Keyboards

The PS/2 Protocol

Assignments...how are they going?

Assignment 3 seemed painful. :(

It is probably the assignment with the most *moving parts*. The other assignments aren't easy, but there is a bit less to concentrate on.

This week: do your best to get backtrace and malloc in on time! You can do it!

You want to start the keyboard assignment as early as possible.

Debugging

Always start from a known working state; stop in a working state. If it breaks, what changed?

Take a simple small step, check it carefully, then take another small step. Programming is much simpler if you figure out a good order to write the code!

Make things visible (printf, logic analyzer, gdb)

Fast prototyping, embrace automation, 1-click build

Systematic (D&C), not random, search for bug. Form hypotheses and perform experiments

Don’t be frustrated by bugs, relish the challenge

gpio
timer
uart
printf
malloc
keyboard
fb
gl
console
shell

Serial vs. Parallel

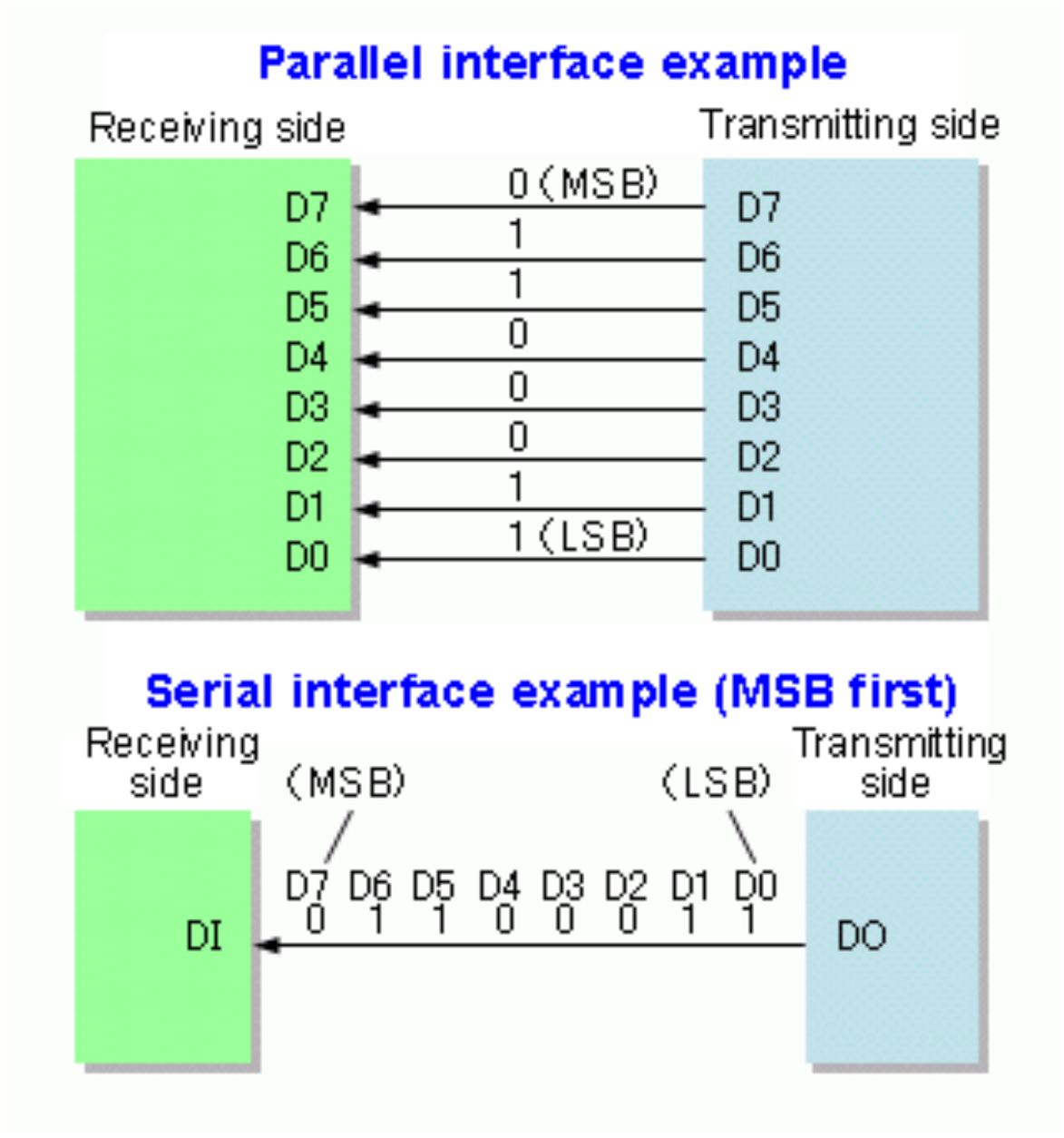


Figure from https://en.wikipedia.org/wiki/Parallel_communication#/media/File:Parallel_and_Serial_Transmission.gif

UART

- **Used in your printf & the bootloader**
- **Start bit, data bits, (0 or 1), stop bits**
- **No clock, requires precise timing**

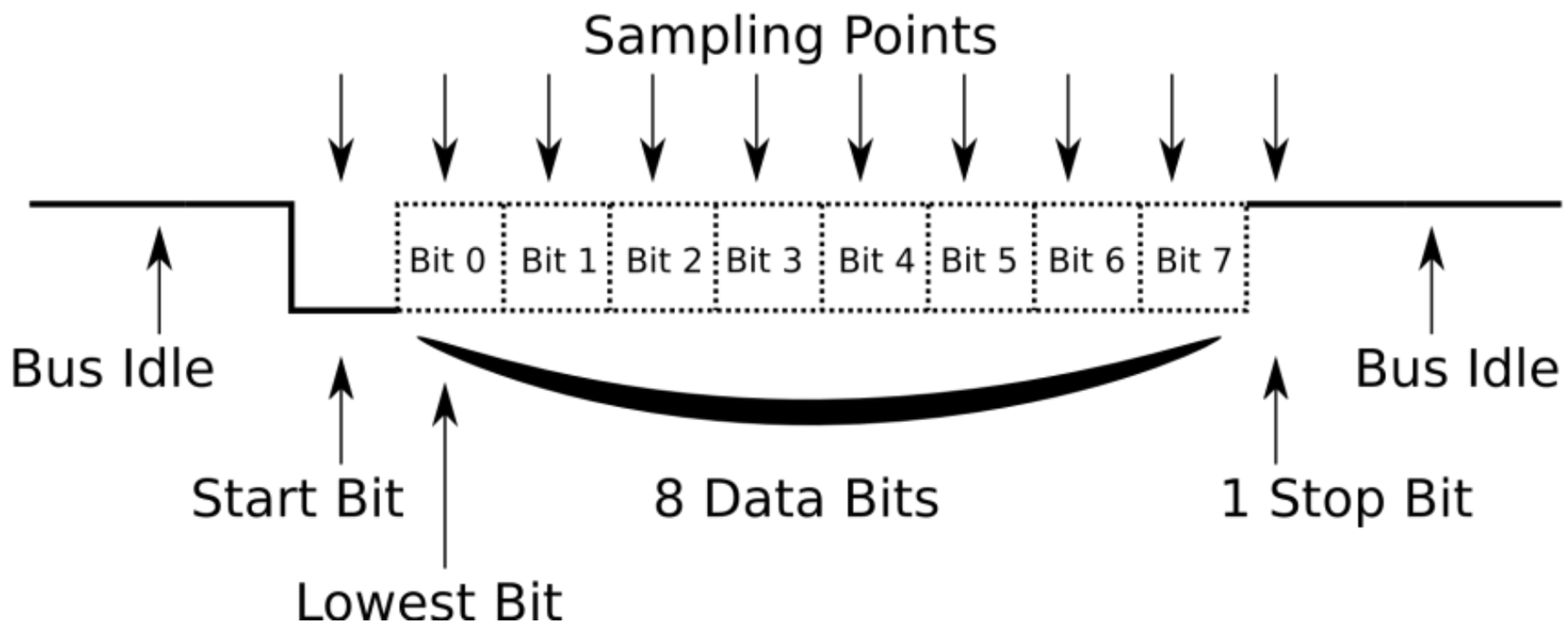
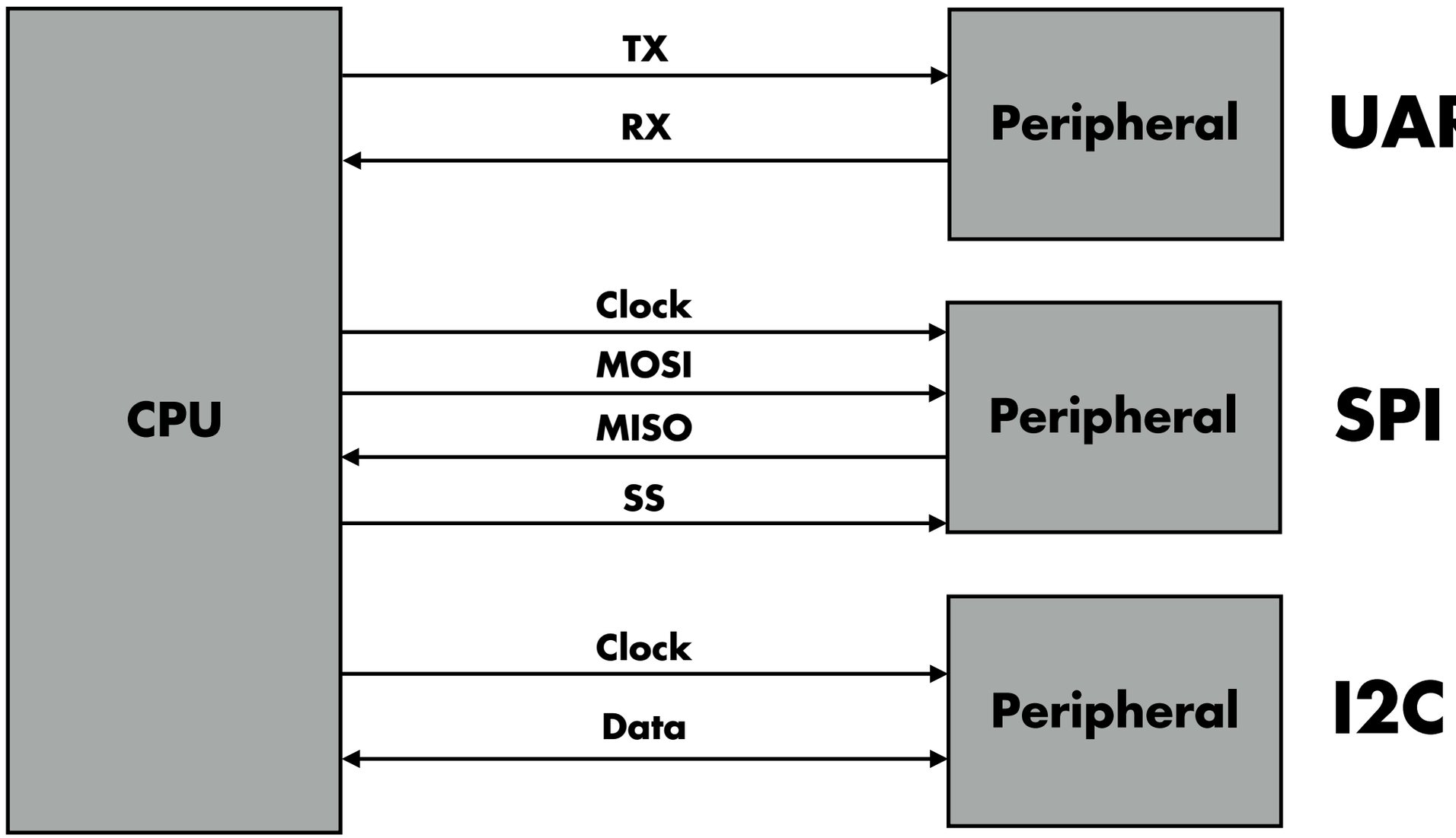


Figure from http://old.myhdl.org/lib/exe/detail.php/projects:rs232image.png?id=projects%3Auart_rs232_receiver_transmitter

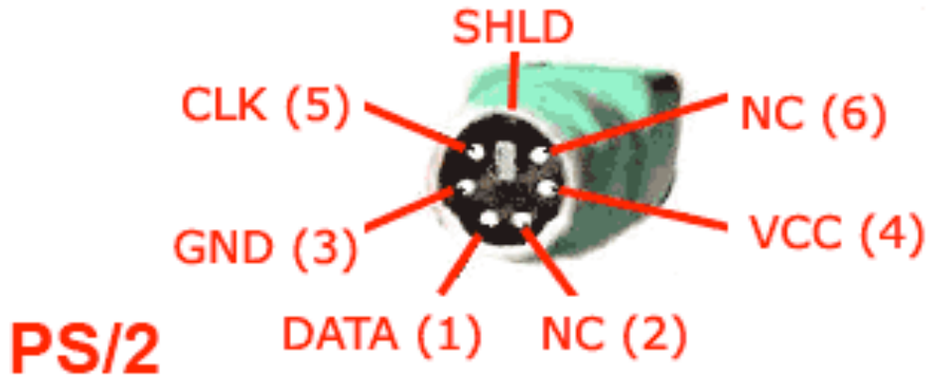
Synchronous vs Asynchronous Serial Protocols



Synchronous has a clock

PS/2 Keyboard

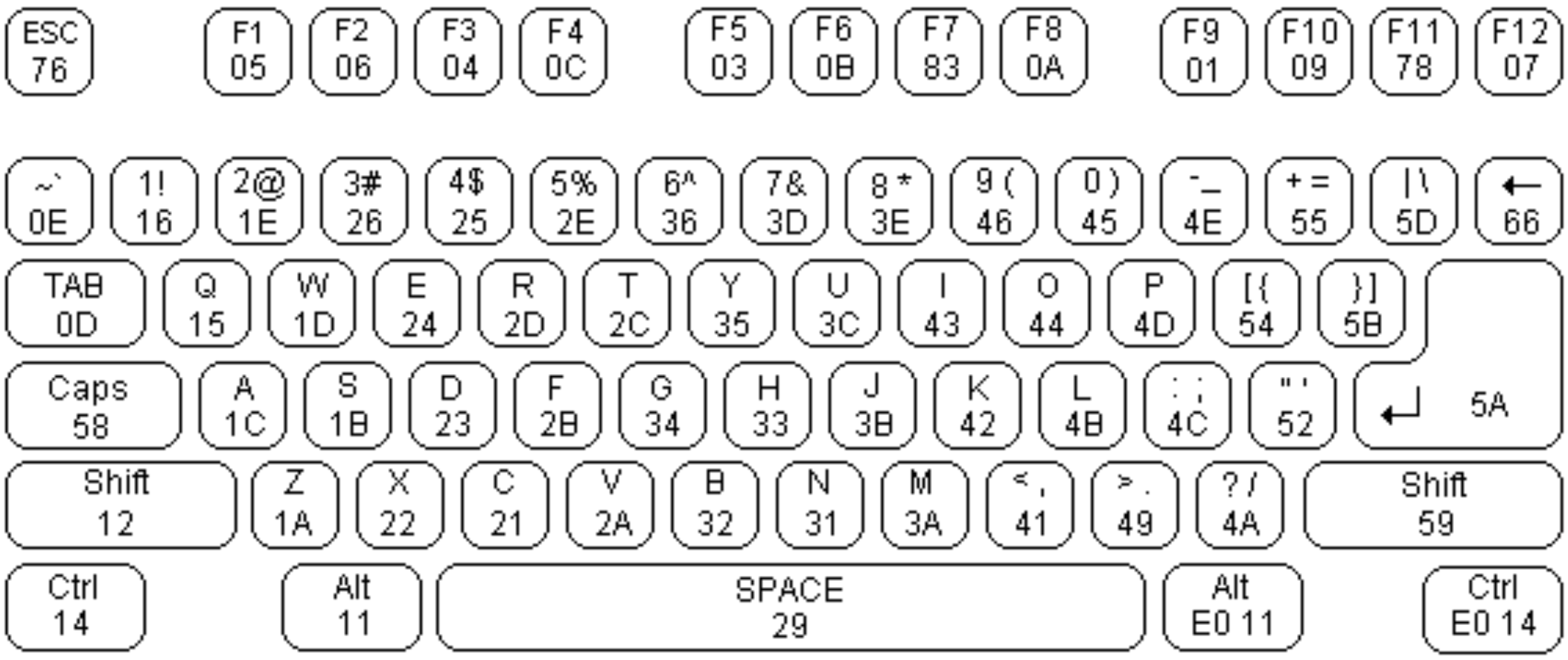
- **PS/2 is an old serial protocol for keyboards (replaced by usb keyboards)**
- **Synchronous: CLK and DATA lines**



6-pin mini-DIN connector

Keyboard Scan Codes

http://www.computer-engineering.org/ps2keyboard/



Make (press) and Break (release) codes `0xF0`

Key	Action	Scan Code
A	Make (down)	0x1C
A	Break (up)	0xF0 0x1C
Left Shift	Make (down)	0x12
Left Shift	Break (up)	0xF0 0x12

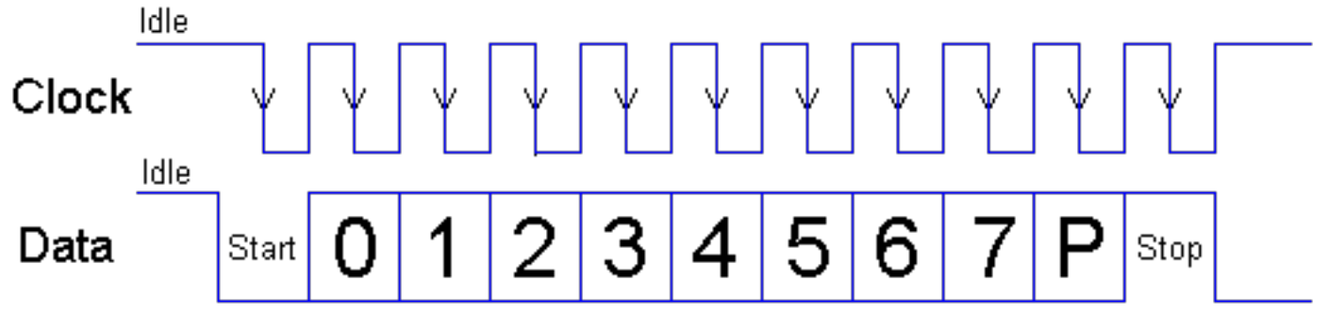
Keyboard Scan Code Demo

PS/2 Protocol

Data changes when clock line is high

Read data when clock is low

Payload: start bit, 8 data bits (lsb-first), parity bit, 1 stop bit (11 total)



http://retired.beyondlogic.org/keyboard/keyboar1.gif

PS/2 Protocol Demo

(logic analyzer)

Keys (Scan Codes) ≠ Characters

Characters are printable

ASCII control codes: tabs, form feeds, SOH, NAK

Special keys - interpreted by the OS or App

- **F1, ..., F12**
- **Arrows, insert, delete, home, ...**

Keys with duplicated functionality

- **Left and right shift, ...**
- **Numbers on keypad vs. keyboard**

Keys ≠ Characters

Modifier keys

- [SHIFT] [OPTION/ALT] [CTRL] [CMD] [FN]

Keyboard Viewer

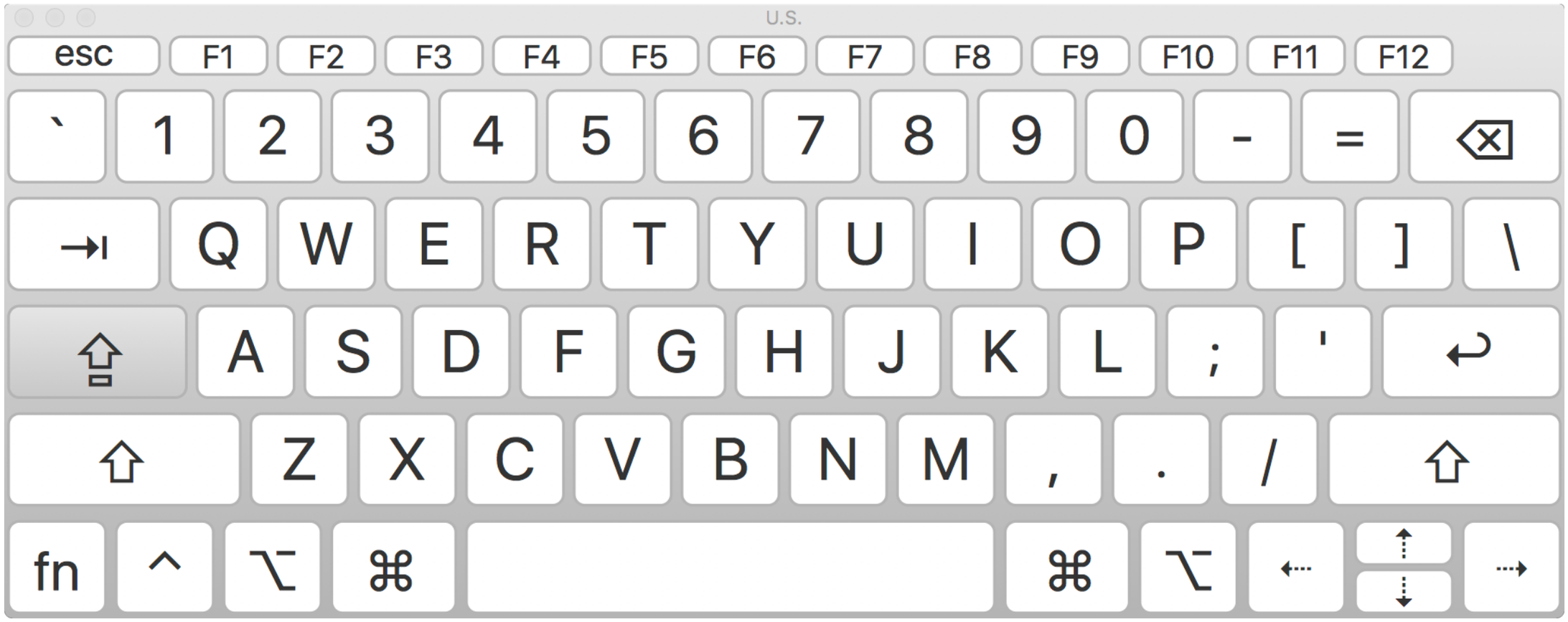
Keys ≠ Characters

Modifier keys

[Shift]

Keys ≠ Characters

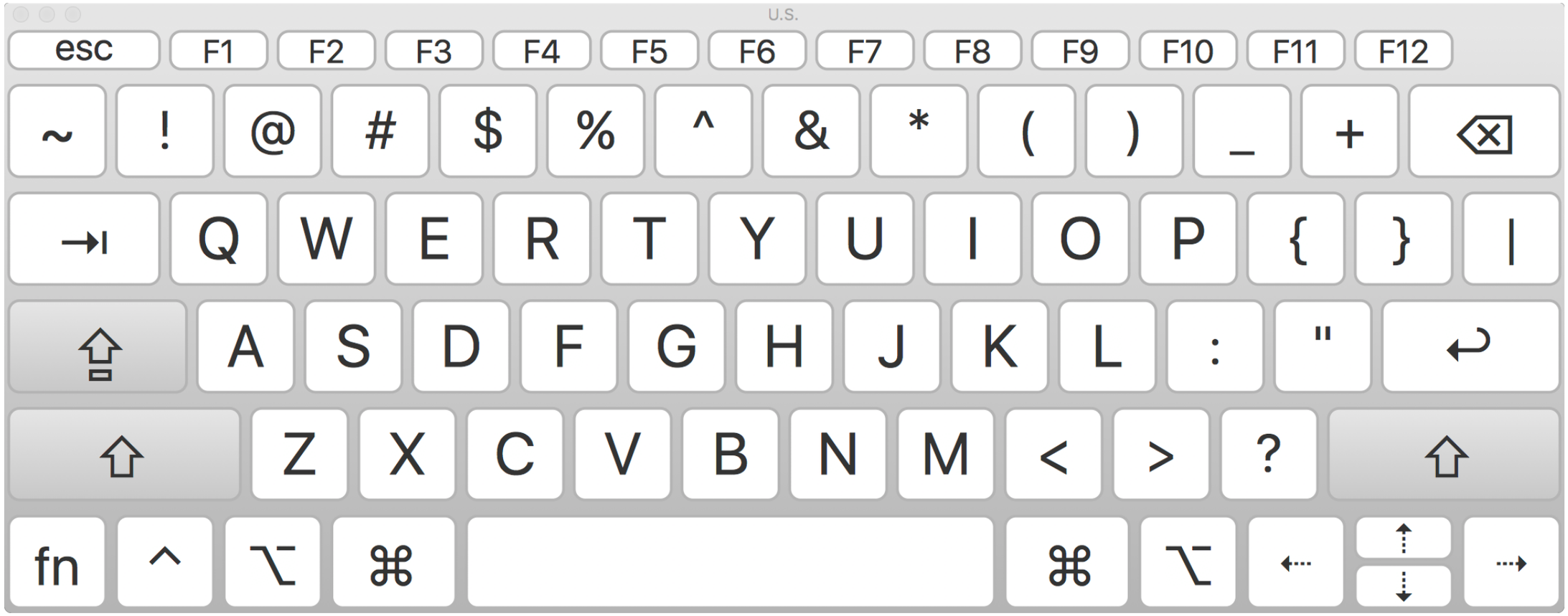
Modifier keys



[Caps Lock]

Keys ≠ Characters

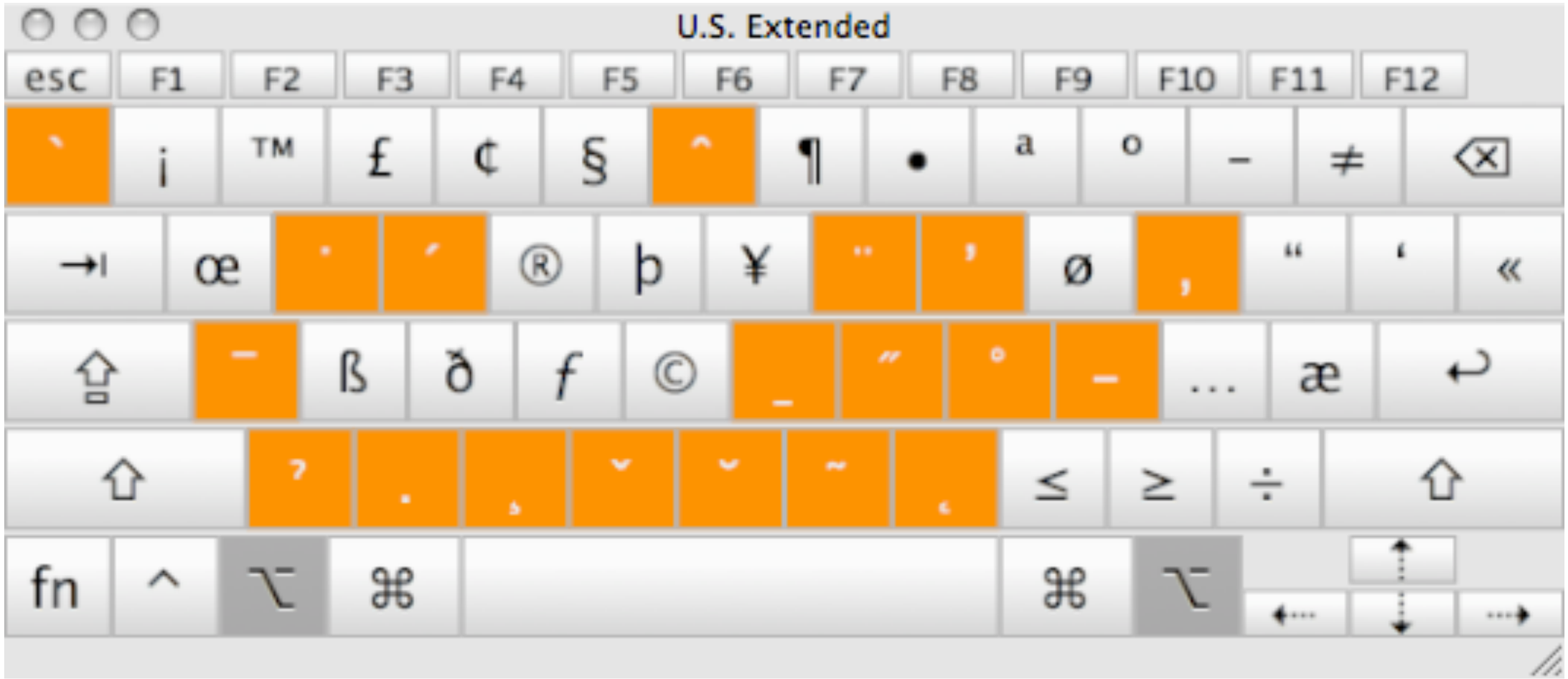
Modifier keys



[Shift + Caps Lock]

Keys ≠ Characters

Modifier keys



[Option]

Orange = Dead Keys

Keys ≠ Characters

Modifier keys

[Option-A]

Layers (keyboard.h)

unsigned char keyboard_read_scancode(void)

- **returns scancode**

int keyboard_read_sequence(unsigned char seq[])

- **returns sequence of up to 3 scan codes (with PS2_CODE_RELEASE=0xF0, PS2_CODE_EXTEND = 0xE0)**

key_event_t keyboard_read_event(void)

- **keeps track of modifier keys**
- **returns key_event struct : scancode, modifiers, action, …**

unsigned char keyboard_read_next(void)

- **maps key events to ASCII characters**
- **returns ASCII character, modifier and special keys >= 0x90**

Parity Bits

Parity = XOR of data bits

Even/odd parity: an even/odd number of 1s (including parity bit)

even

data	data	data	data	data	data	data	data	parity
1	1	0	1	0	1	1	0	1

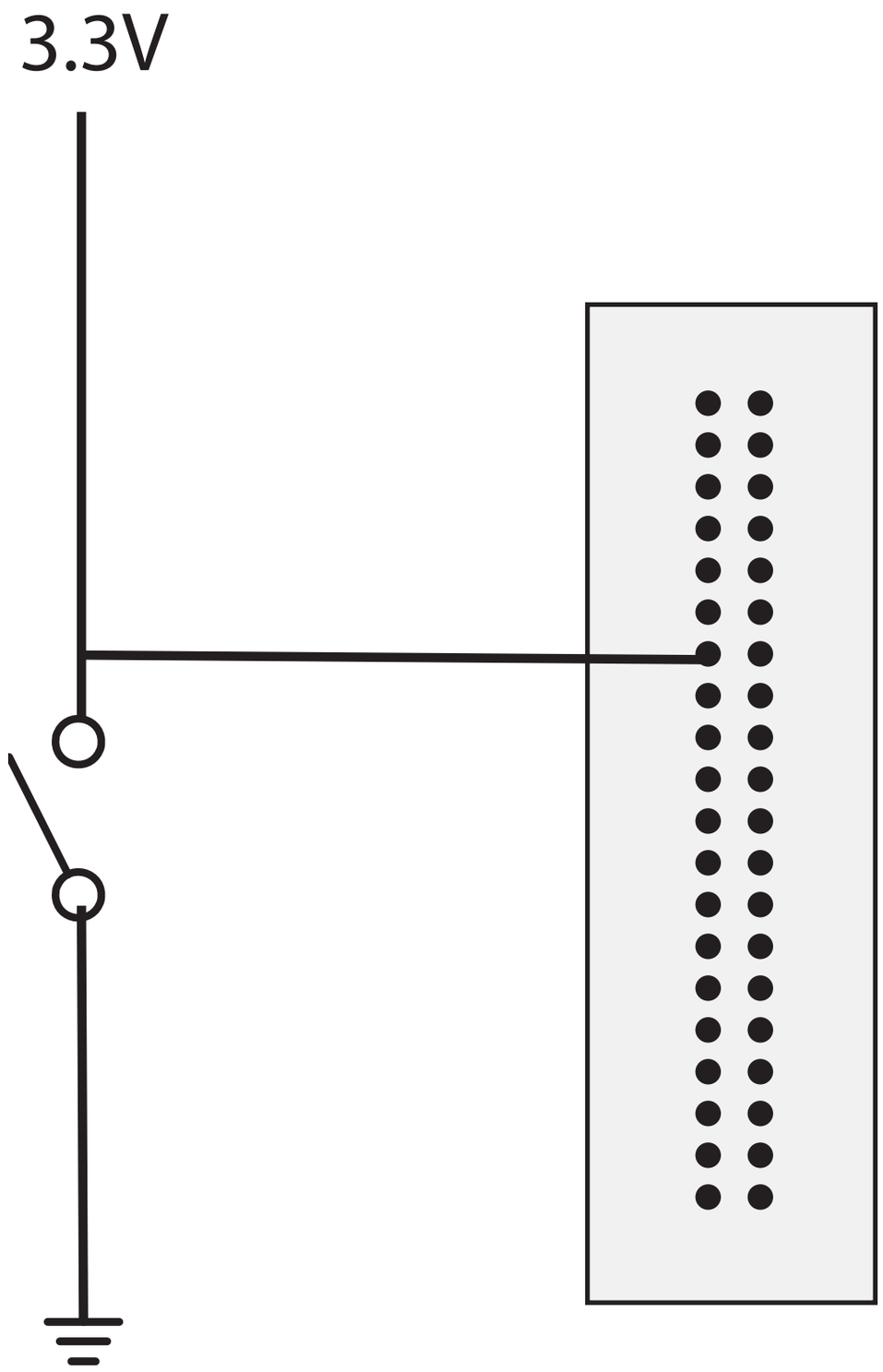
odd

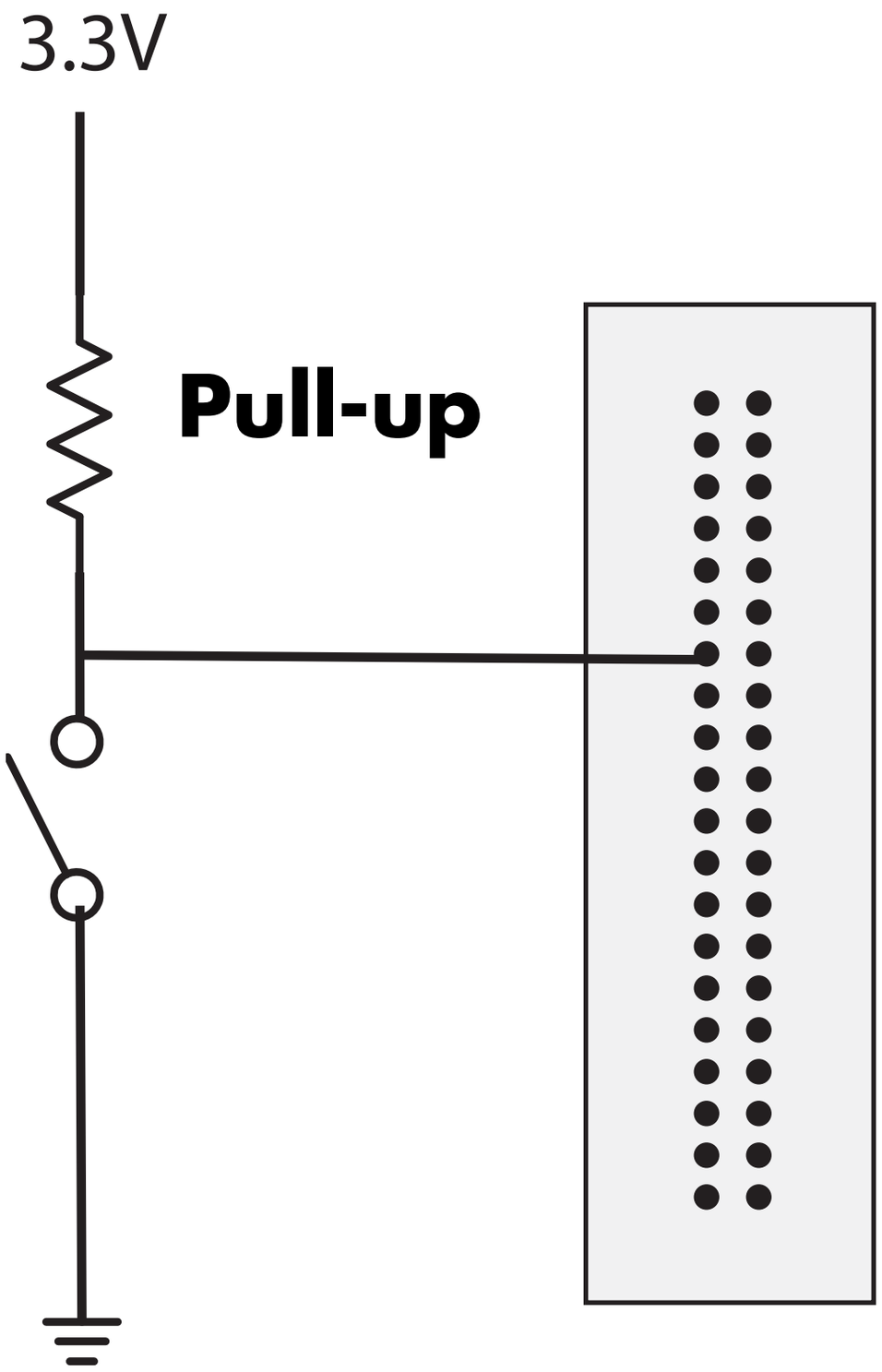
data	data	data	data	data	data	data	data	parity
1	1	0	1	0	1	1	0	0

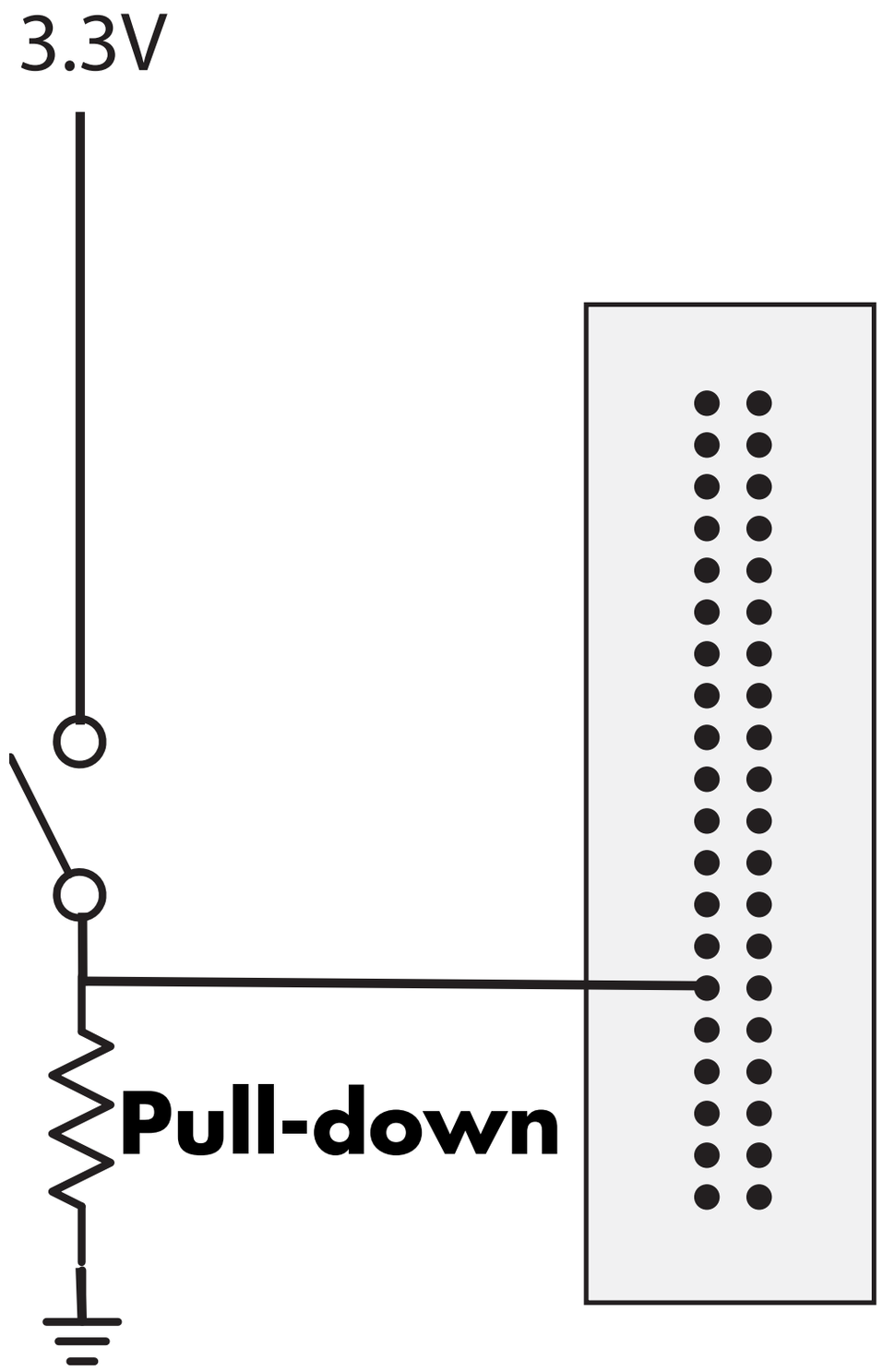
Error in transmission

- **Parity is not correct (one bit was flipped)**
- **Similar to checksum in boot loader**

Switch




3.3V
Pull-up


3.3V
Pull-down

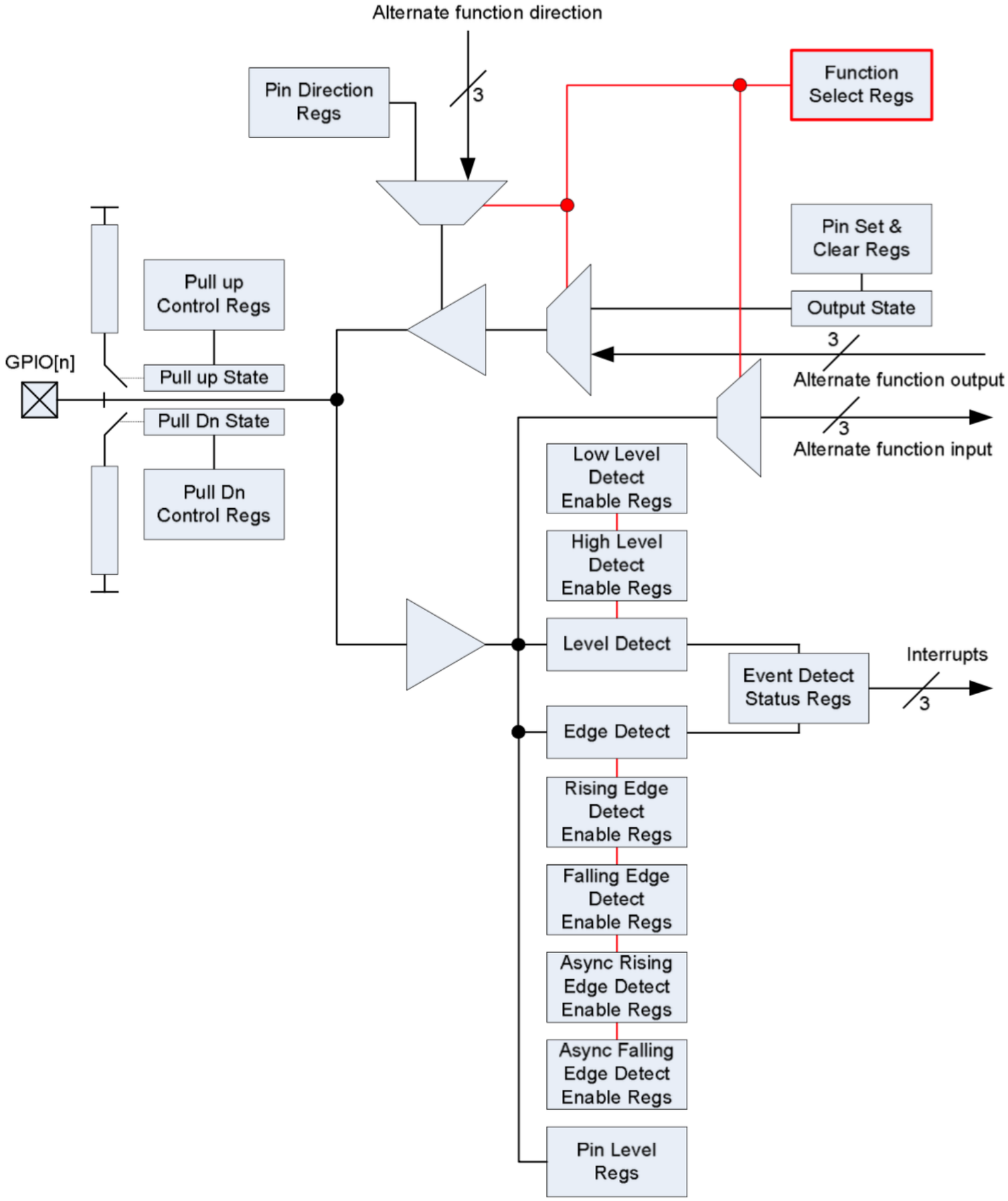
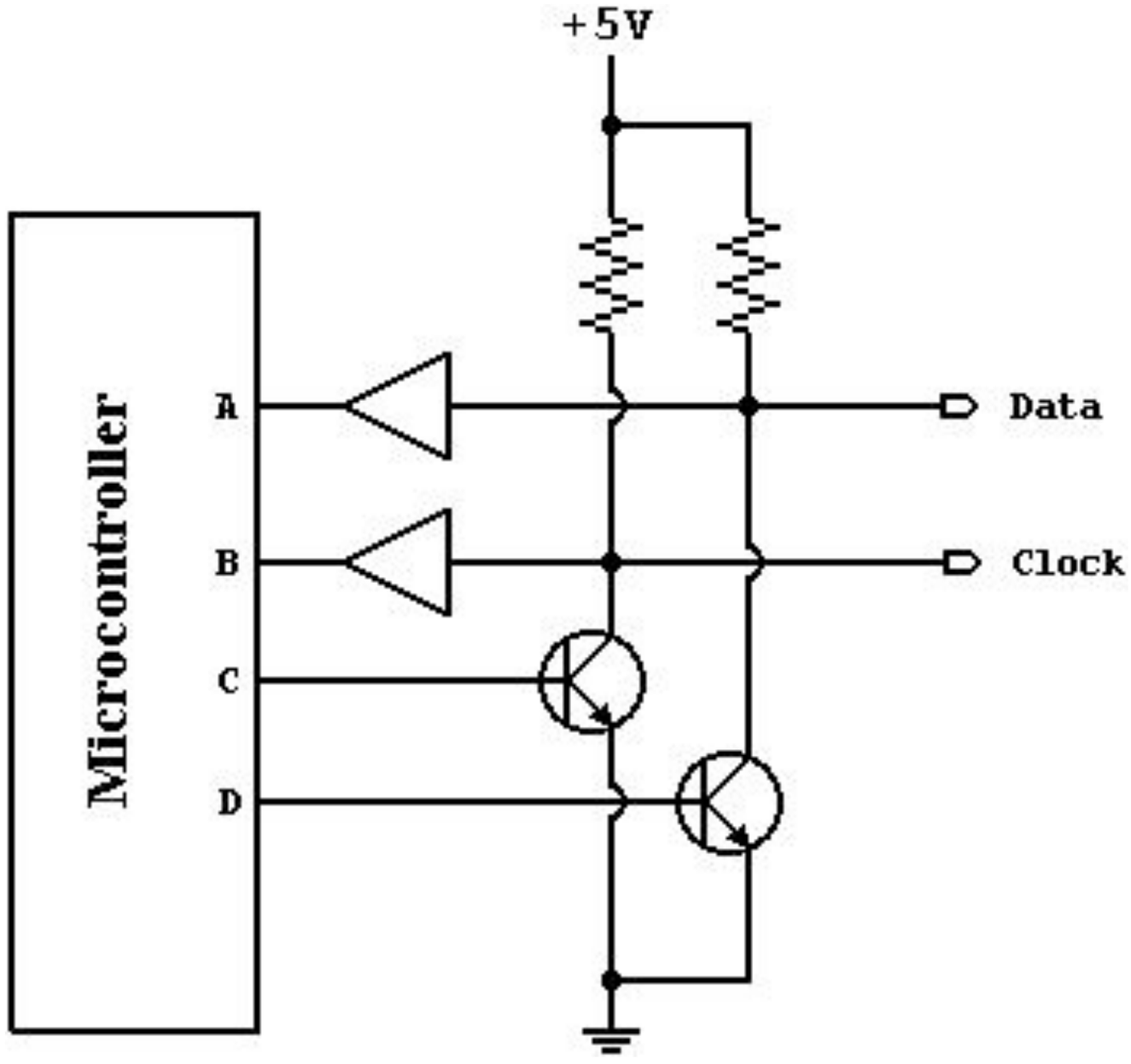


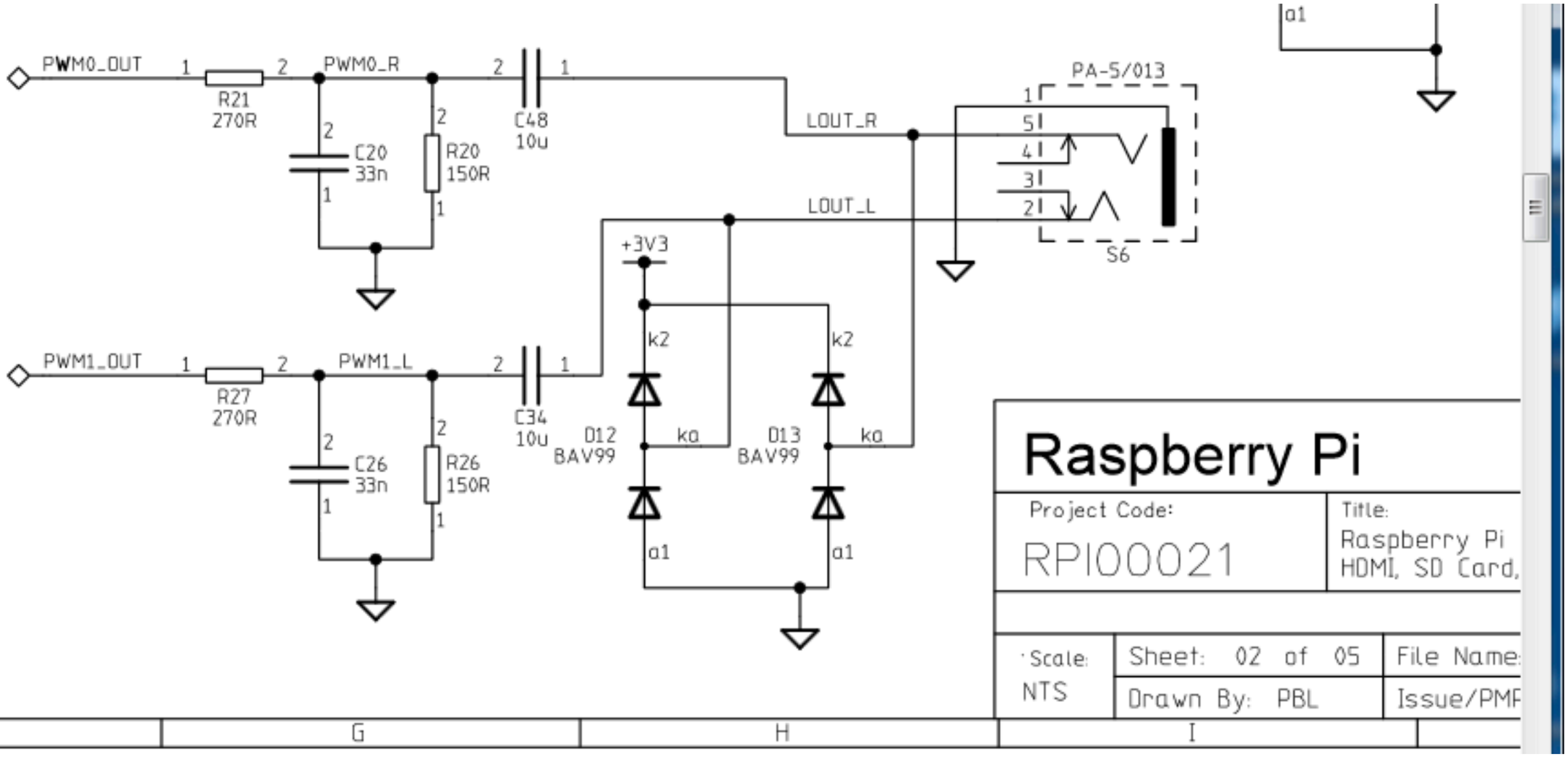
Figure 6-1 GPIO Block Diagram



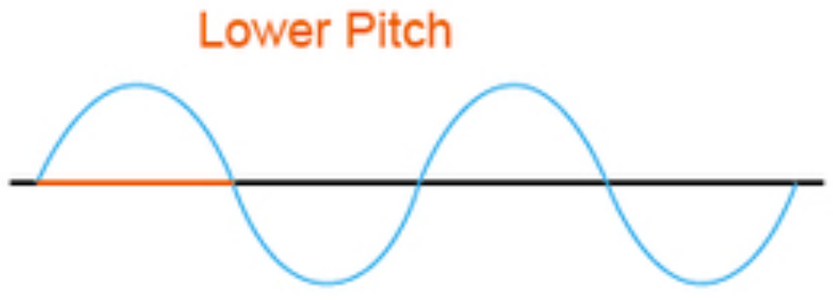
- **DATA and CLK lines are pulled up to 5V**
- **Switching on the transistor sets line to 0V**
- **Enables bi-directional communication (keyboard or Pi can provide data and clock)**

PWM & Sound

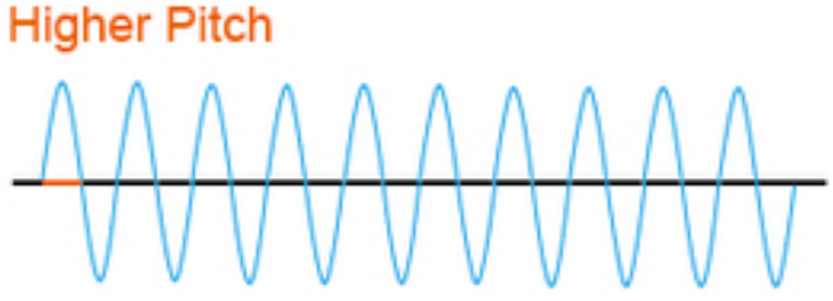
Raspberry Pi Stereo Jack



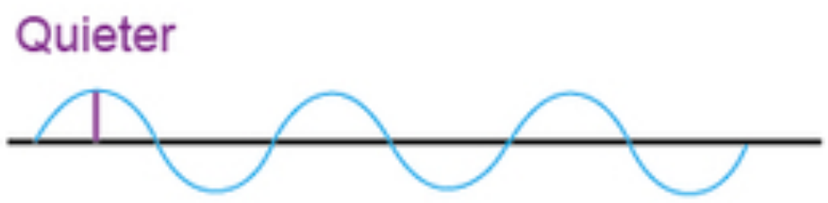
Sound Waves



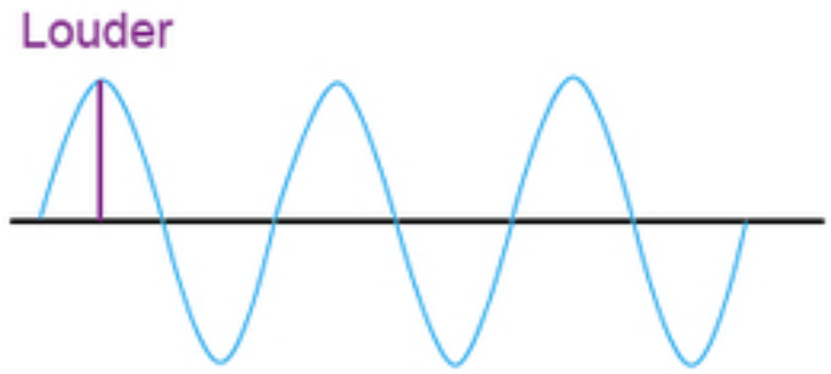
Low Frequency



High Frequency

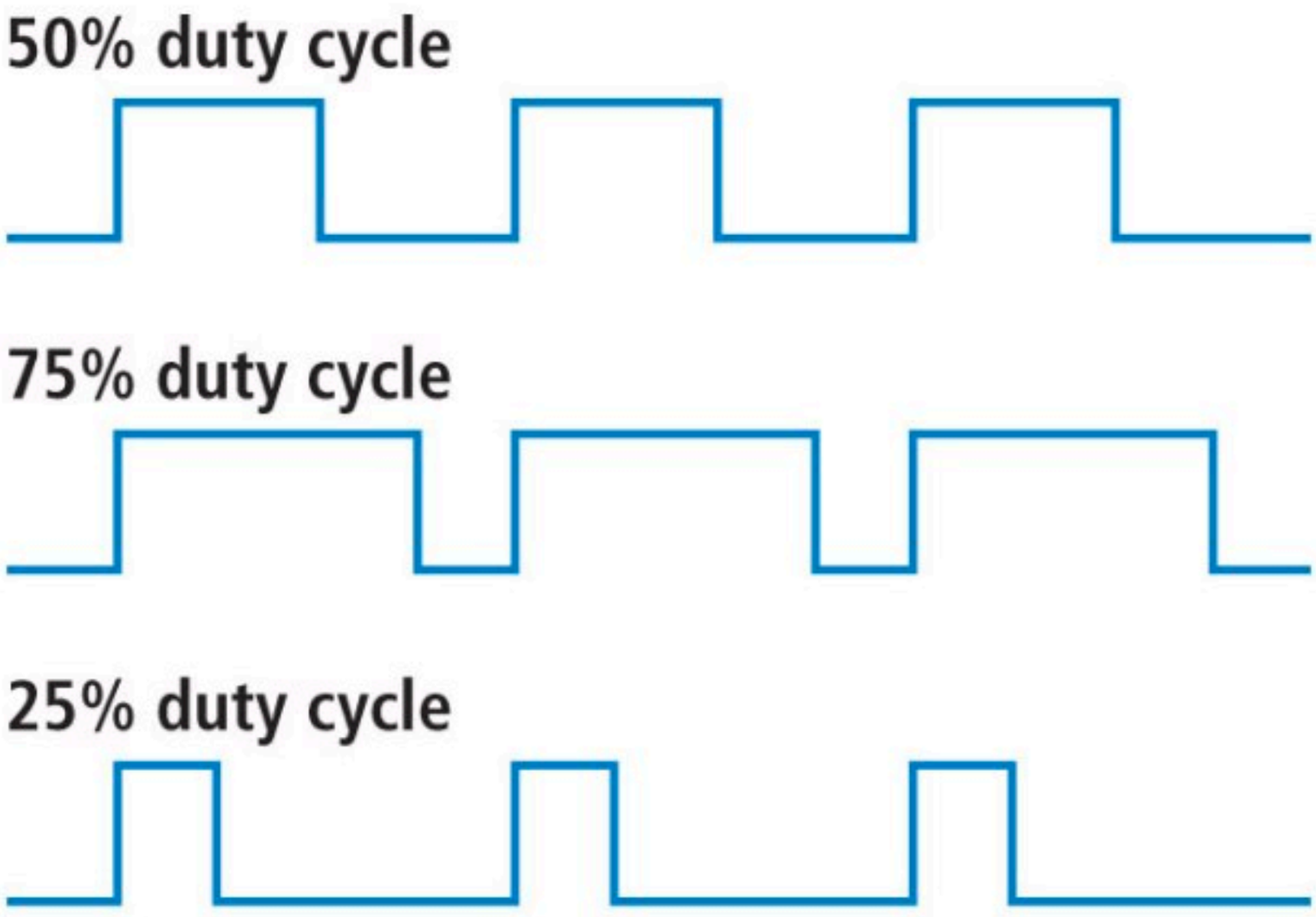


Low Amplitude



High Amplitude

Pulse-Width Modulation (PWM)



`pwm_clock, pwm_range, pwm_width`

`pwm.c`

	PWM0	PWM1
GPIO 12	Alt Fun 0	-
GPIO 13	-	Alt Fun 0
GPIO 18	Alt Fun 5	-
GPIO 19	-	Alt Fun 5
GPIO 40	Alt Fun 0	-
GPIO 41	-	Alt Fun 0
GPIO 45	-	Alt Fun 0
GPIO 52	Alt Fun 1	-
GPIO 53	-	Alt Fun 1

Stereo Jack connected to GPIO_PIN40 and GPIO_PIN45

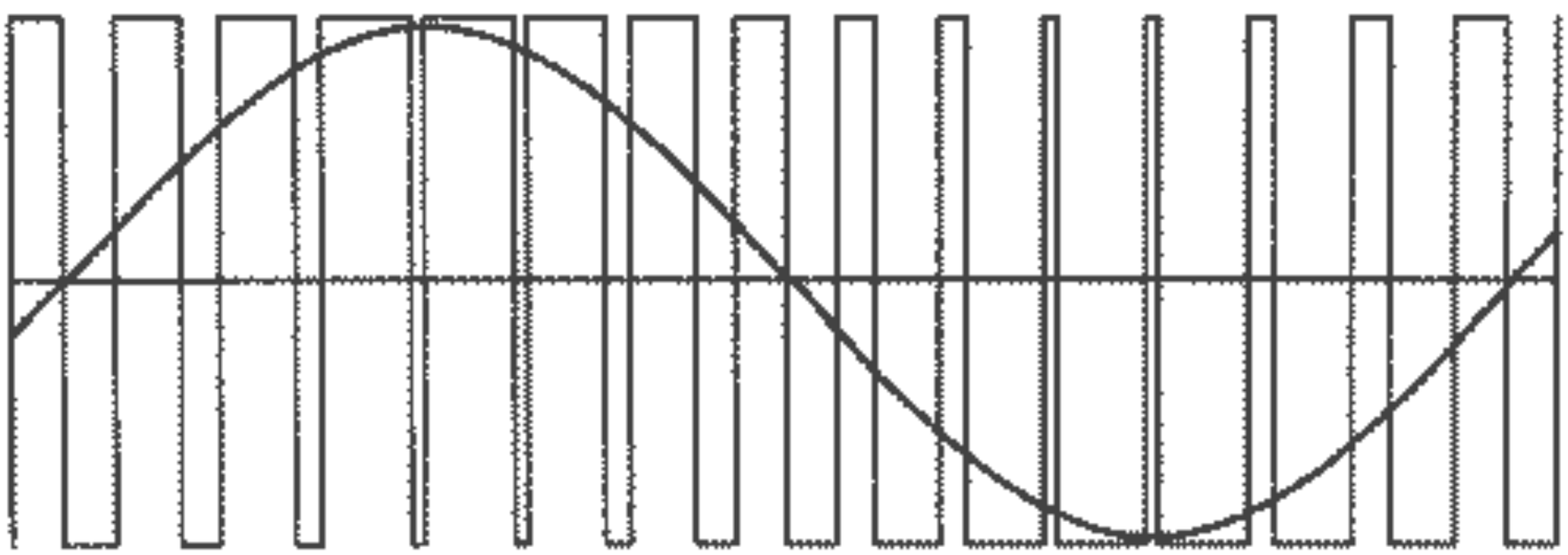
tone.c

melody.c

audio.c

Continuous Values

Can simulate continuous values with fast enough PWM clocking



Like you did to control the LED brightness