EV Charging Infrastructure

EV infrastructure
# Types of electric vehicle charging stations

<table>
<thead>
<tr>
<th>Mode 1 (AC)</th>
<th>Mode 2 (AC)</th>
<th>Mode 3 (AC)</th>
<th>Mode 4 (DC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 VAC, 1-phase, 16 A max.</td>
<td>250 VAC, 1-phase, 32 A max.</td>
<td>250V AC, 1-phase, 32A max.</td>
<td>AC or DC input supply, cord or permanently connected, with control pilot &amp; shock protection</td>
</tr>
<tr>
<td>OR 480 VAC, 3-phase, 16 A max.</td>
<td>OR 480 VAC, 3-phase, 32 A max.</td>
<td>-OR- 480V AC, 3-phase, 32A max.</td>
<td>-OR- 80% charge of a fully depleted battery within 30 minutes*</td>
</tr>
<tr>
<td>Cord with no pilot or auxiliary connections</td>
<td>Cord with control pilot and shock protection</td>
<td>Permanently connected to AC supply with control pilot and shock protection</td>
<td></td>
</tr>
</tbody>
</table>

- **AC Level 1**
  - 120 VAC, 1-phase, 12 A, or 16 A max. continuous current

- **AC Level 2**
  - 208 V-240 VAC, 1-phase, ≤ 80A max. continuous current

- **AC Level 3**
  - 250 VAC, 1-phase, 32 A max.
  - OR 480 VAC, 3-phase, 32 A max.

- **AC Level 4**
  - 380 V-600 VAC, 3-phase input; DC output

- **DC Fast Charger**
  - It delivers DC power, bypassing the vehicle’s on-board charger
  - It typically provides 80% charge of a fully depleted battery within 30 minutes*

*The charge time is dependent on the vehicle’s battery capacity and charge acceptance rate*
Global electric vehicle charging equipment market

EV Charging Equipment, by Type, in 2018

- **AC Level 2**: 90.5%
- **AC Level 1**: 7.6%
- **DC**: 1.8%
- **Wireless**: 0.1%

**EV Charging Equipment Forecast**

- 2018
- 2019
- 2020
- 2021
- 2022
- 2023
- 2024
- 2025
- 2026

**Market Trends and Drivers**

- The production of electrified vehicles is increasing: estimated 6 million vehicles in 2019, growing to 16 million vehicles in 2023
- There is limited charging infrastructure in most regions
- The production of new EV charging equipment will increase at a compound annual growth rate (CAGR) of 22% between 2018 and 2026
- The majority of charging occurs at the home or workplace during a span of several hours (AC charging)
- There is consumer demand for charging times that emulate fuel refilling time for long-distance trips (DC charging)
- The voltage and power output of DC chargers is increasing to support fast charging
- Business models are evolving: increase property value; revenue generation

Sources:
- Boston Consulting Group – The Electric Car Tipping Point, 2018
- Littelfuse estimates

**Source:** Navigant Research – Market Data: Electric Vehicle Charging Equipment, 2017
AC charging station

Service Access Panel:
- Reed or Hall Effect Security Sensor

AC Input:
- Power Fuse Overcurrent Protection
- Fuse Block Mounting Accessory

Auxiliary Power Supply:
- Cartridge Fuse Overcurrent Protection
- TMOV/MOV, GDT Surge Protection
- SMPS Buck/Boost Module
- SMPS Opto-isolator Feedback Control
- SMPS Diode/Rectifier
- TVS Diode Overvoltage Protection
- PPTC Resettable Overcurrent Protection
- NTC Thermistor Temperature Sensing

User Interfaces:
- TVS Diode Overvoltage Protection
- Diode Array/Polymer ESD Suppressor

Communications:
- NFC Analog Front-End
- Diode Array/Polymer ESD Suppressor

Charging Plug:
- NTC Thermistor or RTD Temperature Sensing
AC charger functional block diagram

Legend:
- Power
- Data/Signal

<table>
<thead>
<tr>
<th>Technology</th>
<th>Product Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Fuse</td>
<td>JLLS, JLLN, KLKD</td>
</tr>
<tr>
<td>Fuse Block/Holder</td>
<td>LFT, LPSM</td>
</tr>
<tr>
<td>AC Fuse (PCB level)</td>
<td>314, 324, 215, NANO®</td>
</tr>
<tr>
<td>Metal-Oxide Varistor</td>
<td>AUMOV, TMOV, UltraMOV</td>
</tr>
<tr>
<td>Gas Discharge Tube</td>
<td>CG2, CG3</td>
</tr>
<tr>
<td>TVS Diode</td>
<td>AK3, AK6, AK10, LTKAKE, LTKAK10</td>
</tr>
<tr>
<td>SIDACtor® Protection Thyristor</td>
<td>Pxxx0ME, Pxxx0FNL</td>
</tr>
<tr>
<td>Silicon-Controlled Rectifier</td>
<td>SJ</td>
</tr>
<tr>
<td>Diode (passive rectification)</td>
<td>DPG, VBExx, DST, DSA, DSB</td>
</tr>
<tr>
<td>TVS Diode</td>
<td>P6SMB, SMBJ</td>
</tr>
<tr>
<td>Resettable PPTC</td>
<td>miniSMD</td>
</tr>
<tr>
<td>MOSFET</td>
<td>Polar™Power, CPC37xx</td>
</tr>
<tr>
<td>Optical Isolator</td>
<td>L’OC11x, LIA1xx</td>
</tr>
</tbody>
</table>

Note: Other Littelfuse solutions may be suitable depending on design-specific requirements.
AC charger functional block diagram

1. AC Grid Input
   - Overcurrent Protection

2. Auxiliary Power Supply

3. Communication

4. User Interfaces

5. Access Panel Sensors
   - Over-Temperature Protection

6. AC Output
   - Current Sensor

Legend:
- Power
- Data/Signal

Technology | Product Series
---|---
NFC Analog Front-End | NCD1300
Diode Array | AQ24CAN, SM24CANx
TVS Diode | SMF, SMAJ, SAC
Diode Array Polymer ESD | SEP0xx, SP402x, XGD
Magnetic Sensor | 59060, 59135, 55075, 55100
Temperature Sensor | setP™, PPG, USW, Glass Coated Thermistor

Note: Other Littelfuse solutions may be suitable depending on design-specific requirements.
DC charging station

Service Access Panel:
- Reed or Hall Effect Security Sensor

User Interfaces:
- TVS Diode Overvoltage Protection
- Diode Array/Polymer ESD Suppressor

Communications:
- NFC Analog Front-End
- Diode Array/Polymer ESD Suppressor

Power Module:
- Cartridge Fuse Overcurrent Protection
- TMOV/MOV, GDT, TVS Diode, SIDACtor Surge Protection
- Rectifier Module Power Conversion
- IGBT Power Conversion
- Si or SiC MOSFET Power Conversion
- Gate Driver Control
- Si or SiC Diode Power Conversion
- NTC Thermistor Temperature Sensor

Electrical Distribution:
- Power Fuse Overcurrent Protection
- Fuse Block Mounting Accessory
- Earth-Fault Protection Relay
- Current Transformer Leakage
- Current Sensing

Auxiliary Power Supply:
- Cartridge Fuse Overcurrent Protection
- TMOV/MOV, GDT Surge Protection
- SMPS Buck/Boost Module
- SMPS Opto-isolator Feedback Control
- SMPS Diode/Rectifier
- TVS Diode Overvoltage Protection
- PPTC Resettable Overcurrent Protection
- NTC Thermistor Temperature Sensing

Charging Plug:
- NTC Thermistor or RTD Temperature Sensing
### DC charger functional block diagram

#### AC Grid Input
1. Transient & Overload Protection

#### Rectifier & Power Factor Correction
2. AC Earth-Fault Protection
3. Auxiliary Power Supply
4. Bridgeless, Vienna or Boost Stage

#### DC–DC Converter
5. Gate Drivers
6. Full Bridge, Series Resonant

#### DC Output
7. Gate Drivers
8. Overload & Short-Circuit Protection
9. DC Earth-Fault Protection
10. Over-Temperature Protection

- **Controllers**
- **Communication**
- **User Interfaces**
- **Access Panel Sensors**

**Legend:**
- **Green** Power
- **Blue** Data/Signal

---

### Technology

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<td>CG2, CG3</td>
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<td>Metal-Oxide Varistor</td>
<td>AUMOV, TMOV, UltraMOV</td>
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<td>TVS Diode</td>
<td>AK3, AK6, AK10, LTKAK6, LTKAK10</td>
</tr>
<tr>
<td>SIDACtor® Protection Thyristor</td>
<td>Pxxx0ME, Pxxx0FNL</td>
</tr>
<tr>
<td>Current Transformer</td>
<td>SE-CS30</td>
</tr>
<tr>
<td>AC Earth-Fault Relay</td>
<td>SE-704</td>
</tr>
<tr>
<td>Silicon-Controlled Rectifier</td>
<td>SJ</td>
</tr>
<tr>
<td>MOSFET</td>
<td>X-Class, X2-Class</td>
</tr>
<tr>
<td>Optical Isolator</td>
<td>LOC11x, LIA1xx</td>
</tr>
<tr>
<td>TVS Diode</td>
<td>P6SMB</td>
</tr>
<tr>
<td>Resettable PPTC</td>
<td>miniSMD</td>
</tr>
</tbody>
</table>

**Note:** Power converter topologies may differ based on design-specific requirements.

**Note:** Other Littelfuse solutions may be suitable depending on design-specific requirements.
DC charger functional block diagram

1. AC Grid Input
   - Transient & Overload Protection

2. AC Earth-Fault Protection

3. Auxiliary Power Supply
   - Wireless, CAN Bus

4. Rectifier & Power Factor Correction
   - Bridgeless, Vienna or Boost Stage

5. Gate Drivers

6. DC–DC Converter
   - Full Bridge, Series Resonant

7. Gate Drivers
   - Gate Drives

8. DC Output
   - Overload & Short-Circuit Protection

9. DC Earth-Fault Protection

10. Over-Temperature Protection

11. Communication

12. User Interfaces

13. Access Panel Sensors

Legend:
- Green: Power
- Blue: Data/Signal

Note: Power converter topologies may differ based on design-specific requirements.

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<tr>
<td>Bridge Rectifier</td>
<td>DMA200X1600NA, MDNA240U2200ED</td>
</tr>
<tr>
<td>SiC or Si MOSFET</td>
<td>LSIC1MO, X2-Class Ultra Junction</td>
</tr>
<tr>
<td></td>
<td>XPT™, MIXA, MIXG</td>
</tr>
<tr>
<td>IGBT</td>
<td>XPT™, MIXA, MIXG</td>
</tr>
<tr>
<td>TVS Diode</td>
<td>TPSRx</td>
</tr>
<tr>
<td>Diode</td>
<td>LSIC2SD, SONIC-FRED™, FRED DSE</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>seIP™, USUR1000, Epoxy Coated Thermistor</td>
</tr>
<tr>
<td>High-Speed DC Fuse</td>
<td>L50QS, L70QS, L75QS, PSR</td>
</tr>
<tr>
<td>Gate Driver</td>
<td>IXDN604, IX3480N, IX332B</td>
</tr>
<tr>
<td>SiC or Si MOSFET</td>
<td>LSIC1MO, MCB60P1200TLB, X2-Class Ultra Junction</td>
</tr>
<tr>
<td>TVS Diode</td>
<td>TPSRx</td>
</tr>
<tr>
<td>Diode</td>
<td>LSIC2SD, DCG SiC Diode Module, HiPerFRED™</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>seIP™, USUR1000, Epoxy Coated Thermistor</td>
</tr>
<tr>
<td>Gate Driver</td>
<td>IXDN608, IX2113, IX332B</td>
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DC charger functional block diagram

**Technology**

**Product Series**

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<tr>
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<td>L50QS, L70QS, L75QS, PSR, 505, 525</td>
</tr>
<tr>
<td>Output “ORing” Diode</td>
<td>LSIC2SD, SONIC-FRD™, FRED DSE™</td>
</tr>
<tr>
<td>DC Earth-Fault Relay</td>
<td>SE-601</td>
</tr>
<tr>
<td>Earth Reference Module</td>
<td>SE-QRM</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>setP™, PPG, USW, Glass Coated Thermistor</td>
</tr>
<tr>
<td>NFC Analog Front-End</td>
<td>NCD1300</td>
</tr>
<tr>
<td>Diode Array</td>
<td>AQ24CAN, SM24CANx</td>
</tr>
<tr>
<td>TVS Diode</td>
<td>SMF, SMAJ, SAC</td>
</tr>
<tr>
<td>Diode Array Polymer ESD</td>
<td>SEP0xx, SP402x, XGD</td>
</tr>
<tr>
<td>Magnetic Sensor</td>
<td>59060, 59135, 55075, 55100</td>
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**Note:** Other Littelfuse solutions may be suitable depending on design-specific requirements.

**Legend:**
- Power
- Data/Signal

**Note:** Power converter topologies may differ based on design-specific requirements.
Wireless charging system

**Power Module:**
- Cartridge Fuse Overcurrent Protection
- TMOV/MOV, GDT, TVS Diode, SIDACtor Surge Protection
- Rectifier Module Power Conversion
- IGBT Power Conversion
- Si or SiC MOSFET Power Conversion
- Gate Driver Control
- Si or SiC Diode Power Conversion
- NTC Thermistor Temperature Sensor

**Service Access Panel:**
- Reed and Hall Effect Security Sensor

**Auxiliary Power Supply:**
- Cartridge Fuse Overcurrent Protection
- TMOV/MOV, GDT Surge Protection
- SMPS Buck/Boost Module
- SMPS Opto-isolator Feedback Control
- SMPS Diode/Rectifier
- TVS Diode Overvoltage Protection
- PPTC Resettable Overcurrent Protection
- NTC Thermistor Temperature Sensing

**Electrical Distribution:**
- Power Fuse Overcurrent Protection
- Fuse Block Mounting Accessory
- Earth-Fault Protection Relay
- Current Transformer Leakage Current Sensing
Wireless charger functional block diagram

Note: Power converter topologies may differ based on design-specific requirements.

**Legend:**
- **Power**
- **Data/Signal**

**Technology**

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<td>P6SMB</td>
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<td>miniSMD</td>
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Note: Other Littelfuse solutions may be suitable depending on design-specific requirements.
Wireless charger functional block diagram

Note: Power converter topologies may differ based on design-specific requirements.

Legend:
- Green: Power
- Blue: Data/Signal

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<td>XPT™, MIXA, MIXG</td>
</tr>
<tr>
<td>Diode</td>
<td>LSIC2SD, SONIC-FRD™, FRED DSE</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>setP™, USUR1000, Epoxy Coated Thermistor</td>
</tr>
<tr>
<td>High-Speed DC Fuse</td>
<td>L50QS, L70QS, L75QS, PSB</td>
</tr>
<tr>
<td>Gate Driver</td>
<td>IXDN604, IX4340N, IX332B</td>
</tr>
<tr>
<td>SiC or Si MOSFET</td>
<td>LSIC1MO, MCB60P1200TLB, X2-Class Ultra Junction</td>
</tr>
<tr>
<td>TVS Diode</td>
<td>TPSMx</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>setP™, USUR1000, Epoxy Coated Thermistor</td>
</tr>
<tr>
<td>Gate Driver</td>
<td>IXDN609, IX2113, IX332B</td>
</tr>
</tbody>
</table>

Note: Other Littelfuse solutions may be suitable depending on design-specific requirements.
Wireless charger functional block diagram

**Technology** | **Product Series**
---|---
8 | Temperature Sensor
| set™, PPG, USW, Glass Coated Thermistor
9 | Magnetic Sensor
| 59060, 59135, 55075, 55100
10 | Diode Array (Wired CAN)
| AQ24CAN, SM24CANx
| Diode Array Poly mer ESD (Wireless)
| SEP0xx, SP402x XSG

*Note: Other Littelfuse solutions may be suitable depending on design-specific requirements.*

*Note: Power converter topologies may differ based on design-specific requirements.*
## Select standards for EV charging equipment

<table>
<thead>
<tr>
<th>Standard</th>
<th>Title</th>
<th>General Scope</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61851 Series</td>
<td>Electric Vehicle Conductive Charging System</td>
<td>Various parts of this standard cover general requirements, along with AC chargers and DC chargers specifically.</td>
<td>Global</td>
</tr>
<tr>
<td>IEC 62196 Series</td>
<td>Plugs, Socket-Outlets, Vehicle Connectors, and Vehicle Inlets – Conductive Charging of Electric Vehicles</td>
<td>This provides standards for charging plugs, sockets, and connectors.</td>
<td>Global</td>
</tr>
<tr>
<td>IEC 61980 Series</td>
<td>Electric Vehicle Wireless Power Transfer (WPT) Systems</td>
<td>Various parts of this standard cover general requirements for wireless charging systems, along with specific technology-based requirements.</td>
<td>Global</td>
</tr>
<tr>
<td>GB/T 18487 Series</td>
<td>Electric Vehicle Conductive Charging System</td>
<td>Various parts of this standard cover general requirements, along with AC chargers and DC chargers specifically.</td>
<td>China</td>
</tr>
<tr>
<td>GB/T 20234 Series</td>
<td>Connection Set for Conductive Charging of Electric Vehicles</td>
<td>This provides standards for charging plugs in China.</td>
<td>China</td>
</tr>
<tr>
<td>JIS TS D 0007</td>
<td>Basic Function of Quick Chargers for Electric Vehicles</td>
<td>This provides standards for CHAdeMO (DC) chargers in Japan.</td>
<td>Japan</td>
</tr>
<tr>
<td>SAE J2954*</td>
<td>Wireless Power Transfer for Light-Duty Plug-In/Electric Vehicles and Alignment Methodology</td>
<td>This provides standards for interoperability, electromagnetic compatibility, EMF, minimum performance, safety, and testing for wireless chargers in North America.</td>
<td>North America</td>
</tr>
<tr>
<td>UL 2594</td>
<td>Standard for Electric Vehicle Supply Equipment</td>
<td>This provides safety standards for AC chargers in North America and tri-national standard for U.S., Canada, and Mexico (known as CAN/CSA C22.2 No. 280 in Canada and NMX-J-677-ANCE in Mexico).</td>
<td>North America</td>
</tr>
<tr>
<td>UL 2202</td>
<td>Standard for Electric Vehicle (EV) Charging System Equipment</td>
<td>This provides safety standards for DC chargers in the United States.</td>
<td>United States</td>
</tr>
</tbody>
</table>
EV Charging – Technology for a Sustainable World

- Uninterruptible Power Supply
- Datacenter & Telecom Power Systems
- Solar Inverter & Charge Controller
- Wind Turbine Rectifier & Inverter
- Battery Energy Storage System
- Industrial Battery Charger
Local Resources for a Global Market
Littelfuse Enables Enhanced Safety, Efficiency, and Reliability for Electric Vehicle Charging

Littelfuse offers:

- Reference solutions to help meet global safety requirements
- System-level design compliance support
- Components designed to help meet energy efficiency
- High-volume manufacturing with the highest quality standards