Assembling the Printed Circuit Board for the EDE1200 Robot

This board receives instructions from either a CBL2, a LabPro or (with an adapter cable) an original CBL. The board has two 595 “shift registers” (each providing 8 bits of on-board memory) and two EDE1200 stepper controllers that can keep a stepper motor moving without the need for constant input.

The board provides substantial output capabilities for the robot, including 2 stepper motors for motion, up to 4 servo motors for “arms," and 2 programmable 12-V outputs for solenoids, buzzers, lights or other devices. It also has a power output, to allow easy connections to the Motor Controller for those desiring additional capabilities through the LabPro's second digital output.

Step 1 -- Examine the PC Board (Figure 1)

Look at the printed circuit board (PCB) and be sure you understand how it should be oriented. Almost all of the components will be placed on top of the board while it is oriented as shown at left. On the robot, this side of the board which will face downwards, hanging beneath the robot platform. The last component you will solder--the LED--will be fastened on the opposite side so you can see it through the translucent robot platform.

Notice that the board is "double sided" meaning that it has lines of metal printed on both top and bottom. These metal traces are the "wires" which will conduct electricity. The holes are "plated through" so metal (and electricity) pass through the board at those points.

The board is also coated with a protective covering, so the metal is only exposed in and around the holes. Some of the larger holes have no metal traces, since they will be used for mechanical connections, not electrical connections.

Step 2 -- Identify the Components to be Soldered

The parts to be soldered to the PC board are listed at right and pictured in Figure 2. Identify each one, and lay them out where you can keep track of them. The letters indicate the recommended order of assembly.

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Order	Component	# per board
A	Circuit Board	1
B	Resistor, 10 kohm	4
C	Resistor, 220 ohm	1
D	Socket, DIP 14 pin	1
E	Socket, DIP 18 pin	2
F	Socket, DIP 16 pin	4
G	Crystal, 4 MHz	2
H	Diode, 3A, 1N5400	1
I	Capacitor, 2000 pF, disk	2
J	Capacitor, 47 µF, radial	1
K	Right Angle header, 3P	4
L	Fuse, Resettable, 0.2A	2
M	Modular jack, 6P6C	1
N	Temninal Block, screwless, 2 position	3
O	Terminal Block, screw, 6 position	2
P	Terminal Block, screw, 2 position	1
Q	IC, 7805 Voltage Regulator	1
R	LED	1

Step 3 -- Add the Resistors

Be sure that you and all the people near you are wearing eye protection.

Be very alert to the fact that the soldering iron is hot.

- Insert the 4 10-kohm (brown, black, orange) resistors (B) and solder them in place. The resistors will function correctly no matter which direction you place them, but good practice calls for the color code to be oriented from left to right. Be sure that the solder adheres to both the wire lead and the pad, forming a "kiss-shaped" connection.
- Insert the 220-ohm (red, red, brown) resistor (C) and solder it into place from the bottom of the board.
- Trim off the excess leads, cutting just above the solder. Be careful that the cut wire does not fly off and hit your eyes or those of anyone around you.

Step 4 -- Add the 14-Pin Socket

- Carefully align the 14-pin socket as shown on the board. The notch on the socket should match the outline drawn on the board. The socket will function correctly even if you put it in backwards, but the IC that will go into the socket MUST be correct. The notch on the socket will help you orient the IC correctly, and it will also help anyone who might need to replace the IC.
- Solder all of the pins on the socket, being careful to avoid solder bridges (where solder provides a path from one pin to the next) and cold solder joints (where the solder fails to stick to either the pin or the pad).
- Be sure to give your soldering a visual inspection before you go on. Use desoldering braid or another desoldering tool to remove any solder bridges and use more solder to redo any cold joints.

Step 5 -- Add the Other Sockets (Figure 3)

This is a lengthy part of the soldering process, with exactly 100 solder points to complete. When you finish this step, you will have finished over two-thirds of the soldering. It's important to get every solder point right, since even one error can keep the board from working correctly. If you make a mistake it can be correctly later, but the process of finding and fixing the bad joint is one most people prefer to avoid.

- Insert the two 18-pin sockets (E), being very careful to orient their notches to match the outline on the board. Solder each one into place.
- Insert the four 16-pin sockets (F), again being very careful with the orientation, and solder them into place.

Hint: You may want to use masking tape to hold the sockets in place until they are soldered.

Extra thought: Hand soldering really is an important skill, still used for building prototypes, constructing one-of-a-kind equipment and for making repairs. On the other hand, this is definitely NOT a job that high-paid technicians would do day after day. Almost all assembly of this type is now done either by automated equipment or by low-paid workers abroad.

Step 6 – Add the Crystals (Figure 3)

- Insert the 2 crystals (G) as indicated and solder them into place. They work equally well in either orientation, although it's better to make the lettering on the crystal match the lettering on the board.

Step 7 -- Add the Diode (Figure 4)

- Make sure you know how the diode (H) fits into the board, then use pliers or a lead former to bend the wire leads to fit. The diode must be oriented as shown, with its silver end as shown in the outline on the board. The diode's function in the circuit is to make sure that electricity only flows the correct direction, even if someone attaches the batteries backwards. (If you are very sure that the batteries will never be connected backwards, it is possible to use a jumper wire instead of the diode.)
- When you are sure of the orientation, solder the diode into place. The leads are thicker than the components you have been soldering, it it will take a little extra time and a little more solder to make a good connection. After soldering, trim off the excess leads.

Step 8 – Capacitors (Figures 4 and 5)

The job of the capacitors is to stabilize the voltage on the circuit board. The 2 small capacitors help protect the "shift registers" from noise that might interfere with signals from the CBL or LabPro. The large capacitor helps smooth out slower variations in voltage that are often produced by motors (particularly the robot's main drive motors).

- Be sure you have identified the 2 2000 pF capacitors (I). They look similar to the resettable fuses, but have very different electrical characteristics. (These capacitors have straight leads, and are marked with “202” for 20 x 10^2 pF.) Insert the capacitors into the board where indicated, and solder them into place. Orientation of these capacitors is not important.
- Pay very careful attention to the orientation of the 47-microFarad capacitor (J). Electrolytic capacitors such as this can overheat and rupture if connected backwards, sometimes blowing the top high in the air and potentially causing injury. The negative lead on the capacitor is shorter and is marked with a "-" on the plastic case. This is "pin 2" on the capacitor, and goes into the round hole near the edge of the board. "Pin 1" is the positive side, marked by a longer wire, and goes into the square pad on the board further from the edge. When you are sure of the orientation, solder the capacitor into place and trim the leads.

Step 9 -- Servo Headers (Figure 6)

- Use masking tape to hold the headers (K) in place along the back of the PC board as shown, then solder them.

Note: The headers often come in longer strips, and you may need to break them apart.

Step 10 – Fuses (Figure 7)

- Insert the 2 resettable fuses (L) in the locations identified as “RXE020” and solder them into place. Note that the fuses are designed to stand above the board, since they might become somewhat hot. Orientation is not important.

Each fuse protects one of the board’s 2 programmable outputs, limiting the output current to about 0.2 A. The fuses are self resetting, which means they come back on automatically after a short time. If you ever notice something going on and off at the output, it is probably drawing too much current.

Step 11 --Add the Modular Plug

The modular jack provides a place to connect the Motor Controller board to the CBL, CBL2 or LabPro. It is a US-style telephone jack, but has 6 conductors rather than the usual 4.

- Carefully align the 6 pins of the modular jack (M), then snap the 2 plastic supports into place. Solder all 6 pins. Note that these pins are smaller and closer together than most others on the board. They will require less heat and less solder.

Step 12 -- Screwless Terminals (See Figure 1)

The screwless terminals provide an easy way to connect additional components without the need for tools. The 2 screwless terminals at the back corners of the board are designed to let you attach DC motors, solenoids, lights or other devices that work with 12 volts, DC. These outputs can be turned on and off by the software. The third screwless terminal is always on, providing a constant 12 volts to power the motor controller or other supplementary equipment.

- Carefully position the screwless terminals, making certain that the openings are oriented towards the back of the board. Masking tape can help you achieve better alignment. When you are sure of the positioning, solder them into place.

Step 13 -- Screw Terminals (Figure 8)

The screw terminals provide a more permanent connection, but still allow for easy replacement when necessary. The 2 6-position terminals at the either end of the board are intended to run the robot's main stepper motors. The 2-position screw terminal in the left front of the board is where you will connect power from the robot's batteries.

- Carefully position the 2 6-position terminals (0) and the 2-position terminal (P), making certain that the openings are oriented towards the outside of the board. When you are sure of the positioning, solder them into place.

Step 14 -- Voltage Regulator (Figure 8)

The stepper motors on this robot use 12 volts, but servo motors and the ICs need t-volts. The voltage regulator provides that 5-volt power. As it drops the voltage from 12 to 5 volts some energy is wasted in the form of heat, and the metal back on the voltage regulator provides a way of releasing that heat to the air. Since it can get somewhat hot, the voltage regulator needs to stand slightly away from other components.

- Insert the voltage regulator (Q) as shown, with the printed surface facing forward, and solder all 3 leads. Trim the leads and bend the voltage regulator backwards a bit so it doesn't stick up above the other components.

Step 15 -- LED and Finishing Touches (Figure 9)

When the PC board is attached to the bottom of the robot, the side where you have placed all the components so far will be down. The LED needs to be where you can see it, so it is placed on the opposite side of the board as shown.

- Insert the LED (R) from the opposite side of the PC board as shown. It must be oriented correctly, with its negative lead ("pin 1"), in the square pad. The negative side of the LED is also marked on the plastic case with either a flat side or a notch. Solder and trim the leads.
- The LED was the last of the components that need to be soldered, so this is the time to visually reinspect all of your solder joints. Retouch any that may not make good contact, adding a little more solder. Use solder braid or a desoldering tool to remove an solder bridges.

Unless you used "no-clean" solder, you should now use a solvent to remove the flux from your board to prevent future corrosion. USE ONLY A SOLVENT DESIGNED FOR THIS PURPOSE AND CAREFULLY FOLLOW THE INSTRUCTIONS PROVIDED WITH THE SOLVENT.

Step 16 -- Integrated Circuits (see Figure 1)

The soldering is done, but not the hard work. Each of the 7 integrated circuits must be inserted into its socket. If even one pin is out of place, the robot won't work. Key points to remember are:

1. There are 4 different kinds of IC on this board. Two of them (the ULN2003A and the 595 shift register) will both fit into the 16-pin sockets, but the robot won't work if you put the 595 where the 2003A should go or vice versa.
2. The orientation of the notch on each IC MUST match the outline on the PC board. If you put a socket in backwards, the circuit will still work so long as the IC matches the PC board. You can usually tell that the IC is oriented correctly if the letters on the IC match the letters on the PC board, but some ICs have the lettering upside down. The notches are the authority.
3. Pins on the Ics flare outward, because they are really designed to be inserted by robots, not people. When it picks up an IC, the robot bends the pins inward. Before trying to insert each IC, you should use the work surface, a pair of pliers or a special tool to align the pins so each one is perpendicular to the socket. Be very carefully—the pins are sharp enough to cut your fingers.
4. To insert an IC, lay it on the correct socket and make sure EVERY pin is started into the corresponding hole in the socket. Only then, push down firmly on the top of the IC until it seats fully in the socket. Check visually to be sure no pins bent in or out rather than going into the socket. If they did, use an IC puller or a screwdriver to carefully remove the IC, restraighten the pins, and reinsert the IC.

- Insert each IC in its correct socket with the correct orientation, then double check them all.

Step 17 -- Mounting

Even for testing, it is important that the bare metal bottom of the board not touch any electrical conductors. The sharp edges of cut wires on the bottom of the board can also damage tables or other surfaces.

- From the top of the board, insert a nylon screw (W) with lock washer (X) and attach a nylon standoff (Z) to the bottom of the board at each of the 6 mounting holes.

These same standoffs will be used later to fasten the board to the robot.

Step 18 -- Testing the Board

- Apply 12 to 15 V DC at the power input terminals. Be very careful to attach positive to the positive input and negative to the ground. The LED should light and the current input should be about 200 mA. Touch the voltage regulator and each of the ICs. If any of these is becoming hot, immediately turn off the power and tell the group leader. If your board passes the “smoke test,” turn off the power and move on to the next step.
- If necessary, load the appropriate SAM program group into your calculator. Connect your calculator to the CBL, CBL2 or LabPro and connect the interface to your board. Run the program DCUINIT to verify that the calculator and LabPro are connected properly. If the batteries in the interface have not been changed recently, consider replacing them or using the DC adapter.
- Attach a servo motor to the various servo headers, with the black ground wire to the right. Turn the power back on to the board and use the SAMPUT programs to verify that the servos respond. Before running each program, you must store an angle in degrees (between -90 and +90) as the variable “A” (for example, 45→A) and then run the program. After the motor moves to position A, it should remain in or close to the same position, until you change the value for “A” and run the program again. Disconnect the servos and turn off the power before continuing.
- Attach a 12-V light or buzzer to each of the programmable 12-V outputs. Turn the power back on to the board and use the SAMSW1F and SAMSW2F programs to verify that the light or buzzer responds. Before running each program, you must store time in seconds as the variable “T” (for example, 5→T) and then run the program. The device should go on for the specified time and then go off. Disconnect the device and turn off the power before continuing.
- Use the same light or buzzer to test the constant 12-V output. In this output, the light or buzzer should remain on whenever the main power to the board is on. Disconnect the device and turn off the power before continuing.
- Attach the 6 wires of a stepper motor to one of the 6-position terminals. The two bicolored wires must be attached to the top terminals, both marked “+.” (It doesn’t matter which one goes in which of the two “+” terminals.”) For both motors, the wires below the positive terminals should be connected in the sequence red, blue, black and white. Store a positive value such as 200 to the variable S, then run SAMGOST (SAM GO STeps). The motor should turn 200 steps. Repeat the process for the other 6-position terminal. Disconnect the motor and turn off the power before continuing.

Figure 1

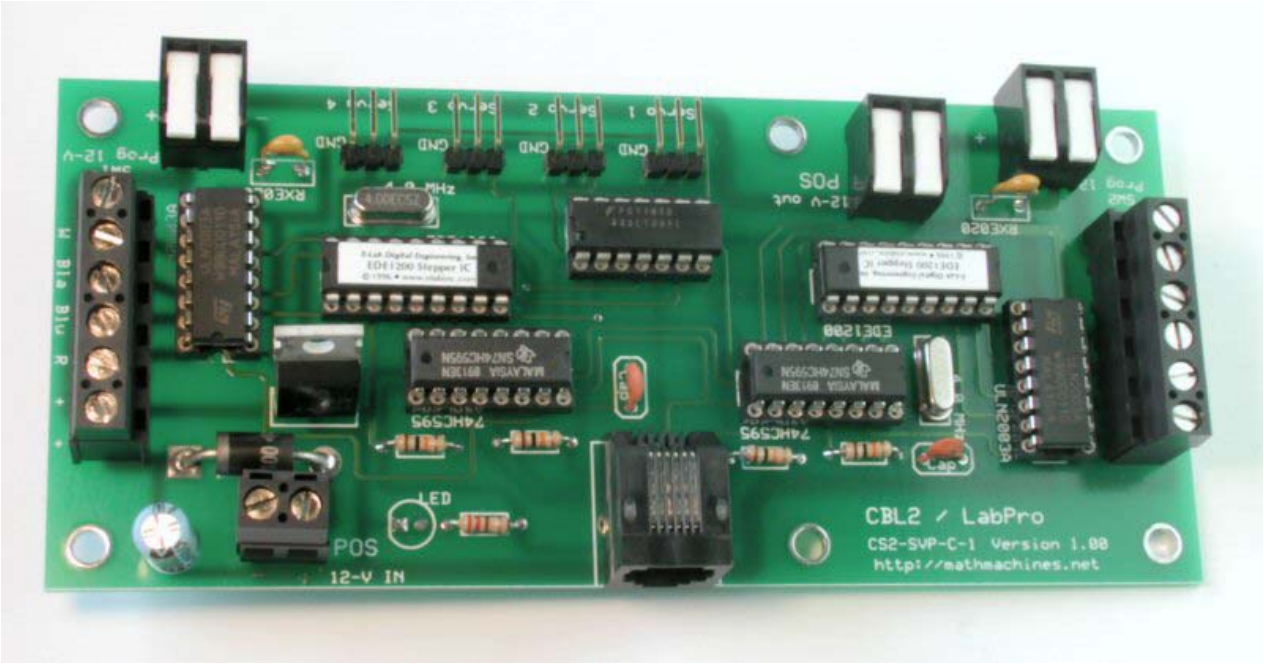

Figure 2

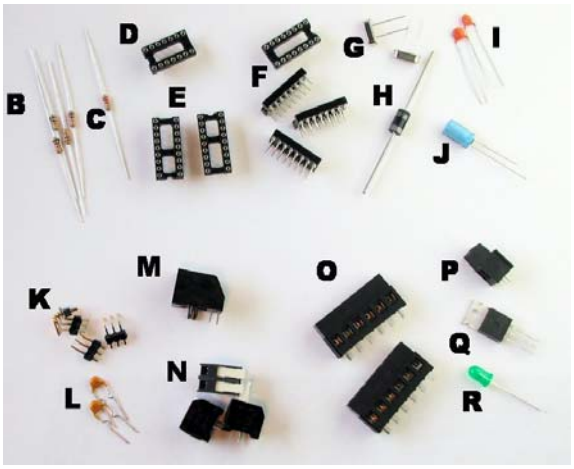

Figure 3

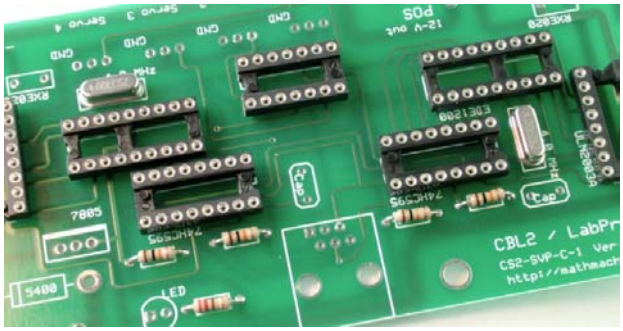

Figure 4

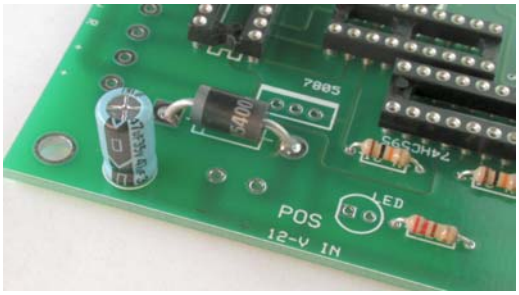

Figure 5

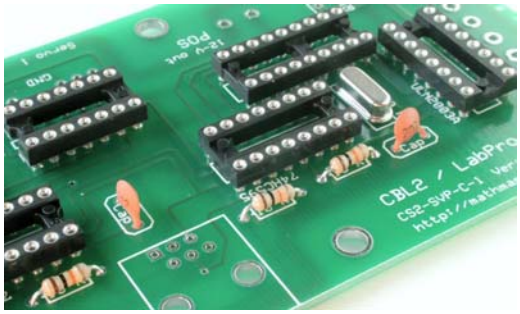

Figure 6

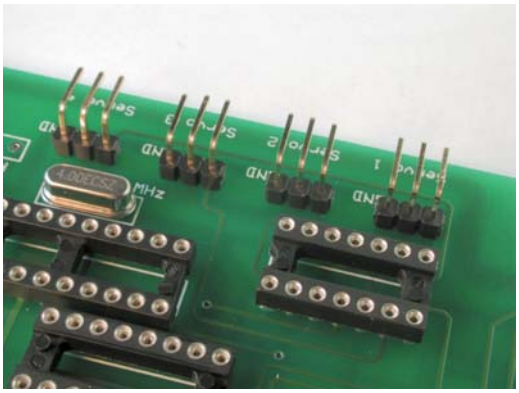

Figure 7

Figure 8

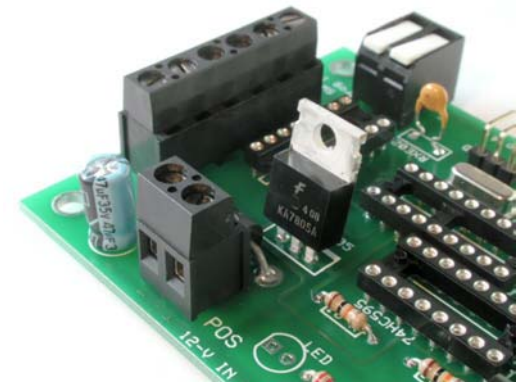

Figure 9