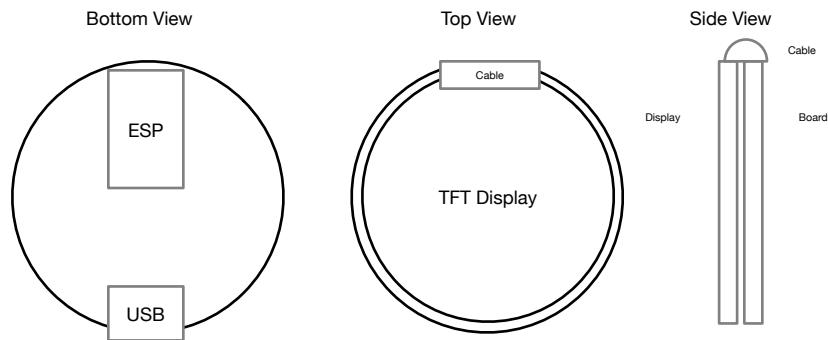
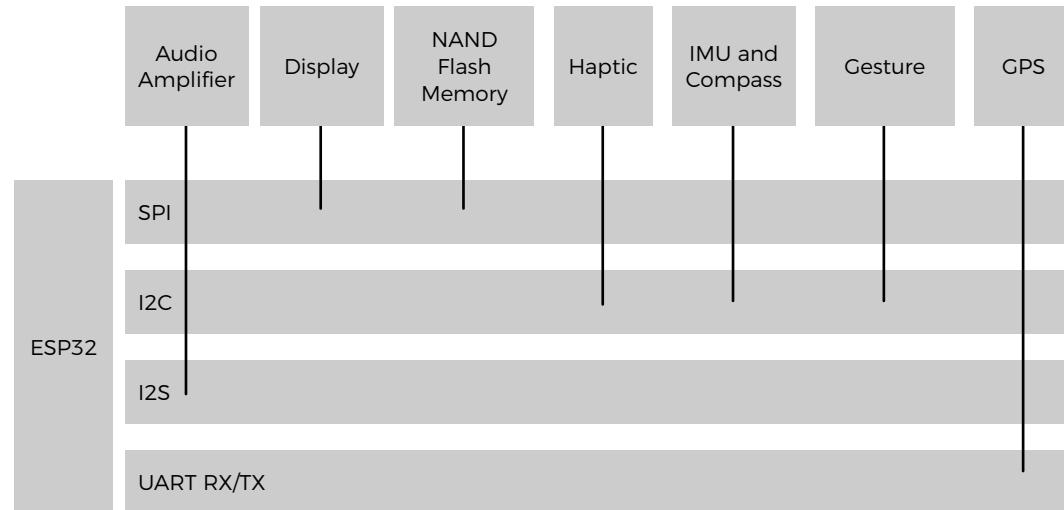


This document shows technical details of the Seuss display prototype. Our design goals:

- 1) Inexpensive off-the-shelf components
- 2) Provide an integration to run animated and musical shows
- 3) Publish the design under an open-source license so all Makers may benefit from it

Sox has: ESP32, 1.28 Inch Round LCD display, gesture sensor, IMU, audio amp, haptic motor driver, SPI Flash memory (NAND, <https://www.adafruit.com/product/4899>), and GPS

Software for Sox is at <https://github.com/frankcohen/ReflectionsOS/tree/main/Devices/Sox/Software>



GPS antenna, pads for battery, gesture, etc, need to be on the back side (non display side)

Sox is a general purpose ESP-32 main board to power storytelling experiences. I named the board versions from Dr. Seuss' writing because Theodor Seuss Geisel was turned down 28 times before being published. I've tried many times to build the display for the Reflections project.

None of this is complicated. However, putting it all together was difficult and time consuming. For example, all but one GPIO pin is used in this design.

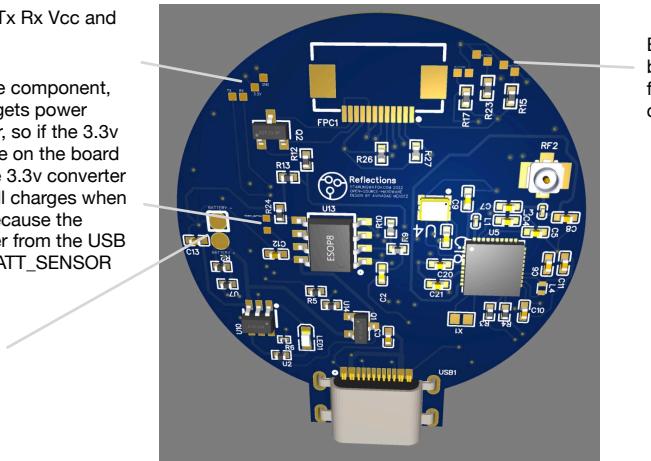
The design uses mostly breakout boards from Adafruit. They provide needed pull-up resistors and level-shifters. The finished board is entirely 3.3 volts and delivered in a 36 mm diameter round board.

Seuss Display Prototype 2021  
Reflections Project  
fcohen@starlingwatch.com  
(408) 364-5508

Sox board design by Avinadad Mendez as of Jan 29, 2022

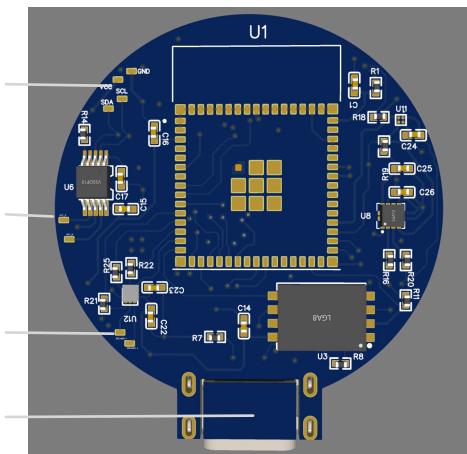
FTDI pads are labeled as Tx Rx Vcc and Gnd

Power switch. Every single component, sans the battery charger, gets power through the 3.3v converter, so if the 3.3v is disabled, everything else on the board is off. This way, even if the 3.3v converter is disabled, the battery still charges when connected to the USB. Because the battery charger gets power from the USB connector itself, VBUS. BATT\_SENSOR

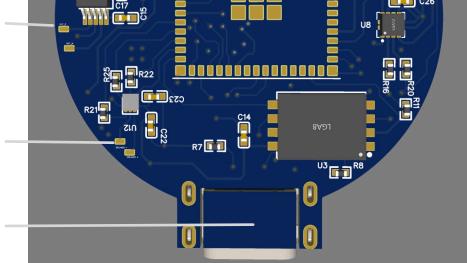


Button pads. Left, Center and Right buttons are connected to pins with RTC functionality. So the status of these pins can be read even in deep sleep mode.

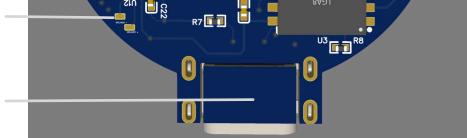
Gesture sensor pads



Haptic motor pads



Speaker pads



USB type C





## ESP-WROOM-32 ESP32 ESP-32S Development Board 2.4GHz Dual-Mode WiFi + Bluetooth Dual Cores Microcontroller

The ESP32 integrated with Antenna switches, RF Balun, power amplifiers, low-noise amplifiers, filters, and management modules, and the entire solution occupies the least area of PCB. 2.4 GHz Wi-Fi plus Bluetooth dual-mode chip, with TSMC Ultra-low power consumption 40nm technology, power dissipation performance and RF performance is the best, safe and reliable, easy to extend to a variety of applications.

Espressif - based in Shanghai, China - makes ESP32. It's an open-source design.

Software drivers and utilities for ESP32 are at:

<https://github.com/espressif/arduino-esp32>

<https://github.com/nodemcu/nodemcu-firmware/tree/dev-esp32>

Notes on using ESP32 with Arduino IDE:

Follow these instructions to install ESP32 to Arduino IDE

<https://github.com/espressif/arduino-esp32/blob/master/docs/arduino-ide/mac.md>

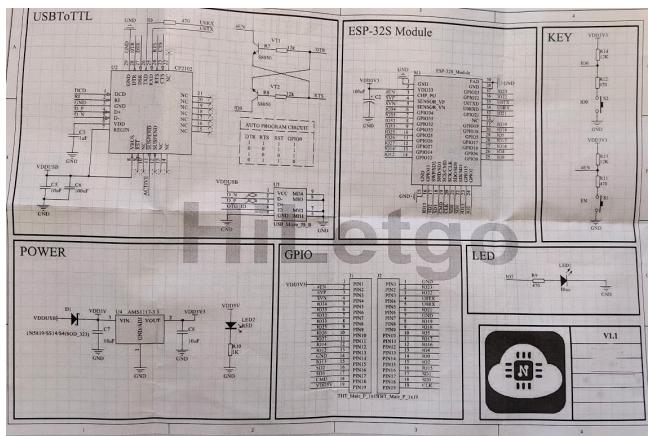
Use ESP32 Dev Board for Board selection

To reference GPIO pins in code use just the number, for example "digitalWrite(13, HIGH)" sets GPIO13 high.

~/Library/Python/2.7/bin. I needed to patch esptool.py following <https://github.com/espressif/arduino-esp32/issues/4408> and changing the +x perms too

<https://randomnerdtutorials.com/solved-failed-to-connect-to-esp32-timed-out-waiting-for-packet-header/>

<https://github.com/me-no-dev/EspExceptionDecoder> to decode stack traces



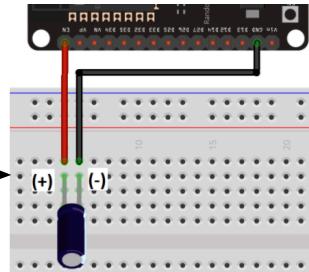
These pages came with the HiLetGo.com ESP32 Development Board

ESP32 provides the easy-of-use of the Arduino environment (forums, experts, IDE), a 32-bit core, and Bluetooth and Wifi networking.

ESP32 development boards provide a breadboard-friendly package with a USB programming interface and power supply.

The downside of the development boards happens when people publish tutorials. Board change pinouts. For example, some boards provide access to ESP32's dual SPI bus pins, others do not.

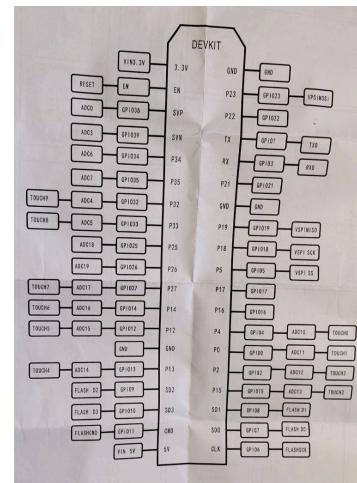
Hold the boot button down to upload a sketch



Note: electrolytic capacitors have polarity. The white/grey stripe indicates the negative lead.

If it works, then you can solder the **10 uF electrolytic capacitor** to the board. Since the EN and GND pins are far apart from each other, you can simply connect the capacitor between the EN and the **GND** of the ESP32 chip as shown in the schematic diagram below:

<https://randomnerdtutorials.com/solved-failed-to-connect-to-esp32-timed-out-waiting-for-packet-header/>



ESP32 Development Board				
RESET	3.3v	19	GND	
Left button	EN	18	GPIO 23	VSPI MOSI
Right button	GPIO 36	17	GPIO 22	SCL I2C
Center/Power	GPIO 39	16	GPIO 01	TX0
GPS TX	GPIO 34	15	GPIO 03	RX0
Display CS	GPIO 35	14	GPIO 21	SDA I2C
Backlight LED	GPIO 32	13	GND	
Audio LRCL	GPIO 33	12	GPIO 19	VSPI MISO
Audio BCLK	GPIO 25	11	GPIO 18	VSPI SCK
Audio DIN	GPIO 26	10	GPIO 05	VSPI SS
HSPI SCK	GPIO 27	9	GPIO 17	Display RST
HSPI MISO	GPIO 14	8	GPIO 16	Display DC
HSPI MOSI	GPIO 12	7	GPIO 04	SD memory CS
Flash D2	GND	6	GPIO 00	Boot
Flash D3	GPIO 13	5	GPIO 02	LED
Flash CMD	GPIO 09	4	GPIO 15	HSPI SS
	GPIO 10	3	GPIO 08	Flash D1
	GPIO 11	2	GPIO 07	Flash D0
	5V	1	GPIO 06	Flash SCK

Pins on ESP32 development board as seen from the top, 5V and GPIO 6 are closest to the USB connector

TX	GPS	GPS TX		
VSPI	Display	Display CS	DC	RST
VSPI	SD memory	SD memory CS		
I2S	Audio	LRCL	DIN	BCLK
I2C	Compass	SDA	SCL	
I2C	Haptic motor			
I2C	Proximity sensor			
HSPI unused				

## Breakout Boards

GPS <https://www.adafruit.com/product/3133>

Compass <https://www.adafruit.com/product/2472>

Display with SD Card <https://www.adafruit.com/product/3787>

Audio <https://www.adafruit.com/product/3006>

Haptic motor <https://learn.adafruit.com/adafruit-drv2605-haptic-controller-breakout>

Proximity sensor <https://www.adafruit.com/product/466>, APDS9960

This is the wiring guide. Use it as a top-of-board legend for all the components.

The most difficult part of this project was to keep track of the multiple uses of each pin. For example, GPIO 35 is input only. GPIO 2 looks normal but has an LED off of it.

BATT\_SENSOR is at GPIO17  
on Avinadads board

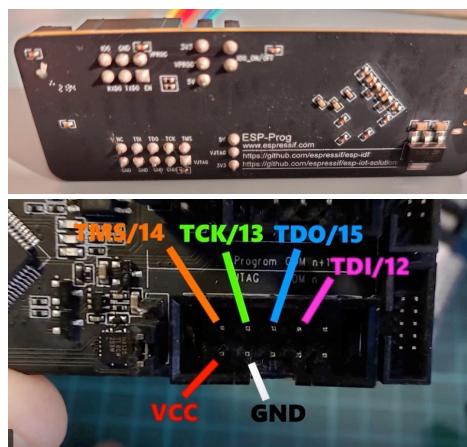
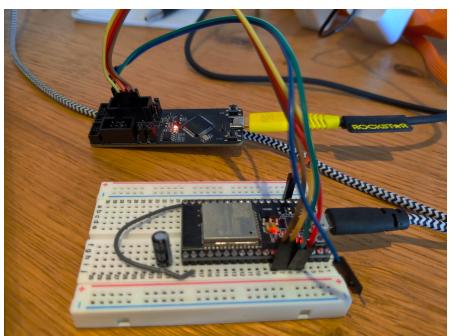
In the end all of the available GPIOs are used. GPIO 14, 12, 13, 15, 4 are used by the internal WiFi system. 9, 10, 11, 6, 7, 8 are used by the ESP32's Flash memory system (different than the SD card in this project). and 1, 3 are used by the USB adaptor.

I found conflicting tutorials, how-to guides, and references to data sheets (that turned out to be for different ESP32 development boards). One tutorial had a typo and kept referring to GPIO 20, which does not exist on the HiLetGo development board.

I also found I could not depend on translating tutorials and wiring guides for Arduino Uno and Arduino Mega to the ESP32 development boards.

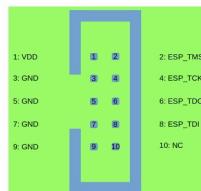
Seuss uses the SD Card reader built into the Adafruit display breakout board - Display SDCS GPIO 4. I tried 2 SD Card reader boards and 2 SD cards. I could not get them to work. I have also read GPIO 4 is not available when using WiFi.

Many tutorials will reference pin numbers. While that works on Arduino Uno, the GPIO numbers are referenced here.



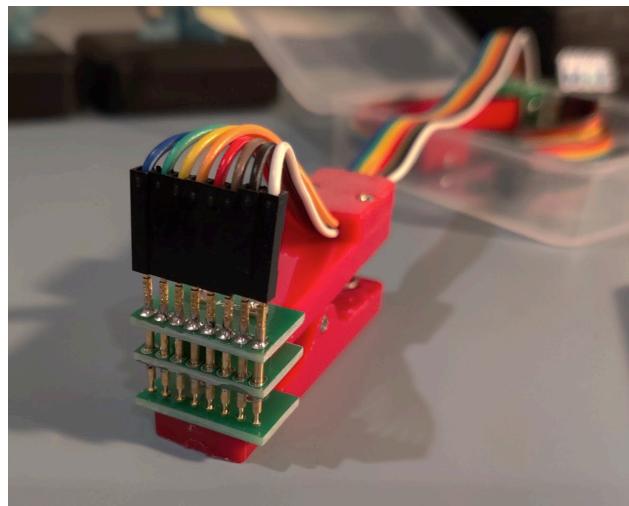
JTAG debugger connections:  
TDI - GPIO 12  
TMS - GPIO 14  
TCLK - GPIO 13  
TDO - GPIO 15

Platformio.ini:  
debug\_tool = esp-prog  
debug\_init\_break = tbreak setup



IO12	MTDI
IO13	MTCK
IO14	MTMS
IO15	MTDO

Pogo pin adaptor for JTAG pads



Sox is compatible with Platform.io and ESP-prog for in-circuit debugging.

## MEMS accelerometer, magnetometer/compass and gyroscope

LIS2DH12 - 3 axis MEMS accelerometer

<https://www.sparkfun.com/products/15760>

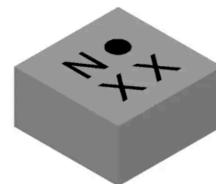
[https://jlcpcb.com/part/componentSearch?  
isSearch=true&searchTxt=LIS2DH12](https://jlcpcb.com/part/componentSearch?isSearch=true&searchTxt=LIS2DH12)



and

Magnetometer - MMC5603NJ

[https://datasheet.lcsc.com/lcsc/1912111437\\_MEMSIC-MMC5603NJ\\_C404328.pdf](https://datasheet.lcsc.com/lcsc/1912111437_MEMSIC-MMC5603NJ_C404328.pdf)



Previous versions used:

[https://lcsc.com/product-detail/Attitude-Sensors\\_STMicroelectronics-  
LSM6DS3TR-C\\_C967633.html](https://lcsc.com/product-detail/Attitude-Sensors_STMicroelectronics-LSM6DS3TR-C_C967633.html)

Tutorial for MPU-92-65

<https://www.youtube.com/watch?v=V4NdsBjUAO0>

BNO055 and BNO085, now out of stock and maybe out of existence. <https://www.adafruit.com/product/2472>. Wiring guide at <https://learn.adafruit.com/adafruit-bno055-absolute-orientation-sensor/overview>, [https://github.com/adafruit/Adafruit\\_BNO055](https://github.com/adafruit/Adafruit_BNO055)

## Display

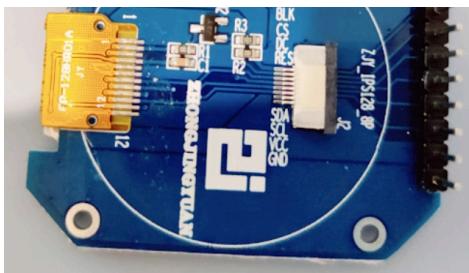
Version: January 23, 2022

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GND  
+3.3

I chose this display unit because it is fast - I can get 15 frames per second - and inexpensive. It uses SPI for both the



SCL - SCK (GPIO 18)  
SDA - MOSI (GPIO 23)  
RES - GPIO 17  
DC - GPIO 16  
CS - GPIO 32  
BLK - +3.3

display.

GC9A01A

<https://es.aliexpress.com/item/1005002389910393.html?gatewayAdapt=glo2esp>  
13 pin cable connector welds to the display board

Previous versions:

<https://www.buydisplay.com/download/ic/GC9A01A.pdf>

<https://www.buydisplay.com/1-28-inch-tft-ips-lcd-display-module-240x240-spi-for-arduino-raspberry-pi>

[https://github.com/PaintYourDragon/Adafruit\\_GC9A01A](https://github.com/PaintYourDragon/Adafruit_GC9A01A)

Shrink video files to no compression,

```
#!/bin/bash
cd /Users/frankcohen/Desktop/ReflectionsExperiments/ReadyForTrial
for i in *.mp4; do /Applications/ffmpeg -i "$i" -vf
"fps=15,scale=240:240:flags=lanczos,crop=240:in_h:(in_w-240)/2:0" -q:v 9 "/Users/
frankcohen/Frank/Votsh/Models/Reflections/Reflections\ Project\ Updates/Sox\
Development\ Board/Demo\ Files/10fps/${i%.}*}.mjpeg"; done

for i in *.mov; do /Applications/ffmpeg -i "$i" -vf
"fps=10,scale=240:240:flags=lanczos,crop=240:in_h:(in_w-240)/2:0" -q:v 9 "/Users/
frankcohen/Frank/Votsh/Models/Reflections/Reflections\ Project\ Updates/Sox\
Development\ Board/Demo\ Files/10fps/${i%.}*}.mjpeg"; done
```

## Audio I2S Sound Board

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Use I2S audio library from  
<https://github.com/schreibfaul1/ESP32-audiol2S>

Previous version used Earle F.



<https://learn.adafruit.com/adafruit-max98357-i2s-class-d-mono-amp>

libfdk\_aac for converting wav to m4a (aac) is not installed by default in ffmpeg. I used these commands to install fumes with libfdk\_aac on Mac OS X:

```
brew tap homebrew-ffmpeg/ffmpeg  
brew install homebrew-ffmpeg/ffmpeg --with-fdk-aac --HEAD
```

Then create an AAC audio file from an mp4 video  
ffmpeg -i input.wav -c:a libfdk\_aac -b:a 8k output.m4a

Using this library to play I2S audio on ESP32:  
<https://github.com/schreibfaul1/ESP32-audioI2S>

Audacity on Mac. Open an MP3, File -> Export, Export As MP3..., Bit rate mode: Constant, 40 KPS, save with .mp3 file extension

Philhower, III,  
earlephilhower@yahoo.com, for  
the WAV audio player library at  
<https://github.com/earlephilhower/ESP8266Audio>

Use ffmpeg to create AAC audio files from mp4 video file input:  
<https://trac.ffmpeg.org/wiki/Encode/AAC>

Tutorial on I2S at <https://diyi0t.com/i2s-sound-tutorial-for-esp32/>

MAX98357

The processor takes input files with:  
sample rate of 44.1 kHz,  
stereo format  
16 bits  
WAVE format

However, to play 240x240 MJPEG uncompressed files requires:  
sample rate of 8000 kHz  
16 bits  
stereo format  
WAV format  
See experiments/  
Stream\_all\_videos\_audio

I use Audacity on a Mac Book Pro

Note: Connect the Gain pin on the MAX board to GND. Do not leave it open/floating.

## Buttons

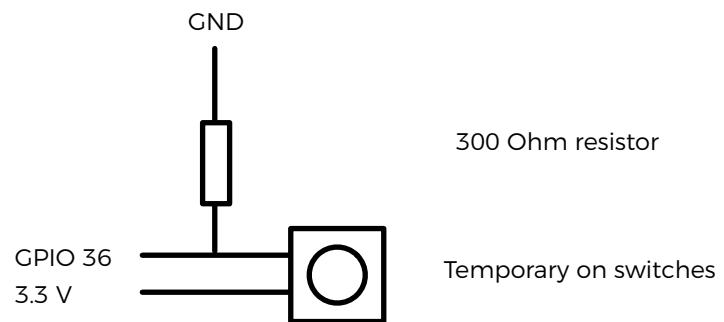
Version: January 19, 2022

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```
#define leftButton 34  
#define centerButton 39  
#define rightButton 36
```

Seuss Display includes a 3 button interface for user control. Includes a left, middle, and right button.

See the buttons.ino sketch for an



example of sensing three buttons

GPIO 39 (center button) is also a control for turning the board on and off. Push and hold for 3 seconds to turn on or off.

## Haptic Feedback

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Seuss includes a haptic feedback system using the Adafruit DRV2605 breakout board.  
<https://learn.adafruit.com/adafruit-drv2605-haptic-controller-breakout>

Software is at:

<https://github.com/fcohen/seuss/>

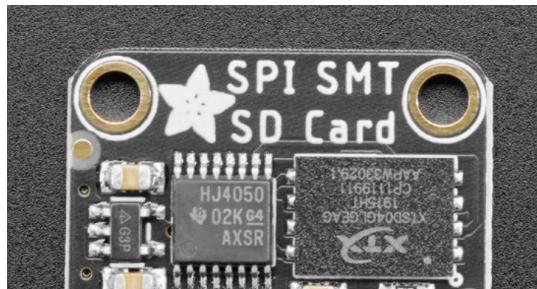


[https://github.com/aaarruit/Adafruit\\_DRV2605\\_Library](https://github.com/aaarruit/Adafruit_DRV2605_Library)

## Memory SPI SD Flash

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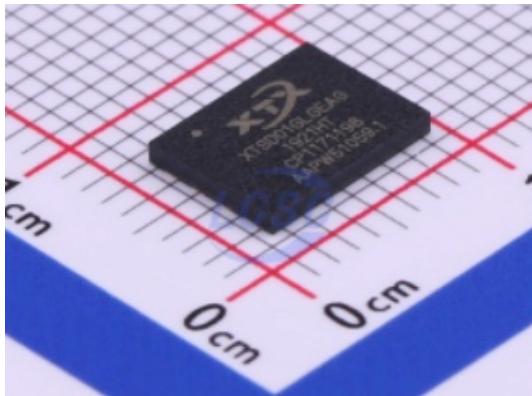
Adafruit SPI Flash SD Card - XTSD  
512 MB PID: 4899

<https://www.adafruit.com/product/4899>

1 Gb NAND - LGA8-8x6mm NAND  
FLASH ROHS is at <https://lcsc.com/>



product-detail/NAND-FLASH\_XTX-  
XTSD01GLGEAG\_C558837.html



## Gesture Sensor

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Changing from APDS-9960 gesture sensor to VL53L5CX sensor.  
<https://www.st.com/resource/en/datasheet/vl53l5cx.pdf>

Depends on SparkFun Electronics VL53L5CX library  
<https://learn.sparkfun.com/tutorials/qwiic-tof-imager-vl53l5cx-hookup-guide>

Finger Gesture Sensor (FGS)  
<https://github.com/frankcohen/ReflectionsOS/tree/main/Devices/Sox/Software/14Gestures>

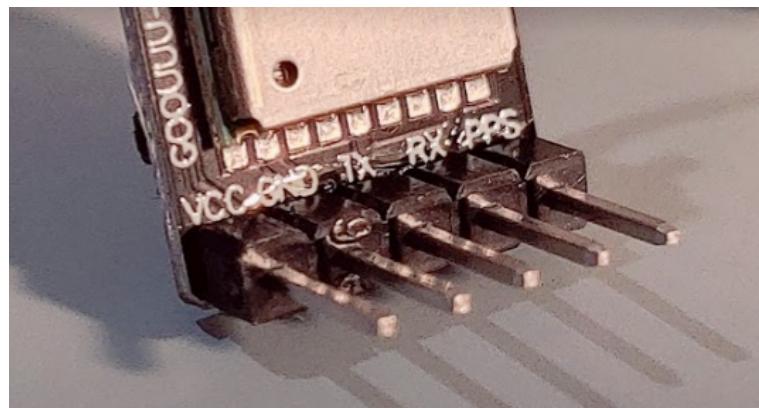
Previous selection:  
download Adafruit\_APDS9960 from the Arduino library manager.



## GPS

Version: December 24, 2021

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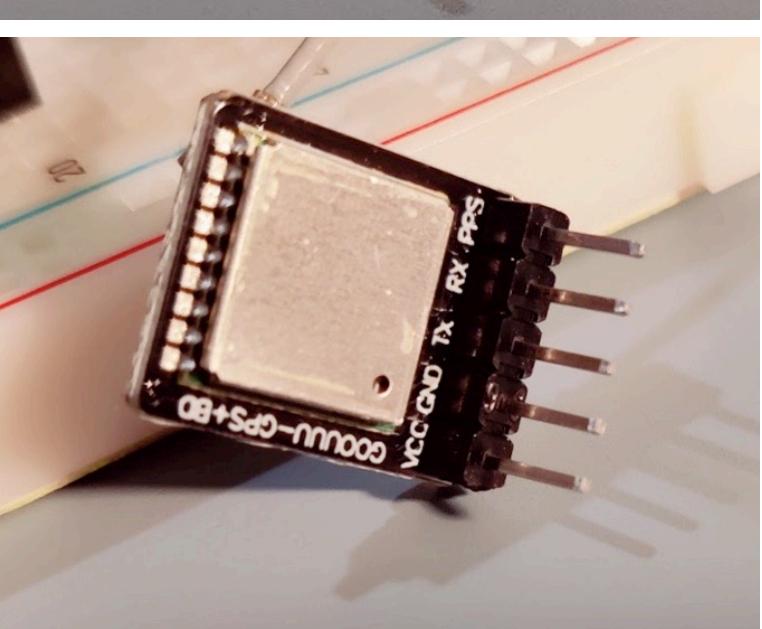
Works with 3.3 V, however, onboard LED  
only lights with 5 V

DFRobot, TELO132, GPS + BDS Beidou  
Dual Module

[https://wiki.dfrobot.com/  
GPS\\_+\\_BDS\\_BeiDou\\_Dual\\_Module\\_SKU\\_TELO132](https://wiki.dfrobot.com/GPS_+_BDS_BeiDou_Dual_Module_SKU_TELO132)

[https://wiki.dfrobot.com/  
GPS\\_+\\_BDS\\_BeiDou\\_Dual\\_Module\\_SKU\\_TELO132](https://wiki.dfrobot.com/GPS_+_BDS_BeiDou_Dual_Module_SKU_TELO132)

Use TinyGPS



Use GPIO 36 (do not use 3 or 4)