LED Wall

By Evan Dagg

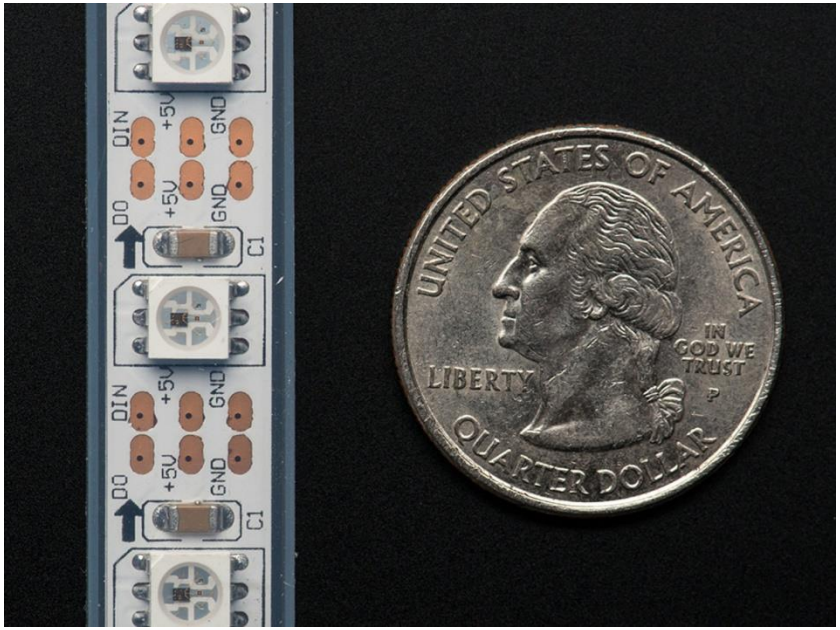
The goal of the project was to make a 60 x 30 RGB LED display. This consisted of 30 strands stacked vertically with 60 RGB LEDS on each.

Materials

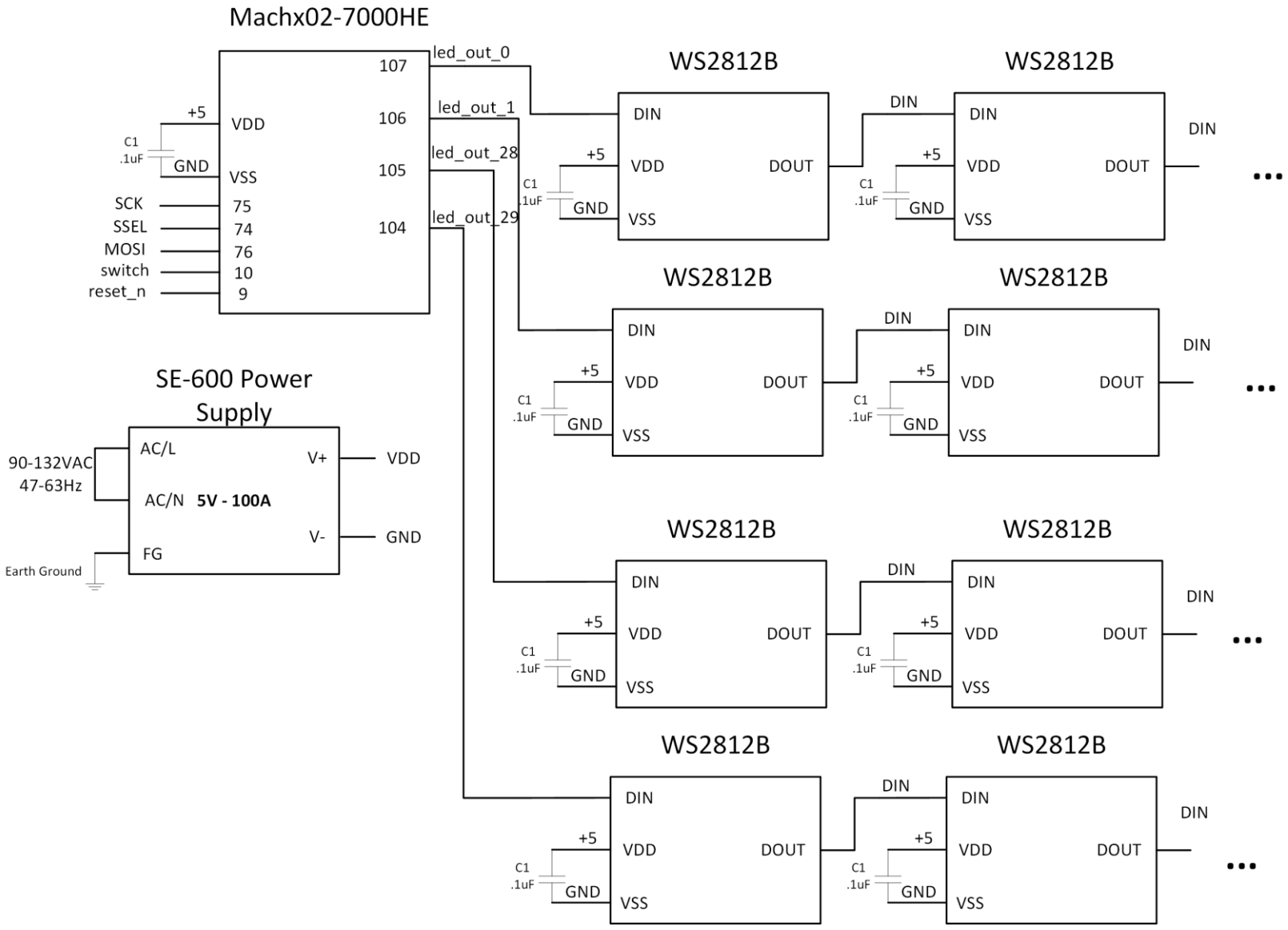
- FPGA – Machx02-7000HE
  - Lattice Diamond Software
- Microcontroller – Teensy 2.0 (ATmega32U4)
- LED – WS2812B RGB LED

LED – WS2812B RGB LED

- Flexible PCB strand of 60 LEDS/meter
- LED is RGB
- +5V, GND, DIN/DO



Schematic


Machx02-7000HE
107
106
105
104
VDD
VSS
+5
C1
.1uF
GND
SCK
SSEL
MOSI
switch
reset_n
75
74
76
10
9
led_out_0
led_out_1
led_out_28
led_out_29
WS2812B
DIN
VDD
VSS
DOUT
SE-600 Power Supply
AC/L
AC/N
FG
V+
V-
5V - 100A
90-132VAC
47-63Hz
Earth Ground
VDD
GND

LED – WS2812S RGB LED

Power

- Max single LED current = 60mA
  - Full brightness, white
- 60 LED per strand – max strand current = 3.6A
- 1800 LEDS total – max current = 108A @ 5V

LED – WS2812S RGB LED

- 24 bits of data/LED (1 byte per R, G, B)
- 256 levels of brightness for each color

Composition of 24bit data:

G7	G6	G5	G4	G3	G2	G1	G0	R7	R6	R5	R4	R3	R2	R1	R0	B7	B6	B5	B4	B3	B2	B1	B0

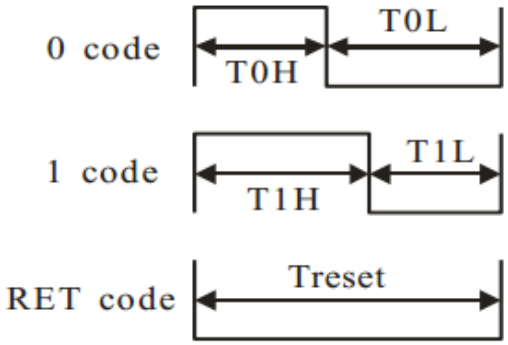
Note: Follow the order of GRB to sent data and the high bit sent at first.

Data transfer time(TH+TL=1.25μs±600ns)

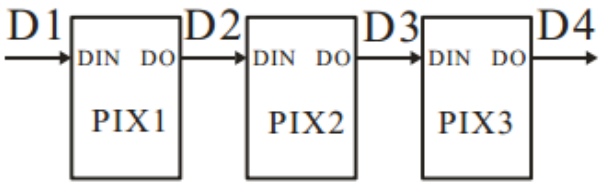
T0H	0 code ,high voltage time	0.4us	±150ns
T1H	1 code ,high voltage time	0.8us	±150ns
T0L	0 code , low voltage time	0.85us	±150ns
T1L	1 code ,low voltage time	0.45us	±150ns
RES	low voltage time	Above 50μs	

LED – WS2812S RGB LED

- Data is cascaded through LEDs



Cascade method:



LED – WS2812S RGB LED

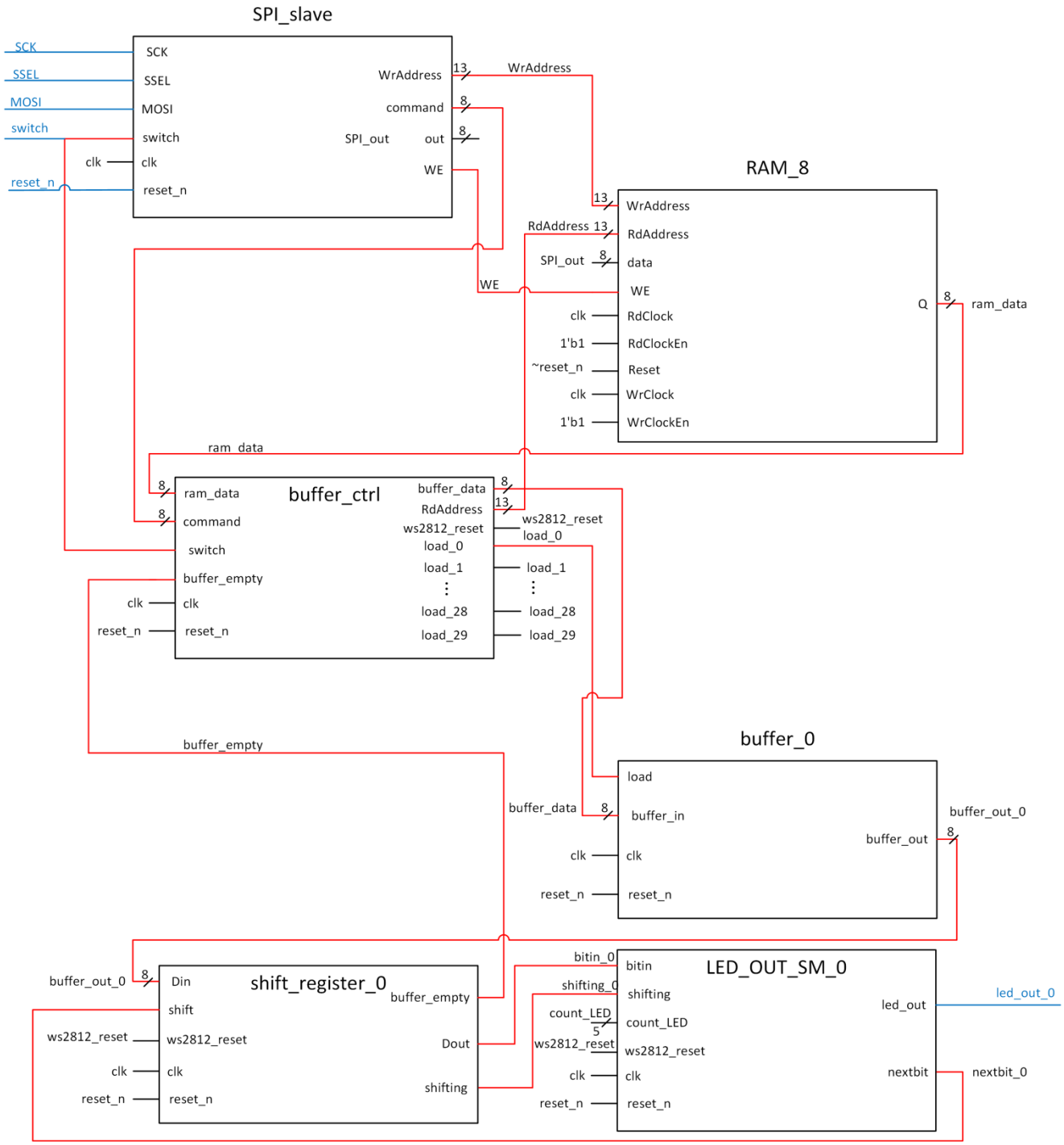
- Testing on a microcontroller
  - Example of LED strands working
- Much easier to test on microcontroller vs. FPGA
- Now to implement on the FPGA
  - With an FPGA you can update each strand at the same time in parallel, a microcontroller would update in series taking 30x longer

Inputs

- SCK
- SSEL
- MOSI
- switch
- reset_n

Outputs

- LED_out_0
- LED_out_1
- …
- LED_out_28
- LED_out_29



FPGA – Machx02-7000HE

LED_OUT_SM part 1

```
always @ (posedge clk, negedge reset_n)
    begin
        if(!reset_n)
            begin
                state <= my_reset;
                nextbit <= 0;
                led_out <= 0;
            end
        else
            begin
            case (state)
                my_idle : begin
                            led_out <= 1;
                            nextbit <= 0;
                            if ( (count_LED == 16) && (bitin) )          //if bitin = 1 count to 16(.8uS) and switch states
                                state <= my_one;
                            else if ( (count_LED == 8) && (!bitin) )     //if bitin = 0 count to 8(.4uS) and switch states
                                state <= my_zero;
                            else if (ws2812_reset)                       //reset signal from buffer_ctrl produces a low signal at output
                                begin
                                    led_out <= 0;
                                    state <= my_reset;
                                end

                          end
                my_zero : begin //bitin = 0
                            led_out <= 0;   //set LED_out to low
                            if (count_LED == 24)    //stay low for a count of 16(.85uS) totaling a count of 24
                                begin
                                    state <= my_reset;
                                    nextbit <= 1;   //ready for nextbit
                                end
                          end
```

FPGA – Machx02-7000HE

LED_OUT_SM part 2

```
            my_one   : begin //bitin = 1
                         led_out <= 0;   //set LED_out to low
                         if (count_LED == 24)    //stay low for a count of 16(.85uS) totaling a count of 24
                             begin
                                 state <= my_reset;
                                 nextbit <= 1;   //ready for nextbit
                             end
                       end
            my_reset: begin
                         nextbit <= 0;
                         if (ws2812_reset)
                             led_out <= 0;
                       else if (shifting)    //once shifting happens I have new data and reset is over
                         state <= my_idle;
                       end
            default : begin
                         state <= my_reset;
                         led_out <= 0;
                       end
    endcase
    end
end
```

FPGA – Machx02-7000HE

- Issue
  - FPGA SPI module takes bytes, stores to RAM, increments RAM WrAddress, and repeats
    - This effectively writes to one row before moving on to the next column
  - But FPGA updates each column at the same time, moves to next column, and repeats.
  - Need to accommodate for this in buffer_ctrl

FPGA – Machx02-7000HE

buffer_ctrl

```
assign RdAddress = row_count + column_addr;
    always @ (posedge clk, negedge reset_n)
        begin

        .
        .
        .

        if (row_count != 5760)
            row_count <= row_count + 180;
        else if (buffer_empty)
            begin
                column_addr <= column_addr + 1;
                row_count <= 0;
            end
        end
```

Microcontroller – Teensy 2.0 (ATmega32U4)

- To demo it we needed something to be displayed
- 5400 byte array
  - 3 bytes = 1 LED
  - 0x8000FF = 50% green, 0% red, 100% blue
  - Update array, transmit over SPI

Microcontroller – Teensy 2.0 (ATmega32U4)

- SPI Transmit Array– 1800 byte array

```
void transmit (void)
{
    int i;
    for (i = 0; i < 1800; i++)                          //1800 = # of LEDS
    {
        switch (array[i])                               //switch case based on the number in the array location
        {
            case 0  :   SPI_masterTransmit(0x00);       //no LED on
                        SPI_masterTransmit(0x00);
                        SPI_masterTransmit(0x00);
                        break;
            case 1  :   SPI_masterTransmit(0xFF);       //green LED
                        SPI_masterTransmit(0x00);
                        SPI_masterTransmit(0x00);
                        break;
            case 2  :   SPI_masterTransmit(0x00);       //red LED
                        SPI_masterTransmit(0xFF);
                        SPI_masterTransmit(0x00);
                        break;
            case 3  :   SPI_masterTransmit(0x00);       //blue LED
                        SPI_masterTransmit(0x00);
                        SPI_masterTransmit(0xFF);
                        break;
            default :   SPI_masterTransmit(0x00);       //default turns off LEDS
                        SPI_masterTransmit(0x00);
                        SPI_masterTransmit(0x00);
                        break;
        }
    }

}
```

Microcontroller – Teensy 2.0 (ATmega32U4)

Example - 1

0x84	0x82	0xFE	0x80	0x80	0x00
0	0	0	0	0	0
0	**1**	**1**	0	0	0
1	0	**1**	0	0	0
0	0	**1**	0	0	0
0	0	**1**	0	0	0
0	0	**1**	0	0	0
0	0	**1**	0	0	0
1	**1**	**1**	**1**	**1**	0

```
const unsigned char ascii [] = {
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, //space
    0x00, 0x00, 0xBE, 0x00, 0x00, 0x00, //!

    0x7C, 0xA2, 0x92, 0x8A, 0x7C, 0x00, //0
    0x84, 0x82, 0xFE, 0x80, 0x80, 0x00, //1
    0x84, 0xC2, 0xA2, 0x92, 0x8C, 0x00, //2
    0x44, 0x92, 0x92, 0x92, 0x6C, 0x00, //3
    0x30, 0x28, 0x24, 0xFE, 0x20, 0x00, //4
    0x9E, 0x92, 0x92, 0x92, 0x62, 0x00, //5
    0x78, 0x94, 0x92, 0x92, 0x60, 0x00, //6
    0x02, 0xE2, 0x12, 0x0A, 0x06, 0x00, //7
    0x6C, 0x92, 0x92, 0x92, 0x6C, 0x00, //8
    0x0C, 0x92, 0x92, 0x52, 0x3C, 0x00, //9
}
```

Transmit A Char

Example - 1

0x84	0x82	0xFE	0x80	0x80	0x00
0	0	0	0	0	0
0	**1**	**1**	0	0	0
1	0	**1**	0	0	0
0	0	**1**	0	0	0
0	0	**1**	0	0	0
0	0	**1**	0	0	0
0	0	**1**	0	0	0
1	**1**	**1**	**1**	**1**	0

```
void transmit_char ( char letter, int p)
{
    int number = 0, n, i;
    block = p/10;
    if (letter == ' ')
        number = 0;
    else if ( letter <= 57)      //Numbers
        number = letter - 46;
    else if ( letter <= 90)      //Capital
        number = letter - 53;

    for (i = 0; i < 7; i++)                  //7 corresponding to 7 rows
    {
        for (n = 0; n < 6; n++)          //6 corresponding to each column
        {
            if ( (ascii[number*6+n] & (0b00000010 << i )) != 0 )
            {
                array[ (block*540) + (i*60) + (59 - p*6 - n) ] = 1;
            }
        }
    }
}
```

Demo

- Snakes on A Wall
- Issues
  - Floating Ground?
  - Ground Loop?
- Questions?