University of Central Florida
Department of Electrical Engineering and Computer Science

3D Persistence of Vision Display

Sponsor: KEMCO Industries

Group 8
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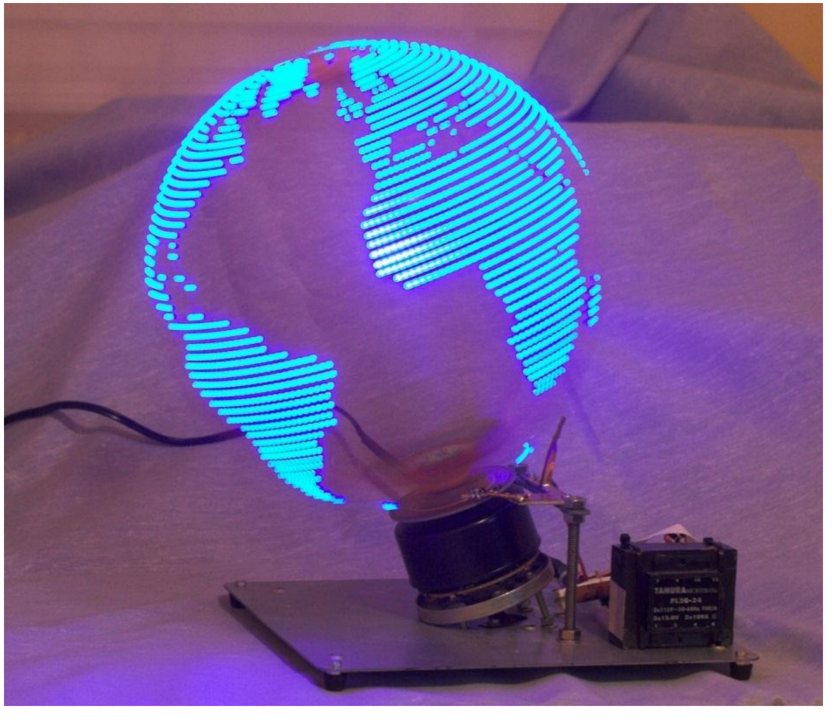
Goals and Objectives

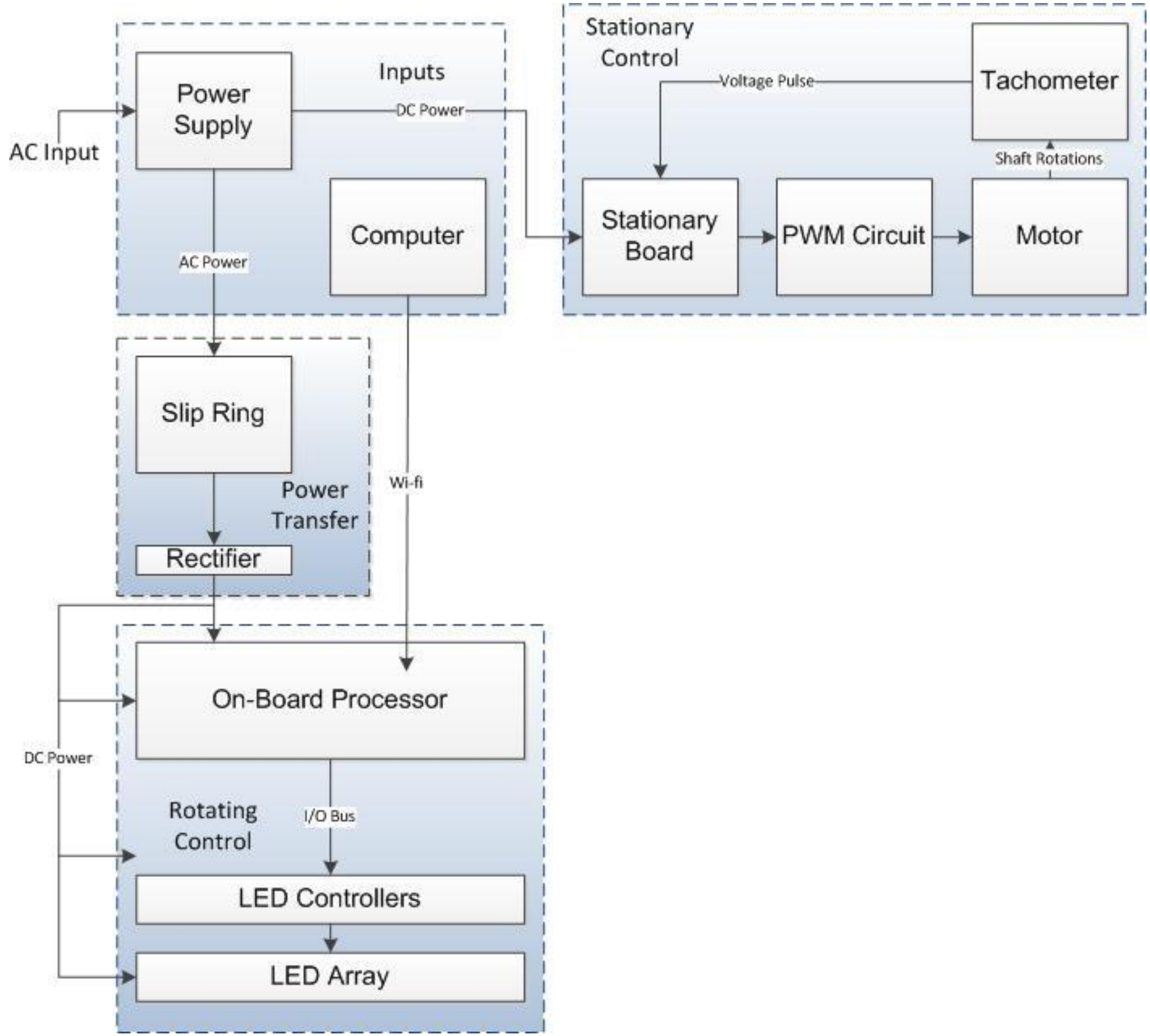
- Computer Interfacing
  - Live program-ability
- High Resolution
  - Capable of displaying complex images and animations.
  - RGB capabilities.
- Portable



Specifications

- 128 RGB LEDs
- 128x384 resolution
- 30 fps or 1800 rpm
- 18” overall diameter
- 24 in. height
- Less than 100 lbs.
- 120 V AC [Standard US outlet]
- 1-2 Mbits/s wireless data transmission.
- 512 Kb onboard flash memory.

Hardware Flowchart

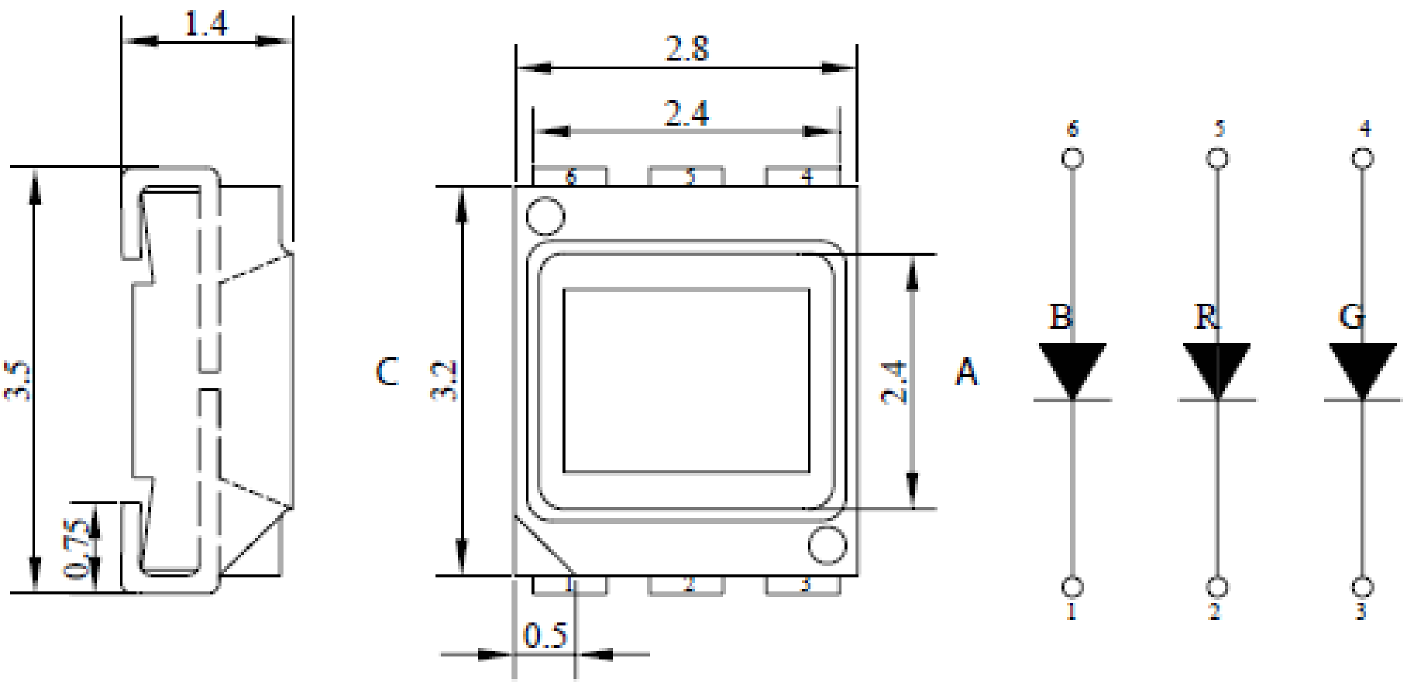


LED Arrays
Main Overview

- Primary LED Array:
  - Used to display the picture
  - Consist of (128) RGB LEDs and (48) LED Controllers
  - Produces an image of (128) pixels x (384) pixels
  - Operate at 5.0 V
- Secondary LED Array:
  - Used to display a text message
  - Text message will appear to “stand off” from the picture being displayed by the Primary LED Array.
  - Consist of (16) Mono-color LEDs and (2) LED Controllers
  - Operate at 3.2 V

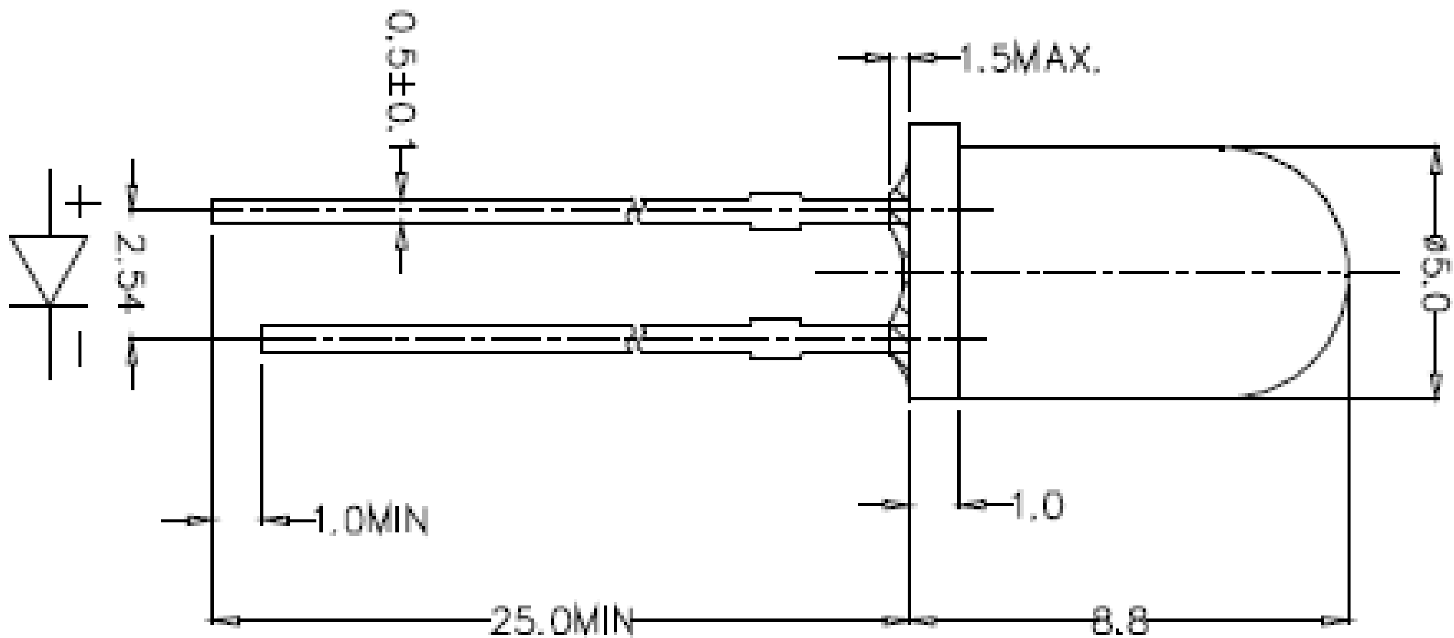
LED Arrays
RGB LED Specifications

- Surface Mount
- Low Profile Package
- Operates at 5.0 V and 30 mA
- Part Number: OVS-3309



LED Arrays
Mono-Color LED Specifications

- Through Hole – T-1 ¾ (5mm) Package
- Green LED
- Operates at 3.2 V and 20 mA
- Part Number: C503B-GAN-CB0F0791



LED Arrays
LED Controllers

- 16 Channel Constant-Current Sink LED Driver
- Each channel has individually adjustable PWM
- PWM has (4096) Steps (12 Bit)
- Drive Capabilities:
  - 0mA to 60mA when Vcc < 3.6 V (Secondary LED Array)
  - 0mA to 120mA when Vcc > 3.6 V (Primary LED Array)
- Serial Data Interface
  - Multiple Controllers can be wired in series or cascaded together and use the same output from the microcontroller
- 30MHz Data Transfer Rate
- Each controller will handle only one color (Red, Green or Blue)
- Part Number: TLC5940PWP (Surface Mount)

LED Arrays
LED Controllers

- Data Transfer Rate is 30MHz

$$f(GSCLK) = 4096\ x\ f(update)$$
$$f(SCLK) = 193\ x\ f(update) x\ n$$
$$Where:$$
$$f(GSCLK)\ equals\ the\ minimum\ frequency\ needed\ for\ the\ gray\ scale\ clock.$$
$$f(SCLK)\ equals\ the\ minimum\ frequency\ needed\ for\ SCLK\ and\ SIN$$
$$n\ equals\ the\ number\ of\ cascaded\ controllers$$

$$f(update) = 384\ x\ 30 = 11{,}520\ Hz$$
$$n = \frac{128}{16} = 8$$

$$f(GSCLK) = 4096\ x\ 11520 = 47.185\ \text{MHz}$$
$$f(SCLK) = 193\ x\ 11520\ x\ 8 = 17.786\ \text{MHz}$$

LED Arrays
LED Controllers

- To overcome the high frequency requirements for *f(GSCLK)*, we created two groups of LED controllers each handling half of the work load.

$$f(update) = 192\ x\ 15 = 2{,}880\ Hz$$

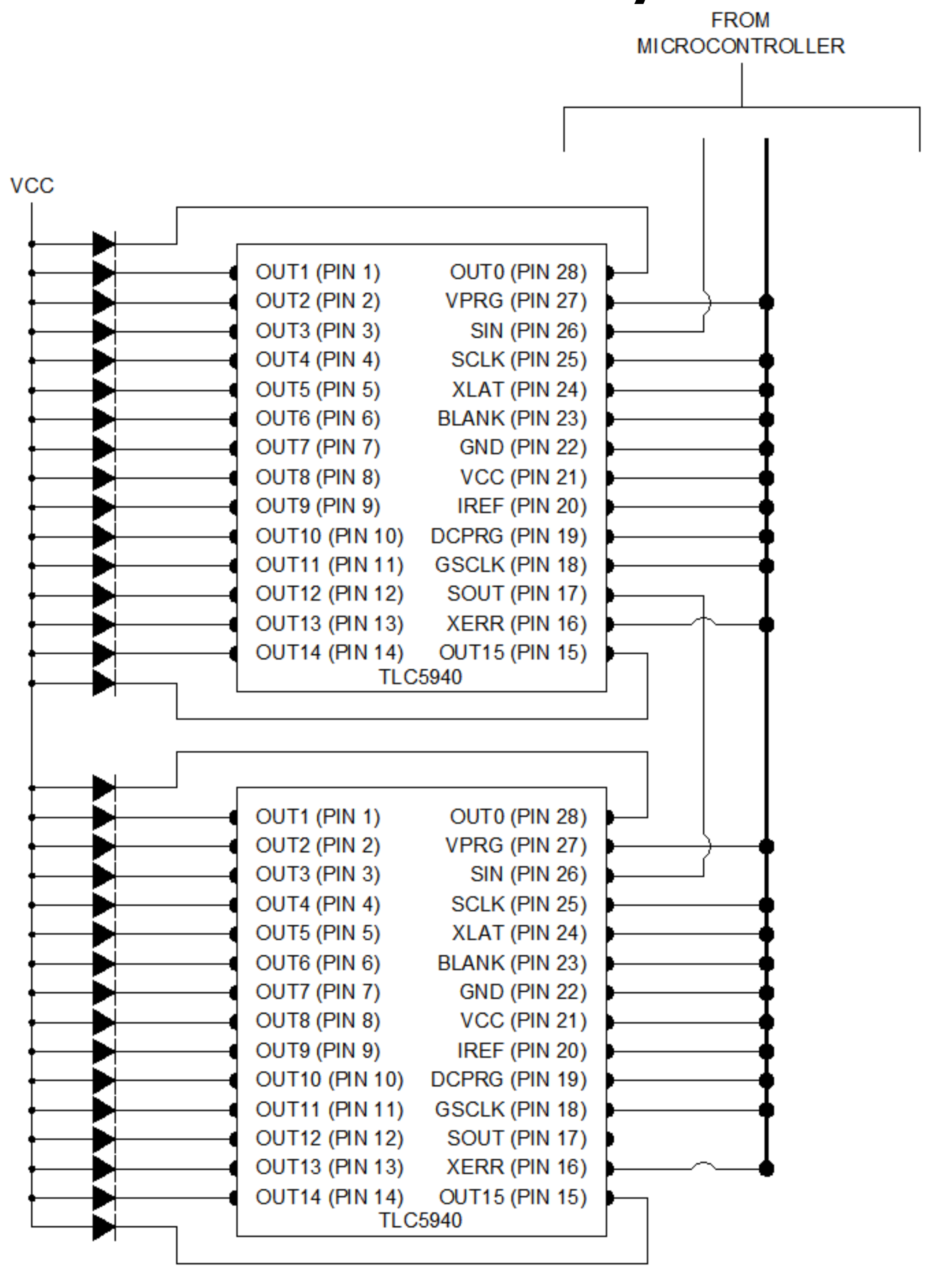
$$n = \frac{128}{16} = 8$$

$$\boldsymbol{f(GSCLK) = 4096\ x\ 2880 = 11.796\ \text{MHz}}$$

$$f(SCLK) = 193\ x\ 11520\ x\ 8 = 4.446\ \text{MHz}$$

Vertical Group A Pixel Column 1	Vertical Group B Pixel Column 2	Vertical Group A Pixel Column 3	Vertical Group B Pixel Column 4	…	Vertical Group A Pixel Column 383	Vertical Group B Pixel Column 382	Vertical Group A Pixel Column 383	Vertical Group B Pixel Column 384
Group A	Group B	Group A	Group B	…	Group A	Group B	Group A	Group B

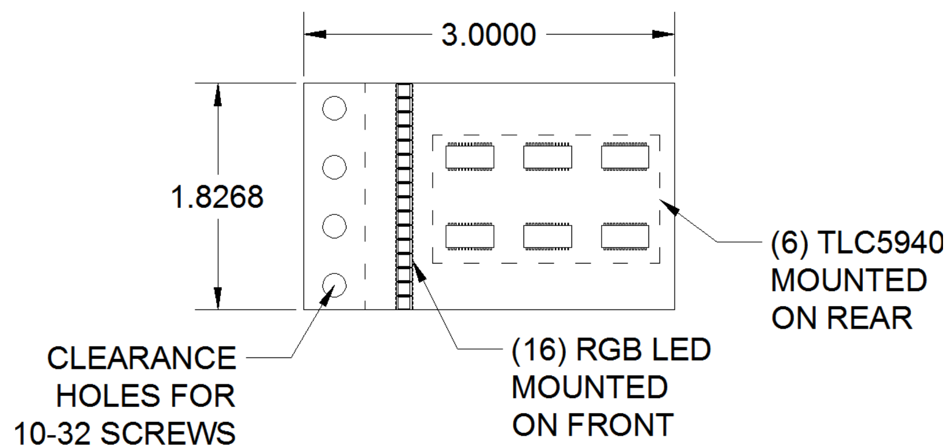
LED Arrays



FROM MICROCONTROLLER
VCC
OUT1 (PIN 1)
OUT2 (PIN 2)
OUT3 (PIN 3)
OUT4 (PIN 4)
OUT5 (PIN 5)
OUT6 (PIN 6)
OUT7 (PIN 7)
OUT8 (PIN 8)
OUT9 (PIN 9)
OUT10 (PIN 10)
OUT11 (PIN 11)
OUT12 (PIN 12)
OUT13 (PIN 13)
OUT14 (PIN 14)
OUT0 (PIN 28)
VPRG (PIN 27)
SIN (PIN 26)
SCLK (PIN 25)
XLAT (PIN 24)
BLANK (PIN 23)
GND (PIN 22)
VCC (PIN 21)
IREF (PIN 20)
DCPRG (PIN 19)
GSCLK (PIN 18)
SOUT (PIN 17)
XERR (PIN 16)
OUT15 (PIN 15)
TLC5940

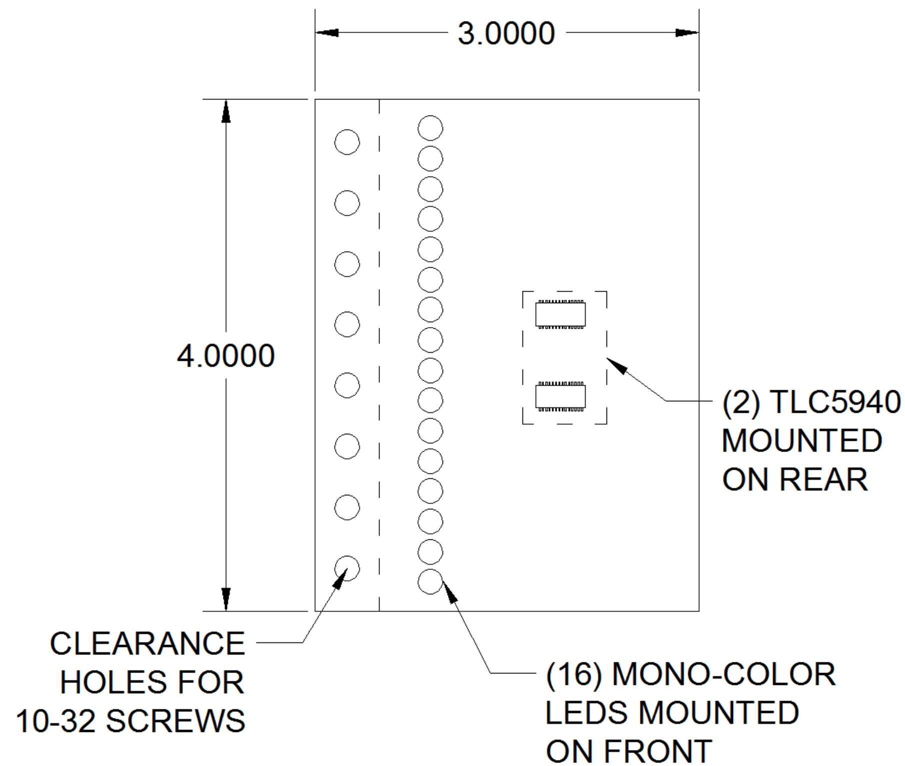
LED Arrays
Primary LED Array Design

- Creating module LED arrays that can be pieced together.
- Each module will contain (16) RGB LEDs and (6) LED Controllers
- Each module will be identical in design
- Each module will have surface mount terminal blocks for jumpering modules together and power supply
- Approximate dimensions of each module will be 1.823” H x 3.00” W



LED Arrays
Secondary LED Array Design

- Similar in design to the Primary LED Array
- Array will contain (16) Mono-color LEDs and (2) LED Controllers
- Array will have surface mount terminal blocks for connection to microcontroller and power supply
- Approximate dimensions of each module will be 4.0” H x 3.00” W



Microcontroller Requirements

- 128 X 384 pixels with 8 bit color.
- 30 FPS refresh rate.
- Gray scale data contains 12 bits per color.
- 128 X 384 X 36 X 30 = 53,084,160 bits of data that must be sent to the LED controllers per second.

Microcontroller Requirements

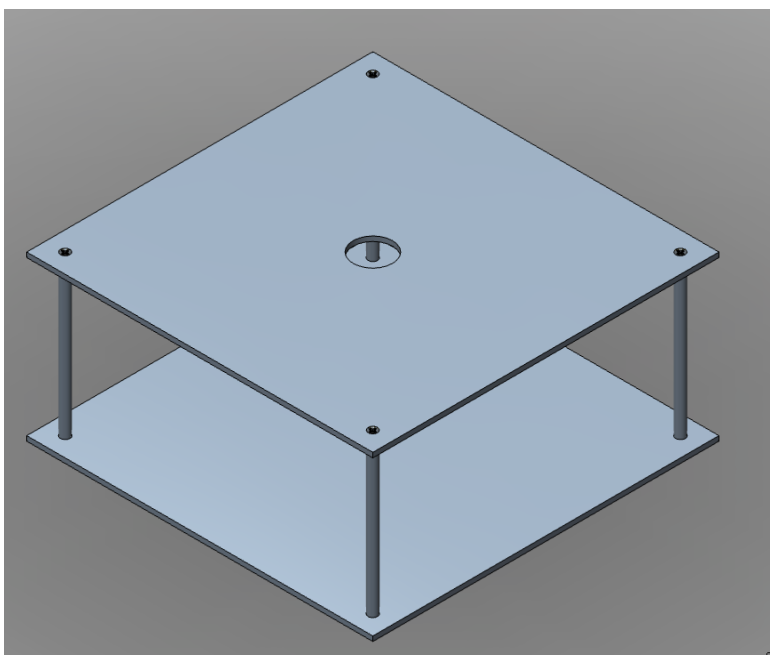
- A single image stored in flash will require 393,216 bits.
- Wi-Fi connectivity to receive a new image.
- An image for the text display will require 6,144 bits.
- Total storage requirement: 399,360 bits

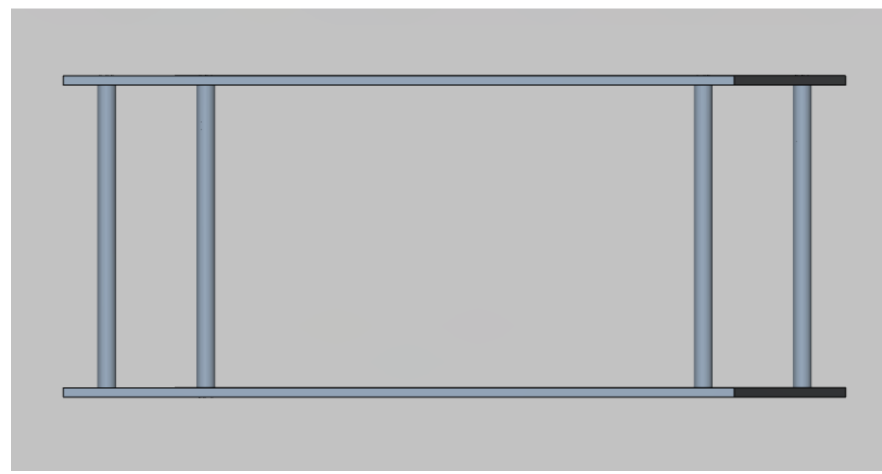
Microcontroller

- chipKIT uc32
- 80 Mhz
- 512K Flash
- 32K SRAM
- 42 available I/O’s

Chassis Design
Chassis Base

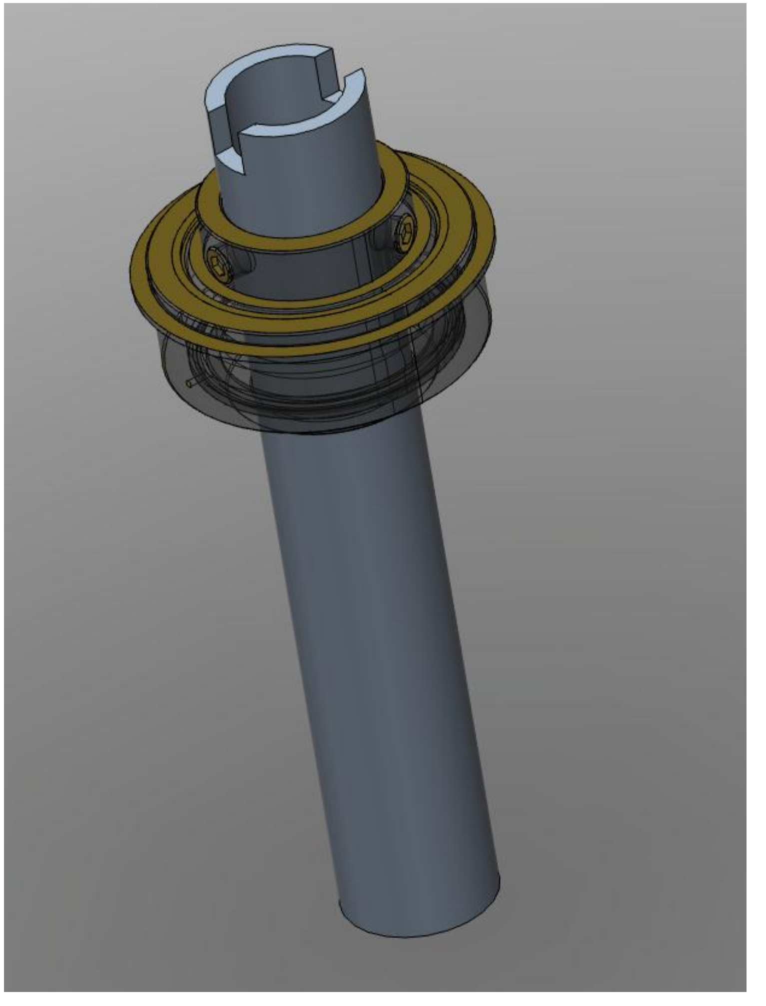
- Constructed from steel
- Painted Satin Black
- Open in middle for mounting motor and power supply
- Approximate Dimensions: 18” W x 18” L x 12.5” H





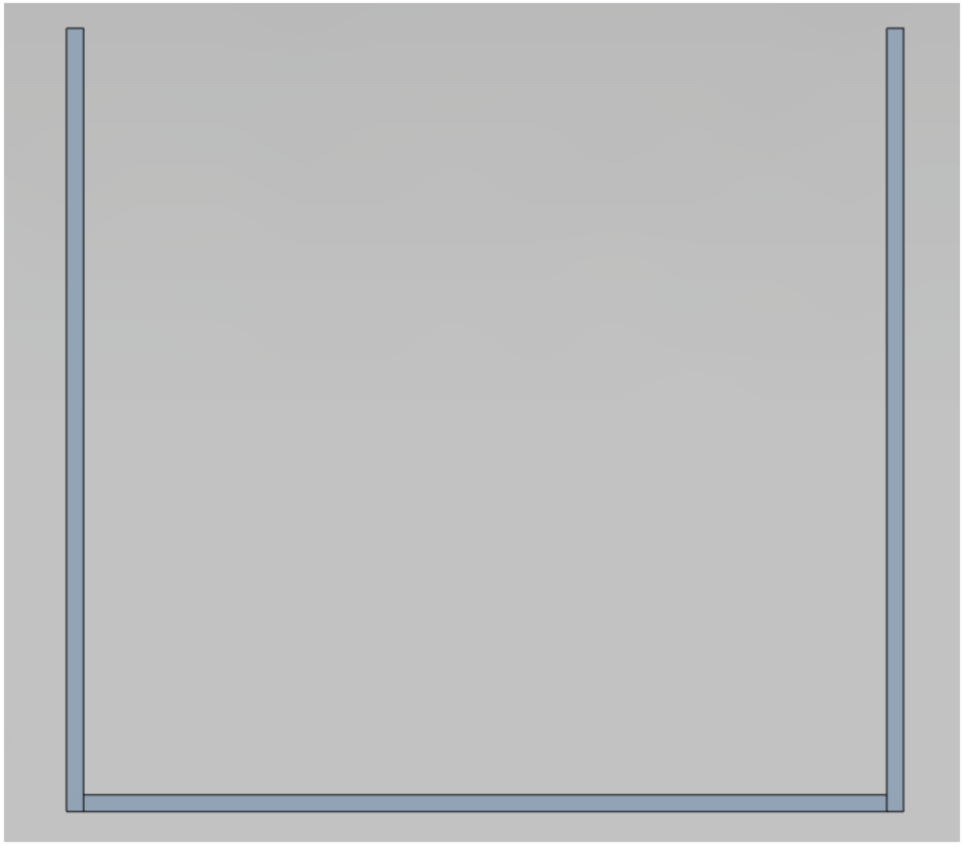
Chassis Design
Rotary Interface

- Extended-Ring Bearing with set screws to secure a pipe to the inner ring of the bearing.
- Bearing to be welded to the top of the chassis base
- Bearing and pipe will be painted black
- Pipe will be notched on top to secure the LED Support Frame



Chassis Design
LED Array Support Structure

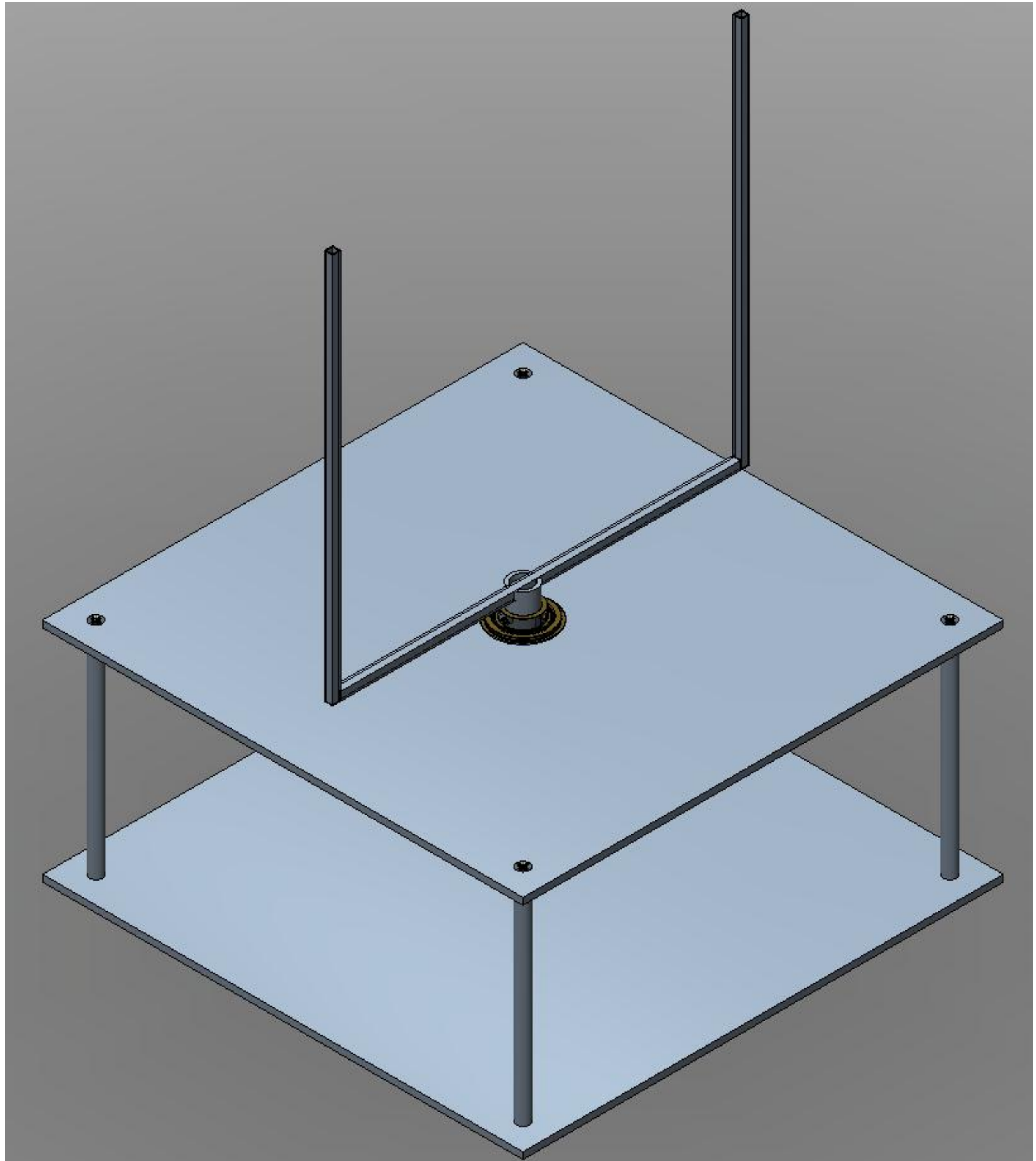
- Construction from carbon fiber square tubing (to reduce weight)
- Holes drilled in vertical frame to secure LED PCB
- Horizontal support frame will be longer on one side for the Secondary LED Array
- Approximate Dimensions: 15” H x 16.5” W



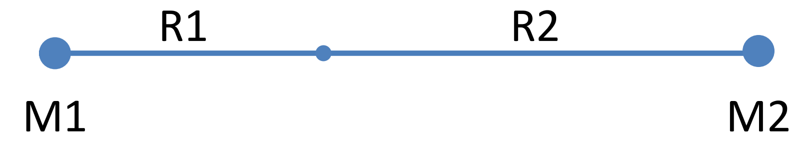
Chassis Design
Motor Interface

- Option 1:
  - Use a pulley system
  - Attach a pulley to the motor shaft
  - Use a flat belt to connect the pulley and the pipe together
  - Advantage: Allows for gear changing (ex. 4:1)

- Option 2:
  - Mount the motor directly under the pipe at the center of rotation
  - Weld a plate to the bottom of the pipe with a hole in the middle for motor shaft
  - Advantage: Easier to implement



Chassis Design
Torque Requirements



Simplified LED Support Structure

$$M1\ (mass\ of\ primary\ LED\ array) = 0.013956\ kg$$
$$M2\ (mass\ of\ secondary\ LED\ array) = 0.013956\ kg$$
$$R1 = 0.35448\ m\ and\ \ 0.0128\ kg$$
$$R2 = 0.40752\ m\ and\ 0.0148\ kg$$

$$I_{M1} = M1\ x\ R1^2 = (0.013956\ kg)x(0.35448)^2 = 0.001688\ kg \cdot m^2$$
$$I_{M2} = M2\ x\ R2^2 = (0.013956\ kg)x(0.40752)^2 = 0.00223\ kg \cdot m^2$$
$$I_{R1} = {}^{1}/_{3}\ x\ MR1\ x\ R1^2 = (0.333)x(0.0128\ kg)x(0.35448)^2 = 0.000537\ kg \cdot m^2$$
$$I_{R2} = {}^{1}/_{3}\ x\ MR2\ x\ R2^2 = (0.333)x(0.0148\ kg)x(0.40752)^2 = 0.000817\ kg \cdot m^2$$

$$\sum I = I_{M1} + I_{M2} + I_{R1} + I_{R2} = 0.00527\ kg \cdot m^2$$

Chassis Design
Torque Requirements

Simplified LED Support Structure

$$\sum I = 0.00527\ kg \cdot m^2$$

$$\alpha = \frac{[(30)x(2\pi)^2]}{[(2)x(1)x(2\pi)^2]} = 47.123$$

$$T = \sum I\ x\ \alpha = 0.248\ N \cdot m$$

Motor Requirements

- The motor needs to be light weight.
- Capable of maintaining 24-30 fps
  - 1440 to 1800 rpm
- Low Noise.
- Capable of handling 0.25 N·m of Torque.
- Large motor shaft
  - For mounting LED array directly or in the case of using a pulley system to rotate array.

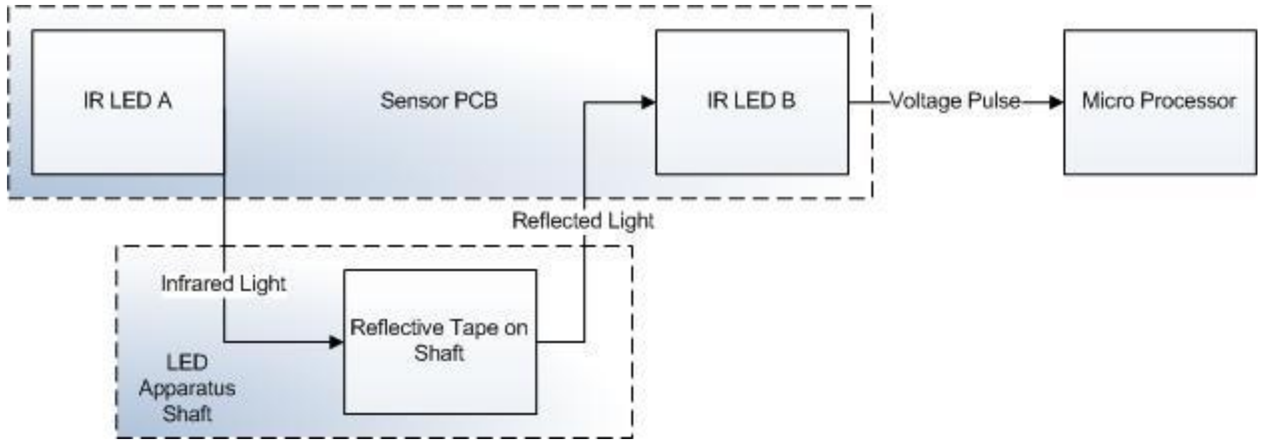
Motor

- Dayton 9FHD7 DC motor
  - Runs on 90 V, 1.5 A.
  - 1800 rated rpm.
  - 0.49 N·m of torque.
  - Light weight.
  - 0.5 in. shaft diameter.
  - 1.38 in. shaft length.

Motor Control

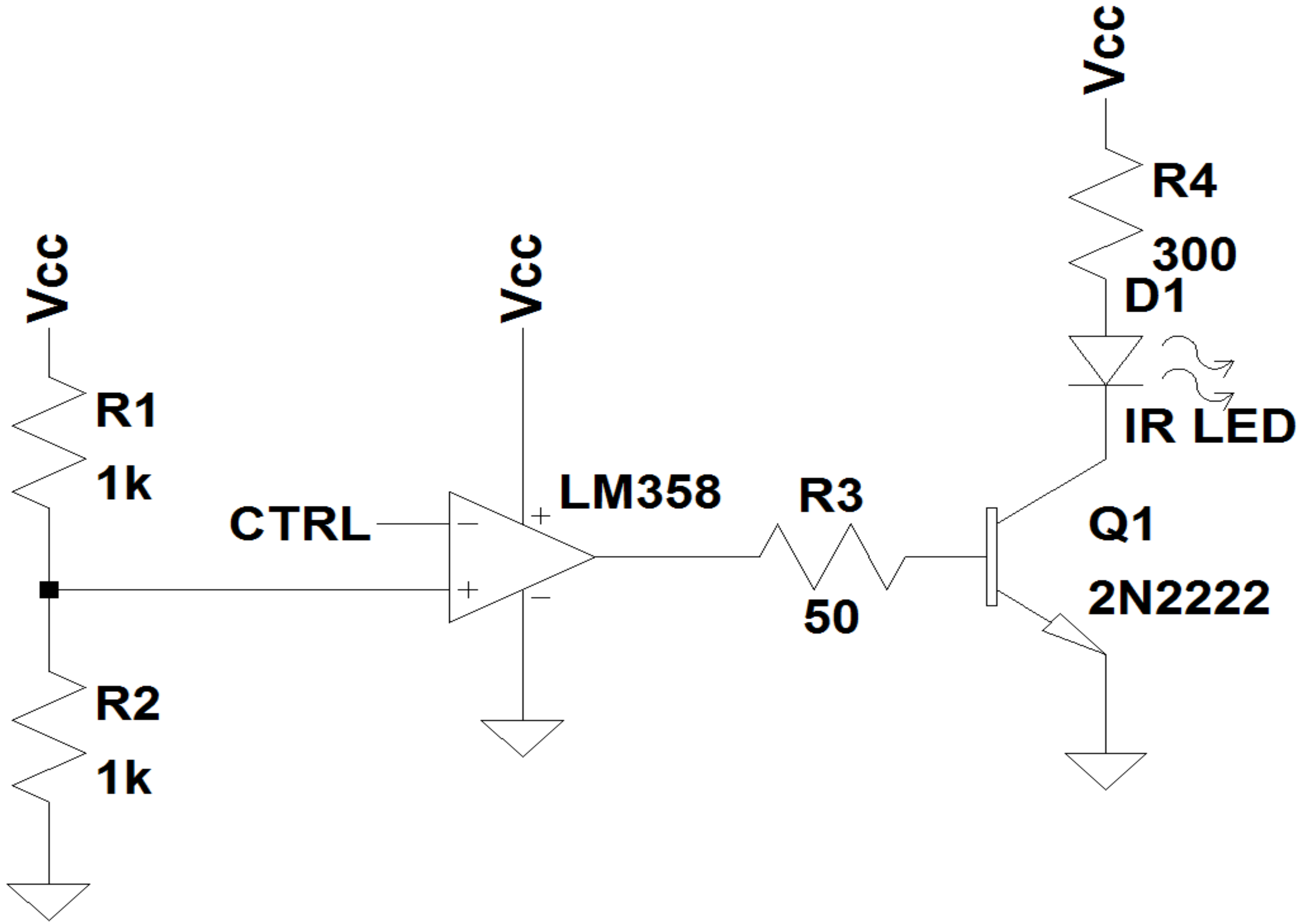
- Limited Functionality
  - Turn on
  - Turn off
  - Maintain
- Inexpensive
- Capable of storing data:
  - Current rpm
  - Time between complete rotations
  - Location of LED apparatus in transit

Tachometer

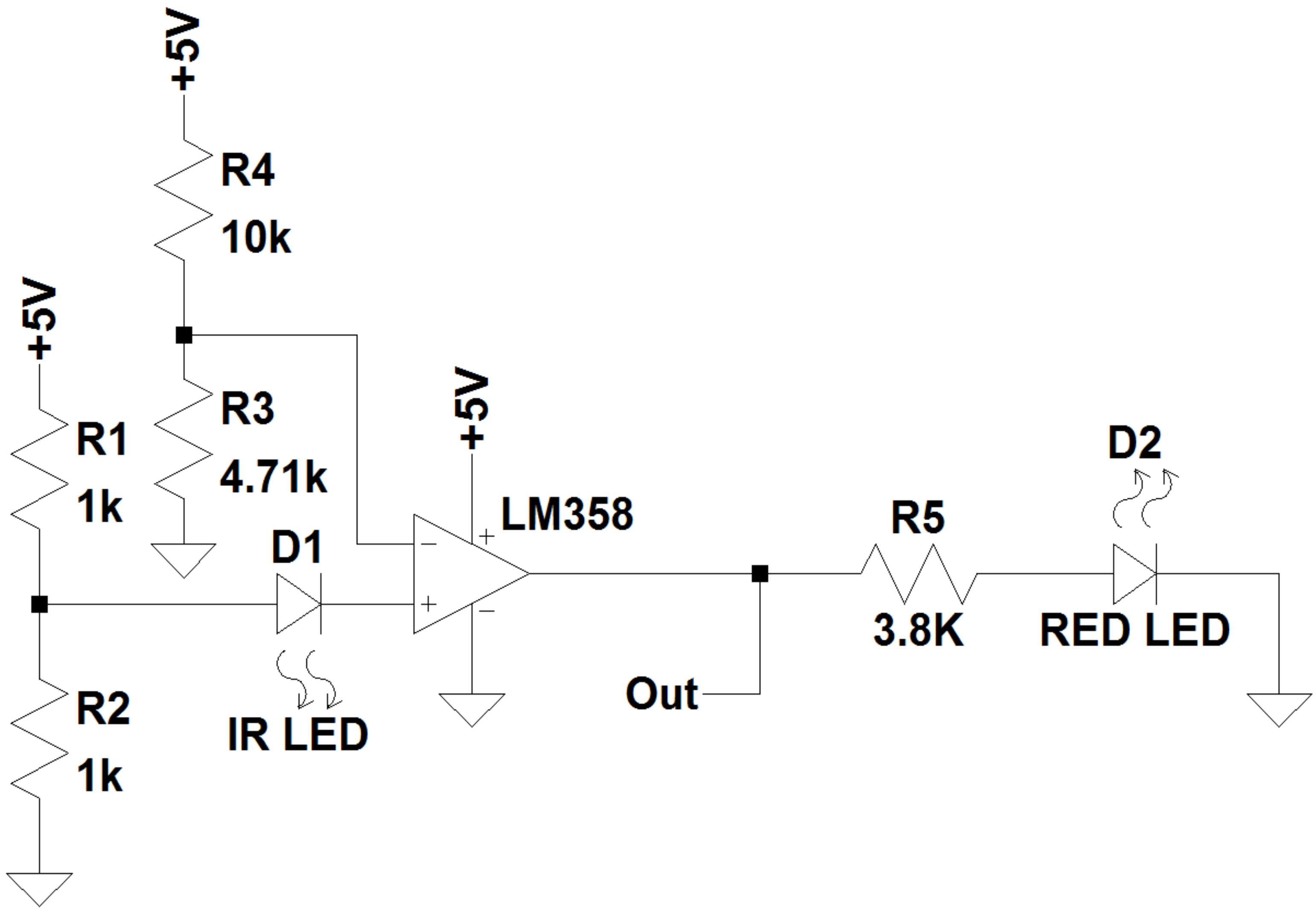


- Works off two IR LEDs and a LM358 Op-amp.
  - Designed around a common principle where LEDs show a voltage drop when light shines on them.
  - Creates a voltage pulse of 3.69 V on the output when the sending LED's light is reflected onto the receiving LED.
  - Both LEDs will be shielded with a black hollow cylinder to help prevent ambient light-noise.

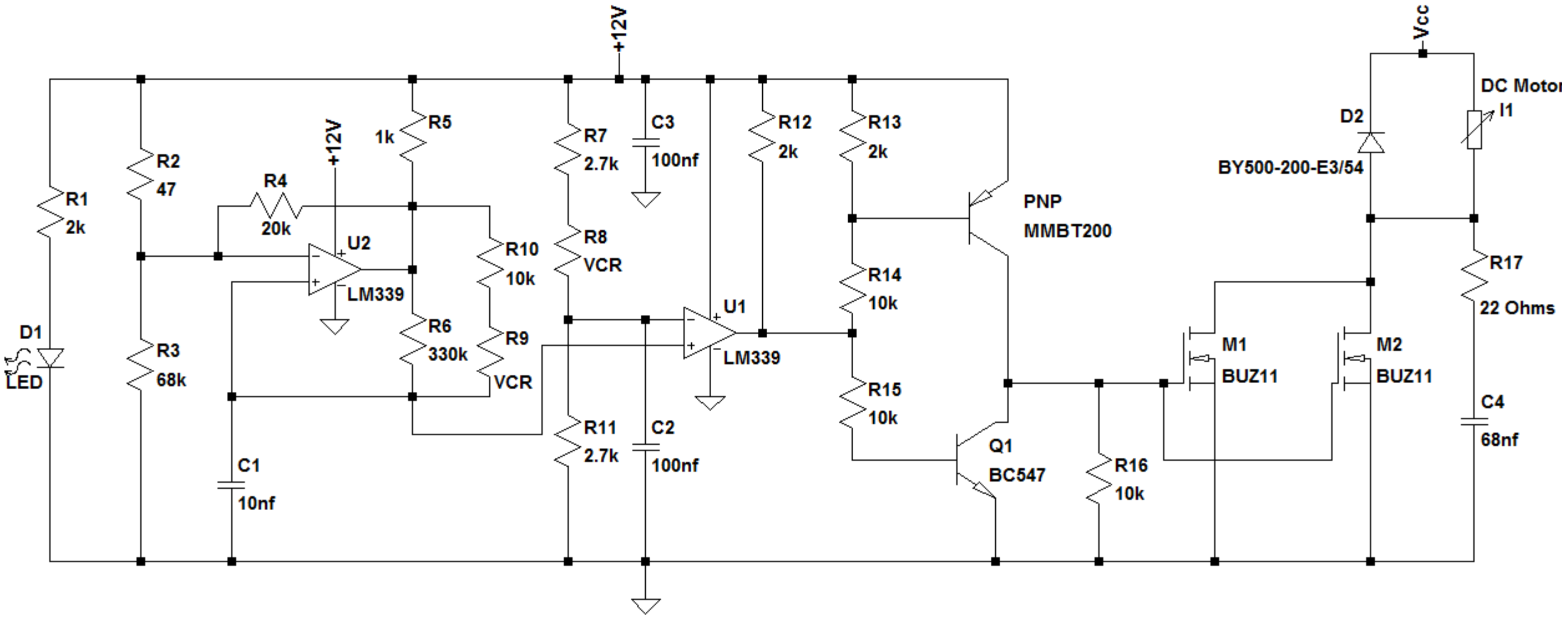
Sender Circuit



Receiver Circuit



PWM Control Circuit



- R9 resistance varies the frequency of the PWM wave from 400 Hz to 3 KHz.
  - This will be preset and unchanged during operation.
- R8 resistance varies the rated rpm value from 0-100%.
  - This will be controlled through the use of a voltage controlled resistance.
  - The voltage to this VCR will be controlled by the stationary micro-controller.

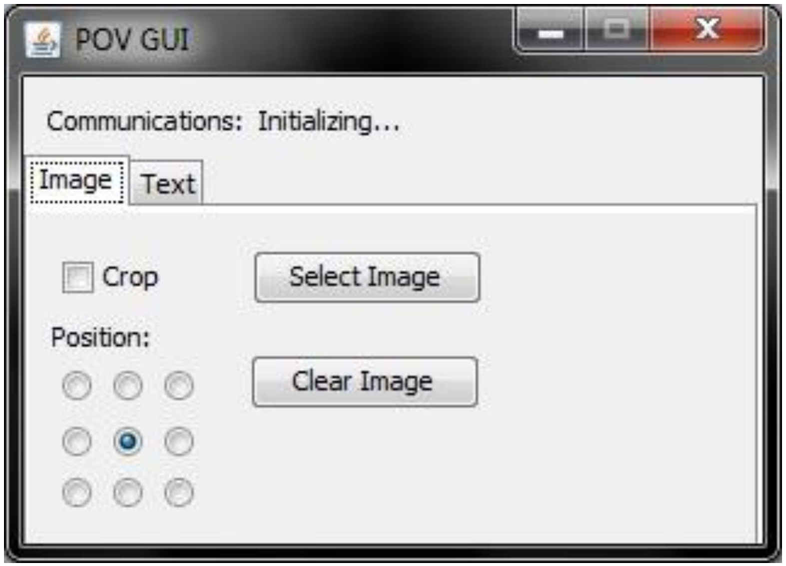
Stationary Controller

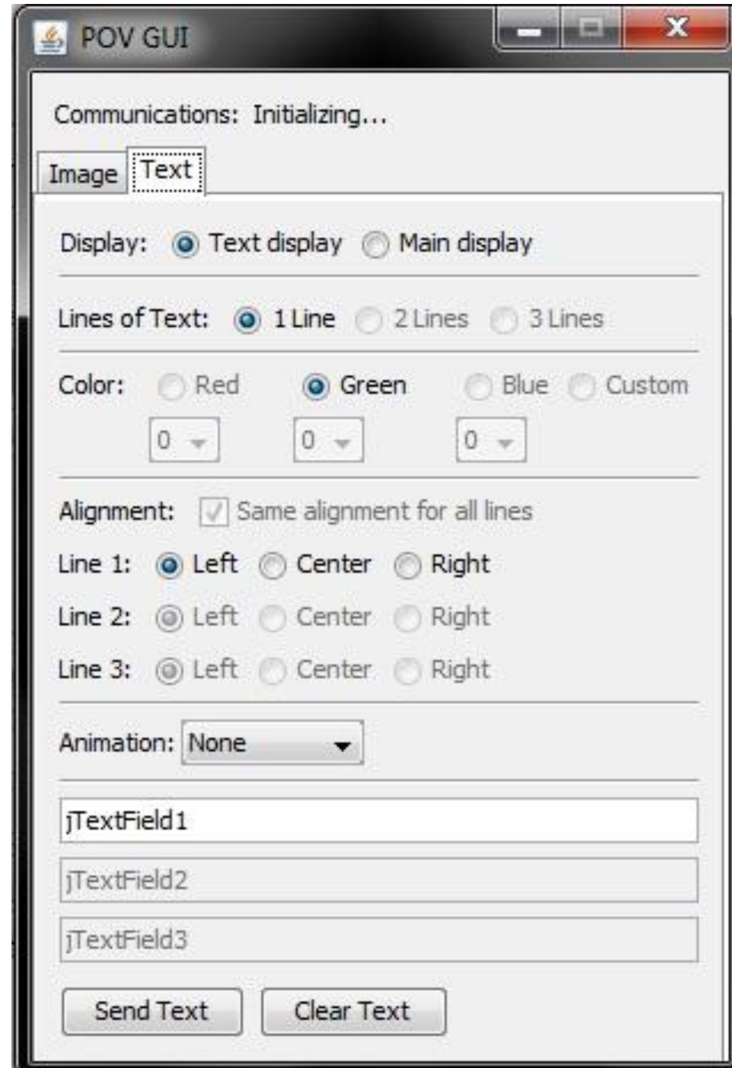
- An Arduino Uno will be sufficient to run the tachometer and PWM circuit for the motor.
  - Can store up to 32 Kb of flash memory.
  - 5 V operating voltage
  - 16 MHz clock speed.

GUI

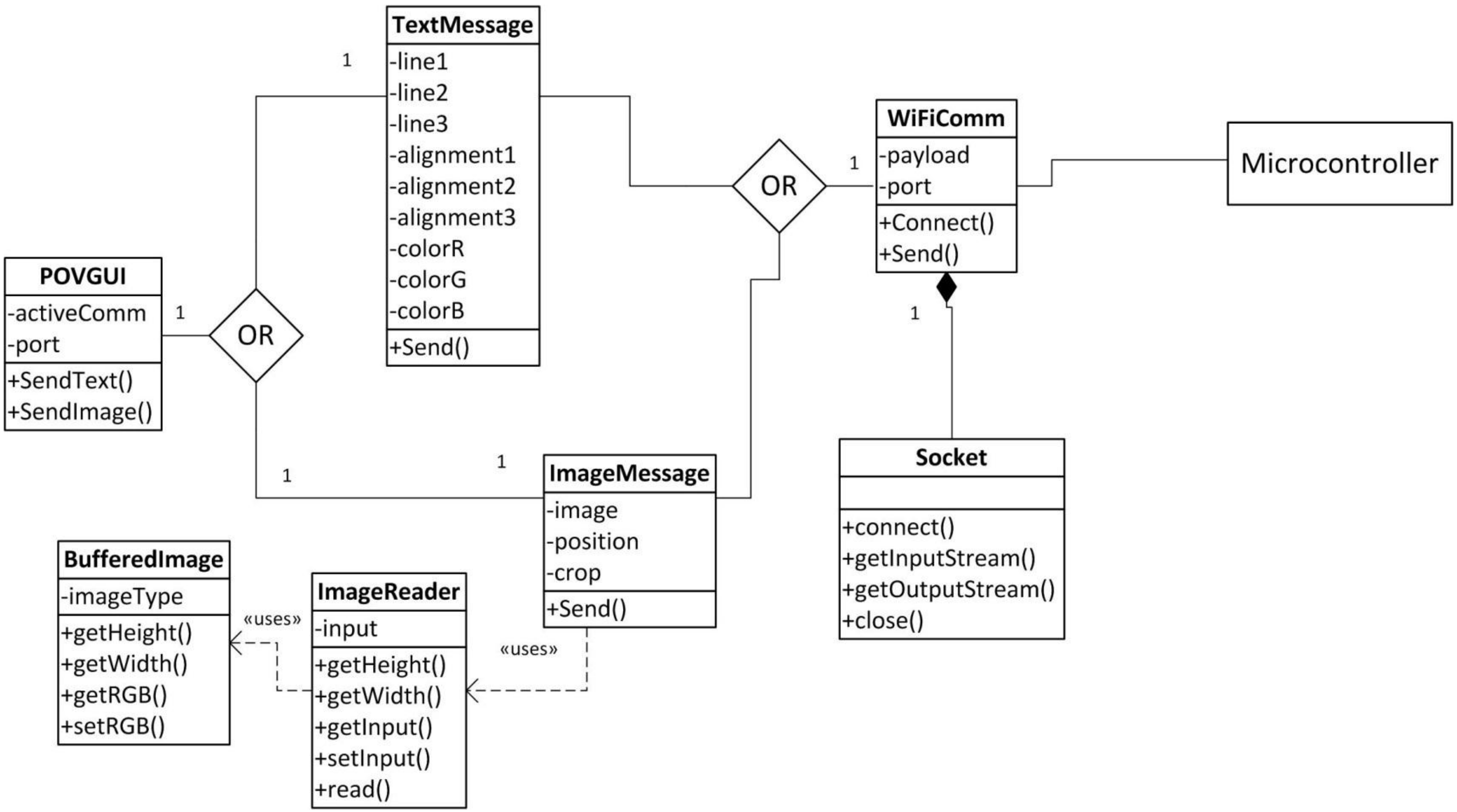
- Easy to use interface
- Allows user to enter a text message or image
- Text: color, animation, and alignment options
- Images: crop, position, and clear options

GUI


POV GUI
Communications: Initializing...
Image
Text
Crop
Select Image
Position:
Clear Image

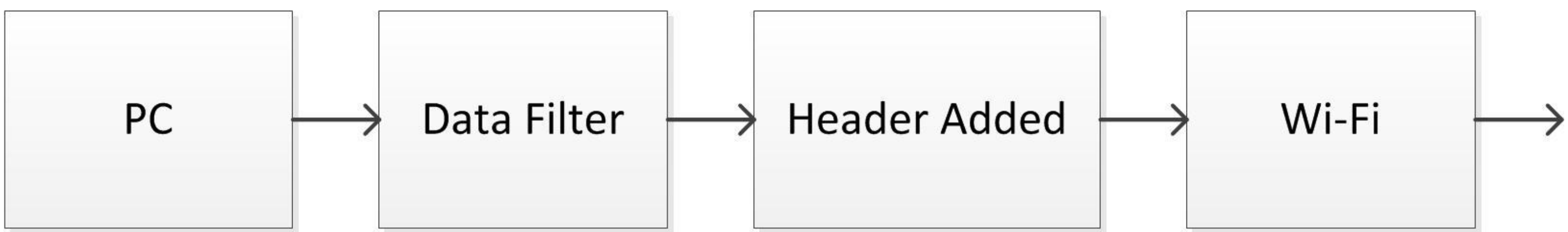

POV GUI
Communications: Initializing...
Image
Text
Display: Text display Main display
Lines of Text: 1 Line 2 Lines 3 Lines
Color: Red Green Blue Custom
0
0
0
Alignment: Same alignment for all lines
Line 1: Left Center Right
Line 2: Left Center Right
Line 3: Left Center Right
Animation: None
jTextField1
jTextField2
jTextField3
Send Text
Clear Text

GUI


TextMessage
-line1
-line2
-line3
-alignment1
-alignment2
-alignment3
-colorR
-colorG
-colorB
+Send()
WiFiComm
-payload
-port
+Connect()
+Send()
Microcontroller
OR
OR
1
1
1
1
1
1
POVGUI
-activeComm
-port
+SendText()
+SendImage()
ImageMessage
-image
-position
-crop
+Send()
Socket
+connect()
+getInputStream()
+getOutputStream()
+close()
BufferedImage
-imageType
+getHeight()
+getWidth()
+getRGB()
+setRGB()
ImageReader
-input
+getHeight()
+getWidth()
+getInput()
+setInput()
+read()
«uses»
«uses»

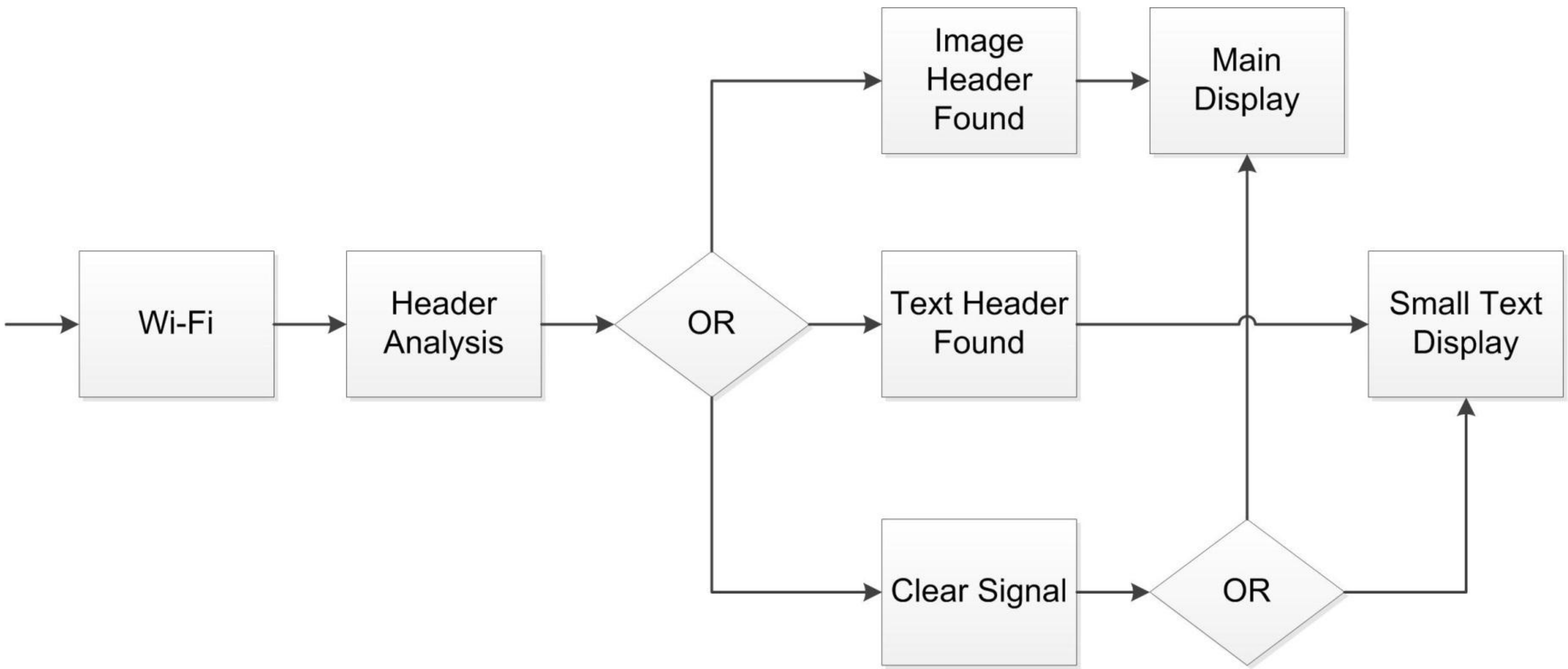
Wi-Fi Client

- PC will connect in ad-hoc mode
- 1-2 Mbps
- TCP protocol
- PC will send formatted data with header



Wi-Fi Server

- chipKIT Wi-Fi shield

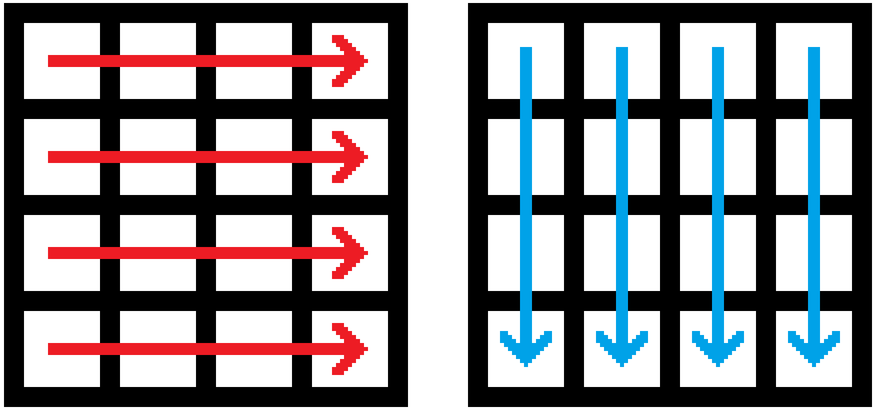


Preprocessing

- Preprocessing occurs on laptop before data transfer to device.
- Primary Display - Converts Image input into data used by the microcontroller.
- Secondary Display - Converts text input into data used by the microcontroller.

Data Formatting

- Truncate image to fit within 384Wx128H
- Pad image and center if necessary
- Store data in the order it will be needed by processor.
- Affix a header describing the data. (Includes scrolling information, etc.)

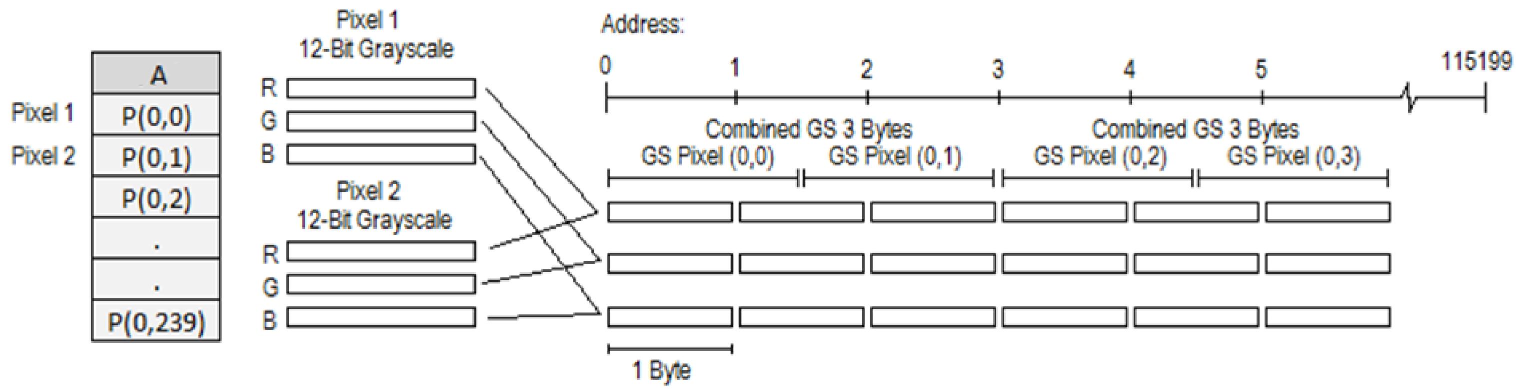


Data Formatting

- Obtain RGB data
- Java Classes Used: ImageIO, ImageReader, BufferedImage.
- ImageIO finds an ImageReader that claims to be able to read the image type
- ImageIO.read() returns BufferedImage
- BufferedImage.getRGB(x,y)

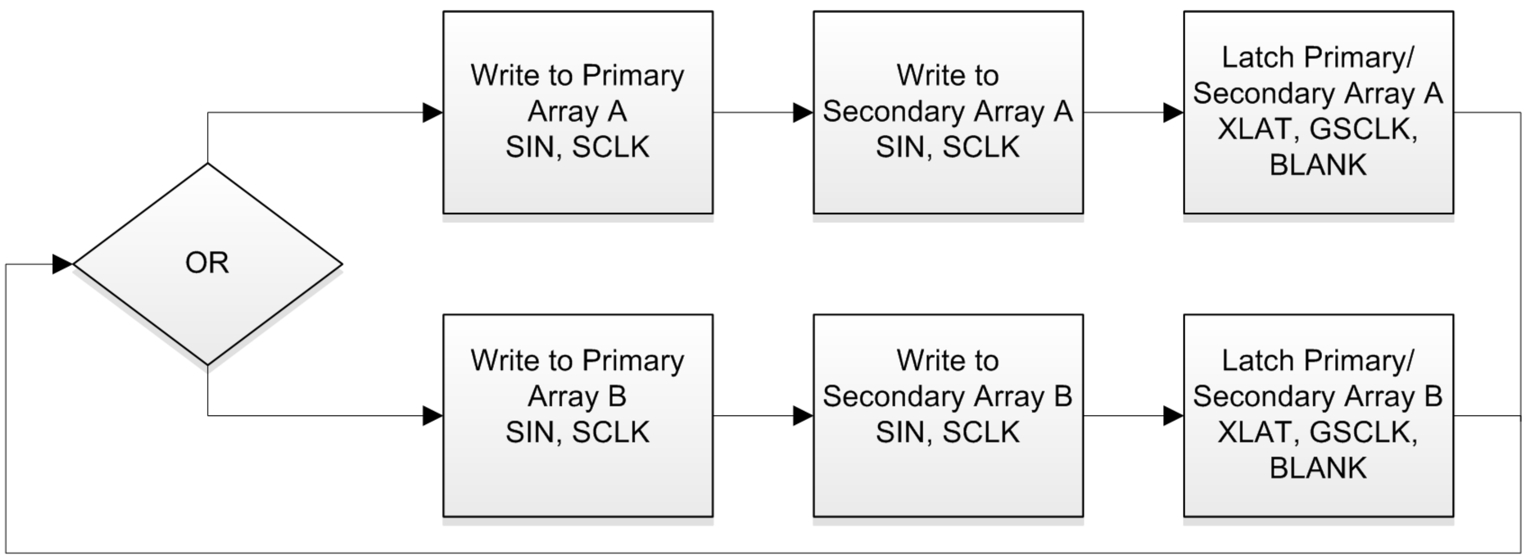
Preprocessing Functions

- TranslateFrame() – Converts image from .jpg, .bmp, etc
- TranslateAndOutput() – Two pixels, stores in output bin
- ConvertToGrayscale() – 12 bit representation of value
- CombineGrayscale() – Combines two grayscale values into a 3 byte structure.



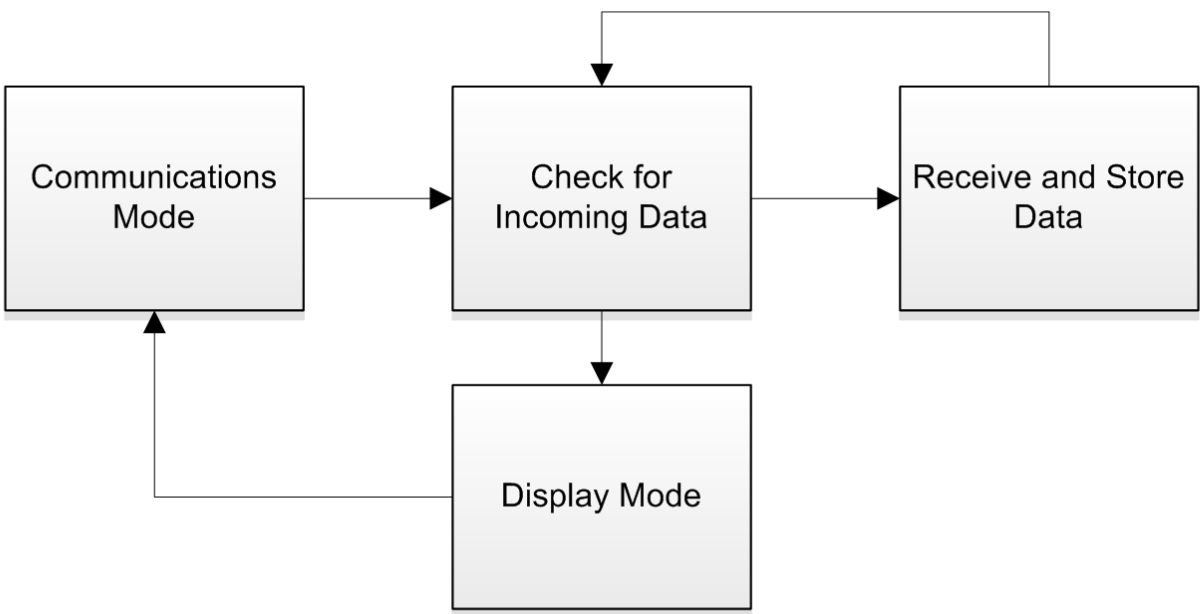
Microcontroller Functions

- Display Mode:
  - Write to LED Controllers via serial communication. SIN, SCLK 30 MHz
  - XLAT, BLANK 11520 Hz, GSCLK 30 MHz



Microcontroller Functions

- Communications Mode:
  - Occasional check for incoming data.
  - Receive data and store in memory.
  - Return to Display Mode operations.



Power Requirements

- Main LED array Power Draw:
  - 90 mA * 5 V * 128 LEDs = 57.6 W
- Secondary LED array Power Draw:
  - 20 mA * 3.2 V * 16 LEDs = 1.024 W
- On board Micro-controller Power Draw:
  - 75 mA * 3.3 V = 0.2475 W
- Total Power Draw: 58.63 W
- Assuming 20% power dissipation through the slip-ring we need to transfer around 70.36 watts to the rotating side.

Power Supply

- Using standard AC outlet (120 V, 60 Hz)
- Use fuses for overcurrent protection
  - One for main incoming AC power
  - One for branch circuit to rotating side
- Using standard full wave rectifier circuits to convert incoming AC to DC
- Three Rectifier Circuits Required:
  - Rectifier 1 Output: 100 Vdc and 150 W
  - Rectifier 2 Output: 5 Vdc and 10 W
  - Rectifier 3 Output: 5 Vdc and 100 W
- Each LED Array Module will have voltage regulator on PCB
- AC power will be transferred to rotating side using slip rings

Slip Ring

- The slip ring will consist of two separate copper washers attached to the shaft of the LED apparatus.
  - Insulating material [glastic] will separate the shaft and the washer from direct contact.
  - One washer will act as the Live while the other will be the neutral or ground line.
- A mounted copper wire with a frayed end will create the contact to the outer wall of the washer.
- A hole will be bore through at a point on the inner wall of the copper washer
  - A wire will be connected here and threaded up through the LED apparatus' shaft to the micro-controller and LEDs.

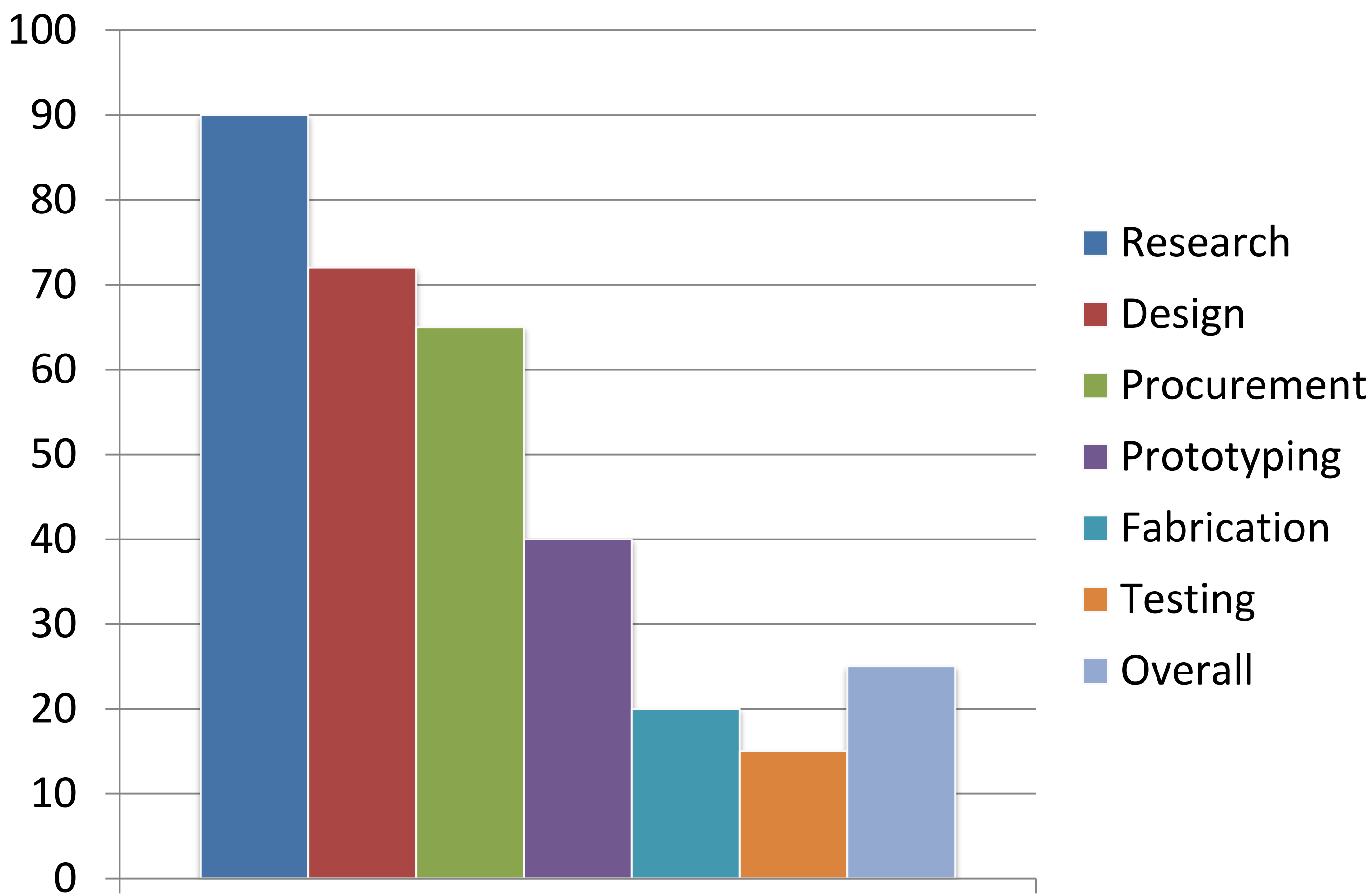
Cost Projection

Description	Quantity	Cost (per unit)	Price
Primary LEDs	128	$1.51	$193.28
Green LEDs	16	$0.27	$4.32
LED Controllers	50	$0.52	$26.00
Motor	1	$35.00	$35.00
Chassis	1	-	Donated
Stationary Controller	1	-	Donated
On-board Controller	1	$34.99	$34.99
Wireless Chip	1	$49.99	$49.99
PCB	-	-	$100.00
Misc. Equipment	-	-	$150.00
Prototyping	-	-	$100
		Total:	$693.58

Division of Labor

	Aaron	Patrick	Tim	Tony
LED Control & Array	75%	5%	15%	5%
Motor Control	5%	85%	5%	5%
Sensors	5%	85%	5%	5%
Power Supply	85%	5%	5%	5%
Power Transmission	15%	75%	5%	5%
Chassis	85%	5%	5%	5%
GUI	5%	5%	5%	85%
Image Processing	5%	5%	85%	5%
Wireless Transmission	5%	5%	30%	60%

Progress


100
90
80
70
60
50
40
30
20
10
0
Research
Design
Procurement
Prototyping
Fabrication
Testing
Overall

Current Issues

- Measuring power dissipation for a rotating device.
- Transmitting 120V AC over slip ring

Questions?