

AUTO ELECTRIC CORNER —

Hybrid Vehicle Batteries & 14557 Mitsubishi Alternator



BY MOHAMMAD SAMII

HV Battery Change...!

The Toyota Prius, which is the most popular and most built/sold hybrid vehicle worldwide, was introduced in the US market in 2001. It was identified as Gen-I (Generation-I) for the 2001-2003 model years, Gen-II (2004-2009), Gen-III (2010-2015), and Gen-IV from 2016 until now, with improvements and sub-model designation in each generation. Japanese philosophy of continuous improvement (Kaizen) is truly evident in each generation of these vehicles as each one of them embodies major improvements in design and reliability.

I have been trained and certified for Toyota Prius repair, and have an ASE L3 certification that is called “The Light Duty Hybrid/Electric Vehicle Specialist”. Each Toyota dealer service department must have at least one L3 certified tech on their staff.

Toyota hybrid HV battery changes is a specialty of mine and we do a few each year. The Prius vehicles that need battery replacement are some Gen-I but their numbers are dwindling. The most common calls now are for the Gen-II, which are built between the 2004-2009 model years. We have replaced HV batteries on Prius vehicles (Prii in plural...!) with mileages as low as 96K (a 2006 model) and miles up to 290K (a 2008 model) and even a 350K on a Gen-I of 2001 vintage which is a rarity. Since Gen-II is the most often candidate for the battery change, I will try to shed some light on its battery and the process in this month's AEC column.

A Gen-II battery pack assembly (see Figure 1) consists of 28 modules of Nickel Metal Hydride (Ni-MH) with 6 cells of 1.2V each that equates to 7.2 Volts nominal voltage per module. The modules are all connected in series via bus bars which gives a total battery voltage of 202 Volts. This is of course off the shelf and at rest but in real operation a total battery voltage ranges from approximately 220 to 240 VDC (see Figure 2). To get an idea of the enormity of this DC voltage, just imagine if you connected 17 to 19 fully charged 12V car batteries in series...! The resulting voltage is absolutely lethal, thus all the safety precautions MUST BE followed to the letter. High voltage wires throughout the HV battery system and hybrid transaxle are triple shielded and identified with a bright orange color. DO NOT touch any orange colored wire unless you are protected with special insulated gloves. Even then, there is no reason to touch orange wires unless the system is disabled (see Figure 3).

An inverter assembly in the engine compartment that contains the power electronics and has its own liquid cooling system can boost that voltage to upward of 500V PDC with varied frequencies to drive the electric motor (Motor-Generator #2 or MG-2) that is connected to the drive wheels (Figure-4). There is also an MG-1 that is



Figure 1 – A Prius GEN-II HV Battery Pack



Figure 2 – Old and New Batteries with Covers OFF

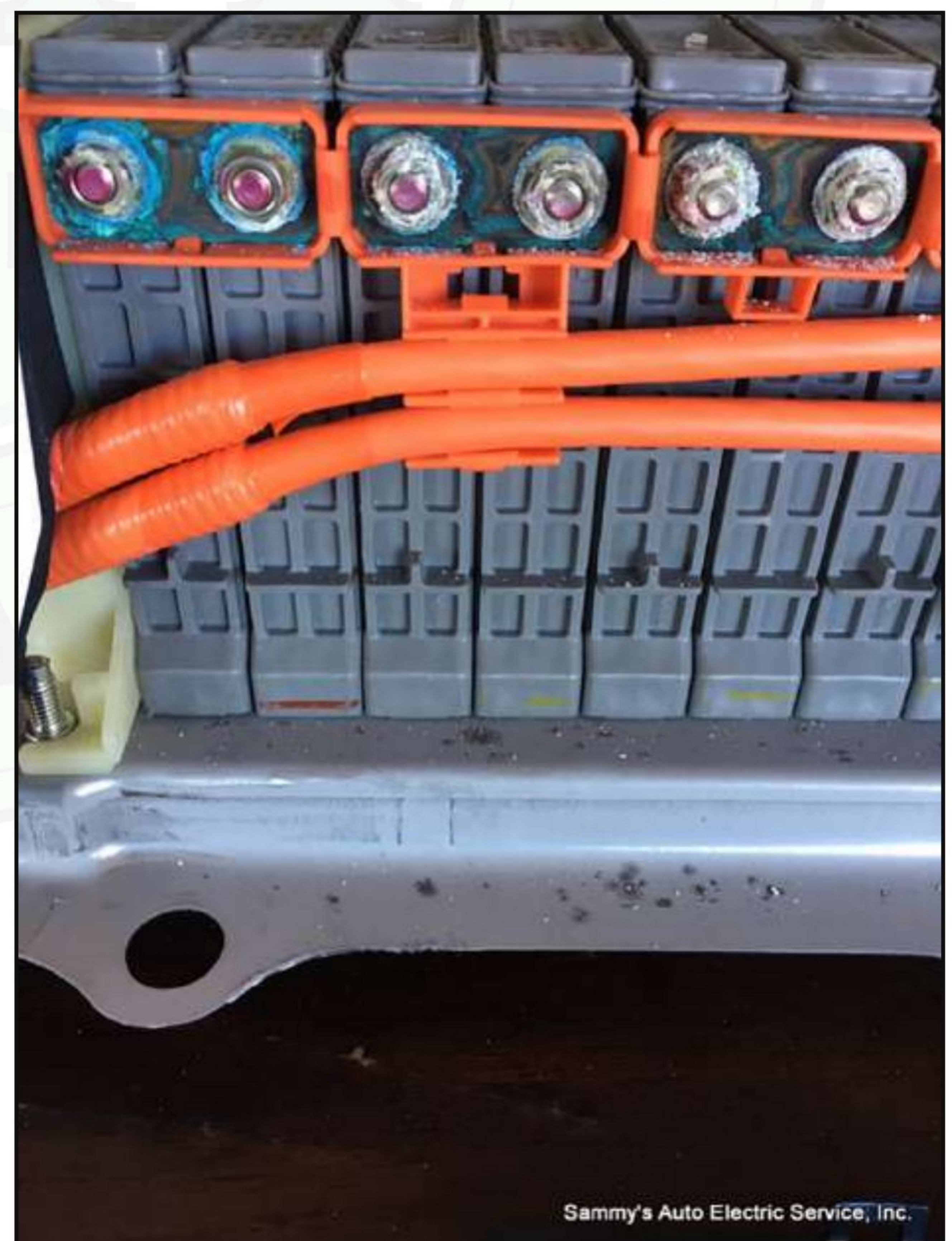


Figure 3 – Orange Wires Mean DO NOT TOUCH...!

AUTO ELECTRIC CORNER

smaller that cranks the engine for starting, and depending on the modes of operation, it can be a generator to charge the HV battery or a motor to assist MG-2 to drive the wheels.

A very clever device that is a mechanical engineering marvel called the Power Split Device combines and manages the power of the ICE (the Internal Combustion Engine), MG-1, and MG-2, depending on the driving mode and the HV battery's state of charge. Both MG's can help drive the wheels or produce electricity, the ICE can either run or be shut down, or a combination of any of the above simultaneously and seamlessly without any input from the driver. The hybrid control system orchestrates the entire operation.

Another power circuit in the inverter changes the high voltage into 14V, and serves like an alternator to charge the small 12V AGM battery that is also in the trunk. When you turn the ignition ON, all this battery does is wake up all the related modules and activate the battery contactor relays. It is not used for cranking. Before closing the relays and applying the HV into the system, it also checks for any HV leakage in the wiring, inverter, or in the hybrid transaxle modules that contain both motor-generators. If all is okay, it then introduces the HV into the system. It does it all in less than 200mS. All you hear is a faint double click, then the "Ready" light comes on the instrument cluster. You can start driving the vehicle as soon as the "Ready" light is on whether the ICE has started or not (see Figure 5).



Figure 4 – Inverter Assembly in Engine Compartment



Figure 5 – "Ready" Light Means All System Go!

Each of the two modules that are called Battery Blocks are also wired into the HV Battery Control Module located inside the battery box. A long list of parameters of each block like the Voltage, State of Charge (SOC), as well as battery temperature are continuously monitored and measured by the HV Battery Module and are easily accessed via the scan tool (see Figure 6).

It is important to know that the Ni-MH battery open cell voltage is not an indication of its state of charge. This is unlike the flooded cell lead-acid batteries that the open cell voltage of 12.6V indicates a fully charged battery. There are other factors involved but the HV Battery Module looks for variations in each block and through a special algorithm, calculates it and shows it as "Delta SOC" that can be seen by the scan tool.

The system is designed to maintain each block at 45 to 55% state-of-charge. Seeing a 50% SOC is a good sign. At the same time, we are looking for the least amount of variation. The closer the variations in Delta SOC is to zero, the better the battery is. In new batteries after the installation this figure is always near 0% (see Figure 7). Bluish corrosion and salt build-up around each module's post is always a sign of a deteriorated module and necessity for HV battery replacement (see Figure 8).

Parameter	Value	Unit
Max Battery Block No	14	
Battery Block Vol -V01	16.38	V
Battery Block Vol -V02	16.37	V
Battery Block Vol -V03	16.36	V
Battery Block Vol -V04	16.36	V
Battery Block Vol -V05	16.39	V
Battery Block Vol -V06	16.38	V
Battery Block Vol -V07	16.38	V
Battery Block Vol -V08	16.36	V
Battery Block Vol -V09	16.41	V
Battery Block Vol -V10	16.39	V
Battery Block Vol -V11	16.37	V
Battery Block Vol -V12	16.34	V
Battery Block Vol -V13	16.38	V
Battery Block Vol -V14	16.39	V

Figure 6 – Partial Scan Tool Data with 14 Block Voltages (Superimposed)

Battery State of Charge	45.5	%
Delta SOC	47.0	%
Batt Pack Current Val	0.06	A
Inhaling Air Temp	81.0	F
VMF Fan Motor Voltage	8.6	V
Auxiliary Battery Vol	12.2	V

Figure 7 – Some HV Battery Parameters (High Delta SOC, Bad Battery)

AUTO ELECTRIC CORNER

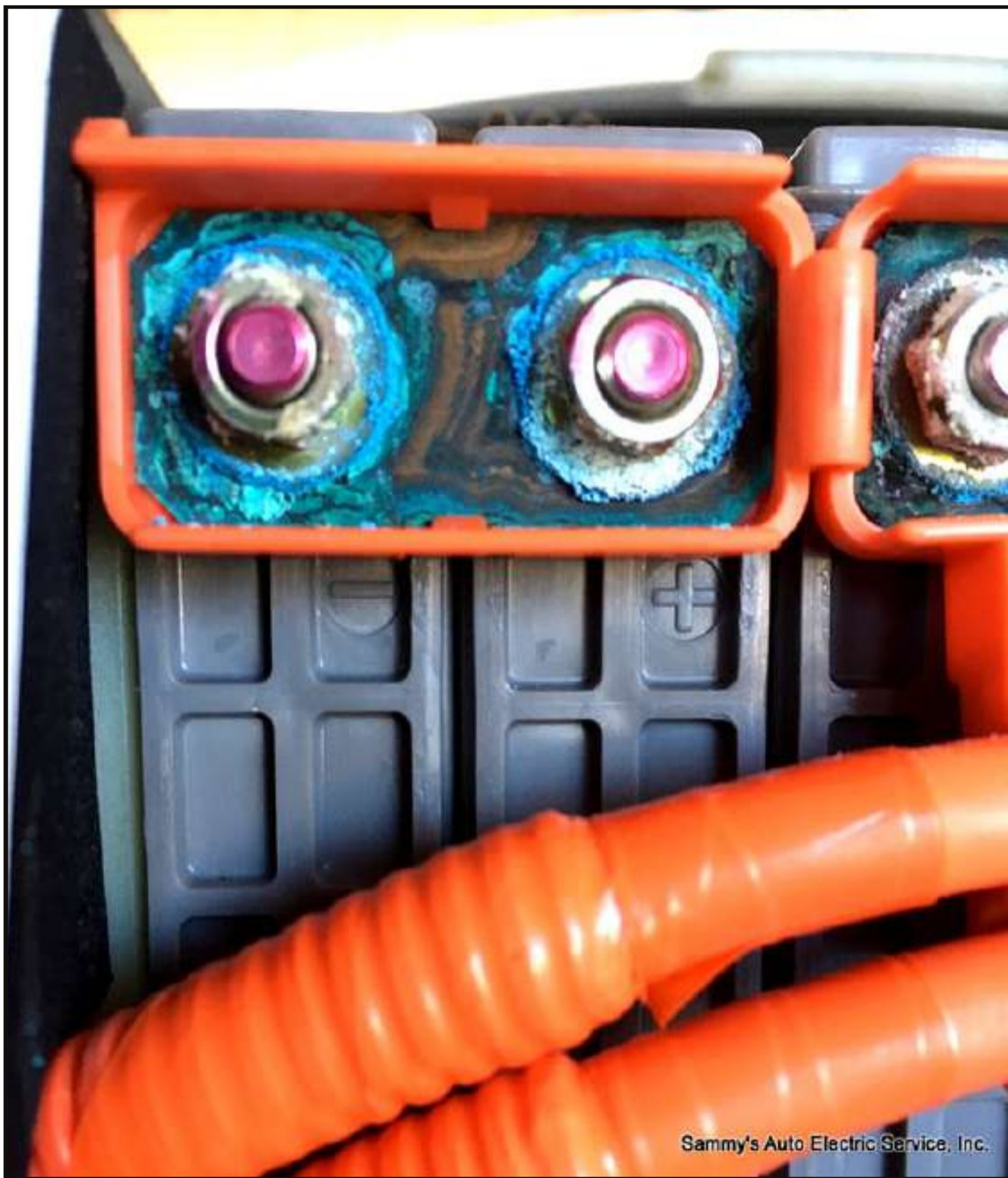


Figure 8 – Blue Corrosion is a Sign of Battery Module Gone Bad

Between battery modules #19 and #20, Block 10, (see Figure 9) there is a split that the two wires go into a removable mechanical switch called the Battery Service Plug that incorporates a 150-Amp special fuse. Removing this plug that is accessible via the trunk disables the battery pack and is a first thing to do if any services of the battery is required (see Figure 10).

Working around an HV battery and servicing or replacing them requires paying detailed attention, using approved safety gloves, CAT-III DMM's, and a thorough familiarity with the system. This segment is simply a brief introduction into the Prius battery to familiarize rebuilders with its intricacies and is not intended to be a substitute for comprehensive hybrid training.

Visiting an Old Unit

The 14557 Mitsubishi alternator was used on 2.6L Mitsubishi engines. These engines for a period of time in the early to late-80's were an optional engine used on some Chrysler products like LeBaron, New Yorker, Town & Country, Dodge Caravan, as well as others. The vehicles that used these engines, namely the Chrysler K-car lines that were the pride and joy of the late Lee Iacocca, who was then the Chairman of the Chrysler Corporation are rare around the Midwest. But they occasionally show up which allows me to brush up the old memories and remember the days when these were very common.



Figure 9 – Service Plug Split between Modules 19-20 (Battery Block#10)



Figure 10 – Service Plug, Removed for any HV Battery Service

The 14557 alternator (see Figure 11) was our first experience then with an automotive unit that had dual rectifiers and a dual-wound stator on one stack, sharing the same rotor and voltage regulator (see Figure 12). The regulator (WAI's IM-204) has "IG" and "L" pins but is energized through the "IG" and not "L" terminal (see Figure 13). More about the "L" terminal later.

The vehicle in question which belonged to an acquaintance of mine (a retired electrician) was a surprise exception. It was a 1982 Chrysler LeBaron convertible, purchased new 38 years ago, kept in his garage, and occasionally driven on nice summer days with the top down. It was truly like new, in showroom condition with only 12,000 miles on the odometer...but now with a charging problem!

To make the story short, the auto part store's alternator (a national brand-name) that was recently installed while away from town had failed, and now he wanted me to investigate and repair the problem. Luckily he had kept his core which facilitated the repair. Thinking I would never see any of these again, I had recently disposed of a couple of such alternator cores that I had kept for years. Therefore I had no available core to rebuild.

His OE core was in clean shape as I expected

AUTO ELECTRIC CORNER

but needed one rectifier and a regulator to be functional again, which was taken care of and all worked well after the installation. The peculiarity of this alternator is this: only one of the rectifiers has a diode trio. The other one—the one I had to replace—does not. The diode trio, in addition to being a source of field current, also feeds the radiator cooling fan relay's control coil. I remembered one of the issues with this alternator in its heyday was that a shorted radiator fan relay would blow the diode trio and disable the alternator. If left unnoticed, the alternator would fail repeatedly and rebuilders used to get the blame for inferior work!

This vintage 2.6L engine was known for oil leaks, and having a very massive, highly sophisticated and hard-to-rebuild carburetor. In the above car, in addition to the charging problem, my friend's concern was also that turning on the A/C no longer raised the engine idle speed, which is a built-in feature of this car. After rebuilding the alternator, the idle RPM kick-up problem disappeared, confirming also that it had something to do with the now active "L" terminal.

The lesson learned was that maybe I should not dispose of all my old units, not knowing when one might become necessary. But that is hard to do as I no longer am so eager to hang on to a lot of old stuff. Maybe this has something to do with my age...!

Well, that's all for this issue. Until I see you again, keep up the good work.

You can contact Mohammad Samii by email at: sammyselectric@sbcglobal.net, or by calling the ERA Tech Help Line at 636-584-8324



Figure 11 – 14557 Mitsubishi Alternator

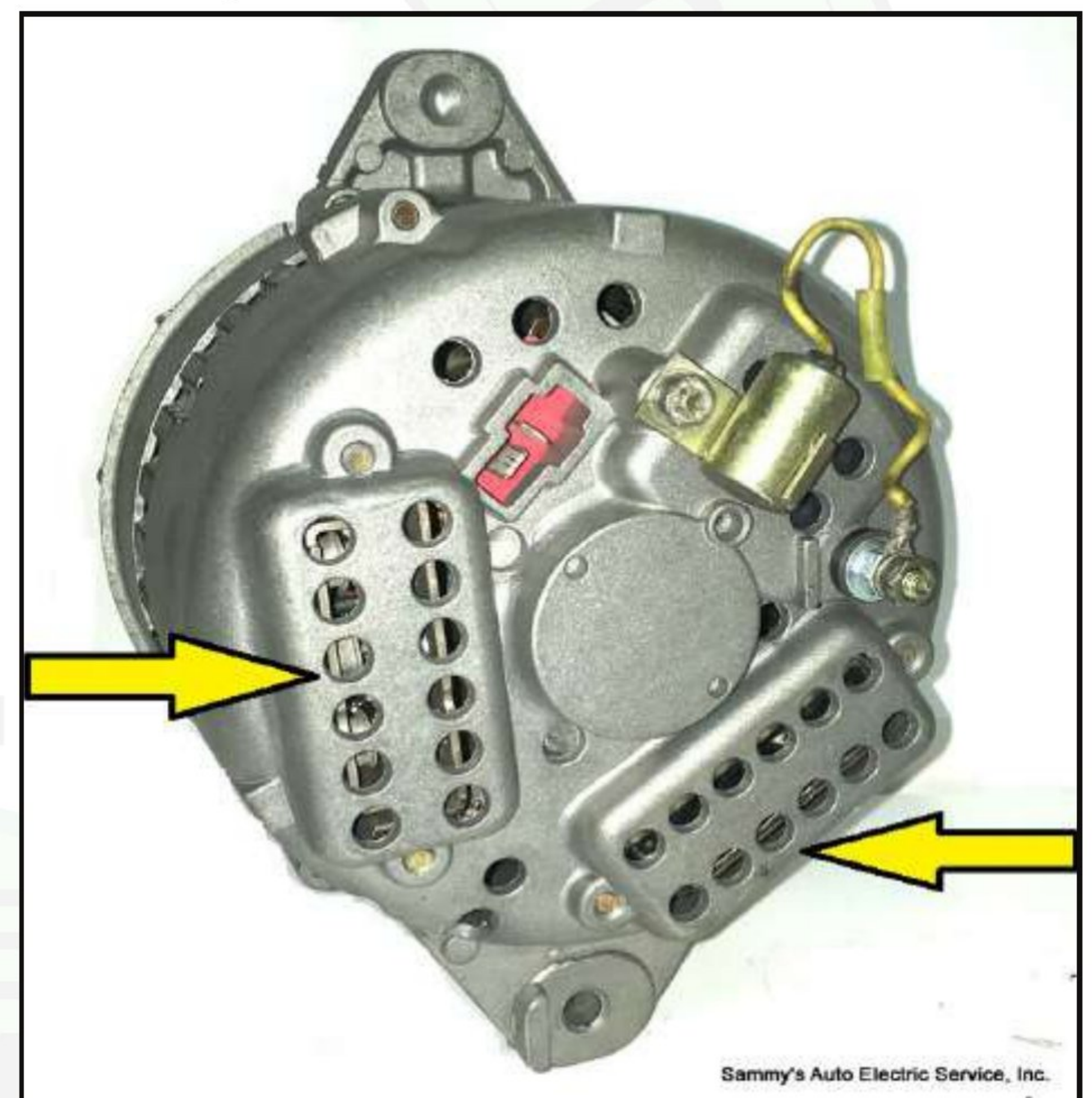


Figure 12 – Dual Rectifier Arrangement

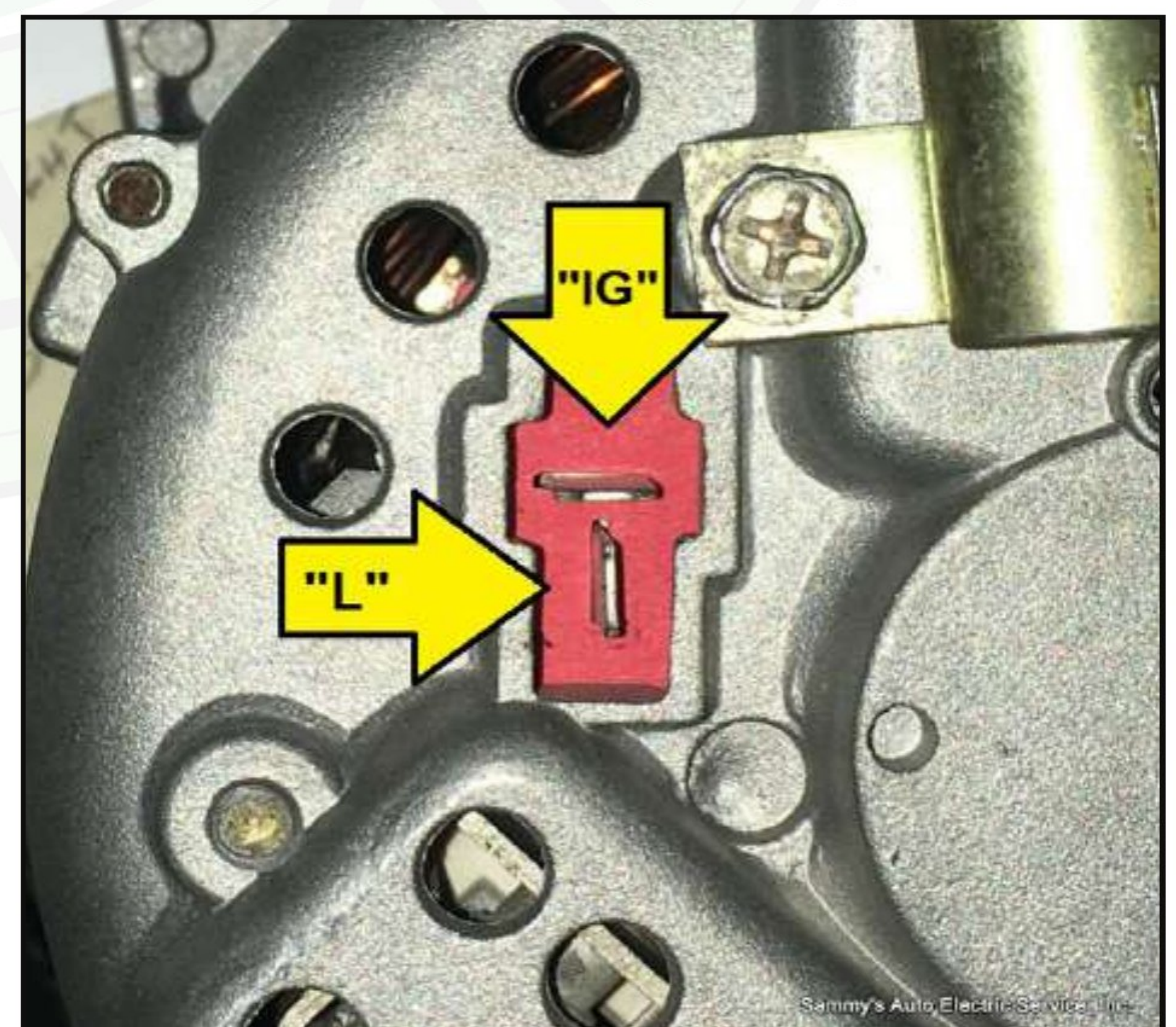


Figure 13 – Plug Code 192 (IG - L) Arrangement