CS 273 Lab 6: Miniboard Assembly

Dept. of Computer Science, NMSU

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Due Date: October 12, 2006.

NOTE: This is a team lab. In this lab we will assemble the HC11 Miniboard to the point of downloading the `hexmon` program and having it pass basic tests. Completing this lab will probably take you at least 10 hours, so be prepared to spend time in SH 118.

1 Procedure

1. Read the assembly instructions in the Miniboard Technical Reference (in your lab manual).
2. Read the beginning of the Robot Builder's Guide (in your lab manual), which discusses soldering techniques and component placement techniques. You do not need to read about motors, sensors, and switches yet.
3. Check your component pack to make sure you have all of the components.
4. Follow the assembly instruction steps to place and solder the components onto the Miniboard.
5. Check your Miniboard to see if it is working.
   (a) Follow the steps on **Testing out the Miniboard** carefully.
   (b) There is a box of miscellaneous wires in one of the cabinets, many of which are already wired up to switches and light sensors. They may or may not work, but you can try them in these checkout steps.

2 Building the Miniboard

You should follow the 17 steps below to build the Miniboard. You can also find these descriptions on your green lab manual. However, pay attention to the extra notes given in this document in addition to the green lab manual. Be careful to follow all of the instructions. Read the whole instruction for each step. Do not read the first sentence and assume you know how to do it. Be deliberate and careful. Do not rush.

Step 1-2

4 Assembly Instructions

This section describes how to construct the Mini Board. Basic soldering and electronic construction skills are assumed.

4.1 Main Assembly

As you go through the following steps, you may wish to check off each instruction as it is completed. These instructions propose a particular order that parts be installed onto the board. This ordering was designed to make the assembly as easy as possible.

Figure 16 is an enlargement of the component silkscreen that is printed on the Mini Board. Many values and markings will be more legible in this diagram than as actually printed on the board. Please refer to this diagram as often as necessary during assembly.

1–☐ Component Side vs. Solder Side. On the Mini Board, a component silkscreen of white printing aids in placing components properly. This silkscreen is on the *component side* of the board. This means that components are inserted down from this side of the board, and soldered from the unprinted *solder side* of the board.

2–☐ Resistor Packs. There are two basic styles of resistor packs: *common ground* and *isolated terminals*. The Mini Board uses a mixture of these two types.

The *common ground* type has a number of resistors that have one of their terminals tied to a common pin. The opposite pin for each resistor is connected to a separate pin of the package. These types must be installed in the proper orientation, because the common terminal pin must install into the board where it is expected.

The common ground position is indicated on the Mini Board with a band printed on the board where the common pin should go. On the resistor pack, the common pin is indicated with a thin band or dot.

The *isolated terminal* type is a set of electrically isolated resistors. Component orientation does not matter for this type of component because it is symetric from an orientation point of view.

It so happens that the Mini Board design uses one 1K $\times$ 3 isolated resistor pack and one 1K $\times$ 5 common ground pack (amongst others). Both of these resistor packs have six pins—thus making them nearly indistinguishable,

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NOTE. RP1 is labelled **"6A 102G"**, RP2 is labelled **"8B 102G"**, and RP3 is labelled **"LC62 1001G 8849"**. RP4, RP5 – **"8X-1-473LF"**. RP6 – **"10A473G"**. Make sure you pay attention to the orientation for those that need it.

Step 3-4

since both also are of the same value. Yet, they are distinct devices and cannot be interchanged.

There are two ways to tell the difference between these two packs. The first is to use an ohmmeter and simply measure resistances to determine which is which. (This is much easier to do before the packs are installed.) The other way is to look for the following symbols: a "V" on the package indicates the isolated type, and an "E" on the package indicates the common ground type. *Please take care to install these devices properly, and to observe correct orientation for all common ground packs.*

Make sure resistor packs are mounted at right angles to the plane of the circuit board. A good soldering technique is to first solder the two end pins and then straighten the pack before soldering the rest of the pins.

○ **RP1**–1KΩ×5, polarized, "E" marking
○ **RP2**–1KΩ×4, non-polarized
○ **RP3**–1KΩ×3, non-polarized, "V" marking
○ **RP4**–47KΩ×7, polarized
○ **RP5**–47KΩ×7, polarized
○ **RP6**–47KΩ×9, polarized

3–☐ Single Resistors. Resistors **R3**, **R4**, and **R5** mount vertically while resistor **R6** mounts flat on the board. Note: if you have trouble discerning colors, please use an ohmmeter to confirm the proper values when installing.

○ **R3**–10KΩ, *brown, black, orange* ○ **R4**–10KΩ, *brown, black, orange*
○ **R5**–100KΩ, *brown, black, yellow* ○ **R6**–2.2MΩ, *red, red, green*

4–☐ IC Sockets. When soldering IC sockets, it is a good idea to first solder two diagonally opposite corners, check that the socket is fully flat to the board, and then proceed with the rest of the soldering.

○ **U2 socket**–14 pin DIP

Orient notch in socket package above notch in component placement figure. This will serve as a reference when installing the IC into the socket.

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Note. R1 and R2 are not used.

Step 5-8

○ **U1 socket**–52 pin PLCC

It is imperative to *orient the notched corner of the PLCC socket above the notched corner of component placement figure.* The socket enforces an orientation on the installation of the IC; it is therefore necessary that the socket be installed correctly.

5–□ **Non-Polarized Capacitors.** There are three 0.1μF capacitors on the board. These have not been labelled with part numbers on the board. Orientation does not matter when mounting these components.

○ **C2**–0.1μF. Mount near **RP1**.
○ **C4**–0.1μF. Mount near **XTAL**.
○ **C5**–0.1μF. Mount near **U4**.

6–□ **XTAL, Ceramic Resonator.** This is a small blue rectangular component labelled with the value "8.000 MHz." Orientation does not matter when installing this device.

7–□ **Q1, PNP Transistor.** Install **Q1**, the 2N3905 or 2N3906 transistor, so that flat edge of device package is oriented above flat edge of component placement figure.

8–□ **LEDs.** Please also note that the parts listing calls for the HLMP1700 series of LED (or equivalent). These LEDs are special low-current draw (2 mA) devices. In particular, **LED5** and **LED10** must be of this variety. Normal T1-sized LEDs may be substituted for the other LEDs if the value of **RP1** is changed to 330 or 470 ohms.

When installing LEDs, make sure that the shorter lead (the cathode) mounts into *shaded half* of component placement figure. If LEDs are installed backwards they will not work.

Note: **LED6** through **LED9** mount along the outside edge of the circuit board.

○ **LED1**–red ○ **LED2**–red ○ **LED3**–red
○ **LED4**–red ○ **LED5**–red ○ **LED6**–green
○ **LED7**–green ○ **LED8**–green ○ **LED9**–green
○ **LED10**–green

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Step 5, these 3 capacitors are the square yellow ones, labeled **"CK05 BX 104K"**

Step 6, the crystal is the rectangular white component with three leads.

Step 7, The **"2N 3905"** part is a black semi-cylinder with three leads. Be careful! There is another part which looks exactly the same, but with a different number in step 13.

Step 8, Orient the LEDs properly, which will not work otherwise. The shaded half is the white half on the printed circuit board, but is the black half on the printout in the lab manual.

Step 9-13

9–☐ Switches.

○ **SW1**–pushbutton ○ **SW2**–pushbutton ○ **SW3**–slide

Please note that the Digikey part number for **SW3** printed on the board is incorrect. The correct part number is *EG1903*.

10–☐ Direct Mount Integrated Circuits. U3 and **U4** are soldered directly to the board. When soldering, be careful not to apply too much heat. It is suggested that a cooling period be allowed after soldering half of each chip.

Make certain of correct orientation. The notch along a short edge of the IC package must be aligned above the notch in the component placement rectangle.

○ **U3**–L293D ○ **U4**–L293D

11–☐ Power Connector. J1 (Digikey part number ED1601) is a small rectangular terminal block with two screw-tightened connections. It is installed so that the wire slots face open over the outside edge of the circuit board.

In some copies of the Mini Board, the component holes for J1 may be drilled too small. If this is the case, it is suggested that the component leads of J1 be "whittled" down, using the sharp edge of a razor knife, until the component can be installed easily into its holes.

12–☐ Polarized Capacitors. The following two components are polarized: make sure to install the lead marked with a (+) into the hole marked (+) on the Mini Board. Depending on the capacitor manufacture, either the (+) lead or the (–) lead may be marked.

○ **C1**–330μF, polarized ○ **C3**–1μF, polarized

13–☐ U5, Power Regulator. The device labelled on the board is the *78L05*. This device would allow the Mini Board to be operated on voltages from 7 volts and up. A recommended substitution is the *LM2931Z-5.0*. This device allows the Mini Board to be operated on voltages as low as 5.6 volts.

Install so that flat edge of device package is oriented above flat edge of component placement figure.

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Step 9, A fourth switch, SW4, is the bigger slide ON/OFF switch. The push button switches may seem to snap into place, but you must solder them to make solid electrical contacts.

Step 11, we do not have this part. We will solder the power wires directly to J3 on the board.

Step 12, C1 is the fairly large blue cylinder, and C3 is a small yellow blob-type capacitor.

Step 13, if you used the correct part in step 7, this is the other three-pronged black semi-cylinder.

Step 14-17

14–☐ **Inductors.** Install upright, but mount so that the component bodies are not based in adjacent holes, to keep the two devices from touching each other.

○ **L1**–1μH, 1 amp inductor ○ **L2**–1μH, 1 amp inductor

15–☐ **Strip Socket Header.** Socket header comes in strips of 36 to 40 connections which must be cut into pieces of several lengths. Make sure to use *female socket header*, not *male pin header*.

To cut the socket header, two methods are suggested. The first is the use of a mitre box and an X-acto saw blade. If these tools are not available, a regular razor knife may be used. Score the header along the detent line at the place of desired separation. After scoring repeatedly on both sides of the header, the header will easily break at the desired line. *If it is attempted to break the header before it has been sufficiently scored, it is likely that one of the two end connections will be damaged.*

Cut seven 8-long pieces, two 9-long pieces, and two 12-long pieces. Install the headers as follows:

○ **Analog Input Bank**–three 8-long pieces
○ **Digital Input Bank**–two 8-long pieces, one 12-long
○ **Port A Bank**–one 8-long piece, two 9-long
○ **Motor Bank**–one 12-long piece

Note that the 12-long piece mounting in the Digital Input Bank extends to the additional serial connector, and the two 9-long pieces in the Port A Bank extended to the piezo connector.

16–☐ **RJ11 Connector.** Solder **J2** (Digikey part number H9117), the triple RJ11 jack into its location. Note that it will mount properly in only one orientation. Solder the metal mounting supports in addition to the electrical jack connections.

17–☐ **Finish Assembly.** Complete the assembly by looking over the connections, making sure that all joints are soldered well. Look for a shiny finish on the solder connections, not a dull or mottled finish. Retouch any connections as necessary.

Clip any excess component leads at this time.

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Step 14, these two devices are the red-wire-wrapped devices. Also, our version of the board has a diode, D1, mounted near the ON/OFF switch, It is larger, cylindrical, and black/grey. The grey stripe goes on the striped side of the white box **"D1"** on the PCB.

Step 15, cut the strip socket header with the diagonal cutters. Make sure you are mounting the female side onto the PCB, not the male side. Be gentle when cutting, because you can crack them.

Step 16, Our single jack goes in the **"single jack"** spot. The mounting areas for the other two jacks are left empty. Also, you must solder the four inner pins to make a solid electrical contact, even though the part snaps into place. It is a good idea to add a bit of solder to the outside mounting snaps as well.

3 Downloading Files to the HC11 with GDL

3.1 Hardware

The phone cord should have a 9-pin adapter attached to this. Plug this end into the TOP 9-pin serial port in the back of the computer. This works only on the Linux workstations. The Windows, Solaris, or HP computers don't work. Then plug the phone cord end into your Miniboard.

3.2 Software

Before running the downloader, you may need to

```
% source /home/CS273/cshrc.cs273
```

This command adds a path to access the `gdl` command. You probably already have this added to your path, but for those of you who haven't, it might be a good idea to put this command in your `.cshrc` file.

To run the downloader itself, give the command

```
% gdl
```

This will bring up the main control panel. The first time you run this tool, you need to set the preferences. Go to the File menu and select Preferences. At the top, make sure the checkbox labelled "hardware-echo" is selected, and the others are not. Then in the "serial port" selection windows, make sure the "dev" folder is opened in the left-hand window, and select "ttyS0" in the right hand window. Click "Ok", and these settings will be saved so you do not have to do this every time you run gdl.

The main gdl window has two overlapping panels, Download and Communicate. The download panel has folder and file selection panes

If you press the Download Program button, it will bring up a file dialog window, which you can use to select a file to download. The download files are always the `.s19` files.

The other panel is the Communication panel, which can be used to communicate with the board when you are using `Hexmon`. This window shows information transmitted from the Miniboard and lets you type in information to send to the Miniboard.

4 Test the Miniboard

Here are 10 steps for verifying that your Miniboard works.

1. Verify the Assembly. If you've followed all of the steps in the manual, you should verify the assembly before you plug in the 74HC04 and 68HC11 chips. This can be done as follows: With a magnifier or a hand held microscope verify that all solder connections on the board are shiny and that there are no "bridges" between them. You can find a lighted magnifier in the lab.

2. Check for shorts

   (a) Attach the battery pack with the switch in the off position to the miniboard.

   (b) Next take two pieces of lead from one of the components you've installed and press them into pin 7 and pin 14 of the 74HC04 socket. Connect a voltmeter with the "+" lead at pin 14 and the "-" lead at pin 7. Now apply power to the miniboard and observe the voltage on the voltmeter. If it is 5V, proceed to the next step.

   (c) If it is not 5V then you have a short on the board somewhere. The most likely place for this is dual headers around the miniboard that are connected to 5V and Gnd. Other possibilities are the pins of the voltage regulator.

   (d) To eliminate a solder bridge you can use a solder "sucker" or solder-wick type remover. Note that if you use a sucker type they can splash molten solder on other parts of the board. You can also hold the board over the tip of your soldering iron, then touch the solder bridge and the excess solder will flow off of the board and on to your iron.

3. Install the integrated circuits

   Install the integrated circuits (CPU + 74HC04) making sure that the pins of the 74HC04 all go into the socket, and that the CPU is firmly seated in its socket.

4. Attach a computer to the serial port

   Now attach a phone cord between the connector on the back of your host computer to the connector on your miniboard.

5. Power up the miniboard

   (a) Set the Run/Download switch into the "Download" position (away from the CPU) and switch the power to the miniboard on. The RED LED labeled PWR should remain off (or at least should be very dim). Note that the phone cord must be in the connector for this step.

   (b) If the RED LED lights up, or the motor LEDS flicker, then you are probably not in download mode. This can be caused by a defective run/download switch or an open connection (i.e., a bad solder joint) on the switch.

6. Download Hexmon40

   (a) Use the GDL instructions to download `/home/CS273/pub/hexmon40clean.s19` to the miniboard. You can also copy this file (and its source, `hexmon40clean.asm`) to your own directory, and load it from there. You will do this many times over the semester, so it may be easier to keep your own copy.

   (b) Watching the LEDs, the PWR LED should remain off during the initial Downloading Boot download and then turn on brightly when GDL switches to Syncing With HC11 and Downloading EEPROM.

   (c) Note that the Downloading Boot section will always appear to work, even with the Miniboard powered off, because the RS-232 stuff hardware-echoes characters.

(d) If the user code fails to load then the CPU is probably in the wrong mode or not running. There are several possible causes:

   - The miniboard isn't powered up. Check the power connections to the screw terminals and that the power switch is "on."
   - The miniboard is not in Download mode. Check the Download/Run switch.
   - The miniboard is not connected to the host, or the cable is loose in the connector.
   - Gdl was not set up with the "hardware echo" option. This causes a "board memory error" to be displayed, but the real reason is the flag on gdl.

   (The above four possibilities cover 99% of all the cases we've ever actually seen. You should check your connections, reset the miniboard, restart gdl, and try again. If you get the same error 3 times in a row, then contact the TA or professor for help.)

   - There is a solder bridge between some of the CPU pins. The important ones here are the R/W, AS, RESET, XIRQ, and IRQ pins.
   - The RESET or IRQ push button is shorted. You can test this by putting your voltmeter on the RESET (or IRQ) pin and it should read 5V, when you press the button it should switch to 0V. If the exact opposite happens that is you push the button and the input goes to 5V then you've got "normally closed" switches and you need to replace them with the "normally open" type. (this will only happen if you didn't use the part #'s in the list.) More likely the input will be stuck at 0V meaning that you have a short to ground somewhere between the switch and the CPU.
   - The crystal is not oscillating. If you didn't get the crystal with three pins then you need a capacitor bypass to ground. This can be achieved with two small ceramic disks (10 - 50pf) which have two legs joined together and then soldered to ground and the remaining legs soldered to each pin of the crystal. This is easiest to do from the bottom of the board.

     Testing for oscillation is difficult without an oscilloscope, however you can sometimes use the "AC" setting of a multimeter to detect a clock signal is present. (0V = no signal, $\approx$2 V signal present)
   - The CPU is defective. This is not very likely but if you have a spare CPU swap it out. Also recheck to see that the CPU is correctly oriented in the socket and that no foreign matter has wedged itself between the pins and the chip itself.

7. Check out Hexmon

   (a) Now put the run/download switch into the RUN position (toward the CPU) and press RESET . The PWR and RCV lights should be on.

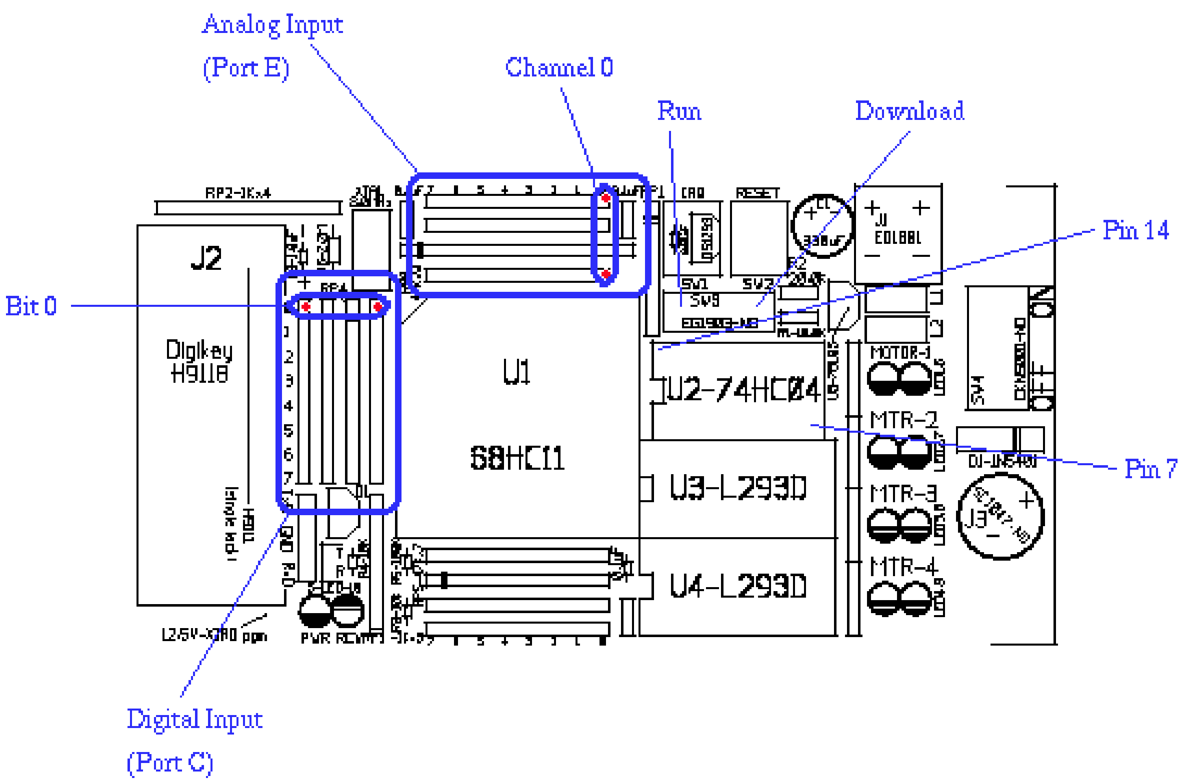
   (b) Bring up GDL's Communication panel and check to see that the miniboard prints a ">" character every time you press reset.

   (c) Type `w00ff005d` and the RED motor LEDs should all light. In the Serial Comm window you should see `>w00ff005dw>`. The miniboard echoed all characters and added `w>` to the end.

   (d) Type `w00f0005d` and all of the Green Motor LEDs should light up and the red ones will turn off. The emulator window will show `>w00ff005dw>w00f0005dw>` (the `>w00ff005dw>` is left over from the previous step).

Congratulations, your miniboard is successfully running Hexmon and is well on its way to being completely checked out. You can find information on the Hexmon monitor program, and what the commands you're using mean, in the lab manual starting on page 76.

For the following steps you need to refer to this figure:



8. Check out the digital input port (PORT C)

   (a) Construct a button sensor (push button with two wires) or touch sensor (microswitch with two wires) and plug it into PORT C, bit 0. Pay careful attention to the orientation shown in the figure - one pin goes into each of two header strips where the two red dots are, the two pins don't go into a single header strip.

   (b) Type r00001003. Hexmon should print back ff (in the Serial Comm window it will look like `>r00001003rff>`).

   If you don't get 'ff' and get something else then convert that number to binary and for every 'bit' that is not '1' you have a short to ground or an open connection to the resistor pack.

   (c) Now, while pressing the button, type `r00001003` again (this requires either some dexterity or a partner) and the resulting display should be `r00001003rfe>`.

   What's happening here is that each position along the header strip corresponds to one bit when the digital input is read. When you push the button on the least significant bit, the result is 11111110 in binary, so when Hexmon reports it in hexadecimal you see fe.

   If the answer comes back anything zero bits other than the least significant bit fe (like fc for instance) then it means you've got a short between the input you've plugging into and an adjacent line. If you still get ff, either you have an open connection on that input bit, or your test switch setup is faulty.

(d) Now move the button to the next space in the connector and repeat this step, each time verifying that one, and only one, bit goes to 0 when you press the button. The correct values are:

Position	Binary	Hexadecimal
0	11111110	fe
1	11111101	fd
2	11111011	fb
3	11110111	f7
4	11101111	ef
5	11011111	df
6	10111111	bf
7	01111111	7f

9. Verify the A/D channels. Checking out the A/D channels is done in the same way except that this time you need to wire up a light sensor.

   For each channel you should type

Command	Channel
r00000054	0
r00000055	1
r00000056	2
r00000057	3
r00000058	4
r00000059	5
r0000005a	6
r0000005b	7

   So to check out channel 1, you would type `r00000055` to hexmon which might yield `>r00000055r03>` or `>r00000055raf>` or something, depending on the photocell you used and the amount of light falling on it. The error condition is that you get either 00 or ff. 00 means you have a short to ground or an open pullup and ff means you have a short to 5v. Some fixed value like 33 means you probably have a resistive short to ground (a cold blob of solder, a bit of lint, etc)

   Once you've verified that the channel changes when you change how much light falls on the sensor, verify that the adjacent channels do not change when you vary the light.

10. Verify the motor drivers. These are pretty straight forward. Wire up one of the Lego motors to a 3 prong plug as shown in the lab manual. Plug it into the Motor 1 port.

   Use the hexmon commands `w0011005d` and `w0010005d` to verify the motor spins first one way then the other. Similarly use:

Direction 1	Direction 0	Motor
w0022005d	w0020005d	2
w0044005d	w0040005d	3
w0088005d	w0080005d	4

   In this test you are looking for the motor either to not spin one direction or the other (indicating a short in the connector pins) or very slow in one direction or the other (indicating a cold solder joint on one of the pins) or multiple motor LEDs lighting (indicating a short between enable pins).

5 Lab Finalization

1. Demonstrate a working board in (or by) October 12 lab time,

   You must show to the TA that you can use hexmon to read a digital switch, read a light sensor, and turn on a motor both forward and reverse.

2. Submit a lab report for this lab. Each person must submit a lab report, although you may collaborate with your lab partners on your report.