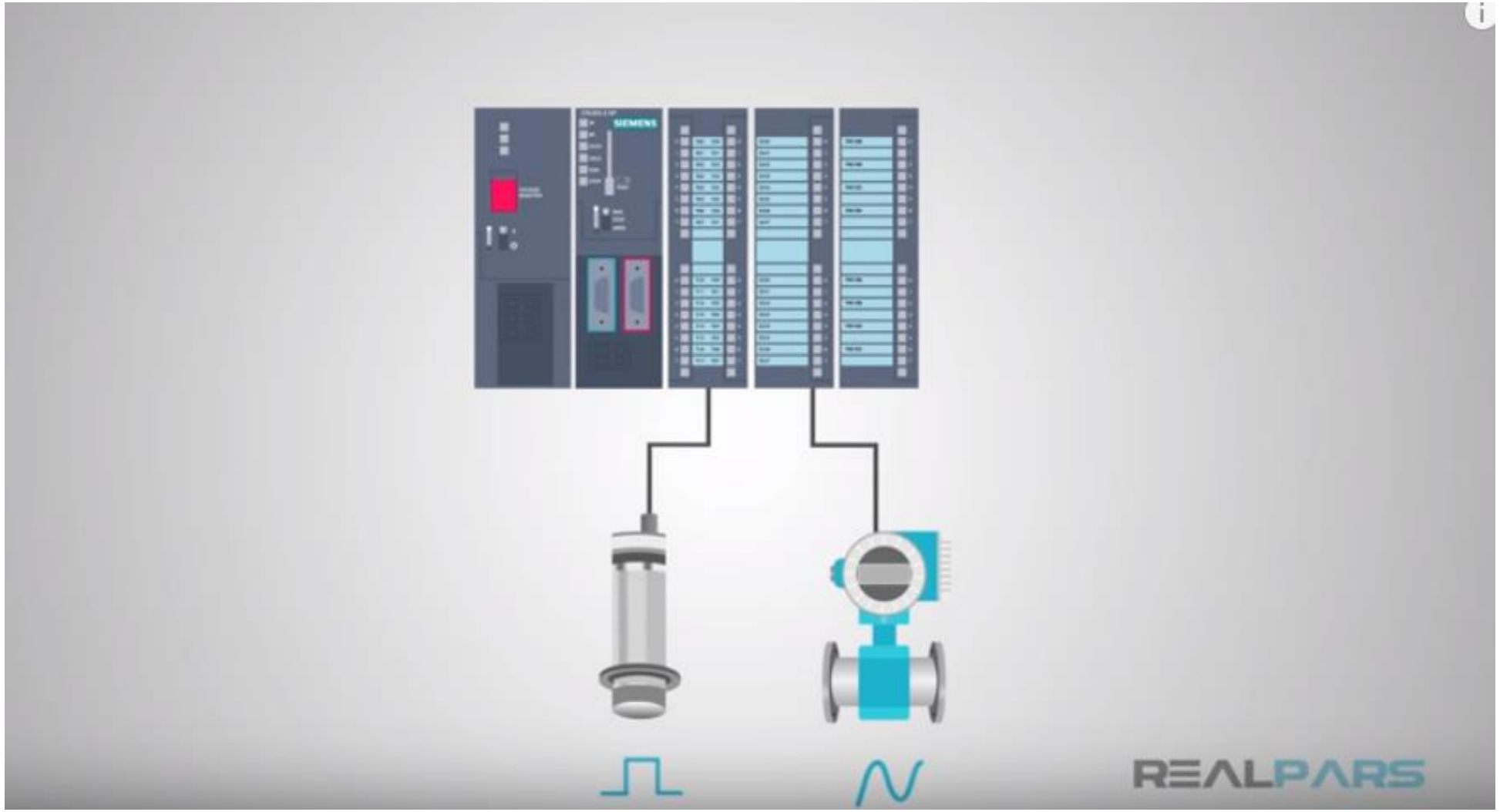
Types of Sensors



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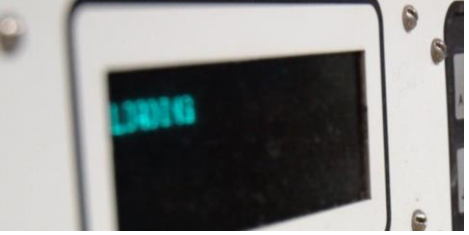
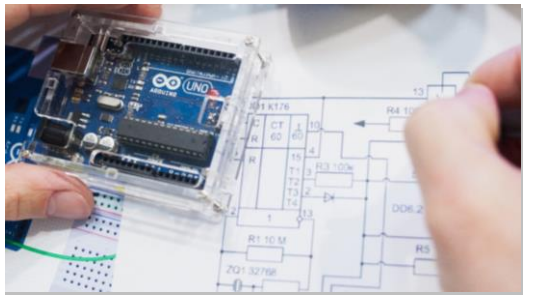




pathways to engineering technology employment

Transistors

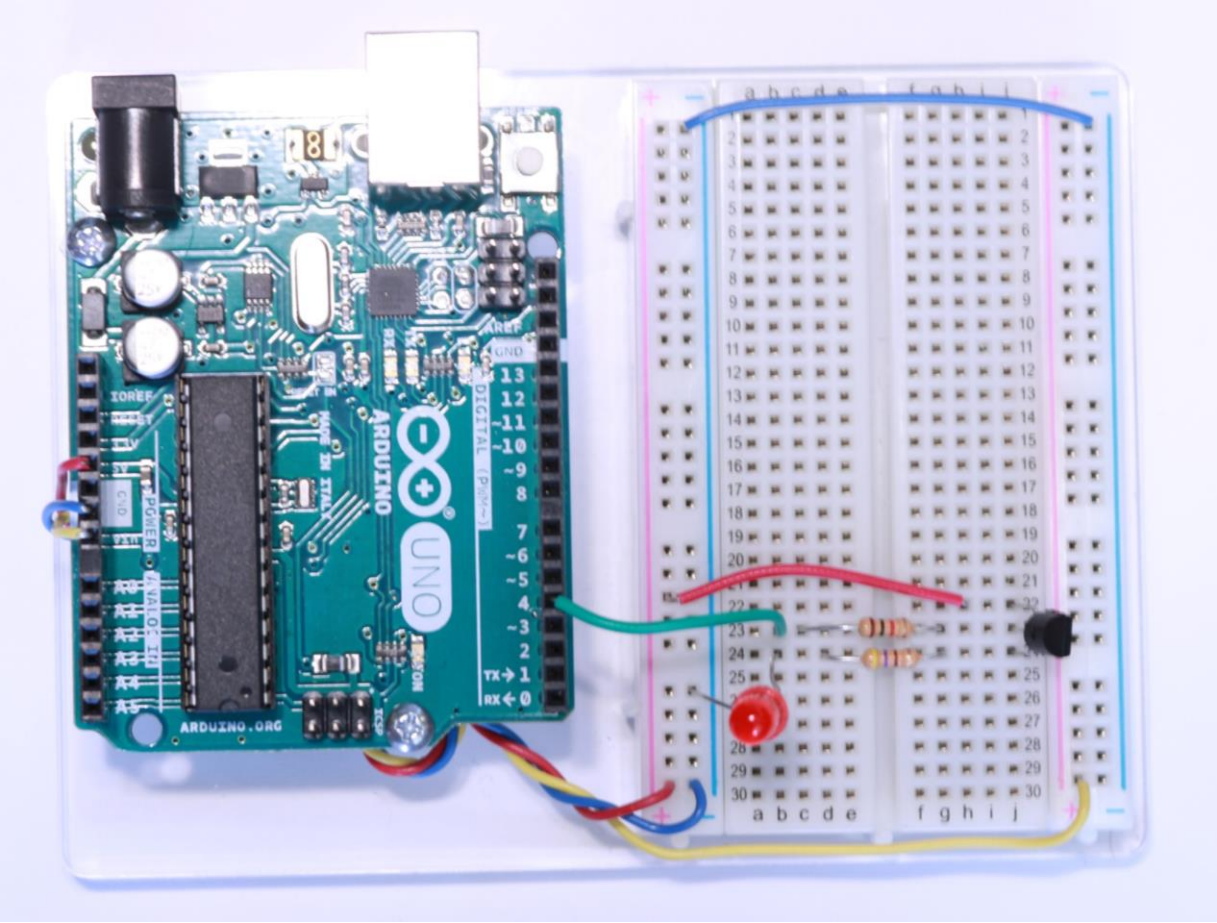
LOUISIANA DELTA
COMMUNITY COLLEGE

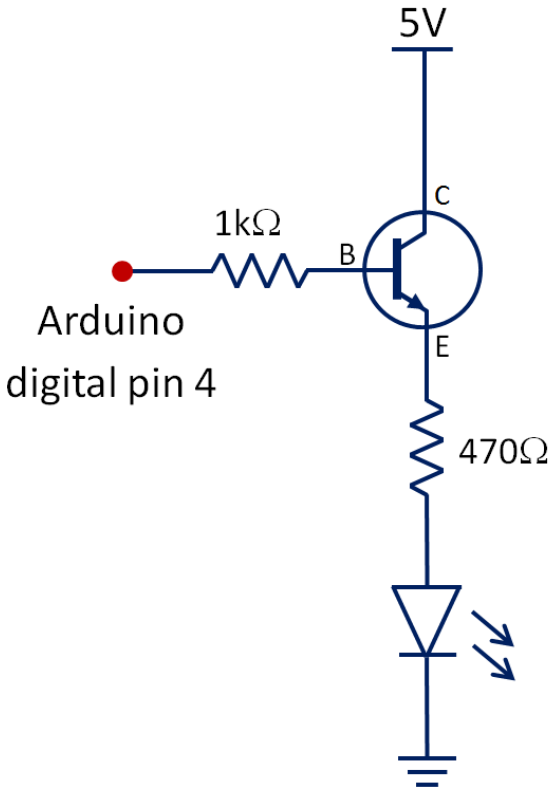
Transistors

- Describe the function of a transistor.
- Build a transistor switching circuit.
- Control a transistor switch with the Arduino.
- Implement a circuit to monitor a thermistor.
- Implement a set point program using a thermistor.

Implementation of a Transistor Circuit

- A **transistor** is a semiconductor device that can be used as an “electrical switch” or as an amplifier
- Implement the transistor circuit on your Arduino





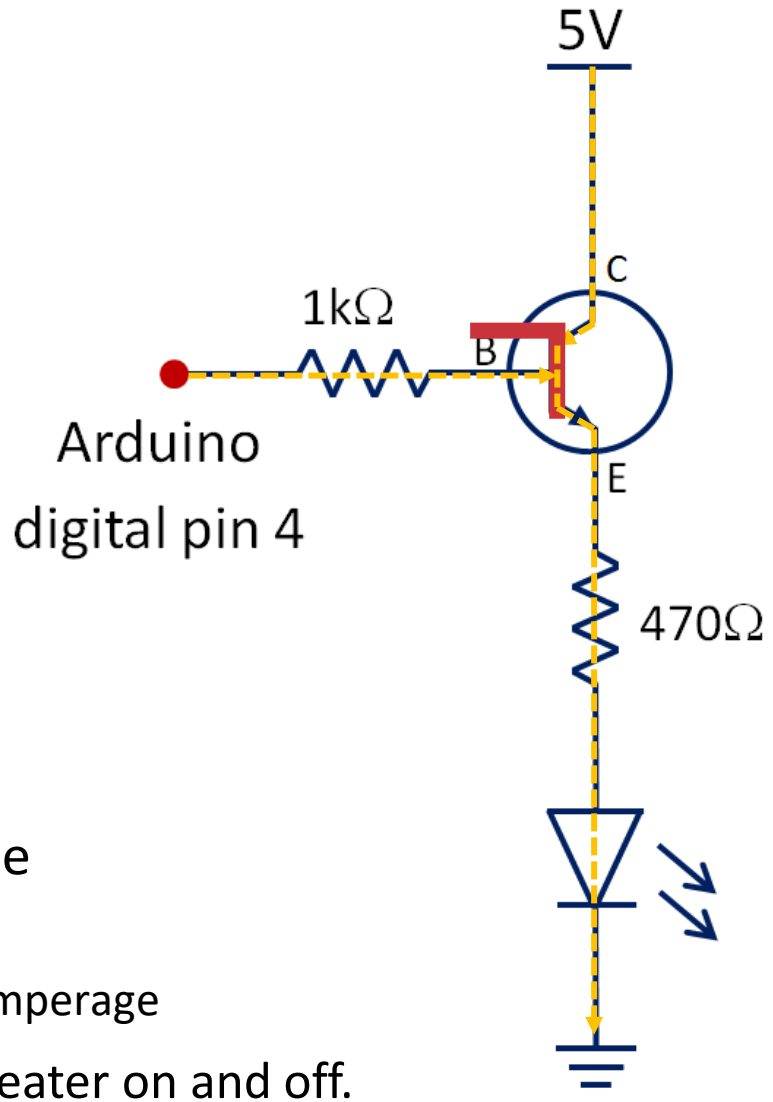
Compare the pin locations of C, B and E to the circuit diagram

WARNING: The transistor will get VERY hot if connected incorrectly

Implementation of a Transistor Circuit

- Write a simple program to make the LED blink on and off

```
void setup() {
    pinMode(4,OUTPUT);
}
void loop() {
    digitalWrite(4, HIGH);
    delay(1000);
    digitalWrite(4, LOW);
    delay(1000);
}
```



- What is the transistor doing? Switching the LED on and Off
- Transistors can be used to have a small current toggle a larger one
  - Your Arduino can output ~40mA of current
  - Using transistors with your Arduino allows you to toggle a much larger amperage
- We will use transistors to activate a relay for switching our sous vide heater on and off.

Transistors

- A **transistor** is a semiconductor device that can be used as an “electrical switch” or as an amplifier.
- Transistors are in most electronic devices
- Advantages of using a transistor over a mechanical switch:
  - Can be very small
  - Works very fast
  - Can be controlled electrically
  - Inexpensive

The A8 chip in an iPhone contains **2 billion** transistors

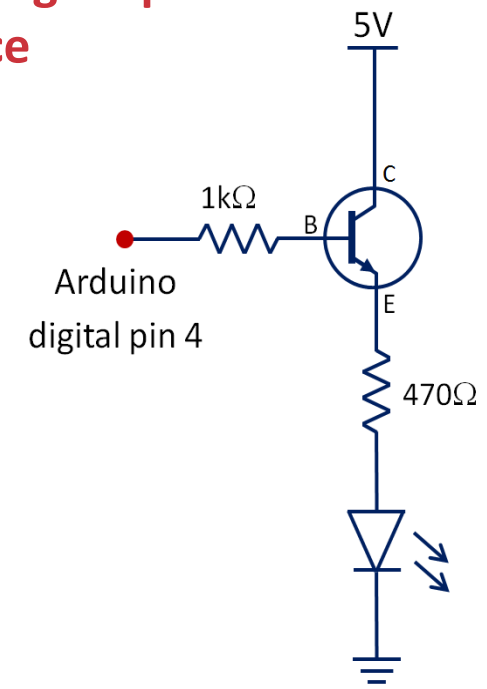
This chip in your multimeter contains multiple transistors

Transistors are made from Semiconductors

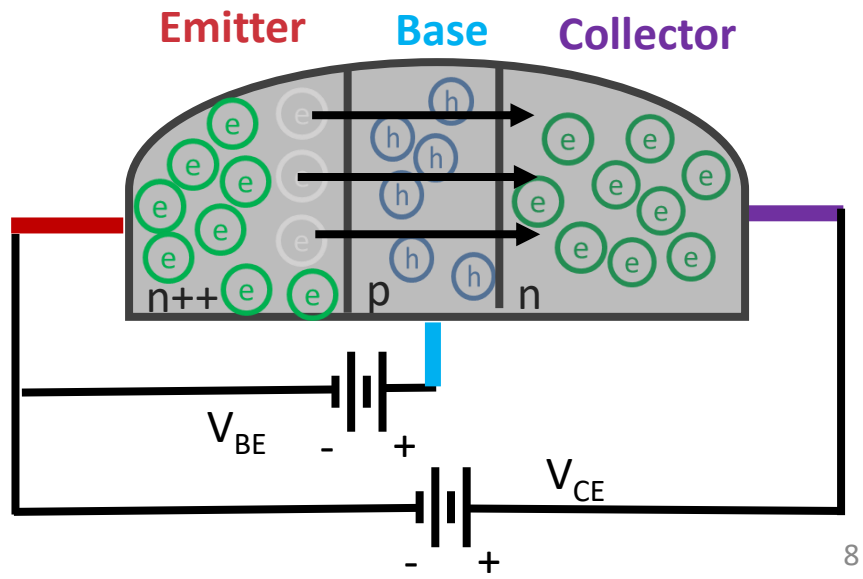
- **Semiconductors** are materials that can either be a conductor or an insulator depending on the conditions
- **Silicon** by nature is an insulator but it is also the most common semiconductor material.
  - Silicon can easily be bonded with other atoms to make it conduct or insulate when desired using a process called doping.
  - Common doping atoms are Phosphorous and Boron .
  - When silicon is doped with phosphorous it yields an extra electron which encourages conduction. This makes the bond more **n**egative and is called **N-Type Doping**.
  - When silicon is doped with boron it yields a hole or missing electron which encourages conduction. This makes the bond more **p**ositive and is called **P-Type Doping**.

Transistors as switches

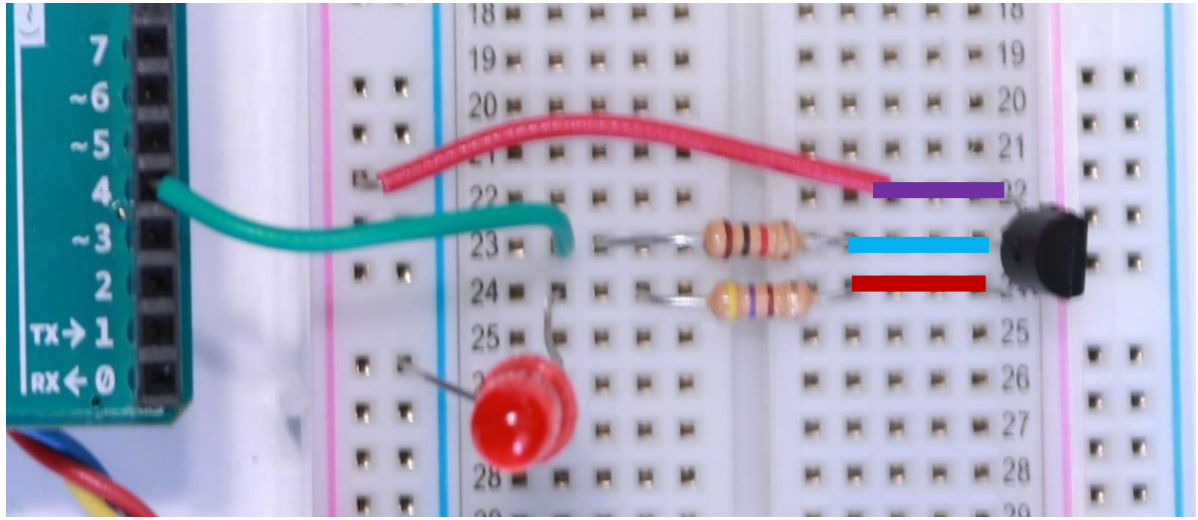
V_{BE} is the voltage from the digital pin & V_{CE} is the 5V power source

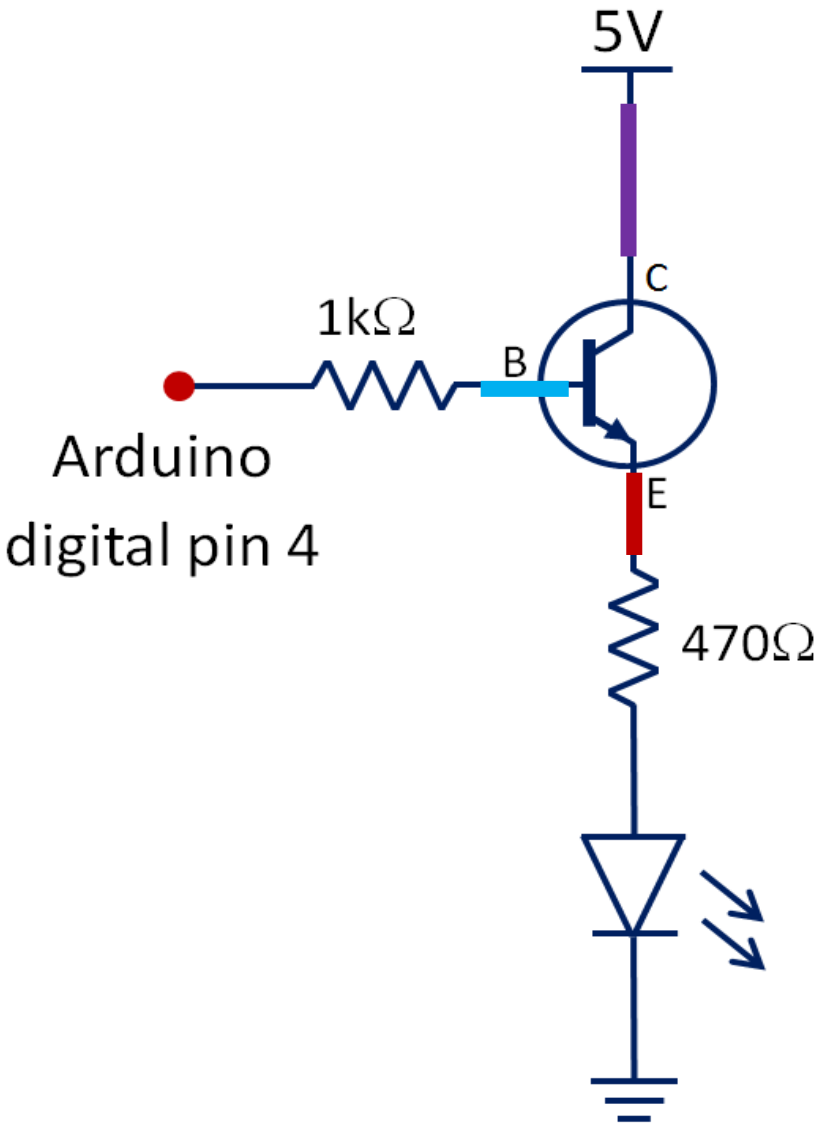


- **Transistors** use both types of semiconductors (N-Type and P-Type) sandwiched together along with strategically applied voltages to switch between insulation and conduction.
- $Voltage_{BE}$ can be used as a switch to turn $Voltage_{CE}$ on and off.
- Think about how that relates the transistor/LED circuit you set up at the beginning of class.
  - You had 2 voltage sources: 5V power source and voltage supplied by digital pin 4
  - Which of the two would be V_{CE} and V_{BE}?
- You were able to switch the LED on by supplying the second voltage (V_{BE}) from the digital pin
- When you turned the pin LOW you removed the second voltage which turned switched the LED off



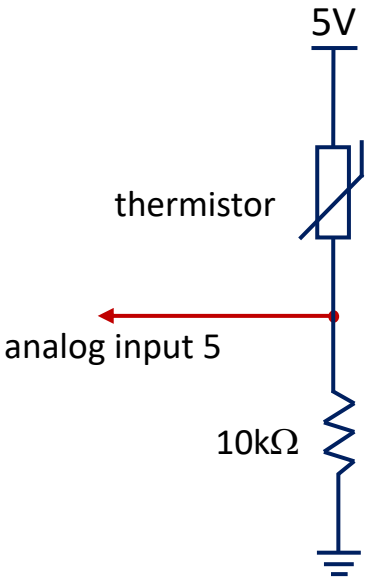
Transistors as switches





Transistors with Arduino Application

- **Goal:** When the temperature read by your thermistor is higher than 77°F, use a transistor to turn on an LED.



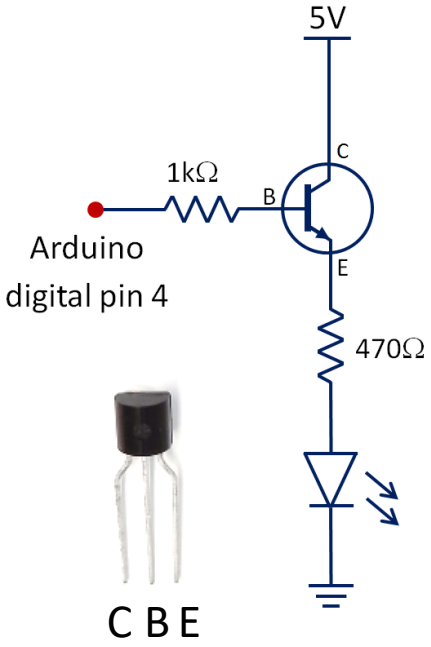
Guiding Steps:

- Implement the transistor/LED circuit and the thermistor circuit.
- Determine your variables. What variables do you think you will have and what data type will each be?

Variable to read in the analog value from the thermistor - **int val;**

Variable to convert the analog value from thermistor to °F - **float tempF;**

Variable for setpoint of 77°F - **float setpoint;**



Programming tip: since setpoint is a constant value, you can set that value at the beginning of the sketch when you define the variable. This makes it easy to change if you need to adjust the setpoint.

float setpoint = 77.0;

Remember to put .0 with your whole numbers so the Arduino looks for the decimal values.

plug C, B, and E correctly

Transistors with Arduino Application

- What do you need to put in your setup function?

  Initialize the serial monitor and pin Mode for digital pin connected to the transistor

- What is the first thing you need to do in your main loop function?

  Collect values from the thermistor

- What type of value are the thermistors points collected as? Analog Values
- You need to convert the analog values into temperature values. How can you do this?

  Use inverted calibration equation

- Remember to print the values you collected from the thermistor and their corresponding °F values on the serial monitor. Why is it good to do this?

  Seeing the values on the serial monitor helps you to know what temperature values you are reading, lets you know where in the sketch you are, and helps you troubleshoot issues with the sketch.

$$\boldsymbol{TempF = 0.2063 * AnalogValue - 26.428}$$

2022 Data: TempF = 0.19 * AnalogValue - 20.943

Transistors with Arduino Application

- Compare your temperature value with your setpoint value. What type of statement do you need to use for the comparison? **If** statement
- What should the comparison statement be? If (tempF > setpoint)
- If the condition is met, what should the Arduino do and how?

  Turn on the LED by using the transistor. Turning the digital pin connected to the transistor to HIGH will turn the LED on.
- How do you make the LED turn off when the condition is not met?

  Turn the digital pin connected to the transistor to LOW in an **else** statement.
- Remember it is a good practice to print to the serial monitor when the condition is met and the LED is on as well as when the condition is not met and the LED is off.

Transistors with Arduino Application

```
1  int val;
2  float tempF;
3  float setpoint = 77.0;
4
5  void setup() {
6  Serial.begin(9600);
7  pinMode(4, OUTPUT);
8  }
9
10 void loop() {
11   val = analogRead(5);
12   tempF = 0.2063*val-26.428;
13   Serial.print("  Analog = "); Serial.print(val);
14   Serial.print(" = "); Serial.print(tempF, 3); Serial.println(" degF");
15   if (tempF>setpoint){
16     digitalWrite(4, HIGH);
17     Serial.println("Temperature is above 77degF and LED is on");
18   }
19   else {
20   digitalWrite(4, LOW);
21   Serial.println("Temperature is below 77degF and LED is off");
22   }
23 }
```

```
Analog = 499 = 76.516 degF   Temperature is below 77degF and LED is off
Analog = 500 = 76.722 degF   Temperature is below 77degF and LED is off
Analog = 500 = 76.722 degF   Temperature is below 77degF and LED is off
Analog = 501 = 76.928 degF   Temperature is below 77degF and LED is off
Analog = 501 = 76.928 degF   Temperature is below 77degF and LED is off
Analog = 501 = 76.928 degF   Temperature is below 77degF and LED is off
Analog = 501 = 76.928 degF   Temperature is below 77degF and LED is off
Analog = 501 = 76.928 degF   Temperature is below 77degF and LED is off
Analog = 502 = 77.135 degF   Temperature is above 77degF and LED is on
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Analog = 502 = 77.135 degF   Temperature is above 77degF and LED is on
```

If the LED represents the heater mechanism on the sous vide, how do you think this activity is similar to the sous vide project that you are working towards?

```
int val;
float tempF;
float setpoint = 75.0;

void setup() {
  Serial.begin(9600);
  pinMode(4,OUTPUT);
}

void loop() {
   val = analogRead(5);
   tempF = 0.2063*val-26.428;
   Serial.print("  Analog = "); Serial.print(val);
   Serial.print(" = "); Serial.print(tempF);Serial.println(" degF");
   if (tempF>setpoint){
     digitalWrite(4,HIGH);
   }
   else {
     digitalWrite(4,LOW);
   }
}
```

Transistors with Arduino Project (Extension)

Objectives:

- When the temperature read by your thermistor is higher than 77°F, use a transistor to turn on a Green LED using a Transistor. (turn OFF bellow 77)
- When a photoresistor detects “dark”, turn on a RED LED (using a digital pin).

Requirements/Rubric:

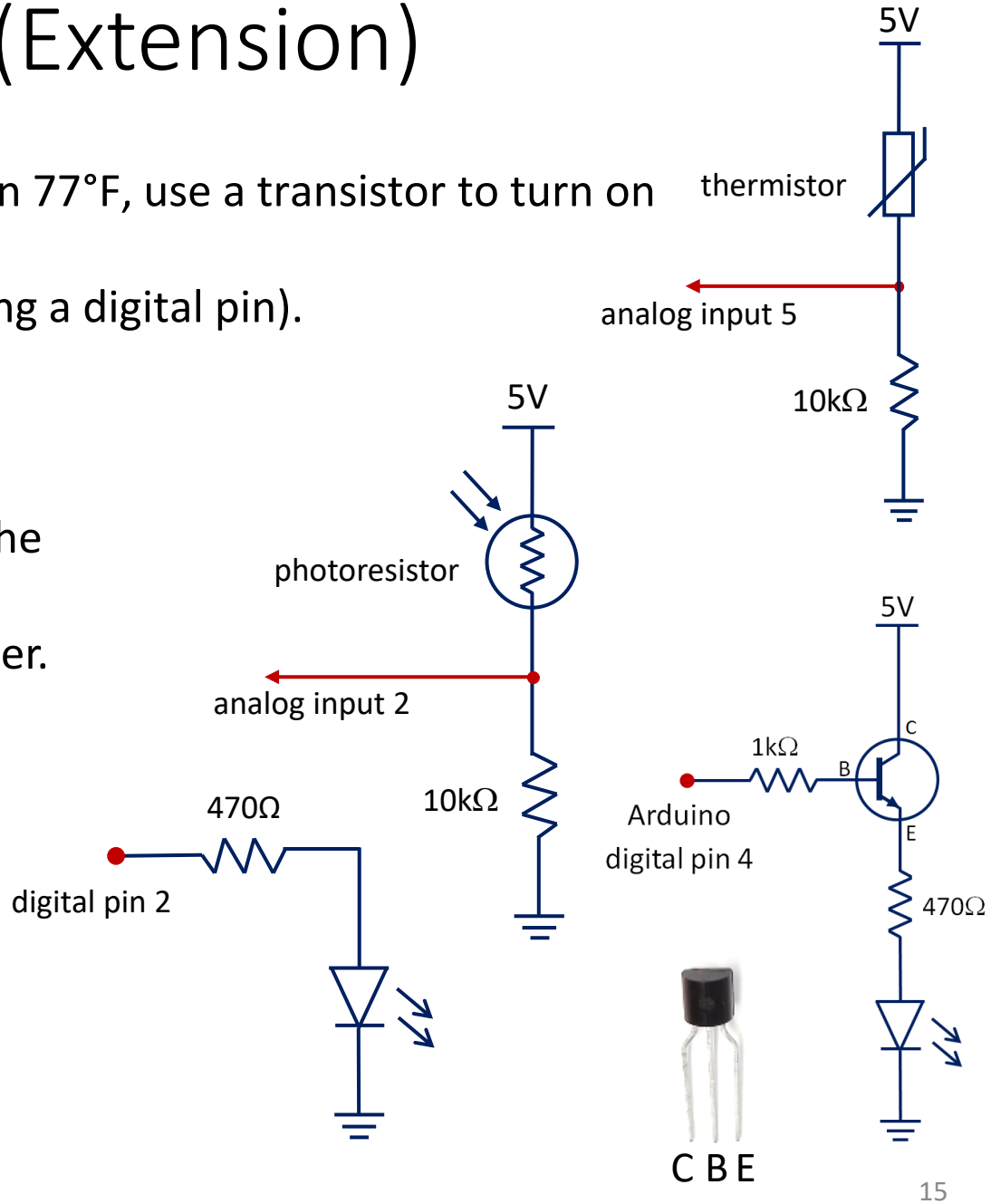
16 • Build the circuits shown on your breadboard.

5 • Print analogRead values and actual temperature in °F to the serial monitor. “TempF = “ ____

5 • Print analogRead value for the photoresistor voltage divider. “Photo = “ ____

16 • Demonstrate your control system (show me it works)

8 • Comment your code (at least 8 lines). Cut and paste your program into a **Word** document and upload it to the Transistors assignment on Classroom.



Start Building Your Capstone Project Documentation "Preliminary Design Review (PDR) Presentation" (Prototype Phase)

- PowerPoint
- Calibration / Equation
  - Derivations / How we got it.
  - How it is used / what it does.
- Circuits
  - Schematics: What they do/how they work
    - Thermistor/Analog Read
    - LED Status Light(s)
    - …
- System Elements / Block Diagram
  - System Block Diagram
  - Labeled Picture of Finished System
- Code
  - Flow Chart
  - Explanation of code functions
  - Commented Code