

# Final Project Report

## EE3390 Electronic Circuits Design Lab

### Custom Liquid Crystal Display (LCD)- Barcode Generation

Prishantha Dunstan  
Kyle Jiang

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Department of Electrical Engineering  
Columbia University

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## 1. Executive Summary

The objective of this project is to create an LCD screen that can display barcodes. The final LCD screen will be of dimensions 50x50mm and will be able to render (due to size limitations) barcodes with 12 or more bars.

The key steps to this project are three fold. The first key step is to design a custom circuit board that can properly run the LCD screen. The second key step is to develop the programmable software that will drive the LCD to display the images we select. And the third key step is to fabricate the LCD display at a high enough resolution to be capable of rendering barcode images.

For the midterm presentation, we made a simple, low resolution LCD to demonstrate the basic concepts we were going to enhance and show an example of the potential final product.

For the final presentation, we completed our custom circuit board and had it manufactured into a PCB. We completed the development of the software that would drive the LCD barcode screen and demonstrated the outputs of the circuit board. We also designed the custom mask needed for fabrication of the LCD screen, but since its delivery was delayed, the mask did not arrive until shortly after the final presentation, and thus the creation of the LCD screen itself did not get completed in time for the final presentation. As such, we demonstrated all the steps involved in the LCD project, showed proof of design, and upon final fabrication of the LCD screen, will later demonstrate the final product as well.

## 2. Block Diagram, Design Targets, and Specifications

### Block Diagram

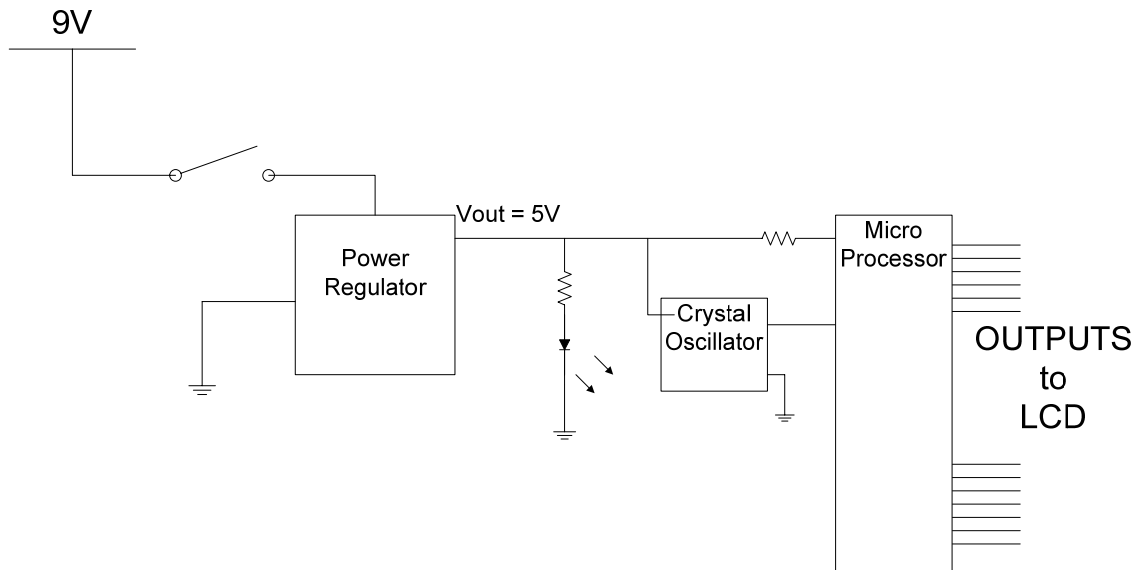


Figure 1

### Design Target and Specifications

Objective: Create wire outputs that can carry varying voltages which are controlled in order to drive an LCD screen.

The LCD screen is designed where the bottom glass has 100 parallel ITO (transparent wire) channels of 0.25mm widths separated by 0.25mm space [see Figure 5 for a diagram]. The top glass has 8 ITO channels, with widths of 6.25mm, separated by 0.25mm space (the last ITO channel is 4.5mm wide) [see Figure 4 for a diagram]. This is done so that each of the ITO channels on the top glass correspond to 13 ITO channels on the bottom glass (with the exception of the last top channel, which corresponds to the remaining 9).

For the design, contacts to the top glass would sit at 2.5V until each wire is triggered in turn. When triggered, they run a square wave by going to 0V, then to 5V, then back to 2.5V until triggered again. Each contact on the top glass is triggered independently (one at a time in fast sequence).

For the bottom glass contacts, each of 13 pins from the microprocessor controls 8 wires to render a multiplexing effect. Of the 100 wire contacts for the bottom glass, every 13<sup>th</sup> wire is controlled by the same pin of the microprocessor. This is because every 13 channels on the bottom glass correspond to a single channel on the top glass. When the channel on the top glass triggers, only the 13 wires underneath it are able to display an image. Each pin from the microprocessor runs the voltage of its 8 wires as a 0V, 5V square wave or a 5V, 0V square wave, depending on whether it wants to make the liquid crystals remain transparent or turn opaque (respectively). While all 8 wires run by a

single pin follow the voltage of that pin, only the single wire that is under the “top” contact that is currently being triggered will actually change the state of the liquid crystals, due to the voltage difference needed to turn them opaque. Thus, while all 100 “bottom” wires are receiving voltage waves, only 13 at a time are actually affecting the liquid crystals.

This is conducted at a high frequency to make the sequential changes unnoticeable.

The software code that runs the microprocessor is attached in the appendix.

### 3. Individual Block Descriptions

#### Power Regulator

The power regulator is implemented to create a consistent voltage of 5V for the system.

#### Crystal Oscillator

The crystal oscillator works as the clock function of the system, used to render the wave forms that run the LCD

#### Microprocessor

The microprocessor is programmed such that 8 pins output waveforms of low, high, mid in turn. 13 other pins are programmed with the information pertaining to the rendering of the barcode image. The software is attached in the appendix.

PCB design of the Microprocessor is below. The Microprocessor was designed in EAGLE and manufactured by Alberta Printed Circuits.

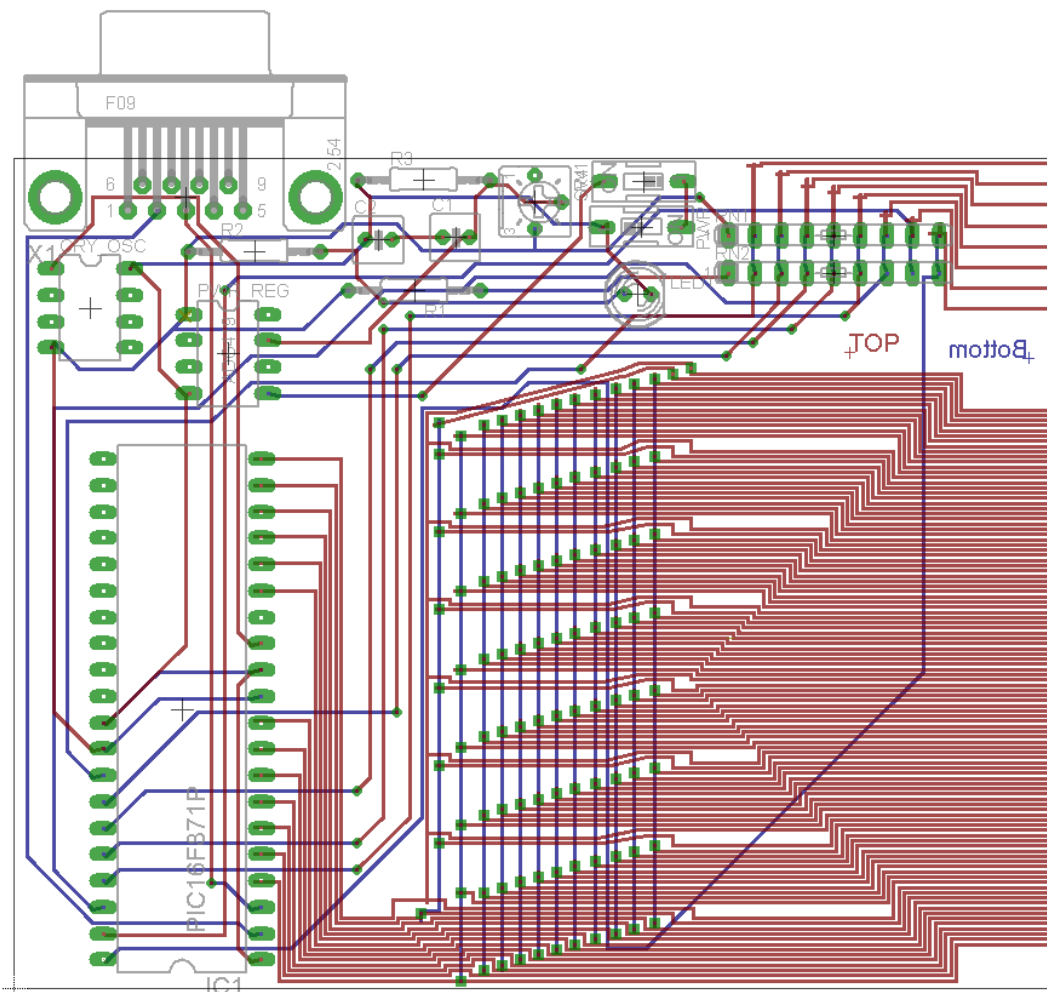


Figure 2

## LCD Overview

The steps we took to make a liquid crystal display in Professor John Kymissis' lab is as follows (diagrams below in Figure 3)

1. 50 x 50 mm pieces of glass with a layer of ITO (indium tin oxide) are purchased for etching
2. A layer of polyresist is added on top to coat the entire ITO
3. A chrome mask (glass plate with a design in chrome) is placed on top of the glass and UV light is shined from above. This weakens the exposed polyresist which is subsequently removed with the aid of a developer solution
4. Nitric and hydrochloric acid are introduced to the top of the glass compound now to remove the exposed ITO (polyresist is unaffected by the acids)
5. Finally, acetone is used to remove the remaining polyresist (ITO is unaffected by acetone).
6. The final product is a sheet of glass with ITO channels custom etched to the pattern desired.

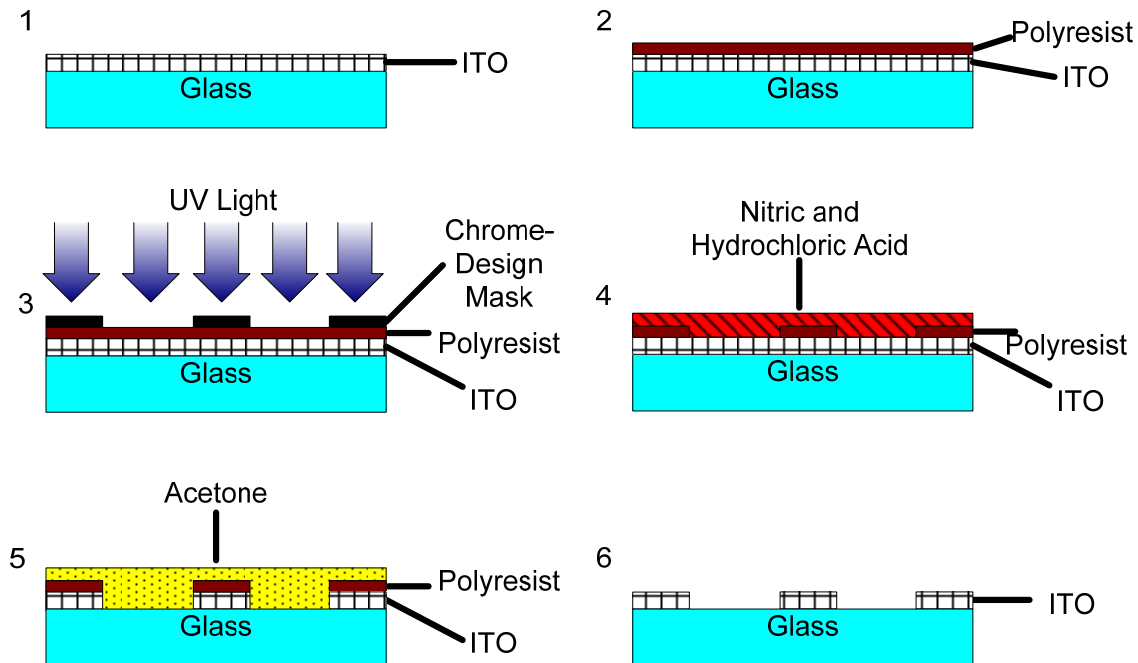


Figure 3

For the barcode LCD, custom masks were designed and manufactured. The “top” plate was designed using the following mask.

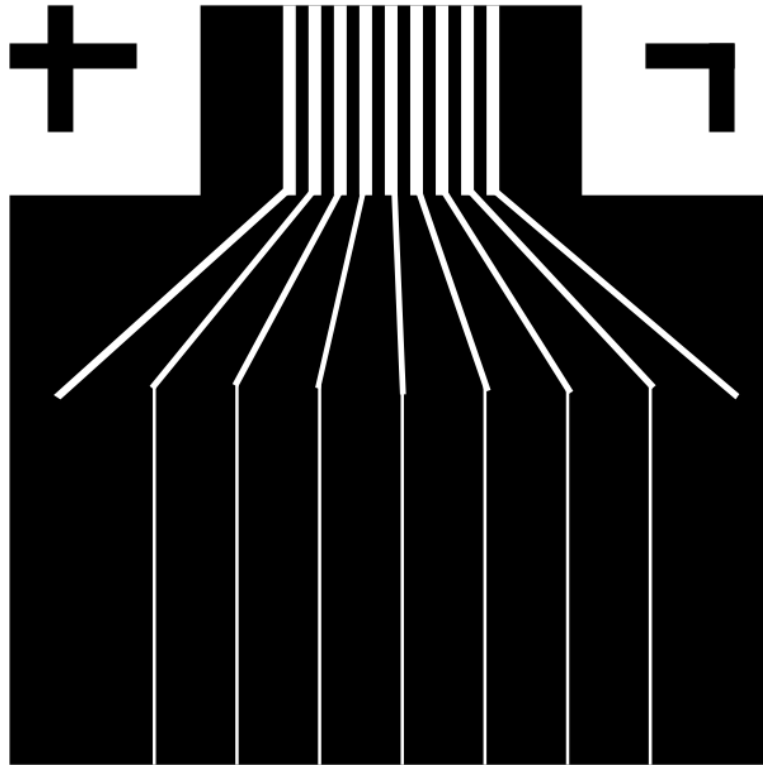


Figure 4

The wire contacts for the 8 “top” wires would connect to the top eight black channels (1mm wide with 1mm spacing). The channels are designed to run the eight lower channels that are 6.25mm wide with 0.25mm spacing. The mask is made to be larger than the actual ITO glass to account for slight errors in alignment. The cross and L bracket are boarder markers to help with alignment (the corners of the ITO glass fit just inside them).



The “bottom” plat was designed using the following mask

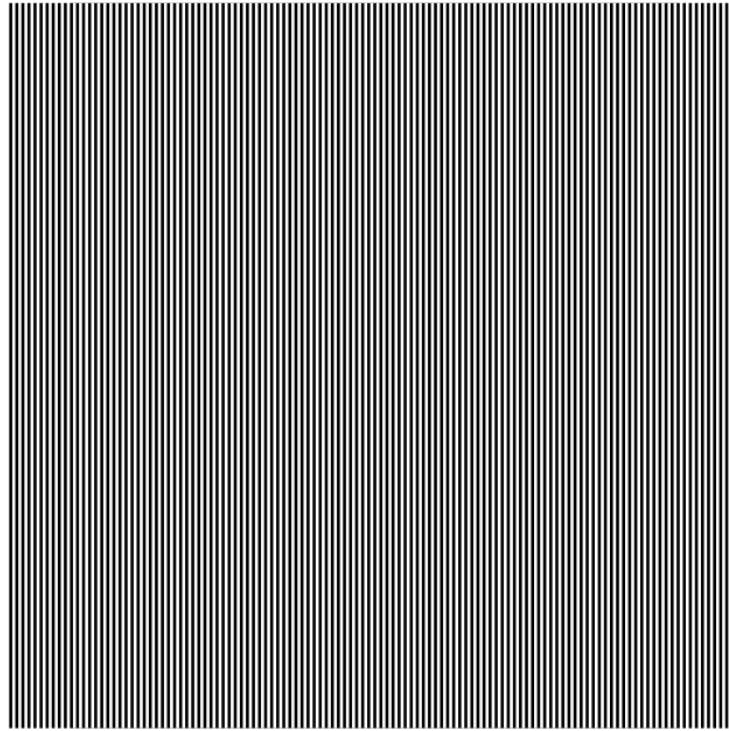


Figure 5

The mask displays 0.25mm wide lines with 0.25mm spacing between the lines. These lines would connect to the 100 “bottom” wires from the PCB. Similar to the other mask, this mask is larger than 50 x 50mm in order to account for misalignment.

The wires on the PCB are connected to the ITO channels in the LCD by using a heat seal connector which, in a sense, looks like tape but has numerous thin wires in it. When heated atop the wires on a PCB or the ITO on glass, the wires in the heat seal connector affix to the surface it is against.

Once the ITO glass plates are made, the ITO side is coated with a nonconductive seal. This is then scratched with an abrasive surface (to which the crystals will align when under a voltage gradient). Then, two plates are sealed on top of each other, with ITO surfaces facing each other and liquid crystal is injected through the side.

The impedance of the LCD screen is analogous to that of a capacitor, since the LCD screen is not supposed to conduct current. When analyzed using a multimeter, the level of capacitance of different LCD screens we had fabricated ranged from as little as 60pF to as much as 120pF. The variation is likely due to the non-uniform distribution of liquid crystals on the screen.

Below is a figure depicting how the waveforms of the “top” wires and the waveforms of the “bottom” wires render barcode images using fewer wires than the bars displayed. Y-axis values for each wire are 0V, 2.5V, or 5V, and x-axis is the progression of time.

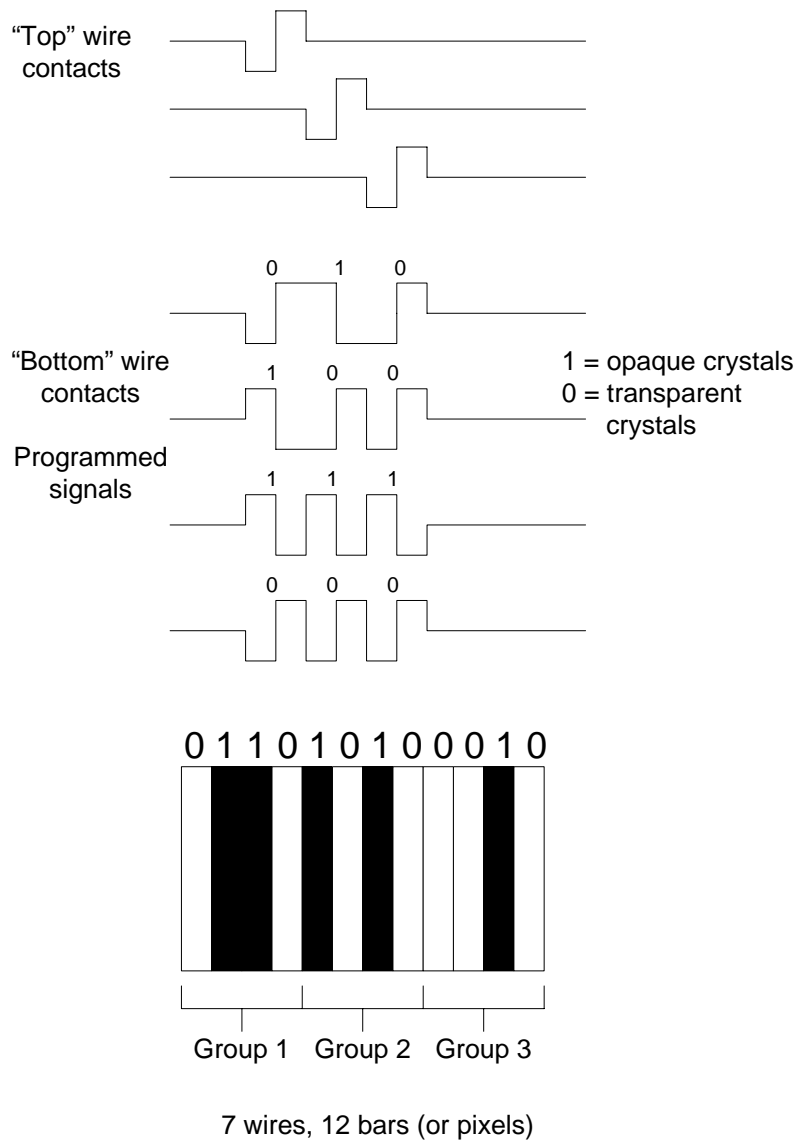


Figure 6

Below is the image of the manufactured, custom Printed Circuit Board. We needed a printed circuit board specifically because the wire size and spacing needed for connecting the circuit board to the ITO channels on the LCD glass needed to be extremely fine and precise. Heat seal connector is then used to connect the wire contacts on the PCB to the LCD glass via hot bonding.

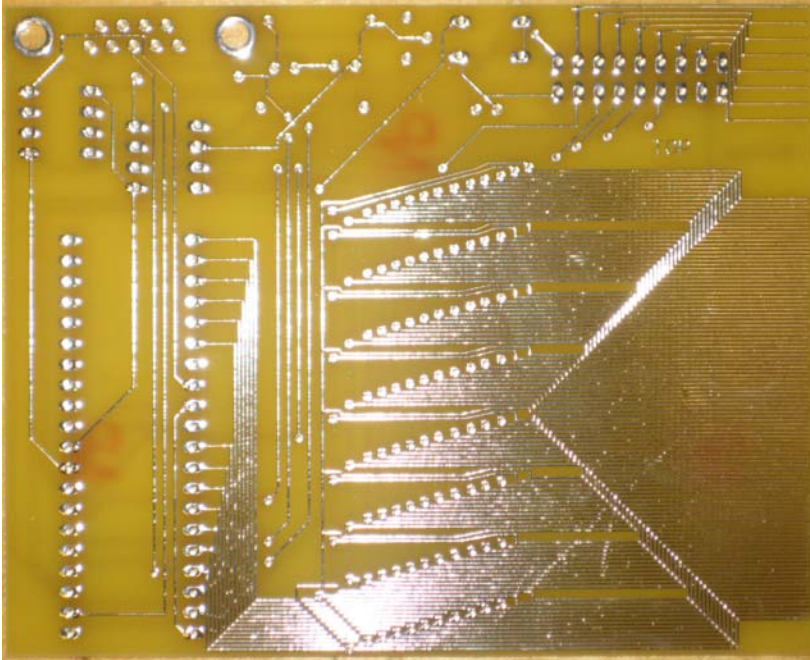


Figure 7

Below is the image of the circuit board fully wired up.

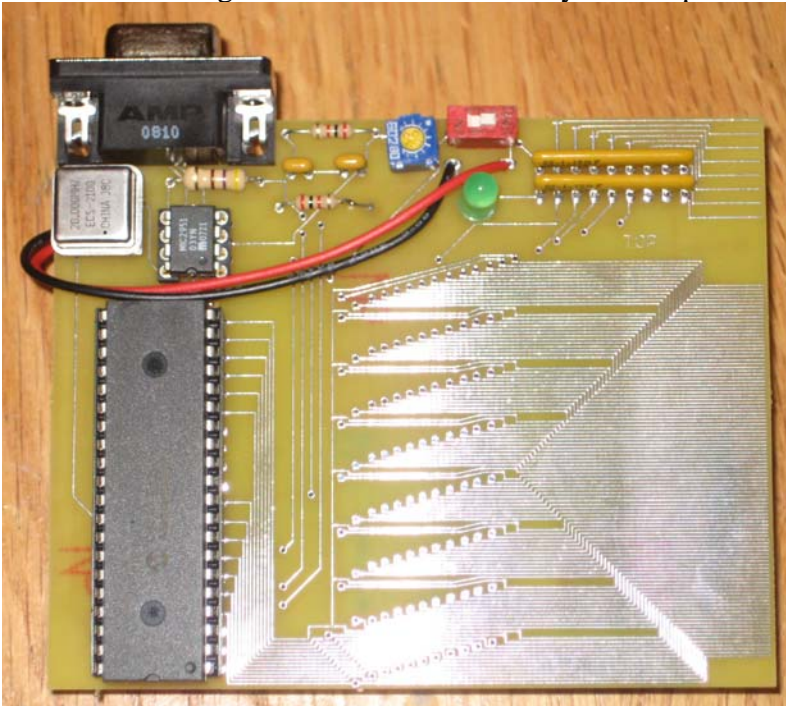
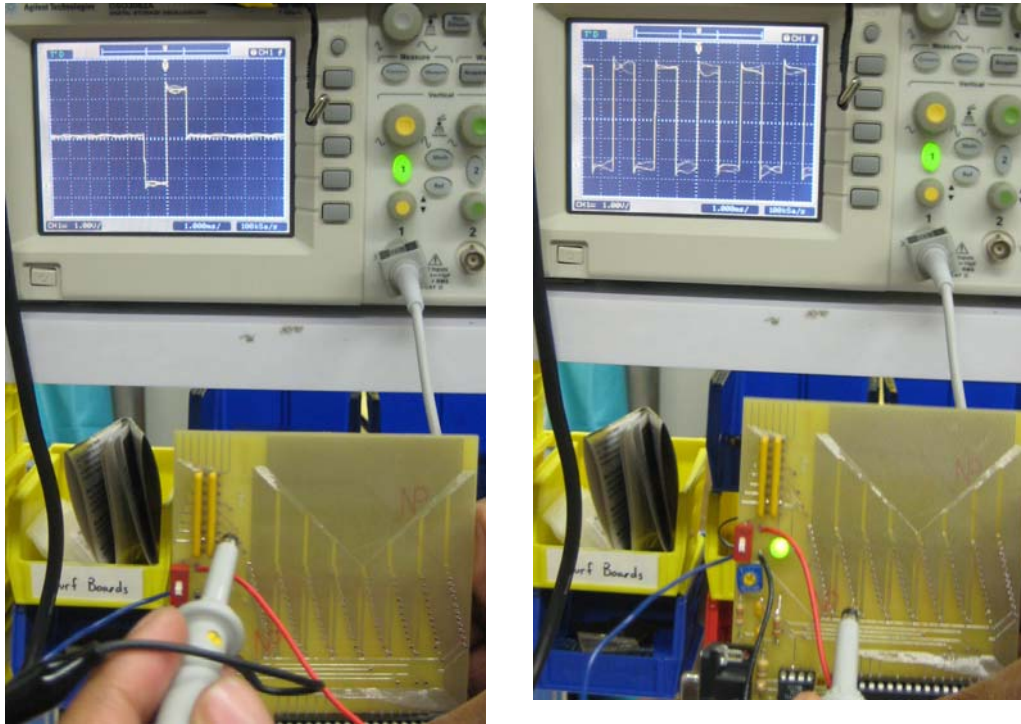


Figure 8

Below are images of the “Top” wire outputs (left) and an example of a “Bottom” wire output (right), showing the circuit board and custom software running the microprocessor as fully functional.



The only item missing from this project are the custom masks for making the ITO glass. At the time of writing this Final Report, the masks are at hand, having arrived shortly after the Final Presentation. Since the programmed microprocessor and the circuit board have been run and proven to function correctly, all that remains to be done is the making of the LCD glass, which is roughly a two day process.

We are confident that the final circuit board and LCD screen will indeed work properly based on the LCD screens we successfully manufactured for the midterm presentation. Since the circuit board and LCD design at that stage were able to render an image (albeit in low resolution), we know that the new design for the circuit board and LCD screen will also be able to render a display.

#### 4. Bill of Materials

Part	Manufacturer	Cost
USB Barcode Scanners	Metrologic, Unitech	\$215.05
Printed Circuit Boards	Alberta Printed Circuits	\$133.80
Total		\$348.85

## 5. Health, Safety, & Environmental Issues

### i. Health

There are no health issues involved with our project.

### ii. Safety

Care should be taken when using the device we have built because there is live voltage running through it and it's not completely sealed. A mild shock may result for misuse.

### iii. Environmental

There are no environmental issues with our project.

## 6. Gantt Chart

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12
Choosing a project												
Defining goals/Research												
Kymissis consultation												
1st LCD 8x8pixel												
EAGLE circuit board design												
3 <sup>rd</sup> Party board manufacturing												
Inkscape Mask Design												
PIC Programming												
Finalizing packaging												

## 7. Criticism of the Course

This course was unique in that it allowed the students to freely design an Electrical Engineering project without the need to attend lectures or be tested. Besides the beginning of the semester, students were left on their own to apply all they have learned throughout their years at Columbia into making a deliverable. Great guidance was provided whenever needed, and the senior design lab had more than enough space and equipment to meet everyone's needs.

One obvious criticism for this course is that more time can be given to complete projects. It took a few weeks at the beginning of the semester just to decide on projects and groups so a full second semester completely working on a project would have been

extremely beneficial. One other criticism for the course is that the requirements for projects are too open and vague. Not all projects are of the same difficulty level and many incorporate elements of Mechanical Engineering and Computer Science among other disciplines. Having more stringent guidelines may help students develop project ideas more easily at the beginning of the semester and allow similar level projects to be done by the whole class.

## Appendix

### Code to drive the MicroProcessor

```
' *****
' * Name      : UNTITLED.BAS
' * Author    : [select VIEW...EDITOR OPTIONS]
' * Notice    : Copyright (c) 2008 [select VIEW...EDITOR OPTIONS]
' *           : All Rights Reserved
' * Date      : 12/10/2008
' * Version   : 1.0
' * Notes     :
' *           :
' *****
' Initializations
DEFINE OSC 20      ' 20Mhz External Oscillator

' CMCON = 7        ' Turn off comparators

TRISA = %11000011  ' Set Port A to Output (as much as we use)
TRISB = %11111111  ' Set Port B to Float, high impedance
TRISC = %11110000  ' Set Port C to Output (as much as we use)
TRISD = %11111100  ' Set Port D to Output (as much as we use)
TRISE = %11111000  ' Set Port E to Output (as much as we use)

' Definitions
Row1 Var PORTB. 7  ' Row1 of LCD
Row2 Var PORTB. 6  ' Row2 of LCD
Row3 Var PORTB. 5  ' Row3 of LCD
Row4 Var PORTB. 4  ' Row4 of LCD
Row5 Var PORTB. 3  ' Row5 of LCD
Row6 Var PORTB. 2  ' Row6 of LCD
Row7 Var PORTB. 1  ' Row7 of LCD
Row8 Var PORTB. 0  ' Row8 of LCD

C1    VAR PORTD. 1
C2    VAR PORTD. 0
C3    VAR PORTC. 3
C4    VAR PORTC. 2
C5    VAR PORTC. 1
C6    VAR PORTC. 0
C7    VAR PORTE. 2
C8    VAR PORTE. 1
C9    VAR PORTE. 0
C10   VAR PORTA. 5
C11   VAR PORTA. 4
C12   VAR PORTA. 3
C13   VAR PORTA. 2

R1mode Var TRISB. 7  ' mode setting of R1
R2mode Var TRISB. 6  ' mode setting of R2
R3mode Var TRISB. 5  ' mode setting of R3
R4mode Var TRISB. 4  ' mode setting of R4
R5mode Var TRISB. 3  ' mode setting of R5
R6mode Var TRISB. 2  ' mode setting of R6
R7mode Var TRISB. 1  ' mode setting of R7
R8mode Var TRISB. 0  ' mode setting of R8

C1mode Var TRISD. 1  ' mode setting of C1
C2mode Var TRISD. 0  ' mode setting of C2
C3mode Var TRISC. 3  ' mode setting of C3
C4mode Var TRISC. 2  ' mode setting of C4
C5mode Var TRISC. 1  ' mode setting of C5
C6mode Var TRISC. 0  ' mode setting of C6
C7mode Var TRISE. 2  ' mode setting of C7
C8mode Var TRISE. 1  ' mode setting of C8
C9mode Var TRISE. 0  ' mode setting of C9
C10mode Var TRISA. 5  ' mode setting of C10
C11mode Var TRISA. 4  ' mode setting of C11
C12mode Var TRISA. 3  ' mode setting of C12
C13mode Var TRISA. 2  ' mode setting of C13

' End of Definitions
' Variables
```



Display VAR Byte[8] 'Eight rows of 8 bit numbers which represent which pixels to turn on or off  
 Extra VAR Byte[8]

```
Display[0] = %01111100
Extra[0]   = %00000000
Display[1] = %01000010
Extra[1]   = %00000000
Display[2] = %01000010
Extra[2]   = %00000000
Display[3] = %01111100
Extra[3]   = %00000000
Display[4] = %01111100
Extra[4]   = %00000000
Display[5] = %01000010
Extra[5]   = %00000000
Display[6] = %01111100
Extra[6]   = %00000000
Display[7] = %01000010
Extra[7]   = %00000000
```

'Note: Last two bits of Display[x] are 0's (fillers),  
 'and last bit of Extra[x] is 0 (filler).

time CON 1 ' 60 frames per second  
 waits CON 0

'Update Display or repeat

'To Do : Serial Port Stuff

'Display Cycle  
 Loop:

```
magi cnum VAR BYTE
magi cnum = %01111111
index VAR Byte
i var byte
j var byte
temp VAR BYTE
temp1 VAR BYTE
temp2 VAR BYTE
temp3 var byte
setd var BYTE
setc var BYTE
midc var BYTE
extr var BYTE
sete var BYTE
seta var BYTE
mida var BYTE
num VAR BYTE
num = 0
```

```
For index = 0 To 7
  temp = display[num]
  extr = Extra[num]
  temp3 = temp << 4
  TRISB = magi cnum 'turn on a specific row
  PORTB = magi cnum 'magi cnum selects the rows in order and makes sure the selected
row
```

```
setd = temp >>6
PORTD = setd
midc = temp << 2
setc = midc >> 4
PORTC = setc
sete = extr >> 5
PORTE = sete
mida = extr << 3
seta = mida >>3
PORTA = seta
num = num+3
num = num//8
pause time
```

```
        PORTC = ~PORTC : PORTB = ~PORTB: PORTD = ~PORTD : PORTA = ~PORTA : PORTE = ~PORTE
    'Invert all ports
        temp1 = magicnum>>3      'move on to the next row
        temp2 = magicnum<<5
        magicnum = temp1|temp2
        pause time

    next

goto loop
END
```