ECE Topics #2 -- Electric Vehicles

Slides downloaded from: https://ecefiles.org/ece-topics/

Companion video at: https://www.youtube.com/watch?v=T4X2I0b-AkA

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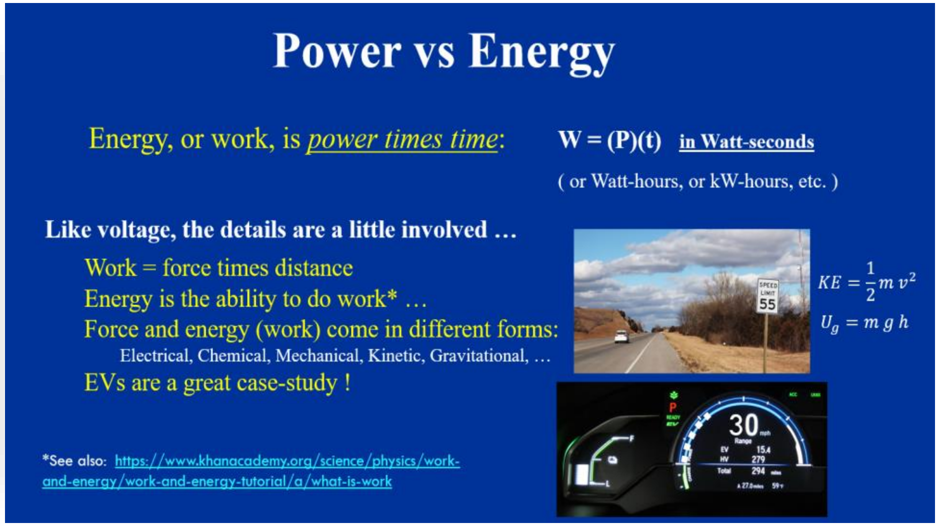
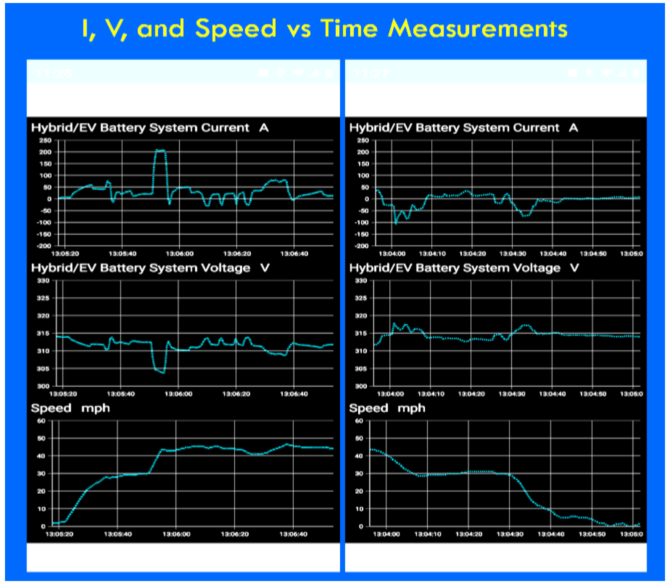
This video focuses on physics and technology concepts important in designing and driving Electric Vehicles (including series plug-in hybrids). As the second episode in our ECE educational series, it discusses EV operation in terms of the voltages and currents used - explaining how those relate to power produced and energy consumed. Topics include sources of electric power (AC and DC), the major components in EVs, and actual measurements of current and voltage on a typical drive cycle, including negative currents during regenerative braking.

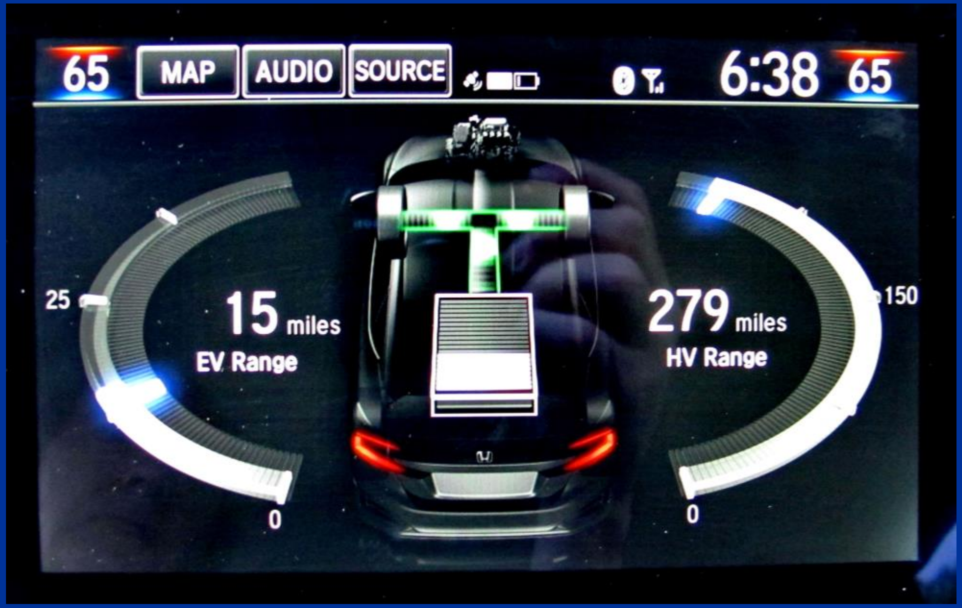


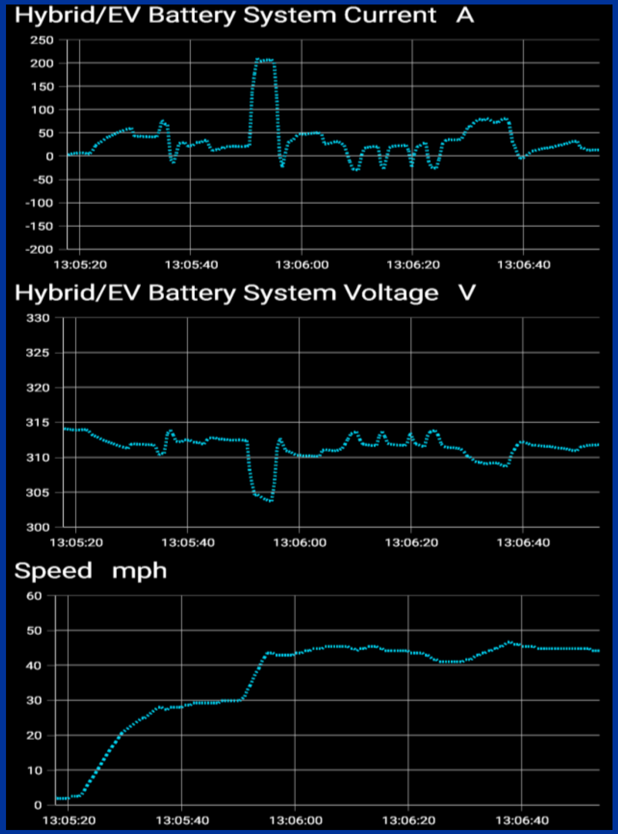


Topics in ECE #2

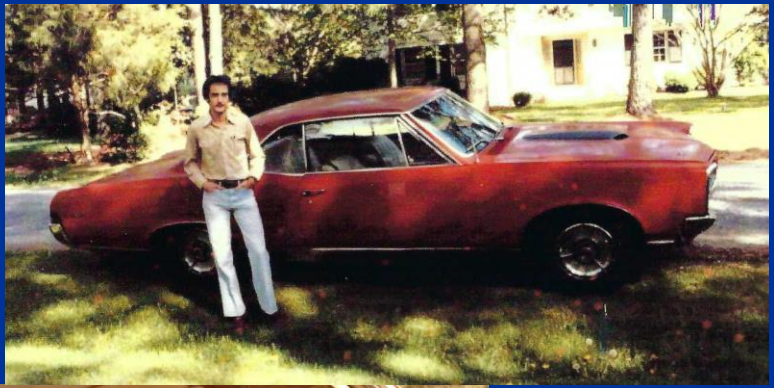
Electric Vehicles

Voltage, Current, Power, and Energy





ICE Car to (PH)EV



Today's Topics

- Sources of Electric Power
- Major Components of EVs
- Power vs Energy
- EV Measurements
- References and Future Videos

Recall: Power = Voltage x Current

$$V\,I = \frac{\Delta W}{\cancel{\Delta Q}}\frac{\cancel{\Delta Q}}{\Delta t} = \frac{\Delta W}{\Delta t} = P \quad or \quad P = VI \quad in\ \ Watts$$

$$or\ \ VoltAmps$$

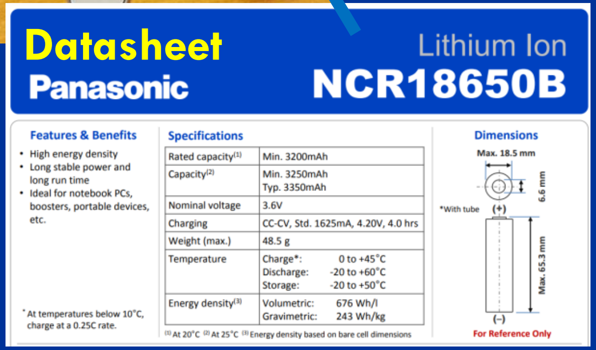
Application	Voltage	Current	Power
Flashlight Bulb	3 V	0.3 A	0.9 W
Red LED	1.8 Volts	0.005 Amps	0.009 Watts (9 mW)
USB Charger	5 V	2 A	10 W
Electric Vehicle Faster EV ☺	400 V 800 V	200 A 400 A	80 kW (108 HP) 320 kW (430 HP)

Some Sources of Voltage

AC

AC to DC conversion

DC



Datasheet Lithium Ion

Panasonic **NCR18650B**

Features & Benefits

- High energy density
- Long stable power and long run time
- Ideal for notebook PCs, boosters, portable devices, etc.

* At temperatures below 10°C, charge at a 0.25C rate.

Specifications

Rated capacity(1)	Min. 3200mAh
Capacity(2)	Min. 3250mAh Typ. 3350mAh
Nominal voltage	3.6V
Charging	CC-CV, Std. 1625mA, 4.20V, 4.0 hrs
Weight (max.)	48.5 g
Temperature	Charge*: 0 to +45°C Discharge: -20 to +60°C Storage: -20 to +50°C
Energy density(3)	Volumetric: 676 Wh/l Gravimetric: 243 Wh/kg

(1) At 20°C (2) At 25°C (3) Energy density based on bare cell dimensions

Dimensions

Max. 18.5 mm

6.6 mm

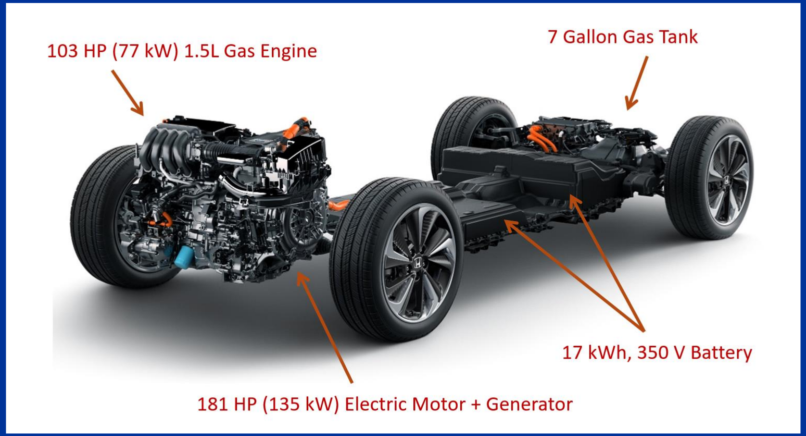
*With tube (+)

Max. 65.3 mm

(–)

For Reference Only

AC and DC



Major Components in an EV (or PHEV here)

Honda Clarity, EV with Range Extender (a.k.a. PHEV)

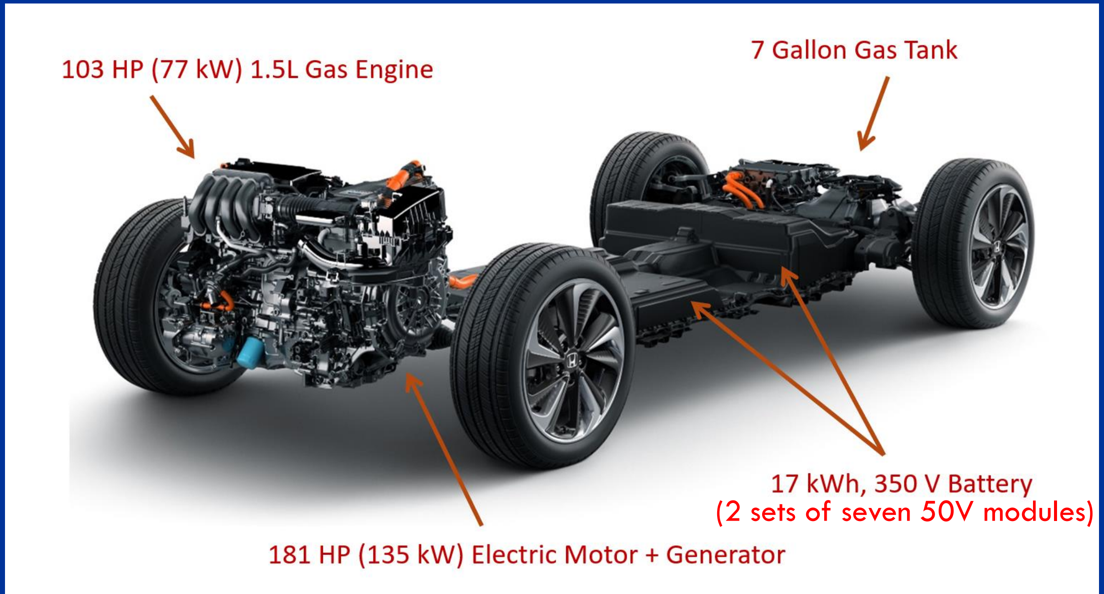
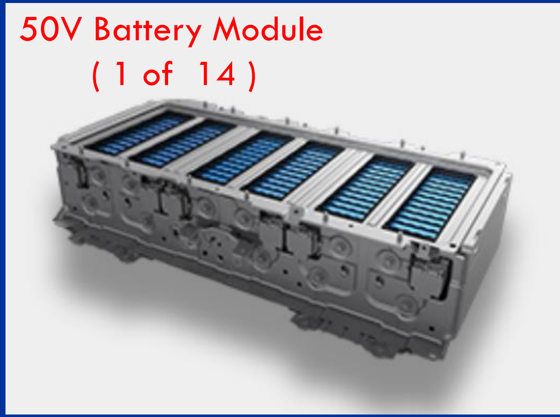
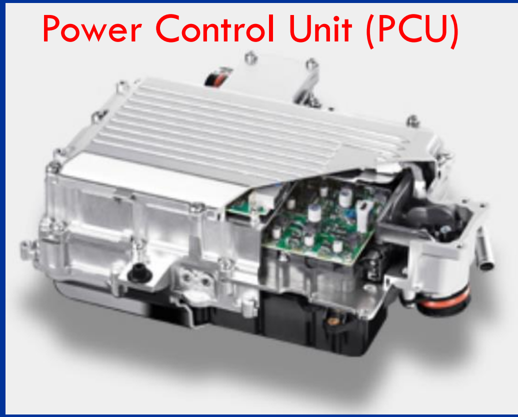
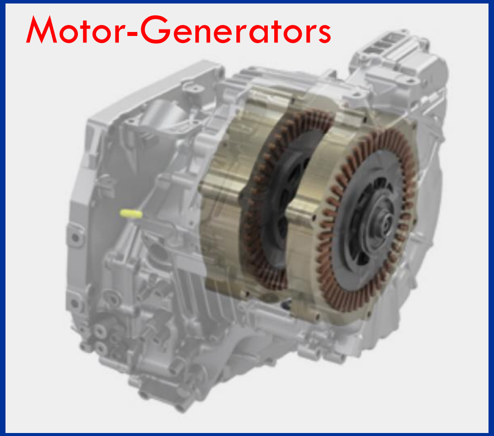
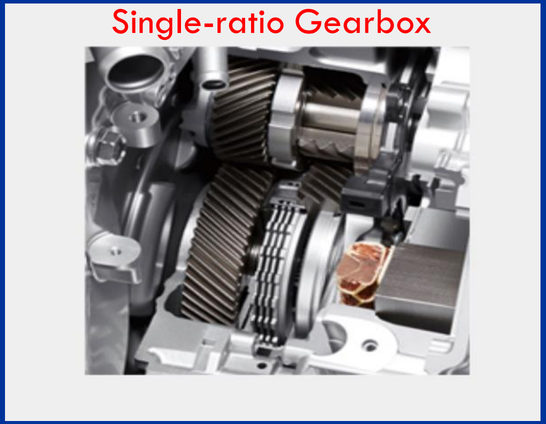


Photo Credit: Honda Motor Co (Annotated)



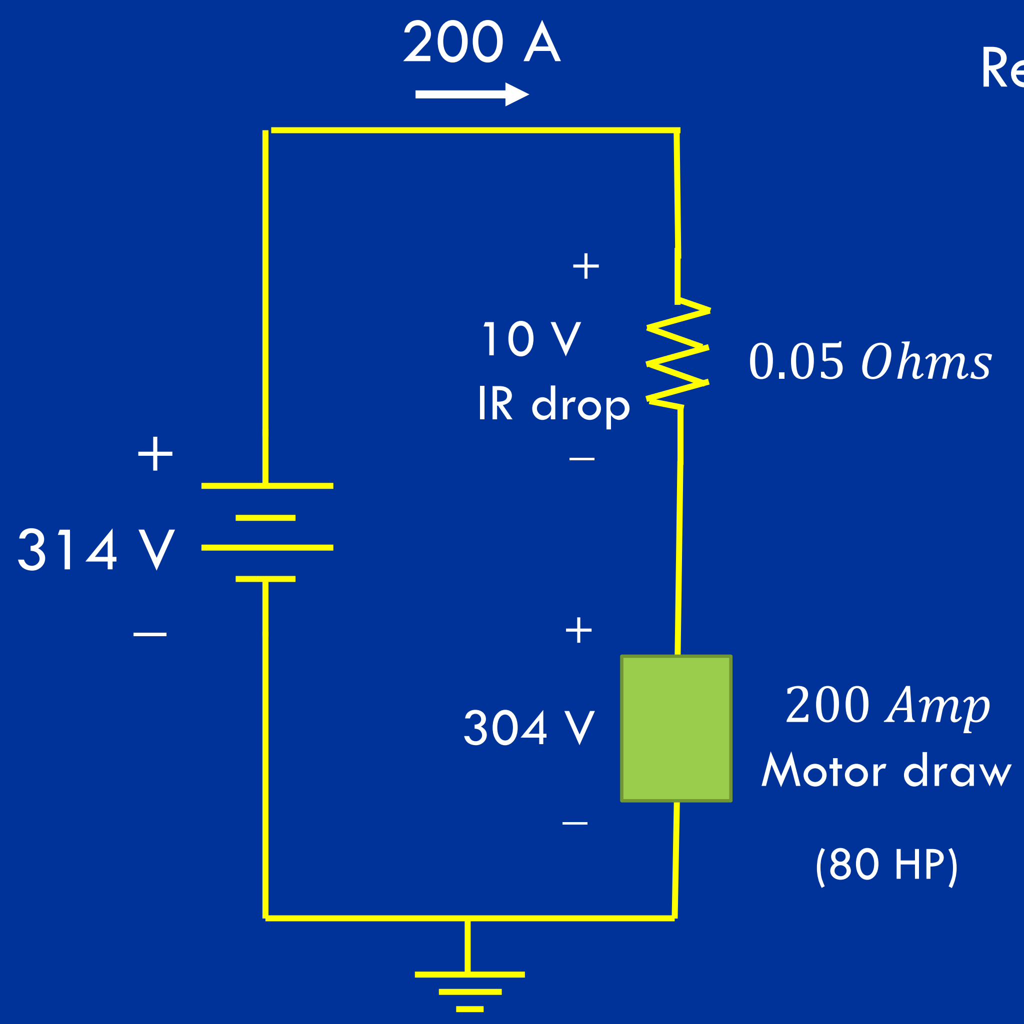






Pics from: https://global.honda/innovation/technology/automobile/hybrid/i-MMD-picturebook.html

Why use such High Voltages?



Recall from Episode 1:

$P = V\,I$ $\quad V drop = I\,R$ $\quad P_{loss} = I^2 R$

So …

- For a given power, as V is increased, required I is decreased
- Lower I allows use of smaller wires
- Lower I means less "loss" in wires for a given resistance
- Lower I increases battery lifetime

Power vs Energy

Power is work (or energy) *per unit time*: $P = V\,I = \dfrac{W}{t}$ in Watts

So… energy is *power times time*: **W = (P)(t)** in Watt-seconds

(a.k.a. Joules)

Or, in general energy is the integral of power over time… $W = \int_{t_1}^{t_2} P(\tau)\,d\tau$

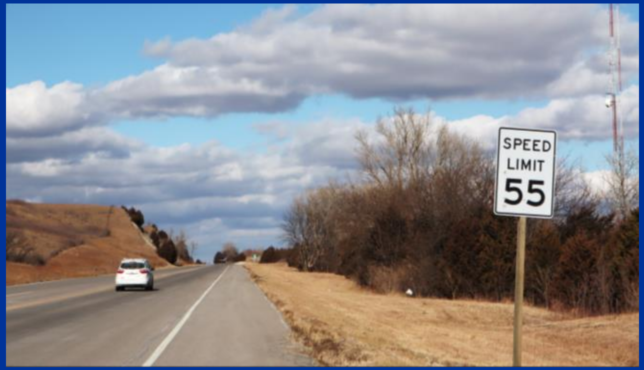
Power vs Energy

Energy, or work, is *power times time*: **W = (P)(t)** **in Watt-seconds**

(or Watt-hours, or kW-hours, etc.)

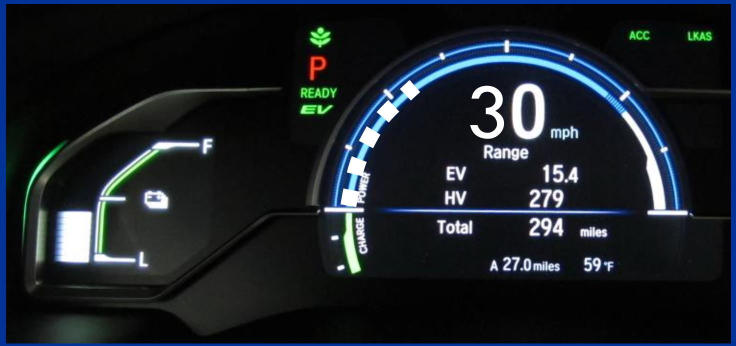
Like voltage, the details are a little involved …

Work = force times distance
Energy is the ability to do work* …
Force and energy (work) come in different forms:
Electrical, Chemical, Mechanical, Kinetic, Gravitational, …
EVs are a great case-study !



$$KE = \frac{1}{2} m\, v^2$$

$$U_g = m\, g\, h$$

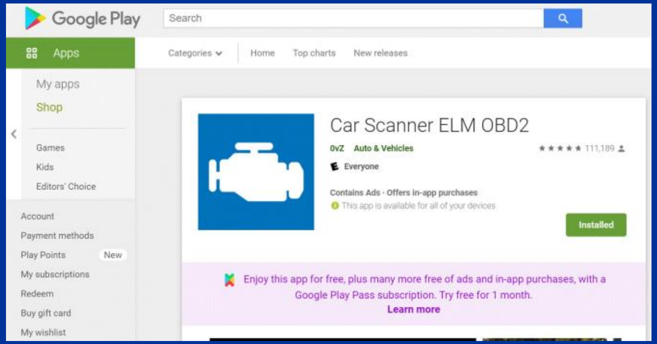


*See also: https://www.khanacademy.org/science/physics/work-and-energy/work-and-energy-tutorial/a/what-is-work

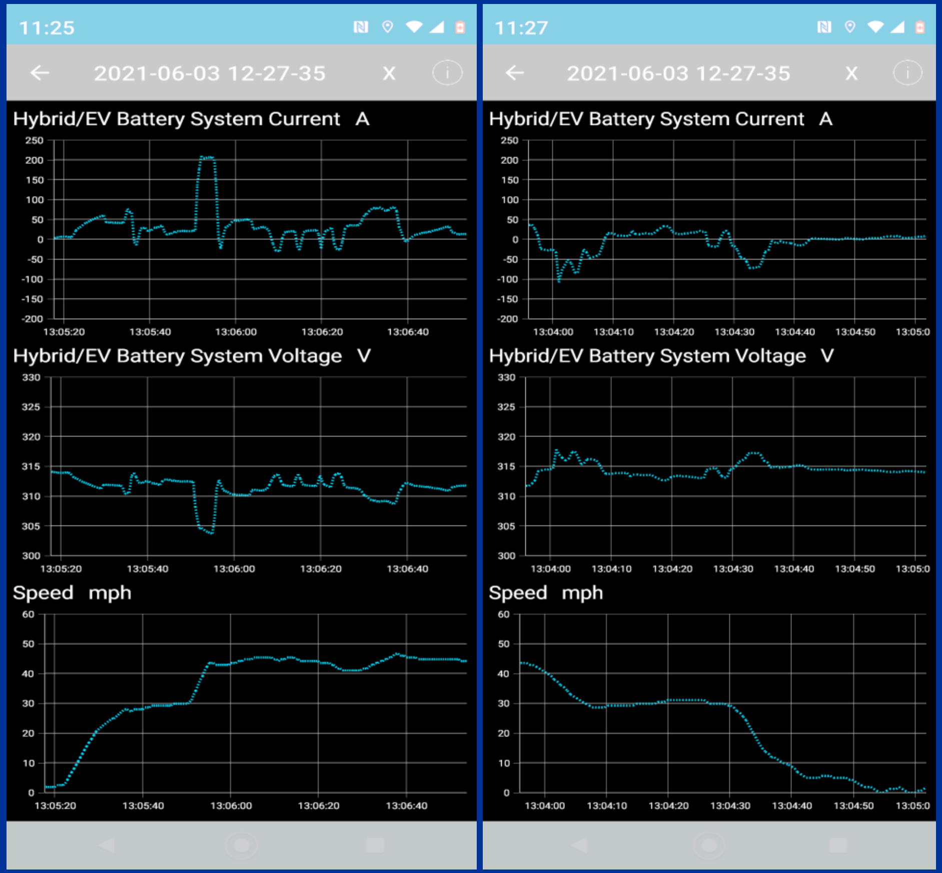
Instrumentation and Measurements

J1772 Level 1 Charging

OBD-2 Scanner



I, V, and Speed vs Time Measurements

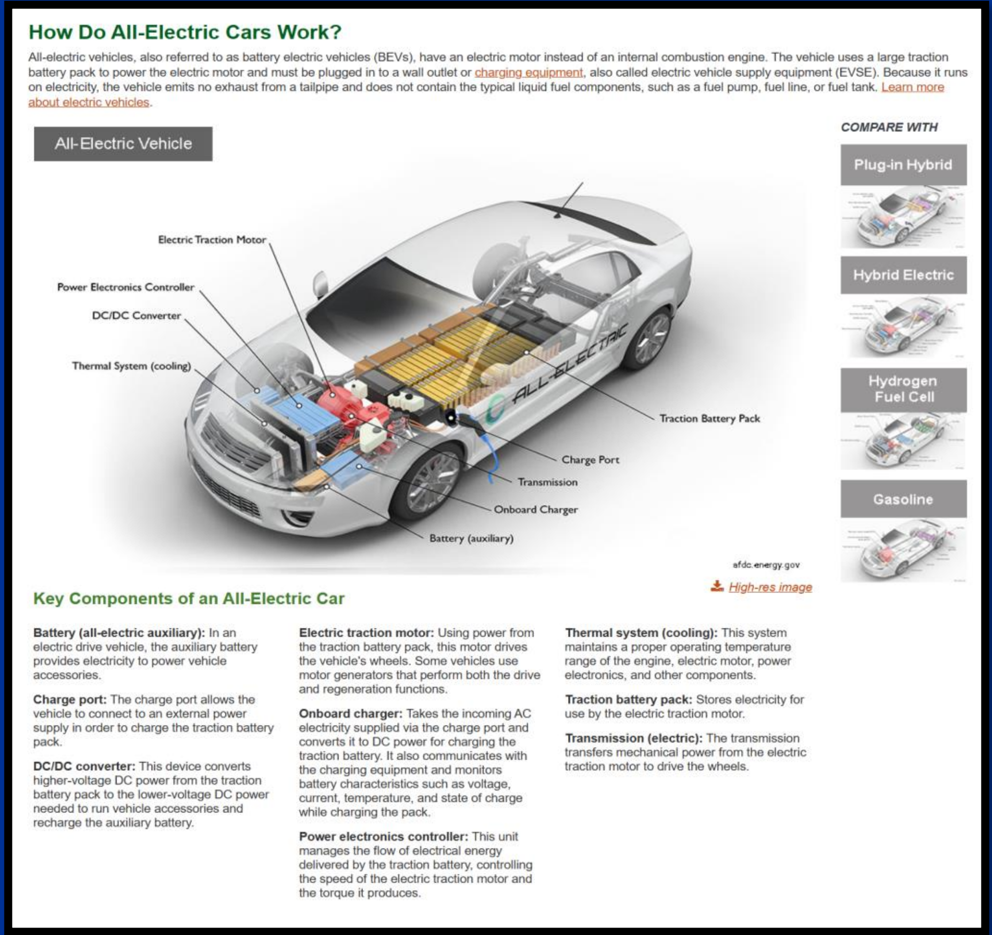


More Measurements

12V Accessory Power

USB Power

References



How Do All-Electric Cars Work?

All-electric vehicles, also referred to as battery electric vehicles (BEVs), have an electric motor instead of an internal combustion engine. The vehicle uses a large traction battery pack to power the electric motor and must be plugged in to a wall outlet or charging equipment, also called electric vehicle supply equipment (EVSE). Because it runs on electricity, the vehicle emits no exhaust from a tailpipe and does not contain the typical liquid fuel components, such as a fuel pump, fuel line, or fuel tank. Learn more about electric vehicles.

High-res image

Key Components of an All-Electric Car

Battery (all-electric auxiliary): In an electric drive vehicle, the auxiliary battery provides electricity to power vehicle accessories.

Charge port: The charge port allows the vehicle to connect to an external power supply in order to charge the traction battery pack.

DC/DC converter: This device converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed to run vehicle accessories and recharge the auxiliary battery.

Electric traction motor: Using power from the traction battery pack, this motor drives the vehicle's wheels. Some vehicles use motor generators that perform both the drive and regeneration functions.

Onboard charger: Takes the incoming AC electricity supplied via the charge port and converts it to DC power for charging the traction battery. It also communicates with the charging equipment and monitors battery characteristics such as voltage, current, temperature, and state of charge while charging the pack.

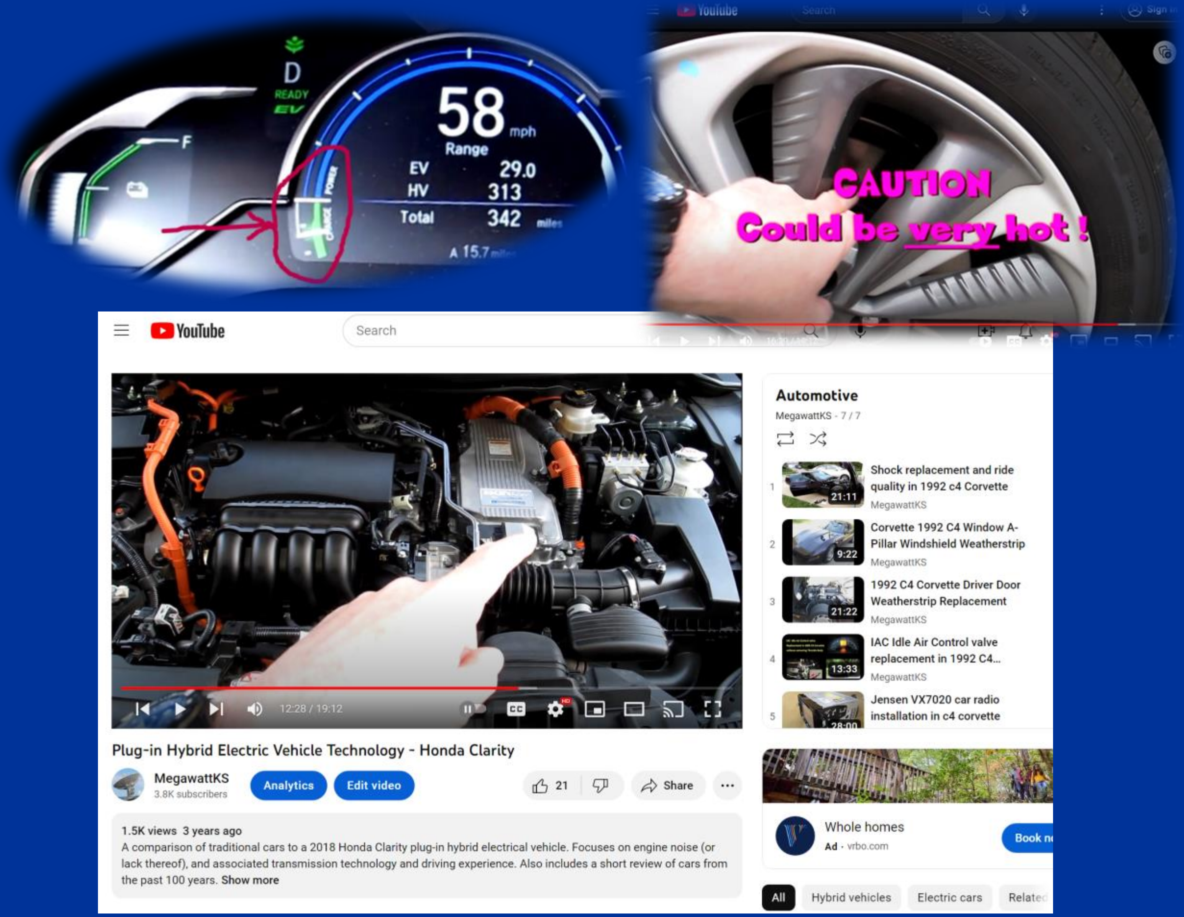
Power electronics controller: This unit manages the flow of electrical energy delivered by the traction battery, controlling the speed of the electric traction motor and the torque it produces.

Thermal system (cooling): This system maintains a proper operating temperature range of the engine, electric motor, power electronics, and other components.

Traction battery pack: Stores electricity for use by the electric traction motor.

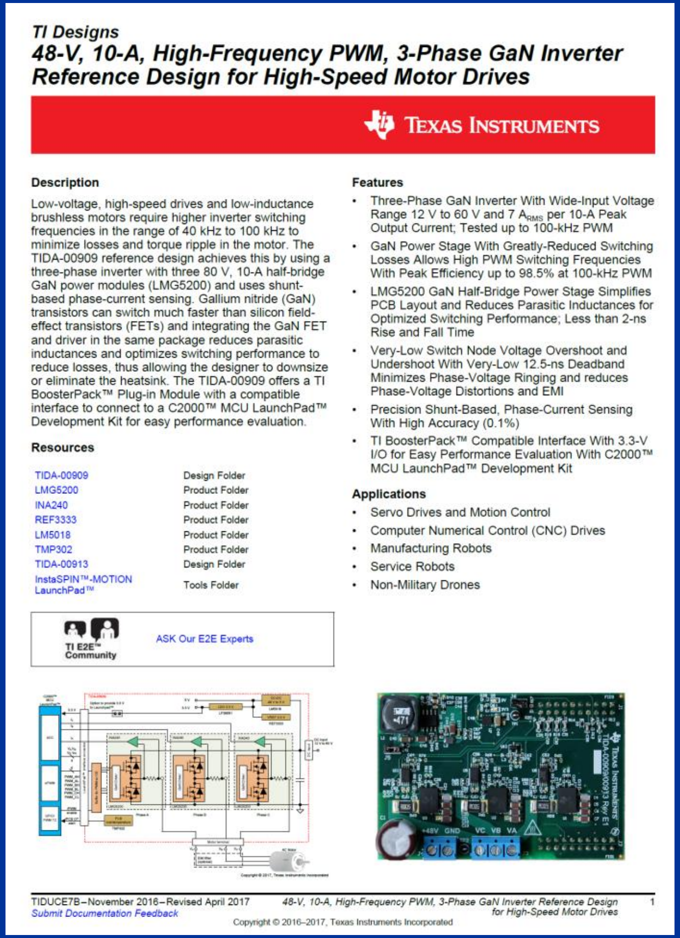
Transmission (electric): The transmission transfers mechanical power from the electric traction motor to drive the wheels.

https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work



https://www.youtube.com/watch?v=ZAG-ttIKDko

Future Videos ?



TI Designs

48-V, 10-A, High-Frequency PWM, 3-Phase GaN Inverter Reference Design for High-Speed Motor Drives

TEXAS INSTRUMENTS

Description

Low-voltage, high-speed drives and low-inductance brushless motors require higher inverter switching frequencies in the range of 40 kHz to 100 kHz to minimize losses and torque ripple in the motor. The TIDA-00909 reference design achieves this by using a three-phase inverter with three 80 V, 10-A half-bridge GaN power modules (LMG5200) and uses shunt-based phase-current sensing. Gallium nitride (GaN) transistors can switch much faster than silicon field-effect transistors (FETs) and integrating the GaN FET and driver in the same package reduces parasitic inductances and optimizes switching performance to reduce losses, thus allowing the designer to downsize or eliminate the heatsink. The TIDA-00909 offers a TI BoosterPack™ Plug-in Module with a compatible interface to connect to a C2000™ MCU LaunchPad™ Development Kit for easy performance evaluation.

Resources

TIDA-00909	Design Folder
LMG5200	Product Folder
INA240	Product Folder
REF3333	Product Folder
LM5018	Product Folder
TMP302	Product Folder
TIDA-00913	Design Folder
InstaSPIN™-MOTION LaunchPad™	Tools Folder

TI E2E™ Community — ASK Our E2E Experts

Features

- Three-Phase GaN Inverter With Wide-Input Voltage Range 12 V to 60 V and 7 A_{RMS} per 10-A Peak Output Current; Tested up to 100-kHz PWM
- GaN Power Stage With Greatly-Reduced Switching Losses Allows High PWM Switching Frequencies With Peak Efficiency up to 98.5% at 100-kHz PWM
- LMG5200 GaN Half-Bridge Power Stage Simplifies PCB Layout and Reduces Parasitic Inductances for Optimized Switching Performance; Less than 2-ns Rise and Fall Time
- Very-Low Switch Node Voltage Overshoot and Undershoot With Very-Low 12.5-ns Deadband Minimizes Phase-Voltage Ringing and reduces Phase-Voltage Distortions and EMI
- Precision Shunt-Based, Phase-Current Sensing With High Accuracy (0.1%)
- TI BoosterPack™ Compatible Interface With 3.3-V I/O for Easy Performance Evaluation With C2000™ MCU LaunchPad™ Development Kit

Applications

- Servo Drives and Motion Control
- Computer Numerical Control (CNC) Drives
- Manufacturing Robots
- Service Robots
- Non-Military Drones

TIDUCE7B–November 2016–Revised April 2017 — *48-V, 10-A, High-Frequency PWM, 3-Phase GaN Inverter Reference Design for High-Speed Motor Drives* — 1

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