Chapter 3: STARTER /CRANKING MOTER AND ITS CIRCUIT

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OBJECTIVES:

After studying this chapter on Starting system the reader should be able to:

- **Constructional and functional details of starter.**
- **Starter drive mechanism & its types.**
- **Describe how the cranking circuit works.**
- **Explain how to disassemble and reassemble a starter motor and solenoid.**
- **Diagnose starter system troubles.**
- **Describe how to perform cranking system testing procedures.**
- **Perform Voltage Drop Test on starting system.((Practical 4 on Starter circuit tests)**
- **Test the starter motor. (Practical 5 on Starter Motor tests)**

The **cranking circuit** includes mechanical and electrical parts required to crank the engine for starting. **The purpose and function of the cranking circuit to create the necessary power by converting electrical energy from the battery into mechanical energy at the starter motor and rotate the engine.**

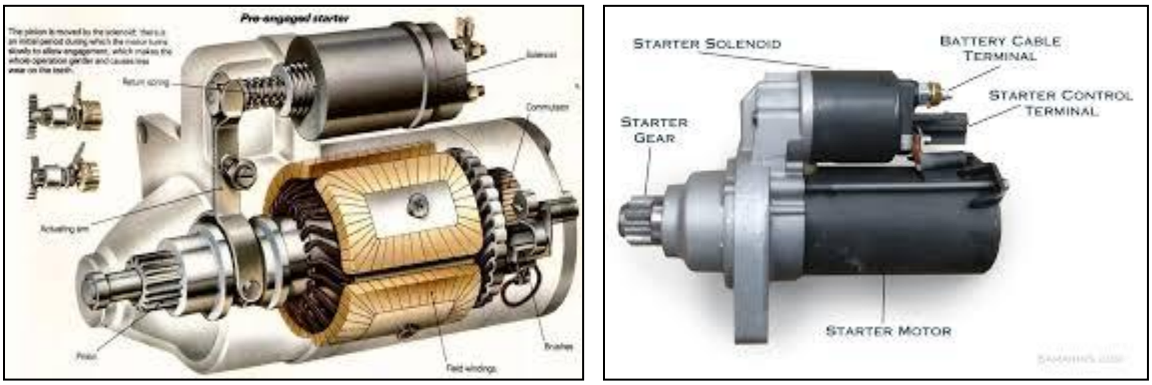

Fig. 4.1 A typical solenoid-operated starter.

Components of Starting System:

1. The **Starter motor**. The starter is normally a 0.5- to 2.6-horsepower (0.4 to 2.0 kilowatts) electric motor that develops nearly 8 horsepower(6 kilowatts) for a very short time when first cranking a cold engine.
2. **The Battery**. The battery must be of the correct capacity and be at least 75% charged to provide the necessary current and voltage for correct operation of the starter.

3. The **Starter solenoid or relay**. The high current required by the starter must be able to be turned on and off. A large switch would be required if the current were controlled by the driver directly. Instead, a small current switch (ignition switch) operates a solenoid or relay that controls the high starter current.

4. The **Starter drive**. The starter drive uses a small gear that contacts the engine flywheel gear and transmits starter motor power to rotate the engine.

5. The **Ignition switch** The ignition switch and safety control switches control the starter motor operation.

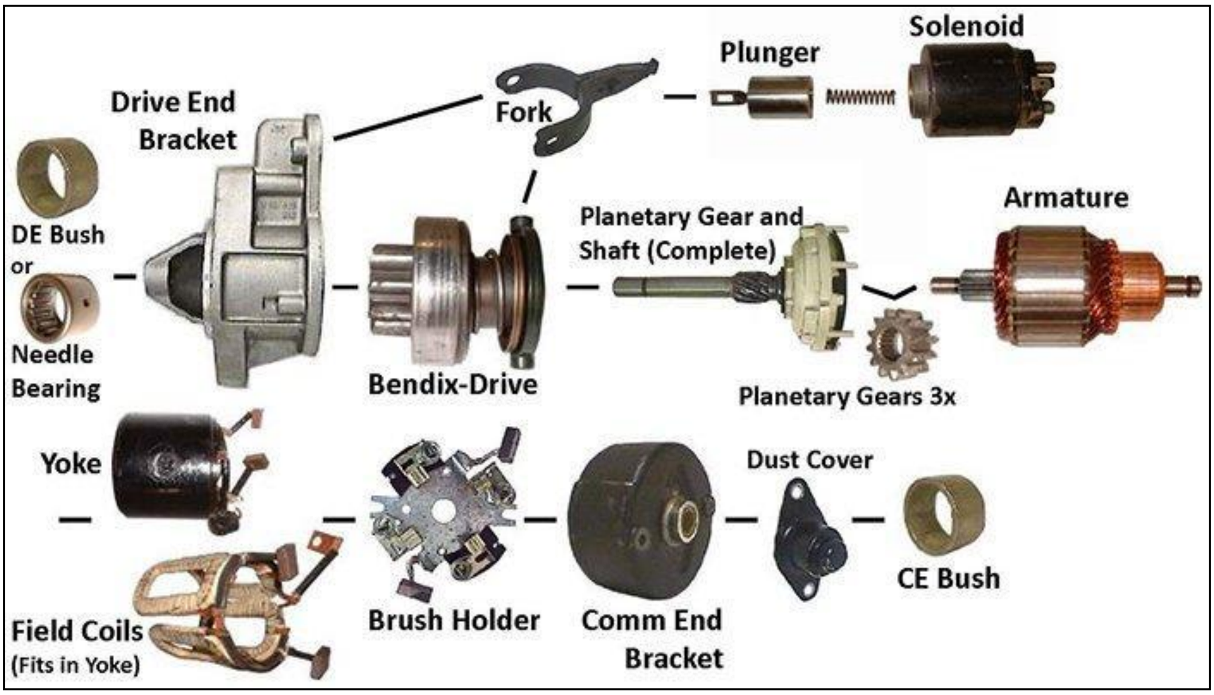

Fig. 4.2 Disassembled view of a typical Starter Motor

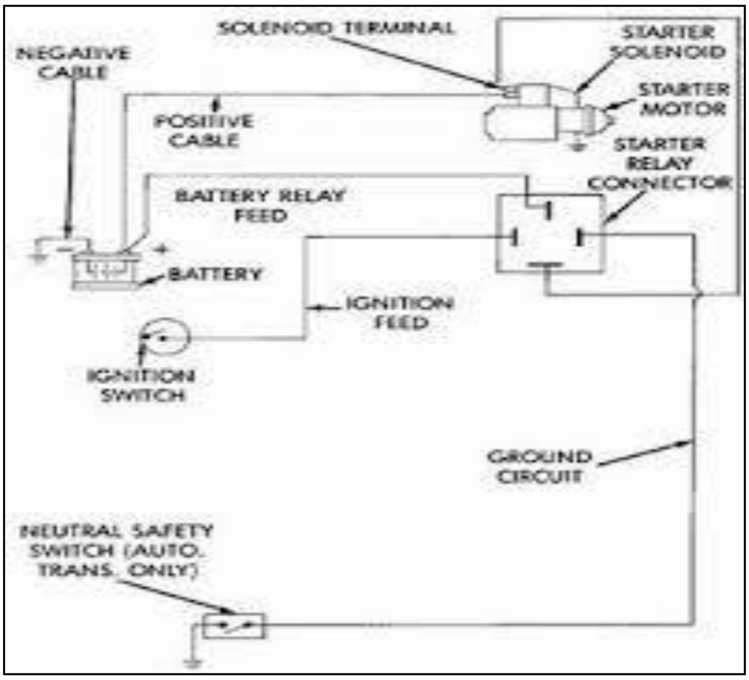

Fig. 4.3 A typical wiring diagram of a starter circuit

The engine is cranked by an electric motor controlled by a key-operated ignition switch.
The ignition switch will not operate the starter unless the transmission is in *neutral* or *park*. Many manufacturers a **neutral safety switch** that opens the circuit between ignition switch and starter to prevent operation unless the gear selector is in neutral or park.

COMPUTER-CONTROLLED STARTING

Some key-operated and most push-button-to-start ignition systems use the computer to crank the engine. The ignition switch *start* position on the push-to-start button is used as an input signal to the power train control module (PCM).

The ignition key can be turned to the start position, released, and the PCM cranks the engine until it senses that the engine has started. The PCM can detect that the engine has started by looking at the engine speed signal.

Normal cranking speed can vary between 100 and 250 rpm. If it exceeds 400 rpm, the PCM determines the engine started and opens the circuit to the "S" (*start*) terminal of the starter solenoid.

Computer-controlled starting is almost always part of the system if a push-button start is used.

Before the PCM cranks the engine, the following conditions is a must:

- The brake pedal is depressed.
- The gear selector is in Park or Neutral.
- The correct key fob (code) is present in the vehicle.

Starting System diagnosis and Testing:

Whenever diagnosing any starter-related problem, open the door of the vehicle and observe the brightness of the dome or interior light(s) while attempting to crank the engine.

- The brightness of any electrical lamp is proportional to the voltage.
- Normal operation of the starter results in a slight dimming of the dome light.
- If the light remains bright, the problem is usually an open circuit in the control circuit.
- If the light goes out or almost goes out, the problem is usually a discharged or defective battery or a shorted or grounded armature of field coils inside the starter.

STARTER DRIVES

A **starter drive** includes a small pinion gear that meshes with and rotates the larger gear on the flywheel for starting. The ends of the starter pinion gear are tapered to help the teeth mesh more easily without damaging the flywheel ring gear teeth.

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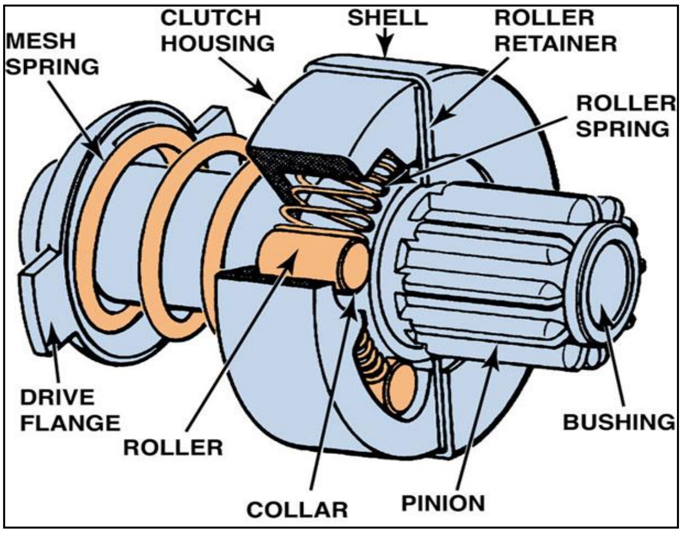

Fig. 4.4 **A cutaway of a typical starter drive.**

The pinion gear must engage with the engine gear slightly *before* the starter motor rotates, to prevent serious damage to either the starter gear or the engine, but the pinion gear must be disengaged after the engine starts.
The ratio of teeth on the engine gear to the number on the starter pinion is between 15:1 and 20:1. A typical small starter pinion gear has 9 teeth that turn an engine gear with 166 teeth. This provides an 18:1 gear reduction; thus, the starter motor is rotating approximately 18 times faster than the engine.

Normal cranking speed for the engine is 200 rpm. This means that the starter motor speed is 18 times faster, or 3600 starter rpm (200 × 18 = 3600).

If the engine started and accelerated to 2000 rpm (normal cold engine speed), the starter would be destroyed by the high speed (36,000 rpm) if not disengaged from the engine.

All starter drive mechanisms use a type of one-way clutch that allows the starter to rotate the engine, but turns freely if engine speed is greater than starter motor speed.

This clutch is called an **overrunning clutch** and protects the starter motor from damage if the ignition switch is held in the start position after engine start.

The overrunning clutch, which is built in as a part of the starter drive unit, uses steel balls or rollers installed in tapered notches.

Whenever the engine rotates faster than the starter pinion, the balls or rollers are forced out of the narrow tapered notch, allowing the pinion gear to turn freely (overruns).

The starter drive (pinion gear) must be moved into mesh with the engine ring gear before the starter motor starts to spin. Most starters use a solenoid or magnetic pull of the shunt coil in the starter to engage the starter pinion.

A starter drive is generally dependable and does not require replacement unless defective or worn. Major wear occurs in the overrunning clutch section of the starter drive unit.

The steel balls or rollers wear and often do not wedge tightly into the tapered notches as is necessary for engine cranking.

A worn starter drive can cause the starter motor to operate freely, not rotate the engine, and makes “whining” noise. The whine indicates the starter motor is operating and the starter drive is not rotating the engine flywheel.

The entire starter drive is replaced as a unit. The overrunning clutch section of the starter drive cannot be serviced or repaired separately because the drive is a sealed unit.

Starter drives are most likely to fail intermittently at first, then more frequently, until replacement becomes necessary. Intermittent starter drive failure (starter whine) is often most noticeable during cold weather.

SOLENOID OPERATED STARTERS

A **starter solenoid** is an **electromagnetic switch** containing two separate but connected electromagnetic windings. This switch is used to engage the starter drive and to control the current from the battery to the starter motor.

The two internal windings contain approximately the same number of turns but are made from a different gauge wire. Together both windings produce a strong magnetic field that pulls a metal plunger into the solenoid.

The plunger is attached to the starter drive through a **shift fork lever**. When the ignition switch is turned to the start position, the motion of the plunger into the solenoid causes the starter drive to move into mesh with the flywheel ring gear.

The heavier-gauge winding (called the **pull-in winding**) is needed to draw the plunger into the solenoid.

The lighter-gauge winding (called the **hold-in winding**) produces enough magnetic force to keep the plunger in position.

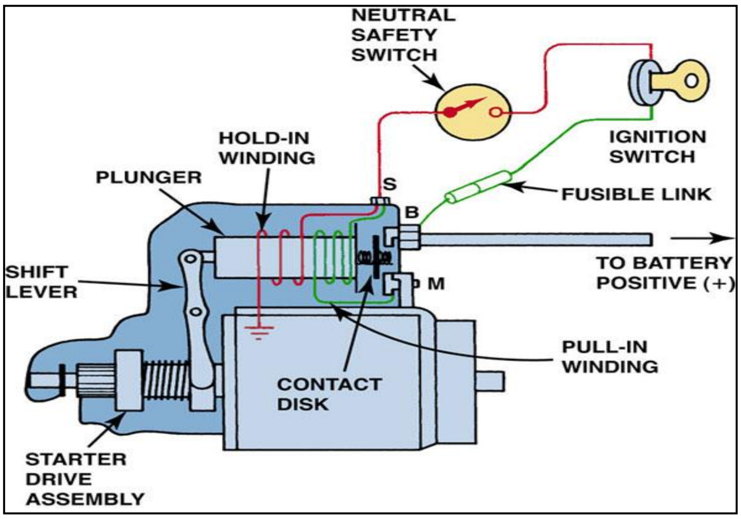

Fig. 4.5 Wiring diagram of a typical starter solenoid. Notice that both the pull-in winding and the hold-in winding are energized when the ignition switch is first turned to the "start" position. As soon as the solenoid contact disk makes electrical contact with both B and M terminals, the battery current is conducted to the starter motor and electrically neutralizes the pull-in winding.

VOLTAGE DROP TESTING

Voltage drop is the drop in voltage that occurs when current is flowing through a resistance.

A voltage drop is the difference between voltage at the source and voltage at the electrical

device to which it is flowing. The *higher* the voltage drop, the *greater* the resistance in the circuit.

NOTE: Before a difference in voltage (voltage drop) can be measured between the ends of a battery cable, current must be flowing through the

cable. *Resistance is not effective unless current is flowin*g. If the engine is not being cranked, current is not flowing through the battery cables and the voltage drop cannot be measured.

- **Low-voltage drop Low resistance**
- **High-voltage drop High resistance**

According to Bosch Corporation, all electrical circuits should have a maximum of 3% loss of the voltage of the circuit to resistance. Therefore, in a 12-volt circuit, the maximum loss of voltage in cables and connections should be 0.36 volt (12 X 0.03 = 0.36 volt.) The remaining 97% of the circuit voltage (11.64 volts) is available to operate the electrical device (load). Just remember:

Basic Check

WARNING

Never operate the starter motor than 30 seconds at a time without pausing to allow it to cool for at least two minutes. Overheating, caused by excessive cranking, will seriously damage the starter motor.

Basic starter testing can be done without tools. The problem is a bad battery and a defective starter cause the same symptoms. First test and charge the battery to confirm it is in good condition.

1. Place a voltmeter across the battery and try to start the car.
2. If starter makes no sounds and voltmeter doesn't move, check the wires from the ignition switch to the starter. Place the voltmeter on the starter wires and check for 12 volts at the little wire when the ignition is turned to *START* . The problem is most likely not the starter, but the solenoid, ignition switch, neutral safety switch or wiring to the starter.
3. If the starter clicks and the voltmeter moves very little, check the solenoid, battery cables and wire connections.
4. If the engine cranks very slow or seems to jam, the starter is the probably bad.
5. If the vehicle is hard to crank warm, but after given time to cool cranks easier, the starter is the most likely problem.

Before condemning the starter, always check the engine's mechanical condition. A good starter cannot crank a damaged engine, or an engine that has been extremely overheated, is low on oil, or has extremely thick and dirty oil.

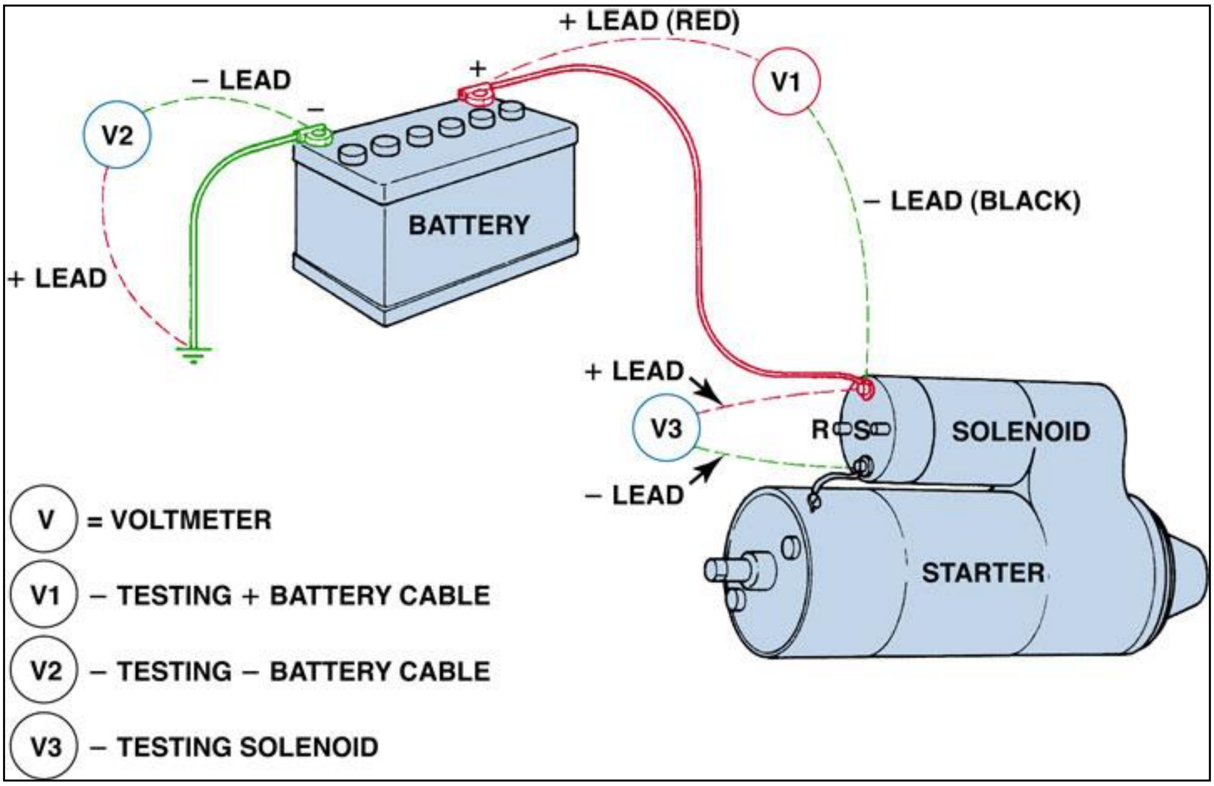

Fig. 4.6 Arrangement for Voltage drop Test on Starting circuit.

Fig. 4.6 To test the voltage drop of the battery cable connection,

Crank the engine with a voltmeter connected to the battery and record the reading, then again with the voltmeter connected across the starter and record the reading. If the difference in the two readings exceeds 0.5 volt, perform the following to determine the exact location of the voltage drop.

Step 1 Connect the positive voltmeter test lead to the most-positive end of the cable being tested. The most-positive end of a cable is the end closest to the positive terminal of the battery.

Step 2 Connect the negative voltmeter test lead to the other end of the cable being tested. With no current flowing through the cable, the voltmeter should read zero because both ends of the cable have the same voltage.

Step 3 Crank the engine; voltmeter should read less than 0.2 volt.

Step 4 Evaluate results. If the voltmeter reads zero, the cable being tested has no resistance and is good. If the voltmeter reads higher than 0.2 volt, the cable has excessive resistance and should be replaced. Before replacing the cable, make certain connections at both ends of the cable being tested are clean and tight.

The control circuit for starting includes the battery, ignition switch, neutral or clutch safety switch, and starter solenoid.

Whenever the ignition switch is rotated to the start position, current flows through the ignition switch and the neutral safety switch and activates the solenoid.

An open or break anywhere in the control circuit will prevent operation of the starter motor.

Starter motor Troubles –Diagnosis Chart

Condition	Possible Cause	Check or Correction
No cranking Light stays bright	Open circuit in switch. Open circuit in starting motor. Open in control circuit.	Checks switch contacts and connections. Check commutator, brushes & connections Check solenoid, relay &other connections.
No cranking Lights dim heavily.	Trouble in the engine. Battery low. Very low temperature. Drive pinion jammed. Frozen shaft bearing, direct short in starting motor.	Check engine to find trouble. Check, recharge or replace battery. Free pinion. Repair starting motor.
No cranking lights dim slightly.	Pinion not engaging. Excessive resistance or open circuit in starting motor.	Clean pinion and sleeve. Replace damage part. Clean commutator. Replace brushes. Repair poor connections.
No cranking lights go out.	Poor connection, probably at battery	Clean cable clamp and terminal. Tighten clamp
No cranking, no lights	Battery dead Open circuit.	Recharge or replace battery. Clean and tighten connections. Replace wiring.
Engine cranks slowly but does not start	Battery run down. Very low temperature. Starting motor defective. Undersized battery cables. Mechanical trouble in engine. Also, driver may have run battery down trying to start.	Check, recharge or replace battery. Battery must be fully charged. Test starting motor. Install cables of adequate size. Check & overhaul engine.

Engine cranks at normal speed but does not start	Ignition system defective. Fuel system defective. Compression leak/engine defective.	Try spark test, ignition timing & ignition system service. Fuel pump, fuel line injector. Check compression, replace gasket or valve timings or engine overhaul.
Solenoid plunger chatters	Hold in winding of solenoid open. Low battery.	Replace solenoid. Charge Battery.
Pinion disengages slowly after starting	Sticky solenoid plunger. Overrunning clutch sticks on armature shaft. Overrunning clutch defective. Shift fork return spring defective.	Clean & free plunger. Clean armature shaft and clutch sleeve. Replace clutch. Install new spring.

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