# General Overview of Electric and Hybrid Vehicles

*By Art Hall*

I bet none of us would buy a car without opening the hood and seeing how things look.

This will give you some definitions and basic understanding of how these vehicles work so that you can start your own research.


# DON’T TOUCH THE ORANGE CABLES !!

Unless you have the proper training, tools, and personal protective equipment

# Wires in color coded conduit have special meaning:

- Black conduit w/ green or blue stripe

  Designed for high temperatures and is used near hot engine parts

- Blue or Yellow Conduit

  Cover wire with voltages of 12 to 24 volts.  While 42 volts is not a shock hazard, it can cause an electric arc (usually used for electric power steering)

- Orange Conduit

  Covers wire with voltage from 144 to 650 volts and can cause fatal electric shocks.  Follow the manufacture's procedures to de-power the equipment before working on.

# Definitions:

- EV – electric vehicle
- ICE – internal combustion engine
- HEV – hybrid electric vehicle
- PHEV – plug-in hybrid electric vehicle
- ZEV – zero emission vehicle

- HV Battery – high voltage battery
- Aux Battery – conventional 12 volt auto battery
- SOC – state of charge, percentage of battery charge

# Definitions (hybrids):

- Series Hybrid – the internal combustion engine is basically an on-board battery charger, and never powers the vehicle directly. Engine operates at its most efficient speed and load. No transmission, clutch, or torque converter is needed.(Chevy Volt)
- Parallel Hybrid - both the electric motor and the engine is connected to the transmission, and either can power the vehicle alone or in combination.
- Series-Parallel Hybrid – can operate on electric power alone or with the assistance of the engine. Single speed transmission. (Toyota and Ford).
- Full Hybrid – a hybrid vehicle that can propel the vehicle using only electric power at low speeds. Also known as a “strong” hybrid.
- Atkinson Engine – a more efficient four-cycle engine that is less powerful. The intake valve is kept open at the beginning of the compression stroke, decreasing the compression ratio compared to the expansion ratio. About 10% more efficient.
- Regenerative Braking – when decelerating, the electric motor acts as a generator and re-charges the battery. This also applies a braking force to the vehicle.

# Electric Vehicles (EV)

- Without an internal combustion engine, you do not have a source of heat or rotating power. Thus, another approach must be taken for:
  - Heat
  - Air Conditioning
  - Power Steering
  - Oil and Water Pumps
  - Aux Battery Charging


Fortunately, we won't need:

Transmission

Torque Converter

Starter

# HV Batteries

- Most common are nickel-metal hydride (NiMH) and Lithium-ion (Li-ion). There are other battery types, each with their advantages and disadvantages.
- Temperature sensors are needed to control heating and cooling and the charging rates. Batteries like to be the kept the same temperature as humans, between 68- and 78-degrees F.  Battery energy must be used to keep them in this temperature range.  Both liquid and air-cooling systems are used, depending on the design.

# HV Batteries


- Battery cells are small, individual units. For Teslas, they are small cylinder units similar to AA batteries. Individual cells are connected in series to create a module, and a vehicle can have several modules connected in parallel to increase amperage.
- Using 1.2 volt NiMH cell, 1.2 volts x 240 cells = 288 volts

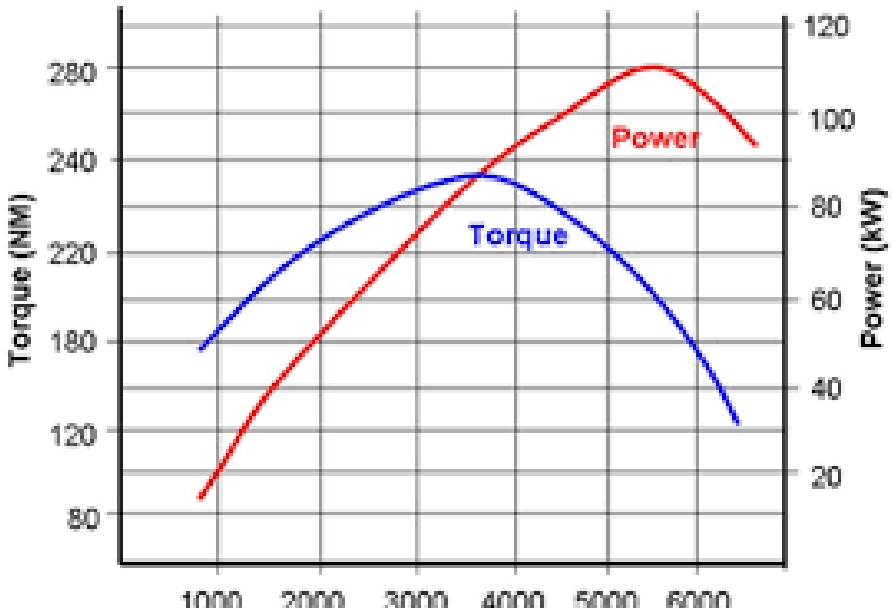
  Using 3.6 volt Li-ion cell, 3.6 volts x 96 cells = 346 volts
- Batteries are rated in kilowatt-hours (kWh). The larger the kWh, the more electrical energy you can store.
- An estimated range on battery power is battery kWh x 3. Thus, 11 kWh x 3 = 33 mile range. Need to account for terrain and temperature also.

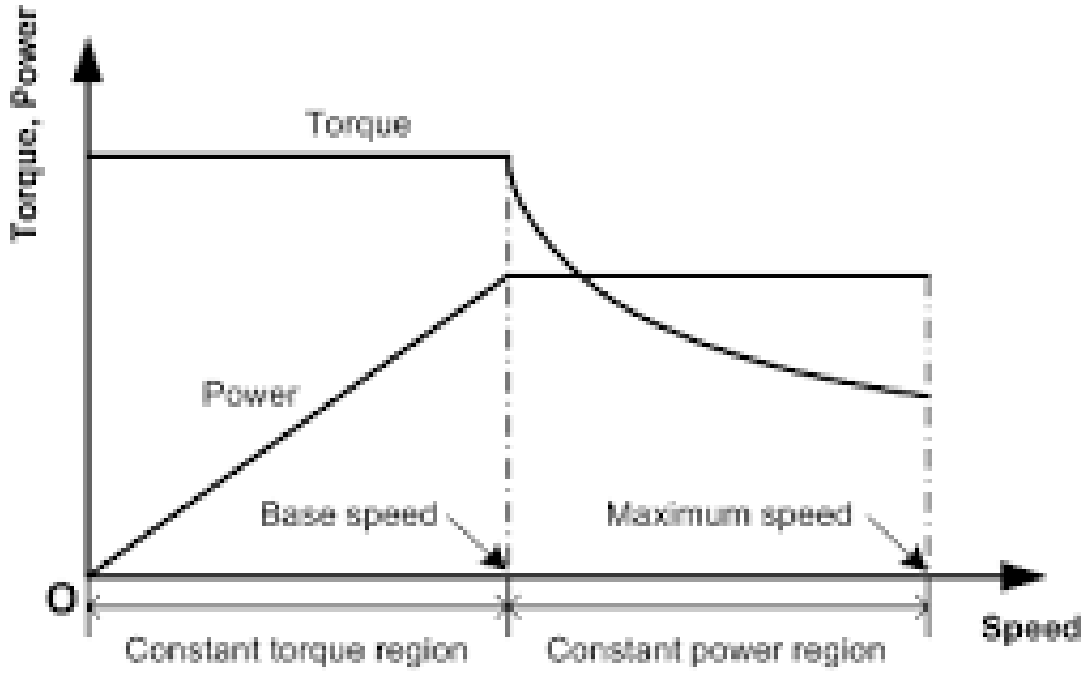
# HV Batteries

- Batteries are not ever fully charged or discharged.  In hybrids, the state of charge (SOC) is usually 60% ± 20%.  This allows some storage capacity for regenerative braking and prevents overheating.  If the battery exceeds SOC limits, regen braking will not activate.
- When purchasing a EV or Hybrid, consider the “mission” the vehicle will be used for under what conditions.

# Electric Motors

- ICE engines produce maximum torque in a very narrow range. That's why we need torque converters and multi-speed transmissions.
- Electric motors produce maximum torque instantly at low RPMs.  When torque drops off, power is constant.



# Electric Motors

- The ratings are different

The power rating of an IC engine is defined as the peak horsepower the engine can achieve. The power rating of an electric motor is the amount of power that can be delivered for one continuous hour.

- Electric Motors are rated in kilo Watts (kW)

0.746 kW = 1.0 horsepower

50 kW = 67 horsepower

75 kW = 100 horsepower

100 kW = 134 horsepower

120 kW = 160 horsepower

# Electric Motors

- Vehicles can use AC Induction Motors (asynchronous) or AC Synchronous Motors
- An electric motor consists of 3 sets of electromagnetic coils that pulse on and off by an AC current to create a rotating magnetic field around the motor housing (stator). This magnetic field forces the rotor to spin.
- To change the speed of the motor, the frequency of the applied current to the stator is changed.
- To change the power, the voltage is changed

# Electric Motors

- The Rotating Magnetic Field (RMF) is controlled by the inverter

  if RMF ≥ RPM  then acts like a motor

  if RMF < RPM  then acts like a generator

# *So what parts do I need for my EV?*

2017 Chevy Bolt

Permanent Magnet Synchronous AC Motor

150 kW Power, 360 Nm Torque,

8810 max. RPM

**You need 5 boxes of Electronics**

1. <u>High Power Distribution Module</u>

   Takes power from HV Battery

   Distributes power to the other modules & to HV battery heater

   Accepts power from DC fast charger

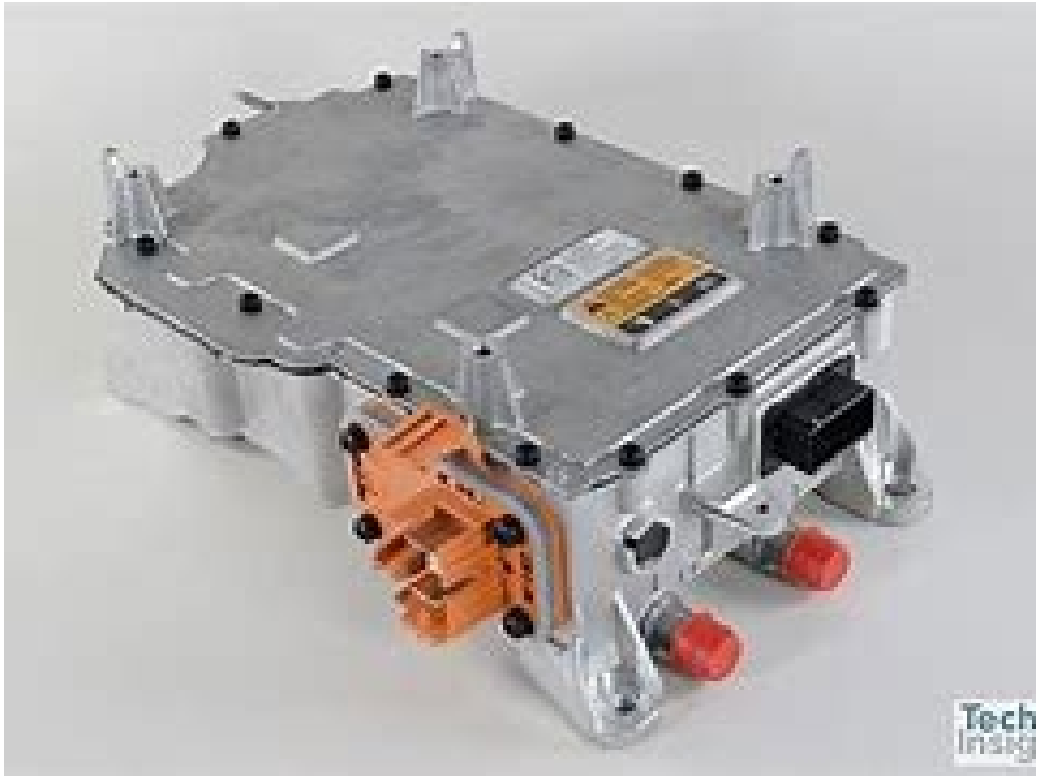
2. <u>Single Power Inverter Module (Inverter)</u>

Takes DC power from the distribution box

Converts DC power to 3 phase AC power to the traction motor

Converts AC from traction motor during regen braking to DC for HV battery

Is liquid cooled, part of power electronics cooling loop

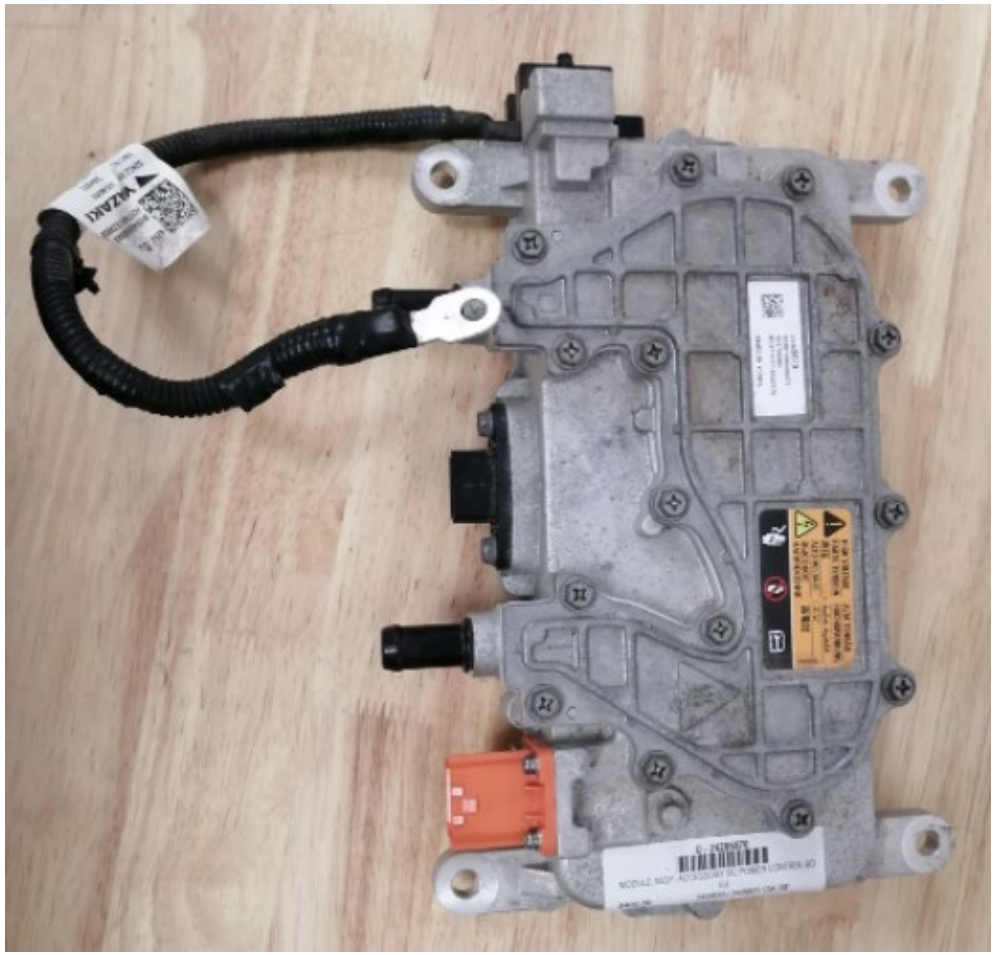


3. <u>Accessary Power Module ( DC to DC Converter)</u>

Takes power from Power Distribution Module

Steps down 400 volts from HV to 14 volts for accessory battery

Liquid cooled



4. <u>On Board Charger Module (OBCM)</u>

Plugs into home electrical outlet

Inputs 110 -240 volts AC and converts to 350-400 volts DC to HV battery

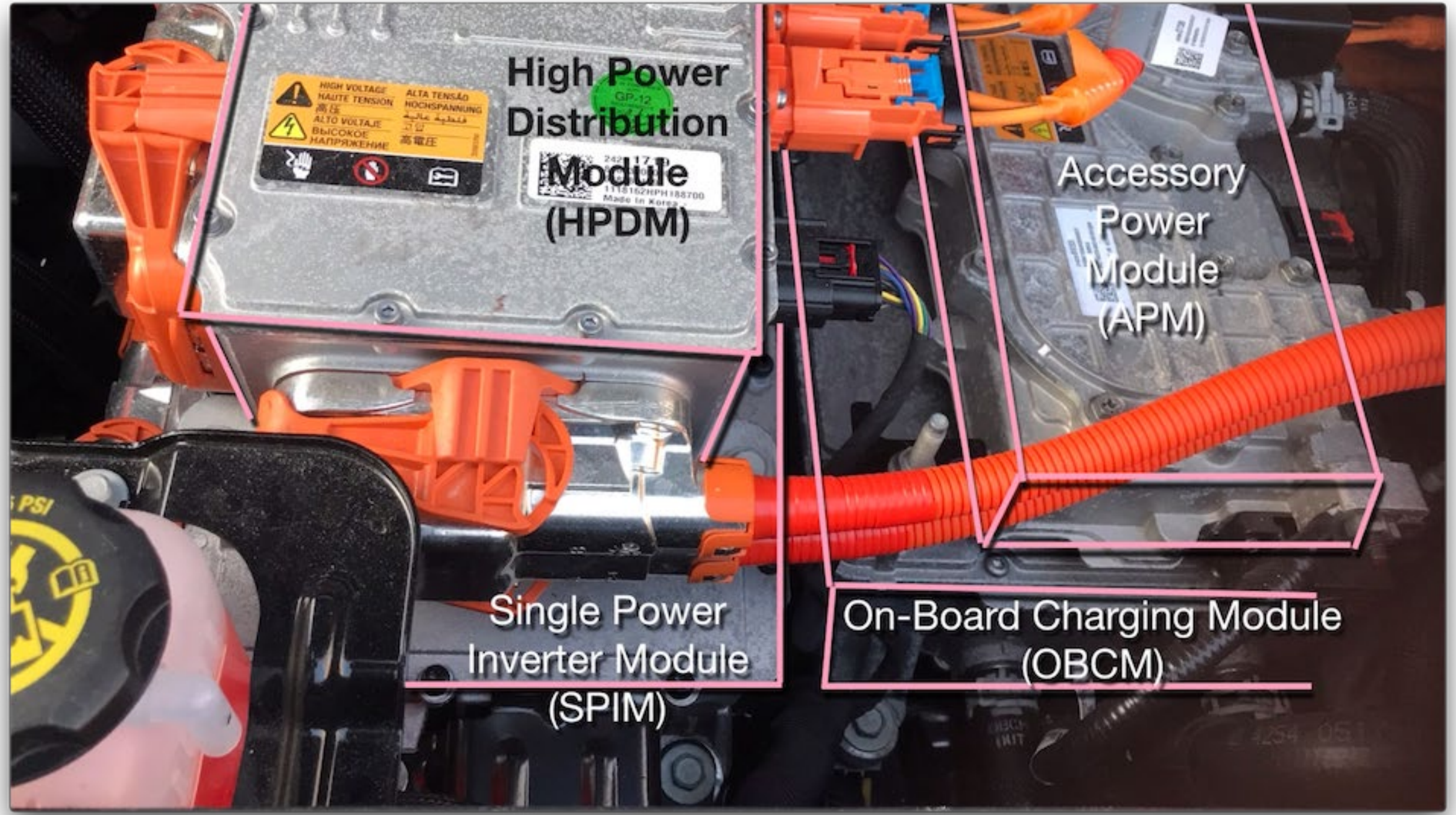
Liquid cooled

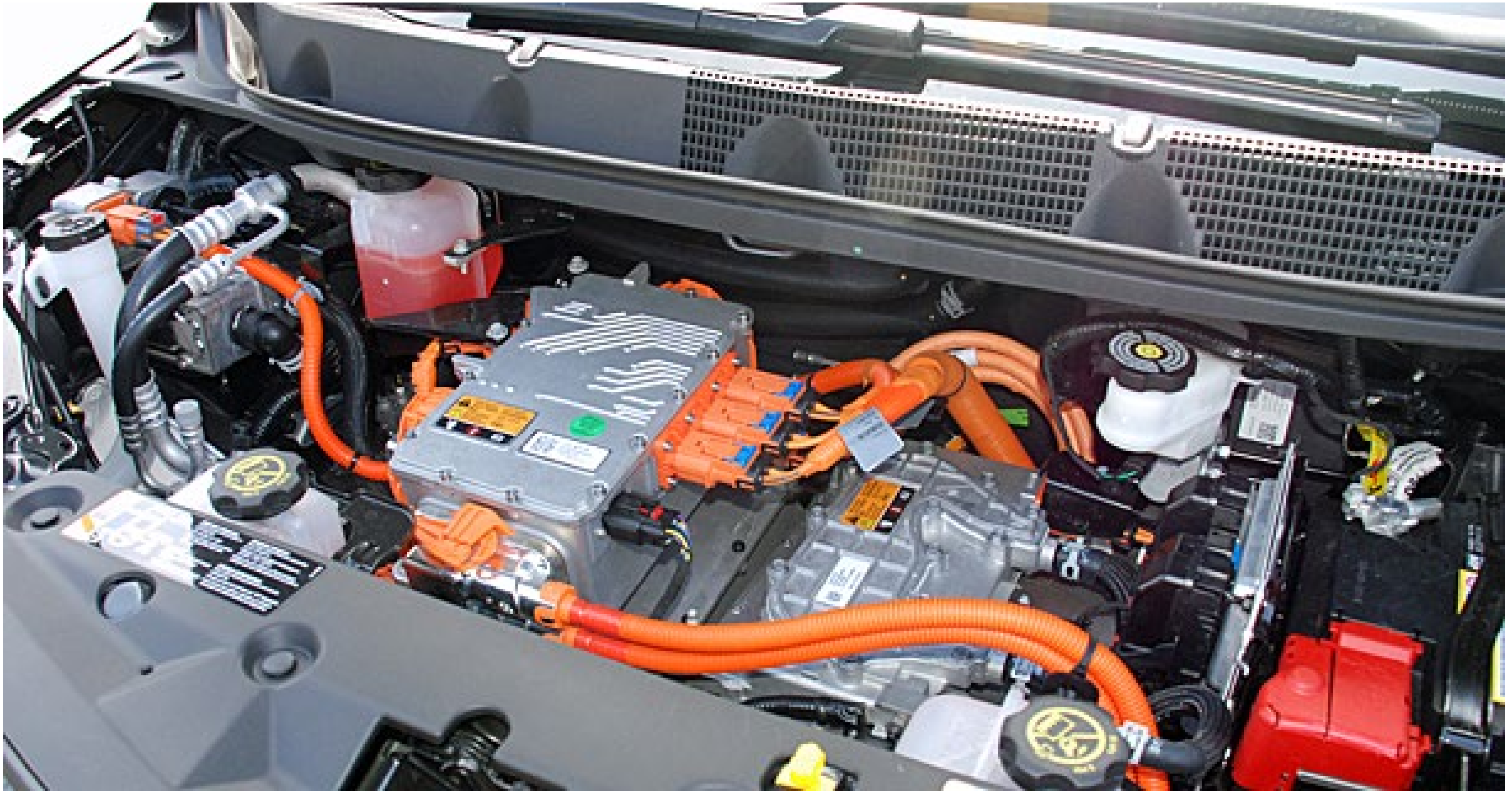
Not used with DC fast charge

5. <u>Cabin Heater Control Module (Coolant Heater)</u>

Takes power from High Power Distribution Box

7.5 kW ceramic style heater element


High Power Distribution Module (HPDM)
Accessory Power Module (APM)
Single Power Inverter Module (SPIM)
On-Board Charging Module (OBCM)



# The Chevy Bolt has 3 Separate Cooling Systems

- 1.  HV battery coolant loop (Reserve Energy Storage System, RESS) both warms and cools the HV battery

- 2. Cabin heater coolant loop

- 3. Power Electronics Coolant  loop for the drive train modules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# Hybrid Operation

Toyota Power Split System (Prius, Camry Hybrid, Highlander)

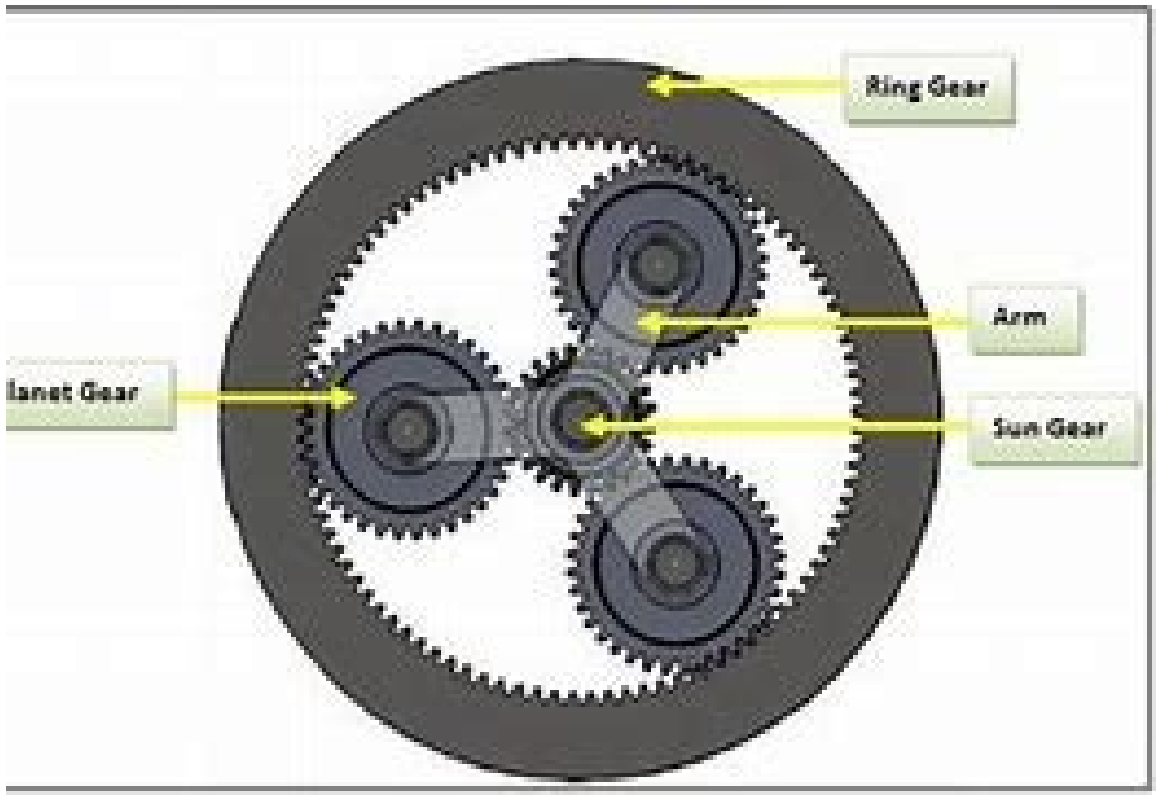
Uses a planetary gear set in which:

MG1 is the sun gear

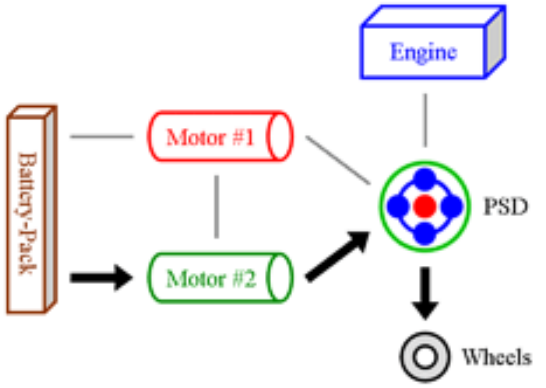
MG2 is the ring gear

ICE is the planet carrier

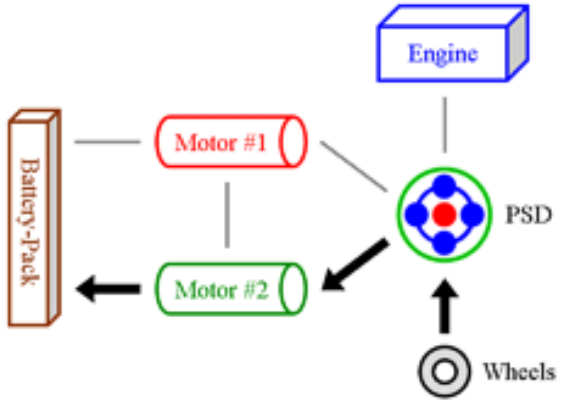
motor- generator (MG1 and MG2)



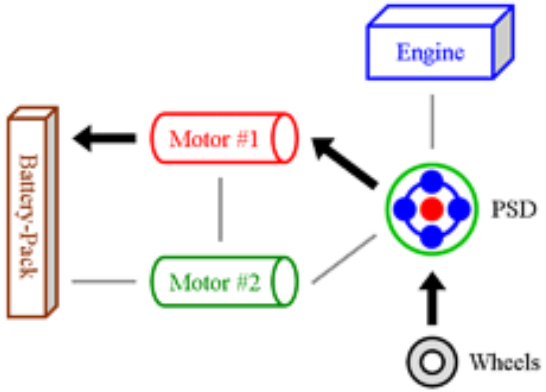
# Hybrid Operation



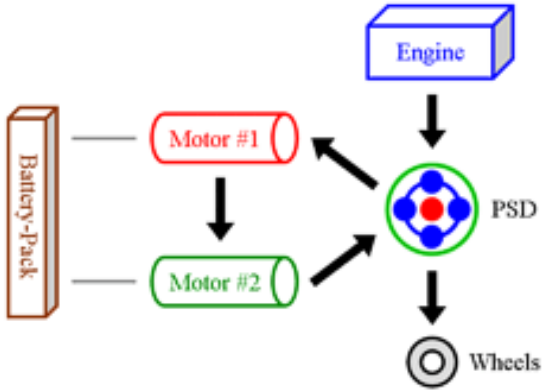

Low Speed and Reverse




Regeneration Braking

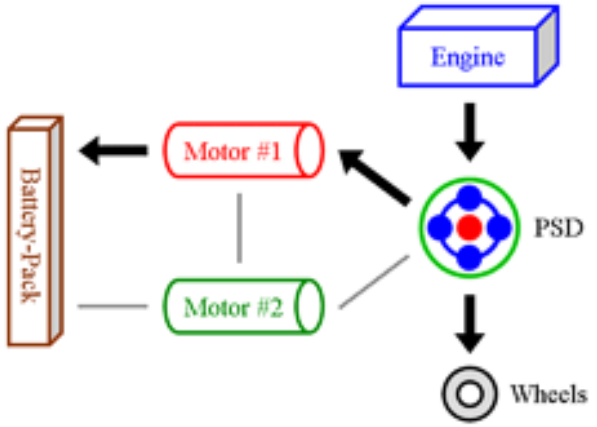



Regeneration Coasting

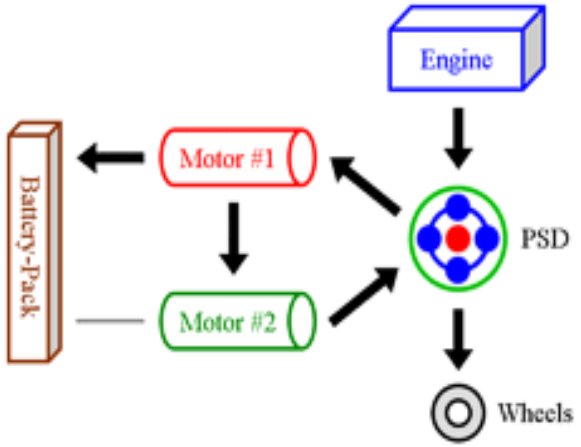



Normal Driving (28% to MG1, 72% to Wheels)

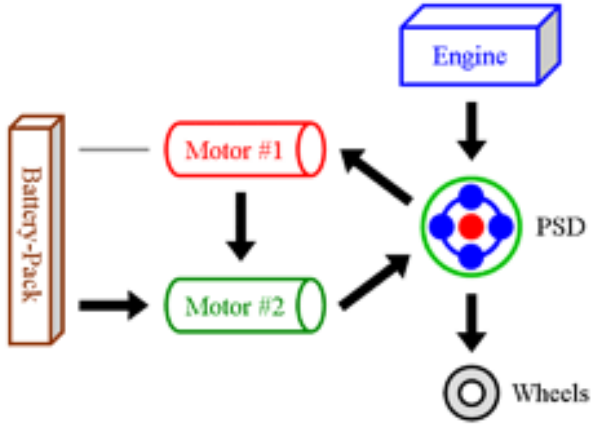
# Hybrid Operation



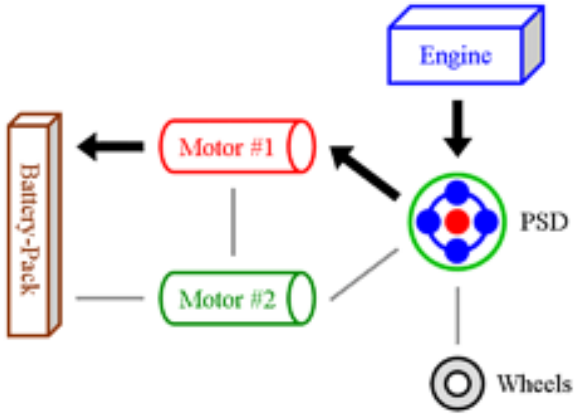

Engine Drive + Charge




Normal Drive w/ Surplus




Full Power




Engine Heat for Catalytic Converter

# References

YouTube

WeberAuto

281K subscribers

# EV Evolution, Hybrid and EV Case Studies

- Timeline of vehicle electrification
- EV Concerns, Pros & Cons
- Review Example Parallel Hybrid
- Review Example Series Hybrid
- Review Example EV
- Real world case studies
- Charging infrastructure

*By Bill Klicker*

# EV Concerns, Pros & Cons

- Government incentives fluctuate
- Concerns about battery replacement costs
- EV Range Anxiety
- System Complexity
- Finite Range for long trips
- Environmental impact
- Cost to charge
- Charging infrastructure

# Vehicle Electrification

## Conventional ICE

## Parallel Hybrid

## Series Hybrid


## Electric Vehicle

# Parallel Hybrid – Toyota Prius

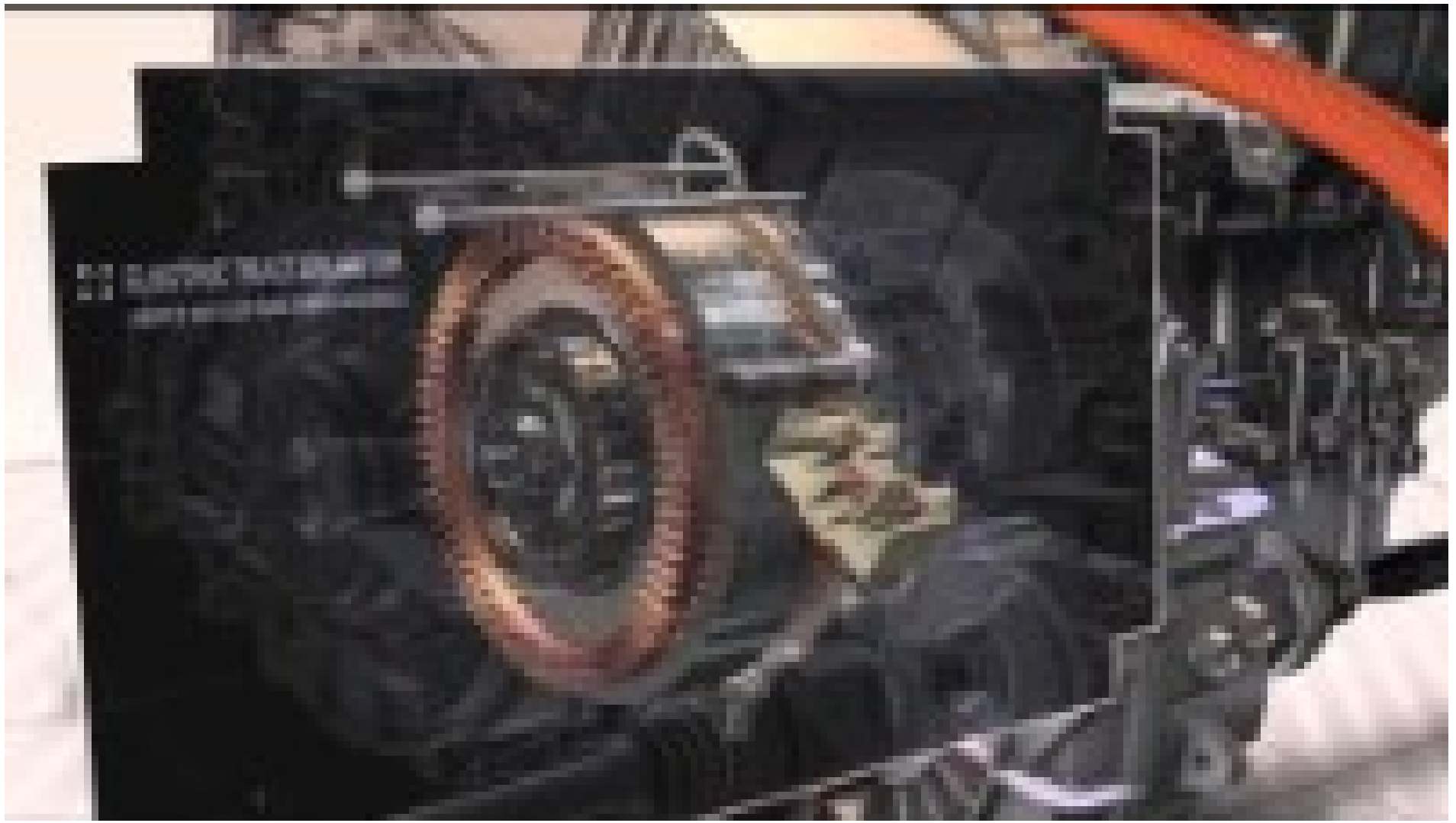
Available 2001 – present in the US
2001 specs (gen 2):
1.5L I4, 109HP & 84 lb-ft torque
1.3kWH NiMH air cooled battery
11.8 gal fuel capacity
3031 lbs
5 seats
eCVT transmission
55mpg

# Parallel Hybrid – Toyota Prius


# Series Hybrid – Chevy Volt

Available 2011 – 2019 in the US
2016 specs (gen 2):
1.5L I4 - 101HP
149HP, 294 lb-ft torque Electric drive unit
18.4kWH Li-Ion liquid heated/cooled battery (14x more capacity than Prius)
8.9 gal fuel capacity
3543 lbs
5 seats
No “transmission”
No belts
Electric power steering
Electric AC
Rated at 53mi electric range, 41MPG on gas generator
Rated at 420mi total range (gas/electric)

# Series Hybrid – Chevy Volt



# EV– Tesla Model S

Available 2012-present in the US
2012 Model S 60:
362HP, 325 lb-ft torque Electric drive unit
60kWH Li-Ion liquid heated/cooled battery (46x more capacity than Prius, 3x more than Volt)
4323 lbs
5 seats (plus 2 optional rear facing child seats)
No “transmission”
No belts
Electric power steering
Electric AC
210 mile range
0-60 5.8 seconds
130MPH top speed

# Real World Experience Example 1

**2009 Mercury Mariner Hybrid AWD** (same as Escape hybrid)
Averaging 25MPG
Can be driven short distances on only electric with very light accelerator application
Regen brakes not very refined
Average performance
FWD would yield much better mileage

# Real World Experience Example 2

**2016 Chevy Volt**

137 lifetime MPG

Max 2500 mi between fill ups

Electric range typically around 50 miles in summer

Winter electric range closer to 38-45.  Use of heat makes big difference

Crisp, quiet acceleration

About 10 hours to fully charge depleted battery on 110v @ 12A

No Range Anxiety

No belts to change

Little brake wear

Middle seat in back has very limited head & legroom

Large hatchback

Comed Hourly Pricing Program

Public Charging Stations

# Is an EV or Hybrid Right for You?

**How far do you drive in a day?**
**What is the cost of electricity in your area?**
**What is the cost of gas in your area?**
**Do you need L2 charger in your house?  If so, is wiring required?**
**Can you charge at work?**
**Can the vehicle you choose work for longer trips?**

# QUESTIONS???