REVERSING DC WINCH MOTORS - Understanding H-Bridge Circuits

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Convertible tops, power windows, power seats, power mirrors, power locks, sunroofs, winches, and lifts. What do all these things have in common? They all use DC motors that can run CW or CCW depending on the direction the current flows.
For smaller automotive motors, such as power mirrors, the reversing of the current is handled in the switch itself. Since the entire switch is replaced as an assembly, we rarely have to think about what is going on inside of it – we just replace the switch.

BIGGER MOTORS, BIGGER SWITCHES

When the motors are larger, and the amp draw increases, such as with a winch motor, small switches cannot handle the higher current. Relays are used to do the switching. Now, in order to diagnose and repair the equipment, you need an understanding of how the circuit is designed and how it works.

H-BRIDGE CIRCUITS

The most common circuit design used to reverse current flow is known as an *H-Bridge*. The name came from the circuit diagram, which resembles the letter *H* (see *Figure 1*). The load (motor) is on the horizontal line and the switches (relays) are on the vertical branches of the *H*.

The important thing to remember is that there are four switches within the bridge. These switches are often referred to as; *left high side, right high side, right low side and left low side* (see *Figure 1*). The switches are always turned on in pairs to control the direction of current flow.

To send power to the motor, you turn on the two switches that are diagonally opposed. In *Figure 2* the *left high side* and the *right low side* switches are turned on. This allows current to flow, and the motor begins to turn. *Figure 3* shows the opposite pair of switches turned on, and you can see that the current flow to the motor is now reversed.

Most circuits are designed so that the motor will turn CW when the *left high side* and the *right low side* are turned on and turn CCW when the *right high side* and the *left low side* are turned on. This is not a hard-and-fast rule though, so always verify that the direction of rotation is correct after repairs.

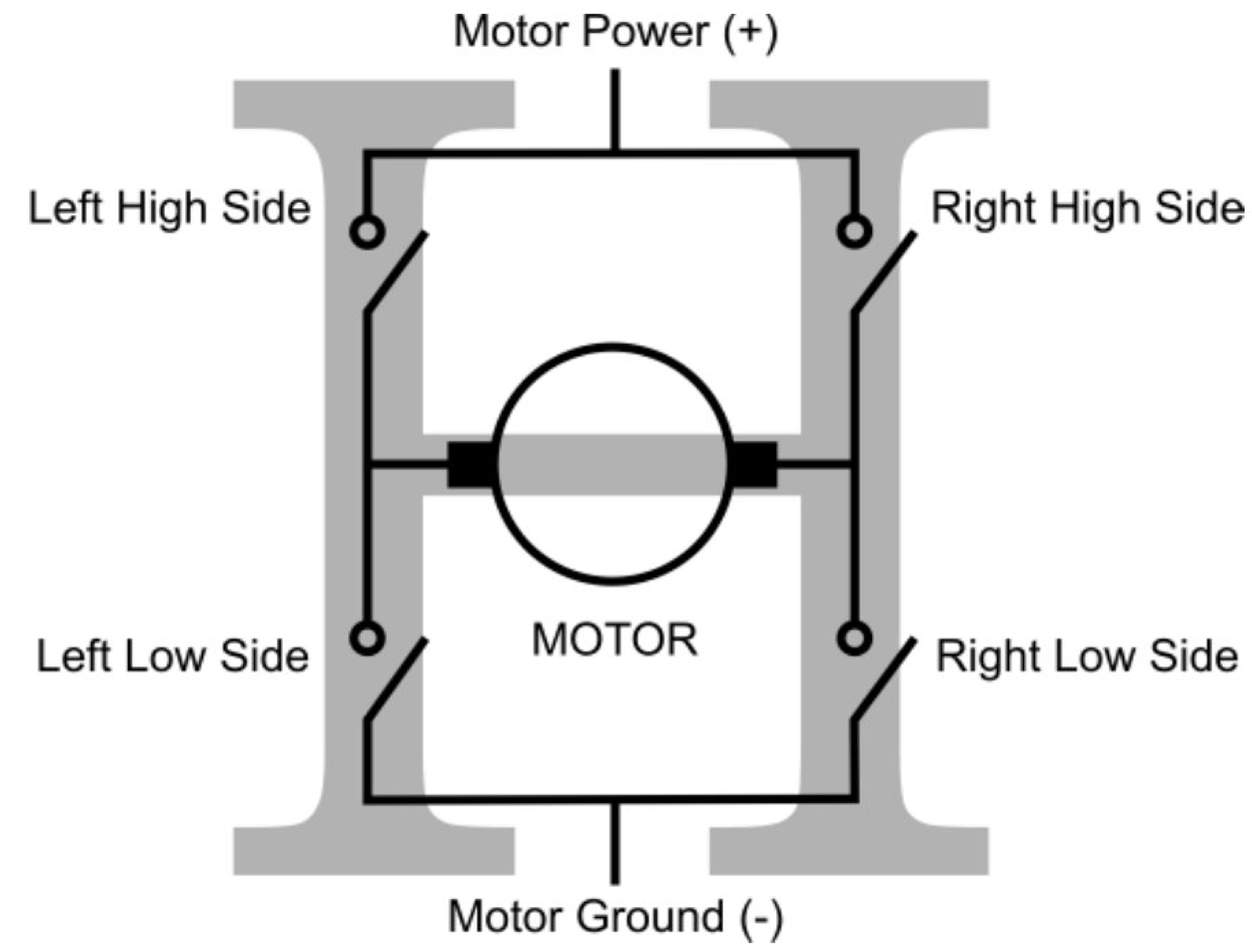


Figure 1 – H-bridge circuit layout

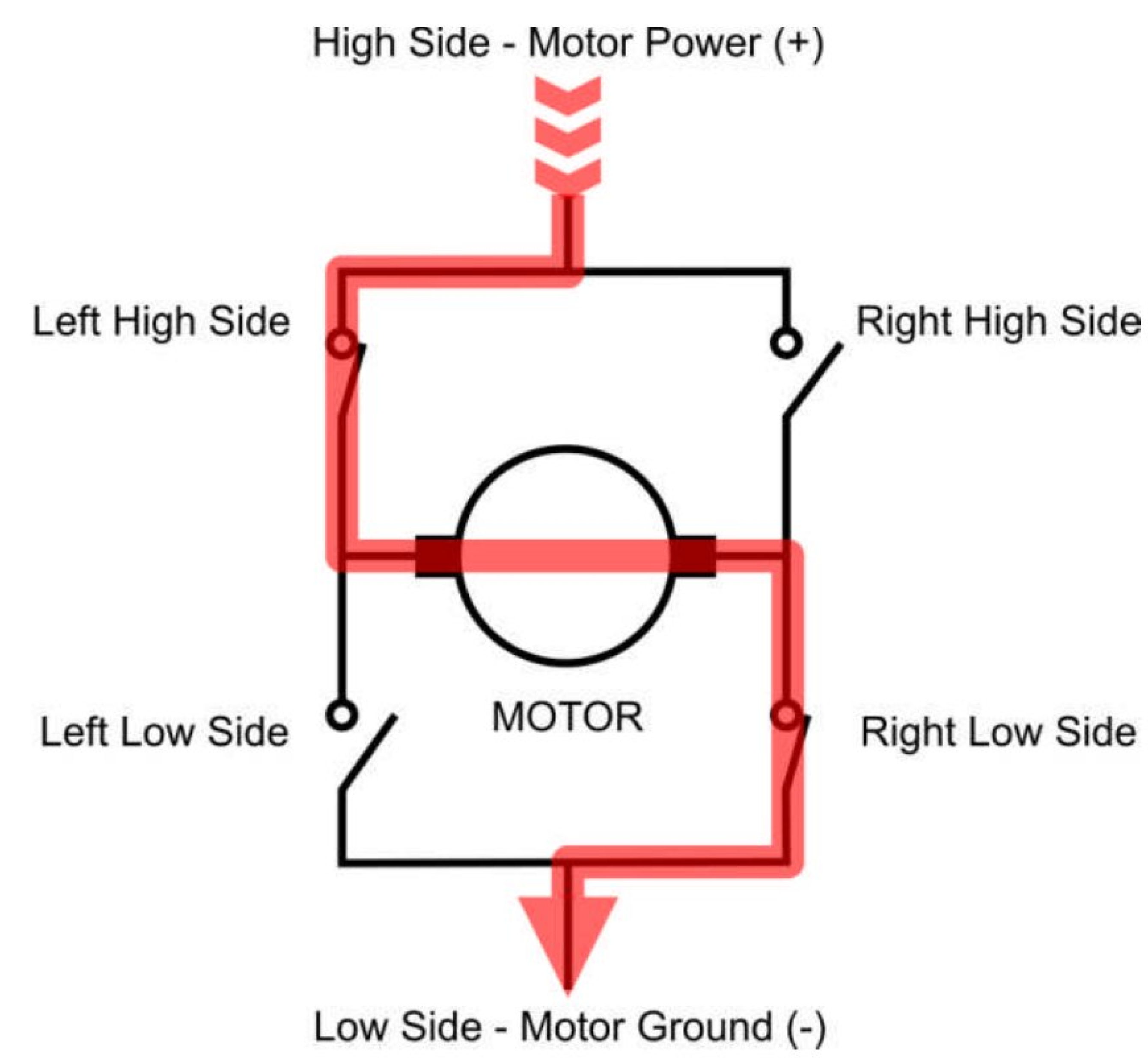


Figure 2 – Left High, Right Low turned on

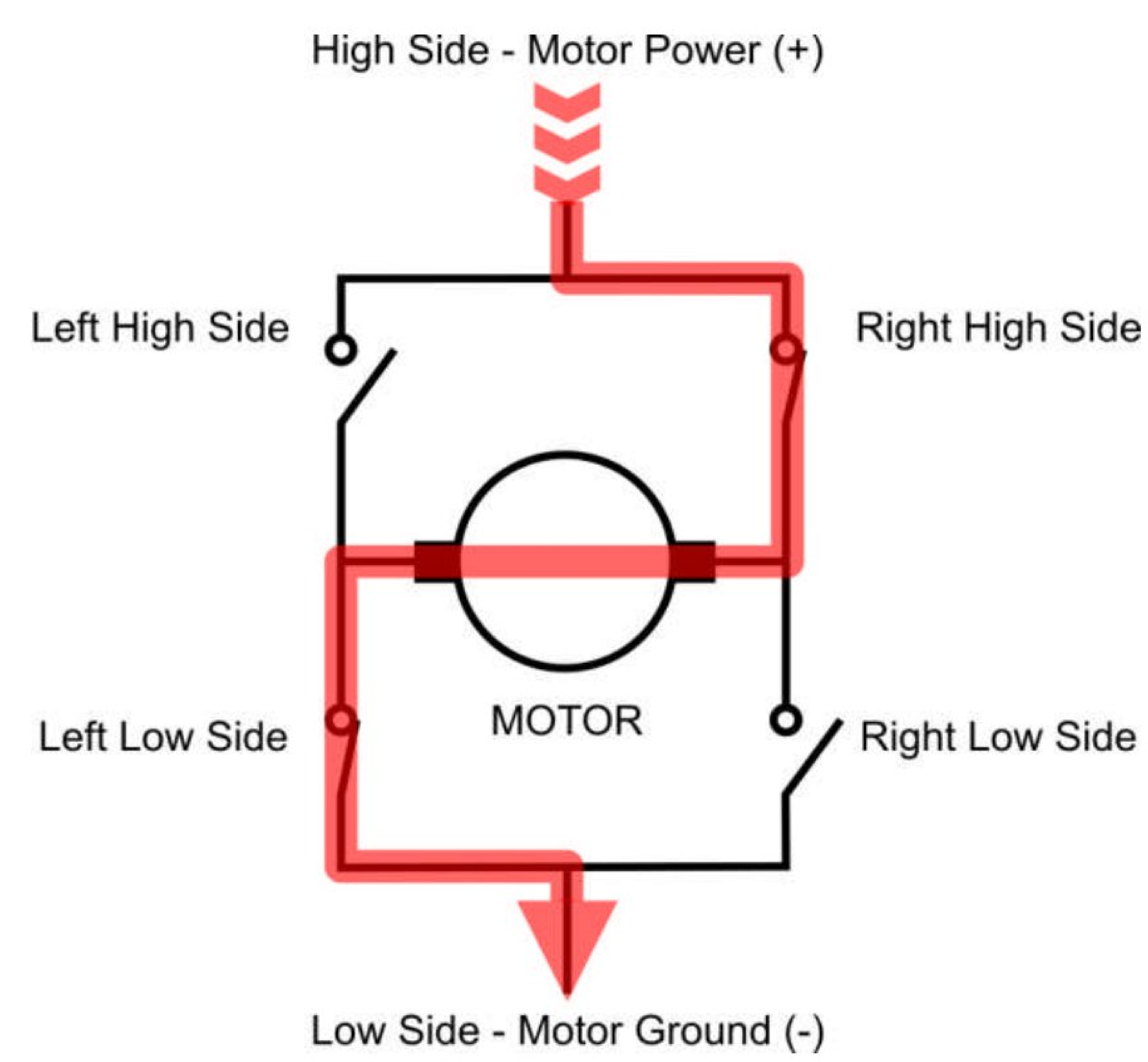
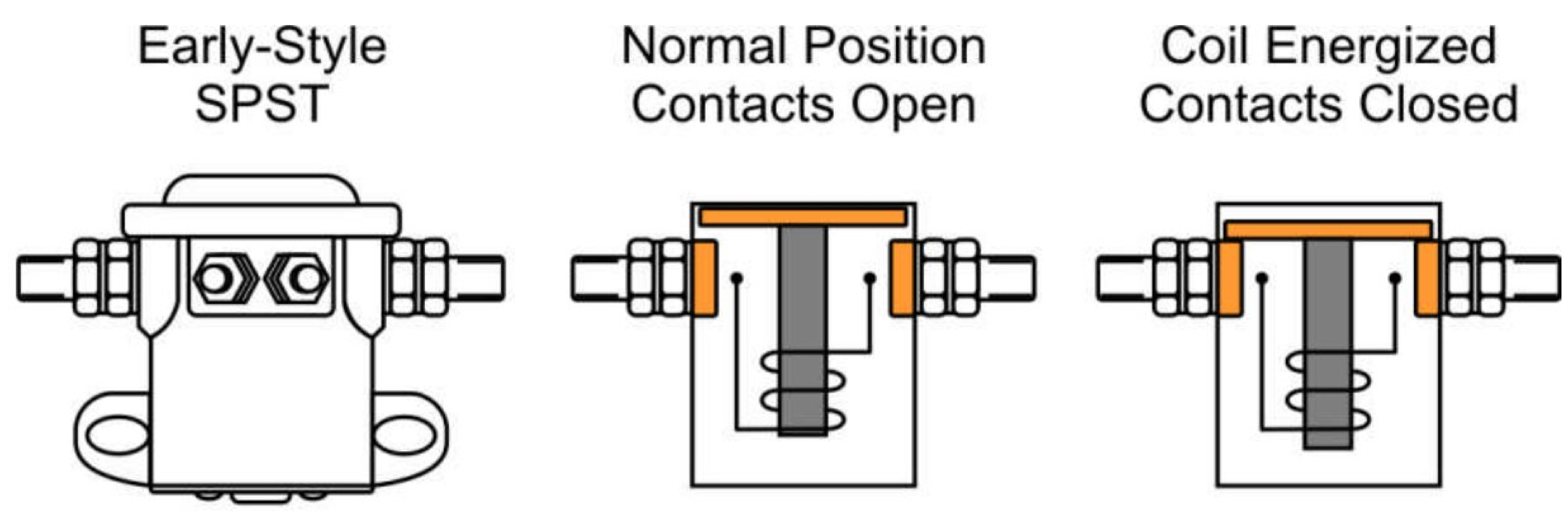


Figure 3 – Right High, Left Low turned on

GENERIC WINCH MOTOR DIAGRAM 1

- **Four Early-Style SPST (single-pole, single-throw) Solenoids**
- **Three-Post Motor with Field Coils**

This example is the setup that is most commonly used on heavy duty winches. It is used by most major winch manufacturers, including Warn and Ramsey. The four corners of the *H-circuit* are single-pole, single-throw solenoids. The solenoids may be tin-can style, as shown in *Figure 4,* or the later style phenolic housing solenoids as shown to the immediate right.



Note: Solenoid coils come in two styles. If the solenoid has only one small stud, then the coil is grounded inside the solenoid. If the solenoid has two small studs, then you must provide a ground connection to complete the circuit. In the example shown above, there are two small studs. This style is known as an *insulated-coil* solenoid.

Figure 4 – Early-Style Solenoid Operation

The solenoid coils may be internally grounded, or they may have *insulated coils*. If the solenoid has one small stud, then the coil is internally grounded. If there are two small studs, then it is the insulated style. See the note in *Figure 4* for information about completing the ground circuit for *insulated-coil* solenoids.

Figure 5 shows the motor current flow highlighted when the winch control switch is in the CW position. In CW mode, the *left high side* and the *right low side* solenoid coils are energized, causing the solenoid contacts to close. Current now flows:

1. From the battery positive post, through the *left high side* solenoid to terminal *C* on the motor.
2. From terminal *C*, it flows through the motor's field coils and exits through terminal *B*.
3. From terminal *B,* it flows through the *right low side* solenoid and back into the motor through terminal *A*.
4. It continues through the positive brushes and armature and finally through the negative brushes to ground.

In CCW mode, the *right high side* and *left low side* solenoids are energized and the current flow is reversed through the field coils, changing their magnetic polarity.

It is important to note that in either CW or CCW mode, the current applied to the armature does not change direction. The current flow through the armature is always from positive to negative.

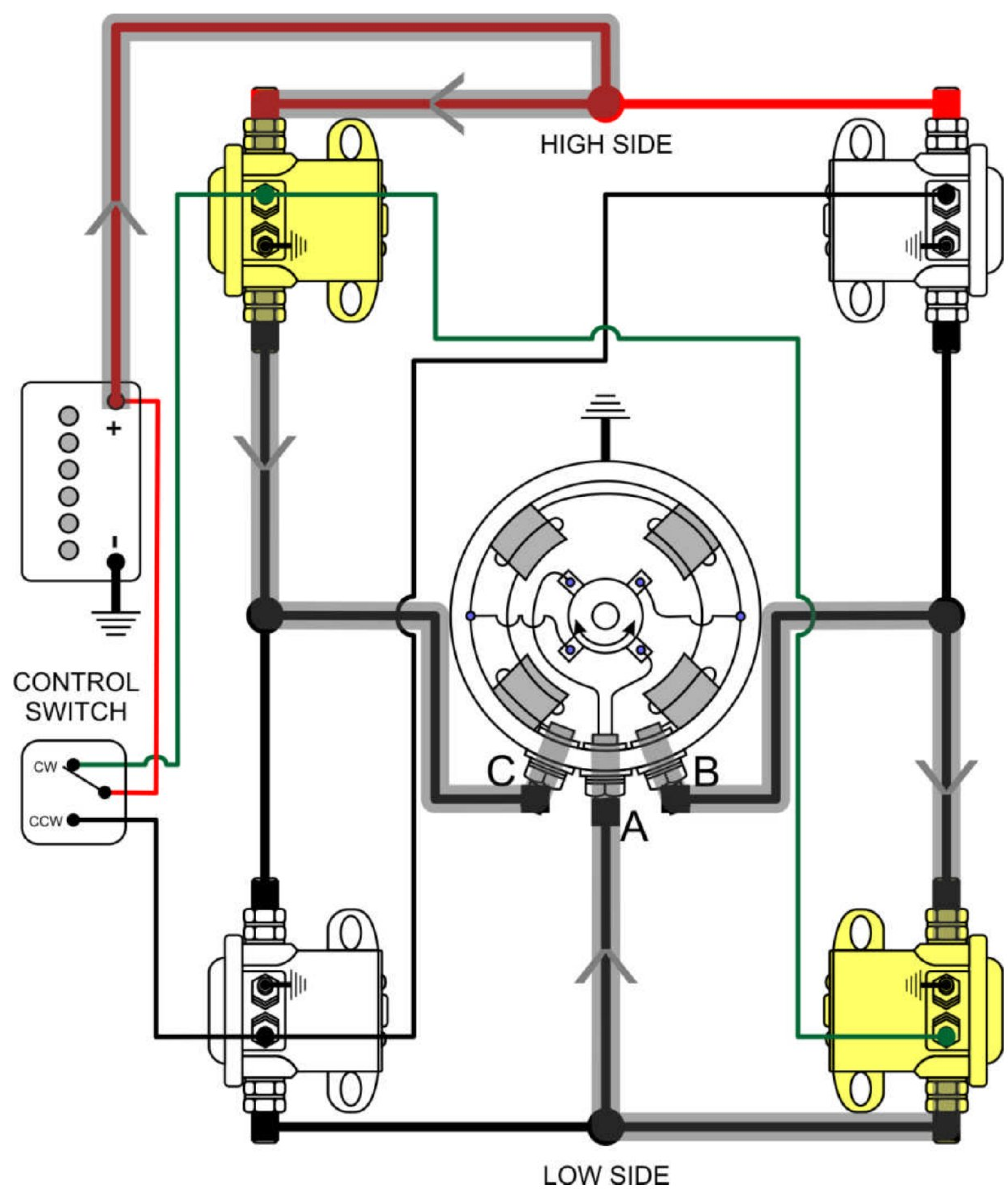


Figure 5 – Early-Style, 4 Solenoids, Three-Post Motor with Field Coils

GENERIC WINCH MOTOR DIAGRAM 2

- **Four Early-Style SPST (single-pole, single-throw) Solenoids**
- **Two-Post Motor with Permanent Magnets**

Permanent-magnet motors are generally used on light-duty, consumer-grade winches. The four corners of the *H-circuit* are single-pole, single-throw solenoids. The solenoids may be tin-can style or later style phenolic housing solenoids as discussed in the previous section. The notes about *insulated-coil* solenoids also apply to this section.

The main difference in the *H-bridge* circuit, when using a permanent-magnet motor, is how the low side is routed to ground. If the winch motor has **field coils**, as in the previous example, the low side current flows through the positive brushes, through the armature, through the negative brushes to ground **at** the motor case. With a **permanent-magnet** motor, however, both sets of brushes are insulated from the motor case. Current flows through one set of brushes, through the armature, through the other set of brushes and is directed to ground **outside** of the motor, on the low side,

Figure 6 shows the motor current flow highlighted when the winch control switch is in the CW position. In CW mode, the *left high side* and the *right low side* solenoid coils are energized, causing the solenoid contacts to close. Current now flows:

1. From the battery positive post, through the *left high side* solenoid to terminal *A* on the motor.
2. From terminal *A*, it flows through the motor's brushes and armature and exits through terminal *B*.
3. From terminal *B,* it flows through the *right low side* solenoid and to ground.

In CCW mode, the *right high side* and *left low side* solenoids are energized, and the current flow is reversed through the brushes and armature.

In circuits using **field-coil** motors, reversing the motor direction is achieved by reversing the current flow through the field coils and thus changing the field coils' magnetic polarity.

In circuits using **permanent-magnet** motors, the magnetic-field polarity is fixed by the permanent magnets and cannot be changed. To reverse the motor direction, the direction of current flow through the armature is reversed.

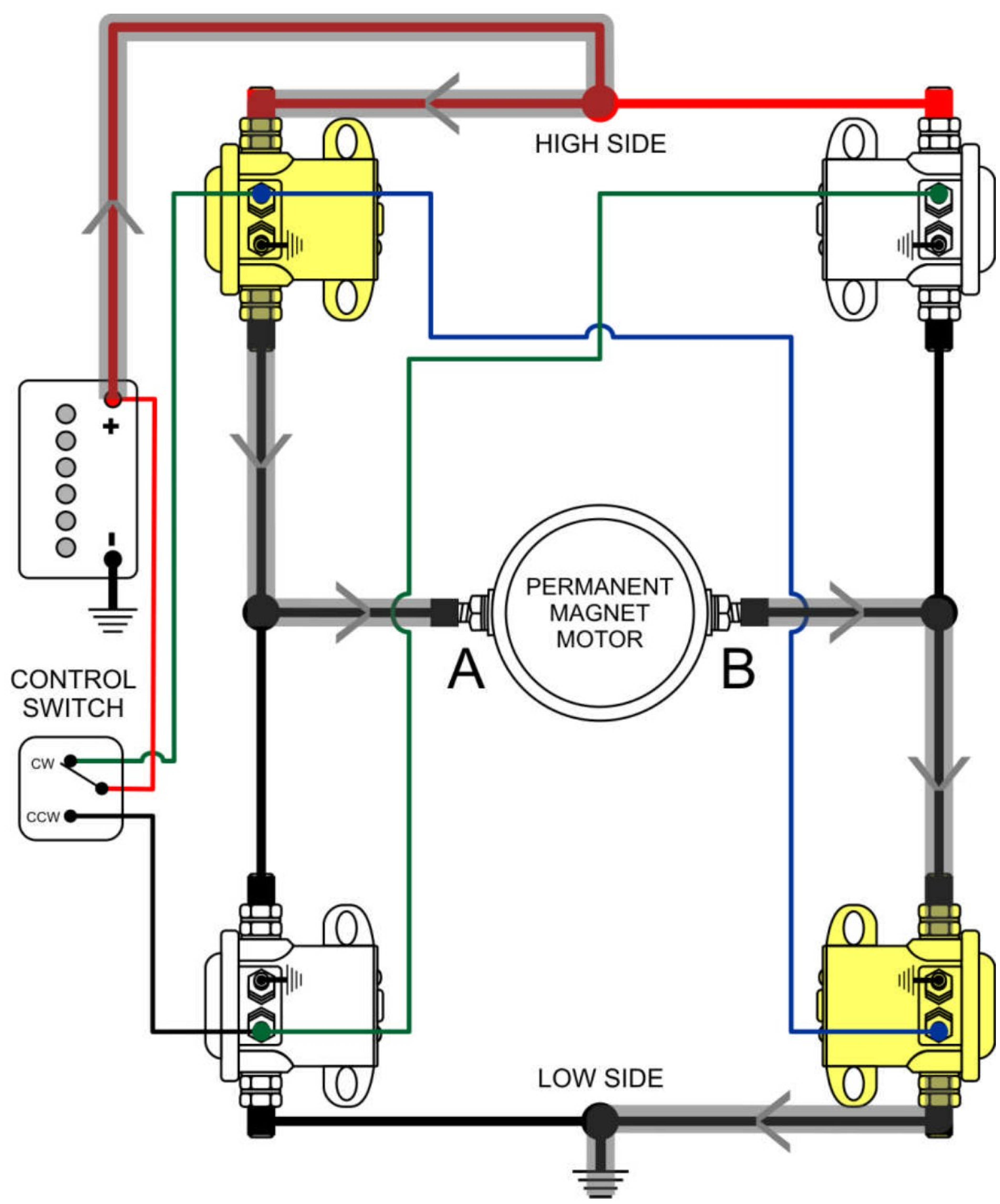


Figure 6 – Early-Style, 4 Solenoids, Two-Post Motor with Permanent Magnets

GENERIC WINCH MOTOR DIAGRAM 3

- **Two Late-Style DPDT (double-pole, double-throw) Solenoids**
- **Three-Post Motor with Field Coils**

By using double-pole, double-throw solenoids, manufacturers are able to use half the number of solenoids in the circuit. Two solenoids do the work of four.

In this type of DPDT solenoid the plunger is spring-loaded to push against the upper set of contacts. When the solenoid coil is not energized, the upper contacts are closed. When the coil is energized, the plunger pulls down, opening the upper contacts and closing the lower contacts.

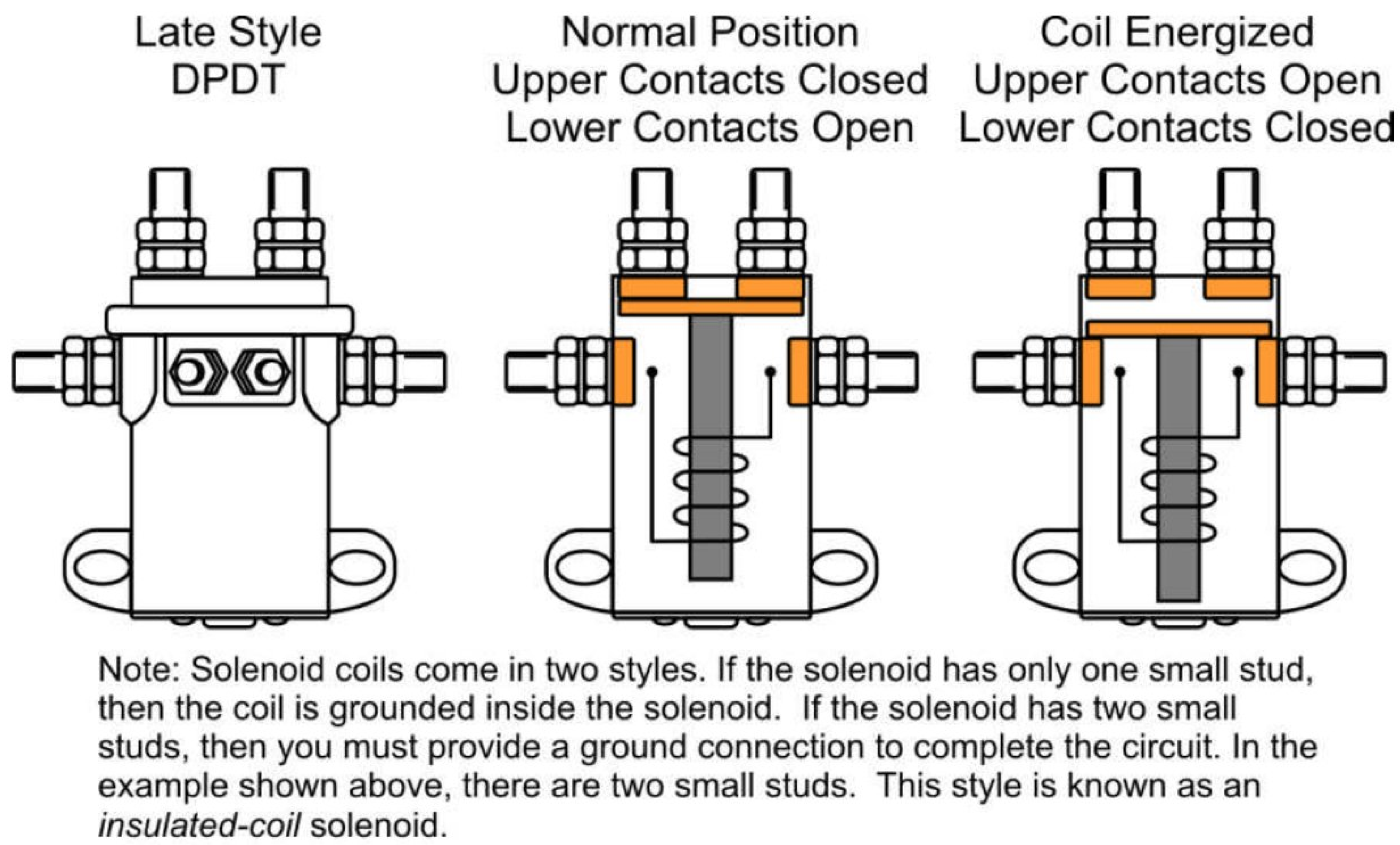


Figure 7 – Late-Style Solenoid Operation

Although it is not as easy to see, all the elements of an *H-bridge* circuit are present in *Figure 8*. The lower contacts of both solenoids compose the high side of the circuit. The upper contacts of the solenoids compose the low side.

Figure 8 shows the motor current flow highlighted when the winch control switch is in the CW position. In CW mode, only the left solenoid is energized. This causes the lower contacts to close, and it becomes the equivalent of the *left high side* switch in *Figure 2*. The right solenoid coil remains unenergized. But, since the upper contacts are normally closed, it is the equivalent of the *right low side* switch in *Figure 2*. Current now flows:

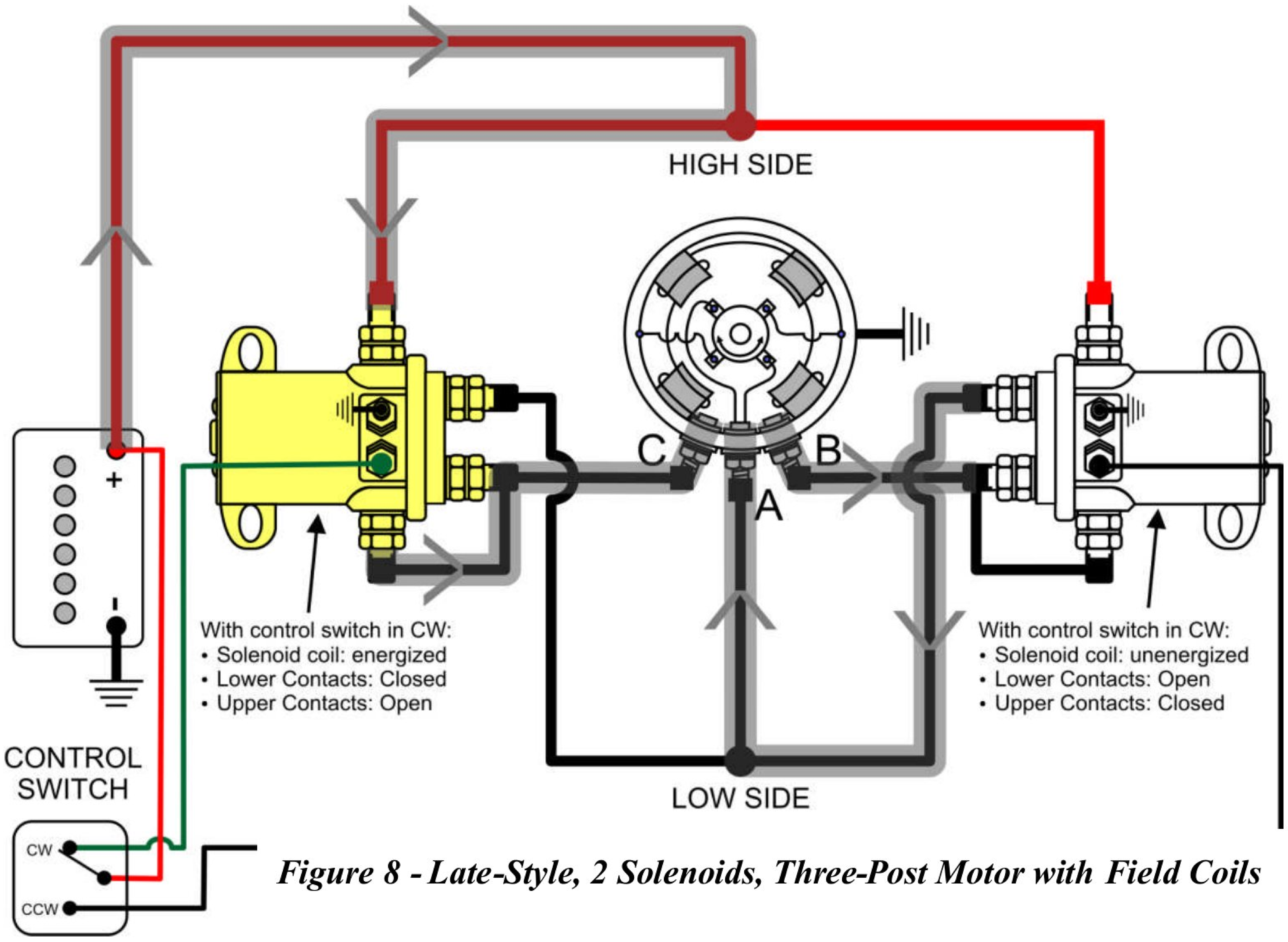


Figure 8 - Late-Style, 2 Solenoids, Three-Post Motor with Field Coils

1. From the battery positive post, through the lower contacts of the left solenoid to terminal *C* on the motor.
2. From terminal *C*, it flows through the motor's field coils and exits through terminal *B*.
3. From terminal *B,* it flows through the upper contacts of the right solenoid and back into the motor through terminal *A*.
4. It continues through the positive brushes and armature and finally through the negative brushes to ground.

In CCW mode, only the right solenoid is energized, and the current flow is reversed through the field coils.

It is important to note that in either CW or CCW mode, the current applied to the armature does not change direction. The current flow through the armature is always from positive to negative.

GENERIC WINCH MOTOR DIAGRAM 4

- **Two Late-Style DPDT (double-pole, double-throw) Solenoids**
- **Two-Post Motor with Permanent Magnets**

This circuit uses the same DPDT solenoids that were described previously in *Generic Winch Motor Diagram 3,* and the same notes about *insulated-coils* apply here.

The main difference in the *H-bridge* circuit, when using a permanent-magnet motor, is how the low side is routed to ground. If the winch motor has **field coils**, as in the previous example, the low side current flows through the positive brushes, through the armature, through the negative brushes to ground **at** the motor case. With a **permanent-magnet** motor, both sets of brushes are insulated from the motor case. Current flows through one set of brushes, through the armature, through the other set of brushes and is directed to ground **outside** of the motor, on the low side.

Figure 9 shows the motor current flow highlighted when the winch control switch is in the CW position. In CW mode, only the left solenoid is energized. This causes the lower contacts to close and it becomes the equivalent of the *left high side* switch in *Figure 2.* The right solenoid coil remains unenergized. But, since the upper contacts are normally closed, it is the equivalent of the *right low side* switch in *Figure 2.* Current now flows:

1. From the battery positive post, through the lower contacts of the left solenoid to terminal *A* on the motor.
2. From terminal *A*, it flows through the motor's brushes and armature and exits through terminal *B*.
3. From terminal *B,* it flows through the upper contacts of the right solenoid to ground.

In CCW mode, only the right solenoid is energized and the current flow is reversed through the brushes and the armature.

In circuits using **field-coil** motors, reversing the motor direction is achieved by reversing the current flow through the field coils and thus changing the field coils' magnetic polarity.

In circuits using **permanent-magnet** motors, the magnetic field polarity is fixed by the permanent magnets and cannot be changed. To reverse the motor direction, the direction of current flow through the armature is reversed.

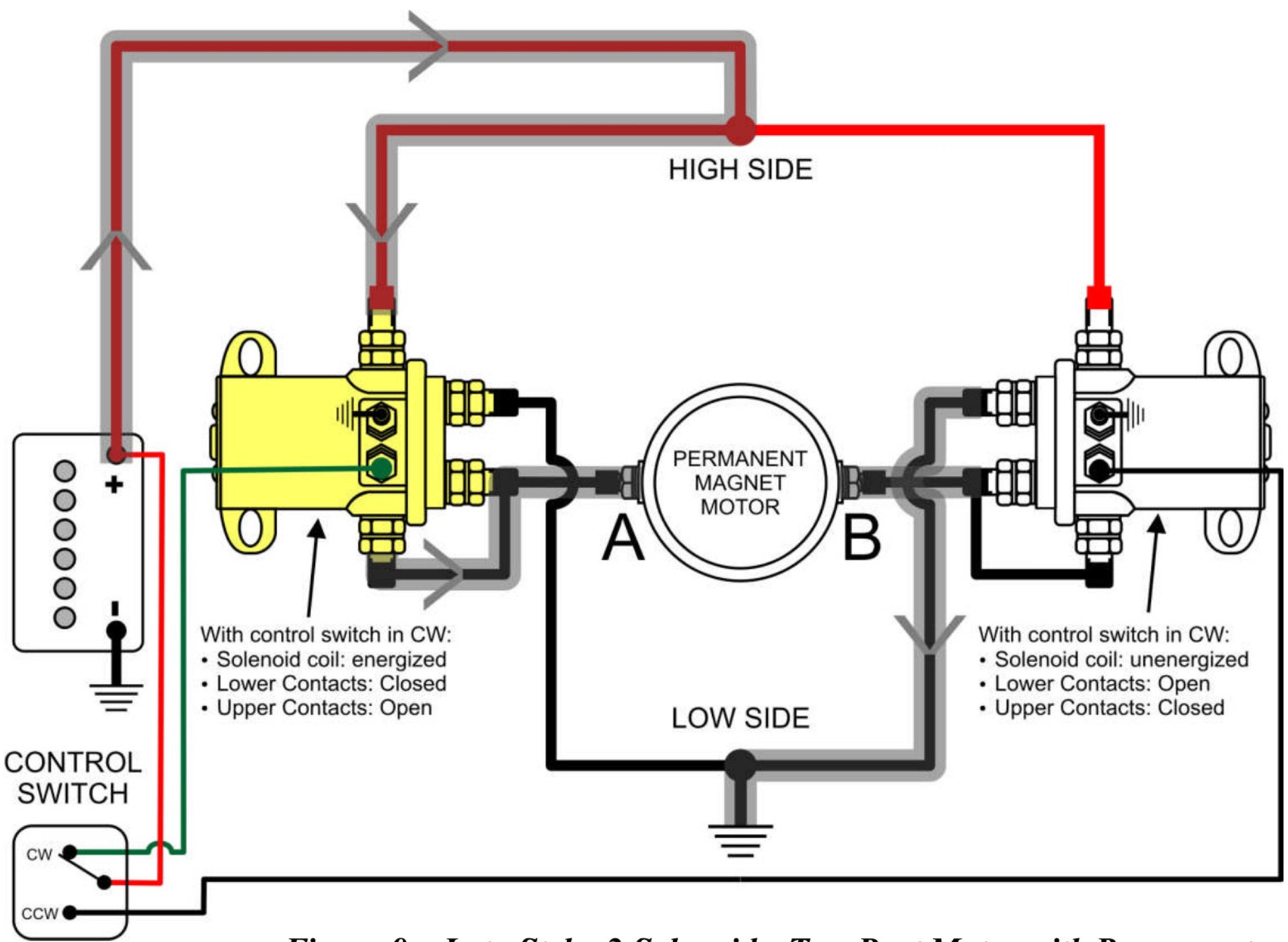


Figure 9 – Late-Style, 2 Solenoids, Two-Post Motor with Permanent Magnets

MOTOR BRAKING AND PERMANENT-MAGNET MOTORS

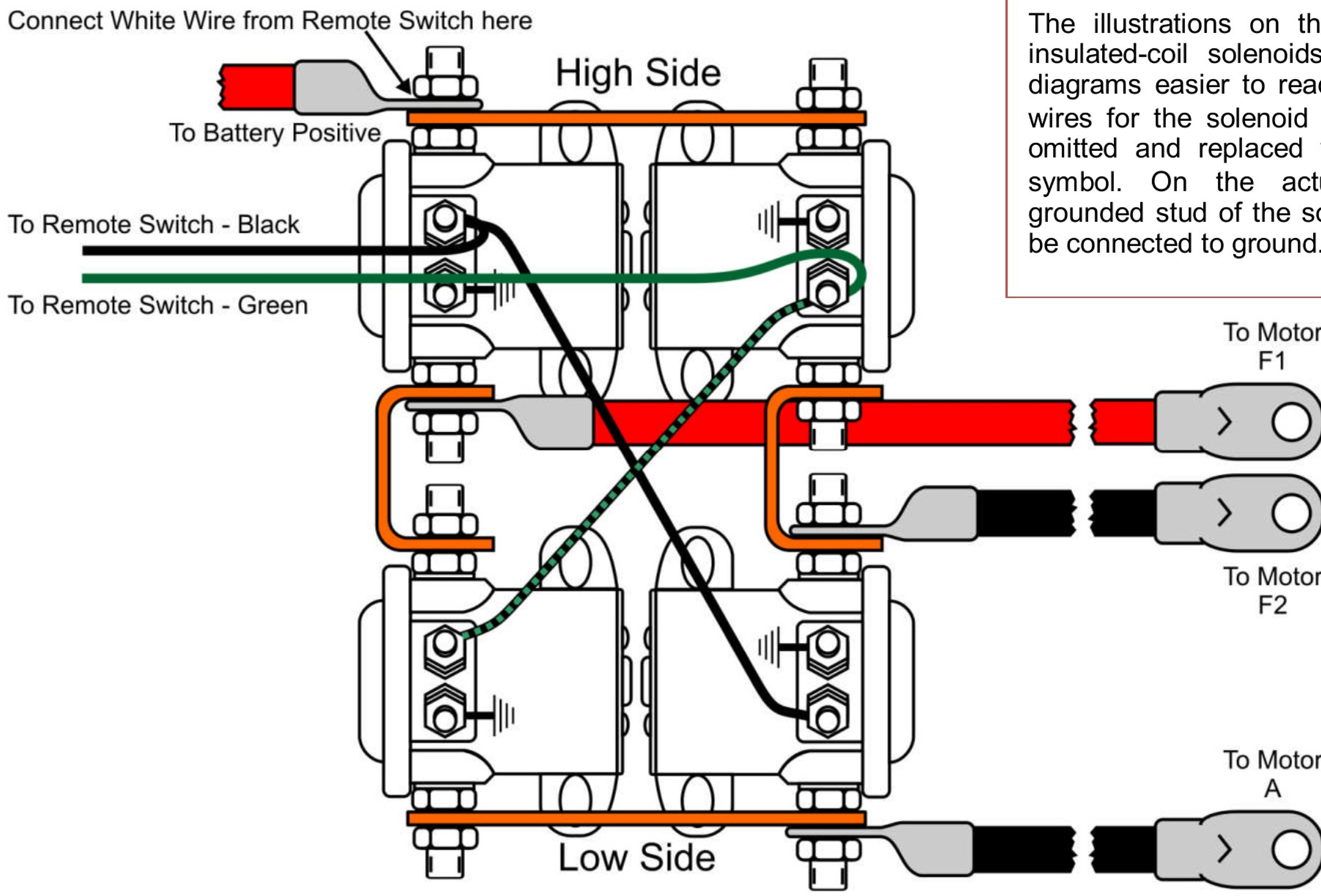
One property of a permanent-magnet motor is that when it spins, unpowered, it becomes a generator. If the circuit is properly designed, this feature can be used to provide a braking effect.

When all power is off to the circuit shown above, the spring-loaded DPDT solenoids *short circuit* both motor terminals to ground. This causes the motor's generator effect to work against itself and causes *motor braking*.

In earlier designs, using four SPST solenoids, all the relays are open when unpowered, and no motor braking occurs.

WARN WINCH SOLENOID PACKS - WITH EARLY-STYLE SPST SOLENOIDS

Tin-can style solenoids with insulated ground



Note about insulated-coil solenoids:

The illustrations on this page contain insulated-coil solenoids. To make the diagrams easier to read, the grounding wires for the solenoid coils have been omitted and replaced with the ground symbol. On the actual winch, the grounded stud of the solenoid coil must be connected to ground.

Figure 10 – Warn Winch Solenoid Pack, Tin-can style

Phenolic-body, flat-style solenoids with insulated ground

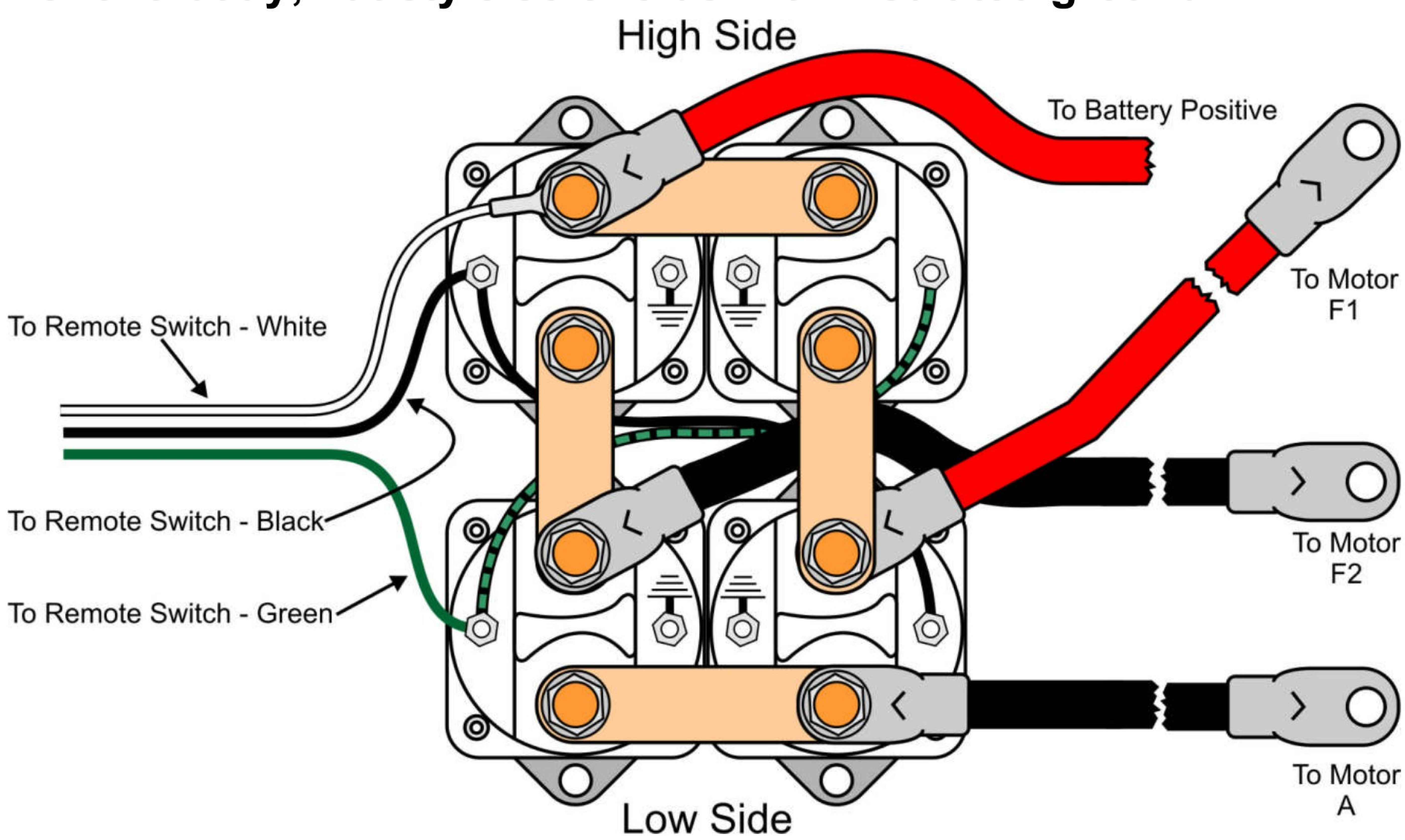


Figure 11 – Warn Winch Solenoid Pack, Phenolic-body style

TWO-POST, PERMANENT-MAGNET MOTOR TESTING

Connect positive to one post, negative to the other. Note rotation. Reverse cables, and rotation will reverse.

THREE-POST MOTOR TESTING

Hook up as shown. The negative battery cable is always connected to the motor case.