EV Charging Station

Grid Infrastructure
Industrial Systems
EE categories within Grid Infrastructure

**Protection & Control**
- Protection Relays
- Circuit Breakers
- Distribution Automation
- Substation Automation
- Residential Wiring

**Monitoring & Communications**
- Power Quality
- Fault Indicators
- Communications Modules
- Communications Infrastructure
- Demand Response Equipment

**Renewable Energy**
- Solar Energy
- Electric Vehicle Infrastructure
- Renewable Energy Storage
- Wind and Hydro Energy
- Energy Harvesting
From Grid to the Vehicle

EV Charging Infrastructure today and the future
From Grid to the Vehicle

http://denso-europe.com/denso-develops-vehicle-to-home-power-supply-system-for-electric-vehicles/
Europe is getting a network of ‘ultra-fast, high-powered’ EV chargers – Nov/2016

Thanks to a partnership between BMW, Daimler, Ford, and VW

- BMW Group, Daimler AG, Ford, and Volkswagen have entered into a partnership to create a network of high-speed charging stations for electric vehicles across Europe. The new chargers will be capable of doling out up to 350 kW of power — which would make them almost three times as powerful as Tesla’s Supercharging stations. The result will be “the highest-powered charging network in Europe,” according to a statement released by the manufacturers.

- The automakers say that construction will begin in 2017 with “about 400 sites” being targeted, and that the network will have “thousands of high-powered charging points” available by 2020. Those four major conglomerates will be “equal partners” in the joint venture, but according to the statement they are encouraging other manufacturers to “participate in the network.”

Global SC TAM for EV Charging Infrastructure

Global EV Charging Stations to Skyrocket by 2020, IHS Report Says

*The global EV Charger (EVC) market is forecast to grow from more than 1 million units in 2014 to more than 12.7 million units in 2020, according to IHS.*

AC charging stations are the dominant type of plug-in vehicle charging type, and we expect AC charging to retain its position long-term. The price can range from $395 USD for a simple domestic wall box to more than $35,000 USD for a DC charging station.

Japan has more than 2,800 DC fast charging stations, using CHAdeMO, the Japanese fast-charging standard. Japan accounts for roughly 50 percent of the global total of all CHAdeMO stations, according to the IHS Automotive report.

---

**Global Market for Semiconductors in the Power & Energy Sector by Equipment Type**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Vehicle Charging Stations &amp; Infrastructure</td>
<td>105.8</td>
<td>142.3</td>
<td>167.4</td>
<td>179.3</td>
<td>183.8</td>
<td>182.4</td>
<td>182.4</td>
<td>9.5%</td>
</tr>
<tr>
<td>Renewable Energy (Hydro/Solar/Wind)</td>
<td>427.0</td>
<td>446.2</td>
<td>467.3</td>
<td>487.8</td>
<td>513.9</td>
<td>531.5</td>
<td>549.6</td>
<td>4.3%</td>
</tr>
<tr>
<td><strong>Sector Total</strong></td>
<td>532.7</td>
<td>588.5</td>
<td>634.8</td>
<td>667.1</td>
<td>695.8</td>
<td>713.7</td>
<td>732.0</td>
<td></td>
</tr>
</tbody>
</table>

Source: Semicast Research  
Table Revised: July 2016

**Global Equipment Production Estimates and Forecasts in the Power & Energy Sector**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Vehicle Charging Stations &amp; Infrastructure</td>
<td>732</td>
<td>1,013</td>
<td>1,224</td>
<td>1,344</td>
<td>1,420</td>
<td>1,455</td>
<td>1,488</td>
<td>12.0%</td>
</tr>
<tr>
<td>Renewable Energy (Hydro/Solar/Wind)</td>
<td>9,318</td>
<td>10,453</td>
<td>11,797</td>
<td>13,193</td>
<td>14,734</td>
<td>16,281</td>
<td>17,900</td>
<td>11.5%</td>
</tr>
<tr>
<td><strong>Sector Total</strong></td>
<td>10,050</td>
<td>11,466</td>
<td>13,021</td>
<td>14,537</td>
<td>16,154</td>
<td>17,736</td>
<td>19,388</td>
<td></td>
</tr>
</tbody>
</table>

Source: Semicast Research  
Table Revised: May 2016
Growth Opportunities in EVSE Market

Source: Global EV Outlook & IHS Automotive market report
Vehicle-to-grid (V2G) describes a system in which plug-in electric vehicles, such as electric cars (BEV) and plug-in hybrids (PHEV), communicate with the power grid to sell demand response services by either returning electricity to the grid or by throttling their charging rate.

Since at any given time 95 percent of cars are parked, the batteries in electric vehicles could be used to let electricity flow from the car to the electric distribution network and back. This represents an estimated value to the utilities of up to $4,000 per year per car.
Levels, Types and Modes demystified

EV Charging Infrastructure
Levels in EV Charging Stations

**AC Charging Station: Level 1 & 2**

- **AC Charging Station: L1 Residential**
  - Power Supply: 120/230VAC & 12 A to 16A (Single Phase)
  - Charger Power: ~1.44kW to ~1.92kW
  - Charging time*: ~17 Hours

- **AC Charging Station: L2 Commercial**
  - Power Supply: 208 ~ 240VAC & 15 A ~ 80A (Single/ Split Phase)
  - Charger Power: ~ 3.1kW to ~19.2kW
  - Charging time*: ~8 Hours

**DC Charging Station: Level 3**

- **DC Charging Station: L3 Fast Chargers**
  - Power Supply: 300 to 600VDC & (Max 400A) (Poly Phase)
  - Charger Power: From 120kW up to 240kW
  - Charging time*: ~30 Minutes

* Charging time does NOT scale linearly with EVSE charge capacity

---

**AC Charging System Power Flow**

- **Grid**
- **EVSE**
- **Electric Vehicle**

**DC Charging System Power Flow**

- **Grid**
- **EVSE + AC/DC Converter**
- **Electric Vehicle**

---

**Table:**

<table>
<thead>
<tr>
<th>EVSE Type</th>
<th>Power Supply</th>
<th>Charger Power</th>
<th>Charging time* (Approx.) for a 24kWH Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Charging Station: L1 Residential</td>
<td>120/230VAC &amp; 12 A to 16A (Single Phase)</td>
<td>~1.44kW to ~1.92kW</td>
<td>~17 Hours</td>
</tr>
<tr>
<td>AC Charging Station: L2 Commercial</td>
<td>208 ~ 240VAC &amp; 15 A ~ 80A (Single/ Split Phase)</td>
<td>~ 3.1kW to ~19.2kW</td>
<td>~8 Hours</td>
</tr>
<tr>
<td>DC Charging Station: L3 Fast Chargers</td>
<td>300 to 600VDC &amp; (Max 400A) (Poly Phase)</td>
<td>From 120kW up to 240kW</td>
<td>~30 Minutes</td>
</tr>
</tbody>
</table>
Modes in EV Charging Stations

The International Electrotechnical Commission modes definition (IEC 62196):

- **Mode 1** – slow charging from a regular electrical socket (single- or three-phase)
- **Mode 2** – slow charging from a regular socket but which equipped with some EV specific protection arrangement (e.g., the Park & Charge or the PARVE systems)
- **Mode 3** – slow or fast charging using a specific EV multi-pin socket with control and protection functions (e.g., SAE J1772 and IEC 62196)
- **Mode 4** – fast charging using some special charger technology such as CHAdeMO

There are three connection cases:

- **Case A** is any charger connected to the mains (the mains supply cable is usually attached to the charger) usually associated with modes 1 or 2.
- **Case B** is an on-board vehicle charger with a mains supply cable which can be detached from both the supply and the vehicle – usually mode 3.
- **Case C** is a dedicated charging station with DC supply to the vehicle. The mains supply cable may be permanently attached to the charge-station such as in mode 4.
Types in EV Charging Station plugs

- **Type 1**: SAE J1772 (Level 1 and 2)
  - North American Standard
  - 2 AC power lines, ground pin, proximity detection, and control pilot signals
  - Uses +/-12V Pilot interface

- **Type 2**: VDE-AR-E 2623-2-2 (Level 1 and 2) European Plug Standard
  - Additional pins for three phase connections
  - Signaling aligns with J1772

- **Type 3**: Combined Charging System - CCS (Level 3)
  - Additional DC pins for level 3 charging added to J1772 and Type 2
  - HomePlug GreenPHY communication protocol

- **Type 4**: CHAdeMO (Level 3)
  - Adopted in Japan and France
  - CAN interface to vehicle

Type 3 – single- and three-phase vehicle coupler equipped with safety shutters – reflecting the EV Plug Alliance proposal. Not active anymore.
Public vs. Residential EVSE

• Public
  – Typically part of a network
  – Require local user authentication (NFC)
  – Have backchannel communication (GPRS/GSM)
  – All are Level 2 or 3, with dedicated power delivery
    • Limited Level 3 deployments due to extreme cost requirements

• Residential
  – All EVs currently supplied with basic Level 1 Charger
    • Plugs into standard household outlet and converts to J1772
  – Some homeowners choose to installed a Level 2 station at home
    • Requires dedicated AC line
    • Could be limited in power delivery by home service level
    • Some integrate advanced communication for control
AC Charging (Pile) Station
AC Charging (Pile) Station

Level 1&2 EVSE

The electric vehicle service equipment for most modern EVs is a simple system that monitors and controls the high voltage power path from the grid to the vehicle. The actual AC/DC conversion and charging is all handled within the vehicle. The term level 1 an level 2 categorize the charger by its power delivery capability. A level 1 charger is limited to single phase 120V and 16A (a common US household outlet) while a level 2 charger uses 240V split phase up to 80A. These differences are largely expressed in the electromechanical components of the EVSE, and not in the electronics.

Most of these EVSEs will utilize the SAE J1772 plug standard, which includes the high voltage power lines, and a low voltage communication signal called the pilot line. This pilot line signals to the car the available current of the charger, and the car will respond with a charging status.

**Types of EVSEs**

- Residential use
- Commercial / Public use

**System Requirements**

- **Microcontroller** will communicate with the vehicle over the pilot line to determine when to open and close power relays. The MCU can also integrate HMI and communications functions if needed.
- **Relay / Gate Driver** is used to control the high power relays or contactors that will enable power flow to the vehicle.
- **Flux-gate sensors or shunt resistors** for Current sensing to enable real-time power usage monitoring.
- **Amplifiers** are used in the Pilot signal path to generate and sense the appropriate signals.
- **AC-DC converter** to power the low voltage electronics and provide sufficient power to the relays/contactors to remain closed.
- **DC-DC converter** to provide multiple power domains for MCU, Pilot signal, and relays.
AC Charging (Pile) Station: L2 Commercial EV Station

Power Supply
- 85-264 V AC Power Supply
- Protection
- PWM Controller
- Voltage Reference
- Opto feedback

Regulator
- 15V
- DC/DC Buck
- DC/DC Buck
- Comparator
- LDO
- ISO Power

Measurement Subsystem
- ESD/EMI Protection
- Sensors
- DSP/MCU
- ADC
- Digital Isolation

Host Processing Subsystem
- SVS/RESET
- PMU
- Crystal
- Keypad
- LCD Driver
- Case Open Detect
- Battery
- RTC
- EEPROM
- FLASH
- SD/SDHC
- 12C

Digital Isolation
- PWM Controller
- ISO Power

Wired Communication
- PLC
- UART

Wireless Communication
- ZigBee
- NFC
- Wi-Fi
- 6LoWPAN
- Cellular

Media Rich HMI
- DDR
- PMIC
- Flash
- MPU/MCU
- LCD Controller
- Touch Controller

Signal Protection
- Sense Circuitry
- Amplifier

Pilot Signal Comms
- J1772 Cable
- Input Protection

Protection
- GFI Test Signal
- Relay Control

Power Stage
- Relay Driver

Opto feedback

Protection

Opto feedback

Relay

Opto feedback

Relay

Opto feedback

Opto feedback
Pilot Wire Communication Standard

• In L1 & L2 chargers, the EVSE is just a supervisor
• Charge rate is determined by the vehicle
• The charging station advertises the available current via the Pilot Signal
  – Via a +/-12V PWM signal on the pilot line
  – The PWM duty cycle is related to the available current

• The vehicle will load the pilot signal to respond with it’s current state
  – Results in a voltage change, measured by the EVSE

• This handshake results in a safe method for supplying power to vehicle
Pilot Wire Handshake Process

1. The EV is plugged in. At this point there is no AC output to the vehicle.
2. EVSE signals its availability with +12V on the pilot line, and a proximity circuit in the plug handle.
3. The EV places a resistor on the pilot line, dropping it to 9V, which the EVSE uses to detect the EV’s presence.
4. The EVSE will start a PWM signal on the pilot line, with a PWM related to the available current.
5. The EV changes the load resistance, and the pilot voltage drops to 6V to finish the handshake.
6. The EVSE will then turn on the AC power, and the EV will begin charging.
7. Charging continues until the EV is done and stops drawing power, an error is signaled and the EVSE cuts power, or the handle is unplugged and the EVSE cuts power.
DC Charging (Pile) Station
An SAE J1772 level 3 DC EVSE differs greatly from the common level 1 and level 2 standard. The level 3 contains its own high voltage AC-DC power supply, which will bypass the one on the vehicle to provide very high power charge levels. These are typically on the order of 200–450VDC and 200A (up to 90kW).

The incredibly high charge rate for DC chargers requires significant changes from the level 1 and 2 requirements. The DC source for these is typically a local storage medium capable of delivering the large instantaneous power for charging, and then recharged at a lower rate from the grid.

The pilot communication is also insufficient since the EVSE and vehicle need to be in constant communication regarding charge status and power requests. There are various communication standards competing for this, but Power Line Communication is the current front runner.

### Types of Level 3 EVSEs
- J1772 L3 Charger
- ChaDeMo Charger
- Super Charger

### System Requirements

**Microcontroller** will communicate with the vehicle and control power delivery subsystems. The MCU can also integrate HMI and communications functions if needed.

**Relay / Gate Driver** is used to control the high power relays or contactors that will enable power flow to the vehicle.

**Flux-gate sensors or shunt resistors** for Current sensing to enable real-time power usage monitoring.

**Digital Power Controller** enables higher efficiency power delivery and better current control vs a traditional DC-DC controller.

**Charge Management System** helps to control the charging of local energy storage.

**Communications** via CAN or PLC to the vehicle.
Power Module: DC Charging (Pile) Station

Power topologies for AC/DC (PFC + Rectifier) stage
- Switched Mode Rectifier (SMR)
- 3 Phase Vienna Rectifier
- Interleaved PFC (<10kW)
- Boost converter with CCM (<10kW)

Power topologies for DC/DC stage
- Dual Phase Shifted Full Bridge
- Three level DC:DC
- Interleaved/Non-IL Phase shifted full bridge (<10kW)
- Hard switched full bridge (<10kW)
- Resonant LLC (<5kW)
DC Charging (Pile) Station – AC/DC

~380VAC

Current Sense
Alternative 1 – x3
ISO ADC
Amp
Alternative 2 – x3
Hall/Flux Sensor
Amp

Voltage Sense x3
Amp

Active Rectifier
MOSFet xN

Gate Drivers

OVP
Amp

MCU
High Speed ADC
PWM Generation
UART/SPI
VRef
MCU
Reset

PSU AC/DC
Flyback Converter
ISO Rails
LDO
Buck
12V
3.3V
ISO 5V
5V
12V

ISO Link

DC/DC

400VDC

5V

ISO Rails

ISO 5V
DC Charging (Pile) Station – HMI/System Control

- **RS485**
- **RS232**
- **IO Exp**
- **Accessory Driver**
- **RTC**
- **ESD Protection**
- **Flash**
- **DDR**
- **DDR Termination**
- **McASP**
- **UART**
- **SPI**
- **CAN**
- **ISO CAN**
- **MAC**
- **RMII**
- **SPI**
- **LCDC**
- **USB**
- **Audio Driver**
- **Touch Controller**
- **Touch Panel**
- **Speaker**
- **Charge Module**
- **12V**
- **5V**
- **NFC**
- **GPRS**
- **E-Panel**
- **ModBus/SCADA**
- **Console**
- **E-Meter Module**
- **GPS**
- **BT Module**
- **Keypad**
- **Fan**
- **PSU AC/DC**
- **AC/DC**
- **Buck**
- **PMIC**
- **SMPS**
- **SMPS**
- **MPU Power**
- **MPU**
EVSE – TI Design Dashboard
AC/DC

- **TiDM-2PHILPFC**
  - Voltage: 300VAC – 400VDC
  - Power: 700W
  - Two-Phase Interleaved Power Factor Correction Converter with Power Metering, >98% Eff, >0.99PFC, <5% THD

- **TIDA-00779**
  - Voltage: 190VAC – 270VDC
  - Power: 3.5kW
  - 230V, 3.5kW, High Efficiency, Cost Competitive, Single Phase Power Regulator Converter

- **TiDM-PSFB-DCDC**
  - Voltage: 400VDC-12VDC
  - Power: 600W
  - Phase-Shifted Full Bridge DC/DC Power Converter

- **TMDSHVRESLLCKIT**
  - Voltage: 400VDC-12VDC
  - Power: 500W
  - HV Resonant LLC Developer’s Kit

- **TiDM-1000**
  - Voltage: 400VAC – 700VDC
  - Power: 2.4kW
  - Vienna Rectifier-Based, Three-Phase Power Factor Correction (PFC) Converter

DC/DC

- **TiDM-1001**
  - Voltage: 400VDC-12VDC
  - Power: 500W
  - Two-Phase Interleaved LLC Resonant Converter Design

- **TiDM-BIDIR-400-12**
  - Voltage: 400VDC-12VDC
  - Power: 300W
  - Bidirectional 400V-12V DC/DC Converter

- **TiDM-PSFB-DCDC**
  - Voltage: 400VDC-12VDC
  - Power: 600W
  - Phase-Shifted Full Bridge DC/DC Power Converter

- **TIDA-00779**
  - Voltage: 190VAC – 270VDC
  - Power: 3.5kW
  - 230V, 3.5kW, High Efficiency, Cost Competitive, Single Phase Power Regulator Converter
TI Designs – V & I Sensing

ADC & Shunts

- **TIDA-00528 (OPA333/INA226)**
  - 40 to 400 V Uni-Directional Current/Voltage/Power Monitoring
  - Max Voltage: 400 V
  - Max Current: 8 A

- **TIDA-00639 (OPA333/INA226)**
  - 600 V Uni-Directional Current/Voltage/Power Monitoring for Smart Combiner Box
  - Max Voltage: 600 V
  - Max Current: 15 A

- **TIDA-00835 (AMC1304/OPA4180)**
  - Expanding input channels using simultaneous sampling \( \Sigma - \Delta \) ADCs in Protection relay

- **TIDA-00555 (AMC1100)**
  - Isolated Current/Voltage Measurement Using Fully Differential Isolation Amplifier
  - Max Voltage: 300 V
  - Max Current: 40 A

- **TIDA-00601 (AMC1304)**
  - Isolated I & V Measurement Using Fully Differential Isolation Amplifier and MSP430F67641
  - Max Voltage: 1 kVAC
  - Max Current: 90 A

- **TIDA-00738 (AMC1304)**
  - Wide Input Current Using Shunts and Voltage Measurement for Protection Relays
  - Max Voltage: 300 V
  - Max Current: 60 A

Non-Isolated

Isolated

Hall

- **TIDA-00218 (DRV5053)**
  - AC Current Measurement with Hall Effect Sensor
  - Max Current: 12 A

Fluxgate

- **TIPD196 (DRV421)**
  - \( \pm 15 \) A Current Sensor Using Closed-Loop Compensated Fluxgate Sensor
  - Max Current: 15 A

- **TIPD205 (DRV425)**
  - \( \pm 100 \) A Bus Bar Current Sensor using Open-Loop Fluxgate Sensors
  - Max Current: \( \pm 100 \) A

- **TIDP184 (DRV441)**
  - \( \pm 100 \) A Closed-Loop Current Sensor Reference Design Using Bi-Polar Supplies
  - Max Current: \( \pm 100 \) A

Max Voltage: 400 V
Max Current: 8 A

Max Voltage: 600 V
Max Current: 15 A

Max Voltage: 1 kVAC
Max Current: 90 A

Max Voltage: 300 V
Max Current: 40 A

Max Voltage: 300 VAC
Max Current: 60 A

Max Voltage: 1 kVAC
Max Current: 90 A

Max Voltage: 1 kVAC
Max Current: 90 A
**TIDEP0015**
- Capacitive Touchscreen Display
- Supports Ethernet, RS-485, CAN, and Display

**TIDA-00198**
- Resistive Dual Touch Reference Design Board with Haptic Feedback for 4-wire Resistive Touch Panels
- Supports 2 finger gestures on resistive panels and haptic feedback control

**TIDM-CAPTIVATE-64-BUTTON**
- 64-Button Capacitive Touch Panel With TI Microcontroller With CapTIvate Technology
- Single and multitouch detection, 100fps and 10ms typical delay

---

**Communications**

**TIDA-00263**
- Isolated Auto-Polarity RS-485 Transceiver
- ≤250 kbps Data

**TIDA-00629**
- Half-Duplex, IEC and ESD CAN transceiver
- IEC 61000 ESD, EFT, and Surge Protected CAN

**TIDC-WL1835MODCOM8B**
- 2.4 GHz WiFi® + Bluetooth® Certified Antenna Design on WiLink™ 1835 Module

**TIDA-00893**
- Isolated RS-485 With Integrated Signal and Power Reference Design
- 5kV Isolation 20Mbps Full Duplex

---

**Texas Instruments**
Level 1&2 Electric Vehicle Service Equipment Reference Design

TIDA-00637

Design Features

- Full implementation of a J1772 compliant service equipment
- High current relay drivers for support of high current contactors
- Standardized pilot wire signaling protocol
- Integrated utility meter grade energy measurement
- GFCI fault detection and protection
- Option for communication daughter card add in

Design Benefits

- Safe failure modes using TI peripheral drivers
- Integrated fault checking
- Configurable power delivery based on installation capacity
- Self-metering to ensure maximum power delivery
- Highly accurate energy metering for $/kWh based billing

Block Diagram

Tools & Resources

Board Image
• TIDA-00637 Tools Folder
• Design Guide
• Design Files: Schematics, BOM, Gerbers, Software, and more
• Device Datasheets:
  - OPA171
  - UCC28910D
  - TPS62063
  - LM7321
  - TPL7407L
  - MSP430F6736

PSU
AC Source (110 – 240)
Terminal Block
Metering and GFCI Current Transformers
Input Voltage Signal of Metering
Input Current Signal of Metering
Relay Driver
User IO
Communication Option
Wi-Fi Enabled Level 1 and 2 Electric Vehicle Service Equipment (EVSE)

TIDC-EVSE-WiFi

Design Features

• Full Implementation of J1772-Compliant Service Equipment
• Wi-Fi Support for Remote Monitoring and Control of EVSE
• High Current Relay Drivers for Support of High Current Contactors
• Standardized Pilot Wire Signaling Protocol
• Integrated Utility Meter Grade Energy Measurement
• Option for Communication Daughter Card Add-in

Design Description

• Wi-Fi connectivity over IEEE-802.11 b/g/n networks from any smartphone, tablet, or computer through a web browser
• Support high accuracy energy measurement (0.5%)
• Expandable to support other applications such as payment, authentication etc.

Tools & Resources

Board Image

• TIDC-EVSE-WiFi Tools Folder
• Design Guide
• Design Files: Schematics, BOM, Gerbers, Software, and more
• Device Datasheets:

Block Diagram
Level 1&2 EVSE With NFC Tag Authentication
TIDC-EVSE-NFC

Features

- Ability to read and write NFC Type 2, 3, 4A, 4B, and 5 Tag Platforms
- Full implementation of a J1772 compliant service station
- Standardized pilot wire signaling protocol
- Integrated utility meter grade energy measurement

Benefits

- Drop in integration of NFC reader to existing platform
- Offers a flexible firmware structure that allows for configurable NDEF and custom proprietary applications
- Safe failure modes using TI peripheral drivers
- Configurable power delivery based on installation capacity
- Self-metering to ensure maximum power delivery
- Highly accurate energy metering for $/kWh based billing

Tools & Resources

- Design Details
- Key Products
  - TRF7970A, OPA171
  - UCC28910, TPS62063
  - LM7322, TPL7407L
  - MSP430F6736

TI Confidential – NDA Restrictions
# Vienna Rectifier-Based, Three-Phase Power Factor Correction (PFC) TIDM-1000

## Features
- Three Phase Rectifier Design using Vienna Rectifier controlled using C2000 MCU
- Vin: Three Phase 110Vrms/50Hz or 220Vrms/60Hz
- Vout: 700V DC
- Pmax: 1.2KW at 110Vrms and 2KW at 220Vrms
- Efficiency Target: 98% peak efficiency
- Low total harmonic distortion (THD) <4%
- 100kHz PWM switching

## Benefits
- powerSUITE enables easy adaptation of the TI Design to a custom power level and tuning of loops
- TMU accelerator enables fast control loop execution
- In built Sigma Delta Demodulators enables accurate current sensing
- On chip windowed comparators reduced components required for protection
- SFRA enables quick verification of control design

## Tools & Resources
- **Design Details**
- **Key Products**
  - TMS320F28377D
  - UCC21520DW
  - OPA4350UA
  - AMC1304
  - DCH010505SN7
  - PTH08080WAH
  - TLV1117-33CDCYR
  - TPS71501DCKR

---

![Diagram of Vienna Rectifier-Based, Three-Phase Power Factor Correction (PFC) TIDM-1000](image)
Two Phase Interleaved LLC Resonant Converter Reference Design
TIDM-1001

**Features**

- Digitally controlled two phase interleaved LLC resonant DC-to-DC converter
- Excellent current sharing between phases without any additional hardware
- Peak efficiency: 94.5%. Efficiency > 90% for all loads above 10% of rated load
- powerSUITE support for easy adaptation of software for a customized power level
- Fault protection: phase/output over-current, output over-voltage, and input under-voltage and overvoltage
- Phase shedding with programmable limits

**Description**

- This design implements a digitally controlled 500W two phase interleaved LLC resonant converter. The system is controlled by a single C2000™ microcontroller (MCU), TMS320F28379, which also generates PWM waveforms for all power electronic switching devices under all operating modes. This design implements a novel current sharing technique to accurately achieve current balancing between phases.

**Tools & Resources**

- **Design Details**
- **Key Products**
  - OPA365
  - PTH8080W
  - TMS320F28379D
  - TPS795
  - UCC27524A
  - UCS7138
HV Resonant LLC Developer’s Kit
TMDSHVRESLLCKIT

Design Features
- High Voltage Resonant LLC converter controlCARD based EVM
- Quick Start Graphical User Interface
- 380-400V DC input, 500 watt 12V regulated DC output
- Supports Synchronous Rectification output control
- Four different feedback methods for experimentation
- Lossless current sensing circuit for fault protection
- Onboard USB JTAG emulation
- Open source hardware and software with full documentation
- Detailed lab and discussion of Resonant LLC Principles

Design Description
- The High Voltage Resonant LLC Developer’s Kit is designed to show users how to quickly implement a digitally controlled Resonant LLC topology DC/DC converter.
- This is a HIGH VOLTAGE kit intended to support voltage levels that are commonly used in end equipment designs, and gives designers the opportunity to experiment with multiple control methods.

Tools & Resources
Board Image
- TMDSHVRESLLCKIT Tools Folder
- Design Guide
- Design Files: Schematics, BOM, Gerbers, Software, and more
- Device Datasheets:
  - TMS320F28035
  - PTI40080W
  - UCC27324
  - OPA2350UA

Block Diagram
# Bidirectional 400V-12V DC/DC Converter Reference Design

## Design Features

- Digitally-controlled isolated bidirectional DC/DC converter based on the TMS320F28035 microcontroller
- 300W rated output operation in either direction
- High voltage DC input: 200-400V
- Low voltage DC output: 9-13.5V (nominal 12V)
- Seamless on-the-fly transitions between buck and boost modes
- Complete software package (please see link below for software download instructions)

## Design Description

- The Bidirectional 400V-12V DC/DC Converter Reference Design is a microcontroller-based implementation of an isolated bi-directional DC-DC converter.
- This digitally-controller system can implement advanced control strategies to optimally control the power stage under different conditions and also provide system level intelligence to make safe and seamless transitions between operation modes and PWM switching patterns.

## Tools & Resources

### Board Image

![Board Image](image)

### TIDM-BIDIR-400-12 Tools Folder

- **Design Guide**
- **Design Files**: Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets**:
  - TMS320F28035
  - ISO1050
  - ISO7240C
  - UCC27524

---

![Block Diagram](image)
Two-Phase Interleaved Power Factor Correction Converter with Power Metering

**TI Designs Number: TIDM-2PHILPFC**

**Design Features**
- Full digital control of dual interleaved PFC power converter topology
- Universal input of 95 VAC to 265 VAC
- 400 VDC bus output operating up to 700 W
- Power Factor of 0.99 at 200 KHz switching frequency and 1.5% THD at full load
- Supports power monitoring of rectified input voltage, RMS input voltage, RMS input power, and input line frequency
- Fully-functional evaluation board includes software, hardware design files, quick start graphical interface and step-by-step documentation.

**Design Description**
- This design is able to achieve 97% efficiency and 1.5% THD at full load with power factor greater than 0.98.
- By minimizing power loss in the power stage, reducing reliability impacts of harmonic distortion, and providing near unity power factor, this design is a great choice for off-line applications and AC/DC power supplies.

**Tools & Resources**

- **TIDM-2PHILPFC Tools Folder**
- **Design Guide**
- **Design Files:** Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets:**
  - TMS320F28035
  - OPA365
  - UCC27524
  - TPS79533
  - SN74LVC2G17
- **Board Image**

**Block Diagram**
Capacitive Touchscreen Display Reference Design

**TI Designs Number:** TIDEP0015

**Design Features**
- Color 7-Inch TFT LCD panel with capacitive touch user interface
- WVGA 800x480 pixel resolution with 24-bit RGB interface
- LCD interface connected to the integrated DSS (Display Sub-System) of the Sitara AM437x processor
- Capacitive Touch Screen connected to the Sitara AM437x processor over I2C
- 27 white LED’s for backlight controlled TPS61081 PWM controlled LED driver
- The required power for the LCD is provided by the TPS65105 Linear regulator supply.
- Complete sub-system reference with schematics, BOM, design files, and HW User's Guide implemented on a fully assembled board developed for testing and validation.

**Tools & Resources**
- **TIDEP0015 Tools Folder**
- **Design Guide**
- **Design Files:** Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets:**
  - AM4376
  - SN74LVC1G04
  - TPS61081
  - TPS65105

**Design Description**
- Capacitive touchscreen displays generally provide a higher quality and better user experience than traditional resistive touchscreen displays.
- This reference design shows how to interface a capacitive touchscreen display to the Sitara AM437x processors.
- The display has an integrated touchscreen controller that interfaces with the AM437x via its I2C port.

**Block Diagram**
IEC 61000 ESD, EFT, and Surge Protected CAN Reference Design

**TI Designs Number:** TIDA-00629

### Design Features
- Board Level IEC ESD, EFT, and Surge Evaluation
- Easy Control of Transceiver Logic I/O Levels
- Pad Site Evaluation of Multiple TVS Diode Structures
- General Purpose Evaluation Module For Half-Duplex Texas Instruments CAN Transceivers

### Design Description
- The TIDA-00629 is a reference design examining how to protect a CAN transceiver against lethal transient waveforms such as IEC ESD, IEC EFT, and IEC surge.
- The reference design shows the level of protection that can be achieved through the implementation of an external protection scheme on the bus lines of a standard CAN bus transceiver.

### Tools & Resources
- **Board Image**
- **TIDA-00629 Tools Folder**
- **Design Guide**
- **Design Files:** Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets:**
  - SN65HVD257D
Isolated RS-485 With Integrated Signal and Power Reference Design

**TI Designs Number:** TIDA-00892

### Design Features
- Small Combination Solution (Equal to ISOW7841 Device Footprint)
- Single Power Supply Solution (No separate supply required for interface side)
- Reduced BOM Cost
- Extendable to Other Full-Duplex RS-485 Transceivers

### Design Description
- The TIDA-00892 reference design provides a compact solution capable of generating isolated DC power while supporting isolated RS-485 communication.
- The design consists of a reinforced digital isolator with integrated power combined with an RS-485 communication transceiver.

### Tools & Resources
- **TIDA-00892 Tools Folder**
- **Design Guide**
- **Design Files:** Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets:**
  - ISOW7842
  - SN65HVD1473

### Block Diagram

![Block Diagram of Reinforced Digital Isolator + DC-DC Converter ISOW7841](image)
V2G Power Architecture

Solar Array -> DC Optimizer

Battery Bank

EVSE

DC Optimizer -> DC-DC

High Voltage DC Bus

Bi-Dir DC:DC
TIDM-BUCKBOOST-BIDIR
TIDM-BIDIR-400-12
DC:DC
TIDM-PSFB-DCDC
TIDM-1001

DC-DC -> DC-AC Inverter

TIDM-SOLAR-DCDC

TIDM-SOLAR-ONEPHINV
TIDM-HV-1PH-DCAC

Grid

AC-DC Rectifier

PFC

TIDM-2PHILPFC
TIDM-1000
Back-up
Public EVSE HMI

- Public EVSEs require some method of communicating information with the user
- Can range from simple LCD, to touch screens, and full WVGA graphics
- Very high end units can even play video and audio
- Sub-systems to look for are
  - LCD Drivers
  - Backlight Drivers
  - CapTouch Interfaces
  - Audio Amplifiers
Public EVSE Authentication

Near Field Communication (NFC) is a radio technology that enables bi-directional short range communication between devices to make life easier and more convenient for consumers around the world by making it simpler to make transactions, exchange digital content, and connect electronic devices with a touch. This technology is adopted in smartphones and a large infrastructure with 100 of million devices is already in place.

- HF - 13.56MHz ISM Frequency Band
- Read range of few centimeters
- Data rates: 26 - 848kbps
- Operating Modes: Peer-to-Peer, Reader/Writer, Card Emulation
- Possibility for passive operation

Park-Tap-Charge
Residential EVSE Communications

• In home EVSEs are usually very simple devices

• Addition of network connectivity enables some tracking features users might be interested in:
  – Power Consumption
  – Status and Remote Control
  – Cloud Service Connectivity
  – Scheduled Charging

• TI Wi-Fi connectivity can be a simple drop in addition

• New TIDesign!
Level 1, 2 & 3 EVSE Customers

**Terra 53/23 Charger**
- 50 to 20 kW DC fast charger supporting CCS, CHAdeMO, GB/T
- 43 to 22 kW AC cable output or 22 kW AC socket output
- Operating temperature -35 °C to +50 °C
- Compliance and safety c UL us IEC 61000 = Class B certified
- Input V range 480 VAC +/-10%, I max 75A
- Output V range 50 to 500 VDC, I max 125A

**Evlink Series**
- 7.4 kW - 32 A (Single Phase) 22.1 kW - 32 A (Three Phase)
- LAN, Wi-Fi and GPRS
- IEC/EN 61851-1 ed 2.0, IEC/EN 61851-22 ed 1.0
- IEC/EN 62196-1 ed 2.0, IEC/EN 62196-2 ed 1.0

**AC and DC Charging Piles**
- Input 260V ~ 456V with a max of 300A
- Output V DC 250V ~ 750V with output power 50KW to 150KW
- Output current max of 250A
- Efficiency >93%, PF >0.99, THD <5%
- Operating temperature -35 °C to +50 °C
- Protection: O/P Short-Circuit, Over-Voltage, Under Voltage, Phase-Lack, Temp

**Other EMEA and NA OEMs**
- GE Energy Industrial Solutions
- Bosch
- Denso
- Siemens

**Other Asia OEMs**
- Cyg
- East
- Gluu
- Zhonhen 中恒
- Hitachi
- Mitsubishi Power Systems
- Delta
- Liteon
- Toshiba

**Texas Instruments**
EV Charging Station Ecosystem
本資料僅供參考，使用本資料需遵守TI的使用條款，詳情請參考www.ti.com.tw