Sox Wiring Guide

Version: January 23, 2022

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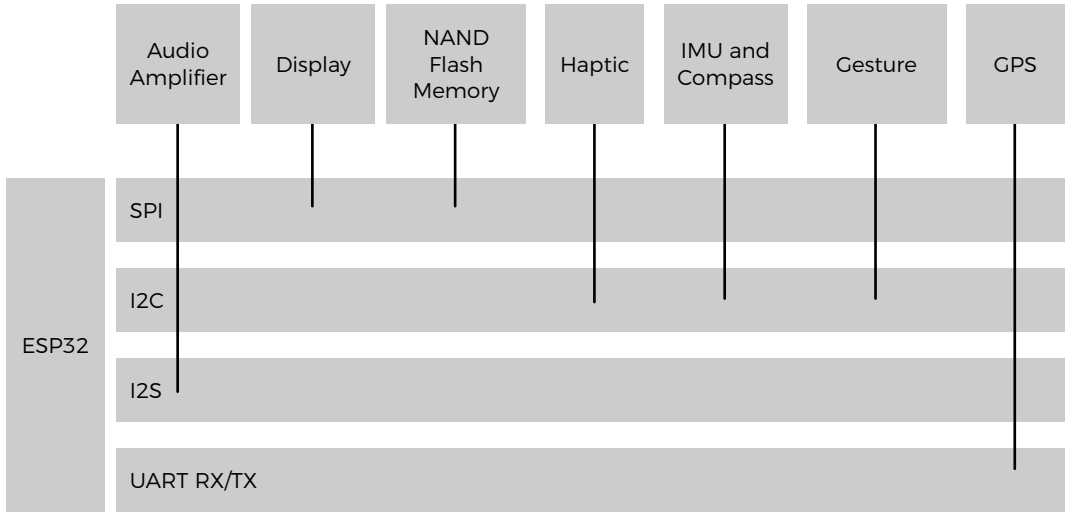
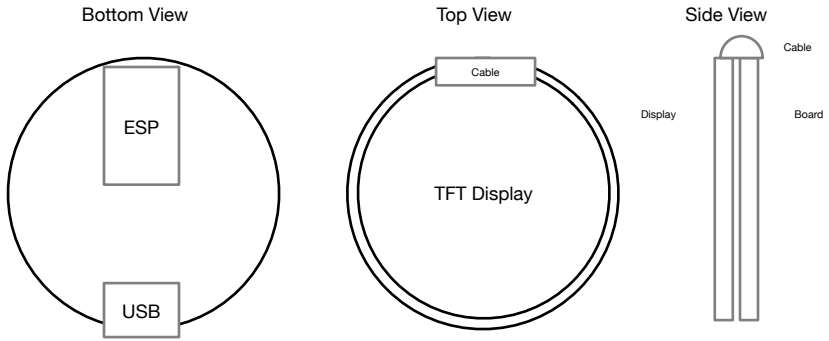
This document shows technical details of the Seuss display prototype. Our design goals:

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 resisters 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
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(408) 364-5508

Connection Pads

Version: January 29, 2022

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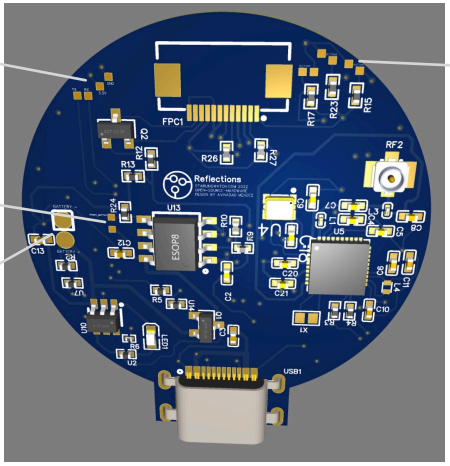
Sox board design by Avinadad Mendez as of Jan 29, 2022

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

Battery pads



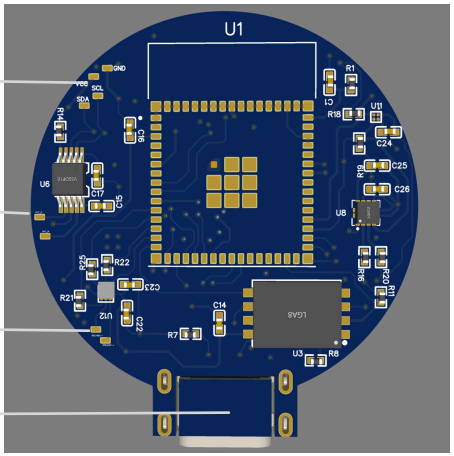
Button pads. Left, Center and Right buttons are connected to pins with RTC functionality. So the status of these pins can be read even in deep sleep mode.

Gesture sensor pads

Haptic motor pads

Speaker pads

USB type C



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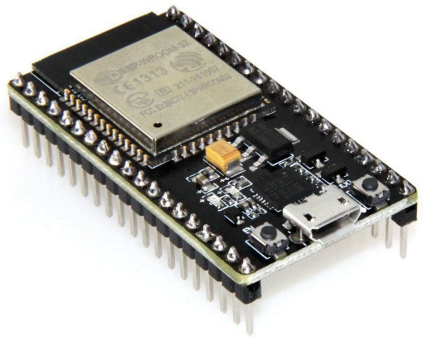


http://www.hiletgo.com/ProductDetail/1906566.html

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

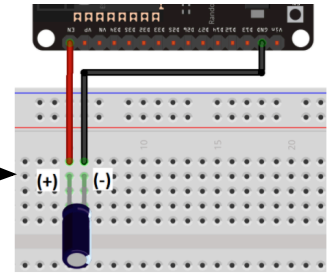
Notes on using ESP32 with Arduino IDE:
Follow these instructions to install ESP32 to Arduino IDE
https://github.com/espressif/arduino-esp32/blob/master/docs/arduino-ide/mac.md
Use ESP32 Dev Board for Board selection
To reference GPIO pins in code use just the number, for example "digitalWrite(13, HIGH)" 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

ESP32 provides the easy-of-use of the Arduino environment (forums, experts, IDE), a 32-bit 2 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.

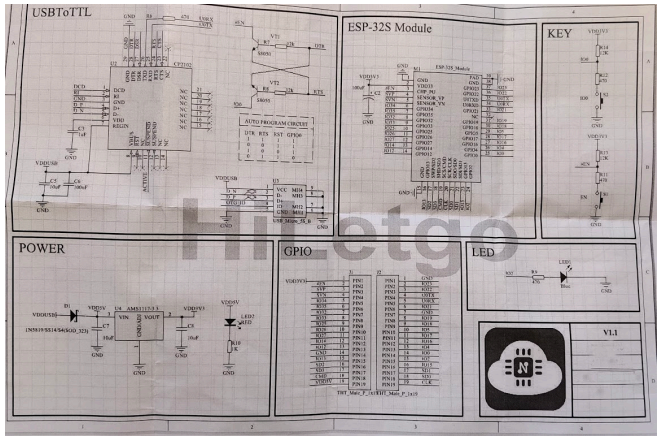
Hold the boot button down to upload a sketch

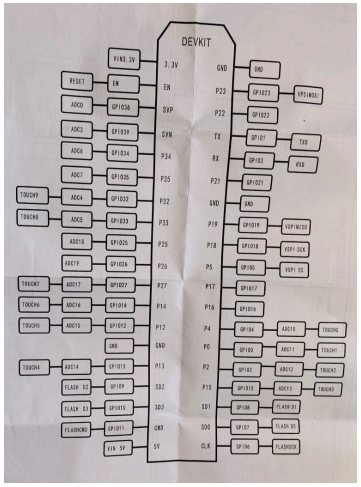


Note: electrolytic capacitors have polarity. The white/grey stripe indicates the negative lead.

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/





These pages came with the HiLetGo.com ESP32 Development Board

Wiring

Version: January 19, 2022

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	ESP32 Development Board			
	3.3v	19	GND	
RESET	EN	18	GPIO 23	VSPI MOSI
Left button	GPIO 36	17	GPIO 22	SCL I2C
Right button	GPIO 39	16	GPIO 01	TX0
Center/Power	GPIO 34	15	GPIO 03	RX0
GPS TX	GPIO 35	14	GPIO 21	SDA I2C
Display CS	GPIO 32	13	GND	
Backlight LED	GPIO 33	12	GPIO 19	VSPI MISO
Audio LRCL	GPIO 25	11	GPIO 18	VSPI SCK
Audio BCLK	GPIO 26	10	GPIO 5	VSPI SS
Audio DIN	GPIO 27	9	GPIO 17	Display RST
HSPI SCK	GPIO 14	8	GPIO 16	Display DC
HSPI MISO	GPIO 12	7	GPIO 4	SD memory CS
	GND	6	GPIO 0	Boot
HSPI MOSI	GPIO 13	5	GPIO 2	LED
Flash D2	GPIO 9	4	GPIO 15	HSPI SS
Flash D3	GPIO 10	3	GPIO 8	Flash D1
Flash CMD	GPIO 11	2	GPIO 7	Flash D0
	5V	1	GPIO 6	Flash SCK

BATT_SENSOR is at GPIO17 on Avinadads board

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.

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.

ESP-prog Debugger

Version: March 5, 2022

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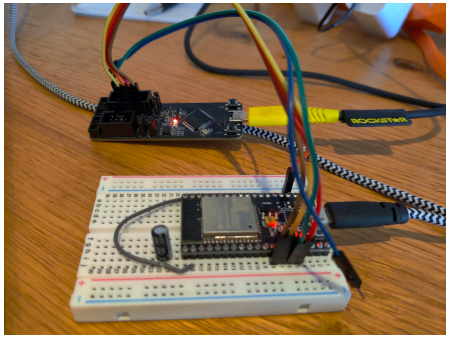
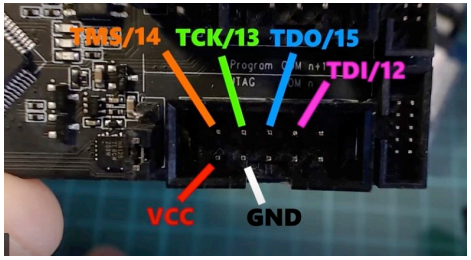
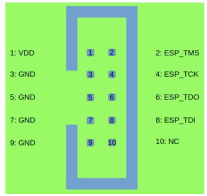
https://medium.com/@manuel.bl/low-cost-esp32-in-circuit-debugging-dbbee39e508b

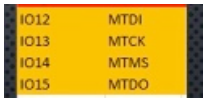




JTAG debugger connections:
TDI - GPIO 12
TMS - GPIO 14
TCLK - GPIO 13
TDO - GPIO 15

Platformio.ini:
debug_tool = esp-prog
debug_init_break = tbreak setup





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

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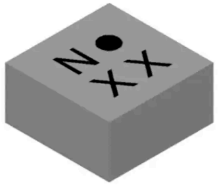
MEMS accelerometer, magnetometer/compass and gyroscope

LIS2DH12 - 3 axis MEMS accelerometer
https://www.sparkfun.com/products/15760
https://jlcpcb.com/parts/componentSearch?isSearch=true&searchTxt=LIS2DH12

and

Magnetometer - MMC5603NJ
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
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

Display

Version: January 23, 2022

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

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

Version: December 23, 2021

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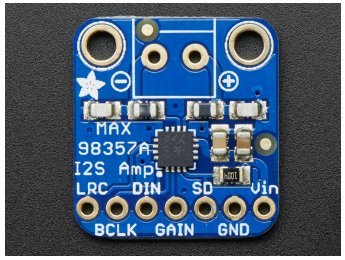

https://learn.adafruit.com/adafruit-max98357-i2s-class-d-mono-amp

```
libfdk_aac for converting wav to m4a (aac) is not installed by default in
ffmeg. I used these commands to install fumes with libfdk_aac on Mac OS X:

brew tap homebrew-ffmpeg/ffmpeg
brew install homebrew-ffmpeg/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
```

Use I2S audio library from https://github.com/schreibfaul1/ESP32-audioI2S

Previous version used Earle F. 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.

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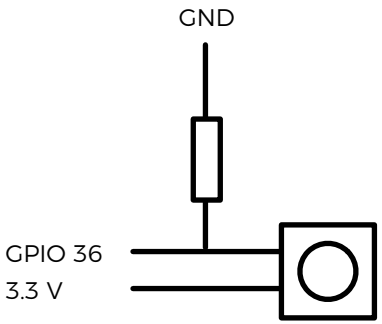
```
#define leftButton 34
#define centerButton 39
#define rightButton 36
```



300 Ohm resistor

Temporary on switches

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.

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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/adafruit/Adafruit_DRV2605_Library

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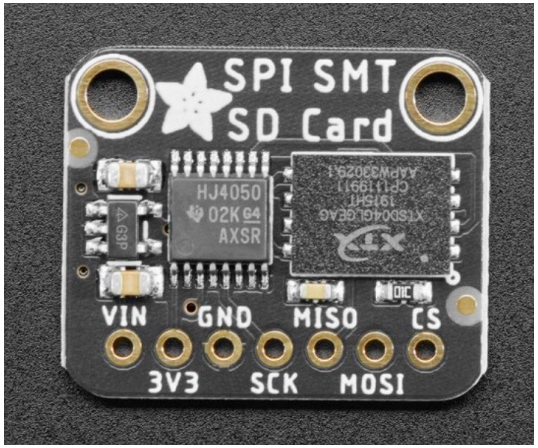

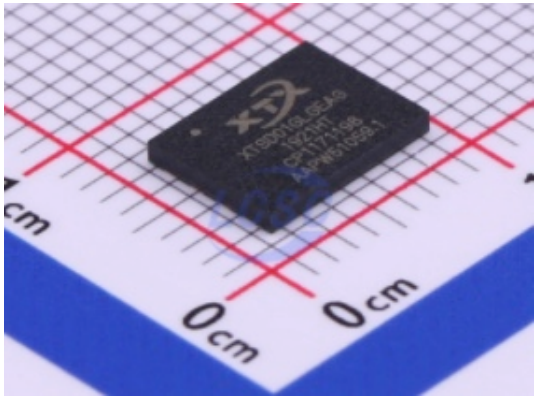

Adafruit SPI Flash SD Card - XTSD 512 MB PID: 4899

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

Version: January 23, 2022

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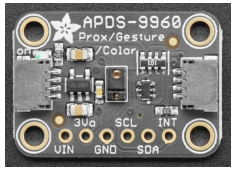
Changing from APDS-9960 gesture sensor to VL53L5CX sensor.
https://www.st.com/resource/en/datasheet/vl53l5cx.pdf

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.



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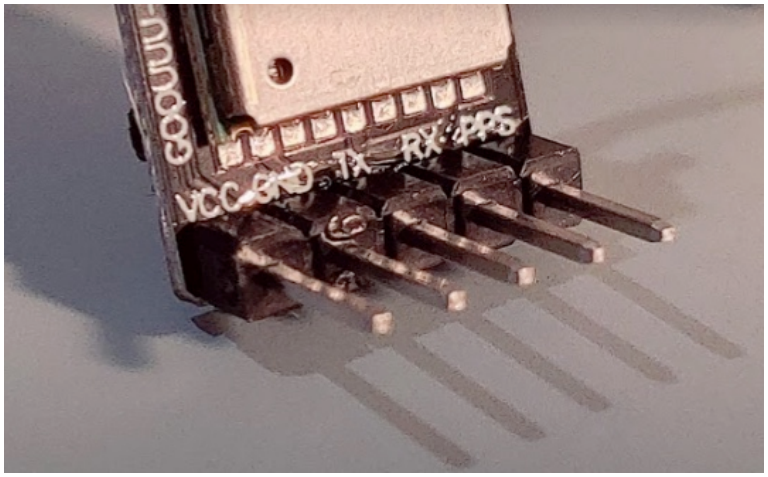
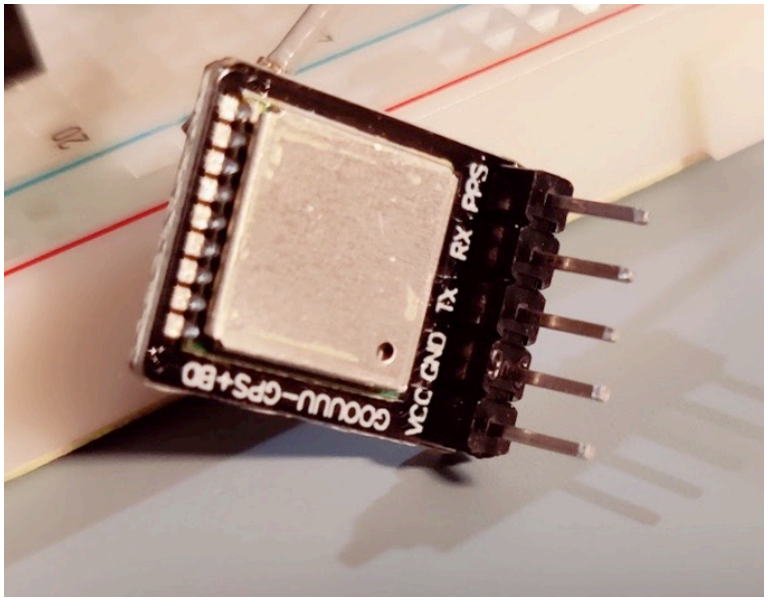


DFRobot, TELO132, GPS + BDS BelDou Dual Module

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

https://wiki.dfrobot.com/GPS_+_BDS_BeiDou_Dual_Module_SKU_TEL0132



Use TinyGPS

https://wiki.dfrobot.com/GPS_+_BDS_BeiDou_Dual_Module_SKU_TEL0132

Use GPIO 36 (do not use 3 or 4)