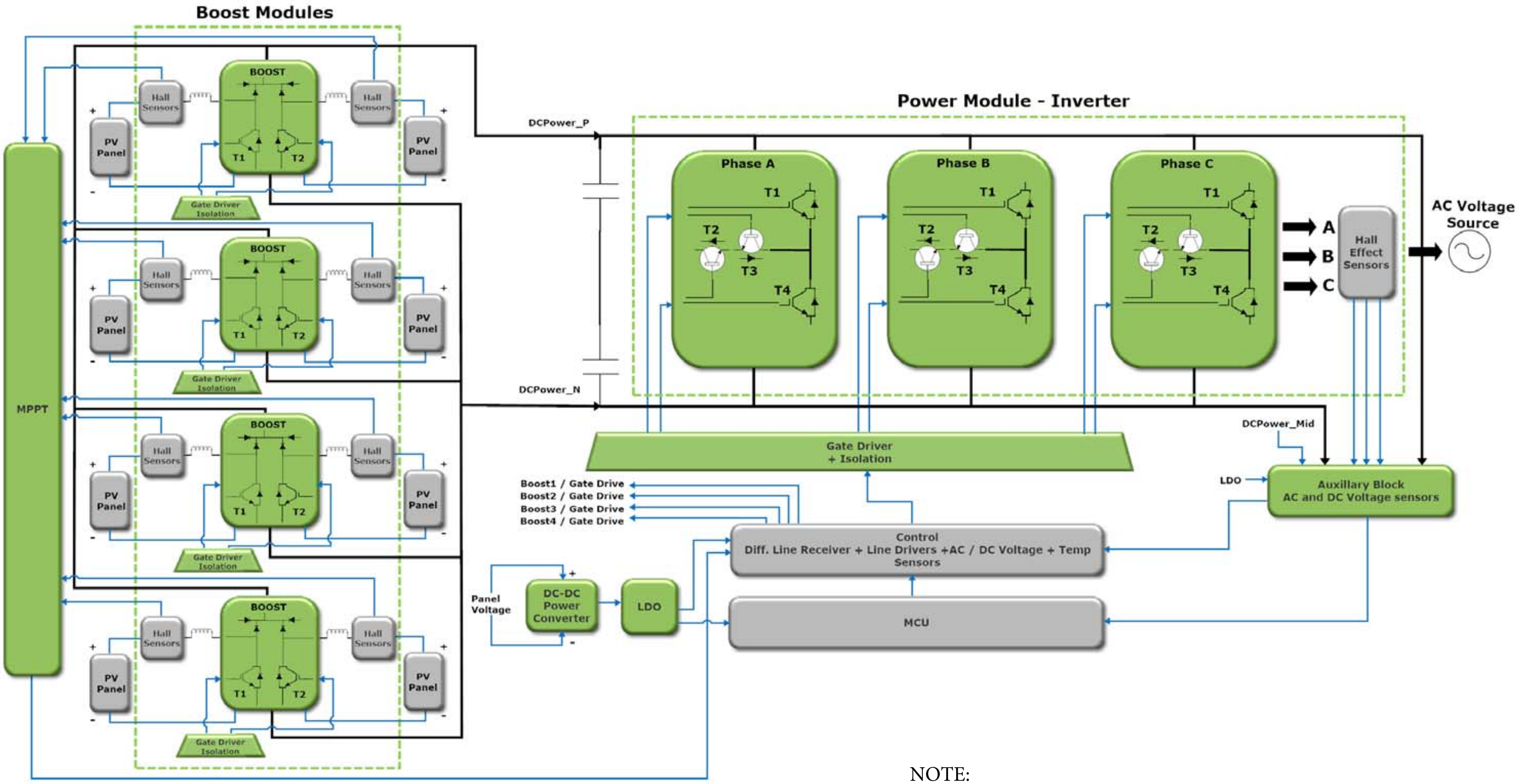
Solar Inverter Block Diagram



NOTE:
Click on green blocks to obtain additional information.

Blocks containing multiple product options will take you to the product recommendation table labeled by block name. Blocks with only one product recommendation will take you to the product page at onsemi.com.

Solution Description

Product Recommendation Table

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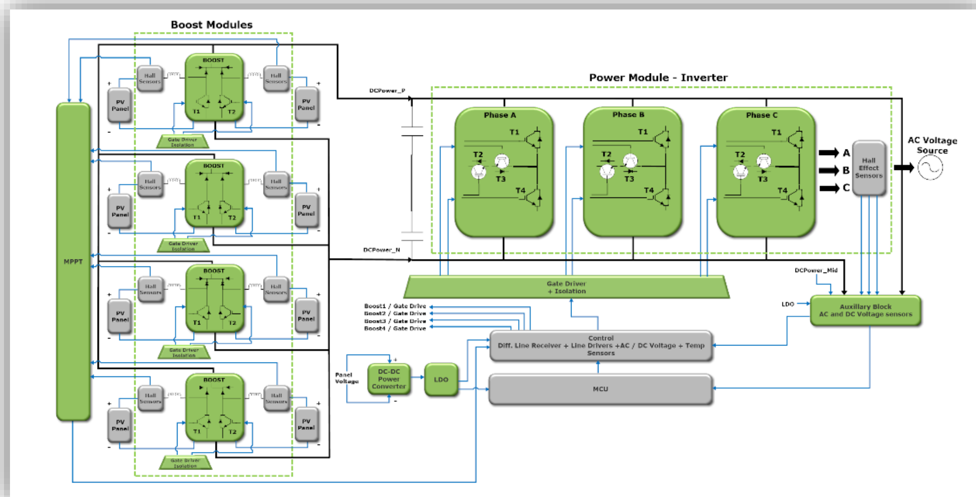
Greetings and welcome to another edition of the Block Diagram of the Month. Each month we provide a specific application solution with recommended ON Semiconductor content from various business units. This month we look at the solar inverter.

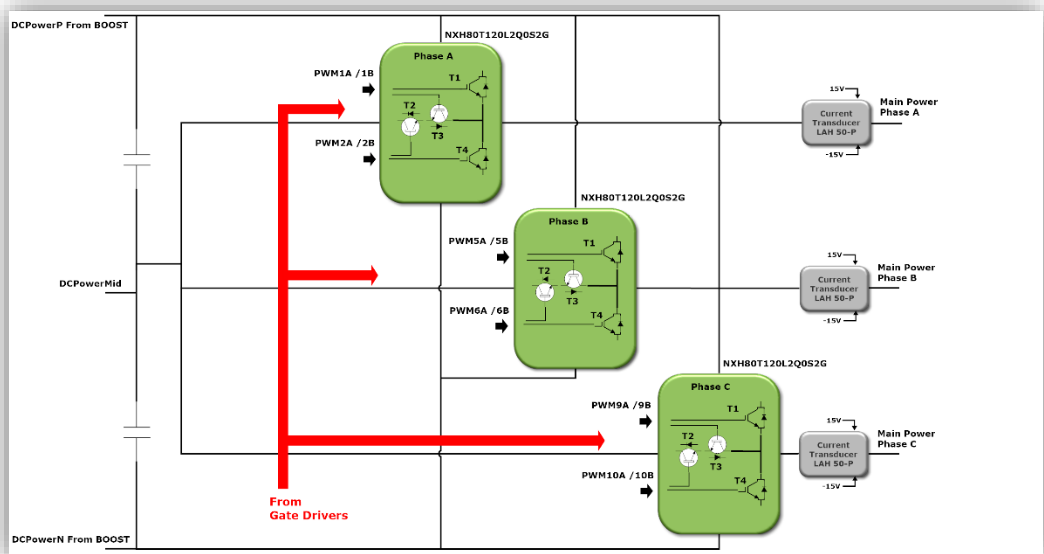
Solar Energy

More than ever, the quest for finding alternative ways in reducing CO_2 emissions is a continual movement in the semiconductor industry. Due to changing conditions and the amount of sunlight irregularities experienced by the photo-voltaic interface or module, harvesting electrical energy from solar panels is a challenging task. Several factors are in constant play when a Solar system is considered:

1) Solar panel temperature variance throughout the day.
2) Non-linear load characteristics or I-V characteristics due to the varying panel voltage output.
3) Varying amount of sunlight illuminating (irradiance) on each photo-voltaic cell.



Power Module - Inverter



The power module - inverter is an electrical component that converts DC electric energy harnessed from the solar panels and converts it to household appliance-friendly alternating current (AC) electricity. The following are the three most common types of inverter configurations on the market:

String Inverters (Centralized): This is the most commonly used option everywhere and is only available in system level monitoring. They are low cost and easy to implement. The downfall is that string inverters produce power only as much as the least producing panels. The factors that may contribute to sub-par panel production output are:

- Nearby landscape objects that introduce shading of the panels during parts of the day – power level of that string is reduced to the power output of that least producing panel.
- Panels facing different directions across an elevated mounting platform.

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String Inverters and Power Optimizer (non-Centralized): Each panel is independently monitored for power delivery, maximizing overall array output and integrates both panel and system level monitoring.

Micro-Inverters: Similar to string inverter and power optimizer but confined within each individual panel. This option is typically at a higher cost point due to greater power semiconductor content density.

The latter two, string inverters and power optimizer, and micro-inverters are often categorized as **Module Level Power Electronics (MLPEs)**. Although much more complicated, due to the higher content density, they are quickly gaining market share due to the surge in popular demand. The increase in popularity is because of the semiconductor content reaching a point of becoming more cost-effective.

Once the DC power rails have been established with the use of the dual boost power module, the elevated DC voltage will now undergo pulse width modulation (PWM) to produce the sinusoidal waveform emulating an AC waveform. The **NXH80T120L2Q0** power integrated module (PIM) performs the inverting function. This Q0Pack Module contains half bridge configured, 1200 V IGBTs and fast recovery diodes with current handing capability of 80 A to withstand the initial high DC voltage occurring at the rails. The neutral point IGBT and rectifier devices are rated for 650 V with 50 A of current handling capability. To produce the household AC plug-in voltage, the gate terminals of the IGBT devices undergo PWM switching.

This switching modulation originates from the use of a microcontroller. By turning on and off a complimentary pair of IGBT devices at a time, a bridged path forms across the household appliance load where one IGBT device provides a path to source current to the load during the "on" cycle and the second IGBT device provides the return pathway current sink back to the sinusoidal node during the "off" cycle. Varying the pulse width upon each of the two device's turn on cycle through a set of programmed modulated pulsing pattern produces the desired "average" valued alternating current recurring at "60 Hz" or "50 Hz" frequency depending on the geographic region.

Module Level Power Electronics (MLPE)

Turning our attention to MLPEs. The incorporation of this topology provides maximum energy production output regardless of the ever-changing external conditions typically encountered within the perimeter where the panel hardware are mounted. Due to the high level of system integration such as voltage, current monitoring, power delivery and processing units embedded into each solar panel, optimum energy production or conversion can be achieved. This approach is also most effective especially where factors such as: i) Module or panel mismatches along hardware mounting zones cannot be avoided, ii) Partial shading ranging from 20 to upwards of 50% and iii) Inconsistent solar irradiance on the PV modules caused by orientation mismatching.

From a system level standpoint, the raw voltage generated by the photo-voltaic panel is fed through a current sensor. A list of viable operational amplifiers for current and voltage sense applications can be found in the product table. The raw panel voltage also provides a feed line into a DC-DC converter for auxiliary power. This auxiliary power block comprised of switch mode PWM converters and LDOs to purposely supply power to the control feedback, gate drivers, MCU, Hall Effect sensors (current transducers), voltage sensors, maximum power point tracking (MPPT) circuitry and other housekeeping blocks.

In order for the solar system to operate efficiently and optimally, voltage and current sensors need to be placed at certain critical nodes along the solar system's power path. The **NCS210R/13R/14R** and the **NCS333/X333** family of current sense and operational amplifiers provide precision level monitoring and reporting requirements. Hall sensors are located at each of the PV panel's outputs prior to the boost converter's input. Due to the varying and unpredictable I-V characteristics and overall impedance seen at the solar array section, the real time information gathered by the current transducers (Hall sensors) are fed into the maximum power point tracker (MPPT) circuit array explained below. These signals are relayed back to the control unit to determine the next PWM cycle activity required to manage, compensate and mitigate for the voltage boosting function. The output of the boost converter is an elevated and regulated DC voltage. Isolated, precision voltage sensors are placed on this node feeding back to control/MCU to modulate the next PWM cycle. Ultimately the boosted voltage is the DC rail for the power inverter.

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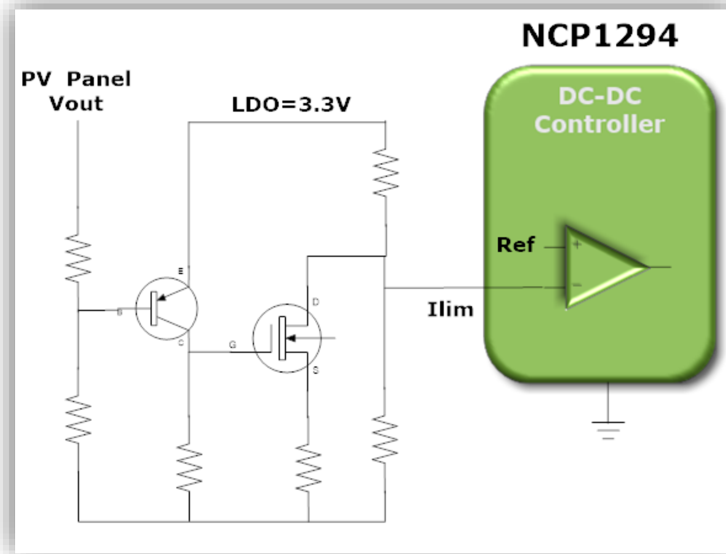
Maximum Power Point Tracking (MPPT)

Due to the unpredictability of the I-V characteristics of the impedance seen from the panels, ambient temperature around the panel interface and the solar irradiance striking at the surface throughout the day, a method is required to distinguish whether if the power drawn from the cell is less than what the cell can optimally deliver. The use of a Maximum Power Point Tracking (MPPT) circuit needs to be employed. Ideally, peak efficiency is achieved when the power drawn from a cell is the maximum power that cell can potentially deliver.



An MPPT circuit is a type of DC-DC converter that would have sets of pre-determined reference voltage and current set points to be compared with the varying voltage and current outputs produced by each individual panel.

A solar array's operating point is defined by the impedance seen by the panel downstream. By sweeping through the collection of stored reference voltage and current set-points within the tracking algorithm of the converter and frequently compared with the dynamic characteristics of the solar cell, a search and seek for the maximum power output for a specific panel output voltage can be performed periodically. By modulating the controller's PWM width or duty ratio would result to increasing or decreasing the impedance downstream through this converter, hence moving toward the optimal peak power point. A possible such circuit deployment is by making use of the **NCP1294** controller. The current limit function of the NCP1294 is utilized through servo-ing an external circuit around the target voltage set-point, being the sensed photo-voltaic panel voltage. Similar to the perturb-and-observe MPPT technique.

The MPPT circuit monitors the individual panel voltage. The circuit will initiate progressive test current pulses until the panel voltage begins to "sag." This voltage degradation (sag) represents the decrease in output power (voltage * current). Reverting back to one current pulse level increment causes the panel voltage to recover (increase in voltage) to the more ideal value before voltage sagging began. This current level value will be stored as the current limit set-point (threshold) featured with the NCP1294 controller (current limit programming resistor). Each of the individual panels that would have its own dedicated MPPT circuit, will have its own unique current set-point threshold. Hence, this approach ensures that the "optimum" voltage and load current are obtained for each solar panel, collectively generating the "overall" maximum power output. Current level incremental steps are dependent on the tracking algorithm implemented in the power optimizer module embedded and integrated alongside each panel.

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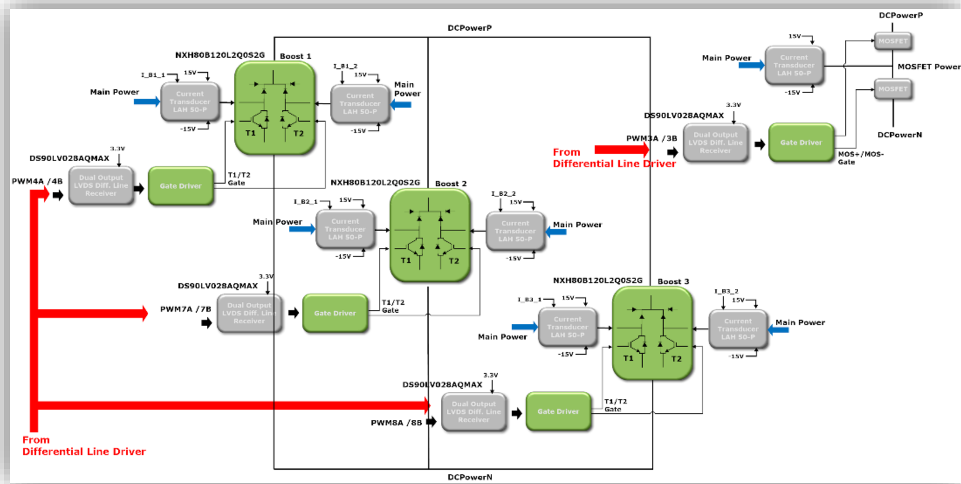
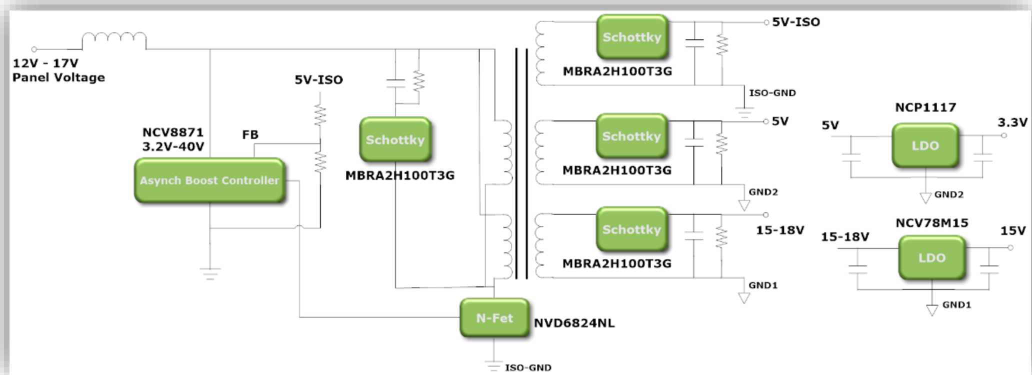
Boost Module - Voltage Boosting



Solar cells or PV cells only produce DC voltages. The intent is to convert this DC energy into useful, 120 V (240 V) alternating current output. From the solar panels' DC voltage, the output is sensed for MPPT determination and analysis. Each of the MPPT circuit and respective panel's optimal operating point will be achieved to obtain maximum efficiency. The panel voltage point value from the DC panel is fed into a DC-DC boost converter. The **NXH80B120L2Q0** is an integrated Dual Boost Power Module. The robust, 1200 V IGBTs can support 40 A of continuous current. With the Q0Boost high density case and on board thermistor, the **NXH80B120L2Q0** is a reliable solution for today solar system needs. Boosted voltages may range between 620 V to 850 V.

DC-DC Converter



Perhaps one of the most vital elements within a solar system is the DC-DC converter responsible for biasing or powering up the essential electrical circuits that enables solar power conversion possible. Immediately at the onset and generation of the panel voltage, a switch-mode power supply takes the raw voltage, converting it to useful and manageable multiple voltage rails. To begin this process, a flyback configured, asynchronous boost controller, the **NCV8871**. It has an input rating of up to 40 V and can facilitate an isolation barrier through a transformer. Independent secondary windings can be configured to cater to a 15 V-18 V rail dedicated for the high current gate drivers. Multiple separate 5 V rails may be an option depending on transformer design and specifications to bias the rest of the low voltage housekeeping through a 3.3 V LDO regulator for MCU/Control/Sensors/Differential Line Drivers and another dedicated 5 V supply rail for the low voltage signals for gate driver function prior to level shifting.

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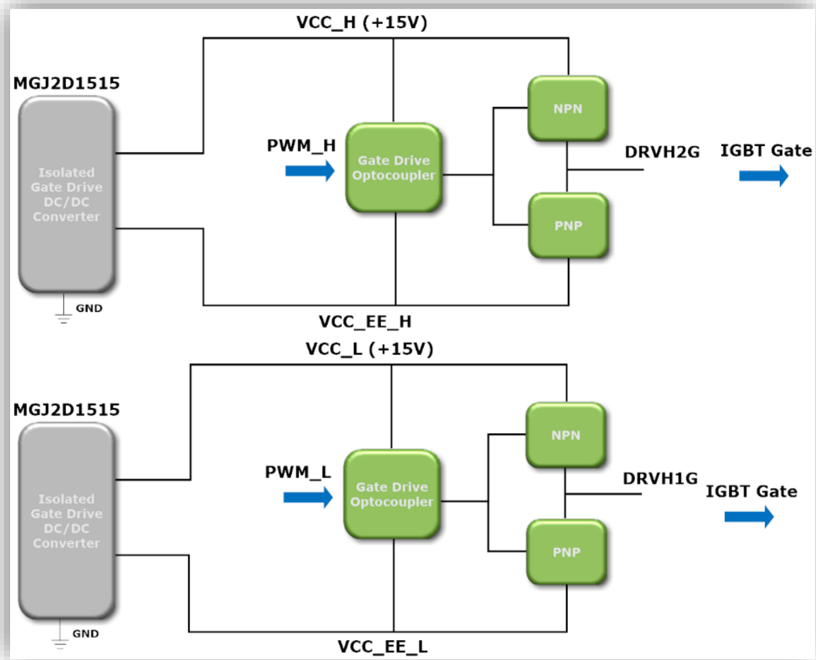
Gate Drivers + Isolation



The IGBT gate terminals of both the Power Inverter Modules and the Dual Boost Modules are driven by a pair of 7 A capable, push-pull, High-Speed Bipolar Devices, the **NSS60601MZ4/NSS60600MZ4**. The **FOD3120** is an Isolated and High Noise Immunity Gate Drive Opto-coupler functions as the pre-driver. Alternatively, integrated power modules such as the **NCD5700x** and **NCD570x**, which are high current, stand-alone IGBT gate drivers are listed in the product table.

Providing the +/- 15 V bias rail, for the gate drivers features a “Hi Pot Test” of up to 5.2 kVDC isolation test voltage. This DC-DC converter module is highly immune to rapid dv/dt and massive inductive spike typically seen downstream in bridged configurations that employ power IGBT and power MOSFET devices.

Alternatively, a quasi-resonant converter may be deployed, providing galvanic isolation. High power gate driver rails can be supplemented through dedicated windings in the secondary stage as mentioned in the DC-DC converter section.

Differential Signaling, Voltage Level Translation and Isolation

Proper voltage level shifting is crucial when propagating PWM signals from the MCU / Control block elements to the high voltage power modules. The use of differential line drivers is essential to convey and implement low voltage differential signaling (LVDS). This is to lower the output voltage levels and reduce power consumption while maintaining high switching speeds.

From the line drivers, dual output low voltage differential signaling (LVDS) line receivers accept the low voltage differential input signals from the MCU/ PWM control block and translates them to 3 V CMOS output levels where the **FOD3120** Isolated gate drivers interprets these low voltage input signals.

The gate driver opto-coupler translates these isolated, low voltage PWM signals to higher voltage levels where the power devices such IGBTs or SuperJunction MOSFETs require gate voltage levels in excess of 15 V to meet power train efficiency targets.

Suggested Block	OPT	QTY	WPN	Why Select?	WPN Description
MPPT - DC-DC Controller	1	1	NCP1294	Accurate Duty Cycle Limit Control	PWM Controller for Flyback or Forward Converters
Boost Module	1	4	NXH80B120L2Q0SNG	Dual Boost, 1200V, 40A IGBT	Power Integrated Module, Dual Boost, 1200 V, 40 A IGBT + 1200 V, 30 A Si Diode
Boost Module	2	4	NXH80B120MNQ0SNG		Full SiC MOSFET Module, Two Channel Full SiC Boost, 1200 V, 80 mohm SiC MOSFET + 1200 V, 20 A SiC Diode
Boost Module	3	4	NXH100B120H3Q0		Power Integrated Module, Dual Boost, 1200 V, 50 A IGBT + 1200 V, 20 A SiC Diode.
Boost Module	4	4	NXH40B120MNQ0SNG	1200V SiC Devices	Full SiC MOSFET Module, Two Channel Full SiC Boost, 1200 V, 40 mohm SiC MOSFET + 1200 V, 40 A SiC Diode
Boost Module	5	4	NXH40B120MNQ1	1200V SiC Devices	Full SiC MOSFET Module, Three Channel Full SiC Boost, 1200 V, 40 mohm SiC MOSFET + 1200 V, 40 A SiC Diode
Boost Module	6	4	NXH240B120H3Q1PG		Power Integrated Module (PIM) 3-channel 1200 V IGBT + SiC Boost, 80 A IGBT and 20 A SiC diode
Boost Module	7	4	FGH75T65SQD	Cost effective and reliable	IGBT, 650 V, 75 A Field Stop Trench
Boost Module	8	4	NGTB40N120FL3	Cost effective and reliable	IGBT, Ultra Field Stop -1200V 40A
Boost Module	9	4	NTH4L020N120SC1	High Power SiC device	Silicon Carbide MOSFET, N-Channel, 1200 V, 20 mΩ, TO247−4L
Boost Module	10	4	NTHL020N090SC1	High Power SiC device	Silicon Carbide MOSFET, N-Channel, 900 V, 20 mΩ, TO247−3L
Boost Module	11	4	FFSP4065BDN-F085	High Power SiC device	Silicon Carbide Schottky Diode, 650 V, 40 A
Boost Module	12	4	FFSH50120A	High Power SiC device	SiC Diode, 1200V, 50A, TO-247-2
Boost Module	13	4	NDSH25170A	High Power SiC device	Silicon Carbide Schottky Diode 1700V, 25A, TO247
Power Module - Inverter	1	3	NXH80T120L2Q0S2G	PIM with 80A, 600V IGBTs	Power Integrated Module (PIM), T-Type NPC 1200 V, 80 A IGBT, 600 V, 50 A IGBT
Power Module - Inverter	2	3	NXH80T120L3Q0	As required by individual design considerations.	Power Integrated Module (PIM), T-Type NPC 1200 V, 80 A IGBT, 600 V, 50 A IGBT
Power Module - Inverter	3	3	NXH160T120L2Q1	As required by individual design considerations.	Power Integrated Module (PIM), IGBT 1200 V, 160 A and 650 V, 100 A
Power Module - Inverter	4	3	NXH200T120H3Q2	As required by individual design considerations.	Si/SiC Hybrid Module, Split T-Type NPC, IGBT 1200 V, 200 A and 650 V, 150 A. SiC Diode 650 V, 75 A.
Power Module - Inverter	5	3	NXH350N100H4Q2	As required by individual design considerations.	SiC Hybrid Module, I-Type NPC 1000 V, 350 A IGBT, 1200 V, 100 A SiC Diode
DC-DC Power Converter - Asynch Boost Controller	1	1	NCV8871	Used for Flyback Control	Non-Synchronous Boost Controller, Automotive Grade
DC-DC Power Converter - Schottky	1	3	MBRA2H100T3G	Fast High Voltage Power Rectifier	Schottky Power Rectifier, Surface Mount, 2.0 A, 100 V
DC-DC Power Converter - N-FET	1	1	FDD86102LZ		N-Channel Shielded Gate PowerTrench® MOSFET 100 V, 35 A, 22.5 mΩ
DC-DC Power Converter - LDO	1	1	NCP1117	3.3 V Output	LDO Regulator, 1 A, Fixed and Adjustable, Positive
DC-DC Power Converter - LDO	1	1	NC78M15	15 V Output	Linear Voltage Regulator, 500 mA, 5 to 24 V, High PSRR, Positive
LDO Power	1	1	NCP59749		LDO Regulator, 3 A, Ultra-Low Dropout, High PSRR, Low Noise, with Bias Rail
Gate Driver - NPN	1	2	NSS60601MZ4		Low VCE(sat) Transistor, NPN, 60 V, 6.0 A
Gate Driver - PNP	1	2	NSS60600MZ4		Low VCE(sat) Transistor, PNP, 60 V, 6.0 A
Gate Driver - Optocoupler	1	2	FOD3120	Noise Immunity	High Noise Immunity, 2.5A Output Current, Gate Drive Optocoupler
Gate Driver	2	-	NCD5700x		IGBT Gate Drivers, High-Current, Stand-Alone
Gate Driver	3	-	NCD570x	High Current Gate Driver	Isolated High Current Gate Driver

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Suggested Block	OPT	QTY	WPN	Why Select?	WPN Description
Auxiliary Block - SMPS Controller			NCV8871		Non-Synchronous Boost Controller, Automotive Grade
Auxiliary Block - Current Sensing			NCS210R		Current Sense Amplifier, 26V, Low-/High-Side Voltage Out, Bidirectional Current Shunt Monitor
Auxiliary Block - Current Sensing			NCS333	with LEM sensor	Low Power, Zero-Drift Operational Amplifier with 10 µV Offset
Auxiliary Block - Current Sensing			NCS2007x	3Mhz BandWidth CMOS OpAmp	Operational Amplifier, Wide supply range, 3Mhz CMOS Op-Amp
Auxiliary Block - Current Sensing			NCS213R		Current Sense Amplifier, 26V, Low-/High-Side Voltage Out, Bidirectional Current Shunt Monitor
Auxiliary Block - Current Sensing			NCS214R		Current Sense Amplifier, 26V, Low-/High-Side Voltage Out, Bidirectional Current Shunt Monitor
Auxiliary Block - Voltage Sensing			NCS333	10uV Offset, 5.5V, Low Drift	Low Power, Zero-Drift Operational Amplifier with 10 µV Offset
Auxiliary Block - Voltage Sensing			NCS2333	30uV Offset, 5.5V, Low Drift	Precision Operational Amplifier, Low Power, Zero-Drift, 30 µV Offset
Auxiliary Block - Voltage Sensing			NCS4333	30uV Offset, 5.5V supply range	Operational Amplifier, 30 µV Offset, 0.07 µV/°C, Low Power, Zero-Drift
Auxiliary Block - OptoCouplers			FOD8163		3.3 V / 5 V, 10 Mbit/sec, Logic Gate Optocoupler in Stretched Body SOP 6-Pin
Auxiliary Block - OptoCouplers			FOD8342		3.0 A Output Current, High Speed Gate Drive Optocoupler in Stretched Body SOP 6-Pin
Auxiliary Block - OptoCouplers			FOD8320		High Noise Immunity, 2.5A Output Current, Gate Drive Optocoupler in Optoplanar® Wide Body SOP 5-Pin

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