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Let's Talk About Starter Solenoids

Back in the "good ol' days" starter pinion gear engagement -and- electrical connection between motor and battery were accomplished with totally manual mechanisms. My 1941 Pontiac had a starter pedal on the floor just to the right of the accelerator.

I believe the first starter featuring automatic engagement of the pinion gear used Bendix drives. If one wished to use a device so modern as a push button for starting, a contactor was needed to handle high current switching duties.

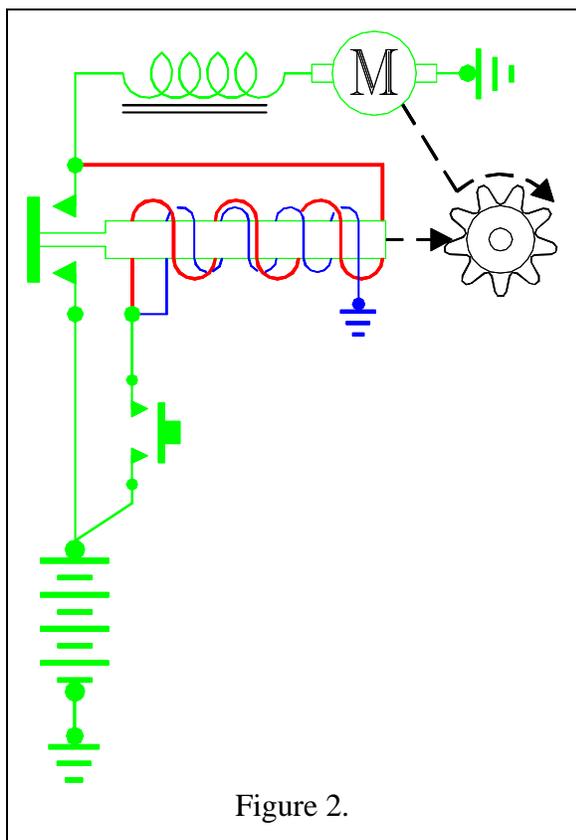


Figure 2.

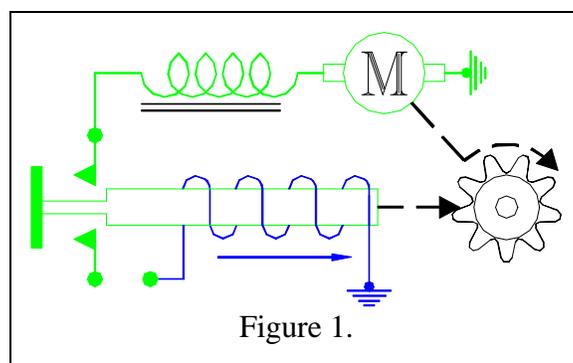


Figure 1.

Later, I believe it was GM who tried a scheme to improve on the shady history of Bendix drives and designed a solenoid engagement system which ALSO featured an integral contactor for switching motor current. A schematic for the device is shown in Figure 1. Here's where the "thing that switches starters" began to be properly called a solenoid. The name stuck and to this day. In automotive vernacular, even remotely mounted contactors are sometimes referred to as "solenoids."

The "solenoid" in Figure 1 has two functions: First, the pinion gear extends to engage the flywheel ring gear. Second: heavy contacts built into one end of the solenoid assembly close to conduct battery power to the starter motor. The mechanism was properly called a solenoid because of its duties as a linear motor with both mechanical and electrical tasks. Given the extra-ordinary effort required of the solenoid coil, it might typically draw 8 to 10 amps during engine cranking.

An interesting aspect of solenoid operation is that it can HOLD a force with a small fraction of the current required to STROKE the same force through the length of its travel. Once the armature bottoms-out it's capable of holding many times the force needed to initially engage the pinion gear. Designers reasond correctly that the total electrical energy and size of solenoid required to operated a starter be reduced along with

a small change in design.

In the Figure 2, note that the solenoid coil is wound with TWO coils of wire. Each winding has the same number of turns . . . one coil is wound with larger diameter wire. The coil wound with smaller wire is connected just like the coil in the Figure 1 . . . power from the starter push button is routed through the winding directly to ground. The second winding also gets power from the starter push-button . . . but it terminates on the OUTPUT terminal of the contactor . . . its path to ground is THROUGH the non-rotating starter motor.

In the Figure 3, I show the starter button closed and electron flow coming through BOTH solenoid windings in the same direction around the core . . . they AID each other in exerting a force on the solenoid armature which begins to move the pinion gear out to engage the ring gear. When the starter motor is not in motion, it looks pretty much like a dead short to ground. Current flowing through the large-wire coil is on the order of 25 amps. Current flowing in the small wire coil is lower . . . about 10 amps. During this time, current through the starter push button is on the order of 35 amps!!! The total magnetic force available to move things is $35 \cdot T$ ampere-turns.

After the pinion gear engages, the contactor closes and puts a short across the large-wire coil reducing its current draw to zero. The Figure 4 shows the contactor closed to (1) apply power from battery to the starter motor and (2) relieve starter push-button loading by about 25.

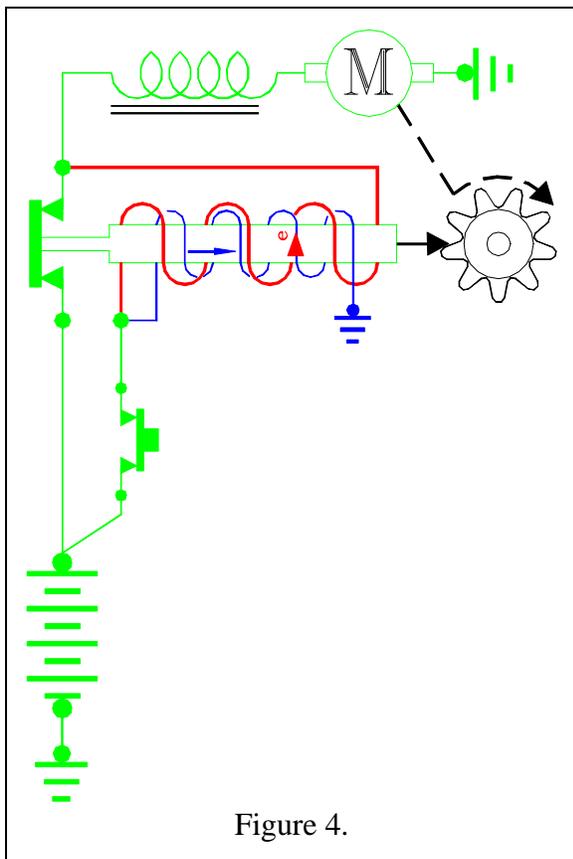


Figure 4.

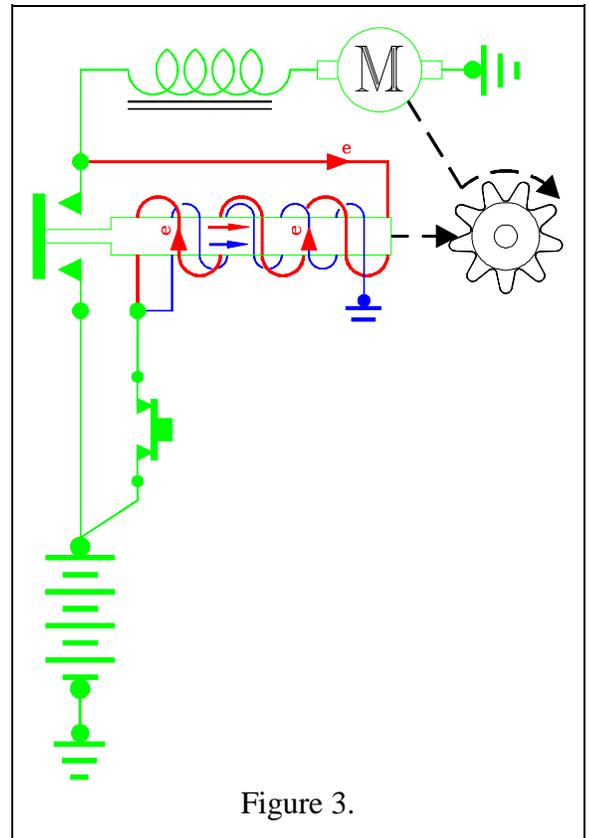


Figure 3.

At this time, the pinion gear is engaged, power is applied to the starter motor, and HOLDING current for the solenoid drops to about 10 amps.

When the engine starts, the starter push button is released which produces an interesting result. Check out what happens in Figure 5. With no source of power through the starter push button, the downstream side of the starter contactor becomes the source of power. The two coils of the starter solenoid are now in series with electron flow in OPPOSITE directions. Current flow at all points within a series circuit are the same. Both coils have the same number of turns. Hence, each coil generates a magnetic field equal to but opposite that of the other. The net force is zero. The solenoid relaxes shutting off power to the starter motor and retracting the pinion gear from the ring gear.

This design has several important operating considerations. (1) current flow through the starter switch for the few milliseconds it takes to close the starter contactor is quite high . . . on the order of 25-35 amps. (2) This high initialization current produces a snappy, high value engagement force to move the pinion gear into position and close the starter contactor. (3) Once the contactor is closed, power to keep the solenoid energised falls to a small fraction of the initial current flow. (4) when the start push button is released, the equal but opposite fields produced by the pair of solenoid windings allows the dis-engagement springs to retract the pinion gear and shut off the motor with greatest possible dispatch.

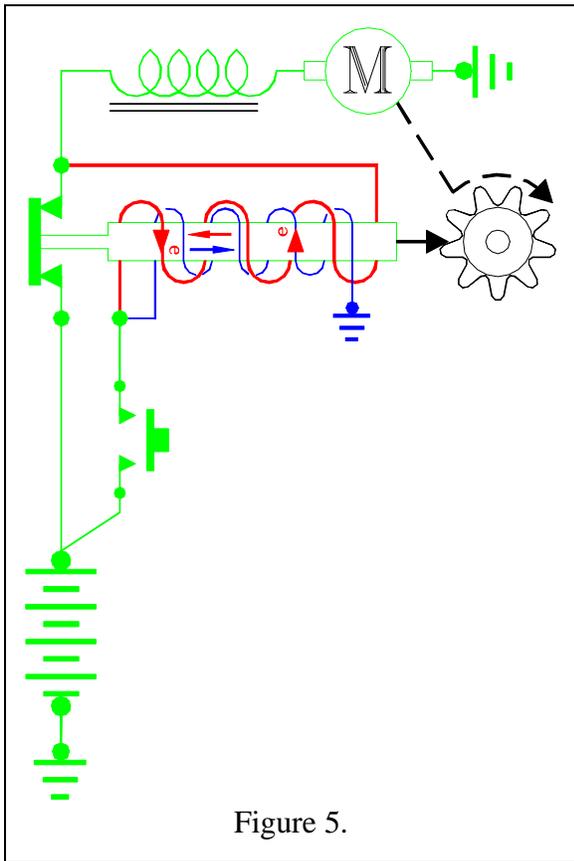


Figure 5.

This arrangement has a major disadvantage . . . it's really hard on starter push buttons. Many of the small import cars that feature this solenoid system suffer from accelerated wear of the contacts in the key lock switch. A few years back, one of my wiring diagrams called for starter switch current to be brought through a 10 amp, essential bus alternate feed fuse. I tried to eliminate the need for a separate starter contactor by utilizing the contactor built into the current offering of lightweight starters. I'd overlooked the 35 amp/50 millisecond pulse required to engage this type of solenoid . . . the E-Bus alternate feed fuse blew immediately.

B&C has always recommended installation of a separate starter contactor and wiring the starter as shown in figure 6. B&C jumpers the starter solenoid coil terminal to the contactor main terminal on every starter shipped. Starter contactors offered by B&C and ourselves have coil resistances of about 4 ohms. Energizing this device from a 12-volt battery produces starter button currents on the order of 3 amps.

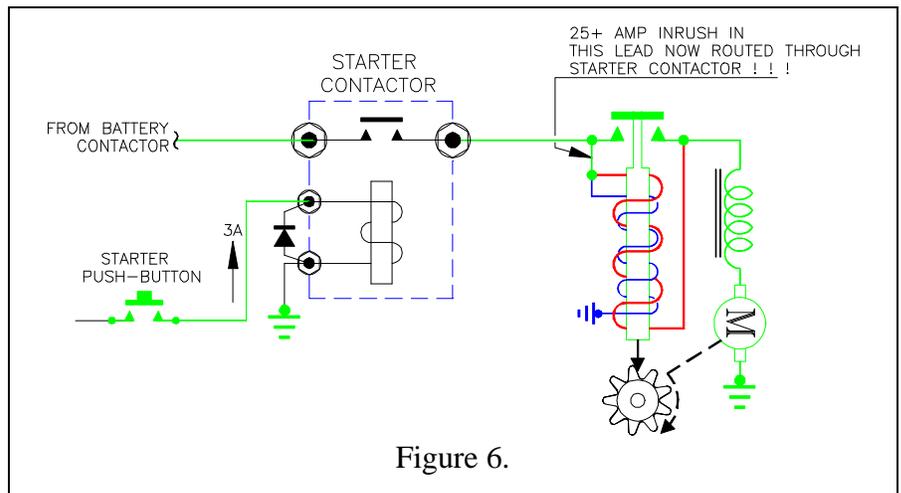


Figure 6.

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