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System Solution Guide - Preview

Welding Equipment

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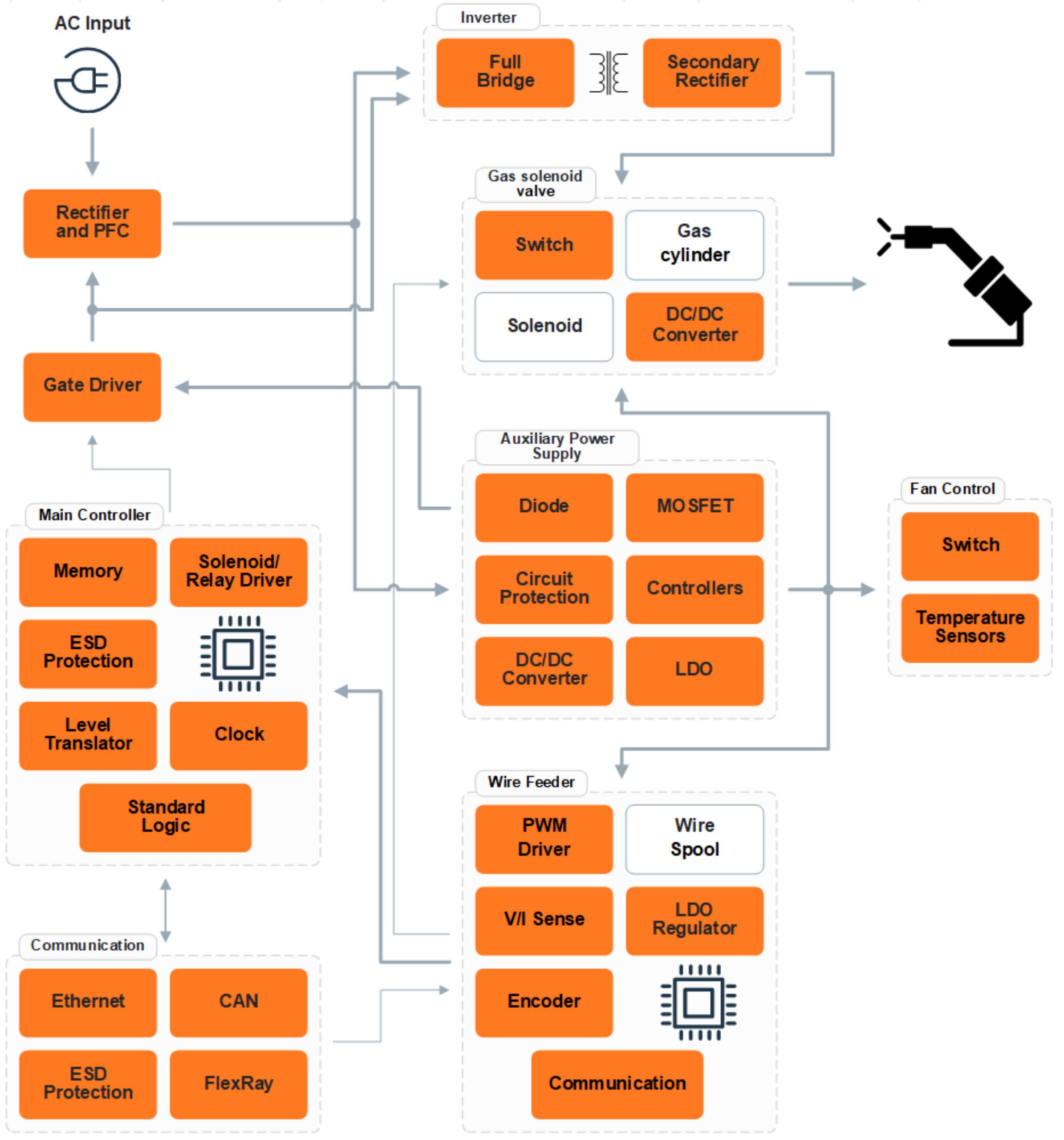
Welding Equipment Top Level Topology

The block diagram below represents a MAG/MIG welding solution, widely used in automotive and commonly integrated with robotic systems. The solution is scaled to 5-10 kW output power, where welding voltage is 20 to 40 V. **onsemi** offers all required power components. PFC is used to increase efficiency, and the inverter scales the voltage down. Silicon MOSFET is used as an output switch. Other building blocks include communication, the main controller and the auxiliary supply. Other welding processes do not use a wire feeder or a solenoid valve or additionally use a high-frequency output.



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Common Welding Inverter Topologies

The inverter in welding machines serves as the key power-processing stage that converts standard AC supply into a controlled output suitable for creating and maintaining the welding arc. It works by first rectifying the incoming AC power into DC, then switching it at high frequency using semiconductor devices, and finally transforming and regulating it to produce a stable, low-voltage, high-current output required for welding. This high-frequency operation enables the use of smaller transformers, making the machine more compact and efficient, while also allowing precise control of voltage and current. As a result, the inverter improves arc stability, weld quality, and energy efficiency compared to traditional transformer-based welders, making it the core element behind modern lightweight and high-performance welding systems.

The inverter topology determines how the output is generated and controlled. Distinct topologies have different efficiency, cost, complexity, and robustness and are suitable for various applications. Some of today's popular inverter topologies are shown and explained below.

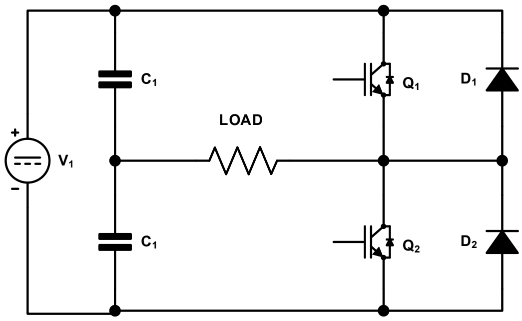

Figure 4: Half-Bridge

Half-Bridge Inverter

- Uses two switches
- Simple to control and cost-effective for low power levels
- Higher EMI and limited switching frequency
- Cost-effective for low-power portable welding machines

Full-Bridge Inverter

- Uses four switches
- Simple to control and cost-effective for lower power levels
- Higher EMI and limited switching frequency
- Can deliver more power than half-bridge but has more devices and more complex drive

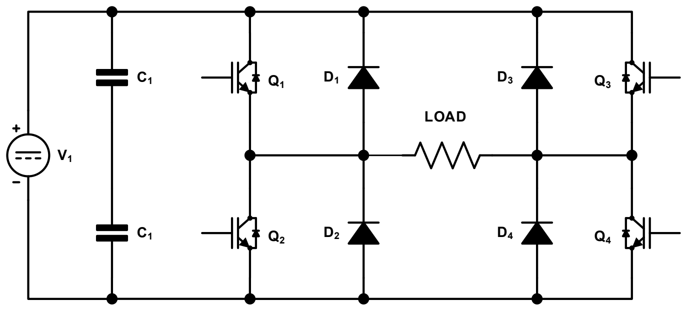

Figure 5: Full-Bridge

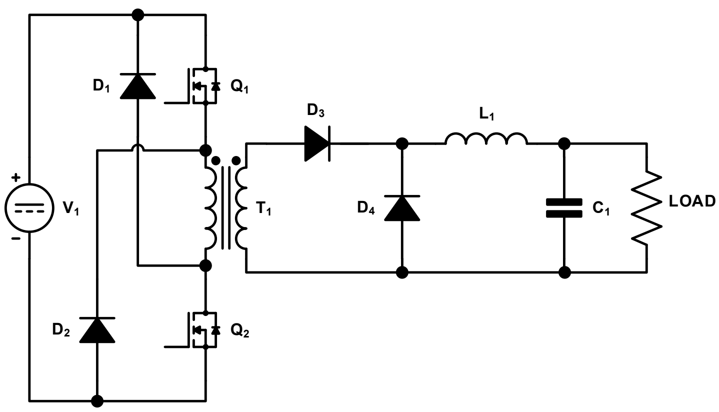

Figure 6: Forward Converter

Forward Converter

- Uses two transistors and two diodes
- Improves reliability and reduces need for complex snubber circuits
- Rugged, simple and low component count
- For mid-power applications (~3–6 kW)
- Performs well in applications with frequent short-circuit conditions

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EliteSiC JFET: Maximizing Efficiency with Ultra-Low Conduction Losses

Junction field effect transistor (JFET) is a type of unipolar transistor. It is similar to a MOSFET as it is operated on the electric field principle, is voltage-controlled and does not require biasing current.

The SiC JFET has some significant advantages over competing technologies, particularly low on-resistance for a given chip area, known as R_{DS}·A. A trade-off for minimal R_{DS}·A is a normally-on characteristic, meaning if there is no gate-source voltage, or if the JFET gate is left floating, then the JFET is fully on. This may be undesired in some applications and poses a challenge in the case of failure.

SiC Cascode JFET (CJFET)

SiC JFET is combined with a low-voltage silicon MOSFET in cascode configuration (figure 14), to create a normally-off device, which retains most of the SiC JFET's technology's benefits. **onsemi** Gen 4 SiC JFET technology utilizes trench structure with reduced cell pitch, reduced substrate thickness, which enables it to achieve the lowest on-resistance per unit area currently available.

Transition to SiC JFET is eased by the possibility of using a wide range of gate drivers, suitable for Si MOSFETs, offering greater design flexibility. The CJFET's gate voltage range is flexible due to the MOSFET gate's 5 V threshold, removing the need for negative voltage. Conductivity remains stable above 9 V gate-source voltage, enabling efficient 0–10 V bootstrap operation.

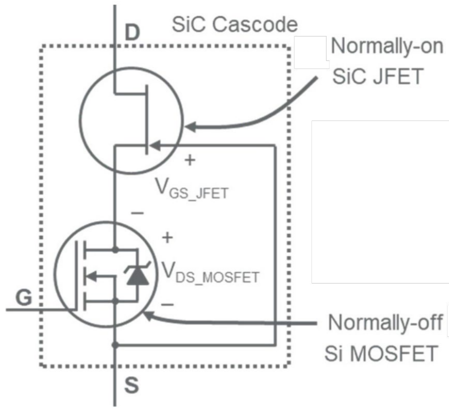

Fig.8: Cascode JFET

The EliteSiC CJFET has lower output capacitance C_{oss} when compared to SiC MOSFETs. Devices with lower output capacitance will switch faster at a low load current and have lower delay times to charge the capacitance. Faster switching speed translates to smaller, lighter, lower-cost end equipment with reduced need for bulky passive components like inductors and capacitors.

Cascode JFETs are highly versatile and can be used as a power switch in a vast range of applications including PFC and DC-DC conversion. Figures-of-merit for soft-switching can be seen in figures 9 and 10.

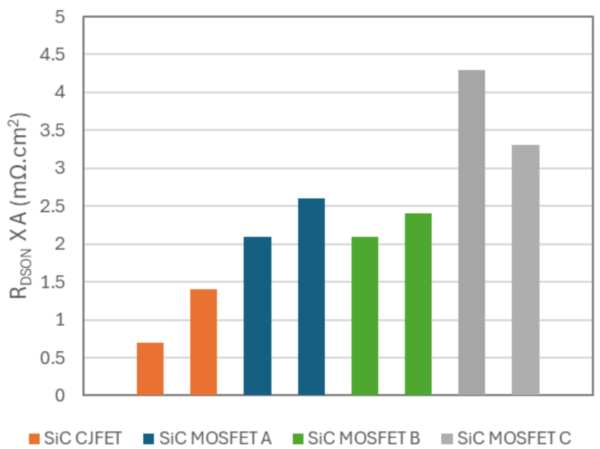

Fig.9: Lowest conduction losses from drain-to-source across useful temperature range, for a given footprint or package type

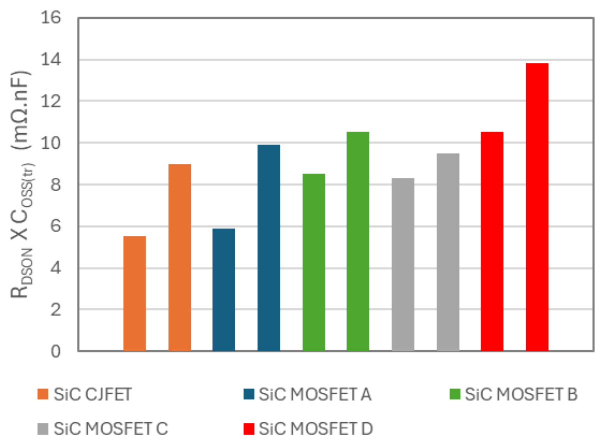

Fig.10: Lowest output capacitance allows faster ZVS transitions enabling higher operating frequency and hence higher power density

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Integrated SiC Power Modules for Faster System Development

onsemi offers power integrated modules that utilize SiC MOSFET technology. They enable huge design improvements and can be used at up to 1200V. SiC devices offer the best performance and power density and are being adopted rapidly. Lower switching losses enable higher efficiency with less cooling efforts or higher switching frequency with reduced size and cost of passive components. These benefits can justify the higher costs of SiC power devices. PIMs can include half-bridge, full-bridge or even an entire three-phase inverter in a single package. Using modules greatly reduces design time, cooling requirements and increases overall integration.

*Table 6: **onsemi** SiC PIM portfolio*

SiC Half-Bridge Modules	SiC Full-Bridge Modules	SiC Six-Pack Modules

SiC Module NXH022S120M3F1PTG

1200V SiC Six-pack module and thermistor with Al2O3 DBC in F1 package.

Key Features:

- 22 mΩ / 1200 V M3S SiC MOSFET 6-Pack
- Al_2O_3 DBC (Direct Bonded Copper)
- Options with and without Pre−Applied Thermal Interface Material (TIM)
- Press-Fit Pins

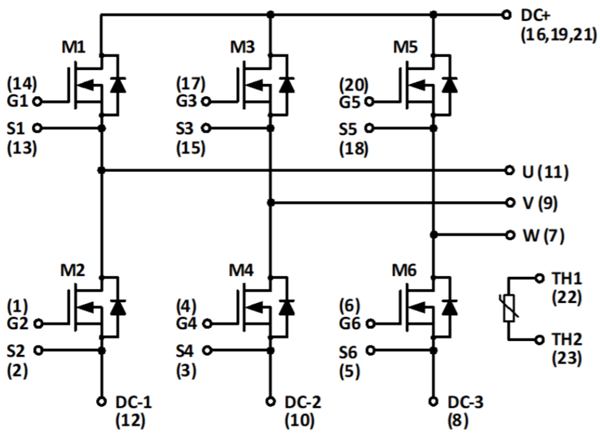

Fig.26: NXH022S120M3F1PTG schematic diagram

SiC Module NXH022S120M3F1PTG

1200V SiC full-bridge module and thermistor with HPS DBC in F2 package.

Key Features:

- 7 mΩ / 1200 V M3S SiC MOSFET full-bridge
- HPS (High-performance substrate) DBC
- Options with and without Pre−Applied Thermal Interface Material (TIM)
- Press-Fit Pins

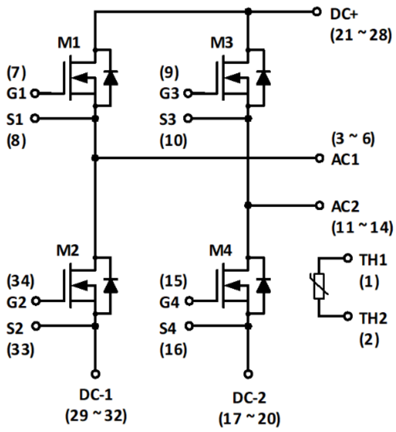

Fig.27: NXH007F120M3F2PTHG schematic diagram

Fig.28: F1 package

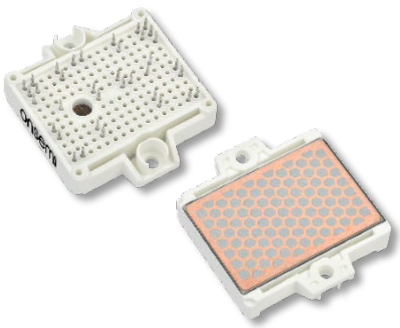

Fig.29: F2 package

Frequently Asked Questions (FAQ)

1

What are the main types of industrial welding processes?

The main industrial welding processes include oxy-fuel welding, arc welding, resistance welding, high-energy beam welding, and solid-state welding. Each method is selected based on material type, thickness, required weld quality, and production environment. Arc welding is the most widely used category, while laser, friction stir, and ultrasonic welding are increasingly adopted in advanced manufacturing applications.

2

Why is arc welding the most widely used welding method?

Arc welding is widely used because it is versatile, cost-effective, and suitable for a broad range of materials and thicknesses. It creates an electric arc between an electrode and the workpiece to generate heat for fusion. Industrial sectors such as automotive, construction, shipbuilding, and heavy equipment manufacturing use arc welding extensively due to its flexibility and scalability.

3

What is the purpose of a welding inverter?

A welding inverter converts standard AC power into a controlled low-voltage, high-current output suitable for welding. It first rectifies AC into DC, then switches it at high frequency before transforming and regulating the output. This approach improves energy efficiency, arc stability, weld quality, and enables smaller, lighter welding equipment compared with traditional transformer-based systems.

4

What semiconductor devices are commonly used in welding inverters?

IGBTs, silicon MOSFETs, silicon carbide (SiC) MOSFETs, and SiC cascode JFETs are commonly used in welding equipment. IGBTs remain popular in traditional inverter designs because of their robustness and high-voltage capability. SiC MOSFETs and SiC JFETs are increasingly adopted in high-frequency, high-efficiency designs due to their lower losses and higher switching performance.

5

Why is galvanic isolation important in industrial welding systems?

Galvanic isolation improves safety and reliability by preventing direct electrical conduction between circuits operating at different potentials. It helps eliminate ground loops, protects sensitive control electronics from high-voltage events, and reduces the risk of electric shock. Isolation is especially important in high-power welding systems where safety and noise immunity are critical concerns.

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