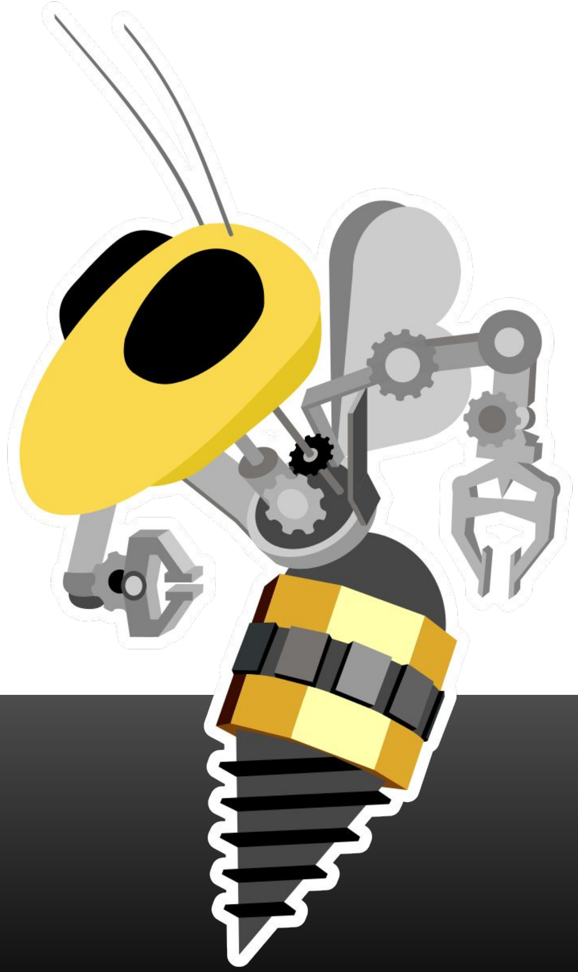
Welcome!

Electrical Training Week 3



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Last Week

- Motors
- Motor Control Circuits
- Pulse Width Modulation (PWM)

This Week!

- Embedded Firmware
  - Data
  - Control structures
  - State Machines
  - Interrupts
  - Communication
  - Lab

What is firmware?

- *"a type of computer program that provides the low-level control for the device's specific hardware."* Wikipedia

- Defines complex behaviors of microcontroller
- Interface with other intelligent devices in circuit

Programming Basics

C and C++ for microcontrollers

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Data Types

- int
  - Integer
  - 16 bits
- float
  - Decimal
  - 32 bits
  - Slow in AVR
- bool
  - True/False
  - 8 bits
- byte
  - Integer
  - 8 bits
  - Good for small numbers

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If Statement

```
if(/*condition*/)
  {
    // action to happen only once
  }
  else if (/*condition #2*/)
  {
    // can have many of these
  }
  else
  {
    // catches all other cases
  }

/* alternative notation for when there
   are no 'if else' or 'else' statements
*/
if(/*condition*/)
  // action to happen only once
```

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Switch Statement

```
switch (/*expression*/)
{
    case /* label 1 */:
      /* code */
      break;
    case /* label 2 */:
        /* with no break statement
           label 3 will also be
           evaluated
    case /* label 3 */:
      break;
  default:
        // catches all other cases
      break;
  }
```

For Loop

```
for(int i = 0; i < counter_limit; i++)
{
    //action to happen a certain number of times
}
/* i is only defined inside for loop function
   i++ adds 1 to i at the end of each loop
   don't forget the semicolons!!
*/
```

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While Loop

```
while(/*condition*/)
{
    /*action to happen repeatedly
    while the condition is met
    */
}
```

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Arduino Code Structure

```
int main() {

  setup();

  while(true){
    loop();
  }

}
```

Functions

```
void myFunction() {
  //Do whatever I want here
}

void setup() {
  //Declare pins, initalize variables
}

void loop() {
  //Code to be called repeatedly
}
```

```
void loop() {
  myFunction();
}
```

Finite State Machines

Programming Robots :D

What is a State Machine?

- Microcontrollers need to perform tasks at various times
  - In sequence
  - In real time (after X number of seconds)
  - In reaction to input
- Chooses output based on system **state**
- Transitions between various modes
  - Combination of inputs and knowledge of current state

Writing a State Machine

1. Define States
2. Identify state transitions
3. Create state variable
4. Create switch statement based on state variable
   a. Set value of state variable based on transitions
   b. Set output based on current state

Scenario

- Robot has 3 modes
  - Driving (apply voltage to motors)
  - Braking (triggers closing of brake calipers)
  - Stopped (do nothing)

- How do we design a controller to switch between 3 modes?

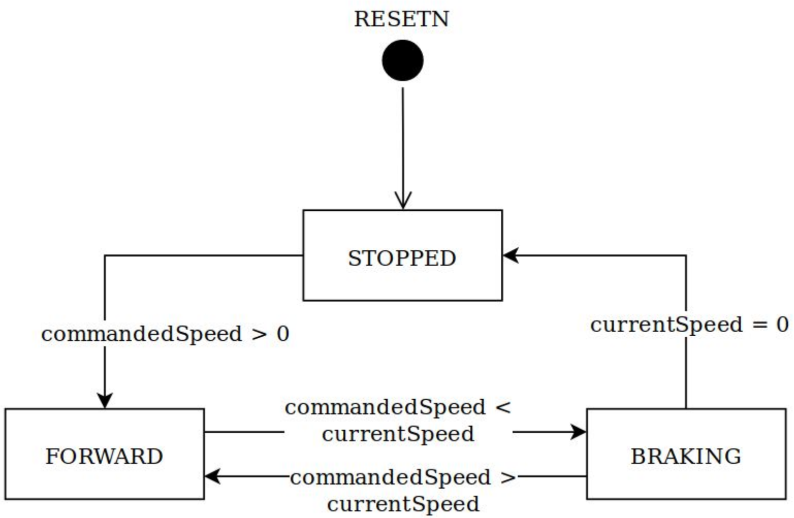
Defining States

- Use preprocessor directive #define
- Replaces a name (all caps) with a value
- Names and numbers can be arbitrarily assigned

```
#define STOPPED 0
#define FORWARD 1
#define BRAKING 2
```

Identify Transitions

- When will your system be allowed to change state?
- What inputs (external info) lead to this change?
- Draw state chart
  - State in box
  - Input on lines



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Writing the Switch Statement

```
int state = STOPPED;

switch (state) {
  case FORWARD:
    //functionality
    driveForward();

    //transition
    if(commandedSpeed < currentSpeed) {
      state = BRAKING;
    }
    break;

  case BRAKING:
    applyBrakes();
    if(commandedSpeed > currentSpeed) {
      state = FORWARD;
    }
    else if(currentSpeed == 0) {
      state = STOPPED;
    }

  case STOPPED:
    //idle in place
    if(commandedSpeed > 0) {
      state = FORWARD;
    }
}
```

Interrupts

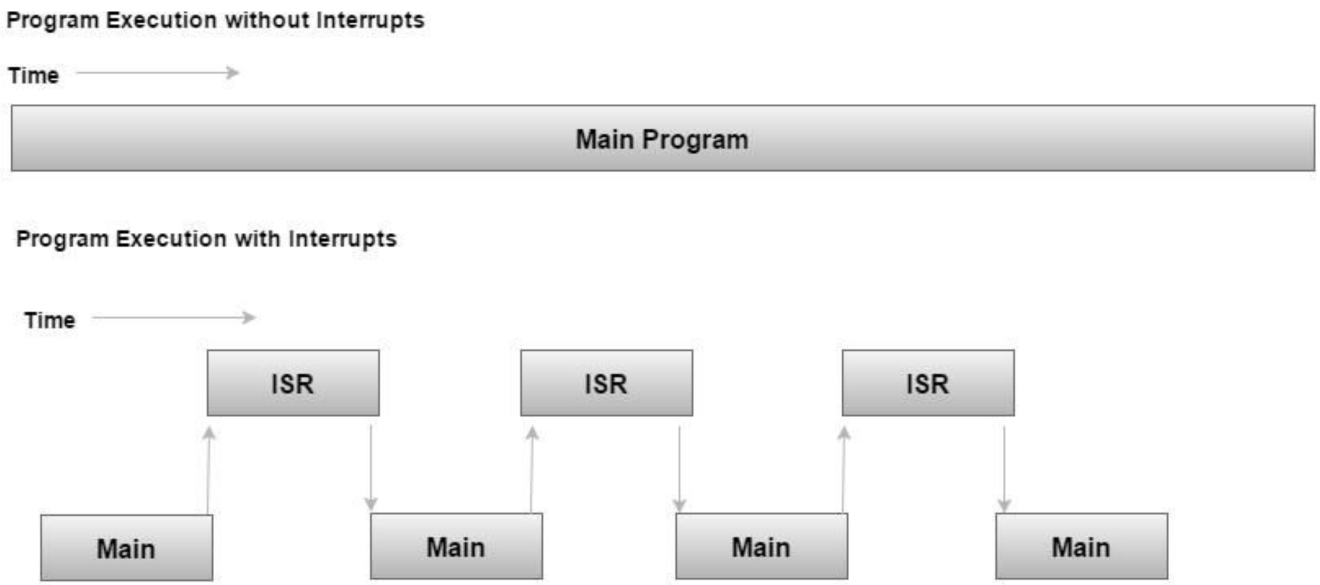
Loop loop loop | new info!! | Loop loop loop

Program Execution

- Microcontrollers can only perform 1 task at a time
- A program consists of a list of tasks in sequence
- **Program Counter** - Number indicating the instruction being executed

Example

- A Function monitors a radio to look for incoming data
  - No knowledge on when this information is coming
  - Function A can cause microcontroller to hang indefinitely and not check the state of any other inputs
- Interrupts will pause execution of Function A to complete their own task (ISR)



ISR : Interrupt Service Routine

Arduino Interrupts

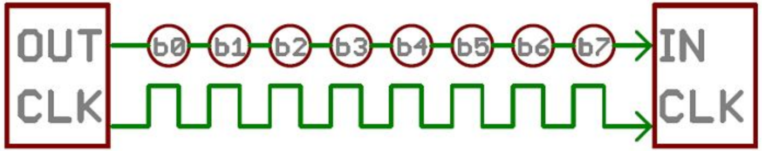
- Function: attachInterrupt()
- Inputs:
  - Interrupt number - found with digitalPinToInterrupt(pin)
  - ISR - name of function you wish to interrupt with
  - Trigger source
    - Rising, Falling, Change, Low

Communication Systems

How many are there again...?

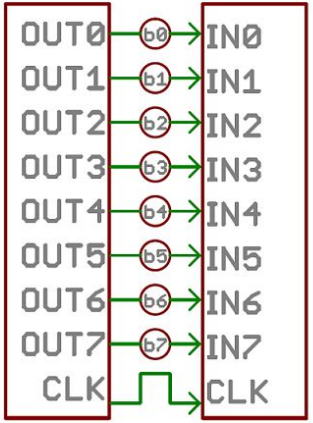
Serial vs Parallel Communication

Serial



- Stream data one bit at a time
- Example: USB, SPI

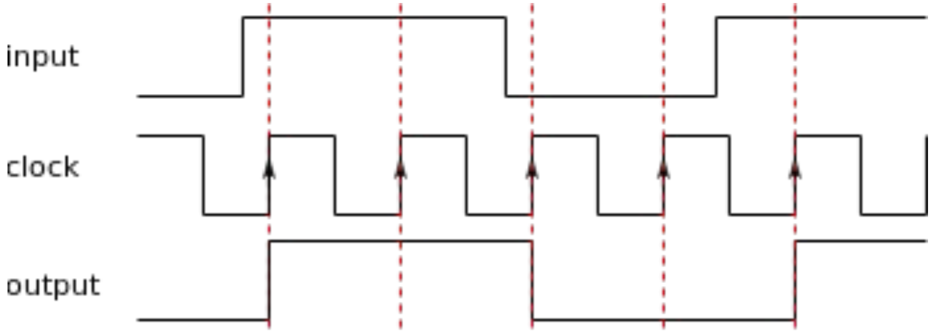
Parallel



- Many bits of data sent at the same time through different wires.
- Example: PCI and DIMM (on computer motherboards)

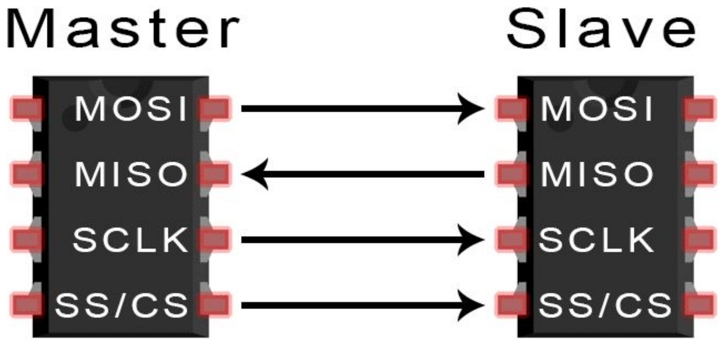
Clock Signals

- Square waves of known frequency (baud rate)
- Edge used to synchronize data reading across communicating devices



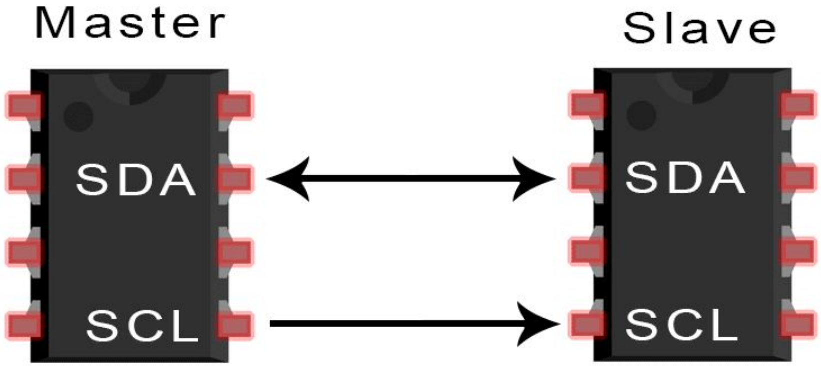
SPI (Serial Peripheral Interface)

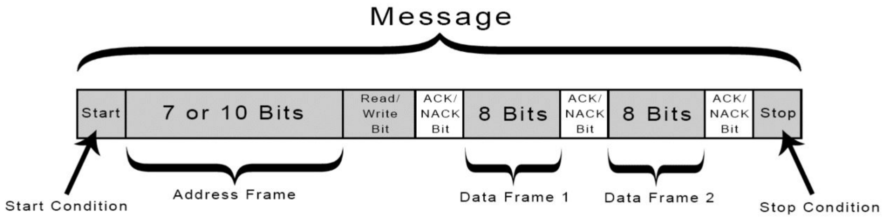
- Continuous bidirectional transfer
- All devices share 3 Lines
  - Unique Slave Select line per device
- Master controls CLK



I2C (Inter-Integrated Circuit)

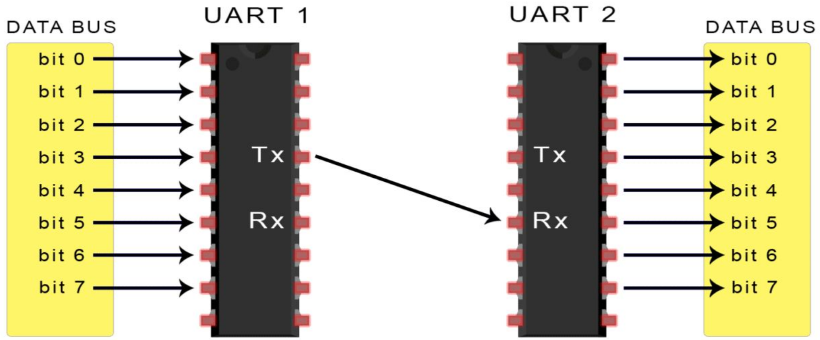
- Synchronous
- Uses only two wires :
  - SCL: Clock signal
  - SDA: Data signal
- Sends data in ‘frames’
- Any device can claim master by controlling SCL





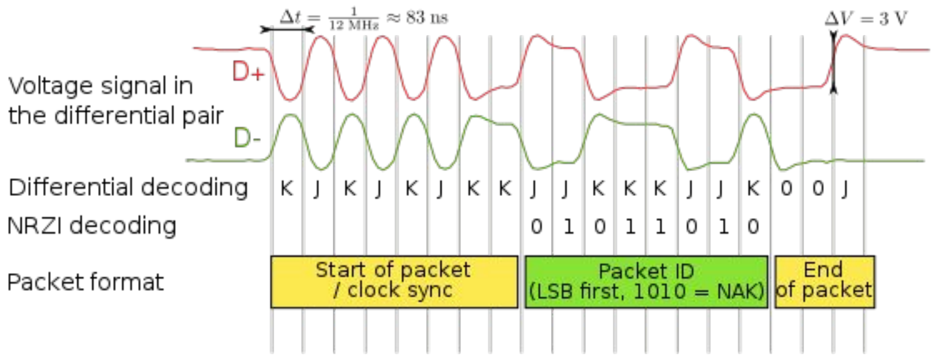
UART (Universal Asynchronous Receiver/Transmitter)

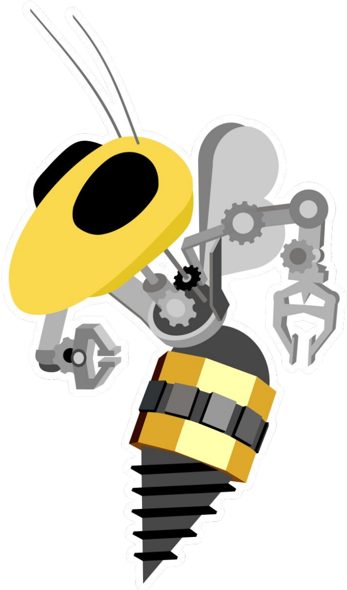
- Asynchronous (no clock needed)
- Uses 2 wires
- Need same baud rate



USB (Universal Serial Bus)

- Differential Pair signal
- Defines rate in “clock sync” phase
- Useful for computer-device communication





Lab Time!