CAPSTONE

MERRIMACK COLLEGE

Touch-Screen Smart Mirror Concept and Implementation

EEN4960A
Design Project I

Kyle Skey

Revision C

Revision Date: December 6, 2016

Revision History

Revision	Date	Author	Notes
0	09/12/2016	K. Skey	Document Creation
A	09/19/2016	K. Skey	Added Specs Section to Market Assessment Added High and Low Level Block Diagrams Added Prelim Tx Array Schematic Added Tx/Rx Sensitivity Section Updated BOM
B	09/26/2016	K. Skey	Changed power supply specs from 5V to 3.3V Added PCB Layout for Demo-Day Board
C	12/6/2016	K. Skey	Added Schematics Added PC Layouts for Tx/Rx Boards Removed Demo-Day Board Removed LTSpice Schematic Removed Rx/Tx Sensitivity

1 Market Assessment

1.1 Introduction

In recent years, the Internet of Things (IoT) market has been expanding, as Wi-Fi speeds increase and embedded processing modules decrease in size and become more affordable. One such product that has immerged from this technology trend is the smart mirror (Figure 1). The most basic of smart mirrors involves placing a 2-way acrylic mirror on top of a computer or TV display. While keeping the background black, any light colored text will emit though the mirror glass and be seen on the user side. While this implementation is novel at best, it lacks customization and usability from someone who knows little or no programming.

Figure 1: Example Basic Smart Mirror

The biggest problem with the hobbyist smart mirror is it has no user interface. There is no easy way for the user to interact with it. To remedy this, an IR touch screen interface can be constructed into the frame of the mirror. The IR touch screen interface can be sold as a kit for hobbyists to install their own custom sized interface, or integrated into a smart mirror product. With the accompaniment of software and application development, users of the smart mirror could be able to type text, load marketplace applications (Android, Apple, etc.), and customize their smart mirror to display information relevant to them.

1.2 Specifications

- Resizable range (active area): Up to 52” x 29” (60” Display)
- Maximum resolution = 4096 x 4096
- Response time: 50-60 rps (response per second).
- Operating temperature: 0 to 70 degree C.
- Interface: USB 1.1 or higher.
- Power: 3.3VDC, 500 mA (power supply included).
- Operating system: Windows 7, 8,10 & Linux
- Driver: Linux/Windows mouse emulation.

2 Technical Assessment

2.1 Touch Screen Overview

There are two mainstream techniques for touch screen construction, capacitive and infrared (IR). While the capacitive touch screen is more desirable in terms of form-factor, its implementation on such a large of scale is difficult and expensive. Therefore, the touch screen will be developed using a grid of IR transmitters and receivers. IR LED transmitters will be placed in one horizontal and vertical axis of the display, side by side. IR Phototransistor receivers will be placed opposite of the transmitters, one for each transmitter. This will create a grid of IR light in the horizontal and vertical axis of the display (Figure 2). When an object (preferably a finger) enters the grid, it will block the IR light from the receiver in the horizontal and vertical axis, resulting in a calculated coordinate of that object. This coordinate can then be sent to a computer as a "click" of a mouse at a certain location.

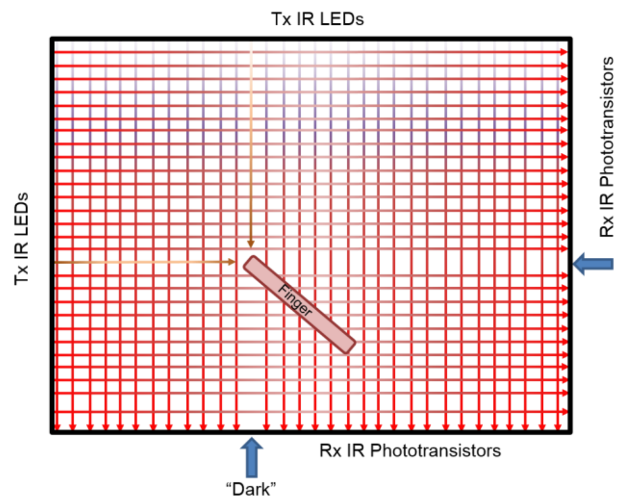


Figure 2: IR Grid Diagram

2.2 IR Tx/Rx Circuits

In theory, it is a simple task to use one IR LED to illuminate one IR Phototransistor and turn that into a binary signal which gets read by a microprocessor. The challenge is having over 200 transmitter-receiver pairs properly aligned and all reading into the same processor. This large scale implementation presents many challenges in the design and fabrication process, which include, but are not limited, to the following:

- Power consumption – Each LED uses approx. 100mA per unit. 200 x 100mA x 3.3V = 66W!!!
- Interference – When trying to read a receiver, adjacent LEDs could provide illumination that set off a false negative
- I/O lines – Microprocessors do not have 200+ I/O lines and using multiple microprocessors is too expensive and tricky
- PCB Construction – In order to have a small form-factor, PCBs will be used to mount the LED Tx/Rx circuits. It will be costly to produce a PCB that is not standard size, especially if there are errors in the first iteration

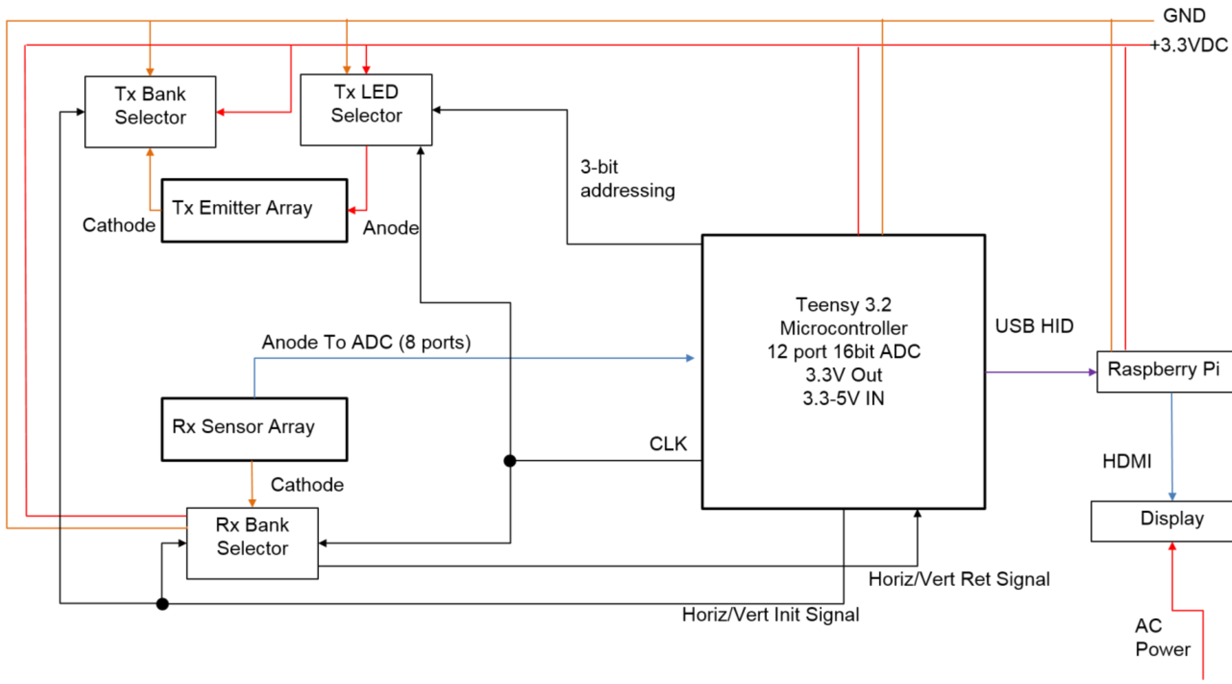
Many of these challenges are solved by only illuminating one LED at a time and taking a reading only on its paired receiver. This will solve the power consumption and interference problems as only one light will be on at a time. To solve the I/O line problem the Tx/Rx units will have to be grouped in units of 8, using transistors, and chained together. These basic groups can be placed in larger groups of 3 or 4 and placed on a PCB. The PCBs are designed in such a way that they are serialized in their communication with the controller. This can be achieved numerous ways, but initial analysis shows the following chips to be the best course of action:

- 74HCT138 - 3-to-8-line decoder/demultiplexer – This will be used to toggle the Tx LEDs, one at a time, within the larger group of 8. The addressable inputs match that of the ADC tied to the receiver being read.
- 74HCT164 - 8-bit serial-in, parallel-out shift register – This will be used to toggle each group of 8. These chips will be daisy-chained from PCB to PCB so that the last valid high in the parallel-out will trigger a high in the serial-in for the next chip.

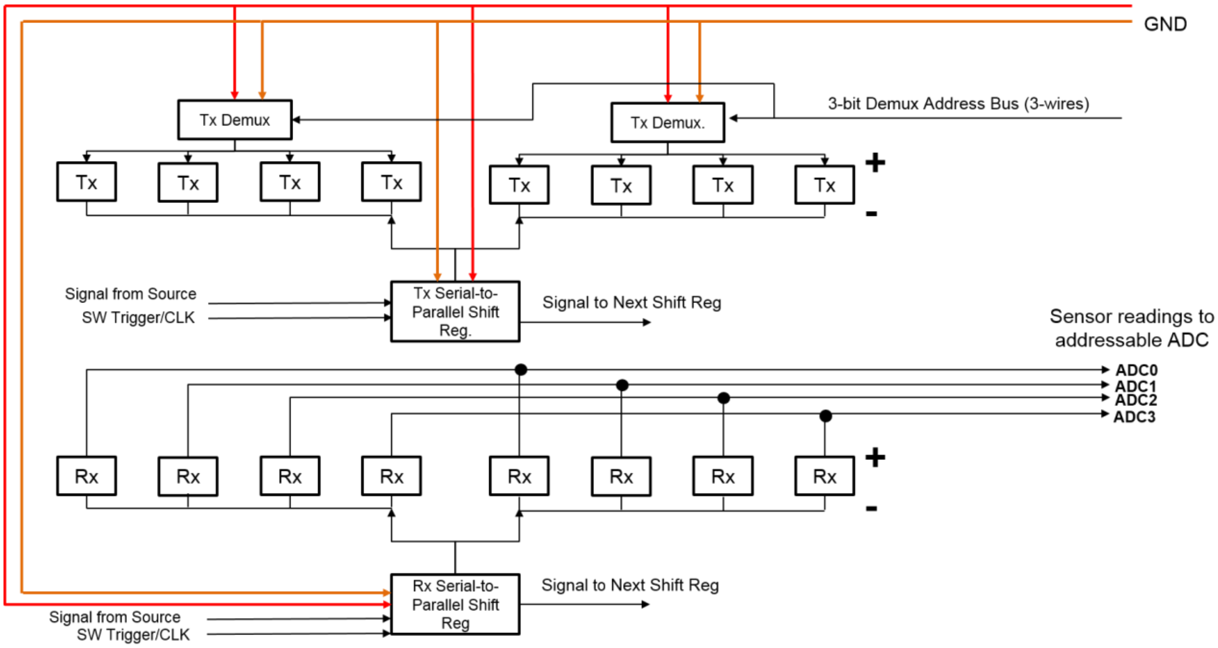
With a clever software triggers and I/O scheme, it is possible to modularize both Tx and Rx boards

2.3 Block Diagrams

2.3.1 High Level

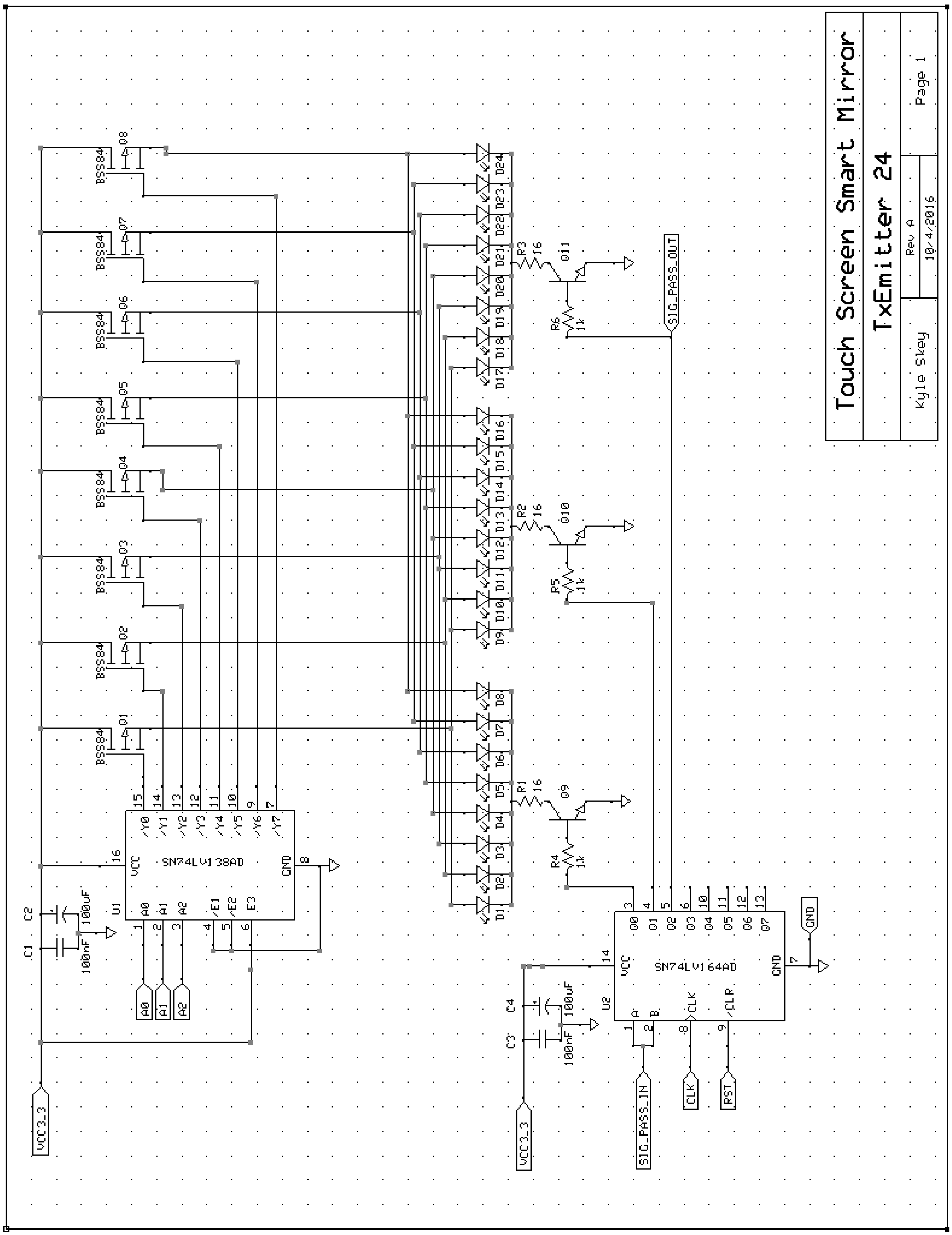


2.3.2 Low Level Rx/Tx Config

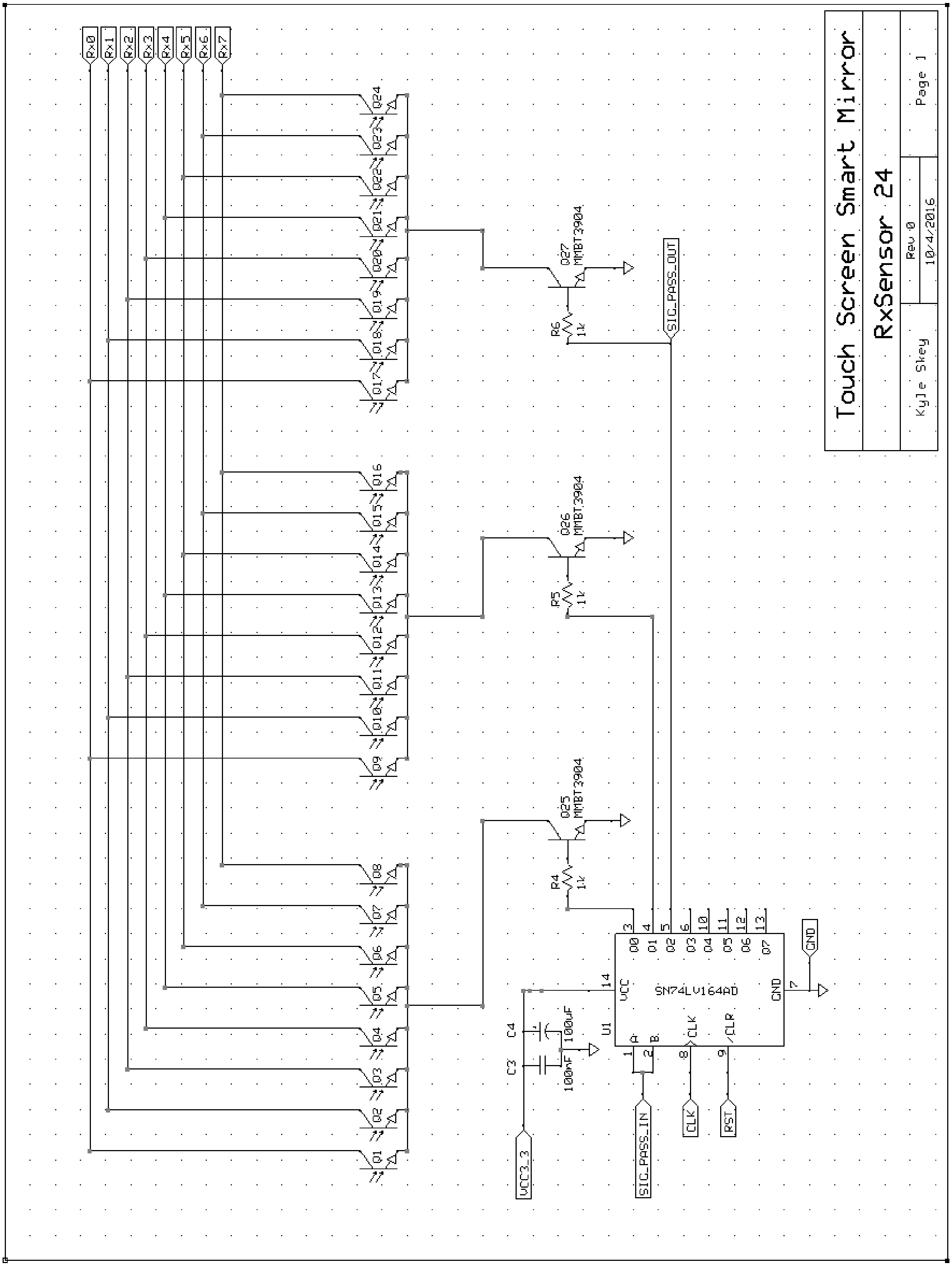


2.4 Schematics

2.4.1 Tx Board

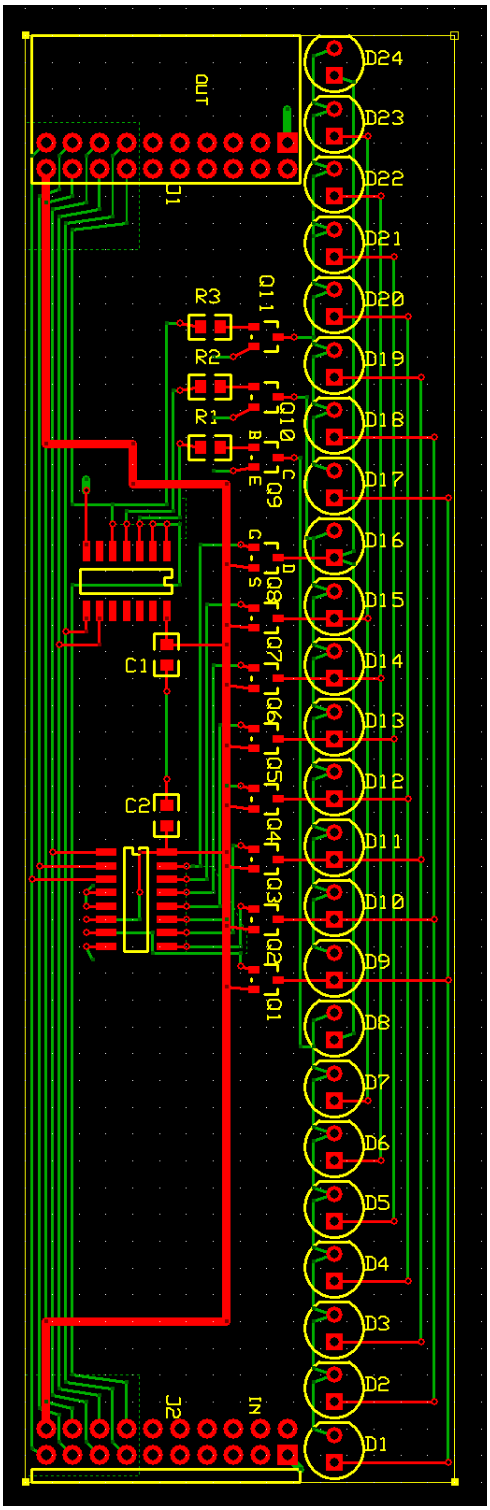


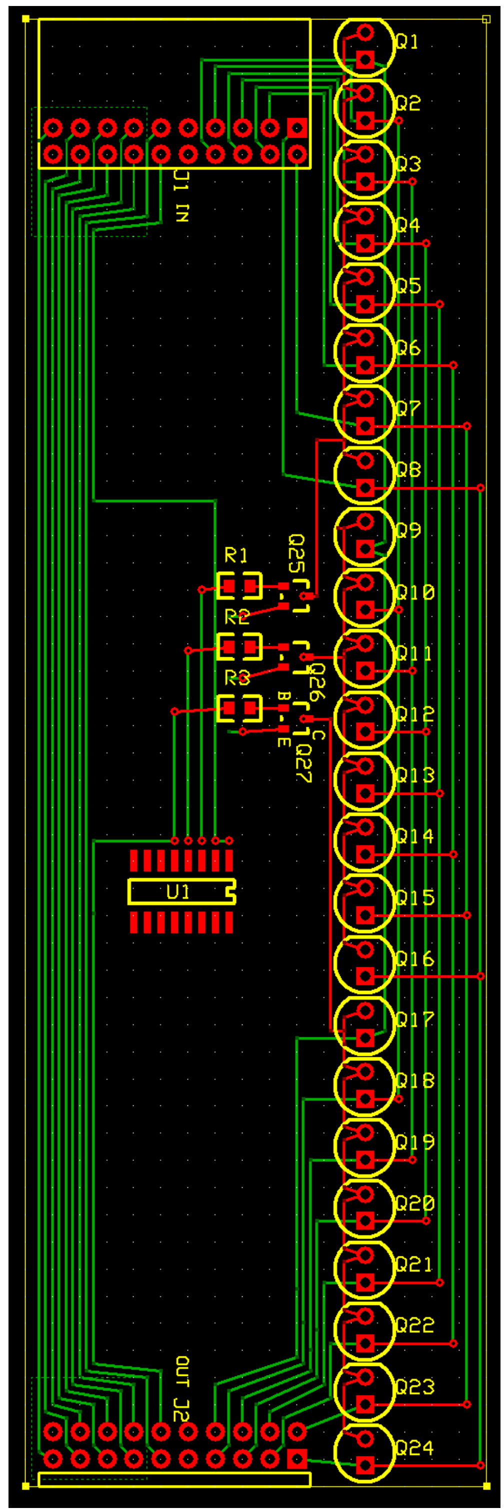
2.4.2 Rx Board


Touch Screen Smart Mirror
RxSensor 24
Kyle Skey
Rev 0
10/4/2016
Page 1
Rx0
Rx1
Rx2
Rx3
Rx4
Rx5
Rx6
Rx7
Q25 MMBT3904
Q26 MMBT3904
Q27 MMBT3904
R4 1k
R5 1k
R6 1k
SIG_PASS_OUT
SN74LV164AD
U1
VCC
GND
CLK
/CLR
C3 100nF
C4 100uF
VCC3_3
SIG_PASS_IN
CLK
RST
GND

2.5 PCB Layout

2.5.1 Tx Board/Rx Board





3 Financial Assessment

From preliminary analysis, the following parts and services will be needed to complete this project. A microprocessor will be chosen once IR grid circuit and clocking scheme is determined. Some prices have been estimated.

Name	Vendor	Part Number	Cost/Unit	Units	Total	Description
IR Tx LED	Digi-Key	QED123-ND	$0.26	250	$66.06	EMITTER IR 880NM 100MA RADIAL
IR Rx Detector	Digi-Key	QSD123A4R0CT-ND	$0.33	250	$82.50	PHOTOTRANSISTOR DETECTOR 5MM
74HCT138	Digi-Key	296-1608-5-ND	$0.50	10	$5.00	IC 3-8 LINE DECODER/DEMUX 16-DIP
74HCT164	Digi-Key	296-2097-5-ND	$0.56	20	$11.20	IC 8-BIT SHIFT REGISTER HS 14DIP
NPN Transistor	Digi-Key	2N3904	$0.06	40	$2.40	TRANS NPN 40V 0.2A TO-92
Resistors	Unk	Unk	$10.00	1	$10.00	Biasing Resistors
Connectors	Unk	Unk	$20.00	1	$20.00	Board-Board Connectors
32" LED TV	Bestbuy.com	NS-32D310NA17	$100	1	$100.00	Insignia8482 32 Class 315 Diag LED 720p HDTV Black
2-Way Acrylic Glass	Unk	Unk	$50.00	1	$50.00	Mirror glass for display
Microprocessor	Adafruit	Teensy 3.2	$19.95	1	$20.00	Processor unit with built-in 16-bit ADC and USB HID capability
RaspberryPi 3	Unk	Unk	$30.00	1	$30.00	Computer to display Smart Mirror apps
PCB			$150	1	$150.00	
				Total	$508.70	