Reference: Electric Vehicle Charging Equipment

INTRODUCTION

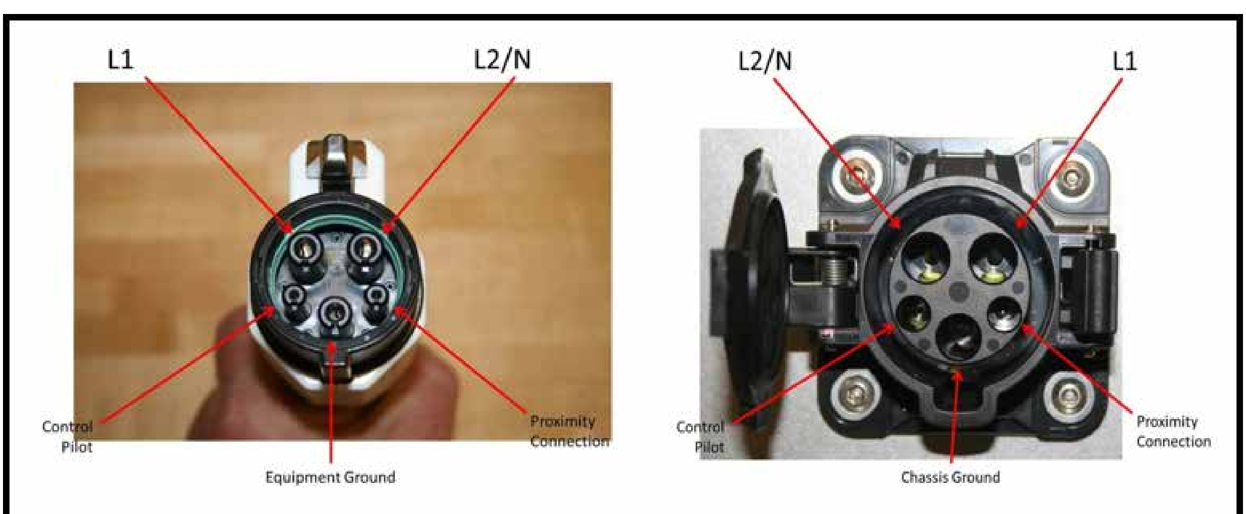
Electric vehicle supply equipment (EVSE) is the equipment that supplies electric power for the recharging of plug-in electric vehicles, including all-electric cars and plug-in hybrids. The EVSE supplies a safe method of connection from the supply to the EV through a group of specially designed pins located on the connector. The connector pin configuration communicates with the EV to confirm good communications, what level of charge is required, and verifies that it is safe to begin the transfer of energy from the EVSE to the EV.

EVSEs offer different levels of electric supply. Current standards are Level 1, Level 2, and multiple levels of DC fast charging. Level 1 charging uses standard 120-volt residential power using standard 15- or 20 -ampere receptacles. Level 1 EVSE is typically included with the purchase of the EV, or may be purchased from a number of different manufacturers.

The connector used to attach from the EVSE to the EV is an SAE J1772. This connector is used for both Level 1 and Level 2 charging, and a revised version of the J1772 connector, called the J1772 combo connector is being used for DC fast charging on some vehicles. Both Level 1 and Level 2 connectors supply AC power to the EV's on-board battery charger, which then inverts the AC for storage in the battery pack. The on-board charger determines the amount of current flow necessary to safely charge the batteries. The J1772 was adopted by car manufacturers such as Chevrolet and Nissan, with the help of funding from several national programs such as ChargePoint and the American Recovery and Reinvestment Act. Typical Level 1 AC chargers use the standard 120-volt AC and operate at 1.4 kilowatts, drawing up to 12 amperes of current, or 1.9 kilowatts drawing up to 16 amperes.

The SAE J1772 electric vehicle charging station can be used for Level 1 charging only.

Courtesy of the Electric Vehicle Infrastructure Training Program.



The design of the SAE J1772 connector minimizes the risk of electric shock or arcing hazards.

Courtesy of the Electric Vehicle Infrastructure Training Program.

The J1772 is designed to ensure the safety of the operator by including several levels of shock protection. Most importantly, the grounding equipment grounding pin connection is the longest pin, offering a first make, last break connection of the equipment grounding connection, to ensure ultimate safety.

The connector's power pins are isolated on the interior of the connector when mated with the inlet. The power pins, L1 and L2, are first make, last break when compared with the control pins. No electrical energy is transferred from the EVSE to the EV until the power pins are mated and the proximity and control pilot are connected.

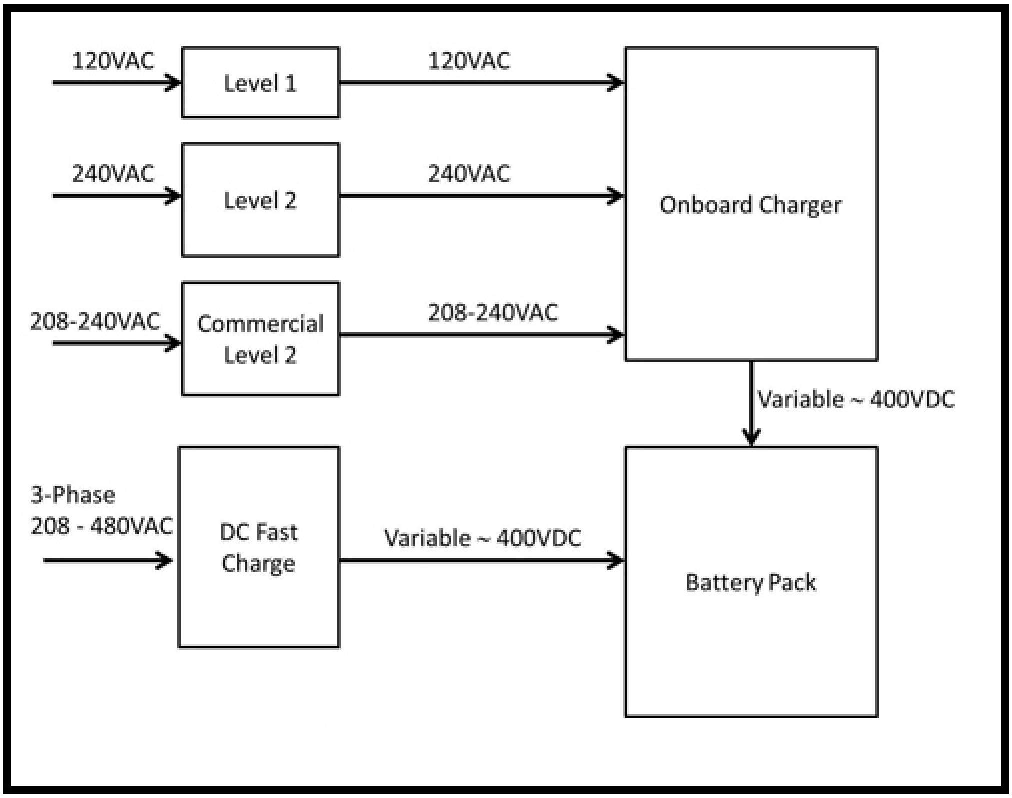
When removing the connector from the EV the first pins to break are the proximity and control pilot, causing electricity to cease flowing before the power pins break, preventing any possibility of arcing. Pressing the switch of the connector handle also changes the resistance on the proximity pin communicating with the EVSE as to the status of the connector: removed from EVSE or connected to the EV. When the J1772 connector is not connected to the EV the reading between the proximity pin and ground should be 150 ohms. When the button on the handle is pressed the reading increases to 480 ohms. The change in resistance signals the status of the connector to the EVSE and will stop the flow of current immediately when the button is depressed.

State	Pilot High	Pilot Low	Frequency	EV Ω	Description
A	+12V	N/A	DC	N/A	Not Connected
B	+9V	-12V	1kHz	2.74k	EV Connected
C	+6V	-12V	1kHz	882	EV Charge
D	+3V	-12V	1kHz	246	EV Charge Vent. Required
E	+0V	+0V	N/A		Error
F	N/A	-12V	N/A		Unknown/Error

Changes in resistance signal to the EVSE when to stop and start the flow of current to the EV.

Courtesy of the Electric Vehicle Infrastructure Training Program.

The main signal is called the pilot. The EV places a resistor and diode in series between the pilot and ground to vary the voltage. The EV reads the voltage and changes state accordingly. A resistance value of 2.74 kiloohms indicates that the EV is connected and ready to charge, and a resistance value of 882 ohms is requesting power from the EVSE. The SAE J1772 specification requires a delay between states, but does not say how long the delay must be.



The method of delivering the charge to the EV differs depending on the size and level of the EVSE.

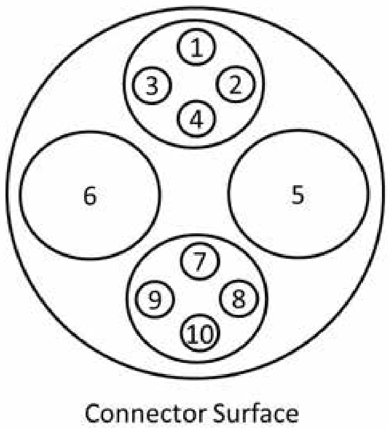
Courtesy of the Electric Vehicle Infrastructure Training Program.

EVSEs come in different sizes and levels of charging. Level 1 uses standard 120 volts AC, however, Level 2 doubles the voltage to 240 volts AC, allows a maximum of up to 32 amperes, and includes an integral GFCI for an added level of safety. Both Level 1 and Level 2 deliver AC power to the onboard charger in the EV. DC fast charge delivers high voltage DC directly to the battery packs of the EV.

Level 2 charging stations deliver AC power safely to the EV onboard chargers. The J1772 allows for communication between the EVSE and the EV, as well as the delivery of power. Once the level of charge is established and a safe connection has been made the EVSE supplies up to 19.2 kilowatts of power at 208/240 volts AC. This increase in power greatly reduces the amount of time necessary to charge the battery pack, however, the amount of time required to charge an EV is still between three and eight hours. While much faster than Level 1 charging, Level 2 still requires long periods of time to fully charge. An opportune time to do this type of charging would be at one's workplace, when the EV will be parked for long periods. Commercially available Level 2 EVSEs are typically 6.6 kilowatts, and up to 19.2-kilowatt stations can be expected in the near future. Once the high-power Level 2 stations become more widely available it will make sense to charge one's EV at places like shopping malls and grocery stores.

DC fast charge stations are by far the fastest way to charge an EV, with charging times reduced to 30 minutes or less. Not all EVs have the capability to connect to a DC fast charge station, as a special inlet port is required. DC fast charging does not supply power to the EV's onboard charger; rather it bypasses the onboard charger and supplies DC power directly to the battery via the battery management system.

This method of high voltage, high current transfer requires much larger pins than the ones included in the J1772, however the proximity and control pilot would remain the same. There are three major leaders in the race to standardize the connector for DC fast charging: CHAdeMO, SAE J1772 "combo connector," and the Tesla Supercharger. The Japanese developed CHAdeMO is used by Nissan, Mitsubishi, and Toyota, while the Society of Automotive Engineers (SAE) J1772 combo is in use by GM, Ford, Chrysler, Audi, Daimler, Porsche, Volkswagen, and BMW. The Tesla Supercharger is proprietary and used only on the Tesla. Some manufacturers of DC fast charging stations incorporate both CHAdeMO and J1772 combo connectors in their commercially available equipment.



Pin #	Function
1	Reference ground
2	Control EV Relay (1 of 2)
3	not assigned
4	Ready to Charge
5	DC Negative
6	DC Positive
7	Proximity Detection
8	Communication +
9	Communication -
10	Control EV Relay (2 of 2)

CHAdeMO connectors have 10 pins, each with an important role in the connection and charging process.

Courtesy of the Electric Vehicle Infrastructure Training Program.

CHAdeMO was developed by The Tokyo Electric Power Company along with several Japanese auto manufacturers. The connector has 10 pins to provide DC power, as well as communication, ground, proximity, and control for EV relays.

Combo couplers are J1772 connectors modified to accommodate DC fast charging.

Courtesy of the Electric Vehicle Infrastructure Training Program.

Rather than adopt the CHAdeMO connector, the SAE is revising the J1772 Standard to add a combo coupler to the existing J1772 connector, with additional pins to accommodate DC fast charging. If the EV has the combo coupler inlet installed, it will accept both the standard J1772 as well as the J1772 combo coupler, enabling the use of Level 1, Level 2, or DC fast charge in one combined design. The estimated time to charge an EV to 80% is under 30 minutes.

Tesla's proprietary Supercharger connects to the vehicle connector located in the tail light housing of the Tesla Model S.
Courtesy of the Electric Vehicle Infrastructure Training Program.

The Tesla Supercharger is proprietary and difficult to get accurate technical information from the manufacturer. All Tesla Model S and Supercharge-enabled EVs are capable of using the Tesla Supercharger. The Supercharger is capable of delivering up to 50% battery capacity in about 20 minutes.

Cable management has long been an issue with publicly available EVSE. Some manufacturers of EVSE are designing their equipment with retractable cables to limit the damage caused by customers not properly storing the cables after they complete their charge. Publicly available EVSEs are open to damage from weather, abuse, and being driven over. Other problems may arise with the moving parts associated with retractable cable management, so there is also talk around the industry of including cables with the EV, although safety comes into play anytime the public is expected to maintain their own cables. One thing is certain, changes are expected to come.

Commercially available EVSE or DC fast charge will probably be associated with some type of revenue collection, or at the very least verification that the person accessing the EVSE is a member of some group that is authorized to use it. Typical access can be granted in a number of ways, including credit card processing, company/fleet authorization card, or pay-by-phone service. All of these require communication with a remote facility, and will most likely be wirelessly connected to a network, although some may be hardwired for fleet networks.

While EVSE networks are in a constant state of flux, there are a number of large networks out there that are sure to be around for the foreseeable future. A sampling of the major networks currently includes Webasto (formerly Aeroviroment), Blink, ChargePoint, Electrify America, Greenlots SKY, NRG eVgo, and SemaConnect. Most, if not all, of these networks provide very intuitive websites to help the driver manage their usage as well as locate the nearest available charging stations. Each network has its own unique model, with the most common approach being monthly or annual membership and typical information provided would include available stations, associated fees, status (in use or available), and driver historical data.

Last, but certainly not least, it is important to understand that the installation of EVSE is governed by the *National Electrical Code (NEC)*. Article 625 of the *NEC* was first created in 1996 and has continued to expand each *Code* cycle. Multiple definitions associated with EVs and EVSEs are included in this article. The scope of Article 625 states that "The provisions of this article cover the electrical conductors and equipment external to an electric vehicle that connect an electric vehicle to a supply of electricity by conductive or inductive means, and the installation of equipment and devices related to electric vehicle charging." Knowledge of this article is imperative to safely install EVSE.