

Electronics Technology and Robotics III

Control and Navigation 10 – Motor Controllers and H-Bridges

- **Administration:**
 - Prayer
- **Motor Controllers:** Motor controllers are circuits that provide directional and speed control of electric motors.
 - Challenges of controlling a motor:
 - Motors draw large currents
 - They may require forward and reverse direction control
 - They may involve variable speed or acceleration control
 - Motors may need to have active braking rather than coasting to a stop
 - Electric motors produce counter-electromotive force (CEMF) in the motor windings
 - Motor controllers offer a way to handle these challenges.
 - Typical Motor Controller Connections:

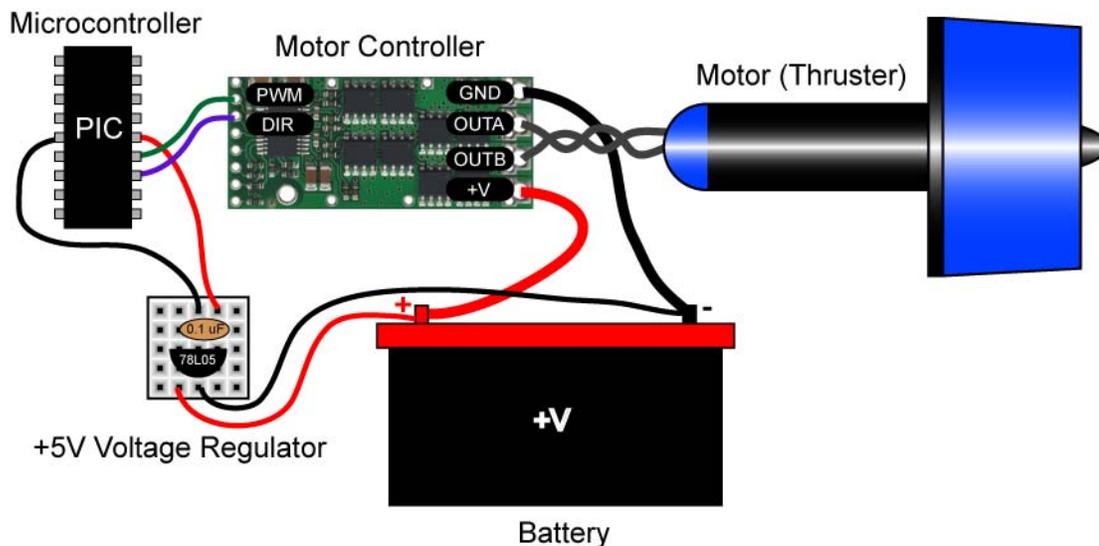


Figure 1: A Sample of Connections to a Motor Controller
([Pololu 18v25 Motor Controller](#) Shown without the Furnished Capacitors)

- It is recommended that ROV builders start by buying a commercial motor controller. Our ROV teams have used the Pololu High-Power Motor Driver 18v25 to successfully drive the Seabotix BTD150 thrusters for several years. See: <http://www.pololu.com/catalog/product/758>.
- Factors when buying a motor controller for a brushed DC motor:
 - How many motors controlled with one motor controller?
 - Check maximum and minimum voltages.
 - Maximum current ratings
 - Built-in protection for overheating, excessive current, reversed battery polarity?
 - Automatic reset if equipped with overheating protection?
 - Are heat sinks extra and do they fit inside the pressure canister?
 - What type of input signals?
 - Does the motor controller include a feature to monitor its status?
 - What is its size? Will it fit into the canister?
 - Easy wire connections?

- **Basics of a Motor Controller – Direction Control of a Motor Using an H-Bridge:**
 - **Four States of a DC Motor Output with Terminals A and B (Figure 2):**
 - **Forward:** Terminal A to GND, Terminal B to $+V_{CC}$. Current flows through the motor to make it rotate in the “forward” direction. (the terms “forward” and “reverse” only serve to indicate opposite relative directions)
 - **Reverse:** Terminal A to $+V_{CC}$, Terminal B to GND. Current flows through the motor, making it spin in the “reverse” direction.
 - **Coast:** No connections to Terminals A and B. The motor is completely free to spin.
 - **Brake:** Terminal A to Terminal B
 - When a force acts on a motor, the motor operates as a generator, resisting the applied force. So as the motor tries to coast to a stop, the motor acting as a generator resists the coasting rotation – thereby serving as a brake.

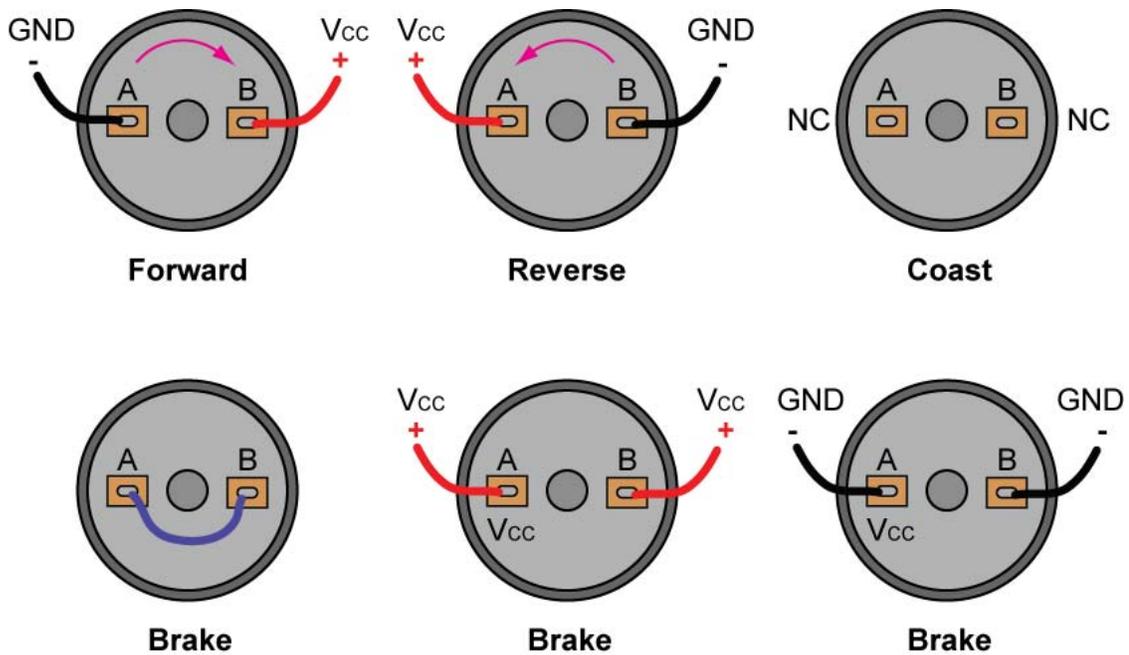


Figure 2: Four States of a DC Motor Output and Their Connections

- As you can see, by changing the direction of current flowing through a DC motor, you change the direction of the motor’s rotation.
- Perform Motor Controllers and H-Bridges LAB 1 – Four States of a Motor Output.

- **Basic H-Bridges Motor Driver Circuit:**
 - The H-Bridge motor driver circuit is known as an H-Bridge because it resembles the capital letter “H”.
 - H-Bridge using SPST switches:
 - The motor in the following circuit will operate only when the diagonally opposite switches are closed.

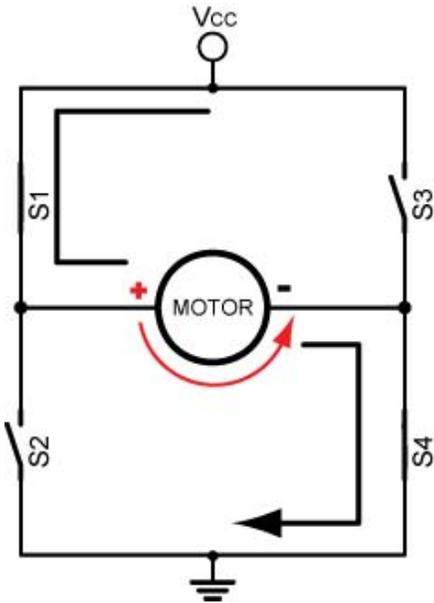


Figure 3: Motor Runs “Forward”
(Switches 1 and 4 Closed)

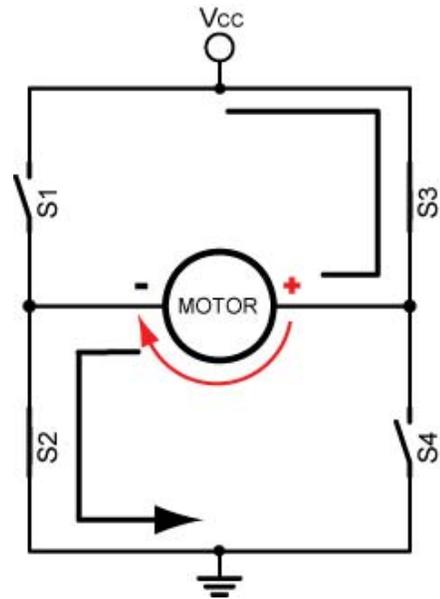


Figure 4: Motor Runs in “Reverse”
(Switches 2 and 3 Closed)

- What happens if S1 and S2 or S3 and S4 are closed simultaneously?
- Perform Motor Control, H-Bridges LAB 2 – H-Bridges with SPST Switches
- The lesson continues on the next page.

- **H-Bridge Using Bipolar Transistors:**

- Transistors can serve as switches in the above circuit and perform the same function.
- The transistors used in Figure 5 have a peak collector current of 800 mA.
- The diodes, D1 – D4, are called clamp or flyback diodes and they protect the transistors from counter-electromotive force or CEMF. Remember, when current through an inductor is increased or decreased, the inductor "resists" the change in current by producing a voltage between its leads in opposing polarity to the change. Since DC motors act as inductors, they can produce voltages 20 times the original voltage. These diodes trap the voltage spikes and protect other components within the circuit.

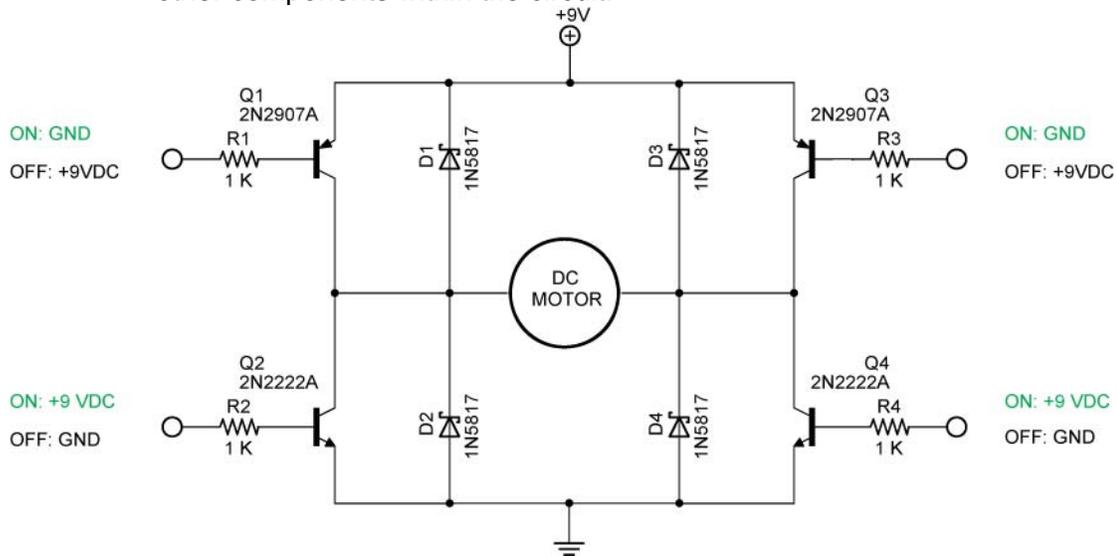


Figure 5: Bipolar NPN and PNP H-Bridge Motor Driver Circuit

- Operations:
 - **Forward Operation:** R1: Grounded, R4: +9 VDC, R3: +9 VDC or No Connection, R2: Grounded or No Connection,

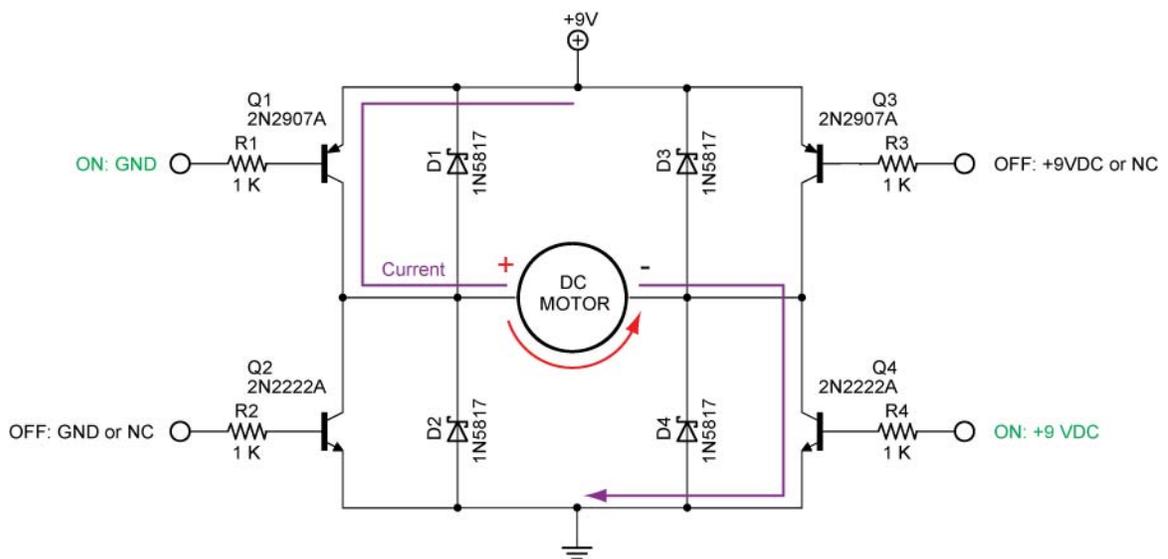


Figure 6: Forward Operation

- **Reverse Operation:** R3: Grounded, R2: +9 VDC, R1: +9 VDC or No Connection, R4: Grounded or No Connection

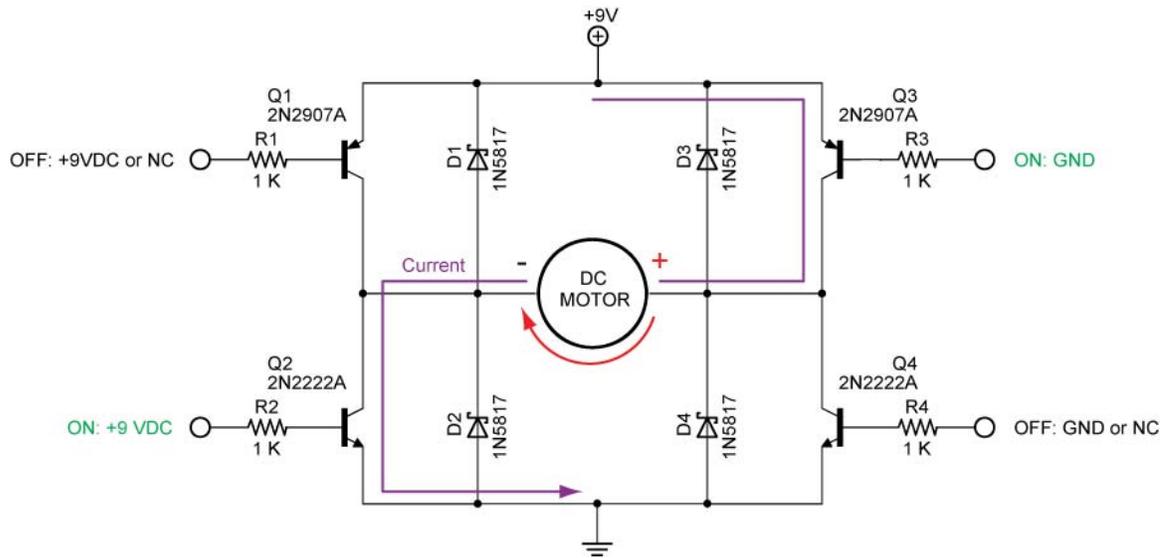


Figure 7: Reverse Operation

- **Braking:** R1 and R3: Grounded with R2 and R4: Grounded or No Connection

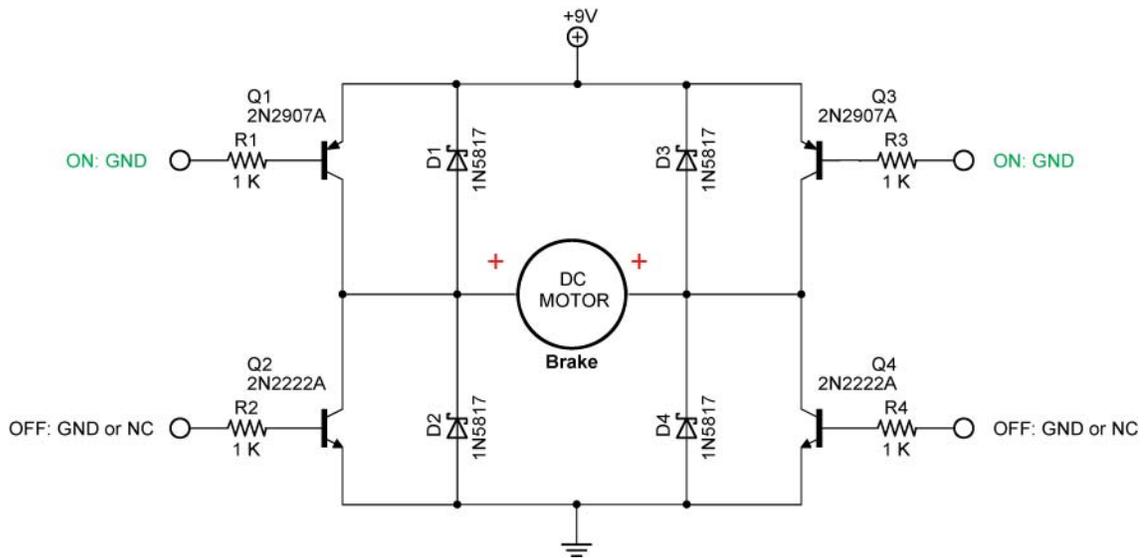


Figure 8: Braking

- **Braking:** R2 and R4: +9 VDC with R1 and R3: +9VDC or No Connection

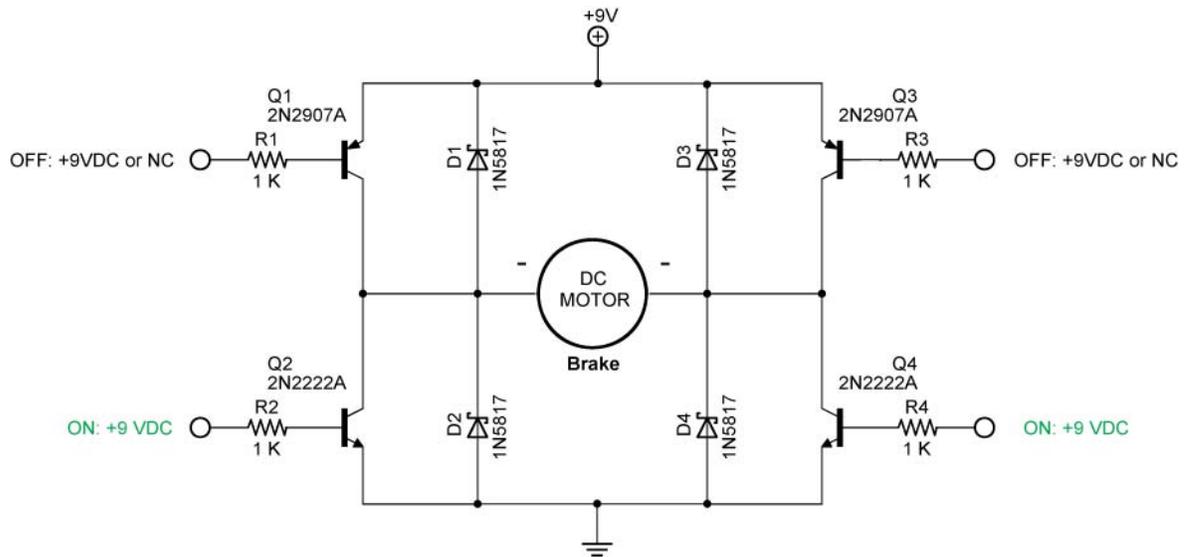


Figure 9: Braking

- **Coasting:** R1 and R3 +9VDC or No Connection, R2 and R4 Grounded or No Connection

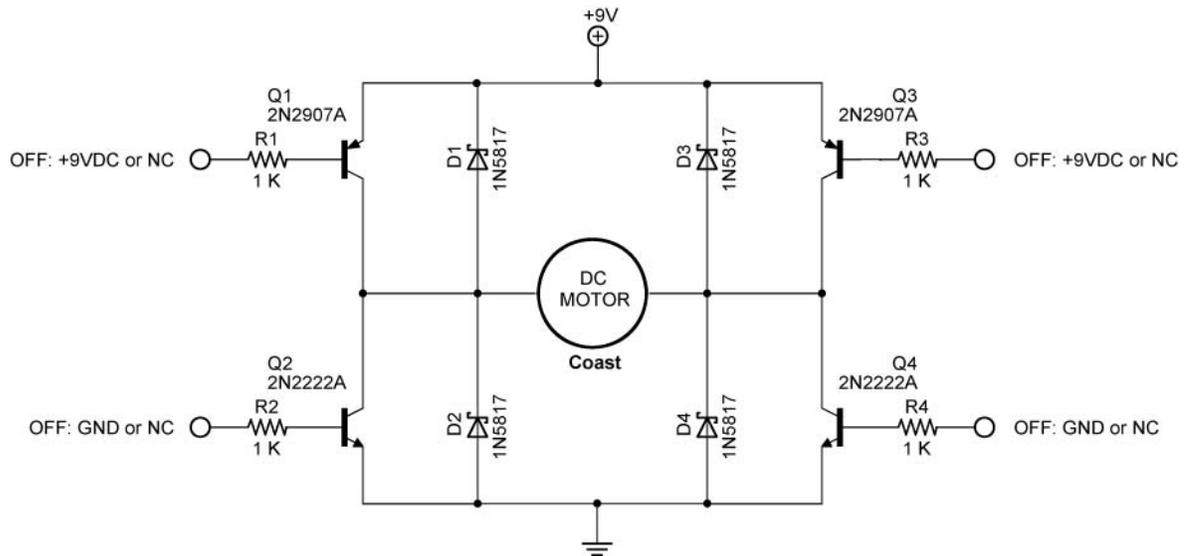


Figure 10: Coasting

- Recall from the Control and Navigation Lesson 7 – Transistors that PNP transistors operate as current sources and NPN transistors act as current sinks. The H-Bridge positions the PNP and NPN transistors to function as current sources and current sinks respectively.
- Perform Motor Control, H-Bridges LAB 3 – Bipolar Transistor H-Bridges Motor Driver

Electronics Technology and Robotics III
Control and Navigation 10 – Motor Controllers and H-Bridges LAB 1 – Four States of a Motor Output

- **Purpose:** The purpose of this lab is to have the student verify the four states of a motor.

- **Apparatus and Materials:**
 - 1 – Small DC Motor and a Wheel Attached to the Shaft so the Motor Can Be Rotated by Hand
 - 1 – 9 Volt Battery

- **Procedure:**
 - Connect the motor in the following manner and record the motor response:
 - Connect motor terminal A to GND and terminal B to +9 VDC.

Motor Response:_____

 - Connect motor terminal A to +9 VDC, and terminal B to GND.

Motor Response:_____

 - Disconnect terminals A & B and turn motor shaft.

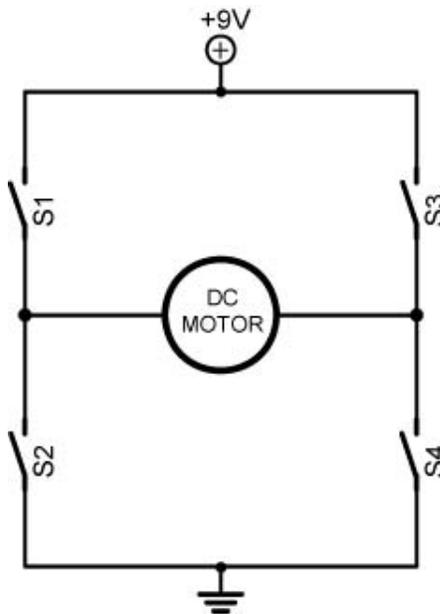
Motor Response:_____

 - Connect terminal A to terminal B and turn motor shaft.

Motor Response:_____

Electronics Technology and Robotics III
Control and Navigation 10 – Motor Controllers and H-Bridges LAB 2 – H-Bridges
with SPST Switches

- **Purpose:** The purpose of this lab is to have the student manually verify the basic function of an H-bridge.
- **Apparatus and Materials:**
 - 1 – Small DC Motor and a Wheel Attached to the Shaft so the Motor Can Be Rotated by Hand
 - 1 – 9 Volt Battery
 - 4 – SPST Switches
- **Procedure:**
 - Wire the circuit below.
 - Close the switches in the sequence listed in the results table (**Do not close S1 and S2 or S3 and S4 simultaneously – it will create a short circuit**).
 - If the motor does not rotate, try to spin the attached wheel to see if the motor coasts or brakes.
 - Document your results.



- **Results:**

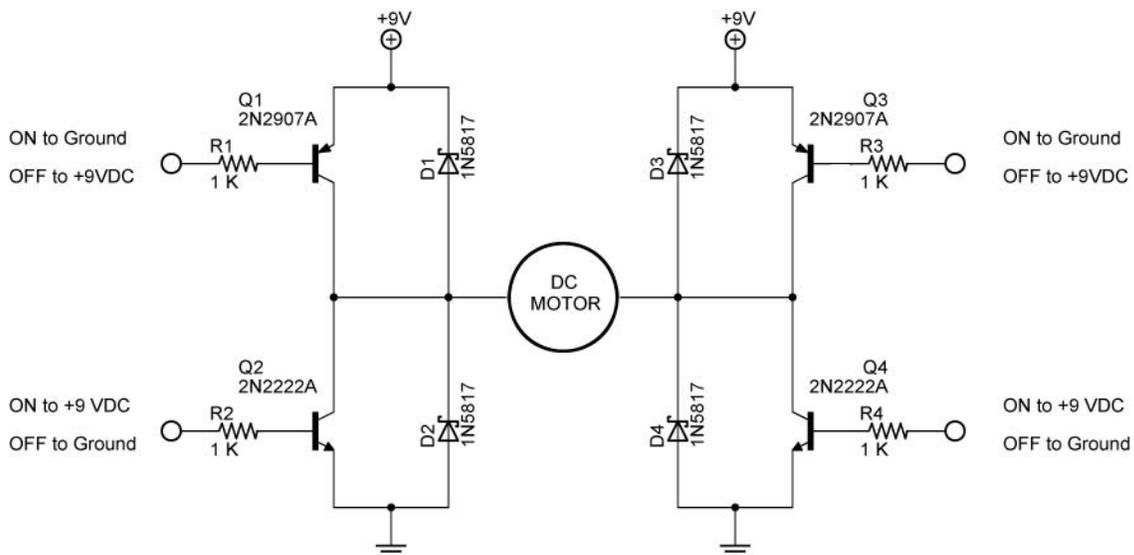
Switch State				Motor Operation
S1	S2	S3	S4	
Closed	Open	Open	Closed	
Open	Closed	Closed	Open	
Closed	Open	Closed	Open	
Open	Closed	Open	Closed	
Open	Open	Open	Open	

Electronics Technology and Robotics III

Control and Navigation 10 – Motor Controllers and H-Bridges LAB 3 – Bipolar Transistor H-Bridges Motor Driver

- **Purpose:** The purpose of this lab is to have the student setup an electronic H-Bridge and to operate it manually.
- **Apparatus and Materials:**
 - 1 – Small DC Motor and a Wheel Attached to the Shaft so the Motor Can Be Rotated by Hand
 - 1 – Solderless Breadboard with 9 Volt Supply
 - 2 – 2N2907A PNP Transistors
 - 2 – 2N2222A NPN Transistors
 - 4 – 1N5817 Diodes
- **Procedure:**
 - **As with switches, do not create a short circuit through the transistors Q1 & Q2 or Q3 & Q4.**
 - Wire the following circuit on the solderless breadboard.
 - Connect the inputs to the transistor bases according to the following table and record the action of the motor:

Transistor Connections				Motor Operation
Q1	Q2	Q3	Q4	
+9V	+9V	GND	GND	
GND	GND	+9V	+9V	
GND	Disconnected	GND	Disconnected	
Disconnected	+9V	Disconnected	+9V	
Disconnected	Disconnected	Disconnected	Disconnected	



- Tie the inputs of Q1 and Q2 together and also connect the inputs of Q3 and Q4 together. What purpose do these connections serve?

Switch State				
S1	S2	S3	S4	Motor Operation
Closed	Open	Open	Closed	Clockwise
Open	Closed	Closed	Open	Counterclockwise
Closed	Open	Closed	Open	Braking
Open	Closed	Open	Closed	Braking

Motor Control, H-Bridges LAB 2 – H-Bridges with SPST Switches