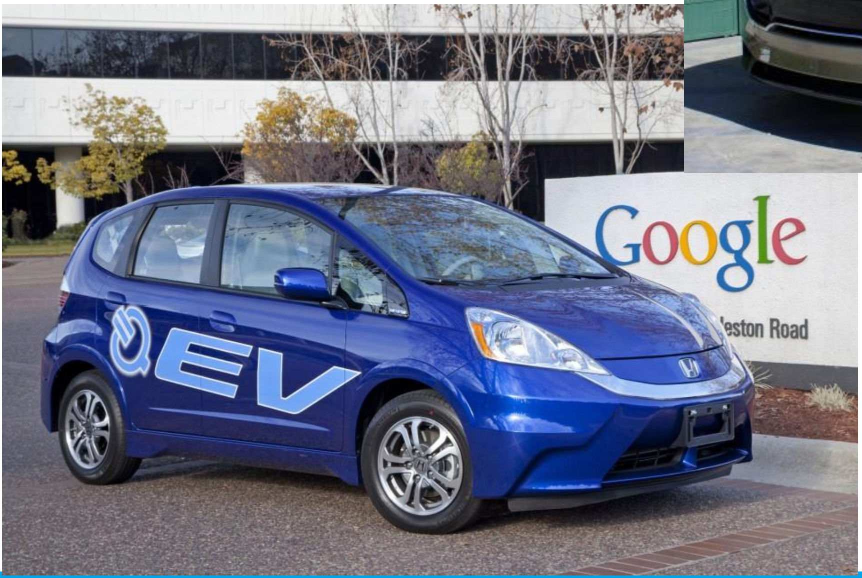
Standards and Codes Related to PEV Charging and Communication



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Overview

- Types of Electric Vehicles/Charging Times
- Basics of PEV charging: AC on-board vs DC off-board
- Basics of PEV and EVSE Digital Communication
- Smart Home Communication Example
- SAE Hybrid Communication Task Force Standards
- Wireless Charging

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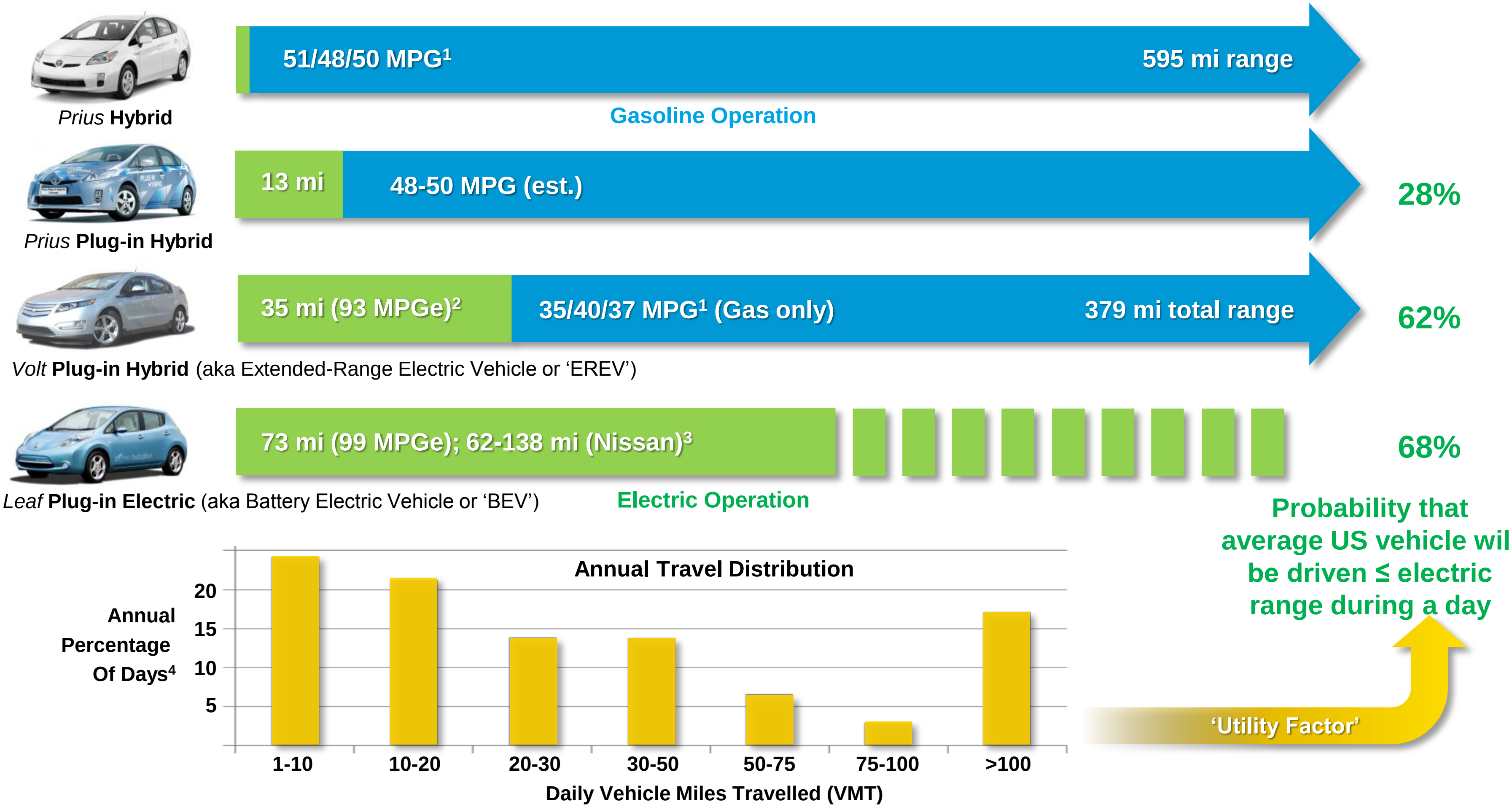
Unique Charging Needed for Each Vehicle Type

- **Plug in Hybrid Electric Vehicle (PHEV)**
  - Very limited electric range – small battery 5-10 kWhr
  - OB Charger Output Power: 1-3 kW
  - 2012 Toyota Prius PHEV Electric Range: 13 miles

- **Extended Range Electric Vehicle (EREV)**
  - Increased electric range – medium battery 10-20 kWhr
  - OB Charger Output Power: up to 6 kW
  - 2012 Chevy Volt Electric Range: 35 miles

- **Battery Electric Vehicle (BEV)**
  - All electric range – large battery >20kWhr
  - OB Charger Output Power: > 6 kW
  - 2012 Ford Focus Electric Range: 76 miles

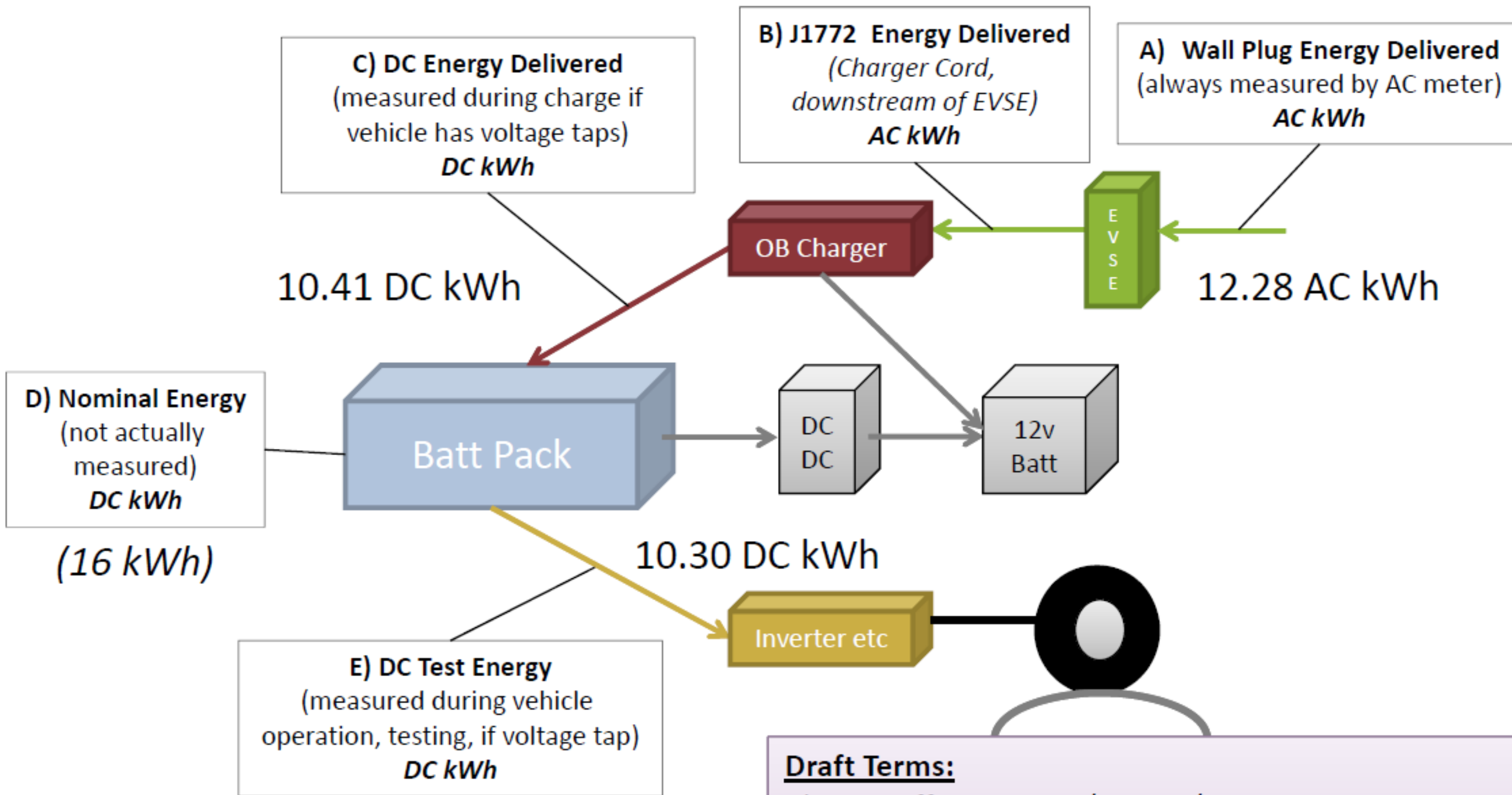
Range Comparisons and Benefits



[1] EPA rated fuel economy on urban/highway/combined driving cycles
[2] MPG equivalent = combined city/highway electric energy consumption translated to fuel economy based on 33.7 kWh per gallon of gasoline
[3] 'Real world' range results by Nissan as a function of climate control, speed, driving style and load/topography
[4] Representative travel distribution; source: http://www.fhwa.dot.gov/policyinformation/pubs/hf/pl10023/fig4_5.cfm

Source: eere.energy.gov

2011 Chevy Volt Charge Energy and Efficiency Analysis



Draft Terms:

Charger Efficiency = C / B = N/A

Charger&EVSE Efficiency = C / A = 84%

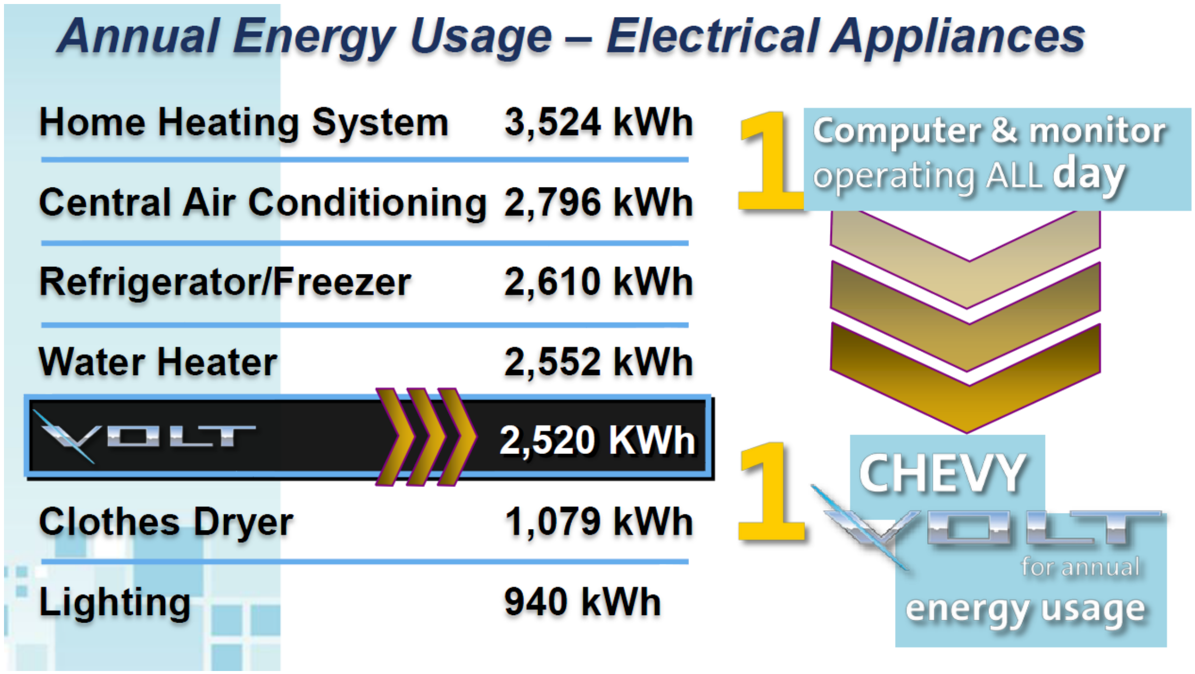
Overall Trip Efficiency = E / A = 84%

Battery Efficiency = E / C = 99%

Pack Utilization = E / D = 65%

Prepared by M. Duoba, ANL
Version 3

Relative Annual PEV Energy Usage (~2500kWh/year or $250/year: ~$21/month)



<u>Electric Only</u>

MPGe = 33.7 kWh/1 gal gas * miles/kWh

2011 EPA 93 MPGe (combined)=> 93 MPGe/33.7 kWh/gal gasoline = 2.76 miles/ kWh

2,520 kWh*2.76 miles/kWh = 6,955 miles

2,520 kWh *(0.84)* 2.76 miles/kWh = 5,842 miles (1,113 miles 'lost' due to OB charger inefficiency)

Assuming $0.10/kWh: 1 kWh(DC)/2.76 miles *(1/0.84) $0.10/kWh (AC)= ~$0.043/mile

<u>Gasoline Only</u>

2011 EPA 37 MPG (combined)

Assuming $4/gallon gas: 1 gal/37mile * $4/gallon = ~ $0.11/mile

www.fueleconomy.gov

How fast can a PEV be charged? (It depends)

The SAE DC charging standards current limits are most relevant. Delivered charging power is limited by vehicle's battery voltage- typically less than 400vdc.

SAE Level 1 DC limit is **80A** at up to 450vdc
SAE Level 2 DC limit is **200A** at up to 450vdc
SAE Level 3 DC limit is **400A** at up to 600vdc

The miles per minute of charge rate is tied to the size of the vehicle. Using simple math of 4 miles/kWh, and a nominal battery voltage of 400v, results in the following:

How fast can a PEV be charge? (It depends)

- Level 1 J1772-DC= 80*400=32kW*4=132 miles per hour of charging, or 132/60 minutes= **2.2 miles/minute**

- Level 2 J1772-DC= 200*400=80kW*4=320 miles per hour of charging, or 320/60 minutes= **5.33 miles/minute**

- Level 3 J1772-DC= 400*400=160kW*4=640 miles per hour of charging, or 640/60 minutes= **10.66 miles/minute**

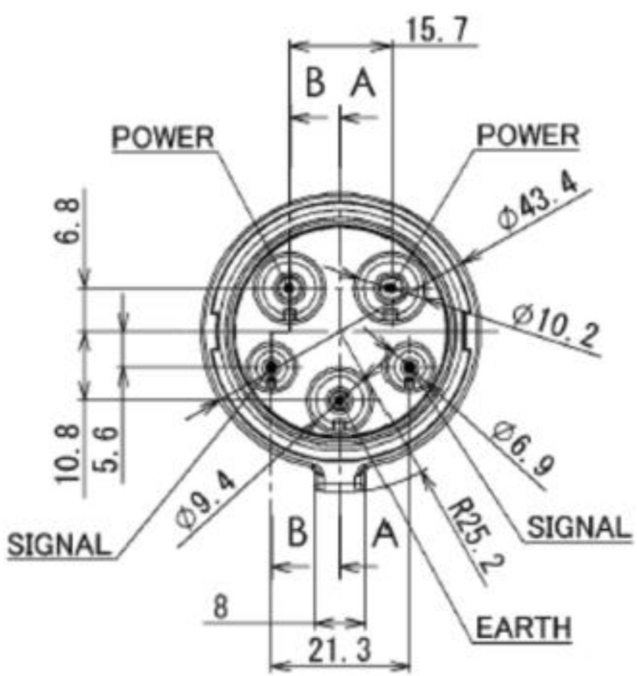
The broad answer is "It depends", and above are some examples of the typical parameters (4 miles/kWh, ~400vdc battery).

Electric Vehicle Supply Equipment (EVSE)

- General Purpose of Electric Vehicle Supply Equipment (EVSE) is to be an intelligent interlocked coupling system
- AC, DC, or wireless high frequency resonant AC
- Cost Ranges from ~$500 AC-1 to $50,000 DC-2 (not including installation/infrastructure fees)

Level	Volts	Amps	kW
AC-1	120	20	2.4
AC-2	240	<80	<19.2
DC-1	<450	<80	<36
DC-2	<450	<200	<90
DC-3	<600	<400	<240

SAE J1772: Conductive Charge Coupler

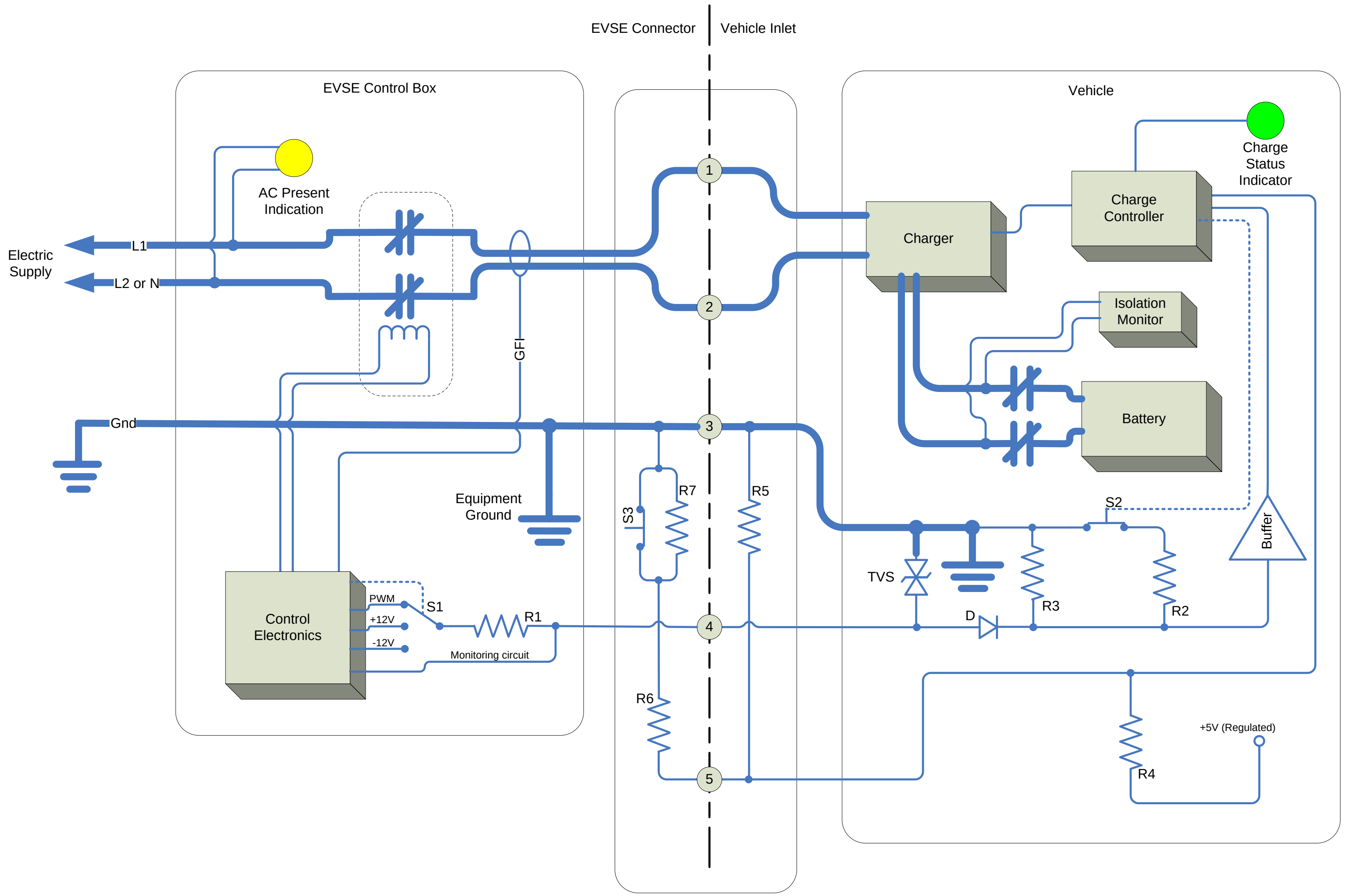


5 pins total:

- Single phase power 2 pins power (80A)
- Ground
- Pilot signal
- Proximity

Contact #	Connector Function	Vehicle Inlet Function	Description
1	AC Power (L1)	Charger 1	Power for AC Level 1 and 2
2	AC Power (L2,N)	Charger 2	Power for AC Level 1 and 2
3	Equipment ground	Chassis ground	Connect EVSE equipment grounding conductor to EV/PHEV chassis ground during charging
4	Control pilot	Control pilot	Primary control conductor (operation described in Section 5)
5	Proximity Detection	Proximity Detection	Allows vehicle to detect presence of charge connector

Electric Vehicle Supply Equipment (EVSE)- AC Level 1 and 2



Electric Vehicle Supply Equipment (EVSE) Pilot Line Circuitry

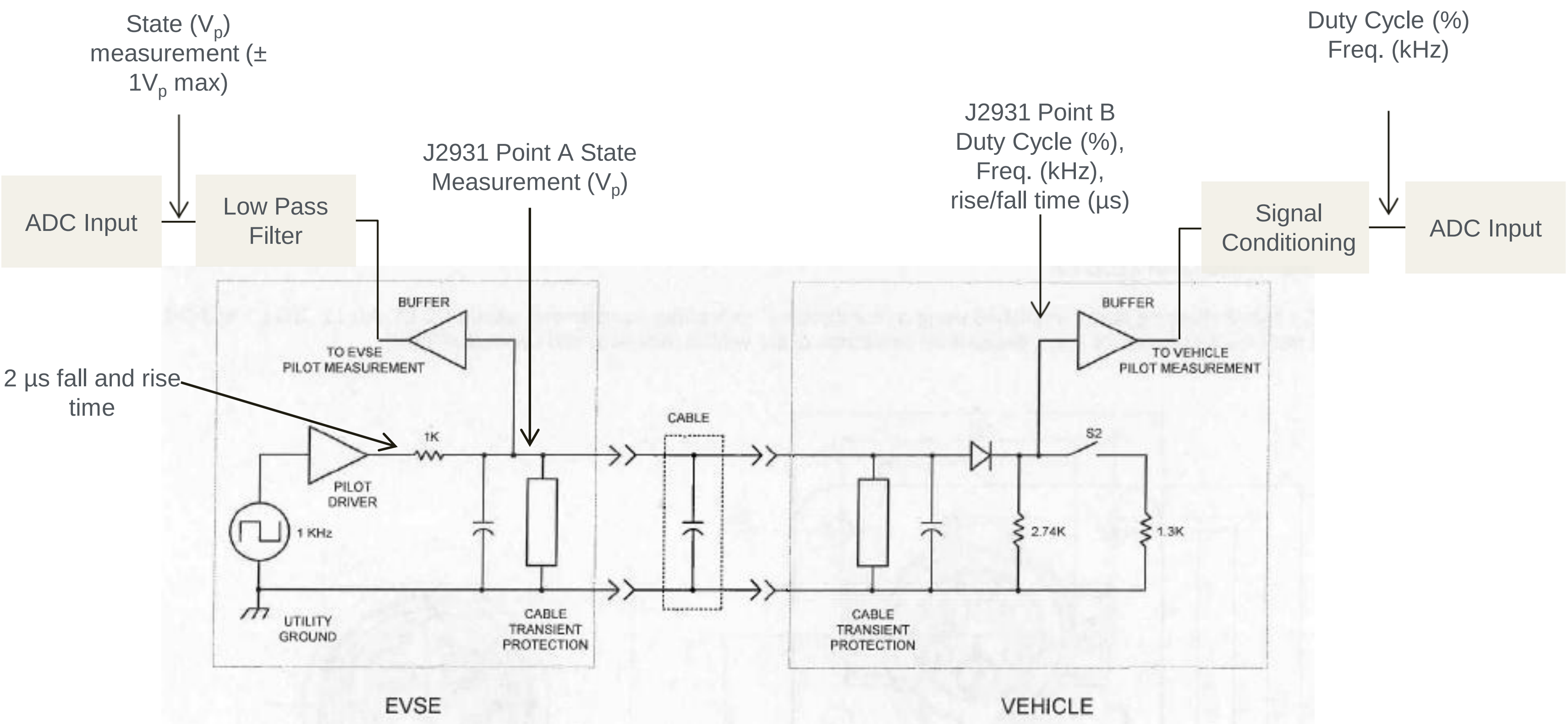


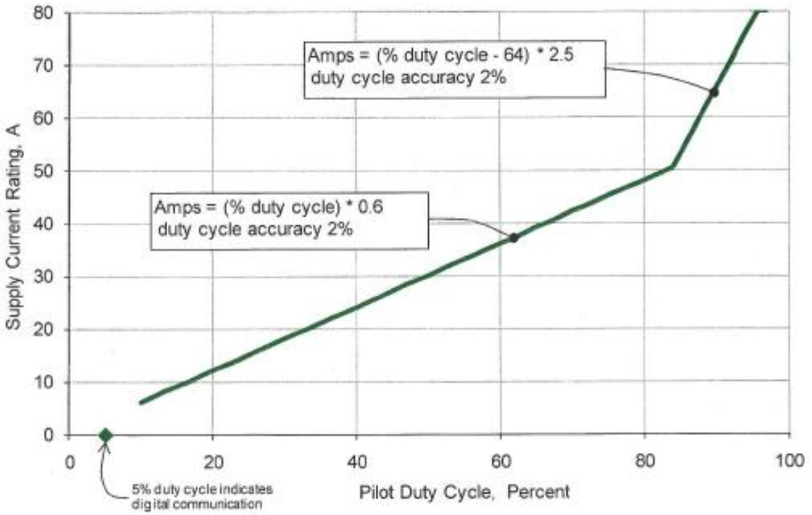
FIGURE D1 - TYPICAL PILOT LINE CIRCUITRY

Electric Vehicle Supply Equipment (EVSE)- AC Level 1 and 2

TABLE 3 - DEFINITION OF VEHICLE / EVSE STATES

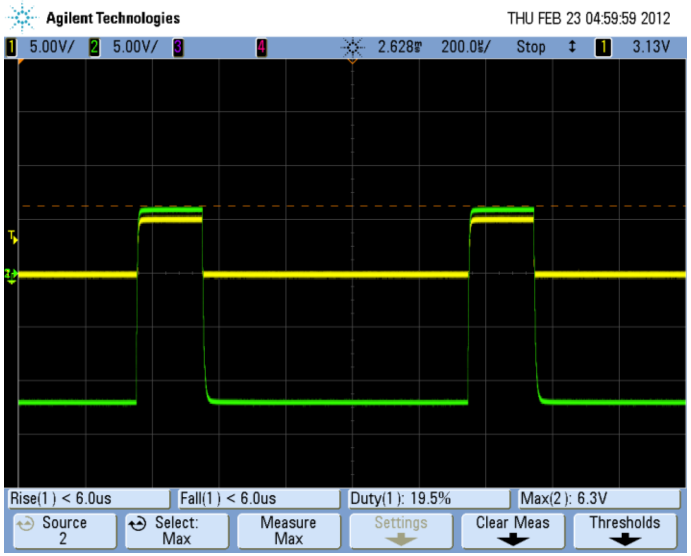
State Designation	Voltage (vdc Nominal)[5]	Description of Vehicle / EVSE State
State A	12.0[1]	Vehicle not connected
State B1	9.0[1]	Vehicle connected / not ready to accept energy EVSE standby state
State B2	9.0[2][3]	Vehicle connected / not ready to accept energy EVSE capable to provide energy
State C	6.0[2]	Vehicle connected / ready to accept energy / indoor charging area ventilation not required EVSE capable to provide energy
State D	3.0[2]	Vehicle connected / ready to accept energy / indoor charging area ventilation required EVSE capable to provide energy
State E[4]	0	EVSE disconnected from vehicle EVSE utility power not available, control pilot short to utility ground
State F	−12.0[1][6]	EVSE detects missing or shorted diode D1.

1. Static voltage.
2. Positive portion of 1 KHz square wave, measured after transition has fully settled.
3. The transition from State B1 to State B2 begins as a static DC voltage which transitions to PWM upon the EVSE detection of vehicle connected / not ready to accept energy and EVSE capable to provide energy.
4. EVSE is not required to actively generate State E.
5. Voltage measured by EVSE as shown in Figure 5.
6. Optionally the EVSE may enter State F upon detecting a self diagnosed fault that prevents the EVSE from delivering power. This option would require user intervention to reset the EVSE to restore normal operation.



EVSE: Measures Pilot State

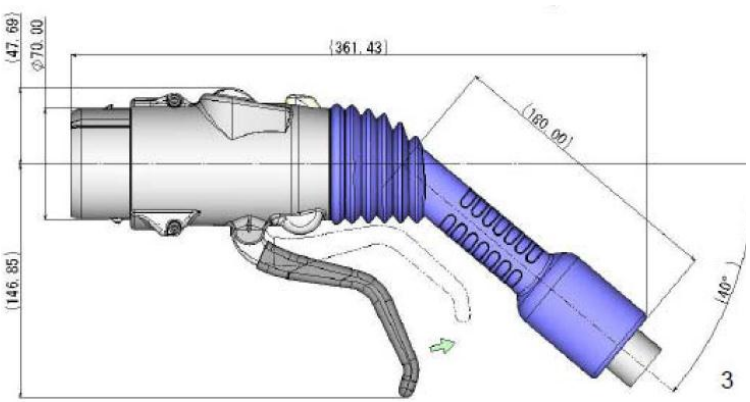
PEV: Measures Duty Cycle

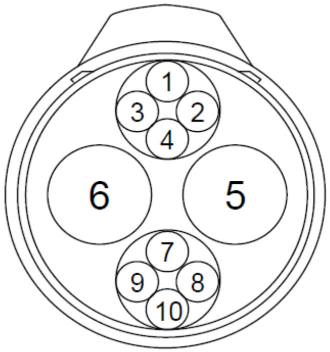


Source: SAE J1772 Standard

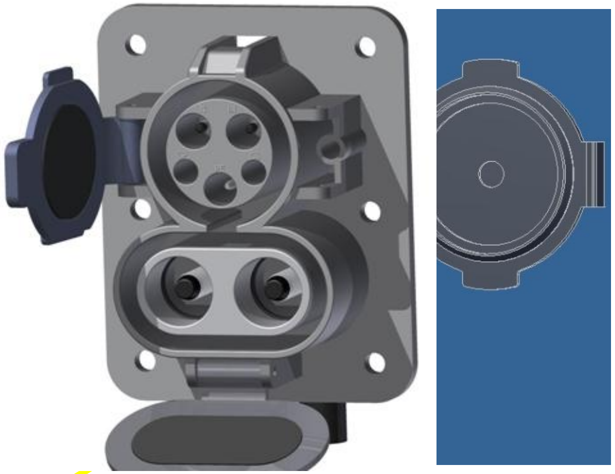
DC Fast Charging Couplers: ChAdEMO or SAE J1772-Combo?

Look mom, no lever! Due to fewer Comm. Pins





Nissan Leaf uses two connectors (DC-ChAdEMO and AC-J1772)



SAE/ISO AC+DC Combo J1772)

CAN Pins avoided via J2931 PLC over Pilot

DC Charging Stations

- Currently only Nissan Leaf and Mitsubishi iMIEV have DC charging inlets (50kW)- (previously ~$900 option, now std.)
- SAE/IEC combination DC-AC charging standards are coming in 2012- vehicles 2014?

- 50kW=50/3=12.6kWhr-> $1.26 of electricity at $0.10/kWhr;
- Including service fee $20/12.6kWhr=<u>$1.59/kWhr</u>

Blink

Coulomb- Acker Wade

Nissan

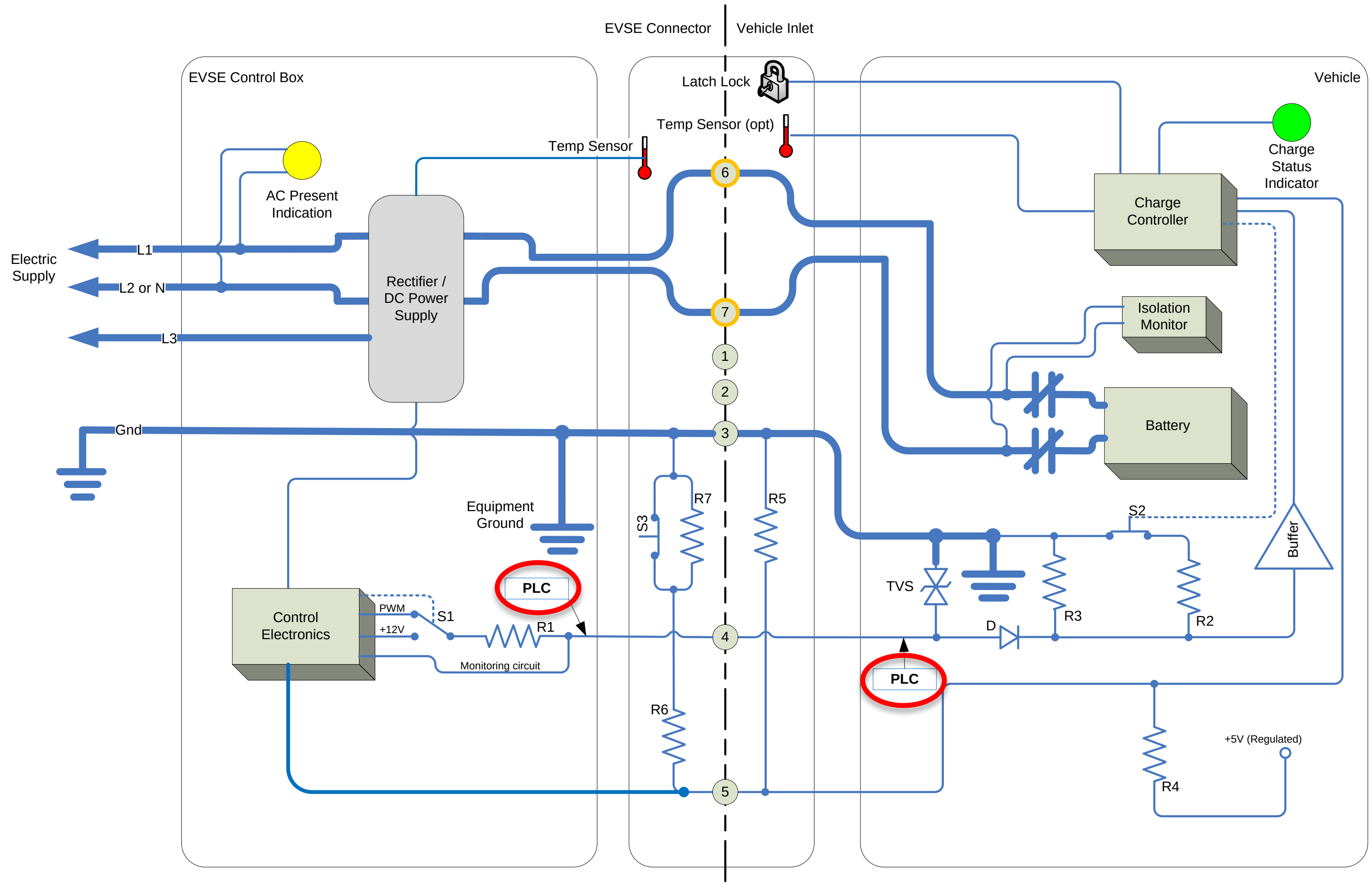

Epyon- Holland,


Aerovironment

All of the above use the ChAdEMO DC coupler

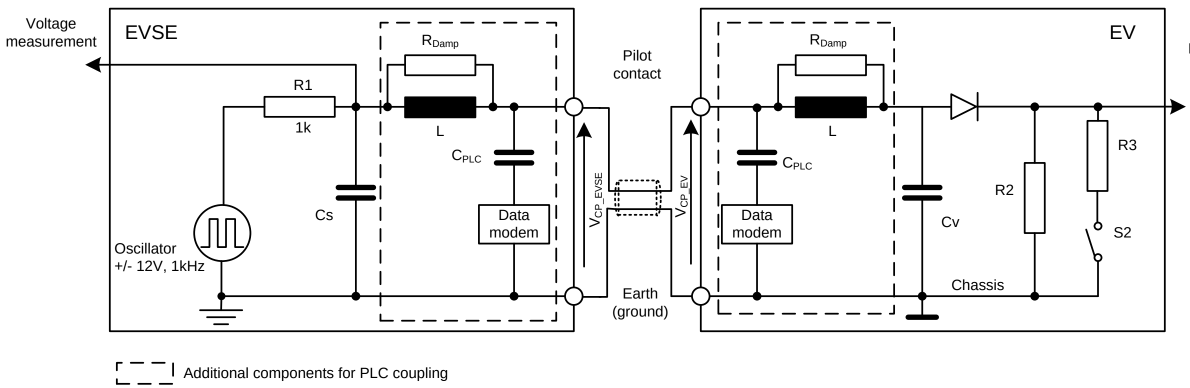
Others include Eaton, Efacec, Delta Products, Fuji Electronics, DBT, etc

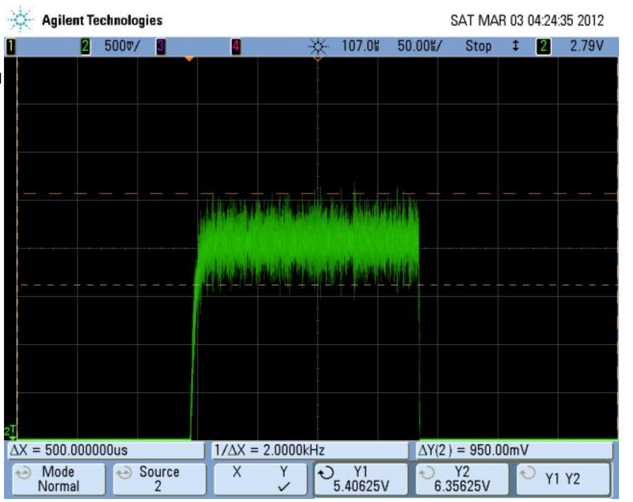
Electric Vehicle Supply Equipment (EVSE)- SAE DC Level 1 and 2



Digital Messaging Needed to “Close Loop”, but no CAN pins?

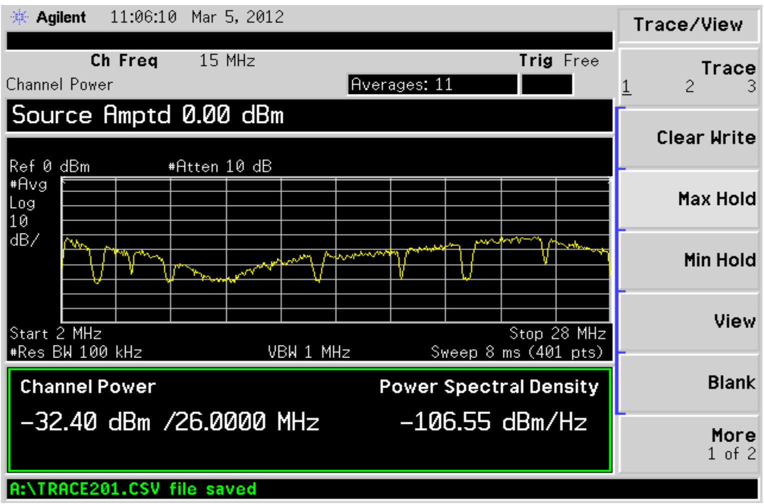
PLC: Power Line Communication





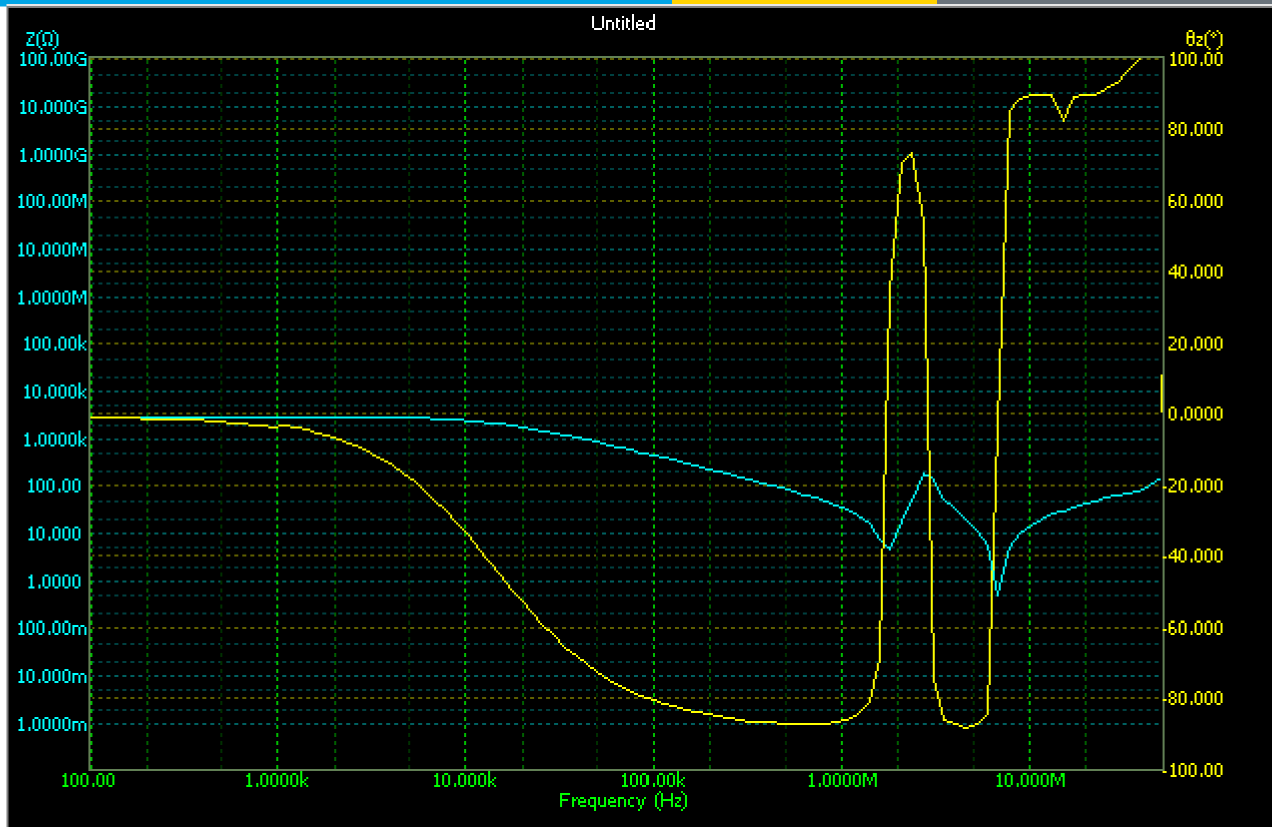
Impresses a modulated carrier signal on existing wiring system.

Netgear XAV2001: HPAV PLC Adapters ~80 Mbps



HomePlug Green PHY: Prime Technology

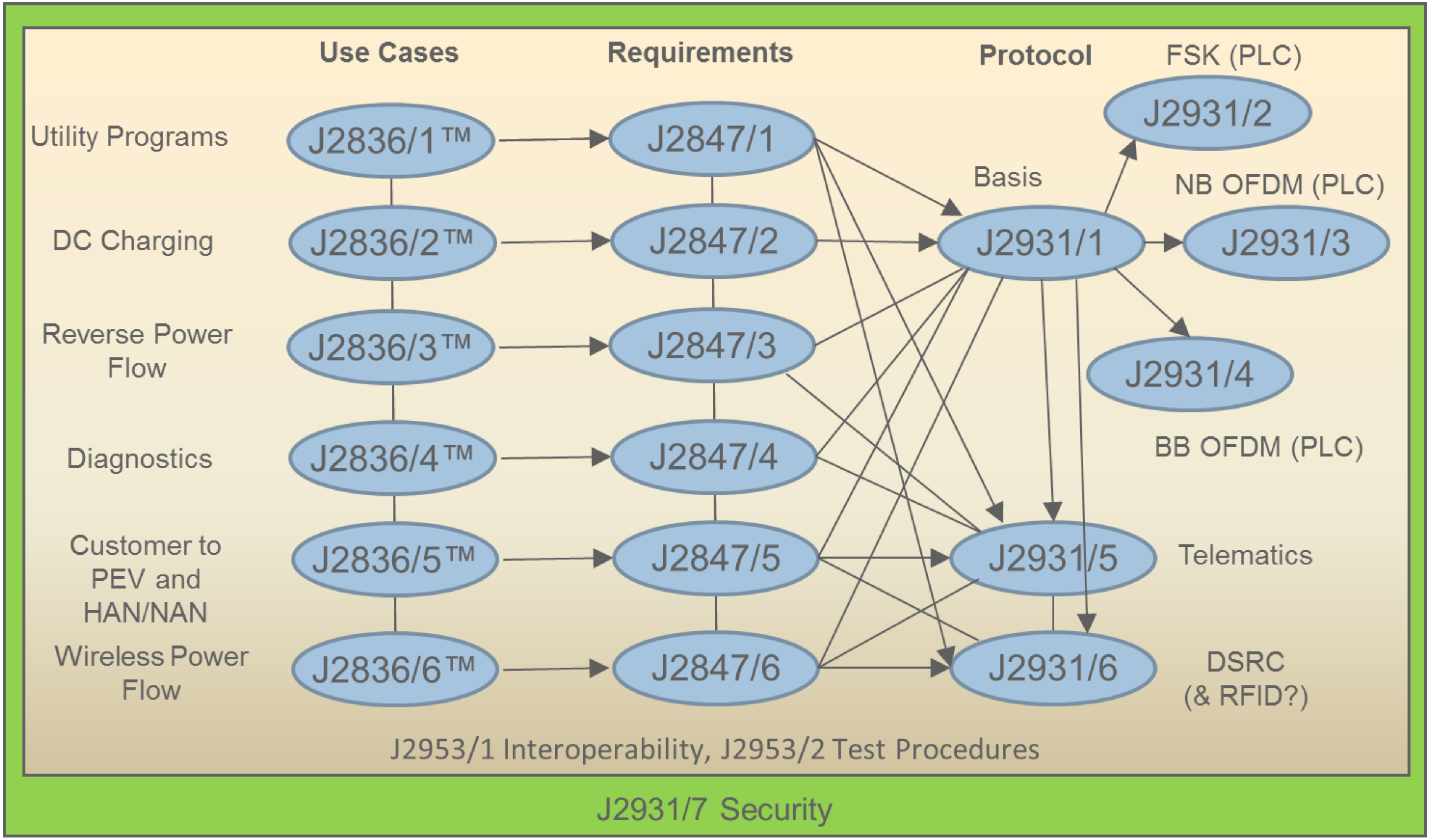
Charger Cordset or HF Transmission Line?



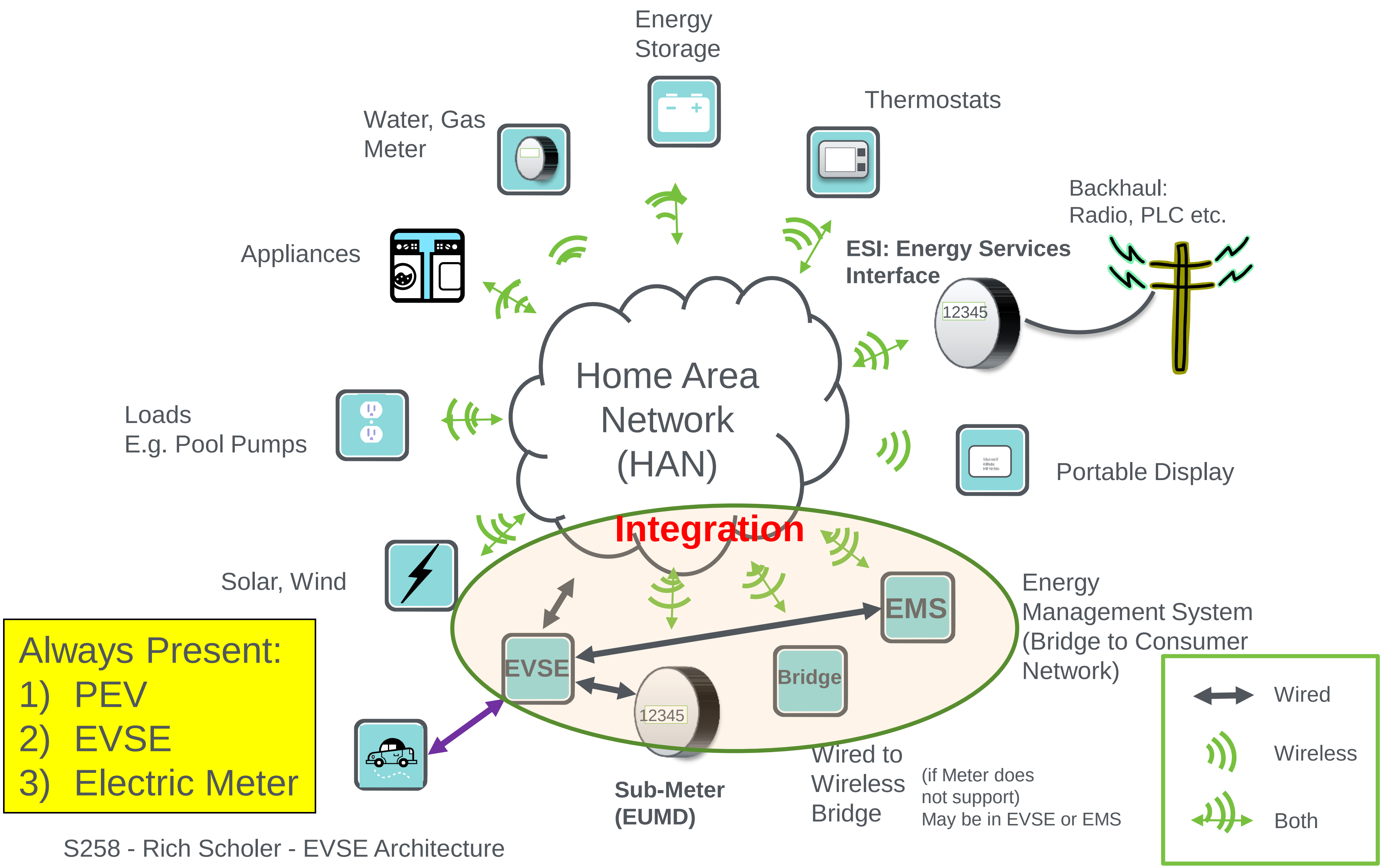
Wayne Kerr 6500B
Impedance Analyzer

Switch Closed
(State C), No PLC
modem connected

SAE Hybrid Communication Task Force Standards



Networks for Energy Management Area
Key Element of Smart Grid Architectures



S258 - Rich Scholer - EVSE Architecture

Historical Perspective on EV Charging Equipment 1900 to Today ….and Tomorrow

1913- 150A/48vdc coupler (30,000 EVs in 1913)

The electric vehicle - raising the standards

Figure 3.25: 150 A charging plug with handle[101]

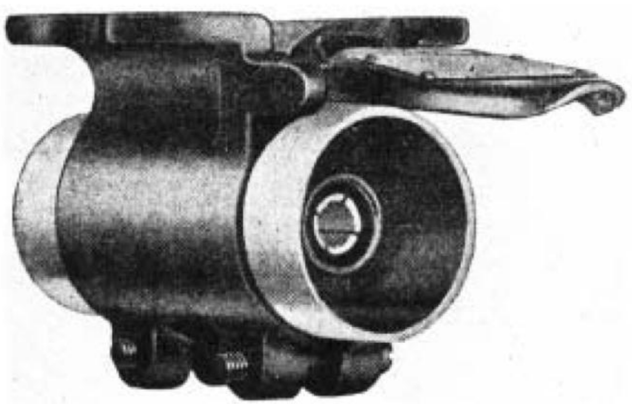
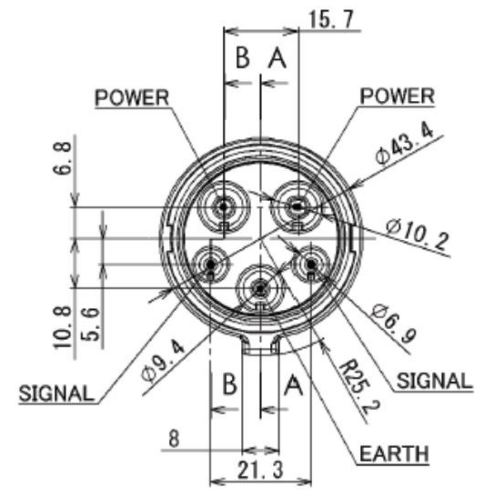


Figure 3.26: 150 ampere-hour (sic) charging receptacle[102]

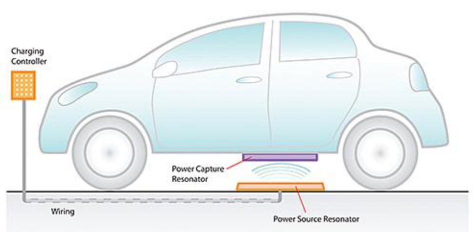
1990's J1772 Conductive

SAE J1773 Inductive

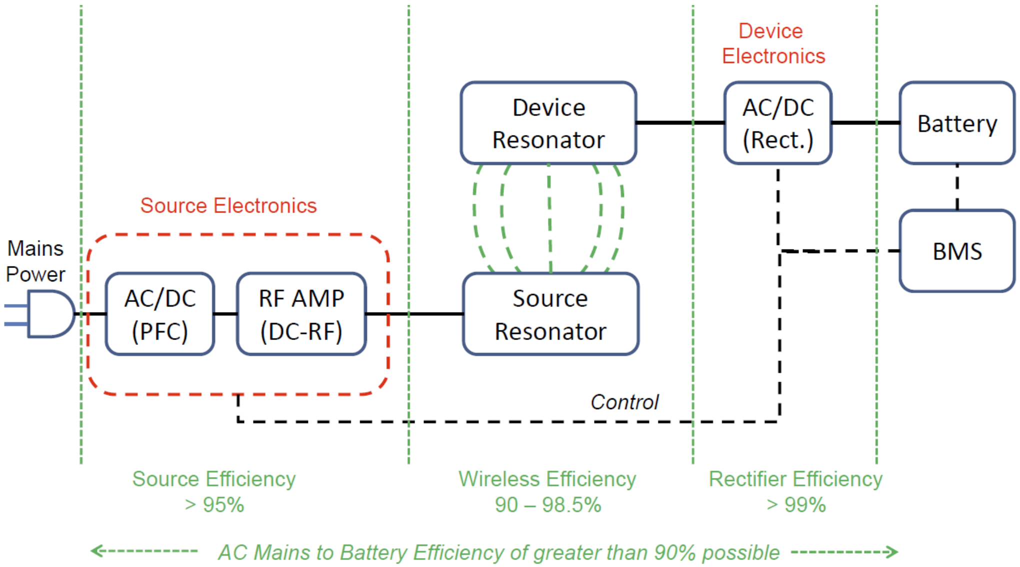
2010 SAE J1772 Level 2 240vac/<80A (32A typ.)



2011 SAE J2954 Wireless Charging



SAE J2954 Wireless Charging

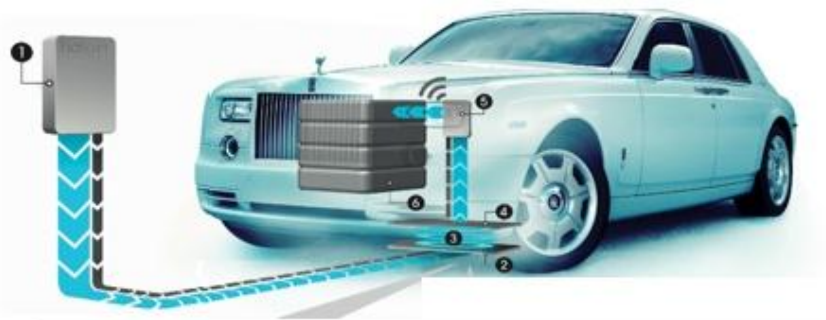


Source: Morris Kessler Witricity Corporation

1 POWER SUPPLY
Converts mains frequency (50Hz) to high frequency (20kHz) current for supply to transmitter pad. High frequency is necessary to ensure highly efficient transfer with low emissions.

2 TRANSMITTER PAD
High-frequency energy creates a strong magnetic field above the pad. The design of the magnetic topology is crucial to transfer power over practical gaps - between 80mm and 400mm.

3 MAGNETIC COUPLING
Power and data flow across the gap in a tightly controlled and contained magnetic field that meets international magnetic field emissions.



4 RECEIVER PAD
High-frequency current is induced in the receiver pad and sent to the controller, excellent magnetics design provides small form factor pads for ease of vehicle packaging whilst maintaining high tolerance to misalignment required.

5 CONTROLLER
Regulates power and converts high frequency to DC for supply to the batteries, communicates with the vehicle control and battery management systems.

6 BATTERY
Stores energy from wireless charging system to power electric motor.

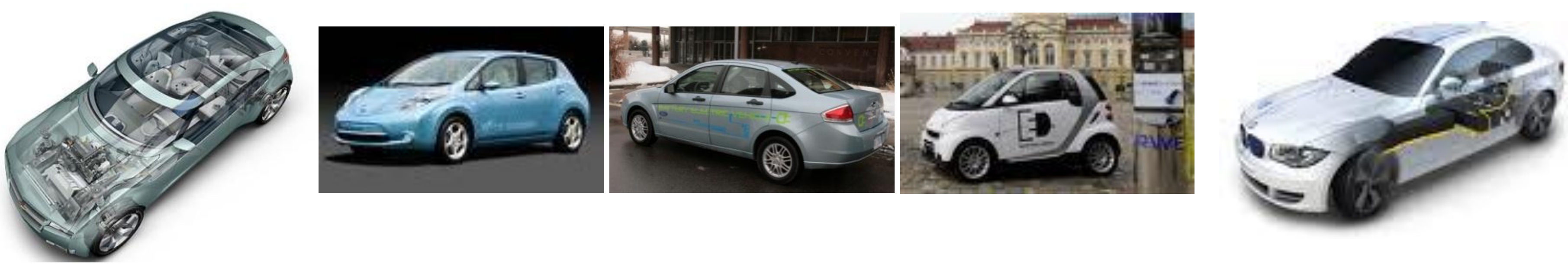
SAE J2953-PEV-EVSE Compatibility

Many Combinations of EVs, EVSE and Utility Region Installations

Occasional use cable | EVSE | DC off board charger

Utilities

? Interoperability ?



Questions?