VISUAL DISPLAY RESEARCH

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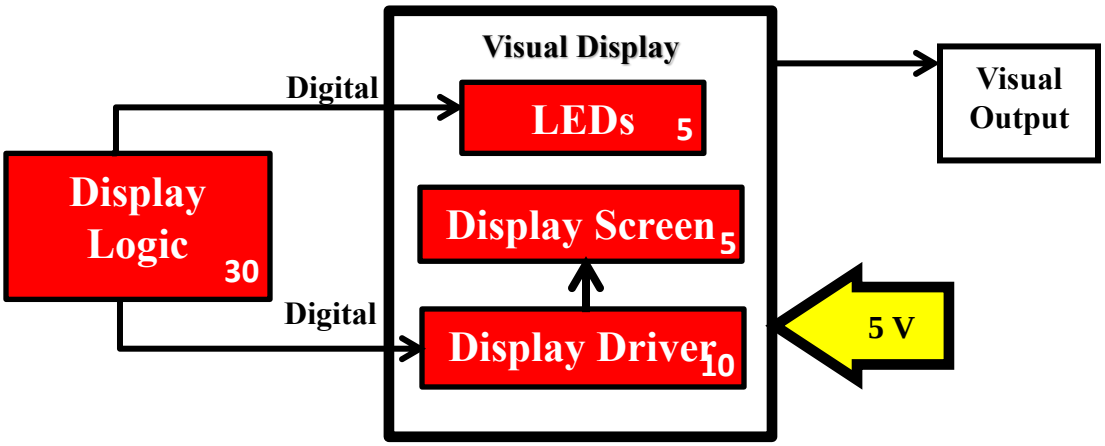
Block Diagram



Block Details:

LEDs on the surface of the shield will react when a hit, heal, stun, or reflection is detected. The elemental type of the action will also determine the color and pattern of the RGB LEDs.

A display screen will also be mounted on the shield facing the holder. It will display the hits by number and type and the thirty second timer.

Table of Contents:

LEDS

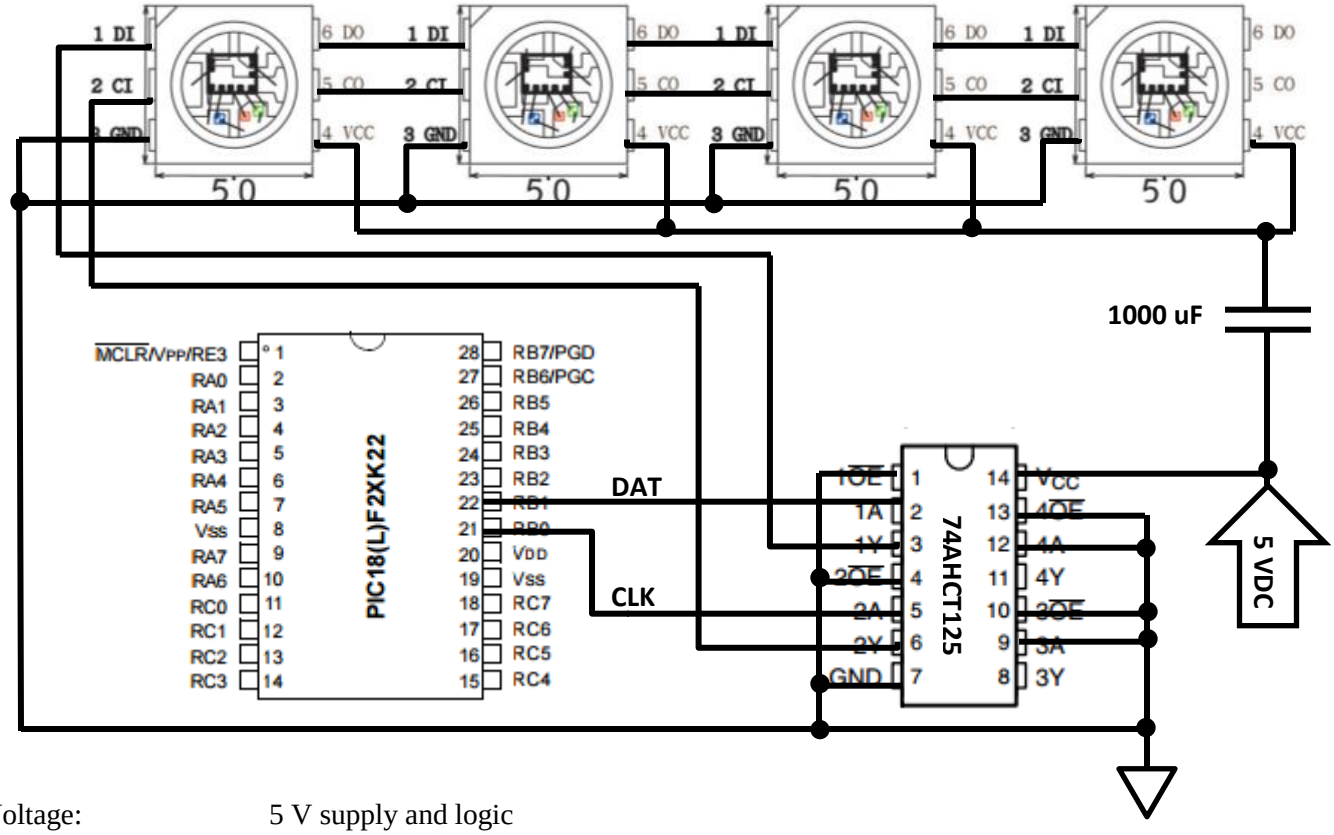
The LEDs I found to be most ideal for the shield project are the Dotstar RGB LEDs available from Adafruit. They are individually addressable, continually cycle through light patterns after talking to the MCU, and use a 2-wire protocol that saves pins and is less sensitive to timing errors. Although they pull a large amount of current, our power block was able to compensate. By using 30 LEDs and fiber optic filament to extend the light to the edges of the shield, we are able to stay under 2A. Adafruit's wide database of reference materials will also assist when prototyping.

Several alternatives were considered for the LED display. Neopixels are another Adafruit product and have even more resources available. They are only slightly cheaper than Dotstars and are more timing-sensitive. The one-pin protocol is more error prone than the SPI of Dotstars because it requires a very specific clock frequency. When we were hoping to use only the I2C communication protocol, the blinkM's were one of the few I2C RGB drivers I could find. They are too expensive for the project, however, at $12.95 per LED. Using nonaddressable regular RGB LEDs would result in a less extravagant display.

Option	**1. Dotstar LEDs**	**2. Neo Pixels**	**3. Blink M**	**4. RGB LEDs W/ Driver**
Cost	$19.95/30 LEDS	$16.95/30 LEDs	$12.95 each	$12.95/25 LEDs $14.95 Driver(8 LEDs)
Communication Protocol	"Soft" SPI	1-wire NRZ	400 kHz I2C	SPI
Fanciness	★★★★	★★★★	★★★★★	★★
Voltage/Current	5 V/1.8 A	5 V/1.8 A	3.6 V/ 60mA each	3-5 V/160 mA (8 LEDs)
Availability of References	★★★★★	★★★★	★★★	★★★★
Refresh Rate	19.2 kHz	400 Hz	5 V/102mA	----

Option 1: "Dotstar" LEDS (APA102C)

PIC registers are for example only and 74AHCT125 is only necessary if operating off 3.3 V logic.

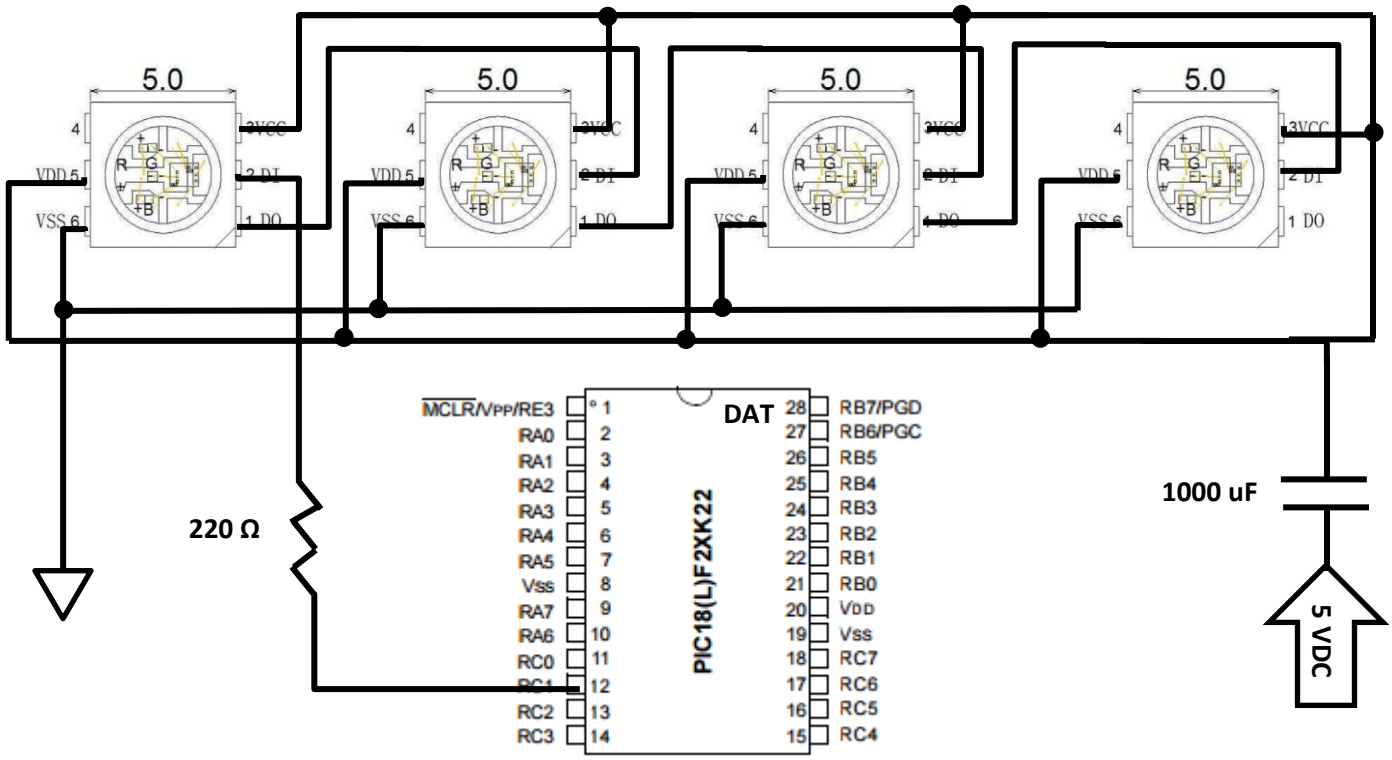


Voltage:	5 V supply and logic
Amperage:	60 mA per RGB LED, 30 LEDs can pull up to 1.8 Amps of current
Cost:	$19.95 for 30 LED strip/meter https://www.adafruit.com/products/2237
	$4.50 for 10 individual LEDs (+$4.95/10 optional PCBs)
Communication:	2-wire SPI ("soft" SPI)
Notes:	Requires 3 bytes ROM/pixel
	Continuous PWM in each LED-chip
	19.2 KHz refresh rate
	Large capacitor recommended (1000 uF) on supply voltage to protect LEDs
	Adafruit Resources
Datasheet:	https://www.adafruit.com/datasheets/APA102.pdf
Helpful Link:	https://learn.adafruit.com/adafruit-dotstar-leds

3.3 to 5 V logic shifter (74AHCT125)

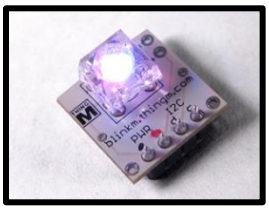
Cost:	$0.39 ($0.51 SMD) http://www.mouser.com/Search/Refine.aspx?Keyword=74AHCT125
Datasheet:	http://www.mouser.com/ds/2/405/sn74ahct125-405651.pdf

Option 2: Addressable RGB LEDs (WS2812) (NeoPixels)



Voltage:	5 -7 V
Amperage:	60 mA per RGB LED, 30 LEDs can pull up to 1.8 Amps of current
Cost:	$16.95 for 30 LED strip/meter https://www.adafruit.com/products/1376 $2.95 for 5 indiv. through-hole LEDs ($4.50 for 10 SMD w/optional $2.95 PCB)
Communication:	1-wire NRZ protocol
Notes:	Time sensitive, will not work with processors slower than 8MHz Low refresh rate (400 Hz) Large capacitor recommended (1000 uF) on supply voltage to protect LEDs 220 to 470 Ω resistor recommended on data pin Most libraries and resources only cater to Arduino Sparkfun and Adafruit Resources
Datasheet:	https://www.adafruit.com/datasheets/WS2812.pdf
Helpful Links:	https://learn.adafruit.com/adafruit-neopixel-uberguide http://www.instructables.com/id/Demystifying-4-pin-addressable-RGB- LEDS/?ALLSTEPS https://learn.sparkfun.com/tutorials/ws2812-breakout-hookup-guide/all

Option 3: Blink M: I2C Controlled RGB LED(COM-08579 ROHS)



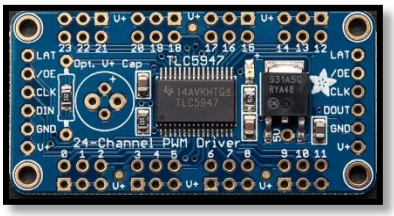
Voltage: 3.6-5 V
Amperage: 60 mA
Cost: $12.95 each https://www.sparkfun.com/products/8579
Communication: I2C
Notes: Create and save a light script or use 18 preprogrammed scripts
Datasheet: http://thingm.com/fileadmin/thingm/downloads/BlinkM_datasheet.pdf
Helpful Link: http://thingm.com//products/blinkm/

Option 4a: Non-addressable RGB LEDs (Common Anode, FD-5WSRGB-A)

Voltage: 1.9-3.4 V
Amperage: 20 mA per RGB LED, 30 LEDs can pull up 0.6 Amps of current
Cost: $12.50 for 25 LEDs
Communication: PWM
Notes: Non-addressable, have to light up all at the same time and the same color
Would require a pin and resistor for each LED leg
Datasheet: https://www.adafruit.com/datasheets/FD-5WSRGB-A.pdf
Helpful Links:

http://www.instructables.com/id/Demystifying-4-pin-RGB-LEDS-Radio-Shack-276-0028/?ALLSTEPS
https://learn.adafruit.com/rgb-led-strips
https://learn.adafruit.com/all-about-leds
https://learn.sparkfun.com/tutorials/light-emitting-diodes-leds?_ga=1.243914572.859611763.1453842146

Option 4b: W/Use of an LED Driver (TLC5947):



Voltage: 3-5 V logic, 5 V Supply
Cost: $14.95 https://www.adafruit.com/products/1429
Communication: SPI
Notes: 8 Different RGB PWM channels
Datasheet: http://www.ti.com/lit/ds/symlink/tlc5947.pdf

Optional Addition of Fiber Optic Filament:

Cost: End Glow: $2.75/100 ft. of .5 mm
$9.95/100 ft. of 1 mm
$18.95/100 ft. of 2mm
Side Glow: $0.99/ft. of 2mm

http://www.ebay.com/itm/100-FT-OF-5-MM-END-GLOW-FIBER-OPTIC-LIGHTING-FILAMENT-/182026570735?hash=item2a61a10bef:g:RSMAAMXQdGJRy3vE
3-d Printed Example of Snap-on Fiber Holder http://www.thingiverse.com/thing:690190
Helpful link: http://www.instructables.com/id/How-to-attach-fiber-optic-filament-to-an-LED/

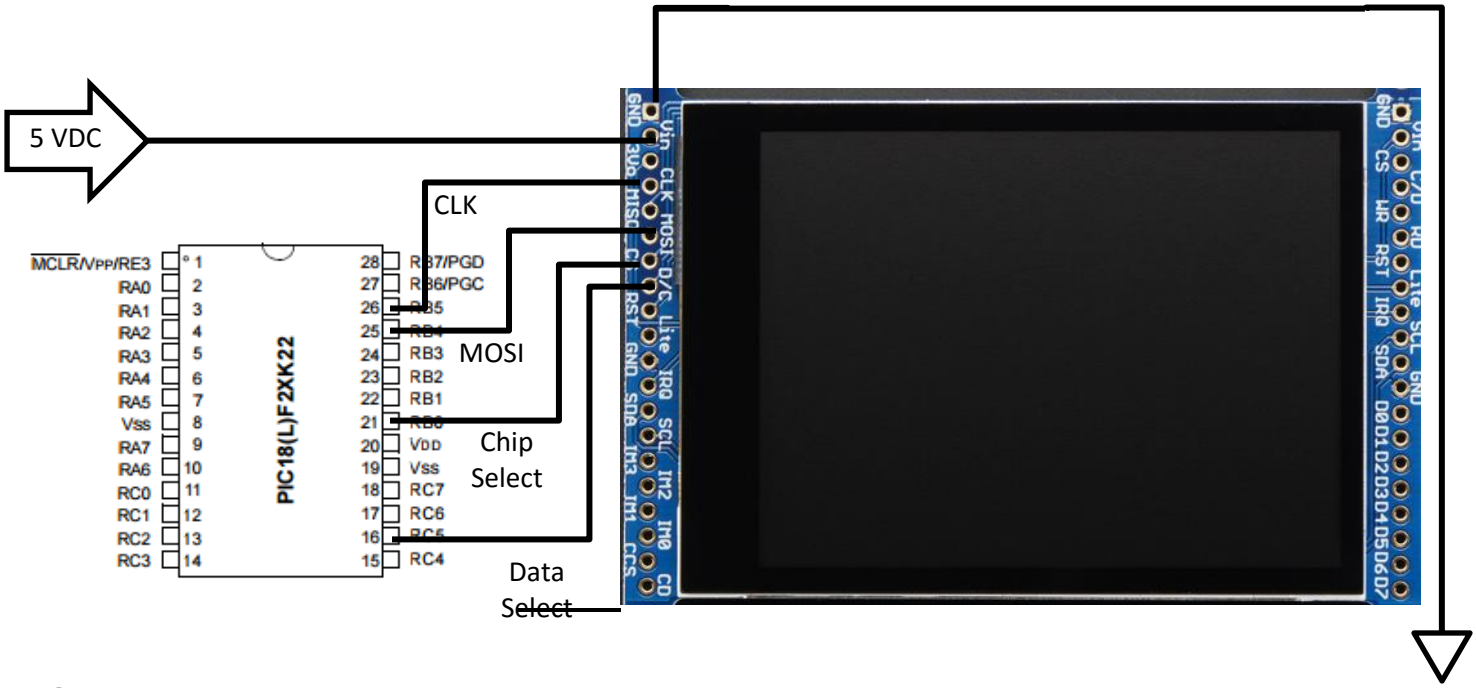
Display Screen and Driver

When choosing a display, I was at first looking for those using the I2C protocol to use less pins. Options 3 and 4 were my first choices until I considered the shipping time it would take to receive them from China. The primary choice for the display screen is now the 2.8” TFT LCD screen with breakout board. A smaller screen meets all of the necessary display requirements, is less expensive, and weighs less. The SPI protocol it uses to communicate with the MCU only uses one more pin than the I2C would have and will be familiar after also using SPI for the LED display. Again, Adafruit has many reference materials and libraries for their product.

My second choice is a larger TFT screen. The size and driver makes it a more expensive option, but could result in a fancier, larger display. My only worry is that a data sheet is available for the IC, but not for the driver board as a whole.

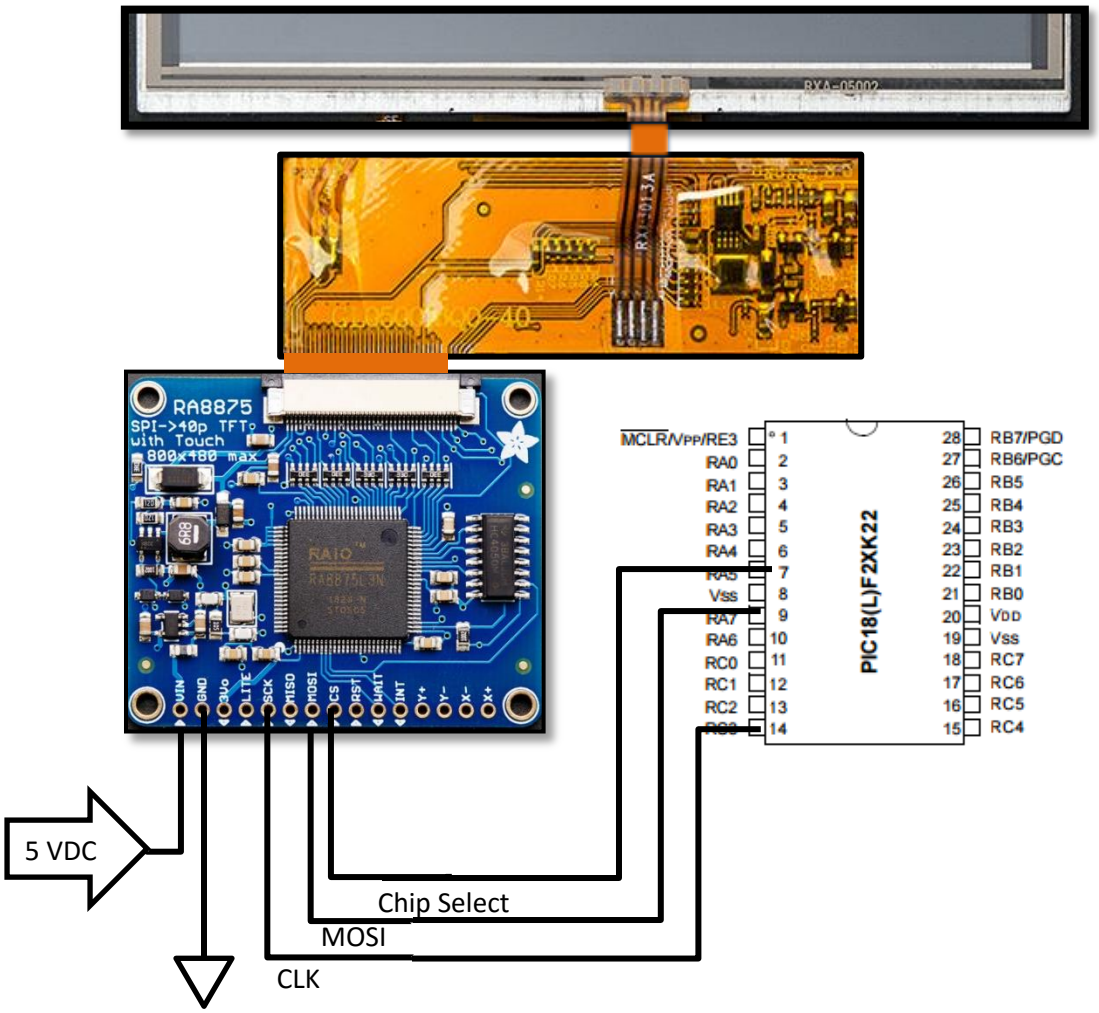
Option	**1. 2.8” TFT Breakout Board**	**2. 5” TFT w/ Driver**	**3. 4 Digit 7-Segment**
Cost	$29.95	$64.90	$11.95
Communication Protocol	4-wire SPI	3-wire SPI	400 kHz I2C
Fanciness	★★★★	★★★★★	★
RAM	172k	768k	128 bits
Availability of References	★★★★★	★★★	★★★★
Voltage/Current	3-5 V/230 mA	3.3 V/150 mA	5 V/102mA
Dimensions	43.2 X 57.6 mm	110 X 67 mm	27 X 50 mm

Option 1: 2.8" TFT LCD with Touchscreen Breakout Board w/MicroSD Socket



Voltage:	3-5 V
Amperage:	230 mA
Dimensions:	43.2 X 57.6 mm X 7.9 mm
Pixels:	240 X 320
Weight:	40 g (1.4 oz.)
Cost:	$29.95 https://www.adafruit.com/products/1770 UPDATE: As of 02/23, this product is out of stock. A similar product is available that adds a capacitive touch screen at $39.95 https://www.adafruit.com/products/2090
Communication:	SPI
Notes:	MicroSD socket 172k RAM Buffering Adafruit Resources
Datasheet:	https://www.adafruit.com/datasheets/MI0283QT-11%20V1.1.PDF https://www.adafruit.com/datasheets/ILI9341.pdf
Helpful Links:	https://learn.adafruit.com/adafruit-2-dot-8-color-tft-touchscreen-breakout-v2 https://github.com/adafruit/Adafruit_ILI9341 https://en.wikipedia.org/wiki/Thin-film-transistor_liquid-crystal_display

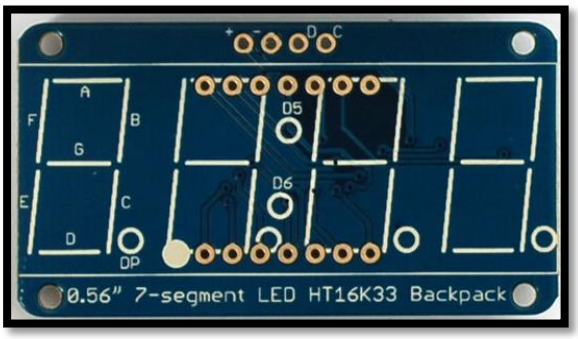
Option 2: 5.0" 40-pin 800x480 TFT Display & Driver (RA8875)



Voltage:	3.3 V
Amperage:	150 mA
Dimensions:	110 X 67 mm
Pixels:	800 X 400
Weight:	61g (2.2 oz.)
Cost:	$29.95 Display https://www.adafruit.com/products/1680
	$34.95 Driver https://www.adafruit.com/products/1590
Communication:	SPI
Notes:	768k RAM buffer
	Adafruit Resources
Datasheet:	https://www.adafruit.com/datasheets/KD50G21-40NT-A1.pdf
	https://www.adafruit.com/datasheets/RA8875_DS_V19_Eng.pdf
	https://www.adafruit.com/datasheets/ra8875%20app%20note.pdf
Helpful Links:	http://microchip.wikidot.com/harmony:plib-spi https://github.com/adafruit/Adafruit_RA8875

https://forums.adafruit.com/viewtopic.php?f=22&t=53779 https://forums.adafruit.com/viewtopic.php?f=19&t=48494

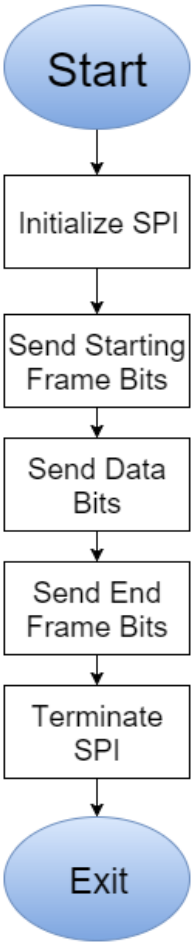
Option 3: 7-Segment Display w/I2C Break Out Board (HT16K33 driver)



Voltage:	5 V
Amperage:	102 mA
Dimensions:	27 X 50 mm
Height:	0.56”
Weight:	14 g (.5 oz.)
Cost:	$11.95
Communication:	400 KHz I2C
Notes:	Limited Display
	Available I2C addresses: 0x70-0x77
Datasheet:	https://www.adafruit.com/datasheets/812datasheet.pdf
	https://www.adafruit.com/datasheets/ht16K33v110.pdf
Helpful Links:	https://learn.adafruit.com/adafruit-led-backpack/

Logic

SPI Flow Chart



Initialize SPI- set data and clock pins to output, begin clock

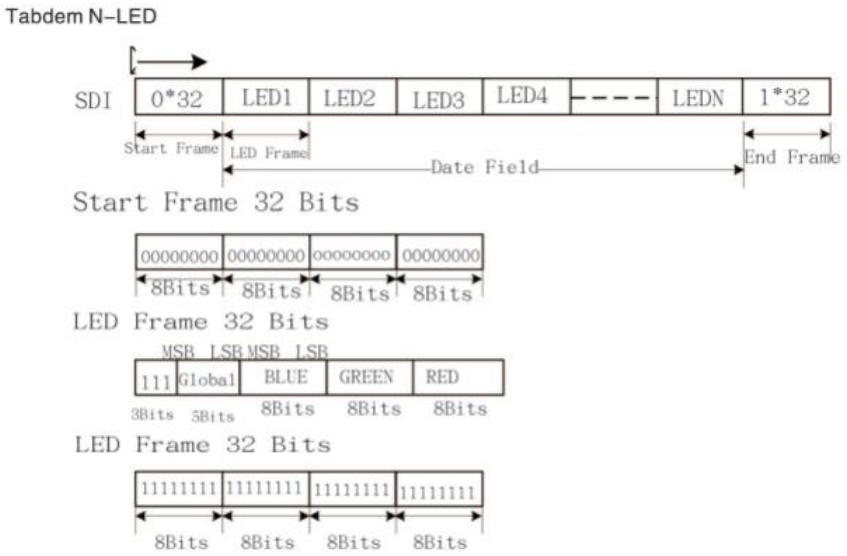
The Dotstar LEDs have a specific protocol that is listed on the following page. Each of the display screens utilize libraries with high level commands that allow quick and easy image setting without having to address each individual pixel.

Terminate SPI- stop clock, set data and clock pins to input

Functions available to the MCU:

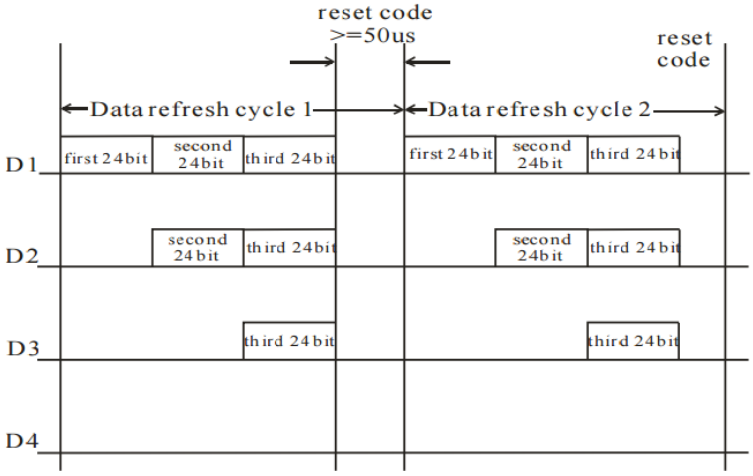
- addHit function that will require the number(1,2,3 or 4) of the hit and the hit type which will display a specific LED response and add the hit to the LCD screen
- damage function that will respond to a 4hit (or one that is not reflected in time) to reflect the damage to the player
- updateCounter function that will update the counter display (dependent on the needs of the MCU loop)
- removeHit function that will require the number(s) of the hit to be removed and the type of reflection
- stopLED function will turn off only the LEDs. This is necessary because the LEDs are continually driven by the PWM on their drivers
- powerOn function to initialize the LEDs and LCD screen
- death function to respond when the player is out of lives
- reset function to zero out the stack of hits

Dotstar SPI



Global bit: 5-bit brightness setting. 10000 (16/31) is half the original PWM settings/ half the driving current.
Source: Dotstar Data Sheet: https://www.adafruit.com/datasheets/APA102.pdf

Neopixel Protocol



Note: The data of D1 is send by MCU, and D2, D3, D4 through pixel internal reshaping amplification to transmit.

Composition of 24 bit 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

Follow the order of GRB to send data and the high bit sent at first.
Source: Neopixel Data Sheet https://www.adafruit.com/datasheets/WS2812.pdf

Light Reactions

Damage:

- Damage: Red
- Fire: Red/Orange
- Water: Blue
- Thunder: Yellow(Flickering)
- Poison: Green
- Ghost: White/Purple
- Psychic: Purple/Pink
- Super Attack: Red/Yellow/Orange

Stun:

- Stun: Yellow
- Ice: Light Blue
- Rock: Dark Orange/Brown
- Shadow: Dark Blue

Healing:

- Heal: Blue/White
- Wind : Yellow/White
- Light: Rainbow

Helpful Links

http://www.circuitvalley.com/2011/08/microchip-spi-basics-tutorial-for-pic18.html
https://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus
https://learn.sparkfun.com/tutorials/serial-peripheral-interface-spi
http://ww1.microchip.com/downloads/en/devicedoc/spi.pdf