10 - Noise Considerations

CEG 4330/6330 - Microprocessor-Based Embedded Systems

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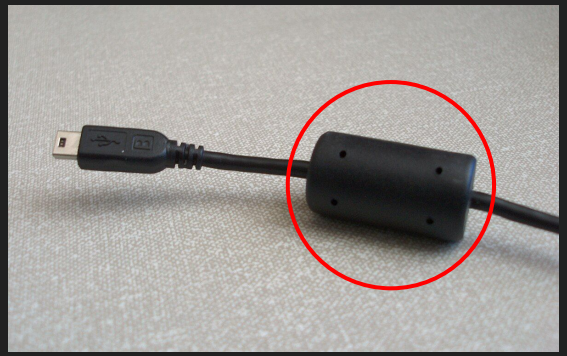
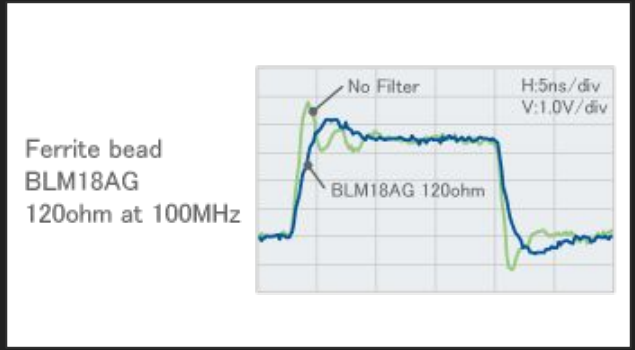
Power Conditioning

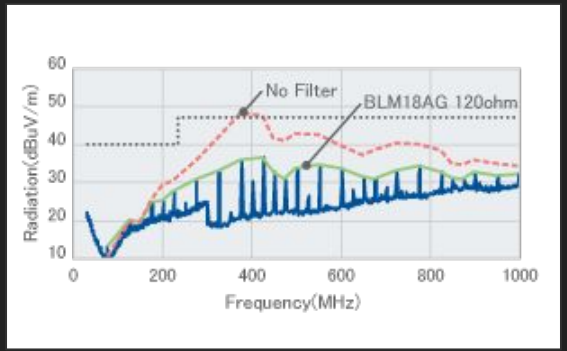
- Noise on power signals is undesirable and can cause unpredictable behavior
- Some ways to mitigate:
  - Ferrite beads
  - Decoupling capacitors

Ferrite Beads

- Commonly found on power cables and USB cables
- Although not physically connected to the power wires, it still a part of the circuit

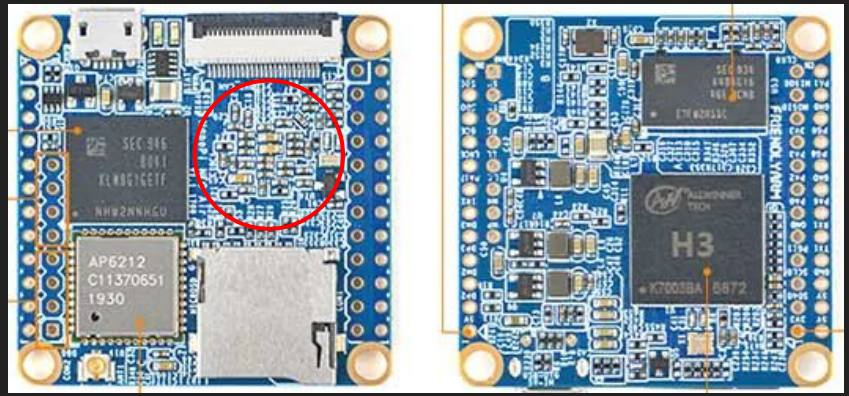


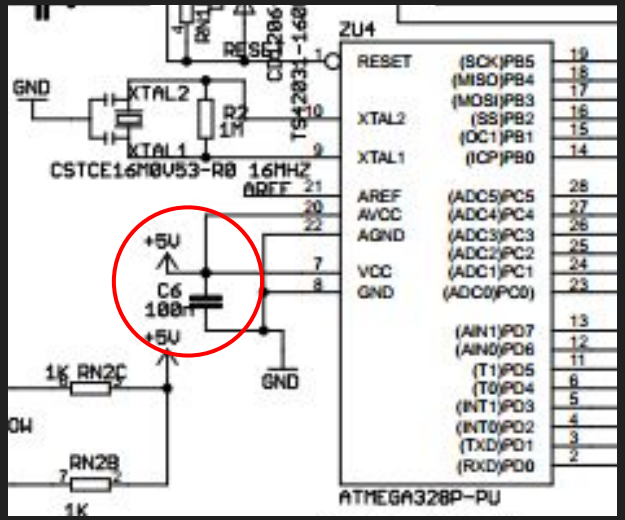




Decoupling Capacitors

- Circuits include many small capacitors connected to power
- Current spikes on each clock edge, decoupling capacitors act as a local storage
- This local storage is kept as close as physically possible to the microcontroller or microprocessor
- Prevents power from being influenced by high frequencies
    - Small capacitance values are better suited for high frequency noise decoupling





AVCC vs VCC

- Microcontrollers and microprocessors sometimes expose two separate power inputs, analog (AVCC) and digital (VCC)
  - An IC that allows for analog + digital processing is called “mixed mode IC”
- This allows you to provide a more noise resistant AVCC signal and a less noise resistant VCC signal
- Analog circuitry is far more sensitive to noise
  - In Arduino:
  - ±0.005V changes analog signal (noise margin)
  - ±2.500V changes digital signal (noise margin)
  - Digital signals are high frequency and can have significant effects on analog circuitry

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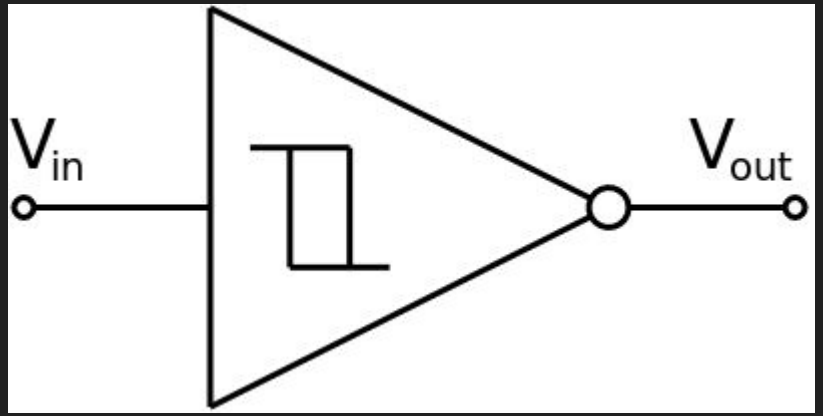
Unused Pins

- Unused pins must be handled differently if they are input, data, or output
- Unused Input Pins
  - Negate or deactivate the pin
  - Connect active high to ground
- Unused Data Pins
  - Leave unconnected
- Unused Output Pins
  - Leave unconnected
- Datasheet may have special requirements for some pins
  - Some pins may indicate “Leave pin floating”

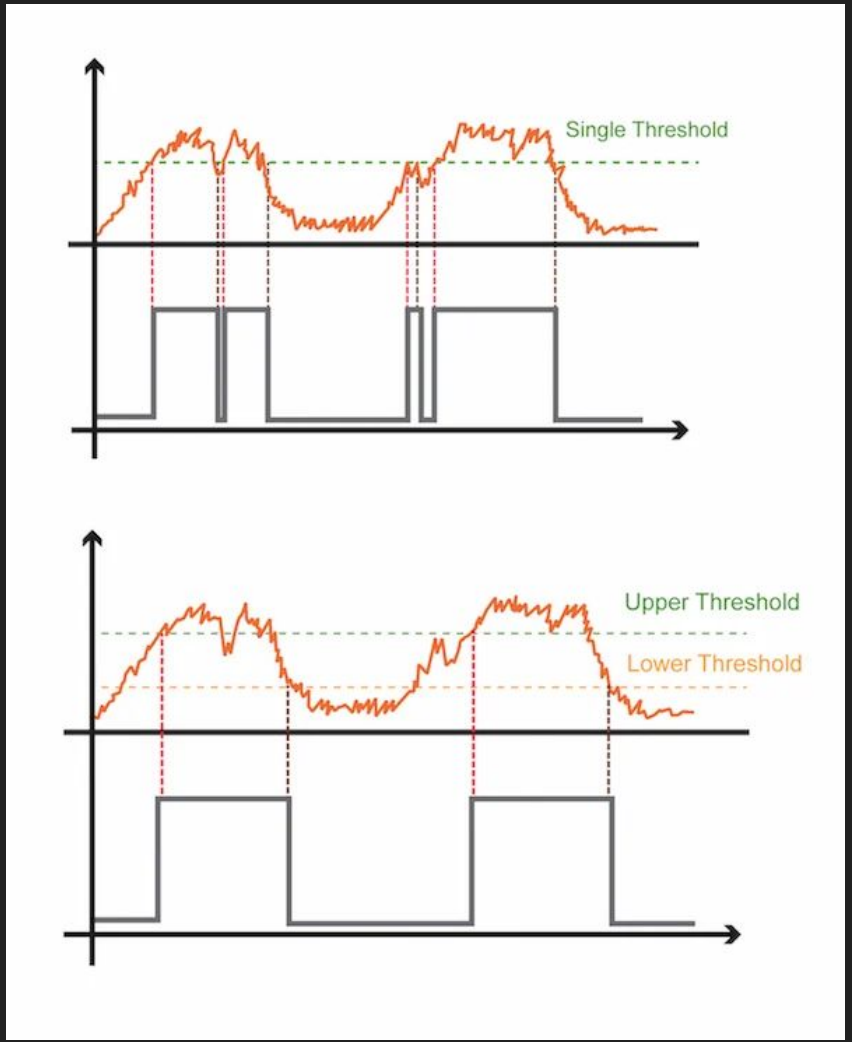
Schmitt Trigger

- Some designs require a threshold range for triggering something
- Imagine a thermostat that activates a heater at exactly 70°F
  - If the temperature fluctuates between 69.999999… and 70.000000… rapidly, the thermostat will become erratic
- A Schmitt Trigger defines a threshold for activation, and a threshold for deactivation
  - In the previous example, use 70.00 as the activation threshold and 65.00 as the deactivation threshold



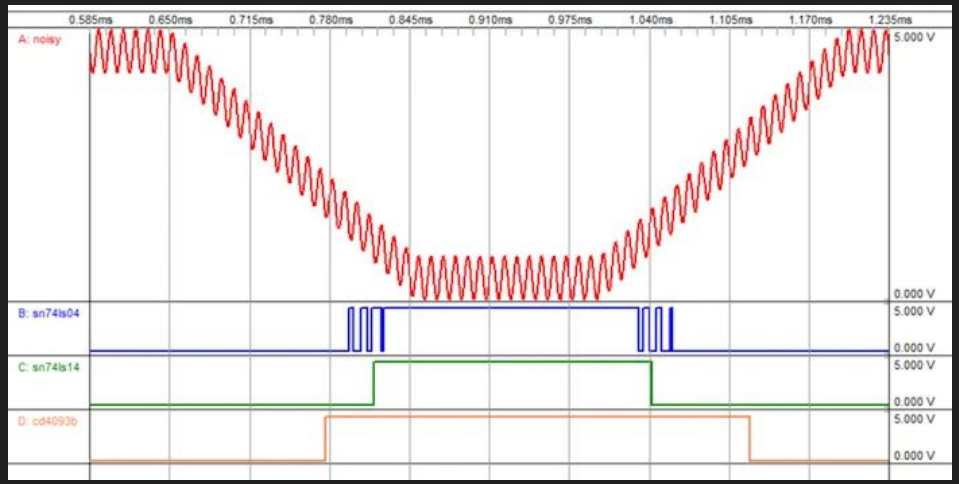
Schmitt Trigger (cont.)

- Schmitt Trigger uses one threshold for rising signal, and one threshold for falling signal
- Provides much higher noise margin



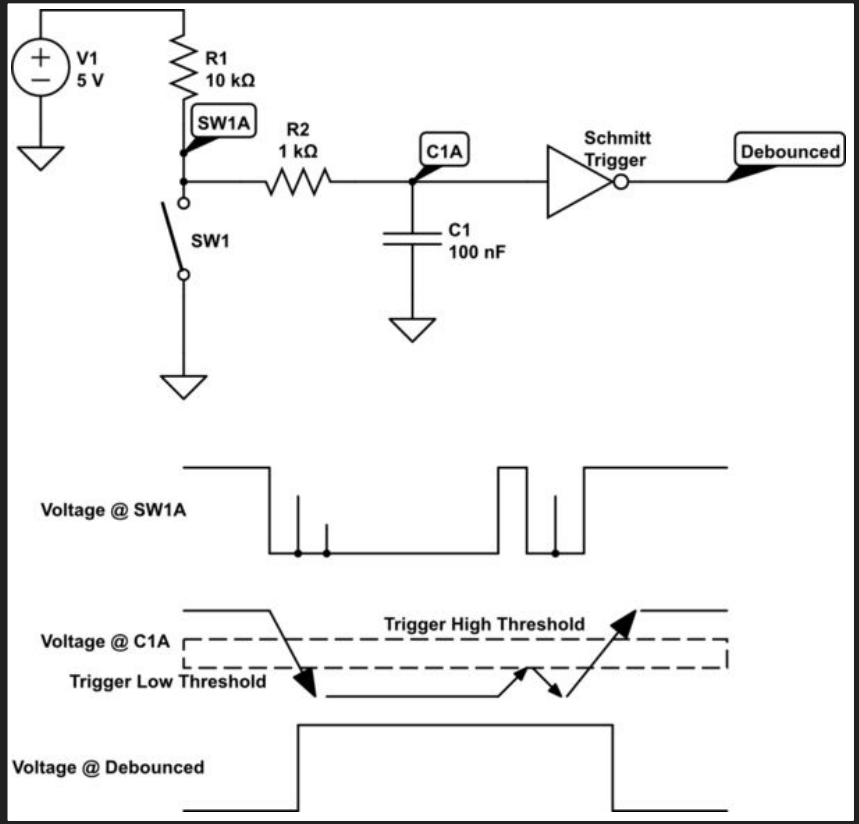
Schmitt Trigger (cont.)

- In noisy environments, falling edges may fluctuate
- Using a single threshold, the output is unsatisfactory
- Using a Schmitt Trigger, the output has a clean rising and falling edge



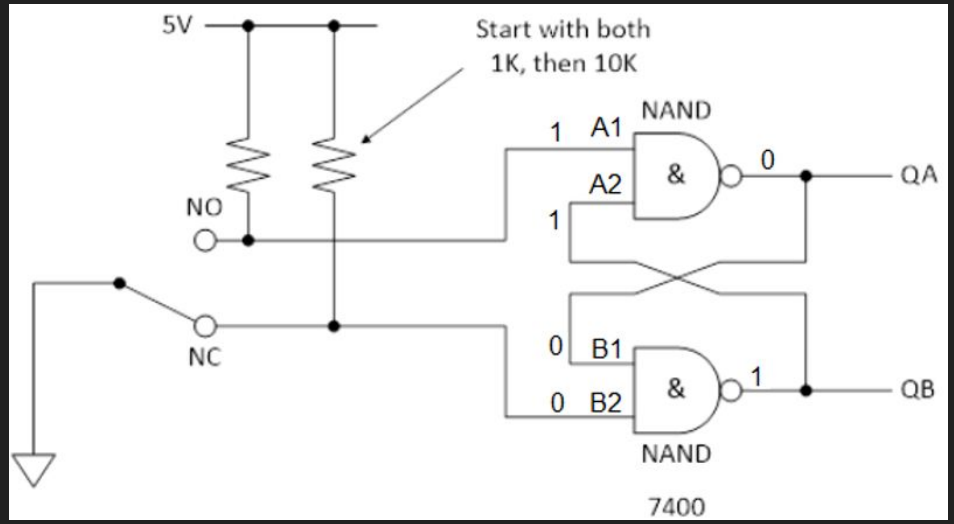
Schmitt Trigger Debouncing

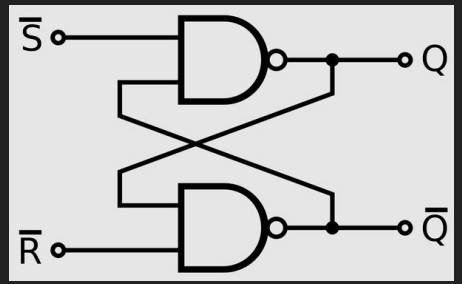
- Using RC low pass filter, bounces can be smoothed out
  - Cutoff Frequency = 1 / (2πRC)
  - Adds some delay to the switch press
- After smoothing from the low pass filter, a Schmitt Trigger can be used for a clean rising/falling edge



Schmitt Trigger Debouncing with SR Latch

- When switching to NO:
  - S pin will bounce between 0 and 1
  - R will remain 1
  - Q will only change to 1 once
- When switching to NC:
  - R pin will bounce between 0 and 1
  - S will remain 1
  - Q will only change to 1 once





$\overline{S}$	$\overline{R}$	Q	$\overline{Q}$	Comments
0	0	1	1	INVALID
0	1	1	0	SET
1	0	0	1	RESET
1	1	NC	NC	No Change (remain present state)

Successive Input Noise Cancellation

- Assume we are detecting a rising edge to trigger an event
- If the signal is noisy, with multiple rising edges, multiple events will be triggered (undesirably)
- ATmega328p allows successive samples to detect a rising edge for input capture
  - Using noise cancellation, 4 equal samples must be measured to trigger the event
  - This adds some delay but may be necessary if the input signal is noisy
- For handshaking and strobing this might also be required

Disable Digital when using Analog

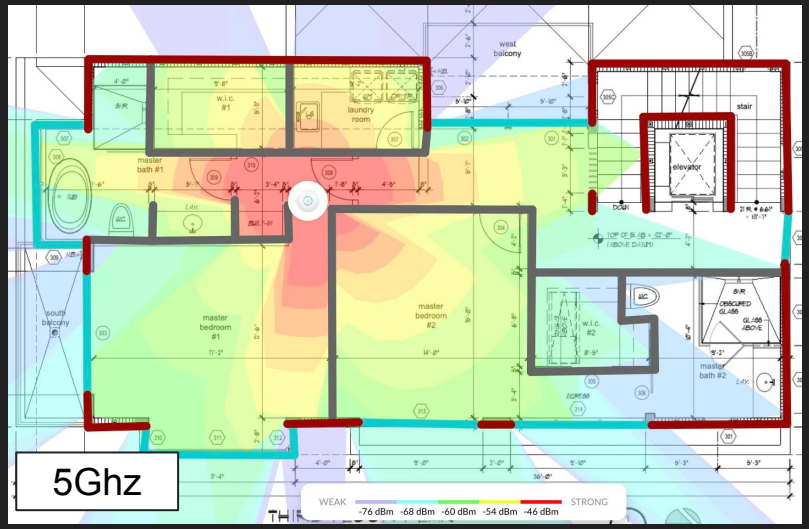
- The digital circuits on a microcontroller or microprocessor can introduce noise to the analog circuits
- The ATmega328p allows for putting the processor to sleep and performing an analog to digital conversion
  - Once the conversion is complete, the ADC interrupt awakens the processor so it can use the ADC value

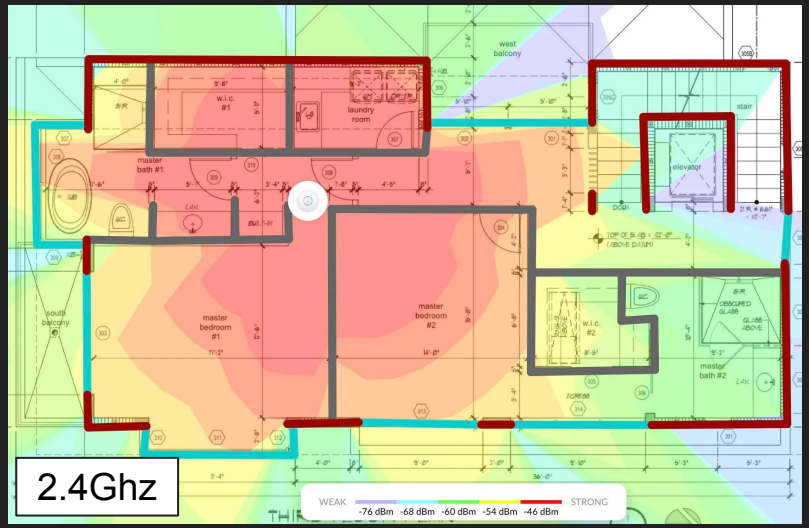
Wi-Fi Communication

- Wi-Fi (Wireless Fidelity)
  - 2.4 Ghz, 100 Mbits/sec (typical)
    - 45 meter transmission distance (typical)
  - 5.0 Ghz, 1000 Mbits/sec (typical)
  - 6.0 Ghz, 2000 Mbits/sec (typical)
    - Speed depends on many factors:
      - Interference from other devices
      - Physical objects blocking waveform from transmitter to receiver
      - Signal strength at *x* distance

Wi-Fi Communication (cont.)

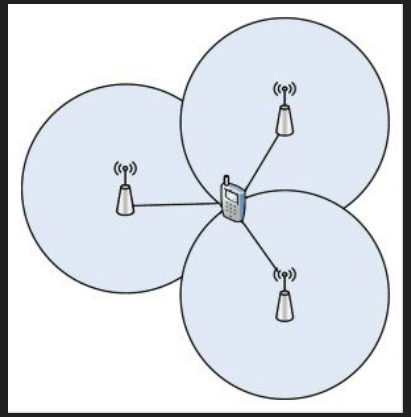
- Why not choose fastest (6G) wifi for all communication?
  - Higher frequencies means more data but less distance, especially with obstacles

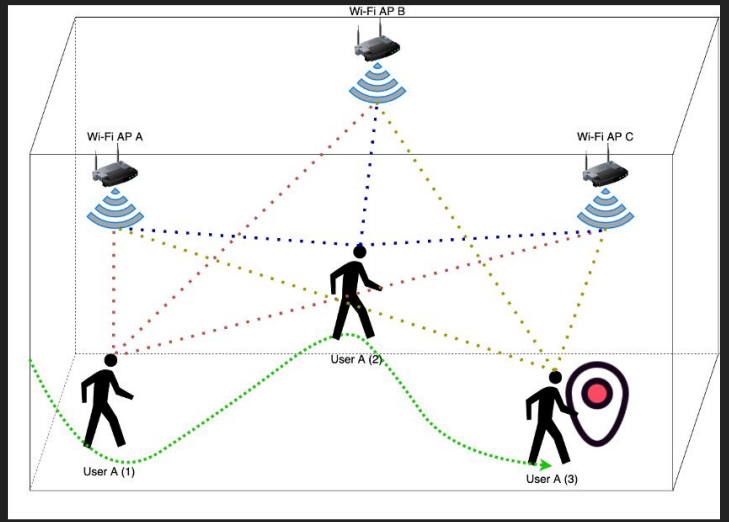




Wi-Fi Positioning

- The strength of a Wi-Fi signal or the transmission delay can allow for triangulation of embedded systems
- This triangulation allows for tracking the position of a Wi-Fi enabled device in a known environment
    - Consider the application of analyzing foot traffic inside of a mall
- In recent breakthroughs, Wi-Fi can also measure a full body's arms, legs, body positions through walls



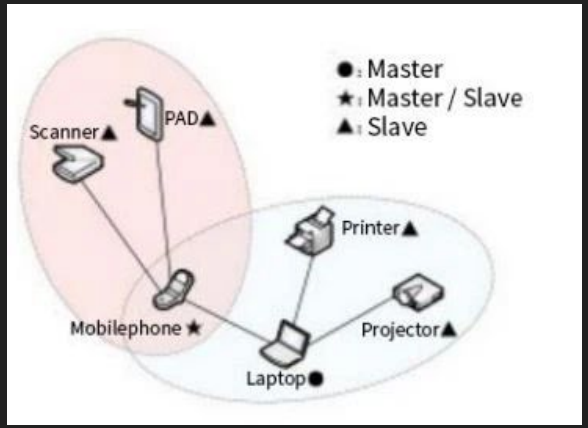


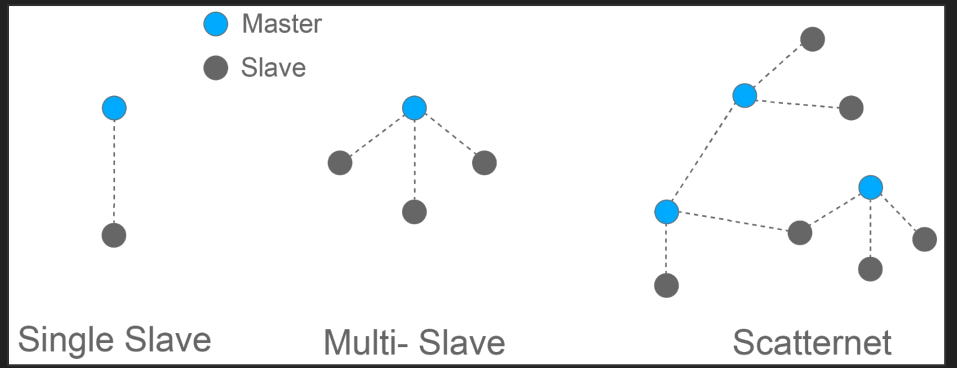
Bluetooth Communication

- Bluetooth
  - 2.4 Ghz, 1-3 Mbits/sec (typical)
    - Better suited for low transmission rate devices
      - Headphones
      - Keyboards
      - Mice
  - 10 meter transmission distance (typical)
  - BLE (Bluetooth Low Energy)
    - Lower power consumption
    - Lower transmission rate
    - Lower transmission distance

Bluetooth Mesh Networks and Multiple Devices

- For Wi-Fi devices, connecting to multiple networks is not a simple process
  - May not be possible depending on the Wi-Fi chip or operating system
- For Bluetooth, it is a common feature
  - Headphones, mice, keyboards, etc. can all be connected to the same device
- Bluetooth devices are either master (main) or slave (subnode)
  - Communication can flow freely between the devices but the main must initiate the connection





Other Wireless Communication Methods

- Zigbee
  - Competitor to Bluetooth
  - Less common
- IrDA
  - Infrared light data transmission
- SMS, 2G, 3G, 4G, 5G, LTE
  - Used in cellphone towers
  - Allows for you to send/receive mobile data
- RFID, NFC
  - Radio Frequency Identification and Near Field Communication
  - Allows for communication by tapping of credit card or badge
  - Only useful for short range
  - Very susceptible to man in the middle attacks (credit card skimmer)