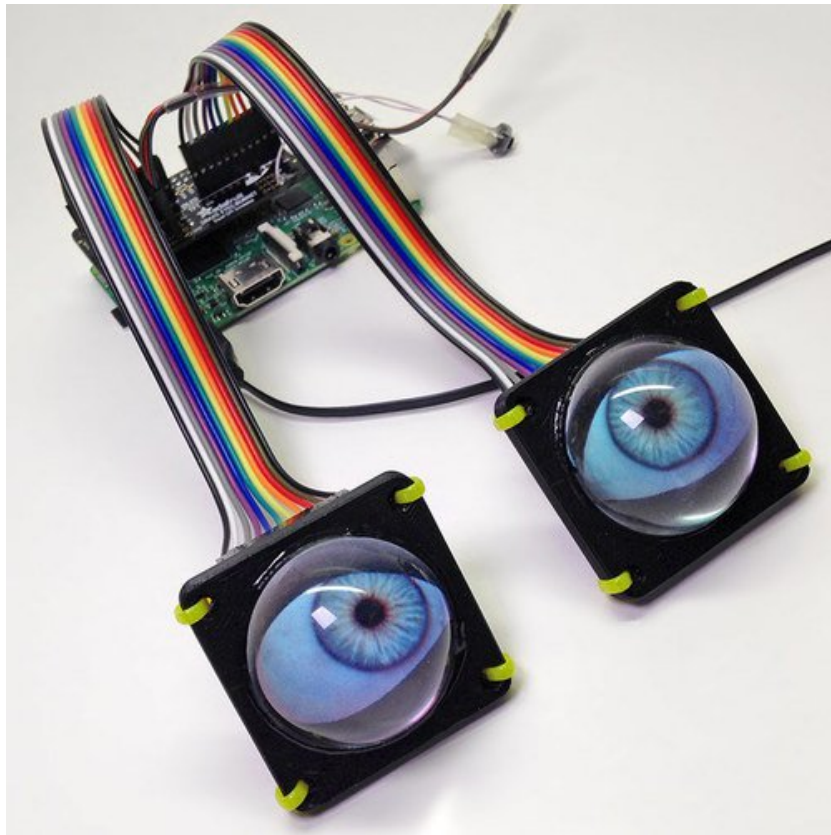


Animated Snake Eyes Bonnet for Raspberry Pi

Created by Phillip Burgess

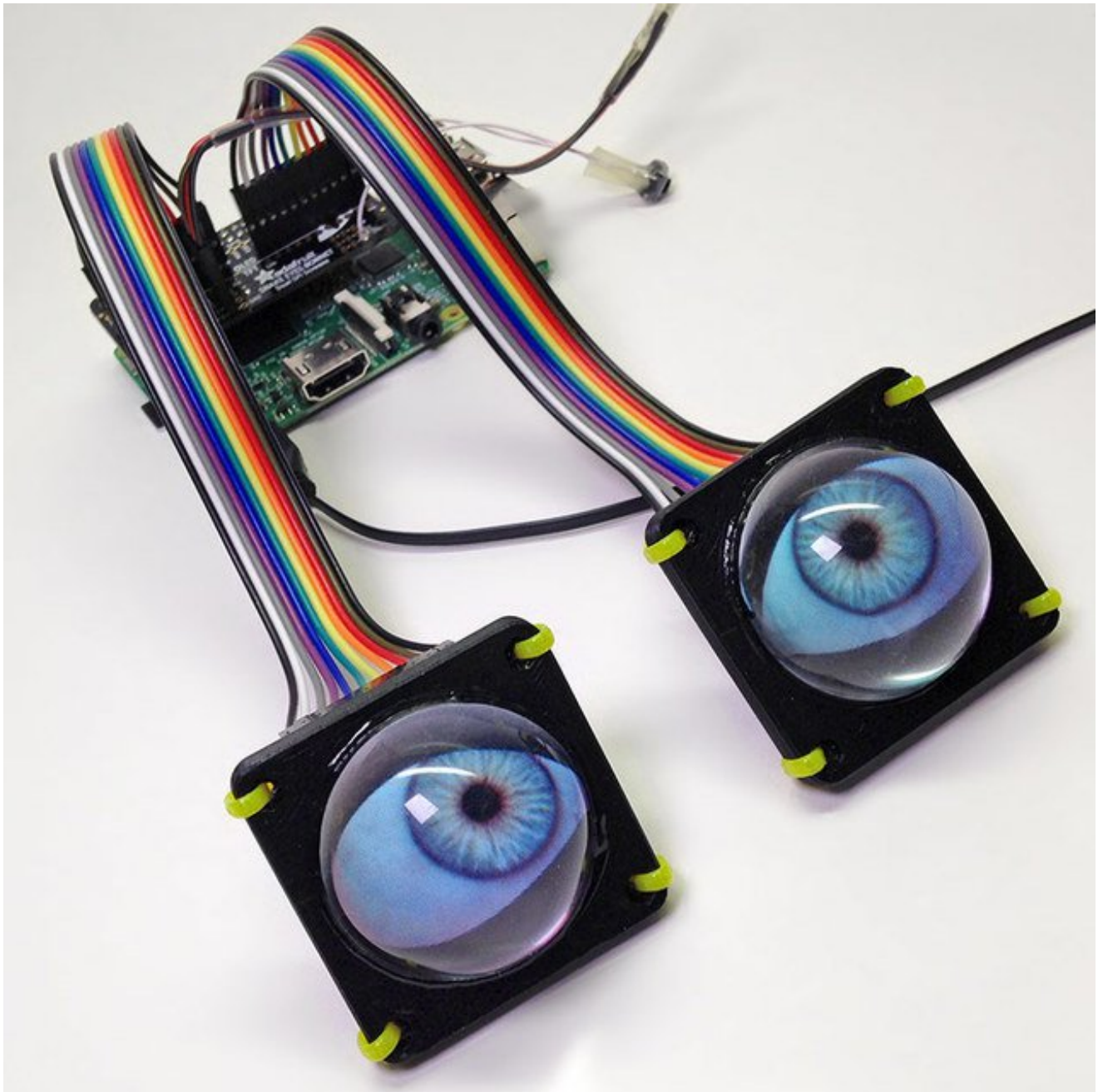


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Overview



The ***Snake Eyes Bonnet*** is a **Raspberry Pi accessory** for driving **two 128x128 pixel OLED or TFT LCD displays**, and also provides **four analog inputs** for sensors.

It's perfect for making cosplay masks, props, spooky sculptures for halloween, animatronics, robots...anything where you want to add a pair of animated eyes!



It's a follow-on of sorts to another project: [Electronic Animated Eyes Using Teensy 3.2](http://adafru.it/j6D) (<http://adafru.it/j6D>). The Teensy 3.2 is a *very* capable microcontroller, and the code for that project squeezed every bit of space and performance from it. I had been experimenting with the Raspberry Pi as an alternative...while it's still very experimental, why not make that work available to others?

The Raspberry Pi offers some potential **benefits**:

- Hardware-accelerated **3D graphics** (OpenGL), including **antialiasing**.
- A **faster CPU**, ample **RAM** and dual SPI buses could yield faster frame rates.
- Standard graphics formats like **JPEG**, **PNG** and **SVG** can be decoded on the fly; **no preprocessing step**.
- The eye rendering code is written in a **high-level language** — Python — making it easier to customize.

And some possible **downsides** to the Pi:

- Raspberry Pi takes time to boot an operating system off an SD card, whereas Teensy

is **instant-on** with all code in flash memory, . The Pi also requires an explicit **shutoff procedure**.

- The Raspberry Pi is **not as suitable** for **wearable** applications...it's larger, uses more power, and the SD card makes it less rugged.

This is a somewhat technical and not-inexpensive project. **Please read through everything first before committing.** If it seems daunting, the original [Teensy Eyes](http://adafru.it/j6D) (<http://adafru.it/j6D>) are more “Arduino-like” to build and customize, or other guides like [Animating Multiple LED Backpacks](http://adafru.it/iwB) (<http://adafru.it/iwB>) provide a more approachable introduction to code and electronics with less of an investment.

A Raspberry Pi 3 or Pi 2 is highly recommended. The code *will* run on a Pi Zero or other single-core Raspberry Pi boards, but performance lags greatly. We're working on this and hope to have solid support for the smallest Pi boards in the future.

Hardware Assembly

Don't forget, our Bonnet only comes with the PCB that lets you connect two displays. The two displays are not included and must be purchased separately!

Compatible Devices

- The code for this project works **only** with our [128x128 pixel OLED \(http://adafru.it/fXP\)](http://adafru.it/fXP) and [TFT \(http://adafru.it/dXI\)](http://adafru.it/dXI) displays. Other displays such as our 160x128 TFT or various PiTFT displays **ARE NOT SUPPORTED AT ALL**, period, not even sorta.
- Any recent Raspberry Pi board with the **40-pin GPIO header** should work. The very earliest Pi boards — Model A and B, with the 26-pin GPIO header — are not compatible. *But...*
- **A Raspberry Pi 3 or Pi 2 is highly recommended.** The code *will* run on a Pi Zero or other single-core Raspberry Pi boards, but performance lags greatly. We're working on this and hope to have solid support for the smallest Pi boards in the future.

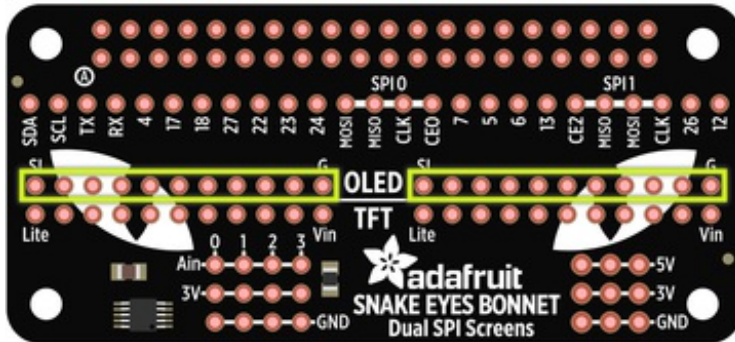
Plan a Head

Before committing to any particular hardware, think your project through. There are some decisions to be made...

- **One** display or **two**? You don't *have* to connect two displays...some of the most creative variants of the "Teensy eyes" [had only a single eye \(http://adafru.it/taM\)](http://adafru.it/taM).
- [OLED \(http://adafru.it/fXP\)](http://adafru.it/fXP) or [TFT LCD \(http://adafru.it/dXI\)](http://adafru.it/dXI) displays? OLEDs have a **wide viewing angle** and **excellent contrast** and **color saturation**, but they're somewhat **pricy**. **TFTs** make good **economy** displays if you're okay with the slightly **washed-out** appearance.
- What model of **Raspberry Pi** to drive it? The latest **multi-core** boards (like the **Pi 3**) have ample performance for **smooth animation**...but their **size** and **power draw** might make them best for stationary displays, like maybe a Halloween window prop. Costume and portable installations may fare better with the diminutive **Pi Zero**, though the animation will be much less smooth.
- Will the animation be running **autonomously**, or do you plan to control the eyes with a **joystick** and **buttons**? Will the pupils react to **light**? These require additional components.

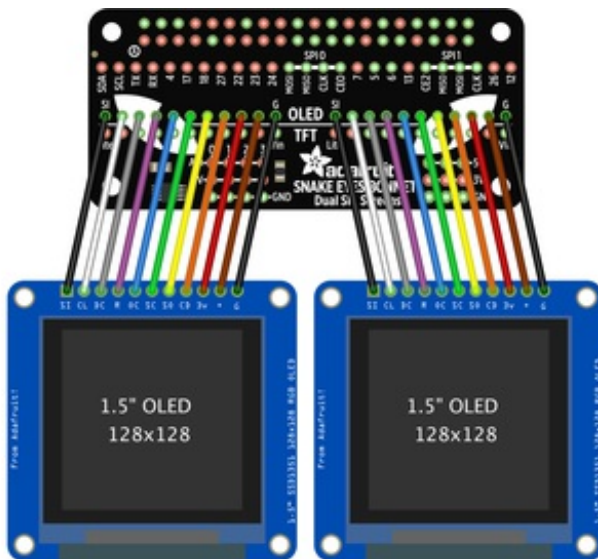
There's one more factor to consider: **how do you want everything connected?** Think about your intended installation. Is it temporary or permanent? Is space at a premium or do you have ample working room? These can influence your choice of wiring and connectors.

The breakout pins along the edge of each display board are wired up to matching pins on the bonnet boards. But you need the *correct* row for each display type...



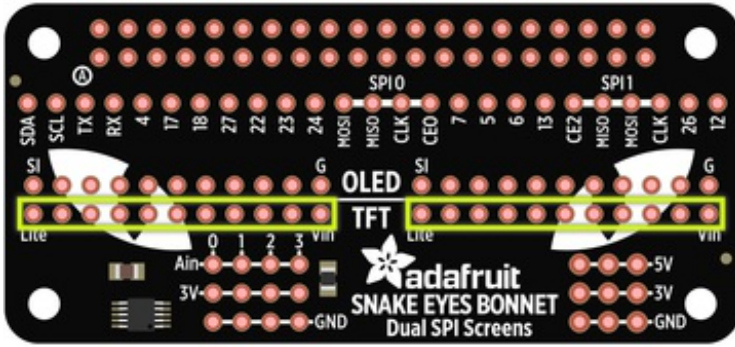
If using OLED display(s): use the “upper” rows (with the word “OLED” between them).

There are **11 pins** on the OLED breakout boards, which map directly to the 11 pins on the bonnet board.



Make absolutely certain the wires are in the same order.

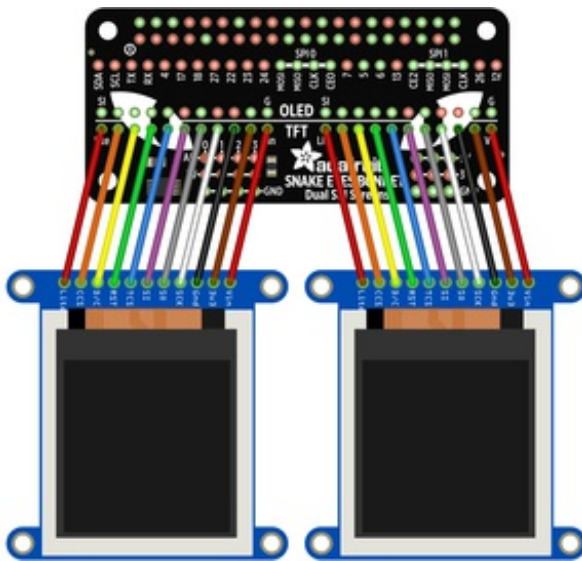
“S1” and “G” on the display board should go to “S1” and “G” on the bonnet, and each pin in-between...no wires should cross.



If using TFT display(s): use the “lower” rows (with the word “TFT” between them).

There are **11 pins** on the TFT breakout boards, which map directly to the 11 pins on the bonnet board.

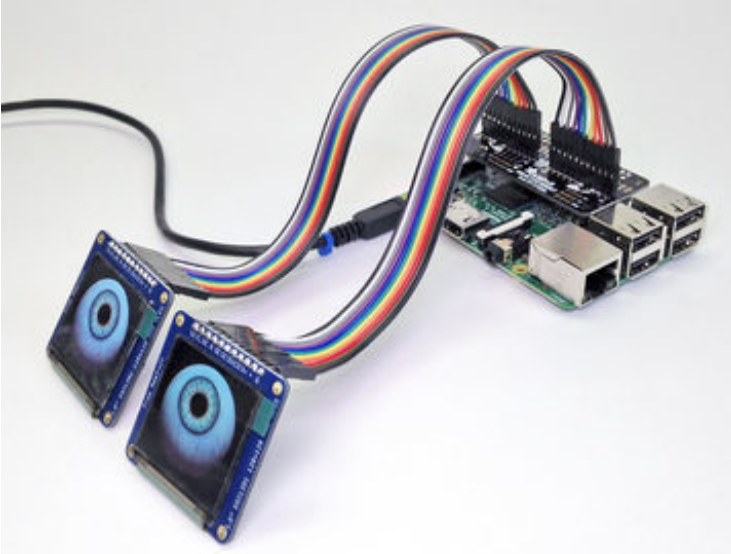
Make absolutely certain the wires are in the same order. “Vin” and “Lite” on the display board should go to “Vin” and “Lite” on the bonnet, and each pin in-between...no wires should cross.



There’s a common trope in science fiction stories: that there is no “up” or “down” in space. Wiring these displays is a little like that...it doesn’t matter if the wires or headers come out the *front* or *back* of the display breakout board, use *straight* or *right-angle* pins...as long as those wires get from the display to the bonnet in the **same positions and order**, everything’s good.

(As for up and down: right now the software assumes the displays are oriented with the **breakout pins along the top edge**; other rotations are not currently handled.)

Here’s a probable layout for a non-portable installation. **Straight header pins** have been soldered

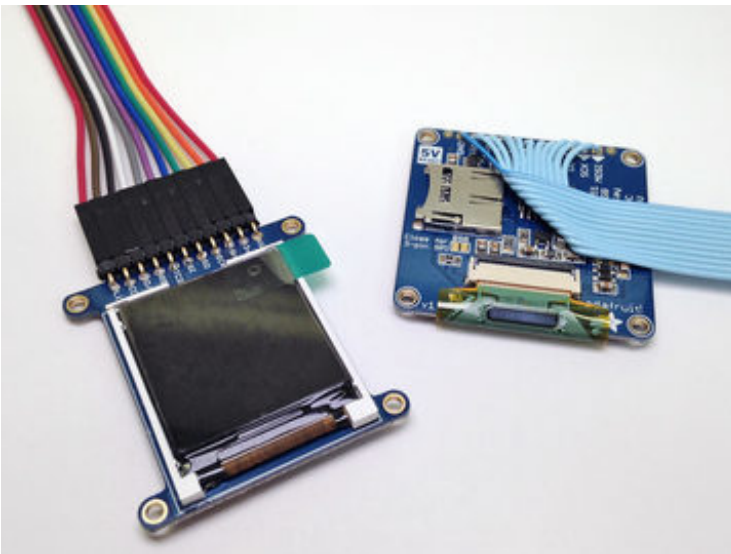


to the bonnet board and the displays, projecting “up” and “back,” respectively. Two 11-pin **female-to-female** ribbon cables then join everything.

This might be easiest to assemble (and disassemble), and the straight header pins on the displays make them easy to **re-use** in breadboard projects later.

...but that’s not the only option.

This TFT display has **right-angle header pins** on the front of the board (front, back, doesn’t matter as long as the wires connect in the same order). This makes it very slim, but also a fair bit taller.



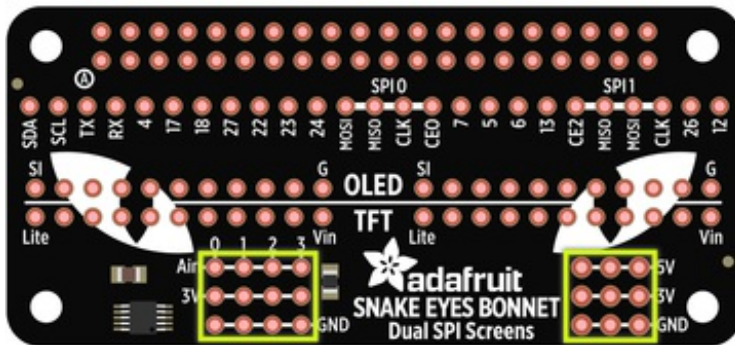
And this OLED has an 11-pin ribbon cable **directly soldered** to the board, no header pins at all. Again...front or back, ribbon could go straight out or can double back across the board...it all depends on your construction and space needs, as long as the pin order is followed. This is the most space-efficient, but requires patience and ace soldering skills, and isn’t easily re-used in other projects.

If using “rainbow” ribbon cables: these have 10 colors, while the displays use 11 wires...this means the cables will have the **same color** wire along both edges. Therefore, **DO NOT** rely on a visual mnemonic like “black wire is ground” or “red wire is Vin,” because your cable may have **two** black wires, or two reds, or two *anything*. Instead, make

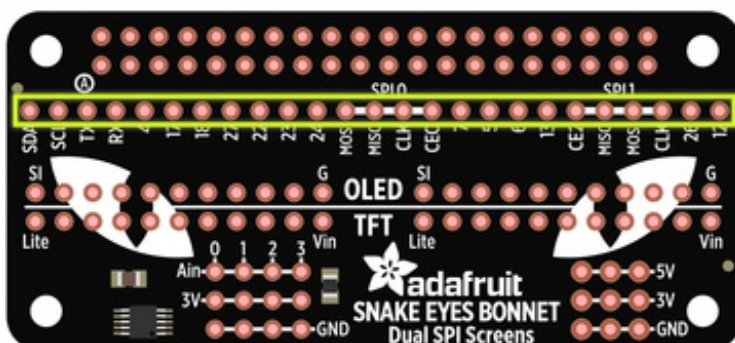
sure to **manually follow the first wire all the way from the bonnet to the display** make sure they line up right, then install the remaining wires in order.

If you're *really* economizing for space, here's a secret: only 7 wires are really *needed*...it's just easier and less error-prone to solder a header at each end and plug all 11 wires straight through. If using the OLED display, the SC, SD, CD and 3V pins can optionally be skipped. If using TFT, the 3v3 SO, CCS and Lite pins can be skipped. Make certain the exact same pins are skipped at the bonnet end, don't mix them up!

To ensure a clean signal from bonnet to displays, aim to keep your wirings **short and tidy**. Electrical interference can lead to animation glitches...we'll explain on the next page how to dial that back if needed. It's *possible* to use long ribbon cables (even a couple meters), but it invites problems with interference or signal reliability.



For optional features like joysticks, light sensors, blink and halt buttons, see the “Customizing the Hardware” page.



When finished soldering, you can **peel the clear plastic covering off the displays.** It's meant to protect them in shipping and during soldering. But unlike the screen protector on a phone or tablet, it's not optically pure and makes the display look cloudy.

Software Installation

Start by [downloading the current version of the Raspbian Lite operating system from the Raspberry Pi web site \(http://adafruit.it/fQi\)](http://adafruit.it/fQi), then [write this to a 2GB or larger micro SD card \(http://adafruit.it/dDL\)](http://adafruit.it/dDL) using Etcher or similar software.

Use Raspbian “Lite” for this project. Full-featured Raspbian is weighted down with things we don’t need here.

If your target system is a Raspberry Pi Zero, you may find the setup process easier with a spare full-size Raspberry Pi board such as a Pi 3, Pi 2 or Model B+, then move the card over to the Pi Zero when finished. If this is not an option, see [this guide \(http://adafruit.it/tbT\)](http://adafruit.it/tbT) for steps to make the Pi Zero act as a “USB Ethernet gadget,” and also create a file called “ssh” in the boot volume to enable ssh login.

Setup will require:

- USB keyboard
- HDMI monitor
- Network, one of:
 - Ethernet
 - WiFi (some Pi boards require a USB WiFi adapter for this)
 - For the Pi Zero, you can share a host computer’s network over USB using the [“Ethernet Gadget” directions in this guide \(http://adafruit.it/t9D\)](http://adafruit.it/t9D).

Insert the micro SD card, connect monitor and USB keyboard (and Ethernet cable, if using a wired network) and power up the board. The system will reboot once shortly after the first boot; this is normal as it readies the SD card. Then, on second boot...

Log in as user *pi*, with password *raspberry*. Then run the **raspi-config** tool for some initial setup...

```
sudo raspi-config
```

The following options are recommended:

- Change **User Password**.
- Under “**Internationalisation Options**,” select “**Change Keyboard Layout**.” If you’re getting unexpected characters from the keyboard, this is usually why.
- Under “**Advanced Options**,” select “**SSH**” and **enable** it. This lets you log into the system using a terminal program across the network, so you won’t need the keyboard

and monitor in the future.

Next step is to **get the Pi on the network**. If using wired Ethernet, it's usually a simple matter of plugging it in. [For WiFi, this tutorial can offer some guidance \(http://adafru.it/jd2\)](http://adafru.it/jd2)... specifically the "Setting Up WiFi on the Command Line" page.

You may need to reboot once or twice during the above setup procedures; this is normal. **Do not continue until the Pi is networked.** You can test with "ping adafruit.com" or similar.

The next part may be easiest if you log in remotely using **ssh**; this allows you to copy-and-paste from this browser window into a terminal. If not, that's okay, log in using keyboard and monitor and type in this next part very carefully...

```
cd
curl -O https://raw.githubusercontent.com/adafruit/Raspberry-Pi-Installer-Scripts/master/pi-eyes.sh
sudo bash pi-eyes.sh
```

This downloads and runs a script which installs all the prerequisite software and does some system configuration. It will ask a few questions along the way...

- Will you be connecting **OLED** or **TFT LCD** displays? Can't mix and match; must be one or the other.
- Do you want to install the **gpio-halt** utility? With a button wired between a GPIO pin and ground, this initiates an orderly shutdown (Linux systems hate it when you just pull the plug).
- Do you plan to use the **ADC** (analog-to-digital converter) pins on the bonnet? This is for extras light joysticks or light sensors.
- If your target system is a **Pi Zero**, do you want to enable **USB Ethernet gadget** support? This lets the Pi Zero share a host computer's network connection over a USB cable...you can also log into the Pi using ssh. Or you may have already enabled this with directions above.

After a confirmation step, the script goes about its business, which may take **20 minutes** or more...some parts of the software are pretty complicated to install!

You'll see some compiler warnings as the script runs. This is normal.

When it finishes, you'll be asked if you want to reboot the system. Enter "Y" to reboot or "N" if there's further work you want to do first (wrap up later with "sudo reboot" or "sudo shutdown").

If the bonnet and displays are attached, you should see animated eyes (or something close to it) following the reboot. It may take about a minute to start up, depending on the Pi model

and SD card speed.

IT'S NORMAL THAT THE EYES MAY EXHIBIT "GLITCHES" ON THE FIRST TRY. We'll fine-tune some parameters to get them working right.

If everything seems to be working well, you can skip ahead to the next page and ignore the steps below.

If the eyes are experiencing glitches (video snow, tearing, dropped frames or weird inverted colors), here's what to do...

Log into the Pi remotely using ssh. Then type the following commands:

```
cd /boot/Pi_Eyes
sudo killall fbx2
```

The displays will stop updating. This is normal.

Then, if you have **OLED** displays, type the following:

```
sudo ./fbx2 -o -b 12000000
```

Or, for **TFT** displays, try:

```
sudo ./fbx2 -t -b 20000000
```

The first argument (**-o** or **-t**) sets the display type in use; OLED or TFT, respectively. Second argument (**-b**) sets the **maximum bitrate** for the displays. The higher the bitrate, the smoother the animation... **but**...there's a limit to how fast this can go, and it can vary with wire lengths, connections, environment (such as interference from other nearby devices) and even slight manufacturing variances from one display to the next.

For **OLED** displays, the default bitrate is **14000000** (14 MHz). For **TFT** displays, default is **24000000** (24 MHz). But if there's trouble, we have to dial these back.

Try a lower value, like the 12 MHz or 20 MHz examples above. Watch the output for a minute...does it seem to have stabilized now? If only *one* of the two displays glitches, you'll still need to work the speed down until *both* run reliably.

Press **Control+C** to kill the program and test again with a different bitrate...maybe work down 4 MHz at a time, then up 1 MHz at a time until you find the "sweet spot" between speed and reliability. Once you find it, Control+C again and let's make the change permanent...

```
sudo nano /etc/rc.local
```

A couple lines from the bottom you'll find this:

```
/boot/Pi_Eyes/fbx2 -o &
```

(or “-t” if using TFT displays)

Insert the additional **-b** and **bitrate value** before the **&** character:

```
/boot/Pi_Eyes/fbx2 -o -b 12000000 &
```

Save changes and **exit** the editor. Then:

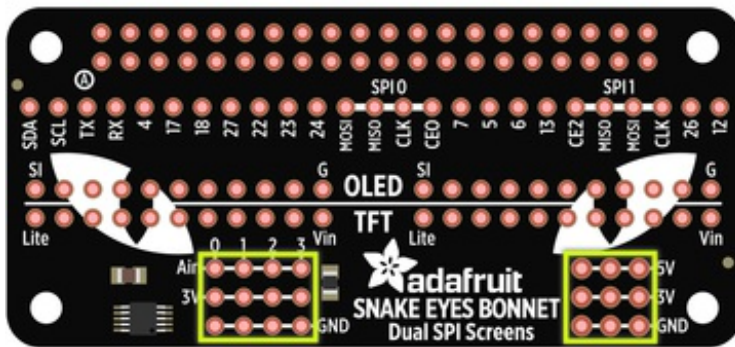
```
sudo reboot
```

After a minute or so the eyes should come up again, glitch-free this time. If not, repeat these steps again, trying a lower bitrate until you find a setting that works reliably.

Another way to reduce glitches is to **solder ribbon cables *directly* between the bonnet and displays, with no headers or plugs in-between**; every intermediary part is an opportunity for noise or connection problems. Consider this if you plan on permanent installation.

Customizing the Hardware

By default the eyes will animate on their own, looking around randomly. With some minor additional hardware (and enabling corresponding lines in the code), the eyes' direction, blinks and pupil dilation can be controlled manually or with sensors...



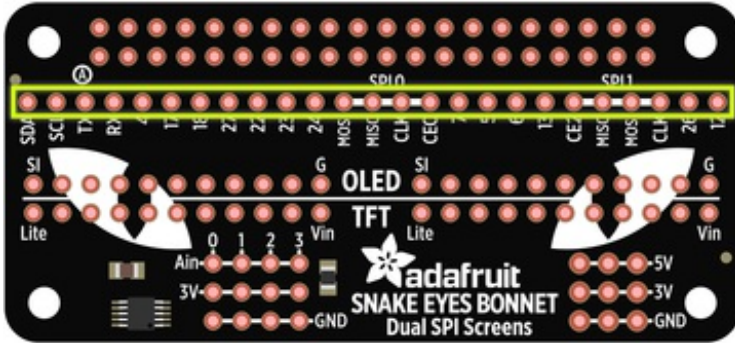
At the bottom-right of the bonnet are a few extra connection points for **5 Volts, 3.3**

Volts and **ground**, if you have a circuit that needs them. These are OK for **small loads** like ICs or a few LEDs, but *not* for big things like servos, which will need their own power source.

To the left are four **analog input pins** (along with four more 3.3V and ground points). You can use these to interface analog circuits such as a **joystick** to steer the eyes, **photocell** to make the pupils react to light, or perhaps to monitor battery voltage (use a voltage divider in this case, since the analog input must be 0 to 3.3 Volts).

Woops, we swapped SDA and SCL on the silkscreen - apologies! SCL is the left-most pin, and SDA is the pin to the right of it!

Additionally, most of the GPIO pins are broken out in a single row across the bonnet. **Some of these serve special purposes and should be avoided**, but technical users still have access to them if really needed...



- **TX** and **RX** are available as **GPIO14** and **15** if the serial console is **disabled** with raspiconfig.
- **SPI0** (SPI bus used for the right eye) uses **GPIO8-11** (CE0, MISO, MOSI and SCLK, respectively). Steer clear!
- **SPI1** (second SPI bus used for left eye) uses **GPIO16** (CE2) and **19-21** (MISO, MOSI, SCLK). Avoid! Also, I2S audio devices can't be used because the pins overlap.
- **GPIO5** and **6** connect to the DC and RESET pins of both displays, so these too should be avoided unless you have some special situation.

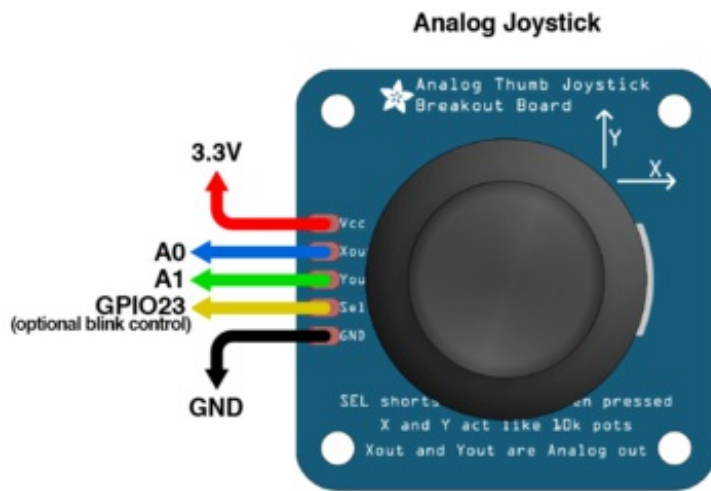
Analog Controls

Any **analog** controls that are added should include connections to the **3.3V** and **GND** pins. Do not use the 5V pins or there will be...trouble.

XOUT and **YOUT** from a joystick can connect to analog pins **A0** and **A1**.

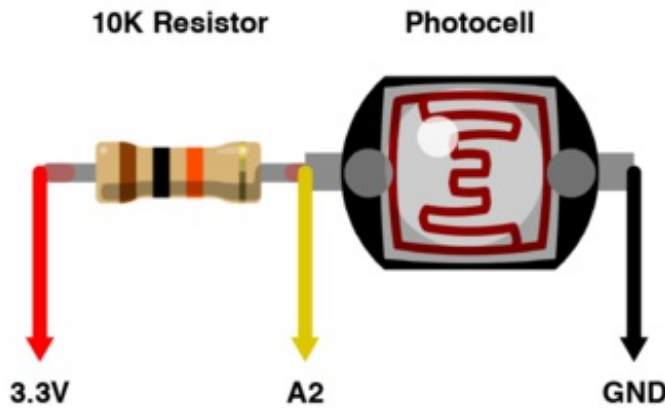
The eyes move autonomously by default — settings in the code enable the joystick instead.

If you need to mount the joystick in a different orientation, there



are also settings to invert each axis. Swap the X and Y pins in the code to use the joystick sideways.

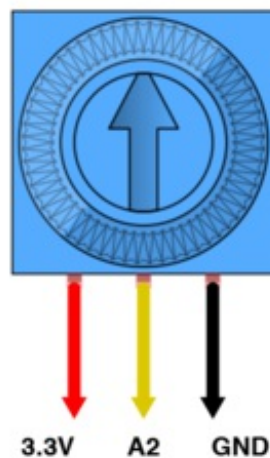
This thumb stick has a click feature, which could be used to control eye blinks if desired. The smaller “mini” stick doesn’t have this, but is *extra tiny* for working into a costume or puppet.



To have the pupils contract or expand in response to light, connect a photocell and 10K resistor in series. The midpoint connects to analog pin **A2**.

Analog input for the pupils (either photocell or the dial below) are enabled in the code by default. You can comment out IRIS_PIN in the code to have this move autonomously.

Potentiometer (10K)

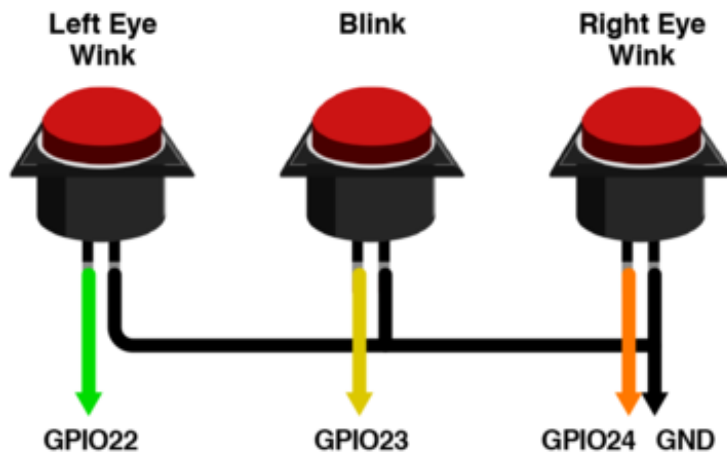


For manual control of pupil dilation (instead of responding to light) a 10K potentiometer can be used. The center leg connects to analog pin **A2** (same input as the photocell, just substituting a different analog control).

Buttons

The eyes normally blink autonomously, but you can also add one or more buttons to make them blink (or even wink individually) on command.

For all buttons, connect one leg of each to **GND**, and the opposite leg to a digital pin:



- GPIO Pin 22 is the **left** eye wink.
- GPIO Pin 23 blinks **both** eyes.
- GPIO Pin 24 winks the **right** eye.

If using our analog joystick breakout board, that stick includes a clicky button when you press down on it (on the SEL pin). This can optionally be used for manual blink control, or you can use a separate button for this (I find the joystick button a bit hamfisted).

Software Changes

Adjustments to the code must be made to use any of the above features. You'll find the code in `/boot/Pi_Eyes/eyes.py`. It's located in `/boot` to simplify "offline" editing on another system...if editing on the same Pi where it runs, you may need to edit as root (e.g. "sudo nano /boot/Pi_Eyes/eyes.py").

After making changes, you could hunt down the background Python process that was run at startup, kill and restart...but it's usually easiest just to **reboot**.

Hardware config settings can be found near the top of the code:

```
# INPUT CONFIG for eye motion -----
```

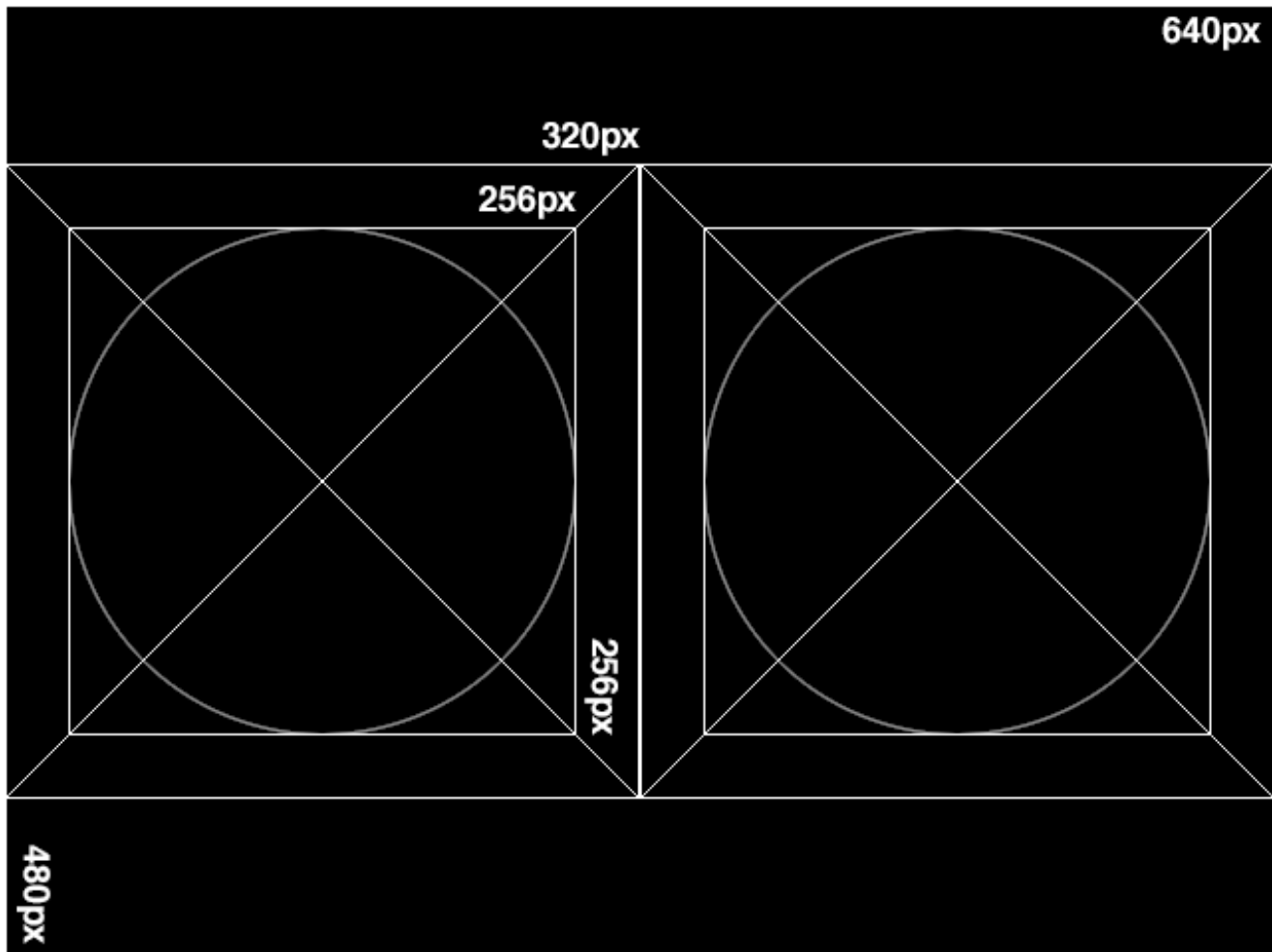
```
JOYSTICK_X_IN = -1 # Analog input for eye horiz pos (-1 = auto)
JOYSTICK_Y_IN = -1 # Analog input for eye vert position (")
PUPIL_IN      = -1 # Analog input for pupil control (-1 = auto)
JOYSTICK_X_FLIP = False # If True, reverse stick X axis
JOYSTICK_Y_FLIP = False # If True, reverse stick Y axis
PUPIL_IN_FLIP  = False # If True, reverse reading from PUPIL_IN
TRACKING       = True  # If True, eyelid tracks pupil
PUPIL_SMOOTH   = 16   # If > 0, filter input from PUPIL_IN
PUPIL_MIN      = 0.0  # Lower analog range from PUPIL_IN
PUPIL_MAX      = 1.0  # Upper "
WINK_L_PIN     = 22   # GPIO pin for LEFT eye wink button
BLINK_PIN      = 23   # GPIO pin for blink button (BOTH eyes)
WINK_R_PIN     = 24   # GPIO pin for RIGHT eye wink button
AUTOBLINK      = True # If True, eyes blink autonomously
```

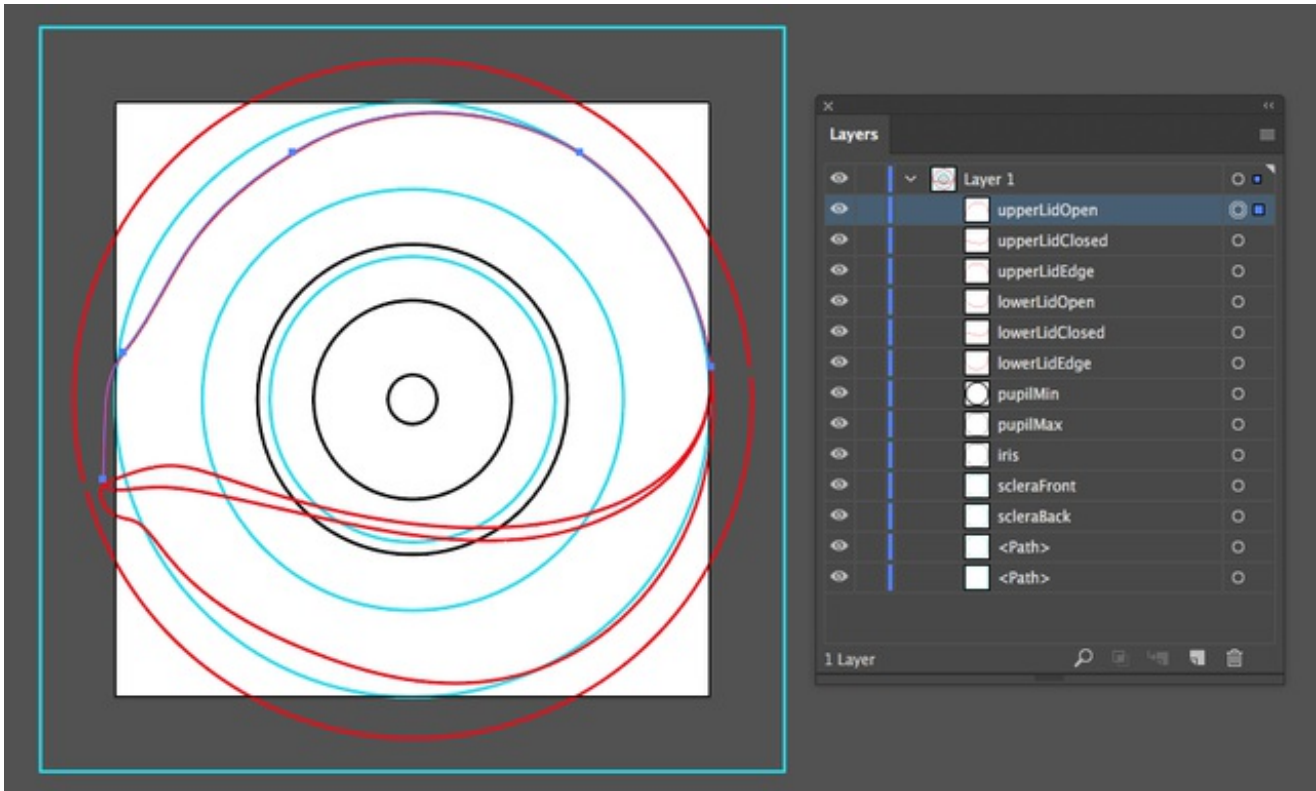
For example, to enable analog joystick input and a photocell, set JOYSTICK_X_IN, JOYSTICK_Y_IN and/or PUPIL_IN to analog channel numbers (0 to 3). If the response from the stick or sensor is backwards, set JOYSTICK_X_FLIP, JOYSTICK_Y_FLIP and/or PUPIL_IN_FLIP to "True" as needed.

Customizing the Look

This page is a work in progress. When finished, it will:

- Explain the graphics files and how they're formatted.
- Explain the Python code and how to customize some things.



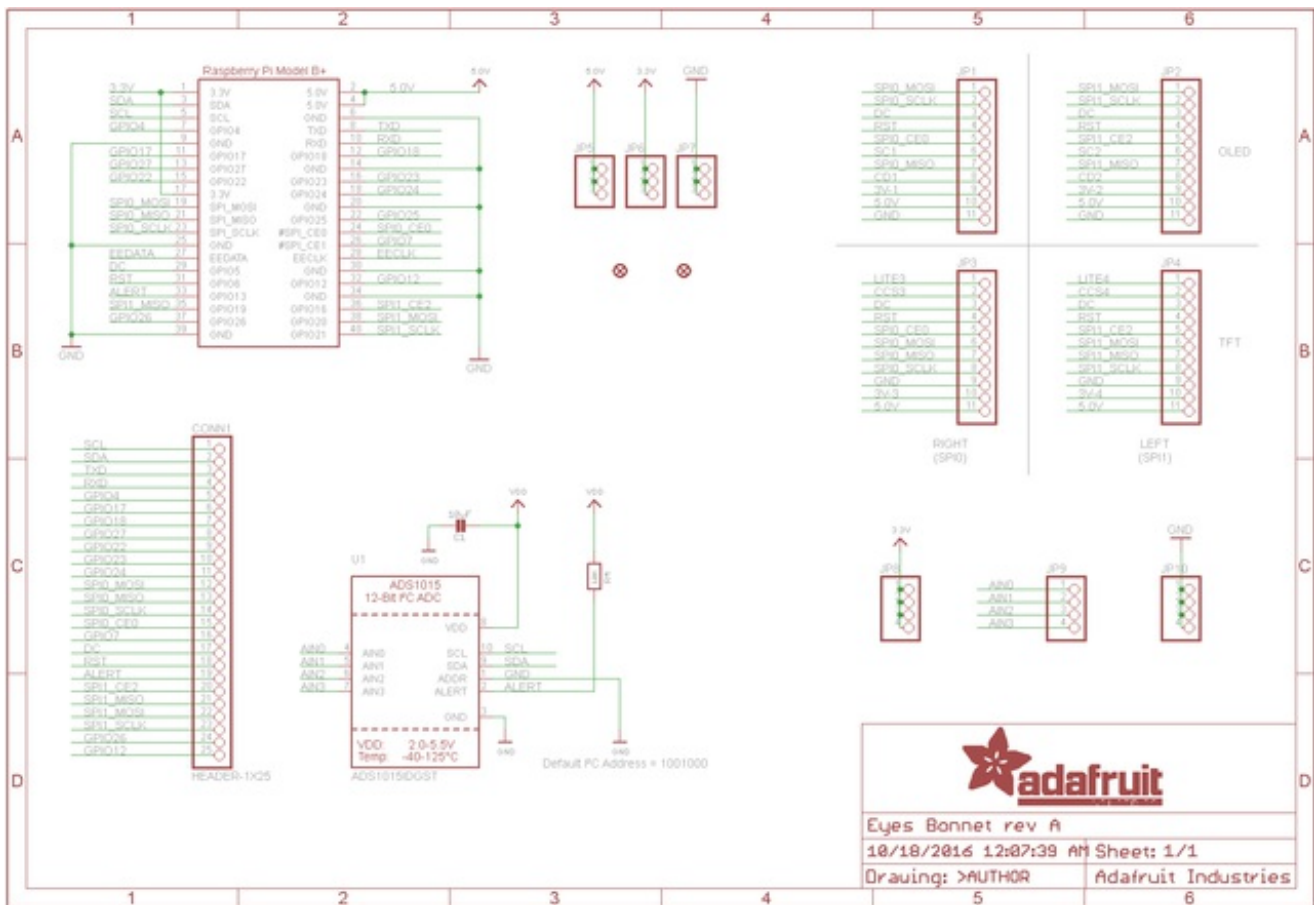


Downloads

Files

- [EagleCAD PCB files on GitHub \(http://adafru.it/tDt\)](http://adafru.it/tDt)
- [Fritzing object in Adafruit Fritzing library \(http://adafru.it/aP3\)](http://adafru.it/aP3)

Schematic



Fab Print

Dims. in mm

