Lesson 3
(High Power)

Controlling Motors, Pumps, Deathrays*, and other high power devices

* No, not for reals...

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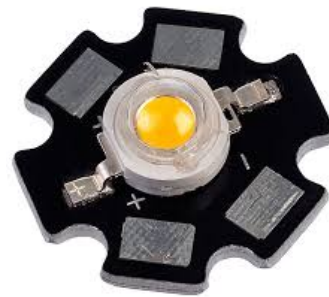
Current Limits

- Arduino UNO max current
  - 40 mA per I/O pin
  - 200 mA total
  - 5V pin can <u>supply</u> **500mA**
    (but, cannot be controlled in program)

20mA **150mA** **300mA** **1.8A**
(each motor)

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Current Limits

- 20mA is only enough for…
  - Small LEDs
  - Small speakers
  - Sensors (...most requires very little current)

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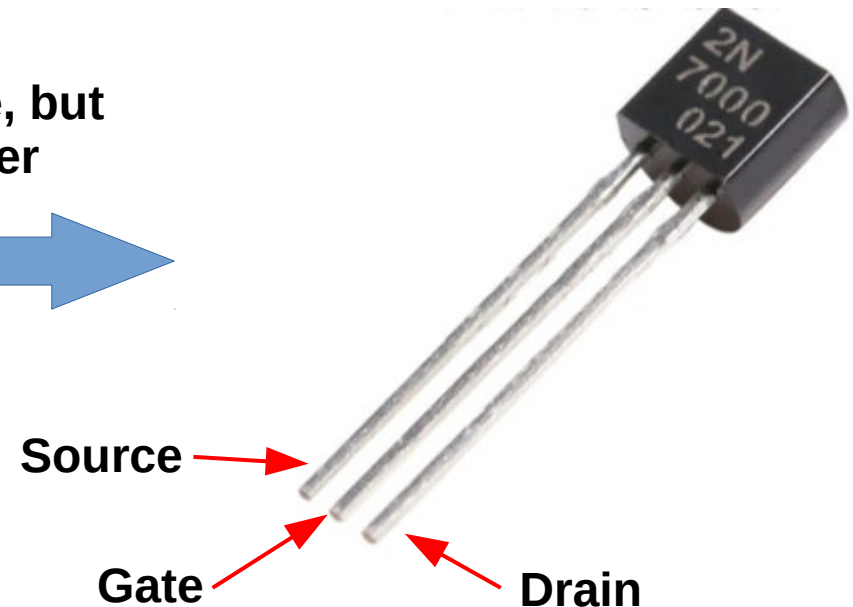
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Transistor

- Works like a switch
  - Can control higher current than an Arduino I/O pin
  - Arduino I/O pin can be used to turn on or off

Works the same, but without the finger

Source

Gate

Drain

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Transistor

Positive Voltage
Connect to Arduino 5V pin.

Can also connect to higher voltages
to drive more powerful devices.

Drain
Connect to the load.
Load can be a buzzer,
LED, motor, etc...

buzzer

D

N Channel
Enhancement type
MOSFET

G

S

Gate
Connect to Arduino I/O
pin (eg. pin 11).

Transistor turns on when
pin 11 is **High (5V)**.

Transistor turns off when
pin 11 is **Low (0V)**.

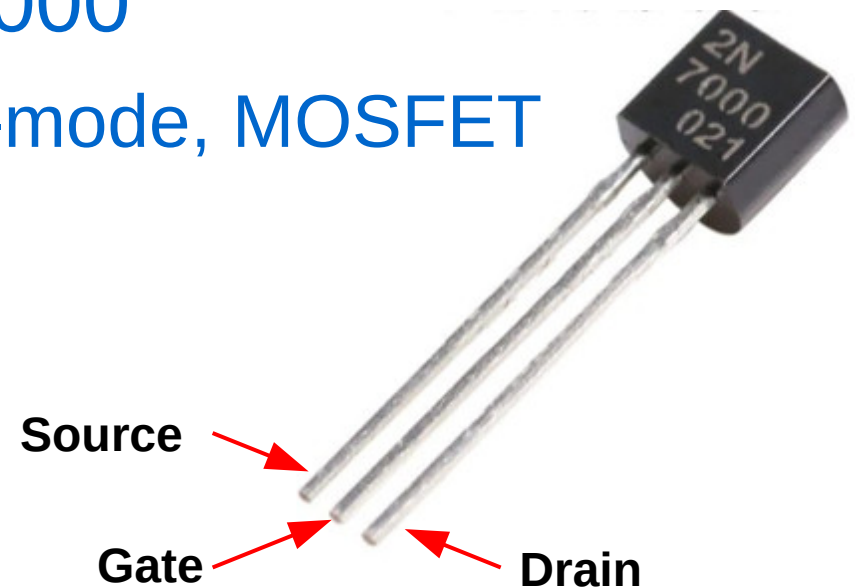**Source**
Connect to Gnd

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Transistor

- Many types of transistors…
  - BJT, Darlington, MOSFET, JFET, PNP, NPN, etc…

- Model we are using: 2N7000
  - N-channel, Enhancement-mode, MOSFET
  - Max voltage 60V
  - Max current 200mA

Source

Gate

Drain

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2N7000

- N-Channel
  - Connect transistor between Load and Ground

- Enhancement-mode
  - Supply voltage to turn on

- MOSFET
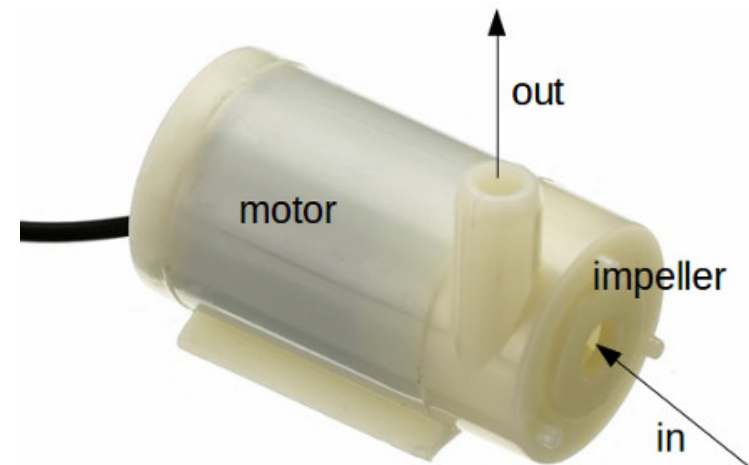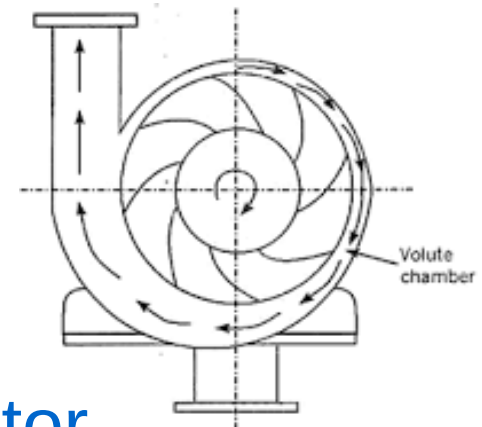 - Gate draws very little current (...treated as zero)

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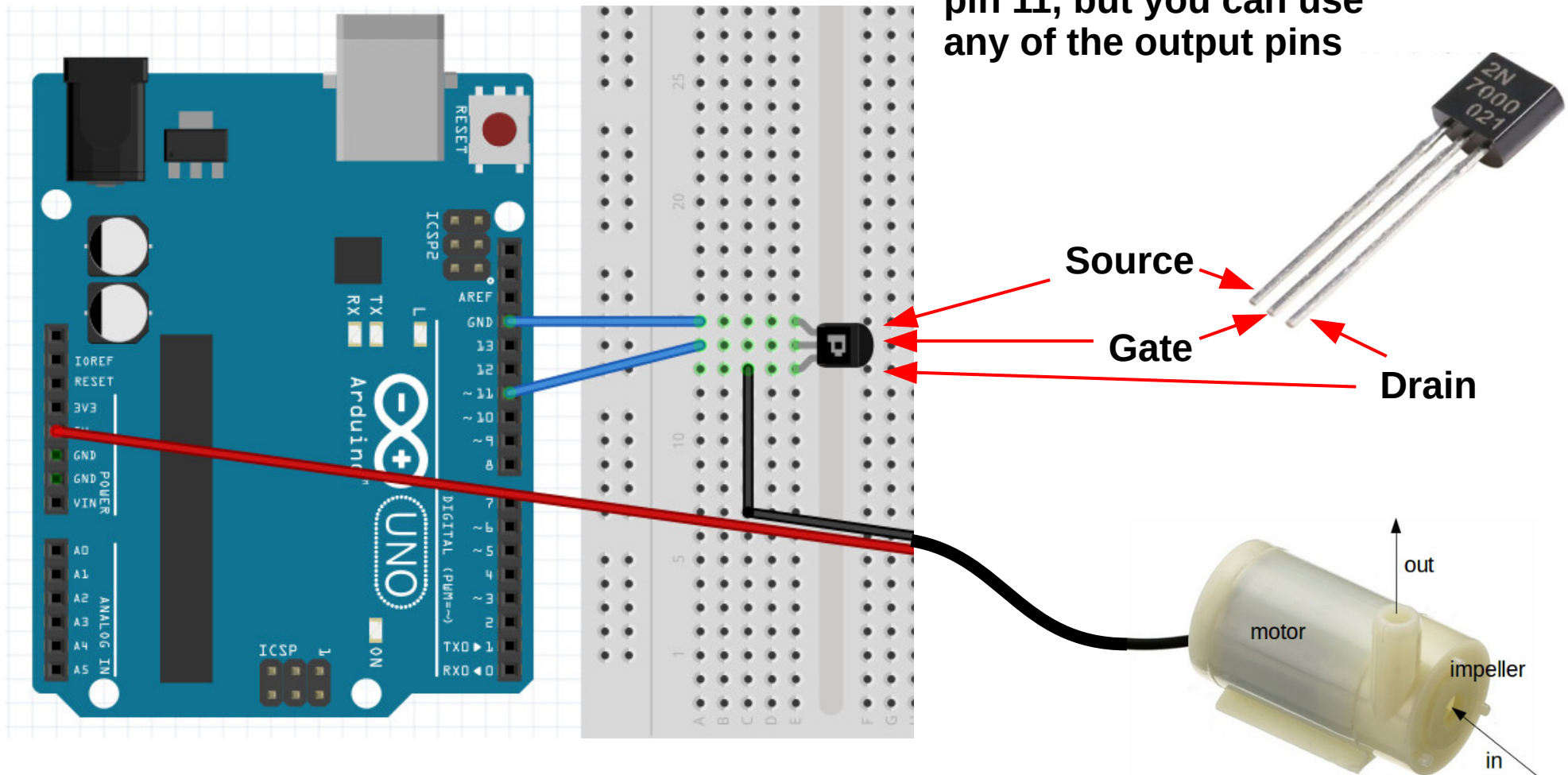# Exercise 1
Connecting Pumps

Pump

- Mini-Submersible Pump
  - Red wire (positive): Connect to 5V
  - Black wire (ground): Connect to Transistor
  - Can be submerged in water
  - Cannot be reversed
  - Centrifugal type pump

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Transistor + Pump

Here we connect gate to pin 11, but you can use any of the output pins

Source

Gate

Drain

out

motor

impeller

in

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Transistor + Pump

- When pin 11 is low (0 V)

- Transistor acts like an opened switch

Same

5V

Pin 11
(0V)

Gnd

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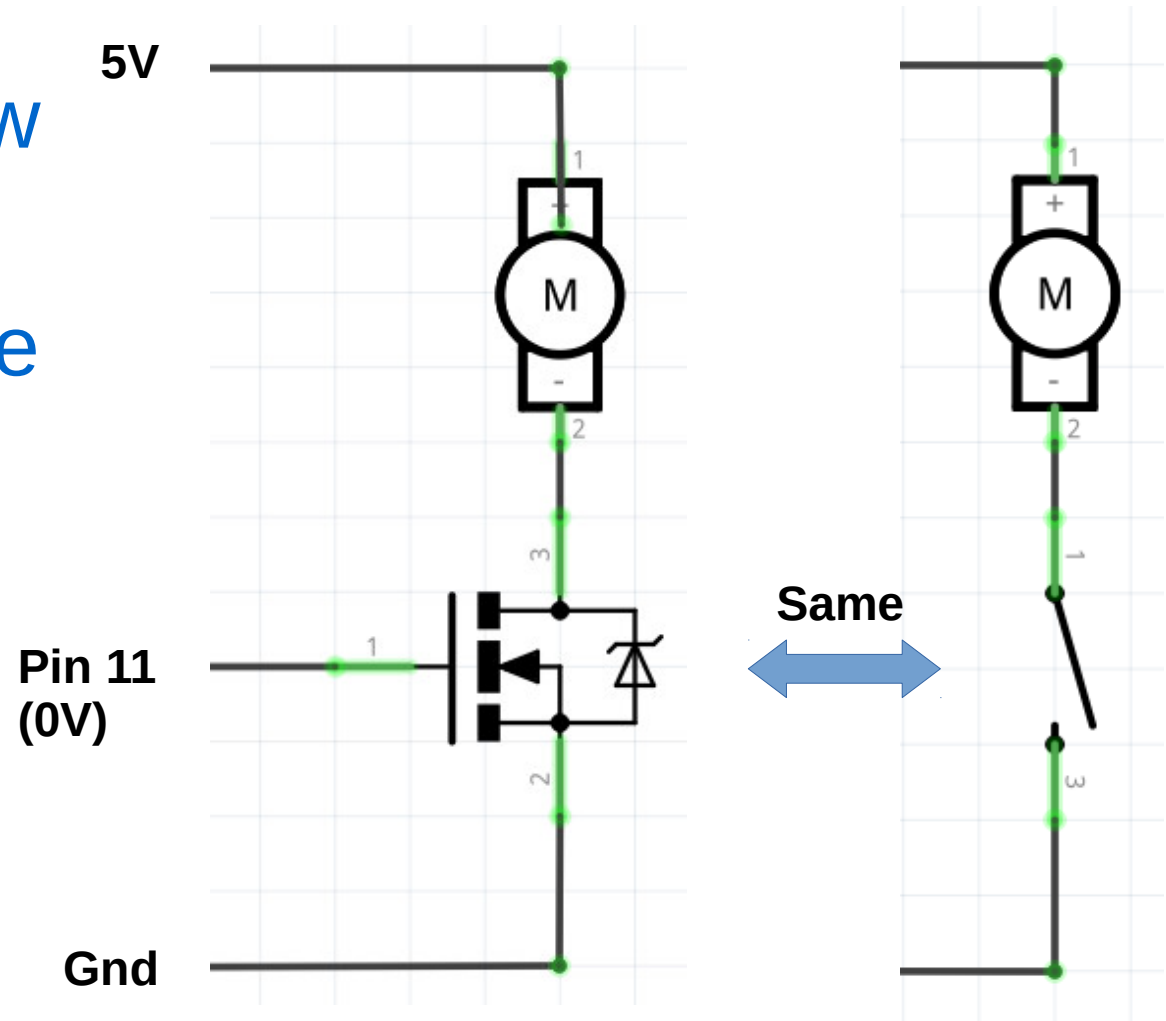
Transistor + Pump

- When pin 11 is high (5 V)

- Transistor acts like an closed switch
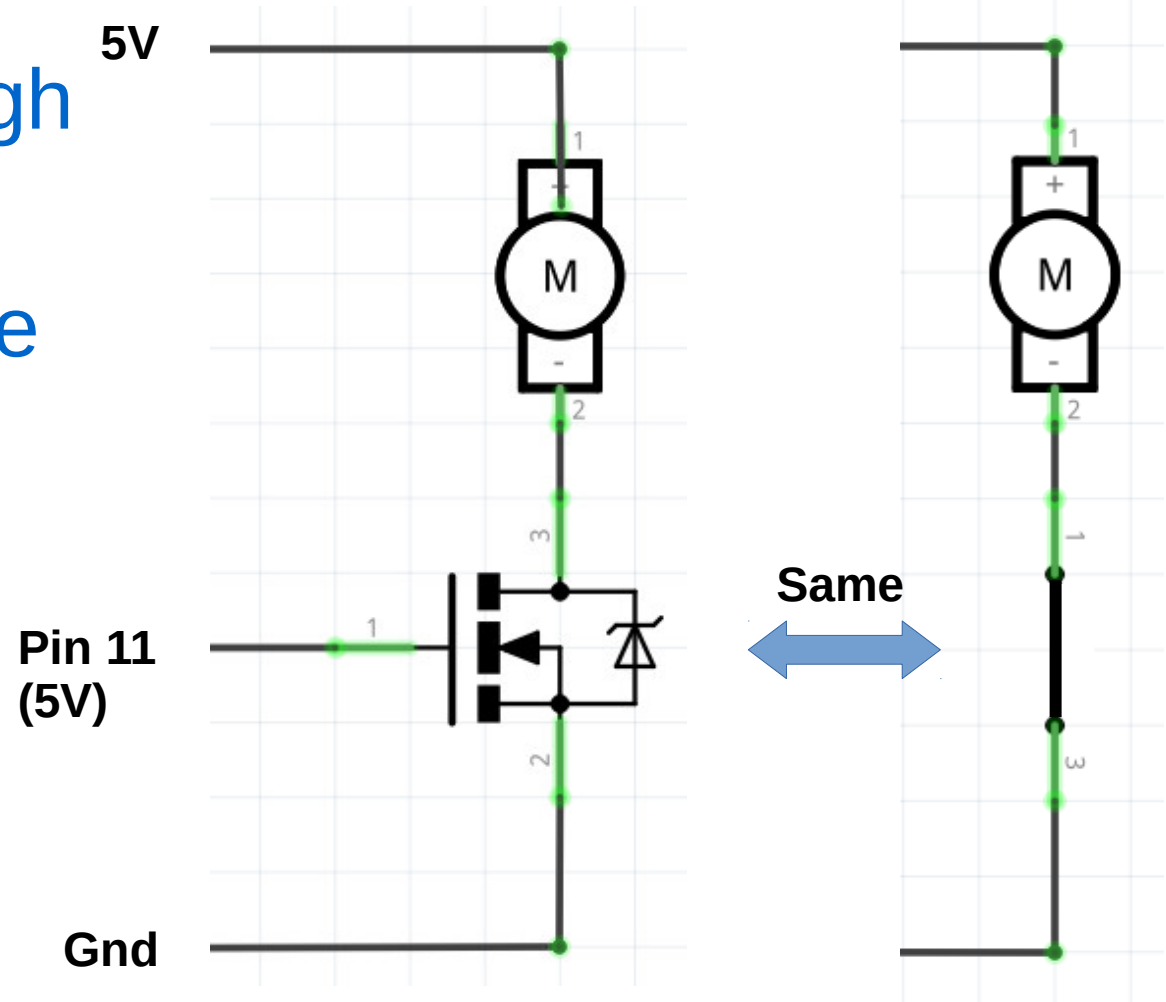
Exercise 2
Controlling Pumps

Try It Out

- Like an LED, we can adjust the power of the pump using PWM.

- Unlike an LED, the pump may not turn at all if the PWM power is too low

What's the lowest power you can set and still have the pump turn?

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Minimum Power

- Unlike an LED, a pump motor has inductance. This means that it takes a while for the current to flow.

- The pump will also need to overcome friction to start turning.

- If the PWM power is too low, it's not enough to overcome friction.

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Up / Down Power

Use 2 buttons as Up/Down power inputs – when Up is pressed, the power increases (pump pumps faster), and when Down is pressed the power decreases…

You can use the Serial Monitor and Serial Arduino class to see the power being used in the program.

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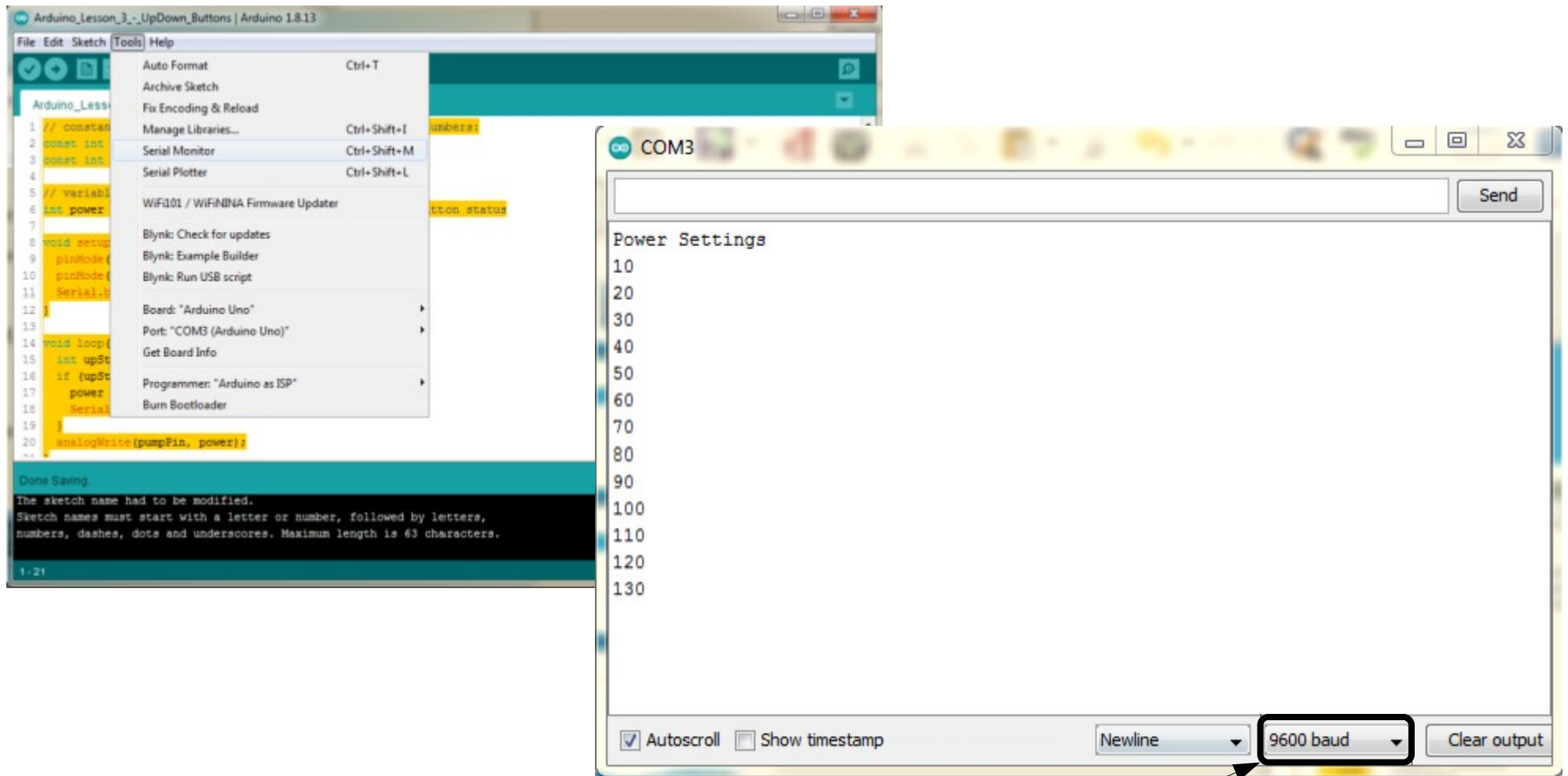
UpDown Buttons

```
const int upPin = 2;     // the Up pushbutton pin
const int pumpPin =  11;     // the pump pin

int power = 0;          // variable for remembering & setting power level

void setup() {
  pinMode(pumpPin, OUTPUT);
  pinMode(upPin, INPUT);
  Serial.begin(9600);  // Create a Serial
  Serial.println("Power Settings");
}

void loop() {
  int upState = digitalRead(upPin);
  if (upState == HIGH) {
    power += 10;
    Serial.println(power);
    delay(500);  // button freeze, to avoid undesired behavior (test without!)
  }
  analogWrite(pumpPin, power);
}
```

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Serial Monitor

Make sure to match the Baud rate here with the one in your program: *Serial.begin(**9600**);*

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Challenges

Hand Sanitizer with Button

- Create a program and circuit that…
  - Has a button to initiate pump squirts
  - Creates a "Off Time" to prevent over-squirting… Can use an LED to indicate when the program is ready to squirt again...

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Functions

Use Functions to Simplify Code:

- Reduce code repetition / redundancy

- Avoid long, hard-to-decipher programs - everything put into one big Loop() function

- Create code bits that are easy to understand and follow

- Modularize the code for quick changes

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Functions

Simplify code by using functions, like "void squirt(int power, int time)", which makes the pump turn on with a certain power and time to effect a squirt.

```
int pumpPin = 11;  // Pump transistor connected to digital pin 11

void setup() {
  pinMode(pumpPin, OUTPUT);
}

void squirt(int power, int time) {
  // Turn on pump with indicated power, for indicated duration, and then shut it
  analogWrite(pumpPin, power);
  delay(time);
  analogWrite(pumpPin, 0);
}

void loop() {
  // Use a button to initiate squirts
  squirt(100, 500);
  delay(5000);
}
```

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Summary

- Use transistors to control high power devices

- Motors require a minimum power to start

- Use Functions to...

  - Replace repeated code

  - Break down complicated programs into smaller parts

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