Like most other systems on late model vehicles, charging systems have become smarter and more complex. Today's computer controlled charging systems can do things traditional charging systems can't, which makes diagnosis more difficult when something goes wrong.

Alternators have one of the highest return rates of any repair part. When a newly installed alternator fails to charge properly, the assumption is that there must be something wrong with the unit. You have an unhappy customer who either wants an exchange or a refund. Yet when most of these returned alternators are bench tested, they work perfectly – which means the real problem is not a bad alternator but something else in the charging control system or the wiring.

How Charging Output Is Controlled
Alternators are either externally or internally regulated. An electromechanical or electronic voltage regulator mounted somewhere in the engine compartment (externally regulated) or mounted on or inside the alternator housing (internally regulated) controls charging output. The voltage regulator raises and lowers the alternator's charging output by changing the current in the field coils on the spinning rotor inside the alternator. Increasing the rotor field current increases the strength of its magnetic field, which in turn induces more current in the stator windings around the rotor to generate more output.

With this type of simple voltage regulation, alternator output is controlled primarily by battery voltage and electrical loads on the system. When the voltage regulator senses the battery state of charge is low, it increases charging output so the battery can be brought back up to full charge. Likewise, when the voltage regulator senses any increase in electrical load from turning on accessories such as the lights, wipers, A/C, heater, defrosters, radio, etc., it increases charging output to meet the demand. Consequently, charging output increases in response to low battery voltage and loads placed on the battery by electrical accessories.

Temperature is also a factor. A cold battery requires a higher charging voltage because the chemical reactions inside the battery are slowed by the drop in temperature. Because of this, a temperature-sensing thermistor is included in the voltage regulator circuit to compensate for temperature changes. This allows the regulator to increase charging output when the battery is cold for faster charging and to reduce charging output when the battery is warm to prevent over-charging (which could damage the battery).

How Charging Output Changes
Normal charging voltage on most vehicles typically ranges from about 13.5 to 14.5 volts at idle depending on the battery's state of charge, electrical load and temperature. The alternator's output current (amperage) depends on engine speed. The higher the speed, the faster the alternator spins and the more amps it generates. Most alternators reach their maximum amp output by 2500 RPM, but only produce

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about 20 to 40 percent of their rated amp output at idle.

With noncomputer voltage regulation, the charging output responds almost immediately to changes in load on the system. When the engine is running above idle, there is usually enough charging output to recharge the battery and meet all of the electrical loads that are placed on the system. But when the engine is idling, the alternator may not produce enough current to keep up with all of the charging demands that are being placed upon it. The battery makes up the difference, which is okay as long as the battery is at or near full charge. But if the engine continues to idle with high electrical loads on the system, it can slowly drain or run down the battery. The battery may also run down if the vehicle is not driven often enough or far enough to fully recharge the battery.

As the charging load on the alternator increases, it takes more horsepower to turn the alternator. This can "lug down" the engine at idle which may cause the engine to stumble and shake (especially small displacement four cylinder engines). Most OBD II vehicles have strategy built into the PCM software to minimize this effect.

**Computer Controlled Charging**

With computer controlled voltage regulation, the output curve of the charging system is no longer tied only to the battery state of charge or electrical loads on the system. Charging output can be increased or decreased independent of these factors to optimize idle quality, battery charging, battery life, alternator life, lamp life, vehicle performance and especially fuel economy.

For example, slowly ramping up the charging voltage following a sudden increase in electrical load (as when turning on the headlights, electric defrosters, heater, etc.) smooths the transition to a higher charging output. This reduces the impact on engine idle quality for less harshness and vibration. A computer controlled charging system may also boost the engine's idle speed if necessary to increase charging output and/or to reduce the lugging effect on the engine (especially following a cold start).

During full throttle acceleration, charging output may be momentarily reduced to maximize available engine power. During deceleration, charging output may be momentarily increased to capture "free" energy (similar to regenerative braking with a hybrid).

Charging output can also be reduced to shift more of the electrical load to the battery when the vehicle is cruising to improve fuel economy.

In the 1980s, Chrysler was the first domestic car maker to reassign the task of voltage regulation to the Powertrain Control Module (PCM). Ford came next, followed by General Motors and most other vehicle manufacturers in the 1990s and 2000s.

With smart charging, there's still a voltage regulator in the back of the alternator on GM and Ford applications, but it is now under the command of the PCM (or the PCM and Body Control Module working together on many GM applications). The regulator uses "Pulse Width Modulation" to switch the current to the rotor's field coils on and off. By increasing the "duty cycle" (on time) of the field coils, the regulator increases charging output. The PCM, in turn, tells the regulator how much duty cycle is required based on its programmed operating logic, battery voltage, battery temperature, the load on the electrical system and other inputs. This allows the computer to change the charging output instantly or gradually as the situation dictates.

**GM's Regulated Voltage Control**

In 2004, GM began using a smart charging approach called "Regulated Voltage Control" (RVC) on some of its cars and trucks. Several versions of RVC have been used, but basically...
Computer Controlled Charging Systems

they all vary the alternator’s charging output according to various operating modes. These include:

- Charge Mode – Bumps up the charging voltage when the battery is low or when there are unusually high loads on the system.
- Fuel Economy Mode – Lowers charging output to just under 13 volts to reduce the alternator’s load on the engine.
- Voltage Reduction Mode – Reduces charging output when the battery is fully charged and electrical loads are low.
- Start Up Mode – Momentarily fixes charging output at a steady 14.5 volts for 30 seconds following an engine start.
- Windshield De-ice Mode – Increases charging output when the defrosters are on.
- Battery Sulfation Mode – Increases charging voltage after 45 minutes if the battery is low.

On some of these systems, the Body Control Module (BCM) is the main module that determines the charging system’s operating mode. The BCM signals the PCM when more or less charging output is required and the PCM responds by changing the duty cycle to the voltage regulator in the alternator (via the L-terminal circuit). It’s a multi-step process that involves feedback from the alternator field duty cycle signal circuit, and input from a battery current sensor connected to the negative or positive battery cable at the battery.

On other GM applications with “Stand Alone Regulated Voltage Control” (SARVC), the Body Control Module does not control charging. Rather, a separate module on the negative battery cable performs this function along with sensing battery voltage, load and temperature.

The operating strategy of both the RVC and SARVC systems is to maintain the battery at an 80 percent or higher state of charge while modifying the charging curve to optimize fuel economy. Ford, Chrysler and other auto makers use a similar operating strategy with their charging systems. How they accomplish this will vary depending on the design of the charging system and the year, make and model of the vehicle – which is why access to factory service information is absolutely critical for testing and diagnosing late model charging systems.

Diagnosis

An alternator in a computer controlled charging system functions essentially the same as an alternator in a noncomputer controlled system. The only difference is that the observed charging voltage may vary more with computer control and change suddenly independent of battery voltage or electrical load. Also, because the alternator is under the control of the PCM, BCM or other module, faults in the control circuit or wiring can cause charging problems that may be mistakenly blamed on a bad alternator. It is very important to check ALL modules for DTCs.

A vehicle may have a charging problem if the battery is low or discharged, a Low Voltage warning light is on, or the charging gauge is indicating lower than normal voltage. The first thing that should always be checked is the charging system’s output voltage. This can be done with a digital voltmeter at the battery terminals while the engine is idling, or with a battery/charging system tester. The latter is usually the best tool to use because most charging system testers can also detect AC ripple voltage problems caused by one or more bad diodes in the alternator rectifier assembly.

The diode trio in the rectifier converts the alternator’s AC (Alternating Current) output to DC (Direct Current). Diode failures can reduce charging output and create AC “noise” in the electrical system that may disrupt the normal operation of other onboard electronics. Bad diodes can also allow voltage leaks back through the alternator that can drain the battery when the key is off.

If the charging voltage is within specifications (typically 13.5 to 14.5 volts), the next step would be to test the battery with a load tester or capacitance tester. The battery must be at least 75 percent charged before using a load tester otherwise the test results may not be accurate. A battery that tests BAD needs to be replaced. If the battery tests GOOD, the battery cables should be inspected, cleaned and retightened.

If the charging voltage is LESS than specifications, a DVOM can be used to test the output power and ground circuits for excessive voltage drop. Voltage drop is measured by using the DVOM volt meter function. One DVOM probe is placed on one side of a connection and the other probe on the opposite side of the connection while current is flowing through the connection. More than 0.2 volts of voltage drop across a connection indicates excessive resistance.

If the alternator overcharges, test the voltage sense circuit for excessive voltage drop.

If an external control problem is...
suspected, start by checking all DTCs in all modules with a scan tool. Follow the OE test procedure for that specific DTC. GM RVC alternators will charge at a default rate of approximately 13.2 to 13.8 volts with the regulator unplugged. Ford PCM controlled alternators will charge at a default rate of about 13.5 volts if there is a control issue, but only if engine speed goes over 4500 RPM for 3 seconds. If these alternators charge at the default rate the DTC is the result of an issue outside of the alternator.

Chrysler does not use an internal regulator. All field current is directly controlled by the PCM. Disconnecting the small 2-wire plug at the alternator will result in no output.

The alternator can also be removed from the vehicle for bench testing to verify if it is good or bad. Bench testing should always be done when a customer brings in a questionable alternator. If the alternator fails to pass both voltage and amp output tests, your customer needs a new alternator. If the alternator tests GOOD, the charging problem is in the wiring or the computer control circuit. This will require additional wiring checks and seeing whether or not the control module is sending a control signal to the alternator.

Scan Tool Diagnostics
A scan tool can also be used to diagnose charging faults. Most scan tools have a PID (PID can be defined as Parameter Identification. It’s basically a menu list of sensor readings and other system data that a scan tool can display.) that displays system voltage. Additional PIDS may be provided to show the charging mode and other charging perimeters. If voltage is out of range (too high or too low) and remains out of range, it should set one or more fault codes. The next step would be to follow the diagnostic charts for any codes that are present to isolate the cause of the problem.

The bottom line is to make sure the fault that is causing a charging system problem has been correctly diagnosed BEFORE any parts are replaced.

Related Sales
- Battery
- Battery cables
- Battery and charging system test equipment

Review Questions February 2013

1. All of the following are TRUE about alternators, EXCEPT:
   a. Typical charging voltage is 13.5 to 14.5 volts
   b. Charging output is highest at idle
   c. They produce AC voltage, then convert it to DC voltage
   d. Charging output can change with engine speed

2. A Computer Controlled Charging System can do all of the following EXCEPT:
   a. Increase charging output gradually when the electrical load suddenly changes
   b. Decrease the charging output when decelerating to save fuel
   c. Reduce the charging voltage when cruising to save fuel
   d. Change the charging voltage independent of load or the battery’s state of charge

3. No charging output can be caused by:
   a. A defective alternator
   b. A defective voltage regulator
   c. A wiring fault or bad PCM, BCM or charging control module
   d. Any of the above

Questions a Customer Might Ask About Computer Controlled Charging Systems:

Q. My Low Voltage warning light is on. Do I need a new battery, alternator or what?
A. It’s hard to say what might be causing your problem. You need to have your charging system and battery tested before the problem can be diagnosed.

Q. I replaced the alternator on my late model vehicle, and it still isn’t charging. The alternator must be no good. I want a replacement.
A. It’s probably not your alternator. But to make sure, we will bench test the unit. If it doesn’t pass the test, we will replace it as long as it is under warranty. If it tests good, the problem is not the alternator but something in the wiring or computer control system.

Q. What kind of tools do I need to check my alternator’s charging voltage?
A. You can use a simple DVOM to check the charging output, or a battery/charging system analyzer, or a scan tool.