

Admin

Wrap of assignments 

Bug Fix Party  today 2-5pm

Final deadline for re-test fixes and full system **5pm Sun Nov 24**

Onto ... projects!

Proposals due now, add to Amazon group order by Monday

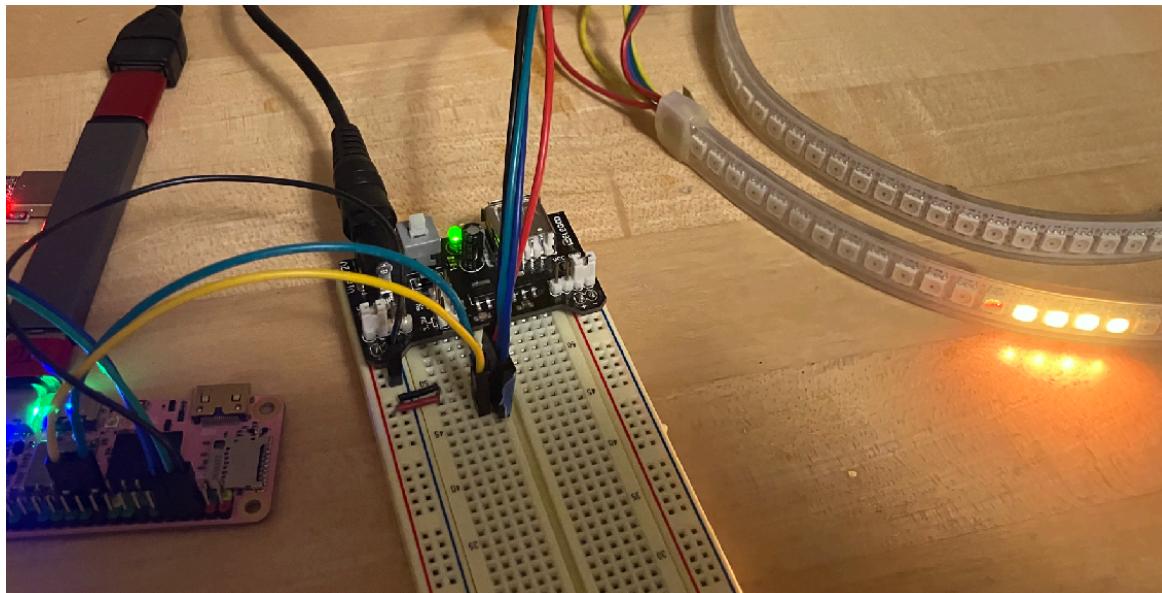
Today: Output

Use gpio to drive outputs

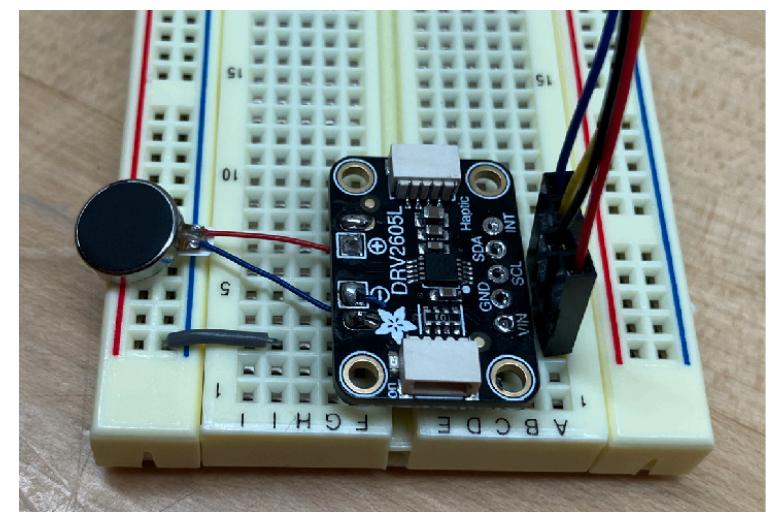
Communicate, make sounds, control servos/motors, ...

Digital to analog conversion

Demo: SPI & I2C

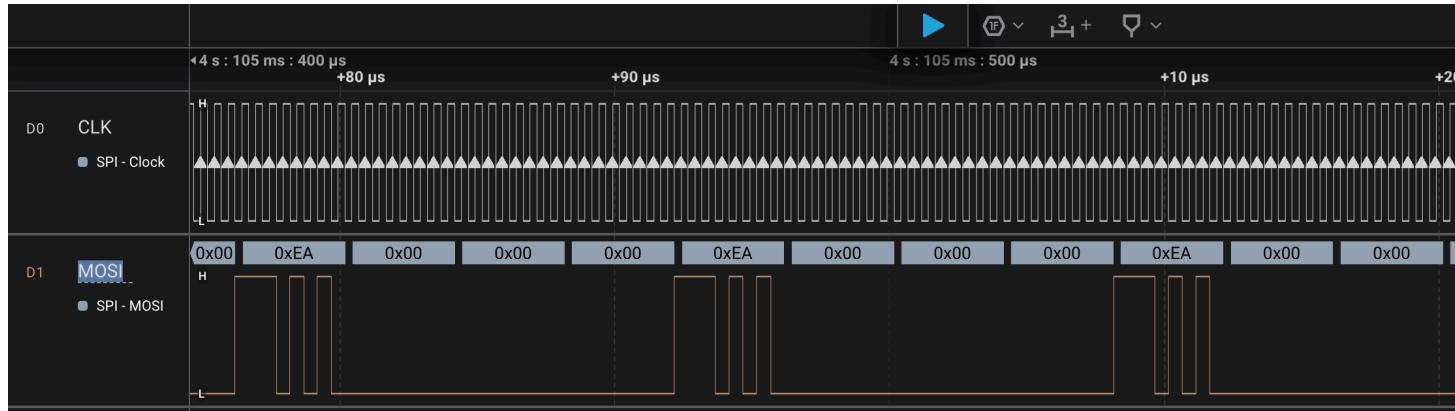


SPI:APA102 DotStar RGB led strip

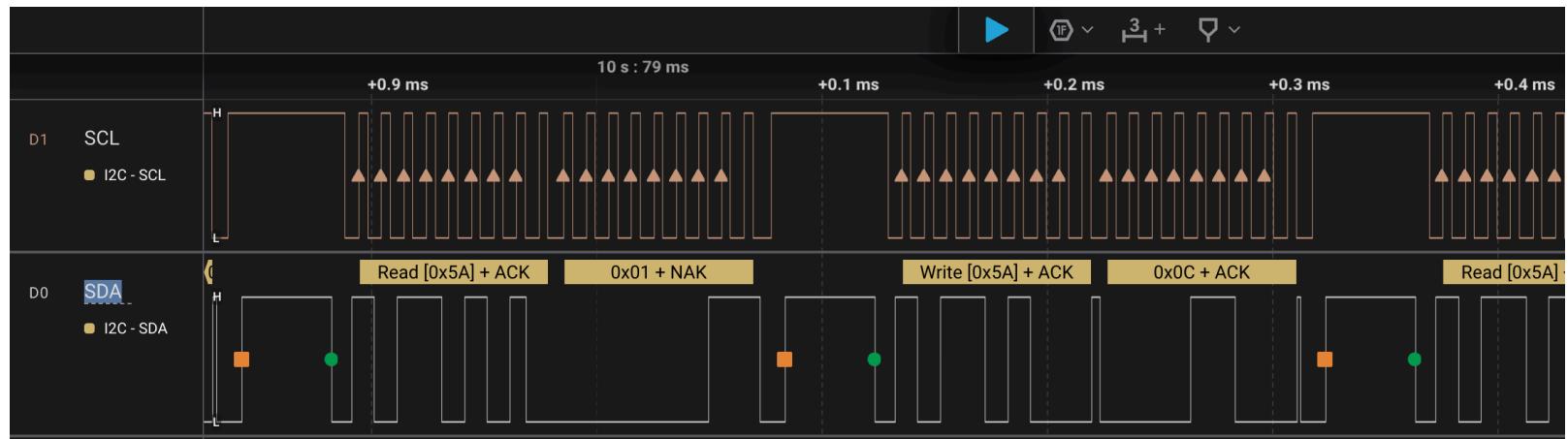


I2C: DRV2605 haptic vibration controller

Logic Analyzer FTW



SPI:APA102 DotStar RGB led strip



I2C: DRV2605 haptic vibration controller

GPIO output is digital

Configure pin as output, write 1 or 0

What can a high/low voltage signal?

Turn on/off: led, transistor, relay

Single bit in comm protocol such as UART or PS/2

How to turn voltage into motion, sound, radio, ...

Electromagnetism in action!



Piezoelectric disk



Passive buzzer



Speaker



Electromagnet



Solenoids



Linear actuator



Vibrating disk



DC motor



Stepper motor



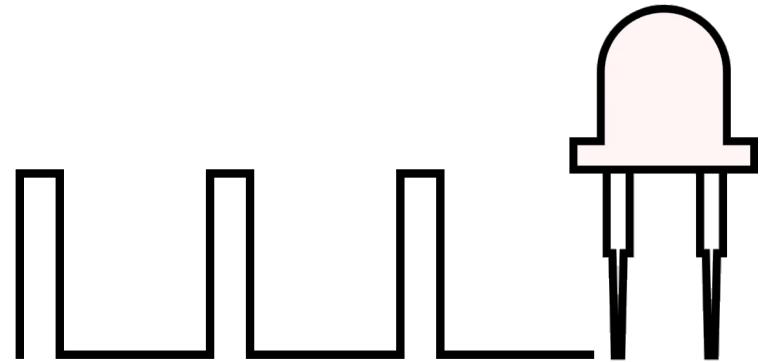
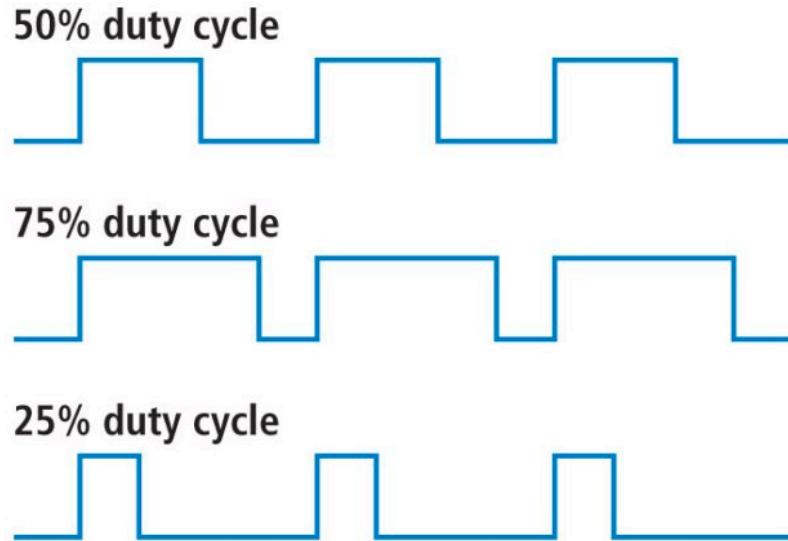
Servo

Demo: electromagnet, solenoid

How to synthesize analog signal from digital hardware?

Digital-to-analog conversion (DAC)

Pulse-width modulation (PWM)



Generate square wave of given frequency

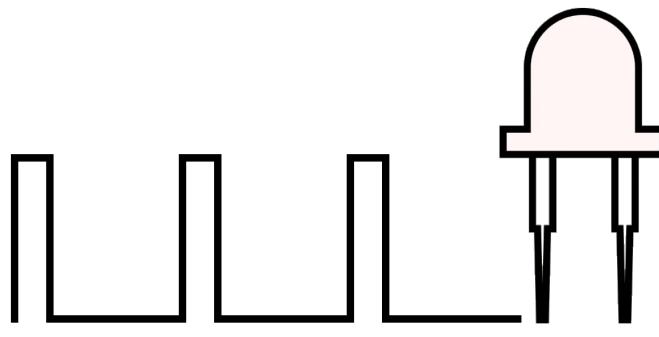
Duty cycle = ratio on/off in one period

Higher/lower frequency — what is effect?

Smaller/larger duty cycle — what is effect?

Demo: Software PWM

Code to "bit-bang" gpio pin



Ramp led on/off

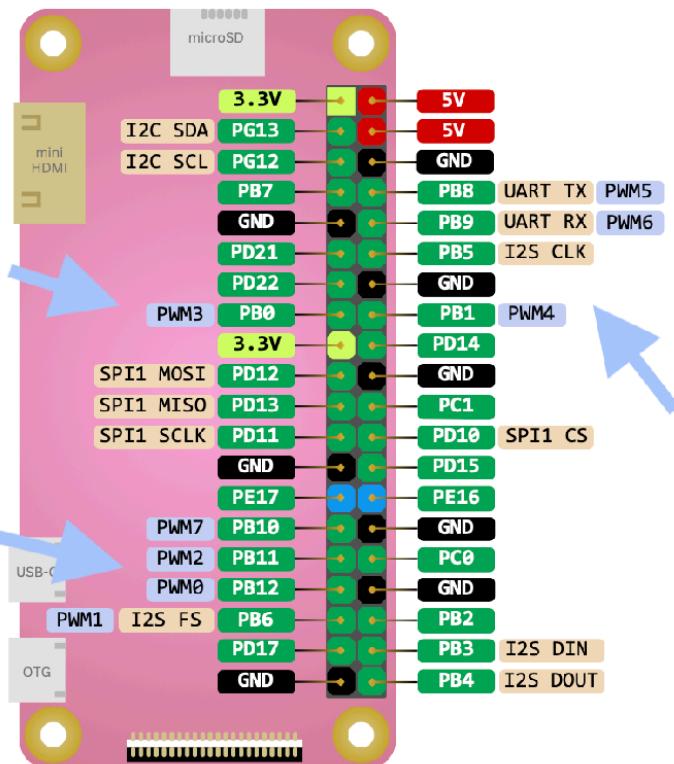
```
for (int i = 0; i < n; i++) {  
    gpio_write(pin, 1);  
    timer_delay_us(on_time);  
    gpio_write(pin, 0);  
    timer_delay_us(off_time);  
}
```

(Q:What happens if substitute motor or buzzer for led?)



Works, but ... CPU consumed with timing-sensitive task

Hardware PWM



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9.11 PWM

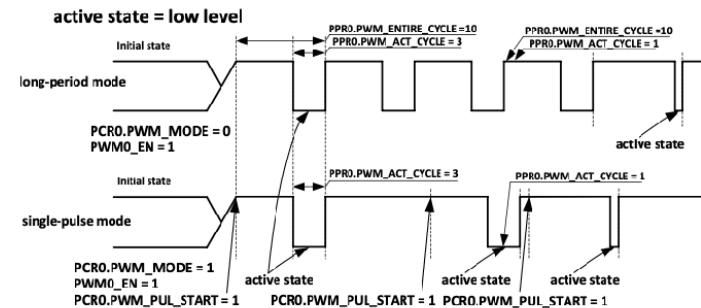
9.11.1 Overview

The Pulse Width Modulation (PWM) module can output the configurable PWM waveforms and measure the external input waveforms.

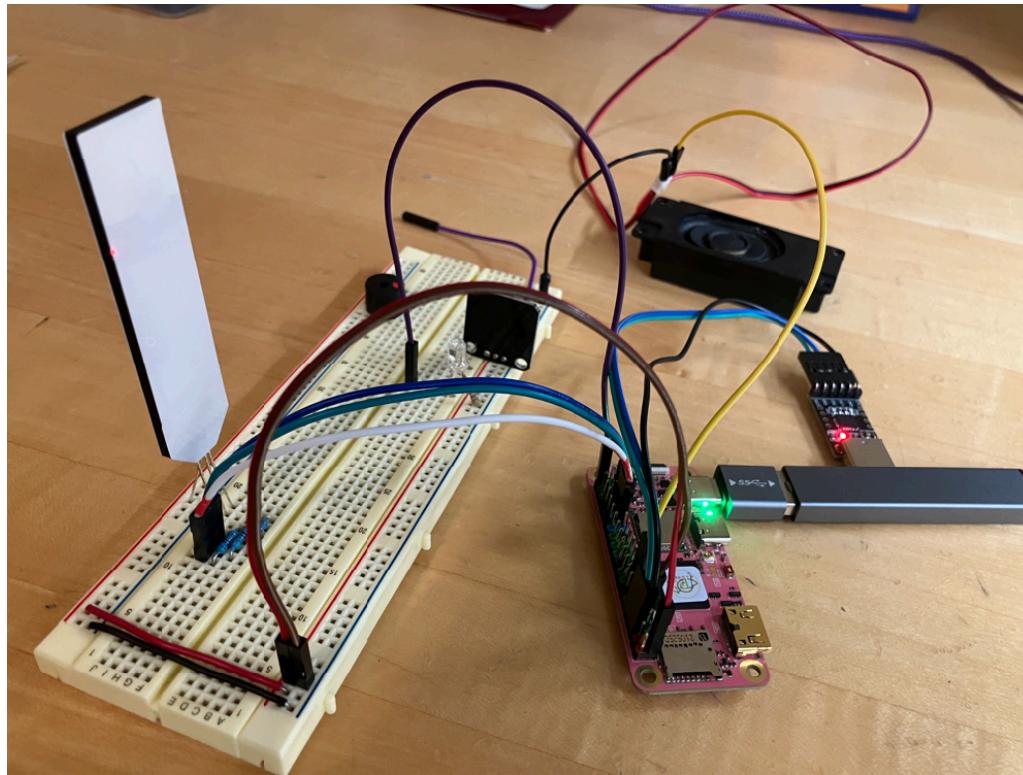
The PWM has the following features:

- Supports 8 independent PWM channels (PWM0 to PWM7)
 - Supports PWM continuous mode output
 - Supports PWM pulse mode output, and the pulse number is configurable
 - Output frequency range: 0 to 24 MHz or 100 MHz
 - Various duty-cycle: 0% to 100%
 - Minimum resolution: 1/65536
- Supports 4 complementary pairs output

Figure 9-89 PWM0 Output Waveform in Pulse Mode and Cycle Mode



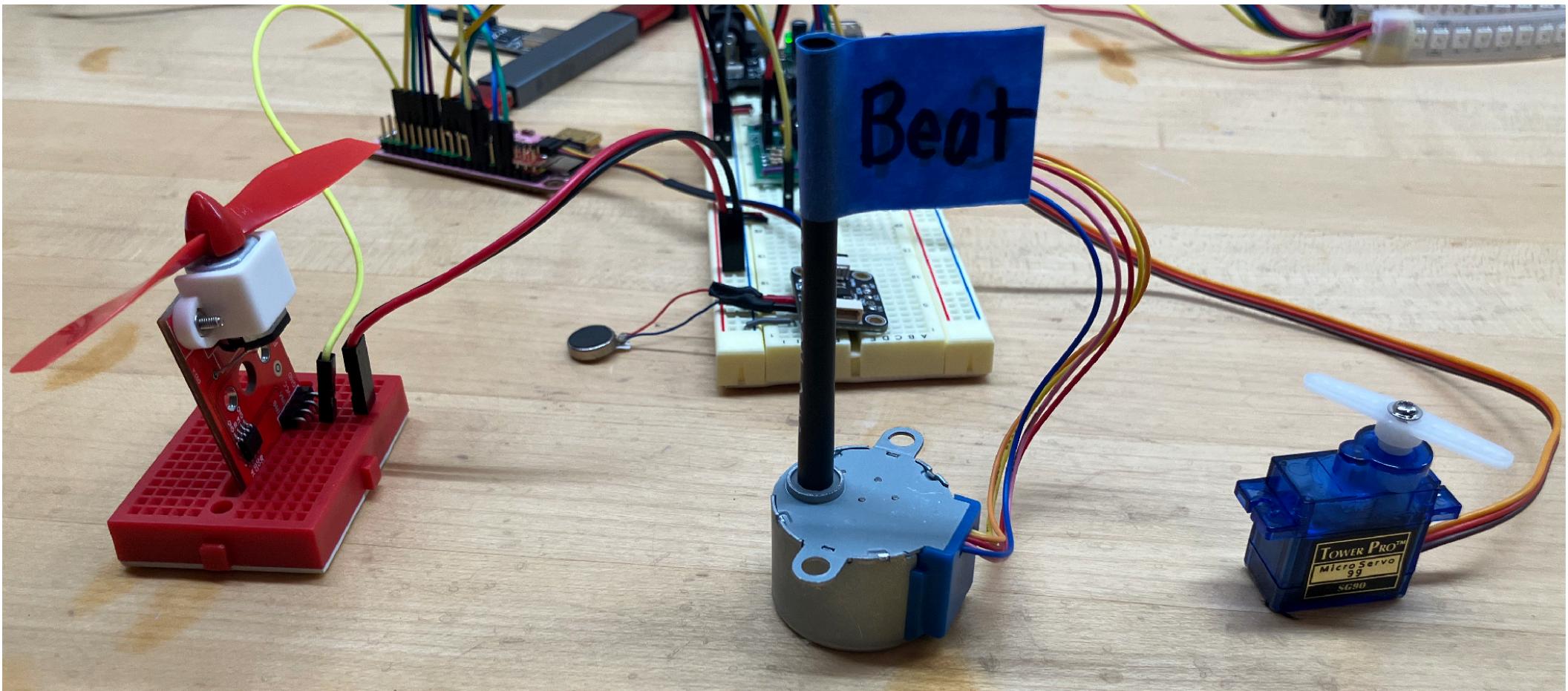
Demo: Hardware PWM



RGB led

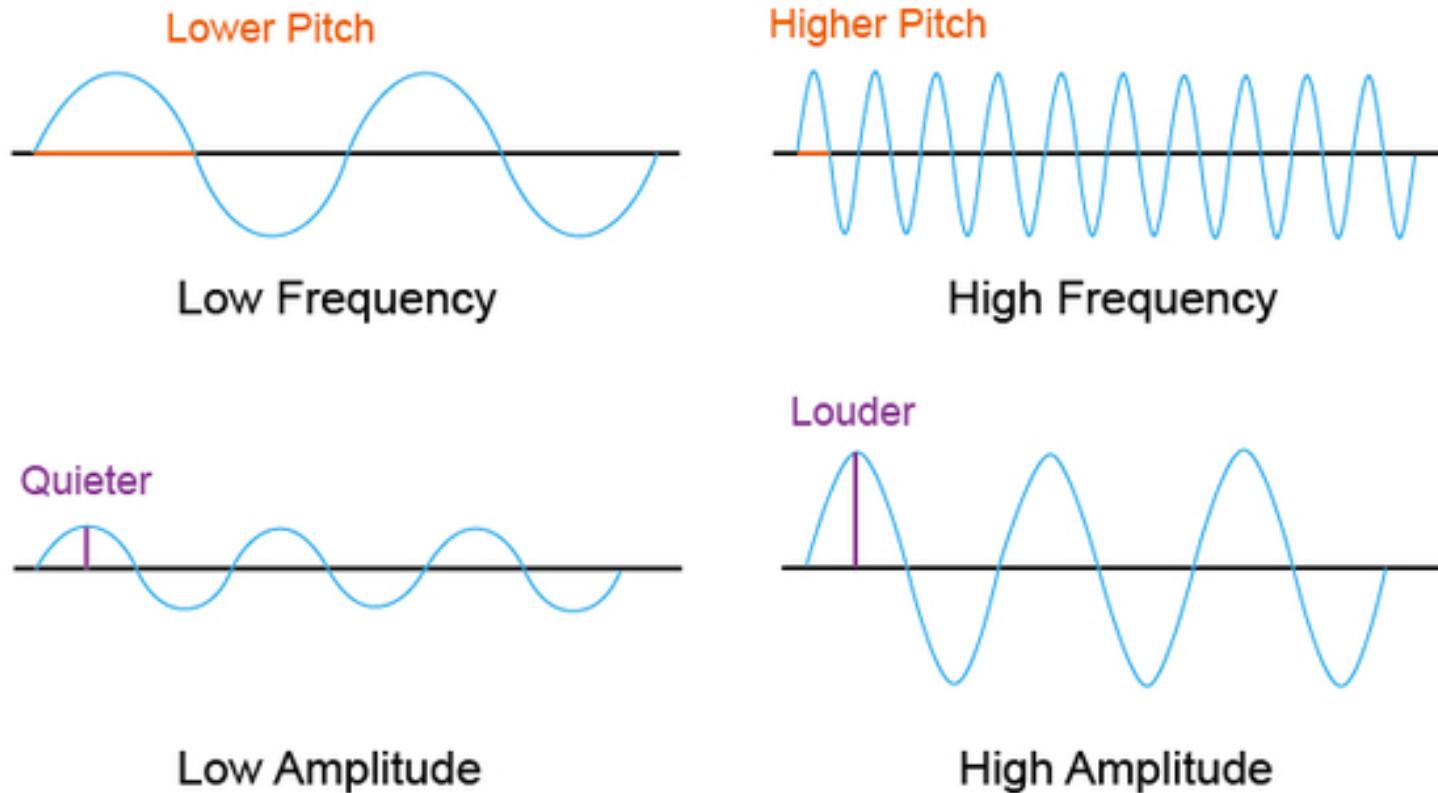
Square wave tones and sound effects

Demo: Motors



DC motor, stepper, servo

Sound Waves



Pulse-Code Modulation

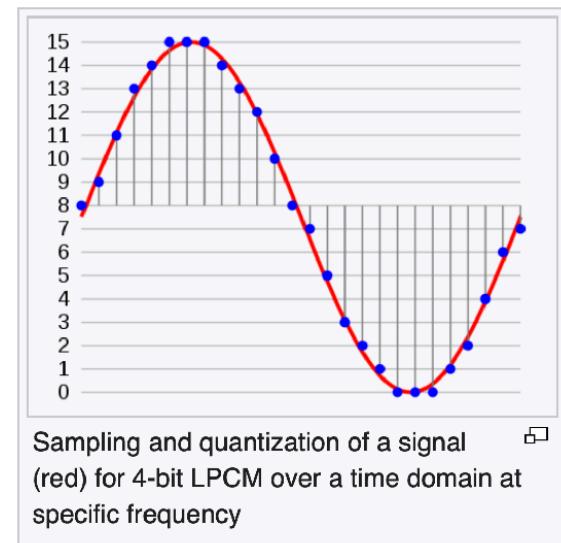
I2S/PCM standard for digital sound

Quantization of sound wave into array
of samples

".wav" file is raw PCM data (MP3 is
compressed form)

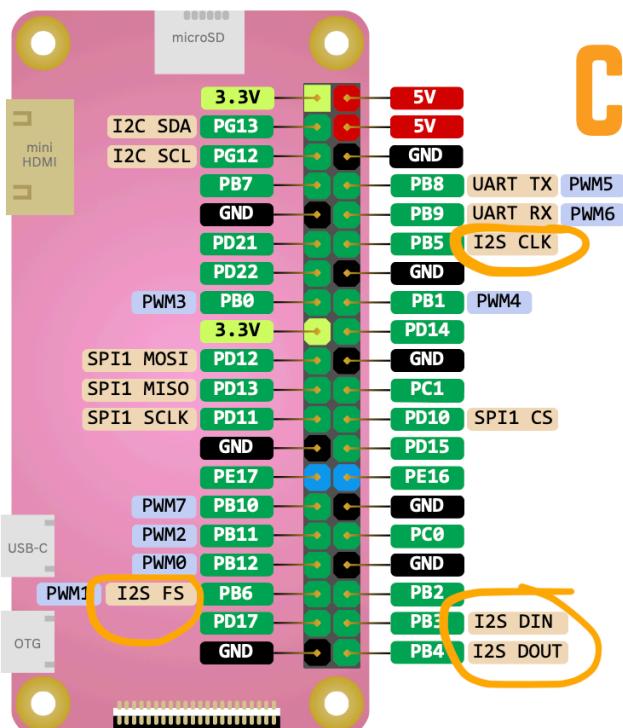
Playback needs sampling rate, bit depth,
num channels

CDs are PCM, sample rate 44.1
kHz, 16-bit, stereo



Source: [Wikipedia](#)

I2S



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8 Audio

8.1 I2S/PCM

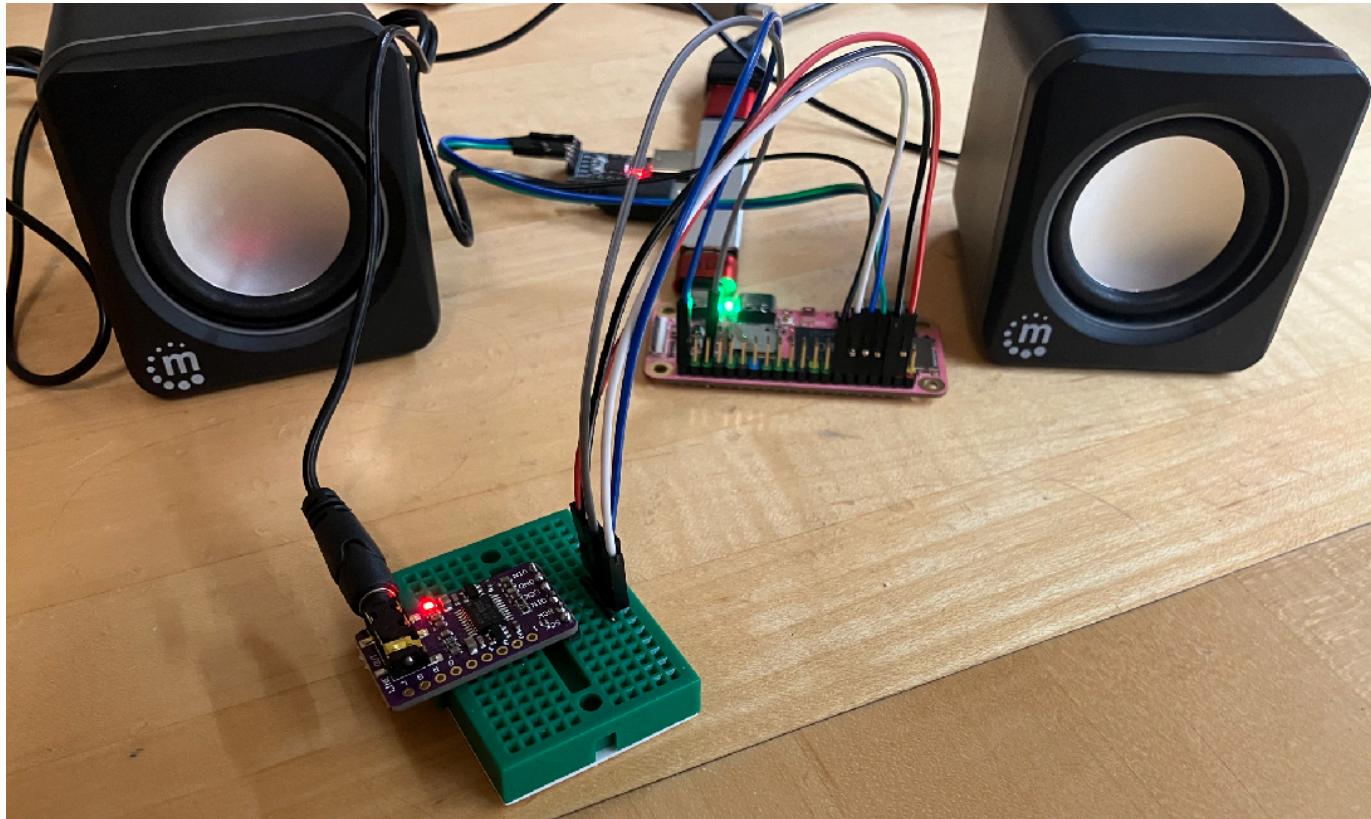
8.1.1 Overview

The I2S/PCM controller is designed to transfer streaming audio-data between the system memory and the codec chip. The controller supports standard I2S format, Left-justified mode format, Right-justified mode format, PCM mode format, and TDM mode format.

The I2S/PCM controller includes the following features:

- Three I2S/PCM external interfaces (I2S0, I2S1, I2S2) for connecting external power amplifier and MIC ADC
- Compliant with standard Philips Inter-IC sound (I2S) bus specification
 - Left-justified, Right-justified, PCM mode, and Time Division Multiplexing (TDM) format
 - Programmable PCM frame width: 1 BCLK width (short frame) and 2 BCLKs width (long frame)

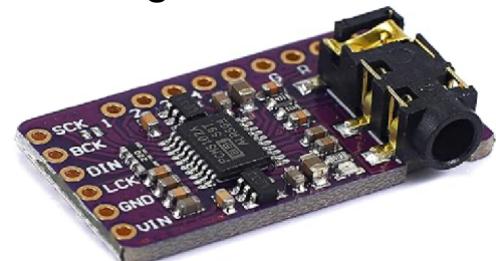
Demo: I2S



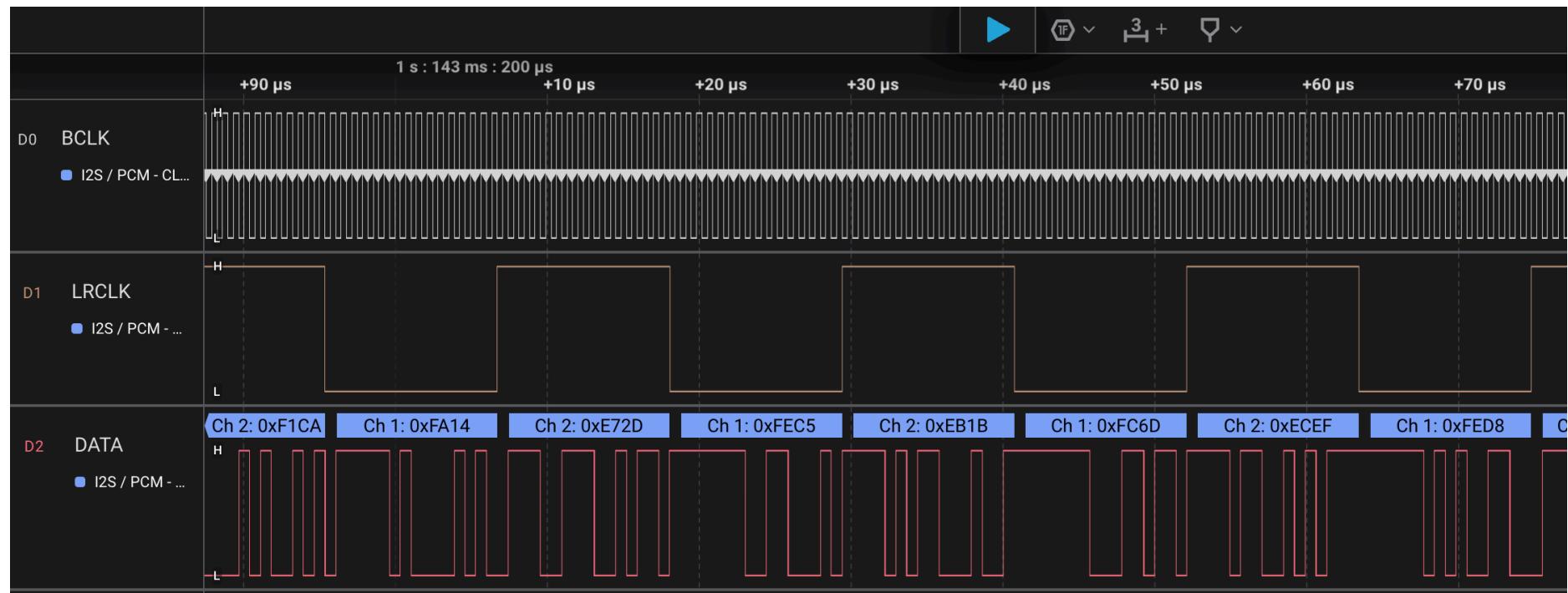
Play wav file

PCM5102A Stereo Digital Audio DAC I2S

python script convert samples into C array compiled into program



I2S protocol capture



Bit clock
LR clock (frame)
Data (sample value)