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SEDC 73600

Lesson Plan 4-5: DC Hobby Motors

Unit: Arduino Motors Unit

Previous lesson: Intro to Digital Motors
Next lesson: Servo Motors

Main objectives: Students will be able to correctly wire a hobby motor using a transistor and flyback diode. SWBAT describe the role of the transistor and diode in this circuit. SWBAT write code to change the speed of the motor. SWBAT incorporate additional circuit elements both physically and in their code, using control flow.

Standards:

- 9-12.IC.7 Career Paths: Investigate the use of computer science in multiple fields.
- 9-12.CT.8 Abstraction and Decomposition: Develop a program that effectively uses control structures in order to create a computer program for practical intent, personal expression, or to address a societal issue.

Timing: This is a 2-period lesson.

In-class exercises: The students will complete the worksheet, below.

Notes: This lesson is much more hardware-focused and less code-focused than the other lessons in this unit. It draws on prior knowledge of Ohm's law, electric power, transistors and diodes. In the beginning of the lesson, students will be writing key information in their handouts. It is recommended that the teacher model this with students by writing directly onto the handout (see answer key on the last page), so the answers to the questions are not on the slides.

Resources: Tutorialspoint tutorial: https://www.tutorialspoint.com/arduino/arduino_dc_motor.htm# Adafruit tutorial: https://learn.adafruit.com/adafruit-arduino-lesson-15-dc-motor-reversing/an-experiment

Materials: Elegoo uno circuits kits (including Arduino Uno, breadboard, DC hobby motor and fan blade, jumper wires, 220 Ω resistor, USB cable), projector, teacher computer, Google slides presentation (the slide deck is in the lesson folder on Github)

Assignments: The class assignment for students is below. The answer key is on the next page.

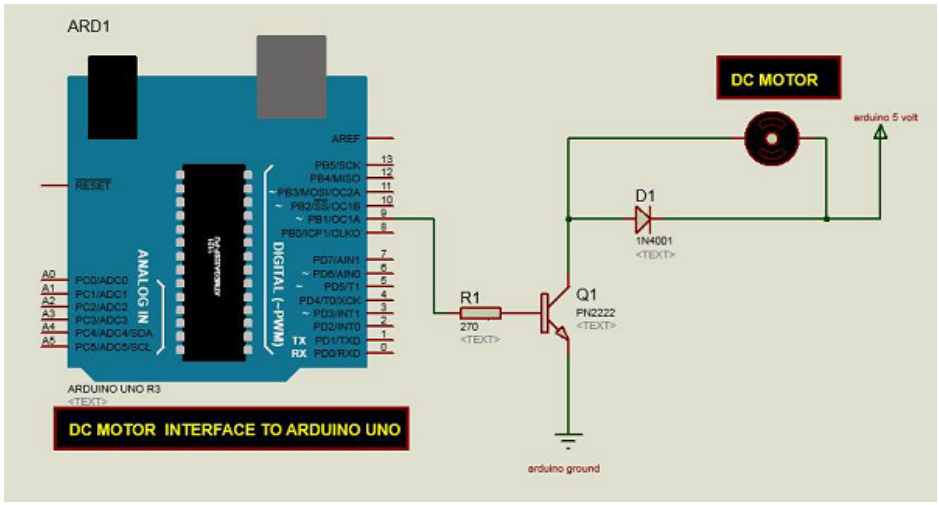
Formative assessment: Student handout (see below)

Lesson:
20 min: Intro

- Use provided powerpoint
- Goals: To learn how to wire and program DC hobby motors
- Recap from intro lesson:

- Can spin CW or CCW
- Crude: either on or off
    - Speed determined by voltage
    - Direction determined by polarity of current
- Unlimited rotation in one direction
- What are some devices that could use hobby motors?
    - Vehicles or fans

- Give students 10 min to work with partners on the "Background" section of the handout. Then review with the class. It is recommended that the teacher model this with students by writing directly onto the handout
- What does a diode do in a circuit?
    - A diode only allows current to flow in one direction
- What does a transistor do in a circuit?
    - A transistor is an electronic switch. When current is supplied to the base, the current is allowed to flow from collector to emitter. When no current is supplied to the base, no current flows from collector to emitter.
- Circuit Diagram:



- Identify the complete path that current takes to power the motor when the transistor is on.
    - Arduino 5V pin → red motor wire → motor → black motor wire → transistor collector → transistor emitter → Arduino ground pin
- What is the minimum resistance that needs to be connected to the output pin in order to avoid damaging the Arduino?
    - $V = IR$
    - $R = V/I = 5V/0.020A = 250\Omega$
- What is the minimum resistance that needs to be connected to this pin?
    - $R = V/I = 5V/1A = 5\Omega$
- What is the maximum power that this pin can supply?
    - $P = VI = 5V*1A = 5W$
- What is the role of the transistor in this circuit?
    - The transistor allows pin 3 on the Arduino to control the motor without the current for the motor actually passing through pin 3. Instead, pin 3 turns on the transistor, which amplifies the current for the motor circuit.

20 min: Work time

- Students work on the attached assignment with their partners

5 min: Day 1 summary

- How were you able to slow down the motor?
    - *analogWrite(motorPin, 100);*

Day 2:

40 min: Work time

- Students work on the attached assignment with their partners

5 min: Summary

- Students share one thing they accomplished, one bug they overcame, or one idea they have for how they could use stepper motors in the future

Names: _____

Arduino DC Hobby Motors

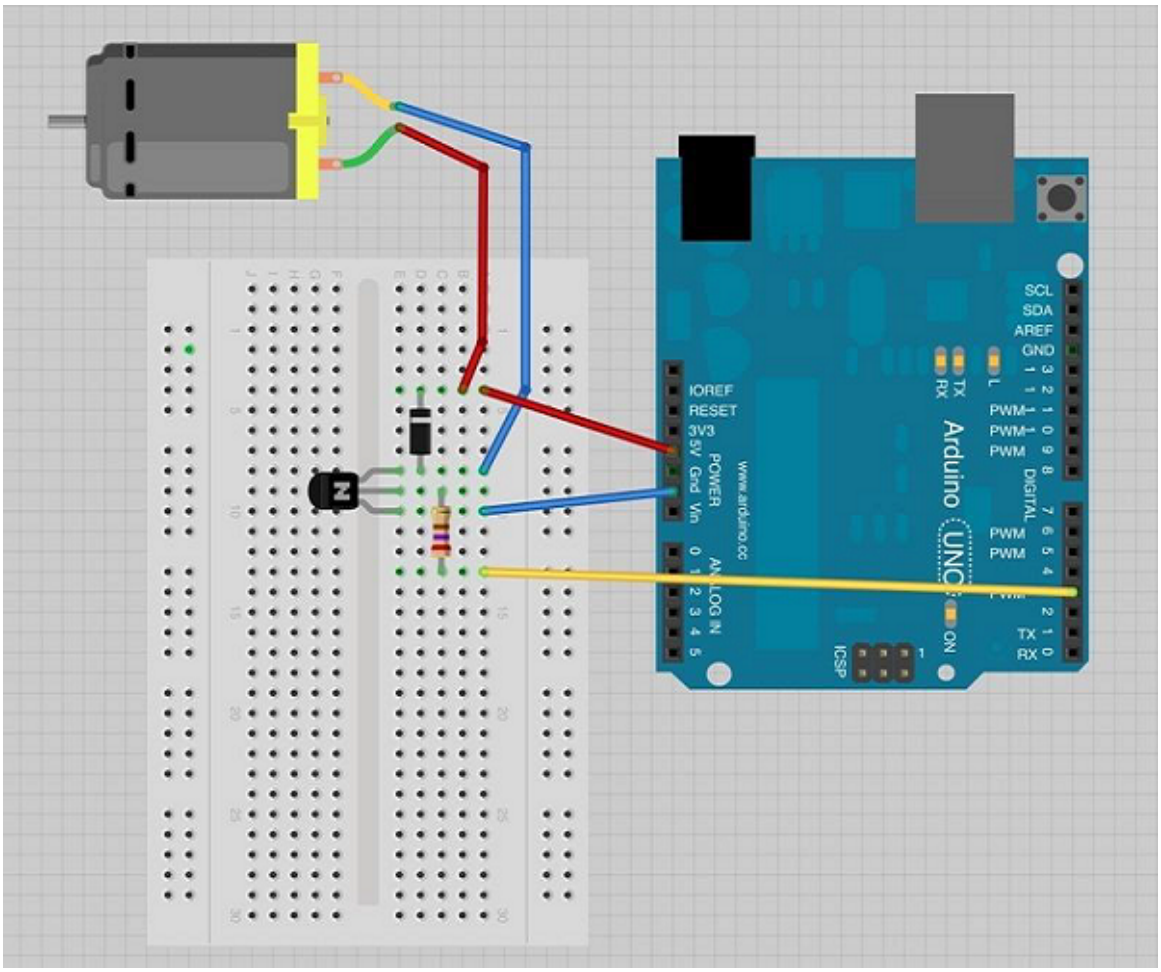
Note: The wire leads on the DC motors break easily. Do not pull on them or lift the motor by its leads.

Background:

A DC (direct current) motor is the most common type of motor. It is a relatively simple motor with two leads, which connect to electromagnets inside the motor. If you connect these two leads directly to a battery, the motor will rotate. If you switch the leads, the motor will rotate in the opposite direction.

We've controlled outputs like LEDs by connecting them directly to output pins on the Arduino board. However, motors should NEVER be directly connected to the Arduino output pins. This is for two reasons: motors exceed the current rating of the Arduino output pins, and motors can produce voltage spikes that can damage the Arduino.

We can solve both of those problems by hooking up the motor with a transistor, diode, and resistor, as shown in the diagram below.



Question: Recall: what does a diode do in a circuit?

Question: Recall: what does a transistor do in a circuit?

Diagram: Sketch a circuit diagram for this circuit. Note that the diode points upward, from the blue wire to the red wire.

Question: Identify the complete path that current takes to power the motor when the transistor is on.

Question: In this circuit, the Arduino output pin 3 is NOT powering the motor. The maximum current recommended for the output pin is 20 mA, which is not enough to power the motor. Recall that the output voltage is up to 5 V. What is the minimum resistance that needs to be connected to the output pin in order to avoid damaging the Arduino?

Question: Instead, to protect against current overload, the motor is being powered by the 5V pin on the Arduino. The maximum current that can be safely drawn from this pin is 1 A. What is the minimum resistance that needs to be connected to this pin?

What is the maximum power that this pin can supply?

Question: What is the role of the transistor in this circuit?

Flyback diode: The diode in this circuit is called a "flyback diode", and its role is to protect against voltage spikes which could blow out the transistor or damage the Arduino. This is necessary because the motor's electromagnets, which are basically large coils of wire, act as inductors, which resist changes in current. Current through an inductor cannot change instantaneously, so when the Arduino stops sending power to the motor, the inductor coils initially continue producing the same current, which dies down over time. Without the flyback diode, the inductor can produce arcing (electrons jumping across electrical contacts) and other unpredictable behavior. The flyback diode produces an alternate pathway for this current to flow.

When pin 3 is HIGH, is the transistor on or off? Is the diode forward biased or reverse biased?

When pin 3 is switched to LOW, is the transistor on or off? Is the diode forward biased or reverse biased?

Part 1: Hardware

***Materials**: Arduino Uno, breadboard, DC hobby motor, transistor, diode, 220Ω resistor, jumper wires, USB cable*

Connect the circuit as shown on the first page. Note that the diode is directional and must be oriented with the stripe pointing up. The transistor must be oriented with the flat side to the right (collector at the top, emitter at the bottom). Also note that in the diagram, the resistor shown is a 270Ω resistor. You can use a 220Ω resistor instead.

Part 2: Software

Open a new program in the Arduino code editor. Copy the starter code below:

Starter code:

```
int motorPin = 3;

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

void loop() {
  digitalWrite(motorPin, HIGH);
}
```

Run the code and check that it works! The motor should rotate continuously.

Change speed: The motor's speed is controlled by the transistor, which is controlled by pin 3. Edit the code so that the motor spins more slowly. Paste your updated code below:

Video: Take a video of your circuit. Include your names. Paste it here or upload it to this Google Classroom assignment.

Part 3: Extras

Complete at least 1 of the tasks below:

Task 1: Button Switch Add a button switch to the circuit (don't forget to wire it properly using a pulldown resistor). Modify your code so that the motor spins when the button is pressed and stops when it is released.

Paste your code here:

Take a video of your circuit. Include your name. Paste it here or upload it to this Google Classroom assignment.

Task 2: Potentiometer Add a potentiometer and wire it to the Arduino. Modify the code such that the potentiometer controls the speed of the motor. For example, when the potentiometer is turned to one extreme (all the way left), the motor should stop spinning. When the potentiometer is turned to the other extreme (all the way right), the motor should spin at max speed. (You'll want to create a function to convert the reading from the potentiometer into a value that can be used by the servo.)

Paste your code here:

Take a video of your circuit. Include your name. Paste it here or upload it to this Google Classroom assignment.

Task 3: IC Chip Instead of controlling the motor with a transistor and diode, the motor can be controlled with an L293D integrated circuit chip. This allows the motor to change direction. Follow the directions here to construct and code the circuit: https://learn.adafruit.com/adafruit-arduino-lesson-15-dc-motor-reversing/an-experiment

Paste your code here:

Take a video of your circuit. Include your name. Paste it here or upload it to this Google Classroom assignment.

Task 4: Get creative Create your own project incorporating the hobby motor!

Paste your code here:

Take a video of your circuit. Include your name. Paste it here or upload it to this Google Classroom assignment.

Arduino DC Hobby Motor KEY

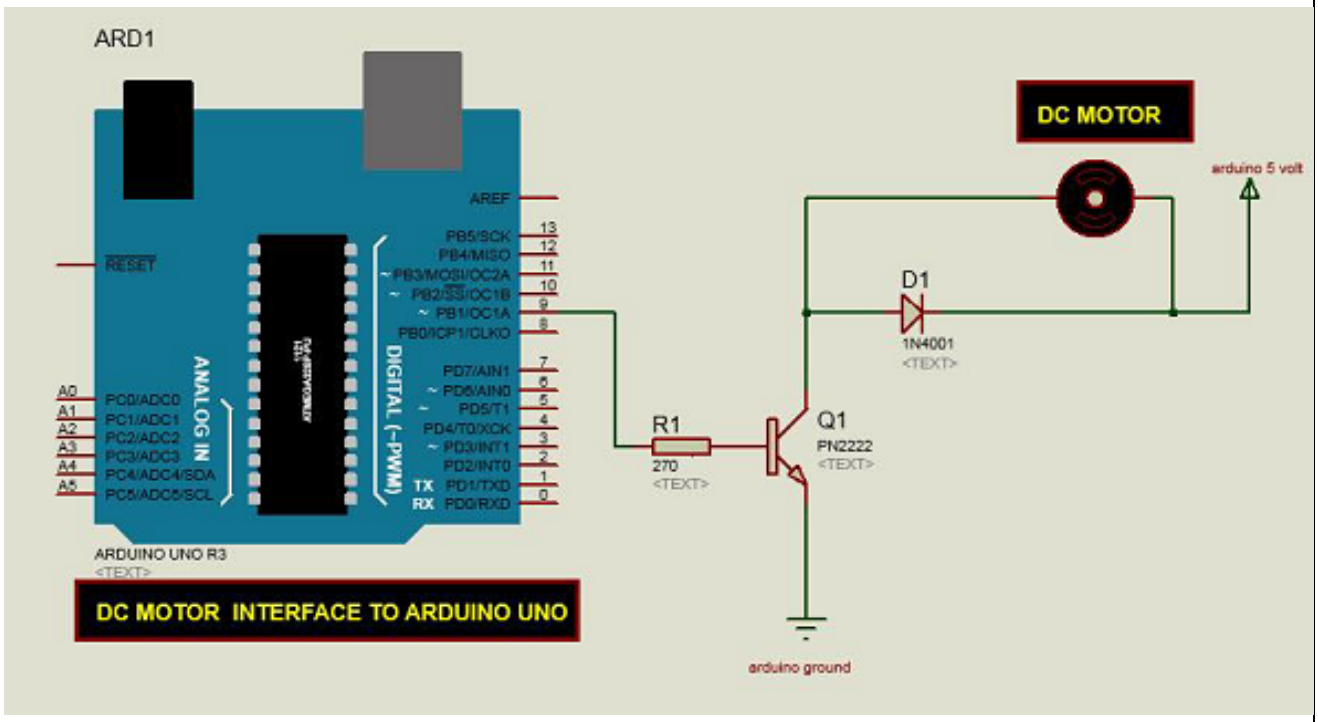
Question: Recall: what does a diode do in a circuit?

A diode only allows current to flow in one direction

Question: Recall: what does a transistor do in a circuit?

A transistor is an electronic switch. When current is supplied to the base, the current is allowed to flow from collector to emitter. When no current is supplied to the base, no current flows from collector to emitter.

Diagram: Sketch a circuit diagram for this circuit. Note that the diode points upward, from the blue wire to the red wire.



Question: Identify the complete path that current takes to power the motor when the transistor is on.

Arduino 5V pin → red motor wire → motor → black motor wire → transistor collector → transistor emitter → Arduino ground pin

Question: In this circuit, the Arduino output pin 3 is NOT powering the motor. The maximum current recommended for the output pin is 20 mA, which is not enough to power the motor. Recall that the output voltage is up to 5 V. What is the minimum resistance that needs to be connected to the output pin in order to avoid damaging the Arduino?

V = IR
R = V/I = 5V/0.020A = 250Ω

Question: Instead, to protect against current overload, the motor is being powered by the 5V pin on the Arduino. The maximum current that can be safely drawn from this pin is 1 A. What is the minimum resistance that needs to be connected to this pin?

$R = V/I = 5V/1A = 5\Omega$

What is the maximum power that this pin can supply?

$P = VI = 5V*1A = 5W$

Question: What is the role of the transistor in this circuit?

The transistor allows pin 3 on the Arduino to control the motor without the current for the motor actually passing through pin 3. Instead, pin 3 turns on the transistor, which amplifies the current for the motor circuit.

When pin 3 is HIGH, is the transistor on or off? Is the diode forward biased or reverse biased?

Transistor is on; diode is reverse biased

When pin 3 is switched to LOW, is the transistor on or off? Is the diode forward biased or reverse biased?

Transistor is off; diode is forward biased

Change speed: The motor's speed is controlled by the transistor, which is controlled by pin 3. Edit the code so that the motor spins more slowly. Paste your updated code below:

```
int motorPin = 3;

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

void loop() {
  analogWrite(motorPin, 100);
}
```

Note: any number below 255 will work