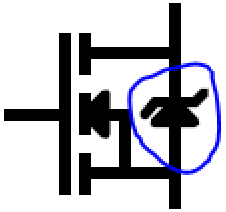
硅材料MOSFET/ Cool Mos



MOSFET发热源:

1,Rds(on)损耗,

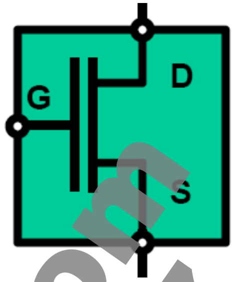
2, 开关损耗,

3,体内二极管反向续流损耗,

4,死区损耗.

氮化镓材料MOSFET -HEMT

氮化镓无体内二极管
但有二极管特性

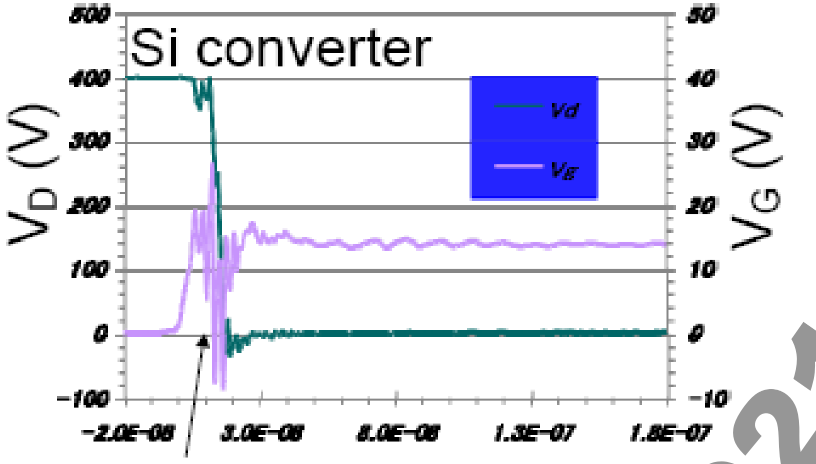


氮化镓MOS发热源:

1,Rds(on)损耗

几乎没有开关损耗和反向续流二极管损耗.因体内没有二极管,但有二极管的特性

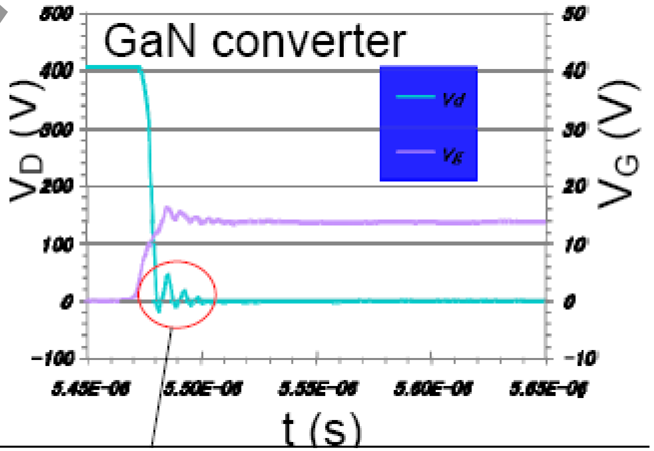
超低的结电容保证较小的死区损耗.

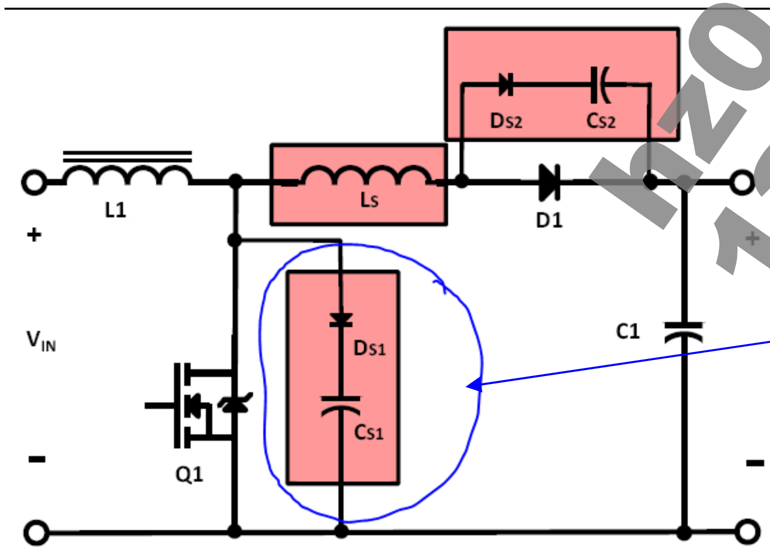


硅 VS 氮化镓

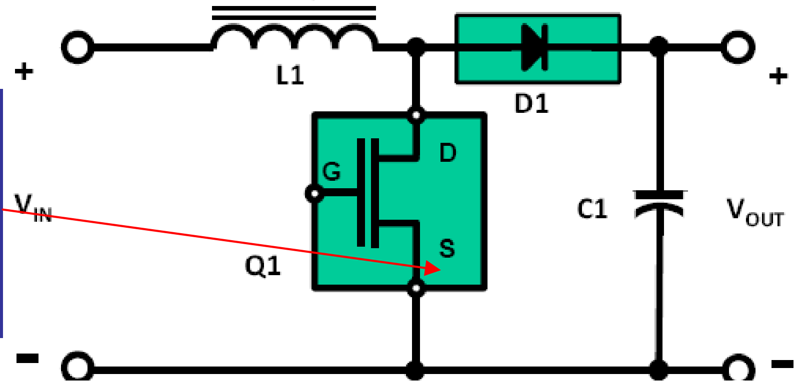
开关损耗

氮化镓明显开关损耗很小





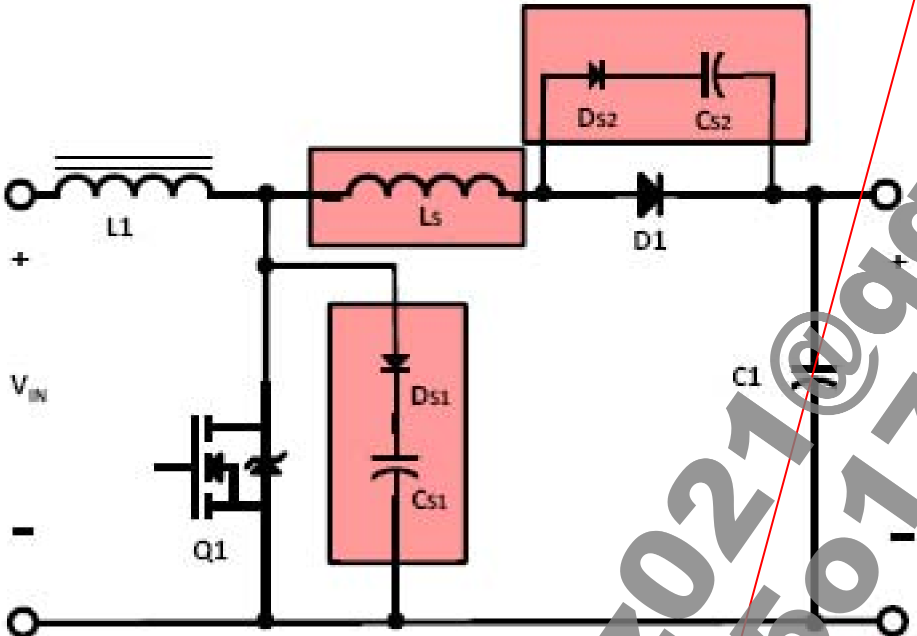
氮化镓无需吸收电路



NIEC EZ-GaN™ 让电路更简化

更换下**MOS**及二极管成氮化镓**MOS**及氮化镓二极管.效率会直接提高**1**个点以上.

用硅半导体做成的升压电路

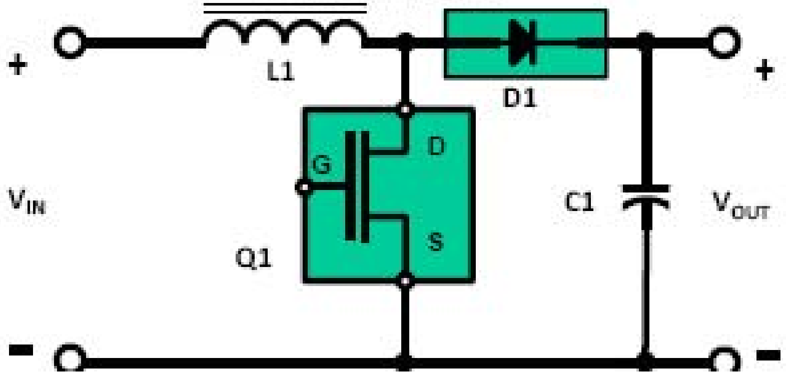


传统的正常**96-97.5%**效率

PFC 应用电路实例

- V in = 220v dc
- V out = 400v dc
- Frequency = 100kHz, 400w
- Uses TPS2012PK; lowest loss 600v/6A GaN diode
- Boost converter efficiency = 99.2%

用氮化镓做的二极管和MOSFET做成的升压电路可做到效率达99%以上.且器件减少.省去高压电容和高压超快恢复二有管.综合成本反下降.



高频率设计小功能PFC电睡

面积只是原来1/3,总成本下降.光是单MOS成本上涨. 提高效率而减小体积

750K以内,电感材料不变,一样的低价格.

62. 5 kHz

- 需二级EMI滤波电路
- 需较大的电感器件

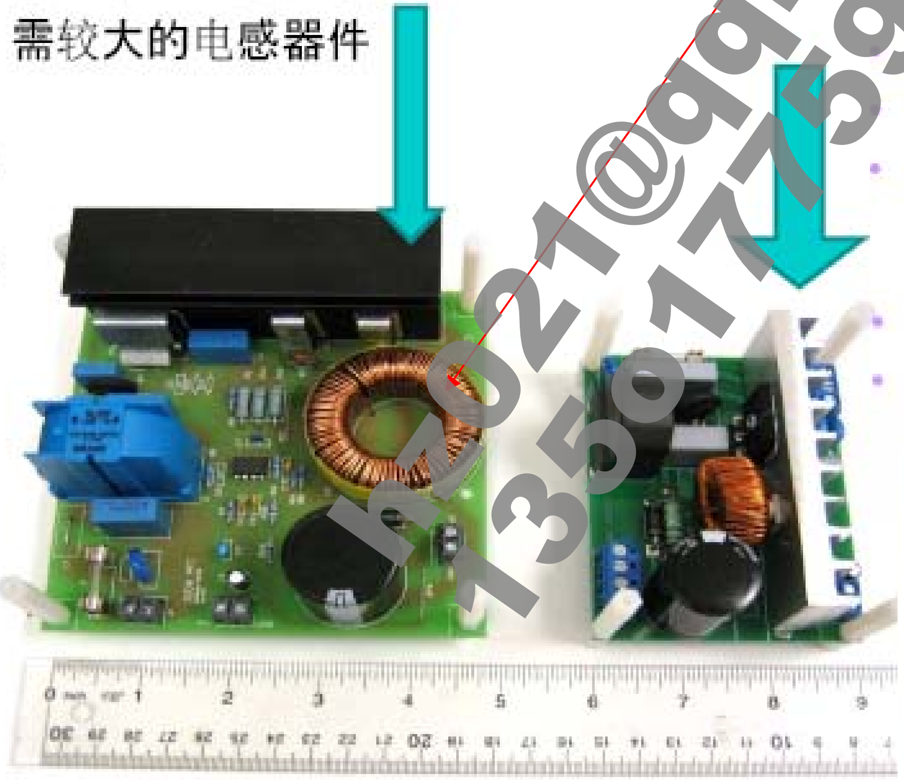
750 kHz

- 非常小的尺寸 (同样大的功率)
- 只需一个小电感,同等磁芯材料
- 可省去一级EMI滤波电路,由于GaN几乎不产生尖峰与振荡.EMI要低10db
- 以上通过改且GaN器件即可实现.
- 总体成本优势明显

左边板子
来自于
INFIENON 400W

Infinoen官方demo板

CoolMos+
SiC二极管



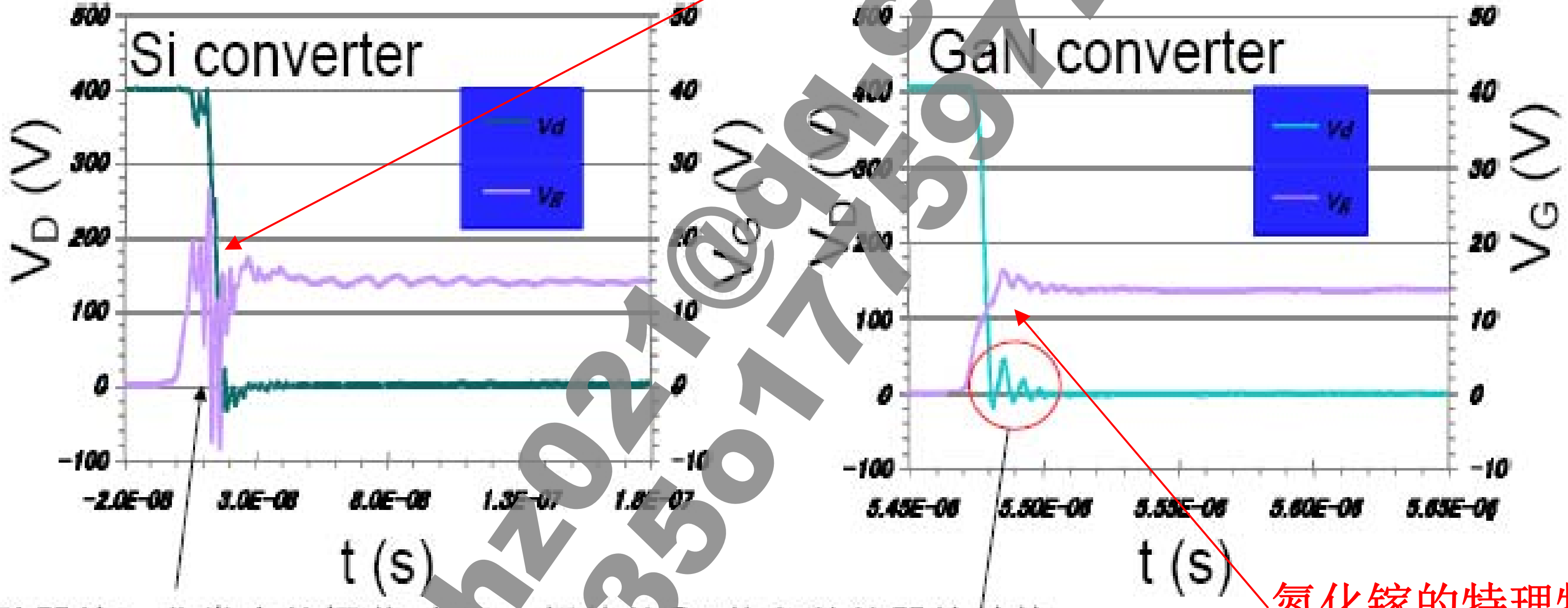
Left hand demo board
Source: Infineon

tr

开关波形比较 Si / GaN

硅材料的MOS/CoolMos决定了开关的的波形/即损耗.开关损耗很大,轻载时会超过Rds(on)损耗

硅器件：Coolmos，385mΩ + 超快恢复二极管，10A 温度为 Tc=25°C
氮化镓器件：GaN HEMT（MOSFET），310mΩ + 氮化镓二极管 TPD2012，2A 温度为 Tc=125°C
R_G=0Ω，f=100kHz，V_{IN}=220V，V_{OUT}=400V，P_{OUT}=760W，

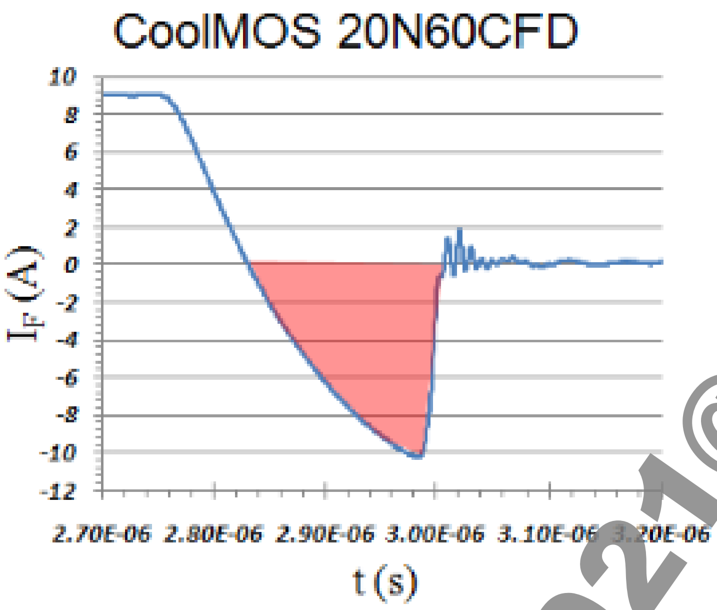


氮化镓的特理特性决定了开关损耗很小很小.也决定了**EMI**很好

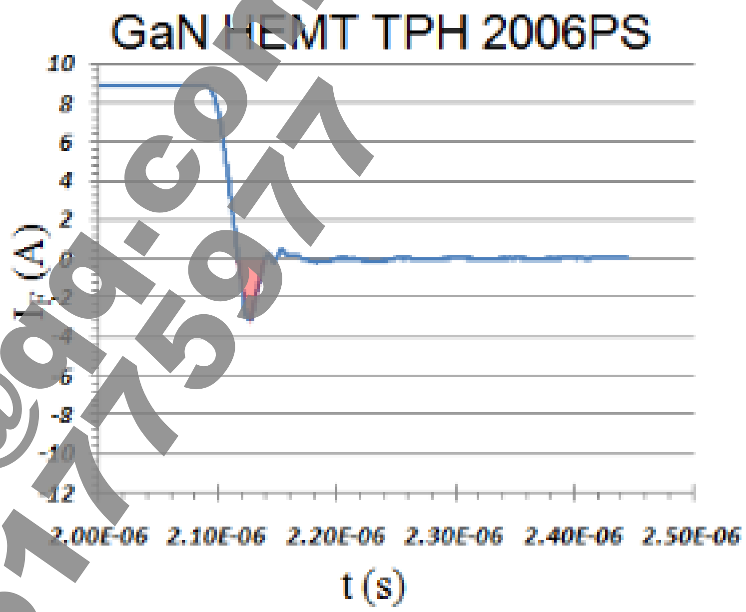
硅器件：　非常大的振荡,由于二极管的Qrr值和差的器件结构.
如改成慢驱动会减少振荡,但会增加器件的损耗.

氮化镓器件：　很干净的波形无振荡即使在高频时.
由于无振荡,所以不会产生EMI和损耗.

GaN HEMT’s Qrr值只有COOLMOS的1/25.



Qrr=1000nC at 9A, 400V



Qrr=40nC at 9A, 400V

- 均应用测试于同一板子上
- NIEC GaN只有很小的振荡
- GaN HEMT拥有比COOLMOS(已是低Qrr的设计)小25倍的Qrr值

NIEC GaN HEMT产品

Trnasphorm的氮化镓与Coolmos对比.

	TPH2002PS	IPP60R385CP	TPH2006PS	IPP60R199CP	TPH2005WS	IPW60R099CP
Package	TO-220	TO-220	TO-220	TO-220	EXT. TO-247	TO-247
V_{DSS}	600V	600V	600V	600V	600V	600V
$R_{DS(on)}$ Max	0.31 ohm	0.385 ohm	0.18 ohm	0.199 ohm	0.090 ohm	0.099 ohm
$I_{D100°C}$	8.5A	5.7A	13.8A	10A	25A	19A
CO(er)	25 pF	36 pF	37 pF	69 pF	72 pF	130 pF
$C_{O(tr)}$	45 PF	96 pF	71 pF	180 pF	142 pF	340 pF
Q_g	6.2nC	17 nC	6.2 nC	32 nC	6.2 nC	60nC
t_{rr}	12 ns	260 ns	24 ns	340 ns	35 ns	450 ns
Q_{rr}	13 nC	3.1 uC	40 nC	5.5 uC	80 nC	12 uC

氮化镓与COOLMOS比较.

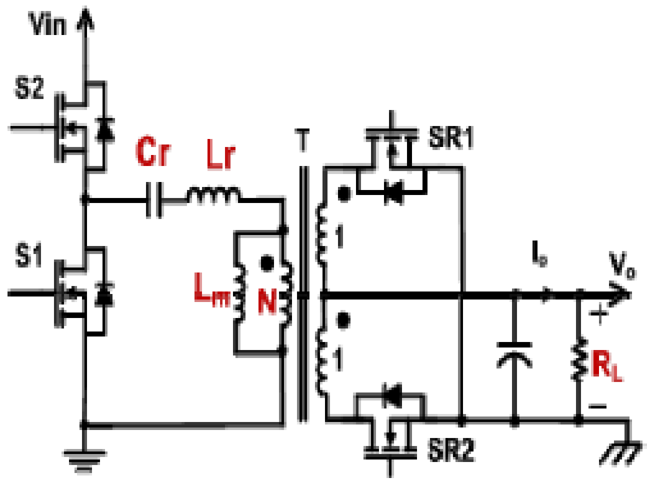
Comparison Between GaN and State-of-Art Si

	Parameters	IPA60R160C6	TPH3006PS
Static	V_{DS}	650V	600V
	R_{DS} (25 C)	0.14/0.16 ohm	0.15/0.18 ohm
	Qg	75 nC	6.2 nC
Dynamic	$C_{o(er)}$	66 pF [1]	56 pF [1]
	$C_{o(tr)}$	314 pF [1]	110 pF [1]
Reverse Operation	Qrr	8200 nC [2]	54 nC [3]
	trr	460 ns [2]	30 nC [3]

[1] V_{GS} = 0V, V_{DS} = 0 – 480V
[2] V_{DS} = 400V, I_{DS} = 11.3A, di/dt = 100A/µs
[3] V_{DS} = 480V, I_{DS} = 9A, di/dt = 450A/µs

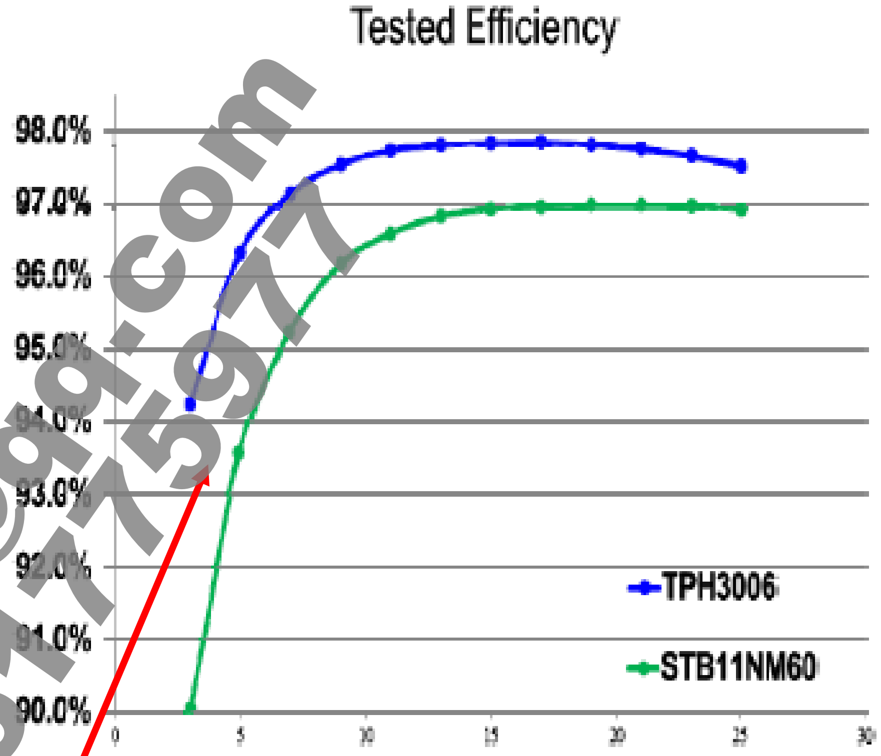
- Smaller driving loss
- Smaller switching loss
- Smaller reverse recovery loss

LLC DC converter’s improved performance with GaN at 500 kHz



Parameters	Value	Parameter	Value
Vin(V)	400	Vo(V)/Io_{max}(A)	12/25
Lm(uH)	100	Lr(uH)	5.05
Cr(nF)	15	Fr(kHz)	530
Td(ns)	120	Fs(kHz)	470

Courtesy: Work done by CPES at Virginia Tech.



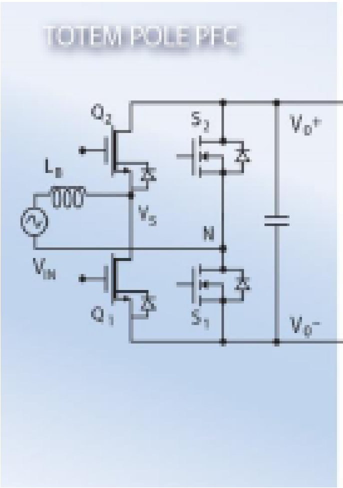
- 500kHz for compact power supply design.
- Peak efficiency gain by GaN is ~ 1%.
- Low-load efficiency gain (2-3%)

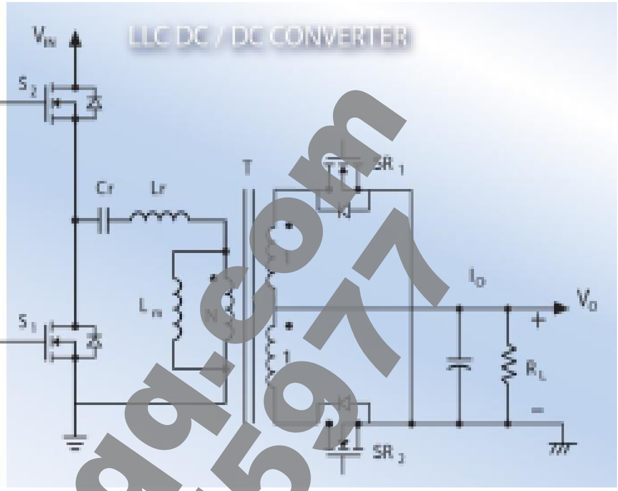
LLC电路上 氮化镓板子与**COOLMOS**的效率对比

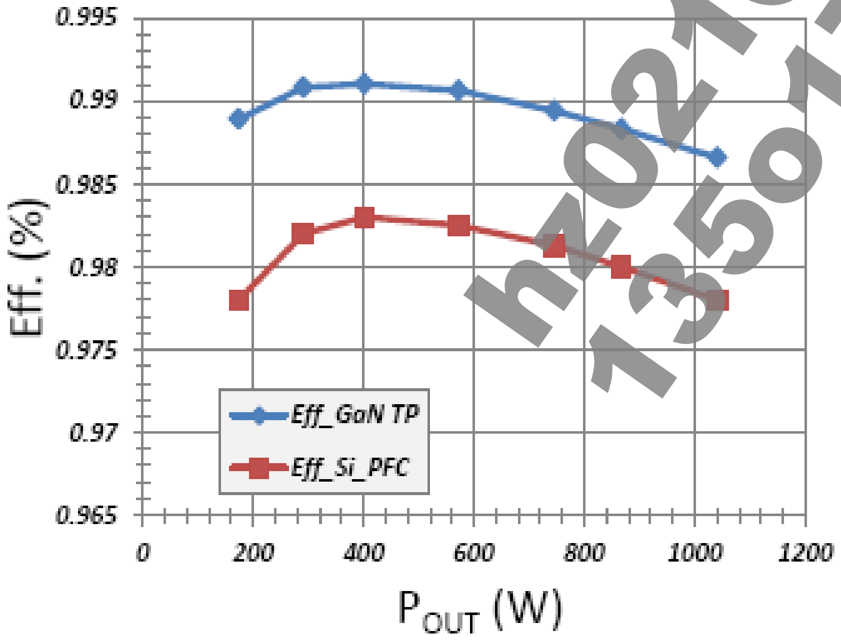
由于氮化镓主要是由**Rds(ON)**损耗,所以当轻载时,损耗最小. 但**Coolmos**损耗还包含开关损耗,体内续流二极管的损耗,及**COOLMOS**的吸收电路的损耗.效率相对较低

High Efficiency GaN Power Supply From AC-DC Up To 97.5%

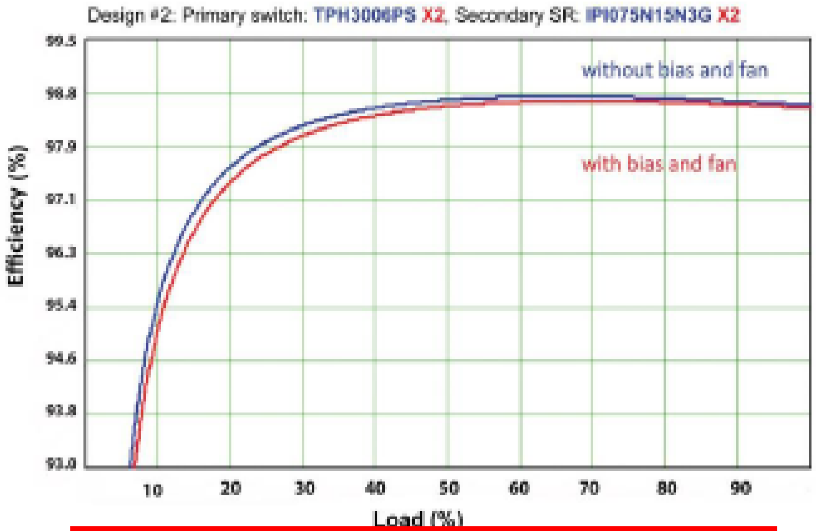
采用氮化镓的无桥PFC及LLC电路,可以做到一个电源从AC到DC效率达到97.5%







LLC converter achieves 98.6% efficiency using TPH3006PS on the primary



1 kW LLC, 400 V dc to 48 V dc, 200 kHz

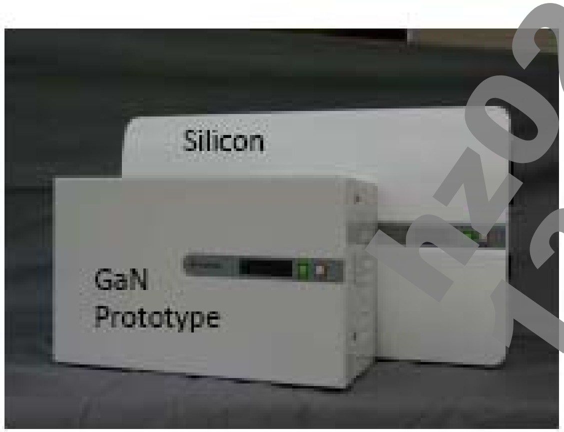
PV converter GaN prototype

- Output power 4.5kw (Single Phase 200V)
- Input voltage 60-400V
- Maximum Power Efficiency > 98% (vs. >96.5% with Silicon)
- Volume about 10L <18L (existing Silicon based)

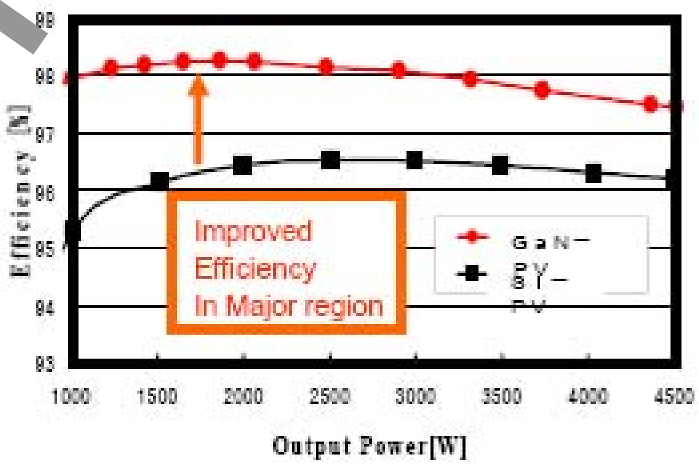
同样大的逆变器产品,氮化镓的体积减小了一半左右,同时整体成本下降**100USD**,售价反提高了**100USD.** 效率反提高了**1.5**个点. **4500W,** 频率从**16K**提到到**50K**

散热器,风散,驱动电路,电感,**EMC**电路可大大减小体积,还有填充物

40% volume reduction

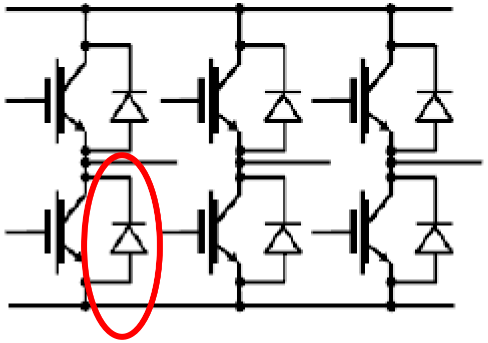


Significant loss reduction



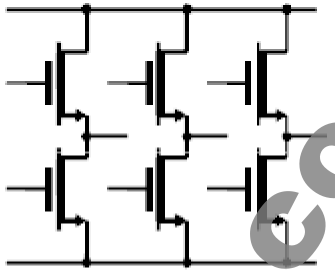
Improved Efficiency In Major region

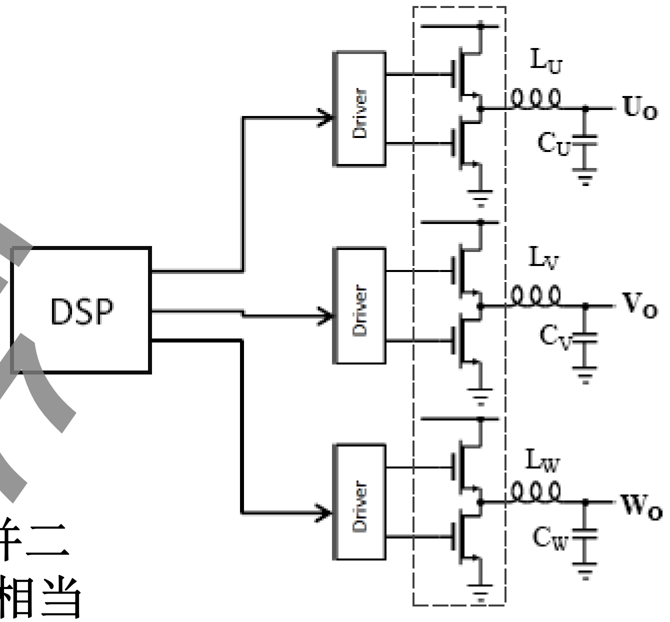
IGBT 3-phase Bridge



有时**IGBT**为了提高效率
还要并一个快速的二极管.

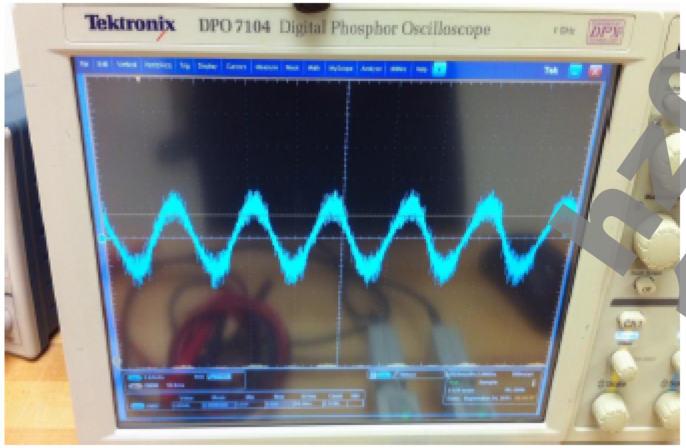
GaN HEMT 3-phase Bridge



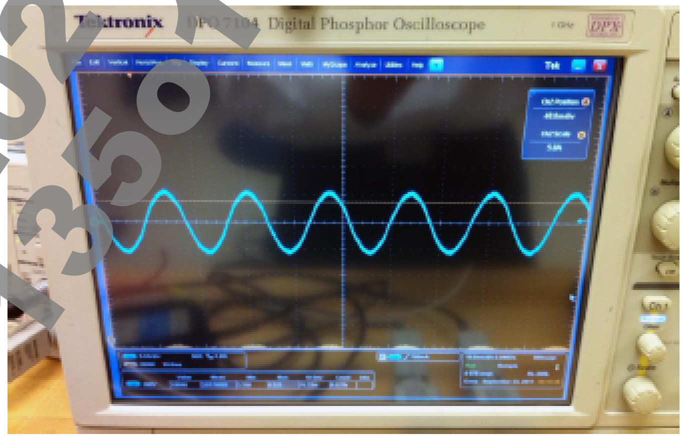


采用氮化镓,无需并二极管,可直接使用.相当于0恢复

IGBT Inverter: PWM Power



GaN Inverter: Sine-wave Power



采用**GaN**的好处:

1,提高了逆变效率
2,输出波形**TH**明显改进很多.
3,TH的改进对输出负载的应用要求降低
4,有助于对逆变的负载/或应用部分的效率提高