集微公开课

Navitas

Let's go GaNFast™

纳微氮化镓芯片集成及应用

[Navitas GaN Power IC Integration and Application]

19 May 2020

Navitas AE Team　Michael Xu

集微公开课 第十三期

打造优质在线培训课程

纳微氮化镓功率芯片集成及应用

直播时间

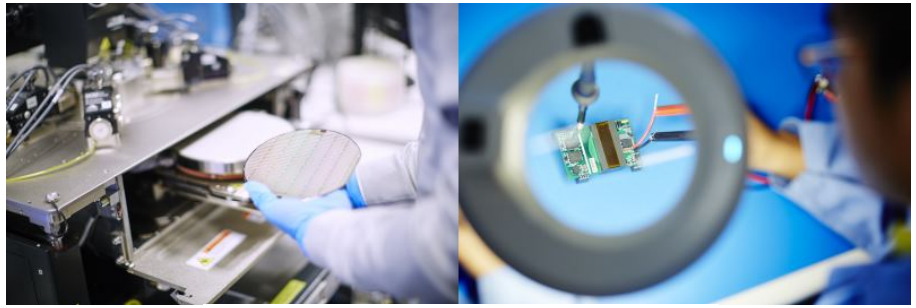
5月19日 10:00

本期讲师

徐迎春 纳微半导体中国区应用中心高级总监

纳微半导体

- 全世界首家氮化镓功率芯片
  - 获JEDEC认证
  - 量产并快速增量
- Navitas: 拉丁文即“能量”
  - 为电力电子行业注入新能量
- 2014年成立
  - 总部：美国加州洛杉矶El Segundo
- 世界级管理团队
  - 70多位雇员
- 世界级制造商合作伙伴
  - 晶圆厂:台积电(TSMC)
  - 封装厂:安靠(Amkor)
- 强大的投资人团队
  - 管理资本超过10亿美金



navitas

noun | en·er·gy

tsmc

Amkor Technology®

CAPRICORN INVESTMENTGROUP

ATLANTIC BRIDGE

https://www.navitassemi.com/products/

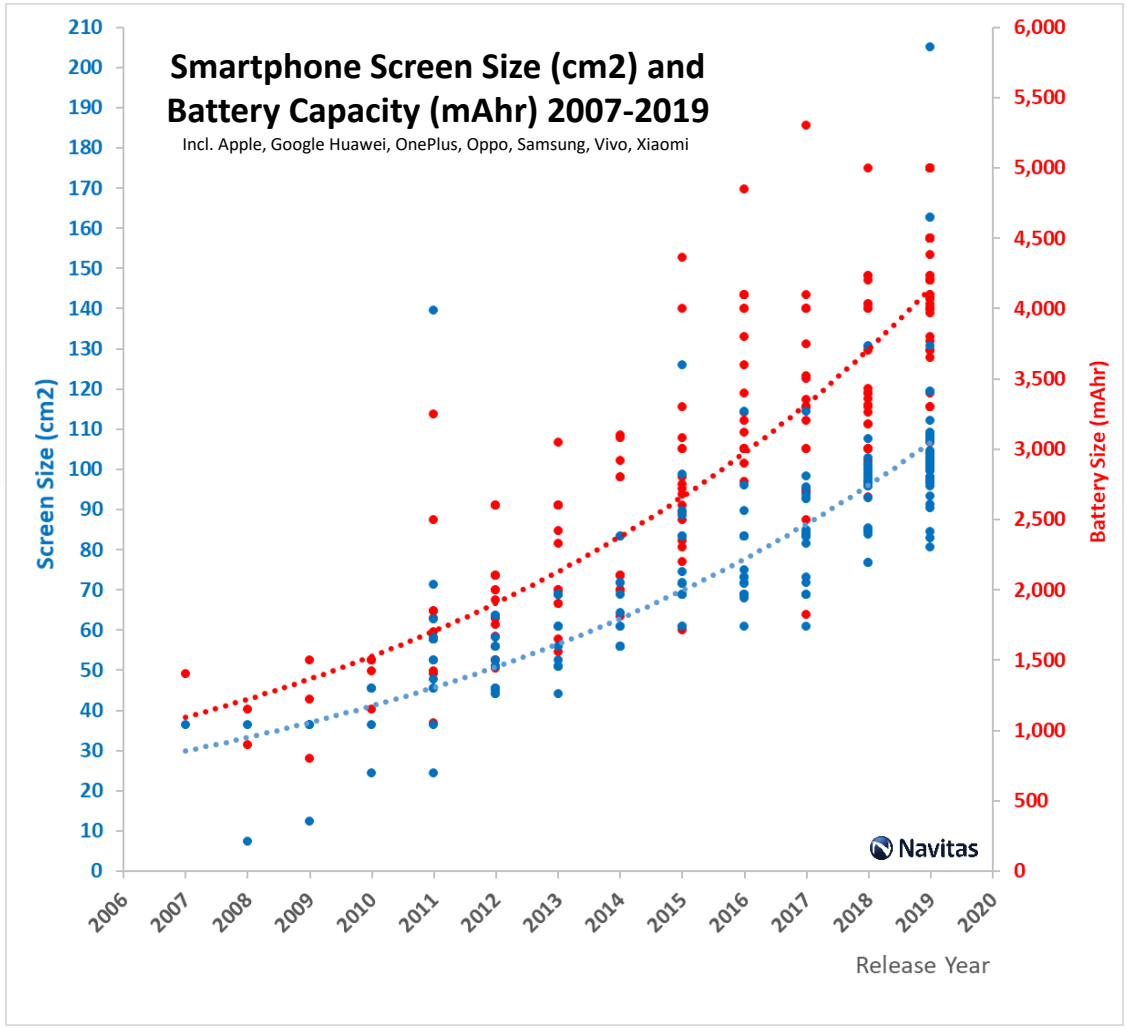
目录

背景: More Screen, More Battery…

2007
Apple
iPhone 1
36.5 cm^2
1,400 mAhr

2013
Samsung
Galaxy S4
68.9 cm^2
2,600 mAhr

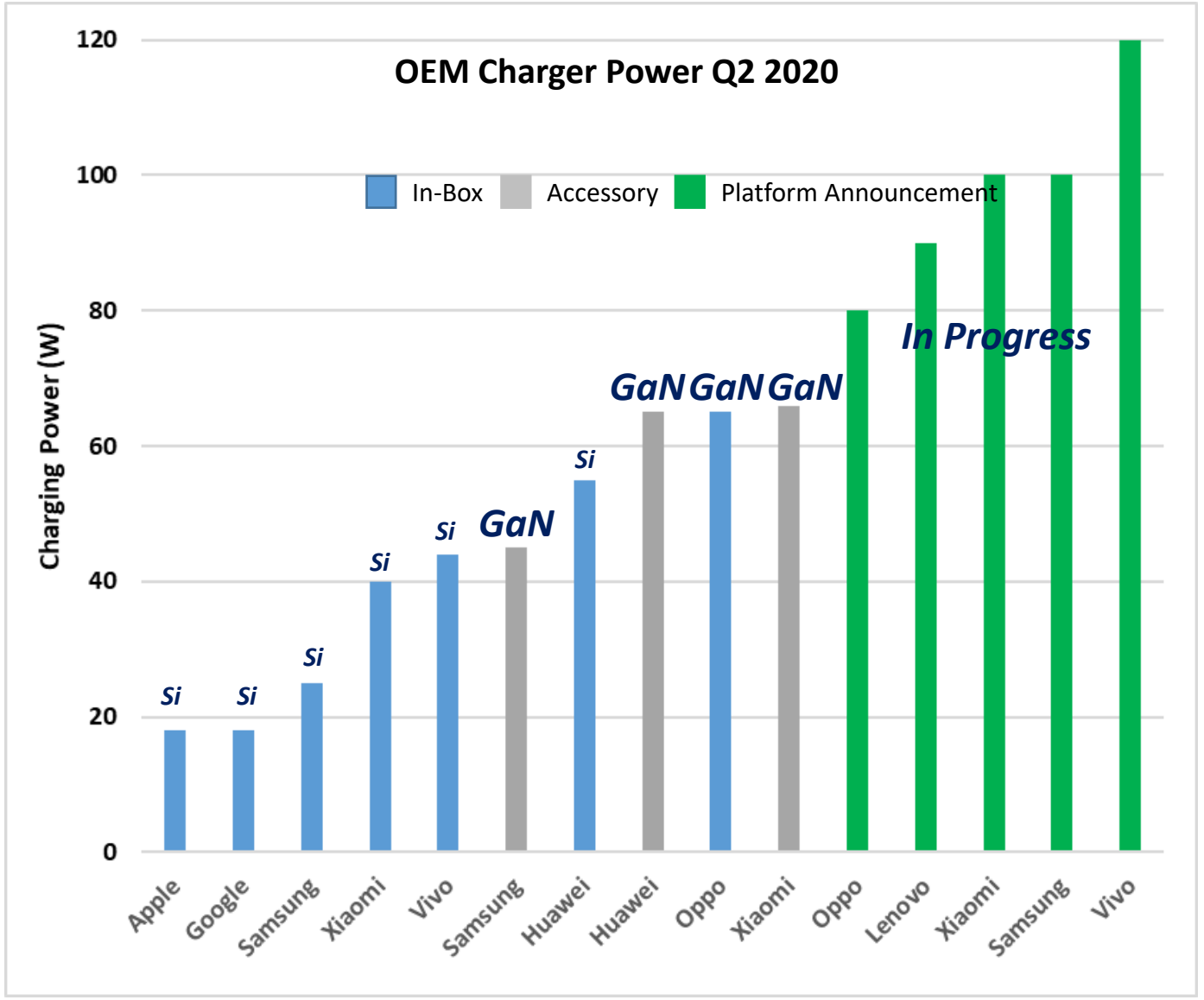
2019
Huawei
Mate X
205 cm^2
4,500 mAhr



Images to scale
Source: gsmarena.com, Navitas

背景：More Power, Faster Charge

Vivo's Super FlashCharge 120W technology, claims 100% charge of a 4,000 mAhr phone battery in just 13 minutes.



Source: Navitas

GaN价值：高功率密度

GaNFast™

Apple Si 18W
42 x 41 x 27 mm
= 47 cc, 60 g
(fixed AC pins)

AUKEY
key **GaN 27W**
36 x 36 x 32 mm
= 41.5 cc, 45 g

70% more Power for Size
(1.7x W/cc)

Apple Si 61W
73 x 73 x 28 mm
= 149 cc, 193 g

EGGTRONIC
Eggtronic GaN 65W
68 x 50 x 19 mm
= 65 cc, 90 g

140% more Power for Size
(2.4x W/cc)

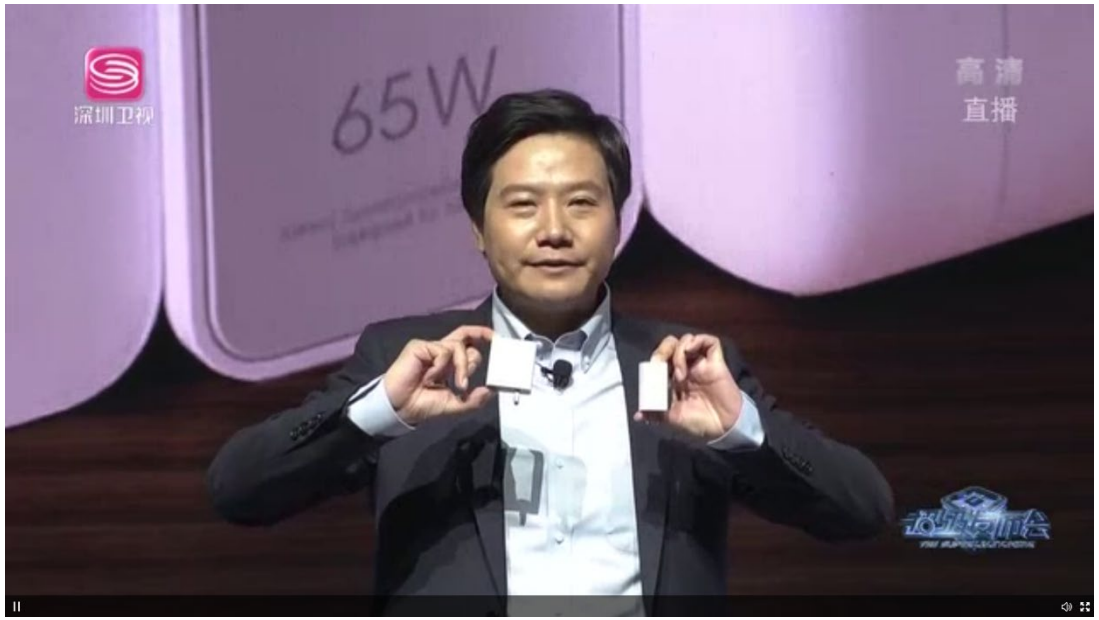
Images to scale

商用案例：Xiaomi Goes GaNFast™

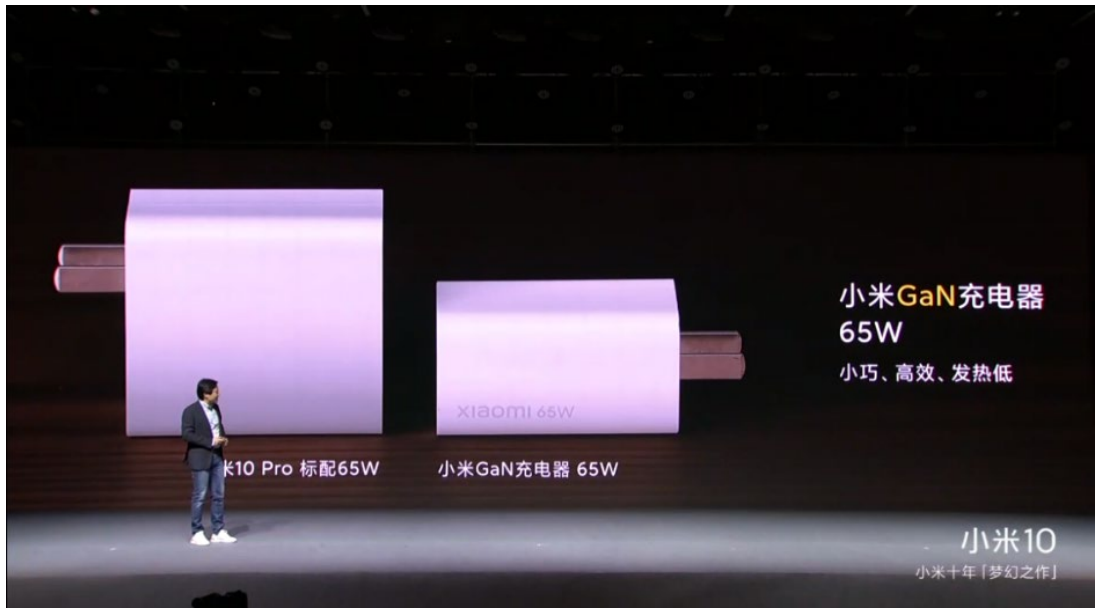
小米 xiaomi.com

65W-1C
53cc

Mi 10, 10 Pro

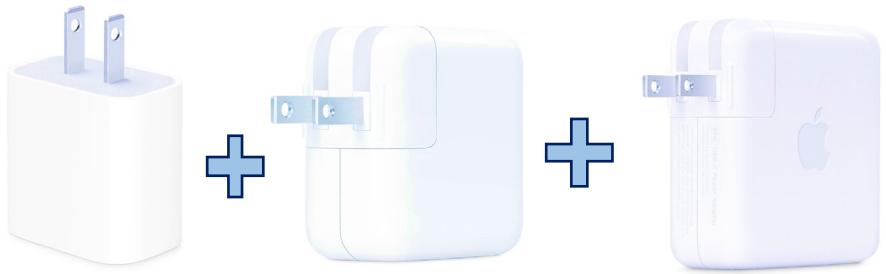


Xiaomi CEO: "How tiny is this GaN charger?"



Xiaomi CEO: "This GaN charger is extremely small & efficient?"

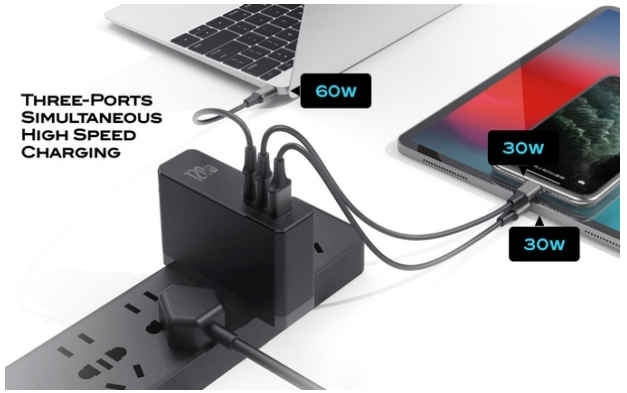
商用：全世界最小的充电器



Apple Si 18W　　Apple Si 30W　　Apple Si 61W

USB-C #1 up to 65W
USB-C #2 up to 30W
USB-A up to 30W

Baseus **GaN** 65W　1/3size



HyperJuice 100W:
2C+2A,
C1, C2: A1, A2:
150 cc
World's smallest 100W 4-output

Baseus120W: 2C+A
USB-C1, -C2 , A
154 cc
World's smallest 120W 3-output

AUKEY Omnia 100W 1C, 2C
（104cc，112cc）

World's smallest 100W

World's Fastest Laptop:
Asus ProArt StudioBook One
NVIDIA Quadro RTXTM 6000

World's Smallest 300W Adapter

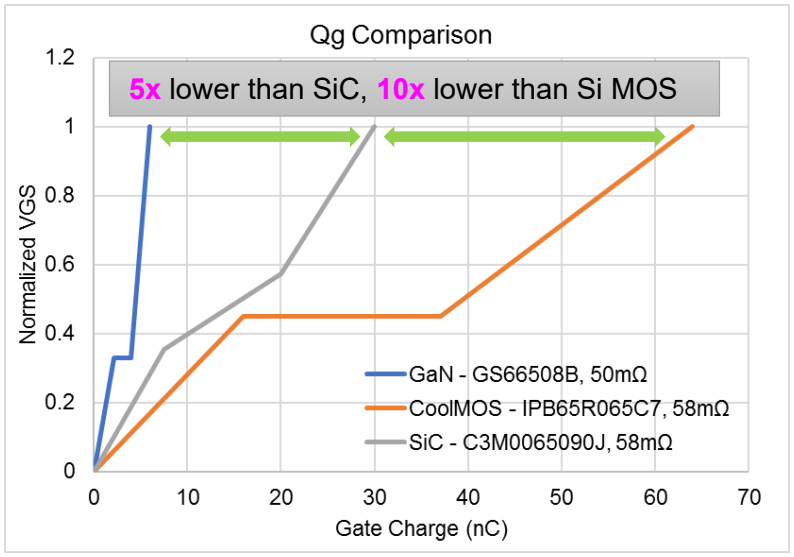
Images to scale

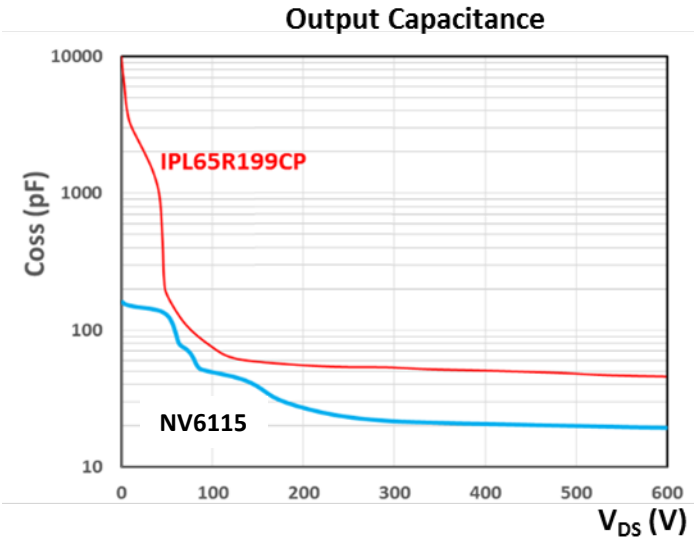
目录

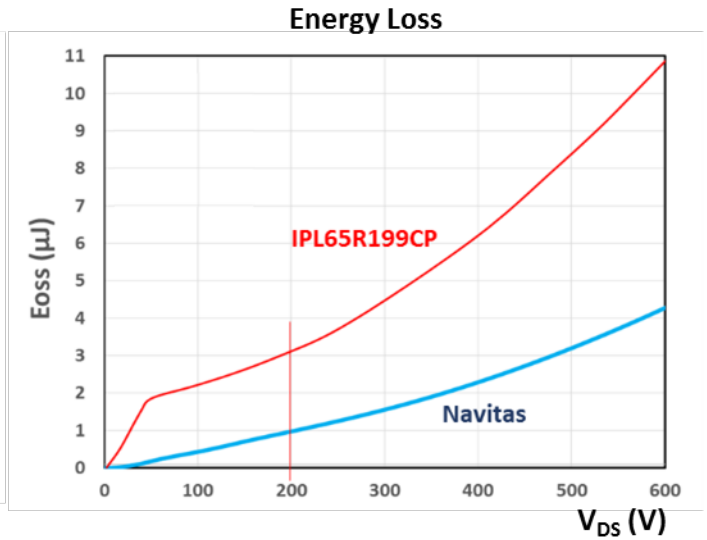
- 氮化镓的技术价值与商用案例
- **氮化镓和传统MOSFET的不同**
- Navitas集成驱动IC简介
- 氮化镓对开关电源性能的提升
- 氮化镓高频开关电源设计注意事项

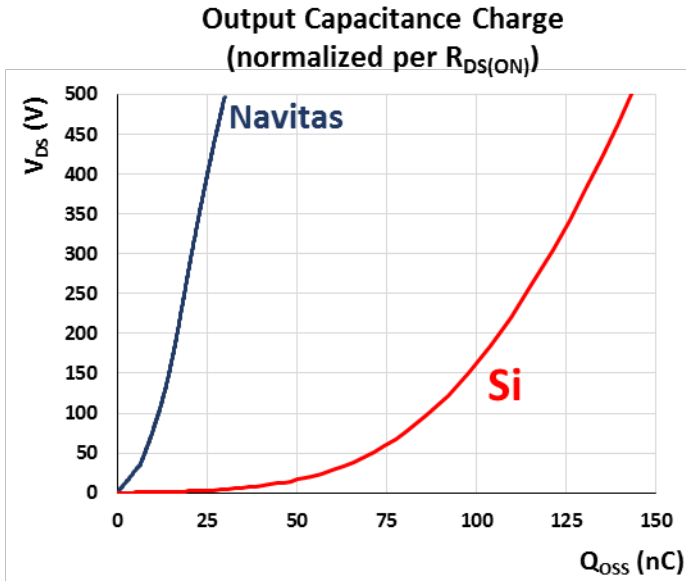
E-Mode GaN的优势

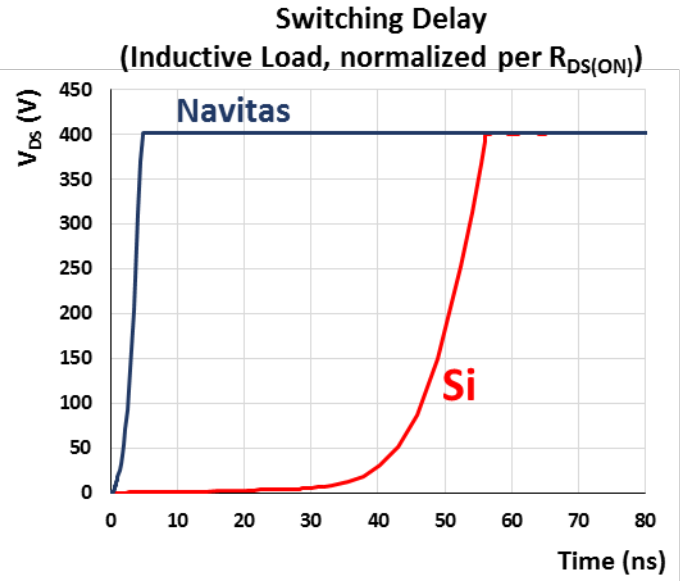
- 低 Rdson
- 没有反向恢复损耗
- Q_g 低，驱动损耗低
- C_{OSS} 小，容性损耗低
- 开关速度快



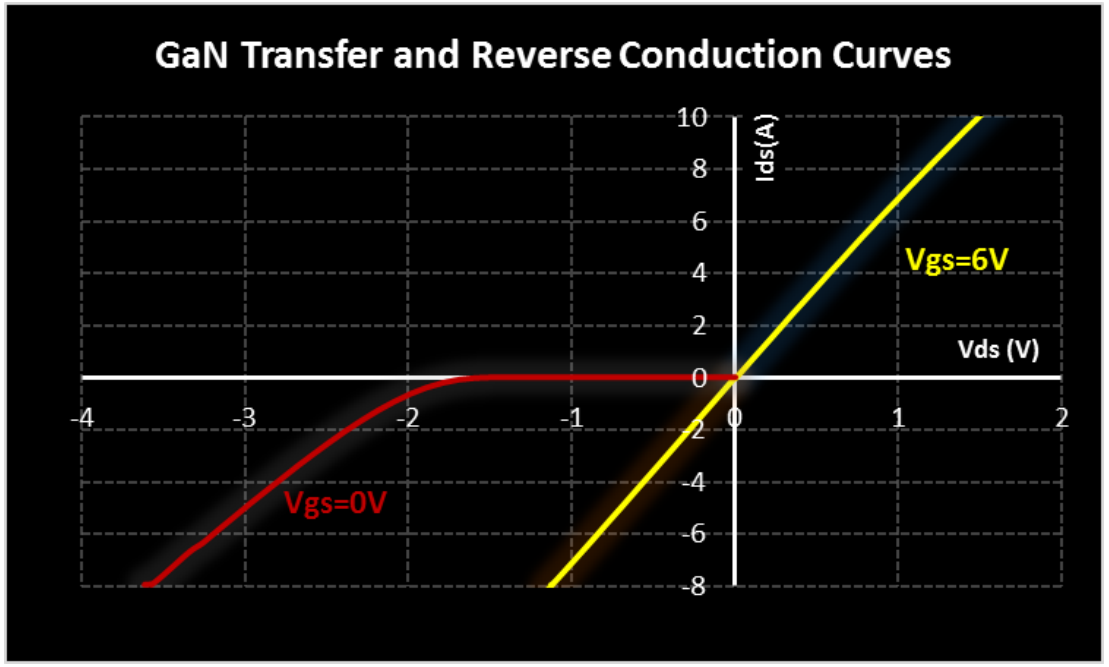


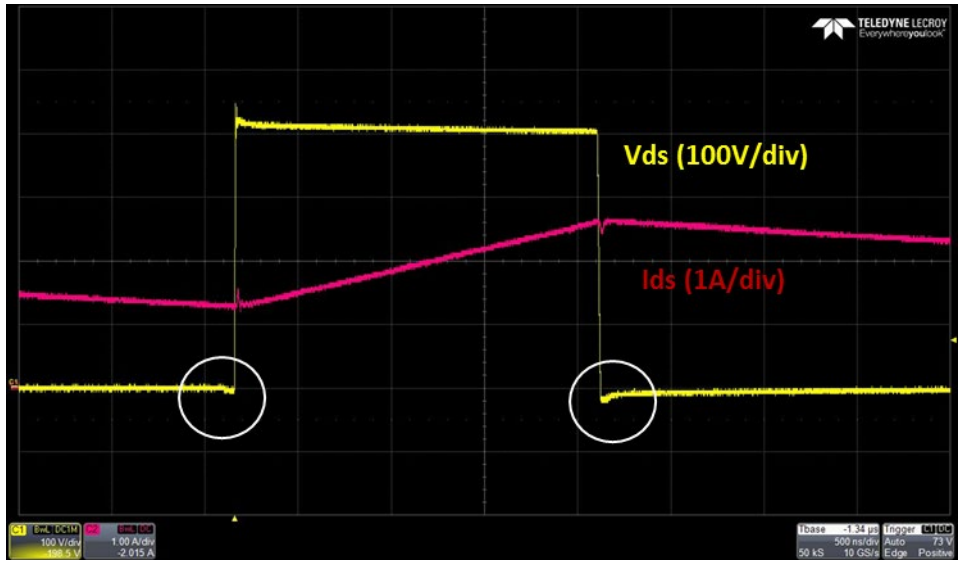






E-Mode GaN 反向导通





- GaN FETs 支持在关断时反向导通
- 对于 650V Navitas GaN, V_{SD} 典型值 3.5V
  - 反向导通没有 Q_{rr} 损耗

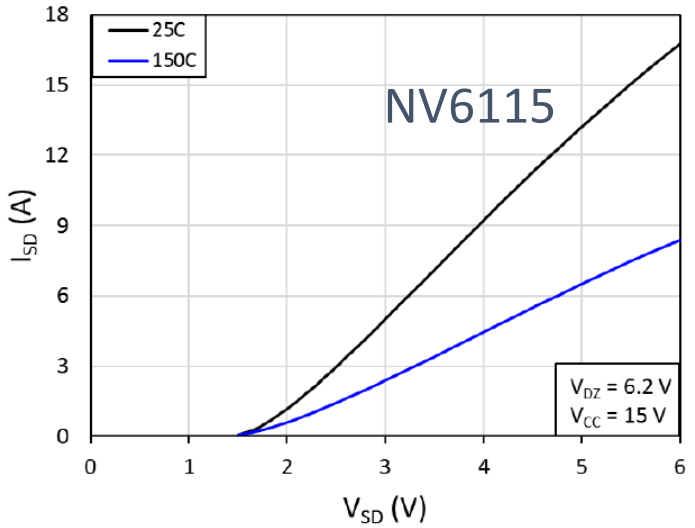
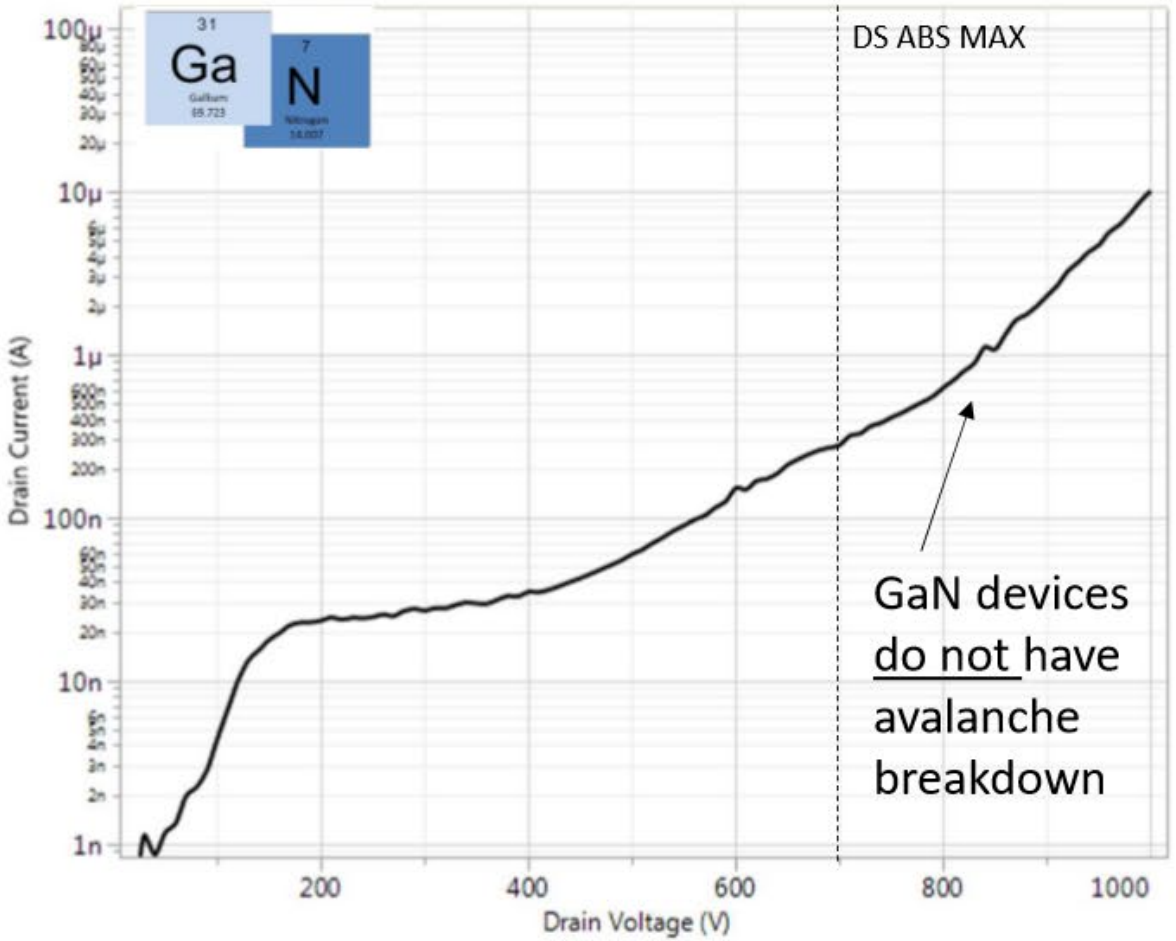
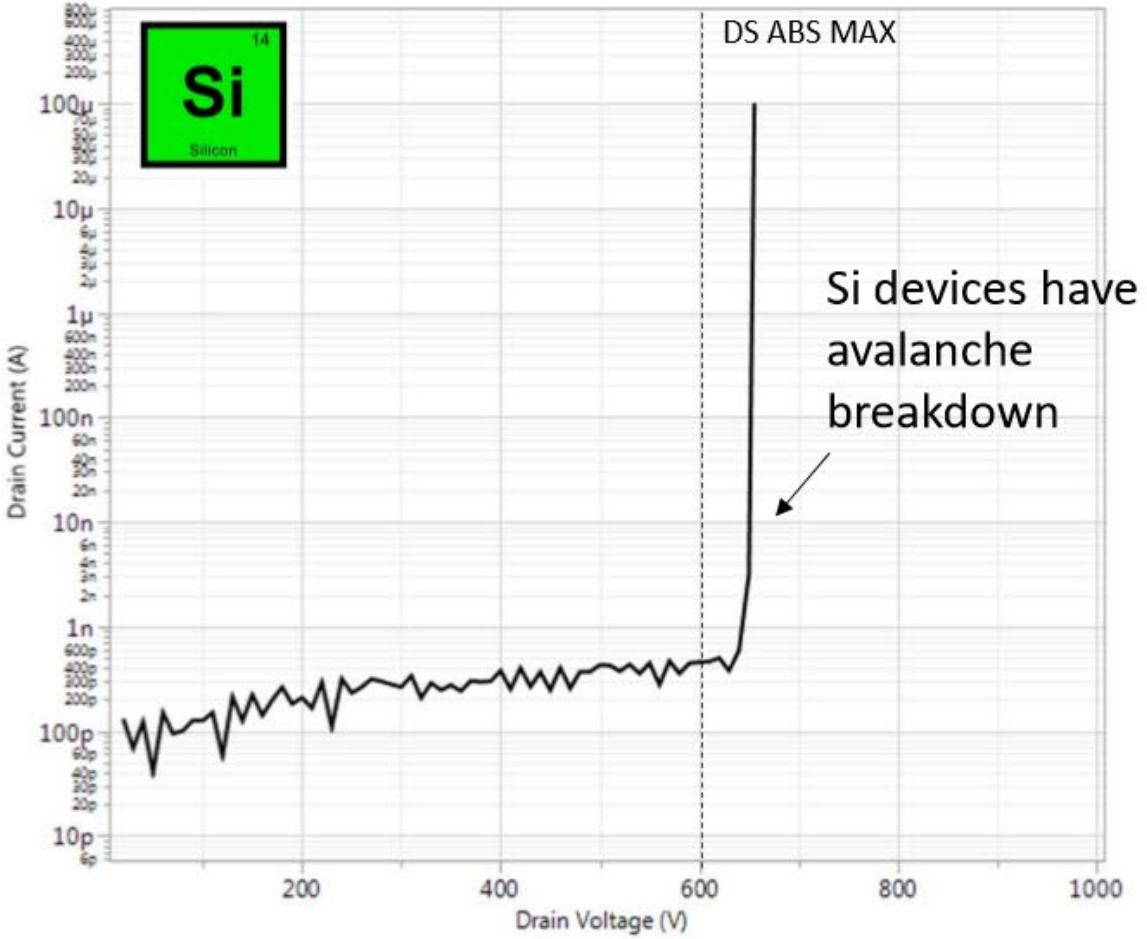


Fig 5. Source-to-drain reverse conduction voltage

Breakdown voltage different



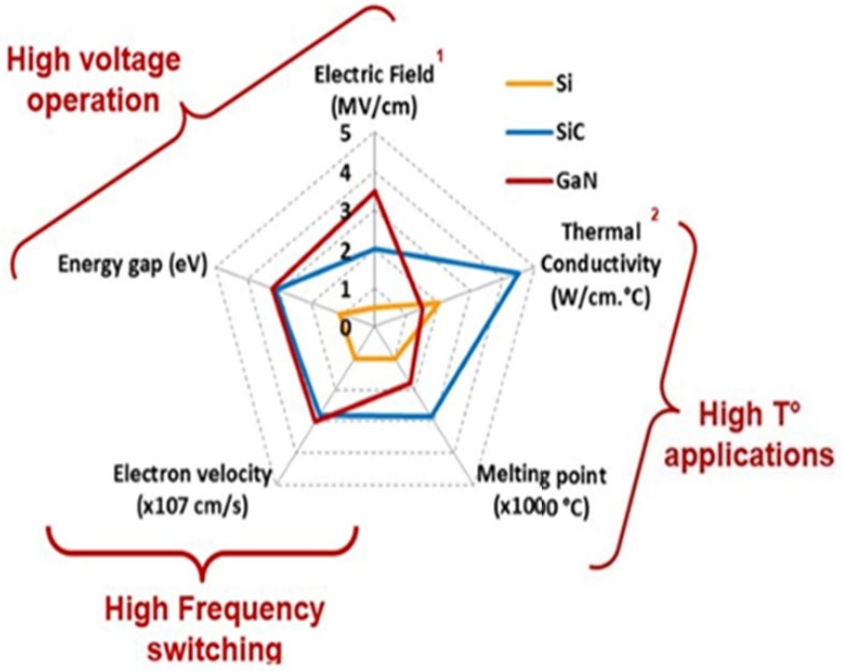


目录

功率氮化镓技术

GaNFast™

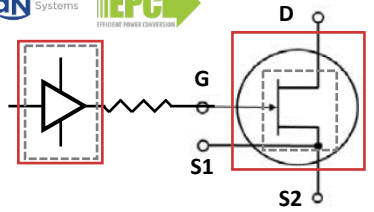
GaN Physical Performance



eMode FET *(normally off)*

dMode FET *(normally on)*

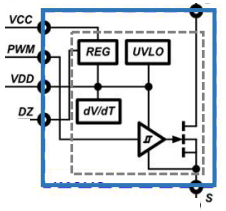
Panasonic Infineon GaN Systems EPC



Need special gate driver to drive sensitive GaN input

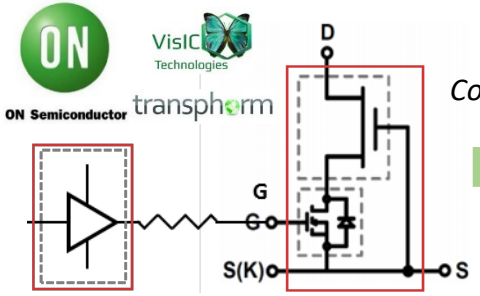
Monolithic Integration

纳微 Navitas



*The **only** fully-integrated single chip solution*

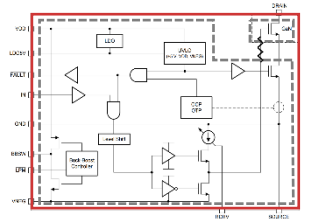
ON Semiconductor VisIC Technologies transphorm



Need extra Si FET in 'cascode' configuration

Co-pack

Texas Instruments power integrations

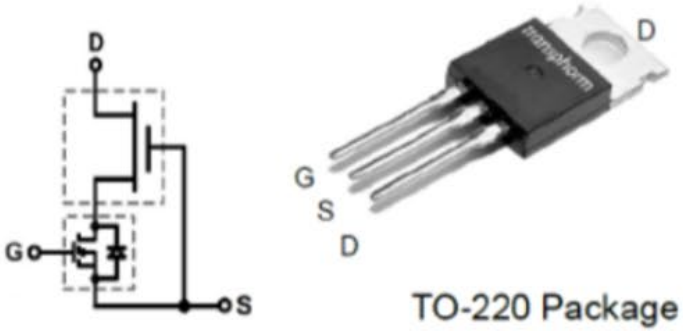


Si controller/driver + Si FET cascode + GaN dMode FET

eMode Vs dMode GaN

GaNFast™

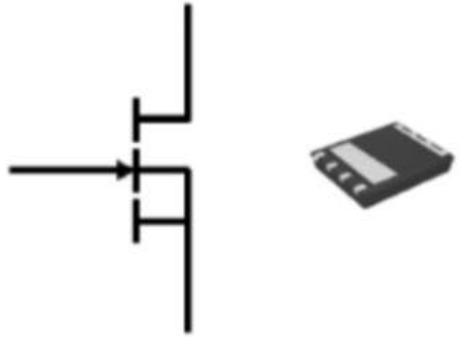
dMode GaN Technology



TO-220 Package

- Depletion mode GaN with Silicon FET Cascode
- Silicon FET gate easy to drive
- Complicated multi chip package
- Prone to oscillations and instability
- No dV/dt control

eMode GaN Technology



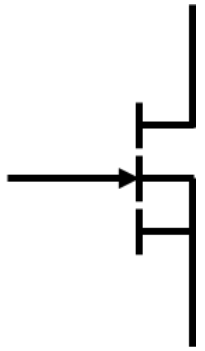
- Low Q_G
- Easy to package and low package inductance
- Good dv/dt control with gate access
- No reverse recovery loss
- Requires careful gate voltage control

eMode GaN FET gates can be easily damaged by voltage or current spikes
→ Integrated Gate Control offers the most promise in terms of realizing the full potential of eMode GaN

全世界首款 GaNFast™ 功率IC

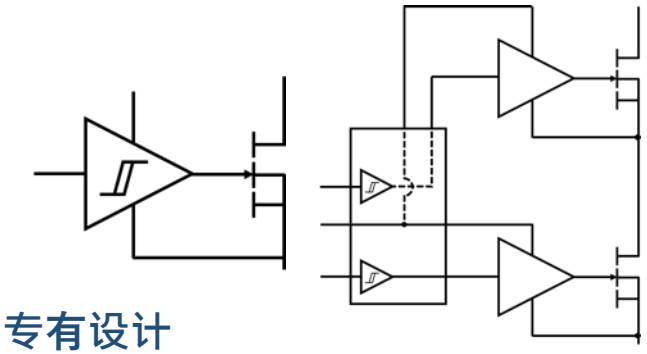
GaNFast™

最快，最高效的GaN功率管



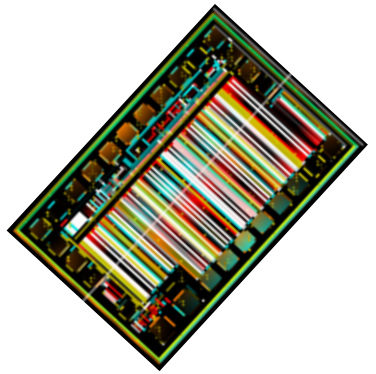
专有设计

首个&最快速集成的GaN 门极驱动器



专有设计

全世界第一款 GaNFast™ 功率 IC



速度高于硅器件20倍以上

速度高于cascoded GaN 5 倍以上

速度高于所有门极驱动器3 倍 以上

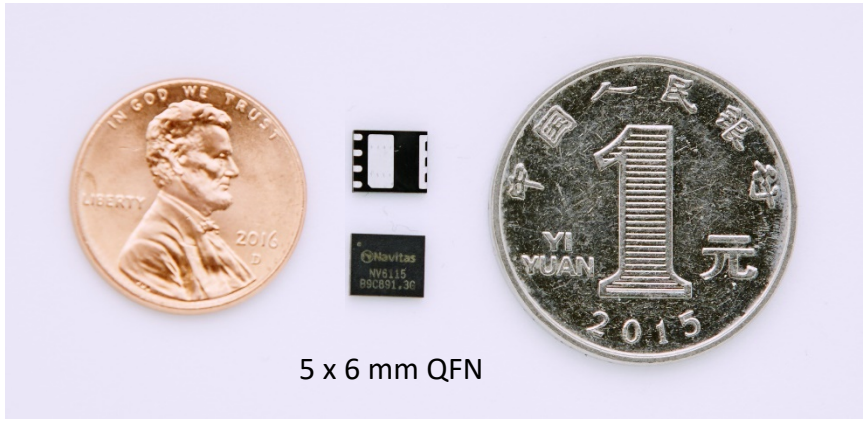
获颁或正在申请的专利超过 75 项

支持高达40MHz开关频率，5倍以上功率密度，系统成本降低20%

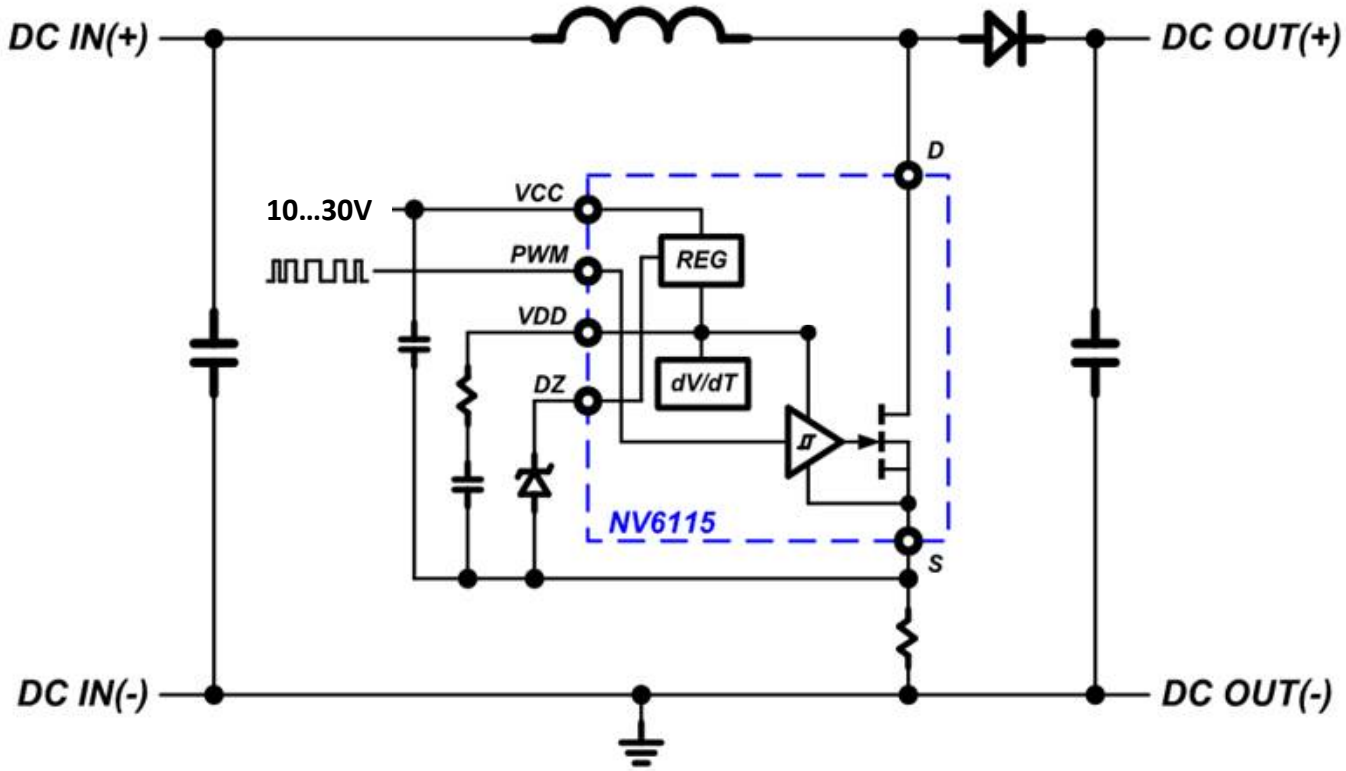
氮化镓功率IC

GaNFast™

- Monolithic integration, 650V
  - GaN FET
  - GaN Driver
  - GaN Logic
- Mass production since Q1’18
- 120, 170, 300 mΩ in 5x6 & 6x8 mm QFN



5 x 6 mm QFN

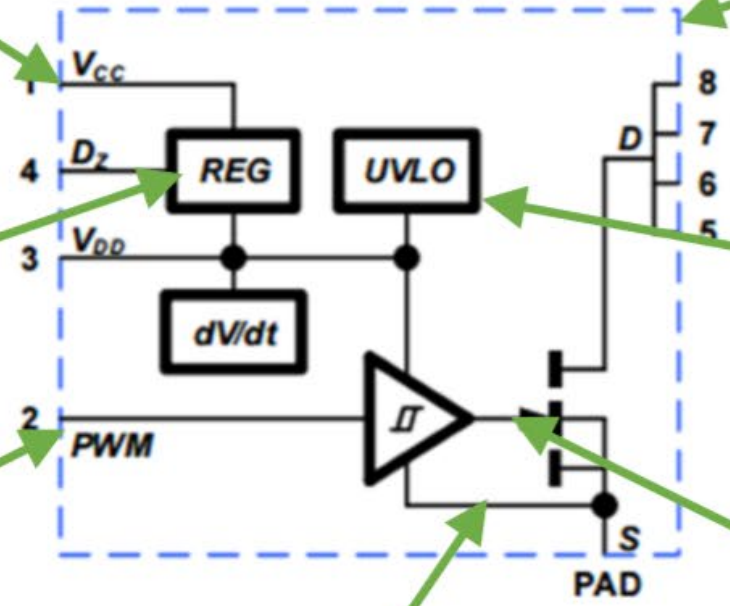


集成驱动

GaNFast™

Wide Range V_{CC} (10-30V)

Total layout flexibility & simplicity



Regulator ensures V_{GS} within SOA

Under voltage lockout protects the driver & FET when full power supply is not available

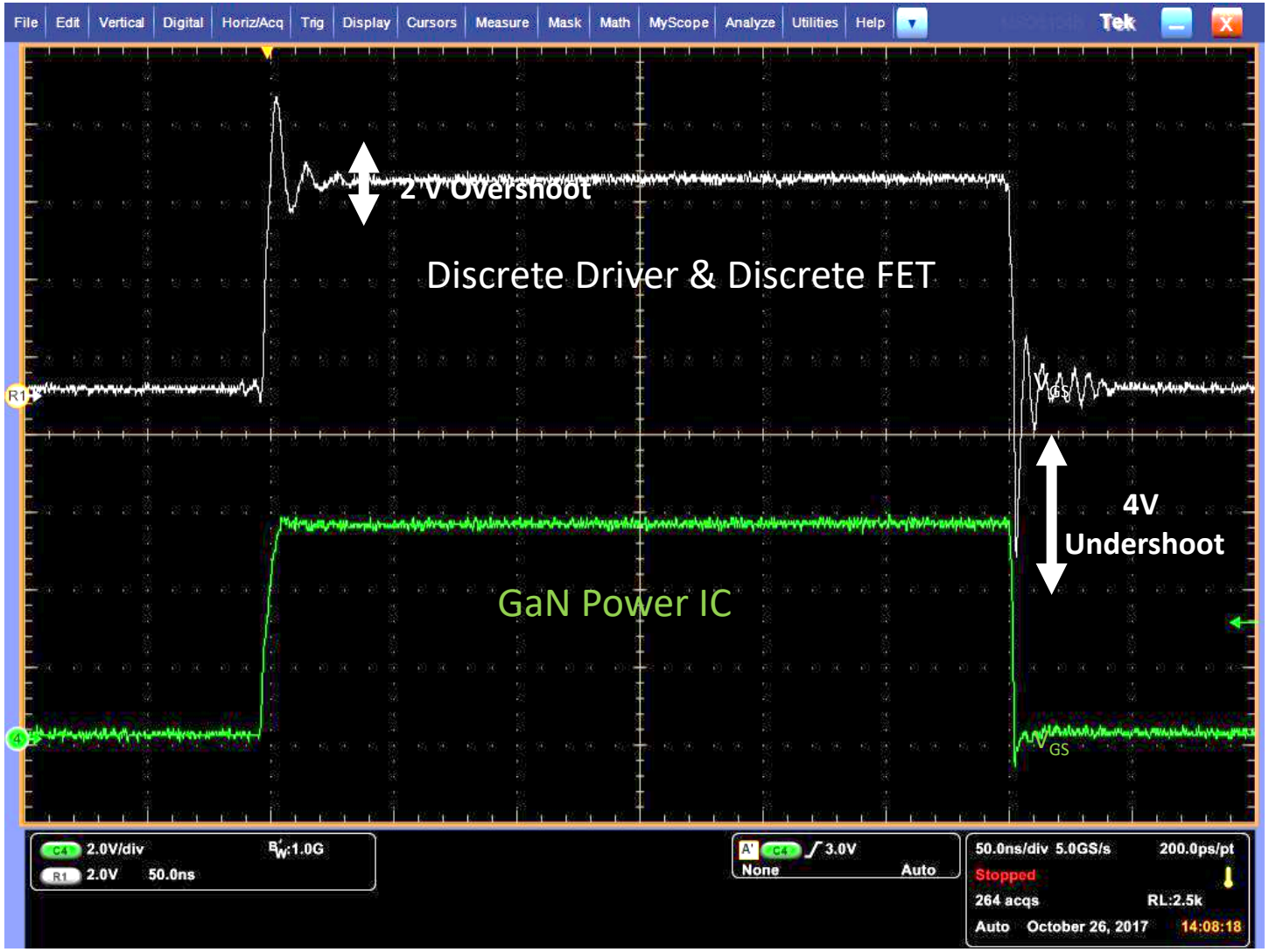
PWM Hysteresis for noise immunity

Gate protected from external noise (Not pinned out of package)

No inductance or ringing in gate loop

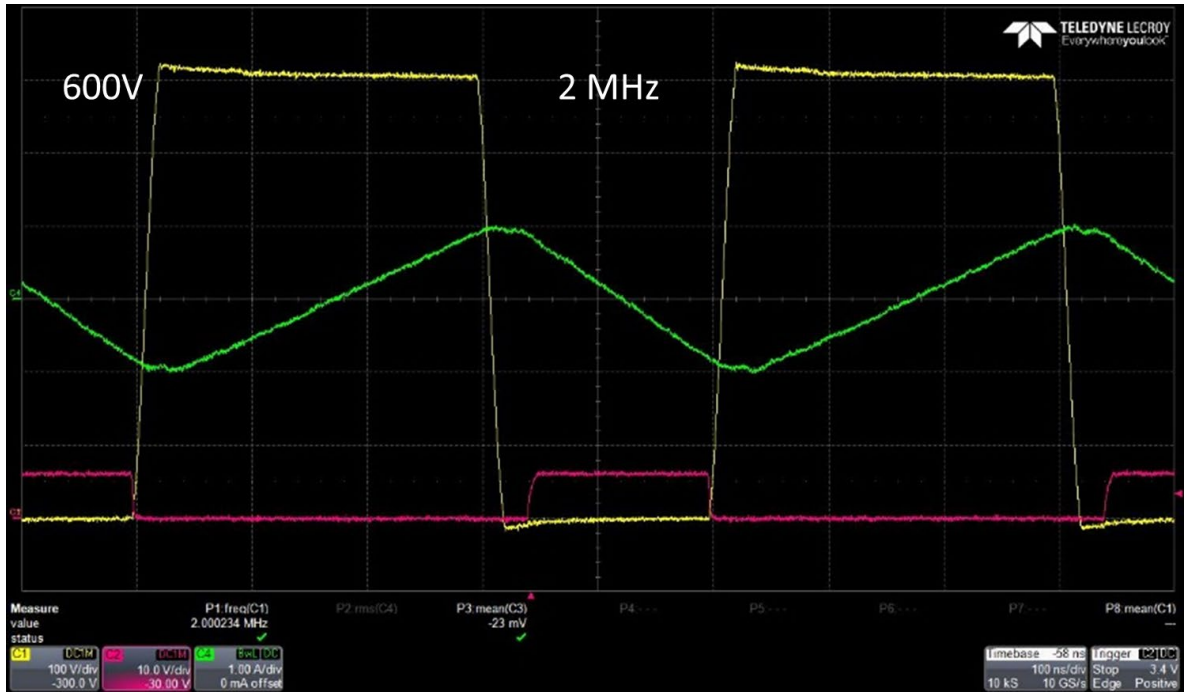
Clean, Controlled FET Gate

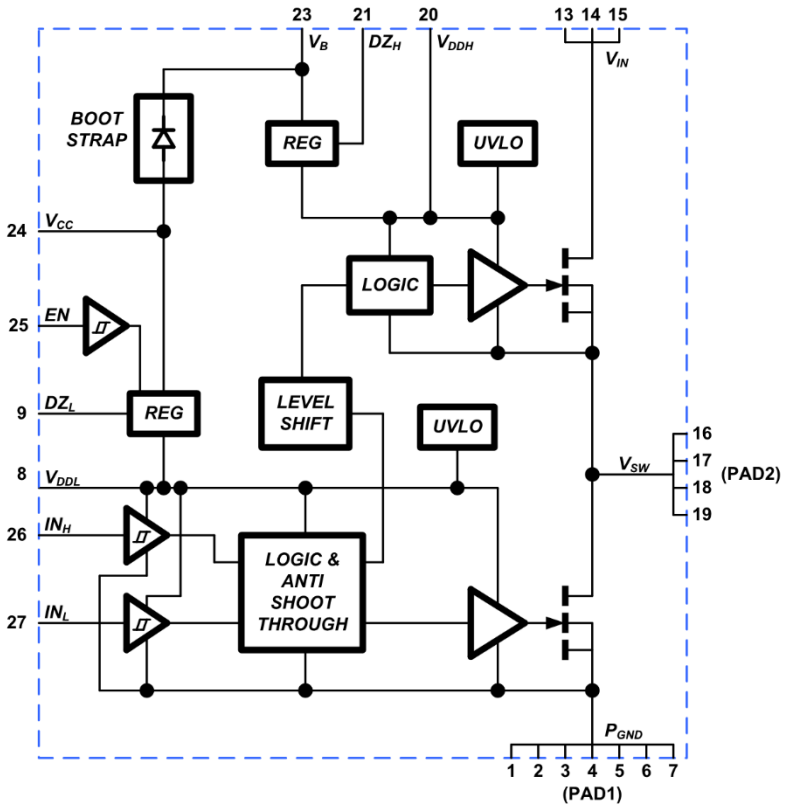
- **Discrete driver**
  - Gate-loop inductance creates overshoot (even with good layout)
  - Reliability concern
- **GaNFast Power IC**
  - No gate loop parasitic
  - Clean and fast gate signal
  - No CdV/dt turn-on
  - No IV crossover turn-off switching losses

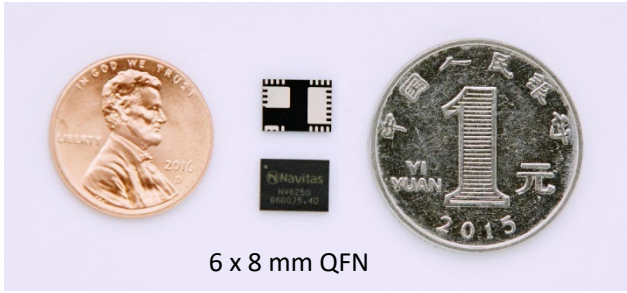


Half-Bridge GaNFast Power IC

- Monolithic integration, 650V
  - 2x GaN FETs
  - 2x GaN drivers
  - GaN Logic (level-shift, bootstrap, UVLO, shoot-through, ESD)

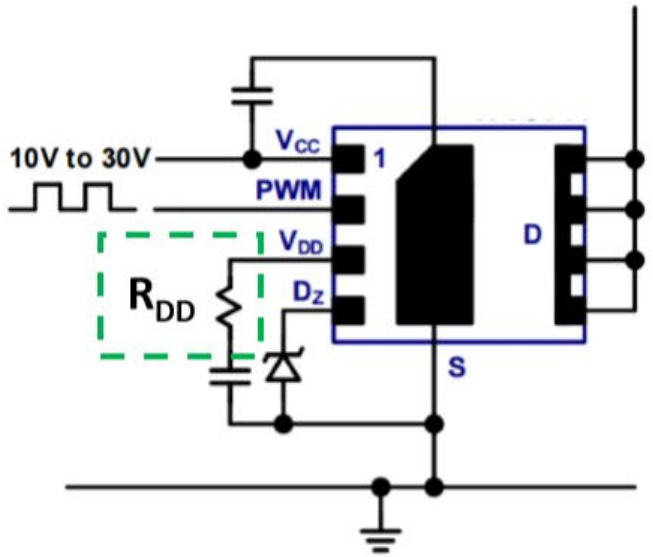


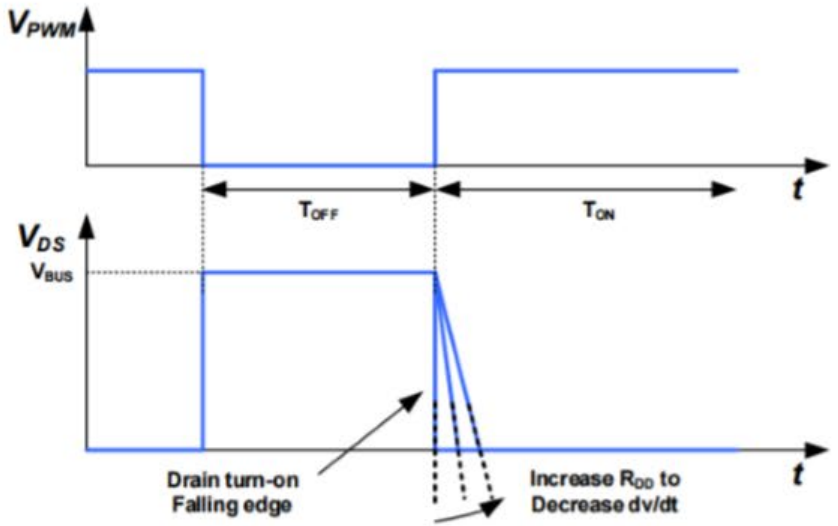


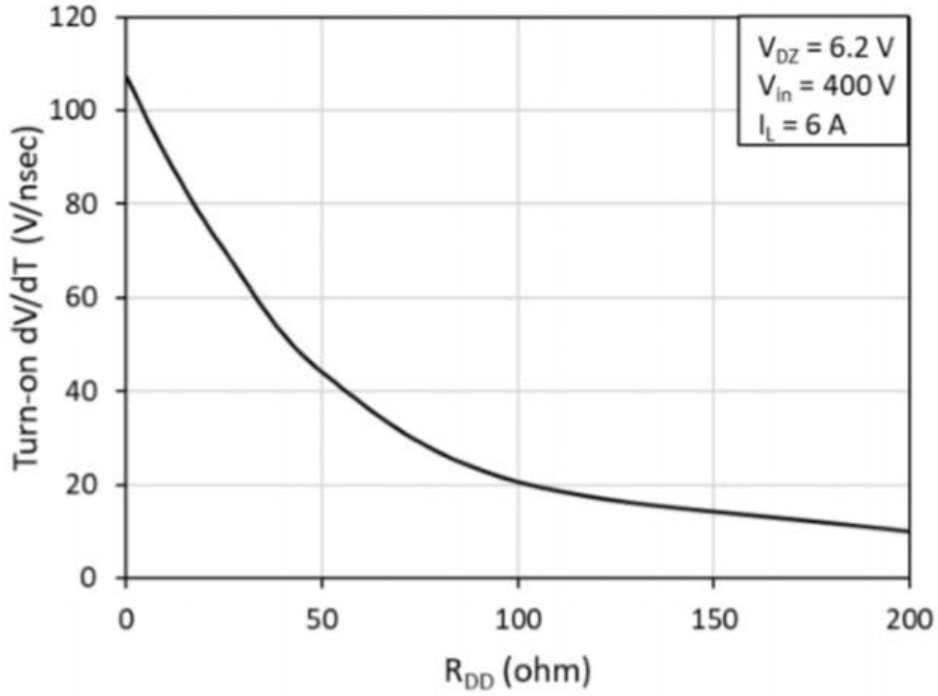


6 x 8 mm QFN

dv/dt可控，易于优化EMI性能





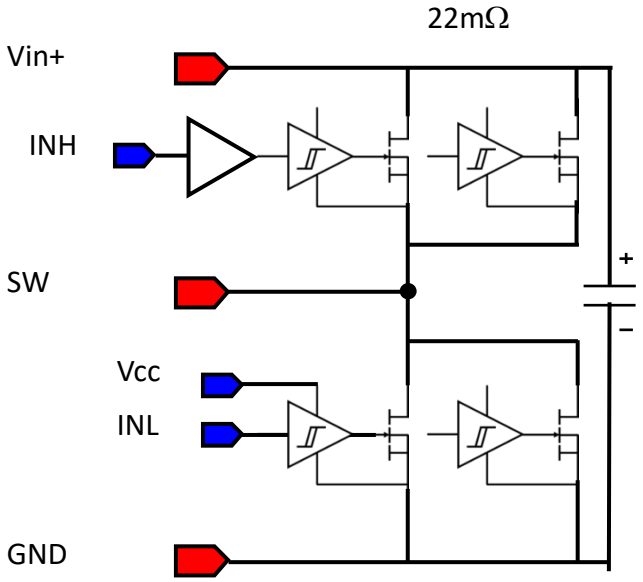


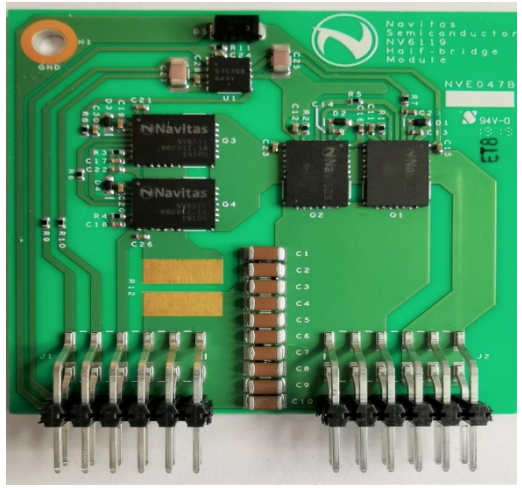
dV/dt controllable from 100 V/ns to 10 V/ns

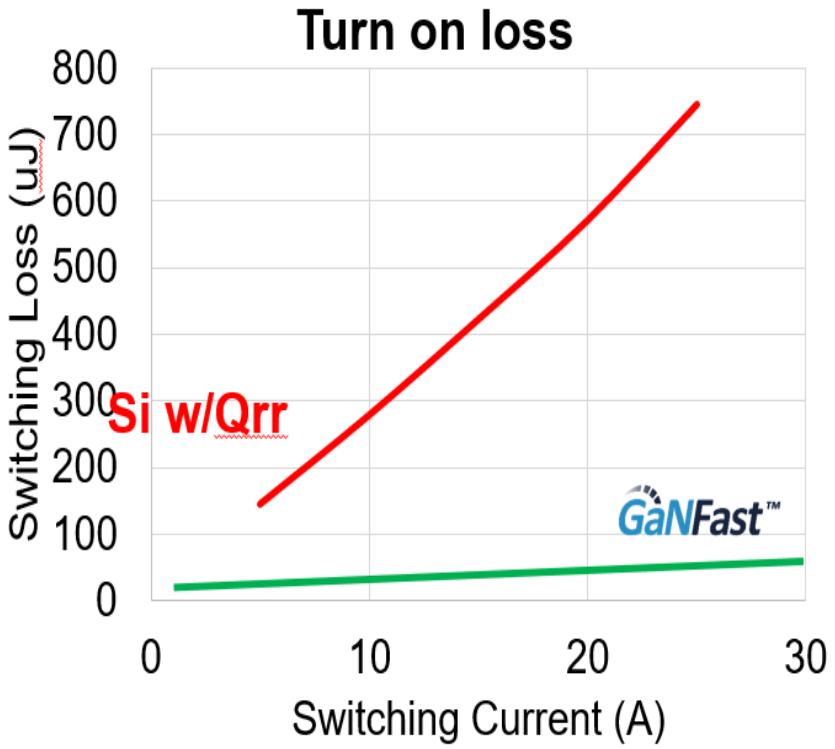
目录

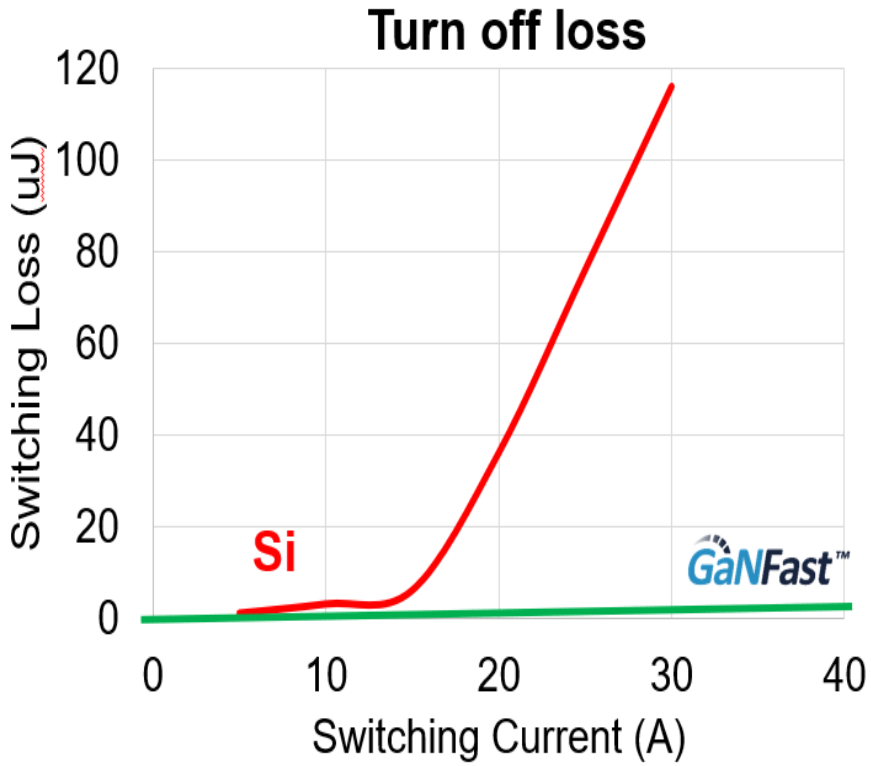
GaN的优势对电源性能的影响

- GaN可以大幅降低开关过程的损耗









85% turn on loss saving and 95% turn off loss saving

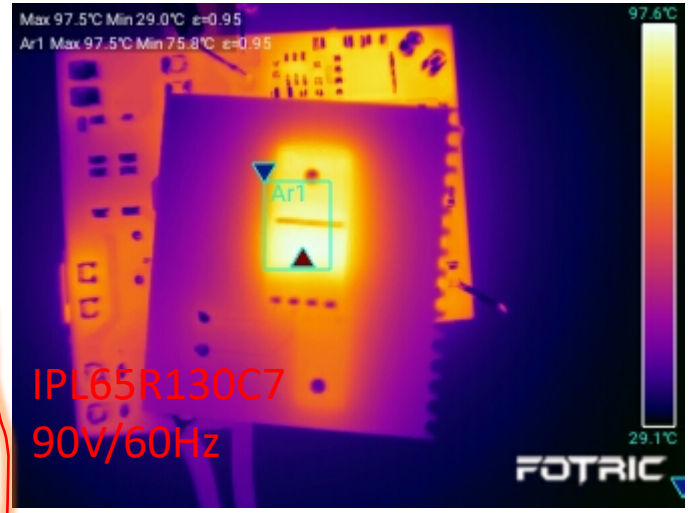
GaN的优势对电源性能的影响

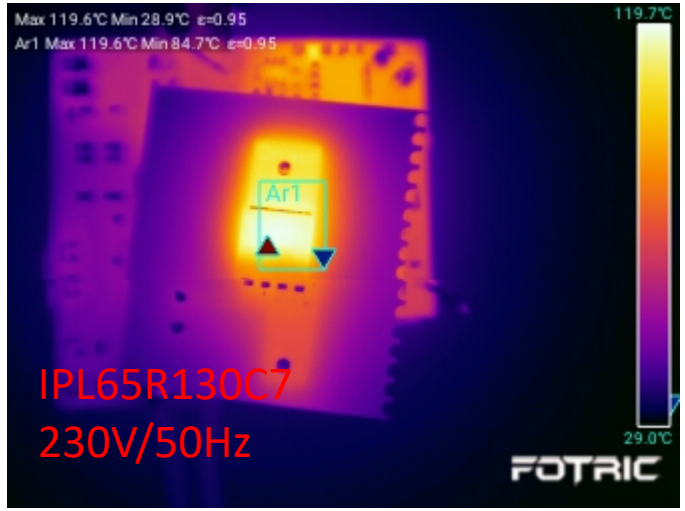
IPL65R130C7 Infineon
NV6127 Navitas

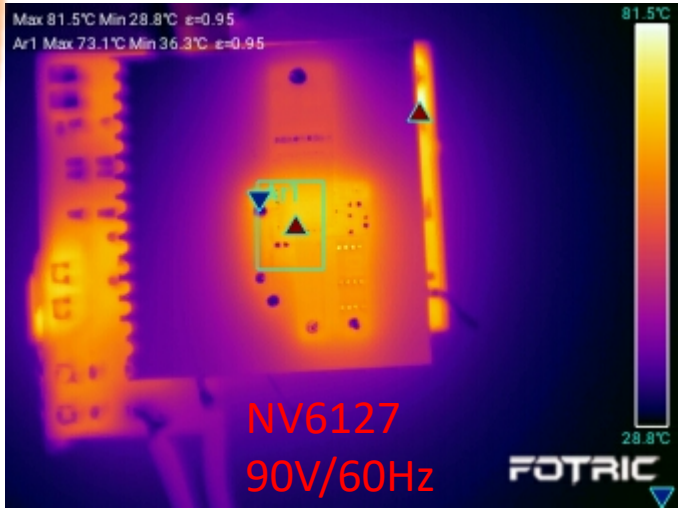
		Vo	Io	Po	Pin	Eff	Thermal
IPL65R130C7(130mR)	90V/60Hz	19.98	3.252	64.97	70.36	92.35%	97.5
	230V/50Hz	19.98	3.252	64.97	69.8	93.09%	119.6

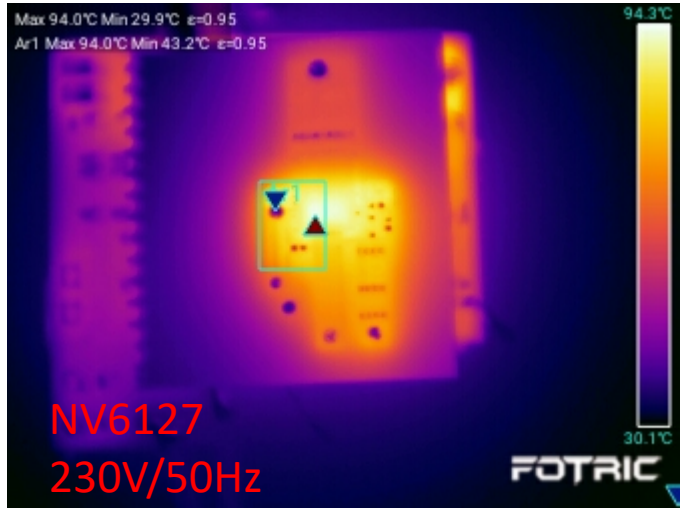
		Vo	Io	Po	Pin	Eff	Thermal
NV6127	90V/60Hz	19.98	3.252	64.97	69.73	93.18%	73.1℃
	230V/50Hz	19.98	3.252	64.97	68.91	94.29%	94℃

20V/3.25A=65W输出
同等测试条件
只更换管子





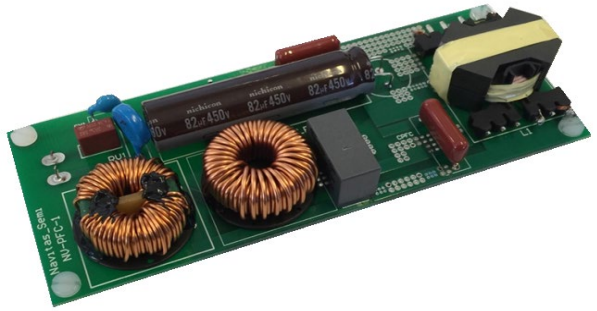




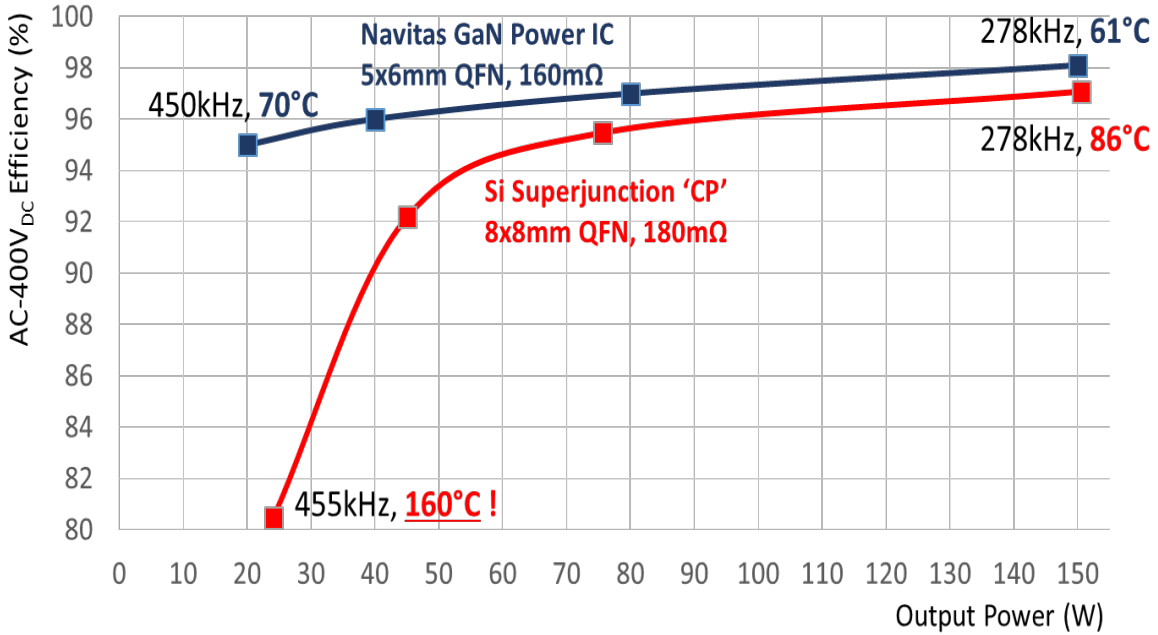
GaN 和 硅在 500kHz CrCM PFC 的应用

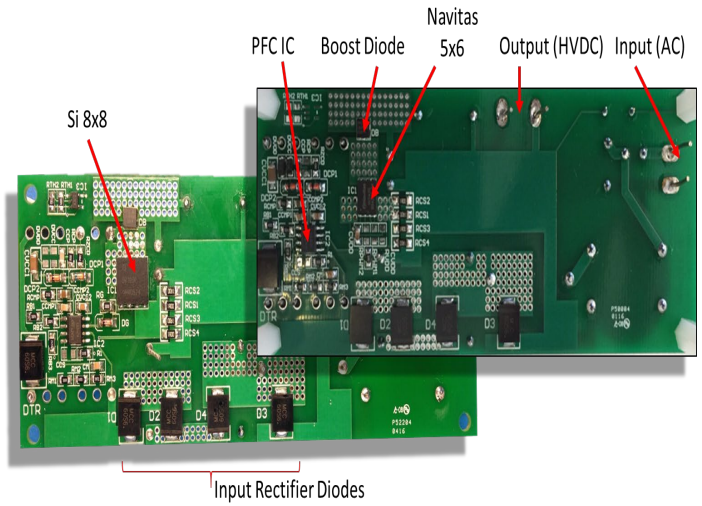
- CrM模式
- $120V_{AC}$ = 167-230kHz
- $220V_{AC}$ = 230-500kHz

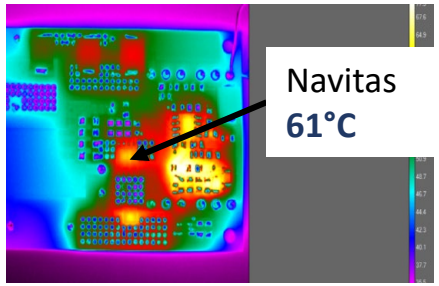
	Pack	$R_{DS(ON)}$ mΩ	Q_G nC	$C_{OSS}(er)$ pF	$C_{OSS}(tr)$ pF
Navitas	5x6	160	2.5	30	50
Si CP Series	8x8	180	32	69	180
Si C7 Series	8x8	115	35	53	579
GaN Benefits	>50 %	n/a	>10 x	>2x	>10x



100 x 50 x 10mm 2-层, 2 oz PCB
没有散热器，没有强制风冷
没有导热硅胶和灌胶
没有散热器

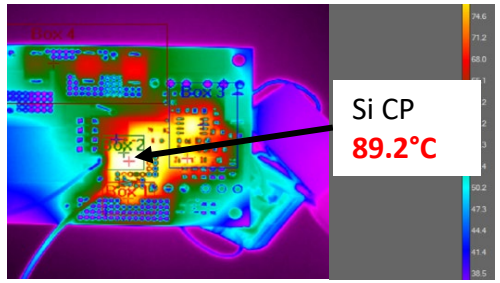






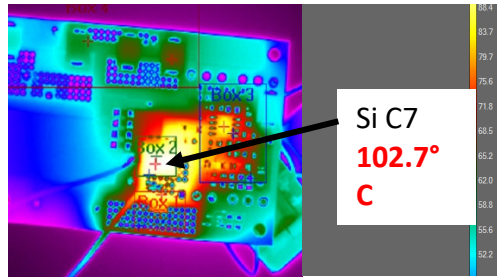
$220V_{AC}$, 150W

- GaN 只有 (61°C)



$220V_{AC}$, 150W

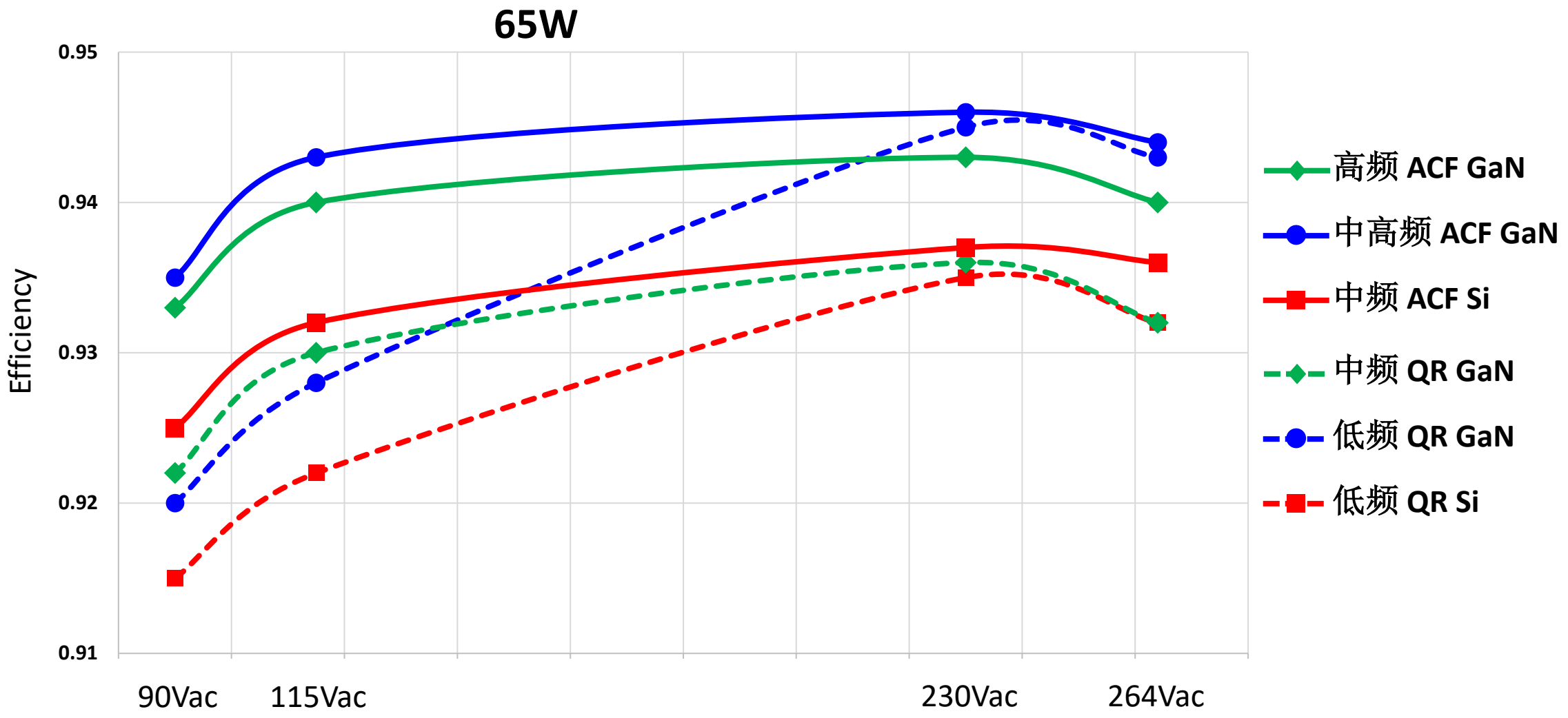
CP 硅管 ~90° C



180V$_{AC}$, 150W

- C7 硅管 在$220V_{AC}$ 时温度太高不能运行

效率对比: QR vs. ACF & Si vs. GaN



结论：GaN适合高频软开关应用

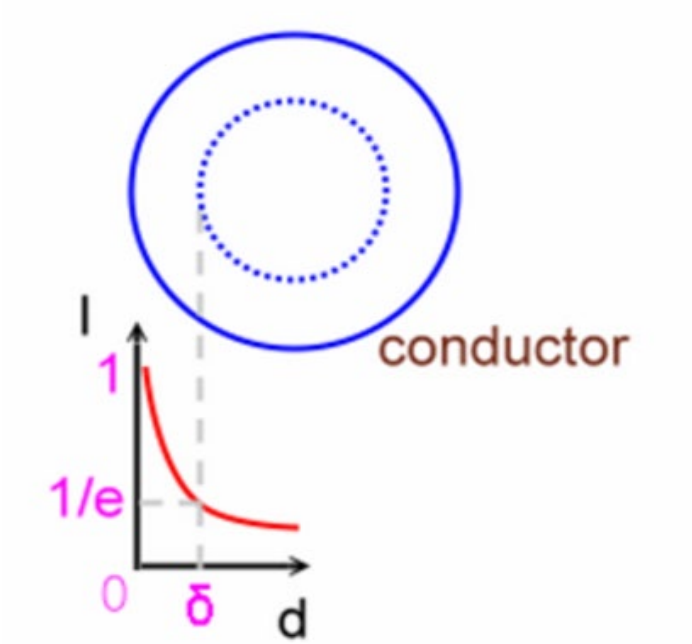
- GaN的开关损耗极低，适合高频开关，纳微GaN集成了驱动，更易于高频使用。
- GaN在低频下只比Si效率高0.5-1.2%
- GaN在高频下远超过Si的效率
  - 高频下EMI器件，变压器，输出电容体积都可以缩小
  - 电源体积是由温度决定的，GaN大概缩小15%-30%体积
  - 电源体积是由元器件体积决定的（高频软开关），GaN可以极大缩小体积
  - 强制风冷或散热条件好的情况GaN 可以极大缩小体积
- GaN的节电容小可以缩小软开关拓扑的死区时间（如LLC,ACF）
  - 有效占空比的提高，降低电流有效值，提高效率
  - GaN更适合高频软开关应用

目录

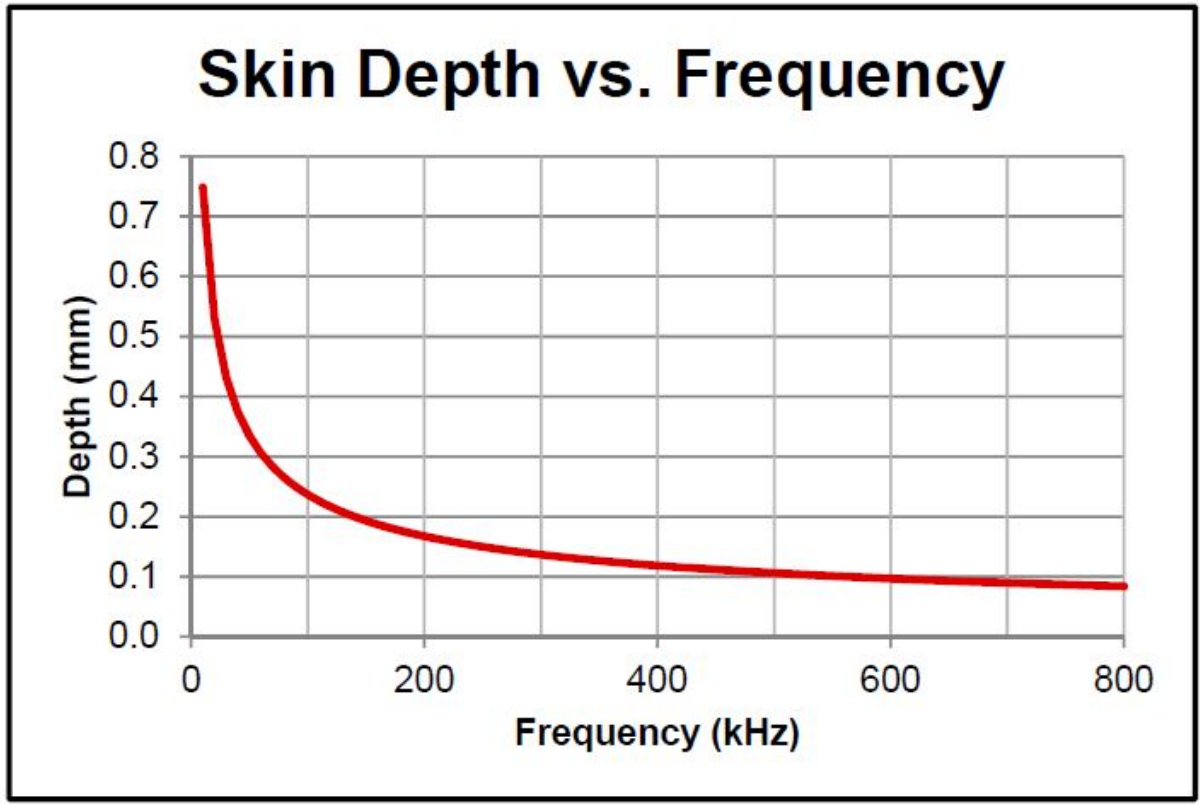
- 氮化镓技术价值与商用案例
- 氮化镓和MOSFET的不同
- 氮化镓特殊的驱动问题，Navitas集成驱动IC简介
- 氮化镓对开关电源性能的提升
- **氮化镓高频开关电源设计注意事项**
  - **变压器**
  - **EMI**

高频变压器注意事项

- 严重的趋附和临近效应
  - 200k以上线圈最好用0.05-0.08mm的利兹线

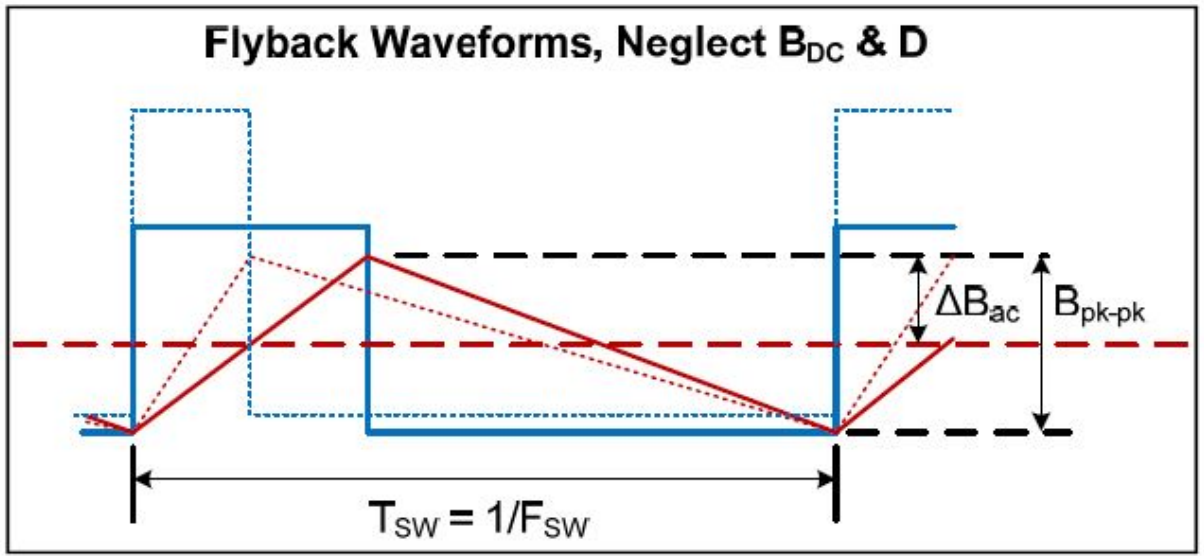


高频导体电流密度分布图

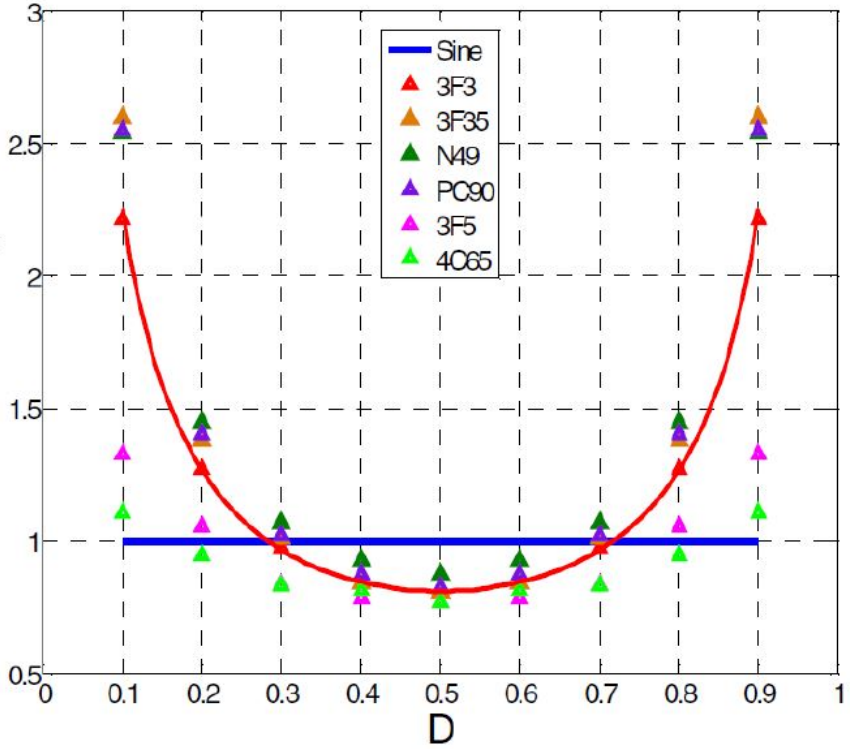


高频变压器注意事项

- 注意电流波形和占空比对磁芯损耗的影响
  - 传统观点认为方波接近正弦波
  - 实际上波形和占空比对损耗影响很大

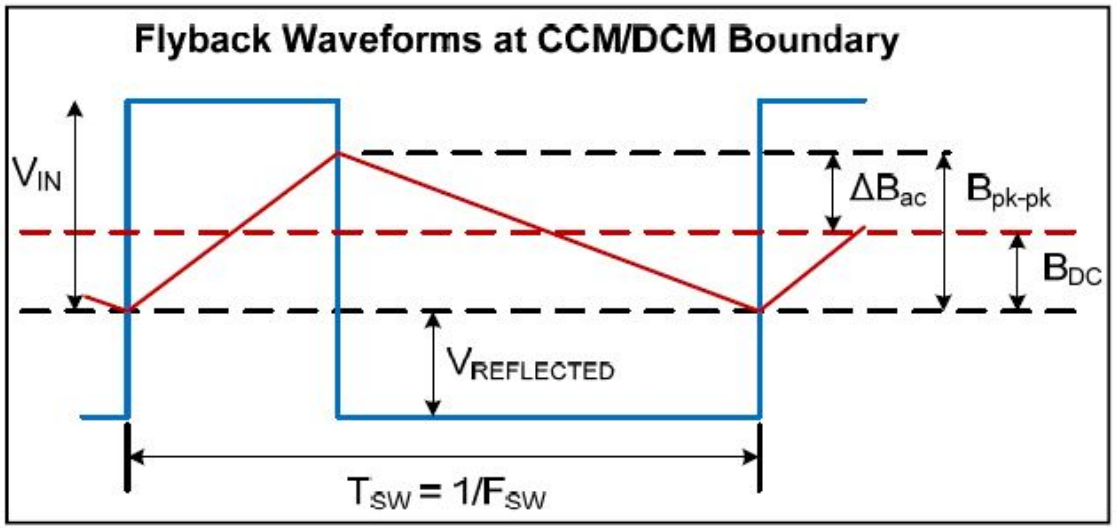


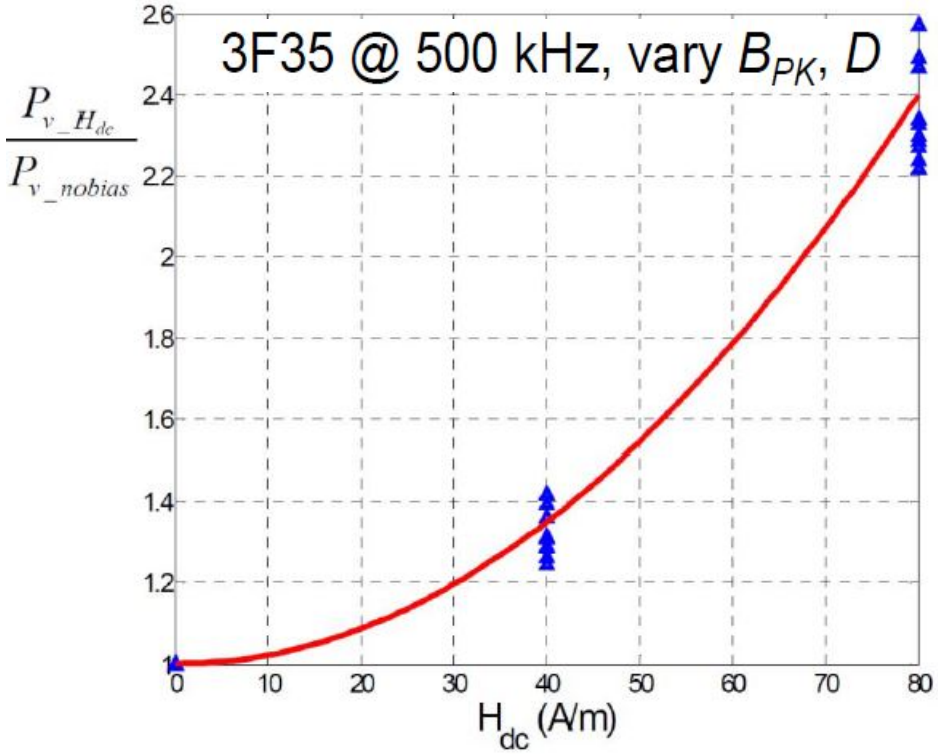
$$\frac{P_{v\_rect}}{P_{v\_\sin}}$$



高频变压器注意事项

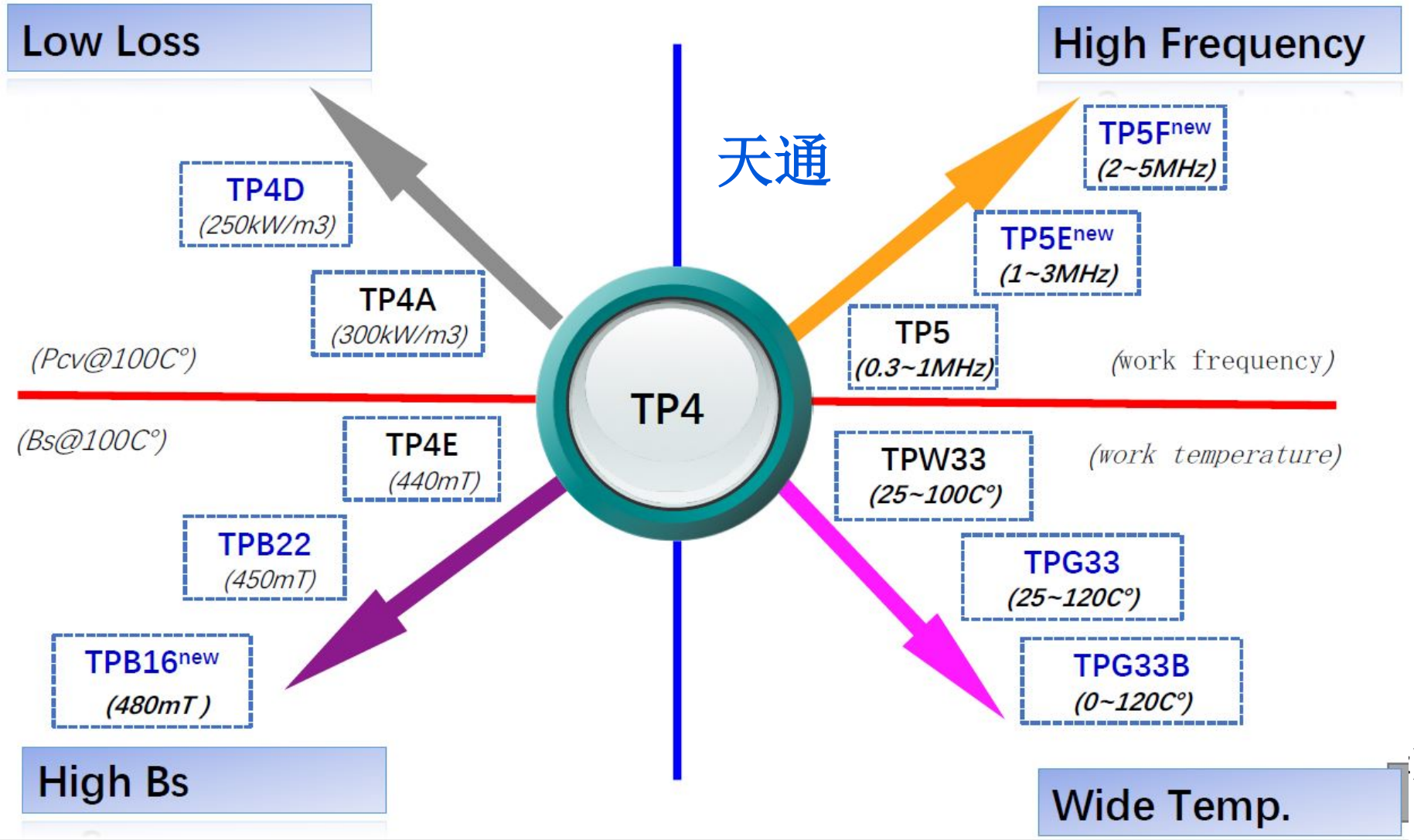
- 注意磁通直流偏置对磁芯损耗的影响
  - 传统观点认为直流偏置对磁损无影响
  - 实际上直流偏置磁通对损耗影响很大





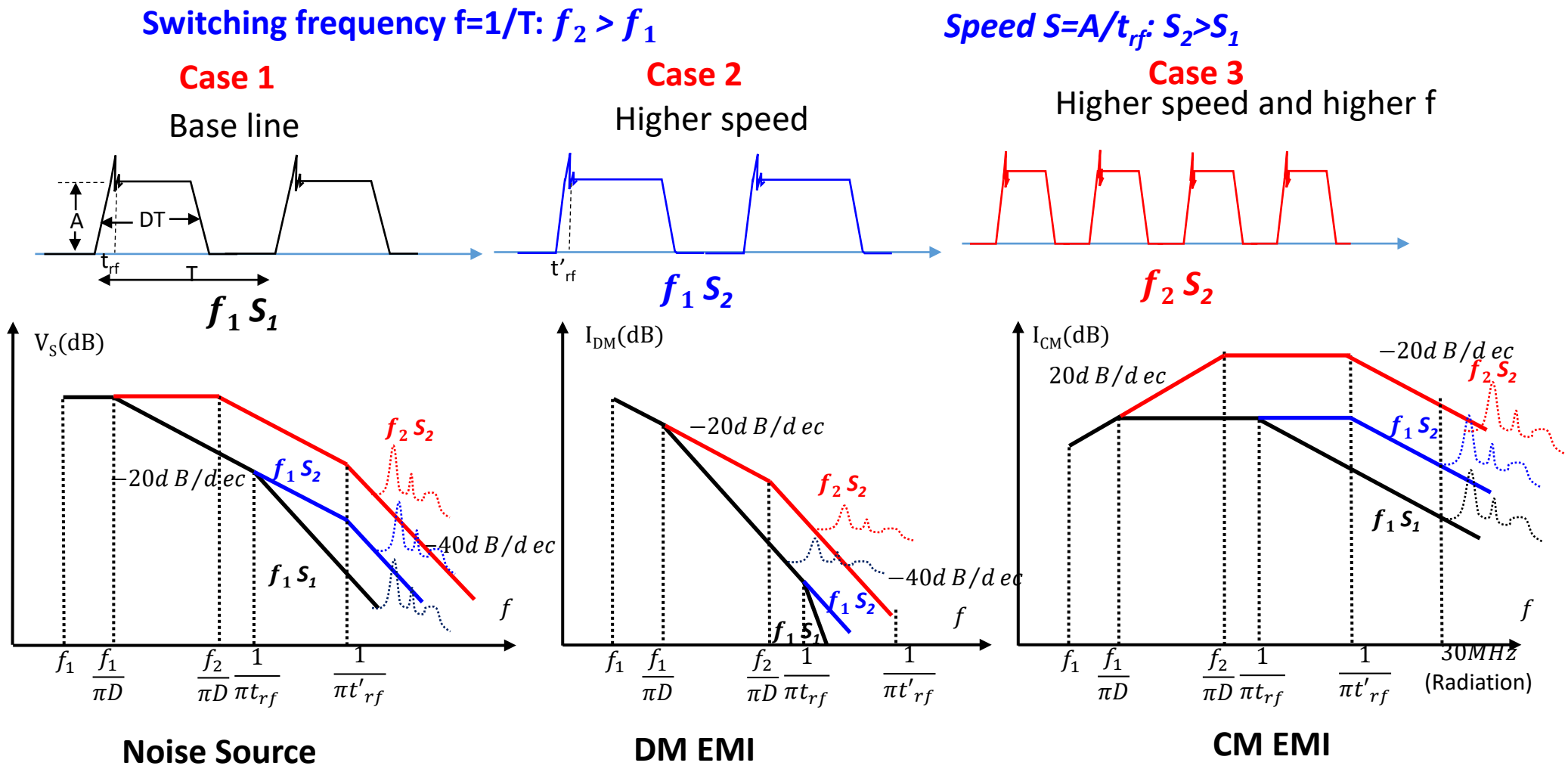
高频变压器注意事项

- 各家磁芯公司都推出了高频磁芯



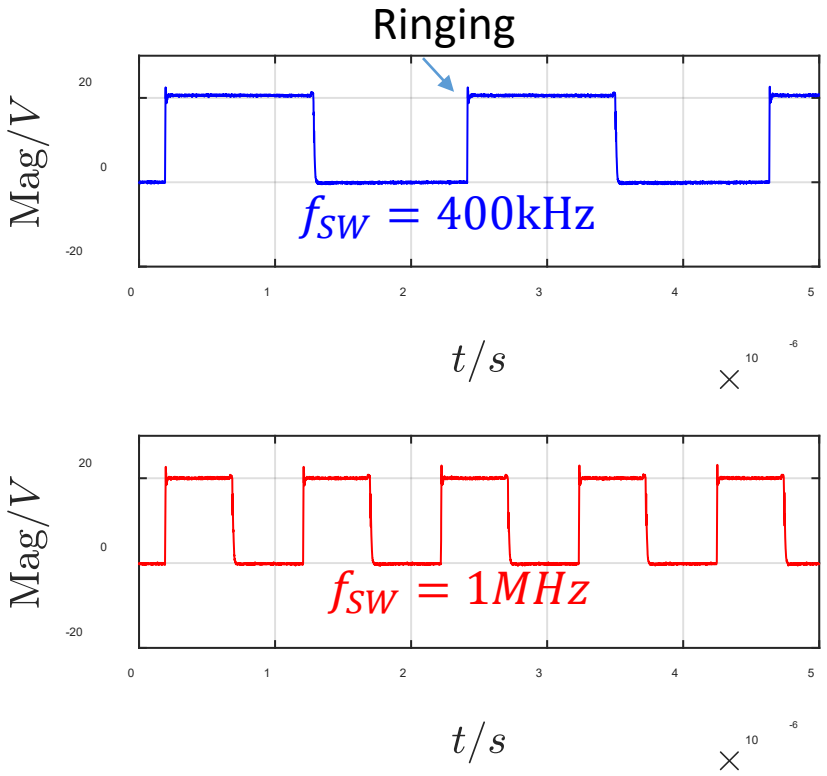
GaN高频电源EMI注意事项

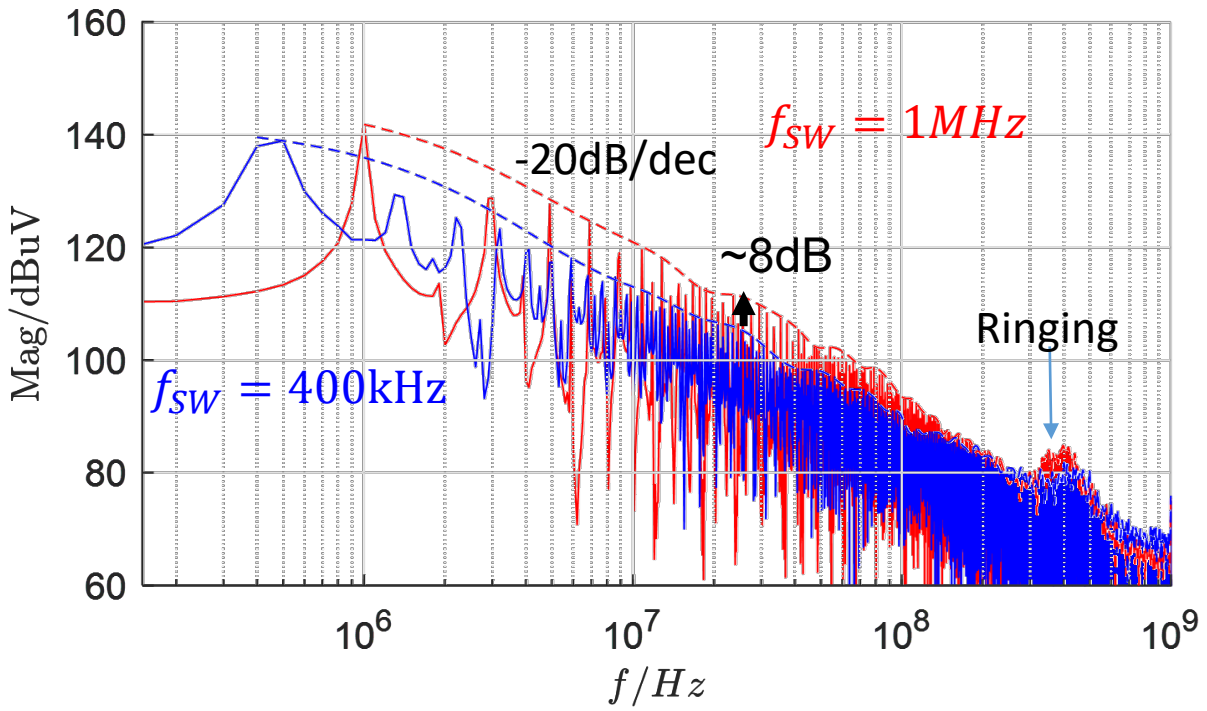
- 开关速度和频率及振铃对噪音源的影响



GaN高频电源EMI注意事项

- 开关频率噪音源的影响

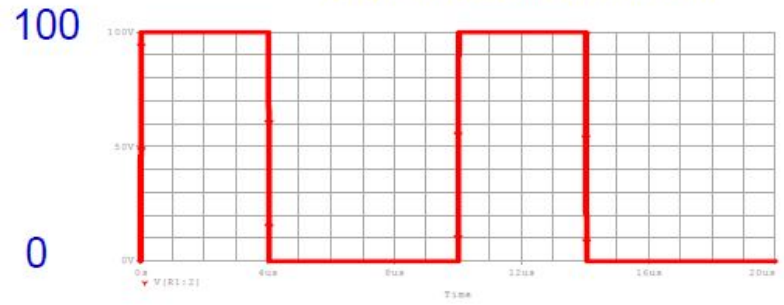




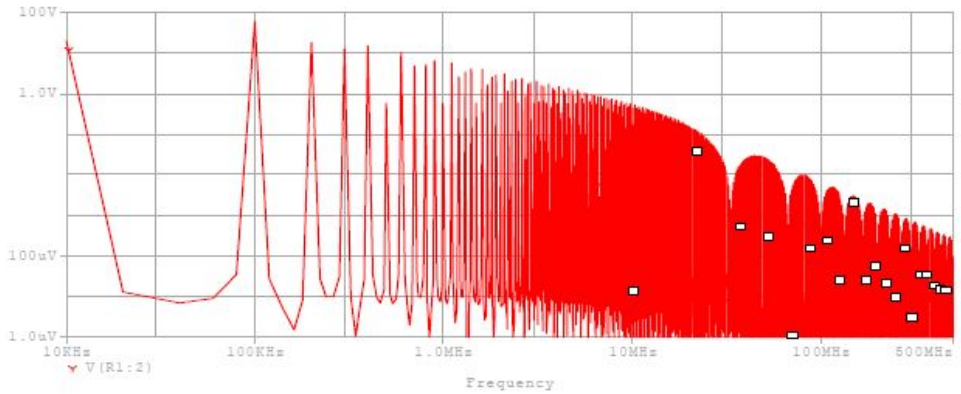
GaN高频电源EMI注意事项

- 开关速度噪音源的影响

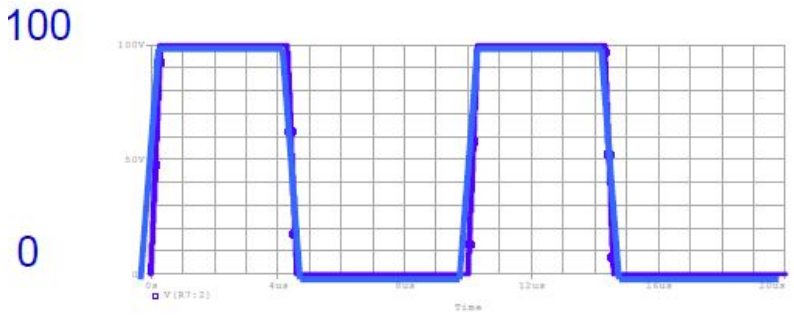
- 30ns rise and fall time

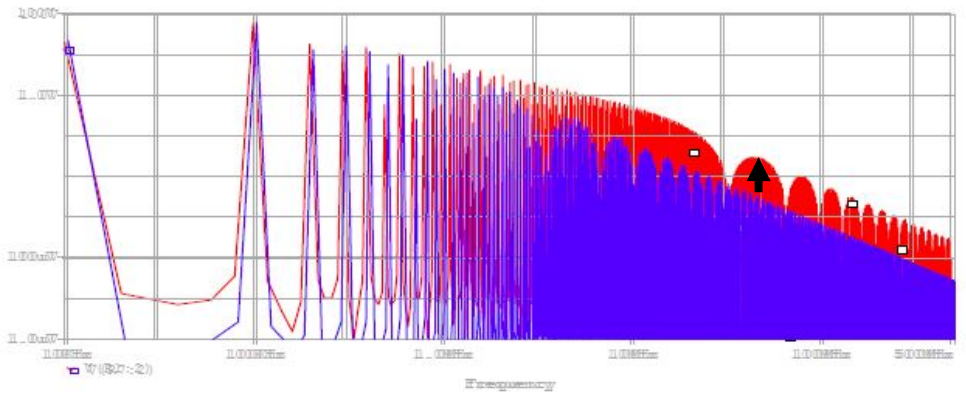


10kHz 500MHz



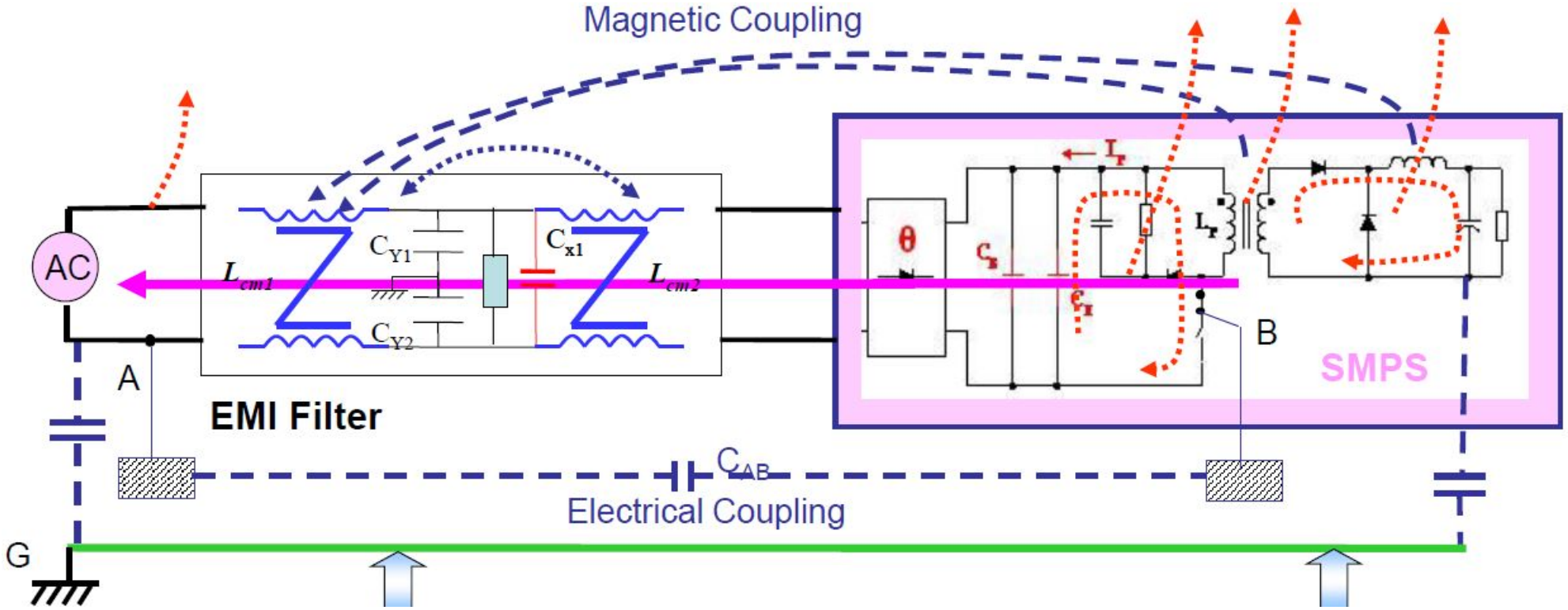
- 300ns rise and fall time





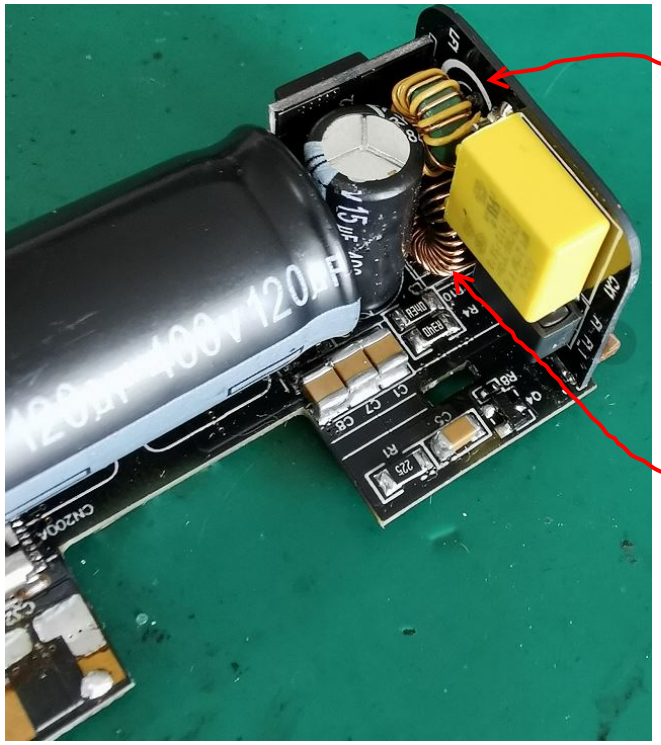
GaN高频电源EMI注意事项

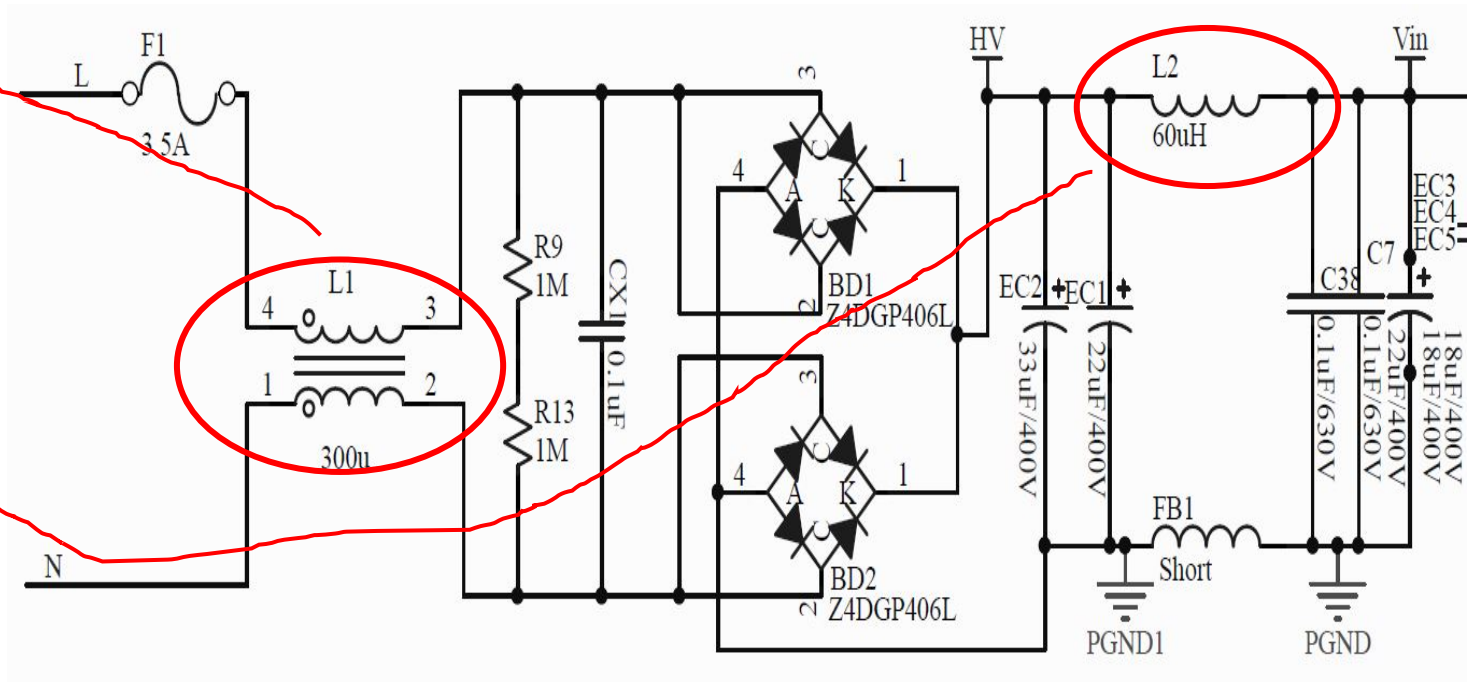
- 更严重的是空间耦合
  - 高dv/dt, di/dt使空间耦合加重



GaN高频电源EMI注意事项

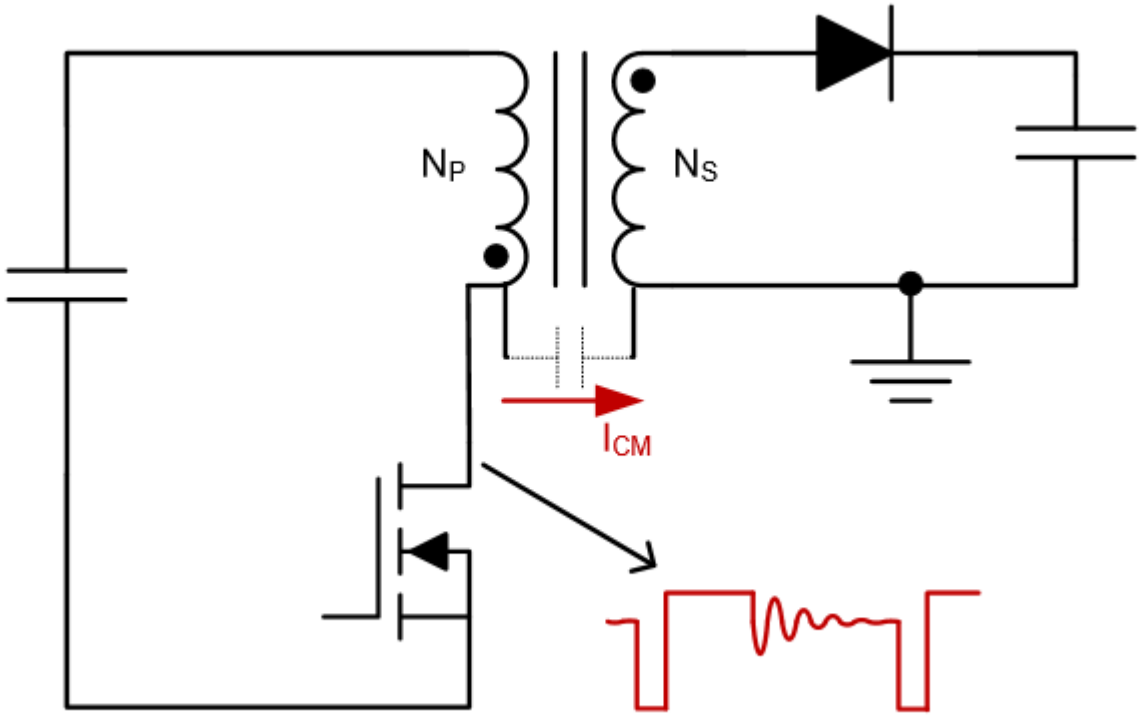
- 高频使的差模转折频率升高，需要的差模电感反而可减小
- 共模主要靠变压器共模电流对消技术





• 共模主要靠变压器共模电流对消技术

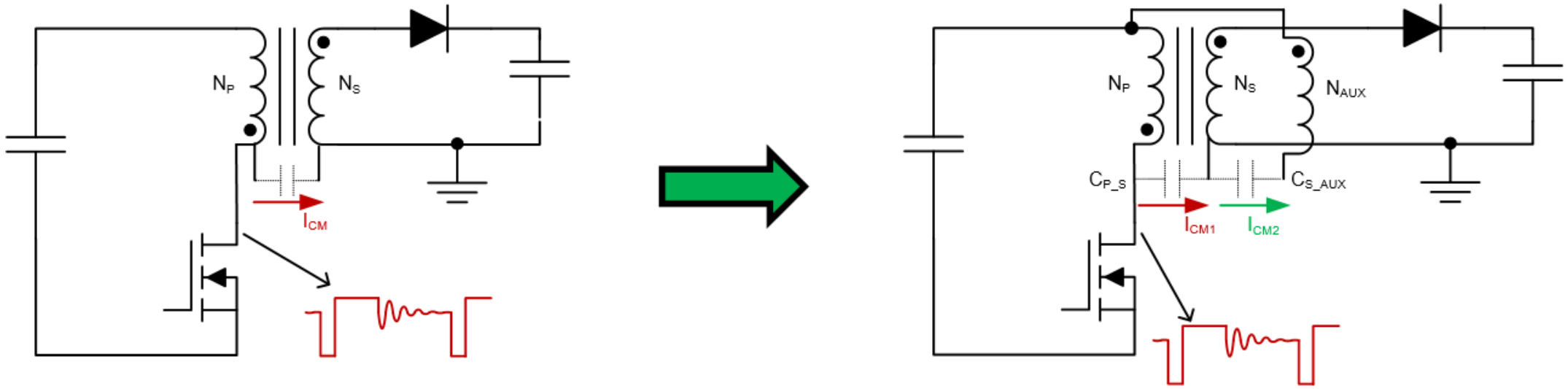
- 原边开关波形Vds
- 耦合共模电流从原边到副边通过原副边寄生电容
- 通常，原副边绕组约贴近，耦合越好，寄生电容越大，产生的EMI就越严重



GaN高频电源EMI注意事项

- 共模主要靠变压器共模电流对消技术

- 共模电流对消的原理如下图：
- 具体实践中，调整Csaux 和Naux产生Icm2来抵消Icm1
- 具体实施过程中，结合辅助绕组，屏蔽层等，圈数取决于层线宽，层的厚度以及胶带层数等等



GaN高频电源EMI注意事项

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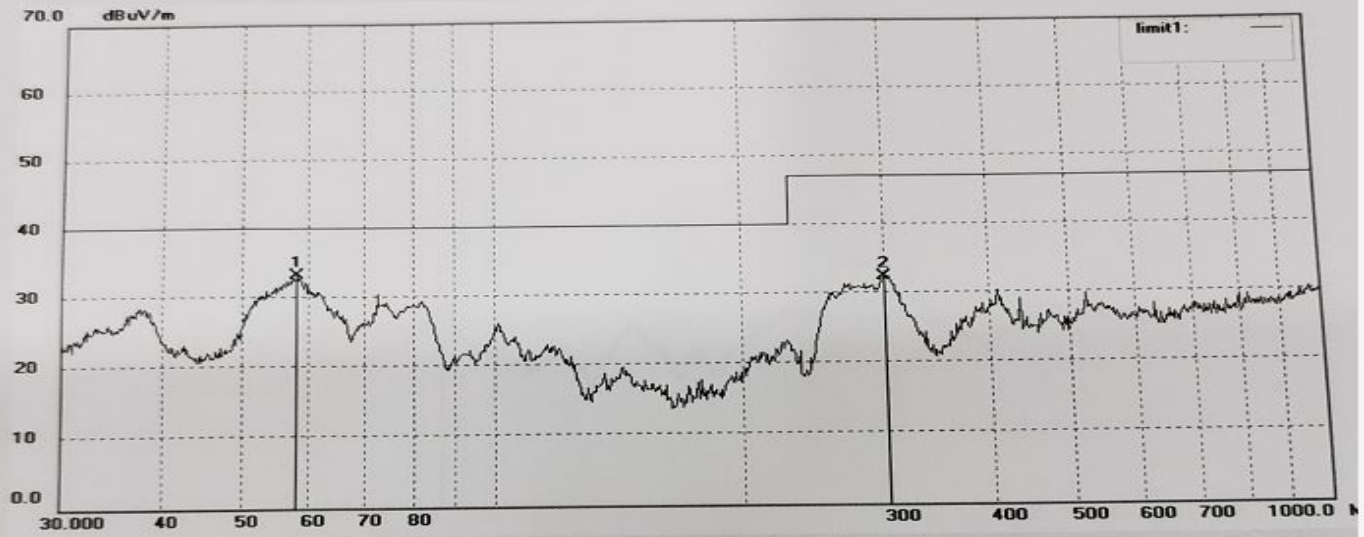
ACCURATE TECHNOLOGY CO., LTD.
F1,Bldg,A,Changyuan New Material Port Keyuan Rd,
Science & Industry Park,Nanshan Shenzhen,P.R.China

Site: 2# Chamb
Tel:+86-0755-26503
Fax:+86-0755-2650

Job No.: NAVITAS #407
Standard: EN55032 CLASS B
Test item: Radiation Test
Temp.(C)/Hum.(%) 23 C / 48 %
EUT:
Mode: FULL LOAD
Model: 100W 20V 5A 2#
Manufacturer:

Polarization: Vertical
Power Source: AC 230V/50Hz
Date: 2019/12/16
Time: 17:04:35
Engineer Signature:
Distance: 3m

Note: 去主Y磁珠 RCD串50R+电融加屏避



No.	Freq. (MHz)	Reading (dBuV/m)	Factor (dB)	Result (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Detector	Height (cm)	Degree (deg.)	Remark
1	58.2030	47.68	-14.59	33.09	40.00	-6.91	peak			
2	300.3672	42.60	-10.29	32.31	47.00	-14.69	peak			

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