How to Control Actuators (Motors) with an Arduino

Outline:
- SUMMARY OF ARDUINO
- SUMMARY OF SENSORS AND ACTUATORS
- WHAT IS A TRANSISTOR
- SPEED CONTROL OF A MOTOR
- TWO DIRECTIONAL CONTROL OF A MOTOR
The Arduino System

The purpose of this Tutorial is to describe how to use an Arduino microcontroller system, to drive a motor.

The Arduino Uno R3, or the Arduino Nano are recommended.

The Arduino System

The Arduino system has several inputs and outputs.

- 14 Digital Inputs/Outputs
- 6 Analog Inputs

[Image of Arduino Board]

[Image of Arduino Nano Board]

https://www.arduino.cc/en/Main/ArduinoBoardUno

https://www.arduino.cc/en/Main/ArduinoBoardNano
The Arduino System Specifications

**Summary**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller:</td>
<td>ATmega328</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>5V</td>
</tr>
<tr>
<td>Input Voltage (recommended)</td>
<td>7 - 12V range</td>
</tr>
<tr>
<td>Input Voltage (limits)</td>
<td>6 - 20V range</td>
</tr>
<tr>
<td>Digital I/O Pins</td>
<td>14 (of which 6 provide PWM output)</td>
</tr>
<tr>
<td>Analog Input Pins</td>
<td>6 (each with 10 bits of resolution (i.e. 1024 different values))</td>
</tr>
<tr>
<td>DC Current per I/O Pin</td>
<td>40 mA (each pin can receive/provide this maximum)</td>
</tr>
<tr>
<td>DC Current for 3.3V Pin</td>
<td>50 mA</td>
</tr>
</tbody>
</table>

Table 1. Technical Details of Arduino Board [1]

Using the Arduino System with Sensors and Actuators

- The analog and digital inputs can be used to gather information from the outside world (via sensors).

- The digital outputs can be used to send digital (on/off) commands to the outside world (such as actuators).

- A LED (light emitting diode) is one type of actuator.
- A speaker is another type of actuator.
- A motor is another type of actuator, that creates motion.

- We will describe how to control motors with an Arduino, but these principles can be used to control any type of actuator.
The Arduino System Power Limits

The Arduino board can provide enough power for an LED, per digital output channel. It can handle up to 20 - 40 mA per channel.

However, there is a limit!
- An Arduino board (by itself) cannot turn on/off large items like a stove element, air conditioner, or a big motor!
- Such items require large amounts of current to function.

We need “something” that can switch large currents on/off, that can be triggered by the low-power digital output of the Arduino.

“Power Transistors” are ideal switches for large currents, that can be triggered by low-power electronics.

Transistors

There are various types of transistors, but only certain categories are good for switching large currents. Generally, switching can be done with high-power MOSFETs.

Images of various typical transistors

Image of MOSFET
Using Transistors to Switch Large Currents

Example of “Mechanical to Electrical Switch”

Big current (10 Amps at 120 Volts) shown in red

Small force from finger (0.1 Newton)

Example of “Electrical to Electrical Switch”

Big current (in red) (1 to 10 Amps at 24 Volts**) Depends on MOSFET selected

Small current from Arduino Digital Output (0.001 Amp at 5 Volts)

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Asside: How MOSFET Transistors Work

Looking inside a transistor, we will see the silicon semiconductors

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Using an N-Channel MOSFET connected to Arduino, to Drive an Electric Motor (one direction only, on/off)

+ Volt Rail (Rated to Maximum Motor Voltage)

Any Digital Output (+5 V) from Arduino

Ground Rail
(Use common ground connected to Motor power supply, and Arduino power supply)

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Controlling a Motor in Two Directions
How can it be done???

+9 Volt Rail

Ground Rail

This diagram will only power a motor in one direction.

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Controlling a Motor in Two Directions

Use an H-Bridge

+9 Volt Rail

This will work!
But we can’t manually turn all those switches on/off!
Besides, we might mess up the order and short circuit the system!

Ground Rail

OK, but Not Recommended!
If you turn these on/off in the wrong order, it will short circuit

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Do Not Use This!
Controlling a Motor in Two Directions
Using an H-Bridge with MOSFETS

Use this! It works Great!
Will not cause short circuit, even if you trigger both sides at once.

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The Arduino Software Programming
Its Really Easy!

- Arduino has a free software IDE (Integrated Development Environment)

- The free software and install instructions are available here:

- Online documentation can be found here:

- Along with useful examples here:

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Here is a sample program written to control a motor (via the MOSFET diagram of page 11) in one-direction only.

In the example below, Pin 3 is set as digital output mode.

The program “main loop” has four commands. It first sets Pin 3 “High”, which turns the transistor “On” allowing current to flow through the motor. Then it waits 1 second. Then turns transistor off. Waits 1 second.

```
// On-Off -Motor Driver
// Motor is connected to Pin 3

void setup() {
    // initialize the digital pin as an output.
    pinMode(3, OUTPUT);
}

void loop() {
    digitalWrite(3, HIGH); // set pin 3 to turn motor "on"
    delay(1000); //wait for 1 second
    digitalWrite(3, LOW); // set pin 3 to turn motor "off"
    delay(1000); // wait for 1 second
}
```

Same basic operation as previous page, but now we PWM - “Pulsed Width Modulation” to rapidly turn the transistor on/off.

The ratio of on-vs-off time is a duty cycle. It is a value between 0 to 255, where 0 = 100%off, 128 = 50%on 50%off, and 256 = 100% on.

By “pulsing” the transistor this way, the motor speed can be controlled.

```
// PWM-Motor Driver
// Motor is connected to Pin 3

void setup() {
    // initialize the digital pin as an output.
    pinMode(3, OUTPUT);
}

void loop() {
    analogWrite(3, 128); // set Motor 3 PWM to duty of 128 (where duty is between 0-->256)
    delay(3000); // wait 3 seconds
    analogWrite(3, 0); // set Motor 3 PWM to duty of 0 (where 0 means "always off")
    delay(1000); // wait 1 second
}
```
This uses the diagram of page 15. Here we now use two digital outputs. Each controls the motor speed (via PWM) in each direction.

```cpp
// Two-Directional, PWM-Motor Driver
// Pin 3 is connected to "forward direction"
// Pin 4 is connected to "reverse direction"

void setup() {
    // initialize the digital pin as an output.
    pinMode(3, OUTPUT);
    pinMode(4, OUTPUT);
}

void loop() {
    analogWrite(3, 128); // Activate pin 3 to PWM duty of 128 (where duty is between 0--
                        // 256)
    delay(3000);        // wait 3 seconds
    analogWrite(3, 0);  // Deactivate pin 3 to duty of 0 (where 0 means "always off")
    delay(1000);        // wait 1 second
    analogWrite(4, 200); // Activate pin 4 to PWM duty of 200 (where duty is between 0--
                         // 256)
    delay(3000);        // wait 3 seconds
    analogWrite(4, 0);  // Deactivate pin 4 to duty of 0 (where 0 means "always off")
    delay(1000);        // wait 1 second
}
```

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**Example of Arduino Based Mobile Robot**

Notice the Four transistors for one H-bridge

Notice the Four transistors for one H-bridge

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Example of Arduino Based Mobile Robot

Early Stage Assembly showing two DC motors (with worm screw engaged on gear driving wheel) Good way to provide high gear reduction!

The Eyes (infrared emitter and receiver pairs)
H-Bridge for right-side DC motor
H-Bridge for left side DC motor

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References:

Motor Driver for Arduino

For NPN Transistor

(Power Rail)
+5 volt

Any digital output

(Power Rail)
GND

NPN transistor

M

E

B

C
Light Detector with Photo transistor. 2016

*Light hitting base (makes Vout get lower)

+5V

* R

(Vout) Analog in #

Analogue

Capacitor to reduce spikes.

10k Ω

IR Emitter Circuit.

Light hitting base (makes Vout get higher) +5V

+5V

Collector (short pin)

Anode (short pin)

Cathode (long pin)

R ≈ 300 Ω

R ≈ 10k Ω

GND

Arduino

GND
Motor Driver for Arduino

Using P-channel Mosfet

+5 volt
Power Rail

Any digital output

Ground Rail

Large Motor
Motor Driver for Arduino

Using **N-channel MOSFET**

![Diagram of electrical circuit using N-channel MOSFET](image)
Two Direction Motor Driver for Arduino 2016.

[Diagram of a circuit with various components and labels, including P-channel and N-channel transistors, voltage rails, and a motor symbol.

Digital output PWM i.e. (5)

GND rail

10kΩ

P-channel

N-channel

GDS

GDS.
H-Bridge

Using T.I. SN754410.

+5VDC from Arduino.

- D05 Arduino
- D06 Arduino

M1 Left

M2 Right

GND = +8 Volt

from FP2 LiPoly Batteries.