline{\text{RING/RxCAR}}$ or CARRIER low, or serial data has been sent or received by the multi-controller. When one of these events occurs, the multi-controller sets its $\overline{\text{KEYIRQ}}$ line low to the CPU. (If the multi-controller is in its power-down condition, keyboard input and $\overline{\text{RING/RxCAR}}$ low are the only events that can occur. If one occurs, the $\overline{\text{KEYIRQ}}$ signal is detected by the PPU, which sets the system to its power-up condition.) In response, the CPU can determine the event by reading the multi-controller register that contains interrupt data.

Input lines (R1 through R8 and C1 through C9) convey keyboard input to the multi-controller. Each main key is identified by the multi-controller by the unique row-column pair. The Shift, CTRL, and Extend-char keys have separate lines (C10 through C12). (Note that the C13 contrast key line doesn't connect to the multi-controller.) The multi-controller samples the keyboard at 86.0 kHz. During each keyboard-sampling cycle, the multi-controller first drives all column lines high and checks for one row line that's pulled high; it then drives all row lines low and checks for one column line that's pulled low. (Column lines C10 through C12 are sampled when the other column lines are sampled.) The multi-controller usually applies a debounce interval to keyboard input before entering the keystroke into its row and column registers. After receiving an interrupt, the CPU can read the keystroke from those registers.

The multi-controller sends and receives serial data from the serial interface (and the modem, which shares serial interface circuitry). The serial output line (SOUT) and serial input line (SIN) connect to the serial interface circuit. The baud rate, parity, word length, and stop bit length for the multi-controller are set by the CPU. Data clocking is performed internally by the multi-controller using the 2.67-MHz KEYCLK signal as its reference. The PPU selects either the serial interface or the modem; the multi-controller passes the serial data.

While the serial interface is selected, a low $\overline{\text{RING/RxCAR}}$ input signal indicates that the serial interface has received a ring signal. A low CARRIER signal from the serial interface indicates that the serial interface isn't receiving a carrier signal. (Refer to section 3.14 for information about the serial interface.)

While the modem is selected, the $\overline{\text{RING/RxCAR}}$ signal toggles at the same frequency as the received signal, such as a ring signal or a carrier signal. A low CARRIER signal from the modem indicates that the modem isn't receiving a carrier signal of sufficient amplitude. (Refer to section 3.15 for information about modem operation.)

The $\overline{\text{RESET}}$ line from the PPU determines the power condition of the multi-controller. If $\overline{\text{RESET}}$ is high, the multi-controller operates at full power and performs all of its normal functions. If $\overline{\text{RESET}}$ is low, the multi-controller operates in its power-down condition, in which most of its functions are inactive. In this condition, all keybaord row lines are held low, it monitors the keyboard column lines and the $\overline{\text{RING/RxCAR}}$ line, and it sets $\overline{\text{KEYIRQ}}$ low if it receives input on any of those lines.

A low signal on the PWO input line resets the multi-controller. When power is first applied to the system and VCC1 is established, capacitor A2C5 holds PWO low long enough to reset the multi-controller. This enables the IC to begin operating from a known condition. If its operation becomes disrupted for any reason (or if it doesn't reset properly when power is applied), a snap-disc button on the battery terminal block PCA grounds the PWO line, resetting the multi-controller (and PPU).

3.9 Keyboard

The keyboard (figure 9-11) consists of a full-sized, low-profile keyboard with short-stroke keys. The keys are connected in a matrix of eight rows by nine columns (the Shift, CTRL, Extend-char, and contrast keys have individual lines to the multi-controller or PPU). When a key is pressed, the corresponding row and column lines are connected; this is detected by the keyboard interface circuit.

3.10 LCD Interface

The LCD interface consists of the LCD controller (A2U3), the display RAM (A2U5), and the I/O bus latches and buffers (A2U10 through A2U15). The LCD controller controls the circuit. The display RAM stores information from the CPU that's used to create the displayed output. The latches and buffers link the I/O address and data buses to the private LCD address and data buses, but they also enable the LCD buses to operate independently of the I/O buses.

3.10.1 LCD Controller

The LCD controller (figure 9-6, lower right) performs the following functions:

- Reads current display data from the display RAM.
- Provides all timing and data signals to drive the liquid-crystal display.
- Implements four display modes.
- Controls CPU access to the display RAM.

The primary purpose of the LCD controller is to drive the display. It does this using information initially provided by the CPU: display data stored in display RAM, and operating information stored in LCD controller registers.

The operating information in the internal registers determines the display format (16-line alpha, 12-line alpha, graphics, or blank), the cursor positions, and the display position. The LCD controller uses this information while it generates the display. To generate the display, the LCD controller retrieves data from the display RAM (character codes and font information, or dot pattern information), interprets this data (and modifies it if necessary for inverse or blinking characters), and sends it to the display. By repeating this process as it cycles through all display positions, the LCD controller continually regenerates the displayed output.

To retrieve display data from the display RAM, the LCD controller specifies the RAM address on the LCD address bus (RA0 through RA12), selects the RAM IC by setting $\overline{\text{RAMCS}}$ low, and specifies a "read" operation by setting $\overline{\text{RAMOE}}$ low. The specified display data is received on the LCD data bus (LD0 through LD7). (The LCD controller sets $\overline{\text{RAMRW}}$ low for a RAM "write" operation.)

The LCD controller generates all of the signals needed to generate the displayed output. It separates the display area into four quadrants, and provides an internal shift register and a serial data line (SD1 through SD4) for each quadrant. It also provides four clock signals: FLM (43.4 Hz), CL1 (2.78 kHz), CL2 (667 kHz), and M (21.7 Hz). The FLM signal represents the refresh rate of the display; it marks the start of each scan cycle. The CL1 signal marks the beginning of each row scan (64 dot rows per quadrant). The CL2 signal marks each "dot" (240 dots per row in each quadrant); for each CL2 cycle, the LCD controller sends one "dot" to each quadrant. The M signal marks each alternation of the biasing signal to the liquid-crystal display; the alternating bias for each refresh cycle minimizes degradation of the display.

Although the LCD controller repeatedly reads data from the display RAM, it also provides "access windows" during which the CPU can access the display RAM or the LCD controller registers.

To access display RAM, the CPU circuit sets $\overline{\text{LCDMCS}}$ low, places the desired address on the I/O address bus (A0 through A15), and sets $\overline{\text{WR1}}$ or $\overline{\text{RD3}}$ low (to write or read from RAM). The LCD controller sets LCDRDY low until the access is possible. During the next access window, the LCD controller sets LCDRDY high, then sets $\overline{\text{ADD}}$ low to latch the address on the LCD address bus, and sets up the display RAM for the operation using $\overline{\text{RAMCS}}$ and $\overline{\text{RAMRW}}$ (write) or $\overline{\text{RAMOE}}$ (read). It then enables either the input buffers by setting $\overline{\text{INL}}$ and $\overline{\text{INH}}$ low, or the output buffers by setting $\overline{\text{OUT}}$ low and LAL and LAH high. (The high bus isn't enabled for one-byte transfers, as indicated by the $\overline{\text{LBHE}}$ CPU signal.) The LCD controller sets LCDRDY low when the transfer is completed. For a 16-bit operation, the LCD controller executes the operation on its bus as two 8-bit operations.

The CPU procedure for accessing LCD controller registers is similar to that for accessing display RAM, except that the CPU sets $\overline{\text{LCDRCS}}$ low (rather than $\overline{\text{LCDMCS}}$). The LCD controller latches the address and enables the buffers as described above (but it doesn't enable the display RAM).

The timing for the LCD controller is provided by the KEYCLK signal (2.67 MHz) from the clock/ready circuit. The LCD controller is enabled by a high LCDEN signal from the PPU.

3.10.2 Display RAM

The 8K-byte display RAM (A2U5) (figure 9-6, lower right) is used to store information that's displayed on the liquid-crystal display. The display data is generated and placed in RAM by the CPU. The LCD controller retrieves the data and sends it to the display.

If the CPU has set the system for an alpha display, it uses the first 6K bytes of RAM to store character codes (and special display information), and uses the last 2K bytes of RAM to store character font data (6 × 8 dot patterns). The CPU fetches the font data from the configuration EPROM at power-up.

If the CPU has set the system for a graphics display, it uses all 8K bytes of RAM to store the graphics image (480 × 128 dots).

The display RAM is enabled by the LCDEN signal from the PPU. The LCD controller controls all access to the display RAM using the $\overline{\text{RAMCS}}$, $\overline{\text{RAMRW}}$, and $\overline{\text{RAMOE}}$ signals.

3.10.3 Bus Latches and Buffers

The bus latches and buffers (figure 9-6, lower right) link the I/O address and data buses to the private LCD address and data buses. These ICs also enable the LCD buses to operate independently of the I/O buses.

When selected by the $\overline{\text{ADD}}$ signal from the LCD controller, the address latches (A2U14 and A2U15) transfer a 13-bit address to the LCD address bus. This address might apply to either the display RAM or the LCD controller registers.

The LCD data bus is an eight-line bus (the I/O data bus has 16 lines). Data transfers are therefore performed in two steps: one step transfers the upper byte and one transfers the lower byte.

When selected by the $\overline{\text{INH}}$ or $\overline{\text{INL}}$ signal from the LCD controller, one of the input buffers (A2U12 or A2U13) transfers one byte (upper or lower) from the I/O data bus to the LCD data bus. When enabled by the LAH or LAL signal from the LCD controller, one of the output buffers (A2U10 or A2U11) latches one byte (upper or lower) from the LCD bus; both bytes are transferred to the I/O bus when the $\overline{\text{OUT}}$ signal from the LCD controller goes low.

The latches and input buffers are enabled by the LCDEN signal from the PPU.

3.11 Liquid-Crystal Display

A 480-by-128 dot liquid-crystal display provides visual output. Alpha output is displayed as either 16 or 12 lines of 80 characters. Graphics output is displayed as a 480-by-128 dot pattern.

The display is separated into four quadrants, each having one serial input data line (SD1 through SD4). The displayed dot pattern in each quadrant is specified dot-by-dot by data on its serial line. Four clock signals provide timing: FLM (43.4 Hz) starts each screen cycle, CL1 (2.78 kHz) starts each row scan, CL2 (667 kHz) marks each data bit on the serial data line, and M (21.7 Hz) marks each alternation of the biasing signal. All of these signals are sent by the LCD controller.

The display requires two supply voltages from the power supply: VCC2 and LCDNEG. These two supplies are present when the system is in its power-up condition. The display turns off when the system switches to its power-down condition (because these supplies turn off).

The LCDNEG voltage controls the contrast of the display. The power supply (under control of the PPU) can vary this voltage over the range of about -7 to -12 Vdc. Contrast is maximized when LCDNEG is most negative.

3.12 Clock/Ready Circuit

The clock/ready circuit (figure 9-6, lower left) consists of a clock IC (A2U19), a counter (A2U20), and several logic gates. This circuit performs the following functions:

- Provides timing signals for the CPU, the multi-controller, the LCD controller, the HP-IL interface, the modem, and the ready circuit.
- Synchronizes accesses by the CPU to other circuits.

Note that this circuit does *not* provide the real-time clock; the PPU performs that function.

The clock IC generates the fundamental clock signal (OSC) at 16.00 MHz. The frequency is derived from crystal A2Y2. The clock IC includes dividers that produce two other clock signals: a 5.33-MHz signal that is used by the ready circuit and that produces the CLK signal for the CPU, and the 2.67-MHz KEYCLK signal for the multi-controller and the LCD controller.

The 16-MHz OSC signal is divided by counter A2U20 to produce a 2-MHz signal and a 1-MHz signal. The 2-MHz signal is gated with LCDEN to produce the HPILCLK signal for the HP-IL interface circuit. The 1-MHz signal is gated with MODEMEN to produce the MODEMCLK signal for the modem.

The ready portion of this circuit generates the READY signal to the CPU according to the conditions of other circuits. (The multi-controller and the LCD controller have specific access times that are indicated by the KEYRDY and LCDRDY signals.) Basically, this circuit keeps RDYI high while KEYRDY and LCDRDY are high (the keyboard interface and LCD interface are ready). When either of these circuits sets KEYRDY or LCDRDY low (it isn't ready for CPU interaction), the ready circuit sets RDYI low. The clock IC synchronizes the RDYI signal to the CLK signal and sends it on the READY line to the CPU.

The clock IC also synchronizes the $\overline{\text{RESET}}$ signal from the PPU to the CLK signal and inverts it on the CRESET line to the CPU.

The counter generates a one-cycle wait interval used for system timing. Each time CALE goes high from the CPU, the counter sets W2 high after one cycle of the 5.33-MHz clock signal.

3.13 HP-IL Interface

The HP-IL interface (figure 9-6, upper center) consists of the the HP-IL controller (A2U4) and associated components. This circuit performs two functions:

- Provides the link between the CPU and HP-IL devices.
- Transfers control information from the serial interface to the CPU.

The HP-IL controller operates under control of the CPU. The CPU can write to and read from eight registers in the HP-IL controller. These registers control the operation of the HP-IL controller and indicate information about its status, interrupt conditions, and HP-IL conditions. The HP-IL controller performs many HP-IL operations automatically, requiring CPU interaction for only certain situations.

The CPU selects the HP-IL controller by setting $\overline{\text{HPILCS}}$ low. The I/O address bus (A1, A2, and A3) selects the HP-IL control register to be accessed. The CPU sets $\overline{\text{WR1}}$ or $\overline{\text{RD3}}$ low causing the HP-IL controller to receive or send data on the upper I/O data bus (D8 through D15).

The CPU can enable certain HP-IL conditions as interrupt events by writing to the interrupt register in the HP-IL controller. The HP-IL controller signals an interrupt event by setting its $\overline{\text{HPILIRQ}}$ output low to the multi-controller (which uses its $\overline{\text{KEYIRQ}}$ signal to cause a high INTR signal to the CPU).

Two signals from the serial interface (DSR and CTS) are received by the HP-IL controller. The controller uses these input signals to set bits in one of its internal registers. The CPU can read this register to determine the states of these signals during serial I/O operations.

The HP-IL controller receives serial data on its RDx0 and RDx1 input lines. A pulse transformer (A2T1) steps up the voltage and provides isolation from the external HP-IL system. Resistors A2R70 and A2R71 provide impedance matching. Zener diodes A2VR6 and A2VR7 protect against high-voltage transients.

The HP-IL controller sends serial data on its TDx0 and TDx1 output lines. A low-pass filter (A2C16, A2C17, A2R72, and A2R73) provides impedance matching. Zener diodes A2VR4 and A2VR5 protect against excessive output levels. A pulse transformer (A2T1) steps down the voltage to the proper level and provides isolation.

The HP-IL controller is enabled by the LCDEN signal from the PPU. The 2-MHz HPILCLK signal from the clock/ready circuit provides timing.

3.14 Serial Interface

The serial interface (figure 9-8, left) is compatible with RS-232-C specifications (and CCITT V.24 and CCITT V.28 specifications). This circuit consists of multiplexers (A2U41 and A2U42), receivers (A2U40), drivers (A2U39), and a voltage-doubler circuit (A2U38, A2Q38, and A2Q39). The serial interface performs the following functions:

- Links the main system and the serial port.
- Provides part of the link between the main system and the modem circuit.

The multiplexers connect the PPU and multi-controller to either of two I/O ports: the serial port or the modem. When the $\overline{\text{MODEMON}}$ signal is high, the multiplexers connect the rest of the serial interface circuit to the PPU and multi-controller. When $\overline{\text{MODEMON}}$ is low, the multiplexers connect the modem circuit to the PPU and multi-controller.

Data to be sent by the serial interface is formatted in serial form by the multi-controller and then sent to the serial interface. Data received by the serial interface is sent to the multi-controller, which stores the data until it's read by the CPU.

The receivers convert signal levels from the serial device (about +10V and −10V) to internal logic levels (+5V and 0V) and inverts them. After incoming control signals CTS and DTR pass through the receivers, they're inverted and buffered by transistors A2Q37 and A2Q40 before going to the HP-IL controller. The incoming RS232CARRIER signal passes through two receivers.

The drivers convert signal levels from internal logic levels to signal levels needed for the serial device. The output signal levels are provided by the voltage-doubler circuit.

The voltage-doubler circuit generates the voltage levels needed for serial output signals (about +10V and −10V). When the RS232PWR signal is low, A2Q41 is off, and NOR gates A2U38 are in a stable condition that leaves A2Q38 off and A2Q39 on; the V+ and V− voltages aren't generated. When the RS232PWR signal is high, A2Q41 is on, and NOR gates A2U38 continually change states, toggling A2Q38 and A2Q39 off and on alternately at about 11 kHz. From their output, the diode-capacitor doubling circuits generate the unregulated V+ and V− voltages.

3.15 Direct-Connect Modem

The direct-connect modem (figure 9-8, lower, and figure 9-10) communicates with the PPU and multi-controller by way of the multiplexers in the serial interface. The modem is compatible with Bell 103/113 protocol. It operates at 300 baud, provides tone and pulse dialing, and operates in originate and answer modes. It consists of several circuits: power switch, modem IC, tone-dial generator, filter, duplexer, protective interface, prelimiter, limiter, carrier detector, and billing delay.

Data to be sent on the phone line by the modem is formatted in serial form by the multi-controller and passed to the modem circuit. The modem circuit transforms each serial bit into a tone of the appropriate frequency and sends it on the phone line. Data is received by the modem as a series of tones, which the modem converts into a sequence of bits. The serial data is passed to the multi-controller, which stores the data until it's read by the CPU.

Because the phone line supports simultaneous two-way communication, the frequencies used to convey data in one direction differ from those used for the opposite direction. Table 3-2 lists the frequencies used by the modem circuit. Originate mode is normally used by the modem at the calling station.

Table 3-2. Modem Frequencies

Operation	Originate Mode Frequency	Answer Mode Frequency
Transmit:		
"0" (space)	1070 Hz	2025 Hz
"1" (mark)	1270 Hz	2225 Hz
Receive:		
"0" (space)	2025 Hz	1070 Hz
"1" (mark)	2225 Hz	1270 Hz

The Federal Communications Commission (FCC) specifies a number of specifications with which a direct-connect device must comply. The modem circuit is designed to comply with these specifications.

3.15.1 Power Switch

The power switch (figure 9-10, lower left) turns on the MPWR supply when $\overline{\text{MODEMON}}$ is low from the PPU. Transistor A3Q32 performs this function. To conserve power, the PPU normally sets $\overline{\text{MODEMON}}$ high when the modem circuit isn't being used.

3.15.2 Modem IC

The modem IC (A3U32) (figure 9-10, center) performs the main functions of converting digital data to tones and converting incoming tones to digital signals. The operating mode of the modem (Originate or Answer) detemines the frequencies to be sent on the output line (TxCAR) and the frequencies to be detected on the input line (RxCAR). The operating mode is indicated by the PPU on the ORIG line (M input).

Data to be transmitted is received at the TxD input. The modem IC converts the digital signal to a digitally-synthesized analog signal at the TxCAR output. The analog signal is created using eight discrete voltage levels from about 1V to 2V. Harmonics of the fundamental frequency are suppressed (but not eliminated) by this technique. In addition, some high-frequency switching noise is also present in the output. (The output signal is filtered again by the filter circuit.)

Data is received by the modem IC on its RxCAR input. The input signal is a square wave between 0V and 5V. The modem IC measures each half-cycle period to detemine the frequency of the analog signal. It sets its RxD output to the corresponding digital level. Because the IC measures each half-cycle, good output stability requires that the analog signal have a 50-percent duty cycle. (This is provided by the prelimiter and limiter circuits.)

After MPWR is turned on, the PPU enables the MODEMCLK (XI input) line, which provides the 1-MHz timing signal. The PPU enables the modem IC for transmission by setting TRANSEN (TxE input) high; this same signal enables data to reach the modem IC by way of A3U37A and A3U37B.

The PPU can set SELFTEST (ST input) high to activate the modem IC self-test mode. In this mode, the IC uses the same frequency band for its output and input. In this way, the modem IC can demodulate its own modulated data.

3.15.3 Tone-Dial Generator

The tone-dial generator (A2U33) (figure 9-8, lower left) is activated when the $\overline{\text{MODEMON}}$ signal goes low from the PPU. The generator scans the column lines ($\overline{\text{MC1}}$ through $\overline{\text{MC3}}$) and generates the high-frequency signal (HB) that corresponds to the low column line. Similarly, the row lines ($\overline{\text{MR1}}$ through $\overline{\text{MR4}}$) determine the low-frequency signal (LB). No tones are produced unless both a row line and a column line are active. (The tone-dial signals are combined by the filter circuit.) The MODEMCLK signal provides the 1-MHz timing reference.

3.15.4 Filter

The filter (figure 9-10, center) consists of a dual active filter (A3U31) and several discrete components. Its purpose is to remove the locally transmitted analog signal from the received signal so that the received signal can be accurately demodulated. (Both signals are present simultaneously on the phone line.) In addition, the filter circuit suppresses harmonics in the transmitted signal.

The high- and low-band active filters in A3U31 are connected to the transmit and receive paths according to the ORIG (O/$\overline{\text{A}}$ input) signal from the PPU. If ORIG is high, the filter transmits through the low-band filter and receives through the high-band filter.

The filter IC provides a reference voltage (VREF) equal to half of MPWR (from the power switch), or 2.5V. This serves as the analog reference voltage (VAG) for this circuit and other modem circuits.

The resistor-capacitor filter at the TxI input suppresses high-frequency switching noise on the transmitted signal from the modem IC and attenuates the input signal (TxI) to the filter. The signal level from the filtered output (TxO) is controlled by adjustable resistor A3R88. This signal is summed with tone-dial signals from the tone-dial generator by an operational amplifier within the filter IC. The A− pin is the inverting input line; the A+ pin is the noninverting input line. The AO pin is the amplifier output, which is the transmit signal that goes to the duplexer circuit.

The duplexer circuit provides the receive analog signal (RxI input) to the filter IC. The filtered output (RxO) is sent to the prelimiter for additional conditioning.

The PPU can set SELFTEST (ST input) high to activate the filter IC self-test mode. In this mode, the IC redirects its filtered TxO output to the RxO output. This sends the filtered output from the modem IC back to the modem IC (via the prelimiter and limiter circuits). The filter IC sets its TxO output to VAG.

3.15.5 Duplexer

The duplexer circuit (figure 9-10, center) interfaces between the two unidirectional signal paths of the modem and the one bidirectional path of the phone line. The circuit has three ports: an input from AO of the filter IC (transmit signal), an output to RxI of the filter IC (receive signal), and an input/output path to SIGNAL of the protective interface (mixed transmit and receive signals). The duplexer circuit strives to provide maximum gain from AO to SIGNAL, maximum gain from SIGNAL to RxI, and minimum gain from AO to RxI.

The transmitted signal (AO) is attenuated slightly by A3R84 as it passes through the duplexer to the protective interface (SIGNAL).

Ideally, the transmitted signal (AO) is present equally at both inputs to the operational amplifier (A3U34B), causing the gain from AO to RxI to be zero. This effect is produced by matching the two resistor-dividers that affect this signal: A3R82/A3R81 and A3R84/R(phone line). Because the line impedance is somewhat variable, the dividers usually don't match exactly, and a low-level AO signal is present in the RxI duplexer output. (This low-level signal is suppressed by the filter circuit described earlier.)

The received signal from the phone line (present in SIGNAL from the protective interface) is attenuated by resistor-divider A3R84/R(phone line). This signal is amplified by the operational amplifier (A3U34B), whose gain is determined by A3R81/A3R82, and passed to RxI of the filter circuit.

The received signal from the phone line isn't transferred to the AO output of the filter since the filter's output impedance is much less that that of resistor A3R84.

3.15.6 Protective Interface

The protective interface (figure 9-8, lower center) connects to the phone lines (A2J4). It serves to isolate and protect the modem circuitry and telephone equipment from damage by spurious electrical signals. (Voltages of up to 1500V at both phone input lines must be tolerated by the modem.)

This circuit is required by FCC rules, and much of its design is based on FCC rules that dictate its electrical characteristics. (Component or circuit changes may not be made without prior approval by the FCC.)

The basic circuit connected to the phone lines includes transformer A2T2 (to isolate the internal SIGNAL line from the phone lines), inductors A2L3 and A2L4 (to reduce electromagnetic interference), resistor A2R74 (to provide required dc impedance), and an electronic switch composed of A2CR14 and A2Q31. The electronic switch is controlled by the oscillator portion of the circuit. The ring detector portion of the circuit is also connected to the basic circuit.

The oscillator (A2Q33 and A2T3) is activated by the OFFHOOK signal from the PPU. (The transformer provides isolation from the basic circuit.) Whenever OFFHOOK is high, the oscillator runs at about 5 kHz, charging capacitor A2C25 and turning on transistor A2Q31. The transistor provides a path for dc phone current to pass through full-wave rectifier A2CR14 and the rest of the basic phone circuit. When OFFHOOK goes low, the oscillator turns off, capacitor A2C25 discharges through A2R100, turning off transistor A2Q31 and opening the basic phone circuit. Diodes A2VR10 and A2VR11 protect components against excess voltage. The high rating of A2VR10 prevents it from conducting during a "ring" signal.

Signal transformer A2T2 passes signals to and from the duplexer on the SIGNAL line. Diode A2VR9 protects against excess voltage. Capacitor A2C71 stabilizes at the VAG reference level (from the filter circuit) that's present on the SIGNAL line.

The ring circuit (including opto-isolator A2U30) is in parallel with the electronic switch. When the switch is open, a "ring" signal can trigger this circuit. A "ring" signal is an ac voltage (up to 150 Vac at 20 Hz) at the phone input. This signal causes the opto-isolator to turn on during about half of each cycle. This produces a pulsed low signal at its open-collector $\overline{\text{RING/RxCAR}}$ output. This signal normally causes a multi-controller interrupt that is processed by the CPU. Diode A2VR8 ensures that only signal levels above 24V are detected by this circuit. (When the electronic switch is closed, no voltage is developed across the ring circuit.)

3.15.7 Prelimiter

The prelimiter (figure 9-10, right center) performs the first stage of converting a received sine-wave signal to a square-wave signal of the same frequency and having a 48 to 52 percent duty-cycle. The circuit amplifies the received signal that has been filtered by the filter circuit. This amplification reduces the effect of input voltage offest for low-level signals.

Operational amplifier A3U34A provides a gain that's determined by A3R85 and A3R86. Diodes A3CR15 and A3CR16 reduce the gain for large signal levels, and leave the signal symmetric around the VAG reference voltage. Capacitor A3C39 reduces the gain at higher frequencies, reducing the effect of high-frequency noise from the filter circuit.

The output signal from the amplifier passes through a low-pass filter (A3R92 and A3C20) that further reduces high-frequency signal noise. Capacitor A3C22 blocks the dc signal component.

3.15.8 Limiter

The limiter (figure 9-10, right center) performs the final stage of converting the received signal to a square-wave signal having 48 to 52 percent duty-cycle. Comparator A3U35B converts the analog prelimiter output signal to 0V to 5V levels as required by the modem IC. The same square-wave signal goes to the multi-controller as the $\overline{\text{RING/RxCAR}}$ interrupt signal. (The CPU can monitor the multi-controller and compute the signal frequency to determine whether the signal is a valid carrier signal.)

The positive reference level for comparator A3U35B is nominally at VAG, which is the dc level of the negative input (from the prelimiter). As the analog input signal crosses the reference level, the comparator changes the state of its output. Capacitor A3C23 couples the output back to the reference input, causing the voltage at resistor A3R97 to change the reference level in opposition to the change in the input signal. (This eliminates high-frequency oscillations.) But the capacitor quickly charges, removing the reference offset before the next input signal crossover occurs. This coupling ensures a sharp crossover at each transition without changing the reference level at which the circuit changes state.

Gate A3U37A connects the $\overline{\text{RING/RxCAR}}$ signal from the limiter comparator to the modem IC whenever the TRANSEN signal from the PPU is high.

3.15.9 Carrier Detector

The carrier detector (comparators A3U35C and A3U35D) (figure 9-10, lower right) indicates whether the received signal (from the prelimiter) has sufficient amplitude for reliable demodulation. The MODEMCARRIER signal to the multi-controller goes high while a usable carrier is present. The signal goes low when the amplitude of the carrier is too low or when the phone connection is disconnected.

The positive input to the first comparator (A3U35C) is the prelimiter output signal with a dc level equal to VAG (through A3R95). The negative (reference) level is generated from VAG by resistor-divider A3R89, A3R90, and A3R91. The open-collector comparator output goes low whenever the prelimiter output is more negative than about 0.2V below VAG. Thus, if the signal amplitude exceeds about 0.2V peak, then the comparator A3U35C output goes low for part of the signal period. Otherwise, the output remains off.

While the output of the first comparator (A3U35C) is off, capacitor A3C28 charges through A3R93 to 5V (MPWR) and keeps the negative input to the second comparator (A3U35D) at that level. The output (MODEMCARRIER) of the second comparator is low in this situation. When the prelimiter signal has sufficient amplitude, a low pulse from the first comparator discharges capacitor A3C28 and causes the output of the second comparator to go high. This changes the resistor-divider configuration at the reference input to the first comparator, making the reference slightly higher (providing hysteresis and stability). When the prelimiter signal exceeds the reference level (during part of its cycle), capacitor A3C28 holds the input to the second comparator low long enough for the next cycle to occur. Thus, the MODEMCARRIER output is high whenever the prelimiter output signal has an amplitude greater than about 0.2V.

If the signal amplitude becomes too small, the output from the first comparator stays off. The capacitor is then able to charge above VAG, causing the MODEMCARRIER output to go low.

3.15.10 Billing Delay

The billing delay (figure 9-10, left center) provides a delay of at least 2 seconds after the OFFHOOK signal from the PPU goes high before the modem can transmit or receive data. This delay is required by FCC rules when receiving an incoming call.

When signal OFFHOOK goes high, capacitor A3C27 provides a high input to comparator A3U35A (relative to the VAG reference level). The comparator sets its output low, disabling the data paths through gates A3U37C and A3U37D. After the capacitor has charged for about 2 seconds through resistor A3R103, the comparator negative input drops below VAG. This returns the comparator output high, enabling the data paths between the modem IC and the multi-controller.

3.16 Power Supply

The power supply circuit contains several circuits that operate under control of the PPU. They perform the following functions:

- Provide battery power.
- Provide the regulated supply voltage (VCC1).
- Provide the switched supply voltage (VCC2).
- Recharge the battery.
- Indicate battery-voltage levels.
- Provide the selectable LCD supply voltage (LCDNEG).

3.16.1 Battery and Terminal Block

The 6-volt (nominal), three-cell, lead-acid battery has a closed design. The electrolyte is completely enclosed by the case, eliminating leakage under normal conditions. When fully charged, the battery has 2½ ampere-hours of stored power and a large short-circuit current capacity.

The terminal block PCA (figure 9-7, upper left) attaches to the battery terminals. This PCA contains a diode and fuse that provide circuit protection. If the battery is connected backwards, the diode (which is normally reverse-biased) bypasses the system circuitry and conducts enough current to blow the ½-amp fuse. (The terminal block PCA also contains the reset button from the PPU circuit.)

3.16.2 Regulator

The 5-volt regulator (figure 9-7, upper right) generates two regulated supplies (VCC1 and VCC2) from the battery voltage (VBAT). When the system is in its power-up condition (when SLEEP is low from the PPU), the VCC1 and VCC2 supplies are regulated at 4.9V to 5.1V. When the system is in its power-down condition (when SLEEP is high), the VCC1 supply is set to 3.3V and the VCC2 supply is turned off. The regulator also indicates information about the battery voltage using the LOBAT and SHUTDOWN lines to the PPU.

The main regulator is transistor A2Q13. Zener diode A2VR3 provides the reference voltage (1.235V). Resistors A2R33, A2R34, and A2R35 divide the regulated output for comparison with the reference voltage. Transistors A2Q16 and A2Q17 form a differential amplifier that controls the main regulator (A2Q13). Transistors A2Q14 and A2Q15 amplify the differential amplifier output to the regulator.

The A2Q18 circuit operates on the voltage difference between VBAT and VCC1. While VBAT is more than 0.8V higher that VCC1, A2Q18 and A2Q34 are on and the LOBAT output is low. If VBAT drops to less than 0.8V above VCC1 (VBAT about 5.8V), these transistors turn off, setting LOBAT high to the PPU.

The A2Q19 circuit operates similarly. It sets SHUTDOWN high if VBAT is less than 0.6V above VCC1 (VBAT about 5.6V).

The SLEEP input from the PPU controls the VCC1 and VCC2 voltages. If SLEEP is low, the circuit operates as described above. If SLEEP is set high, transistor A2Q20 turns off, turning off the VCC2 supply. In addition, a high SLEEP signal changes the resistor-divider configuration and the feedback amplification for the differential amplifier. This changes the VCC1 output to 3.3V.

3.16.3 Charger

The battery charger circuit (figure 9-7, upper left) turns on when a recharger is connected. It charges the battery according to the voltage level of the battery and according to the FAST signal from the PPU. This circuit also indicates to the CPU whether a recharger is connected ($\overline{\text{CHARGE}}$) and whether the battery voltage is too low for normal charging ($\overline{\text{BATDOWN}}$). Because optimum battery-charging conditions depend upon temperature, this circuit provides temperature compensation. (Voltages given below are approximate values at 20°C.)

When the recharger is first connected, diodes A2CR2, A2CR3, and A2VR1 provide a startup signal that turns on A2Q5 and A2Q6, connecting the VBAT voltage to the A2U27 comparators (and setting $\overline{\text{CHARGE}}$ low to the PPU). The startup signal also turns on the comparators if VBAT is too low (such as if the battery is shorted)—otherwise, the comparators operate from the VBAT voltage.

Rectifier A2CR1 rectifies the 8 Vac recharger input. For normal charging, transistor A2Q4 regulates the charging voltage at 7.0 Vdc. This voltage is monitored by comparator A2U27C: the VBAT charging voltage (modified by resistor-divider A2R18, A2R19, A2R20) is compared with the CHGREF voltage from A2VR3 and resistor-divider A2R22, A2RT1, A2R16. (Resistor A2RT1 provides temperature compensation for CHGREF.)

If the battery is sufficiently discharged, it may draw more than about 300 milliamperes. In this situation, the ac voltage from the external recharger decreases, causing the regulator voltage (VBAT) to drop. As the battery charges, the charge current decreases and VBAT recovers to its proper level.

Comparator A2U27D compares VBAT (modified by resistor-divider A2R13 and A2R14) with CHGREF. If the battery pulls VBAT below 6.2V, the comparator sets its output low. This sets $\overline{\text{BATDOWN}}$ low to the PPU. It also changes the resistor-divider configuration to include A2R15. This changes the VBAT threshold level to 7.2V, and the comparator will set its output high when VBAT exceeds this voltage.

If the PPU sets the FAST signal high, transistor A2Q7 turns on and changes the resistor-divider configuration for the regulator. This causes the regulated output of A2Q4 to increase to 7.5 Vdc. The PPU causes this action when it receives a low $\overline{\text{BATDOWN}}$ signal.

In effect, the charger circuit and PPU maintain the battery in a charged condition. If VBAT falls below 6.2V (the battery is about 66-percent charged), $\overline{\text{BATDOWN}}$ goes low, and the PPU establishes a fast-charge condition (FAST high). (See figure 3-3.) When VBAT reaches 7.2V, $\overline{\text{BATDOWN}}$ goes high (the battery is about 80-percent charged), and the PPU computes the period for which $\overline{\text{BATDOWN}}$ was low. The PPU keeps FAST high for an additional interval equal to the $\overline{\text{BATDOWN}}$ period—but not more than 4 hours—(until the battery is about 98-percent charged); then it sets FAST low, establishing normal charging of the battery.

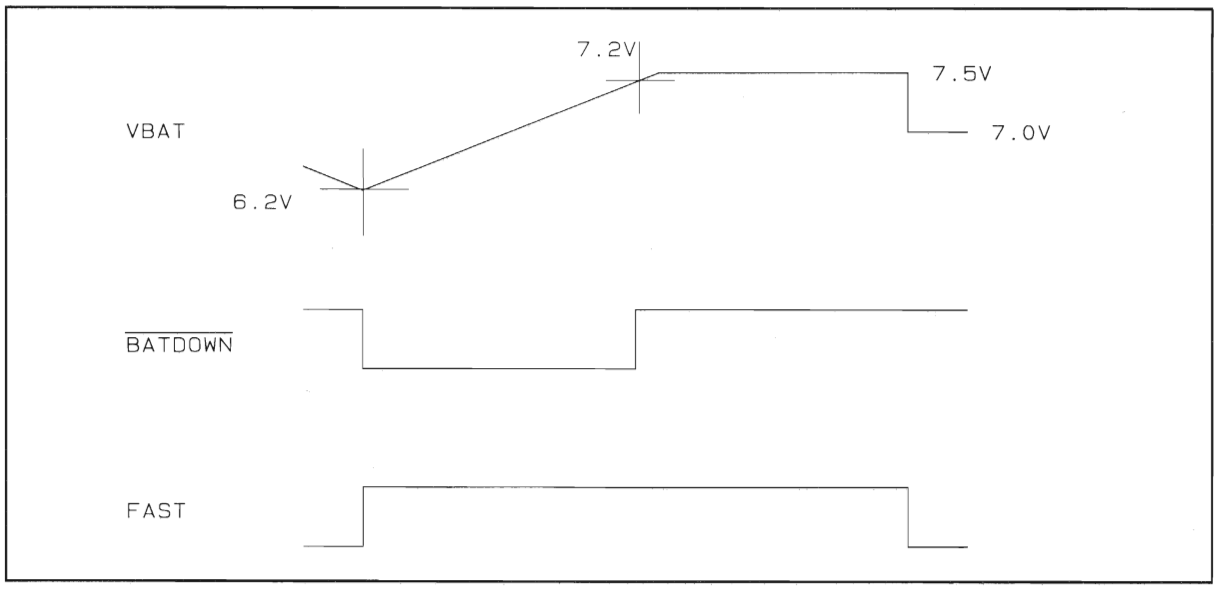


Figure 3-3. Low Battery Sequence

Another portion of this circuit protects against battery failure. If the battery pulls VBAT below 5.3V, comparator A2U27B sets its output low. This turns on transistor A2Q3, which turns off the main regulator (A2Q4). It also turns on transistor A2Q2, which is a 15-mA current source that charges the battery. If VBAT later exceeds 5.3V, the current source turns off and the main regulator turns on.

3.16.4 LCD Supply

The LCD supply (figure 9-7, lower) is a switching power supply that generates a controlled voltage (LCDNEG) of −7V to −13V for the display. The actual voltage is defined by four signals from the PPU (STEP1, STEP2, STEP4, and STEP8). These signals essentially form a four-bit binary pattern, with STEP8 being the most significant bit. The binary pattern 1111 causes the largest negative voltage. (The design assumes that the load resistance of the display is between 1000 and 4700 ohms.)

Transistor A2Q28 is the switching component. It switches at about 25 KHz. Its "off" time is constant; its "on" time depends upon the four input lines and upon VBAT. The circuit is active only while the system is in its power-up condition (VCC2 turned on).

While VCC2 is turned on, transistors A2Q21 and A2Q12 are turned on, activating the comparator circuit (A2U26). While the comparator output is low (as it is when the circuit is first turned on), transistors A2Q24 and A2Q25 are turned off. The negative comparator input (−) equals 1.2V from A2VR3. The positive input (+) increases as A2C12 charges through A2R49, A2R50, and the resistor-divider network that's configured by the four STEP lines. (For each STEP line that's high, its corresponding transistor (A2Q8 through A2Q11) is turned on, and its corresponding resistor (A2R43 through A2R46) decreases the charging voltage.) When the positive input exceeds the negative input, the comparator output goes high. This turns on transistors A2Q24 and A2Q25. Transistor A2Q25 reduces the negative comparator input to 0.6V. Transistor A2Q24 reduces the charging voltage for A2C12, causing it to begin discharging at a rate that's independent of the STEP signals. When the positive comparator input goes below 0.6V, the comparator output goes low, repeating the cycle.

The switching output of the comparator controls transistor A2Q28. While the comparator output is low, the transistor is turned on, sending current through A2L1. While the comparator output is high, the transistor is turned off, inducing a reverse voltage across A2L1. This voltage draws current through A2CR13 and charges capacitor A2C14 to a negative voltage (LCDNEG). A2L1 and A2C14 are the energy-storing components for the LCDNEG supply. Diode A2VR2 limits the supply voltage to −15V.

3.17 Power-Up Routine

The following discussion describes the process that occurs when the system "turns on"—that is, when the system changes from its power-down state to its power-up state.

During the power-down state, only two main circuits operate: the PPU and the multi-controller. These circuits monitor the keyboard and maintain the real-time clock.

When a key is pressed in the power-down state, the multi-controller senses the pulled row and column lines and sets $\overline{\text{KEYIRQ}}$ low to the PPU. (If the contrast key is pressed, the PPU senses this directly on its C13 line. (The timing of the power-up sequence is illustrated in figure 3-4.)

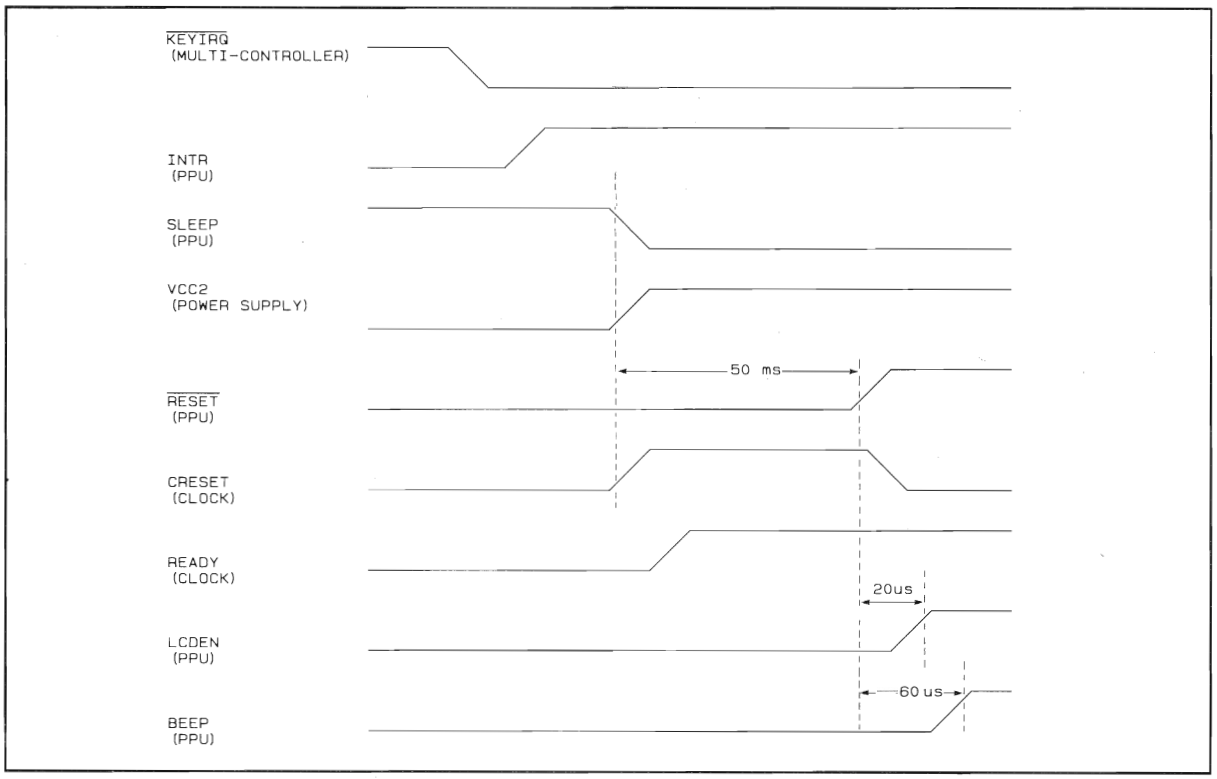


Figure 3-4. Power-Up Sequence

The PPU directs the power-up process. It keeps $\overline{\text{RESET}}$ low to other circuits. It sets SLEEP low to the power supply, which establishes the operating voltage for VCC1 and turns on VCC2. When VCC2 turns on, inactive system circuits begin operating.

When VCC2 turns on, the clock circuit sets CRESET high to the CPU. When other circuits signal that they're ready, the clock circuit sets READY high to the CPU.

After about 50 milliseconds, the PPU sets $\overline{\text{RESET}}$ high. The clock circuit then sets CRESET low, triggering the CPU to perform its initialization routine.

The PPU then enables the display circuit and HP-IL circuit by setting LCDEN high. The PPU also sets BEEP high (its normal power-up state).

Chapter 4
Troubleshooting

4.1 Overview

This chapter presents the troubleshooting procedures that you'll use to check and repair the HP 110. The procedures include information for both assembly-level repair and component-level repair.

- 4.2 Troubleshooting Procedures.
- 4.3 Burning an EPROM.
- 4.4 Testing the Recharger.

Troubleshooting is often begun by the customer, who has two diagnostic tools available: the built-in diagnostic tests and the "Utilities"-disc diagnostic tests. (The owner's manual tells the customer how to perform these tests.)

The troubleshooting procedures that you'll use are based on additional, more extensive diagnostic tools: the service disc-based diagnostic tests and the EPROM diagnostic tests. (Refer to table 4-1.)

Table 4-1. Comparison of Diagnostic Tests

Diagnostic Test	Strengths	Limitations
Customer Tests:		
Built-In Tests	Contained in ROM (requires minimum functionality).	Doesn't test all functions.
"Utilities" Disc Tests	Tests many functions.	Loaded from disc into RAM (requires much functionality). Doesn't test several functions.
Additional Service Tests:		
Service Disc Tests	Tests almost all functions.	Loaded from disc into RAM (requires much functionality).
EPROM Tests	Contained in EPROM (requires minimum functionality). Tests many functions.	Unit must be disassembled. Doesn't test several functions.

All repairs begin with the procedures described in section 4.2. Figure 4-1 illustrates the flow of the troubleshooting procedures.

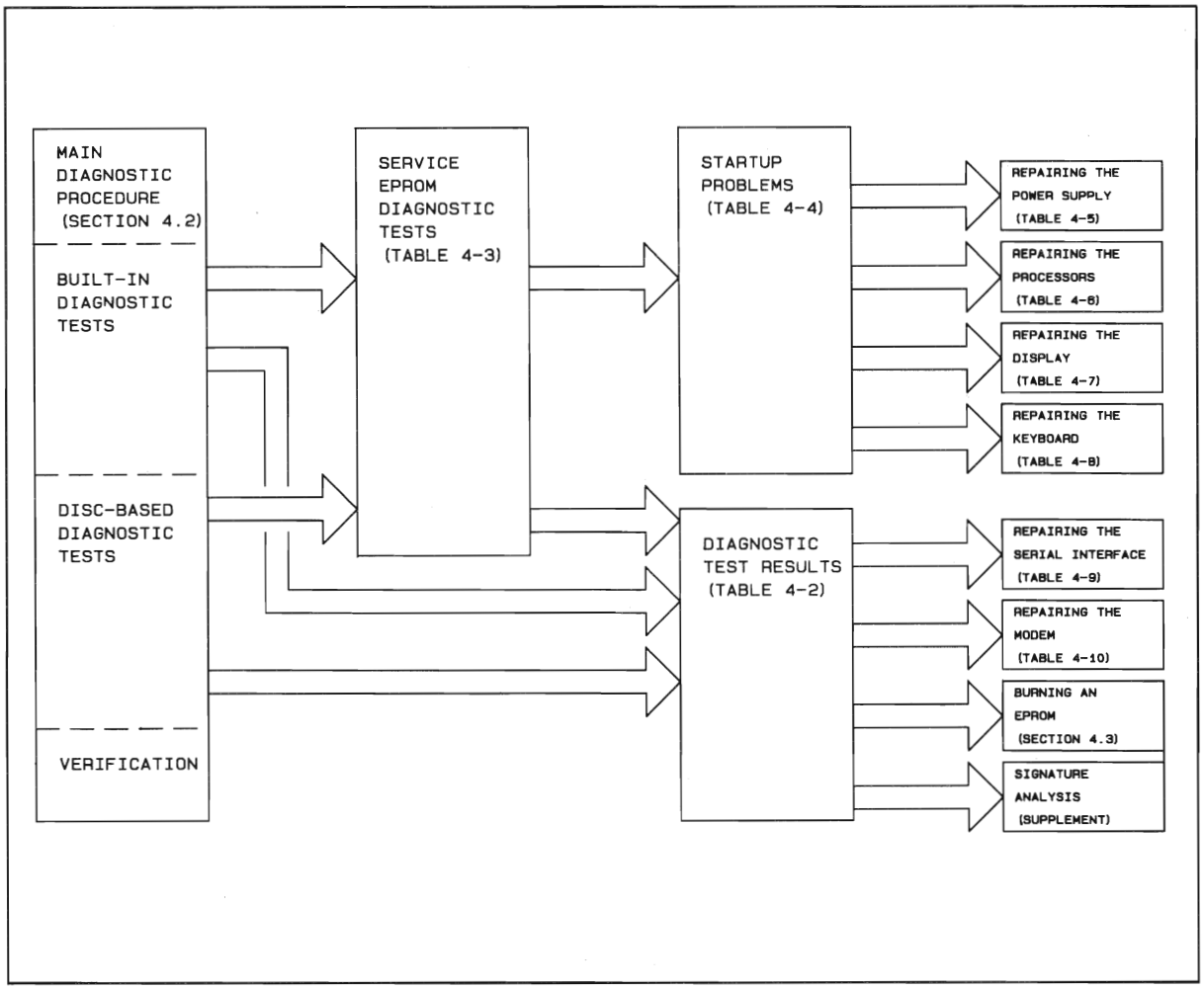


Figure 4-1. Overview of Troubleshooting Procedures

The troubleshooting procedures are based mainly upon the disc-based diagnostic tests. These tests are included on the service disc. (The user receives some of these tests on the "Utilities" disc, which comes with the HP 110.) For most problems, the disc-based tests indicate the assembly and component that are bad. Other tests are available to help determine and verify the problem with a unit.

The following list summarizes the tests that you'll use:

- **Built-in diagnostic tests.** Tests that are included in and executed from HP 110 ROM. You use a menu for selecting tests of ROM, RAM, and HP-IL.
- **Disc-based diagnostic tests.** Tests that are included on the service disc, loaded into HP 110 RAM, and executed from RAM. You use a menu for selecting tests of each portion of the HP 110. (One of the routines burns new configuration EPROMs.)
- **Service EPROM diagnostic tests.** Tests that are included in and executed from EPROM installed in the diagnostic module. They duplicate many of the disc-based diagnostic tests. (Several routines establish conditions for using a signature analyzer or an oscilloscope to check circuits.)

A summary of each diagnostic test is included in chapter 7, "Reference Information."

For assembly-level repair, the diagnostic tests indicate a bad assembly.

For component-level repair, the diagnostic tests indicate a bad component. You can use signature-analysis routines to isolate and verify the fault. These routines are the main techniques provided for tracing faults through the system. Signature analysis routines are contained in the *HP 110 Signature Analysis Service Supplement* (part number 00090-90044).

After you repair a unit, you'll verify that it's good by performing a complete system test.

Tools and equipment that you'll need to check and repair the HP 110 are listed in table 1-3. (Reference information about the diagnostic module and the RS-232 test connector is contained in section 7.4.)

4.2 Troubleshooting Procedures

This section describes how to use the diagnostic tests and procedures to locate and repair a problem. Begin troubleshooting at the main diagnostic procedure in section 4.2.1 below.(For version B units, ignore references to the modem function.)

CAUTION

Be sure to wear a grounded wrist strap and work at a bench that is electrostatically protected. Many components (especially the display module) are highly susceptible to damage by electrostatic discharge.

4.2.1 Main Diagnostic Procedure

Check the unit by performing the following steps. For a good unit, you'll proceed through the entire main sequence without branching to any of the repair procedures of section 4.2.2.

Problem Analysis:

1. **Read Comments.** Determine the customer's concern, if possible. Frequently the customer includes with the unit a message describing the problem.
   - If the message indicates a problem with a particular portion of the unit, you'll test only that section of the unit in the steps below (and other sections that may relate to the problem).
   - If the message indicates a problem with a *peripheral* (rather than the HP 110 itself), you'll test the corresponding interface of the HP 110. (You'll also check the HP-IL function of an HP-IL peripheral.) To check a peripheral completely, test it according to its service manual.
   - If the message indicates a problem with the recharger, test it according to the procedure in section 4.4.
2. **Observe Symptoms.** If possible, try to observe the trouble by duplicating the situation described. Determine how the observed or reported behavior differs from the proper behavior. (Also take note of functions that work properly.)
3. **Separate Problems.** Separate the symptoms into distinct problems. Use the troubleshooting procedure below to correct one problem at a time, starting with the more critical system functions.
4. **Consider Causes.** Consider possible causes for each problem. Keep them in mind as you perform the troubleshooting procedure.

Built-In Diagnostic Tests:

5. **Start Test.** If the HP 110 is turned on, turn it off (either press (f8) in the main P.A.M. screen, or else press and hold (◑) key for at least 15 seconds). Start the built-in diagnostic tests by holding down (Shift) and (Extend char), then pressing (f8).
   - If the test menu appears, proceed to the next step (step 6).
   - If the test menu *doesn't* appear, try to turn on the HP 110 normally (press (◑) or other keys, if necessary). If a normal display appears (such as P.A.M. or MS-DOS), skip to step 9; if a normal display doesn't appear, check the unit according to table 4-3, "Service EPROM Diagnostic Tests."

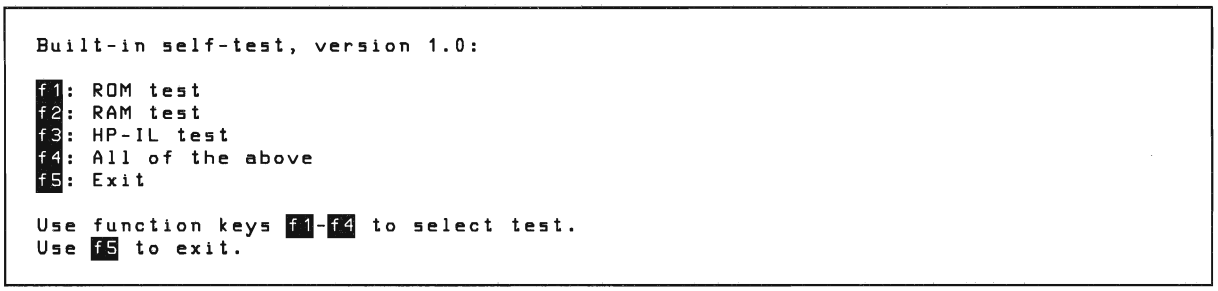


Figure 4-2. Menu for Built-In Diagnostic Program

6. If the customer indicates a problem that's *not related* to the HP-IL function, *skip to step 9.*
7. **Test HP-IL.** Press (f3) to select the HP-IL test. Then connect a good HP-IL cable between the IN and OUT receptacles of the HP 110 (no devices are connected). From the HP-IL menu, select the "no devices" test.
   - If no problem occurs, proceed to the next step.
   - If the test indicates a problem, replace the assembly or component indicated by the test. Refer to table 4-2 for specific information. Then repeat the same test to ensure that the problem is repaired.

     Note: If you're equipped to perform signature analysis, you can verify that the address, data, and control lines are good before replacing a component. You should do this if you're not reasonably certain that the indicated component is bad. Refer to the signature analysis supplement for information about performing signature analysis.
8. **Test Peripheral.** If the customer has shipped a peripheral with the HP 110, connect it to the HP 110 using good HP-IL cables and turn it on. Select the HP-IL test again, but select the "devices" test from the HP-IL menu.
   - If no problem occurs, the HP 110 HP-IL circuit is good, and the HP-IL portion of the peripheral is good. (You can test the peripheral further according to its service manual.) Proceed to the next step.
   - If the test indicates a problem, check the HP-IL connections and check that the peripheral is turned on. Replace the assembly or component indicated by the test. Refer to table 4-2 for specific information. Then repeat the same test to ensure that the problem is repaired.

     Note: If you're equipped to perform signature analysis, you can verify that the address, data, and control lines are good before replacing a component. You should do this if you're not reasonably certain that the indicated component is bad. Refer to the signature analysis supplement for information about performing signature analysis.

Disc-Based Diagnostic Tests:

9. **Set Up System.** Turn off the HP 110 (press and hold ◑ for at least 15 seconds), then connect it to a good HP 9114 Disc Drive using two good HP-IL cables. (Don't connect any other HP-IL devices at this time.) Turn on the disc drive, then the HP 110 (press ◑ or other keys, if necessary).
   - If the main P.A.M. screen appears, proceed to the next step.
   - If the MS-DOS system (not P.A.M.) is active at turn-on, type **pam** (Return) to obtain the main P.A.M. screen. Then proceed according to either of the other choices for this step.
   - If any other display appears, or if no display appears, restart the built-in diagnostic test (step 5 above), then press (f4) to select all of the tests. If the tests indicate a bad component, replace it (refer to table 4-2), then repeat the tests. If the tests find no problem, check the unit according to table 4-3, "Service EPROM Diagnostic Tests."
10. **Configure System.** Configure the system for one disc drive. In the main P.A.M. screen, press (f6) (System Config). Use the tab or cursor keys to select the "External disc drives" field, then use the "Next Choice" and "Previous Choice" function keys to select one drive. Use the "Exit Config" function key to return to the main P.A.M. screen.
11. **Load Service Disc.** Insert the service disc in the disc drive. Load and run the disc-based diagnostic test program. (Type **C:STEST** and press (Return).)
    - If the test menu is displayed, proceed to the next step.
    - If the test menu *doesn't* appear, the system isn't operating properly. Check that the disc drive is connected properly and is turned on. Check that the service disc is inserted properly. Test the HP 110 according to table 4-3, "Service EPROM Diagnostic Tests."

```
Disc-based service tests, version 1.0:

f1: System test                          Shift f1: RS-232 test
f2: CPU test                             Shift f2: Beeper test
f3: ROM test                             Shift f3: Timer test
f4: RAM test                             Shift f4: Continuous tests (CPU,ROM,RAM)
f5: LCD test                             Shift f5: Configuration EPROM programmer
f6: Keyboard test                        Shift f6:
f7: HP-IL test                           Shift f7: Sleep
f8: Modem test                           Shift f8: Exit

Use Shift and function key to select test or exit.
```

Figure 4-3. Menu for Disc-Based Diagnostic Program

12. **Select Test.** Select the appropriate test by pressing the corresponding special-function key (shifted or unshifted). Note the results of the test.

    - If the customer indicated a functional area that has a problem, select the test for that area. (If more than one area is noted, check each area mentioned starting from the top of the menu.)
    - If the nature of the problem isn't indicated, select the system test.

    Note: Four disc-based tests require special preparations:

    The *HP-IL test* requires either that you connect a good HP-IL cable between the IN and OUT receptacles (for the "no devices" test) or that you connect the HP 110 and one or more devices in a loop (the "devices" test).

    The *RS-232 (serial interface) test* requires that you connect the RS-232 test connector to the serial port.

    The *modem test* includes "dial" and "ring" options that require you to connect a phone line to the modem port.

    The *system test* performs the three tests listed above and requires the preparations for each of them.

13. **Follow Up.** Take action according to the results of the test:

    - If no problem occurs, the tested function is probably good and no action is required. (However, if the customer indicates a problem and you haven't found anything so far, consider whether another function might be involved—then test that function. If the test might be missing the problem, check the unit according to table 4-3, "Service EPROM Diagnostic Tests."
    - If the test indicates a problem, replace the assembly or component indicated by the test. Refer to table 4-2 for specific information. Then repeat the same test to ensure that the problem is repaired.

      Note: If you're testing a B version unit, *ignore all modem failures*. The B version has no modem, causing the test to indicate modem failures such as codes 331 and 332.

      Note: If you're equipped to perform signature analysis, you can verify that the address, data, and control lines are good before replacing a component. You should do this if you're not reasonably certain that the indicated component is bad. Refer to the signature analysis supplement for information about performing signature analysis.
    - If the test doesn't operate properly, check the unit according to table 4-3, "Service EPROM Diagnostic Tests."

Verification:

14. **Verify Operation.** After repairing any faults, verify that the unit is good by repeating steps 9 through 13 above. In step 12, select the complete system test (from the disc-based test menu). Recall that the HP-IL, RS-232, and modem tests require certain connections at the appropriate receptacles (refer to step 12 above).

15. **Set Time.** Set the time zone and time to their correct values. In the main P.A.M. screen, press (f3) (Clock Config). Move through the menu using the tab or cursor keys. Change entries as needed by pressing the "Next Choice" or "Previous Choice" keys. Press the "Exit Config" key to save the time you've selected.

16. **Restore LOTUS Configuration File.** If power has been disconnected from the unit, the LOTUS configuration file is lost. Restore this file ("123.CNF") by performing these steps:

    a. Turn on the HP 110, then select LOTUS 1-2-3 from the main P.A.M. menu. If "Missing or illegal configuration file" is displayed, proceed to the next step. If no error message is displayed, the configuration file still exists; proceed to step i.

    b. Press (Return).

    c. Press (/) to select command options.

    d. Press (W) to select worksheet options.

    e. Press (G) to select global options.

    f. Press (D) to select default options.

    g. Press (U) to restore the configuration file.

    h. Press (Q) to return to the LOTUS worksheet.

    i. Press (/) (Q) (Y) to return to the main P.A.M. menu.

17. **Recharge Battery.** If power has been disconnected from the unit, the battery "gauge" resets to either 0 or 99 percent—even though the battery may not be at that level. Connect the unit to a recharger and allow the battery to charge for at least 12 hours while the unit is turned off. This will return the "gauge" and battery to about 95–99 percent. (As an alternative, include a note to the customer suggesting that a recharger be connected until the "gauge" reaches 99 percent.)

This completes the main diagnostic procedure.

Table 4-2. Diagnostic Test Results

Use this table to interpret the results of built-in, disc-based, and service EPROM diagnostic tests. (This table is repeated as table 7-1 in chapter 7.)

For assembly-level repair, replace the assembly indicated in the "assembly-level" column (or take the steps listed).

For component-level repair, replace the component indicated in the "component-level" column (or take the steps listed); when directed, use signature analysis (S/A) according to the reference in the last column to the signature analysis supplement.

Note: If you're equipped to perform signature analysis, you can verify that the address, data, and control lines are good before replacing a component. You should do this if you're not reasonably certain that the indicated component is bad. Refer to the signature analysis supplement for information about performing signature analysis.

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
Failure Codes:			
101	System PCA.*	Replace A1U1 (CPU).	"Analyzing the CPU"
120–127	System PCA.*	If only one or two RAMs indicated, replace individual A1U20–U27 (RAM). If more than two RAMs indicated, latch or transceiver suspected. Trace using S/A.	"Analyzing System RAM"
128–151	System PCA.*	If only one or two RAMs indicated, replace individual A1U28–U51 (RAM). If more than two RAMs indicated, latch or transceiver suspected. Trace using S/A.	"Analyzing Mass Storage RAM"
152–163	If only one or two ROMs indicated, replace individual A1U52–U63 (ROM).* If more than two ROMs indicated, replace system PCA.*	If only one or two ROMs indicated, replace individual A1U52–U63 (ROM).* If more than two ROMs indicated, latch or transceiver suspected. Trace using S/A.	"Analyzing System ROM"

Table 4-2. Diagnostic Test Results (Continued)

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
166–167	System PCA.*	If only one or two RAMs indicated, replace individual A1U66–U67 (RAM). If more than two RAMs indicated, latch or transceiver suspected. Trace using S/A.	"Analyzing System RAM"
201	I/O PCA.†	Trace using S/A; replace A2U1 (PPU).	"Analyzing the PPU"
202	I/O PCA.†	Replace A2U2 (multicontroller).	"Analyzing the Keyboard Circuit"
203	I/O PCA.†	Replace A2U3 (LCD controller).	"Analyzing the Display Controller"
204	I/O PCA.†	If occurs during HP-IL test, check HP-IL components using S/A; replace A2U4 (HP-IL controller). If occurs during RS-232 test, replace A2U4 (HP-IL controller).	"Analyzing the HP-IL Circuit"
205	I/O PCA.†	Verify using S/A; replace A2U5 (display RAM); replace A2U3.	"Analyzing Display RAM"
228	Replace A2U28 (EPROM)—burn new EPROM IC before installing (section 4.3)	Replace A2U28 (EPROM)—burn new EPROM IC before installing (section 4.3)	"Analyzing the Configuration EPROM"
331‡	Check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem circuit according to table 4-10, "Repairing the Modem" (may not be A3U31).	
332‡	Check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA, as indicated.	Check modem circuit according to table 4-10, "Repairing the Modem" (may not be A3U32).	

Table 4-2. Diagnostic Test Results (Continued)

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
4rcc (*r* is row number) (*cc* is column number)	Swap top case (if possible) or swap keyboard module, then retry. If fixed, replace keyswitch (or keyboard module) after checking continuity; if not fixed, replace I/O PCA.†	Swap top case (if possible) or swap keyboard module, then retry. If fixed, replace keyswitch (or keyboard module) after checking continuity; if not fixed, replace A2U2 (multi-controller).	
Messages:			
Broken loop	Try new cable; check connections; check I/O plate (or swap and retry); replace I/O PCA.†	Try new cable; check connections; inspect internal connections to I/O plate assembly (or swap assembly and retry); check continuity of HP-IL interface circuit (see schematic); replace A2U4 (HP-IL controller).	"Analyzing the HP-IL Circuit"
Loop error, data not received as sent	Remove peripherals and run "no devices" test; try new cable; check connections; bad HP-IL peripheral; check I/O plate (or swap and retry); replace I/O PCA.†	Remove peripherals and run "no devices" test; try new cable; check connections; bad HP-IL peripheral; check I/O plate (or swap and retry); check HP-IL components using S/A; replace A2U4 (HP-IL controller).	"Analyzing the HP-IL Circuit"
Number of devices on HP-IL loop= *wrong number*	Check connections; bad HP-IL peripheral; if occurs for every peripheral, replace I/O PCA.†	Check connections; bad HP-IL peripheral; if occurs for every peripheral, replace A2U4 (HP-IL controller).	
Transmitted or Rcvd. Data line(s) bad	Check test connector; replace I/O PCA.†	Check test connector; trace signals using scope routine.	
CTS line bad DSR line bad DTR line bad RTS line bad Carrier Det line bad	Check test connector; replace I/O PCA.†	Check test connector; check serial interface according to table 4-9, "Repairing the Serial Interface."	

Table 4-2. Diagnostic Test Results (Continued)

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
Ring Det line bad	Check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem PCA connection; check test connector; check serial interface according to table 4-9, "Repairing the Serial Interface."	
Pwr Supply Stuck On	I/O PCA.†	Trace power supply signals according to table 4-9, "Repairing the Serial Interface."	
Display Test Observations:			
Display doesn't scroll properly	I/O PCA.†	Replace A2U3 (LCD controller).	
Border line improper	Display assembly.	Display assembly.	
Extra or missing pixels	Swap top case assembly and retry; replace display assembly or I/O PCA†, as indicated.	Check VCC2 at A2U3 pin 1; swap top case assembly and retry; check display circuit using S/A or replace display assembly, as indicated.	"Analyzing the Display Controller"
Row (or column) dark or light	Display assembly.	Display assembly.	
Blinking or inverse display improper	Display assembly.	Display assembly.	
12- or 16-line display format improper	I/O PCA.†	A2U3 (LCD controller).	
Two cursors improper	I/O PCA.†	A2U3 (LCD controller).	
Quadrant bad	Check continuity between A2U3 and display assembly; swap I/O PCA or top case assembly, then retry; replace display assembly or I/O PCA†, as indicated.	Check continuity between A2U3 and display assembly; use scope to check for toggling signals at A2U3 pins 9–16; replace display assembly or A2U3 (LCD controller), as indicated.	
Adjacent rows (or columns) duplicated	Display assembly.	Display assembly.	

Table 4-2. Diagnostic Test Results (Continued)

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
Modem Observations:			
During optional pulse dialing test, telephone doesn't ring	Check modem connections; check phone number; check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem connections; check phone number; verify circuit using standard modem test; check modem circuit according to table 4-10, "Repairing the Modem."	
During optional tone dialing test, telephone doesn't ring	Check modem connections; check phone number; check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem connections; check phone number; verify circuit using standard modem test; check modem circuit according to table 4-10, "Repairing the Modem."	
During optional ring-detect test, HP 110 doesn't beep or indicate call received	Check modem connections; check phone number; check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem connections; check phone number; verify circuit using standard modem test; check modem circuit according to table 4-10, "Repairing the Modem."	

* Whenever you replace system ROMs, you must ensure that the configuration EPROM (A2U28) matches the system ROMs (contains the proper ROM checksum values). (Refer to tables 6-8 and 6-9.)

- If the *same-revision ROMs* are installed, leave the original configuration EPROM in the I/O PCA.
- If *new-revision ROMs* are installed, burn a new configuration EPROM (section 4.3), then install it in the I/O PCA.

† Whenever you replace the I/O PCA, remove the configuration EPROM (A2U28) from the old PCA and install it in the new PCA. (This does not apply if you install new-revision ROMs or if you suspect that the configuration EPROM itself is bad.)

‡ Ignore this result for all B versions. These units don't have modems.

4.2.2 Repair Procedures

The following tables describe procedures that you'll be told to follow for repairing certain problems. Because these procedures assume certain results from previous tests, use them only when directed by other procedures.

For assembly-level repair, follow the indicated procedures only as far as required to make an informed decision as to which assembly is bad. After substituting a new assembly, repeat the appropriate test to verify the repair. Then complete the main diagnostic procedure in section 4.2.1.

For component-level repair, follow the indicated procedures as described.

Table 4-3. Service EPROM Diagnostic Tests

Use this procedure when the built-in diagnostic tests and the disc-based diagnostic tests can't be used.

CAUTIONS

Use care while connecting and disconnecting internal cables. The cables may be damaged by careless handling because the connectors provide no strain relief.

Be sure the connectors are aligned properly when connecting the diagnostic module to the PCAs. If they're connected with the pins misaligned, components may be damaged or system operation disrupted.

Step	Response
1. Remove the battery, separate the case, and remove the I/O and system PCAs from the HP 110 (procedures 5.2, 5.3, and 5.4).	
2. Connect the I/O PCA to the cable extending from the module. Connect the system PCA cable to the receptacle on the module. Connect the keyboard to the I/O PCA using a keyboard extension cable (00090-60910). Check that the connectors are aligned properly.	

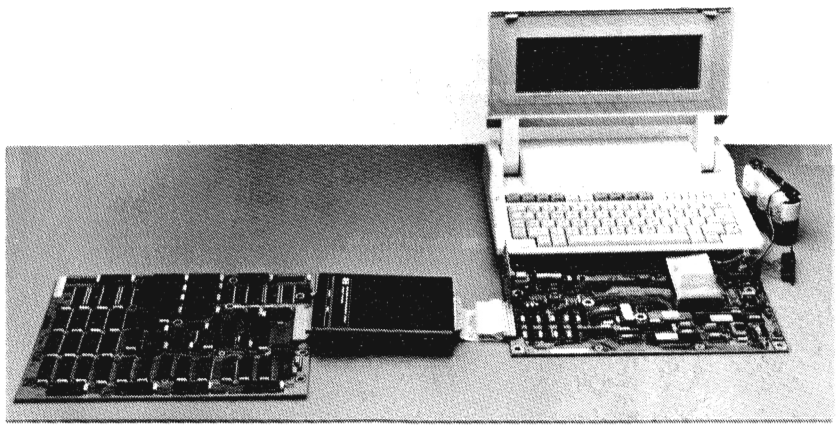


Table 4-3. Service EPROM Diagnostic Tests (Continued)

Step	Response
3. Check the position of the two-pin jumper near the I/O PCA end of the module. (If necessary, open the case to do this.) It should connect the two pins (so that the module performs its diagnostic function).	
4. Connect a recharger to the HP 110—it isn't necessary to connect the battery. (However, you *can* use a service battery assembly rather than the recharger if it's more convenient.)	If the test menu is displayed, proceed to the next step. If the test menu *doesn't* appear, try the following (if the test menu then appears, proceed to the next step): • Check the installation of the diagnostic module. • Press (◑) (or other keys, if necessary) to turn on the HP 110. • Press and hold (◑) for at least 15 seconds to reset the HP 110. • Connect a recharger to the unit (if not already connected), then try the previous keystrokes again. • Press the reset button on the terminal block PCA (several times, if necessary). • Check the unit according to table 4-4, "Startup Problems."

```
ET-based service tests, version 1.0:

f1: System test                    Shift f1:
f2: CPU test                       Shift f2: Beeper test
f3: ROM test                       Shift f3: Timer test
f4: RAM test                       Shift f4:
f5: LCD test                       Shift f5: SA and Scope Menu 1
f6:                                Shift f6: SA and Scope Menu 2
f7:                                Shift f7: Sleep
f8:                                Shift f8:

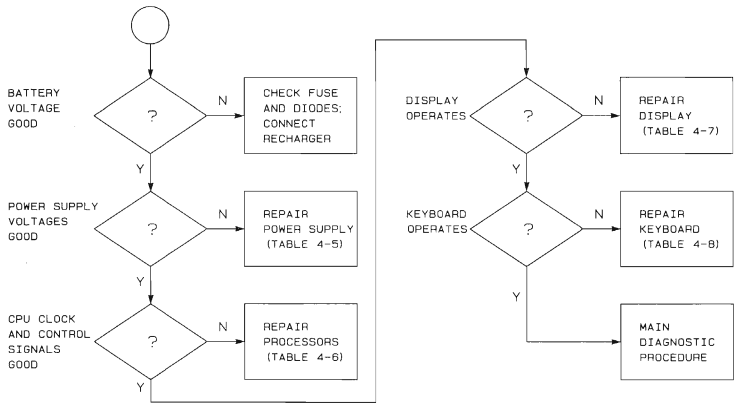
Use Shift and function key to select test.
```

Table 4-3. Service EPROM Diagnostic Tests (Continued)

Step	Response
5. Select the system test by pressing (f1). This runs each of the diagnostic tests in the menu. Note the results of each test.	If no problem occurs for an individual test, the tested function is good. Continue through the system test. If a test indicates a problem, replace the assembly or component indicated by the test. Refer to table 4-2 for specific information. Then repeat the same test to ensure that the problem is repaired. **Note:** If you're equipped to perform signature analysis, you can verify that the address, data, and control lines are good before replacing a component. You should do this if you're not reasonably certain that the indicated component is bad. Refer to the signature analysis supplement for information about performing signature analysis.
6. Disconnect the recharger (if any) and service battery assembly from the unit. Disconnect the diagnostic module and connect the system and I/O PCAs on your bench. (Disengage the module cable by gently prying the connectors apart with a flat-bladed screwdriver, then pulling on the cable. Disengage the system cable by pressing outward on the two tabs of the module receptacle. To ensure a good connection between the cable and the system PCA, press down on the clamp where the cable attaches to the PCA.) Then reconnect the recharger or service battery assembly.	If the system is able to turn on properly, proceed to the next step. If the system *isn't* able to turn on properly, press the reset button on the terminal block PCA (several times, if necessary).
7. Check the continuity of the customer's terminal block PCA and its cable. Check that the fuse is good and that the diode has continuity in only one direction.	If the terminal block PCA is good, proceed to the next step. If any components are bad, replace them as required. The diode causes the fuse to blow if the battery is connected backwards, protecting the system circuits.
8. Verify that the unit is good by performing the main diagnostic procedure in section 4.2.1. (Select the complete system test from the disc-based menu.)	

Table 4-4. Startup Problems

Use this procedure if the unit doesn't turn on properly and you can't use any of the diagnostic tests. If you make a repair at any step, check whether the unit seems to operate enough to use a diagnostic test; if it does, go back to the main diagnostic procedure in section 4.2.1.



Step	Response
1. If the display is turned on, turn it off (either press (f8) in the main P.A.M. screen, or else press and hold (◑) key for at least 15 seconds).	
2. Separate the bottom case from the unit, and remove the I/O PCA and system PCA from the case (procedures 5.3 and 5.4). Connect the assemblies on your bench. Connect the keyboard using a keyboard extension cable. Connect a recharger or the service battery assembly.	
3. Try to start the built-in diagnostic tests by holding down (Shift) and (Extend char), and pressing (f8).	If the test menu appears, perform the system test. If indicated, repair the unit according to table 4-2; otherwise, proceed to the next step. If the test menu *doesn't* appear, the system isn't operating properly. Proceed to the next step.

Table 4-4. Startup Problems (Continued)

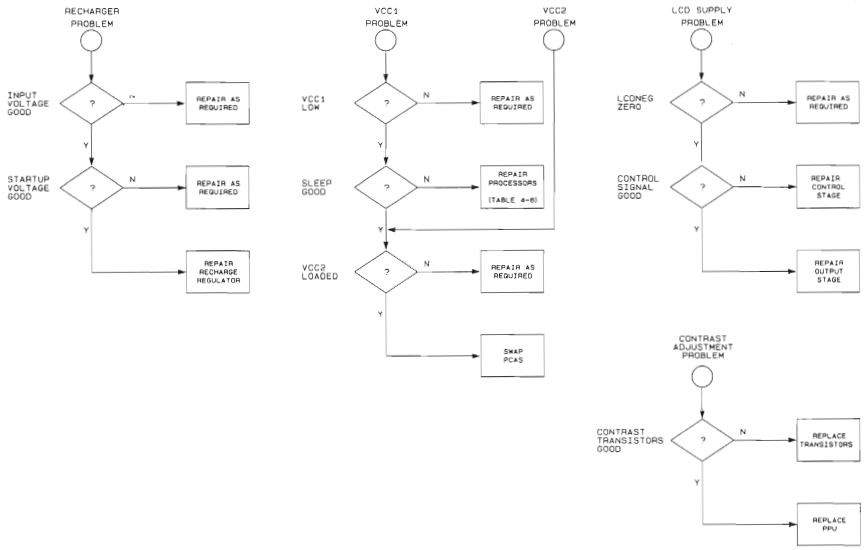
Step	Response
4. Measure the battery voltage (VBAT) while the battery is connected to the system. Measure the voltage at the terminal block.	If the voltage is 6.2 Vdc or above, the battery is sufficiently charged. Proceed to the next step. If the voltage is below 3 Vdc, recheck the battery while removed from the unit. Replace the battery if low; otherwise, check the circuit for shorts. If the voltage is between 3 and 6.2 Vdc, connect the customer's recharger (or another recharger). • If the voltage increases to 6 Vdc or above, proceed to the next step. (If the unit can turn on, perform the main diagnostic procedure in section 4.2.1 instead.) • If the voltage remains low, first verify that the recharger is good (substitute a good recharger or use procedure 4.4), then check the power supply using the procedure in table 4-5, "Repairing the Power Supply."
5. Measure VCC1 at A2U1 (PPU) pin 40.	If VCC1 is between 4.9 and 5.1 Vdc, proceed to the next step. If VCC1 is between 3.2 and 3.4 Vdc, the power supply is in its power-down state. Repeat this step while pressing ◑ (and other keys, if necessary): if VCC1 stays the same, check the power supply using the procedure in table 4-5, "Repairing the Power Supply." If VCC1 is outside these ranges, check the power supply using the procedure in table 4-5, "Repairing the Power Supply."
6. Measure VCC2 at A2U8 pin 20.	If VCC2 is between 4.9 and 5.1 Vdc, proceed to the next step. If VCC2 is outside 4.9 and 5.1 Vdc, check the power supply using the procedure in table 4-5, "Repairing the Power Supply."
7. Measure LCDNEG at the anode of A2VR2 (unstriped end).	If LCDNEG is between −7 and −13 Vdc, proceed to the next step. If LCDNEG is outside −7 and −13 Vdc, check the power supply using the procedure in table 4-5, "Repairing the Power Supply."
For assembly-level repair: Find the bad assembly by temporarily substituting a good I/O PCA, system PCA, or top case assembly, then repeating the main diagnostic procedure in section 4.2.1. **For component-level repair:** Continue testing using the following steps.	

Table 4-4. Startup Problems (Continued)

Step	Response
8. Using a scope, check the following signals for the proper activity in order. Monitor each signal either while the HP 110 is on or while the HP 110 is *turning on.* (Turn on the HP 110 by pressing (◑) or other keys while the unit is off. Turn off the HP 110 by pressing and holding (◑).) CLK (A1U1 pin 19): 5.33-MHz signal. CRESET (A1U1 pin 21): 5V for 50 ms at turn-on, then 0V. READY (A1U1 pin 22): 5V. $\overline{\text{CALE}}$ (A1U1 pin 25): toggles at turn-on. $\overline{\text{CRD}}$ (A1U1 pin 32): toggles at turn-on. $\overline{\text{CWR}}$ (A1U1 pin 29): toggles at turn-on. $\overline{\text{CDEN}}$ (A1U1 pin 26): toggles at turn-on. $\overline{\text{CDT}}$ (A1U1 pin 27): toggles at turn-on. $\overline{\text{BHE}}$ (A1U1 pin 34): toggles at turn-on. M/$\overline{\text{IO}}$ (A1U1 pin 28): toggles at turn-on.	If all signals are proper, proceed to the next step. If any signal is improper, check the system processors using the procedure in table 4-6, "Repairing the Processors."
9. Note whether the display has properly shown the main P.A.M. screen (or any other display) during the previous steps.	If the display appears to be operating properly (even though the expected P.A.M. screen may not be displayed), proceed to the next step. If the display appears to be improperly presented (including altered characters), check the display function using the procedure in table 4-7, "Repairing the Display." If the display doesn't turn on (after pressing (◑) or other keys), check the display function using the procedure in table 4-7, "Repairing the Display."
10. Note how the unit has responded to keystrokes during the previous steps.	If the unit has responded to some keys, but other keys don't get a response, check the keyboard function according to table 4-8, "Repairing the Keyboard." If the unit hasn't responded to any keys, check the keyboard function according to table 4-8, "Repairing the Keyboard." If the unit has responded to all keys, repeat the main diagnostic procedure (selecting the system test from the test menu).

Table 4-5. Repairing the Power Supply

Use this procedure if any of the supply voltages appears to be improper. If you make a repair at any step, check whether the voltage is proper; if it's good, go back to the main diagnostic procedure in section 4.2.1.



Step	Response
1. Note the symptom that indicated a power supply problem.	If a good recharger, when connected to the unit with a low battery, doesn't increase the battery voltage (VBAT) to at least 6 Vdc, proceed to the next step. If the VCC1 supply always stays at its power-down level (3.2–3.4 Vdc) but VBAT is above 6.2 Vdc, *skip to step 5.* If the VCC1 supply is outside its proper range (4.9–5.1 Vdc or 3.2–3.4 Vdc) but VBAT is above 6.2 Vdc, *skip to step 5.* If the VCC2 supply is outside its proper range (4.9–5.1 Vdc) but VCC1 is proper (4.9–5.1 Vdc), *skip to step 7.* If the LCDNEG supply is outside its proper range but VCC1 and VCC2 are proper (4.9–5.1 Vdc), *skip to step 8.* If the contrast adjustment doesn't operate properly but VCC1, VCC2, and LCDNEG are proper, *skip to step 10.*

Table 4-5. Repairing the Power Supply (Continued)

Step	Response
Charger Problem:	
2. Connect a good recharger to the HP 110.	
3. Measure the voltage at A2C6 "+" lead.	If the voltage is between 10 and 20 Vdc, proceed to the next step. If the voltage is 0 Vdc, check the connections at the I/O plate (RECH receptacle), check CR1 (rectifier), check C6; replace the I/O PCA. If the voltage is greater than 0 Vdc but *not* between 10 and 20 Vdc, replace the I/O PCA.
4. Measure the voltage at the cathode of A2CR2 (striped end).	If the voltage is between 10 and 20 Vdc, check A2Q4; replace A2U27; replace the I/O PCA. If the voltage is 0 Vdc, check A2C7, A2CR2, A2CR3; replace the I/O PCA. If the voltage is greater than 0 Vdc but *not* between 10 and 20 Vdc, replace the I/O PCA.
VCC1 Regulator Problem:	
5. Measure VCC1: A2U1 (PPU) pin 40.	If VCC1 is less than 1 Vdc, check A2VR3 (produces regulated voltage of 1.23 to 1.24 Vdc), check A2Q13, A2Q16, A2Q17 for open circuit; replace the I/O PCA. If VCC1 is between 3.2 and 3.4 Vdc, proceed to the next step. If VCC1 is between 4.0 and 4.9 Vdc, proceed to the next step. If VCC1 is the same as VBAT (measured at the terminal block), replace A2Q13; replace the I/O PCA. If VCC1 is outside any of the above ranges, replace the I/O PCA.
6. Monitor the SLEEP signal with a scope while pressing (◑) (or other keys): A2U1 pin 17.	If the SLEEP signal goes low (less than 1V), proceed to the next step. If the SLEEP signal stays high or "floats" between high and low, check the processors using the procedure in table 4-6, "Repairing the Processors."
7. Unsolder and lift the drain lead of A2Q20, then measure VCC2 at the lifted drain lead.	If the drain voltage is between 4.9 and 5.1 Vdc, swap the system PCA; swap the I/O PCA. If the drain voltage stays low, check A2Q13; replace the I/O PCA.

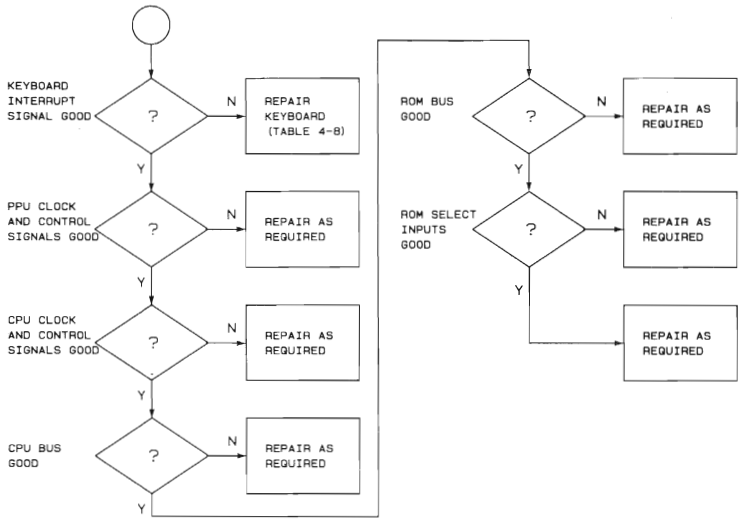
Table 4-5. Repairing the Power Supply (Continued)

Step	Response
LCD Supply Problem:	
8. Measure LCDNEG: anode of A2VR2 (unstriped end).	If LCDNEG is between −7 and −13 Vdc, the voltage is in its proper range. To check the LCD supply circuit for display-contrast adjustment, *skip to step 10.* If LCDNEG is between 0 and −1 Vdc, proceed to the next step. If LCDNEG is outside the above ranges, swap the I/O PCA. If LCDNEG is still out of range, remove the display load (unplug the keyboard cable from the I/O PCA); if LCDNEG goes more negative than −10 Vdc, check for shorts in path to display, replace display module (if LCDNEG goes more negative than −20 Vdc, replace A2VR2 also).
9. Monitor the signal at A2U26 pin 7 with a scope. (Compare the observed signal with the corresponding waveform shown on the schematic diagram, figure 9-7.)	If the signal looks proper (with a peak voltage equal to VBAT), check A2Q28, A2CR13, A2L1, A2VR2; replace the I/O PCA. If the signal looks proper (but the peak voltage is lower than VBAT), check A2Q24; replace the I/O PCA. If the signal stays at 0 Vdc or at VBAT, check A2Q24, A2U26; replace the I/O PCA. If the signal is improper in any other way, replace the I/O PCA.
Display-Contrast Adjustment Problem:	
10. Monitor the STEP1, STEP2, STEP4, and STEP8 signals with a scope while pressing (◑) and (Shift) (◑): A2U1 pins 33, 34, 35, 36.	If all signals toggle between 0 and 5 Vdc in a binary pattern each time you press (◑) (or (Shift) (◑)), proceed to the next step. (STEP1 should change state every keystroke, STEP2 should change state every two keystrokes, and so on.) If any signal doesn't toggle between 0 and 5 Vdc in a binary pattern, replace A2U1.
11. Monitor the signals at the anodes of A2Q11, A2Q10, A2Q9, and A2Q8 with a scope while pressing (◑) and (Shift) (◑).	If all signals toggle between 0 Vdc and a voltage less than 5 Vdc in a binary pattern each time you press (◑) (or (Shift) (◑)), the contrast adjustment is operating properly. If any signal doesn't toggle in a binary pattern, replace the corresponding transistor (A2Q8 through A2Q11).

Table 4-6. Repairing the Processors

Use this procedure if the system processors aren't operating properly. If you make a repair at any step, check whether the unit can turn on. If it turns on, go back to the main diagnostic procedure in section 4.2.1.

In the following steps, use a scope to check the indicated signals for the proper activity in order. Monitor each signal either while the HP 110 is on (or while the HP 110 is *turning on*, if indicated). (Turn on the HP 110 by pressing (◑) or other keys while the unit is off. Turn off the HP 110 by pressing and holding (◑).) Refer to the schematic diagrams in chapter 9 while tracing bad signals.



Step	Response

The following diagram illustrates the proper signal responses at power-up.

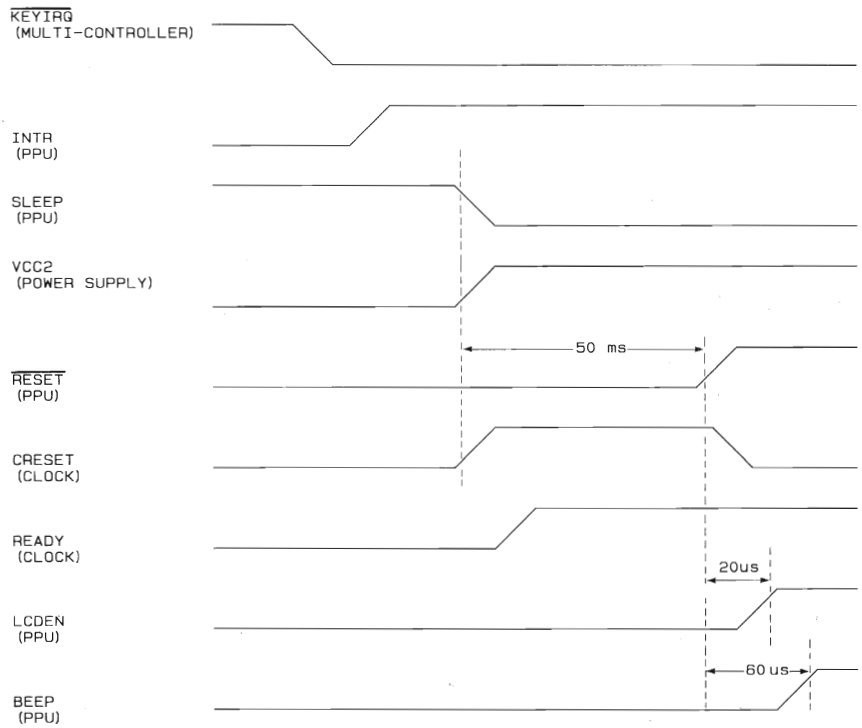


Table 4-6. Repairing the Processors (Continued)

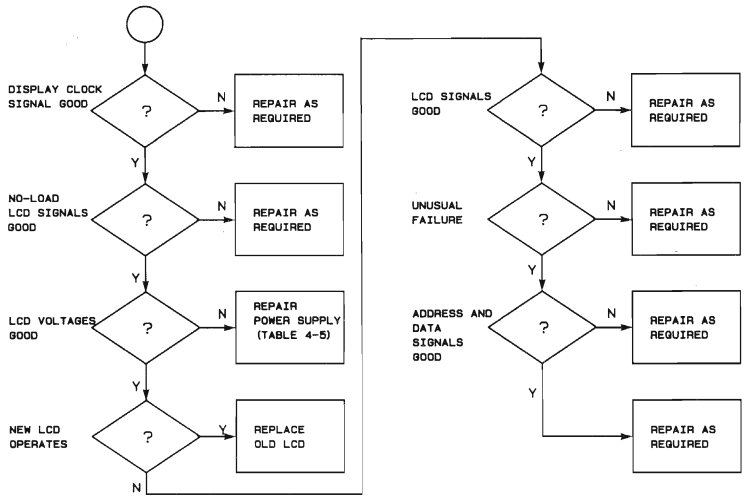
Step	Response
1. $\overline{\text{KEYIRQ}}$ (A2U1 pin 5): pulses to 0V while pressing almost any key.	If bad, check that C13 (A2U1 pin 2) is 0V (while pressing (◑)). If C13 is bad, or if other keys get no response, check the keyboard function according to table 4-8, "Repairing the Keyboard." If C13 is good, replace A2U1.
2. SLEEP (A2U1 pin 17): 0V.	If bad, check A2Q36, A2Q20; replace A2U1.
3. $\overline{\text{RESET}}$ (A2U1 pin 16): 0V for 50 ms at turn-on, then 5V.	If bad, replace A2U1.
4. LCDEN (A2U1 pin 12): 0V for 50 ms at turn-on, then 5V.	If bad, replace A2U1.
5. BEEP (A2U1 pin 19): 0V for 50 ms at turn-on, then 5V.	If bad, replace A2U1.
6. The clock signal (A2U19 pin 8): 5.33-Mhz signal.	If bad, check for 16-MHz signal at A2U19 pins 16 and 17. If present, replace A2U19; if absent, check A2Y2, replace A2U19, as required.
7. CLK (A1U1 pin 19): 5.33-MHz signal.	If bad, trace signal back to A2U19 pin 8.
8. CRESET (A1U1 pin 21): 5V for 50 ms at turn-on, then 0V.	If bad, trace signal back to A2U19 pin 10; trace $\overline{\text{RESET}}$ (0V for 50 ms) from A2U19 pin 11 back to A2U1 pin 16.
9. READY (A1U1 pin 22): 5V at turn-on, then toggles.	If bad, trace signal back to A2U19 pin 5 and A2U18 pin 3; check for correct signal at A2U19 pin 4; check for correct LCDRDY signal at A2U3 pin 2 and KEYRDY signal at A2U2 pin 35; check for correct signal at A2U20 pin 10.
10. CALE (A1U1 pin 25): toggles at turn-on.	If bad, trace signal to A1U2 pin 8; unsolder A1U2, then check whether signal toggles at turn-on; replace bad component.
11. $\overline{\text{CRD}}$ (A1U1 pin 32): toggles at turn-on.	If bad, trace signal to A1U2 pins 3, 4, and 5; unsolder A1U2, then check whether signal toggles at turn-on; replace bad component.
12. $\overline{\text{CWR}}$ (A1U1 pin 29): toggles at turn-on.	If bad, trace signal to A1U2 pins 1 and 2; unsolder A1U2, then check whether signal toggles at turn-on; replace bad component.
13. $\overline{\text{CDEN}}$ (A1U1 pin 26): toggles at turn-on.	If bad, trace signal to A1U2 pin 7; unsolder A1U2, then check whether signal toggles at turn-on; replace bad component.

Table 4-6. Repairing the Processors (Continued)

Step	Response
14. CDT (A1U1 pin 27): toggles at turn-on.	If bad, trace signal to A1U2 pin 6; unsolder A1U2, then check whether signal toggles at turn-on; replace bad component.
15. $\overline{\text{BHE}}$ (A1U1 pin 34): toggles at turn-on.	If bad, trace signal to A1U3 pin 7; unsolder A1U3, then check whether signal toggles at turn-on; replace bad component.
16. M/$\overline{\text{IO}}$ (A1U1 pin 28): toggles at turn-on.	If bad, trace signal to A1U3 pin 8; unsolder A1U3, then check whether signal toggles at turn-on; replace bad component.
17. Check the connectors and cables between the main PCAs and between the top case assembly and the I/O PCA.	If bad, replace bad part.
18. While the system is turned on, press keys and check for a toggling signal on each CPU bus line at A1U1 (CPU): pins 2–16 and 39.	If any line never toggles, check the printed-circuit traces for shorts; swap system PCA and retry; replace A1U1 or check connectors and A2U6–A2U9, as indicated.
19. While the system is turned on, press keys and check for a toggling signal on each ROM line (A1U62 and A1U63 only): all pins *except* 1, 14, 26, and 28.	If any line never toggles, trace input signal back to source (such as A1U2, A1U4, A1U5, or A1U12), then isolate ICs; replace as required.
20. While the system is turned on, press keys and check for a toggling signal at A1U12: pins 1–4, 6, 7, and 9–13.	If any input line never toggles, trace signal back to source (A1U2 or A1U3), then isolate ICs. If any output line never toggles, but all input lines toggle, replace A1U12.

Table 4-7. Repairing the Display

Use this procedure if the LCDNEG supply voltage has already been checked and is good and the system processors are operating, but the display doesn't operate properly. If you make a repair at any step, check whether the display seems to operate properly; if it does, go back to the main diagnostic procedure in section 4.2.1.



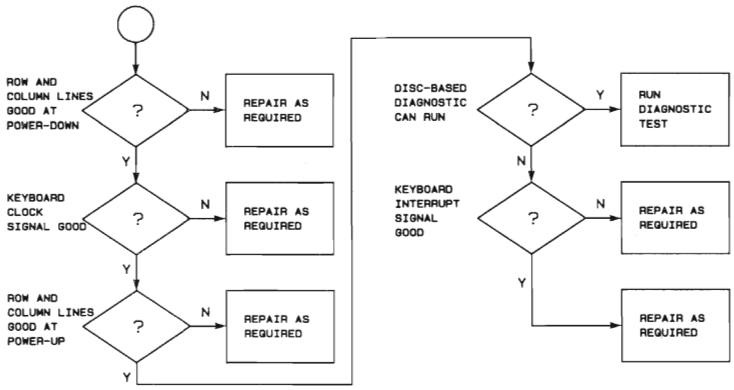
Step	Response
1. Using a scope, check for a 2.67-MHz signal (KEYCLK) at A2U3 pin 3.	If present, proceed to the next step. If signal is missing or bad, verify that unit is turned on. Then trace signal back to A2U19 pin 2; unsolder and disconnect pin at A2U19, then check signal to see if A2U19 is the problem; determine whether the problem is A2U2 or A2U3 by isolating one IC from the signal.
2. Disconnect the keyboard cable from the I/O PCA.	
3. Using a scope, check for toggling output signals at A2U3: pins 9–16.	If each signal toggles, proceed to the next step. If any signal never toggles, check traces; replace A2U3.
4. Measure the voltages at the keyboard connector on the I/O PCA. Pin 1: 0 Vdc (GND). Pin 17: −7 to −13 Vdc (LCDNEG). Pin 18: 4.9 to 5.1 Vdc (VCC2).	If all voltages are proper, proceed to the next step. If any voltage is out of range, check connections and traces; check the power supply according to table 4-5, "Repairing the Power Supply."
5. If available (this step is optional), connect a good top case assembly to the I/O PCA. Note whether the display operates properly.	If the display operates properly, replace the LCD module assembly in the original unit. If the display *doesn't* operate properly, *skip to step 8.*

Table 4-7. Repairing the Display (Continued)

Step	Response
6. Connect the original top case to the I/O PCA.	
7. Using a scope, check for proper output signals at A2U3. Pins 9–12: toggling (SD1–SD4). Pin 13: 21.7 Hz (M). Pin 14: 667 Hz (CL2). Pin 15: 2.78 kHz (CL1). Pin 16: 43.4 Hz (FLM).	If each signal is proper, proceed to the next step. If any signal *isn't* proper, check path through keyboard and display cable; replace LCD module assembly.
8. Take action based upon the observed behavior of the display.	If the display doesn't turn on, replace A2U3. If the display pixels are observed (most easily at high contrast) but the display is blank, replace A2U3. If only two horizontal black stripes are present, replace A2U3. If a repetitive pattern is displayed on the entire screen, press the reset button on the terminal block PCA (several times, if necessary); check for a bad cable connection. If a random pattern is displayed, proceed to the next step.
9. Using a scope, check for a toggling signal on these LCD controller lines: A2U3 pins 17–23, 25–30, and 35–42.	If all lines toggle, swap the I/O PCA (retaining the configuration EPROM). If any address line never toggles, replace A2U3. If all address lines toggle, but any data line never toggles, check that A2U3 pins 31, 33, and 34 each toggle: if they don't toggle, replace A2U3; if they toggle, replace A2U5.

Table 4-8. Repairing the Keyboard

Use this procedure if the system processors are operating, but the keyboard doesn't operate properly. If you make a repair at any step, check whether the keyboard seems to operate properly; if it does, go back to the main diagnostic procedure in section 4.2.1.



Step	Response
1. Turn off the HP 110. (Press (f8) in the main P.A.M. screen, or else press and hold (◑) for at least 15 seconds.)	
2. Measure the voltage of each column line: A2U2 pins 6–14, 46–48. A2U1 pins 2 and 7.	If all voltages are above 2.5 Vdc, proceed to the next step. If any voltages are below 2.5 Vdc, check the voltage with the keyboard disconnected from the I/O PCA. • If the voltages remain low, check continuity on the I/O PCA; replace A2U2. • If the voltages go above 2.5 Vdc, check and repair the keyboard module.
3. Measure the voltage of each row line: A2U2 pins 15–22.	If all voltages are below 1 Vdc, proceed to the next step. If any voltages are above 1 Vdc, check the voltage with the keyboard disconnected from the I/O PCA. • If the voltages remain high, check continuity on the I/O PCA; replace A2U2. • If the voltages go below 2.5 Vdc, check and repair the keyboard module.
4. Turn on the HP 110. (Press (◑) or other keys, if necessary.)	

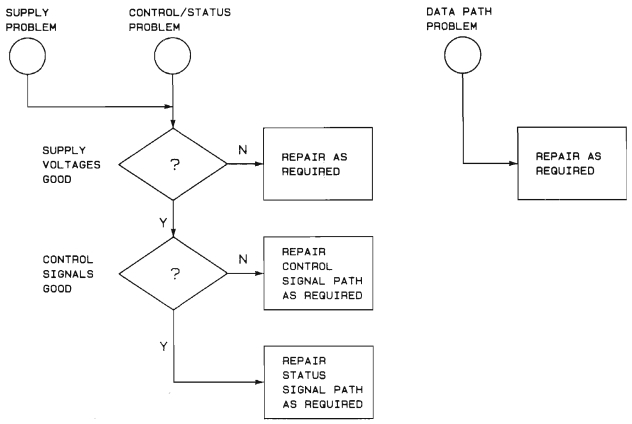
Table 4-8. Repairing the Keyboard (Continued)

Step	Response
5. Using a scope, check for a 2.67-MHz KEYCLK signal at A2U2 pin 23.	If present, proceed to the next step. If signal is missing or bad, verify that unit is turned on. Then trace signal back to A2U19 pin 2; unsolder and disconnect pin at A2U19, then check signal to see if A2U19 is the problem; determine whether the problem is A2U2 or A2U3 by isolating one IC from the signal.
6. Check individual keys: use a scope to monitor the corresponding column line (and then row line) at A2U2 while pressing and holding the key. (Refer to figure 9-11.) C1 (pin 14) C2 (pin 13) C3 (pin 12) C4 (pin 11) C5 (pin 10) C6 (pin 9) C7 (pin 8) C8 (pin 7) C9 (pin 6) C10 (pin 47) C11 (pin 46) C12 (pin 48 and A2U1 pin 7) C13 (A2U1 pin 2) R1 (pin 22) R2 (pin 21) R3 (pin 20) R4 (pin 19) R5 (pin 18) R6 (pin 17) R7 (pin 16) R8 (pin 15)	For C10 through C13: if the signal is lower than 1V while the key is held and higher than 2V while the key is released, the key is good; otherwise, replace the keyboard module. For other lines: If a square-wave signal is observed on both the row line and column line, the key is good. • If you can load and run the disc-based diagnostic tests, check the keyboard using the main diagnostic procedure in section 4.2.1. • If you can't use the disc-based diagnostic test, proceed to the next step. If a different signal is observed on either the row line or column line, check the signals for other keys in that row and for other keys in that column. • If the signal is bad for only one key, replace the keyswitch (or keyboard module). • If the signal is bad for an entire row or column, check continuity between A2U2 and the keyboard; replace A2U2.
7. Using a scope, monitor the $\overline{\text{KEYIRQ}}$ line (A2U2 pin 34) while pressing and holding any key (but *not* (◑)).	If signal periodically pulses low while key is pressed, swap the I/O PCA (retaining the configuration EPROM). If signal *doesn't* pulse low while key is pressed, replace A2U2.

Table 4-9. Repairing the Serial Interface

Use this procedure if the diagnostic tests indicate a problem with the serial (RS-232) interface. If you make a repair at any step, repeat the RS-232 test to see if the circuit is repaired; if it's good, go back to the main diagnostic procedure in section 4.2.1.

Note: The RS-232 scope routine switches the interface circuit on and off while it's running. The signals described in the steps below should be those observed while the circuit is "on."



Step	Response
1. Note the outcome of the RS-232 diagnostic test.	If any of the CTS, DSR, DTR, RTS, Carrier Detect, or Ring Detect lines are indicated bad, proceed to the next step. If the Transmit or Receive Data lines are indicated bad, *skip to step 6.* If "Power Supply Stuck On" is indicated, proceed to the next step.
2. Start the "RS-232 Oscilloscope Routine" with the RS-232 test connector installed. To select this routine, select "SA and Scope Menu 2" from the main disc-based diagnostic menu, then select the RS-232 option.	
3. Monitor V+ and V− supply voltages while the RS-232 scope routine (disc-based diagnostic) is running: A2U39 pins 14 and 1. (Use a scope, not a dc meter.)	If V+ is between 8 and 12 Vdc, and if V− is between −8 and −12 Vdc while the supply is "on," the voltages are good. Proceed to the next step. (If "Power Supply Stuck On" was indicated, repeat the RS-232 test instead.) If V+ is outside its range, *skip to step 7.* If V+ doesn't turn "on" and "off," *skip to step 7.*

Table 4-9. Repairing the Serial Interface (Continued)

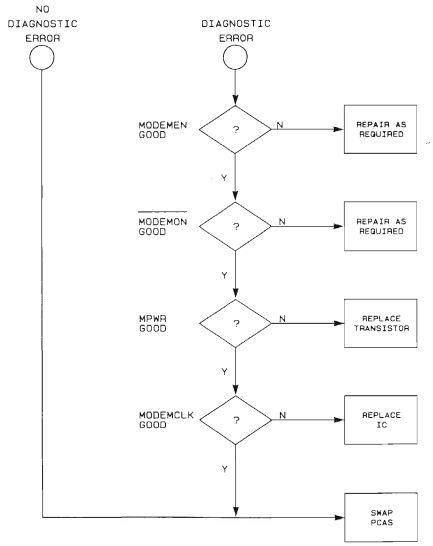
Step	Response
4. Monitor the DTR control signal while the RS-232 scope routine is running: A2U39 pin 8.	If the DTR signal pulses periodically between V+ and V−, trace the signal to RS-232 connector pin 1, then to RS-232 connector pins 6 (DSR line) and 9 (RS232RING). Trace DSR through the circuitry to the HP-IL IC (A2U4 pin 16). Trace RS232RING through the circuitry to the multi-controller (A2U2 pin 3). Repair as required. (Use the schematic diagrams in chapter 9 for reference.) If the DTR signal doesn't pulse, trace the signal back through the circuitry to the PPU (A2U1 pin 29). Repair as required. (Use the schematic diagrams in chapter 9 for reference.) If the DTR signal pulses periodically at voltages less than V+ and V−, check traces, check again with RS-232 test connector removed, replace A2U39 or A2U40, as indicated.
5. Monitor the RTS control signal while the RS-232 scope routine is running: A2U39 pin 6.	If the RTS signal pulses periodically between V+ and V−, trace the signal to RS-232 connector pin 4, then to RS-232 connector pins 5 (CTS line) and 8 (RS232CARRIER). Trace CTS through the circuitry to the HP-IL IC (A2U4 pin 15). Trace RS232CARRIER through the circuitry to the multi-controller (A2U2 pin 4). Repair as required. (Use the schematic diagrams in chapter 9 for reference.) If the RTS signal doesn't pulse, trace the signal back through the circuitry to the PPU (A2U1 pin 30). Repair as required. (Use the schematic diagrams in chapter 9 for reference.) If the RTS signal pulses periodically at voltages less than V+ and V−, check traces, check again with RS-232 test connector removed, replace A2U39 or A2U40, as indicated.
6. Monitor the RS-232 data path while the RS-232 scope routine is running. Start from SOUT at the multi-controller (A2U2 pin 25) and trace the signal through the circuitry to RS-232 receptacle pin 2 (TxD line), then to RS-232 receptacle pin 3 (RxD line). Trace RxD through the circuitry to SIN at the multi-controller (A2U2 pin 45). (Use the schematic diagrams in chapter 9 for reference.)	If the signal pulses periodically, continue tracing the signal through the circuitry. If the signal *doesn't* pulse, trace it back to the bad component. Repair as required.
7. Monitor the signals in the voltage doubler circuit and compare them with the proper signals indicated in figure 9-8 (left center).	Repair as required.

Table 4-10. Repairing the Modem

Use this procedure if the diagnostic tests indicate a problem with the modem circuit. (This procedure assumes that the serial interface operates properly.) If you make a repair at any step, repeat the modem test to see if the circuit is repaired; if it's good, go back to the main diagnostic procedure in section 4.2.1.

CAUTION

Don't adjust variable resistor A3R88 (on the original modem PCA or a new PCA). It is preset at the factory to give transmission levels that meet FCC requirements.



Step	Response
1. Note the outcome of the modem diagnostic test.	If failure code 331 or 332 occurred, proceed to the next step. If no failure codes were indicated for the modem (codes 331 or 332), but any other modem problem occurred, *skip to step 7.*
2. Start the "Modem Oscilloscope Routine." To select this routine, select "SA and Scope Menu 2" from the main disc-based diagnostic menu, then select the modem option.	
3. Monitor the MODEMEN signal while the modem scope routine is running: A2U1 pin 21 (or A2U25 pin 12). (Use a scope, not a dc meter.)	If MODEMEN is high while the circuit is "on," this signal is good. Proceed to the next step. If MODEMEN stays low, isolate A2U25 from A2U1 (PPU) and check the signal again at A2U1 pin 21: if the signal is still low, replace A2U1; if the signal goes high, replace A2U25.

Table 4-10. Repairing the Modem (continued)

Step	Response
4. Monitor the $\overline{\text{MODEMON}}$ signal while the modem scope routine is running: A2U1 pin 13. (Use a scope.)	If $\overline{\text{MODEMON}}$ is low while the circuit is "on," this signal is good. Proceed to the next step. If $\overline{\text{MODEMON}}$ doesn't toggle low, isolate individual IC's from A2U1 pin 13 (PPU): if the signal never toggles low, replace A2U1; otherwise, replace the indicated component.
5. Monitor the MPWR signal while the modem scope routine is running: A3U32 pin 16. (Use a scope.)	If MPWR is high while the circuit is "on," this signal is good. Proceed to the next step. If MPWR stays low, replace A3Q32, check traces.
6. Monitor the MODEMCLK signal while the modem scope routine is running: A2U25 pin 11. (Use a scope.)	If MODEMCLK oscillates at 1 MHz while the circuit is "on," this signal is good. Proceed to the next step. If MODEMCLK doesn't oscillate at 1 MHz, replace A2U25.
7. Swap the modem PCA, then recheck the operation. (Alternatives: trace signals through the circuit using the schematic diagrams in figures 9-8 and 9-10 and replace faulty components; use signature analysis as described in the signature analysis supplement.)	Replace the I/O PCA (retaining the configuration EPROM) or modem PCA, as indicated.

4.3 Burning an EPROM

Use the following procedure to prepare a 27C64 configuration EPROM (A2U28) before installing it in the system. This procedure stores the serial number of the unit and the EPROM checksum. (The procedure *can't* burn the entire EPROM memory.)

A new EPROM must be burned and installed whenever the original is bad and whenever you install a revised set of system ROM ICs.

1. Remove the top case of the diagnostic module using a Pozidriv screwdriver.
2. Remove the battery, separate the case, and remove the I/O and system PCAs from the HP 110 (procedures 5.2, 5.3, and 5.4).

> **CAUTION**
>
> Be sure the connectors are aligned properly when connecting the module to the PCAs. If they're connected with the pins misaligned, components may be damaged or system operation disrupted.

3. Connect the I/O PCA to the cable extending from the module. Connect the system PCA cable to the receptacle on the module. Connect the keyboard to the I/O PCA using a keyboard extension cable (00090-60910). Check that all connectors are aligned properly.

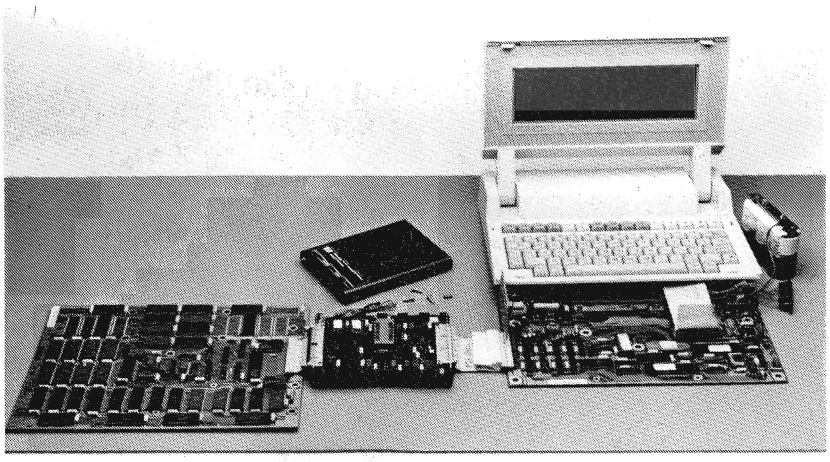


Figure 4-4. Connecting the Diagnostic Module

4. Remove the jumper from the two pins (at the I/O PCA end). This enables the module to perform its EPROM-burning function. (You can store the jumper by placing it on only one of the pins.)
5. Connect a recharger to the HP 110—it isn't necessary to connect the battery. (However, you *can* use a service battery assembly rather than the recharger if it's more convenient.)

   Note: If the system isn't able to turn on properly, press the reset button on the terminal block PCA (several times, if necessary).

6. Ensure that a "good" EPROM (A2U28) is present in the I/O PCA. A "good" EPROM is one that functions properly, but which may not have the proper serial number or ROM checksums stored internally (such as the original one if it still functions, or one that hasn't been burned yet). *This is not the EPROM that will be burned*—it merely allows the system to operate.
7. Connect a good HP 9114 Disc Drive using two good HP-IL cables.
8. Turn on the disc drive, then apply power to the HP 110 to turn it on. (If it doesn't turn on, press any keys to turn it on.)
9. Configure the HP 110 for one disc drive. Press (f6) (System Config) in the main P.A.M. screen. Use the tab or cursor keys to select the "External disc drives" field, then use the "Next Choice" and "Previous Choice" function keys to select one drive. Use the "Exit Config" function key to return to the main P.A.M. screen.
10. Insert the service disc in the disc drive.
11. Load and run the disc-based diagnostic program. Type **C:STEST** and press (Return).
12. Select the "EPROM Burner" option from the menu by pressing (Shift) (f5).
13. Connect a 25-Vdc power supply to the red and black wires at the two-pin power connector at the system PCA end of the module: RED (+25 Vdc) and BLACK (Ground and Common, if present). (For a new module, first trim the insulation from the ends of the wires.)

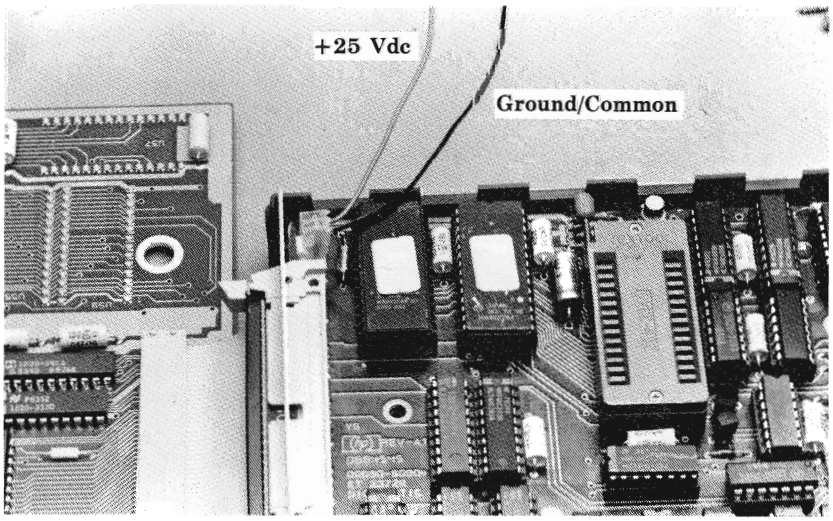


Figure 4-5. Connecting EPROM-Burner Power Supply

14. Turn on and adjust the power supply to 25 Vdc (24.8 to 30 Vdc).
15. Press any key to continue.
16. Raise the locking lever on the EPROM socket, install the new EPROM in the socket with pin 1 nearest the lever, then press the locking lever down. (Be sure the pins are *between* the contacts in the holes.)
17. Press any key to continue. (If a "BLANKCHECK" error occurs, check the power supply connections. The inserted EPROM may be bad or used; try burning it again or use another EPROM.)
18. When prompted, enter the serial number from the bottom case of the unit being repaired—including letters in upper case. Use the (Back space) key to correct an error. (The serial number is located next to the bottom label. Refer to section 1.4 to check the proper format for a serial number.)

19. Confirm the serial number by pressing (Y) (yes) or (N) (no). If it's not correct, go back to step 16.
20. Take action according to the message that appears after the EPROM is burned.
    - "Verify–ok" indicates that the EPROM was burned correctly. Proceed to the next step.
    - "Verify–error" indicates that the EPROM *wasn't* burned correctly, and that it must be discarded. Possible causes for this result are that the power supply voltage is too low (refer to step 14) or that the power supply wires or connector aren't providing a good path for the EPROM-burning current (you can measure the supply voltage on the module).
21. Remove the EPROM from the socket after raising the lever.

CAUTION

Be sure to turn off the +25V power supply *before* you disconnect the recharger or battery from the HP 110. If this isn't done, components may be damaged.

22. Turn off and disconnect the power supply. Carefully wrap and store the wires inside the module. Tape or cover the ends of the wires so that they don't touch each other or the PCA.
23. Disconnect power from the HP 110.
24. Install the jumper across the two pins in the diagnostic module. (This enables the module to perform its diagnostic function.)
25. If necessary, disconnect the diagnostic module from the system. Disengage the module cable from the I/O PCA by gently prying the connectors apart with a flat-bladed screwdriver, then pulling on the cable. Disengage the system PCA cable by pressing outward on the two tabs of the module receptacle. To ensure a good connection between the cable and the system PCA, press down on the clamp where the cable attaches to the PCA.
26. Install the top case on the diagnostic module.

4.4 Testing the Recharger

Various ac rechargers (table 4-11 and figure 4-6) are available for use with the HP 110.

Table 4-11. Rechargers

Model Number	Voltage*	Identification
HP 82059D	110	United States
HP 82066B	220	Europe
HP 82067B	220	United Kingdom
HP 82067B Opt 001	220	United Kingdom with RSA plug
HP 82068B	220	Australia
HP 82069B	110	Europe

* Indicates nominal voltage; acceptable ranges are 210 to 250 Vac and 90 to 120 Vac.

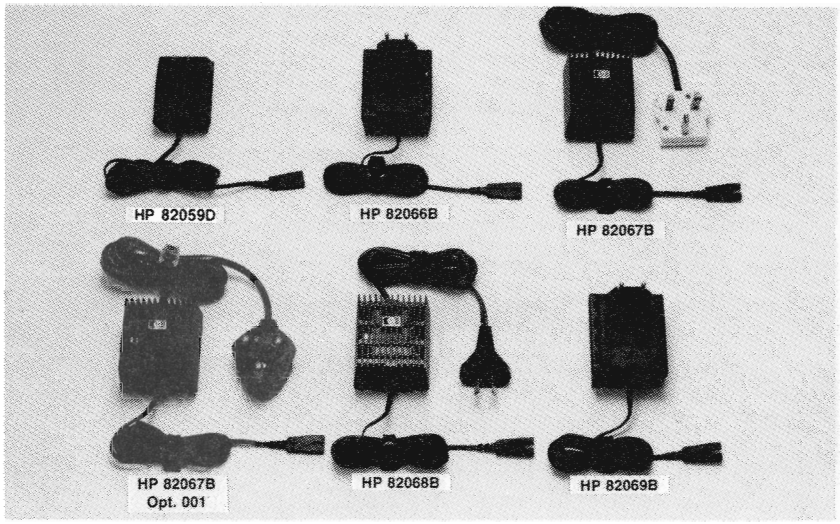
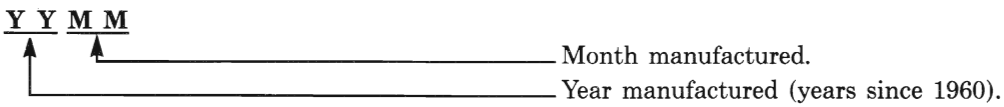


Figure 4-6. Rechargers

The serial number located on the recharger indicates the month that the unit was manufactured. The format is described below.



To determine whether the recharger is functioning properly, perform this procedure:

1. Plug the recharger into an outlet of the proper voltage. (Refer to table 1-11.) Measure the power-outlet voltage (VIN) using an ac voltmeter.
2. Measure the recharger ac output voltage (VOUT) under no-load conditions using an ac voltmeter. VOUT should be between 9.9 and 13.3 Vac at power voltages of 110.0 or 220.0 Vac. More generally, VOUT should equal

   $$(\text{VIN} / 110) \times 11.6 \text{ Vac} \pm 1.7\text{V} \quad \textit{or} \quad (\text{VIN} / 220) \times 11.6 \text{ Vac} \pm 1.7\text{V}$$

   where VIN is the ac voltage of the power outlet.
   - If VOUT is inside the allowable range, proceed to the next step.
   - If VOUT is outside the allowable range, the recharger is bad and should be discarded. Stop testing here.
3. Connect a 12-ohm, 5%, 5W resistor across the recharger output contacts.
4. Measure the ac voltage (VOUT) across the load using an ac voltmeter. The voltage should be between 5.3 and 7.3 Vac at power voltages of 110.0 and 220.0 Vac. More generally, VOUT should equal

   $$(\text{VIN} / 110) \times 6.3 \text{ Vac} \pm 1.0\text{V} \quad \textit{or} \quad (\text{VIN} / 220) \times 6.3 \text{ Vac} \pm 1.0\text{V}.$$

   - If VOUT is inside the allowable range, proceed to the next step.
   - If VOUT is outside the allowable range, the recharger is bad and should be discarded. Stop testing here.
5. While measuring the ac voltage across the load, wiggle and pull the wire at the transformer and at the connector.
   - If the voltage stays above 5 Vac, the recharger is good.
   - If the voltage drops below 5 Vac, the recharger is bad and should be discarded.

Chapter 5
Removal and Replacement

5.1 Introduction

This chapter describes the procedures that you'll use to remove and install assemblies while repairing the HP 110. Use these procedures to gain access to assemblies and components that you must test or replace.

- 5.2 Removing the Battery.
- 5.3 Separating the Case.
- 5.4 Replacing the PCAs.
- 5.5 Removing the Keyboard Module.
- 5.6 Removing a Keyswitch.
- 5.7 Removing the Display Module.
- 5.8 Removing the Clutches and Display Cable.
- 5.9 Removing ICs.

The procedure for installing an assembly is the reverse of the procedure for removing that assembly. Special "reassembly notes" advise you of additional information that you'll need to properly install an assembly.

CAUTION

Be sure to wear a grounded wrist strap and work at a bench that is electrostatically protected. Many components (especially the display module) are highly susceptible to damage by electrostatic discharge.

5.2 Removing the Battery

WARNING

A fully charged battery has an enormous short-circuit current capacity. Be careful to not short its contacts together. A short circuit can cause sparks and can melt metal, leading to burns or other injuries.

The battery contains an electrolyte that is sealed in. Avoid damaging the battery case. Use care when handling a damaged battery. The electrolyte can cause burns.

After disconnecting the recharger:

1. **Remove the battery cover** by pressing in on the ribbed latches and sliding the cover down.

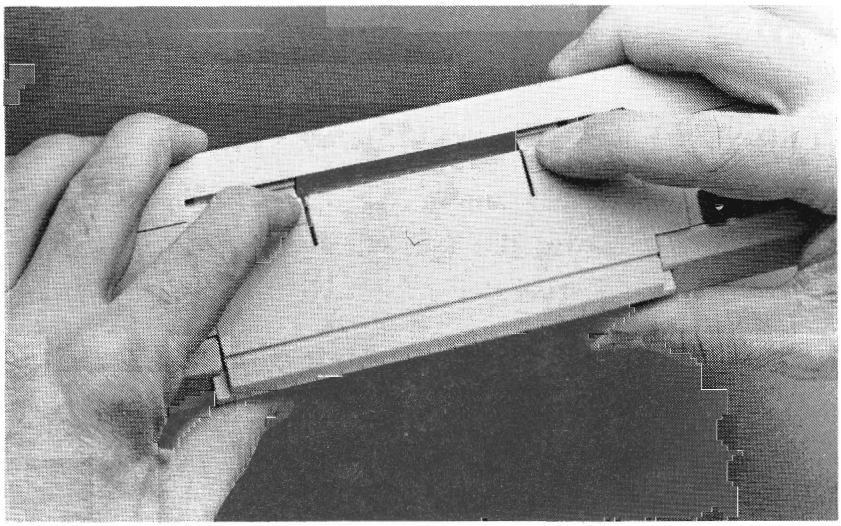


Figure 5-1. Removing the Battery Cover

CAUTION

Be careful that the disconnected plug doesn't slip against the pins on the PCA. If it makes contact with the wrong pins, a short circuit may occur.

2. **Unplug the battery cable** from the terminal PCA.

   Reassembly Note: Install the connector with its red wire next to the RED marking on the terminal PCA (next to the ground stud).

3. **Disconnect the ground straps** from the terminal PCA by removing the nut.

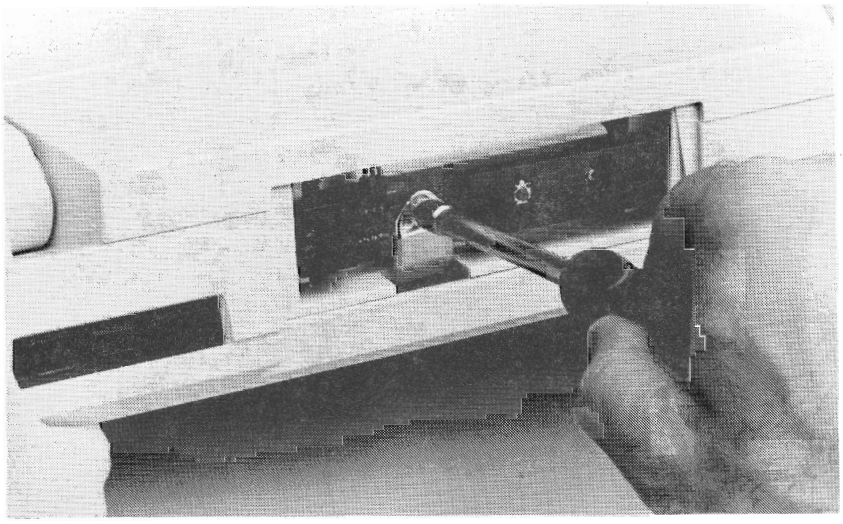


Figure 5-2. Disconnecting the Ground Straps

4. **Remove the terminal block** by removing the two screws.

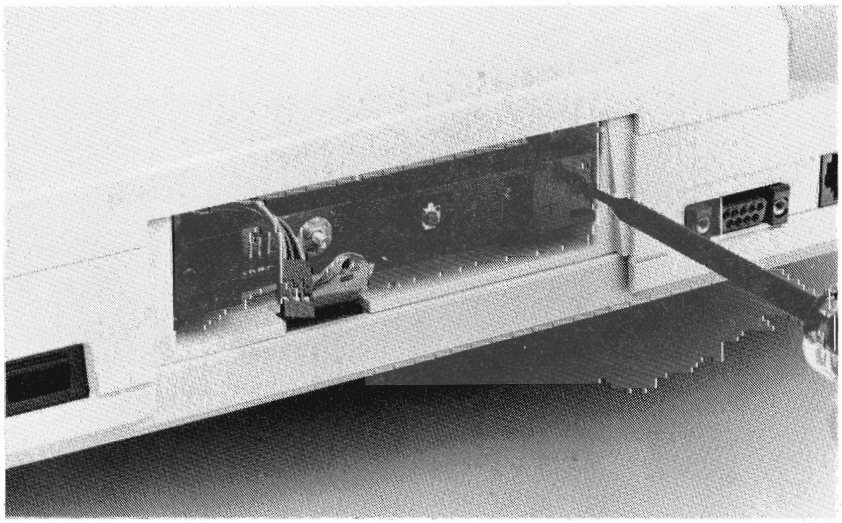


Figure 5-3. Removing the Terminal Block

Reassembly Note: Install the end marked "—" toward the I/O plate.

5. **Remove the battery.**

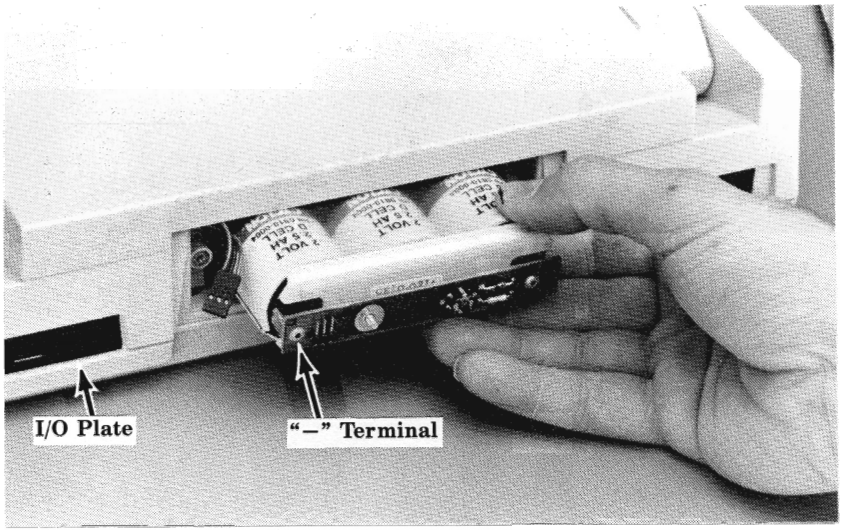


Figure 5-4. Removing the Battery

Reassembly Note: Fold the battery cushion around the battery before inserting them into the battery compartment. Insert the battery so that its "–" terminal is closest to the I/O plate.

6. **If necessary, disconnect the terminal PCA** by carefully prying the PCA off the battery's lugs with your fingers.

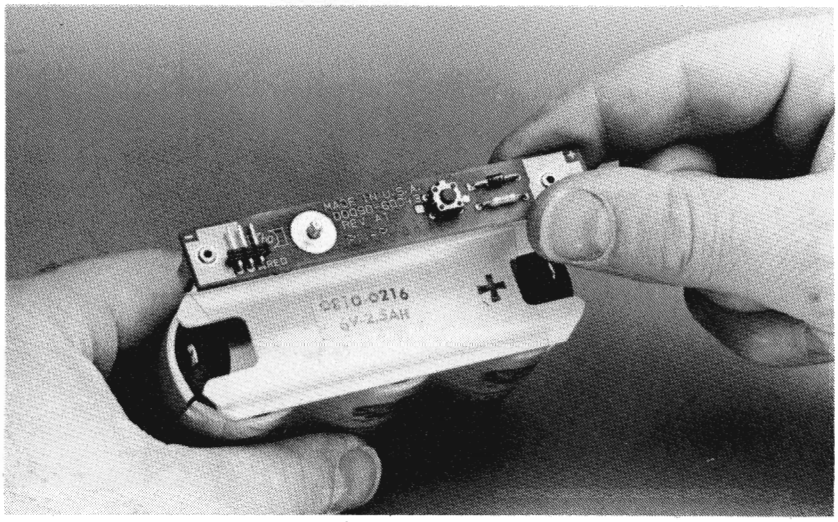


Figure 5-5. Disconnecting the Terminal PCA

Reassembly Note: Install the end marked "–" on the negative battery contact. This end should be toward the I/O plate.

5.3 Separating the Case

After removing the battery (procedure 5.2):

1. **Remove and discard the bottom label** by peeling it off. Start by inserting a pointed knife under the center rear part of the label and peeling off the label.

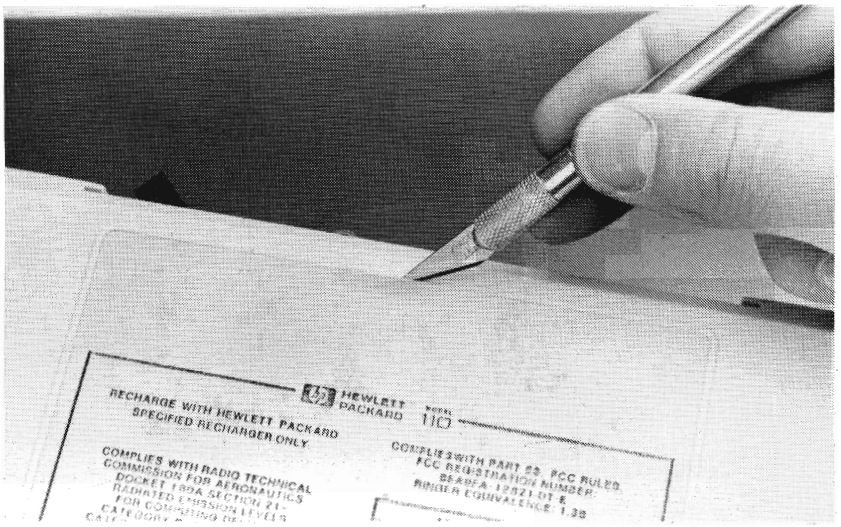


Figure 5-6. Removing the Bottom Label

Reassembly Note: Install the top of the label next to the back of the case.

2. **Remove and discard the four feet** from the bottom case. Peel them off using a sharp knife.
3. **Remove and discard the two inserts** between the foot recesses on the bottom case. Peel them off using a sharp knife.
4. **Remove the 11 screws** from the bottom case.

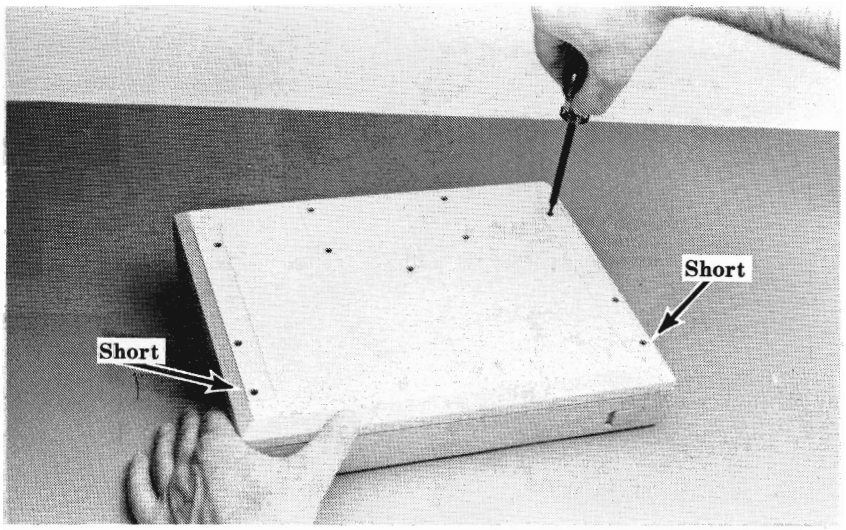


Figure 5-7. Removing the Bottom Screws

CAUTION

Don't install longer screws at the front corners—they will damage the top case. The two *shorter* screws go at the front corners.

5. **Partly open the case, then unplug the keyboard cable and battery cable.** Do this by lifting the rear of the top case just enough to reach and unplug the two connectors. The front edge doesn't separate while the cables are connected.

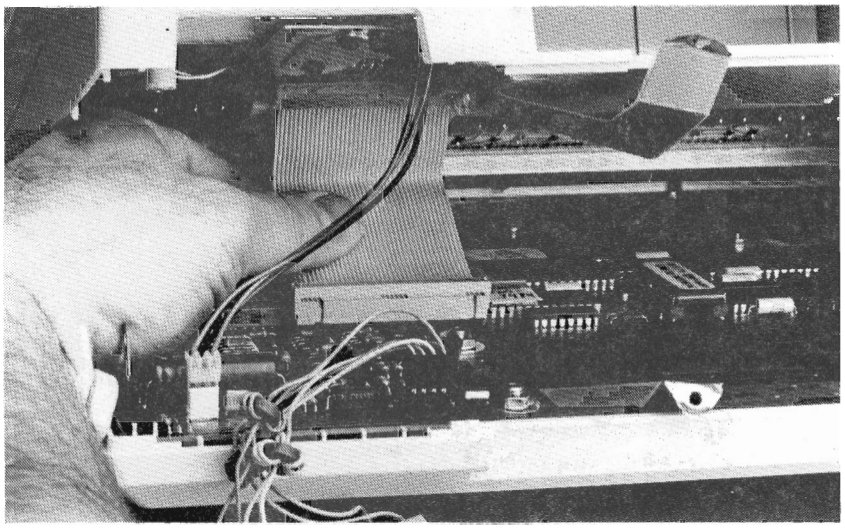


Figure 5-8. Unplugging the Top Case Cables

Reassembly Note: Install a piece of tape (half piece of transducer tape, 0460-1802) to hold the battery cable connector. Arrange the toroids (in the I/O plate leads) so that they are on top of the I/O plate. Be sure the I/O plate is held in place by the retaining fingers in both cases.

For version B units, ensure that the modem cutout plug is located in the modem cutout in the top case. The small tab on the plug points up into the top case.

6. **Separate the case** by swinging the top case up until it disengages from the bottom case.

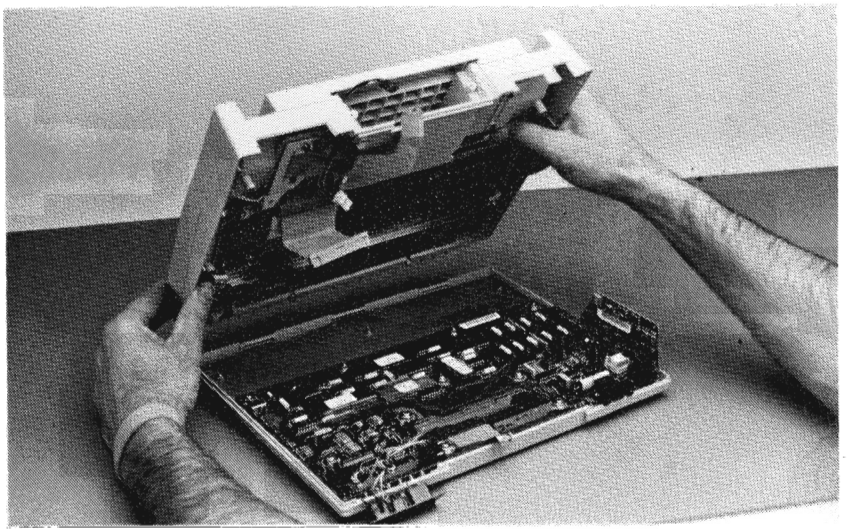


Figure 5-9. Separating the Case

Reassembly Note: Engage the cases by holding the top case vertically with its front edge placed along the front of the bottom case, then hinging the top case onto the bottom case.

5.4 Replacing the PCAs

After removing the battery and separating the case (procedures 5.2 and 5.3):

1. **Unplug the modem PCA** from the I/O PCA (version A units).

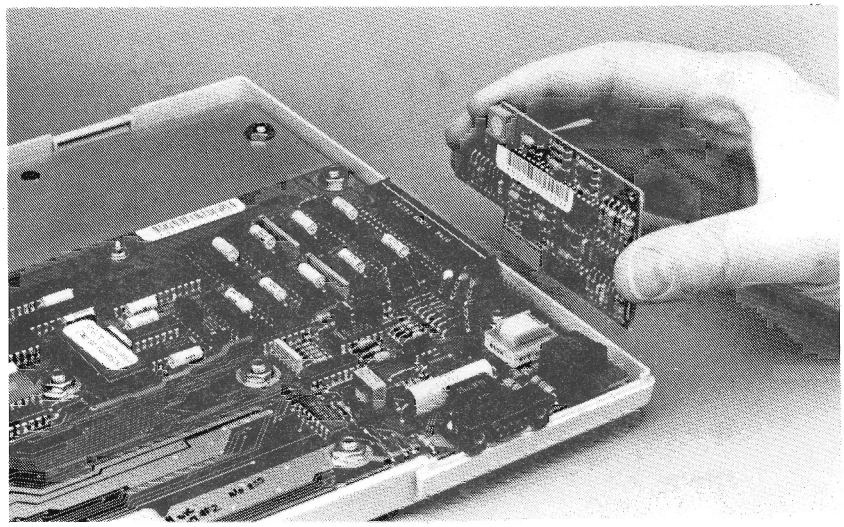


Figure 5-10. Unplugging the Modem PCA

Reassembly Note: Install a piece of tape (part number 0460-1802) on the side of the connector on the modem PCA. Leave a flap at the front edge and fold it back. Install the modem PCA on the I/O PCA, then press the flap onto the I/O PCA.

2. **Remove the 14 nuts** that hold the I/O and system PCAs.
3. **Remove the (lower) ground strap.**

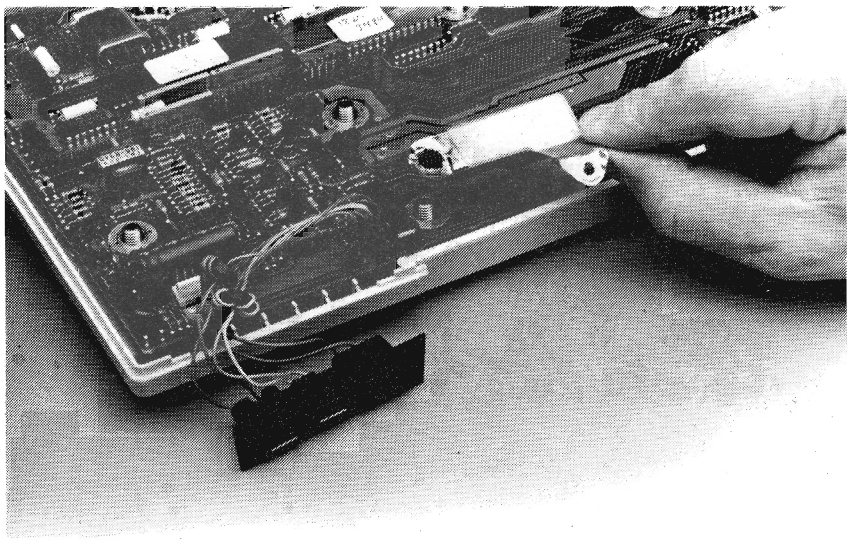


Figure 5-11. Removing the Lower Ground Strap

Reassembly Note: Install the ground strap on the stud near the I/O plate.

4. **Unplug and remove the I/O PCA.** Do this by lifting (about 30°) the side of the PCA opposite the main ribbon cable and carefully unplugging the cable from the PCA. You may need to start the connector by prying with a small flat-bladed screwdriver.

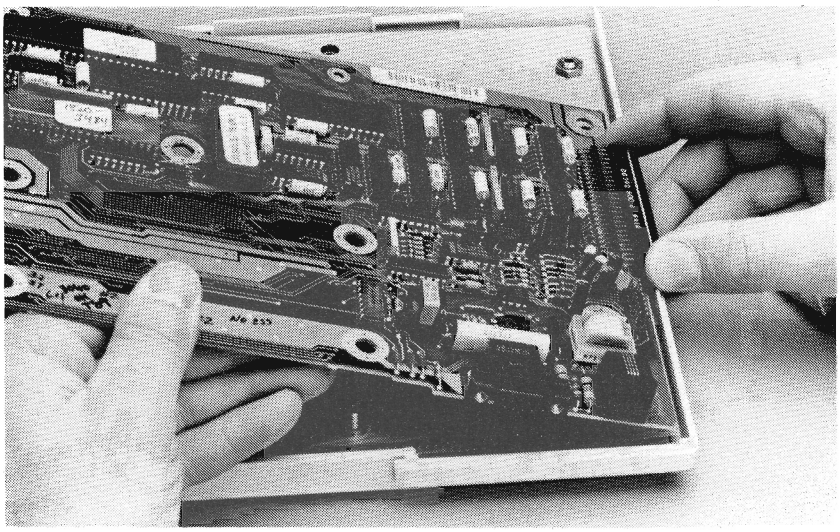


Figure 5-12. Unplugging the I/O PCA

Reassembly Note: Be sure that all leads on the back side of the PCA are trimmed less than 1.5 mm. Plug in the I/O PCA before lowering the opposite side onto the posts.

5. **Lift off the 11 spacers and the EMI shield.**

Reassembly Note: Check that the coating of the EMI shield isn't pierced or damaged. The notched side of the EMI shield fits around the ribbon cable. No spacers go on the front three posts on top of the shield.

6. **Lift off the 14 spacers and the system PCA.**

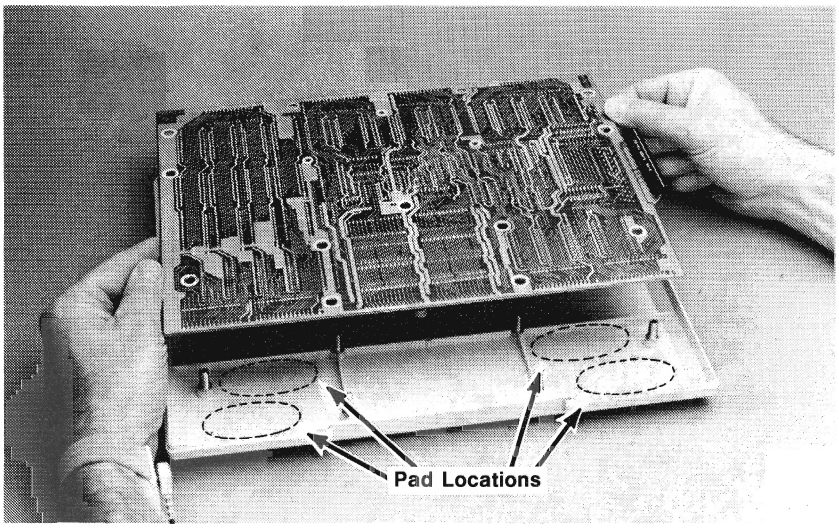


Figure 5-13. Removing the System PCA

Reassembly Note: Be sure that all leads on the back side of the PCA are trimmed less than 1.5 mm. Press on the clamp where the cable attaches to the PCA to ensure a good connection. The component side of the system PCA faces down. Spacers go on all posts.

If necessary, stick four support pads (part number 00090-80065) to the inside rear of the bottom case at the locations shown above. This is necessary only if you've replaced the original system PCA or if you've replaced an original bottom case that had pads attached.

5.5 Removing the Keyboard Module

After removing the battery and separating the case (procedures 5.2 and 5.3):

1. **Remove the hinge cover** by removing the four screws (and upper ground strap) on the underside of the top case assembly. The ground plate remains fastened to the keyboard PCA.

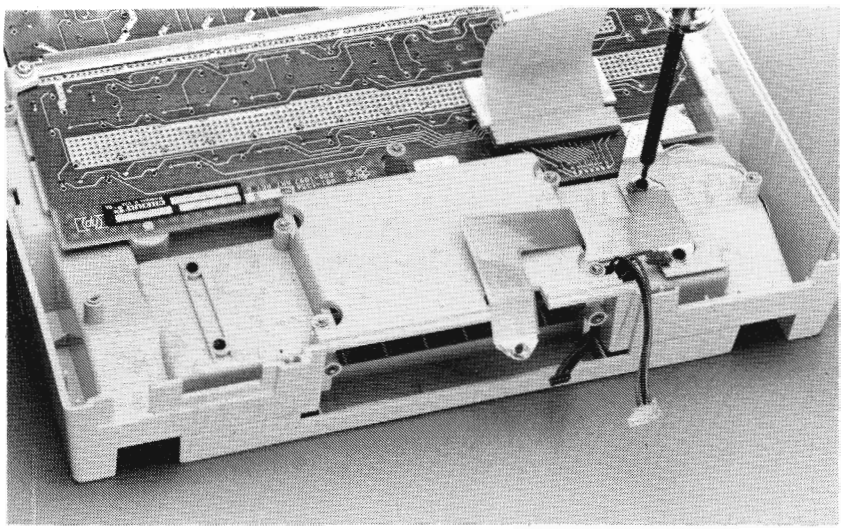


Figure 5-14. Removing the Hinge Cover

Reassembly Note: Be sure the (upper) ground strap is held by the two screws (with washers) near the I/O opening, and also that the ground lug on the display cable is held by the one screw nearest the I/O opening.

2. **Unplug the display connector** that was covered by the hinge cover.
3. **Remove the four nuts** along the top edge of the keyboard. Remove the ground plate.

Reassembly Note: First install nuts on the three studs on the keyboard PCA. Then insert the ground plate stud through the fourth hole in the keyboard PCA and loosely install the fourth nut. After positioning the ground plate over the holes for the hinge cover screws, tighten the fourth nut at the top edge of the keyboard PCA.

4. **Remove the four nuts** on the underside of the keyboard PCA. Do this with the display open and the assembly tipped back on the display case.

5. **Pivot and remove the keyboard module.** The rear edge of the keyboard pivots out the bottom of the case. The module then slides out the bottom of the case.

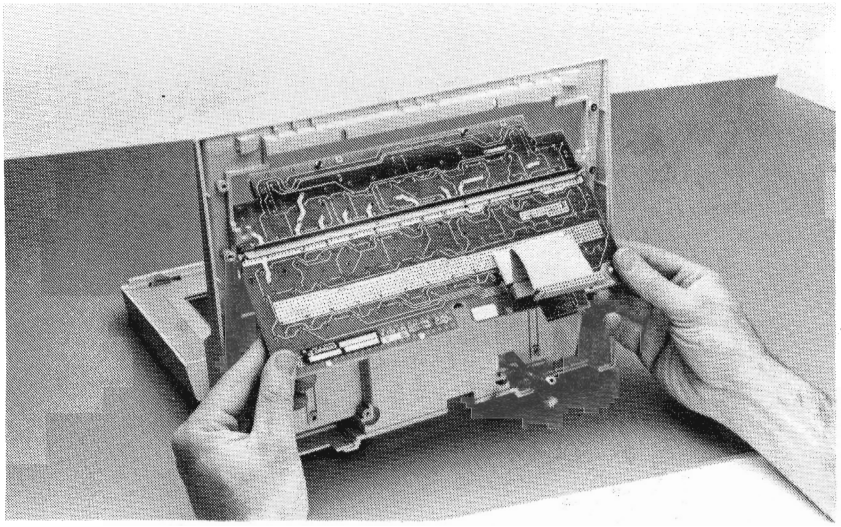


Figure 5-15. Removing the Keyboard Module

Reassembly Note: Insert the front edge of the keyboard just below and behind the tabs at the sides of the main opening.

If you're installing a new keyboard in an HP 110 with a non-U.S. keyboard, replace the keycaps according to procedure 5.6. Install the keycaps from the old keyboard or from a new set of keycaps (table 6-2).

5.6 Removing a Keyswitch

After removing the battery and separating the case (procedures 5.2 and 5.3):

1. **Remove the keycap** from the switch using a keycap puller or a bent paperclip. (For each of the four widest keys, the keycap is also connected to a stabilizer bar underneath; unhook the keycap from the bar by sliding the keycap to one side and unhooking the opposite end, then repeat for the other end. You may have to remove the adjacent keycap to do this.)



Figure 5-16. Removing a Keycap

Reassembly Note: For a wide key with a stabilizer bar, hook its two pivot clips onto the stabilizer bar, then press the keycap onto the switch. (If you're installing a *new* wide key, position the two new pivot clips on the stabilizer bar according to the slots in the keycap. Then place a *small* drop of cyanoacrylate adhesive (such as Loctite 495) in each of the pivot slots of the keycap, and press the cap onto the switch and pivot clips.)

2. **Unsolder the two pins** from the underside of the PCA.

5.7 Removing the Display Module

WARNING

Avoid touching, swallowing, or breathing material from a broken display module. The liquid crystal material is mildly toxic. If the material gets on your skin, rinse it off immediately with alcohol, then wash with water.

Discarded display modules should be disposed of by approved handlers of hazardous chemicals.

CAUTION

Take precautions against physical and electrostatic damage to the display module:

Be sure that you're wearing a grounded wrist strap and working at a bench that is electrostatically protected. The display module is extremely sensitive to damage from electrostatic discharge (ESD).

Be careful to *not* exert pressure on the display module. The LCD display and its PCA can become misaligned, causing damage that can't be repaired.

Don't touch the front surface of the display module. Body oils or other contamination can damage the optical properties of the polarizer.

Don't touch or clean the back surface of the bezel window. It has no coating and can be easily scratched or marred.

1. **Remove the cap from the display bezel** by gently prying out the two ends at the latch slots. Remove and discard the piece of two-sided tape that held the cap in place.

   Reassembly Note: Install a new piece of tape (part number 00090-80033) along the top recess. Install the cap with its two small tabs placed into the latch openings.

2. **Remove the two screws** at the top of the bezel.

   Reassembly Note: If a new display module was installed, remove the protective film before installing the bezel. Avoid over-tightening the two screws—tighten them until they're just snug. (Over-tightening could damage the threads or cause the latches to bind.)

3. **Lift off the bezel.**

   Reassembly Note: Before installing the bezel, clean the glass on the display module with freon or petroleum benzene (*using only light pressure*), and clean only the front side of the bezel window with mild detergent or plastic cleaner.

4. **Remove the eight nuts** along the top and bottom of the display module.

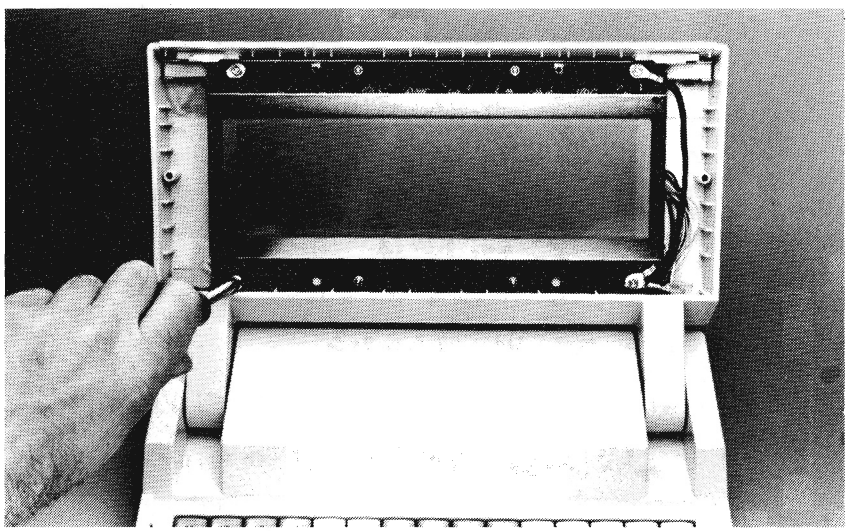


Figure 5-17. Removing the Display Nuts

Reassembly Note: If the unit had a braided ground strap installed between the upper and lower brackets, install it under the nuts at the right corners. (If you're installing a new display module that has a wide ground trace around the edge of the *back side,* then don't install the ground strap. If the new display module *doesn't* have the ground trace, then you must install a ground strap.)

Before tightening the nuts, slide the display module down toward the keyboard so that all play in the mounting holes is taken up in one direction. Then tighten the bottom nuts. (Be sure the braided ground wire from the keyboard is secured by the bottom right nut.)

At the top, tighten the two corner nuts before the center nuts. While tightening each upper corner nut, press the top bracket toward the latch, checking that the latch can snap freely into its closed position (that it's not pinched between the bracket and display back or ground wire, but doesn't have excessive play).

5. **Lift out the display module and unplug the cable** at the back of the module.



Figure 5-18. Removing the Display Module

Reassembly Note: Before installing the display module, check that the top bracket and hex spacers are installed (in that order) along the top of the display back. The bottom bracket should be installed so that it extends to the left side of the display back, with its flange facing toward the back; the display insulator should be installed over it.

5.8 Removing the Clutches and Display Cable

To replace only the left clutch, remove the battery and separate the case (procedures 5.2 and 5.3), then perform only steps 1 through 6 below (skipping step 3 as described).

To replace the right clutch and display cable, remove the battery, separate the case, and remove the display module (procedures 5.2, 5.3, and 5.7), then perform the steps below.

1. **Remove the hinge cover** by removing the four screws (and upper ground strap) on the underside of the top case assembly. The ground plate remains fastened to the keyboard PCA.

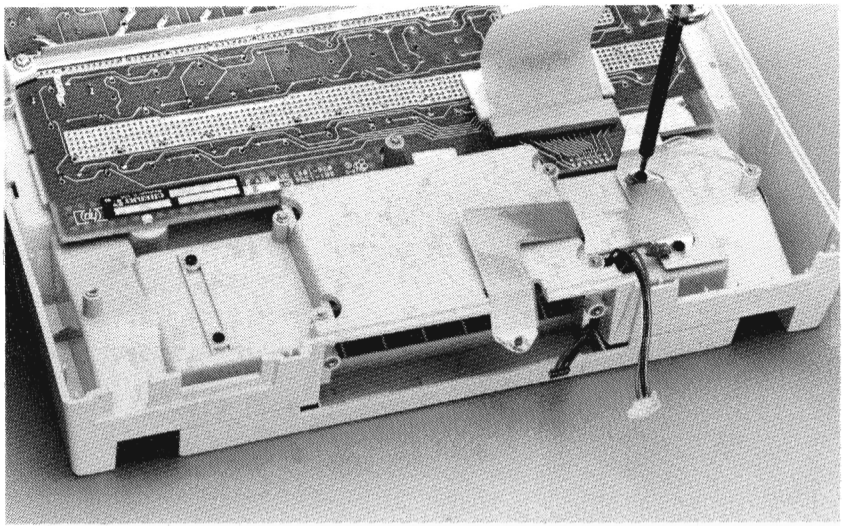


Figure 5-19. Removing the Hinge Cover

Reassembly Note: Be sure the (upper) ground strap is held by the two screws near the I/O opening, and also that the ground lug on the display cable is held by the one screw nearest the I/O opening.

2. **Unplug the display connector** covered by the hinge cover.
3. **If necessary, remove the transducer wires from the connector.** Do this by carefully lifting the plastic tab on the connector body while pulling on the wire. (This step is necessary only if you're replacing the cable and right clutch.)

Reassembly Note: The two transducer wires have no polarity. Insert each contact into either hole in the connector.

4. **Remove the four nuts** holding the clutches.

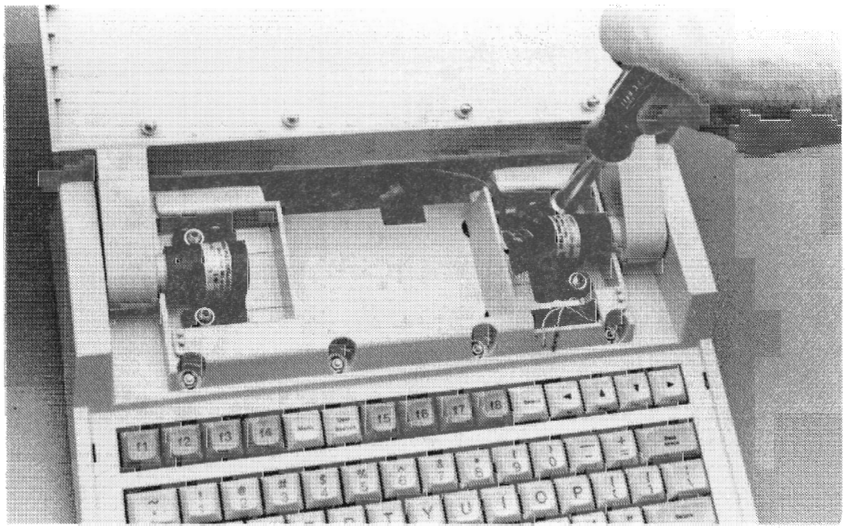


Figure 5-20. Removing the Clutch Nuts

Reassembly Note: Before tightening the four nuts, adjust the position of the display assembly so that it aligns with the main case along the two sides. Tighten the two nuts nearest the keyboard first. Check the alignment again after tightening the four nuts.

5. **Lift the display assembly off the top case.** If you didn't separate the transducer wires, invert the display on the rear of the main case, being careful to avoid straining the transducer wires.

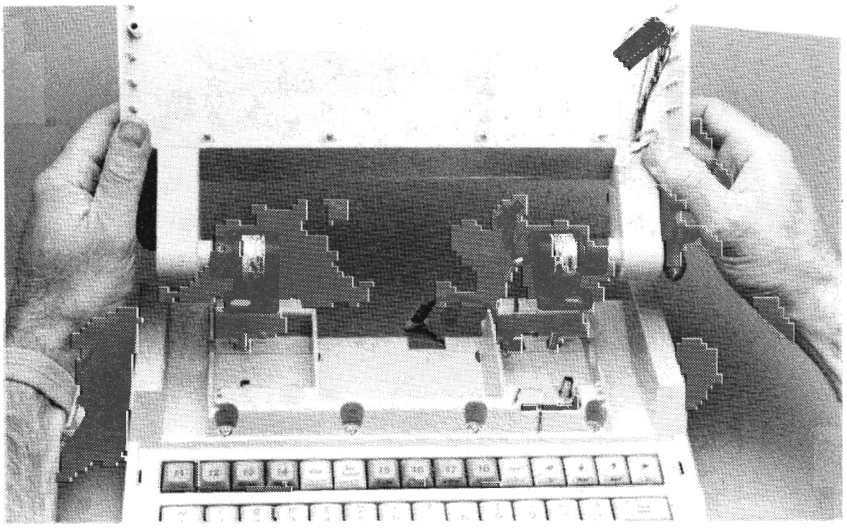


Figure 5-21. Removing the Display Assembly

Reassembly Note: Before installing the display assembly, twist the clutches so that the assembly will lay over the keyboard in its closed position.

6. **Pull the left clutch off the spline.** (Stop here if you're replacing only the left clutch.)

7. **Pull the right clutch off the spline.**

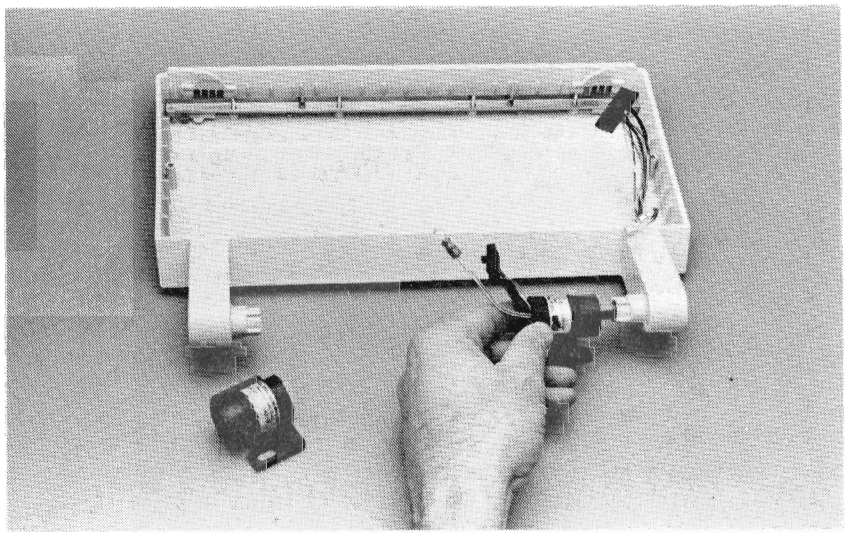


Figure 5-22. Removing the Clutch

8. **Unlatch the display front.** Do this by pulling out on the front piece at one end while depressing the end plastic latch inside until it disengages. (Use a small screwdriver.) While keeping tension on the front piece, disengage other latches toward the opposite side.

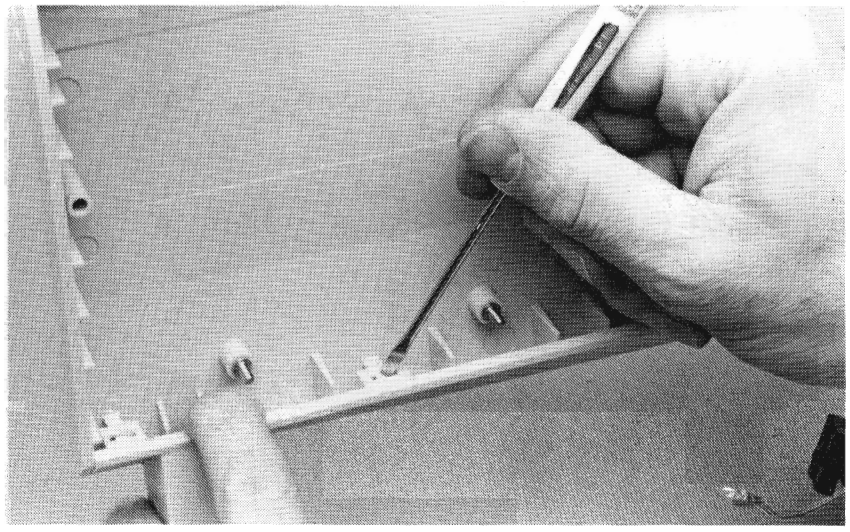


Figure 5-23. Unlatching the Display Front

9. **Remove the display front** by tipping it out until it disengages near the hinges.

Reassembly Note: Hold the display front at about 30° from the display back while engaging them at the hinges. Then lower the top of the display front and press along the top until all of the latches engage.

10. **Loosen the ferrite core** by slicing the adhesive holding it to the display back.

    Reassembly Note: Put a bead of RTV adhesive (part number 0470-0913 or equivalent) along each rib. Then press the core onto the adhesive.

11. **Lift out the clutch and display cable.**

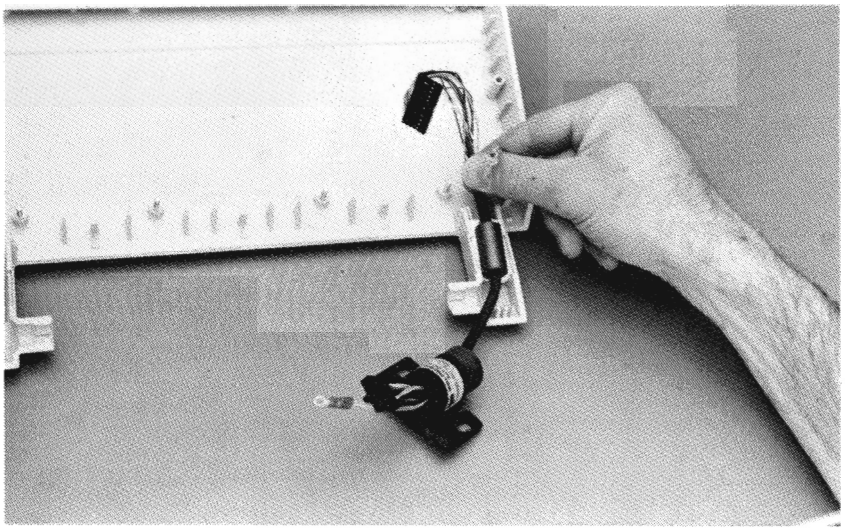


Figure 5-24. Removing the Clutch and Display Cable

Reassembly Note: When installing a new cable, ensure that about 10 cm (4 inches) of the display cable extend out of the spline.

5.9 Removing ICs

The following steps describe the proper procedure for using the optional IC desolderer (extractor) to remove a 28-pin IC from a PCA.

After removing the battery, separating the case, and removing the PCAs (procedures 5.2, 5.3, and 5.4):

1. **Straighten any bent pins** on the underside of the PCA.
2. **Apply solder flux** (rosin-based) to the soldered pin connections.

3. **Premelt the solder** at all pins for about 4 seconds. Do this by placing the IC desolderer across all of the IC pins on the underside of the PCA.

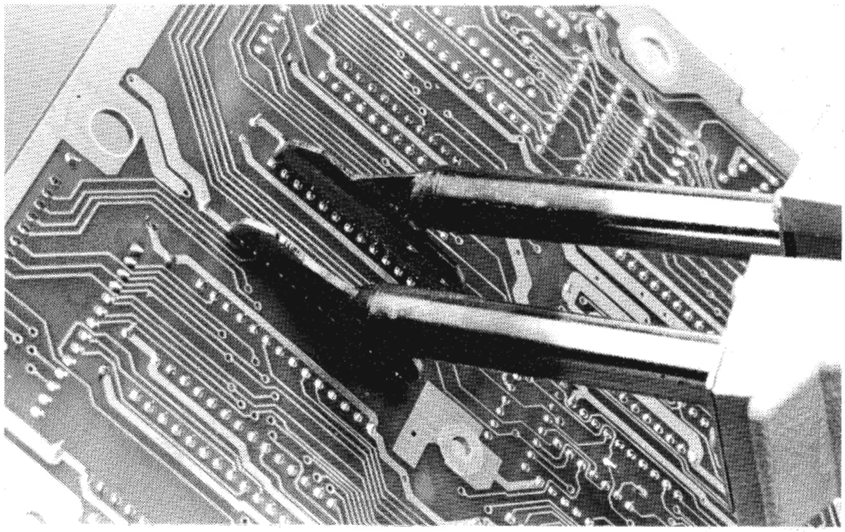


Figure 5-25. Premelting the Solder

4. **Desolder and extract the IC** by placing the desolderer across all IC pins on the top side of the PCA. Lift out the IC with the desolderer when the solder melts. Excessive force shouldn't be required. (If you want to salvage the IC, desolder it from the *underside* of the PCA instead.)

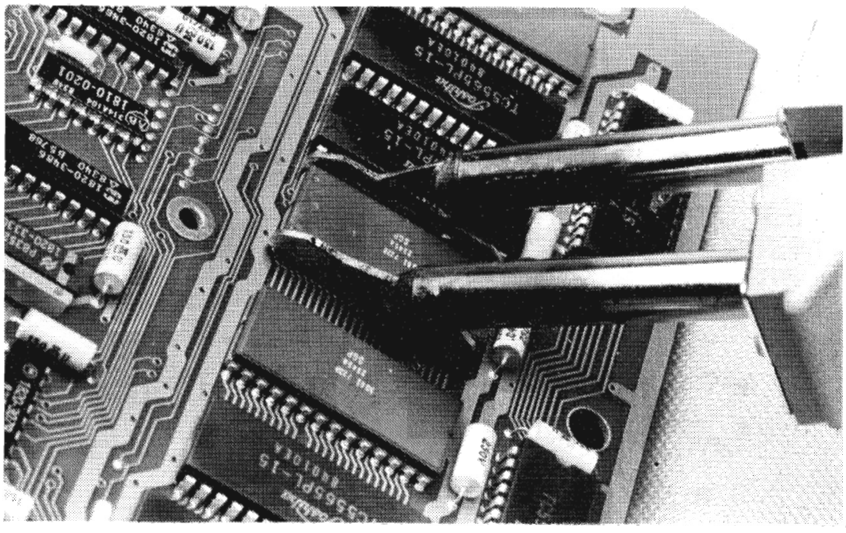


Figure 5-26. Extracting the IC

5. **Install the new IC** using a conventional soldering tool.

CAUTION

Be sure all flux is removed from the PCA. Flux contamination can cause conditions that may damage components or cause the system to operate improperly.

6. **Remove all flux** from the PCA using alcohol and a stiff brush.

Chapter 6
Replaceable Parts

This chapter lists the replaceable parts and assemblies of the HP 110.

The following structure illustrates how replaceable assemblies are related and gives references to the tables and figures for replaceable parts:

HP 110 (table 6-1, figure 6-1).
- Top Case Assembly (table 6-2, figure 6-2).
  - Display Assembly (table 6-3, figure 6-3).
- Base Assembly (table 6-4, figure 6-4).
  - System PCA (table 6-5, figure 9-1).
  - I/O PCA (table 6-6, figure 9-5).
  - Modem PCA (table 6-7, figure 9-9)—A versions only.

For assemblies that differ between A versions and B versions, the "Quantity" column is separated into two parts labelled "A" and "B". Other differences between versions are noted under "Description". (For versions A and AL, the version is indicated on the bottom label. For all B versions, the bottom label indicates "45710B"—press (Shift)/(CTRL)/(Break) simultaneously to momentarily display the version at the end of the serial number.)

You can order replacement parts and assemblies from Hewlett-Packard Corporate Parts Center or from Parts Center Europe.

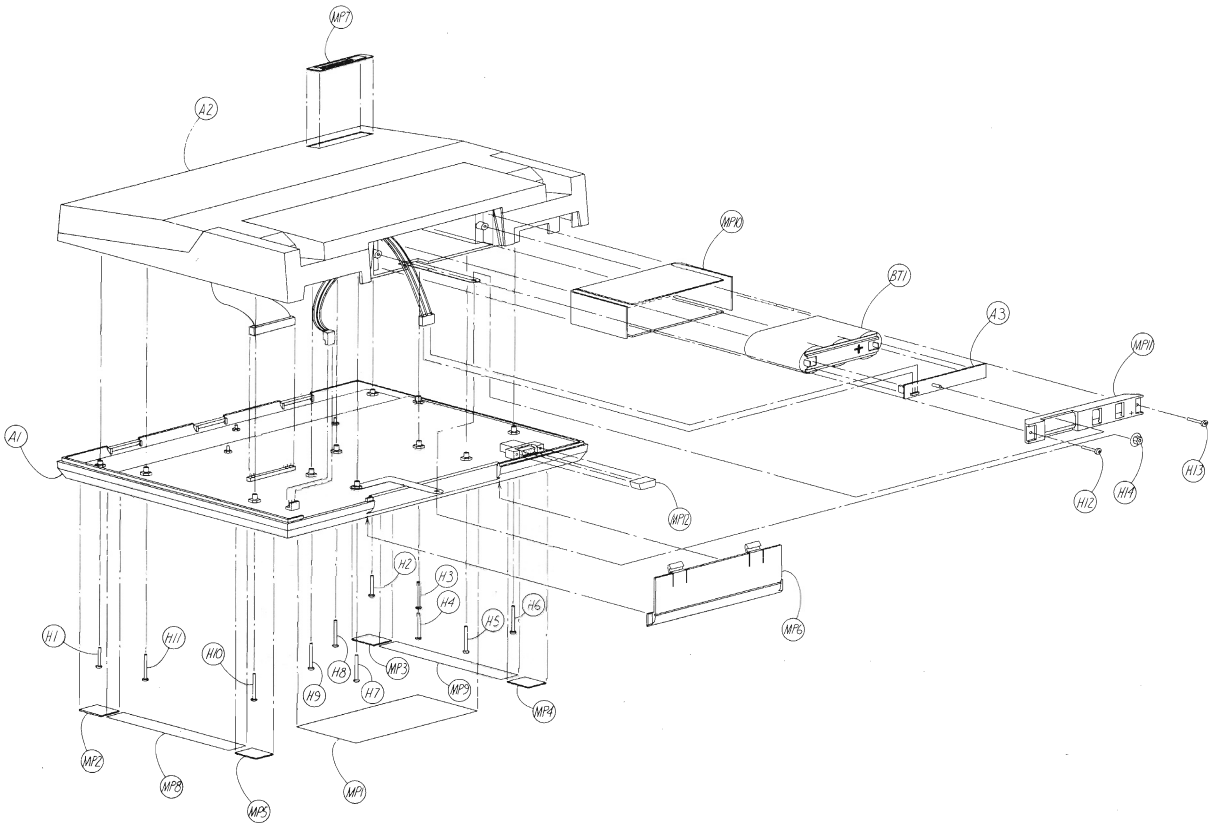


Figure 6-1. HP 110 Exploded View

Table 6-1. HP 110 Replaceable Parts

Reference Designation	HP Part Number	Description	Quantity A	Quantity B
A1*	(table 6-4)	ASSEMBLY, base	1	1
A2*	(table 6-2)	ASSEMBLY, top case	1	1
A3*	00090-60005	ASSEMBLY, PC, terminal block	1	1
A3CR1*	1901-0704	• RECTIFIER, silicon	1	1
A3F1*	2110-0716	• FUSE	1	1
A3S1*	3101-2770	• SWITCH, reset	1	1
BT1	1420-0329	BATTERY	1	1
H1, H2	0515-1878	SCREW, M2.5 × 20	2	2
H3–H11	0515-1881	SCREW, M2.5 × 26	9	9
H12, H13	0515-1882	SCREW, M2.5 × 8	2	2
H14	0535-0063	NUT, M3, flanged	1	1
MP1	00090-80007†	LABEL, bottom (version A—U.S.)	1	–
	00090-80081†	LABEL, bottom (version AL—Canada)	1	–
	00090-80089†	LABEL, bottom (all version B)	–	1
MP2–MP5	00090-80022†	FOOT, rubber	4	4
MP6	00090-40004	COVER, battery	1	1
MP7	00090-80006	LABEL, top	1	1
MP8, MP9	00090-80016†	COVER, screw	2	2
MP10	00090-80017	CUSHION, battery	1	1
MP11	00090-40009	BLOCK, terminal	1	1
MP12	1252-0220	CAP, serial receptacle	1	1
	00090-80086	LABEL, D.O.C. (version AL—Canada)	1	–
	5041-4306	PLUG, modem insert	–	1
	0460-1802	TAPE, battery cable and modem	2	1

* These reference designations are for "top-level" assemblies. They shouldn't be confused with the reference designations for the three main PCAs (A1, A2, and A3) used in other chapters of this manual. The three main PCAs are actually part of the base assembly (table 6-4).

† These parts are included in the following service kits. (The bottom label is different for each kit.)
00090-60919 (version A—U.S.): 25 bottom labels, 50 screw covers, 100 feet.
00090-60942 (version AL—Canada): 5 bottom labels, 10 screw covers, 20 feet.
00090-60943 (all version B): 5 bottom labels, 10 screw covers, 20 feet.

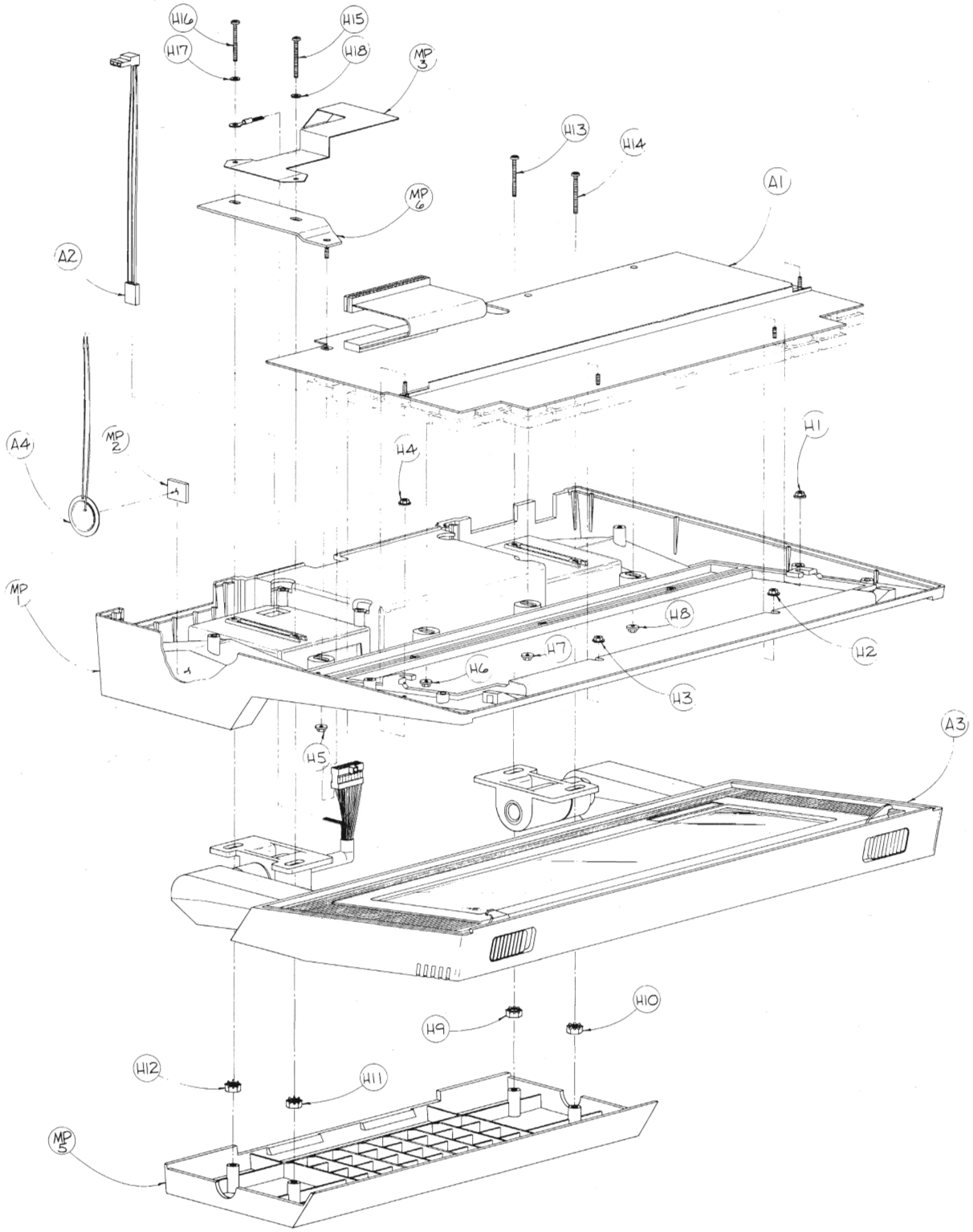


Figure 6-2. Top Case Assembly Exploded View

Table 6-2. Top Case Assembly Replaceable Parts

Reference Designation*	HP Part Number	Description	Quantity A	Quantity B
A1†	00090-60901	ASSEMBLY, keyboard module (all versions)	1	1
	00090-40013	• KEYCAP SET (all version A, version BK—Int'l)	1	1
	00090-80025	• KEYSWITCH	75	75
	00090-80026	• KEYSWITCH, space bar	1	1
	00090-60936	ASSEMBLY, keycap set (version BD—Germany)	–	1
	00090-60937	ASSEMBLY, keycap set (version BF—France)	–	1
	00090-60938	ASSEMBLY, keycap set (version BZ—Italy)	–	1
	00090-60939	ASSEMBLY, keycap set (version BU—U.K.)	–	1
A2†	00090-60032	ASSEMBLY, battery wire	1	1
A3†	(table 6-3)	ASSEMBLY, display	1	1
A4†	00090-60017	ASSEMBLY, transducer	1	1
H1–H8	0535-0063	NUT, M3, flanged	8	8
H9–H12	0535-0062	NUT, M6 locking	4	4
H13–H15, H25	0515-1881	SCREW, M2.5 × 26	4	4
MP1	00090-40001	CASE, top	1	1
MP2	0460-1802	TAPE, double-sided, transducer	1	1
MP3	00090-80047	STRAP, upper ground	1	1
MP5	00090-60030	ASSEMBLY, hinge cover	1	1
MP6	00090-00006	PLATE, ground	1	1
MP7, MP8	3050-0367	WASHER, flat	2	2

* Use the prefix "Top Case A2" with reference designations for parts of the top case assembly.

† These reference designations are for "top case" assemblies. They shouldn't be confused with the reference designations for the three main PCAs (A1, A2, and A3) used in other chapters of this manual. The three main PCAs are actually part of the base assembly (table 6-4).

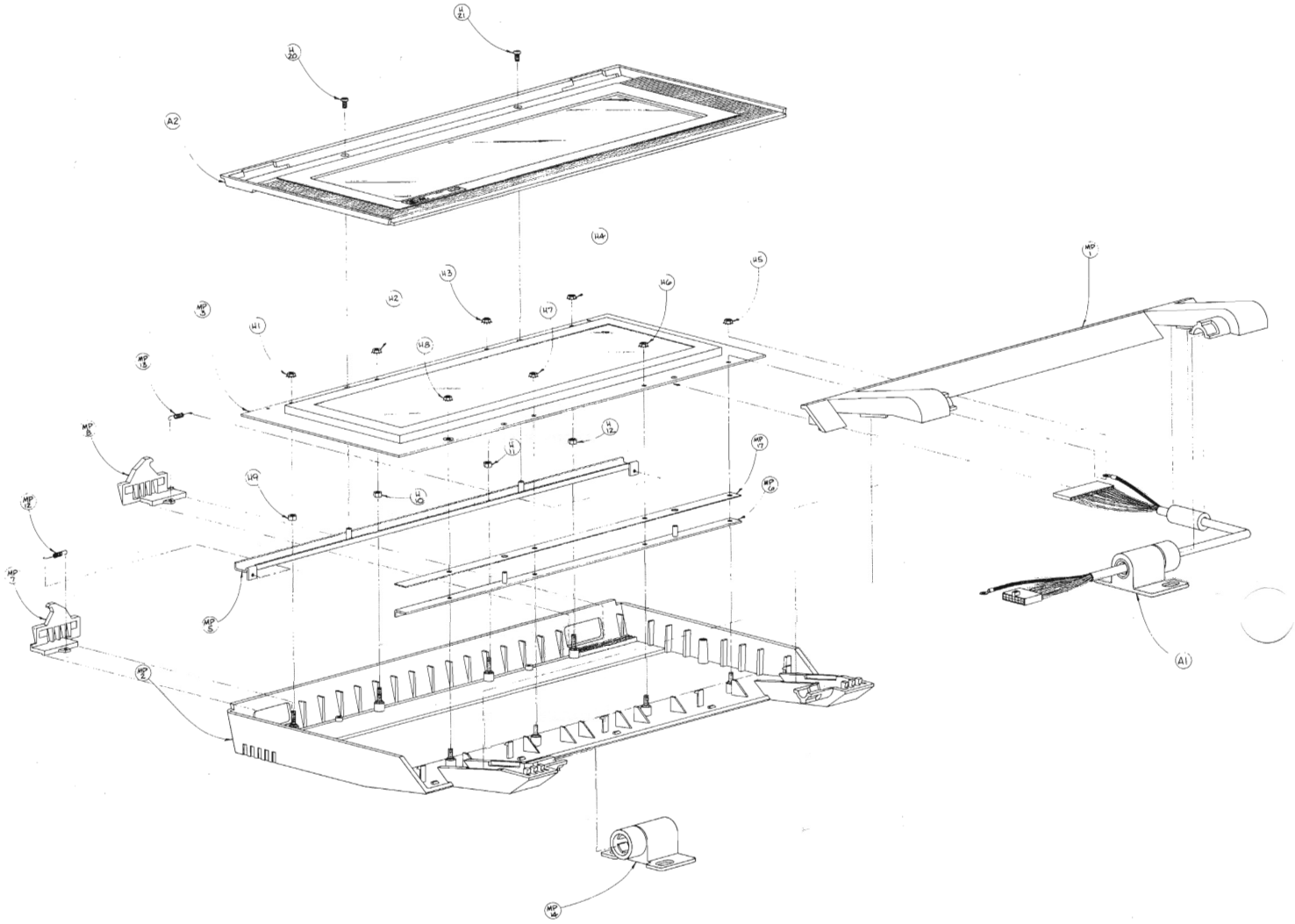


Figure 6-3. Display Assembly Exploded View

Table 6-3. Display Assembly Replaceable Parts

Reference Designation*	HP Part Number	Description	Quantity
A1†	00090-60907	ASSEMBLY, clutch/cable, service	1
A2†	00090-60906	ASSEMBLY, bezel, service	1
	00090-60920	ASSEMBLY, bezel cap/tape, service	1
H1–H8	0535-0063	NUT, M3, flanged	8
H9–H12	00090-80021	SPACER, hex	4
H20, H21	0515-1246	SCREW, M3 × 6	2
MP1	00090-40005	FRONT, display	1
MP2	00090-40006	BACK, display	1
MP3	00090-60902	ASSEMBLY, LCD module, service	1
MP5	00090-00004	BRACKET, display top	1
MP6	00090-00005	BRACKET, display bottom	1
MP7	00090-40007	LATCH, left	1
MP8	00090-40008	LATCH, right	1
MP12, MP13	00090-80032	SPRING, latch	2
MP14	00090-80064	CLUTCH	1
MP17	00090-40010	INSULATOR, display	1
MP23	0470-0913	RTV, adhesive	
	00090-60033	STRAP, ground	1‡

* Use the prefix "Top Case A2A3" with reference designations for parts of the display assembly.

† These reference designations are for "display" assemblies. They shouldn't be confused with the reference designations for the three main PCAs (A1, A2, and A3) used in other chapters of this manual. The three main PCAs are actually part of the base assembly (table 6-4).

‡ Used only with an LCD module that has no ground trace around the edge of the back side.

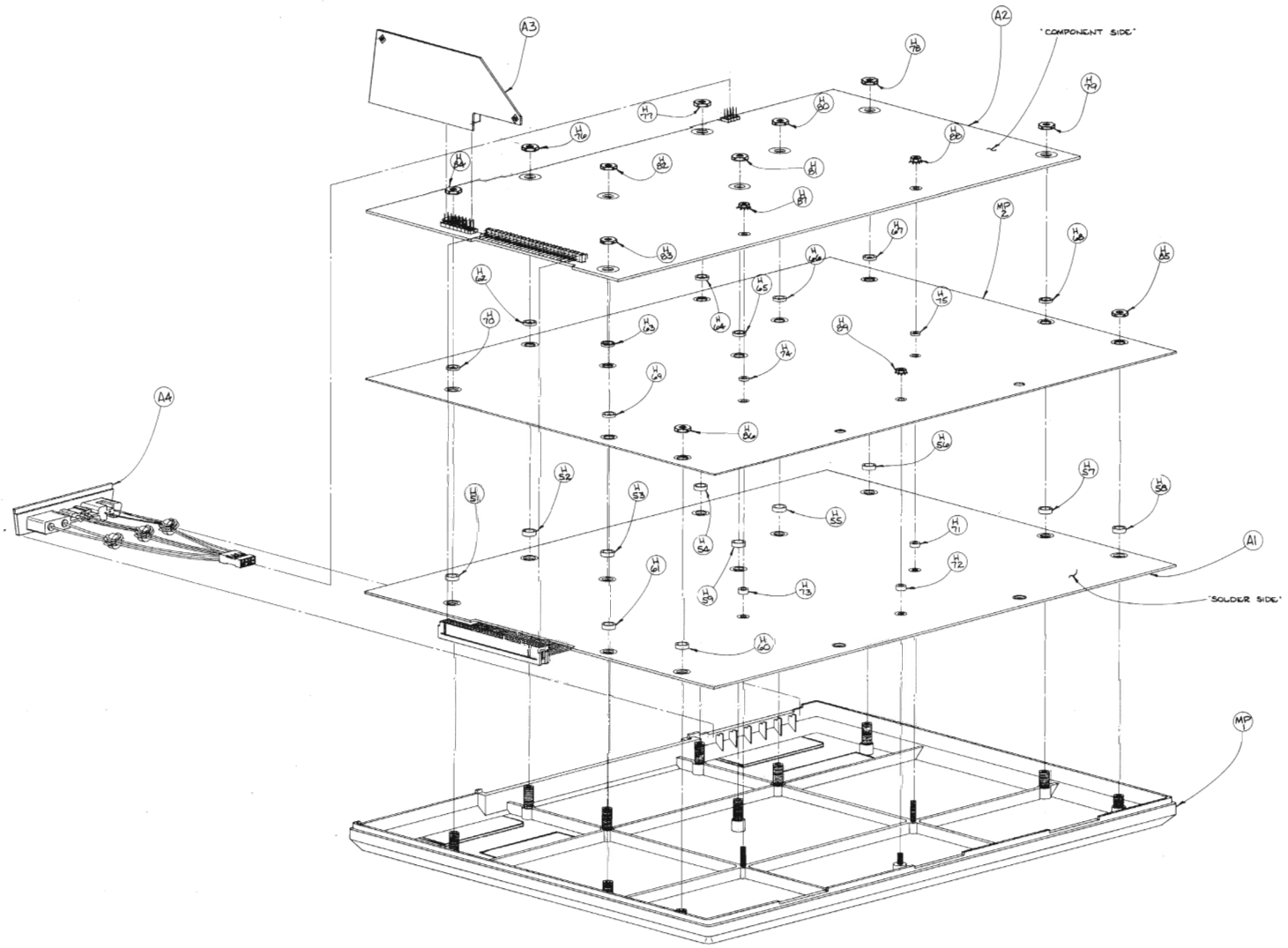


Figure 6-4. Base Assembly Exploded View

Table 6-4. Base Assembly Replaceable Parts

Reference Designation*	HP Part Number	Description	Quantity A	Quantity B
A1	00090-60916† 00090-69006‡	ASSEMBLY, system PC (table 6-5)	1	1
A2	00090-60917† 00090-69002‡	ASSEMBLY, I/O PC (all version A) (table 6-6)	1	–
	00090-60940† 00090-69005‡	ASSEMBLY, I/O PC (all version B) (table 6-6)	–	1
A3	00090-60918†	ASSEMBLY, modem PC (table 6-7)	1	–
A4	00090-60006	ASSEMBLY, I/O plate	1	1
H51–H70	00090-80057	SPACER, 6 × 2.35	20	20
H71–H75	00090-80046	SPACER, 3 × 2.35	5	5
H76–H86	0535-0014	NUT, M6, jam	11	11
H87–H89	0535-0063	NUT, M3, flanged	3	3
MP1	00090-40002	CASE, bottom	1	1
MP2	00090-00002	SHIELD, EMI	1	1
MP3	00090-80045	STRAP, ground, lower	1	1
U28§	(table 6-9)	INTEGRATED CIRCUIT, configuration EPROM, service	1	1
U52-U64§	(table 6-8)	INTEGRATED CIRCUIT, 32K ROM	12	12
	00090-80065	PAD, IC support	4	4

* Use the prefix "Base A1" with reference designations for parts of the base assembly.

† New part.

‡ Exchange part.

§ These components are usually associated with the system or I/O PCA, although they're not included as part of those assemblies.

Table 6-5. System PCA Replaceable Parts

Reference Designation*	HP Part Number	Description	Quantity
C1, C3, C5–C7, C9, C10, C13, C14, C16, C20–C41, C43–C64, C66, C67	0160-5941	CAPACITOR, 0.047 μF, 20%, 100V	56
R1	1810-0201	RESISTOR NETWORK, 100 kΩ	1
R2, R3	1810-0378	RESISTOR NETWORK, 47 kΩ	2
U1	1820-3533	INTEGRATED CIRCUIT, CPU, 80C86	1
U2–U7	1820-3486	INTEGRATED CIRCUIT, latch, 82C82	6
U8–U11	1820-3330	INTEGRATED CIRCUIT, transceiver, 74HC245	4
U12–U17	1820-3079	INTEGRATED CIRCUIT, 3-8 decoder, 74HC138	6
U18, U19, U65	1820-3014	INTEGRATED CIRCUIT, 2-4 decoder, 74HC139	3
U20–U51, U66, U67	1818-3183†	INTEGRATED CIRCUIT, 8K RAM	34
U52-U64	‡	INTEGRATED CIRCUIT, 32K ROM	

* Use the prefix "Base A1A1" with reference designations for components on the system PCA. The last "A1" refers to the system PCA, and corresponds to the reference designations for the three main PCAs (A1, A2, and A3) used in other chapters of this manual.

† Part number 5061-7228+D is equivalent.

‡ Components U52 through U64 (system ROMs) aren't included with the system PCA. They're listed in table 6-4 as part of the base assembly and in table 6-8.

Table 6-6. I/O PCA Replaceable Parts

Reference Designation*	HP Part Number	Description	Quantity A	Quantity B
C1, C2	0160-4805	CAPACITOR, 47 pF, 5%, 100V	2	2
C3, C4	0160-4787	CAPACITOR, 22 pF, 5%, 100V	2	2
C5, C8–C10, C68, C87, C91, C101	0160-4835	CAPACITOR, 0.1 μF, 50V	8	8
C6	0180-3167	CAPACITOR, 1000 μF	1	1
C7, C11, C14	0160-3490	CAPACITOR, 1 μF, 20%, 50V	3	3
C12, C25, C26	0160-4822	CAPACITOR, 1000 pF, 5%, 100V	3	1
C13	0160-4791	CAPACITOR, 10 pF, 5%, 100V	1	1
C15, C69	0160-4832	CAPACITOR, 0.01 μF, 100V	2	2
C16, C17	0160-4812	CAPACITOR, 220 pF, 5%	2	2
C18	0160-2388	CAPACITOR, 0.47 μF, 400V	1	–
C43–C66, C70	0160-5941	CAPACITOR, 0.047 μF, 20%, 100V	25	25
C67	0180-3457	CAPACITOR, 33 μF, 20%, 16V	1	1
C71, C93–C99	0180-2951	CAPACITOR, 33 μF, 16V	8	7
C80	0160-4801	CAPACITOR, 100 pF, 5%	1	1
C81	0160-6145	CAPACITOR, 0.03 μF, DIP	1	1
C88–C90	0160-4810	CAPACITOR, 330 pF, 5%, 100V	3	3
C92	0160-4574	CAPACITOR, 1000 pF, 10%	1	1
C100	0180-3422	CAPACITOR, 10 μF, 10%	1	–
CR1	1906-0284	DIODE BRIDGE, 1A, 50V	1	1
CR2–CR7, CR17–CR22, CR26, CR27	1901-1098	DIODE, switching	14	11
CR13	1901-0734	DIODE, Schottky, 1A, 30V	1	1
CR14	1906-0283	DIODE BRIDGE, 1A, 400V	1	–
CR23–CR25	1901-1080	DIODE, 1N5817	3	3
J1	1251-5269	CONNECTOR, 2 × 25 pin, system PCA	1	1
J2	1251-8214	CONNECTOR, 2 × 20 pin, keyboard	1	1
J3	1251-4926	CONNECTOR, 2 × 4 pin, I/O plate	1	1
J4	1251-7532	JACK, RJ11C, phone	1	–
J5	1251-8906	CONNECTOR, 9 pin, RS-232	1	1
J6	1251-8702	CONNECTOR, 2 × 8 pin, modem PCA	1	–
J8	1252-0025	CONNECTOR, 3 pin, battery	1	1
L1	9140-0975	INDUCTOR, 30 mH, 35 mA	1	1
L3, L4	9100-1625	INDUCTOR, 33 μH, 5%	2	–
MP3	0890-0324	TUBING, flex (for C80)		

Table 6-6. I/O PCA Replaceable Parts (Continued)

Reference Designation*	HP Part Number	Description	Quantity A	Quantity B
Q1–Q3, Q18, Q19, Q30, Q36	1853-0563	TRANSISTOR, 2N3906	7	6
Q4	1853-0558	TRANSISTOR, 2N6554	1	1
Q5, Q7–Q11, Q21, Q24, Q34, Q35, Q37, Q40, Q41	1855-0556	TRANSISTOR, N-channel MOSFET, 60V	13	13
Q6, Q12, Q38	1855-0550	TRANSISTOR, P-channel MOSFET, 30V	3	3
Q13	1853-0559	TRANSISTOR, MPSW55	1	1
Q14, Q15	1853-0569	TRANSISTOR, 2N5087	2	2
Q16, Q17	1854-1040	TRANSISTOR, 2N5088	2	2
Q20	1855-0522	TRANSISTOR, P-channel MOSFET	1	1
Q25	1855-0557	TRANSISTOR, dual-gate MOSFET, 20V	1	1
Q28	1853-0565	TRANSISTOR, 2N4403	1	1
Q31	1855-0551	TRANSISTOR, N-channel MOSFET, 500V	1	–
Q33	1854-1028	TRANSISTOR, 2N3904	1	–
Q39	1855-0555	TRANSISTOR, N-channel MOSFET, 30V	1	1
R1	0683-1035	RESISTOR, 10 kΩ, 5%, ¼W	1	1
R2, R8, R19, R29, R56, R149, R150, R163, R164	0683-1045	RESISTOR, 100 kΩ, 5%, ¼W	9	9
R3, R5, R10, R21, R52	0683-4735	RESISTOR, 47 kΩ, 5%, ¼W	5	5
R4	0683-4705	RESISTOR, 47 ohm, 5%, ¼W	1	1
R6	0683-2235	RESISTOR, 22 kΩ, 5%, ¼W	1	1
R7, R9	0683-4715	RESISTOR, 470 ohm, 5%, ¼W	2	2
R11	0698-3160	RESISTOR, 31.6 kΩ, 1%, ⅛W	1	1
R12, R14, R48	0757-0442	RESISTOR, 10 kΩ, 1%, ⅛W	3	3
R13, R15	0698-3161	RESISTOR, 38.3 kΩ, 1%, ⅛W	2	2
R16	0757-0467	RESISTOR, 121 kΩ, 1%, ⅛W	1	1
R18	0699-1209	RESISTOR, 43.2 kΩ, 0.25%	1	1
R20	0698-3193	RESISTOR, 10.0 kΩ, 1%, ⅛W	1	1
R22	0757-0200	RESISTOR, 5.62 kΩ, 1%, ⅛W	1	1
R25	0683-2255	RESISTOR, 2.2 MΩ, 5%, ¼W	1	1
R26, R27	0683-3345	RESISTOR, 330 kΩ, 5%, ¼W	2	2

Table 6-6. I/O PCA Replaceable Parts (Continued)

Reference Designation*	HP Part Number	Description	Quantity A	Quantity B
R28	0683-3315	RESISTOR, 330 ohm, 5%, ¼W	1	1
R30, R37, R40, R100, R101, R116, R117	0683-1055	RESISTOR, 1 MΩ, 5%, ¼W	7	5
R31, R32, R161	0683-2245	RESISTOR, 220 kΩ, 5%, ¼W	3	3
R33	0699-1254	RESISTOR, 536 kΩ, 1%, ⅛W	1	1
R34	0698-3454	RESISTOR, 215 kΩ, 1%, ⅛W	1	1
R35	0698-8827	RESISTOR, 1 MΩ, 1%, ⅛W	1	1
R36, R41	0683-1545	RESISTOR, 150 kΩ, 5%, ¼W	2	2
R38, R39, R42, R157–R160	0683-4745	RESISTOR, 470 kΩ, 5%, ¼W	7	7
R43	0698-4493	RESISTOR, 34.0 kΩ, 1%, ⅛W	1	1
R44	0683-6835	RESISTOR, 5%, ¼W	1	1
R45	0683-1345	RESISTOR, 130 kΩ, 5%, ¼W	1	1
R46	0683-2745	RESISTOR, 270 kΩ, 5%, ¼W	1	1
R49	0757-0461	RESISTOR, 68.1 kΩ, 1%, ⅛W	1	1
R50	0757-0444	RESISTOR, 12.1 kΩ, 1%, ⅛W	1	1
R51	0683-1525	RESISTOR, 1.5 kΩ, 5%, ¼W	1	1
R53, R54	0757-0465	RESISTOR, 100 kΩ, 1%, ⅛W	2	2
R57, R58, R127–R129	0683-4725	RESISTOR, 4.7 kΩ, 5%, ¼W	5	4
R64	0683-1815	RESISTOR, 180 ohm, 5%, ¼W	1	1
R65–R69, R124	1810-0378	RESISTOR NETWORK, 47 kΩ	6	6
R70, R71	0683-1535	RESISTOR, 15 kΩ, 5%, ¼W	2	2
R72, R73	0698-3446	RESISTOR, 383 ohm, 1%, ⅛W	2	2
R74	0812-0057	RESISTOR, 33 ohm, 5%, ½W	1	–
R76	0699-0922	RESISTOR, 4.7 kΩ, 5%, 2W	1	–
R77	0683-5635	RESISTOR, 56 kΩ, 5%, ¼W	1	–
R99	0683-2215	RESISTOR, 220 ohm, 5%, ¼W	1	–
R115	0683-1065	RESISTOR, 10 MΩ, 5%, ¼W	1	1
R121	0683-1515	RESISTOR, 150 ohm, 5%, ¼W	1	1
R151	0683-3935	RESISTOR, 39 kΩ, 5%, ¼W	1	1
R152	1810-0367	RESISTOR NETWORK, 4.7 kΩ, 2%, ⅛W	1	1
RT1	0837-0284	THERMISTOR, 2 kΩ, 5%	1	1

Table 6-6. I/O PCA Replaceable Parts (Continued)

Reference Designation*	HP Part Number	Description	Quantity A	Quantity B
T1	9100-4226	TRANSFORMER, HP-IL	1	1
T2	9100-4380	TRANSFORMER, modem	1	–
T3	00090-20001	TRANSFORMER, oscillator	1	–
U1	1820-3484	INTEGRATED CIRCUIT, PPU, MC146805G2	1	1
U2	1LK5-0001	INTEGRATED CIRCUIT, multi-controller	1	1
U3	1LK6-0001	INTEGRATED CIRCUIT, LCD controller	1	1
U4	1LB3-0003	INTEGRATED CIRCUIT, HP-IL	1	1
U5	1818-3183	INTEGRATED CIRCUIT, 8K RAM, display RAM	1	1
U6, U7	1820-3330	INTEGRATED CIRCUIT, transceiver, 74HC245	2	2
U8–U15, U36	1820-3486	INTEGRATED CIRCUIT, latch, 82C82	9	9
U16	1820-3546	INTEGRATED CIRCUIT, shift register, 74HC299N	1	1
U17	1820-3181	INTEGRATED CIRCUIT, shift register, 74HC165	1	1
U18	1820-3081	INTEGRATED CIRCUIT, D-type flip-flop, 74HC74	1	1
U19	1820-3488	INTEGRATED CIRCUIT, clock, 82C84	1	1
U20	1820-3208	INTEGRATED CIRCUIT, counter, 74HC393	1	1
U21	1820-3014	INTEGRATED CIRCUIT, 2-4 decoder, 74HC139	1	1
U22	1820-3079	INTEGRATED CIRCUIT, 3-8 decoder, 74HC138	1	1
U23, U24	1820-2924	INTEGRATED CIRCUIT, quad NOR, 74HC02	2	2
U25	1820-3097	INTEGRATED CIRCUIT, quad AND, 74HC08	1	1
U26	1826-1162	INTEGRATED CIRCUIT, comparator, LP311N	1	1
U27	1826-0666	INTEGRATED CIRCUIT, comparator, LM339A	1	1
U28	†	INTEGRATED CIRCUIT, configuration EPROM		
U30	1990-0494	INTEGRATED CIRCUIT, opto-isolator	1	–
U33	1820-3487	INTEGRATED CIRCUIT, tone generator, MC14410	1	–
U38	1820-1745	INTEGRATED CIRCUIT, quad NOR, MC14001	1	1
U39	1820-0509	INTEGRATED CIRCUIT, RS-232 driver, MC1488L	1	1
U40	1820-3185	INTEGRATED CIRCUIT, receiver, 74HC14N	1	1
U41, U42	1820-3177	INTEGRATED CIRCUIT, multiplexers, 74HC157N	2	1
VR1	1902-0950	DIODE, zener, 4.7V, 5%	1	1
VR2	1902-0962	DIODE, zener, 15V, 5%	1	1
VR3	1826-1167	DIODE, zener, 1.235V	1	1

Table 6-6. I/O PCA Replaceable Parts (Continued)

Reference Designation*	HP Part Number	Description	Quantity A	Quantity B
VR4, VR5	1902-0953	DIODE, zener, 6.2V, 5%	2	2
VR6, VR7	1902-0970	DIODE, zener, 33V, 0.4W	2	2
VR8	1902-0967	DIODE, zener, 24V, 5%	1	–
VR9	0837-0281	DIODE, suppression	1	–
VR10	0837-0277	DIODE, suppression	1	–
VR11	1902-0958	DIODE, zener, 10V, 5%	1	–
VR12	1902-0952	DIODE, zener, 5.6V, 0.4W	1	1
W5	1258-0235	JUMPER (replaces U41)	–	1
XU28	1200-0567	SOCKET, 28 pin, for U28	1	1
Y1	0410-1522	CRYSTAL, 1 MHz	1	1
Y2	0410-1519	CRYSTAL, 16 MHz	1	1

* Use the prefix "Base A1A2" with reference designations for components on the I/O PCA. The "A2" refers to the I/O PCA, and corresponds to the reference designations for the three main PCAs (A1, A2, and A3) used in other chapters of this manual.

† Component U28 (configuration EPROM) isn't included with the I/O PCA. It's listed in table 6-4 as part of the base assembly and in table 6-9.

Table 6-7. Modem PCA Replaceable Parts

Reference Designation*	HP Part Number	Description	Quantity
C20	0160-5612	CAPACITOR, 4700 pF, 5%	1
C22, C28, C30, C31, C33, C40, C41	0160-4835	CAPACITOR, 100 nF, 50V	7
C23	0160-4801	CAPACITOR, 100 pF, 5%	1
C27, C29	0180-3422	CAPACITOR, 10 μF, 10%	2
C37	0160-4810	CAPACITOR, 330 pF, 5%, 100V	1
C38	0160-4832	CAPACITOR, 10 nF, 100V	1
C39	0160-4812	CAPACITOR, 220 pF, 5%	1
C42	0180-3440	CAPACITOR, 47 μF, 10%	1
CR15, CR16	1901-1098	DIODE, switching	2
J7	1251-8907	RECEPTACLE, 16 pin	1
Q32	1853-0563	TRANSISTOR, 2N3906	1
R78, R79	0683-2235	RESISTOR, 22 kΩ, 5%, ¼W	2
R80, R104	0683-4715	RESISTOR, 470 ohm, 5%, ¼W	2
R81	0683-8235	RESISTOR, 82 kΩ, 5%, ¼W	1
R82, R96	0683-3335	RESISTOR, 33 kΩ, 5%, ¼W	2
R83, R118	0683-4735	RESISTOR, 47 kΩ, 5%, ¼W	2
R84	0683-2715	RESISTOR, 270 ohm, 5%, ¼W	1
R85	0757-0440	RESISTOR, 7.5 kΩ, 1%, ⅛W	1
R86, R123	0698-3280	RESISTOR, 63.4 kΩ, 1%, ⅛W	2
R88	2100-3214	RESISTOR, variable, 100 kΩ	1
R89	0757-0444	RESISTOR, 12.1 kΩ, 1%, ⅛W	1
R90	0757-0467	RESISTOR, 121 kΩ, 1%, ⅛W	1
R91	0683-1055	RESISTOR, 1 MΩ, 5%, ¼W	1
R92	0683-3325	RESISTOR, 3.3 kΩ, 5%, ¼W	1
R93	0683-8245	RESISTOR, 820 kΩ, 5%, ¼W	1
R94, R102	0683-5635	RESISTOR, 56 kΩ, 5%, ¼W	2
R95	0683-1535	RESISTOR, 15 kΩ, 5%, ¼W	1
R97	0683-3345	RESISTOR, 330 kΩ, 5%, ¼W	1
R98, R106	0683-5625	RESISTOR, 5.6 kΩ, 5%, ¼W	2
R103	0698-3458	RESISTOR, 348 kΩ, 1%, ⅛W	1
R119	0683-1545	RESISTOR, 150 kΩ, 5%, ¼W	1

Table 6-7. Modem PCA Replaceable Parts (Continued)

Reference Designation*	HP Part Number	Description	Quantity
R120	0683-2225	RESISTOR, 2.2 kΩ, 5%, ¼W	1
R130	0683-3935	RESISTOR, 39 kΩ, 5%, ¼W	1
U31	1820-3721	INTEGRATED CIRCUIT, filter	1
U32	1820-2166	INTEGRATED CIRCUIT, modem, MC14412VP	1
U34	1826-0346	INTEGRATED CIRCUIT, op-amp, LM358	1
U35	1826-0138	INTEGRATED CIRCUIT, comparator	1
U37	1820-3097	INTEGRATED CIRCUIT, quad AND, 74HC08	1

* Use the prefix "Base A1A3" with reference designations for components on the modem PCA. The "A3" refers to the modem PCA, and corresponds to the reference designations for the three main PCAs (A1, A2, and A3) used in other chapters of this manual.

Table 6-8. System ROMs

Reference Designation	HP Part Number	Function/Revision
U52, U53	U52: 1LJ8-0017 U53: 1LJ8-0018	LOTUS 1-2-3.
U54, U55	U54: 1LJ8-0019 U55: 1LJ8-0020	Diagnostics; I/O operating system; HP-IL drivers; disc copying, formatting, checking; printing.
U56, U57	U56: 1LJ8-0009 U57: 1LJ8-0010	LOTUS 1-2-3; MemoMaker; Terminal 0; disc drivers.
U58, U59	U58: 1LJ8-0011 U59: 1LJ8-0012	LOTUS 1-2-3; LOTUS 1-2-3 help.
U60, U61	U60: 1LJ8-0013 U61: 1LJ8-0014	HPLINK; P.A.M. help, menu, commands.
U62, U63	U62: 1LJ8-0015 U63: 1LJ8-0016 U62: 1LJ8-0038 U63: 1LJ8-0039	P.A.M. startup; binary directory; MS-DOS; I/O operating system; startup code. Revised June 1984: Read mass storage RAM (drive A).

Table 6-9. Configuration EPROMs

Configuration EPROM HP Part Number (Service)	System ROM HP Part Numbers	
00090-60908* (version A—U.S.)	U52: 1LJ8-0017	U53: 1LJ8-0018
	U54: 1LJ8-0019	U55: 1LJ8-0020
	U56: 1LJ8-0009	U57: 1LJ8-0010
	U58: 1LJ8-0011	U59: 1LJ8-0012
	U60: 1LJ8-0013	U61: 1LJ8-0014
	U62: 1LJ8-0015	U63: 1LJ8-0016
00090-60945 (all version A) 00090-60925* (all version A) 00090-60931 (version BK—International) 00090-60932 (version BD—Germany) 00090-60933 (version BF—France) 00090-60934 (version BZ—Italy) 00090-60935 (version BU—U.K.)	U52: 1LJ8-0017 U54: 1LJ8-0019 U56: 1LJ8-0009 U58: 1LJ8-0011 U60: 1LJ8-0013 U62: 1LJ8-0038	U53: 1LJ8-0018 U55: 1LJ8-0020 U57: 1LJ8-0010 U59: 1LJ8-0012 U61: 1LJ8-0014 U63: 1LJ8-0039

* Obsolete revision. EPROM isn't available. Repair by updating EPROM and appropriate ROMs to newer revision.

Chapter 7
Reference Information

7.1 Introduction

This chapter contains HP 110 reference information and additional service information.

- 7.2 Diagnostic Test Results.
- 7.3 Signal Names.
- 7.4 Descriptions of Diagnostic Tests.
- 7.5 Service References.
- 7.6 Service Equipment.

7.2 Diagnostic Test Results

Use the information in table 7-1 to interpret the results of built-in, disc-based, and service EPROM diagnostic tests. (This information is repeated from table 4-2 in chapter 4.)

For assembly-level repair, replace the assembly indicated in the "assembly-level" column (or take the steps listed).

For component-level repair, replace the component indicated in the "component-level" column (or take the steps listed); when directed, use signature analysis (S/A) according to the reference in the last column to the signature analysis supplement.

> **Note:** If you're equipped to perform signature analysis, you can verify that the address, data, and control lines are good before replacing a component. You should do this if you're not reasonably certain that the indicated component is bad. Refer to the signature analysis supplement for information about performing signature analysis.

Table 7-1. Diagnostic Test Results

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
Failure Codes:			
101	System PCA.*	Replace A1U1 (CPU).	"Analyzing the CPU"
120–127	System PCA.*	If only one or two RAMs indicated, replace individual A1U20–U27 (RAM).	"Analyzing System RAM"
		If more than two RAMs indicated, latch or transceiver suspected. Trace using S/A.	
128–151	System PCA.*	If only one or two RAMs indicated, replace individual A1U28–U51 (RAM).	"Analyzing Mass Storage RAM"
		If more than two RAMs indicated, latch or transceiver suspected. Trace using S/A.	
152–163	If only one or two ROMs indicated, replace individual A1U52–U63 (ROM).*	If only one or two ROMs indicated, replace individual A1U52–U63 (ROM).*	"Analyzing System ROM"
	If more than two ROMs indicated, replace system PCA.*	If more than two ROMs indicated, latch or transceiver suspected. Trace using S/A.	
166–167	System PCA.*	If only one or two RAMs indicated, replace individual A1U66–U67 (RAM).	"Analyzing System RAM"
		If more than two RAMs indicated, latch or transceiver suspected. Trace using S/A.	
201	I/O PCA.†	Trace using S/A; replace A2U1 (PPU).	"Analyzing the PPU"
202	I/O PCA.†	Replace A2U2 (multicontroller).	"Analyzing the Keyboard Circuit"

Table 7-1. Diagnostic Test Results (Continued)

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
203	I/O PCA.†	Replace A2U3 (LCD controller).	"Analyzing the Display Controller"
204	I/O PCA.†	If occurs during HP-IL test, check HP-IL components using S/A; replace A2U4 (HP-IL controller). If occurs during RS-232 test, replace A2U4 (HP-IL controller).	"Analyzing the HP-IL Circuit"
205	I/O PCA.†	Verify using S/A; replace A2U5 (display RAM); replace A2U3.	"Analyzing Display RAM"
228	Replace A2U28 (EPROM)—burn new EPROM IC before installing (section 4.3)	Replace A2U28 (EPROM)—burn new EPROM IC before installing (section 4.3)	"Analyzing the Configuration EPROM"
331‡	Check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem circuit according to table 4-10, "Repairing the Modem" (may not be A3U31).	
332‡	Check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA, as indicated.	Check modem circuit according to table 4-10, "Repairing the Modem" (may not be A3U32).	
4*rcc* (*r* is row number) (*cc* is column number)	Swap top case (if possible) or swap keyboard module, then retry. If fixed, replace keyswitch (or keyboard module) after checking continuity; if not fixed, replace I/O PCA.†	Swap top case (if possible) or swap keyboard module, then retry. If fixed, replace keyswitch (or keyboard module) after checking continuity; if not fixed, replace A2U2 (multi-controller).	

Table 7-1. Diagnostic Test Results (Continued)

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
Messages:			
Broken loop	Try new cable; check connections; check I/O plate (or swap and retry); replace I/O PCA.†	Try new cable; check connections; inspect internal connections to I/O plate assembly (or swap assembly and retry); check continuity of HP-IL interface circuit (see schematic); replace A2U4 (HP-IL controller).	"Analyzing the HP-IL Circuit"
Loop error, data not received as sent	Remove peripherals and run "no devices" test; try new cable; check connections; bad HP-IL peripheral; check I/O plate (or swap and retry); replace I/O PCA.†	Remove peripherals and run "no devices" test; try new cable; check connections; bad HP-IL peripheral; check I/O plate (or swap and retry); check HP-IL components using S/A; replace A2U4 (HP-IL controller).	"Analyzing the HP-IL Circuit"
Number of devices on HP-IL loop= *wrong number*	Check connections; bad HP-IL peripheral; if occurs for every peripheral, replace I/O PCA.†	Check connections; bad HP-IL peripheral; if occurs for every peripheral, replace A2U4 (HP-IL controller).	
Transmitted or Rcvd. Data line(s) bad	Check test connector; replace I/O PCA.†	Check test connector; trace signals using scope routine.	
CTS line bad DSR line bad DTR line bad RTS line bad Carrier Det line bad	Check test connector; replace I/O PCA.†	Check test connector; check serial interface according to table 4-9, "Repairing the Serial Interface."	
Ring Det line bad	Check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem PCA connection; check test connector; check serial interface according to table 4-9, "Repairing the Serial Interface."	

Table 7-1. Diagnostic Test Results (Continued)

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
Pwr Supply Stuck On	I/O PCA.†	Trace power supply signals according to table 4-9, "Repairing the Serial Interface."	
Display Test Observations:			
Display doesn't scroll properly	I/O PCA.†	Replace A2U3 (LCD controller).	
Border line improper	Display assembly.	Display assembly.	
Extra or missing pixels	Swap top case assembly and retry; replace display assembly or I/O PCA†, as indicated.	Check VCC2 at A2U3 pin 1; swap top case assembly and retry; check display circuit using S/A or replace display assembly, as indicated.	"Analyzing the Display Controller"
Row (or column) dark or light	Display assembly.	Display assembly.	
Blinking or inverse display improper	Display assembly.	Display assembly.	
12- or 16-line display format improper	I/O PCA.†	A2U3 (LCD controller).	
Two cursors improper	I/O PCA.†	A2U3 (LCD controller).	
Quadrant bad	Check continuity between A2U3 and display assembly; swap I/O PCA or top case assembly, then retry; replace display assembly or I/O PCA†, as indicated.	Check continuity between A2U3 and display assembly; use scope to check for toggling signals at A2U3 pins 9–16; replace display assembly or A2U3 (LCD controller), as indicated.	
Adjacent rows (or columns) duplicated	Display assembly.	Display assembly.	
Modem Observations:			
During optional pulse dialing test, telephone doesn't ring	Check modem connections; check phone number; check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem connections; check phone number; verify circuit using standard modem test; check modem circuit according to table 4-10, "Repairing the Modem."	

Table 7-1. Diagnostic Test Results (Continued)

Test Result	Assembly-Level Replacement	Component-Level Replacement	Signature Analysis Reference
During optional tone dialing test, telephone doesn't ring	Check modem connections; check phone number; check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem connections; check phone number; verify circuit using standard modem test; check modem circuit according to table 4-10, "Repairing the Modem."	
During optional ring-detect test, HP 110 doesn't beep or indicate call received	Check modem connections; check phone number; check modem PCA connection; swap modem PCA and retry; replace modem PCA or I/O PCA†, as indicated.	Check modem connections; check phone number; verify circuit using standard modem test; check modem circuit according to table 4-10, "Repairing the Modem."	

* Whenever you replace system ROMs, you must ensure that the configuration EPROM (A2U28) matches the system ROMs (contains the proper ROM checksum values). (Refer to tables 6-8 and 6-9.)

- If the *same-revision ROMs* are installed, leave the original configuration EPROM in the I/O PCA.
- If *new-revision ROMs* are installed, burn a new configuration EPROM (section 4.3), then install it in the I/O PCA.

† Whenever you replace the I/O PCA, remove the configuration EPROM (A2U28) from the old PCA and install it in the new PCA. (This does not apply if you install new-revision ROMs or if you suspect that the configuration EPROM itself is bad.)

‡ Ignore this result for all B versions. These units don't have modems.

7.3 Signal Names

Table 7-2 lists the names, descriptions, and sources of the primary signals used by the HP 110.

Table 7-2. Signal Names

Name*	Description	Source
1MHZ	1-MHz Clock	Counter A2U20
2MHZ	2-MHz Clock	Counter A2U20
A0–A15	Main Address Bus	CPU (via A2U8, A2U9)
A16–A19	Auxiliary CPU Address	CPU
AD0–AD15	CPU Address/Data Bus	CPU
ADD	Latch CPU Address	LCD controller
ALE	Address Latch Enable	CPU (via A1U2)
BA0–BA13	RAM/ROM Address Bus	CPU (via A1U4, A1U5)
BATDOWN	Battery Voltage Down	Charger A2U27D
BD0–BD15	RAM/ROM Data Bus	CPU (via A1U8, A1U9), A1U20–A1U27, A1U52–A1U63
BEEP	Beep	PPU

Table 7-2. Signal Names (Continued)

Name*	Description	Source
BUSY	Busy PPU	PPU
C1–C13	Keyboard Columns	Keyboard
CARRIER	Carrier Interrupt	Multiplexer A2U41
CHARGE	AC Charge Indicator	Charger A2Q5
CHGREF	Charger Reference	Regulator A2VR3 (via A2R22)
CL1	Clock (LCD Rows)	LCD controller
CL2	Clock (LCD Quadrants)	LCD controller
CLK	CPU Clock (5.33 MHz)	Clock A2U19 (via A2R121)
CRESET	CPU Reset	Clock A2U19
CTS	Clear To Send	(External)
D0–D15	Main Data Bus	(Shared)
DATACLK	PPU Serial Data Clock	PPU
DSR	Data Set Ready	(External)
DT	Direction Transmit	CPU (via A1U2)
DTR	Data Terminal Ready	PPU (via A2U39C)
FAST	Fast Charge	PPU
FLM	Frame Clock (LCD Refresh)	LCD controller
HB	High Dial Signal	Tone-dial generator A2U33
HPILCLK	HP-IL Clock	Counter A2U20 (via A2U25C)
HPILCS	HP-IL Select	CPU (via A2U22)
HPILIRQ	HP-IL Interrupt	HP-IL controller
INH	Input High Data (to LCD RAM)	LCD controller
INL	Input Low Data (to LCD RAM)	LCD controller
INTA	Interrupt Acknowledge	CPU
INTR	Interrupt CPU	PPU, multi-controller (via A2U23A)
IOEN	I/O Enable	CPU (via A1U19)
KEYCLK	Keyboard Clock (2.67 MHz)	Clock U19
KEYCS	Keyboard Select	CPU (via A2U22)
KEYIRQ	Keyboard Interrupt	PPU, multi-controller
KEYRDY	Keyboard Ready	Multi-controller
LAH	Latch High Data (from LCD RAM)	LCD controller
LAL	Latch Low Data (from LCD RAM)	LCD controller
LB	Low Dial Signal	Tone-dial generator A2U33

Table 7-2. Signal Names (Continued)

Name*	Description	Source
LBHE	Latch Bus High Enable	CPU (via A1U3)
LCDEN	LCD Enable	PPU
LCDMCS	LCD Memory Select	CPU (via A1U12)
LCDNEG	LCD Negative Supply	LCD supply A2Q28
LCDRCS	LCD Registers Select	CPU (via A2U22)
LCDRDY	LCD Ready	LCD controller
LD0–LD7	LCD Data Bus	CPU (via A2U12, A2U13), LCD controller
LEN	Low Memory Enable	CPU (via A1U19)
LM	Latch Main Memory	CPU (via A1U3)
LOBAT	Low Battery Voltage	Regulator A2Q34
LS0–LS2	Latch Select	CPU (via A1U17)
M	Multiplex Clock (Alt. Refresh)	LCD controller
M/IO	Main/IO Memory Select	CPU
MA1–MA13	Mass Storage Address Bus	CPU (via A1U6, A1U7)
MC1–MC3	Modem Key Column	PPU
MD0–MD15	Mass Storage Data Bus	CPU (via A1U10, A1U11), A1U28–A1U51, A1U66, A1U67
MODEMCARRIER	Modem Carrier	Carrier detector A3U35D
MODEMEN	Modem Enable	PPU
MODEMON	Modem On	PPU
MODEMSIN	Modem Serial Data In	Modem IC A3U32 (via A3U37D)
MPWR	Modem Power	Modem power switch A3Q32
MR1–MR4	Modem Key Row	PPU
MSEN	MS RAM Enable	CPU (via A1U19)
MSSEL	MS RAM Address Select	CPU (via A1U18)
OFFHOOK	Modem Off Hook	PPU
ORIG	Modem Originate Mode	PPU (via A2U41)
OSC	Master Oscillator	Clock A2U19
OUT	Output Data Enable	LCD controller
PPUBUSY	PPU Busy Interrupt	PPU (via A2U23D)
PWO	Power-On Reset	PPU
R1–R8	Keyboard Rows	Keyboard
RA0–RA12	LCD RAM Address Bus	CPU (via A2U14, A2U15), LCD controller
RAMCS	LCD RAM Select	LCD controller
RAMOE	LCD RAM Output Enable	LCD controller

Table 7-2. Signal Names (Continued)

Name*	Description	Source
RAMRW	LCD RAM Write	LCD controller
RD1	Read 1 Strobe (ROM)	CPU (via A1U2)
RD2	Read 2 Strobe (MS)	CPU (via A1U2)
RD3	Read 3 Strobe (I/O)	CPU (via A1U2)
RDx0, RDx1	HP-IL Receive Data	(External)
READY	Ready	Clock A2U19
RESET	Reset	PPU
RING/RxCAR	Ring/Carrier Interrupt	Modem limiter A3U35B
ROMCS	EPROM Select	CPU (via A2U21)
RS232CARRIER	Serial Carrier	(External)
RS232PWR	Serial Power	PPU (via A2U41)
RS232RING	Serial Ring	(External)
RTS	Request To Send	PPU (via A2U39B)
RxD	Received Data	(External)
SA–SF	ROM Select	CPU (via A1U12)
SA14–SA19	Select Address	CPU (via A1U3)
SD1–SD4	Serial Data for Quadrants	LCD controller
SDATIN	PPU Serial Data In	CPU (via A2U18B)
SDATOUT	PPU Serial Data Out	PPU
SELFTEST	Modem Self-Test	PPU (via A2U42)
SHUTDOWN	Shutdown Battery Voltage	Regulator A2Q35
SIGNAL	Phone Signal	Protective interface A2T2, filter A3U34B (via A3R84)
SIN	Serial Data Input	Multiplexer A2U41
SLEEP	Sleep	PPU
SOUT	Serial Data Output	Multi-controller
STEP1,2,4,8	Contrast Step	PPU
SYS	PPU Select	CPU (via A2U22)
SYSEN	System RAM/ROM Enable	CPU (via A1U19)
SYSRD	PPU Read	CPU (via A2U21)
SYSWR	PPU Write	CPU (via A2U21)
TDx0, TDx1	HP-IL Transmit Data	HP-IL controller
TRANSEN	Transmit Enable	PPU
TxD	Transmitted Data	Multi-controller (via A2U39A)
VAG	Analog Reference Voltage	Filter A3U31

Table 7-2. Signal Names (Continued)

Name*	Description	Source
VBAT	Battery Supply Voltage	Battery, charger A2Q4
VCC1	+5V Unswitched	Regulator A2Q13
VCC2	+5V Switched	Regulator A2Q20
WR1	Write 1 Strobe (I/O)	CPU (via A1U2)
WR2	Write 2 Strobe (MS)	CPU (via A1U2)

* The signal names don't include the logic sense of the signal (bars aren't included over signal names) because some signals are present in the HP 110 with both logical senses.

7.4 Descriptions of Diagnostic Tests

The following paragraphs summarize the operation of the built-in, disc-based, and EPROM diagnostic tests. This information may be useful for interpreting unusual test results.

In order for the test program to run and display its menu, certain functions of the HP 110 must operate, either partially or entirely. These functions include:

- Display.
- Display controller.
- Display RAM.
- Latches, buffers, and decoders for the CPU circuit, display circuit, and address/control circuit.
- Clock circuit.
- PPU.
- Power supply.
- Configuration EPROM.
- Keyboard (key not stuck).
- Certain ROM ICs (several for disc-based test; highest two for built-in and EPROM tests).
- Multi-controller (for disc-based test).

The built-in test checks part of the CPU and display RAM during its startup routine.

7.4.1 System Test

The System test includes all of the tests described below except for the Sleep test.

7.4.2 CPU Test

The CPU test checks about 90 percent of the CPU functionality, including tests of its registers, addressing, and stack operations.

7.4.3 ROM Test

The ROM test computes the checksum for each system ROM IC (plus the configuration EPROM) by stepping through the address space sequentially; then it compares the value with the proper value stored in the configuration EPROM. The test further computes the checksum for each system ROM IC by cycling through the address space in 16-byte steps; then it compares the value with the proper value from the configuration EPROM.

7.4.4 RAM Test

The EPROM-based RAM test clears memory; the disc-based RAM test preserves memory. This test checks system RAM and mass storage RAM, but it *doesn't* check the display RAM.

The RAM test checks the RAM select circuit, RAM address latches, and transceivers by sending one byte to each of the RAM ICs, then reading those bytes back from all ICs. It repeats this cycle starting at each RAM IC.

The test checks data retention by storing 0's at all addresses, waiting 4 seconds, then reading from all addresses. This cycle is repeated using 1's.

The test checks internal addressing of the RAM ICs by repeating a read-store cycle four times, using 0's (then 1's) and working from low to high addresses (then high to low). The test further checks the internal addressing by storing at each address the lower eight bits of that address, then reading them back; it then repeats this cycle using the upper eight bits of the address.

7.4.5 LCD Test

The LCD test checks the LCD controller registers by writing to and reading from them.

The test checks the LCD controller and display module using messages and visual patterns. The visual test includes scrolling (in alpha and graphics modes), border lines, horizontal and vertical lines, blinking and inverse characters, 12- and 16-line alpha displays, and dual cursors.

The test checks the display RAM using all of the RAM tests described above for the RAM test. While this test is executing, the display reflects the patterns caused by the bytes stored in display RAM.

7.4.6 Keyboard Test

The Keyboard test displays the keyboard layout derived from the configuration EPROM and prompts the operator to press each key in sequence. The test provides no key roll-over (unlike normal keyboard operation). As each key is pressed, the test checks the operation of the interrupt register, row/column registers, and the debounce function in the multi-controller.

7.4.7 HP-IL Test

The HP-IL test checks the operation of the HP-IL interface using two tests.

The "no devices" test requires that one HP-IL cable be connected between the HP 110 IN and OUT receptacles. (No peripheral devices should be connected.) This test checks the continuity of the HP-IL circuit by sending an End Of Transmission message on the loop.

The "devices" test requires that the HP 110 and one or more peripheral devices be connected in a loop. This test checks the continuity of the HP-IL circuit by sending an End Of Transmission message. It also checks that each connected peripheral device is operating—it does this by sending an Auto Address message, which assigns an address to each peripheral device. The test displays the number of peripheral devices based upon the modified HP-IL addressing message that returns to the HP 110.

Both of these tests then check the controller functions and scratch pad of the HP-IL controller IC.

7.4.8 Modem Test

The Modem test puts the multi-controller UART (universal asynchronous receiver-transmitter) function in its self-test mode, then sends and receives 256 bytes of data at 9600 baud to check its operation. During the data transfer, the test checks the UART control and status registers and the interrupt function.

The test checks the operation of the modem circuit and PPU by setting the modem IC and active filter IC to their self-test modes, then sending and receiving data at 300 baud. This is done in both Originate and Answer modes.

The optional tone-dialer part of the test exercises the tone-dial generator IC, PPU, and related circuitry. The test requires that the HP 110 be connected to a phone line; it dials the phone number entered by the user.

The optional pulse-dialer part of the test exercises the PPU and related circuitry. The test requires that the HP 110 be connected to a phone line; it dials the phone number entered by the user.

The optional ring-detect part of the test exercises the PPU and related circuitry. The test requires that the HP 110 be connected to a phone line and that its number be dialed from another phone; it beeps and displays a message when it detects a ring signal.

7.4.9 RS-232 Test

The RS-232 test checks the serial interface. The test requires that the RS-232 test connector be installed at the serial receptacle. This connector provides a path for output signals to be fed back to input lines.

The test toggles the output (control) lines and checks the status of the input (status) lines. This checks the operation of the PPU, HP-IL controller, and serial interface circuit.

The test then checks the data path by sending and receiving 256 bytes of data on the transmit and receive lines. If an error occurs, the test checks the multi-controller by setting the multi-controller UART to its self-test mode, then sending and receiving data at two baud rates.

7.4.10 Beeper Test

The Beeper test checks the PPU and beeper (transducer) by sounding three normal beeps.

7.4.11 Timer Test

The Timer test first checks the real-time clock in the PPU by writing to and reading from its clock registers.

The test then checks the count-down timer in the multi-controller by writing to and reading from its registers, and by starting and stopping the timer at different values. The test also checks the CPU-interrupt function of the multi-controller.

7.43.12 Sleep Test

The Sleep test checks that the CPU and PPU can power-down the system.

7.5 Service References

The following references provide additional information about the HP 110 and about components used in the HP 110.

Hewlett-Packard Company. *HP 110 Owner's Manual.* HP reorder number 00090-90004, ©1984.

Intel Corporation. *Microsystem Components Handbook*, Volume I. ©1984.

Kane, Gerry, et al. *The HP-IL System: An Introductory Guide to the Hewlett-Packard Interface Loop.* Osborne/McGraw-Hill, Berkeley, California, ©1982.

McNamara, John E. *Technical Aspects of Data Communication.* Digital Equipment Corporation, Bedford, Massachusetts, ©1977.

7.6 Service Equipment

7.6.1 RS-232 Test Connector

Figure 7-1 shows the wiring for the RS-232 test connector.

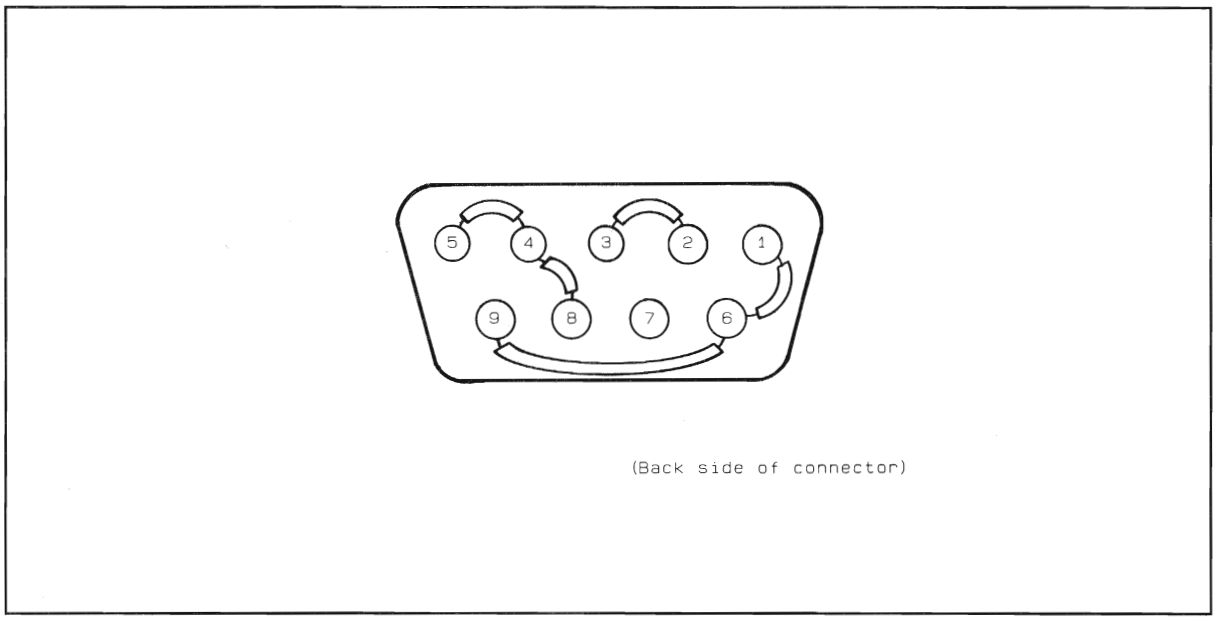


Figure 7-1. RS-232 Connector Wiring Diagram

7.6.2 Diagnostic Module

The diagnostic module is used while the HP 110 is dissassembled. The module connects in parallel with the 50 lines that connect the system and I/O PCAs. The module (figure 7-2) contains circuitry to provide the control signals for signature analysis, circuitry to burn configuration EPROMs for the HP 110, and two 8K-byte EPROMs that contain the diagnostic tests. The code located in the diagnostic EPROM provides the software for system testing, EPROM burning, and signature analysis.

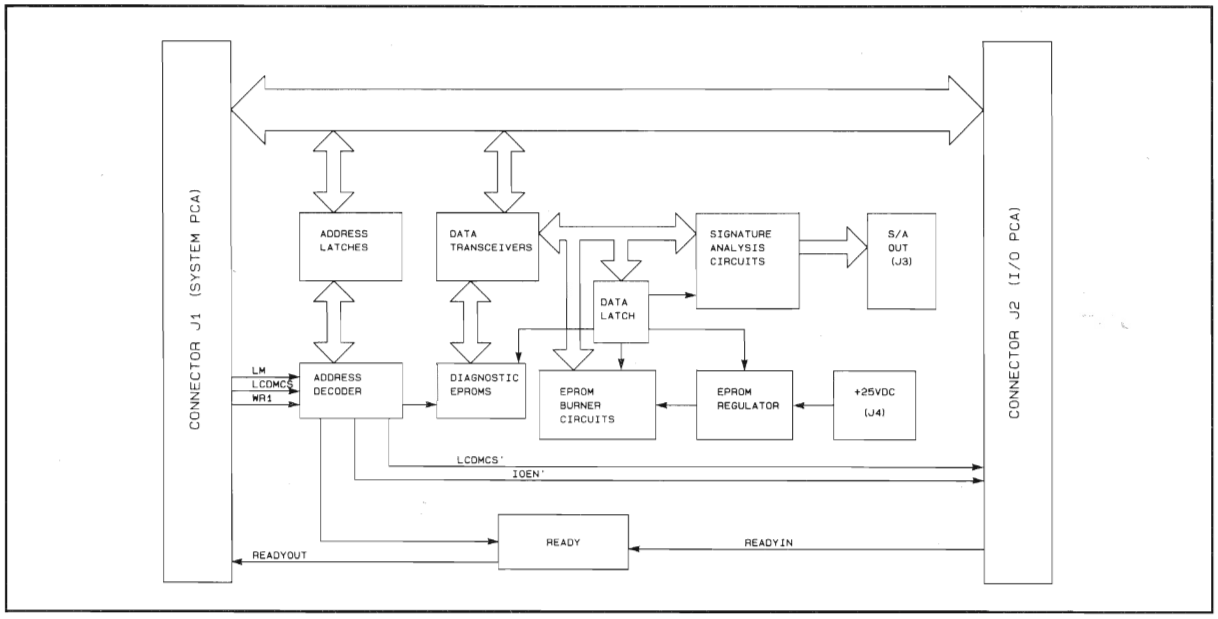


Figure 7-2. Diagnostic Module Block Diagram

The diagnostic module is contained on one PCA. The PCA contains all circuits necessary to communicate with the HP 110. (Table 7-3 lists the replaceable parts for the diagnostic module. Figures 7-4 and 7-5 show its component location diagram and schematic diagram.)

The diagnostic module latches the addresses and data sent on the CPU bus by HP 110 circuits. The addresses are decoded to determine what function the module should perform. The HP 110 must write data to I/O address 00C3 and then either read an EPROM address (for diagnostic testing), or write data to addresses (for EPROM burning or for controlling the signature analysis control lines).

EPROM Diagnostic Test Function. The diagnostic EPROM is located in the last 16K bytes of display RAM (addresses 8C000 through 8FFFF). When the module is connected to the HP 110 and jumper J5 is installed, the diagnostics are run at power-up. At power-up the CPU checks for "55" at address 8C000. If "55" is present, the CPU jumps to and excutes the code in the diagnostic EPROMs (U5 for odd addresses, U10 for even addresses). If "55" is not present, the CPU follows its normal power-up routine.

HP 110 data is transferred through tristate transceivers U3 and U4.

Signature Analysis Function. Software located in the diagnostic EPROMs provides the necessary routines that generate the control signals for signature analysis and provide the stimulus (signal patterns on the bus). When data is sent on D0 to I/O address 00C2, the module toggles the START and STOP outputs for signature analysis. The signature analysis clock is driven from one of several signals (CALE, $\overline{\text{WR1}}$, LM, or $\overline{\text{RD3}}$), according to data sent on D8 through D13 to I/O address 00C3. This provides a reliable clock signal for the signature analyzer.

Signature analysis start/stop signals (address 00C2)
D0 low: START high, STOP low.
D0 high: START low, STOP high.

Signature analysis clock selection (address 00C3)
D8 high: CALE.
D9 high: $\overline{\text{RD3}}$.
D10 high: $\overline{\text{WR1}}$.
D11 high: LM.
D12 high: $\overline{\text{IOWR}}'$.

EPROM Burner Function. The configuration EPROM in the HP 110 has information that is unique to that unit (such as the serial number). When an HP 110 configuration EPROM is bad, the diagnostic module is used to burn another EPROM. In order to burn an EPROM, the EPROM-burner program must be loaded into HP 110 RAM, the top of the diagnostic module must be removed, jumper J5 must be disconnected, and a 25-Vdc power supply must be connected to J4.

Data sent to the diagnostic module determines whether the EPROM (in socket XU14) is to perform a "read" or "write" operation, controls the burn-in voltage, and enables the burn duration (one-shot) timer.

Circuit Description. Connector J1 is the connection to the HP 110 system PCA; connector J2 connects to the HP 110 I/O PCA. Address latches U1 and U2 capture the 16-bit address on the HP 110 CPU bus when ALE goes high.

Tristate data transceivers U3 and U4 control the transfer of data between the diagnostic module and the HP 110. The DT line controls the direction of the data transfer; the $\overline{\text{IOEN}}$ line enables the data transfer.

EPROM U5 contains the odd-address memory; EPROM U10 contains the even-address memory.

Data latch U6 is enabled at I/O address 00C3. A high data line D15 turns on EPROM U14 (an HP 110 configuration EPROM). When D14 and $\overline{\text{WRT}}$ are asserted, the "clear" input to multivibrator U15 is also asserted. When D13 is high, Q1 turns on. This lowers the output voltage from regulator U7, causing the U14 programming voltage to drop from approximatly 21 Vdc to about 5 Vdc. D12 determines the $\overline{\text{IOWR}}'$ (I/O write') state, D11 determines the $\overline{\text{IORD}}'$ (I/O read') state, D10 determines the $\overline{\text{WR}}'$ (write') state, D9 determines the $\overline{\text{RD}}'$ (read') state, and D8 determines the ALE' (address latch enable') state. When U6 is enabled, data on lines D12 through D8 are ANDed with their system signals to provide the clocking pulses for the signature analyzer clock (for example, D10 $\overline{\text{WR}}'$ is ANDed with $\overline{\text{WR1}}$).

Eight-bit comparator U8 enables the data latch (U6) when I/O address 00C3 is on the CPU bus and $\overline{\text{WR1}}$ is asserted.

Half of 2-to-4 line decoder U9 enables U8 and U13 when address line A15 is low, LM is low, and $\overline{WR1}$ is asserted. The second half of U9 has two functions: to enable the module's EPROMs and provide the address portion to trigger U15 (when lines A15 and A14 are high and $\overline{LCDMCS}$ is asserted); and to determine when the LCD memory should be accessed. The first 16K bytes of display RAM contains the display data and is enabled when A15 and A14 are low and $\overline{LCDMCS}$ is asserted.

D-type flip-flops U11 and U12 and comparator U13 provide the start and stop signals for signature analysis. Comparator U13 is enabled when the CPU writes to I/O address 00C2 (refer to previous paragraph). The output from U13 clocks both flip-flops in U11. Data line D0 triggers both D inputs for U11. The output of the first flip-flop clears and triggers the second flip-flop in U12 to generate the "stop" signal. The output of the second flip-flop in U11 triggers and clears the first flip-flop in U12 to generate the "start" signal for signature analysis. The signature analysis "clock" signal clocks both flip-flops in U12.

U15 is a dual-trigger monostable multivibrator. It determines the EPROM burn time for data at each address. Typically, this time is about 55 milliseconds. U15 is triggered when the address on the bus is above C000 (A15 and A14 are high; refer to second paragraph above) and $\overline{WR1}$ is asserted. (The second multivibrator isn't used.)

D-type filp-flop U23 is synchronized with the system clock and generates a READYout signal. The flip-flop is triggered when U15 asserts the $\overline{Q}$ line; the flip-flop is clocked by the $\overline{IOEN}$ line. The output of the flip-flop is ANDed with the READYIN line from J2 to form the READYOUT signal.

Checking the Signature Analysis Circuit. Use the following procedure to check the signature analysis circuit of the diagnostic module:

1. Remove the battery, separate the case, and remove the I/O and system PCAs from the HP 110 (procedures 5.2, 5.3, and 5.4).
2. Open the module case and remove jumper H2 from J5 near the I/O PCA end of the module. (You can store the jumper by placing it on only one of the pins.)
3. Connect the I/O PCA to the cable extending from the module. Connect the system PCA cable to the receptacle on the module. Connect the keyboard to the I/O PCA using a keyboard extension cable (00090-60910). Check that the connectors are aligned properly. (See figure 7-3.)

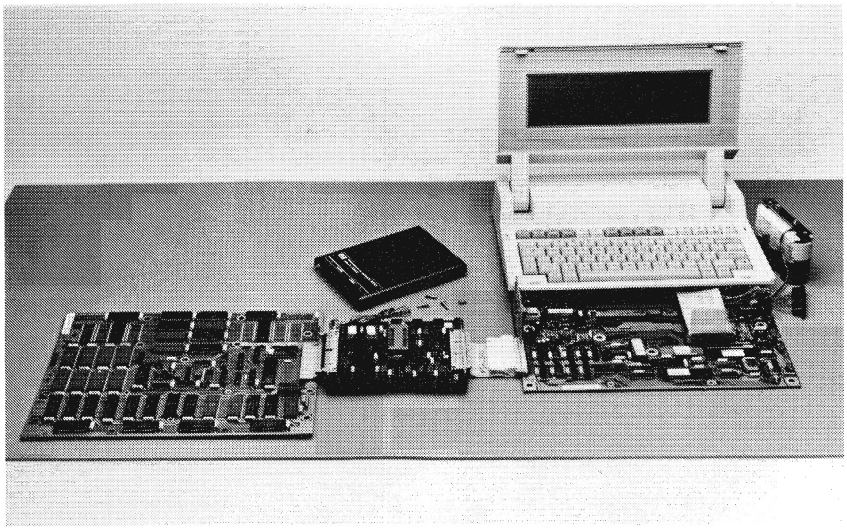


Figure 7-3. Checking the Diagnostic Module

4. Connect a recharger to the HP 110—it isn't necessary to connect the battery. (However, you *can* use a service battery assembly rather than the recharger if it's more convenient.)
5. Connect the HP 110 to an HP 9114 Disc Drive using two HP-IL cables. Turn on the disc drive and insert the service disc.
6. Turn on the HP 110 and configure it for one disc drive. Press (f6) (System Config) in the main P.A.M. screen. Use the tab or cursor keys to select the "External disc drives" field, then use the "Next Choice" and "Previous Choice" function keys to select one drive. Use the "Exit Config" function key to return to the main P.A.M. screen.
7. Type **C:DEBUG** and press (Return).
8. Type **o c3 00** and press (Return). This clears latch U6. Measure the voltage at U6 pins 12–19. All pins should measure low (about 0 Vdc).
9. Type **o c3 01** and press (Return). The voltage at U6 pin 19 should measure high (about 5 Vdc); U6 pins 12–18 should measure low.
10. Type **o c3 02** and press (Return). The voltage at U6 pin 18 should measure high; U6 pins 12–17 and 19 should measure low.
11. Type **o c3 04** and press (Return). The voltage at U6 pin 17 should measure high; U6 pins 12–16 and 18–19 should measure low.
12. Type **o c3 08** and press (Return). The voltage at U6 pin 16 should measure high; U6 pins 12–15 and 17–19 should measure low.
13. Type **o c3 10** and press (Return). The voltage at U6 pin 15 should measure high; U6 pins 12–14 and 16–19 should measure low.
14. Type **o c3 1f** and press (Return). Probe connector J3 pin 4. The signature analysis "Clock" signal should be present. (Pressing any key will increase the clock frequency.)
15. Probe connector J3 pin 1 to observe the effects of the "start/stop bit." Type **o c2 00** and press (Return); the START signal at pin 1 should then be high. Type **o c2 ff** and press (Return); the signal at pin 1 should go low.
16. Probe connector J3 pin 2 to observe the effects of the "start/stop bit." Type **o c2 00** and press (Return); the STOP signal at pin 2 should then be low. Type **o c2 ff** and press (Return); the signal at pin 2 should go high.
17. Type **q** and press (Return) to terminate the program.
18. Install jumper H2 on J5 in the diagnostic module. (This enables the module to perform its diagnostic function.)

Checking the EPROM Burner. Use the following procedure to calibrate and test the EPROM burner:

1. Remove the battery, separate the case, and remove the I/O and system PCAs from the HP 110 (procedures 5.2, 5.3, and 5.4).
2. Open the module case and remove jumper H2 from J5 near the I/O PCA end of the module. (You can store the jumper by placing it on only one of the pins.)
3. Connect the I/O PCA to the cable extending from the module. Connect the system PCA cable to the receptacle on the module. Connect the keyboard to the I/O PCA using a keyboard extension cable (00090-60910). Check that the connectors are aligned properly. (See figure 7-3 above.)
4. Connect a recharger to the HP 110—it isn't necessary to connect the battery. (However, you *can* use a service battery assembly rather than the recharger if it's more convenient.)

5. Connect a 25-Vdc power supply to the red and black wires at the two-pin power connector J4 at the system PCA end of the module: RED (+25 Vdc) and BLACK (Ground and Common, if present).
6. Connect the HP 110 to an HP 9114 Disc Drive using two HP-IL cables. Turn on the disc drive and insert the service disc.
7. Turn on the HP 110 and configure it for one disc drive. Press (f6) (System Config) in the main P.A.M. screen. Use the tab or cursor keys to select the "External disc drives" field, then use the "Next Choice" and "Previous Choice" function keys to select one drive. Use the "Exit Config" function key to return to the main P.A.M. screen.
8. Type **C:DEBUG** and press (Return).
9. Type **o c3 80** and press (Return). This activates the EPROM-burner power supply.
10. Calibrate the power supply. Measure the voltage at U7 pin 2 and UX14 pin 27. The voltage should be between 20.5 and 21.5 Vdc. If the voltage is higher, clip out resistor R6; if the voltage is lower, install resistor R6 (if removed) or decrease its resistance.
11. Type **o c3 a0** and press (Return). Measure the voltage at U7 pin 2 and UX14 pin 27. The voltage should be between 4.5 and 5.5 Vdc (from the HP 110 power supply).
12. Disconnect the 25V power supply.
13. Type **q** and press (Return) to terminate the program.
14. Connect a good HP 9114 Disc Drive using two good HP-IL cables. Then turn it on.
15. Insert the service disc in the disc drive.
16. Type **C:ETSTROBE.EXE** and press (Return).
17. Calibrate the EPROM-burner timer. Probe UX14 pin 27 and adjust potentiometer R8 until the width between pulses is between 50 and 52 milliseconds.
18. Turn off and disconnect the power supply. Carefully wrap and store the wires inside the module.
19. Disconnect power from the HP 110.
20. Install jumper H2 on J5 in the diagnostic module. (This enables the module to perform its diagnostic function.)

Table 7-3. Diagnostic Module Replaceable Parts

Reference Designation*	HP Part Number	Description	Quantity
C1, C3–C5, C8–C11, C13, C15, C17–C22	0160-5941	CAPACITOR, 0.047 μF	16
C7	0180-0269	CAPACITOR, 1 μF	1
C23	0180-2904	CAPACITOR, 0.1 μF	1
C24	0180-0291	CAPACITOR, 1 μF	1
C25	0160-4807	CAPACITOR, 33 pF	1
CR1	1901-1098	DIODE, 1N4150	1
H1	1251-5751	JUMPER, 2 pin	1
H2	1258-0189	JUMPER, 2 pin	1
J1	1251-8465	CONNECTOR, 50 pin	1
J2	1251-8832	CONNECTOR, 50 pin	1
J3	1252-0257	CONNECTOR, 4 pin	1
J4, J5	1251-6978	CONNECTOR, 2 pin	2
Q1	1854-0477	TRANSISTOR, 2N2222A	1
Q2, Q3	1853-0036	TRANSISTOR, 2N3906	2
Q4	1854-0215	TRANSISTOR, 2N3904	1
R1	0757-0394	RESISTOR, 51.1 ohm, 1%, ¼W	1
R2	0699-0208	RESISTOR, 1 ohm, 5%, ¼W	1
R3	0698-3440	RESISTOR, 196 ohm, 1%, ¼W	1
R4, R7, R10–R12	0683-2235	RESISTOR, 22 kΩ, 5%, ¼W	5
R5	0757-0421	RESISTOR, 825 ohm, 1%, ¼W	1
R6	0683-2225	RESISTOR, 2.2 kΩ, 5%, ¼W	1
R8	2100-3253	RESISTOR, variable, 50 kΩ	1
R9	0683-3935	RESISTOR, 39 kΩ, 5%, ¼W	1
U1, U2, U6	1820-3486	INTEGRATED CIRCUIT, 82C82	3
U3, U4	1820-3330	INTEGRATED CIRCUIT, 74HC245	2
U5	00090-60922	INTEGRATED CIRCUIT, service, odd	1
U7	1826-0772	INTEGRATED CIRCUIT, LM317L	1
U8, U13	1820-3209	INTEGRATED CIRCUIT, 74HC688	2
U9	1820-3014	INTEGRATED CIRCUIT, 74HC139	1
U10	00090-60923	INTEGRATED CIRCUIT, service, even	1
U11, U12, U23	1820-3081	INTEGRATED CIRCUIT, 74HC74	3
U15	1820-3673	INTEGRATED CIRCUIT, 74HC123	1
U16, U20	1820-3298	INTEGRATED CIRCUIT, 74HC32	2

Table 7-3. Diagnostic Module Replaceable Parts (Continued)

Reference Designation*	HP Part Number	Description	Quantity
U17, U18	1820-3097	INTEGRATED CIRCUIT, 74HC08	2
U19, U21	1820-2924	INTEGRATED CIRCUIT, 74HC02	2
U22	1820-2921	INTEGRATED CIRCUIT, 74HC04	1
XU5, XU10	1200-0567	SOCKET, 28 pin	2
XU14	1200-0870	SOCKET, 28 pin, EPROM burner	1
	00090-60911	CABLE, I/O	1
	5041-4110	CASE, bottom	1
	5041-4111	CASE, top	1
	5040-9207	FOOT	4
	00090-80038	LABEL, connector	1
	00090-80039	LABEL, instruction	1
	00090-80037	LABEL, top	1
	00090-80040	PLATE, I/O end	1
	00090-80041	PLATE, system end	1
	0624-0400	SCREW, self-tapping, 6-19 x 0.5 inch	3

* Use the prefix "Diagnostic Module" with reference designations for parts of the diagnostic module (part number 00090-60904). This will help avoid confusion with parts for the HP 110.

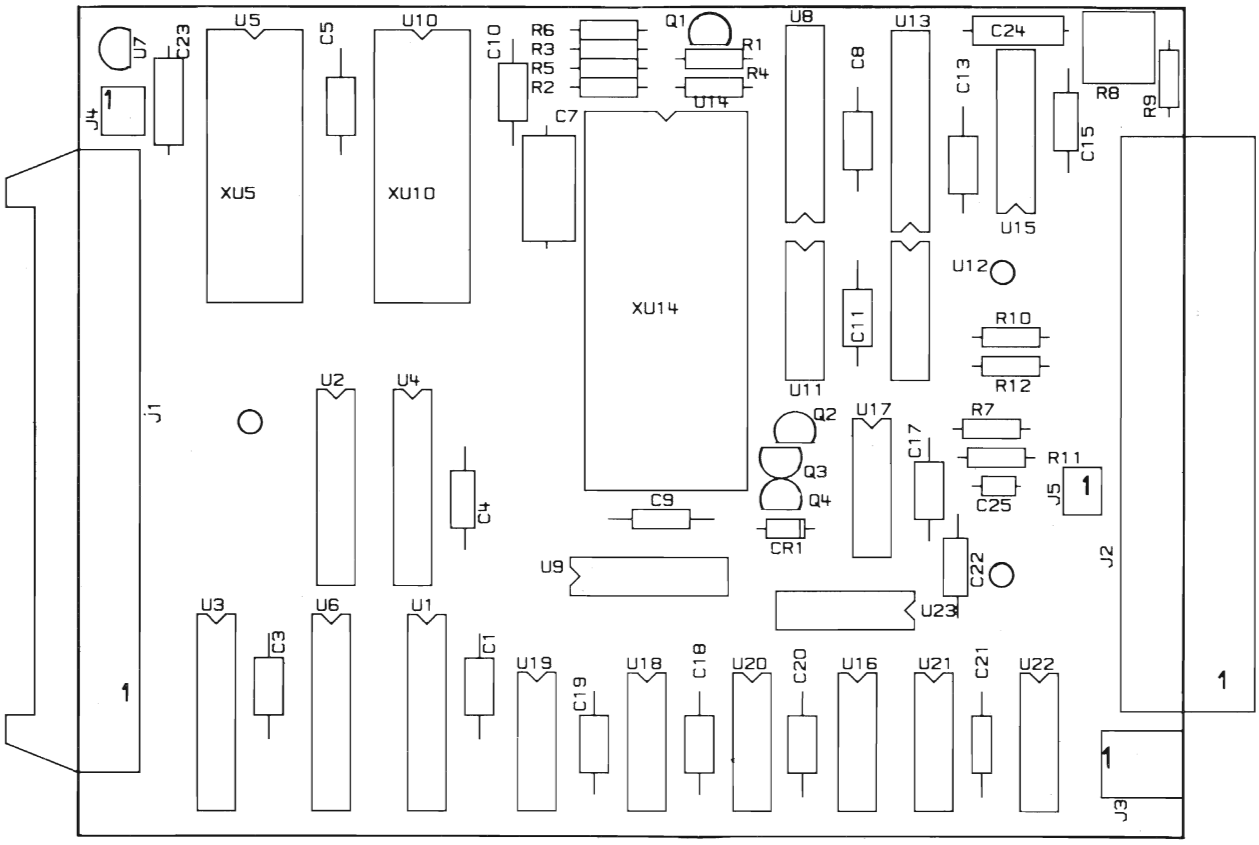


Figure 7-4. Diagnostic Module Component Location Diagram

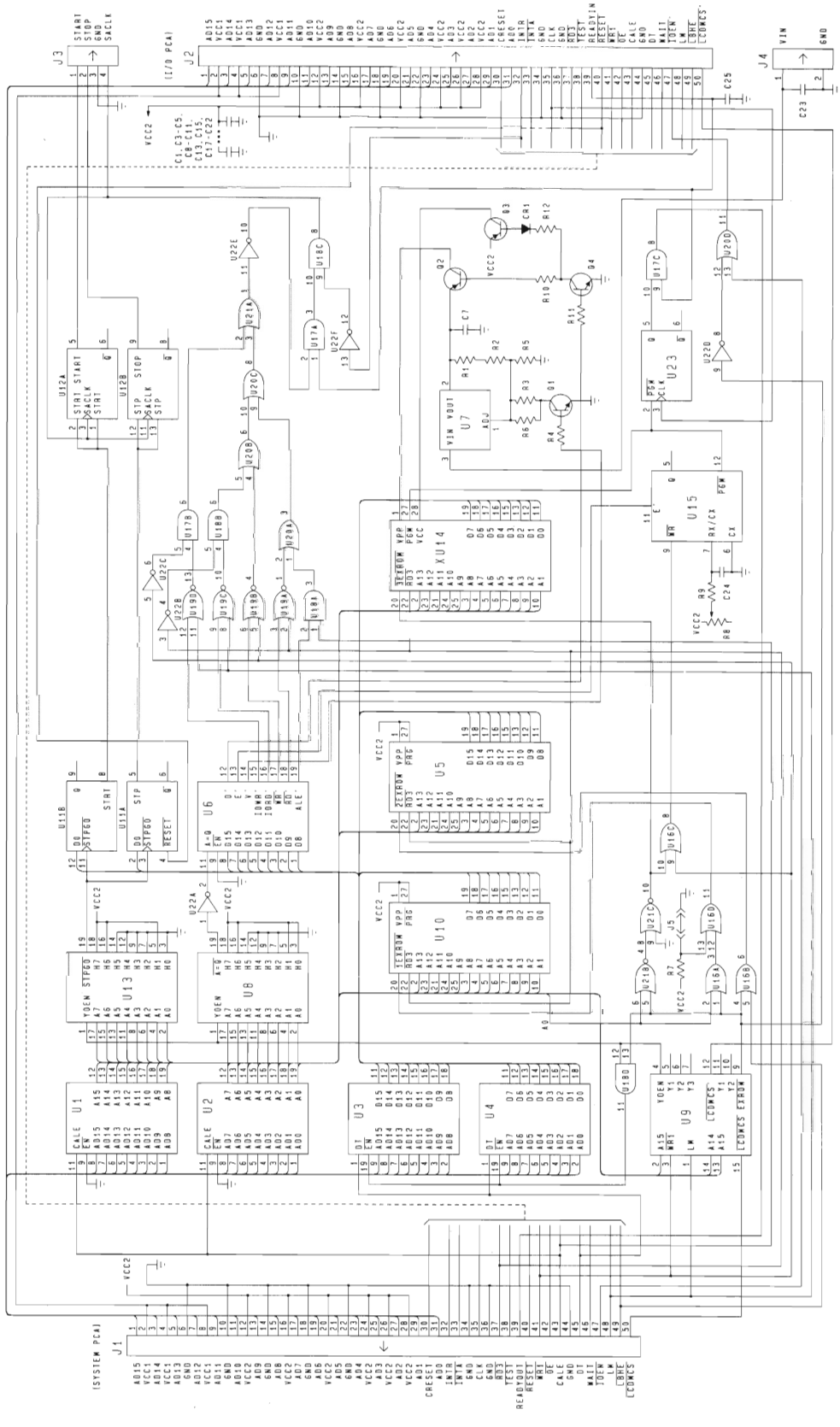


Figure 7-5. Diagnostic Module Schematic Diagram

Chapter 8
Product History

8.1 Introduction

This chapter contains information for using this manual with earlier units for which the content doesn't apply directly.

To use this manual with an earlier unit, refer to table 8-1 to determine the backdating information that applies to a particular unit. Then refer to section 8.2 for a detailed description of each item. (Units not identified in the table have no backdating information.)

Table 8-1. Backdating Summary

Version	Serial Numbers	Applicable Items*
A (U.S.)	before 2419A-----	1, 2, 4, 5, 6
A (U.S.)	2419A----- to 2421A02306	1, 2, 5, 6
A (U.S.)	2421A02307 to 2423A03109	1, 5, 6
A (U.S.)	2423A03110 to ----A06999	1, 3, 5, 6
A (U.S.)	----A07000 to 2426A08255	3, 5, 6
A (U.S.)	2426A08256 to 2428A04245	5, 6
A (all versions)	2428A04246 to 2440A17888	6
B (all versions)	before 2440A17889	6

* Certain items may not apply if a unit has been repaired previously. Check the unit to determine if the item applies.

8.2 Backdating History

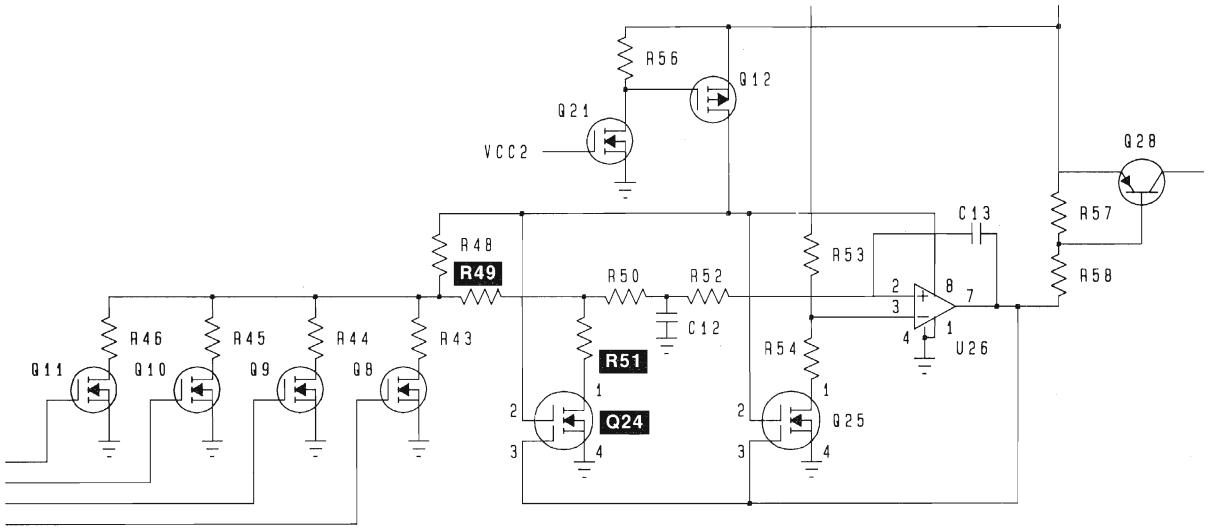
The following list provides detailed information about each backdating item. (Also, the indicated service notes describe the backdating items.) Refer to table 8-1 to find the items that apply to a particular unit.

1. **Version A, serial numbers through ----A06999.** Two ROMS (A1U62 and A1U63) and the configuration EPROM (A2U28) have been updated. If any of them fail, replace all three with updated parts. If you replace the system PCA, install an updated PCA and an updated configuration EPROM. Refer to table 6-9 for updating information. (Service Note 110-01.)

2. **Version A, serial numbers through 2421A02306.** Transistor A2Q24 and resistors A2R49 and A2R51 are not as specified in chapter 6. If one of these components fails, replace it according to the following list. (Service Note 110-02.)

Reference Designation	HP Part Number	Description
Q24	1855-0557	TRANSISTOR, dual-gate MOSFET, 20V
R49	0757-0463	RESISTOR, 82.5 kΩ, 1%, ⅛W
R51	0757-0278	RESISTOR, 1.78 kΩ, 1%, ⅛W

The following schematic diagram shows how these components are connected in the LCD supply circuit on the I/O PCA (see figure 9-7).



3. **Version A, serial numbers from 2423A03110 through 2426A08255.** Transistor A2Q25 (part 3N171) is not as specified in chapter 6. If it fails, replace it with part number 1855-0557 (as specified in table 6-6). (Service Note 110-04.)

4. **Version A, serial numbers before 2419A------.** A jumper wire on the system PCA is not installed. The unit may lock up at power-up, with only the contrast key or reset button having any effect. Repair the system PCA by soldering a wire from A1U3 pin 6 to A1R1 pin 11. (Service Note 110-05.)

5. **Version A, serial numbers through 2428A04245.** The modem PCA (A3) is not secured to the I/O PCA with a piece of tape. The unit may experience intermittent operation of the modem. Repair the unit by installing a piece of tape (part number 0460-1802) between the modem PCA (connector A3J7) and the I/O PCA. Refer to section 5.4. (Service Note 110-07.)

6. **All A versions and all B versions, serial numbers through 2440A17888.** Resistor A2R49 is not as specified in chapter 6. If the customer complains of limited contrast range (LCDNEG supply voltage is −11 to −12 Vdc at the darkest setting), replace A2R49 according to table 6-6. This should cause LCDNEG to be −12 to −12.5 Vdc. (Service Note 110-13.)

Chapter 9
Diagrams

This chapter includes reference diagrams for the HP 110: schematic diagrams and component-location diagrams for the system PCA, I/O PCA, modem PCA, keyboard, and terminal block PCA.

Replaceable parts for these assemblies are listed in chapter 6.

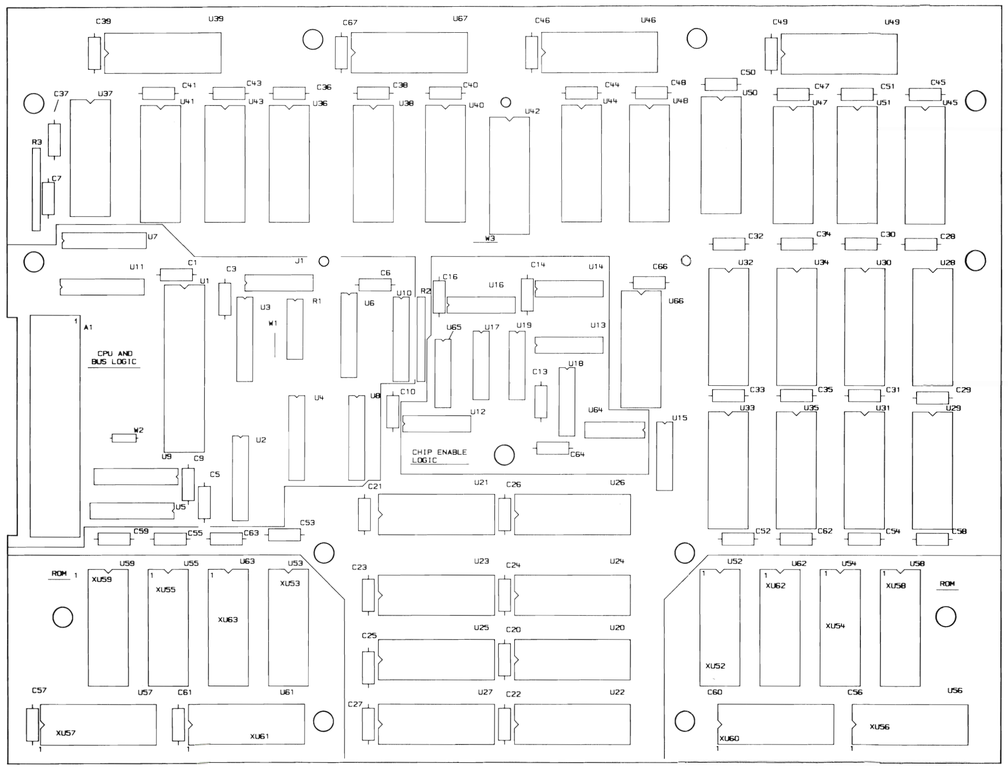


Figure 9-1. System PCA Component Location Diagram

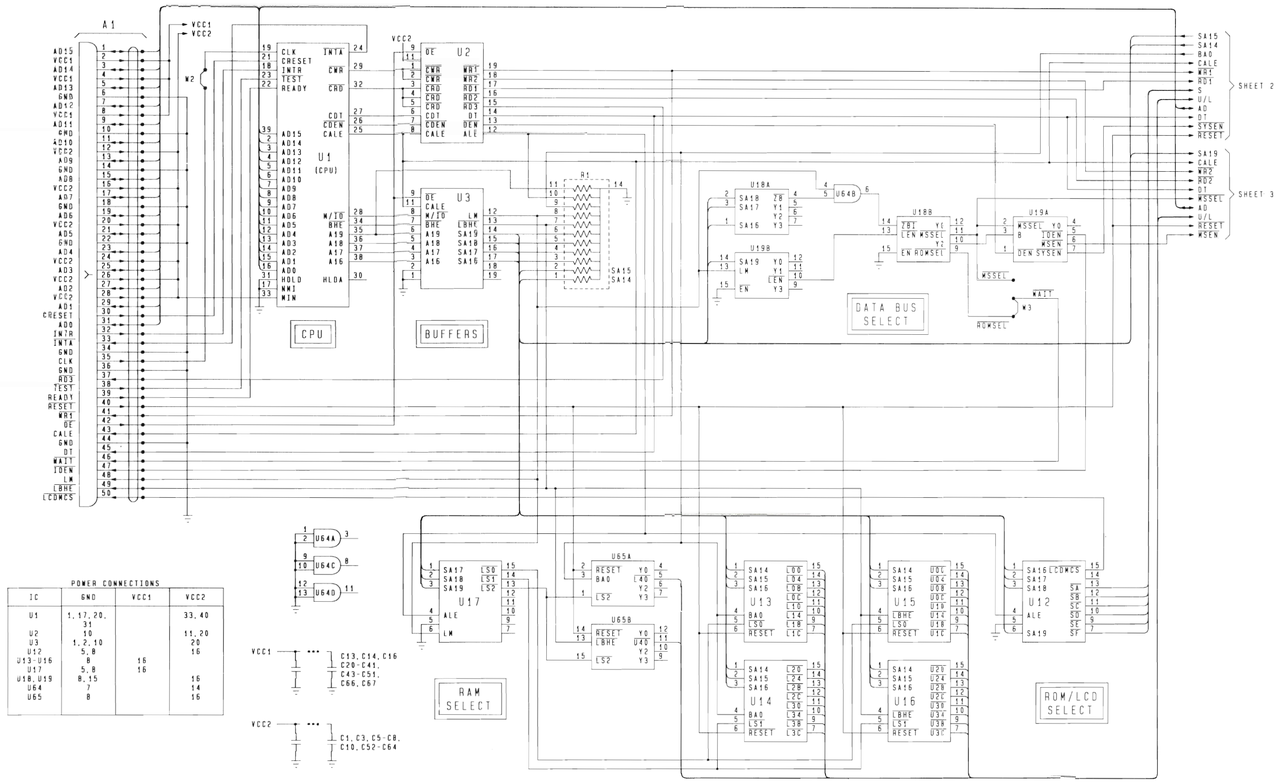


Figure 9-2. System PCA Schematic Diagram —Sheet 1

POWER CONNECTIONS

IC	GND	VCC1	VCC2
U4, U5	9, 10		20
U8, U9	10		20
U20-U27	14	28	
U52-U63	14		1, 28

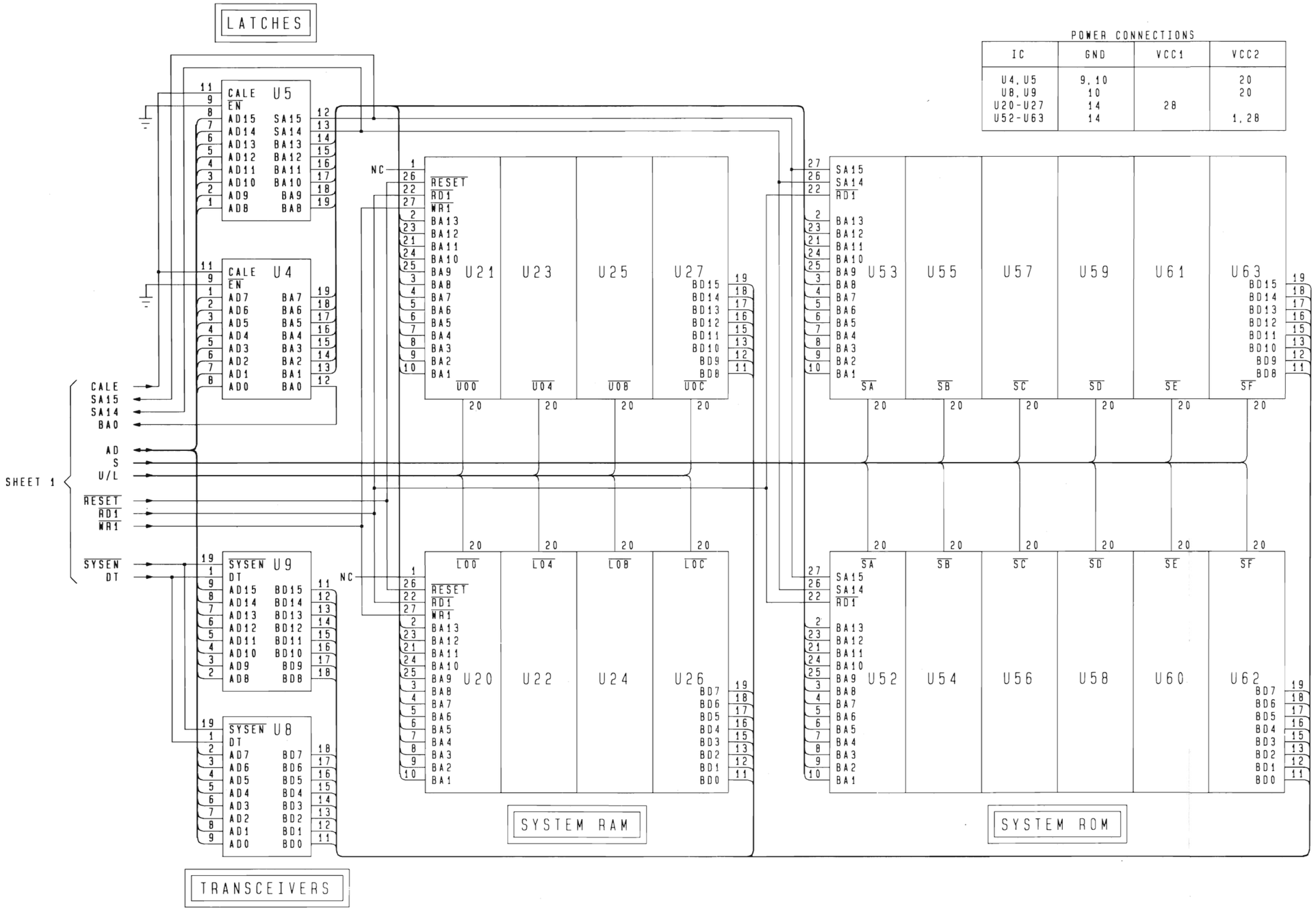
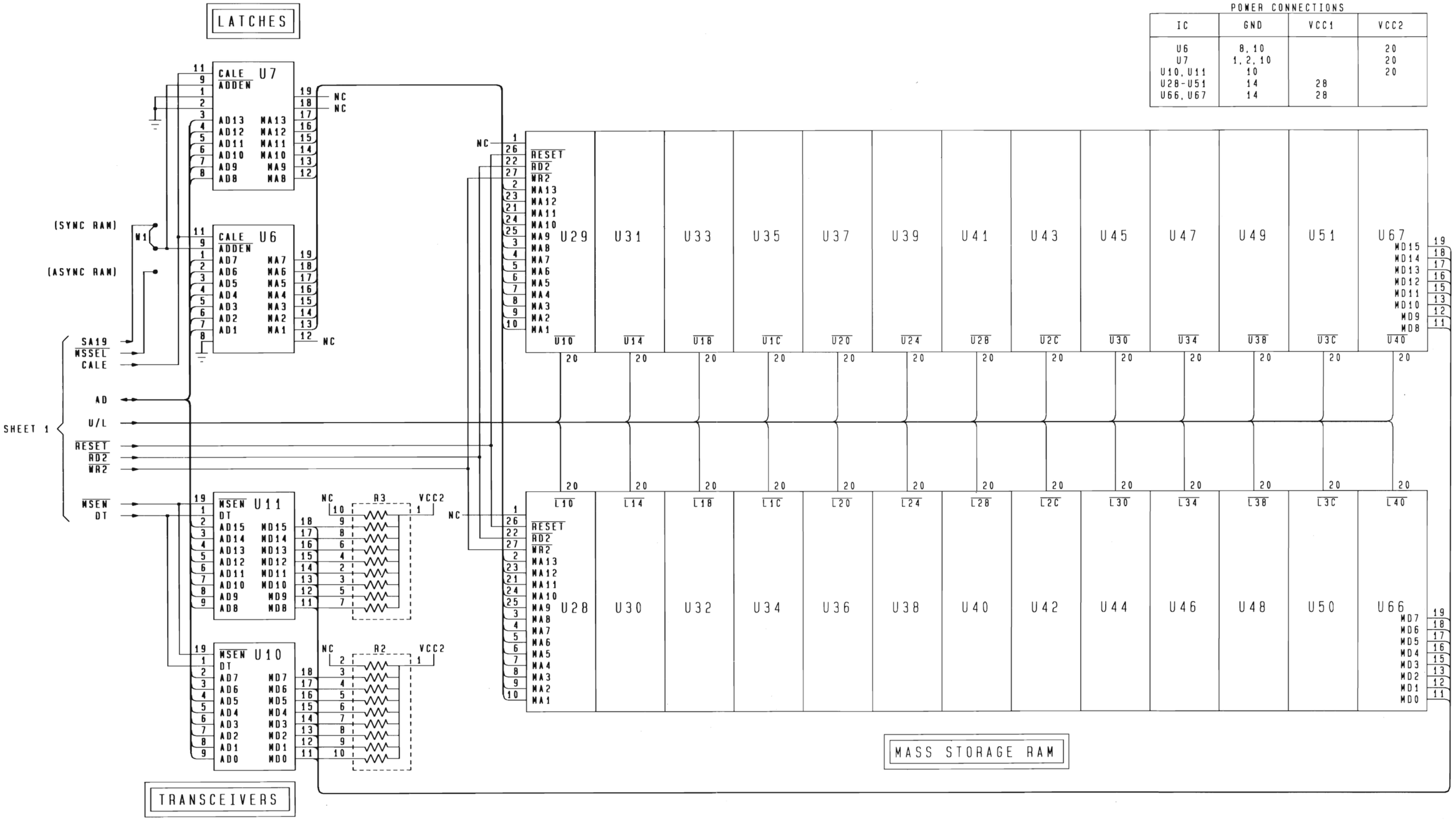


Figure 9-3. System PCA Schematic Diagram —Sheet 2



POWER CONNECTIONS

IC	GND	VCC1	VCC2
U6	8, 10		20
U7	1, 2, 10		20
U10, U11	10		20
U28-U51	14	28	
U66, U67	14	28	

Figure 9-4. System PCA Schematic Diagram —Sheet 3

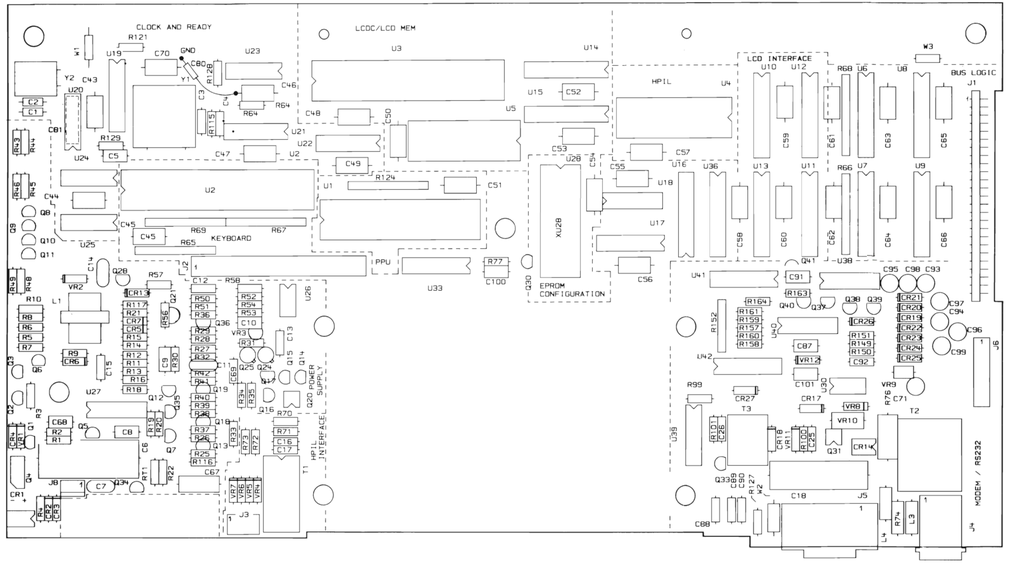


Figure 9-5. I/O PCA Component Location Diagram

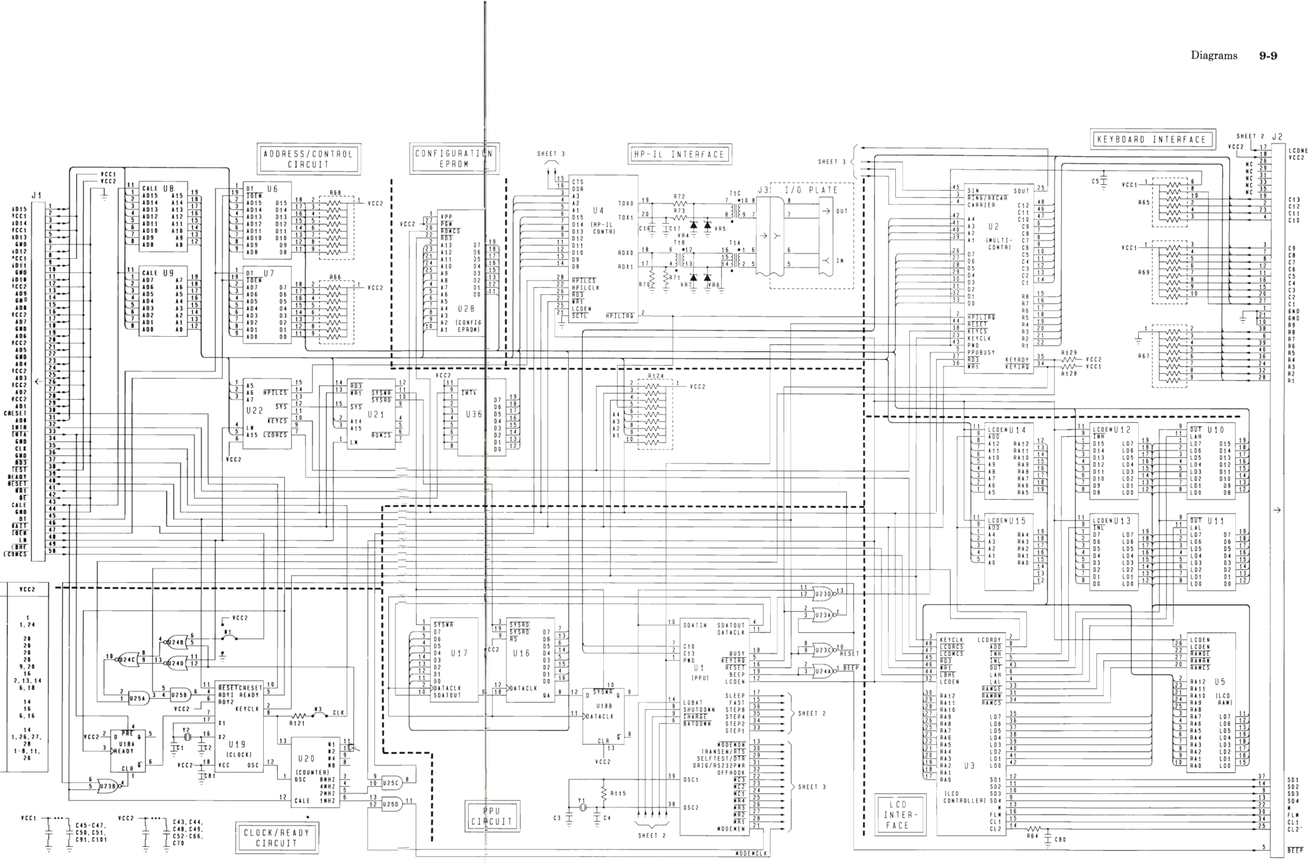


Figure 9-6. I/O PCA Schematic Diagram—Sheet 1

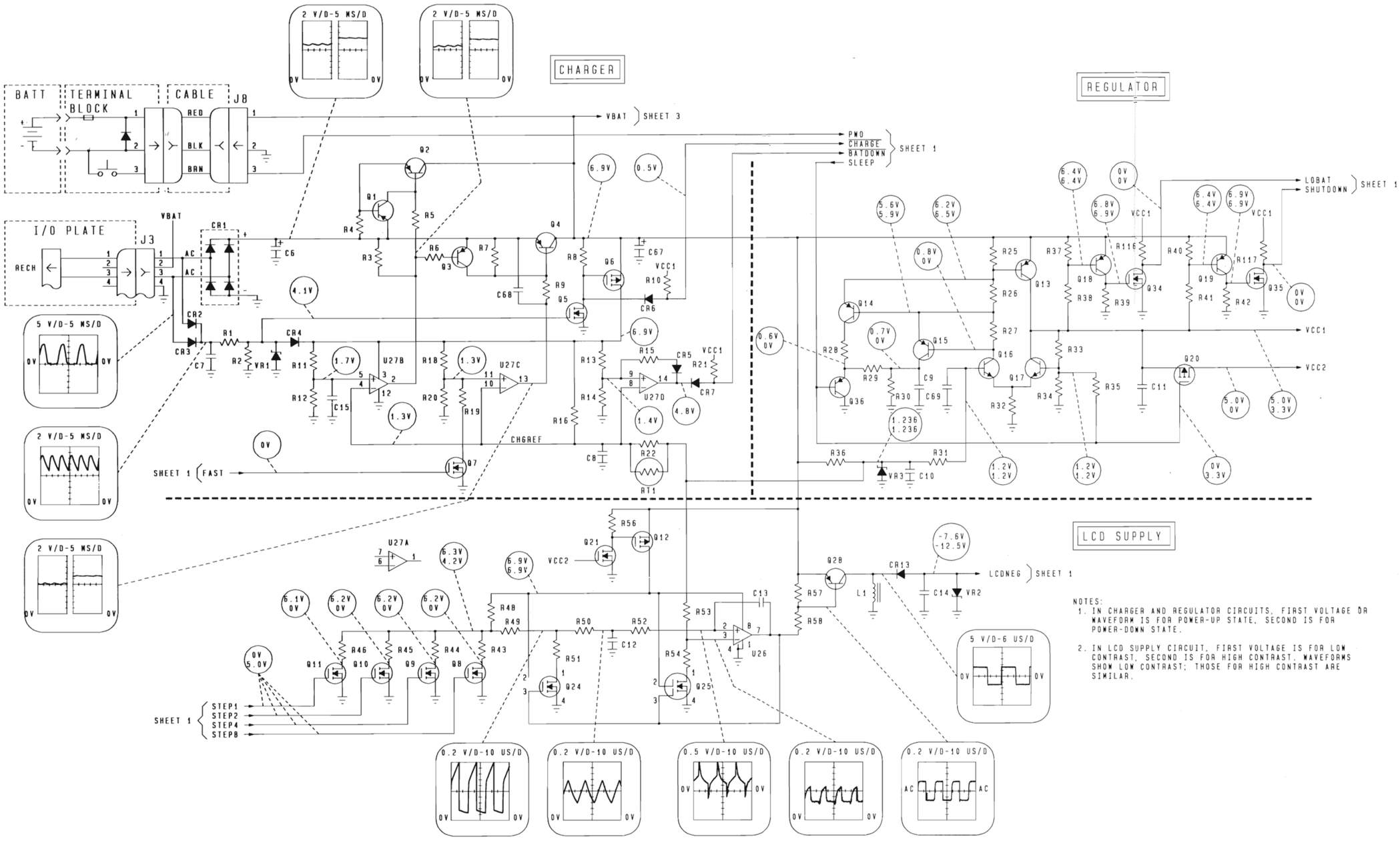
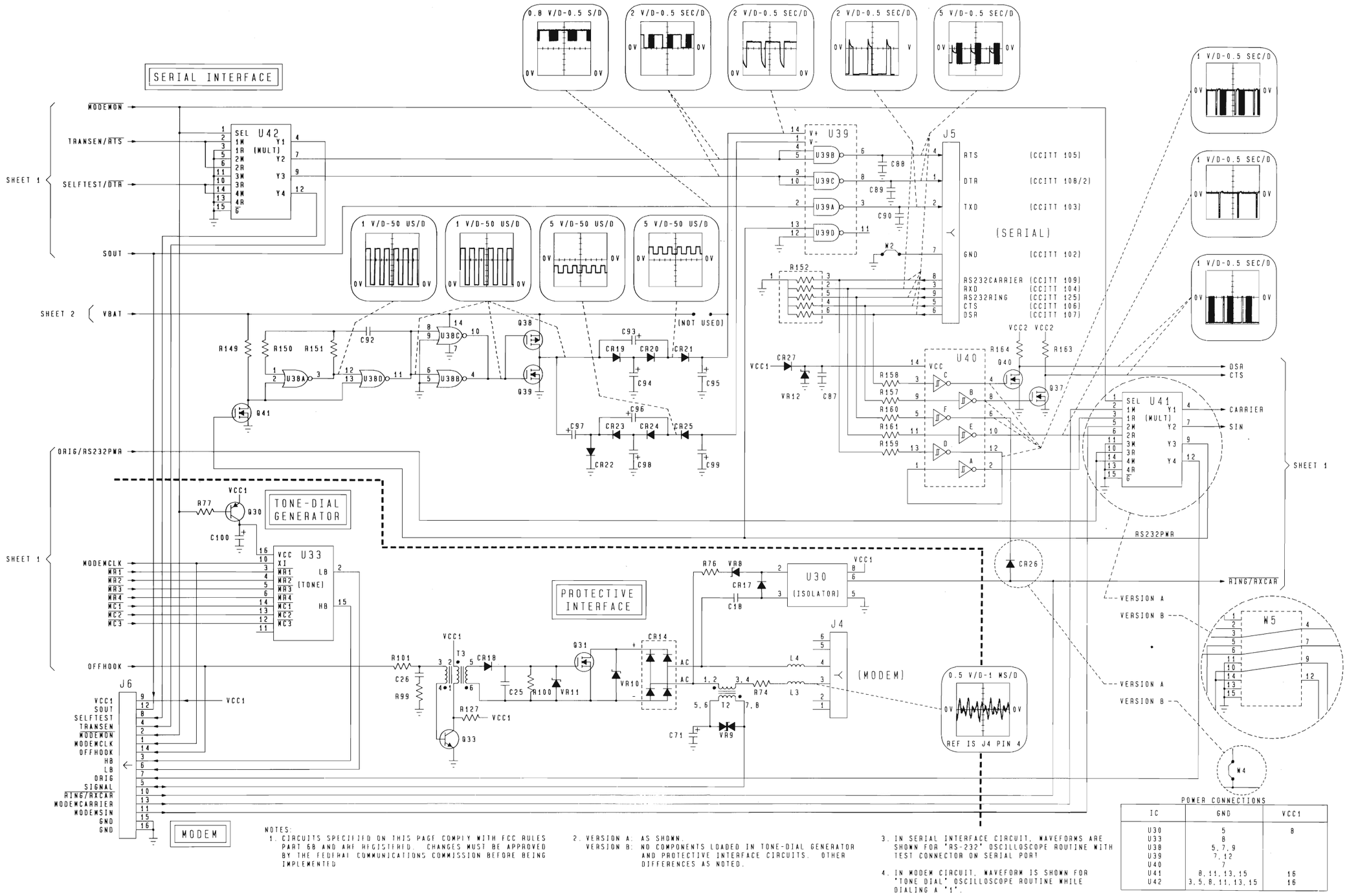


Figure 9-7. I/O PCA Schematic Diagram —Sheet 2



NOTES:

1. CIRCUITS SPECIFIED ON THIS PAGE COMPLY WITH FCC RULES PART 68 AND ARE REGISTERED. CHANGES MUST BE APPROVED BY THE FEDERAL COMMUNICATIONS COMMISSION BEFORE BEING IMPLEMENTED.
2. VERSION A: AS SHOWN.
   VERSION B: NO COMPONENTS LOADED IN TONE-DIAL GENERATOR AND PROTECTIVE INTERFACE CIRCUITS. OTHER DIFFERENCES AS NOTED.
3. IN SERIAL INTERFACE CIRCUIT, WAVEFORMS ARE SHOWN FOR "RS-232" OSCILLOSCOPE ROUTINE WITH TEST CONNECTOR ON SERIAL PORT.
4. IN MODEM CIRCUIT, WAVEFORM IS SHOWN FOR "TONE DIAL" OSCILLOSCOPE ROUTINE WHILE DIALING A "1".

POWER CONNECTIONS

IC	GND	VCC1
U30	5	8
U33	8	
U38	5, 7, 9	
U39	7, 12	
U40	7	
U41	8, 11, 13, 15	16
U42	3, 5, 8, 11, 13, 15	16

Figure 9-8. I/O PCA Schematic Diagram —Sheet 3

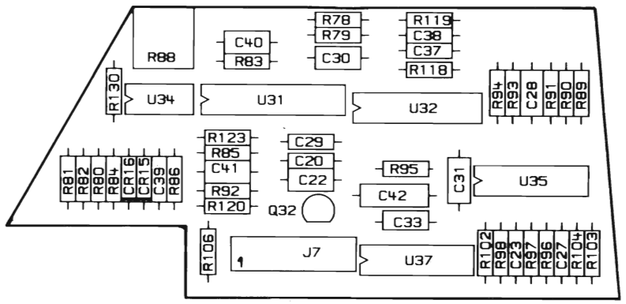
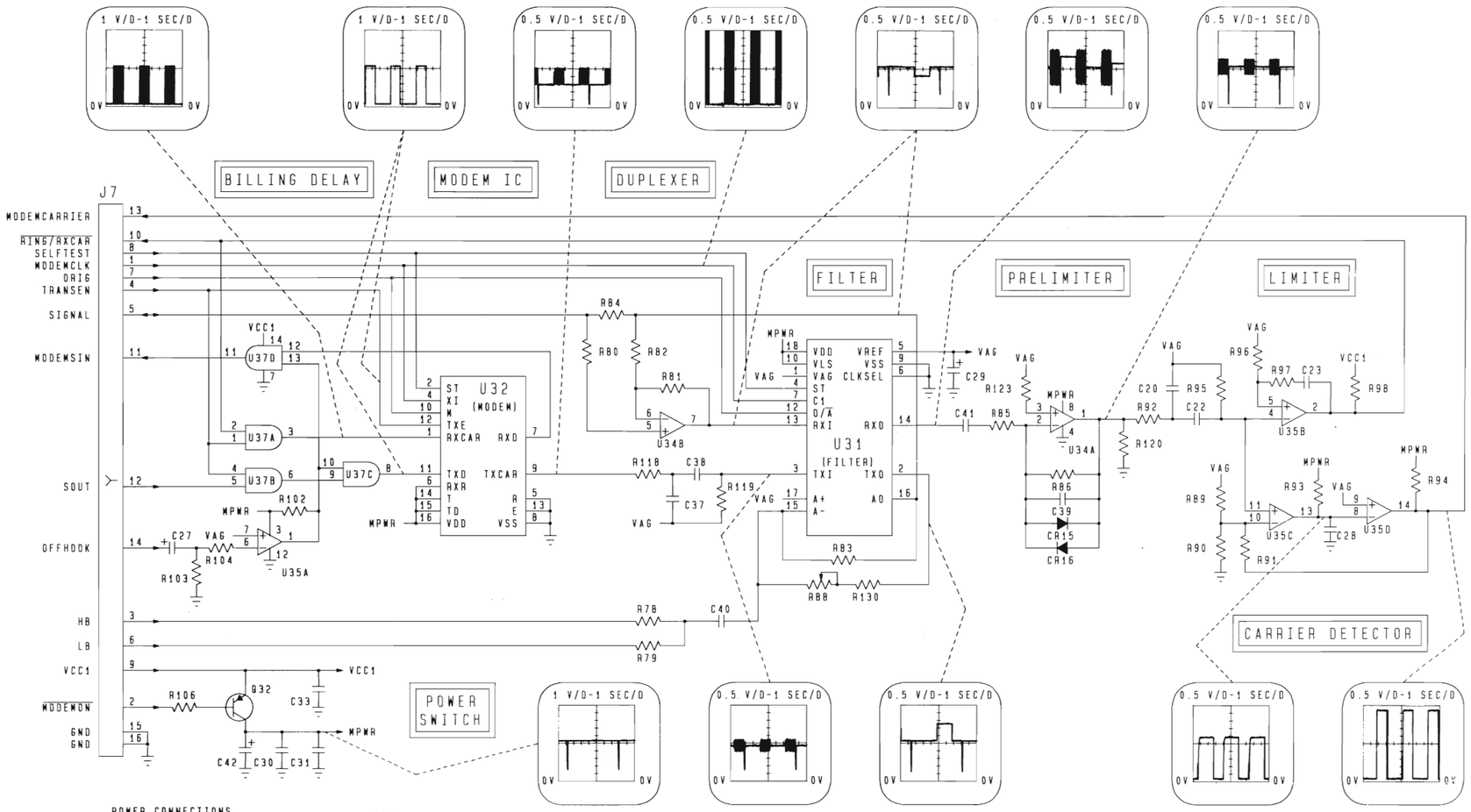


Figure 9-9. Modem PCA Component Location Diagram



POWER CONNECTIONS

IC	GND	VCC1	MPWR
U31	6, 9		10, 18
U32	5, 8, 13		6, 14, 15, 16
U34	4		8
U35	12		3
U37	7	14	

NOTES:
1. CIRCUITS SPECIFIED ON THIS PAGE COMPLY WITH FCC RULES PART 68 AND ARE REGISTERED. CHANGES MUST BE APPROVED BY THE FEDERAL COMMUNICATIONS COMMISSION BEFORE BEING IMPLEMENTED.
2. WAVEFORMS ARE SHOWN FOR "MODEM LOOPBACK" OSCILLOSCOPE ROUTINE.

Figure 9-10. Modem PCA Schematic Diagram

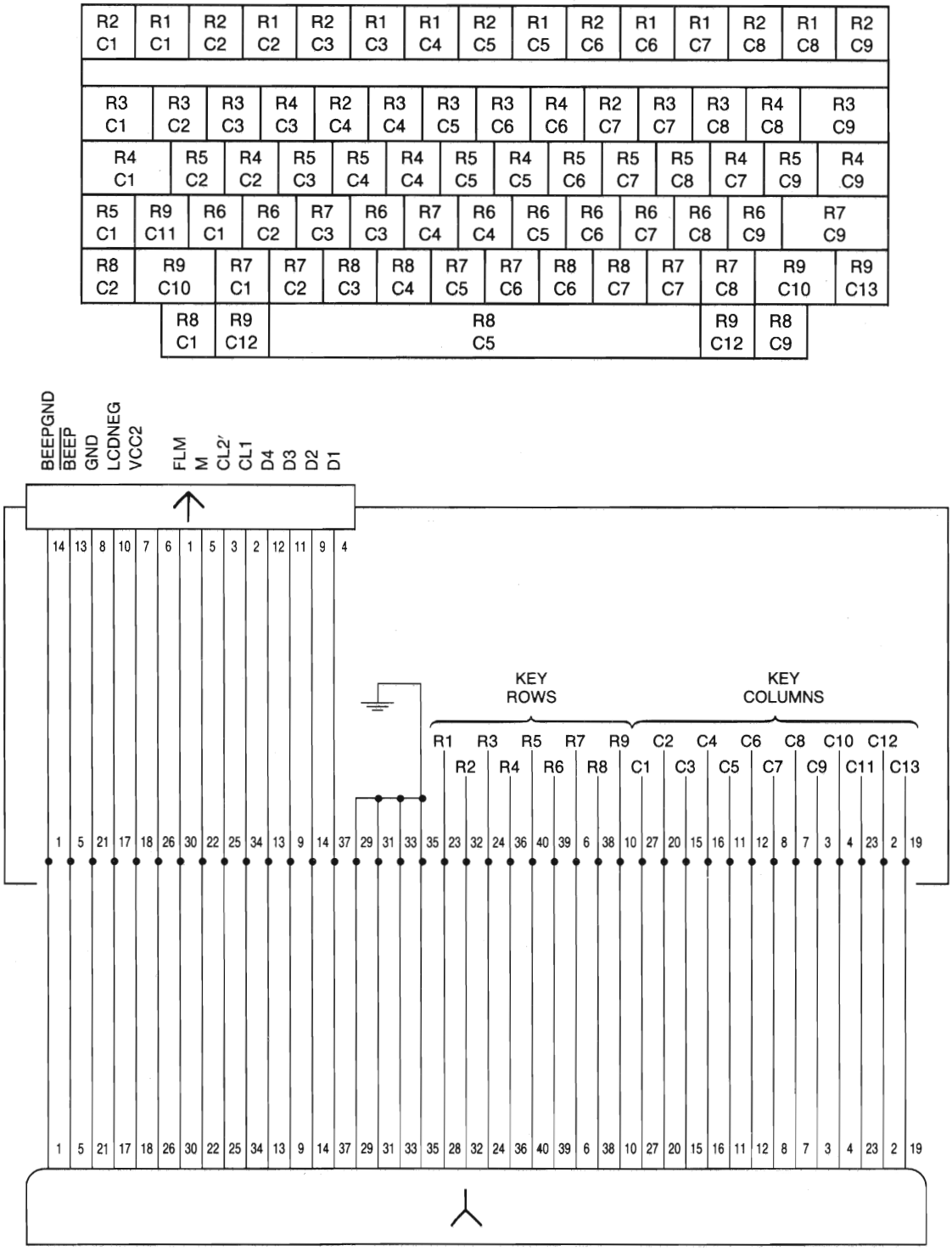


Figure 9-11. Keyboard PCA Schematic Diagram

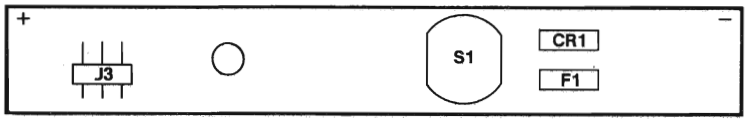


Figure 9-12. Terminal Block PCA Component Location Diagram

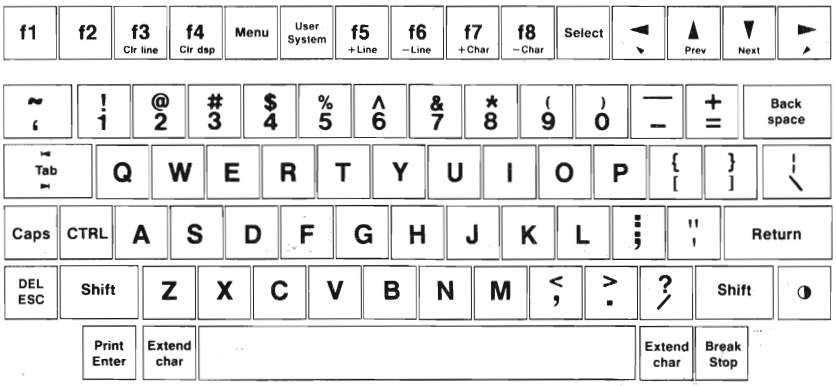


Figure 9-13. U.S. Keyboard Layout

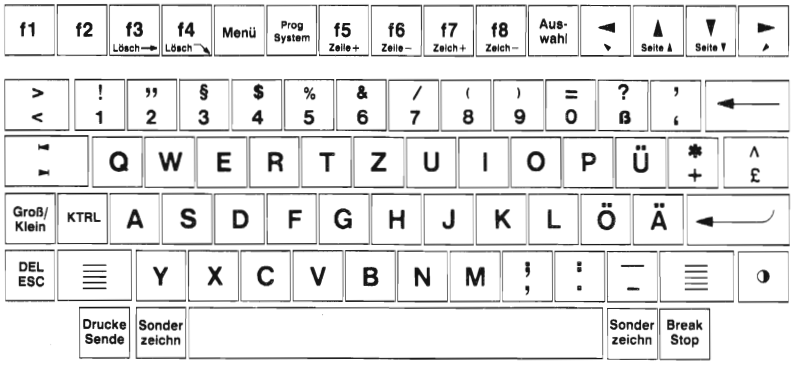


Figure 9-14. German Keyboard Layout

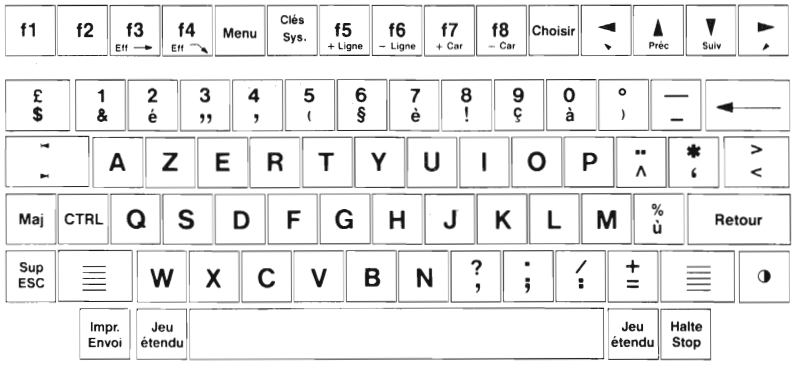


Figure 9-15. French Keyboard Layout

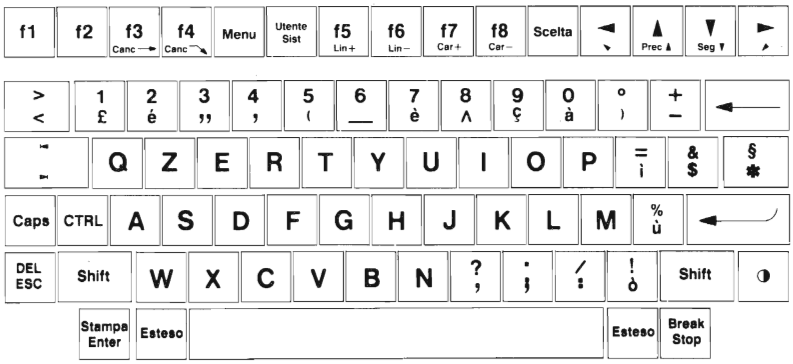


Figure 9-16. Italian Keyboard Layout

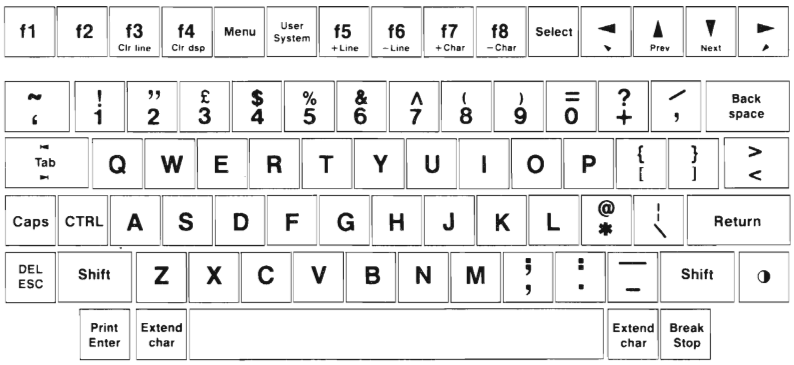


Figure 9-17. U.K. Keyboard Layout

HEWLETT PACKARD

Portable Computer Division
1000 N.E. Circle Blvd., Corvallis, OR 97330, U.S.A.

Reorder Number
00090-90021

Printed in U.S.A. 10/84
Mfg. No. 00090-90116