The Infinity Portal – Craig A. Lindley – 03/16/2011

OK, I'll admit it. I'm a sucker for colored flashing lights especially if controlled by a micro processor (uP). So recently when I came upon a really good deal on RGB LEDs on eBay and another really good deal on the new Arduino Uno processor board I knew I had to build something but I wasn't sure quite what. As luck would have it, as I was clearing out my parents home I found an ***Infinity Mirror*** I had purchased for my father in the 1980's. All of the sudden I knew what I should build, an updated version of an Infinity Mirror with multi-color LED light sources controlled by an Arduino. Since this was to be a major update to the Infinity Mirror concept, I decided to call my creation an ***Infinity Portal***.

For those not familiar with what an Infinity Mirror is, it is usually a smallish enclosure similar to a shadow box that one looks into which has light sources (typically white) around the interior perimeter. The single layer of lights looks to extend far beyond the depth of the the enclosure with the lights seeming to repeat 20 to 30 times in concentric patterns. So in other words, the reflected lights seem to go on for six to eight feet inside of an enclosure that is only inches deep.

I had to determine just how the Infinity Mirror effect was accomplished if I was going to build one and it turns out the effect is easy to reproduce. Regardless of the size or shape of an Infinity Mirror they are all based on the same concept and construction. Internally, an Infinity Mirror consist of one fully reflective mirror, one partially reflective/partially transparent mirror and the light sources sandwiched between them. When a light ray from a light source strikes one of the mirrors, the ray is reflected in accordance with the Law of Reflection: the angle of incidence equals the angle of reflection**.** The reflected image then reflects off the second mirror back toward the first, and so on to infinity, assuming the mirrors are parallel. The details of the pattern are altered by distortions and reflective losses in the semi-transparent mirror, small variations in the angle of the mirrors, and by the view point from which the pattern is observed.

So to build an Infinity Portal requires an enclosure of some type, a fully reflective mirror mounted in the rear of the enclosure, a series of uP controlled RGB LED light sources and a partially reflective mirror through which the observer looks. Hardware aside, one also requires some clever software to drive the LEDs in bright, creative and colorful ways.

Figures One and Two show the Infinity Portal I built and that will be discussed in this article. Commercial examples of Infinity Mirrors can be found at http://lightenergystudio.com/infinitymain.html amongst other places on the Internet. As with any one off project like this, I experienced a few *issues* while building my portal which I will describe at the appropriate points in the article.

In this article I will describe how the hardware and software for the Infinity Portal work but I will leave the packaging to you and your imagination. I made my enclosure out of half inch MDF which I painted black with a facade made of walnut.

The Portal Hardware

32 RGB LEDs are used in this design with eight mounted on the each of the four sides of the enclosure. When you consider that each RGB LED is really three separate LEDs in a single package, you soon realize that we are really talking about controlling 96 LEDs in total. Individual control over each LED amounts to a lot of drivers that the uP has to control. Luckily Texas Instruments produces a chip for just such applications called the TLC5940 (see Resources for a pointer to a data sheet). There is a lot to these chips but for our application you can think of them as made up of a serial shift register driving 16 PWM (Pulse Width Modulated) constant current drivers. These chips are made to be cascaded together to control lots and lots of LEDs but even with 16 channels of control per chip it would require six TLC5940's to control 96 LEDs in a typical design. Fortunately I used multiplexing in this design to control the LEDs which reduces our TLC5940 chip count to just two devices. Each LED channel supports 12 bits of PWM brightness data which range in value from 0 (off) to 4095 (full brightness). **NOTE:** TLC5940's are constant current sinks so they must be used with common anode RGB LEDs.

One issue I had while building my portal was the mass of wiring needed to connect all 96 LED channels to the controller hardware. I used small gauge solid wire to connect the LEDs but even so, the wire bundle was bigger than I had anticipated which made the space in my enclosure cramped to say the least. Keep this fact in mind when deciding how to package your portal. The insides of my portal are shown in Figure Three.

LED multiplexing requires both hardware and software support. In terms of hardware, I divided the 32 RGB LEDs into four rows of eight. Each of the rows have a common buss to which the anode lead of each LED in the row are connected. See the schematic, Figure Four, for clarification.

A PNP power Darlington transistor, controlled via a digital output pin from the Arduino, controls the current source for each row. When the digital output is low, current flows to the LEDs in a given row. When the digital output is high, all LEDs in the row are turned off. While multiplexing, only one row of LEDs should be on at a time.

Serial data for controlling each LED channel is fed to the two cascaded TLC5940 chips via the SPI (Serial Peripheral Interface) interface provided by the Arduino. Data is shifted out in big endian format with the most significant bits going first. The three color LEDs which comprise a RGB LED are connected to sequential TLC5940 channels. The blue LED channel is the least significant while the red LED channel is the most significant. As designed, only 12 of the 16 channels available on each TLC5940 are being used. You, however, could use all of the LED channels.

The current available for each channel's constant current sink is set by a resistor connected to pin 20 of each TLC5940 chip. In my design I used 10K ohm, 20 turn trimmers for setting the current. I have the current set to around 20 mA and the LEDs are plenty bright enough even with multiplexing. As set, all of the components in the Infinity Portal run cool to the touch which is important for an enclosure without ventilation.

I had a few requirements for powering the portal. First, I didn't want to use a wall wort type of supply because I didn't want any electricity consumed when the portal was turned off. Second, I wanted to power the portal with just a single, 5V supply. Finally, I thought it better to buy a regulated power supply instead of building one myself. In looking around I found a surplus 5V, 12 amp power supply with over and under voltage protection and current limiting that was small (3” x 5” x 1”) and cheap, $5.75 from allelectronics.com. A 12 amp power supply was severe overkill as the portal will run from the power supplied by the USB cable from my MacBook Pro laptop. Any power supply capable of a couple of amps at 5V will easily power the portal with plenty of reserve power to spare.

The Portal Software

It turns out using an Arduino processor to control TLC5940 chips for control of LEDs and stepper motors is a popular past time. So much so that an Arduino library exists for TLC5940 chips. This library (see Resources) was provided to the Arduino community by Alex Leone and is controlled in accordance with the GNU General Public License. By using this library you needn’t understand all of the details of the Arduino/TLC5940 interaction. The TLC5940 library exists in two forms. The first, for controlling TLC5940 chips serially chained together and the second for controlling TLC5940's used in multiplexing schemes. Unfortunately, the multiplexing version of the library doesn't work as provided but can be made to work with a few small changes to the hardware design and the library code. See http://www.arduino.cc/cgi-bin/yabb2/YaBB.pl?num=1286580054 for the details if you are interested. The design presented here implements these changes allowing multiplexing to work.

For those of you who haven't worked with Arduino before, there is a free set of development tools available (see Resources). Figure Five shows the Integrated Development Environment or IDE which comes with the tools package. It is both simple and useful for Arduino code development. The Arduino programming language is based on C/C++ so it should be familiar to many. There are two entry points to all Arduino programs: setup() and loop(). The setup() function is called first and it is within this function where you do all hardware initialization. Subsequently the loop() function is called which contains all of the operational code for your program.

Once you have downloaded and installed the Arduino tools on your development machine you connect a USB cable to your Arduino processor board. After writing and verifying (compiling and linking) your code, you click a button in the IDE to transfer the executable code to your target. Print statements to the pseudo serial port in the code provide a means of debugging your program.

The file, *InfinityPortal.pde* (available electronically see Resources), is the sum total of all of the code I developed for the Infinity Portal. This file contains the fixes to the TLC5940 library, code for configuring the library for multiplexing and the code for each of the display patterns (of which there are currently 24) used in the portal. In its current form, the Infinity Portal's code selects display patterns randomly from the time the portal is turned on until it is turned off.

Before showing how display patterns are developed it is interesting to note there are two asynchronous processes running simultaneously within the code. These are referred to as the foreground and the background process. Both these processes share a single data buffer; the foreground process puts data into the buffer and the background process shifts the data out of the buffer to the TLC5940 chips.

The background process runs at interrupt time when the PWM timer times out indicating the full PWM cycle for controlling LED brightness has completed. A counter called *shiftRow* is consulted at interrupt time to determine which row of the multiplexed LED data is to be shifted out to the TLC5940s and then which of the four row selects is pulled low enabling that row of LEDs. Afterwards, *shiftRow* is incremented so that a different row will be selected next interrupt time. This background process repeats continuously without regard for the actual data that is being sent to the TLC5940's for each row.

The foreground process is where display patterns run. Code implementing the display pattern writes data into the shared data buffer where the background process picks it up and sends it out. It is important to understand/remember that once data is placed in the data buffer it stays there until overwritten. If you want to light an LED and then turn it off you have to first set the data and then zero the data to turn it back off.

There is a lot of code in *InfinityPortal.pde* but you can ignore most of it. What you must understand is that the 32 LEDs are addressed by number (0 .. 31) as shown below:

```
     23 22 21 20 19 18 17 16
    ________________________
    |         top          |
  24|                      |15
  25| l                  r |14
  26| e                  i |13
  27| f                  g |12
  28| t                  h |11
  29|                    t |10
  30|                      |9
  31|                      |8
    |       bottom         |
    _______________________
      0  1  2  3  4  5  6  7
```

The following functions from the code are used for pattern development:

Function Name	**Operation**
TlcMux_clear();	Clears the data buffer causing all LEDs to turn off
delay(milliseconds);	Delays program execution for specified number of milliseconds
setLEDOff(ledNum)	Turns the specified LED off
setLEDRGB(ledNum, red, green, blue)	Set ledNum LED to the specified red, green and blue

Function Name	Operation
	values. Valid values 0 .. 4095.
void setLEDRGB(ledNum, struct RGB rgb)	Same as above except a structure contains the RGB value to set

As an example, the following code turns all LEDs on in an alternating red, green pattern:

```
TlcMux_clear();                     // Turn off all LEDs

 for (int i = 0; i < 32; i++) {     // Loop through all 32 LEDs
   if (i % 2 == 0) {                // Is this an even numbered LED ?
     setLEDRGB(i, 4095, 0, 0);      // Turn ith LED to red, full brightness
   }
   else  {
     setLEDRGB(i, 0, 4095, 0);      // Turn ith LED to green, full brightness
   }
 }
```

As mentioned, the Infinity Portal has 24 display patterns built in. As the simple code above illustrates it is really easy to add new patterns or change existing ones. Figure Six shows the Infinity Portal displaying a full spectrum of colors.

Portal Packaging

There are no end of possibilities for packaging a Infinity Portal. I've seen Infinity Mirrors packaged in a square box (similar to what I did), in a rectangular box, a triangular box, a round box and even a star shaped box. The important things are to have the semi-transparent mirror facing the viewer and to have the mirrors mounted parallel to each other. The light sources (RGB LEDs) are mounted around the perimeter of whatever enclosure you use, spaced half way between the parallel mirrors. If the lights are not equally spaced between the mirrors the reflections you see in the portal will be unequally spaced. This may be an effect you want to utilize in your packaging.

Since I have access to woodworking tools I made my portal out of MDF with walnut trim. Once finished, the MDF box was painted black as this color scheme matches the furniture in our living room where the portal resides.

Finally, a word must be said about the partially reflective mirror used in the portal. Three possibilities were investigated: “one way mirror” glass, partially reflective acrylic and the use of reflective window film over plain glass. For cost considerations I decided to use mirrored window film available at most hardware stores over plain glass. The film must be applied to the glass using soapy water so that it lays out flat with a minimum number of bubbles. This is easy to do after a little practice.

Resources

Arduino information can be found at: http://arduino.cc.
The free development environment can be downloaded from: http://arduino.cc/en/Main/Software
A TLC5940 data sheet is available at http://www.ti.com/lit/gpn/tlc5940.
The Arduino Tlc5940 and Tlc5940Mux libraries can be found at: http://code.google.com/p/tlc5940arduino/
The Infinity Portal code (*InfinityPortal.pde*) is available from the Nuts & Volts website: http://nutsvolts.com
Reflective window film (Gila #PRS361) was purchased at Lowe's as were the 12”x12” rear mirror and the window glass for the partially reflective mirror.

BIO

Craig ("Mr. Flashing Lights") has been fascinated with flashing colored lights since he was a kid playing in rock bands. This fact is evidenced by the articles he has written for this magazine which include building a digital color organ (Jan 2008) and a laptop computer picture frame (Jan 2010) running his custom ArtRays software. He lives in the mountains of Colorado and can be contacted at calhjh@gmail.com. When not messing about with electronics and/or computer projects, he does a solo musical act around Colorado Springs.

Figure One
Infinity Portal Front View

My enclosure measures 17” x 17” x 4.75” and is constructed from MDF and walnut wood.

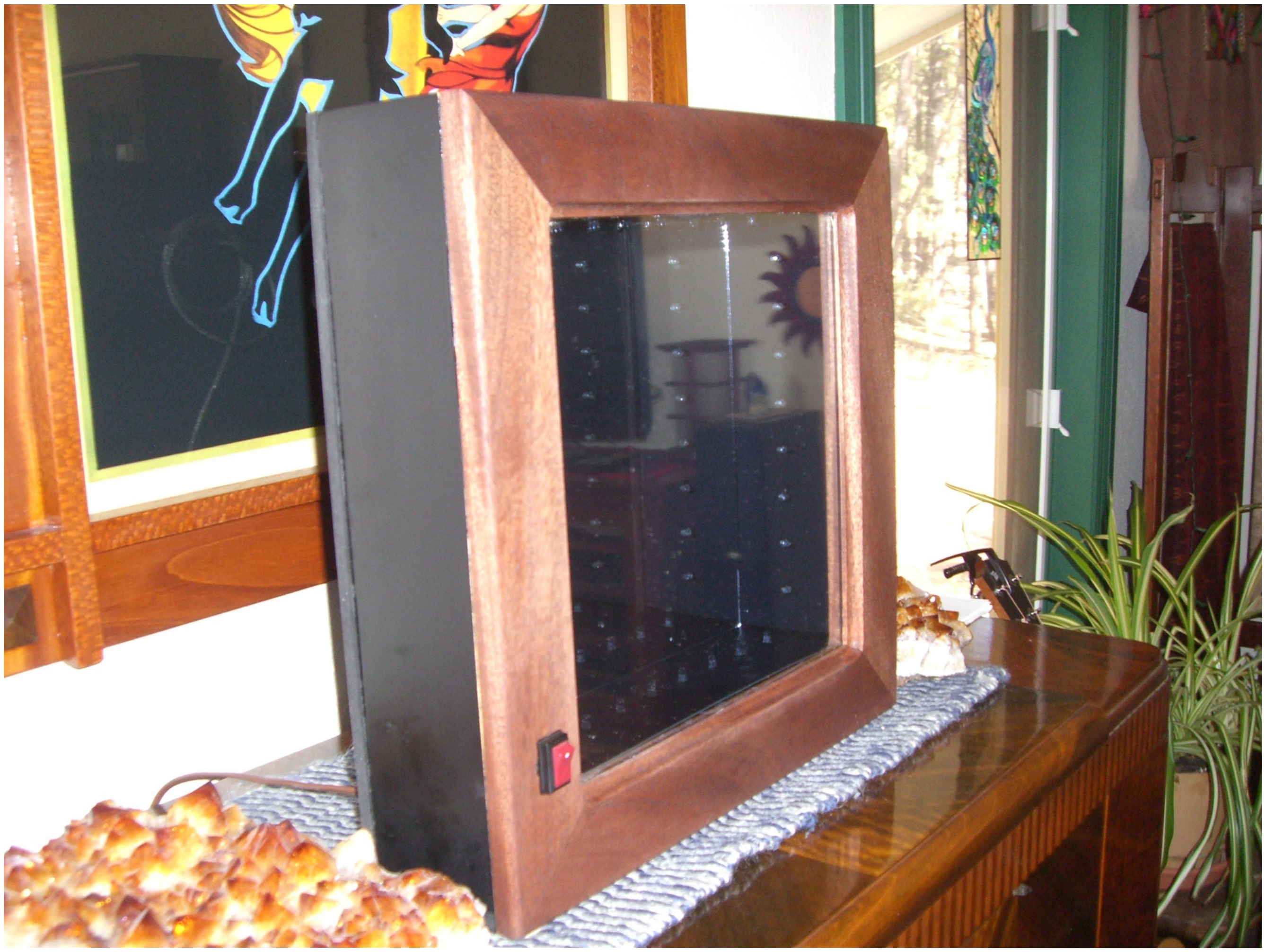

Figure Two
Infinity Portal Rear View

NOTE: The USB programming cable and power cable protrude from the rear of the portal. I used velcro to secure the USB cable when not in use.

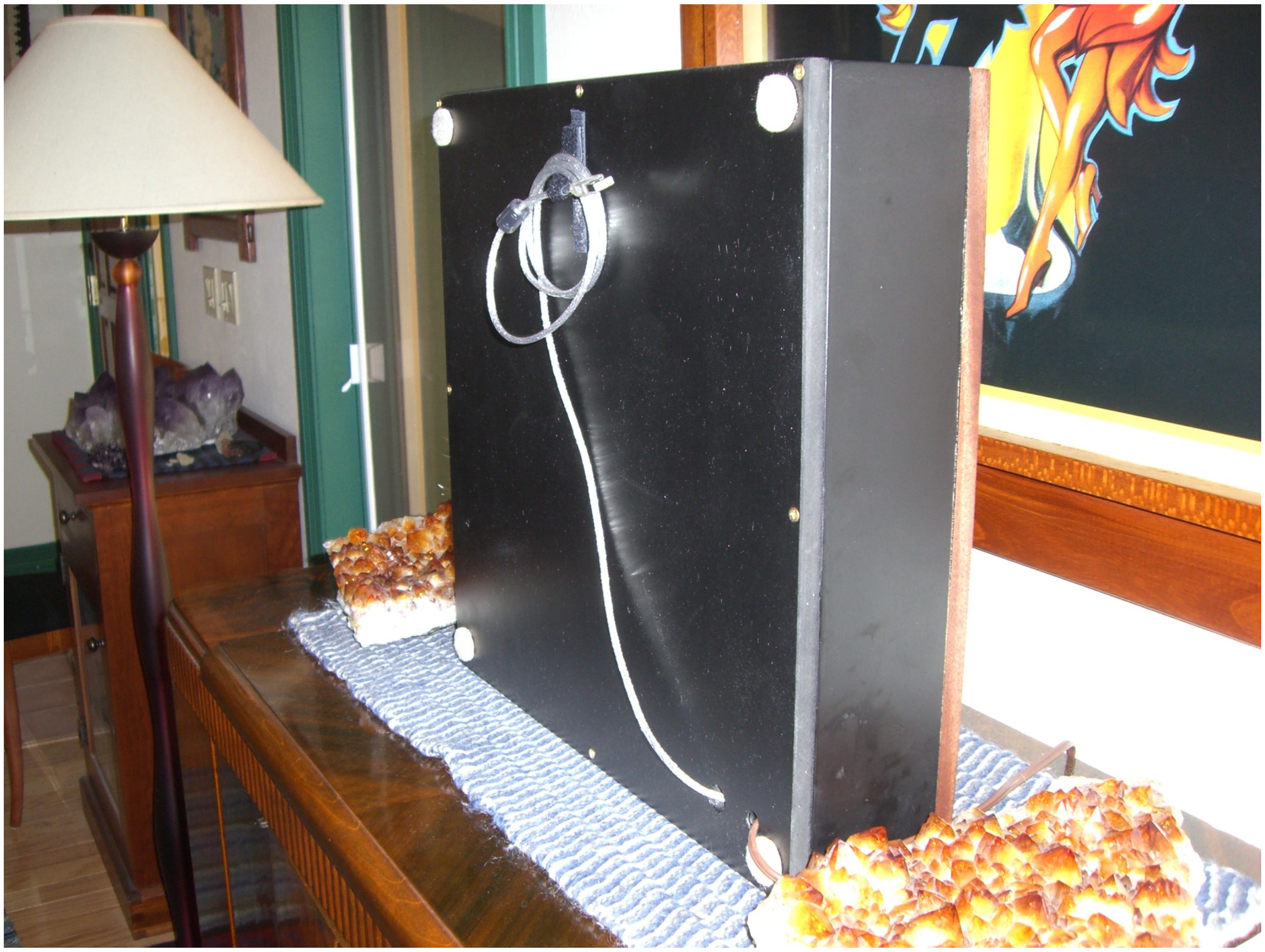

Figure Three
The insides of the Infinity Portal

All components were mounted to the back of the enclosure with the exception of the power switch and the partially reflective mirror which are mounted on its front. The power supply is shown on the left. The Arduino Uno (blue PCB) is near the front and the custom circuitry is built onto two brownish pref board on right. The 32 RGB LEDs are mounted on black matt boards which frame the rear 12” x 12” mirror. The USB programming cable is attached to the Arduino and passes out the back of the enclosure through a hole.

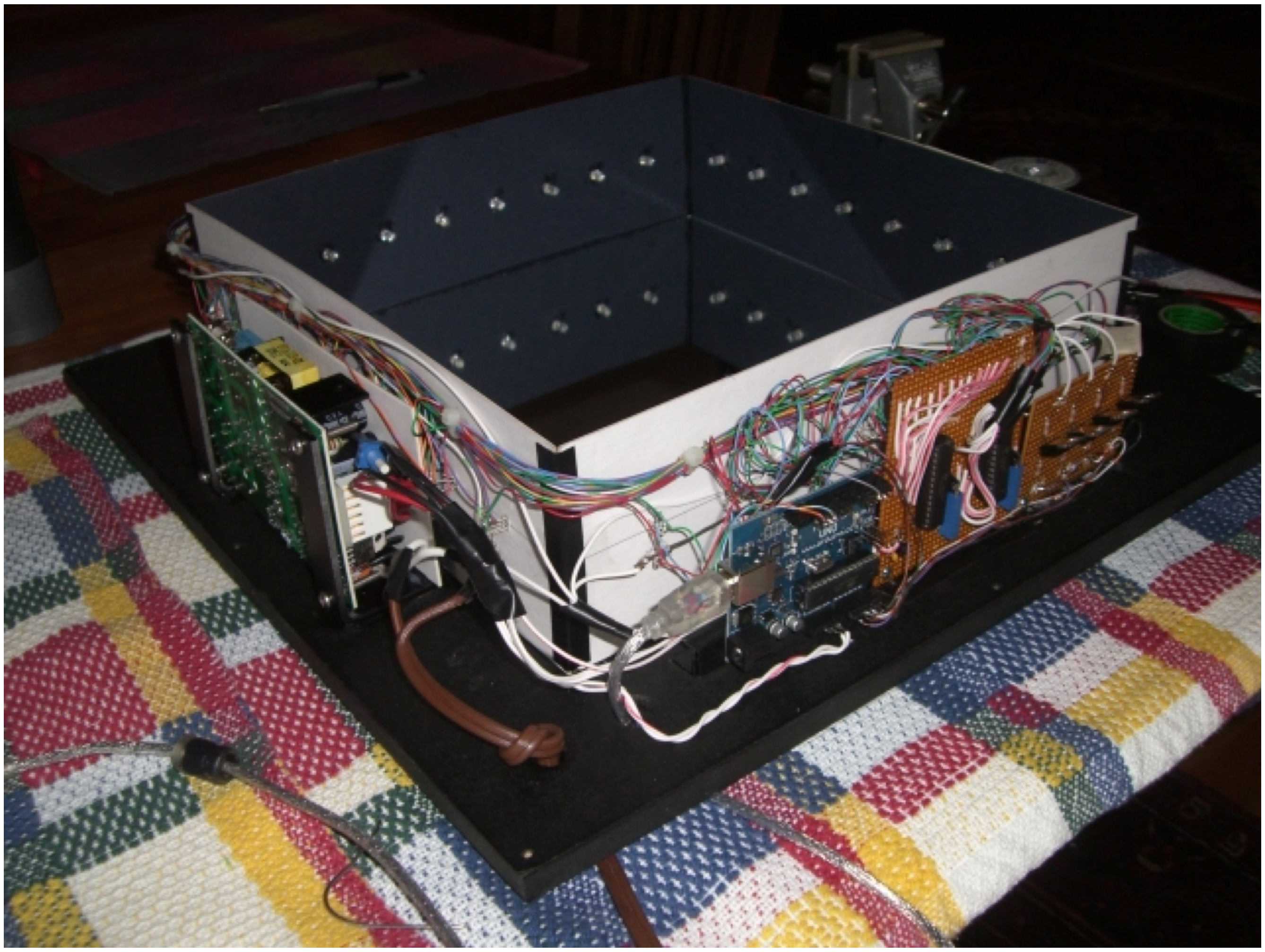

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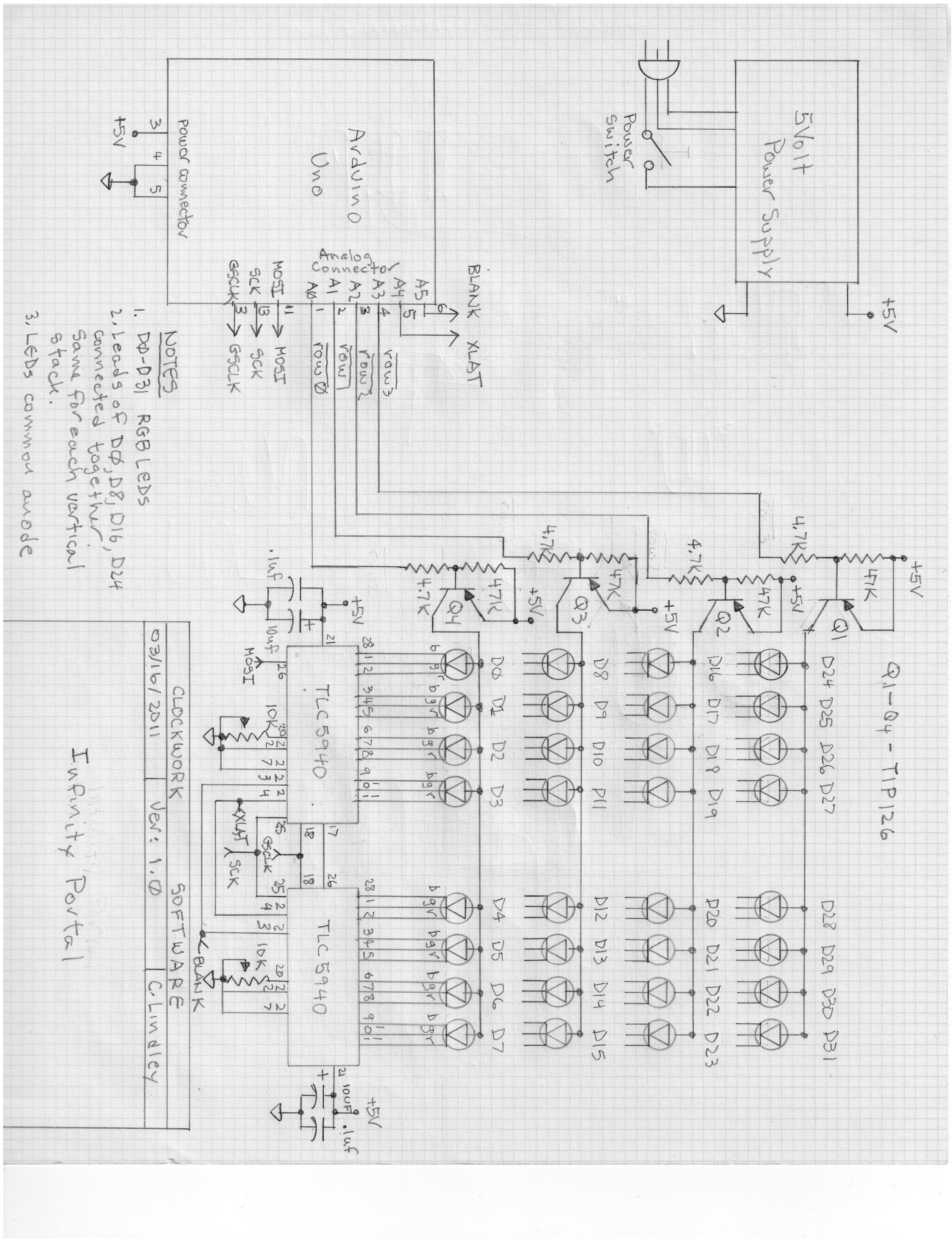
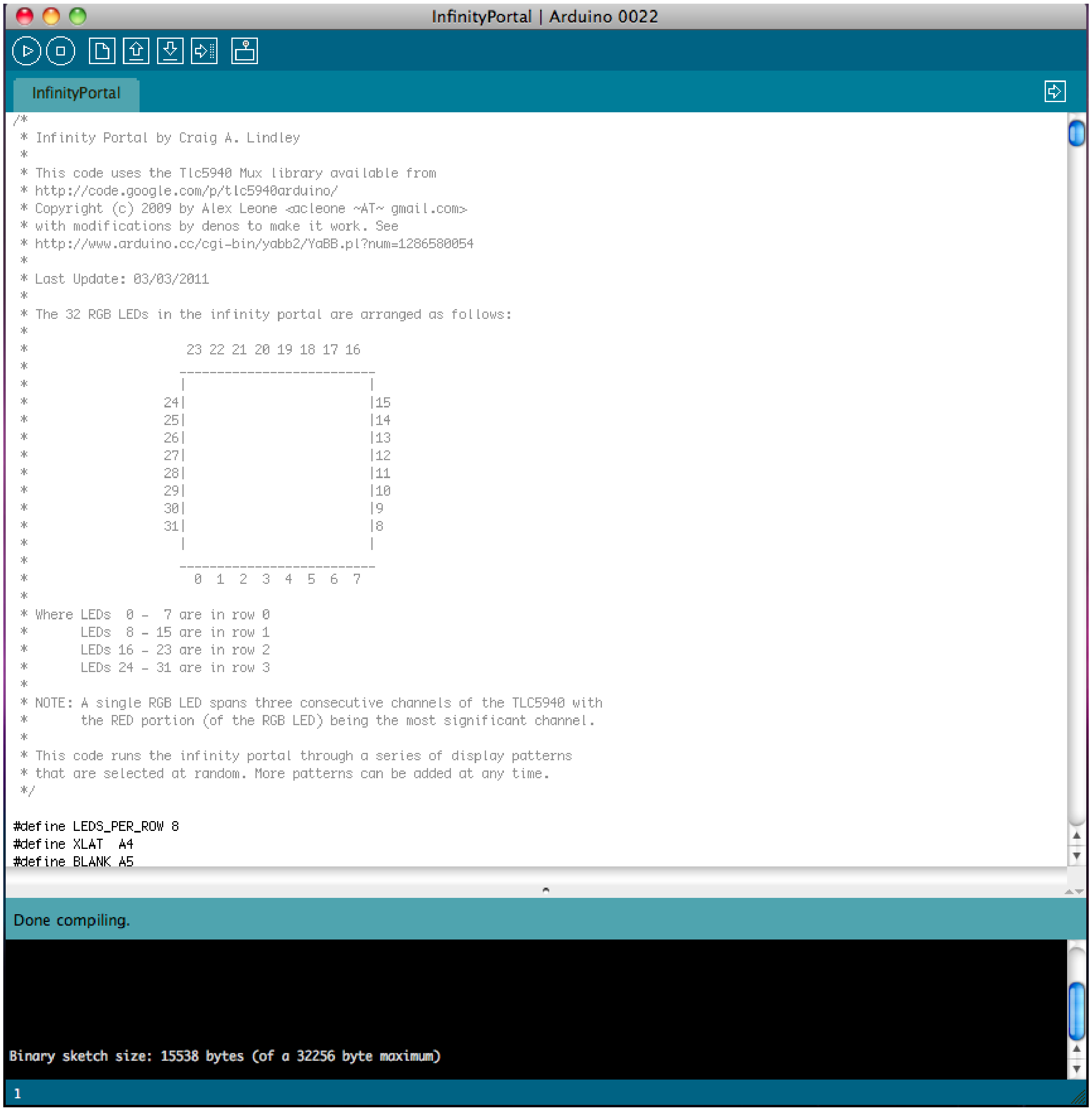
Figure Four
The Infinity Portal Schematic



NOTES
1. D0-D31 RGB LEDS
2. Leads of D0, D8, D16, D24 connected together. Same for each vertical stack.
3. LEDs common anode

Figure Five
The Arduino IDE

Displaying the *InfinityPortal.pde* code.



```
/*
 * Infinity Portal by Craig A. Lindley
 *
 * This code uses the Tlc5940 Mux library available from
 * http://code.google.com/p/tlc5940arduino/
 * Copyright (c) 2009 by Alex Leone <acleone ~AT~ gmail.com>
 * with modifications by denos to make it work. See
 * http://www.arduino.cc/cgi-bin/yabb2/YaBB.pl?num=1286580054
 *
 * Last Update: 03/03/2011
 *
 * The 32 RGB LEDs in the infinity portal are arranged as follows:
 *
 *                      23 22 21 20 19 18 17 16
 *
 *                     --------------------------
 *                     |                        |
 *                   24|                        |15
 *                   25|                        |14
 *                   26|                        |13
 *                   27|                        |12
 *                   28|                        |11
 *                   29|                        |10
 *                   30|                        |9
 *                   31|                        |8
 *                     |                        |
 *
 *                     --------------------------
 *                       0  1  2  3  4  5  6  7
 *
 * Where LEDs  0 -  7 are in row 0
 *       LEDs  8 - 15 are in row 1
 *       LEDs 16 - 23 are in row 2
 *       LEDs 24 - 31 are in row 3
 *
 * NOTE: A single RGB LED spans three consecutive channels of the TLC5940 with
 *       the RED portion (of the RGB LED) being the most significant channel.
 *
 * This code runs the infinity portal through a series of display patterns
 * that are selected at random. More patterns can be added at any time.
 */

#define LEDS_PER_ROW 8
#define XLAT  A4
#define BLANK A5
```

Done compiling.

```
Binary sketch size: 15538 bytes (of a 32256 byte maximum)
```

1

Figure Six
The Infinity Portal displaying a rainbow of colors. The LED colors are much more vivid than this photo indicates.