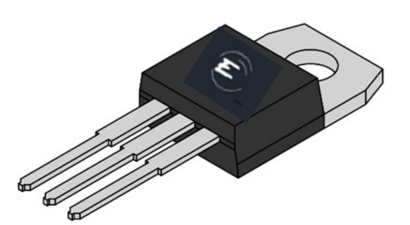
增强型GaN与耗尽型GaN对比



江苏能华微电子科技发展有限公司

Why is GaN?

Comparison of material GaN、SiC and Si：

特性	Si	SiC	GaN	结果
带隙（WBG)能量，E_g(eV)	1.12	3.26	3.39	耐压、耐热和抗噪能力
绝缘击穿电场，E_{crit}(10^6V/cm)	0.23	2.7	3.5	击穿电压能力
饱和漂移速度，V_s(10^7cm/s)	1	2.2	3.3	高频开关能力
电子迁移率，μ_n（cm^2/Vs）	1500	650	2000	导电能力
相对介电常数（ε_r）	11.8	9.7	9	导电能力

GaN power deice features:

- Lower junc. cap
- Lower Rdson per unit area-lower 10 times
- Higher switching capability -100MHz
- Higher junc. temp and Anti noise capability
- Excellent FOM Value-(40-100 times)

Why is GaN?

FOM=Rdson*Area

Legend	
Si MOSFETs	Si super junction MOSFETs
EPC GaN	Transphorm GaN
SiC Transistors	Panasonic GaN
GaN System GaN	CorEnergy GaN
	Inno GaN

Specific On-resistance(Ohm-cm^2) vs. Breakdown Voltage(V): Si limit, Sic limit, GaN limit. Y axis: 0.01, 0.1, 1, 10, 100, 1000; X axis: 10, 100, 1000, 10000.

Why is GaN?

$$R_{on} = \frac{4V_{BR}^2}{\varepsilon_s \mu_n E_{crit}^3}$$

Electron Mobility Comparison：

器件	300KHz	77KHz
GaN HEMT	8000	54000
GaAs FET	4800	6200
Si FET	630	1500

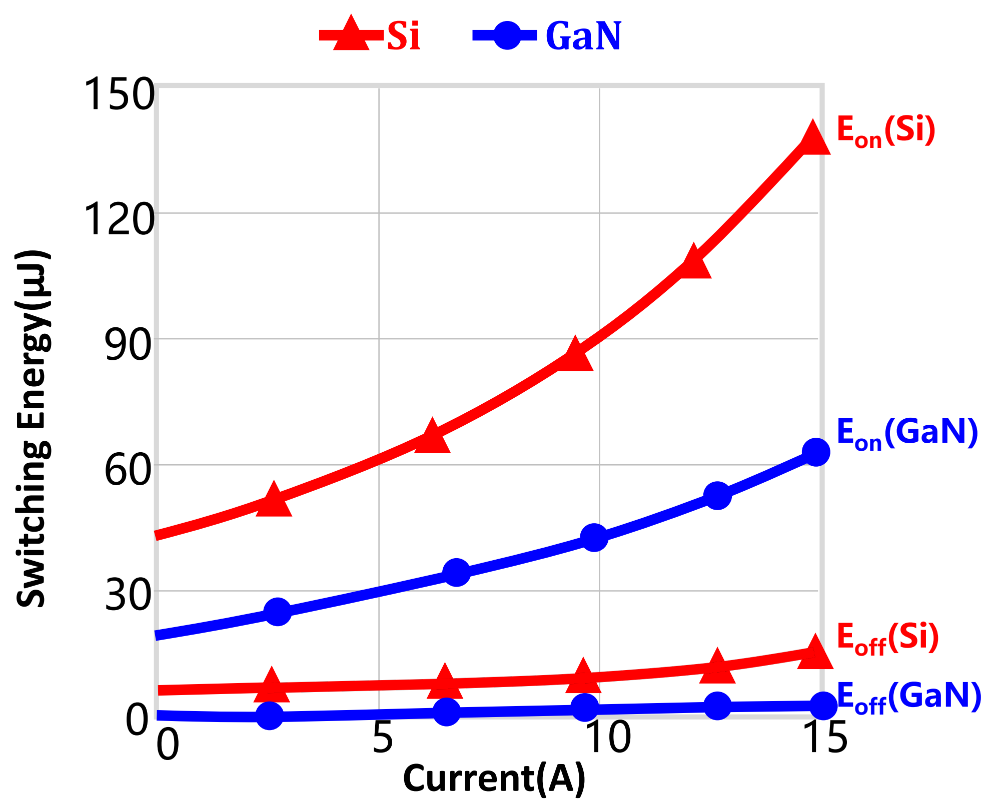
1. 高电子迁移率晶体管也称调制掺杂场效应管，又称二维电子气场，它是利用调制掺杂方法，在异质结界面形成的三角形势阱中的二维电子气作为沟道的场效应晶体管，简称HEMT

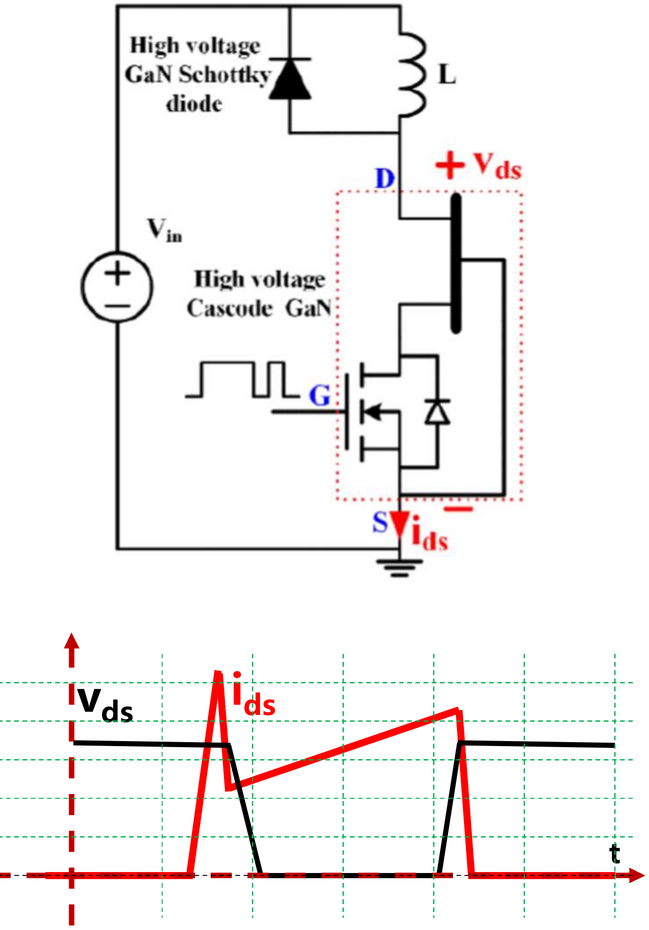
2. 高电子迁移率晶体管（High Electron Mobility Transistor, HEMT），也称为2-DEG场效应晶体管，传讯速度的关键在于电子移动速率快慢，HEMT中的电子迁移率很高，因此器件的跨导大，截止频率高、噪声低、开关速度快

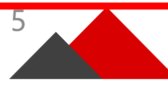
3. HEMT是通过栅极下面的肖特基势垒来控制异质结构中的2-DEG的浓度实现控制电流的，栅电压可以改变三角形势阱的深度和宽度，从而可以改变2-DEG的浓度，所以能控制HEMT的漏极电流C

Why is GaN ?

Switching Loss Comparison



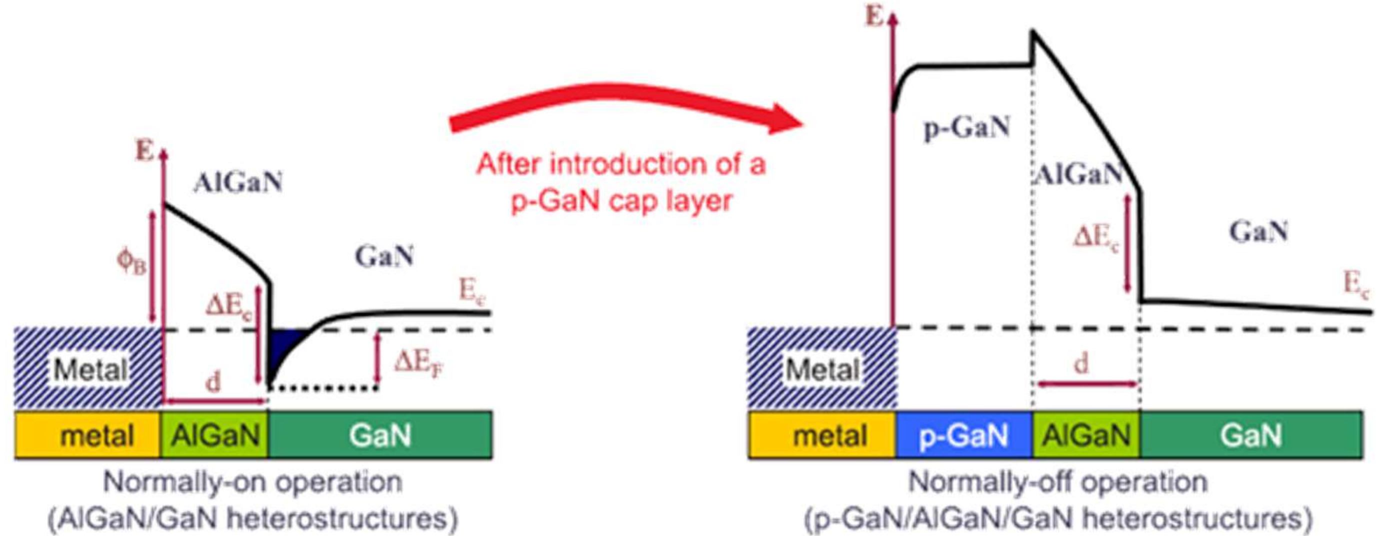


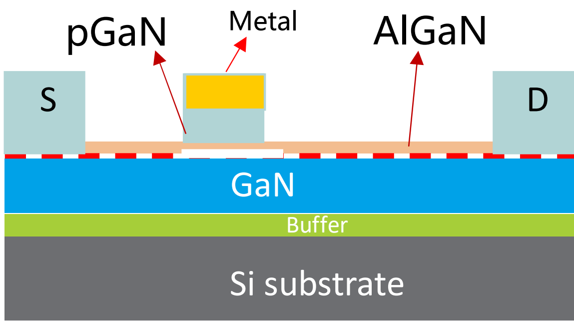


Difference BT. D/E Mode GaN

D Mode GaN

E Mode GaN

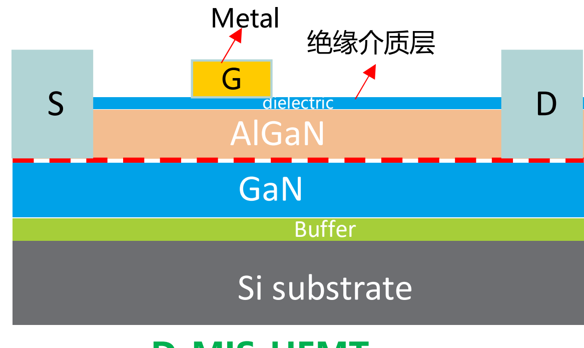




E-mode pGaN Schoktty Contact

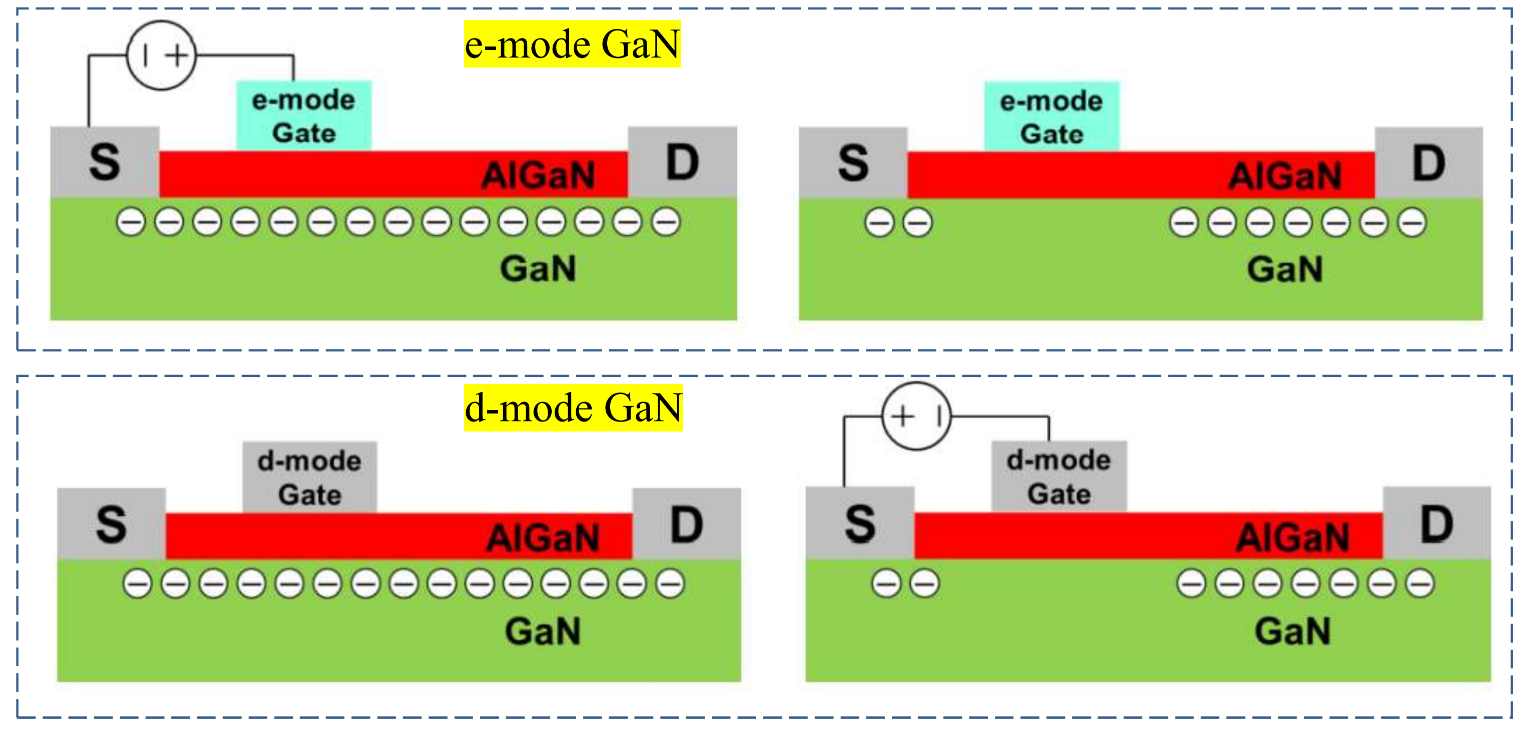
常开型GaN

常闭型GaN



D-MIS-HEMT

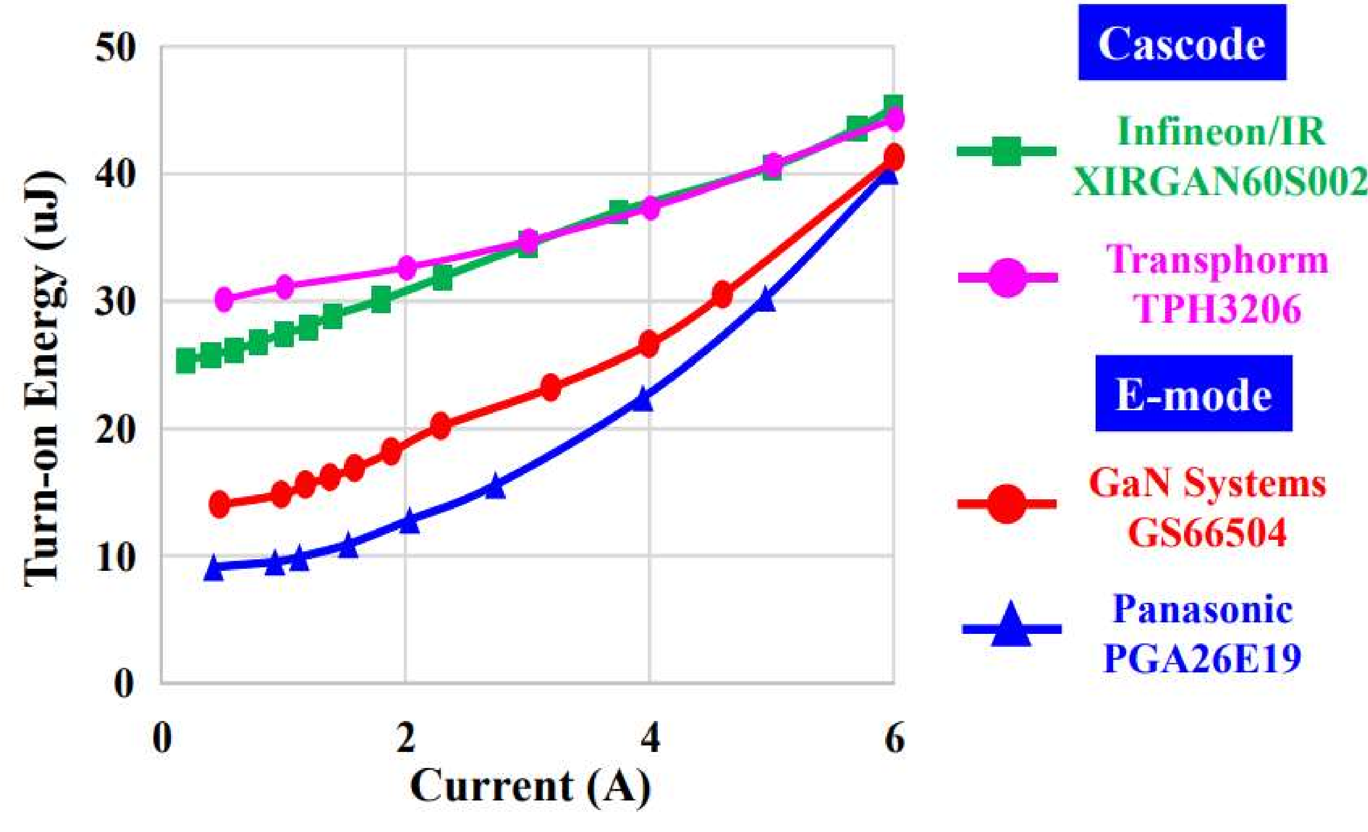
Normally off, Easy to design the startup circuit

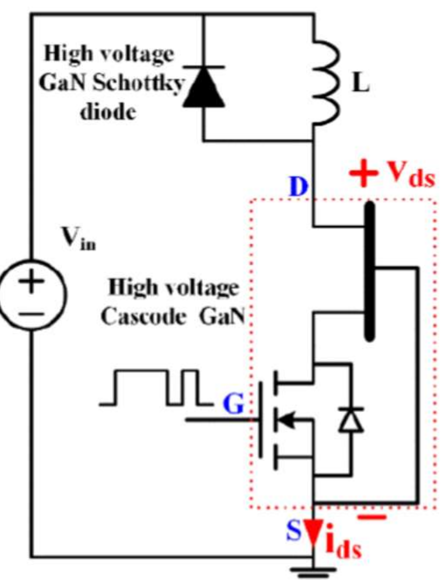


Why is E-mode GaN?

Lower turn-on loss(higher switching speed and no Qrr):

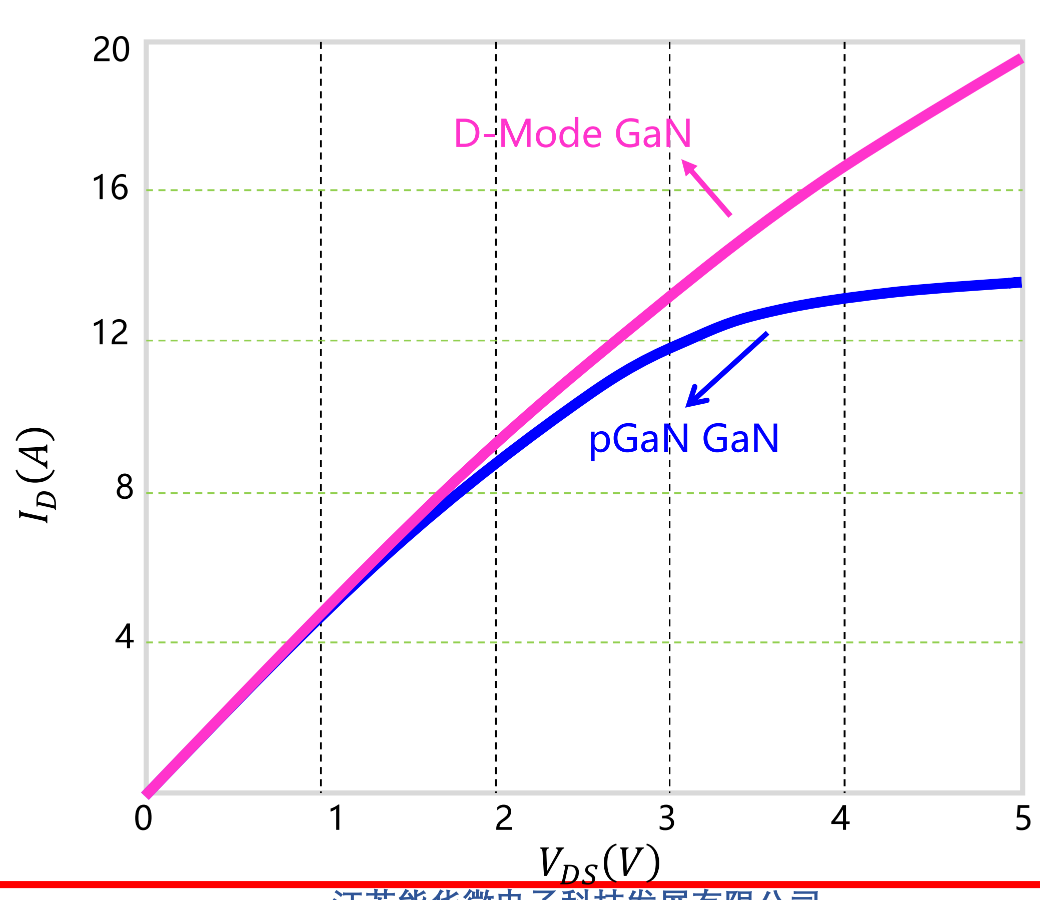
高频特性更优

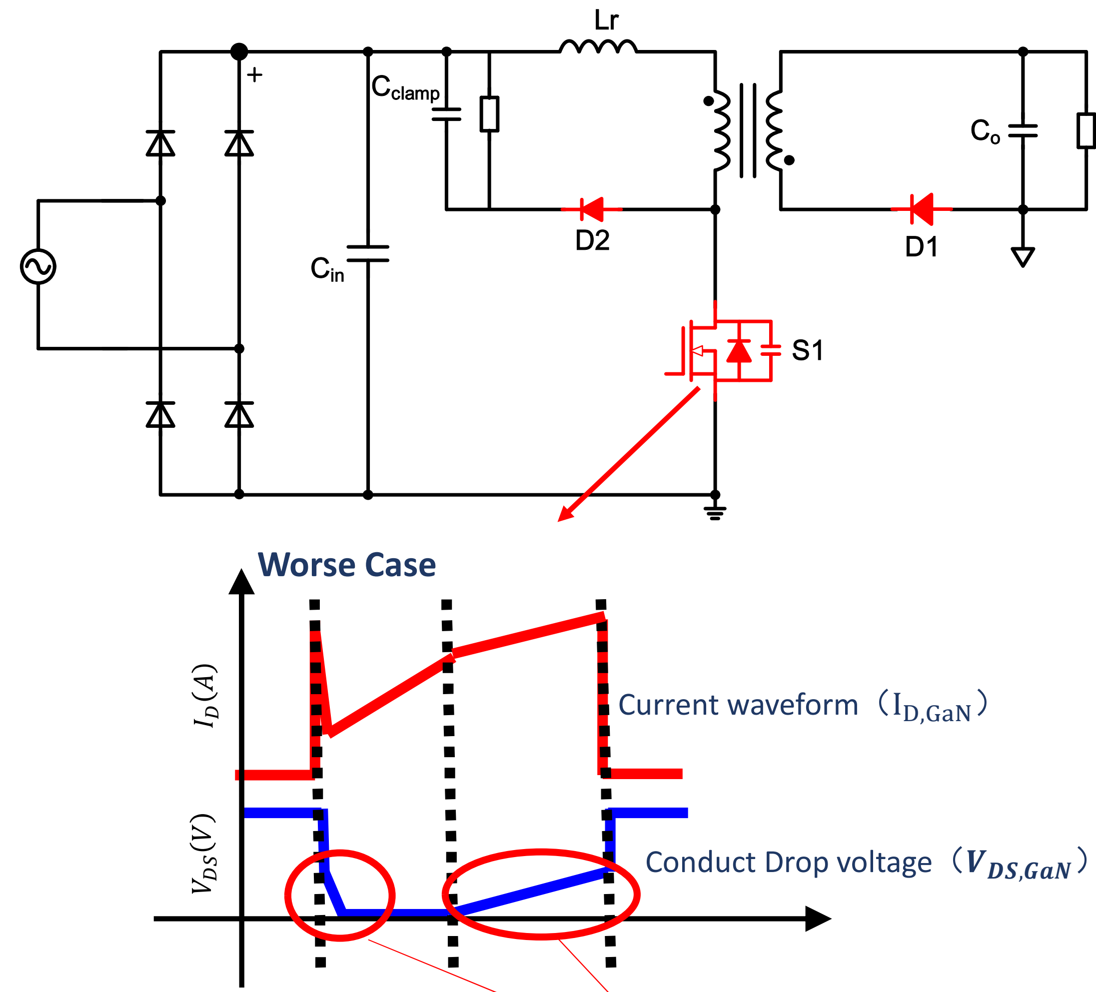




Why is D-mode GaN?

1. Higher Saturation Current:





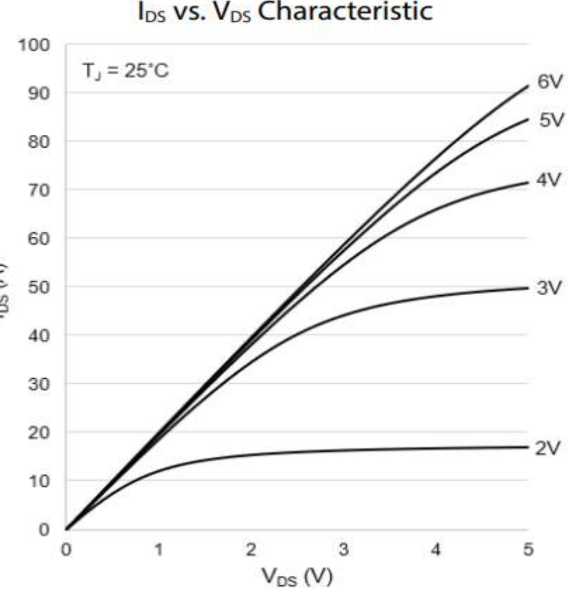
◆ D-GaN has stronger current capacity

Why is D-mode GaN?

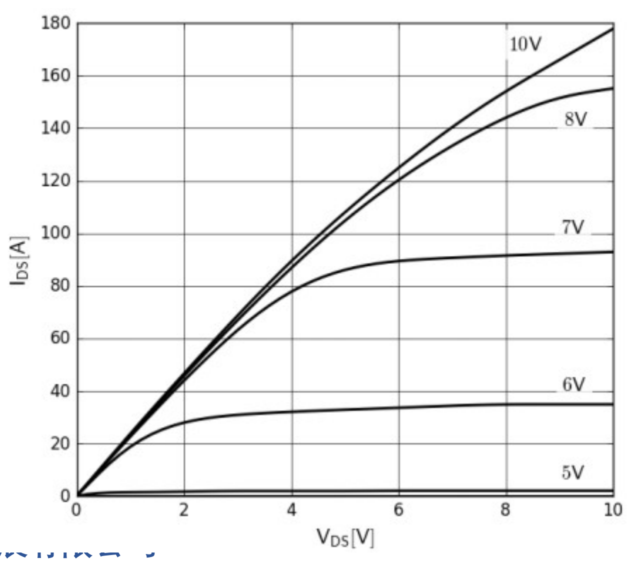
1. Higher Saturation Current：

P/N	Company	E or D Mode?	Rdson	Pulse Current
GS66508B	GaN System	E mode	50m	60A
TP65H050WSQA	Transphorm	D Mode	50m	150A
GAN063-650WSA	Nexperia	D mode	50m	150A

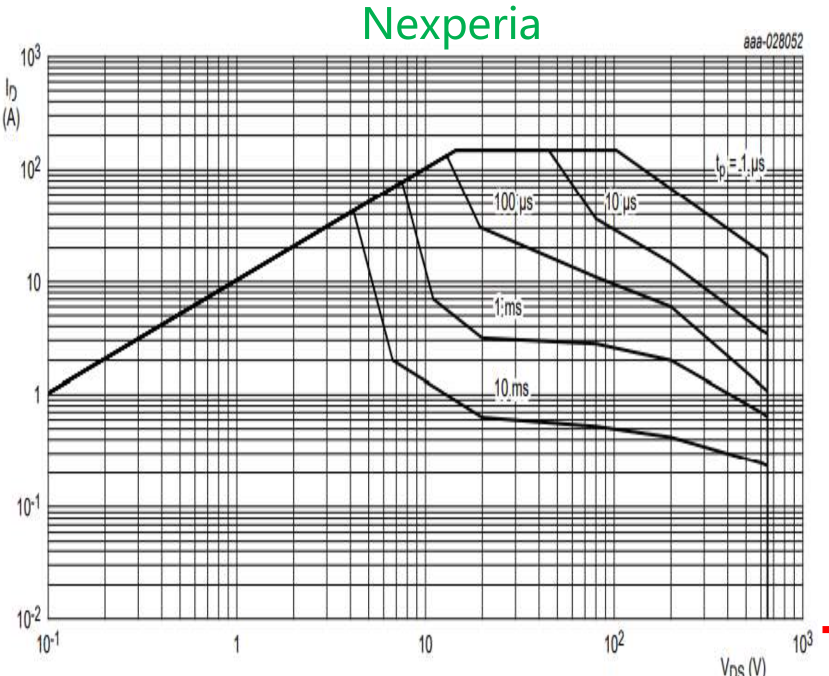
GaN System



Transphorm

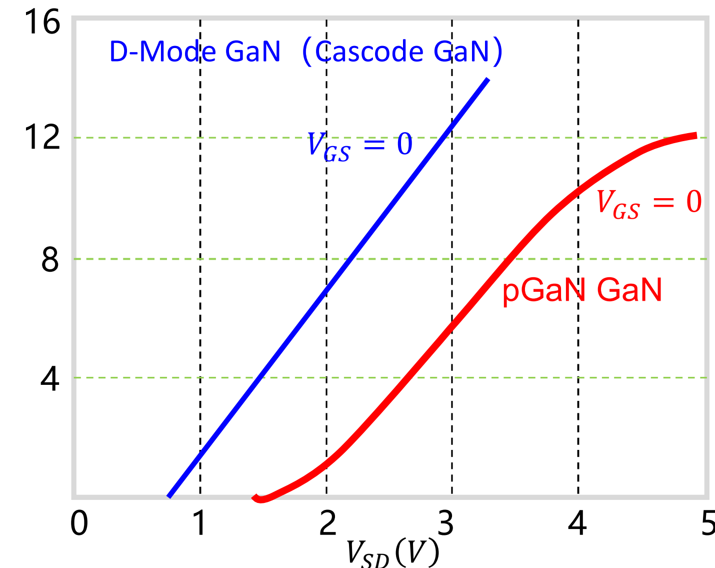


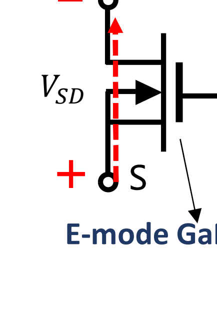
Nexperia

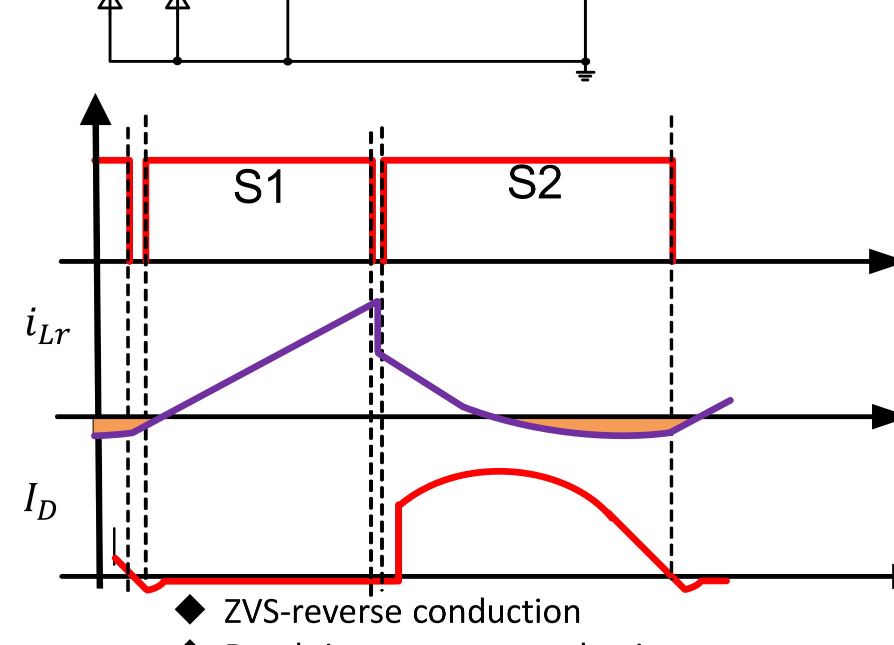


Why is D-mode GaN?

2. Smaller Reverse Conduction Voltage Drop







For E-mode GaN

$$V_{SD} = V_{TH} + I_{SD}/\beta_{SD} - V_{GS}$$

For D-mode GaN(+Si Fet)

$$V_{SD} = V_{D,Si} + I_{SD} \times R_{on}$$

D-mode GaN

D

G

S

V_{SD}

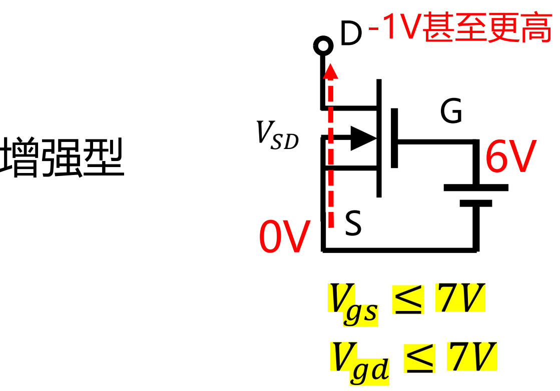
LV Si Mosfet

- ZVS-reverse conduction
- Dead time-reverse conduction
- Sync Rec.-reverse conduction

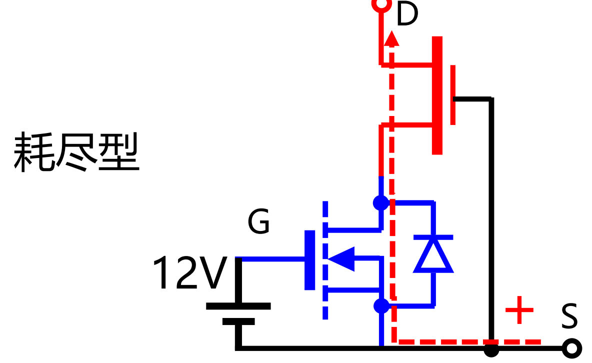
Why is D-mode GaN?

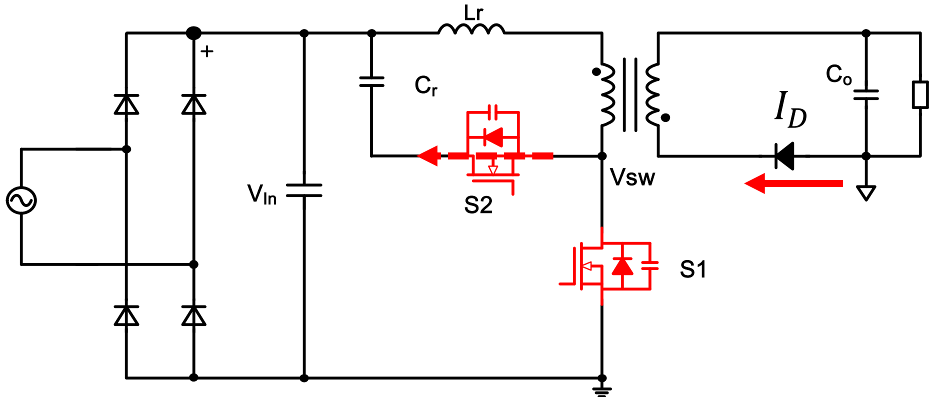
3. Higher Reverse Surge Current Capability

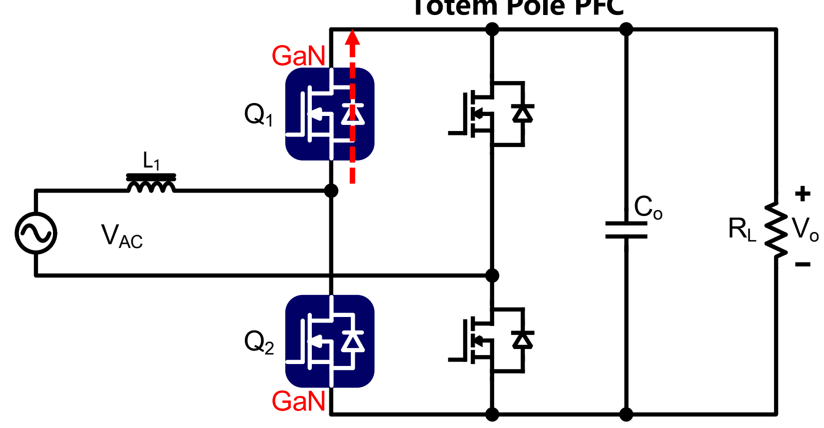
增强型



耗尽型





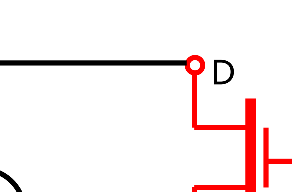


Why is D-mode GaN?

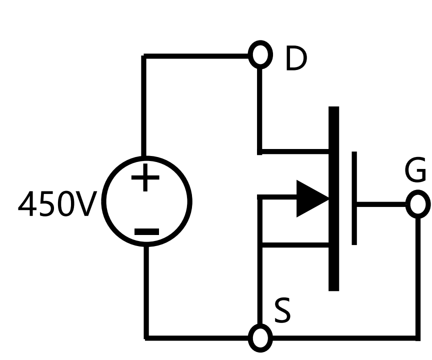
4. Smaller off Leakage Current

注意：漏电流会影响栅极长期可靠性！

D-mode GaN



E-mode GaN



充电头

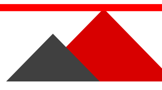
	D-Mode GaN HEMT	E-Mode GaN HEMT
Threshold Voltage(V_{TH})	-12V	2V
Operating Turnoff Voltage	-25V	0V
$V_{GS_OFF} - V_{TH}$	-13V	-2V

外置电源六级能效标准（单输出45W以下）

DoE Level VI（美国VI级）		CoC Tier 2（欧盟VI级）		
Average Eff	Standby loss	Average Eff	Standby loss	Av.Eff@10% load
≤87.59%	≤ 100mW	≤87.59%	≤ 75mW	≤ 77.59%

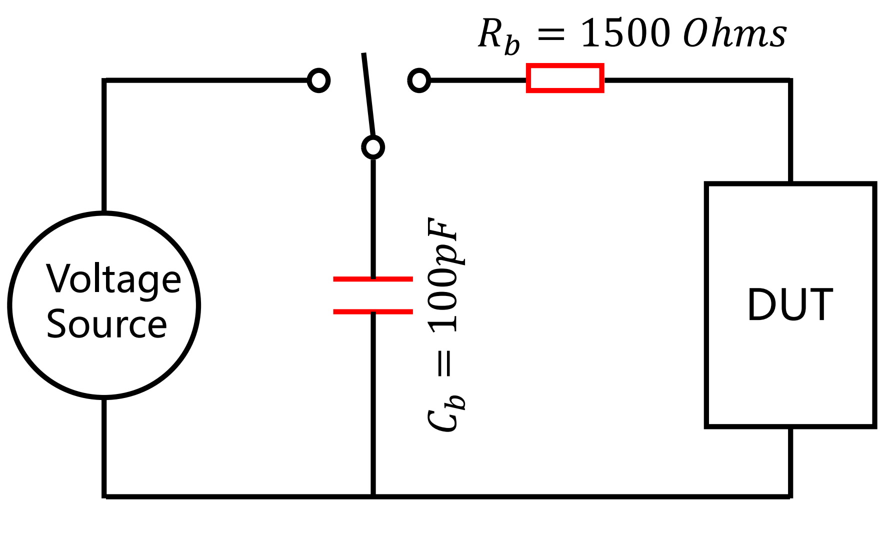
- ◆ 相同工艺下，D Mode GaN关断更深，所以漏电流更小

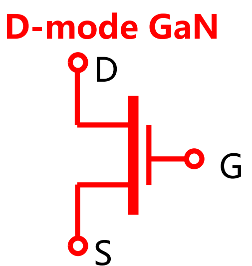
- ◆ 功率器件的漏电流是充电头轻载或待机损耗的重要来源
- ◆ 六级能效标准对充电器空载能耗有要求

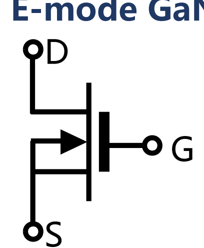


Why is D-mode GaN?

5. Strong ESD Capability







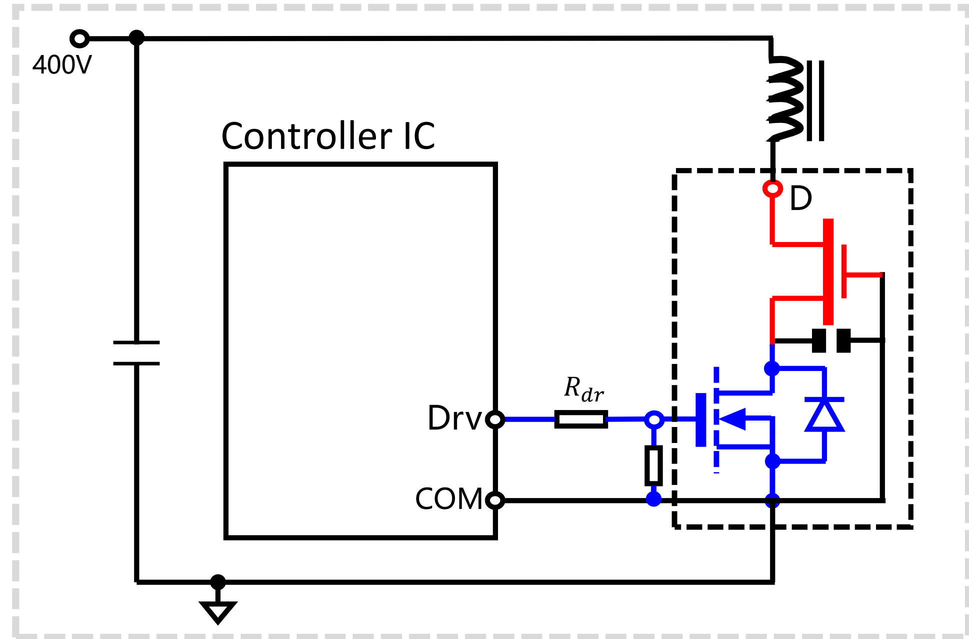
- ◆ HBM人体模型表征人体带电接触器件放电，Rb为等效人体电阻Cb为等效人体电容

- ◆ ESD 加在DS之间，D mode GaN是常开，直接消耗在沟道里；E mode GaN是常关靠DS之间的结电容来吸收这部分能量，所以D mode GaN的DS抗ESD能力比E-mode GaN强

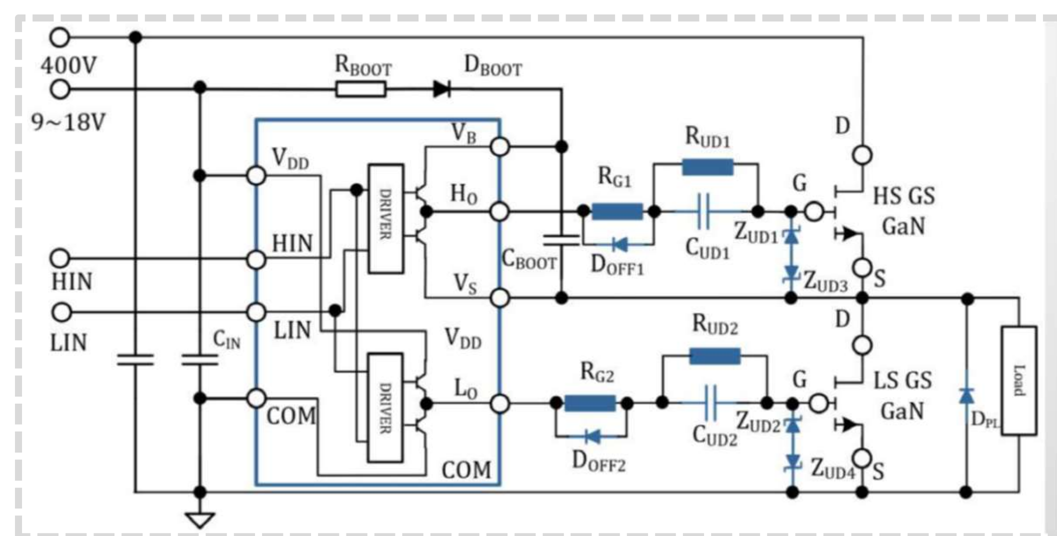
- ◆ ESD加在GS之间，D mode GaN的栅极电压范围比E-mode GaN的栅极电压范围宽，所以D mode GaN的栅极抗ESD能力比E-mode GaN强

6. D-mode GaN HEMT+Low Voltage Si： Compatible with Si MOSFET Driver, easy to drive

Cascode connection



GaN System EZDrive Solution for e mode GaN

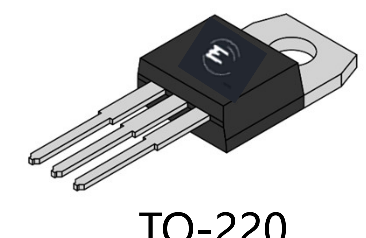


- Compatible with Si and no need special driver IC
- No need to drive clamp circuit
- Wide driving voltage range and high reliability

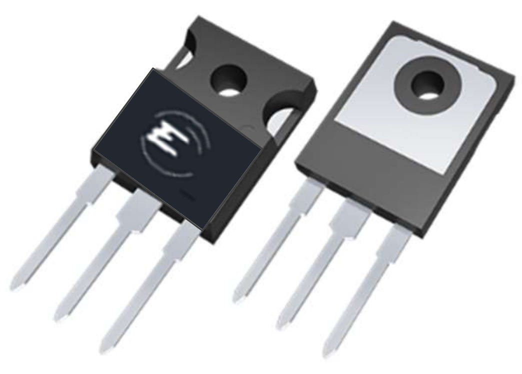
- The driving circuit is complex and too many discrete devices
- The speeding cap is easy to lead to system failure due to false welding
- Not suitable for high frequency drive

Why is D-mode GaN?

7. More packaging styles



TO-220



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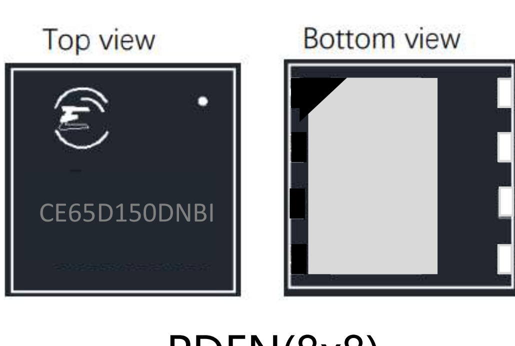
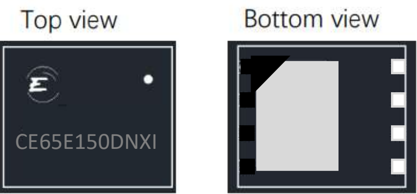


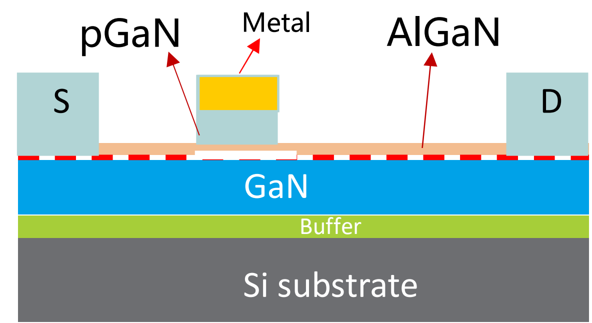
PDFN(8x8)



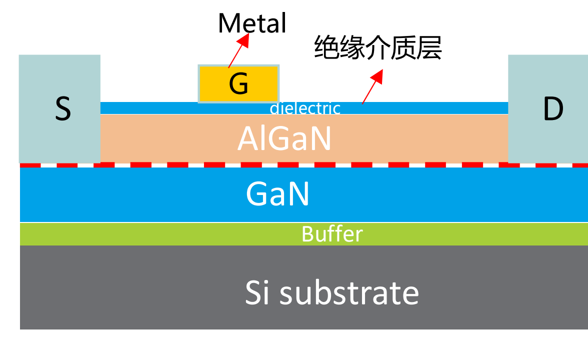
PDFN(5x6)

Why is D-mode GaN?

8. Lower Cost



E-mode pGaN Schoktty Contact



D-MIS-HEMT

- E mode GaN 2DEG lower concentration, higher Rdson per unit area
- D mode GaN 2DEG higher concentration, lower Rdson per unit area
- For the specific Rdson, D mode GaN die has smaller area
- D-mode GaN has lower cost due to smaller die area and no pGaN process