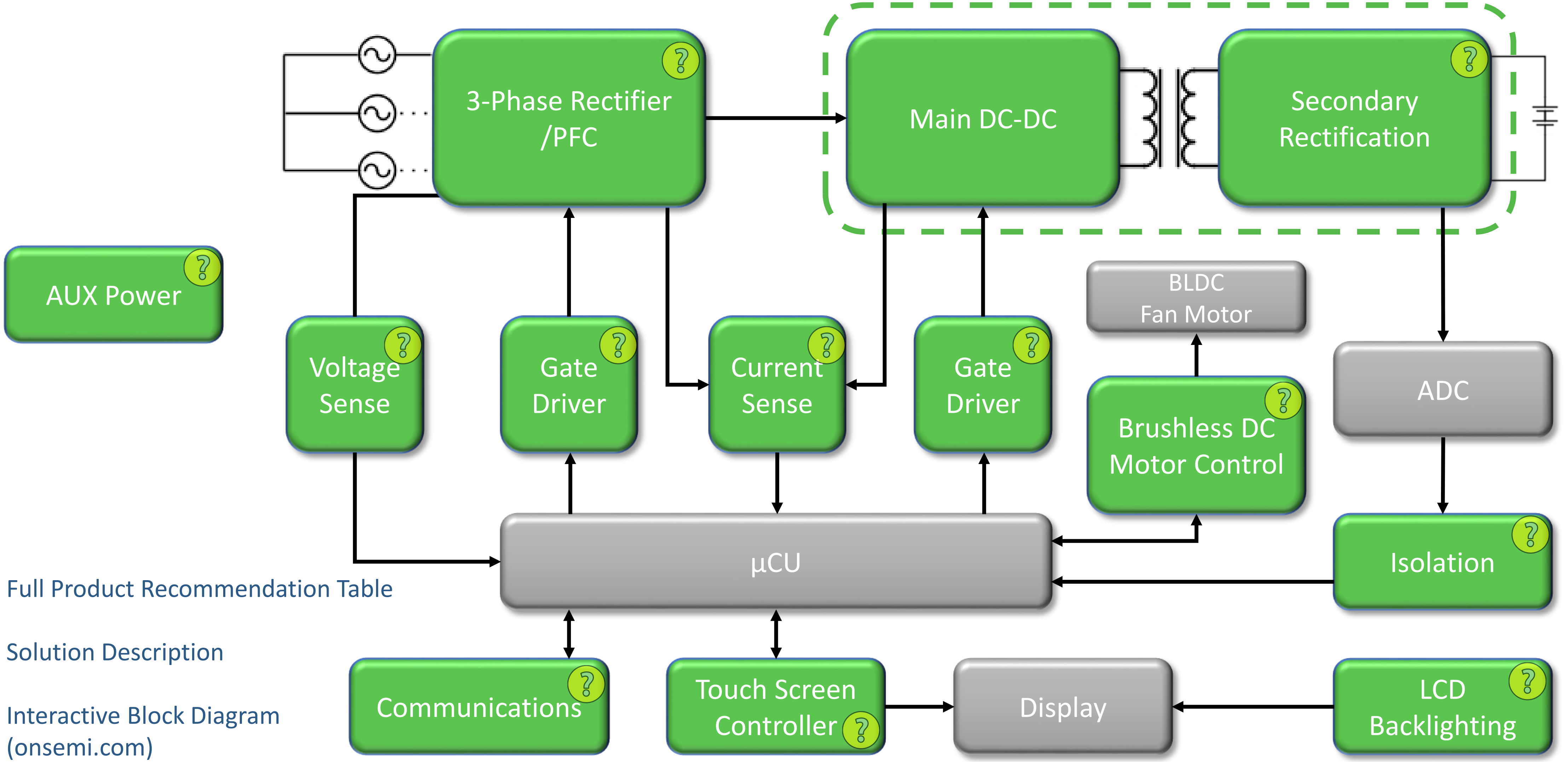
EV Charging Block Diagram



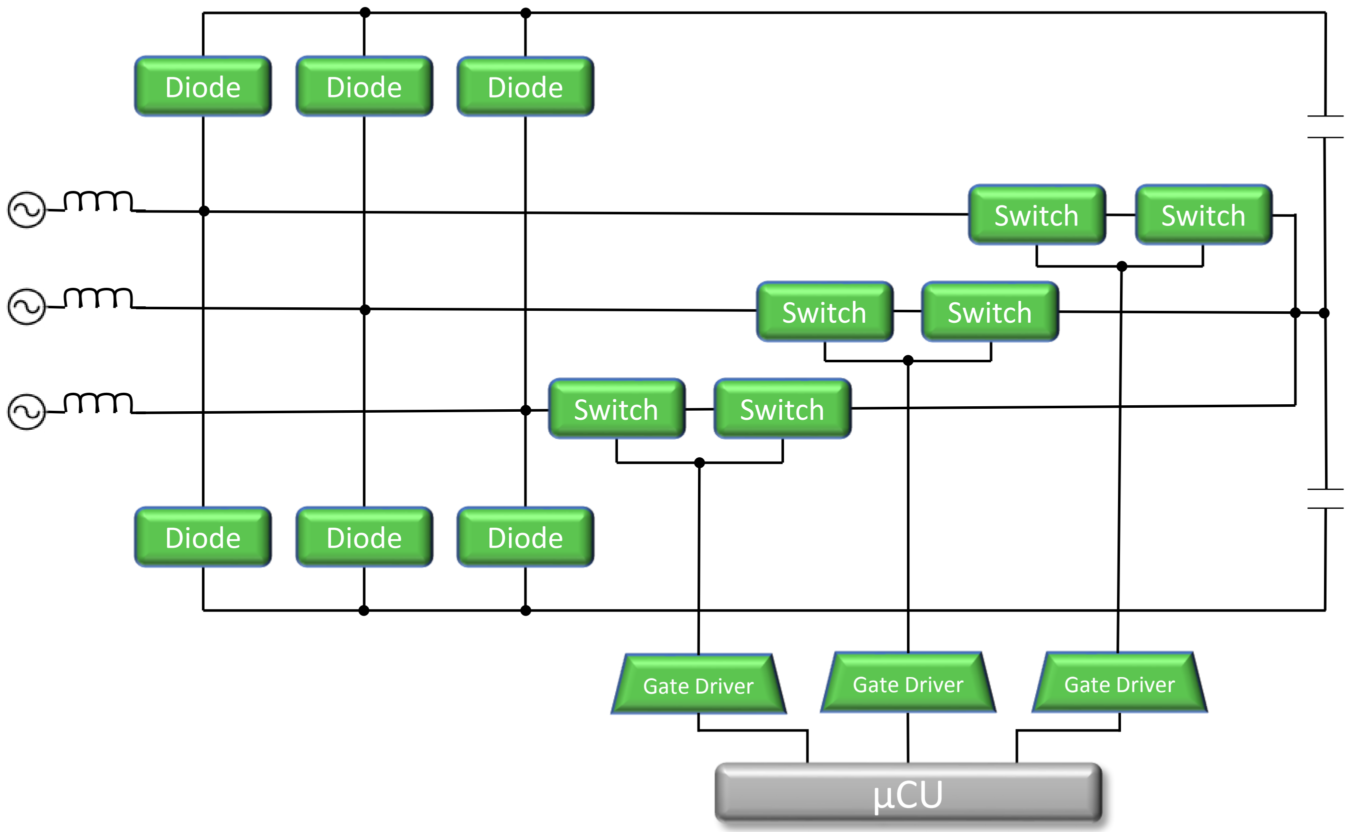
Full Product Recommendation Table

Solution Description

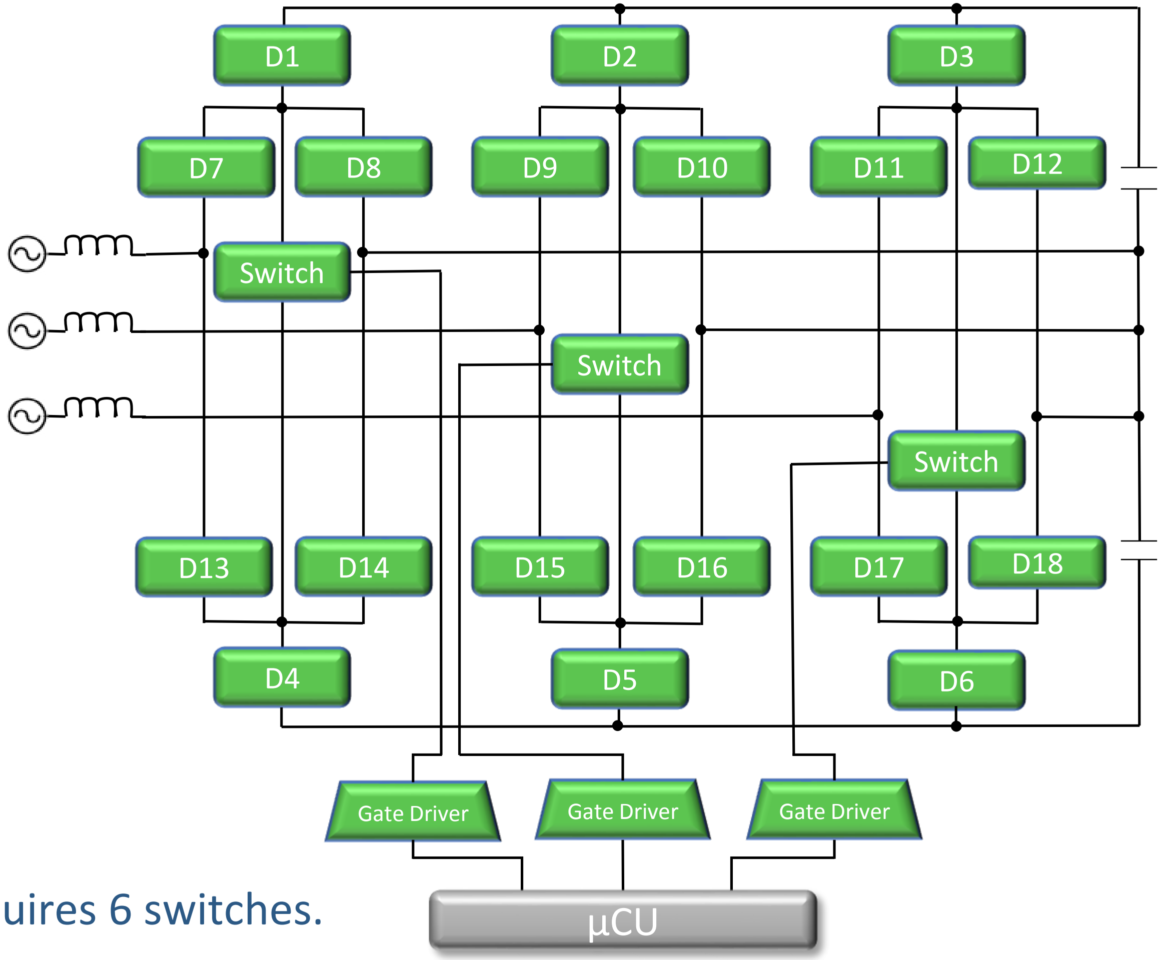
Interactive Block Diagram (onsemi.com)

3-Phase Rectifier / PFC

Topology 1



Topology 2



Topology 1 – Less components, higher efficiency, 1200 V diodes, requires 6 switches.

Topology 2 – Cost effective, 600 V diodes, requires only 3 switches but diodes are in series, hence the lower efficiency.

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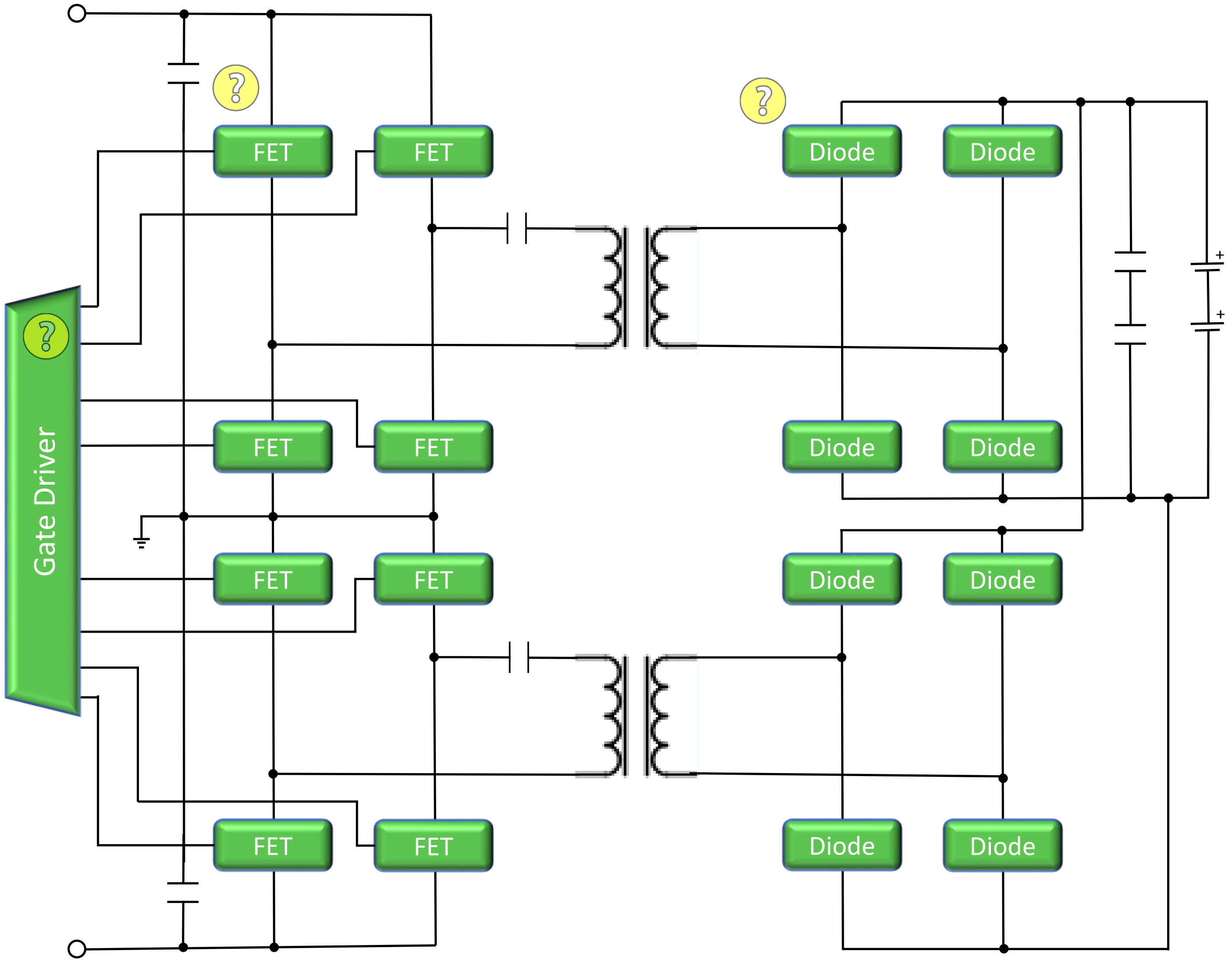
Main DC-DC / Secondary Rectification: LLC Configuration



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EV Charging Background Information

Introducing the Block Diagram of the Month for the month of May - The Electric Vehicle (EV) or Off-Board Charging Platinum Block Diagram. Our goals for publishing the "Block Diagram" of the month are to highlight power solution requirements demanded by the industry and to provide, promote, and expose ON-Semiconductor's full line of end to end solution and expertise in power semiconductors. Charging Stations, as a major part of the Transportation Infrastructure Network, have now become a reality. The ability of the Electric Vehicle Service Equipment (EVSE) to effectively charge the traction Batteries in Plug-In Electric Vehicles (PEV) in a timely fashion is the main driving force for developing High Power, High Performance, Full-Featured Protection EV (Off-Board) Chargers.

Before getting into and dissecting what's inside an Off-Board EV charger, let us define the different classification and metrics of the various charging level tiers.

Level 1 Charging

- 120 V residential Home based AC electrical outlet. Output current up to 15 A.
- 1 hour of charging through the Electric Vehicle Service Equipment (EVSE) chord set at 120 VAC will add approximately 4 miles of travel.
- Typically, Plug-in EV (PEV) batteries can be fully charged overnight.
- Fully drained PEV traction batteries may take up to approximately 20 hours of charge time with Level 1 charging standards.

Level 2 Charging

- 220 V residential or 208 V commercial AC electrical outlet. Output current up to 40 A
- Level 2 equipment requires professional installation utilizing dedicated wiring circuits
- 1 hour of charging through a level 2 EVSE chord will add approximately 15 miles of travel time with a 3.3 kW on board charger
- 1 hour of charging through a 6.6 kW, level 2 EVSE chord (on-board charger) will add approximately 30 miles of travel time.
- Fully drained PEV traction batteries may take up to approximately 7 hours of charge time with Level 2 EVSE standards

DC Fast Charging (DCFC)

- 480 V Commercial Grade AC power hardware and equipment. DC current up to 125 A
- 20-30 minutes of charging will add approximately 90-100 miles of travel.
- DCFC EVSE directly converts AC power to DC power, bypassing the EV's On-Board Charger to deliver high DC current into the PEV's traction batteries.
- DCFC EVSE is connected directly onto the charging inlet of the Vehicle.

For this block diagram, we will focus our attention on the DC Fast Charging (DCFC) Tier. Interest is very high for this solution for the obvious reason that waiting around for a battery to recharge before continuing down the road is not something consumers want to do. Of course it goes without saying that this comes with a price. High power, high current and high temperature ratings normally associate themselves with quality components and sometimes exotic components. This trade off requires rectifier components with blocking voltage ratings in excess of 1200 V. Two lower voltage rated diodes may be mounted in series but with compromise in efficiency due to the voltage drop being twice as much. Silicon Carbide diodes are also available but are costly due to being "newer" technology – more on this comparison will be discussed below.

Because the DCFC current rating is in the 125A range, the secondary rectification block requires magnetic isolation with optimized heat transfer characteristics and minimized transformer loss. An option of having a multiple secondary winding tap points topology in the secondary rectification stage is also available to cater to improved heat transfer and high output current requirements. Multiple transformers connected in parallel configuration can mitigate current stresses on the primary windings with the cost of power density due to this solution taking up a larger footprint.

With high power comes heat. Efficiently and reliably providing air circulation throughout the Main and Secondary stages is of primary importance, particularly with the main power transformer. A 3-phase BLDC (brush-less DC) motor driving a fan can prevent device and transformer winding over-heating. This will dramatically reduce system shutdown/restart events because every sub-system module in this off-board DCFC will be equipped with its own thermal protection via Over Temperature Protection (OTP). The circuitry required for a BLDC motor includes a motor driver controller, bridge circuitry, and direct communication with the EV charger's Microcontroller Unit (MCU).

To achieve DC high power delivery from the 3-phase AC source to charge the traction batteries to full charge, the following high power blocks are required:

- Power Factor Correction for each AC phase Line (times 3)
- Full Bridge LLC Resonant Converter
- Secondary Rectification
- Blocking Diodes to prevent reverse current

The remaining wrap around circuitry to aid successful operation are the following:

Primary Winding Side:

- High Voltage Gate Driver
- Voltage Sense Block
- Current Sense Amplifier
- Auxiliary Power Block to power the Gate Drivers, Voltage and Current Sense
- Power Line Communications Modem (PLC): ie. for detecting that the charger is in charging inlet of the vehicle
- Digital Signal Processor (not an ON part): sends PWM pulses to the PFC and Main DC/DC gate drivers.
- LCD Back Lighting Block
- 3-Phase BLDC Motor Controller with Integrated Gate Drivers
- H-Bridge Topology (6 x 40V MOSFET) to drive the BLDC Fan Motor
- Thermal Sensors for the 3-Phase / PFC block and Main DC/DC stage feeding back to the MCU/DSP

Secondary Winding Side:

- ADC (not an ON part)
- Isolation Optocoupler: Used for the feedback network between Secondary to Primary voltage sense transfer back to the MCU/DSP.

HV MOSFET (Power MOSFET) vs IGBT vs Silicon Carbide Devices

The EV charging application requires high voltage, high current and high performance in an elevated temperature environment. Below is a summary of the advantages and dis-advantages of the 3 types of devices that can be employed in each of the sub-blocks (PFC, Main DC-DC bridge, Secondary Rectifier, and Blocking Diodes) that make up the Off-Board EV charging system.

Power MOSFET or SuperJunction MOSFETs are constructed vertically. By stacking P+ tubs on top of each other, the net effect is a dramatic increase in blocking voltage tolerance, compared to its laterally construction, low voltage MOSFET counterpart. In addition to the higher blocking tolerance during reverse bias conditions, this simultaneously allows these stacked P+ tubs to be closer together, increasing cell density. Furthermore and most importantly, this allows the N epi region to be thinner and much more heavily doped leading to lower R_{epi} per unit area contributing to a much lower total overall on-state silicon resistance while featuring very high voltage blocking rating.

IGBT has a gate terminal insulated by SiO2 (similar control input gate function as a Power MOSFET) and having the advantages of High-Current, due to being a majority carrier device, and low saturation voltage (Vce) features that of a bipolar device. In other words, they have the precision gate control of a field-effect transistor and the extreme high-current capacity of a bipolar power transistor as a switch. They do not have the disadvantage of being a minority carrier device such as the Power MOSFET as far as current density is concerned. The disadvantage occurs when turning off this device. Due to the injection layer being of P-type that interfaces with the N-type Drift Layer, this large interface area has to go through reverse recovery causing a long device turn-off period that in turn produces a long tail current.

Silicon Carbide is a wide-bandgap device (3.3 eV compared to 1.1 eV for Si devices such as power MOSFETs and IGBT above). Some advantages of this wider band gap are a higher electric field breakdown, higher thermal conductivity and higher operating temperature tolerances. The drift region is physically narrower (thinner) than regular silicon devices by 10x which translates into much lower on resistance producing more efficient power solutions.

Criteria	HV MOSFET (SuperJunction)	IGBT	Silicon Carbide
High Voltage Blocking	Good	Good	Best
Thermal Conductivity	Good	Good	Best
On - State Conduction Efficiency	Good	Best	Best
Fast Switching Speed	Better	Good	Best
High Current Handling	Good	Better	Best
Well Controlled Switching Times	Better	Good	Best
High Temperature Reliability	Good	Best	Best
High Switching Speed Limitation	Yes	Yes	No
Cost Effectiveness	Good	Best	Worst
Condensed Form Factor	Good	Good	Best
Drawback	Charging / Discharging of Input Capacitance (Cgd or Miller cap) at gate terminal limits switching speed and electron transit times across the drift region where E-field develops and collapses.	Recombination during device turn-Off. Long tail current due to injection layer's excess hole carriers that require recombination.	HIGH COST Manufacturability not perfected Progress still being made in development.
Usage Trends	Most common power switch used in <75kW DC chargers due to its high efficiency in fast switching applications and moderate costs.	Used in low cost DC chargers that are not concerned about efficiency and space requirements.	Will be used in >100kW DC chargers as efficiency and space become the most critical requirements. Example, keeps a 150kW station the same size as a 50kW SuperJunction station (already the size of a traditional gas pump).

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Block Diagram Name: **HEV/EV Charging**

Suggested Block	Option	WPN	Why Select?	WPN Desciption
EV Charging Block Diagram - Main				
3-Phase Rectifier/PFC (See below)	-	-	-	See detailed breakout below
Main DC-DC (See below)	-	-	-	See detailed breakout below
AUX Power	1	NCV5171		Boost Converter, 280 kHz, 1.5 A, for Automotive
AUX Power	2	MC34063A		Buck / Boost / Inverting Regulator, Switching, 1.5 A
Voltage Sense	1	MC34071A	Wide Bandwidth: 4.5MHz, Wide - Single Supply Operation: 3V to 44V, Wide Input Common Mode Voltage Range with Fast Slew Rate 13V/us	Operational Amplifier, Single Supply 3.0 V to 44 V, Low Input Offset Voltage, Single
Voltage Sense	2	NCS211R	Wide Common Mode Input Range: -0.3V to 26V, Low Offset Drift: 0.5uV/ C: Gain: 500V/V	Current Sense Amplifier, 26V, Low-/High-Side Voltage Out, Bidirectional Current Shunt Monitor
Gate Driver - MOSFET	1	FAN3224C		CMOS input, dual non-inverting output, peak 5A sink, 5A source current Low-Side Gate Driver
Gate Driver - MOSFET	2	FAN7171_F085		625V, 4A, SOIC-8, High-Side Gate Drive IC
Gate Driver - IGBT	1	NCD5700	Non-isolated	IGBT Gate Drivers, High-Current, Stand-Alone
Gate Driver - IGBT	2	NCD57000	Isolated	Isolated high current and high efficiency IGBT gate driver with internal galvanic isolation.
Gate Driver - SiC	1	NCP51705	SiC driver	SiC MOSFET Driver, Low-Side, Single 6 A High-Speed
Current Sense	1	NCS214R	Wide Common Mode Input Range: -0.3V to 26V, Low Offset Drift: 0.5uV/ C: Gain: 100V/V	Current Sense Amplifier, 26V, Low-/High-Side Voltage Out, Bidirectional Current Shunt Monitor
Isolation	1	FOD8160		High Noise Immunity, 3.3 V / 5 V, 10 Mbit/sec, Logic Gate Optocoupler
Communications	1	NCN49597	Power line carrier modem using spread-FSK (S-FSK) modulation for robust low data rate communication over power lines.	Power Line Communication (PLC) Modem
Communications	2	NCN49599	The NCN49599 is a powerful power line communication SoC combining low power Cortex M0 processor with a high precision analogue front end. Based on a dual 4800 Baud S-FSK channel technology, it offers an ideal compromise between speed and robustness for operations in a harsh environment.	Power Line Communication (PLC) Modem
Touch Screen Controller	1	LC717A30UR		Capacitance-Digital-Converter for Electrostatic Capacitive Touch Sensors
LCD Backlighting	1	CAT4106		LED Driver, 4-Channel, 6 Watt with Diagnostics
LCD Backlighting	2	FAN5702	I2C Interface	LED Driver with I2C Interface
Brushless DC Motor Controller	1	LV8907UW	Integrated DC motor controller with gate driver. Compact design and low profile packaging and footprint.	Sensor-less Three-phase, Brushless DC Motor, Controller, with Gate, Drivers, for Automotive
Brushless DC Motor Controller	1	NTTFS015N04C	High Current Power Mosfet with 40V Breakdown Rating. Compact design and low profile packaging and footprint.	Power MOSFET; 40 V, 17.3 m, 27 A, Single N−Channel
3-Phase Rectifier/PFC - Topology 1				
Diode	1	RHRG75120	Lower cost.	75A, 1200V, Hyperfast Diode
Diode	2	RHRG30120	Lower cost.	30A, 1200V, Hyperfast Diode
Diode - SiC	3	FFSH40120ADN	Higher efficiency.	SiC Diode, 1200V, 40A, TO-247-3, Common Cathode
Switch - MOSFET	1	FCH023N65S3	Lower RDS(on) for higher efficiency.	FET Option: Power MOSFET, N-Channel, SUPERFET® III, Easy Drive, 650 V , 75 A, 23 mΩ, TO-247
Switch - MOSFET	2	NTH027N65S3F	Lower RDS(on) for higher efficiency.	FET Option: Power MOSFET, N-Channel, SUPERFET® III, FRFET®, 650 V, 75 A, 27.4 mΩ, TO-247
Switch - MOSFET	3	FCH040N65S3	Lower cost.	FET Option: Power MOSFET, N-Channel, SUPERFET® III, Easy Drive, 650 V, 65 A, 40 mΩ, TO-247
Switch - MOSFET	4	NTHL040N65S3F	Lower cost.	FET Option: Power MOSFET, N-Channel, SUPERFET® III, FRFET®, 650 V, 65 A, 40 mΩ, TO-247
Switch - IGBT	1	NGTB40N120FL3	Robust and cost effective.	IGBT Option: IGBT, Ultra Field Stop -1200V 40A
Switch - IGBT	2	NGTB40N120L3	Higher efficiency.	IGBT Option: IGBT, Ultra Field stop - 1200V 40A, Low VCEsat
Switch - SiC	1	NTHL080N120SC1	SiC	Silicon Carbide MOSFET, N-Channel, 1200 V, 80 mΩ, TO247−3L
Gate Driver - MOSFET	1	FAN3224C		CMOS input, dual non-inverting output, peak 5A sink, 5A source current Low-Side Gate Driver
Gate Driver - MOSFET	2	FAN7171_F085		625V, 4A, SOIC-8, High-Side Gate Drive IC
Gate Driver - IGBT	1	NCD5700	Non-isolated	IGBT Gate Drivers, High-Current, Stand-Alone
Gate Driver - IGBT	2	NCD57000	Isolated	Isolated high current and high efficiency IGBT gate driver with internal galvanic isolation
Gate Driver - SiC	1	NCP51705	SiC driver	SiC MOSFET Driver, Low-Side, Single 6 A High-Speed

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Suggested Block	Option	WPN	Why Select?	WPN Desciption
3-Phase Rectifier/PFC - Topology 2				
D1 to D6 (Diode Rectifier)	1	ISL9R3060G2	Higher efficiency.	30A, 600V, STEALTH™ Diode
D1 to D6 (Diode Rectifier)	2	RHRG3060	Lower ringing and transient spikes.	30A, 600V, Hyperfast Diode
D7 to D18 (Diode Rectifier)	1	RHRG3060		30A, 600V, Hyperfast Diode
Switch - MOSFET	1	FCH023N65S3	Lower RDS(on) for higher efficiency.	FET Option: Power MOSFET, N-Channel, SUPERFET® III, Easy Drive, 650 V , 75 A, 23 mΩ, TO-247
Switch - MOSFET	2	NTH027N65S3F	Lower RDS(on) for higher efficiency.	FET Option: Power MOSFET, N-Channel, SUPERFET® III, FRFET®, 650 V, 75 A, 27.4 mΩ, TO-247
Switch - MOSFET	3	FCH040N65S3	Lower cost.	FET Option: Power MOSFET, N-Channel, SUPERFET® III, Easy Drive, 650 V, 65 A, 40 mΩ, TO-247
Switch - MOSFET	4	NTHL040N65S3F	Lower cost.	FET Option: Power MOSFET, N-Channel, SUPERFET® III, FRFET®, 650 V, 65 A, 40 mΩ, TO-247
Switch - IGBT	1	NGTB40N120FL3	Robust and cost effective.	IGBT Option: IGBT, Ultra Field Stop -1200V 40A
Switch - IGBT	2	NGTB40N120L3	Higher efficiency.	IGBT Option: IGBT, Ultra Field stop - 1200V 40A, Low VCEsat
Switch - SiC	1	NTHL080N120SC1	SiC	Silicon Carbide MOSFET, N-Channel, 1200 V, 80 mΩ, TO247–3L
Gate Driver - MOSFET	1	FAN3224C		CMOS input, dual non-inverting output, peak 5A sink, 5A source current Low-Side Gate Driver
Gate Driver - MOSFET	2	FAN7171_F085		625V, 4A, SOIC-8, High-Side Gate Drive IC
Gate Driver - IGBT	1	NCD5700	Non-isolated	IGBT Gate Drivers, High-Current, Stand-Alone
Gate Driver - IGBT	2	NCD57000	Isolated	Isolated high current and high efficiency IGBT gate driver with internal galvanic isolation.
Gate Driver - SiC	1	NCP51705	SiC driver	SiC MOSFET Driver, Low-Side, Single 6 A High-Speed
Main DC-DC / Secondary Rectification				
FET	1	NTH027N65S3F	Higher efficiency.	Power MOSFET, N-Channel, SUPERFET® III, FRFET®, 650 V, 75 A, 27.4 mΩ, TO-247
FET	2	NTHL040N65S3F	Higher efficiency.	Power MOSFET, N-Channel, SUPERFET® III, FRFET®, 650 V, 65 A, 40 mΩ, TO-247
FET	3	NTHL065N65S3F	Lower cost.	Power MOSFET, N-Channel, SUPERFET® III, FRFET®, 650 V, 46 A, 65 mΩ, TO-247
FET	4	NTHL082N65S3F	Lower cost.	Power MOSFET, N-Channel, SUPERFET® III, FRFET®, 650 V, 40 A, 82 mΩ, TO-247
Diode	1	RHRG75120	Lower cost.	75A, 1200V, Hyperfast Diode
Diode	2	RHRG30120	Lower cost.	30A, 1200V, Hyperfast Diode
Diode - SiC	1	FFSH30120A	Higher efficiency.	SiC Diode, 1200V, 30A, TO-247-2
Diode - SiC	2	FFSH40120A	Higher efficiency.	SiC Schottky Diode, 1200 V, 40 A
Diode - SiC	3	FFSH50120A	Higher efficiency.	SiC Diode, 1200V, 50A, TO-247-2
Gate Driver - MOSFET	1	FAN3224C		CMOS input, dual non-inverting output, peak 5A sink, 5A source current Low-Side Gate Driver
Gate Driver - MOSFET	2	FAN7171_F085		625V, 4A, SOIC-8, High-Side Gate Drive IC
Gate Driver - IGBT	1	NCD5700	Non-isolated	IGBT Gate Drivers, High-Current, Stand-Alone

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