EV Charging Infrastructure

Supercharged Solutions to Enhance Safety, Efficiency, and Reliability
Types of Electric Vehicle Charging Stations

**AC Level 1**
- 120V AC, 1-phase, 12A or 16A max. continuous current
  - Mode 1 (AC)
    - 250V AC, 1-phase, 16A max. -OR- 480V AC, 3-phase, 16A max.
    - Cord with no pilot or auxiliary connections
    - Delivers AC power from the wall socket to vehicle’s on-board charger
    - Typically takes 8-12 hours* to charge fully depleted battery

**AC Level 2**
- 208V-240V AC, 1-phase, ≤ 80A max. continuous current
  - Mode 2 (AC)
    - 250V AC, 1-phase, 32A max. -OR- 480V AC, 3-phase, 32A max.
    - Cord with control pilot & shock protection
    - Delivers AC power from the wall socket to vehicle’s on-board charger
    - Typically takes 4-6 hours* to charge fully depleted battery

**DC Fast Charger**
- 380V-600V AC, 3-phase input; DC output
  - Mode 3 (AC)
    - 250V AC, 1-phase, 32A max. -OR- 480V AC, 3-phase, 32A max.
    - Permanently connected to AC supply with control pilot & shock protection
  - Mode 4 (DC)
    - AC or DC input supply, cord or permanently connected, with control pilot & shock protection
    - Delivers DC power, bypassing the vehicle’s on-board charger
    - Typically provides 80% charge of fully depleted battery within 30 minutes*

*Charge time dependent on vehicle’s battery capacity and charge acceptance rate

As defined by SAE J1772
As defined by IEC 61851-1
Global Electric Vehicle Charging Equipment Market

<table>
<thead>
<tr>
<th>EV Charging Equipment, by Type, in 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Level 1</td>
</tr>
<tr>
<td>AC Level 2</td>
</tr>
<tr>
<td>DC</td>
</tr>
<tr>
<td>Wireless</td>
</tr>
</tbody>
</table>

**Market Trends and Drivers**

- Increasing production of electrified vehicles: estimated 6 million vehicles in 2019 growing to 16 million vehicles in 2023
- Limited charging infrastructure in most regions
- Production of new EV charging equipment to increase at a compound annual growth rate (CAGR) of 22% between 2018 and 2026
- Majority of charging to occur at home or workplace during a span of several hours (AC charging)
- Consumer demand for charging times to emulate fuel refill time for long-distance trips (DC charging)
- Increasing voltage and power output of DC chargers for fast charging
- Evolving business models: increase property value; revenue generation

**EV Charging Equipment Forecast**


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

* Switched-mode Power Supply

**User Interface:**
- 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

Practice: Protect, Control, Sense
AC Charger Functional Block Diagram

Legend:
- Power
- Data/Signal

<table>
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<tr>
<th>Technology</th>
<th>Product Series</th>
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</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, LTKAK6, LTKAK10</td>
</tr>
<tr>
<td>SIDACtor® Protection Thyristor</td>
<td>Pxxx0ME, Pxxx0FNL</td>
</tr>
<tr>
<td>Silicon-Controlled Rectifier (active rectification)</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>LOC11x, LIA1xx</td>
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Note: Other Littelfuse solutions may be suitable depending on design-specific requirements.
AC Charger Functional Block Diagram

Legend:
- Power
- Data/Signal

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 Interface:
- 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

* Switched-mode Power Supply
DC Charger Functional Block Diagram

1. **AC Grid Input**
   - Transient & Overload Protection

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

3. **DC-DC Converter**
   - Full Bridge, Series Resonant

4. **DC Output**
   - Overload & Short-Circuit Protection

5. **Current Transformer**
   - SE-CS30

6. **AC Earth-Fault Relay**
   - SE-704

7. **Auxiliary Power Supply**

8. **Controllers**

9. **Gate Drivers**

10. **Gate Drivers**

11. **Communication**

12. **User Interfaces**

13. **Access Panel Sensors**

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

**Technology & Product Series**

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<td>JLS JLLS, LDC</td>
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<tr>
<td>AC Fuse (PCB level)</td>
<td>606, 504, 505, 314, 215, NANO&lt;sup&gt;®&lt;/sup&gt;</td>
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<td>Gas Discharge Tube</td>
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<tr>
<td>SIDAct&lt;sup&gt;®&lt;/sup&gt; Protection Thyristor</td>
<td>Pxx0ME, Pxx0FNL</td>
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<td>SE-704</td>
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<tr>
<td>Silicon-Controlled Rectifier</td>
<td>SJ</td>
</tr>
<tr>
<td>MOSFET</td>
<td>X and X2-Class Ultra Junction FETs</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>
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*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

AC Grid Input

1. Transient & Overload Protection
2. AC Earth-Fault Protection
3. Auxiliary Power Supply

Rectifier & Power Factor Correction

4. Bridgeless, Vienna or Boost Stage
5. Gate Drivers

DC-DC Converter

6. Full Bridge, Series Resonant
7. Gate Drivers

DC Output

8. Overload & Short-Circuit Protection
9. DC Earth-Fault Protection
10. Over-Temperature Protection
11. Communication
12. User Interfaces
13. Access Panel Sensors

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Technology

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<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>IGBT</td>
<td>XPT™, MIXA, MIXG</td>
</tr>
<tr>
<td>TVS Diode</td>
<td>TPSMx</td>
</tr>
<tr>
<td>Diode</td>
<td>LSIC2SD, SONIC-FRD™, FRED DSE</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>set™, USUR1000, Epoxy Coated Thermistor</td>
</tr>
<tr>
<td>High-Speed DC Fuse</td>
<td>L50QS, L70QS, L75QS, PSR</td>
</tr>
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<td>Gate Driver</td>
<td>IXDN604, IX4340N, IX332B</td>
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<td>TPSMx</td>
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DC Charger Functional Block Diagram

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1. AC Grid Input
   - Transient & Overload Protection

2. AC Earth-Fault Protection

3. Auxiliary Power Supply

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

5. Gate Drivers

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

7. Gate Drivers

8. DC Output
   - Overload & Short-Circuit Protection

9. DC Earth-Fault Relay

10. Earth Reference Module

11. Temperature Sensor
   - setP™, PPG, USW, Glass Coated Thermistor

12. NFC Analog Front-End
   - NCD1300

13. Diode Array
   - AQ24CAN, SM24CANx

14. TVS Diode
   - SMF, SMAJ, SAC

15. Diode Array Polymer ESD
   - SEP0xx, SP402x XGD

16. Magnetic Sensor
   - 59060, 59135, 55075, 55100

Note: Other Littelfuse solutions may be suitable depending 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

*Switched-mode Power Supply
Wireless Charger Functional Block Diagram

1. AC Grid Input
   - Transient & Overload Protection

2. AC Earth-Fault Protection
   - Auxiliary Power Supply

3. Gate Drivers
   - Bridgeless, Vienna or Boost Stage

4. Gate Drivers
   - Full Bridge, Series Resonant

5. Gate Drivers
   - Impedance Matching Network

6. Gate Drivers
   - Power Transmission Coils

7. Over-Temperature Protection

8. Access Panel

9. Sensors

10. Communication

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Wireless Charger Functional Block Diagram

1. AC Grid Input
   - Transient & Overload Protection

2. AC Earth-Fault Protection

3. Auxiliary Power Supply

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

5. Gate Drivers

6. High-Frequency Inverter
   - Full Bridge, Series Resonant
   - Impedance Matching Network

7. Gate Drivers

8. Wireless Power Transfer
   - Power Transmission Coils
   - Over-Temperature Protection

9. Access Panel Sensors

10. Communication

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Wireless Charger Functional Block Diagram

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Legend:
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# Select Standards for EV Charging Equipment

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<tr>
<th>Standard</th>
<th>Title</th>
<th>General Scope</th>
<th>Region</th>
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</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 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>Standards for charging plugs in China.</td>
<td>China</td>
</tr>
<tr>
<td>GB/T 20234 Series</td>
<td>Connection Set for Conductive Charging of Electric Vehicles</td>
<td></td>
<td>China</td>
</tr>
<tr>
<td>JIS TS D 0007</td>
<td>Basic Function of Quick Charger for the Electric Vehicle</td>
<td>Standard for CHAdeMO (DC) chargers in Japan.</td>
<td>Japan</td>
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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
Littelfuse Enables Enhanced Safety, Efficiency, and Reliability for Electric Vehicle Charging

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