Power Electronics and Drives

Wide-BandGap Devices

Presented by:
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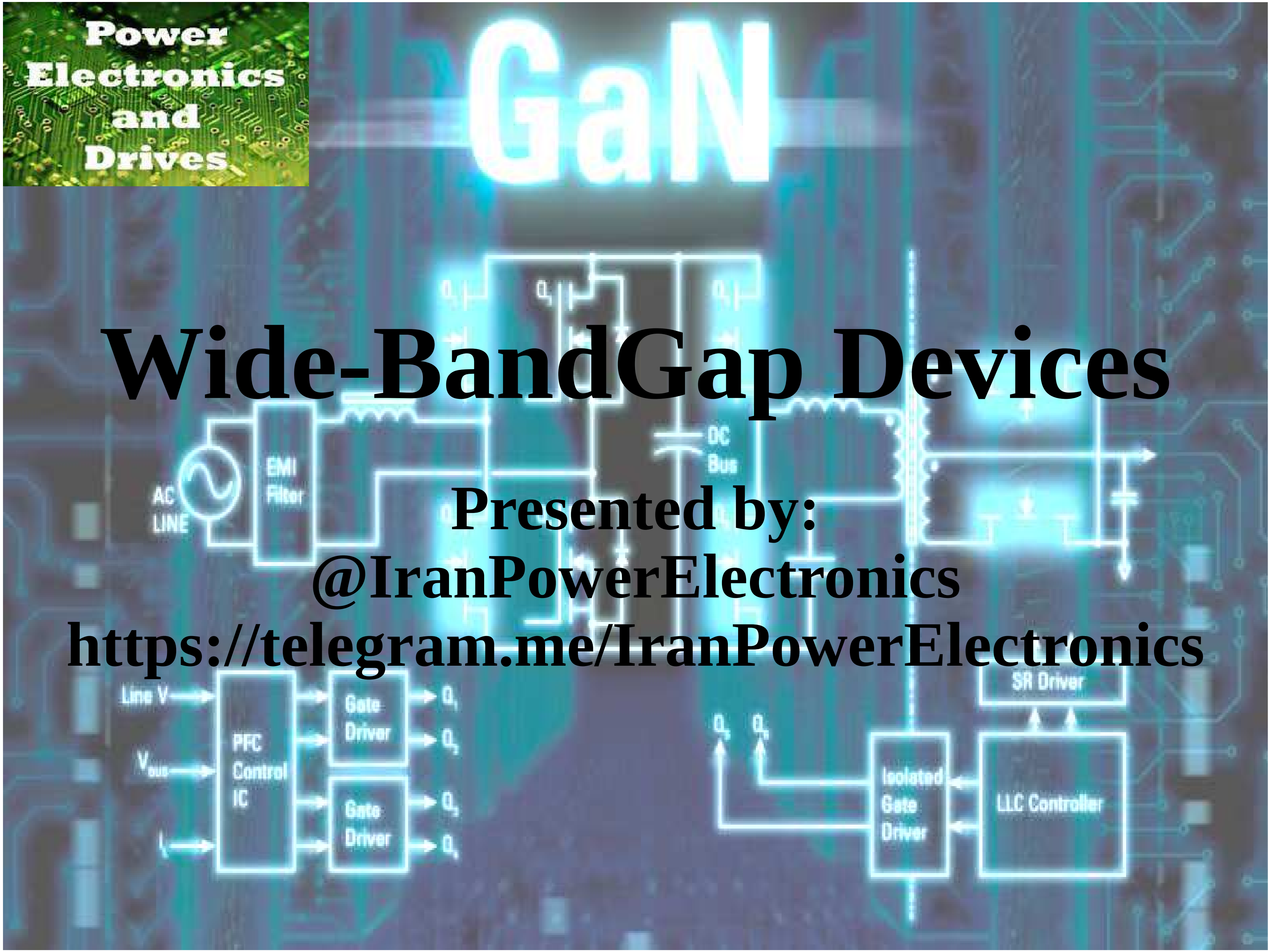


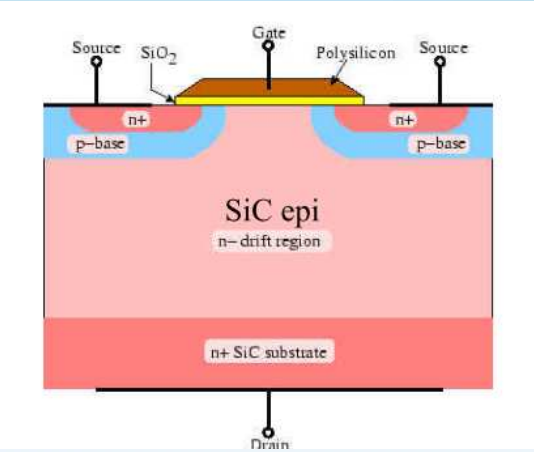
Outlines

- Wide Bandgap devices
  - Sic
  - GaN
- Comparison between Si, Sic, and GaN
- Advantages of Gallium Nitride (GaN)
- Application of GaN devices in power electronic converters

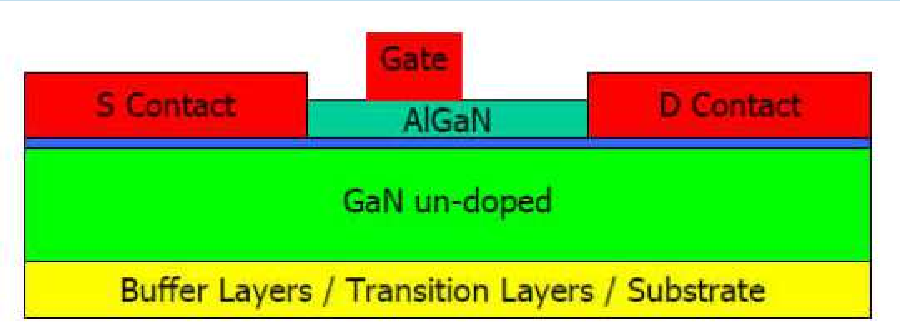
Wide Bandgap Materials

The characterization of a material as being wide bandgap pertains to the energy required for an electron to jump from the top of the valence band to the bottom of the conduction band within the semiconductor. Materials which require energies typically larger than one or two electron-volts (eV) are referred to as wide bandgap materials.

Silicon Carbide (SiC) Gallium Nitride (GaN)



Vertical DMOS SiC MOSFET



Lateral MOSFET using GaN with transitional layer material to align the lattice using Si or SiC as a substrat Vertical DMOS SiC MOSFET.

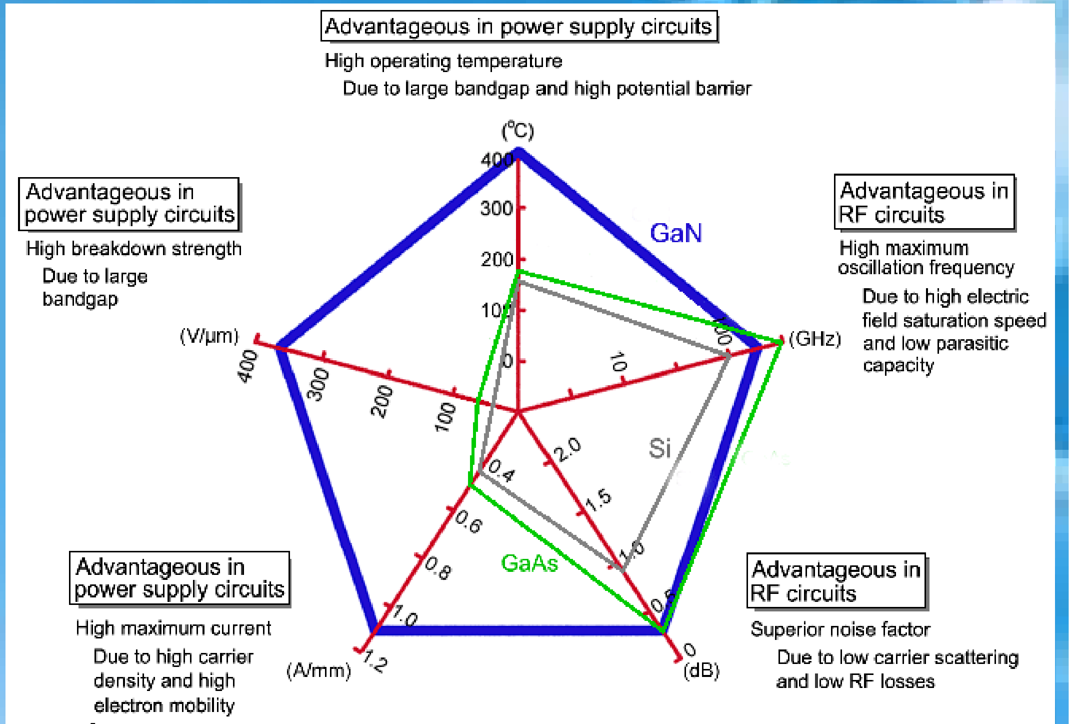
Comparison SiC and GaN versus Si

The high critical field of both GaN and SiC compared to Si is a property which allows these devices to operate at higher voltages and lower leakage currents.
Higher electron mobility and electron saturation velocity allow for higher frequency of operation. While SiC has higher electron mobility than Si, GaN's electron mobility is higher than SiC meaning that GaN should ultimately be the best device for very high frequencies.
Higher thermal conductivity means that the material is superior in conducting heat more efficiently. SiC has higher thermal conductivity than GaN or Si meaning that SiC devices can theoretically operate at higher power densities than either GaN or Si. Higher thermal conductivity combined with wide bandgap and high critical field give SiC semiconductors an advantage when high power is a key desirable device feature.
The relatively poor thermal conductivity of GaN makes heat management for GaN devices a challenge for system designers.

Materials Property	Si	SiC-4H	GaN
Band Gap (eV)	1.1	3.2	3.4
Critical Field 10^6 V/cm	.3	3	3.5
Electron Mobility (cm^2/V-sec)	1450	900	2000
Electron Saturation Velocity (10^6 cm/sec)	10	22	25
Thermal Conductivity (Watts/cm^2 K)	1.5	5	1.3

Advantages of Gallium Nitride (GaN)

GaN devices offer five key characteristics: high dielectric strength, high operating temperature, high current density, high speed switching and low on-resistance. These characteristics are due to the properties of GaN, which, compared to silicon, offers ten times higher electrical breakdown characteristics, three times the bandgap, and exceptional carrier mobility.



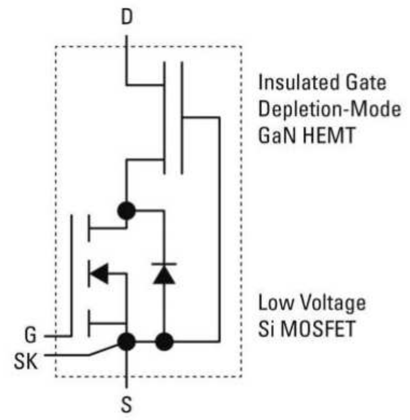
Technical advantages

- •Reduced heat sink requirements
- •80% reduction in system volume and weight
- •Lower voltage drop for unipolar devices
- •Increased output power
- •Improved transient characteristics and switching speed
- •Reduced electrical noise from smaller system packages
- •Reduced electrical noise due to virtually zero recovery charge

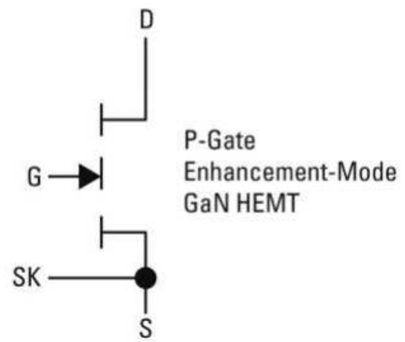
High Electron Mobility Transistor (HEMT)

The new breed of GaN devices are High Electron Mobility Transistors (HEMTs). To be cost-effective, HEMTs are manufactured on Silicon substrates, rather than Silicon Carbide or pure GaN which are both easier, but considerably more expensive.

Early 600 V GaN HEMTs developed for power electronics were depletion-mode devices.
To solve the normally-on issue, the depletion-mode HEMT was combined with a low-voltage Silicon MOSFET to form a normally-off hybrid device known as a GaN cascode.



Enhancement-mode GaN HEMTs at 600 V (which areintrinsically normally-off) were perhaps more challenging to develop, but are also now just becoming available on the market.



Application of GaN devices in power electronic converters

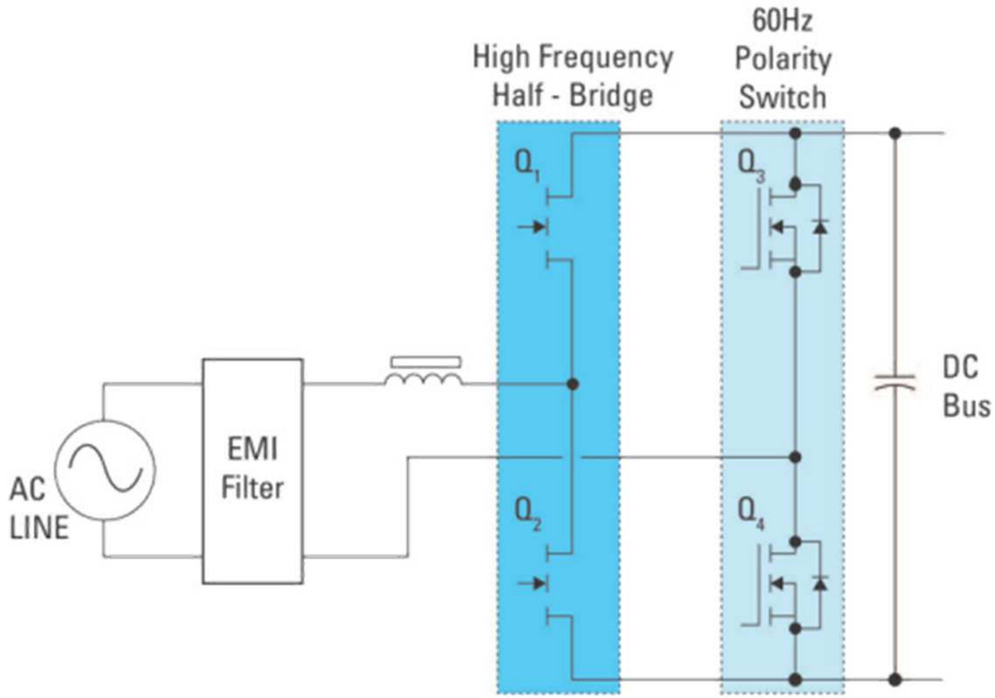
Infineon and IR

Features

- Input voltage range of 7V to 13.2V
- Output voltage range of 0.6V to 5.5V
- Output current up to 30A
- Benchmark peak and full load efficiency – no heat sink required
- Operation up to 3MHz
- Ultrafast, PowIRtune™ gate driver
- Wireless, low noise flip-chip design
- Industry-standard TTL compatible Enable and PWM inputs
- Small footprint LGA package (7.7mm x 6.5mm x 1.7mm)

Applications

- Server, Storage and Netcom POL
- General DC/DC Converters



Totem-pole bridgeless boost topology
(full-bridge, no diodes)

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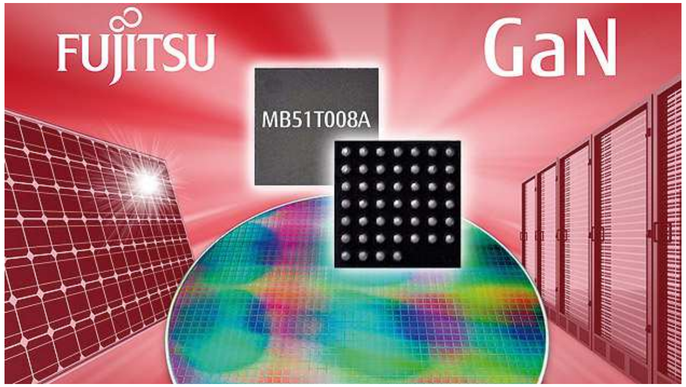
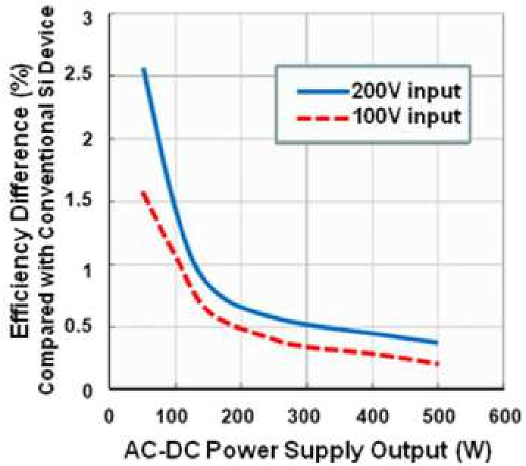
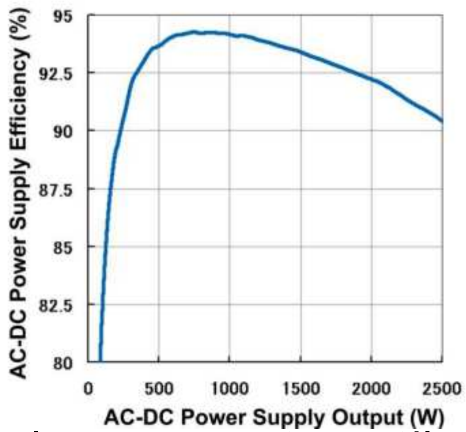
Fujitsu

Fujitsu Semiconductor Europe (FSEU) today announced that it has achieved high output power of 2.5kW in server power-supply units equipped with gallium-nitride (GaN) power devices built on a silicon substrate. Using GaN technology in power supply applications enhances power efficiency and helps reduce the carbon footprint. Compared with conventional silicon-based power devices, GaN-based power devices feature lower on-resistance and the ability to perform high-frequency operations. Since these characteristics improve the conversion efficiency of power supply units and make them more compact, this technology is ideal not just for servers but for a broad range of applications including solar inverters, battery chargers or electric vehicles. Fujitsu is planning to develop new gallium nitride-based semiconductor devices with breakdown voltages of 600 V and 30 V. Fujitsu makes these gallium nitride devices by using high electron mobility transistor technology.



150V gallium nitride-based power devices from Fujitsu for power supply design





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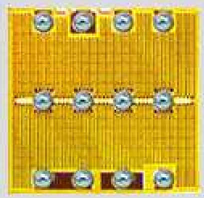
Efficient Power Conversion (EPC)

EPC is the leading provider of gallium nitride (GaN)-based power management technology and is doing more than just improving efficiency of electrical power. It is also enabling new, life-changing applications that didn't exist five years ago. From wireless power and autonomous vehicles to high-speed mobile communications, low cost satellites, and transformations in medical care, among many others, GaN is becoming the preferred technology for progressive companies that are eager to remain at the forefront of their industries.

EPC2025 - Enhancement Mode Power Transistor

V_{DS}, 300 V
$R_{DS(ON)}$, 150 mΩ
I_D, 4 A
Pulsed I_D, 20 A
RoHS 6/6,
Halogen Free



Die Size: 1.95 mm x 1.95 mm

Applications

- Ultra High Frequency DC-DC Conversion
- Medical
- Solar
- LED Lighting

Benefits

- **Higher Switching Frequency** – Lower switching losses, lower parasitic inductance, and lower drive power
- **Higher Efficiency** – Lower conduction and switching losses, zero reverse recovery losses
- **Smaller Footprint** - Higher power density

Texas Instruments

LM5113 Evaluation Board

The LM5113 evaluation board is designed to provide the design engineers with a synchronous buck converter to evaluate the LM5113, a 100V half-bridge enhancement mode Gallium Nitride (GaN) FET driver. The active clamping voltage mode controller LM5025 is used to generate the PWM signals of the buck switch and the synchronous switch. The specifications of the evaluation board are as follows:

- Input Operating Voltage: 15V to 60V
- Output Voltage: 10V
- Output Current: 10A @ 48V, 7A @ 60V
- Measured Efficiency at 48V: 93.9% @ 10A
- Frequency of Operation: 800kHz
- Line UVLO: 13.8V (Rising) /10.8V (Falling)
- Board size: 3.00 x 2.83 inches

LM5114 Evaluation Board

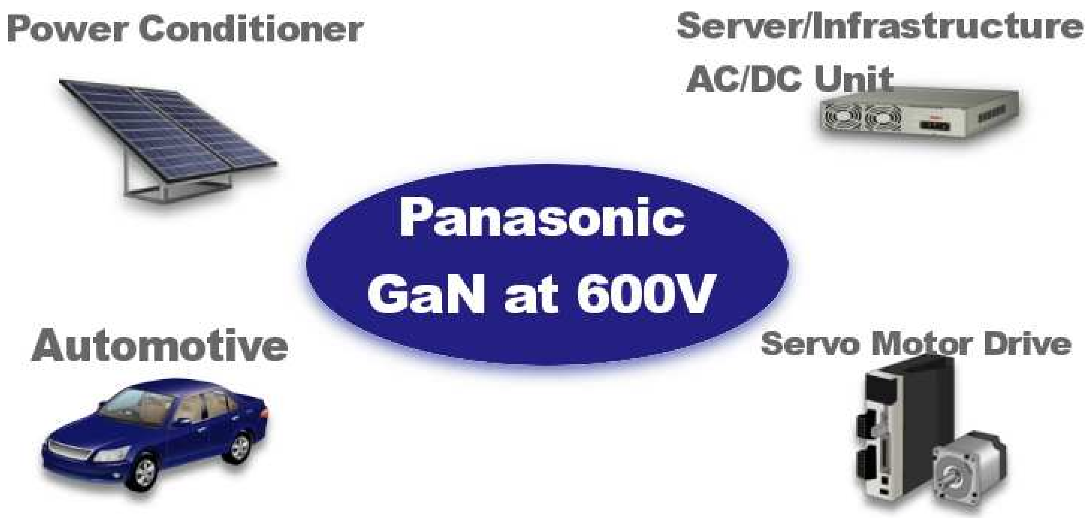
The LM5114 is a single low-side gate driver with 7.6A/1.3A peak sink/source drive current capability. It can be used to drive standard Si MOSFETs or enhancement mode GaN FETs in boost type configurations or to drive secondary synchronous FETs in isolated topologies. The LM5114 evaluation board is designed to provide the design engineer with a fully functional boost dc-dc converter to evaluate the LM5114. A 100V enhancement mode GaN FET (EPC2001) is used as the boost power switch. The control circuitry is implemented with the LM5020, a 100V current mode PWM controller.

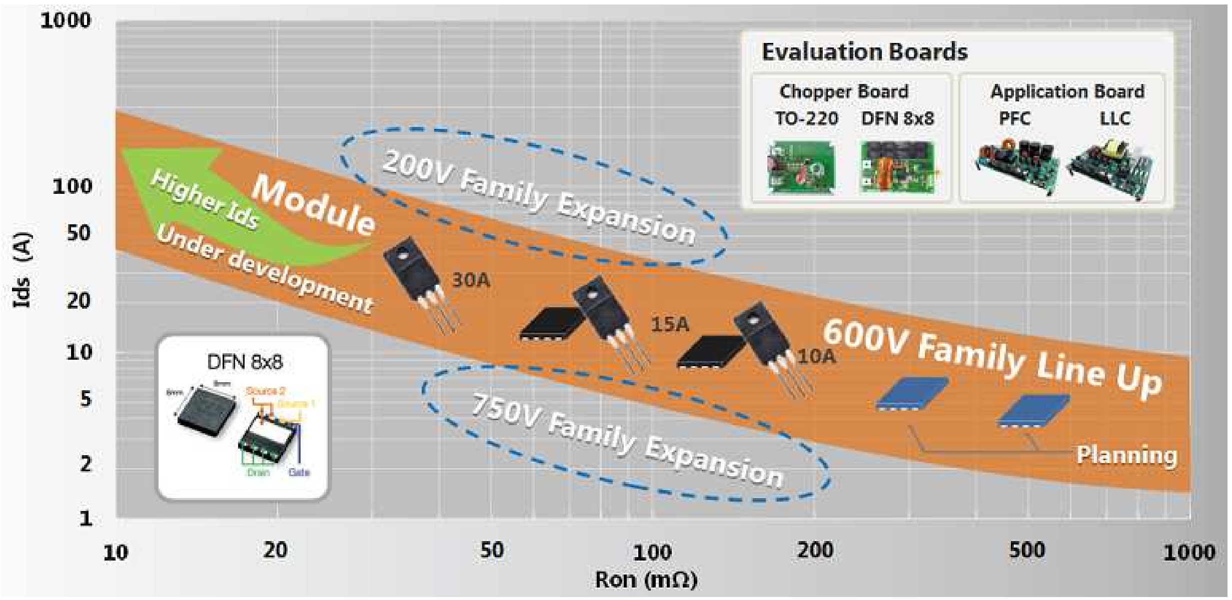
The specifications of the evaluation board are as follows:

- Input Operating Voltage: 24V to 66V
- Output Voltage: 75V
- Output Current: 2A
- Measured Efficiency at 48V: 97% @ 2A
- Frequency of Operation: 500 kHz
- Line UVLO: 23.6V (Rising) /21.6V (Falling)
- Board size: 2.99 x 3.26 inches

Panasonic

Panasonic developed GaN power devices with high efficiency, low heat generation, and small size suitable for different applications such as power supplies, HEV/EV, and PV inverter and many others.





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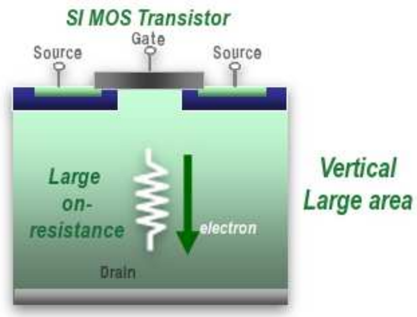
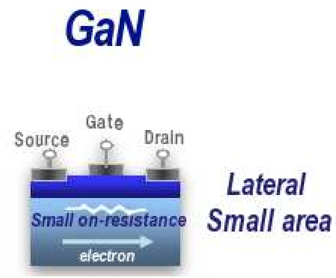
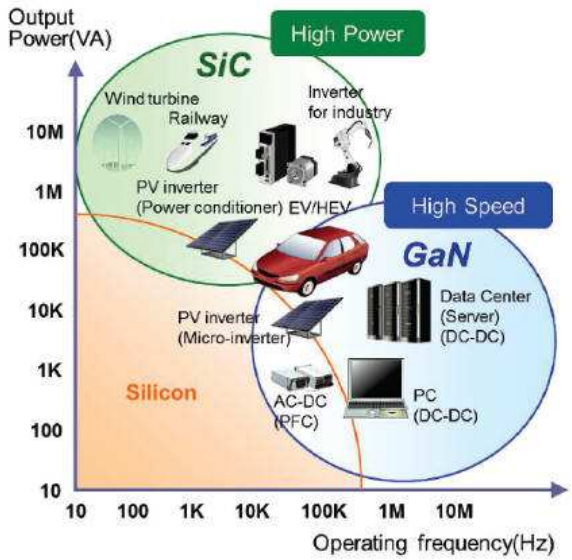
Conclusion







GaN Devices

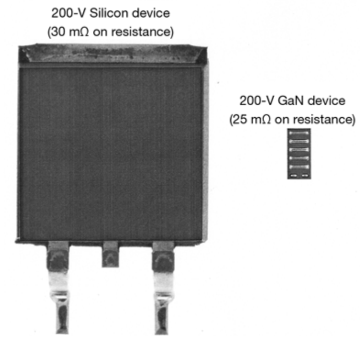
High dielectric strength

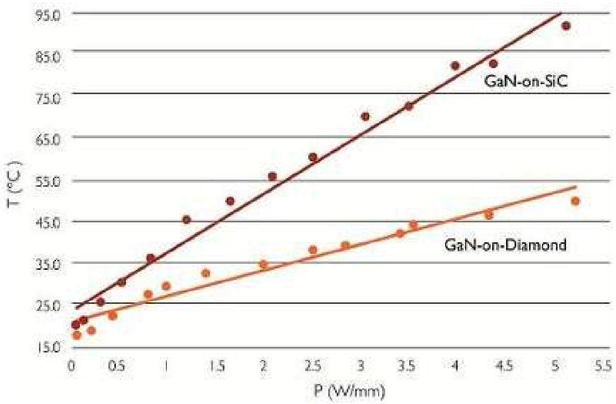
High operating temperature

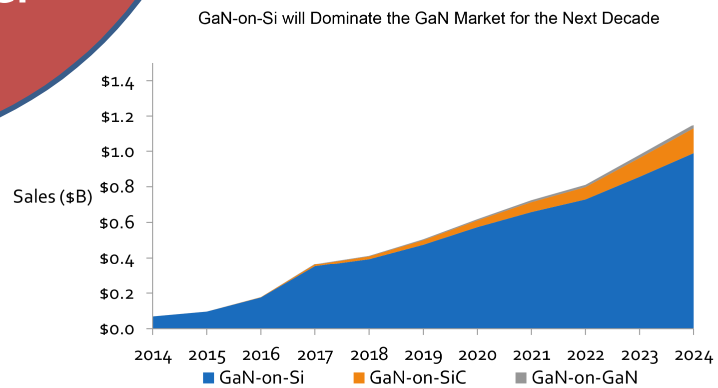
High current density

High speed switching

Low on-resistance.







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