Assembling the Handy Board

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This document presents step-by-step assembly and testing instructions for building the Handy Board version 1.2.

These are incremental assembly/test instructions, meaning that for each assembly step there is a requisite testing step. This method will insure that the Handy Board is working properly at each step of the way, and should minimize debugging if there are any problems. *The whole purpose of this assembly method is to eliminate cases where somebody builds a whole board and then says, "It doesn't work, what's wrong?"* If these instructions are followed, then any problem conditions will be localized and debugging will be **MUCH** easier.

Technical support for the Handy Board is provided via the Handy Board mailing list, `handyboard@media.mit.edu`. To join the list, please send an e-mail to Fred Martin, `fredm@media.mit.edu`, requesting to join the Handy Board mailing list. If you encounter any problems during the Handy Board assembly, please send a detailed message regarding your situation to this list. Explain which steps your Handy Board has passed, and at which step you are encountering a problem.

Again, it cannot be over-emphasized that it is better to "nip a problem in the bud"— when it first occurs during assembly—than plowing on ahead. Do not go forward on the blind hope that the board will magically work when all the parts are installed. If your board does not pass a test step, please contact the users on the mailing list for assistance before proceeding. Everyone wants to get their board up and running as fast as possible, but patience and diligence are always rewarded during the assembly process.

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1   Handy Board Assembly Tips

This section contains general hints for assembling the Handy Board. Some previous experience building and solder electronic components is assumed.

1.1   Component Side versus Solder Side

The component side of the Handy Board is clearly marked **COMPONENT SIDE**, near the location where the piezo speaker is installed. The component side has the *silkscreen legend* printed on it—the white labels that indicate where the components are placed.

All components sit on the component side, with their leads poking through to the solder side. The board is then soldered from the solder side.

Don't get it backward because the board won't work, unless it is transported to a parallel universe.

1.2   The Square Pad Convention

On the Handy Board, square pads are used when a component is polarized and hence must be installed in a particular orientation. The square pad may have one of two meanings:

- **Negative Terminal.** This applies to capacitors, LEDs, and diodes.

- **Pin 1.** This applies to integrated circuits and resistor packs.

Following is information on the specific components that are polarized:

- **LEDs.** Install so that the cathode (negative terminal) goes into the square pad. The square pad is underneath the white, shaded half of the LED placement silkscreen legend. On the LED itself, the cathode is indicated as the shorter of the two leads.
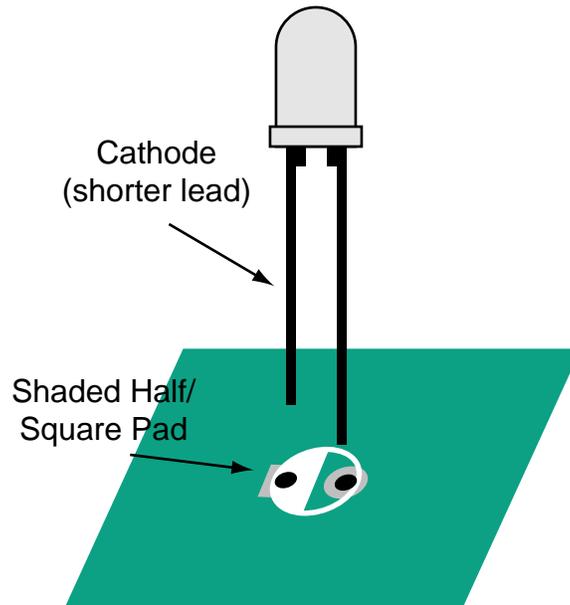
The above diagram shows a side view of an LED and the part silkscreen legend. The shorter lead of the LED is the cathode, which goes in the square hole.

- **Diode.** Install so that the cathode goes into the square pad.

The cathode is marked with a band nearer to the cathode end (see above diagram).

- **Capacitors.** If the capacitor is polarized (e.g., electrolytics and tantalum), either the $+$ or $-$ terminal will be marked. That is, there may be a $+$ marking indicating the $+$ terminal, or a $-$ marking indicating the $-$ terminal. Figure out which is the $-$ terminal and stick it in the square pad.

  If a capacitor is non-polarized (e.g., any value $0.1~\mu$F or less), don't worry if the board has a square pad and a round pad. It doesn't matter how the capacitor is installed.

- **Integrated circuits.** The square pad is pin 1. It's a nice idea to mount sockets so that its notch indicates where the notch on the chip goes. After soldering everything down it is significantly harder to see where the square pads are.

```
         14  13  12  11  10  9   8
Notch
              ┌────────────────────┐
    ─────────▶│                    │
              │                    │
              └────────────────────┘
         1   2   3   4   5   6   7

              14–pin DIP
Pin 1          TOP VIEW
```
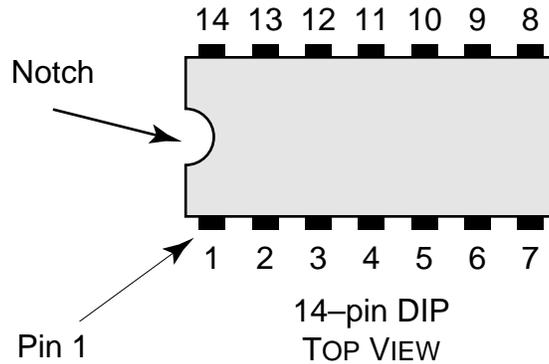
The above diagram shows how to count pins on a DIP (dual in-line package). Find the notch, and then pin 1 is in the lower left corner beneath it. The pin numbering proceeds counter-clockwise from pin 1.

DIP sockets have a notch like the notch seen on the chips themselves.

- **Resistor packs.** Most of these are polarized. The banded end is pin 1, which goes in the square hole.

```
    ┌──────────────┃┐      ┌──────────────⊙┐
    └┬┬┬┬┬┬┬┬──────┘      └┬┬┬┬┬┬┬┬──────┘

         ▲                      ▲
    Pin 1 marked          Pin 1 marked
      by band                by dot
```
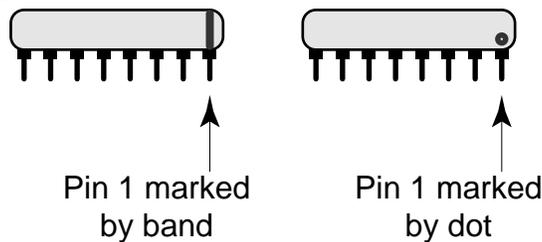
The above diagram shows two sample 8–pin resistor packs. The left-hand pack has the "band style" marking; the right-hand pack has the "dot style" marking. In either case, the marking indicates pin one of the resistor pack, which goes in the square hole.

1.3 The 6811

1.3.1 PCB Mounting

There is no square pad indicating pin 1 on the 6811. The 6811 is mounted in a PLCC (plastic leaded chip carrier) socket. The socket is soldered down to the board, and the 6811 is inserted into the socket.

3
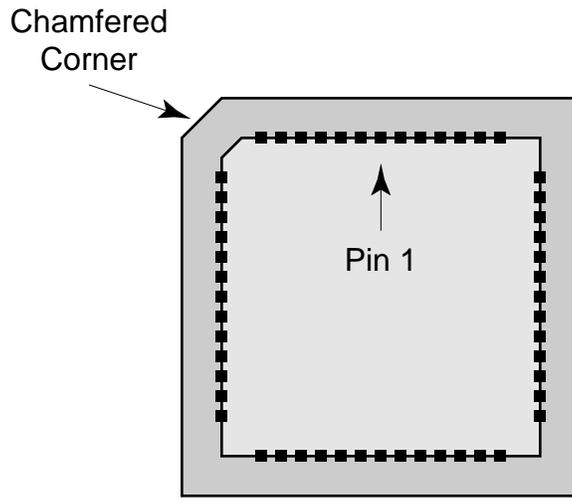
The above diagram shows the 6811 socket, with its chamfered (or truncated) corner in the upper left. The 6811 itself has a matching chamfer in its upper left corner (the 6811's pin 1 is indicated with a dot).

It is imperative to install the PLCC socket with its chamfered corner directly above the chamfered corner of the silkscreen legend. This is because once the socket is soldered down, the 6811 only fits into it one way, so the socket must be soldered correctly.

1.3.2   6811 Pin Numbering

Several of the assembly steps require testing signals on the 6811 chip. This can be done either from the top of the chip, by inserting a thin wire to make contact with the actual 6811 leads, or from the bottom of the board at the PLCC socket leads.

Looking down at the 6811, the numbering of its pins proceed counter-clockwise from the pin 1 dot. E.g., pin 2 is immediately to the left of pin 1, and pin 52, the highest-numbered pin, is immediately to pin 1's right (see Figure 1).

There is a non-obvious translation from the simple numeric progression of the 6811 pin numbering to how the pins appear at the PLCC socket leads. Figure 2 shows the pin numbering, *looking up at the PLCC socket from the bottom of the PC board.* In other words, the diagram shows the pin numbering assuming the board is turned upside down, and the viewer down at it.

1.4   Cutting Female Strip Header

Female strip header can be difficult to cut properly. If it is just snapped, it does not break cleanly between two pins; one pin adjacent to the break is generally destroyed.

A recommended method is to repeatedly score the header at the desired break point, using an X-acto or matte knife to gradually dig deeper and deeper into the cut line. Score
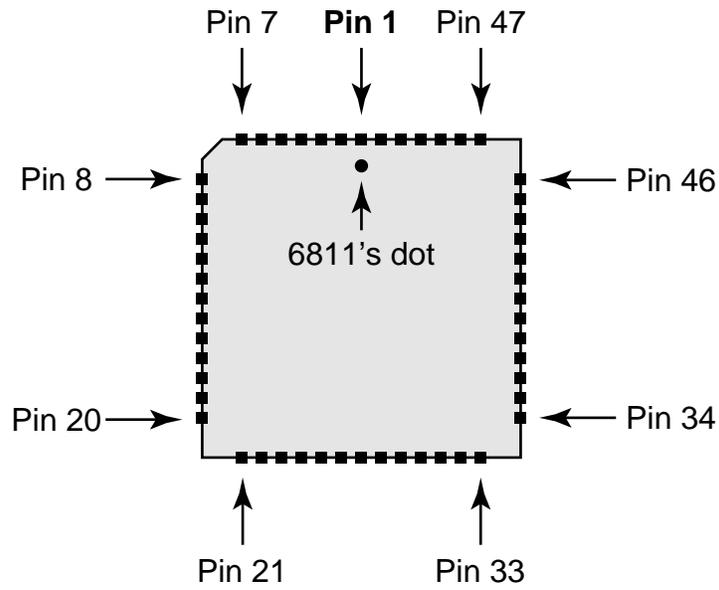
Figure 1: 6811 Chip Pin Numbering, **TOP VIEW**
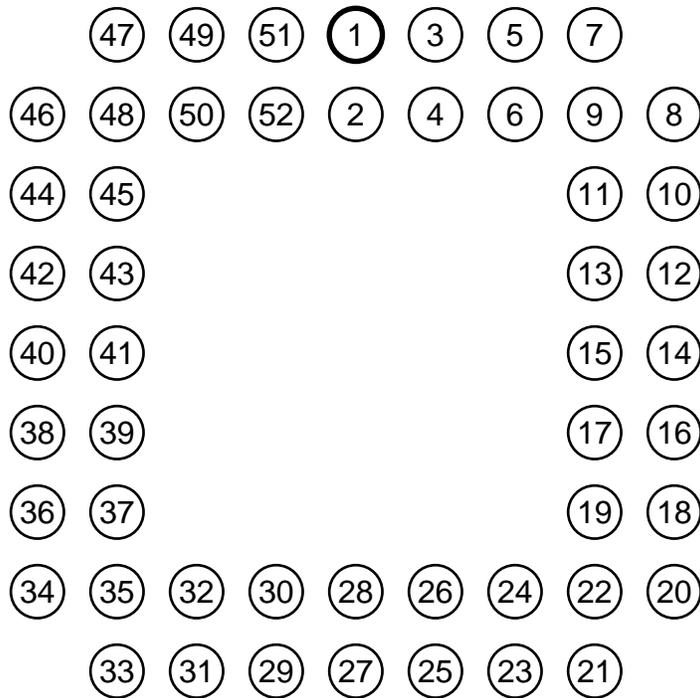
Figure 2: 6811 PLCC Socket Pin Numbering, **BOTTOM VIEW**

the header several times on both sides of the groove between two socket pins until the header can be gently snapped by hand.

If done patiently, this process ensures clean breaks between the header sockets.

2 Hardware and Software Assembly Tools

In order to perform the testing required as part of this assembly, the following equipment and software is needed.

2.1 Equipment

- A voltmeter. Any model, digital or analog, will do.

- A logic probe or an oscilloscope.

2.2 Miscellaneous

- A modem cable to connect the host computer to the Interface/Charger Board.

- A 4–wire telephone cable to connect the Handy Board to the Interface/Charger Board.

- A DC wall adapter for the Handy Board (12 volt DC output, 2.1 mm inside diameter coaxial power plug).

2.3 Choosing a 6811 Downloader

The 6811 downloader is used to load Interactive C's operating program (filename "`pcode_hb.s19`") into the Handy Board's memory. Depending on which computer operating system *and* which version of the 6811 you are using, you have the following choices. If there is more than one option, the recommended software is listed first.

MS-DOS, 6811 A1 version: Randy Sargent's *DL* or Fred Martin's *DLM*

MS-DOS, 6811 E1 version: Fred Martin's *DLM*

Windows 3.1 or Windows 95, either 6811 version: Vadim Gerasimov's *HBDL*

Macintosh, 6811 A1 version: Fred Martin's *6811 Downloader*, Randy Sargent's *Initialize Board*

Macintosh, 6811 E1 version: Fred Martin's *6811 Downloader*

Unix, 6811 A1 version: Randy Sargent's *DL*

Unix, 6811 E1 version: *There is no downloader tool for this configuration at this time.*

2.4 Using the 6811 Downloader

Each of the downloader tools has its own way of being used. This information is given here rather than being scattered throughout the assembly/debugging instructions.

from MS-DOS: If using *DL*, type "`dl pcode_hb.s19`" at the MS-DOS prompt.

> If using *DLM*, type "`dlm pcode_hb.s19`" at the MS-DOS prompt.

from Macintosh: If using *Initialize Board*, double-click on the appropriate version to select the modem port or printer port.

> If using *6811 Downloader*, double-click on the file named `pcode_hb.s19`.

from Windows 3.1 or Windows 95: Run the *HBDL* application. Select "Download" from the File menu, and choose the `pcode_hb.s19` file.

from Unix: Type "`dl pcode_hb.s19`" from the shell prompt.

2.5 Initializing the CONFIG register

Some of the downloaders require a special sequence for **initializing the 6811's CONFIG register**. When the main assembly text indicates that it is necessary to initialize the CONFIG register, refer to these directions for information on how to do so.

Note: The process of initializing the CONFIG register only has to be done once to factory-fresh 6811's. Very occasionally, a particularly nasty voltage spike will cause the 6811 to lose the contents of its CONFIG register, necessitating its re-programming, but this is rare.

DL downloader: All versions of DL automatically perform initialization of the CONFIG register.

HBDL downloader: HBDL automatically programs the CONFIG register to the value entered in the CONFIG text box. Make sure that the value "`0c`" is present.

Macintosh, Initialize Board: This program automatically performs initialization of the CONFIG register.

Macintosh, 6811 Downloader: Go into the Download Options dialog box, and select "Download into EEPROM." Place the Handy Board into download mode (hold down the STOP button when turning it on), and double-click on the file named `config0c.s19`.

The program should attempt to download a single byte, and exit with an error. Do the same process a second time, and it should complete without error. This indicates that the CONFIG register has been successfully programmed.

Make sure to return the Download Options dialog to "Download into RAM" for loading the pcode_hb.s19 file.

MS-DOS, DLM downloader: Place the Handy Board into download mode (hold down the STOP button when turning it on), and type "dlm config0c.s19 -eeprom"at the MS-DOS prompt.

The program should attempt to download a single byte, and exit with an error. Do the same process a second time, and it should complete without error. This indicates that the CONFIG register has been successfully programmed.

2.6 Configuring Interactive C

It is necessary to make sure that the proper set of Handy Board library files are loaded onto the host computer, and that **Interactive C** is properly configured to use them.

The following files are required:

- lib_hb.lis, the master list file for the Handy Board libraries.

- lib_hb.c, the standard library file code for the Handy Board.

- hbtest.c, a file containing test programs for the Handy Board.

These files must be placed in the default Interactive C library path. See the **IC** documentation for the platform-specific pathnames.

Additionally, **IC** must be configured to use lib_hb.lis rather than lib_r22.lis file. With the Macintosh version of **IC**, this is done with **ResEdit** to change an STR resource. With the MS-DOS and Unix versions, this is done by executing **IC** with the command-line argument -config. Please refer to the **IC** documentation for the latest information on configuration procedures.

When **IC** is configured properly, it should load the Handy Board library file lib_hb.lis automatically when booted.

3   Assembling the Interface/Charger Board

This is the beginning of the Handy Board assembly process. We will begin with the Interface/Charger board because it's the simpler of the two boards, and because we will use it when testing the Handy Board itself. During this assembly sequence the entire Interface/Charger Board will be constructed.

For this assembly sequence, collect the following parts:

- **Resistors:**
  R9 (2.2K–*red, red, red*)
  R10 (1K–*brown, black, red*)
  R11 (47 ohm, 1/2 watt–*yellow, purple, black*)
  R12 (47 ohm–*yellow, purple, black*)

- **Capacitors:**
  C10, **C11**, **C12**, and **C13** (10 μF, radial electrolytic)
  C14 (0.1 μF, labelled "104")
  C15 and **C16** (47 μF, axial electrolytic)

- **Diodes and LEDs:**
  D2 (4–pin DIP bridge rectifier)
  LED12 (green, HLMP1790)
  LED13 (red, HLMP1700)
  LED14 (yellow, HLMP1719)

- **Connectors:**
  J10 (side-entry RJ11 telephone jack)
  J11 (DC power jack)
  J9 (DB-25 female connector)
  DIP6 (16–pin DIP socket)

- **Switches:**
  SW4 (small black SPDT slide switch)

- **Integrated Circuits:**
  U16 (MAX232CPE serial transceiver)
  U17 (LM2931Z-5.0 voltage regulator)

In the instructions that follow, component names indicated with an asterisk (e.g., **D2***) are *polarized* and must be installed in the proper orientation. **POLARIZED COMPO-NENTS THAT ARE INSTALLED BACKWARD WILL NOT WORK; please take care that all components indicated with an asterisk are installed correctly.**
Refer to the component installation instructions given in Assembly Tips before proceeding.

3.1 Interface/Charger Board Power Circuit
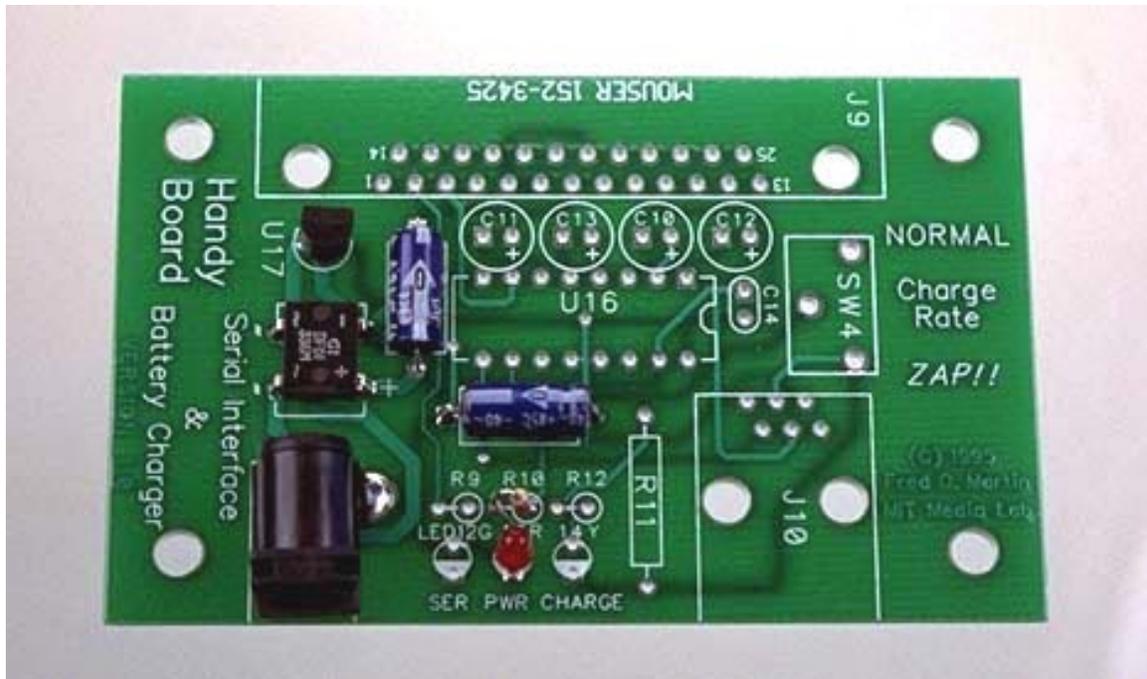
Figure 3: Interface/Charger Board Power Circuit

In this step the power supply circuitry for the Interface/Charger Board is installed. Figure 3 shows how the board should look after this step is completed.

The power circuit uses a component known as a *bridge rectifier* (**D2**) to normalize the power coming in from the DC adapter. Then this unregulated voltage, which might be as high as 17 volts, is given to **U17**, a five-volt regulator. Two capacitors (**C15** and **C16**) are used to smooth out ripples in the power supply voltage. A red LED (**LED13**) provides a visual indication of **U17**'s voltage output.

3.1.1 Installation

Install **D2*** (lining up the terminals marked + and − on the chip with the matching pads on the board), **C15***, **C16***, **R10**, **LED13R***, **U17***, and **J11***.

3.1.2 Testing

Apply power to the Interface/Charger Board using the 12 volt DC adapter by plugging into **J11**. The power indicator LED, labelled "**PWR**" (**LED13R**) should light.

Now measure the board voltage. A convenient spot is the holes for component **C14**. Place the voltmeter's black lead onto the square hole (the minus terminal) and the red lead onto the round hole (the plus terminal). You should see a voltage between 4.9 and 5.1 volts.

If the voltage reading across the **C14** terminals checks out, proceed to the next assembly step; otherwise, follow the debugging instructions below.

3.1.3 Debugging

If the LED does not light, or if no voltage is present at the **C14** terminals, verify that the DC power adapter is providing power by measuring the voltage at the two terminals labelled "~" on **D2**. If there is no voltage here, then the adapter is not working (check that it is plugged in).

If power is present, check for voltage on the output terminals of **D2**. There should be between 15 and 18 volts DC across the terminals marked + and −. If there is no power here, then **D2** is suspect.

If **D2** is outputting the correct voltage, then **U17** is suspect. Check that it is installed correctly. If it is very hot, there is a good chance it's installed backward.

Finally, check the polarity (orientation) of the two ripple-smoothing capacitors (**C15** and **C16**). If either of these are installed backward, the circuit will not function.

3.2 Interface/Charger Serial Circuit

In this assembly step, the MAX232 serial level converter chip (**U16**) and its associated components are installed. This chip performs the function of translating between the "RS-232" voltages that a computer uses on its serial port (signals between −12 and +12 volts) and the voltage required by the 6811 microprocessor (signals between 0 and 5 volts).

Figure 4 shows how the board should look after this step is completed.

3.2.1 Installation

Install **DIP6**, the 16–pin socket for **U16**. It is convenient to install the socket so that its "pin 1 marking"—the notch in one of its shorter lengths—lines up above the corresponding notch in the component placement marking on the circuit board. This notch indicates the correct orientation for the chip that is plugged into the socket.

Install capacitors **C10***, **C11***, **C12***, and **C13***, making sure to observe polarity. Install **C14**, **R9**, and **LED12G***.

Install the MAX232 chip, **U16***. As indicated in the diagram, the pin 1 notch is to the right.

Figure 4: Interface/Charger Serial Circuit

3.2.2 Testing

To verify that **U16** is operating correctly, use a voltmeter to test the following voltages. Make sure that the DC adapter is plugged into the board and the red PWR LED is on. Using **pin 7** of **J9** as a ground reference (i.e., touch the black voltmeter probe to pin 7), measure the voltage at **pin 2** of **U16**. It should read between $+9$ and $+10$ volts.

Now measure the voltage at **pin 6** of **U16**. It should read between -9 and -10 volts. The presence of these two voltages demonstrate that the MAX232 chip is properly generating the voltages required for RS-232 communication. If these two voltages are *not* present, check the orientation of capacitors **C10** through **C13** and the orientation of **U16**.

The next test exercises the MAX232's ability to transmit data to the Handy Board. Using a scrap piece of wire, temporarily make a connection between **pin 2** of **J9** (the serial input line to the MAX232) and **pin 6** of the MAX232. *This simulates the host computer transmitting data to the Handy Board.* The green LED labelled "SER" (**LED12G**) should light.

Finally, the MAX232's ability to transmit data to the host computer is tested. Again using **pin 7** of **J9** as a ground reference, measure the voltage at **pin 3** of **J9**. This is the MAX232's serial output. It should read between -9 and -10 volts. Now temporarily jumper the -10 volt supply (**pin 6** of the MAX232) to **pin 10** of the MAX232, which is the input side of this output stage. Again measure the voltage at **pin 3** of **J9**—it should now read between $+9$ and $+10$ volts.

3.2.3 Debugging

Not yet prepared

3.3 Interface/Charger Board, Charge Circuit and Jacks

In this step, the circuitry for charging the Handy Board's battery is installed, along with the remaining jacks. Figure 5 shows how the board should look after this step is completed.

The charge circuit is a based on **R11**, a 47 ohm resistor, as a current-limiting device. The power supply provides between 12 and 15 volts to the charge circuit of **R11** and the Handy Board's 9.6 volt battery. There will then be a voltage drop of about 2 to 5 volts across **R11**, yielding a charge current between 40 and 100 mA (milliamps).

SW4, the charge rate switch, is used to short out **R11**, providing a "zap charge mode" in which charge current is limited only by the performance of the DC adapter and any current-limiting effect that **D2**, the bridge rectifier, may have. In practice, this works out to about 1 ampere, which is quite a lot, since the standard charge rate of the battery pack is 50 mA. The Handy Board should never be left on zap charge unattended; after the battery pack begins to get warm, it's time to remove it from zap charge.

Figure 5: Interface/Charger Board, Charge Circuit and Jacks

3.3.1 Assembly

Install the remaining components of the Interface/Charger Board: **R11**, **R12**, **LED14Y***, **SW4**, **J9**, and **J10**. Make sure **J10** is the side-entry (not top-entry) style of RJ11 jack (unless the kit has two top-entry models). If the RJ11 jack has only four wires, that's fine; the circuit only uses the center four conductors of the jack, and board has six holes so that it is physically compatible with six-wire jacks.

3.3.2 Testing

Using the appropriate modem cable, plug the Interface/Charger Board into the host computer. The green **SER** LED may light. Connect power to the board, and verify that the red **PWR** LED is lit.

Run the 6811 downloader software. At this point, the green **SER** LED should light up, if it was not before. The software will display an error message, since there is no Handy Board present for it to communicate with.

Check-out of the charge circuit (yellow LED and switch) will be done later.

3.3.3 Debugging

Not yet prepared

4 Power, Power Monitor, CPU, and Serial Line Circuitry

This is the start of the assembly sequence for the main Handy Board unit. In this assembly sequence, the 6811 power supply and power monitoring circuitry, the 6811 itself, and the serial communications circuitry will be installed.

For this assembly sequence, collect the following parts:

- **Resistors**–all resistors are 1/8 watt unless noted otherwise**:**
  R1 (2.2M–*red, red, green*)
  R2 (1K–*brown, black, red*)
  R8 and **R15** (47 K–*yellow, purple, orange*)
  R13 (47 ohm–*yellow, purple, black*)
  R14 (47 ohm–*yellow, purple, black*, 1/2 watt)
  RP4 (1 K x 4 resistor pack, 8 pins, labelled "102")

- **Capacitors:**
  C1 and **C2** (22 pF, labelled "220") *Note: these are only provided if* **X1** *is a crystal. If* **X1** *is a ceramic resonator, these are not used.*
  C3 (470 μF, axial electrolytic)
  C7 and **C9** (0.1 μF, labelled "104")
  C8 (4.7 μF, tantalum, labelled "4μ7")

- **Diodes and LEDs:**
  D1 (1N914 signal diode, glass casing)
  D3 (1N4001 power diode, black casing)
  LED10G (HLMP–1790, green)
  LED11R (HLMP–1700, red)
  LED15Y (HLMP–1719, yellow)

- **Integrated Circuits:**
  U1 (MC68HC11A1FN or MC68HC11E1FN microprocessor)
  U12 (DS1233–10 voltage monitor)
  U13 (LM7805 5 volt regulator)

- **Connectors and Sockets:**
  J5 (RJ11 telephone jack, top entry)
  J12 (coax DC power jack)
  PLCC (52–pin plastic leaded chip carrier socket)

- **Switches:**
  SW1 (silver/red SPDT slide switch)
  SW3 (pushbutton switch)

- **Other:**
  X1 (8 MHz crystal or ceramic resonator)

4.1 Microprocessor Power Circuitry

Figure 6: Microprocessor Power Circuitry

The first order of business is to install the microprocessor power supply and battery charge circuit. The Handy Board battery will not be connected until the end of the overall assembly job, however; instead, power will be supplied to the board through the battery charge circuit.

Figure 6 shows how the board should look after this step is completed.

4.1.1 Assembly

Install **C3***, **C7**, **C8***, **C9**, **LED15Y***, **D3***, **R13**, **J12**, **SW1**.

Mount **R14**, **raising it about 1/8" above the surface of the board;** it will need to be pressed a bit to the left when **J6** is installed later.

Mount **U13***, the main power regulator, so that its tabbed side is closer to **SW1**, as indicated in the board photograph.

4.1.2   Testing

Apply power to the board from the adapter jack and switch the board on using **SW1**. For a brief instant each time the board is switched on, the **CHARGE** LED (**LED15Y**) should flash. This indicates power flowing into the board, which in this case is used to charge **C3**, the main system capacitor.

Turn the board on, and measure the system power voltage. A convenient place is the terminal marked **+5v** and **GND** on the connector for **U4** (the LCD display). The voltage should read between 4.9v and 5.1v.

4.1.3   Debugging

If the **CHARGE** LED does not light, first check the polarity on the DC adapter. Set the voltmeter to a 20 volt range and measure the output of the adapter. The center opening should be the negative terminal and the outer shield should be the positive terminal. If these are reversed, the adapter cannot be used to supply power to the Handy Board via its charge jack. The adapter still may be used with the Interface/Charger, however.

If the adapter polarity is correct, check that **LED15Y** is installed with the correct orientation.

If the system voltage does not read between 4.9v and 5.1v, check the orientation of **U13**. Touch the tab of **U13**, if it is getting hot, remove power immediately. Either **U13** or **D3** is probably installed backward.

4.2   Voltage Monitor Chip

U12, the Dallas Semiconductor DS1233–10, is a voltage monitor chip that measures the system voltage and asserts a reset signal to the microprocessor whenever the voltage is invalid (i.e., below 4.5v). This ensures that the microprocessor is idle during power-on, when system voltage is ramping up from zero volts to its normal operating level, and during power-off, when system voltage falls from normal operating level to zero volts.

The output of the voltage monitor chip is connected to an LED (**LED11R**, marked **BATT**). When the chip asserts the "invalid" signal, the **BATT** LED will light. This happens for a brief interval when power is switched off, and for 1/3 of a second when it is switched on. The **BATT** LED also serves as a low-battery indicator, since if the battery is not charged

Figure 7: Voltage Monitor Chip

enough to raise the system voltage to its normal operating level, the DS1233 chip will continuously assert the signal that lights the **BATT** LED.

Figure 7 shows how the board should look after this step is completed.

4.2.1   Assembly

Unplug the DC adapter, if it is still plugged into the board. Install **U12***, **R2**, and **LED11R***.

4.2.2   Testing

Plug the DC adapter back into the board, and switch it on. The **BATT** LED should light for about 1/3 of a second, and then go off. Switch the board off; the **BATT** LED should light and then fade as board power dissipates.

4.2.3   Debugging

If the **BATT** LED does not light as it should, check its orientation, as well as the orientation of **U12**.

4.3   Microprocessor and Oscillator Circuit

In this assembly step, the microprocessor and its oscillator circuit are installed. The testing step assures that the microprocessor is correctly driving the oscillator circuit, which is the first indication of its proper operation.

Figure 8 shows how the board should look after this step is completed.

4.3.1   Assembly

Unplug the board, if it is still plugged in. Install **PLCC***, the square, 52–pin socket for **U1** (the 6811 microprocessor). **Make absolutely sure to get the orientation correct:** the chamfered corner (i.e., the diagonally truncated corner) of the socket **must** align with the chamfer in the socket outline printed on the board. The chamfered corner installs in the upper left when viewing the board from the normal reading orientation indicated by the photographs.

> *The socket must be installed correctly because the 6811 can only be placed into the socket in one orientation, so the socket orientation must be correct.*

Solder all 52 pins of the socket.

Install **U1**, the 6811 microprocessor, into its socket, aligning the chamfered corner with the one on the socket. **Press firmly and evenly until the 6811 is fully seated in the socket.** It should click into place.

Figure 8: Microprocessor and Oscillator Circuit

Install **R1** (2.2M–*red, red, green*).

Install **X1**, which may be either a ceramic resonator (rectangular plastic package with three leads) or quartz crystal (oval metal package with two leads).

- *If X1 is the crystal*, install **X1**, **C1**, and **C2**.

- *If X1 is the ceramic resonator*, install **X1** only. **C1** and **C2** are not used because they are already *built into the resonator package*. Do not install anything in the **C1** and **C2** component positions.

In the photograph, **X1** is the ceramic resonator.

4.3.2   Testing

Apply power to the board through the charge jack and turn the board on. By examining the system clock output of the 6811 (known as the *E clock*), the following test will verify that the 6811 oscillator circuit is operating properly. The E clock signal is at **pin 5** of the 6811. It should be a 2 MHz square wave.

In order to test this signal, either an oscilloscope, logic probe, or voltmeter are required, in declining order of preference (i.e., the oscilloscope is best).

1. With an oscilloscope, measure the E clock signal. It should appear as a 2 MHz square wave over the zero to +5v range.

2. With a logic probe, examine the E clock signal. The pulse output LED of the logic probe should flash, indicating oscillation. (Make sure that the logic probe's pulse memory feature is turned off.)

3. With a volt meter, put it in a DC voltage range and measure the E clock signal. It should register as a 2.5v signal.

Note that cases (2) and (3) do not measure the actual frequency of the signal. It will be assumed that if the clock signal is indeed generated, it is of the proper frequency.

The behavior of **LED15Y** (**CHARGE**) and **LED11R** (**BATT**) should be as before.

4.3.3   Debugging

If the E clock signal is not present, this could indicate faulty soldering between the crystal or resonator and the 6811, or an improper value of the biasing resistor **R1**.

It is less likely but still possible that the 6811 is defective. First check that the 6811 is receiving power and ground properly (on pins 26 and 1, respectively). To measure the ground, use the logic probe to verify a definite logic low, or measure the potential from the +5v supply.

As a last resort, try another 6811.

4.4   Serial Line and Stop Switch
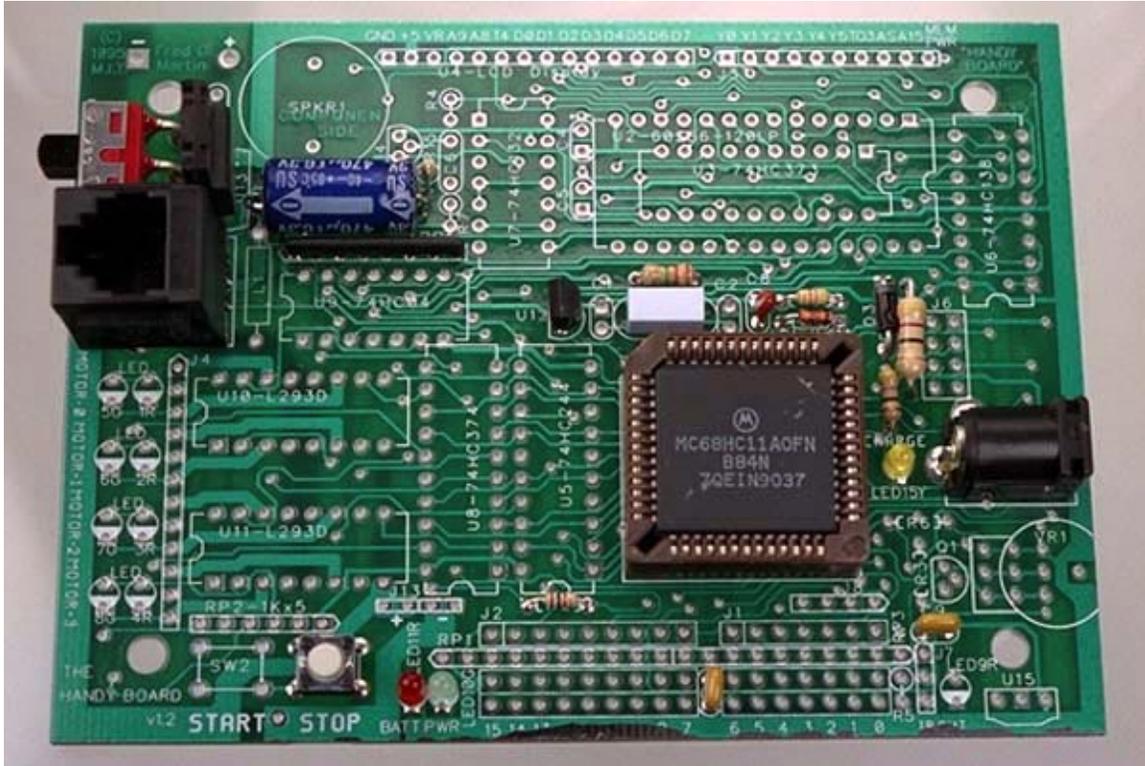
Figure 9: Serial Line and Stop Switch

In the next step, circuitry is installed that allows the 6811 to communicate over a serial line to the host computer. This includes a green LED to indicate when the 6811 is transmitting data, and a pushbutton switch that allows the 6811 to be placed into a special "bootstrap" mode. This bootstrap mode allows the 6811 to accept an initial operating program that is downloaded by the host computer.

Figure 9 shows how the board should look after this step is completed.

4.4.1   Assembly

Remove power from the board. Install **R8**, **R15**, **RP4**, **D1***, **LED10G***, **SW3**, and **J5**.

4.4.2   Testing

Apply power to the board and turn it on. **LED10G**, labelled **PWR**, should light. Now *hold down* **SW3** *(***STOP***)* and turn power on. Continue to hold the **STOP** switch while

the **BATT** LED cycles on and then off. *The* **PWR** *LED should turn off when the* **BATT** *LED turns off.* This indicates that the 6811 has entered bootstrap mode, and is waiting for a program to be downloaded over its serial line.

Back at the host computer, connect the Interface/Charger board to a serial port using the appropriate modem cable. Connect the DC adapter power to the Interface/Charger board.

Connect the main board to the Interface/Charger board using the 4–wire telephone cable. Power will be supplied to the main board via the telephone cable. Put the board in download mode by turning it on while holding down the **STOP** switch. The Handy Board's **PWR** and **BATT** LEDs should both light for about 1/3 of a second, and then both LEDs should turn off. **This state, in which board power is on but both LEDs have turned off, is the mode required for bootstrap download to function properly.**

Now run the appropriate version of the 6811 downloader software. During the first download phase, the green **SER** LED on the I/C board (transmit from the host computer to the 6811 board) and the green **PWR** LED on the main board (transmit from the 6811 board to the host computer) should both blink visibly.

The downloader software should reach the second download phase in which it attempts to download the `pcode_hb.s19` program. It will then generate an error, because the Handy Board does not have memory to receive this program.

But the point of this test is to see if the downloader reaches the second phase. If it does, congratulations! Serial communication between the host computer and the 6811 board has been established. This is a big step in the process of bringing up a new Handy Board.

4.4.3   Debugging

There are a lot of things to get right in this step. Most likely problems involve software configuration (i.e., choosing the correct serial port) and cabling (using the proper modem cable to connect the Interface/Charger Board to the host computer; having a telephone cable that is wired correctly).

5   Memory Circuitry

In this assembly sequence, the 32K static memory is installed and tested.

For this assembly sequence, collect the following parts:

- **Capacitors:**
  C4 (4.7 μF, labelled "4μ7")
  C5 (0.1 μF, labelled "104")

- **Integrated Circuits:**
  U2 (62256LP-120, 32K static RAM)
  U3 (74HC373, octal transparent latch)
  U7 (74HC132, quad schmitt NAND gates)
  U14 (LM2931Z-5.0, +5v regulator)

- **Connectors and Sockets:**
  DIP3 (28–pin DIP socket)
  DIP5 (14–pin DIP socket)

5.1   Memory Power Circuit

The memory chip has its own power circuit that provides it with power even when main board power is turned off. This is necessary to keep the memory from losing its contents when the board is off.

Figure 10 shows how the board should look after this step is completed.

5.1.1   Assembly

Install **C4***, **C5**, and **U14***.

5.1.2   Testing

Apply power to the board via the charge jack, and turn the board *off*. Measure the voltage at **pin 28** of **U2** (the voltage supply for the RAM chip). Any ground may be used as reference (e.g., the pin labelled **GND** on the **U4** connector).

The power to the RAM should be between 4.9v and 5.1v, whether main board power is switched on or off.

Figure 10: Memory Power Circuit

5.1.3 Debugging

Make sure power exists on the main +5v supply when the board is turned on (e.g., the **+5v** pin of the **U4** connector). Make sure there is power to the input side of **U14**, which is the pin closest to **C3**.

Check that **U14** is installed correctly—the flatted side should face toward the **SPRK1** component. Check polarity on **C4**—the + terminal should be nearer to the top edge of the board.

5.2 Memory Addressing Latch

Figure 11: Memory Addressing Latch

U3, the 74HC373, is known as a *transparent latch*. This chip is used in the memory circuit to temporarily store, or latch, the lower eight bits of the address being selected from the memory. The 6811 first generates the low address bits, instructs **U3** to store them, and then generates the high address bits and performs the memory read or write operation.

In the Handy Board component layout, **U3** is mounted *underneath* the memory chip itself. This construction trick saves board space, and since **U3** and the memory chip are highly interconnected, works out in terms of the board's printed wiring.

The only downside to this method is that **U3** must be soldered directly to the board. Vertical clearance would be a problem if a socket were used. This should not cause any great consternation; as long as **U3** is soldered carefully (and in the correct orientation!) there should not be any difficulty.

Figure 11 shows how the board should look after this step is completed.

5.2.1   Assembly

Install **U3*** (74HC373). This chip is soldered directly to the main board—no socket is used. Since **U3** is soldered directly to the board, make absolutely sure that the notch indicating pin 1 of the chip lines up with the notch on the printed component outline.

Get **DIP3**, the 28–pin socket for the memory chip. Using an X-acto knife or diagonal cutters, remove the center plastic support from the socket so that the socket may be installed *around* **U3**. Install the socket its mounting holes, aligning the notch on the socket with the notch on the printed component outline. Solder it in place.

5.2.2   Testing and Debugging

There are no testing and debugging procedures for this assembly step.

5.3   Memory Chip and Decoding Gates

In addition to **U3**, the latch chip, the memory requires a couple gates from **U7**, a package of four NAND gates. (Logic gates for interfacing digital circuits are generically known as "glue logic" in digital design.)

In this assembly step the remainder of the circuitry for proper functioning of the memory is installed. Figure 12 shows how the board should look after this step is completed.

5.3.1   Assembly

Install **DIP5**, the 14–pin socket for **U7**. Align the notch in the socket with the notch in the printed component outline.

Place **U7*** (74HC132) in the socket, aligning its notch with the one on the socket.

Place **U2*** (62256–12LP), the memory chip, in its socket. Make sure to align the notch on the chip with the notch on the socket/component placement marking.

Figure 12: Memory Chip and Decoding Gates

5.3.2 Testing

Testing requires the use of custom memory-test software that is not yet prepared. For now, just move ahead to the next assembly section; the test will be running Interactive C itself.

5.3.3 Debugging

Debugging requires the use of the custom software mentioned above. Please write to `handyboard@media.mit.edu` *for debugging assistance.*

6 Beeper and LCD Circuitry
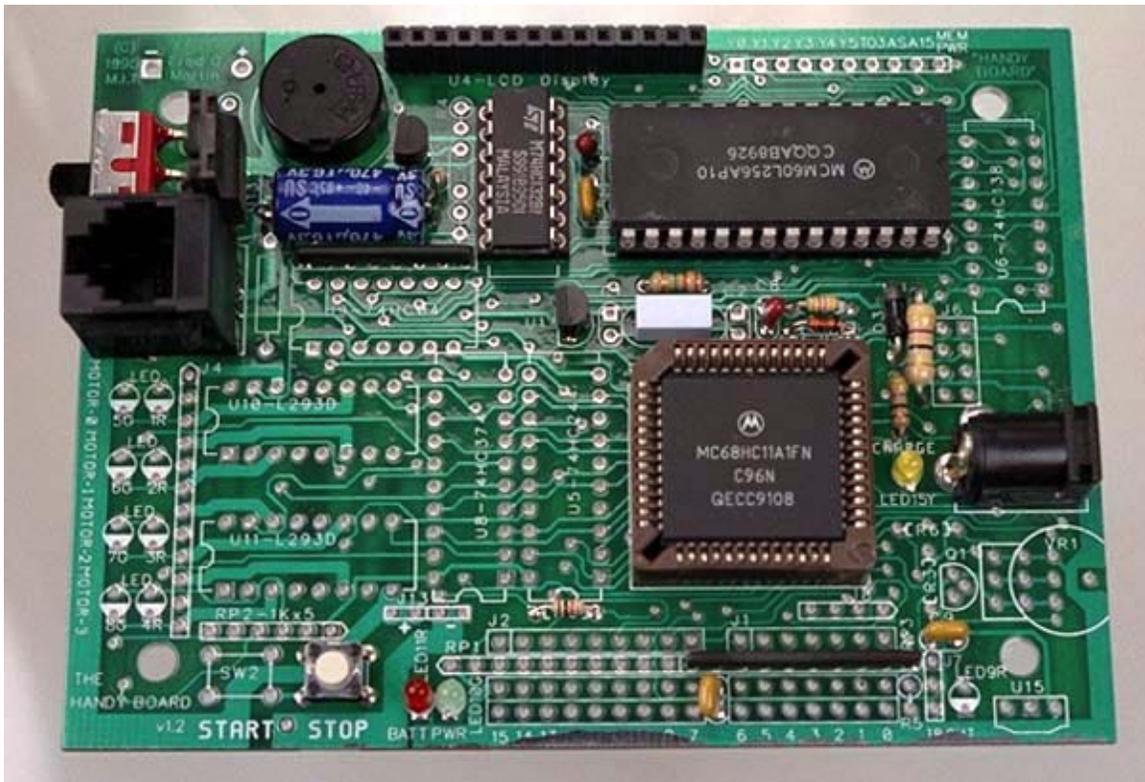
Figure 13: Beeper and LCD Circuitry

In this assembly sequence, the beeper and LCD screen are installed, and Interactive C is brought up on the Handy Board. Figure 13 shows how the board should look after this step is completed.

For this assembly sequence, collect the following parts:

- **Resistors:**
  RP3 (47K x 9 resistor pack, 10 pins, labelled "473")

- **Integrated Circuits:**
  U4 (16x2 LCD screen, Hitachi LM052L or equivalent)

- **Connectors and Sockets:**
  J14 (14–pin female socket strip)
  J15 (14–pin male pin strip)

- **Other Components:**
  SPKR1 (piezo beeper)

The LCD screen is presently required for proper functioning of Interactive C. The beeper is not necessary, but provides helpful audio feedback. The resistor pack is used to provide "hardware defaults" to some 6811 pins; these are required for the 6811 to operate correctly.

6.0.4 Assembly

Install **SPKR1**. Orientation is not important.

Get **J14**, a 14–long strip of female header socket and install in the position of **U4**. *If the female socket header is not precut to the correct length, the socket strip must be cut to size. See the Assembly Tips for instructions on how to do this.*

Get **J15**, a 14–long strip of male pin header and install it in **U4**, the LCD screen. If the male pin header is not precut to the correct length, simply snap the header to break off a 14–pin segment (a pair of long-nose pliers is helpful when doing this).
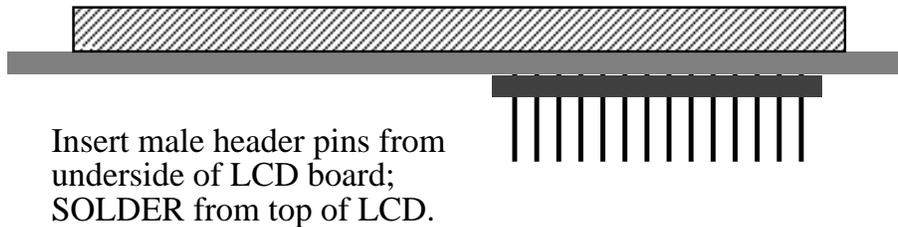
TOP OF LCD (Display Side)

Insert male header pins from underside of LCD board; SOLDER from top of LCD.

Insert the pins from underneath the LCD screen, and solder from the top (see diagram above).

Install **RP3*** (47K x 9 resistor pack, 10 pins). *Make sure to get the pin 1 markings on the resistor packs lined up with the square pads.*

6.0.5 Testing

Plug LCD into board and connect the telephone cable from the Interface/Charger board. Make sure the I/C board has power from the wall adapter. Turn on the Handy Board, and observe the LCD screen. The display light dimly, showing a single row of sixteen faint blocks.

Put the Handy Board in bootstrap download mode (hold down the **STOP** button and turn it on), and run the appropriate version of the 6811 downloading software. **If using DLM for MS-DOS or 6811 Downloader for Macintosh, please perform the sequence required to initialize the CONFIG register**.

After initializing the CONFIG register, have the downloader load the file `pcode_hb.s19`. After the downloader finishes, power-cycle the board (make sure the LCD is still plugged

in). The board should beep, and the LCD screen should display the Interactive C startup message (e.g., *Interactive C V 2.81 9/28/93*). If so, congratulations! The Handy Board memory circuit is working properly and communication between the Handy Board and the host computer is functioning.

With the Handy Board still connected and turned on, boot the **Interactive C (IC)** application on the host computer. **IC** should communicate with the Handy Board, download some library files, and display the "C>" prompt. If this works, take a deep breath and relax! From this point on it's smooth sailing.

Try typing an expression; for example,

```
1 + 2;
```

When the return key is pressed, **IC** will compile this expression, download it to the Handy Board, and cause the Handy Board to execute it. The result is returned to **IC**; the following should then appear in **IC**'s console window:

```
Downloading 7 bytes (addresses C200-C206):  7 loaded
Returned <int> 3
```

Try another:

```
printf("%f\n", sqrt(10.));
```

On its LCD screen, the Handy Board should display the result of computing the square root of 10. Note that the Handy Board is performing this calculation, not the host computer.

6.0.6 Debugging

If the LCD screen either does not light at all, or lights strongly, when power is turned on, it may be plugged in backward. Look for a **pin 1** marking on the LCD screen; this should plug into the leftmost pin on the Handy Board (labelled **GND** on the silkscreen legend).

If the download process appears to go correctly, but then the Handy Board does not boot with the Interactive C prompt, the memory circuit may not be working properly. Check the orientations of chips **U2** (the memory chip itself), **U3** (the 74HC373 chip underneath the memory), and **U7** (the 74HC132 chip). If any of the chips is getting hot, it is probably plugged in backward.

Check the soldering joints on the above mentioned chips, re-heating any that appear suspect.

Finally, check continuity for each of the wires in the memory circuit (including address lines, data lines, and select lines). Check that any adjacent wires are not shorted together.

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7 Peripheral Selector, Digital Input, and Motor Output Circuitry

In this sequence, the chip used to control peripheral input and output, the digital input circuitry, and the motor output circuitry is installed.

For this assembly sequence, collect the following parts:

- **Resistors:**
  RP1 (47K x 9 resistor pack, 10 pins, labelled "473")
  RP2 (1K x 5 resistor pack, 6 pins, labelled "102")

- **LEDs:**
  LED1R, **LED2R**, **LED3R**, and **LED4R** (HLMP1700, red)
  LED5G, **LED6G**, **LED7G**, and **LED8G** (HLMP1790, green)

- **Integrated Circuits:**
  U5 (74HC244 tristate bus driver)
  U6 (74HC138 3-to-8 decoder)
  U8 (74HC374 octal output latch)
  U9 (74HC04 hex inverters)
  U10 and **U11** (L293D or SN754410 motor driver)

- **Connectors and Sockets:**
  DIP1 and **DIP2** (20–pin DIP socket)
  DIP4 (14–pin DIP socket)
  DIP6, **DIP7**, and **DIP8** (16–pin DIP socket)
  J2 (3 pcs. of 9–pin female socket strip)
  J4 (12–pin female socket strip)

- **Other Components:**
  L1 (1 uH iron core inductor)
  SW2 (pushbutton switch)

7.1 Peripheral Selector

U6, the 74HC138, is used to create a memory-mapped addressing for up to four input latches and four output latches. One of each of these is implemented on the main Handy Board (i.e., the digital input circuit and motor output circuit); the remaining six addressing outputs of **U6** are available via the Handy Board's expansion connector. **U9**, the 74HC04 hex inverter chip, is used as glue logic in this peripheral addressing circuit.

Figure 14 shows how the board should look after this step is completed.

Figure 14: Peripheral Selector

7.1.1 Assembly

Install **DIP6**, the 16–pin socket for **U6**. Align the notch in the socket with the notch in the printed component legend.

Install **U6*** (74HC138) in the socket, making sure to line up the notch on the chip and the notch on the socket/printed legend.

Install **DIP4**, the 14–pin socket for **U9**. Align the notch in the socket with the notch in the printed component legend.

Install **U9*** (74HC04) in the socket, making sure to line up the notch on the chip and the notch on the socket/printed legend.

7.1.2 Testing

The following test should be done with a logic probe. If one is not available, simply skip ahead.

Plug the LCD screen back into the board. Connect the Handy Board to the computer via the Interface/Charger board; run **DL** to load the Handy Board runtime file (`pcode_hb.s19`). Restart the Handy Board and verify the Interactive C boot beep and LCD screen message.

While the board is running, examine **pin 9** of **U6** (the 74HC138). This pin should be continuously pulsing, with a duty cycle indicating a predominantly high state and repetitive logic low pulses. Make sure the pulse memory feature of the logic probe is turned off.

7.1.3 Debugging

It is assumed that booting the Interactive C runtime file on the board is not a problem (otherwise back up to the step where this was supposed to be done).

Using the logic probe, examine the signals at **pins 1, 2, 3, 4, 5, and 6** of **U6**. These should all be pulsing continuously. If any of these lines is not pulsing, check its solder connections and trace its continuity.

Turn board power off and check for short circuits between all combinations the same pins. There should be no shorts.

7.2 Digital Input Circuit

In this step, **U5**, the digital input latch, is installed, along with the header connectors for the digital inputs and the **START** pushbutton switch.

Figure 15 shows how the board should look after this step is completed.
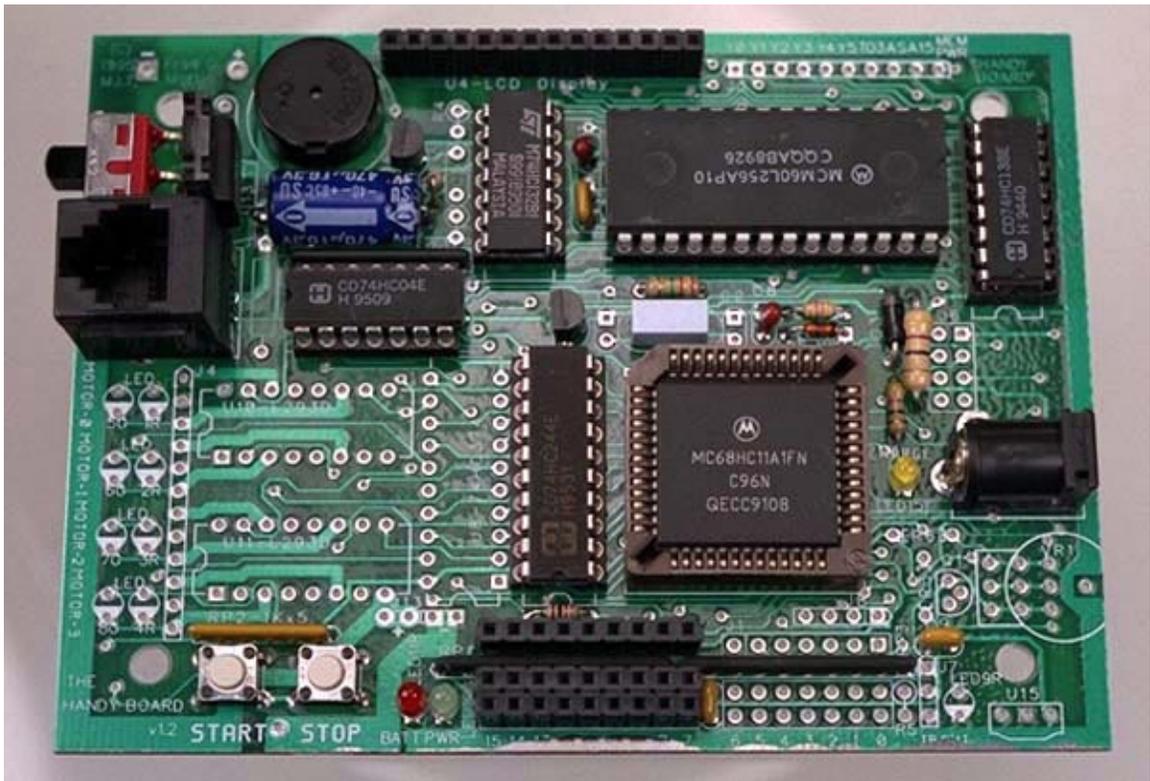
Figure 15: Digital Input Circuit

7.2.1 Assembly

Install **DIP2**, the 20–pin socket for **U5**. Align the notch in the socket with the notch in the printed component legend.

Install **U5*** (74HC244) in the socket, making sure to line up the notch on the chip and the notch on the socket/printed legend.

Install resistor packs **RP1*** (47K x 9, 10 pins) and **RP2*** (1K x 5, 6 pins). These are pullup resistors for the input latch to give a default value to the inputs when nothing else is plugged in. *Make sure to get the pin 1 markings on the resistor packs lined up with the square pads.*

Install **SW2***, the **START** switch. The value of this switch is read through the digital input latch.

Get three strips of 9–long female header socket and install in the **J2** position. *If the female socket header is not precut to the correct length, the socket strip must be cut to size. See the Assembly Tips for instructions on how to do this.*

7.2.2 Testing

Plug the LCD screen back into the board. From the computer, run **DL** to load `pcode_hb.s19`. Restart the board so that the "Interactive C" message is displayed on the LCD.

Boot the **Interactive C** application on the host computer. It should communicate with the Handy Board, download some library files, and display the "C>" prompt.

Now load the Handy Board testing file. Type at the **IC** prompt:

```
load hbtest.c
```

IC should display a message like the following:

```
Loading hbtest.c.
Initializing interrupts
Downloading 2517 bytes (addresses 8000-89D4):  2517 loaded
Globals initialized.
```

(The number of bytes downloaded will probably not match, allowing for updates to the `hbtest.c` file.)

If **IC** is unable to find the `hbtest.c` file, go back to the section on Configuring IC and make sure all Handy Board library files are on the host computer, and **IC** is correctly configured to point to them.

After `hbtest.c` is loaded into the Handy Board, type at the **IC** prompt:

```
testdigitals();
```

(This runs the function `testdigitals()`, which is defined in the `hbtest.c` file.)

Look at the Handy Board LCD screen. It should be displaying the message "`Press START ...`"; it is waiting for you to press the **START** button. Do so, and the board should beep, and prompt you to press the **STOP** button. If this works, the digital input circuit is at least partly functional—the **START** button is scanned through the digital input circuit.

Press the **STOP** button (this is wired directly to a 6811 digital input), and the test program should display a screen like this:

```
Digital inputs:
000000000
```

This will be on the Handy Board LCD screen, not the **IC** console window. The display should be flashing gently, indicating that the Handy Board is repeatedly updating the screen.

Each of the 0's corresponds to a digital input. The left-most zero corresponds to the left-most digital input—the one labelled "15" on the printed Handy Board legend. The right-most zero corresponds to the digital input labelled "7."

To test the inputs, get a scrap piece of a component lead and bend it into the shape of a "U." Insert the ends of the wire into a digital input column, connecting a pin of the uppermost header to the corresponding pin of the lowermost header. When the two header pins are shorted together, the LCD display should show the numeral "1" in the appropriate bit position.

With the scrap piece of wire, systematically test all nine digital inputs, verifying correct operation.

7.2.3 Debugging

For these debugging instructions, it is assumed that the `hbtest.c` file has been successfully loaded, and the `testdigitals()` function can be run from the **IC** command line.

There are at least two failure modes from this point:

- Complete failure. The digital input circuit does not work at all; pressing the **START** button does not advance the Handy Board from the "`Press START ...`" display screen.

- Partial failure. The **START** button works, but at least one of the digital input lines is not functioning properly (it is either stuck in the zero or one state).

We will begin with the partial failure case.

Partial Failure   Check that **RP1** is installed in the correct orientation.

Determine which digital inputs are not working, and trace their wiring. For inputs stuck on zero, check for bad solder joints and damaged PC board traces. For inputs stuck on one, check for solder bridges and other shorts.

Refer to the Digital Input schematic; note that the three right-most inputs (labelled 7, 8, and 9) are wired directly to 6811 inputs and not through the 74HC244 input latch. Also note that the **START** and **STOP** buttons are wired to the two high bits of the latch.

Complete Failure   Check that **U5**, **U6**, and **RP1** are installed in the correct orientation. If **U5** or **U6** is getting hot, it is probably installed backward. Check that **U5** and **U6** have valid power and ground voltage levels.

While the `testdigitals()` is running, examine **pin 1** and **pin 19** of **U5** (the 74HC244) with the logic probe. Both of these pins should be pulsing with a pattern of mostly logic high. If these pins are not flashing, check **pin 7** of **U6** (the 74HC138). If it *is* flashing, then the connection between these two chips is suspect. If **pin 7** of **U6** *is not* flashing, then the **U6** circuit is faulty. Go back to the Peripheral Selector Testing.

7.3   Motor Output Circuit

The motor output circuit consists of a digital output latch (**U8**, a 74HC374), two high-current motor driver chips (**U10** and **U11**, L293D's), and eight LEDs to indicate motor state.

Figure 16 shows how the board should look after this step is completed.

7.3.1   Assembly

Install **DIP1**, the 20–pin socket for **U8**. Align the notch in the socket with the notch in the printed component legend.

Install **U8*** (74HC374) in the socket, making sure to line up the notch on the chip and the notch on the socket/printed legend.

Install **DIP7** and **DIP8**, the 16–pin sockets for **U10** and **U11**. Align the notches in the sockets with the notches in the printed component legends.

Install **U10*** and **U11*** (L293D) in their sockets, making sure to line up the notches on the chips and the notches on the sockets/printed legends.

Get a 12–long female header socket strip and install it in the **J4** position. If the female socket header is not precut to the correct length, the socket strip must be cut to size. See the Assembly Tips for instructions on how to do this.

Install **L1** (1 uH iron core inductor). Orientation is not important.

Install **LED1R***, **LED2R***, **LED3R***, **LED4R***, **LED5G***, **LED6G***, **LED7G***, and **LED8G***. Be sure to get the orientation correct; see the Assembly Tips for instructions.

Figure 16: Motor Output Circuit

7.3.2 Testing

Boot the Handy Board and **Interactive C**; load the `hbtest.c` file. Type "`testmotors();`" at the **IC** prompt.

The motor LEDs should begin flashing one at a time, beginning with Motor 0–green, Motor 0–red, Motor 1–green, etc. After Motor 4–red, the cycle should repeat with Motor 0–green.

7.3.3 Debugging

Check the orientations of **U8**, **U10**, and **U11**. If any of them is getting hot, it is probably installed backward.

With the logic probe, examine **pin 1** of **U8** (the 74HC374 output latch). It should be pulsing continuously. If not, trace the signal back to **pin 9** of **U6**.

If you do not have a logic probe, turn the board power off and measure the resistance between **pin 1** of **U8** and **pin 9** of **U6**. It should be zero ohms. If it is an open circuit (infinite resistance), check the two pins' solder joints and then look for a PC board defect in the trace connecting these two pins.

Verify motor supply voltage on **pin 8** of **U10** and **U11**. There should be about 15 volts at these pins.

With board power off, check continuity across component **L1**. It should read a resistance of near zero ohms (i.e., less than 10 ohms).

8 Analog Input, Infrared, and Expansion Header Circuitry

In this sequence, the analog input connectors, infrared input and output circuitry, and expansion connectors are installed.

For this assembly sequence, collect the following parts:

- **Resistors:**
  R3 and **R7** (10K–*brown, black, orange*)
  R4 (3.83K precision resistor–*orange, grey, orange, brown*)
  R5 (1K–*brown, black, red*)
  R6 (47K–*yellow, purple, orange*)
  VR1 (20K trimmer potentiometer knob)

- **Capacitors:**
  C6 (0.0068 μF, labelled "682")

- **LEDs:**
  LED9R (HLMP–1700, red)

- **Integrated Circuits:**
  U15 (Sharp IS1U60 infrared demodulator)

- **Connectors and Sockets:**
  J1 (3 pcs. of 7–pin female socket strip)
  J3 (10–pin female socket strip)
  J6 (2 pcs. of 4–pin female socket strip)
  J8 and **J13** (4–pin female socket strip)
  J7 (3–pin female socket strip)

- **Other Components:**
  L1 (1 uH iron core inductor)
  Q1 (Zetex ZTX614 NPN Darlington transistor)
  SW2 (pushbutton switch)

8.1 Analog Inputs

The Handy Board analog input bank connects directly to the 6811's analog inputs. **RP3**, which has already been installed, is used to provide a default value to these inputs.

Figure 17 shows how the board should look after this step is completed.

Figure 17: Analog Inputs

8.1.1 Assembly

Get three strips of 7–long female header socket and install in the **J1** position. If the female socket header is not precut to the correct length, the socket strip must be cut to size. See the Assembly Tips for instructions on how to do this.

Install **VR1** (20K trimmer potentiometer).

8.1.2 Testing

Boot the Handy Board and **Interactive C**; load the hbtest.c file. Type "testanalogs();" at the **IC** prompt.

The Handy Board will display the message "Press START to test knob..." on its LCD screen. Press the **START** button, and the screen will show the message "Turn knob; STOP to end -> xxx," where xxx is the current value of the knob. Turn the knob and the value should vary with a minimum of zero and a maximum of 255.

Press the **STOP** button, and the Handy Board will show the message "Press START to test analog ins." Press the button, and the display will then show a series of seven numbers. They should all be in the range of 250 to 255.

To test the inputs, get a 10K resistor and bend its leads into the shape of a "U." For each sensor column, insert the resistor end in the outermost two connector sockets.

The first number on the display is the value of analog input 6. Insert the resistor into this position; the value being displayed should change to around 45. Check each of the seven analog inputs in this fashion.

8.1.3 Debugging

If particular analog inputs are not working, trace their wiring continuity back to the 6811. Perhaps the 6811 socket leaves are not pressing firmly against the 6811 itself.

If none of the analog inputs works, including the knob, verify that **pin 52** of the 6811 is +5v, and **pin 51** of the 6811 is ground. These are the voltage reference high and voltage reference low for the 6811 analog input circuit, respectively.

8.2 Infrared Input and Output

The Handy Board includes the Sharp IS1U60 infrared demodulator, a device that is used to decode common household TV and VCR infrared transmissions. It also has an oscillator and power output stage for driving infrared LEDs to generate such signals.

Figure 18 shows how the board should look after this step is completed.

Figure 18: Infrared Input and Output

8.2.1 Assembly

Output Stage   Install **R4**, **R7**, **C6**, **R3**, **R5**, **Q1***, and **LED9R***.

Get the 3–long piece of female header socket and install in the **J7** position. If the female header is not precut, see instructions in the Assembly Tips.

Input Stage   Install **R6** and **U15***.

8.2.2 Testing

Output Stage   Boot the Handy Board and **Interactive C**. At the **IC** prompt, type

```
poke(0x1000, 0x40);
```

This turns on the 6811 pin that controls the infrared output oscillator. **LED9R** should light up.

Using an oscilloscope, measure the signal at **pin 2** of **U9** (the 74HC04). It should be a square wave with a frequency of about 40 kHz (between 39,000 Hz and 41,000 Hz).

From **IC**, issue the command

```
poke(0x1000, 0);
```

LED9R should turn off, and the square wave should disappear.

Input Stage   Boot the Handy Board and **Interactive C** At the **IC** prompt, type:

```
while (1) {if (4 & peek(0x1000)) fd(0); else bk(0);}
```

This statement causes the infrared input signal control the Motor 0 port.

Get a household VCR or TV remote, aim it at the green IS1U60 infrared demodulator, and press a button. Motor 0 should flash green and red while transmitting IR data to the Handy Board, and should light steady green otherwise.

8.2.3 Debugging

Output Stage   If **LED9R** fails to light after the `poke` command is issued, trace the following progression of signals. Please refer to the infrared output schematic:

- **6811 Timer Output 2.** This is the signal from the 6811 that enables the IR transmission circuit. Check **pin 28** of the 6811; it should be high. The signal is wired to **pin 2** of **U7**; it also should be high.

- **Oscillator Output.** Look at the signal on **pin 3** of **U7**; when the 6811 timer output 2 is high, it should be a 40 kHz square wave. If not, check for proper installation of **U7**, **R4**, and **C6**.

- **Inverter.** The 40 kHz square wave should go to **pin 1** of **U9**, where it is inverted and output on **pin 2** of the same chip.

- **Transistor Drive.** The 40 kHz signal then passes through **R3**, where it is delivered to the base of **Q1**. Check for the signal's presence at these points.

- **Transistor and LED Wiring.** Check that the emitter lead of the transistor is properly grounded, and that **LED9R** and **R5** have good solder joints.

Input Stage Check power and ground on the IS1U60: the center pin is ground; the right-most pin (nearest to the corner of the board) is +5v.

View the output line (the left-most pin) with a logic probe, and aim a TV/VCR remote at the device. Press buttons on the remote, and the output line should strobe low.

A very few TV/VCR remotes will not be compatible with the sensor; if you are stuck try a different remote.

8.3 Expansion Connectors

The Handy Board presents a variety of signals available for use by expansion boards, including: the full 6811 data bus (on the LCD connector), select lines for controlling input and output latches, four 6811 analog inputs, the 6811 high speed synchronous communications port (SCI), and motor power and ground.

In this assembly step, the female socket headers for these signals are installed. Figure 19 shows how the board should look after this step is completed.

8.3.1 Assembly

Get four pieces of 4–long female header socket and install in the **J13**, **J8**, and **J6** positions.

Get the piece of 10–long female header socket and install in the **J3** position.

If the female header is not precut, see instructions in the Assembly Tips.

8.3.2 Testing and Debugging

There are no testing or debugging procedures for this assembly step.

Figure 19: Expansion Connectors

9 Fuse, Battery Wiring, and Final Assembly

This is the final series in the Handy Board assembly. In this sequence, the PolySwitch resettable fuse and the 9.6v rechargable battery pack are installed.

For this assembly sequence, collect the following parts:

- **BAT1** (9.6 volt AA nicad battery pack)

- **ENCL1** (LMB model 402 plastic enclosure)

- **F1** (RUE250 PolySwitch resettable fuse)

- four self-tapping screws

9.1 Fuse Installation

Figure 20: Fuse Installation

The RUE250 PolySwitch fuse protects against excessive current flow in the case of a board short. Figure 20 shows how the board should look after this step is completed.

9.1.1 Assembly

Install the rectangular fuse element (PolySwitch RUE250) in its designated location (near the upper left corner of the Handy Board).

9.1.2 Testing and Debugging

There are no testing and debugging instructions for this assembly step.

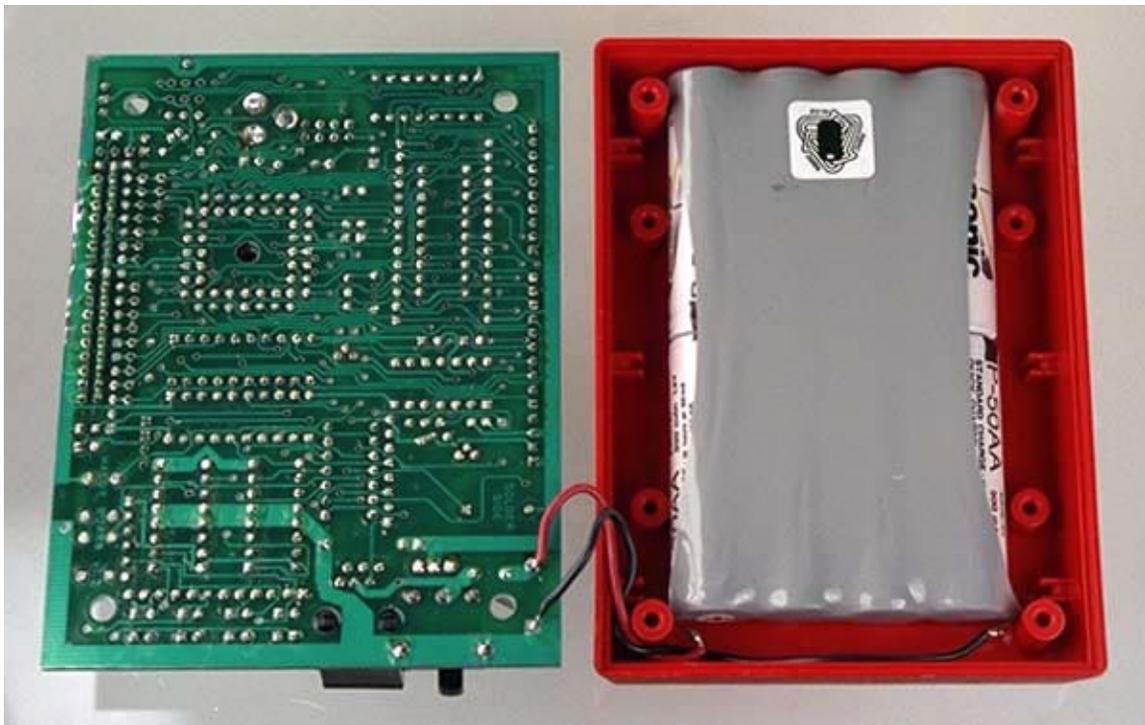## 9.2 Battery Installation

Figure 21: Battery Installation

CAUTION: BATTERY PACKS ARE OFTEN DELIVERED FULLY OR PARTIALLY CHARGED, AND *EXTREME CARE* **MUST BE TAKEN NOT TO SHORT THE TWO BATTERY TERMINALS TOGETHER.**
In practice, this means that you must not let the two exposed wire ends inadvertently come into contact with each other, nor should you cut through pre-attached wires in the same snip.

The reason for this is that Nickel Cadmium batteries are capable of driving huge amounts of current through a short circuit, far more than common household Alkaline batteries. Shorting out Nicad batteries, even for a brief interval, CAN POSE A SERIOUS EXPLOSION AND FIRE HAZARD.

9.2.1 Assembly

If the pack does not some with wires pre-soldered, solder a three to four inch length to each of the the battery terminals. Use a reasonably heavy gauge (20 or less) and preferably stranded rather than solid wire. Color-code the positive terminal with a red wire and the negative terminal with a black wire. *Do not yet strip off the insulation at the ends away from the battery.*

If the pack comes with pre-soldered wires, *individually* clip the wires to approximately three to four inches in length. *Do not yet strip off the insulation at the ends away from the battery.*

Position the battery pack in the lower half of the LMB enclosure (the half with the taps for screws). Route the wires around the screw posts as indicated in Figure 21.

Make sure the Handy Board's main power switch is turned off.

Strip about 1/4 inch of the insulation off of the red (positive terminal) wire. Twist the wire strands together, and insert into the round battery hole (marked with a + on the component side). *Insert the wire from the bottom of the Handy Board and solder from the top.*

Now do the black negative terminal wire in the same fashion, soldering it into the square hole (marked with a − on the component side). *Be careful not to let the exposed black wire touch any point of the Handy Board other than the hole in which it is mounted. This could apply the 9.6v battery voltage to components that are only rated for 5v, causing those components to be destroyed.*

If you have a hot glue gun, add a dab of hot glue to the battery wires on the underside of the board.

9.2.2 Testing

Plug the DC adapter into the Handy Board's battery charging jack. The Handy Board's yellow **CHARGE** LED should light continously.

Now plug the adapter into the Interface/Charger Board, and connect to the Handy Board with the telephone cable. Put the Charge Rate switch on the I/C Board into the **NORMAL** position. The yellow **CHARGE** LED on the Interface/Charger Board should now light. Flip the Charge Rate switch to *ZAP!!*, and the **CHARGE** LED will turn off.

Battery charging tips:

- In Normal charge mode, the Handy Board will fully charge its battery in 10 to 15 hours (assuming its power is turned off).

- In Zap charge mode, the battery will charge in about three hours, after which it will become warm and should be placed in Normal charge. **Do not** leave the Handy Board on Zap charge indefinitely—it will cause the battery to fail prematurely.

- The charge jack on the Handy Board itself is equivalent to the Normal charge mode.

9.2.3 Debugging

If the **CHARGE** LEDs do not light as expected, check their polarity.

9.3 Final Assembly

Flip the Handy Board on top of the battery pack, and use the self-tapping screws to mount it in place. Do not tighten the screws so much as to dig the screw heads into the printed circuit wires that pass underneath them. If nylon washers are available, mount them between the board top surface and the screw heads.

Note that only half of the plastic enclosure is used in the final mounting (holding the battery pack underneath the Handy Board).

If the Handy Board is to be used with LEGO parts, glue four flat LEGO pieces to the underside of the case. Make sure to first mount the LEGO pieces on a baseplate so they are installed at valid LEGO spacings! Cyanoacrylate glues (e.g., *Crazy Glue*) are recommended for affixing LEGO pieces to the Handy Board case.

Congratulations! The Handy Board assembly is complete. Figure 22 shows how the completed board.

A   Revision History

This appendix records revisions to this document.

January 2, 1997 Fixed incorrect reference to **J14** in the *Beeper and LCD Circuitry* section.
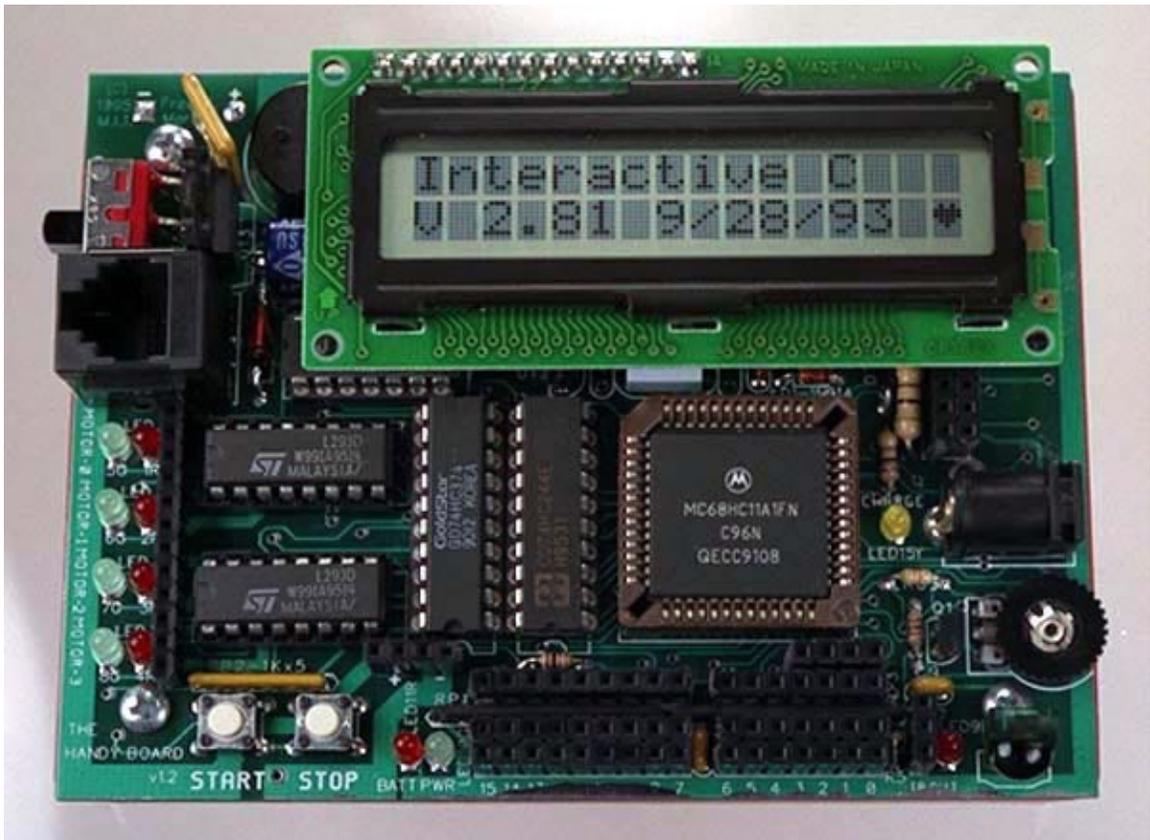
July 16, 1996 First release of hard copy version.

Figure 22: Final Assembly