Electronics Technology and Robotics III
Control and Navigation 8 – Relays

- **Administration:**
    - o Prayer
- **Introduction:**
    - o In many cases, it is impractical to use a manual switch to power a circuit. For instance, you would not want to control your home air conditioner by throwing a manual switch every time you wanted to turn on or off the AC. An automatic switching device better serves the purpose.
    - o A relay is an electrically activated switch. It is a device that is used to control a large voltage, large current circuit by means of a low voltage, low current circuit.
    - o Three Types of Relays:
        - ▪ Mechanical relays:
            - • High currents, slow switching speeds
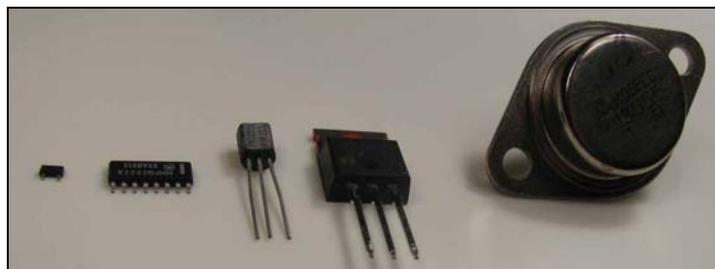

Figure 1: Assortment of Mechanical Relays

        - ▪ Reed relays:
            - • Moderate currents, moderate switching speed
            - • Can be damaged by power surges


Figure 2: Reed Relays

        - ▪ Solid-state relays (See Control and Navigation 7 – Transistors):
            - • No moving parts
            - • Wide range of currents, very fast switching speeds
   - • Can be damaged by power surges

Figure 3: Solid-state Relays

- o Major Parts of a Mechanical Relay (Figures 4 and 5):
  - ▪ Coil – an electromagnet
  - ▪ Armature – the lever arm
  - ▪ Contact points – points make connection and allow current to flow
 - ▪ Spring – holds the armature in the de-energized position
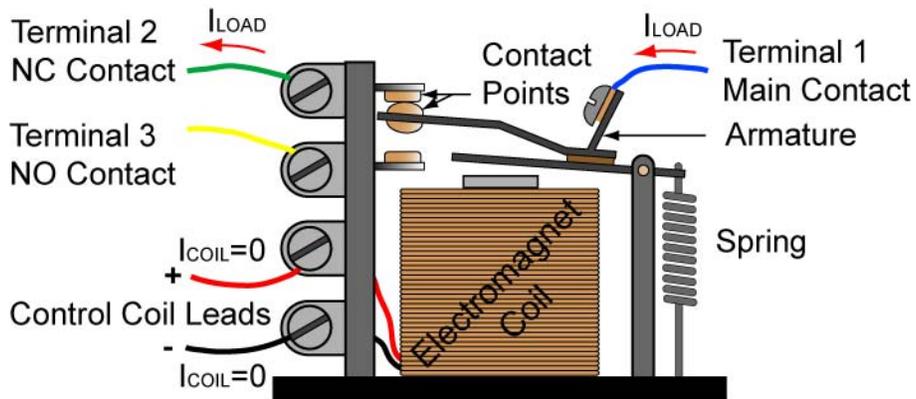
Figure 4: De-energized SPDT Relay – Spring Holds Armature in the Up Position
Continuity from Terminal 1 (Main Contact) to Terminal 2 (Normally Closed Contact)
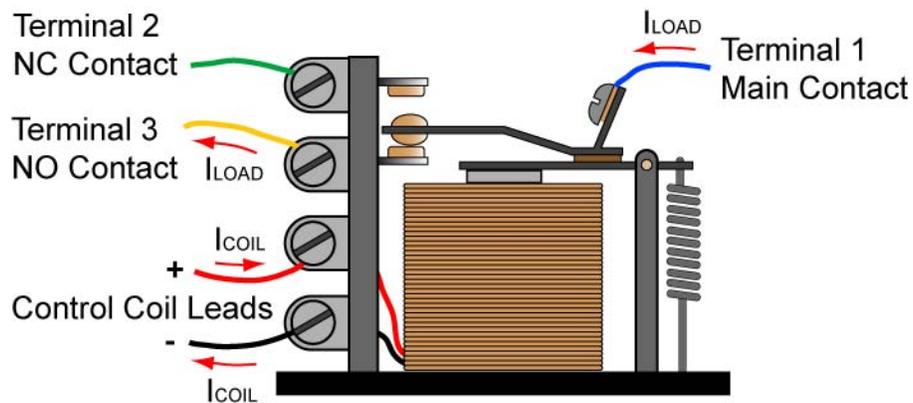

Figure 5: Energized SPDT Relay – Electromagnet Pulls Armature into the Down Position
Continuity from Terminal 1 (Main Contact) to Terminal 3 (Normally Open Contact)

o Action: A relay consists of two separate and completely independent circuits (Figure 6). The first circuit is on the left side of the schematic and drives the relay coil. When the switch S1 is closed, the coil's attraction force pulls a lever arm called the armature toward the coil. The armature is acting as a switch in the second circuit. When the coil is energized, the armature serves as a closed switch in the second circuit. When the coil is de-energized (Figure 7), the spring pulls the armature away from the closed position; the armature acts as an open switch in the second circuit. The two circuits can have two different voltages that are connected mechanically by the relay. The two circuits are not connected electrically.
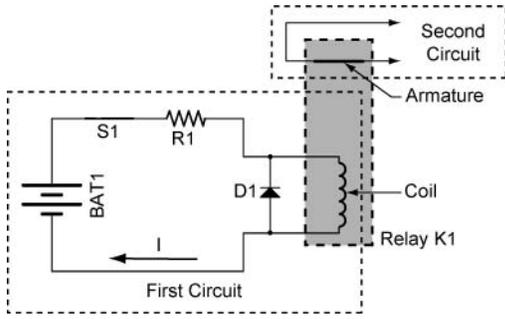
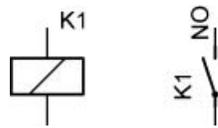

Figure 6: Relay Coil Energized

S1 is closed and the relay coil is energized. This causes the switch in the relay K1 to close, which turns on the secondary circuit.
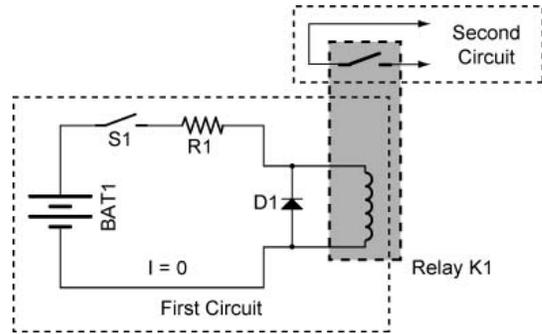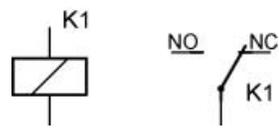
Figure 7: Relay Coil De-energized

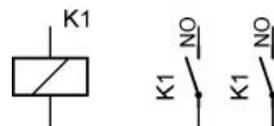With S1 open, the relay coil is not energized and the relay switch remains open.
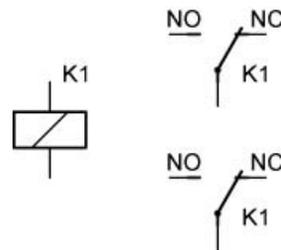
o Schematic Symbols:

SPST Relay
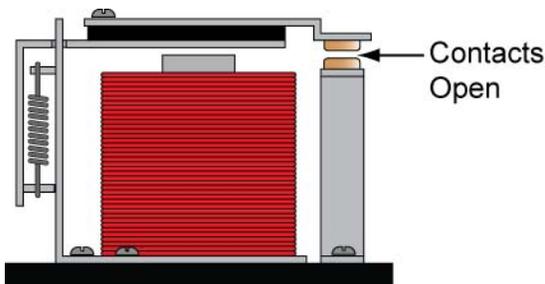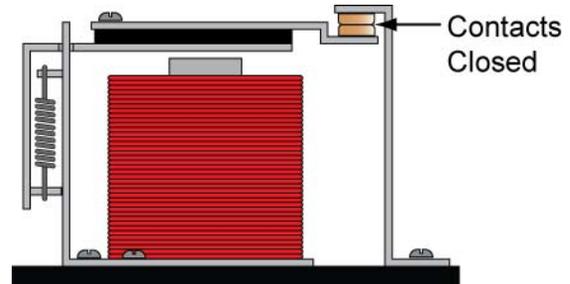
SPDT Relay

DPST Relay

DPDT Relay

Figure 8: Relay Schematic Symbols

o Perform Control and Navigation 8 – Relays Lab 1 – Voltage Separation

3

- Normally Open (NO) and Normally Closed (NC) Relays:
  - NO and NC relays are similar to NO and NC switches in their operation.
  - Normally Open relay contacts are open when the relay coil is de-energized (Figure 9). The contacts remain open until the coil is activated.
  - Normally Closed relay contacts are closed when the relay coil is de-energized (coil current = 0). See Figure 10.
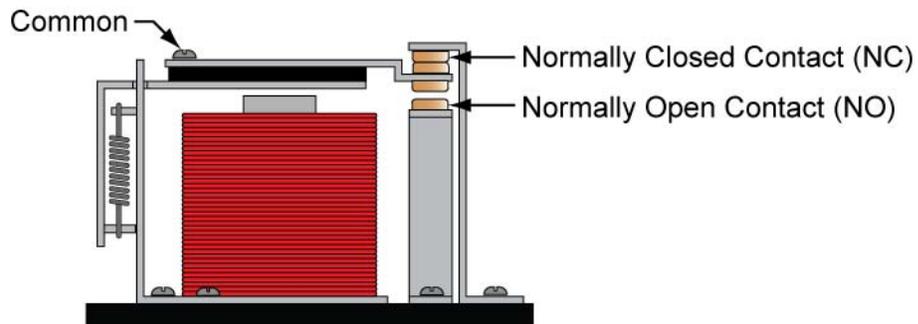
Figure 9: Normally Open SPST Relay **Figure 10: Normally Closed SPST Relay**

- SPDT & DPDT relays have both NO & NC contacts (Figure 11).

Figure 11: NC and NO Contacts in a De-energized SPDT Relay (Coil Current = 0)

- See: http://www.bcae1.com/relays.htm

- Just as a SPDT switch can act as a SPST switch, a SPDT relay can serve as a SPST relay by not making connection to one of the contacts. Refer to Figure 12.
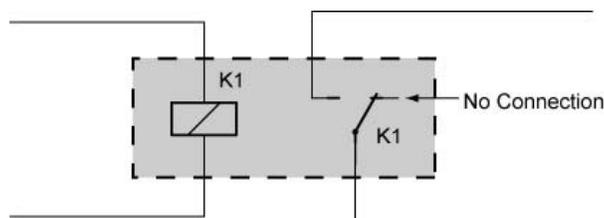
Figure 12: SPDT Relay Acting as a SPST Relay

- o Benefits of Using Relays:
  - An electrical equipment operator is exposed to lower, safer control voltages rather than high equipment voltages (Figure 13).
  - Equipment can be controlled from remote locations (Figure 13).
  - Smaller wires can be run from the control room to the equipment (Figure 13).
  - One relay can control several loads at the same time (Figure 14).
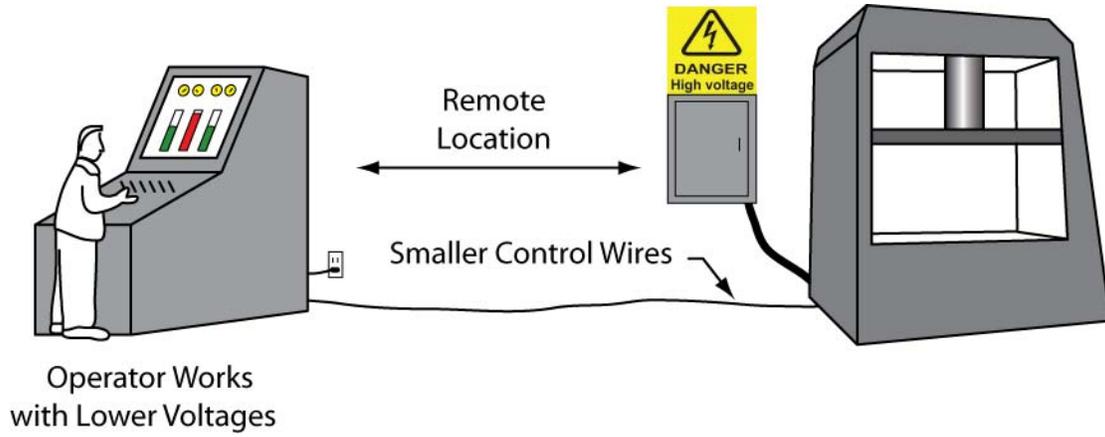
**Figure 13: Several Benefits of Using Relays**
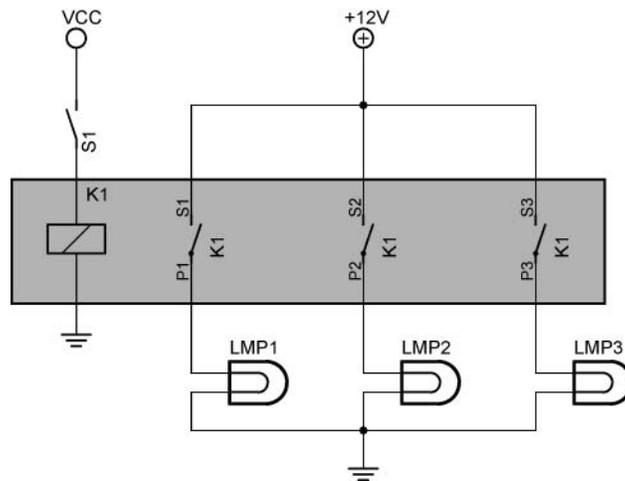
Figure 14: Multiple Loads Controlled by One 3PST NO Relays

- o Using Relays vs. Transistor Switches:
  - Transistors cannot switch AC or high voltages and they are not usually a good choice for switching large currents (> 5A).
  - Advantages of relays compared to a transistor:
    - Relays can switch AC and DC, transistors can only switch DC.
    - Relays can switch high voltages, transistors cannot.
    - Relays are a better choice for switching large currents (> 5A).
    - Relays can switch many contacts at once.

- Disadvantages of relays compared to a transistor:
  - Relays are bulkier than transistors for switching small currents.
  - Relays cannot switch as rapidly as transistors.
  - Relays use more power due to the current flowing through the coil.
  - Relays require more current than many ICs can provide, so a low power transistor may be needed to switch the current for the relay's coil.
  - Relays have moving parts that wear out.

(Relay/transistor comparison from: http://www.kpsec.freeuk.com/trancirc.htm)

- o Common Relay Problems:
  - Contamination: Contamination creates open circuits when it deposits dirt on relay contacts. Contamination can be from a thin carbon coating due to arcing across the terminals, manufacturing chemical deposits, or even ant mounding between the contacts.
  - Mechanical Wear: Contacts erode from sparking. In fact, the life of a relay is typically determined by the life of its contacts
  - Break in the Coil Windings: An open relay coil will prevent the coil from creating a magnetic field to pull the armature.
- o Notes on Relays:
  - The voltage across the relay coil should be within 25% of the relay specification.
  - If you are driving a motor with a relay, the surge of starting a motor requires that you select a relay with a current rating that is equal to at least two times the current draw when the motor is running.
  - If current flow through a relay coil is suddenly interrupted, the coil will produce a very large voltage spike in the reverse direction of the applied voltage. To handle these reverse voltage spikes, place a transient suppressor diode (sometimes called a flyback diode) across the relay's coil a shown in Figure 15.
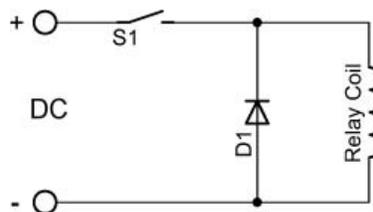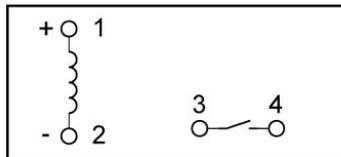

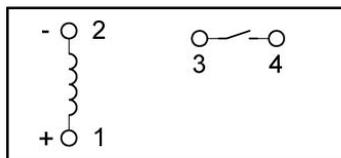**Figure 15: Flyback Diode D1 across a DC Driven Relay Coil**

- o Perform Control and Navigation 8 – Relays Lab 2 – Relay Application 1
- o Control and Navigation 8 – Relays Lab 3 – Relay Application 2
- o Perform Control and Navigation 8 – Relays Lab 4 – Controlling a DC Motor's Direction with Relays

Cornerstone Electronics Technology and Robotics III
Control and Navigation 8 – Relays Lab 1 – Voltage Separation

- **Purpose:** The purpose of this lab is to demonstrate that the voltage source which controls a relay coil can be separate from the voltage source that controls the secondary circuit.

- **Apparatus and Materials:**

  - 1 – Breadboard with a +5 V and +9 V Power Supplies
  - 1 – 1N4004 Diode
  - 1 – SPST Relay (Digikey # Z945-ND)
    http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail?name=Z945-ND
  - 1 – SPST Switch
  - 1 – 1K Resistor
  - 1 – LED

- **Procedure:**
  - Build Relay Circuit 1 on your breadboard. The circuit uses a voltage source of +5 V to energize the relay coil and a separate a voltage source of +9 V to power the LED circuit.
  - Notice that the two circuits in Relay Circuit 1 are not connected electrically. Their interaction is by the coil generating a magnetic field which closes the contacts (switch) in the relay.
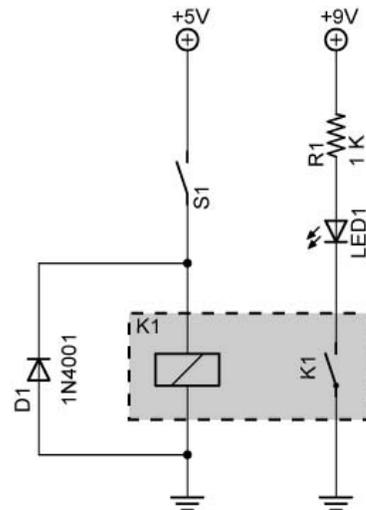

K1 (Z945-ND Top View)

K1 (Z945-ND Bottom View)

SPST Relay Wiring Diagram

Relay Circuit 1

- **Results:**

Position of Switch	LED Response
S1 Open	
S1 Closed	

- **Conclusions:**
  - The data sheet for the relay states, "When mounting two or more relays side by side, provide a minimum space of 3 mm between relays." Why?

- **Purpose:** The purpose of this lab is to demonstrate an application of a relay.
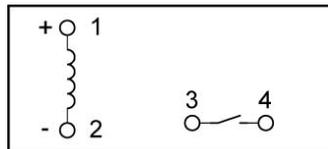
- **Apparatus and Materials:**

  - 1 – Breadboard with a +5 V Power Supply
  - 1 – 1 K Tripot
  - 1 – Photoresistor
  - 1 – 4.7 K Resistor
  - 2 – 1 K Resistors
  - 1 – 2N2222A NPN Transistor
  - 1 – 1N4001 Diode
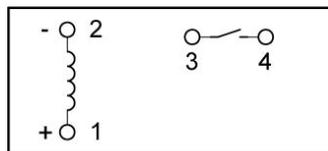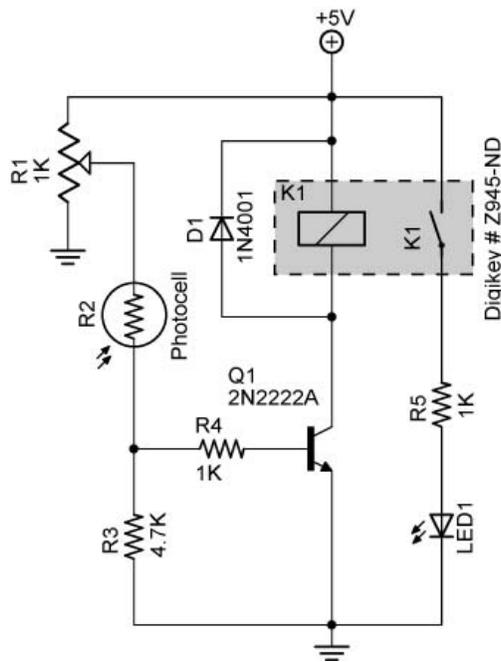 - 1 – LED
  - 1 – SPST Relay (Digikey # Z945-ND)
    http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail?name=Z945-ND

- **Procedure:**
  - Wire the following light activated relay circuit.
  - Adjust R1 so the LED just turns off.
  - Shine the flash light into the photocell to activate the relay, making the LED turn on.

K1 (Z945-ND Top View)
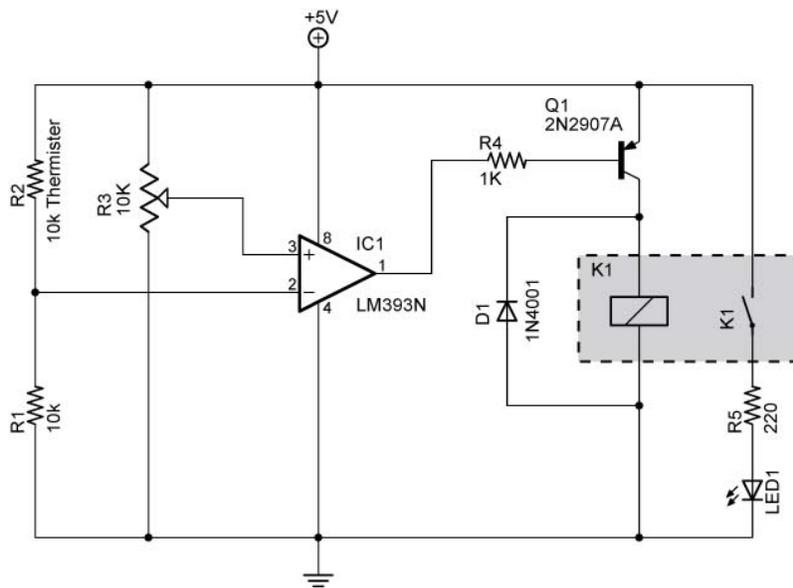
K1 (Z945-ND Bottom View)

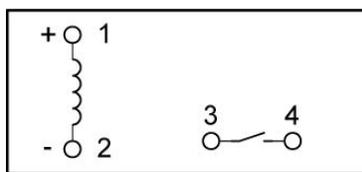**SPST Relay Wiring Diagram**   **Light Activated Relay Circuit**

Cornerstone Electronics Technology and Robotics III
Control and Navigation 8 – Relays Lab 3 – Relay Application 2

- **Purpose:** The purpose of this lab is to demonstrate another application of a relay.

- **Apparatus and Materials:**
    - 1 – Breadboard with a +5 V Power Supply
    - 1 – LM393N Comparator
    - 1 – 220 Resistor
    - 1 – 1 K Resistor
    - 1 – 10 K Resistor
    - 1 – 10 K Tripot
    - 1 – 10 K Thermistor
    - 1 - LED
    - 1 – 2N2907A PNP Transistor
    - 1 – 1N4001 Diode
    - 1 – SPST Relay (Digikey # Z945-ND)
      http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail?name=Z945-ND
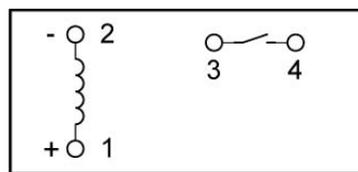
- **Procedure:**
    - Build the temperature activated relay circuit below.
    - At room temperature, adjust R3 such that the LED just turns off.
    - Now hold R2, the thermister, between your fingers to lower the resistance of the thermister. The LED should go on.

Temperature Activated Relay Circuit


K1 (Z945-ND Top View)   K1 (Z945-ND Bottom View)

SPST Relay Wiring Diagram

Cornerstone Electronics Technology and Robotics III
Control and Navigation 8 – Relays Lab 4 – Controlling a DC Motor's Direction with Relays

- **Purpose:** To demonstrate how relays can be used to control the polarity of a dc motor.

- **Apparatus and Materials:**
    - 1 – Breadboard with a +5V and +12V Power Supply
    - 1 – 12V DC Motor with Full Load Current Rating < 125 mA
    - 2 – 1N5817 Schottky Diodes
    - 2 – SPDT DC Reed Relays, 5V DC Coil Voltage, Switching Current Max = 250 mA (Digi-Key #HE112-ND)
        - Source: http://www.digikey.com/scripts/DkSearch/dksus.dll?WT.z_header= search_go&lang=en&keywords=he112-nd&x=0&y=0&cur=USD
        - Datasheet (Part #HE721C0500): http://www.hamlin.com/specsheets/HE700.pdf
    - For a relay to control more robust motors, see the PCB Parts List in Lesson 27 – Final ROV Construction.

- **Procedure:**
    - Build the dc motor control circuit below:
    - Turn switches S1 and S2 on and off to complete the table in results. Closing S1 energizes relay K1 (Relay 1 ON).
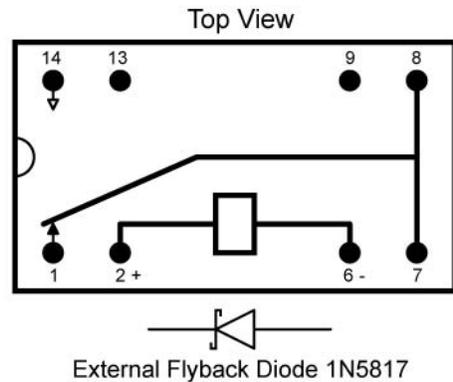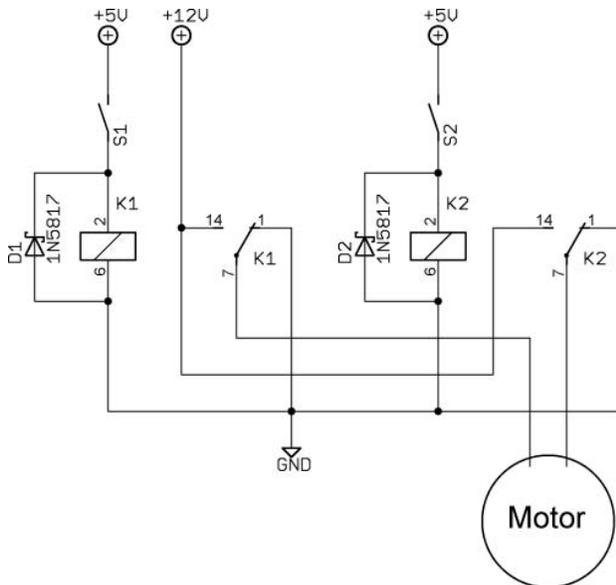
**Motor Control Using Two SPDT Relays**

Pinout for SPDT Reed Relay

- **Results:**

| Motor Relay Logic		
Relay 1	Relay 2	Motor Status
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

- **Conclusions:**
  - Using arrows to represent current draw the current through the relays and motor in each schematic below. Also show the polarity at the motor terminals and the direction of the motor rotation. If there is no current, just show the polarity at the motor terminals.
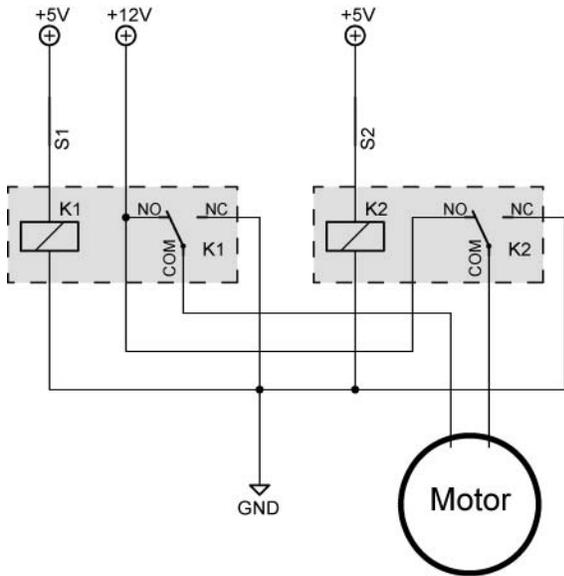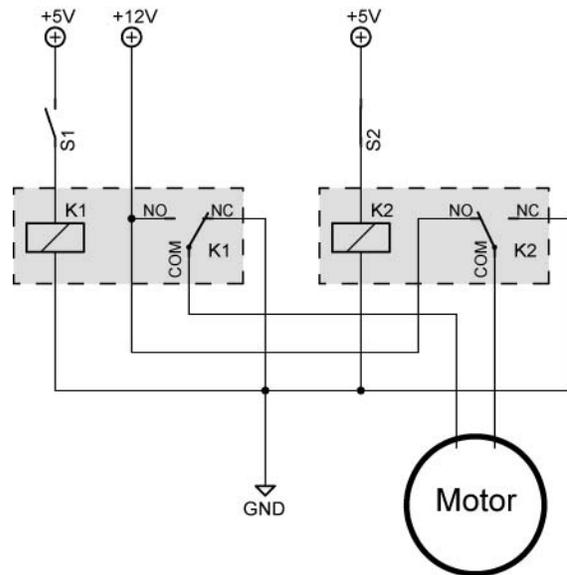

S1 and S2 Closed, Relays 1 and 2 ON
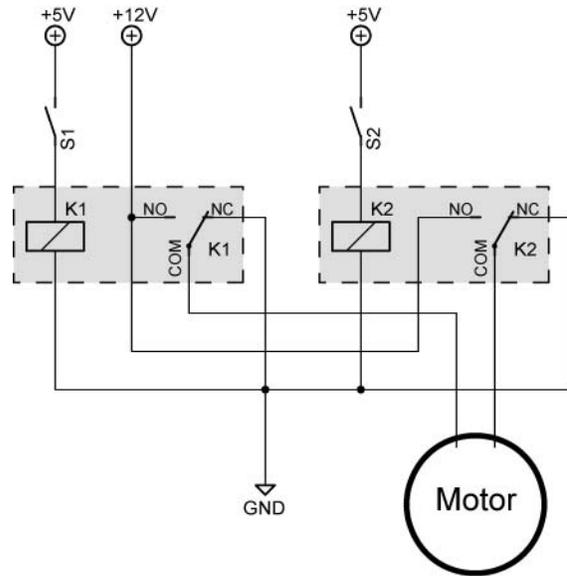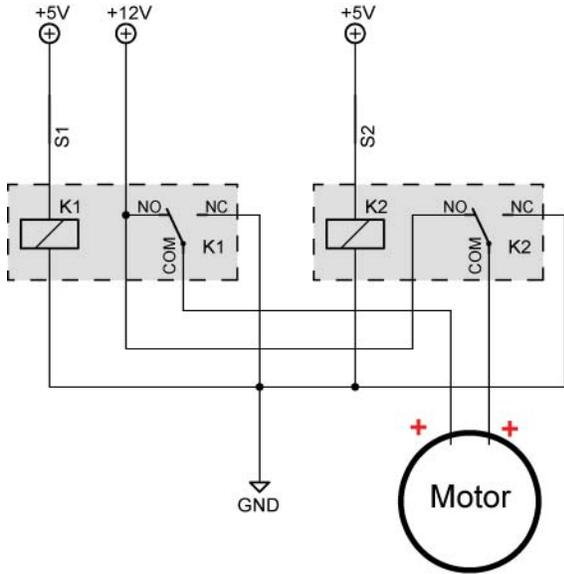
S1 and S2 Open, Relays 1 and 2 OFF
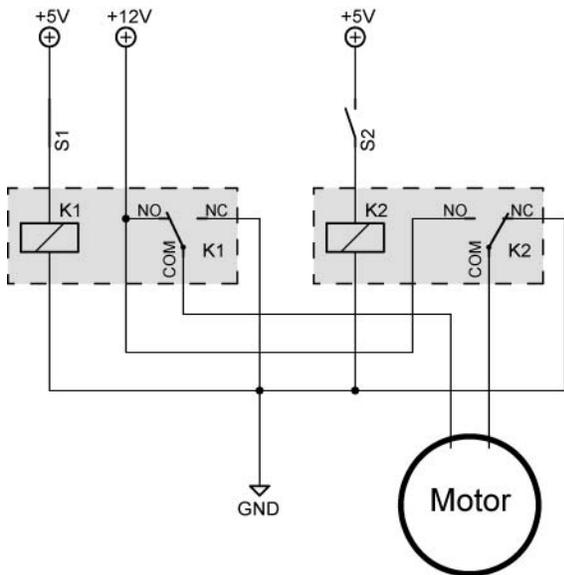
**S1 Closed, S2 Open,
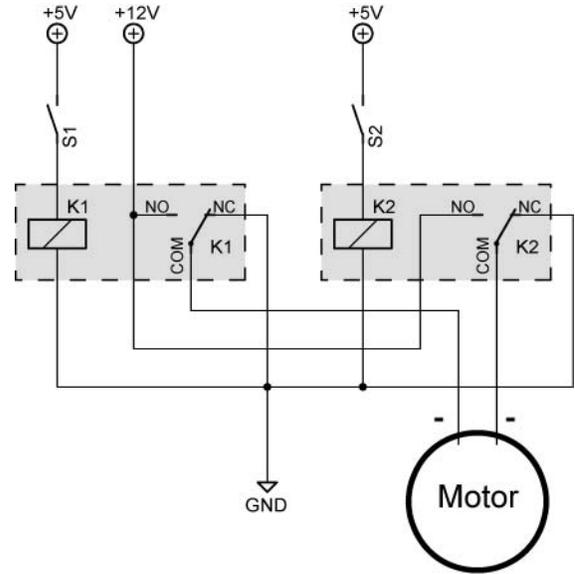Relay 1 ON, Relay 2 OFF**
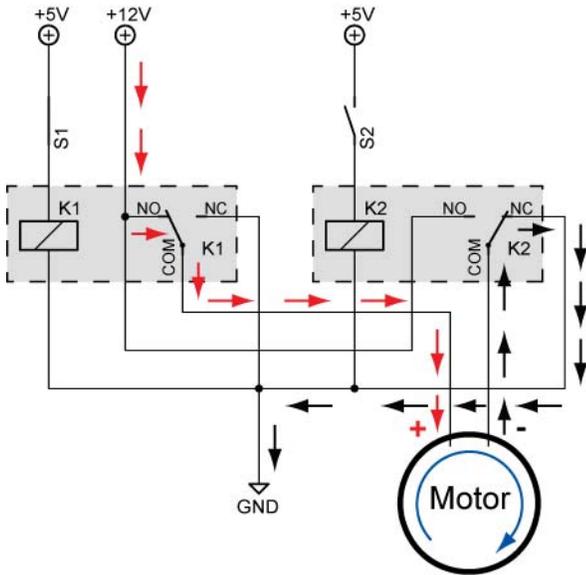
**S1 Open, S2 Closed,
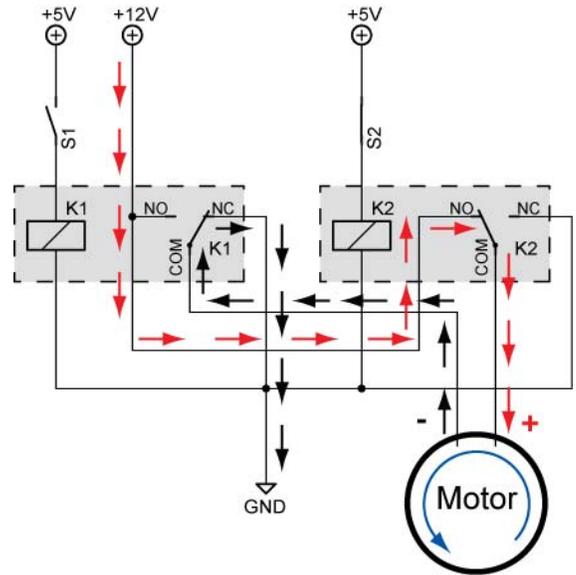Relay 1 OFF, Relay 2 ON**

- **Answers:**

S1 and S2 Closed, Relays 1 and 2 ON

S1 and S2 Open, Relays 1 and 2 OFF

**S1 Closed, S2 Open,
Relay 1 ON, Relay 2 OFF
(Rotation May Be Opposite)**

**S1 Open, S2 Closed,
Relay 1 OFF, Relay 2 ON
(Rotation May Be Opposite)**