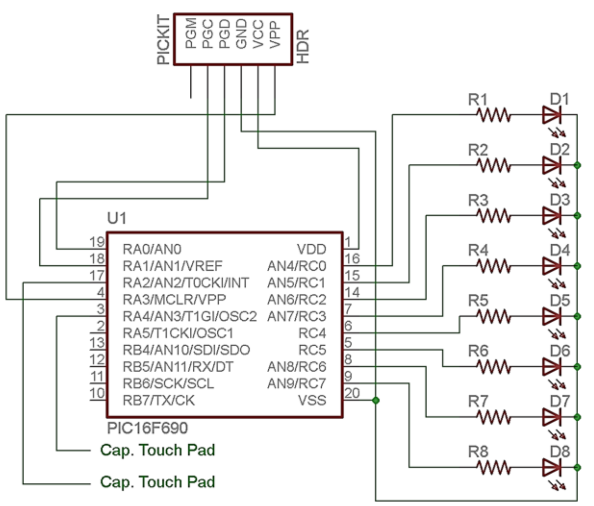
A Simple and Easy Guide to Surface Mount Soldering

(The Executive Summary for those who don't have time to read the next dozen pages or so.)

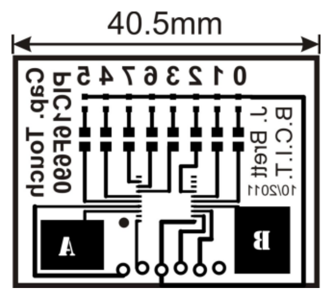
by Jason Brett, BCIT Technology Teacher Education Program

1) Buy some solder paste and SMD components. See next page for a list of supplies and suppliers.
2) Make some circuit boards. See diagrams, below. Section 1 describes one way to do it.
3) Slap a tiny little bit of solder paste on the board. Section 2 has some photos and tips.
4) Place your components on the solder paste.
5) Blast the whole thing with a heat gun until the solder melts. Section 3 has some tips.
6) Program the board. Section 4 has the code and describes how it works.
7) See? Simple! Easy! A surface mount microcontroller project with capacitive touch sensing in 30 minutes or less that costs about $3.00 and uses almost no special tools.

The Schematic



The Board (mirrored and ready for transfer)
See Section 1 for links to more drawings.



Parts Placement on the Board

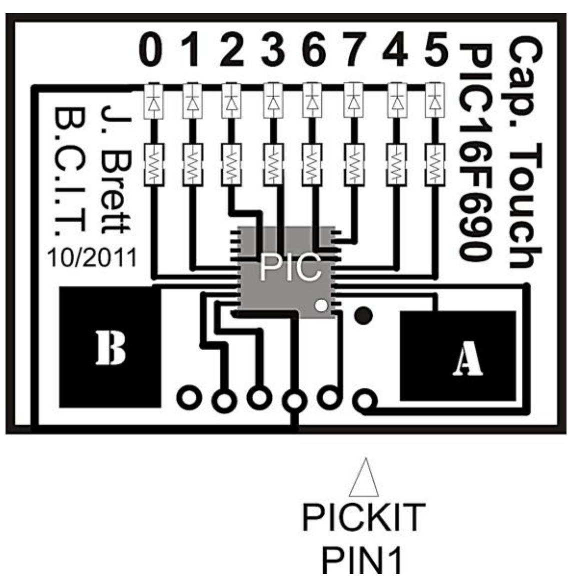
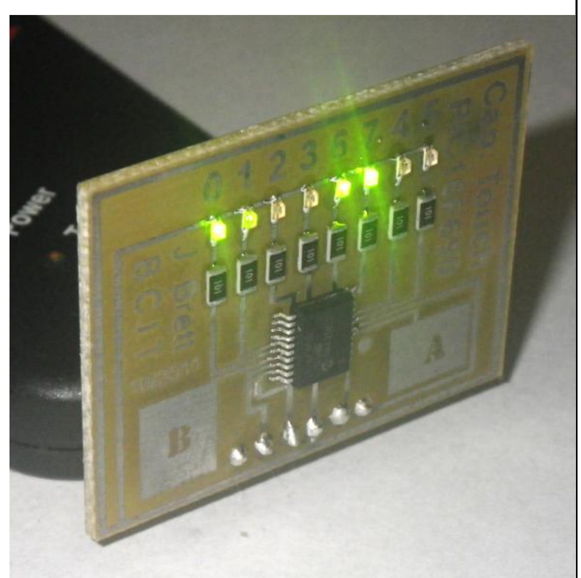


Photo of Finished Board



A Simple and Easy Guide to Surface Mount Soldering

by Jason Brett, BCIT Technology Teacher Education Program

I've wanted to try my hand at surface mount soldering for years now, but have always been put off by the idea that is was going to take too long to master, require expensive tools, and end up being too difficult for high school students to apply to their projects. Turns out I was pretty much wrong about all three. In some ways it is faster and easier than making traditional "through hole" boards. So let's do it!

Parts and Supplies:

These are the parts and supplies that I will be using in this demo project.

Consumables:

Microchip PIC 16F690 in the 20 pin SSOP package.

Digikey.ca part number: PIC16F690-I/SS-ND, $1.80 each in quantities of >10
This is the smallest version of this PIC. The "pin pitch" is just 0.65mm. In retrospect, I should have used the SOIC version of the device with a 1.27mm pitch. It would have made the soldering even easier… but I figure why not tackle the littlest one first? With SMD it's "Go *small*, or go home!"

8 x 100Ω resistors in the 0805 SMD package

Available at Lee's Electronics in Vancouver or
Digikey.ca part number RMCF0805JT100RCT-ND, $0.0038 in quantities >1,000
These will be the biggest, easiest parts to solder. And, yeah… that price is right. A thousand of these suckers costs less than four bucks.

8 x LEDs in the 0603 SMD package

Available at Lee's Electronics in Vancouver or
Digikey.ca part number 475-2558-1-ND, $0.06 in quantities >100
Also available in different colours, these measure just 1.6mm x 0.8mm. Check the data sheet to determine polarity before removing them from the package. The ones I got at Lee's had nice little green dot on the cathode side, but the ones from digikey were not marked as clearly.

6 x 1 pin header strip can be either straight or 90 degree bend

Available at Lee's Electronics in Vancouver or your local electronics shop
Digikey part number WM6436-ND, strips of 36 pins are $0.94 each in quantities >10

Single Sided Printed Circuit Board 32mm x 42mm (for one board)

For digital versions of the board layout and schematic in Eagle and a 28-board layout in Microsoft .xps format, visit http://botshop.wordpress.com

Sheet of "Water Dissolving Paper" (optional)

http://www.sciencebobstore.com/water-dissolving-paper/
Use your own favourite method to produce the boards, but this is my source for "water dissolving paper" which works pretty reliably for me using the toner transfer process

Solder Paste

Available in small pots from Lee's Electronics or in a syringe (much preferred, as it comes with a fine tipped needle for dispensing!) from Digikey as Part Number SMD291AX10-ND. This stuff isn't cheap, about $22 for 10 cc, but it will go a long way if you look after it. *Note that it should be kept refrigerated*.

Liquid Tid (optional)

Available from RP Electronics as part #421-500ml, $35 for a 500ml bottle. This will allow you to plate the copper traces, thickening them, and reducing the risk of corrosion.

Equipment:

Microchip PICKIT 2 USB Programmer (or equivalent)

Available at www.microchipdirect.com as part number PG164120, $35 each or from Digikey as part number PG164120-ND for $40 each (may not be in stock) There are clones available for less on ebay, but I have found these to be reliable and robust. The PICKIT3 is available too, and should work well… I haven't tried the PICKIT3 or the clones… if you try them, please let me know how they work for you! Other programmers may be adapted to fit the 5-pin programming interface used by the PICKIT

Non-Magnetic Tweezers

Plastic ones are available from Lee's Electronics in Vancouver for about $2.00 each or you can get stainless ones from Digikey (part #EROP7SA-ND) for about $4.00 each. You can get away with using very fine tipped needle nose pliers to place the components, but life got much happier for me when I switched to using the plastic tweezers from Lee's.

Heat Gun

A typical, commercial heat gun. Ideally one with an option to run the fan at low speed and the heater on high temperature. Mine appears to be an "Ungar 6966C" also sold as the "Weller 6966C", but try using whatever you've got on the shelf. It will probably work fine!

T-Shirt Transfer Press and Etching Tank (optional)

Use whatever printed circuit board technique you are happy using. I use a Lancer LT1500 T-shirt press for the toner transfer technique.

Fine Tipped Soldering Iron, and solder

The fine tip is for making any repairs, the standard, rosin core solder is for going over any traces that have small break.

Magnifying Glass or Microscope, and Light

I've got decent close up vision, but find a 5x or 10x lens really helps pick out the details. The photos you see in this document were taken using a USB microscope ($70, on sale, from London Drugs). Most photos were at about 20x, except for the close up of the LED at closer to 200x. If you suffer from "short arm syndrome" and your close-up vision isn't what it once was, you'll definitely need to find a magnifying solution that works for you.

Step 1: Etch the Board(s)

There are many good ways to mask and etch a circuit board. If you've got a technique that works for you, and allows you to etch traces down to 0.010", then please ignore this section and stick with what you do.

1A) Prepare a circuit board image. I have placed the schematic and board files for this project, along with graphics of a single board and 28 board sheet as part of a .zip file on my "Botshop" blog at:
http://botshop.wordpress.com/2011/10/15/surface-mount-soldering-made-sorta-easy/

Print a copy of the board, or boards, on normal paper. Note that if you are using the .xps file that the board has already been mirrored. The .xps format is supposed to preserve all document formatting, but check to ensure that the measurements between the outer registration marks (the cross hairs in the hollow circles) are 178mm wide x 234mm high. Individual boards should measure approximately 41mm x 31mm from outer edge to outer edge. If you print directly from Eagle your board will look different from the version presented here as I exported the board from Eagle as an .eps file and then did some post-production work in Corel Draw to make the board look nicer (and to generate the 28 board layout.)

1B) Print the image on toner transfer paper. I like to use the water dissolving paper from "ScienceBobStore.com" for making my boards, as it saves the hassle of lifting the paper off the board after performing the toner transfer. It does require a few different steps from using glossy magazine paper (which works, too).

Set the *T-shirt press to 400°F* and let it heat up. Note that this is hotter than for some other toner transfer processes.

I find the water dissolving paper is not stiff enough to make it through my laser printer on its own. If you are printing all 28 boards, tape one sheet of water dissolving paper to the normal paper sheet you printed in step 1A. One strip of scotch tape folded over the leading edge of the paper should be sufficient.

For a smaller number of boards, cut out a piece of water dissolving paper and tape it over the desired number of boards on the sheet you printed in step 1A. I find one strip of scotch tape covering the entire leading edge, and another covering the entire trailing edge of the water dissolving paper prevents jams.

Once you have printed the board pattern on the water dissolving paper, cut or peel the tape away from the water dissolving paper. Keep your grubby, oily, greasy fingers off the black toner!

1C) Prepare your circuit board material. This step is very important in ensuring good adhesion between the toner and the copper.

Cut out a piece of single-sided PCB material slightly larger than the board you want to etch. Use steel wood, or a scotchbrite pad to buff the copper to a fine shine. Yes, it all has to be shiny, at least anywhere where you want toner to stick.

Wash the copper. Hot soapy water might work, but *Windex works really well*. Keep your grubby, greasy, oily fingers off the nice, clean copper!

Dry the copper. After wiping the circuit board reasonably dry using paper towels, I'll *put it in the t-shirt press (copper side up, towards the heating element) and lower the heating element down to about 1 cm above the surface of the board*. I'll wait about ten seconds... if there is still steam coming off the board, I'll give it another ten seconds.

Leave the circuit board material on the t-shirt press, fully open the press and quickly....

1D) Place the water dissolving paper on the copper. The copper on your board will be a little warm, so carefully place your water dissolving paper onto the circuit board. Remember, toner side of the paper goes towards the copper side of the board.

Try to get the position of the paper right on your first attempt. As the copper is hot, some of the toner might stick, causing problems if you try to re-position the paper even a little bit. If you are having problems with this, then you are probably cutting your printed circuit board material just a little too small.

Close the t-shirt press tight, and *wait for approximately two minutes*.

1E) Open the T-shirt press. The paper should be flat and browned. Without touching the paper, gently and swiftly slide the board out of the press. ***Wait for the board to cool!*** A hot board means that you have hot (soft) toner. If you put a large, heavy, flat piece of metal on the board it will act as a heat sink and cool the board more rapidly.

1F) Dissolve the paper in water. 100% of the toner should be stuck to the board. If not, you will have to decide if you can repair the missing toner using an etch-resist pen. Note that when I follow this procedure exactly that I normally do not need to make any "fixes" to the resist. You may be better to clean the board with acetone and start over than to carry on with a flawed board.

You will find that tiny fibres are left behind, embedded in the toner. You can remove most of these fibres by rubbing them with your fingertips while the board is damp. *You won't get all the fibres, but you don't have to*. Spending a couple minutes giving the board a vigorous rub will help speed up the etching process, however.

1G) Etch the board. The little fibres that are left may cause the board to take considerably longer to etch than you are used to. Before you remove the toner, c*heck the board very carefully* under a magnifying lens to ensure that all unwanted copper has been removed. Remove the toner from the board with acetone, give the board a quick buffing with steel wool, and plate the traces with liquid tin if desired. (See section 2 for photos of flaws to watch for on your boards.)

Step 2: Apply the Solder Paste and Place the Components

2A) <u>Double check your board under a magnifying lens</u> for incomplete traces (figure 2A, 2B) and shorts (figure 2C). Even the tiniest flaw to your eyes will be a giant flaw for an electron! I mark flaws with a felt pen, but am careful to not put the ink on the traces, in the event I want to solder over them later. You may be able to repair an incomplete trace by drawing solder along it with a fine tipped iron, or repair a short with a few careful scratches with an x-acto knife. If you are in doubt, use an ohmmeter to check your repair. You'll find it much easier to deal with these problems now than you will once the components are attached.

Figure 2A: Two Incomplete Traces, Easily Repairable

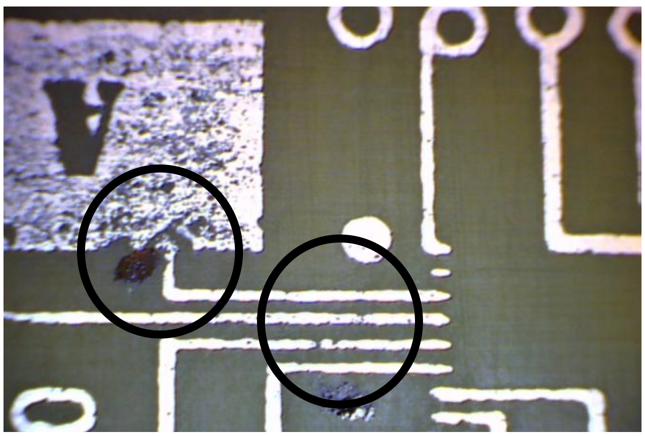


Figure 2B: Incomplete Traces, Difficult Repair

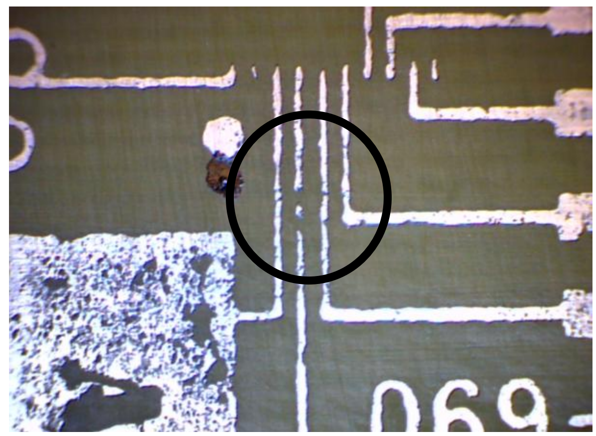


Figure 2C: A Short Between Traces

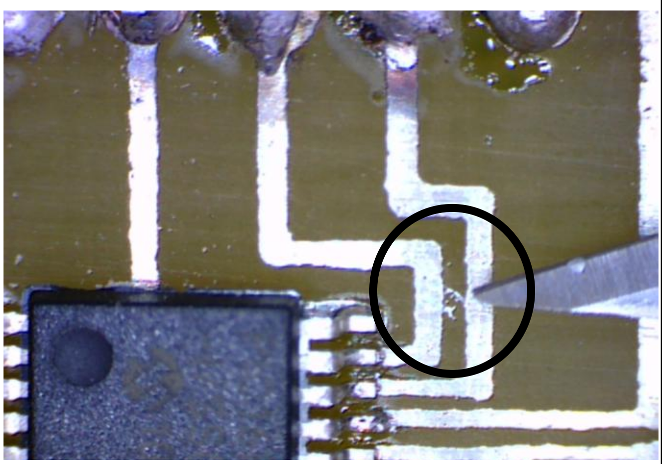
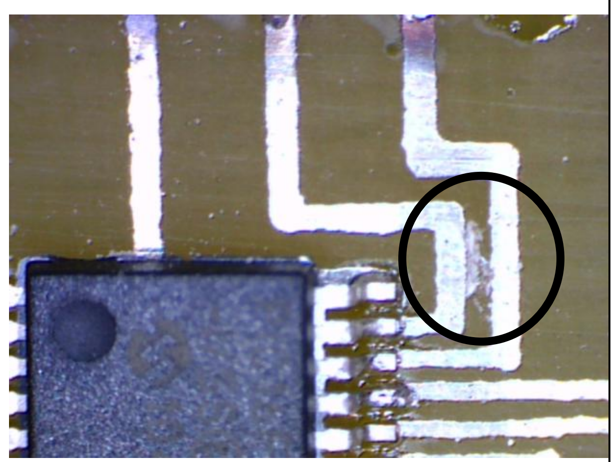


Figure 2D: The Short from 2C, Repaired



NOTE: When using a syringe of solder paste in the next few steps, push the plunger VERY gently, and wait ten seconds to see how much solder flows. You only need tiny amounts of expensive solder paste.

The solder paste flows slowly, creating thicker lines, when it is cool. You may find that taking it out of the fridge a half hour before using it will help you get thinner lines.

2B) Place a small line of solder paste, slightly thinner than a resistor's lead, across the pads for the PIC leads. (Figure 2E) I suggest doing this first as it is the most difficult application of solder paste on this board. If your first effort is too thick, you can actually scrape some of it off using a clean resistor lead, or similar gauge wire, then wiping the lead on a tissue. Go back and scrape a bit more off until you have just a thin layer of paste. (If you end up with a complete mess, you can clean it all off and start over!)

The real trick is to make sure that there is just *a little bit of solder paste on each pad*. It doesn't matter that it jumps from pad-to-pad, as when we heat it up, the surface tension will pull the solder away from the board and towards the "more easily wetted" metal leads and pads. Figure 2F shows about the right amount of solder on the top pads, but a little too much on the bottom pads. This resulted in the solder joints shown in Figure 2G, where there is clearly a solder joint between the leads of the PIC. This was fixed later using a fine tipped soldering iron and some copper braid to wick the extra solder away.

Figure 2E: Solder Line with resistor for size comparison

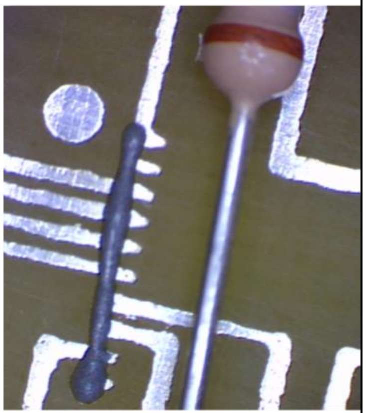


Figure 2F: The top line of solder is "about right". There is too much on the bottom.

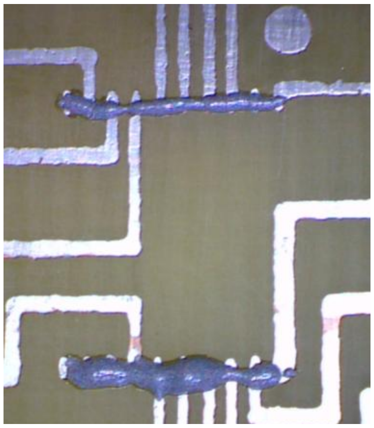
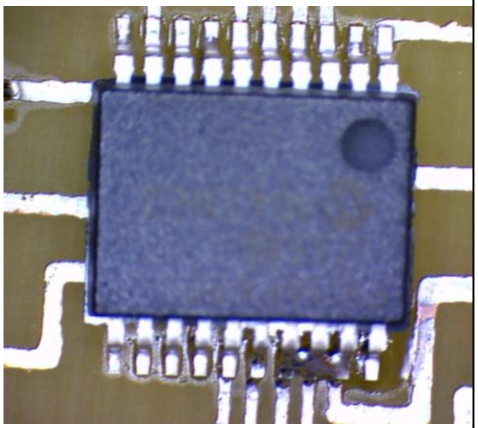


Figure 2G: The result, after soldering, of the solder paste in figure 2F. The top row is fine, but the bottom is not.



Placing a line of solder this fine can be a real challenge, even when using a syringe. If you are doing a lot of SMT work and want something more reliable, you can purchase laser cut stencils (http://www.applied-electronics.com/category/smt-stencils/), or make your own by etching copper foil, or even carefully cutting out the pads from a sheet of overhead projector film. I have yet to experiment with stencils.

2C) <u>Apply "dots" of solder to the resistor and LED pads</u>. This should be much easier to do as the spacing between the pads is much larger. I'd suggest "warming up" on the resistor pads first, as the LED pads are kind of tiny, but after getting the thin bead laid down for the PIC, this should be a piece of cake. You don't have to be perfect... just so long as there is a tiny little dab of solder paste on each pad, you'll be fine.

Figure 2H: Applying solder paste from a syringe

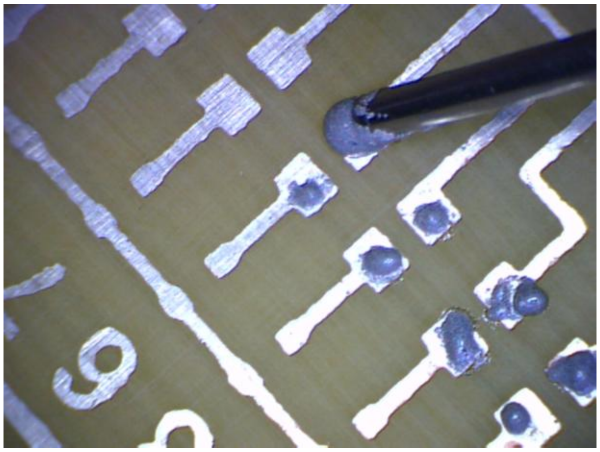
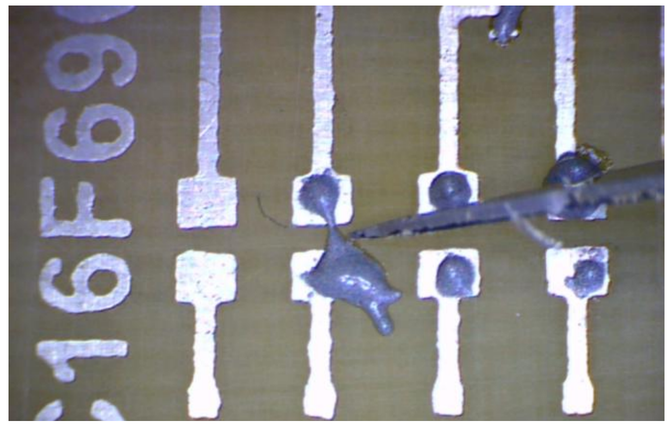


Figure 2I: You can use a knife to clean up any jumps between pads



2D) <u>Place the Resistors on their pads.</u> My first couple boards were done using fine tipped needle-nosed pliers. It worked, but was a pain. The non-magnetic tweezers make this task almost fun. Once the resistors are placed, I give them a gentle push down to make sure they are "stuck" in the solder paste.

Don't worry if you are slightly off in your alignment! The beauty of surface mount is that the surface tension of the liquid solder can overcome the insignificant mass of your tiny components and pull them into alignment when you heat the board.

Figure 2J: The resistors in their packaging

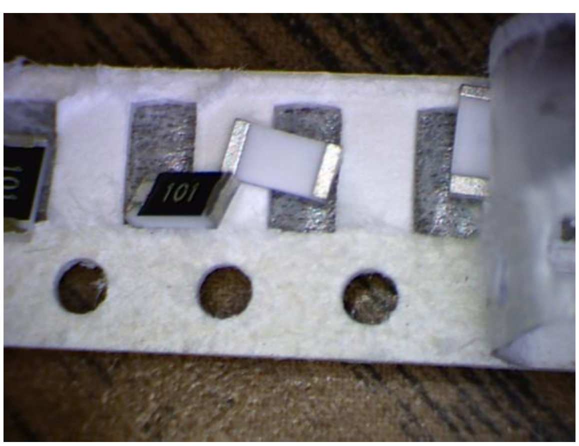
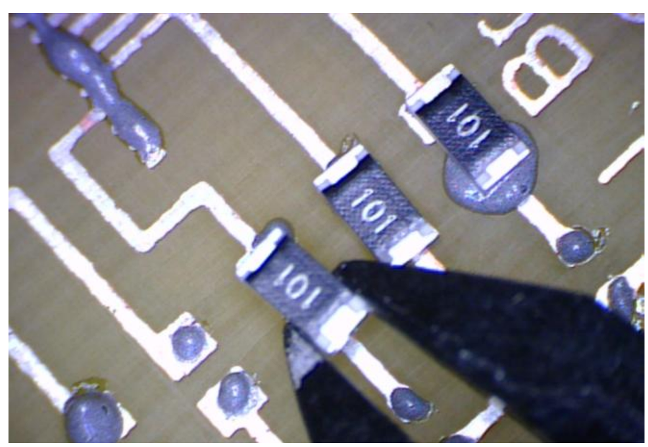


Figure 2K: Placing the Resistors



2E) Place the LEDs on their pads. Make sure you can identify the cathode. There is usually some indication. On the LEDs from Lee's there was a small green dot that you could just barely see with your naked eye. On the LED's from digikey, the datasheet says there is supposed to be an even smaller dot pressed in to the cathode end. Figure 2L shows one of the Digikey LED's at almost 60x magnification. I don't see the dot... but I do see the tiny little balls of solder that make up the solder paste!

Figure 2L: An LED from Digikey, showing polarity

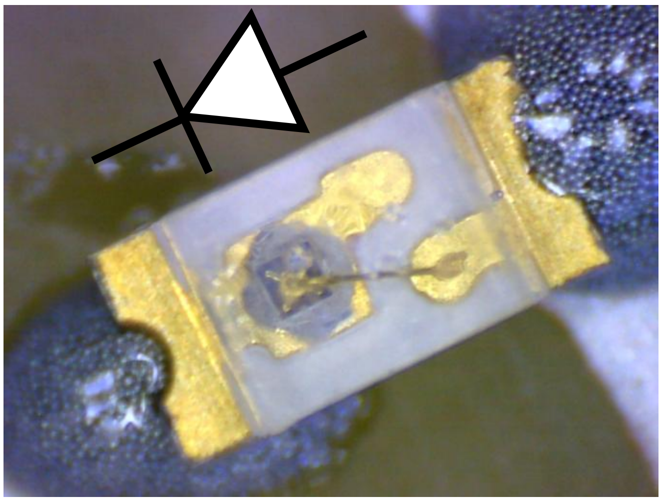
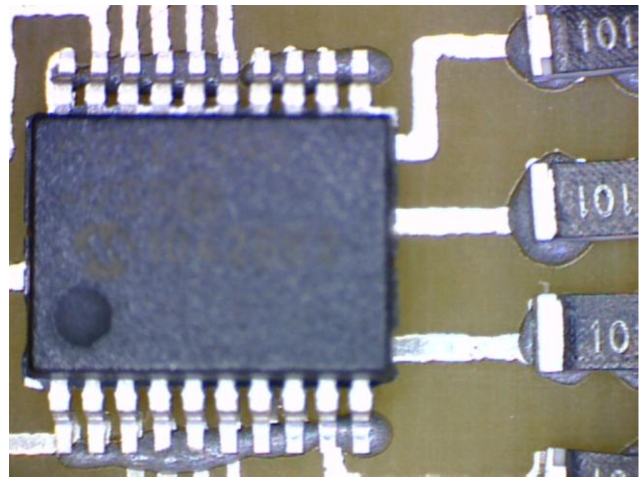


Figure 2M: The PIC chip, ready for soldering



2F) Check your work. Make sure all components are touching solder and a pad. Double-check LED polarity and resistor values under a magnifying glass. You are going to solder everything at once, so it is much easier to "get it right the first time!"

Step 3: Solder It All Up!

This is the "Simple and Easy" part, as promised. Just take a heat gun, set the airflow fairly low (so you don't blow those tiny little LED's around) and gently oscillate it back and forth over the board. The solder paste should dry up, going a dull grey, and then it should melt, transitioning to a nice, shiny solder finish. If you've got just the right amount of solder, the surface tension will pull the solder together, soldering only the leads, and moving the components in to their exact, correct, positions.

Check your board for shorts between the leads of the PIC. If there is a short, try drawing it out the traces with a soldering iron. If it is really bad, try absorbing some of the excess solder with a copper braid.

Add a header strip and you are ready to program!

Step 4: The Software.

This board is set to plug directly in to a PICKIT 2 (or PICKIT 3) programmer. If you get an error from the PICKIT, or the PICKIT won't load the software, check your board for an error. You likely have a tiny one… somewhere!

The LED's are attached to Port C, and the port numbers are displayed on the board. "4", for instance, refers to PORTC.4 Set PORTC.4 high, and TRISC.4 low, and LED #4 turns on.

The touch pads, A and B, use a technique described in Microchip Application note AN1298 (http://ww1.microchip.com/downloads/en/AppNotes/01298A.pdf) to perform capacitive touch sensing using only the on-chip analog to digital convertors. In this application I have configured two touch pads, but as the 16f690 has 12 ADC inputs, up to 12 "buttons" could be printed on your circuit board. Note that as they are capacitive sensors, you do not actually need to touch the sensors to activate them.

The software is written in Great Cow Graphical Basic and is available for download from http://botshop.wordpress.com. (Great Cow is available from http://gcbasic.sourceforge.net/)

You can use the serial UART built in to the PICKIT to receive a "real time" reading of the values being returned by the capacitive touch sensors and, if needed, use those values to "tune" your sensing.

The software code is:

```
;Chip Settings
#chip 16F690,8
#config MCLRE=OFF, WDT=OFF, OSC=INTOSCIO

;Defines (Constants)
#define SendAHigh set PortA.0 off
#define SendALow set PortA.0 on
#define CAP_SW_1 PortA.2
#define CAP_SW_2 PortA.4

;Variables
Dim LOOP As byte
Dim CAP_A As word
Dim CAP_B As word

STARTUP
Do Forever
	READ_CAP_A
	SerPrint 1, " A"
	SerPrint 1, CAP_A
	If CAP_A < 750 Then
		portc.0 = 1
	Else
		portc.0 = 0
	End If
	READ_CAP_B
	SerPrint 1, "  B"
```

```
      SerPrint 1, CAP_B
      If CAP_B < 750 Then
            portc.4 = 1
      Else
            portc.4 = 0
      End If
Loop

Sub STARTUP
      TRISA = 0
      PORTA = 255

      ''Configure Analog Inputs AN2 and AN3
      ANSEL = 12
      InitSer 1, r2400, 1, 8, 1, None, Invert
      TRISC = 0
For LOOP = 0 To 255
PORTC = LOOP
Wait 10 ms
Next
PORTC = 1
SerPrint 1, "It Works!"
End Sub

Sub READ_CAP_B
      CAP_B = 0
For LOOP = 1 To 1

''Set ADC Clock speed to Fosc/16
ADCON1 = 80

''Set Secondary Channel to 5V
trisa.4 = 0
porta.4 = 1

'Point ADC to Secondary
ADCON0 = 141

''Ground Sensor Line
TRISA.2 = 0
PORTA = 17

''Set Sensor Line as Input
TRISA.2 = 1

'Point ADC to sensor channel and begin conversion
ADCON0 = 139
Wait 3 10us
CAP_B = (256*ADRESH)+ADRESL
value = CAP_B
Next
End Sub

Sub READ_CAP_A
      CAP_A = 0
For LOOP = 1 To 1
```

```
''Set ADC Clock speed to Fosc/16
ADCON1 = 80

''Set Secondary Channel to 5V
trisa.2 = 0
porta.2 = 1

'Point ADC to Secondary
ADCON0 = 137

''Ground Sensor Line
TRISA.4 = 0
PORTA = 5

''Set Sensor Line as Input
TRISA.4 = 1

'Point ADC to sensor channel and begin conversion
ADCON0 = 143
Wait 3 10us
CAP_A = (256*ADRESH)+ADRESL
Next
End Sub
```

Good luck, have fun! Please add any helpful comments you may have to
http://botshop.wordpress.com/2011/10/15/surface-mount-soldering-made-sorta-easy/