Electrical Systems, Part 1

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In 1982, Porsche did something that changed its cars forever: It introduced Digital Motor Electronics, which was first installed in the then-new 944. The 911 got DME a year later, for 1984. Based around a computer control unit, DME collected input signals from multiple engine sensors and in turn set engine spark timing and fuel enrichment parameters. The highly complex DME systems in today's Porsches were developed from these early engine management systems.

With the introduction of the electronic control unit (ECU) came another change: Cars became very sensitive to electrical system issues like ground connections, overvoltage, current spikes, and, especially, reversed polarity. Corroded ground connections could cause a car to run terribly, while diode failure in the alternator could allow A/C voltage into the ECU and cause the car to not run at all. Additionally, computer-controlled systems are highly vulnerable to badly executed jump starts — which some consider the equivalent of playing Russian Roulette with the ECU.

In this *Tech Forum*, we'll look at some issues relating to Porsche electrical systems in everything from 356s to 997s.

Porsche's lithium-ion "starter battery" is not intended to power accessories with engine off.

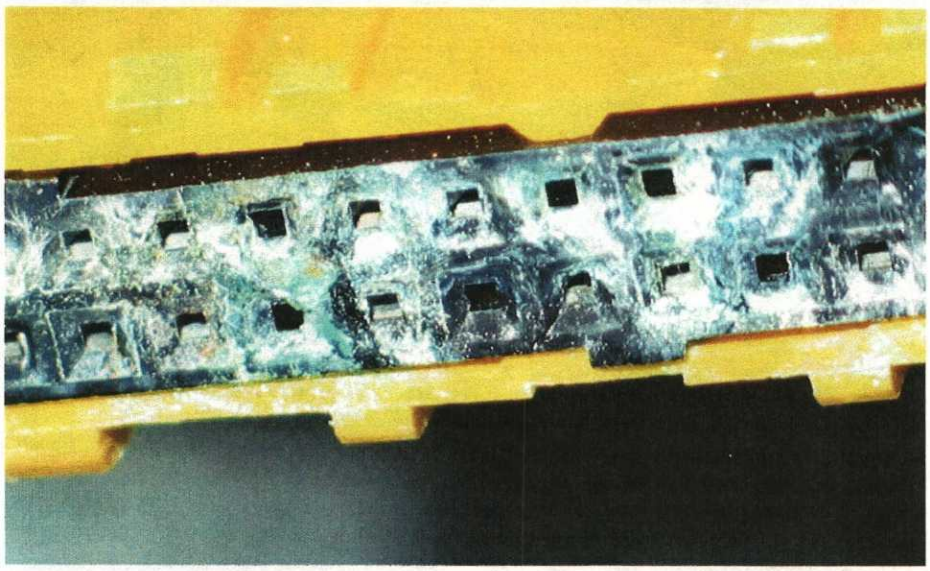
Don't Always Blame the Battery

Every time electrical energy passes through a wiring connection point such as a terminal, harness connector, or wire splice, a small amount of the energy is lost; this is known as a voltage drop. When connections are not good, significant energy can be lost. Ideally, all wiring connections should be clean and tight, allowing the easiest transfer of electrical energy. If a poor connection is suspected, use a digital volt ohmmeter (DVOM) to check the connection and/or resistance through it.

Corrosion at electrical connections is a common problem in all cars, and Porsches are no exception. Corrosion is the disintegration of metals caused by long-term exposure to a corrosive environment or a chemical reaction between dissimilar metals. Corrosion issues are generally more prevalent in climates where humidity and salt/air content are high or where snowfall and salt-treated roads exist. If an electrical contact shows signs of oxidation, there will be a higher resistance at that point and a reduction in electrical energy available to the device at the wiring destination.

In addition to having clean surfaces, all electrical connections must be tight. Loose wiring connections will exacerbate the loss of electrical energy and create more resistance and heat. If a connection is very loose, it can cause a circuit to become intermittent. Intermittent connections or circuits can be difficult to diagnose; it's like chasing a ghost — one moment there's a problem, the next everything is working fine.

All Porsche models can suffer from poor ground connections. This is particularly problematic in computer-controlled cars, where they can cause poor or even non-operating conditions. All electronic devices like the ECU, radio, etc. depend on a solid ground to ensure proper operation. Likewise, the engine needs a solid ground so that higher current will flow through the starter and alternator circuits.



Top: Corrosion of the connectors at a control unit in a 993/911 Turbo that suffered water intrusion. Bottom: A close-up view of the yellow plug clearly shows significant corrosion; this car was experiencing multiple intermittent electrical issues.

One common mistake is leaving the engine/transmission ground strap off following an engine replacement. If this cable is left off, the engine may start and run because the electrical ground is facilitated through the engine and transmission mounts, not to mention other subsystems' ground wires. The ground strap is a critical connection, however.

Regularly inspect the ground connection from the battery to the chassis and the engine and/or transmission to the chassis. It is critical that they are corrosion-free and tight. If the main grounding points are compromised, the whole electrical system can be affected. Electricity will always take the path of least resistance, but, if necessary, it will take whatever path is available. And that can cause problems.

Sometimes, the only way to ensure the ground and other connections are in good condition is to take them apart, inspect them, and clean them. Always disconnect the battery when working on the electrical system — unless you have a 1996-or-later car with Onboard Diagnostics 2, or OBD-2. When disconnecting a battery, disconnect the negative terminal first and reconnect it last.

To clean the connections, you will need a battery terminal brush, some fine steel- or brass-wire brushes, steel wool and/or 3M Scotch Brite pads, and a Dremel tool or power drill with wire brushes and grinding-wheel attachments. You will also want eye protection and a high-quality respirator that catches fine dust particulates; you do not want to breathe this stuff.

Clean the metal surfaces with baking soda and water — which will neutralize any battery acid at the connection — and let them dry completely. Use the appropriate cleaning tools based on accessibility. Clean until you obtain a shiny metal surface with no hint of oxidation. If the metal is badly damaged, replace the component. Once the metal is clean, reinstall the pieces — making sure the connection is tight. Finally, apply a moisture-proofing sealant such as Dow Corning DC4 for electrical connections; this will help keep these connections dry, airtight, and (usually) trouble-free for years.

Okay, Blame the Battery

The National Transportation Safety Board reports that some 400 people are injured every year from lead-acid battery explosions and mishaps. Charging a lead-acid battery creates hydrogen gas from the internal electrolyte. Under normal operation, the charging rate is low — so a low volume of hydrogen gas is produced and is easily vented and dispersed. Overcharging or quick-charging can cause the electrolyte to boil and produce concentrated levels of hydrogen gas that could be explosive.

You should only load-test or test a battery's acid if it is fully charged, i.e. 12.68 volts. Charging a battery fully can take four to six hours. You don't want to quick-charge a battery, as doing so can cause damage to the lead plates due to warping from heat. Additionally, leaving the battery low on electrolyte (which allows air to make contact with the lead plates) or partially discharged for long periods can cause problems due to a condition called sulfation. Sulfation is a buildup of lead sulfate on the surface of the positive and negative lead plates when the battery is discharging. When lead sulfate is left in the battery for a period of time, it tends to crystallize into a hard sulfate that coats the surface of the electrode plates and may only partially dissipate when the battery is recharged. Sulfation is the primary issue that can shorten a battery's life.

Cells can die individually and the battery can appear to be okay until put under a load. The only sure way to see if the battery electrolyte is okay is to check it with a refractometer or hydrometer to verify the specific gravity (SG) of the acid. The lower the SG, the more it is water; the higher the SG, the greater the concentration of acid.

Disconnecting the battery while any car is running will cause alternator damage. Disconnecting the battery at any time on a 1996-or-later Porsche with OBD-2 erases important data, including fuel-injection trim and ignition-system misfire adapta-

tions. These adaptations were learned by the engine management in an effort to run a given engine in its environment, and erasing them could lead to engine damage if preexisting problems were being compensated for. Thus, we recommend running bridge power when changing a 1996-or-later Porsche's battery — or making sure the car is running properly before disconnecting its battery to perform electrical work where the battery must be disconnected as a safety precaution. (We'll cover more on this in Part 2 of this series.)

Today, premium lead-acid batteries are available with an 84-month warranty. If your car is driven regularly, a four- to five-year lifespan is considered good. Lower-priced batteries are available; just remember to keep your cell phone charged and with you. For those who drive their Porsche periodically, the best option is to use a high-quality trickle charger, which will mimic the action of the car's charging system with a low charge rate that varies slightly at around two amps. It will also shut off when the battery is fully charged.

The lead-acid battery is available in four different configurations. These include wet cell, maintenance-free, Gel Cell, and Absorbed Glass Mat (AGM) batteries. Wet-cell batteries are the best value but require the most maintenance, as each cell should be checked every two months for correct electrolyte level and topped up with mineral-free (distilled) water as needed. Maintenance-free wet-cell batteries are sealed and never require electrolyte monitoring. Gel Cell batteries have silica added to their electrolyte, giving it a thick consistency.

The AGM is the newest lead-acid battery design; its electrolyte is impregnated into a fiber-type mat between multiple positive and negative panels in each cell. These batteries cannot leak, even if cracked open. When not in use, AGM batteries will lose about one to three percent of their charge per month where a wet-cell battery can lose up to one percent per day. The only bad news is that AGM batteries can cost twice as much as a premium wet-cell battery.

Something New

Porsche is the first automobile manufacturer to offer a lithium-ion starter battery, and does so in a selected few of its cars. These include the 2010 GT3, 2010 GT3 RS, 2011 GT2 RS, and 2011 Boxster Spyder. Lithium-ion technology was first proposed by Dr. M. Stanley Whittingham in the 1970s, though most of us today recognize lithium-ion as technology utilized in batteries for laptops and cell phones — and the $100,000 Tesla full-electric roadster.

Porsche delivers cars ordered with its lithium-ion battery with a standard lead-acid battery in place and the (uninstalled) lithium-ion battery in the trunk. The latter is not suited for use in temperatures below 32° F due to its more limited capacity. The optional battery costs about $1,700 and weighs 13 pounds — more than 22 pounds lighter than the standard battery. Some may say that's not much weight saved for the money, but those in motorsport at almost any level would likely view this piece as a bargain. After all, winners are measured in thousandths of a second. Pretty cool stuff.

Above: This 993 engine wiring harness did not get replaced in time; the integrity of its wiring insulation has failed, allowing bare conductors to make contact.

If You Must: Jump Start Guidelines

Due to the potential for damaging an ECU or other sensitive electronic components on a computer-controlled Porsche, jump-starting a modern Porsche with a dead battery should be avoided. Tow trucks or Good Samaritans *can* provide a jump start, but the condition of their equipment is not always known or properly voltage-regulated. The jump-starting equipment on tow trucks typically operates at 18 volts but can run as high as 24 volts, which is too high for electronics designed to operate at 12 volts. Finally, even helpful people can make mistakes. And mistakes made — even those unknowingly — during a jump start can permanently damage a very expensive Porsche ECU.

Thus, jump-starting a computer-controlled car should be avoided if at all possible. Doing so is a gamble; your car may be okay — but losing the bet might cost you thousands in repairs. If possible, a better choice is to have your car towed home or to a repair shop where the problem can be properly diagnosed. Of course, this is a huge inconvenience. But the damage to your electronics might be a far bigger one.

If you *must* jump-start a car, the following procedure should help — but in no way will it fully protect your car.

1: **Move both cars'** batteries as close together as possible. Use only the highest quality (if available) jumper cables. Wear protective eyewear.

2: **Turn both cars off** (key out is even better). Turn off all lights, radios, cigarette-lighter adaptors, etc. Connect the (usually red or orange) positive (+) jumper cable to the dead battery's positive (+) post. Make sure all cable ends are separated from one another.

3: **Connect the positive lead** (usually orange or red) to the positive (+) post on the good battery.

4: **Connect the ground lead** (usually black or brown) to the ground (–) post on the good battery. Start the car with the good battery.

5: **Do NOT (!) connect** the cable's other ground (–) connection to the dead battery; it *must* be connected to a clean, unpainted metal nut, bracket, or the engine block on the dead car to help avoid the chance of an explosion. When you connect this ground, expect to see a spark since you are completing a circuit.

6: **Start the dead car.** If it will not crank over

sufficiently, check all connections and try again. If you are still having a problem, rev up the running car to around 2000–3000 rpm and wait for two to three minutes before trying again.

7: Once the dead car starts, turn its headlights on; this will help minimize the chances of damaging its electrical system. Let both cars idle for two to three minutes before removing any cables. This is critical, as it helps minimize the possibility of a dangerous voltage spike.

8: Disconnect the ground (–) cable on the dead car first, then remove the negative (–) cable from the good battery post. Now remove the positive (+) cable from the good battery post and then, finally, the positive (+) cable from the dead battery.

9: Drive directly to a shop or wherever you are buying and installing a new battery. It would be best for someone to follow you in case your charging system isn't working properly.

356s with 6-volt Systems

Over the years, 356 owners have faced a dilemma. The perception is that 356s with their original 6-volt systems are hard to start due to a slower starter cranking speed. Some also say the lights in 6-volt cars are dimmer than those of 12-volt cars. Converting 6-volt 356s to 12-volt systems yields more choices in components, and some opine that 356s seem to operate better on 12 volts. The downside? A proper conversion costs a lot of money and time.

Lately, there's been a trend to install 8-volt batteries in 6-volt 356s and adjust the voltage regulator to 9.6 volts to provide the correct voltage for charging the 8-volt battery. The remainder of the electrical system is unchanged. This change supplies more voltage so that the 6-volt lamps burn brighter and the starter motor spins faster. There is a catch: Be prepared for a shorter life of all electrical-system consumers, especially light bulbs.

Neither the 12- nor the 8-volt conversion address the real issue, however. Over 50 to 60 years, some or all of the connections in a 356 have been affected by corrosion to some degree. Also, some components may be worn and require rebuilding or replacement. Using our guidelines for cleaning ground connections, a thorough cleaning of all connections in a 356 will pay big dividends. Yes, it's a big job — but it can be done in sections.

We suggest 356 owners consider keeping their 6-volt systems because their Porsches, as new cars, worked just as well as any 12-volt cars did. With clean connections, a 6-volt 356 will operate like new and the originality of the car is maintained. Of course, owners of early 911s, 912s, and 914s should consider cleaning and repairing all wiring connections, too — or, at the very least, all ground connections.

1984–89 911 Overcharging

The 1984–89 911 Carrera came with a larger-capacity alternator than its predecessors. When these alternators start to go bad, they tend to intermittently overcharge the electrical system. Two common symptoms are an erratic tachometer needle and a radio that shuts off, then comes back on. This can continue until the overcharging is severe enough to kill the tachometer and blow the internal fuse in the radio.

You can sometimes smell when an alternator is overcharging because boiling battery acid causes a sulfur or rotten egg-like smell. The smell is that of hydrogen gas being produced, which is extremely dangerous and explosive. Additionally, the overcharging can damage the battery and, more importantly, the ECU and other sensitive electronic components. Once the 1989-on 964 models arrived, this symptom was never seen again.

993 Engine Wiring Harness

Porsche AG initiated a voluntary customer service campaign designated W301 for the 1995 and 1996 911 (993) Carrera and Carrera 4 as well as the 1996 (993) 911 Turbo. This service campaign is considered open-ended, meaning there is no specific end date. The issue to be addressed is the inspection and replacement of the engine wiring harness due to potential deterioration of the insulation on the wires inside the harness. Symptoms of a problematic harness include a rough-running engine, stalling, dead battery, starter malfunction, climate-control system issues, and an illuminated Check Engine light.

When the wire insulation deteriorates, the conductors will short circuit and the resulting damage can be considerable. The heat from the short circuit accelerates the insulation breakdown and, under certain conditions, fire can result. The 993 wiring harness is also sensitive to overvoltage and jump-starting, especially if the jumper cables are connected in reverse.

986/996 Alternator Issues

The 986 Boxster and 996-based 911 Carrera have a history of alternator failures. This usually happens when the car has been idling at operating temperature for a period of time. Usually, the volt meter on the far left of the 996's instrument cluster will start out in the 13–14-volt range when the engine is started but will quickly drop to 12 volts, 10 volts, or less depending on the severity of the faulty alternator. This low reading indicates the alternator is not charging adequately and should be replaced. A consistent 13 volts or higher on the instrument cluster voltmeter is a good reading. Unfortunately, the Boxster never had a volt meter. The later, 997-based 911 didn't, either.

On 997s, Bad Cables = Dead Battery

The 997 has a series of three cables that were manufactured with poor crimping of the connector ends onto the electrical conductor. As a result, these connections start to corrode and cause severe voltage drops. The symptom is an undercharged or dead battery. If the battery is replaced, the new battery will go dead in a short time.

The three cables in question are (1) the cable from the battery's positive post to the outside firewall bulkhead connection; (2) the cable from the interior-side firewall bulkhead connection to a connection on the passenger side, next to the transmission; and (3) the cable from the connection at the transmission to the starter and alternator. If you're experiencing the dead-battery symptom, performing a voltage-drop test between any two connections on this cable

series should be performed. An acceptable voltage drop through any normal cable-to-cable connection point is 0.1 volt.

In this series of cables, Porsche recommends a maximum voltage drop through the three installed cables from the battery's positive terminal to the alternator to be 0.4 volts at idle and operating temperature. If these values are exceeded, replacement of these cables is recommended. Generally, the third cable mentioned above (the one for the starter and alternator) is the most likely failure point — but that is not always the case.

AC/DC

While an alternator generates Alternating Current (A/C), a car's electrical system operates using only Direct Current (D/C) energy. Inside the alternator, a set of diode bridges function as a rectifier and convert A/C to D/C. If these diodes fail, possibly due to an improper jump start, A/C voltage can escape into the charging system. A/C voltage can permanently damage any automotive computer or control unit.

When diagnosing a car that has multiple fault codes in every control unit, check for stray A/C voltage. With everything connected and the engine running, set a digital volt ohmmeter (DVOM) to read A/C volts. Attach its probes across the positive and negative battery terminals; you should see no more than 0.1 volts A/C.

An important point to remember when performing an electrical-system diagnosis on a computer-controlled car is to only use a high-quality, high-impedance DVOM. Most of the analog (moving pointer) multimeters or volt ohmmeters (VOM) are low-impedance units and draw power from the circuit being measured to deflect the pointer. Sensitive computer electronics will see this current draw as a short circuit and this may damage the ECU. The high-impedance input of the DVOM impedes current flow from the circuit being measured.

Conclusion

Checking the battery and charging system on your Porsche should be a normal part of your maintenance program. If the battery's condition is weakening or marginal, a preemptive replacement of the battery could save you significant time and money. Enjoy your Porsche.