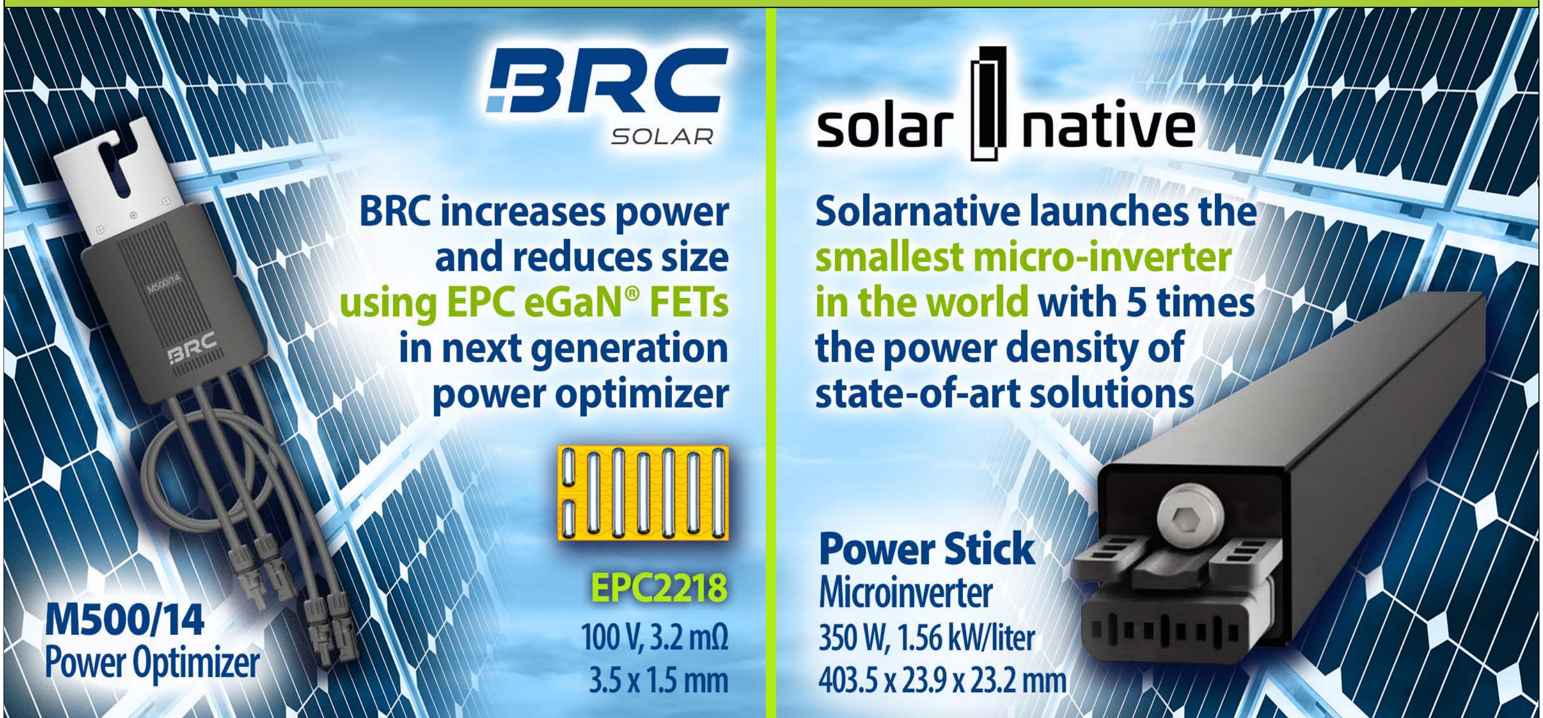
GaN FETs and ICs for Solar Power Applications

EFFICIENT POWER CONVERSION



GaN devices are being widely adopted for solar applications because they offer significant benefits for efficiency, size, weight, and long lifetime.

Solar applications need to guarantee:

- Long lifetime, greater than 20 years
- Excellent thermal behavior
- High power density to increase power in the same form factor or for integration with the panel

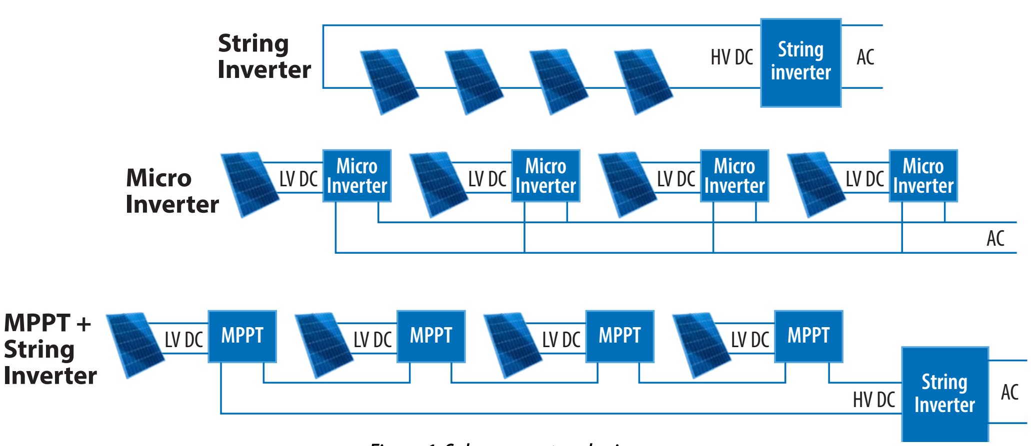


Figure 1: Solar power topologies

The trend for higher power density results in very expensive cooling systems and state-of-art silicon MOSFET solutions cannot longer meet the power density required. Therefore, the leading solar companies are adopting GaN.

GaN FETs are extremely small with very low switching losses. This allows higher switching frequency to increase power density, while still delivering higher efficiency vs. silicon MOSFET solutions to address thermal challenges and save cooling cost. The excellent reliability of GaN supports 25 years life.

EPC 100 V, 150 V, 170 V, and 200 V GaN devices are ideal for the primary stage of microinverters or separate MPPT/optimizers. EPC 200 V and 350 V devices can also be used in multilevel topology for Battery Energy Storage Systems or string inverters.

Solar Optimizer

A solar panel optimizer optimizes the power from each solar panel, no matter how the other panels are performing. It allows the system more output power from a solar panel, which means more energy and a more efficient solar system.

A typical optimizer requires 100 V switches for a single panel and 200 V or 160 V switches for dual panels. The optimizer can use different topologies. One very common choice is buck boost, as represented in figure 2. Typically, for a single panel, V_{IN} varies between 12.5 V and 60 V and V_{OUT} between 30 V and 60 V and the maximum current is ~ 20 A. A dual panel optimizer requires the double the voltage. In this hard switching topology, GaN offers the best figure of merit and lower power losses, resulting in the highest efficiency.

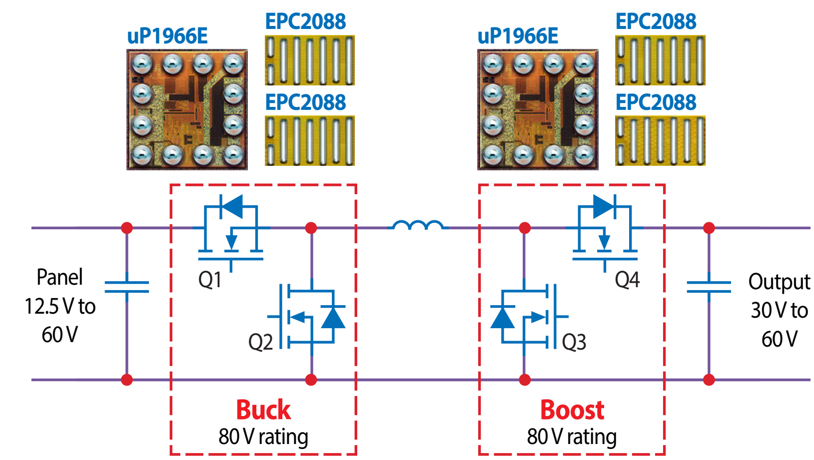


Figure 2: Optimizer single panel buck boost solution

Microinverters

A microinverter with a multilevel inverter is shown in figure 4. There are several topologies for microinverters. The most common are the flyback topology and the full bridge topology (figure 4). The primary stage requires 150 V for the flyback topology and 100 V FETs for the full bride topology, the secondary stage requires 650 V FETs. EPC 100 V and 150 V GaN FET are ideal to optimize size and efficiency.

Generally the full-bridge topology allows higher efficiency and higher power than the flyback topology. The proposed topology for maximum efficiency and smaller size is the LLC as shown in figure 3.

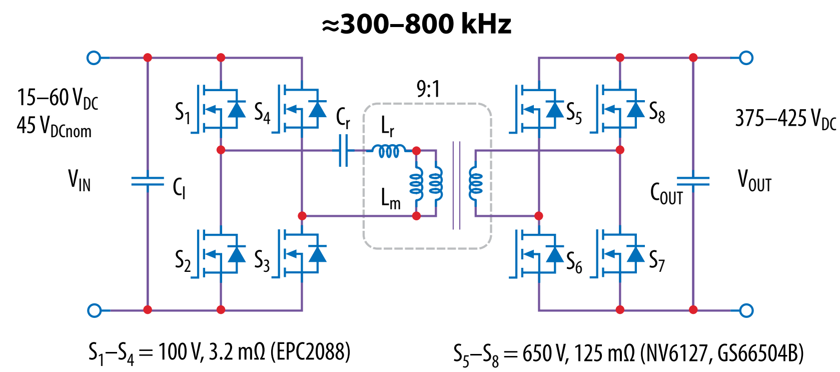


Figure 3. Microinverter LLC topology

For all solutions, GaN offers higher power density, excellent thermal performance for easier cooling or to increase power, excellent reliability and proven lifetime [1, 2]. An additional benefit is that users can take advantage of the GaN performance to increase the frequency up to 1 MHz for the highest density.

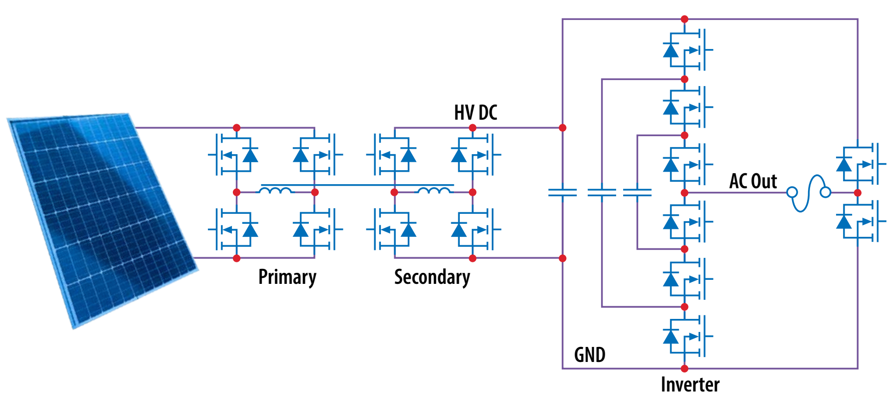


Figure 4. Micro inverter with multilevel inverter

Energy Storage System

Multilevel topology based on 200 V and 350 V GaN FETs can be used for the energy storage system. This allows use of smaller voltage devices with smaller form factor, reduces dV/dt and increases equivalent output frequency resulting in higher efficiency and density, simplifies cooling and limits stress in the components for longer lifetime.

GaN vs. Silicon

GaN transistors are very cost-effective vs. silicon MOSFETs. The chart in figure 5 demonstrates EPC's price competitiveness relative to silicon MOSFET 100 V products. GaN transistors offer smaller $R_{DS(on)}$ at lower price than silicon MOSFETs.

Additionally, as shown in figure 6, GaN transitors offer low $R_{DS(on)}$ in 1/3 of the size plus significant lower Q_G, Q_{OSS}, Q_{GD}, and 0 Q_{RR}.

Solar power systems must operate efficiently over a very wide range of conditions (i.e. duty cycles ranging from 1.2% to 98.8%). While in different application a good silicon MOSFET can be selected for a narrow range of operation trading off $R_{DS(on)}$ and Q (Q_{RR}, Q_{OSS}, and Q_{GD}), silicon MOSFET cannot be effective in the whole solar operating range.

A big value of GaN devices for solar applications is that GaN devices offer both low $R_{DS(on)}$ and low Q (Q_{RR}, Q_{OSS}, and Q_{GD}) and therefore the same device is optimized for the whole wide range of operations (duty cycle, current and voltage).

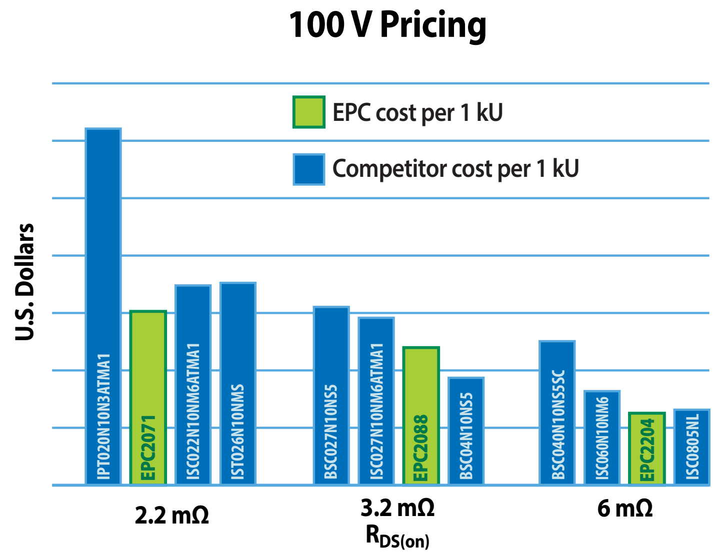
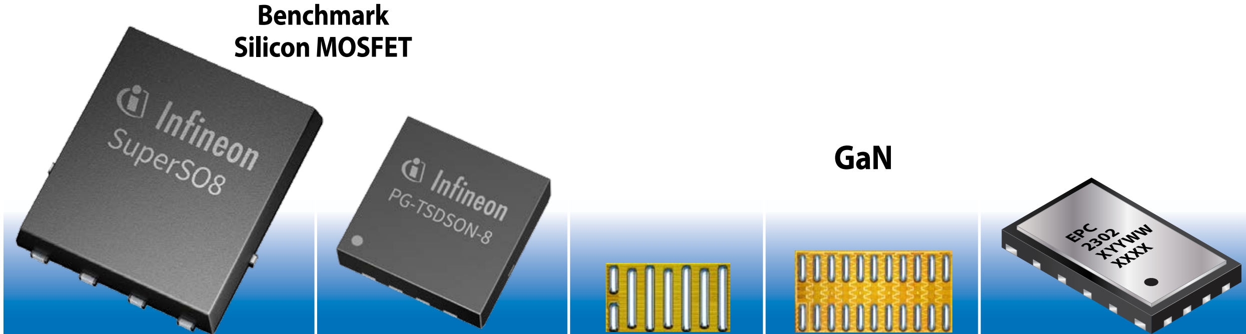


Figure 5: 100 V GaN vs. Silicon MOSFET Prices

In summary, power transistors for solar applications must have it all: Low conduction losses, low switching losses, excellent thermal behavior, and low cost. GaN transistors meet all these requirements. Figure 6 shows that GaN transistors have much lower R x Q for superior performance in 1/3 of the size. They have also been shown to be more robust than silicon and very cost effective.

Benchmark Silicon MOSFET

GaN



Parameter	BSC027N10NS5 (@ 10 V_{GS})	BSZ096N10LS5 (@ 10 V_{GS})	EPC2088 (@ 5 V_{GS})	EPC2071 (@ 5 V_{GS})	EPC2302 (@ 5 V_{GS})
$R_{DS(on)}$ max	2.7 mΩ	9.6 mΩ	3.2 mΩ	2.2 mΩ	1.8 mΩ
Q_G typ	89 nC	22 nC	11.8 nC	22 nC	18 nC
Q_{GD} typ	18 nC	4.1 nC	1.6 nC	1.9 nC	3 nC
Q_{RR} typ	89 nC	29 nC	0 nC	0 nC	0 nC
R_{TJC}	20 °C/W max	1.1 °C/W typ	0.5 °C/W max	0.3 °C/W typ	0.2 °C/W typ
Device size	31 mm^2 (6.15 x 5.15 mm)	11 mm^2 (3.3 x 3.3 mm)	7 mm^2 (2 x 3.5 mm)	10.2 mm^2 (2.3 x 4.45 mm)	15 mm^2 (3 x 5 mm)

Figure 6: 100 V GaN vs. Silicon MOSFET performance

Product Selection

The typical solution today is designed for 400 W–800 W but the market trend is to increase power above 1 kW, making GaN a far more compelling option. While EPC2204 can be used up to 400 W, EPC2088 is the ideal device for up to 800 W and EPC2071 or EPC2302 for above 800 W. EPC also offers solutions with integrated drivers, such as EPC23101 and EPC23102, for the highest density.

Part Number	Configuration	V_{DS} max	V_{GS} max	Max $R_{DS(on)}$ (mΩ) @ 5 V_{GS}	Q_G typ (nC)	Q_{GS} typ (nC)	Q_{GD} typ (nC)	Q_{OSS} typ (nC)	Q_{RR} (nC)	C_{ISS} (pF)	C_{OSS} (pF)	C_{RSS} (pF)	I_D (A)	Pulsed I_D (A)	Max T_J (°C)	Package (mm)	Development Board
EPC2252	Single–AEC-Q101	80	6	11	3.5	1	0.5	15	0	440	190	1.3	8.2	75	150	BGA 1.5 x 1.5	EPC9092
EPC2206	Single–AEC-Q101	80	6	2.2	15	4.1	3	72	0	1610	1100	15	90	390	150	LGA 6.05 x 2.3	EPC90122
UP1966E	Half Bridge Driver IC	80														BGA 1.6 x 1.6	EPC90123
EPC2204	Single	100	6	6	5.7	1.8	0.8	25	0	644	304	2.3	29	125	150	LGA 2.5 x 1.5	EPC9097
EPC2306	Single	100	6	3.8	11.0		1.1	41	0	1544	482	3.4	48	197	150	QFN 3 x 5	EPC90145
EPC2619	Single	100	6	3.3	8.3	2.1	1	27	0	1180	310	3	29	164	150	LGA 2.5 x 1.5	EPC90153
EPC2088	Single	100	6	3.2	12.5	4.4	1.4	47	0	1864	557	3.6	60	231	150	LGA 3.5 x 1.95	EPC90123
EPC2071	Single	100	6	2.2	18	6	1.8	71	0	2664	878	5.4	64	350	150	LGA 4.45 x 2.3	EPC90146
EPC2302	Single	100	6	1.8	23	8	2.3	85	0	3200	1000	7	101	408	150	QFN 3 x 5	EPC90133/ EPC90142
EPC2361	Single	100	6	1.0 (typ)	28	7.2	2.5	86	0	4094	1147	12	101	519	150	QFN 3 x 5	EPC90156
EPC2308	Single	150	6	6	11	3.8	1.3	50	0	1454	405	2.6	48	157	150	QFN 3 x 5	EPC90148
EPC2305	Single	150	6	4	21	6.3	2.6	105	0	2900	920	7	80	329	150	QFN 3 x 5	EPC90143
EPC2059	Single	170	6	9	5.7	1.3	0.9	35	0	633	267	1.6	24	102	150	LGA 2.8 x 1.4	EPC9098
EPC2207	Single	200	6	22	4.5	1.3	0.7	23	0	454	130	0.7	14	54	150	LGA 2.8 x 0.9	EPC90124
EPC2307	Single	200	6	10	10.6		1.3	58	0	1401	326	1.2	48	130	150	QFN 3 x 5	EPC90150
EPC2215	Single	200	6	8	13.6	3.3	2.1	69	0	1356	390	2	32	162	150	LGA 4.6 x 1.6	EPC9099
EPC2304	Single	200	6	5	21	0.0	2.6	115	0	2786	649	2.4	102	260	150	QFN 3 x 5	EPC90140

ePower™ Stage

Part Number	Configuration	Function	VPwr	I_{OUT}	I_{OUT} Peak	V_{DD}	Input Logic	F (Max)	UVLO	Package (mm)	Development Board
EPC23101	HS FET + Driver + Level Shift	ePower™ Stage	100	65	240	6	5.5 V	3 MHz	0.5–4	QFN 3.5 x 5	EPC90142
EPC23102	HS FET + Driver + Level Shift	ePower™ Stage	100	35	140	6	5.5 V	3 MHz	0.5–4	QFN 3.5 x 5	EPC90147
EPC23103	HS FET + Driver + Level Shift	ePower™ Stage	100	25	61	6	3.3 V or 5 V	3 MHz		QFN 3.5 x 5	EPC90151
EPC23104	HS FET + Driver + Level Shift	ePower™ Stage	100	15	44	6	3.3 V or 5 V	3 MHz		QFN 3.5 x 5	EPC90152

Summary

Compared with silicon MOSFETs and PMICs, GaN is smaller, more efficient and able to switch at a higher frequency, lower cost, and with increased reliability.

The key advantages that GaN brings to the table is the excellent thermal performance and improved efficiency. GaN devices enable a substantial size reduction and easier cooling to avoid heat sink and complex cooling. The ultra-small $R_{DS(on)}$, Q_G, Q_{GD}, Q_{OSS} parameters, and zero Q_{RR} allow higher efficiency, especially for hard switching topologies. Additionally, with GaN devices the switching frequency, typically 125 kHz for silicon MOSFETs, can be increased to 400 KHz–1 MHz to shrink the size of the passive components, reducing the size and weight of the total solution and for thin design for integration into panels. Excellent thermal performance and low power losses can be leveraged to increase power levels and power density. Efficiencies around 98%, 3% higher than silicon MOSFET solutions, can be achieved with GaN. Finally, solar solutions need to be able to guarantee more than 20 years of life, and the excellent GaN reliability of GaN and high fault tolerance for overvoltage and overcurrent help to meet this requirement.

For more information on reliability, download reports: Reliability Report Phase 12 [1] and Reliability Report Phase 14 [2].

References

[1] **Reliability Report Phase 12** (https://epc-co.com/epc/Portals/0/epc/documents/product-training/Reliability%20Report%20Phase%2012.pdf)
[2] **Reliability Report Phase 14** (https://epc-co.com/epc/Portals/0/epc/documents/product-training/Reliability%20Report%20Phase%2014.pdf)