



博通光耦栅极驱动器助力 SiC/GaN 实现安全高效功率转 换器

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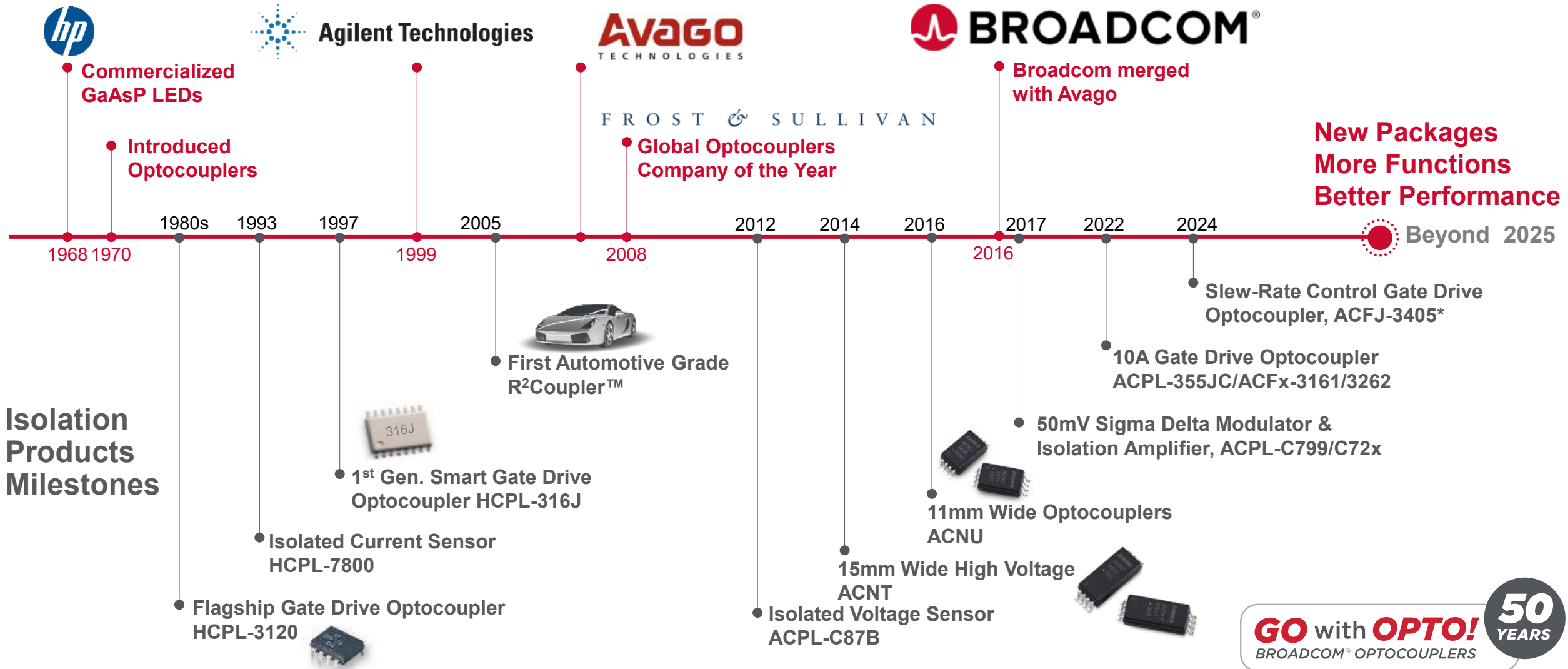


议程 – 驱动SiC和GaN功率器件的Broadcom光耦

- Broadcom光耦简介
- SiC（碳化硅）和GaN（氮化镓）功率开关——特性和优势
- SiC 模块驱动开发板参考设计
- GaN FET半桥评估板
- 带有转换速率控制 (Slew Rate Control) 的门极驱动器
- 问与答



Broadcom 光耦里程碑：50 年制造功力



*ACFJ-3405: Advance information, subject to change.



Broadcom 光耦概述

产品系列

数字光耦 信号隔离

- 数字光耦
(高达50MBd)
- 数字隔离器 (高达100MBd)
- 模拟光耦&特殊功能

栅极驱动器 功率器件栅极驱动

- IPM接口
- IGBT/MOSFET栅极驱动器
- 智能栅极驱动器
- 基本栅极驱动器

隔离放大器 电流/电压感测

- 隔离的ADC
- 模拟输出隔离放大器

细分市场

工业

IEC/EN/DIN EN 60747-5-5
UL 1577
CSA

汽车

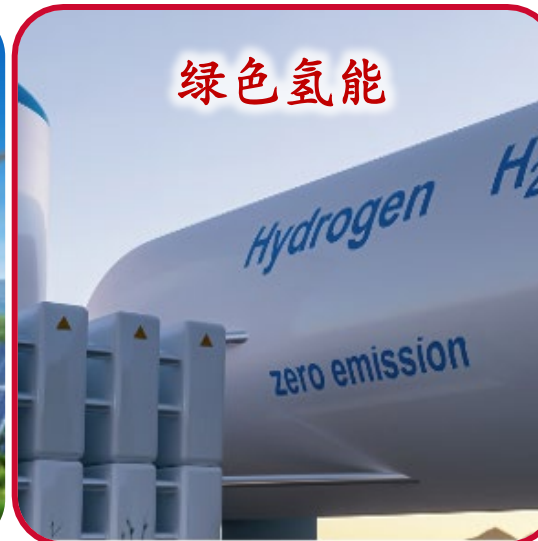
AEC-Q100认证

密封光耦

军规MIL-PRF-38534 认证



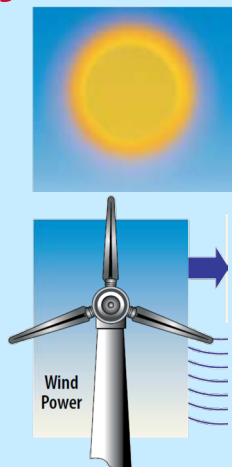
满足各种工业应用需求的栅极驱动光耦



绿色能源产业 – 光耦助力低碳转型

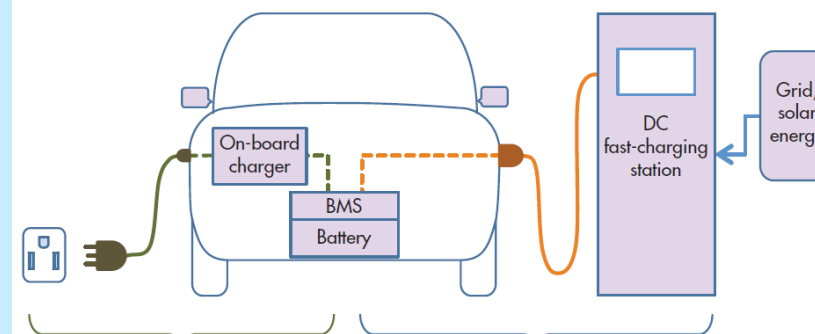
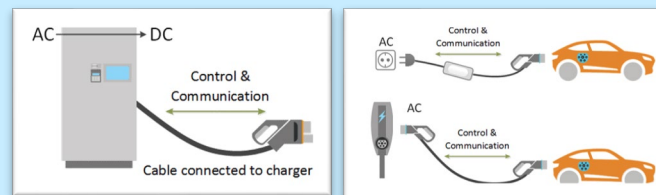
Renewable Energy Inverters

- Solar Inverters
 - Micro Inverter
 - String Inverter
 - Central Inverter
- Wind Turbines



EV Chargers

- DC Fast Chargers
- AC Wall Boxes, In-Cable Control & Protection Devices (IC-CPD)



- AC charging
- Every vehicle has an on-board charger.
 - Limited power, slow charging.

- DC charging
- Infrastructure investment is shared among hundreds of users.
 - Large power rating, fast charging.
 - Capable of integration with renewable resources.

Energy Storage System

- Battery Management System
- Power Conversion System
 - AC/DC, DC/AC conversion
 - Could also be EV chargers (V2H), PV inverters



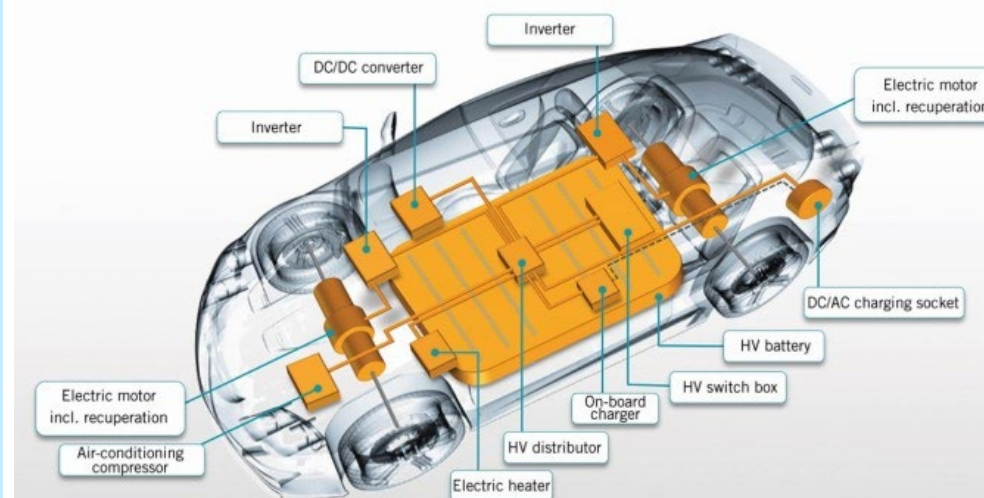
Grid



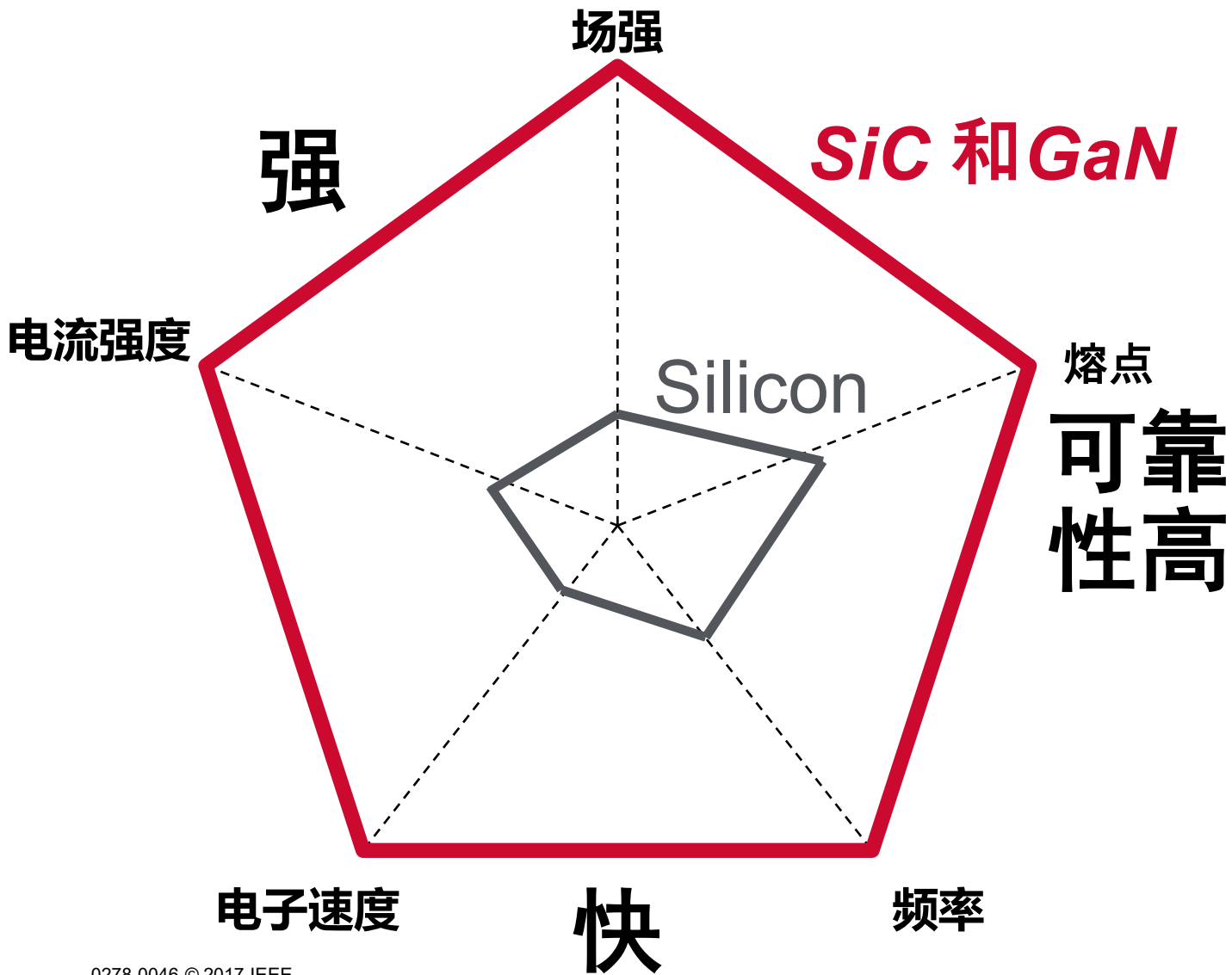
Residential

Electric Vehicles

- Motor Inverters
- OBC / BMS
- DC-DC, A/C, Heaters, Other auxiliaries



SiC和GaN功率开关——特性和优势



更紧凑、小巧、高效
成本效益高

Silicon
Power Switch



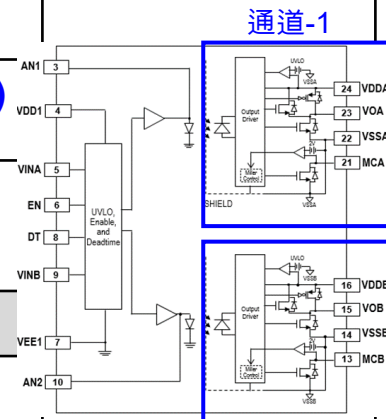
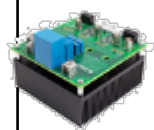








SiC/GaN
Power
Switch



INVERTERS & DRIVES



适用于SiC/GaN的博通栅极驱动器

栅极驱动器		第一代 < 5A (2018年)		第二代 10A (2022)		第三代, 高速 (2023起)	
		基本	智能	基本	智能	基本	
		ACPL-P/W346 ACPL-P/W349	ACPL-352J	ACFL-3161 (1-CH) ACFJ-3262 (2-CH)	ACPL-355JC	ACFJ-332B (2-通道)	
峰值输出电流	典型	~4A	~7A	10A	10A	4A (典型)	
	最小	2.5A	5A	6A	7.5A		
传播延迟		120ns (最大)	150ns (最大)	95ns (最大)	150ns 最大)	65ns (最大)	
上升/下降时间		8ns (典型)	37ns (典型)	7ns (典型)	37ns (典型)	10ns (典型)	
CMTI		>100kV/μs	>100kV/μs	>100kV/μs	>100kV/μs	>150kV/μs	
参考设计		https://www.broadcom.com/products/optocouplers/reference-designs					
		 <p>半桥评估套件 第2代SiC KIT8020-CRD-8FF1217P-1</p>	 <p>150V, 5A斩波器板 X-GaN™</p>	 <p>半桥评估套件 650V/60A GaN晶体管 GAN039-650NBB</p>	 <p>Dual1B/FM3 1200V SiC驱动器板 FF11MR12W1M1 FF23MR12W1M1 CAB011M12FM3 CAB016M12FM3</p>	 <p>扫描二维码, 查看 参考设计详细信息</p> <p>https://www.broadcom.com/products/optocouplers/reference-designs</p>	
		 <p>半桥 评估板 GaN E-HEMT GS66516T-EVBDB2 GS66508T-EVBDB2</p>	 <p>三相SiC 栅极驱动器板</p>	 <p>1200V TO247 SiC MOSFET SCTWA70N120G2V4 C3M0021120K</p>	 <p>62mm 1200V/300A FF2MR12KM1 FF3MR12KM1 FF6MR12KM1 WAB300M12BM3 WAB400M12BM3</p>		



ACFL-3161/ACFJ-3262 10A 单通道和双通道栅极驱动光耦

ACFL-3161 – 10A IGBT/SiC Gate Drive (Single)

Released!

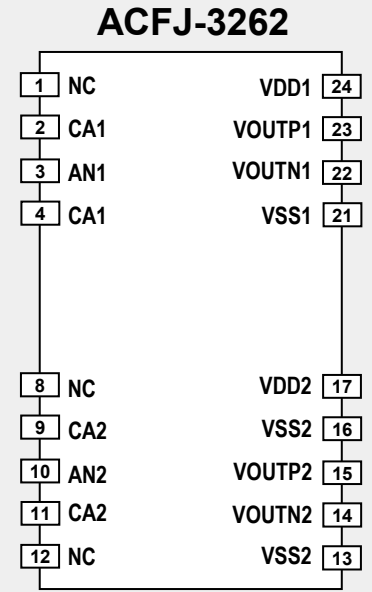
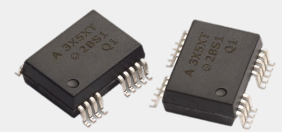


Features

- **10A_{pk}** typ, 6A_{pk} min rail-to-rail output
- **Single channel** in SO-12 package
- R_{DS,OH} 1.3Ω max; R_{DS,OL} 1.2Ω max.
- **Separate source and sink** outputs
- **95 ns max. propagation delay**
- 500kHz operation
- **CMR >100 kV/μs** min @V_{CM}=1000V
- **13.6V UVLO with hysteresis**
- Wide Oper. V_{DD} Range: 15 to 30V
- Industrial temp. : **-40 °C to 125°C**
- **CTI>600V**
- Safety Approval
 - UL Recognized 5000 V_{RMS} / 1min.
 - CSA
 - IEC/EN 60747-5-5 V_{IORM} = 1,230V_{pk}

ACFJ-3262 – 10A GaN/Power MOSFET GD (Dual)

Released!



Features

- **10A_{pk}** typ, 6A_{pk} min rail-to-rail output
- **Dual Channel** in SO-24 package
- >2.8mm channel-to-channel separation
- R_{DS,OH} 1.3Ω max; R_{DS,OL} 1.2Ω max.
- **Separate source and sink** outputs
- **95 ns max. propagation delay**
- 500kHz operation
- **CMR >100 kV/μs** min @V_{CM}=1000V
- **8.6V UVLO with hysteresis**
- Wide Oper. V_{DD} Range: 10 to 25 V
- Industrial temp. : **-40 °C to 125° C**
- **CTI>600V**
- Safety Approval Pending
 - UL Recognized 5000 V_{RMS} for 1min.
 - CSA
 - IEC/EN 60747-5-5 V_{IORM} = 1,230V_{pk}



ACPL-355JC – 10A 带保护栅极驱动光耦

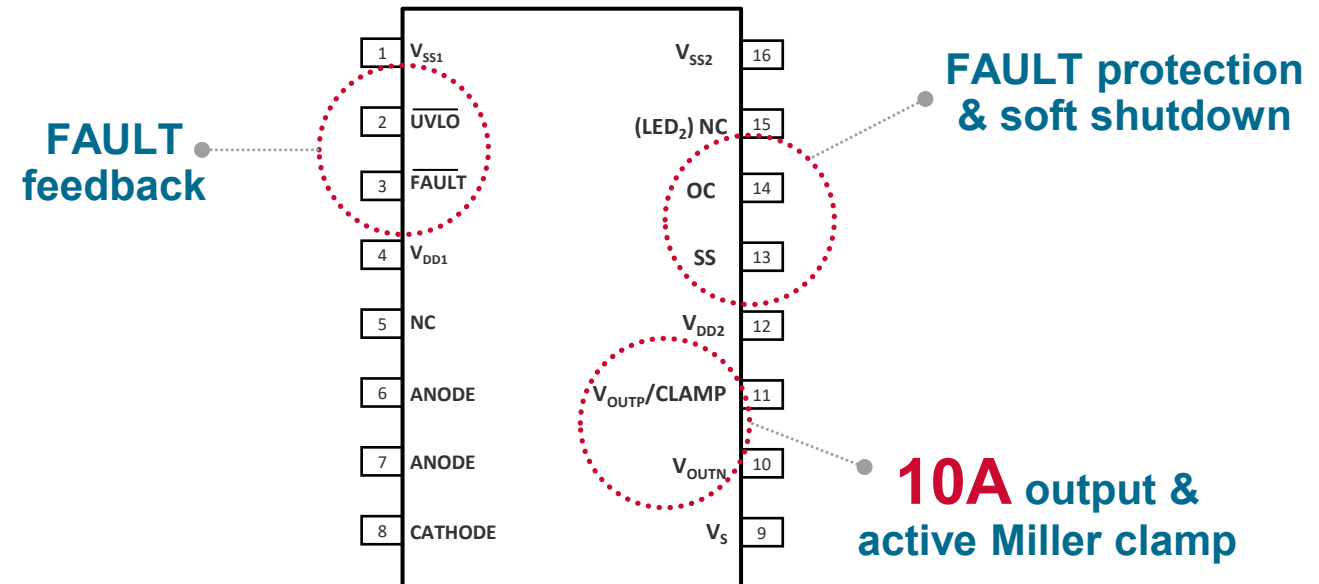
Features

- **10A peak** typical, peak output current
- **CTI > 600V**, material **Group I** package
- $V_{IORM} = 2262V_{PEAK}$ continuous working voltage
- Over current **FAULT protection & feedback**
- UVLO FAULT protection & feedback
- Adjustable **soft shutdown** during FAULT
- Integrated **active Miller clamp**
- Noise immunity, **CMR > 100 kV/μs**
- **150 ns max.** propagation delay
- **WW Safety Approval**
 - UL/cUL Recognized 5000 V_{RMS} for 1min.
 - IEC/EN/DIN EN 60747-5-5 $V_{IORM} = 2262 V_{PEAK}$

Applications

- Mid-Voltage Motor Drives (**IEC 61800-5-1**)
- 1500V PV Inverter (**IEC 62109-1**)
- Static Var Generator (SVG) / High Voltage Converter (HVC) (**IEC 61439-2**)
- Driving IGBT and SiC power switches

Pin-out & Functions



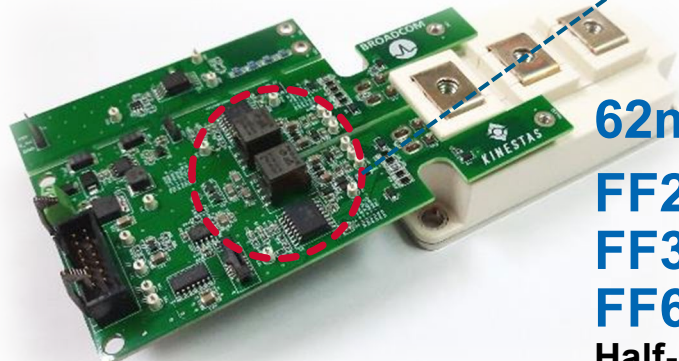
ACPL-355JC - SiC 模块参考设计



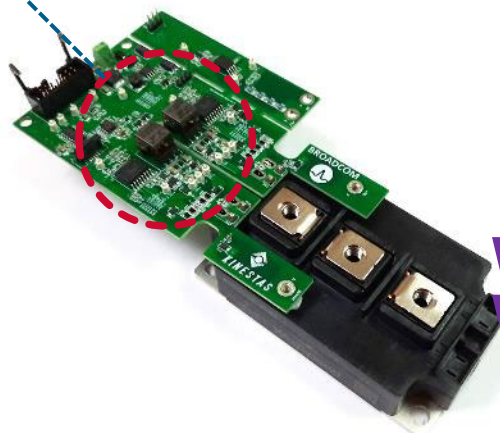
Dual 1B Module
FF23MR12W1M1_B11
FF11MR12W1M1_B11
Half-Bridge SiC Module
1200V 50-100A



FM3 Module
CAB011M12FM3
CAB016M12FM3
Half-Bridge SiC Module
1200V 78-105A



62mm Module
FF2MR12KM1
FF3MR12KM1
FF6MR12KM1
Half-Bridge SiC Module
1200V 250-500A

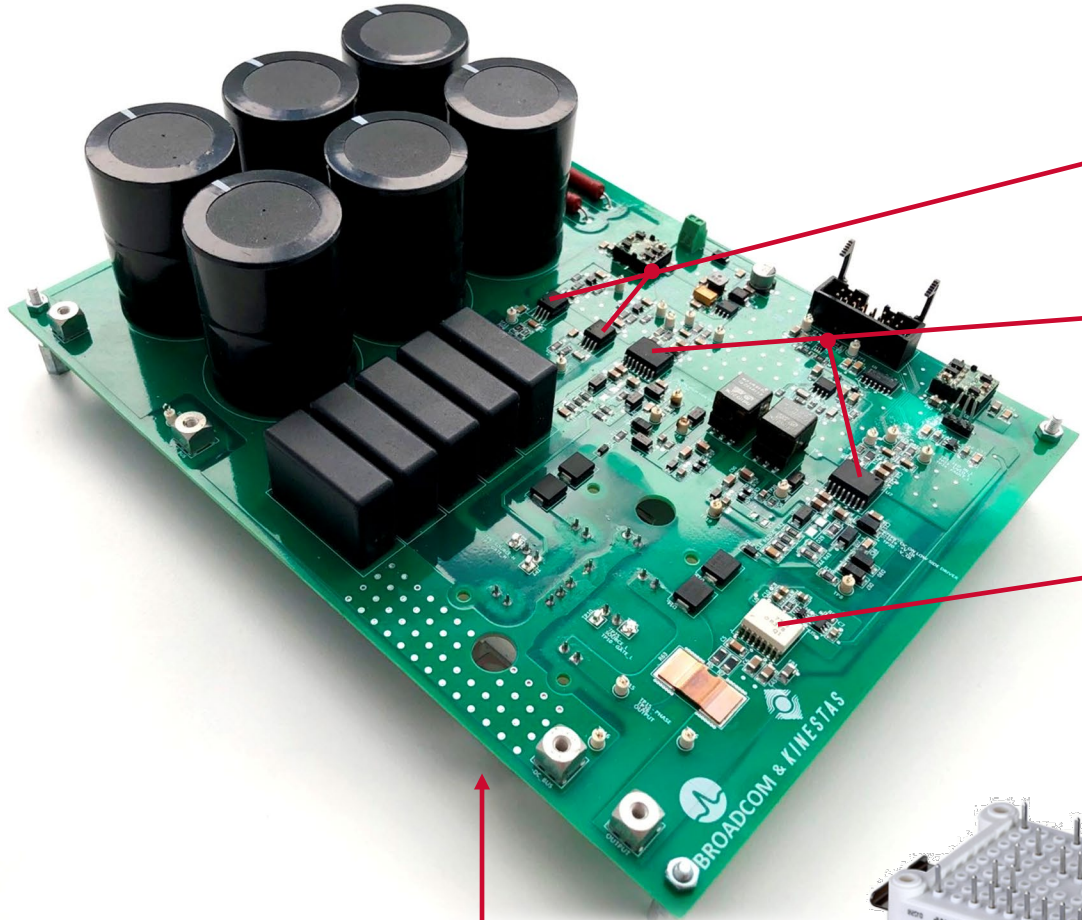


62mm Module
WAB300M12BM3
WAB400M12BM3
Half-Bridge SiC Module
1200V 300-400A

ACPL-355JC
10A Gate Drive Optocouplers
with Short Circuit Protection



SiC DUAL 模块驱动板



ACPL-C87B
Isolated Voltage Sensor for IGBT thermistor sensing and BUS voltage sensing

ACPL-355JC
10A Gate Drive Optocouplers with Short Circuit Protection

ACPL-736J
 $\pm 50\text{mV}$ external clocked Isolated Sigma-Delta Modulator for current sensing



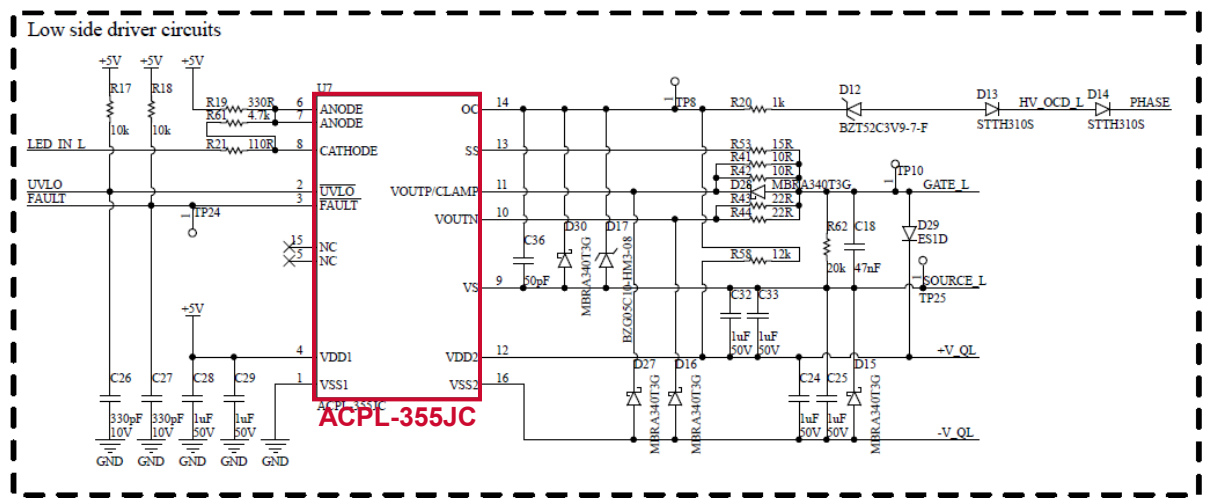
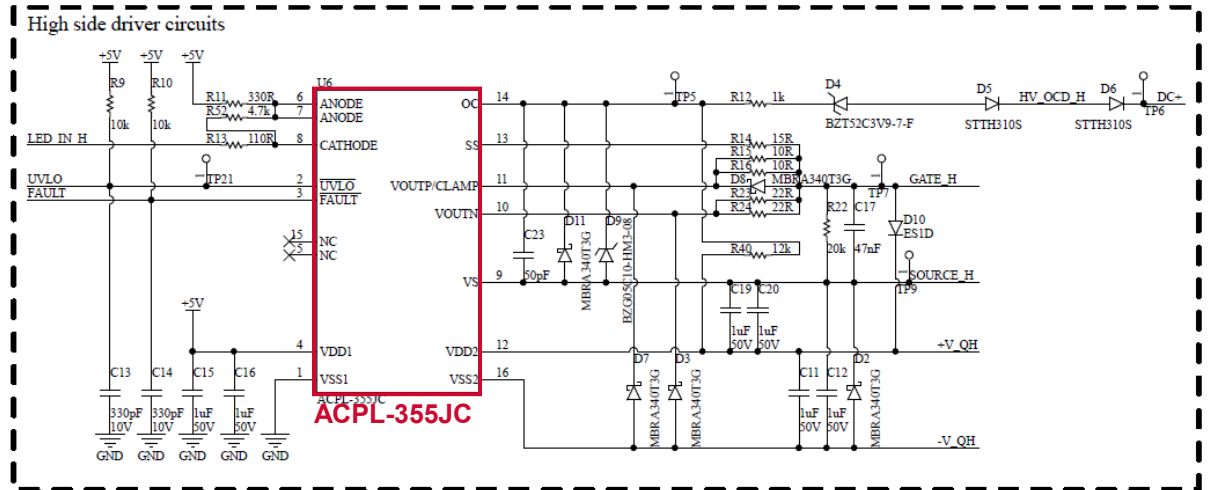
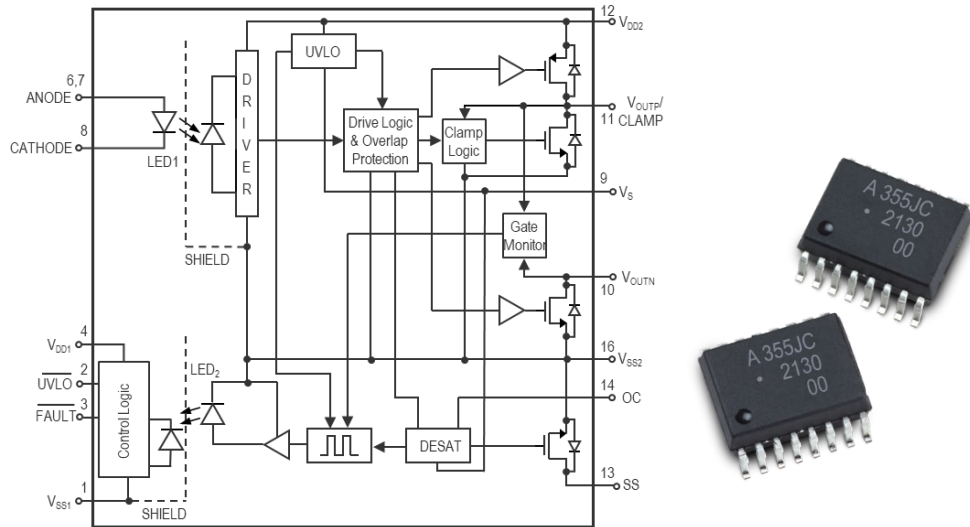
FF23MR12W1M1_B11
FF11MR12W1M1_B11
Module
1200V 50-100A



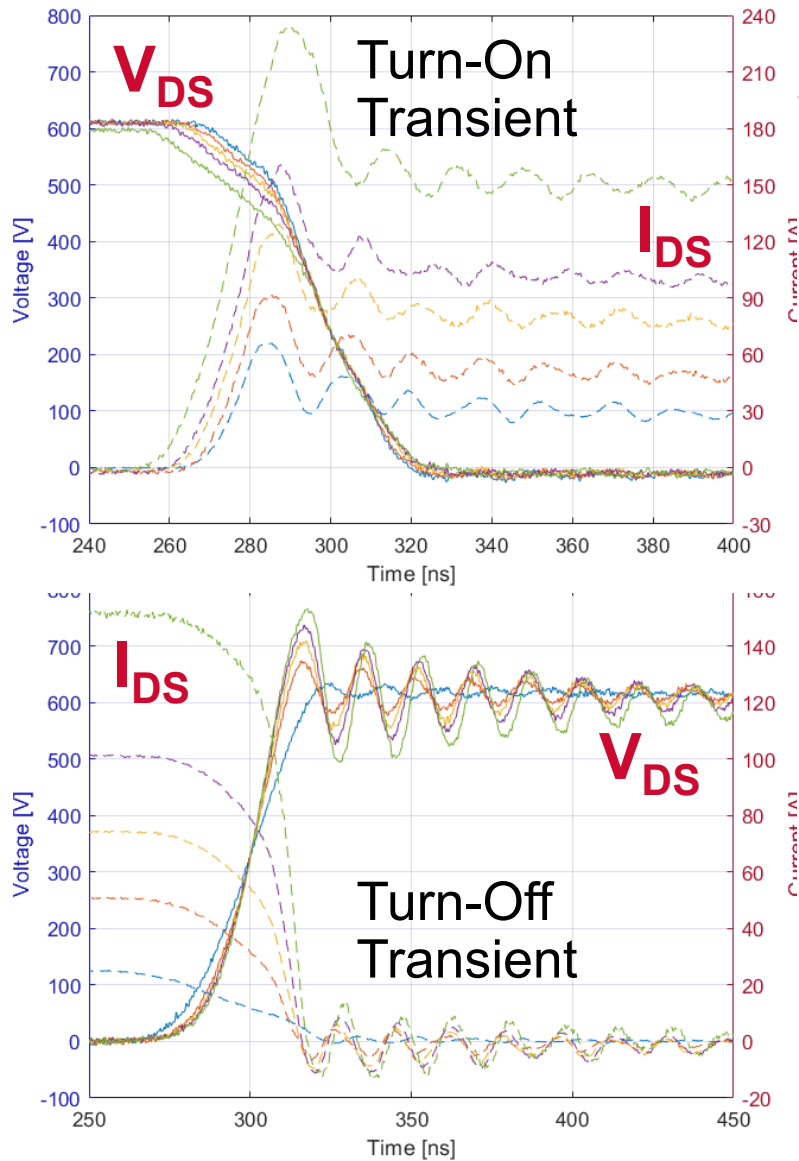
SiC 驱动板 – ACPL-355JC智能门极驱动器

Features

- **10A** peak output current
- $V_{IORM} = 2262V_{PEAK}$ working voltage
- **CTI > 600V, Material Group I** Package
- Short Circuit Protection with Feedback
- Noise Immunity, $dv/dt > 100kV/\mu s$

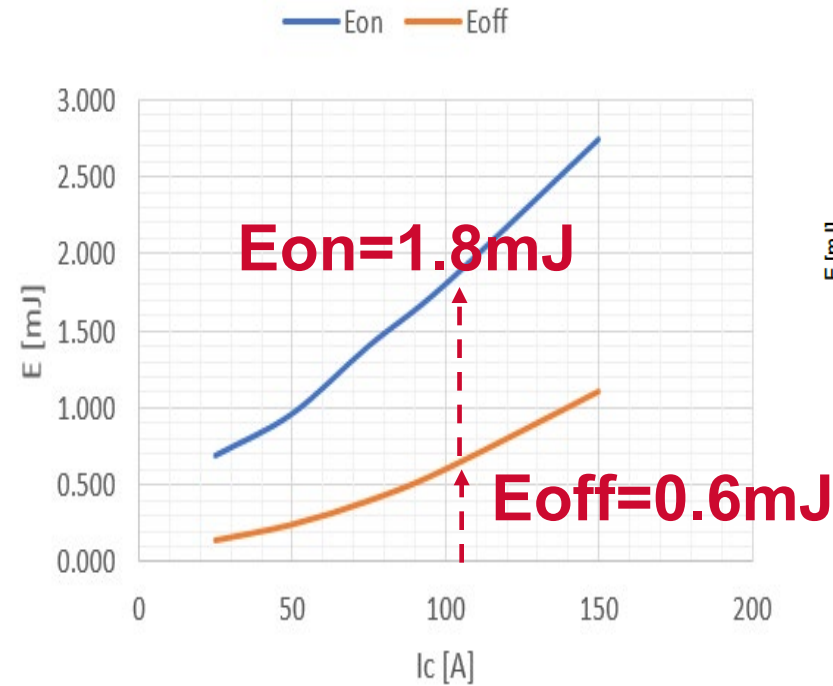


SiC 驱动板 – SiC开关性能



Board Measurements

Eon & Eoff
 @600Vdc, $R_{g_on_off} = 5\Omega, 25^\circ\text{C}$

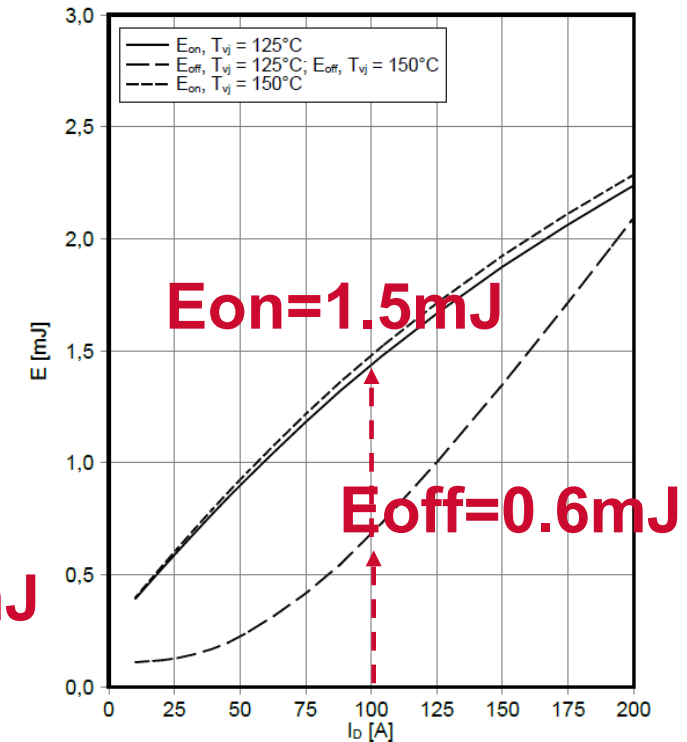


SiC Datasheet

switching losses MOSFET (typical)

$$E_{on} = f(I_D), E_{off} = f(I_D)$$

$V_{GS} = -5\text{ V} / 15\text{ V}, R_{Gon} = 3,9\ \Omega, R_{Goff} = 3,9\ \Omega, V_{DS} = 600\text{ V}$

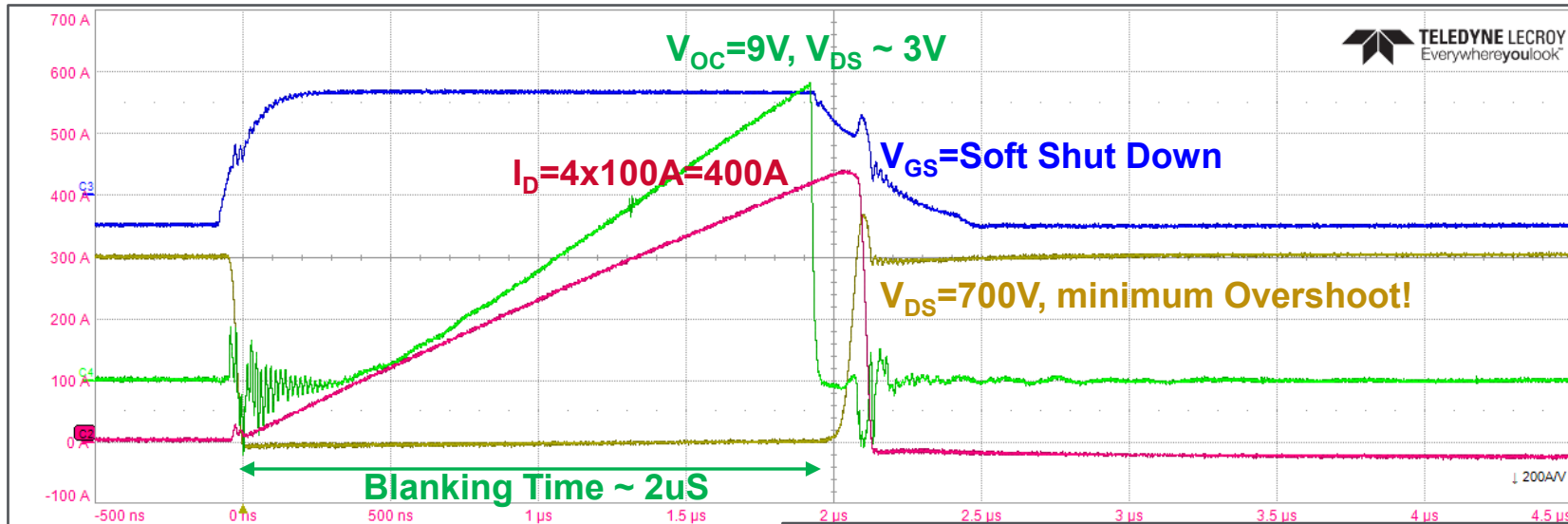


FF11MR12W1M1_B11

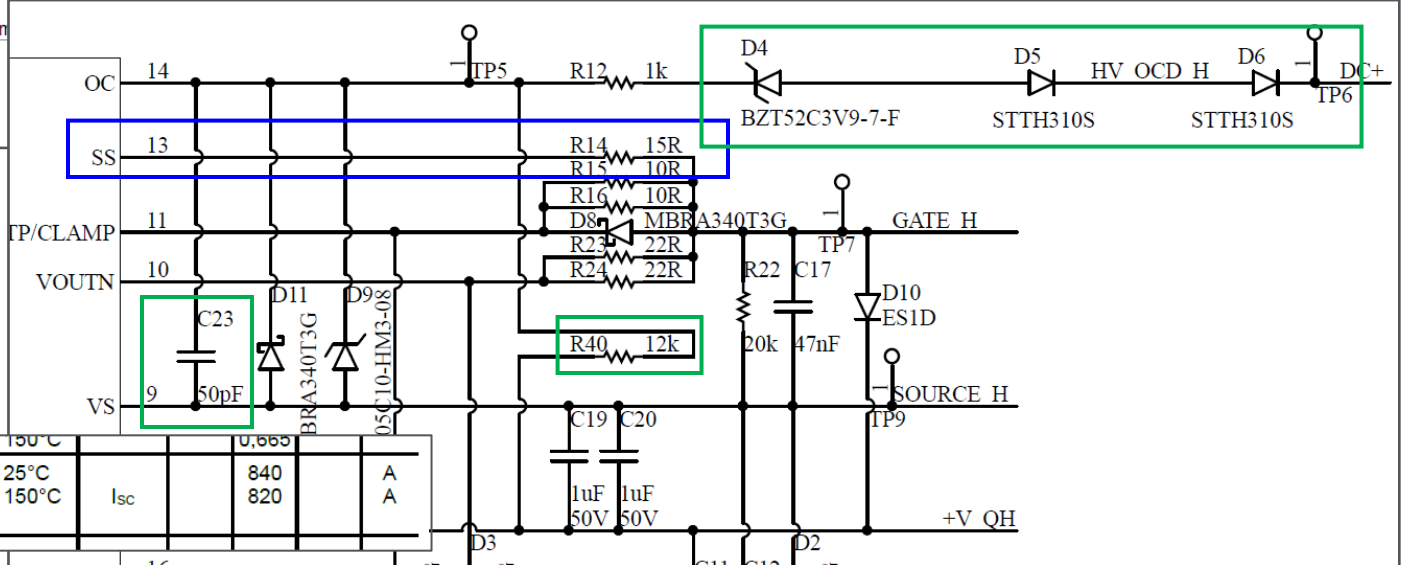
Datasheet 1200V/100A



SiC 驱动板 – SiC 短路测试



StdVer	P1:pkpk(C2)	P2:amp(C2)	P3:max(C2)	P4:min(C2)	P5:sdev(C2)	P6:m
value	468 A	468 A	441 A	-28 A	149.7 A	
status	✓	✓	✓	✓	✓	✓
C1: SINK(DCTM)	C2: SINK(DCTM)	C3: SINK(DCTM)	C4: SINK(DCTM)			
200 V/div	100 A/div	10.0 V/div	2.00 V/div			
-600.0 V	-300.0 A	10.00 V	-4.000 V			



FF11MR12W1M1_B11
Datasheet 1200V/100A

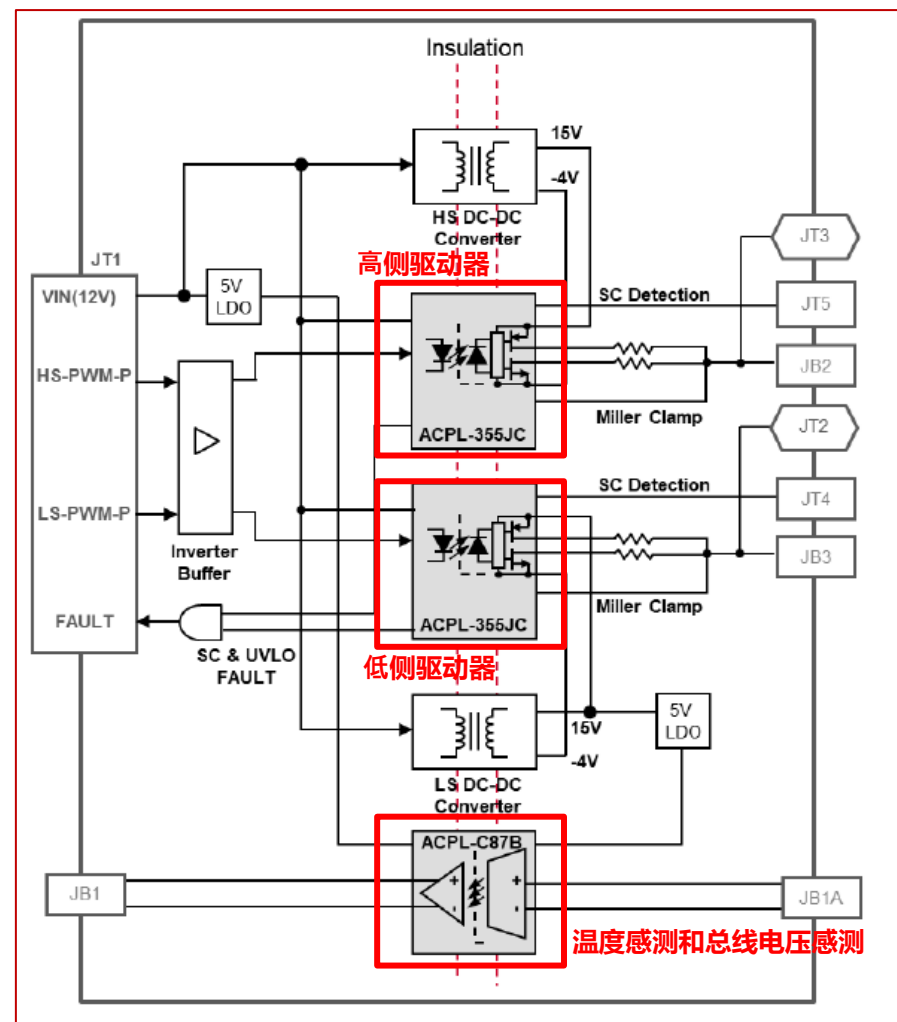
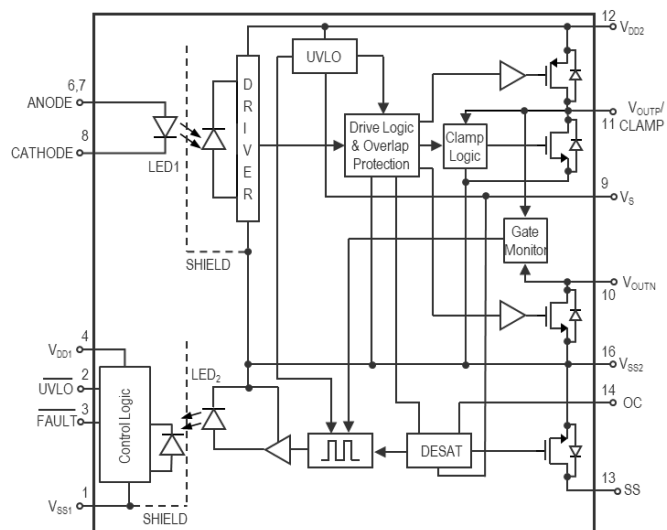
	$V_{GS} = -5 V / 15 V, R_{Goff} = 3,90 \Omega$	$I_{vj} = 150 A$	0,665
Kurzschlussverhalten SC data	$V_{GS} = -5 V / 15 V, V_{DD} = 800 V$ $V_{DSmax} = V_{DSS} - L_{dS} \cdot di/dt$ $R_G = 10,0 \Omega$	$t_p \leq 2 \mu s, T_{vj} = 25^\circ C$ $t_p \leq 2 \mu s, T_{vj} = 150^\circ C$	Isc
			840 820
			A A



FM3驱动器板-ACPL-355JC智能栅极驱动器

特性

- **10A**峰值输出电流
- $V_{IORM} = 2,262V_{PEAK}$ 工作电压
- **CTI > 600V, Material Group I** 封装
- 带反馈的短路保护
- 抗扰性, $dv/dt > 100kV/\mu s$

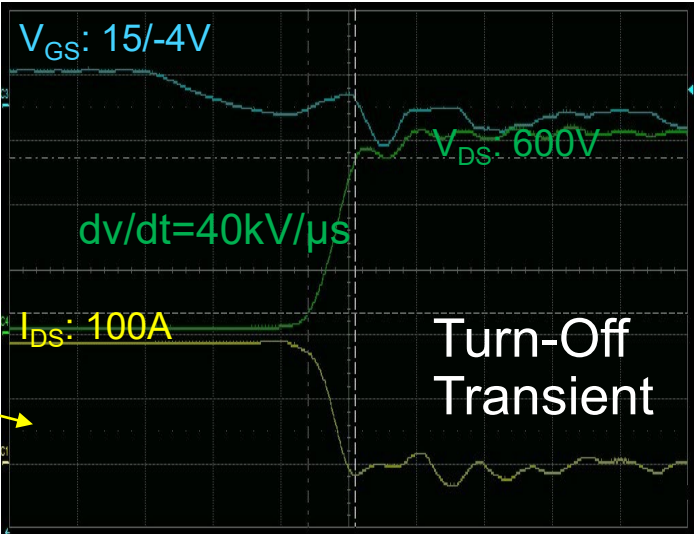
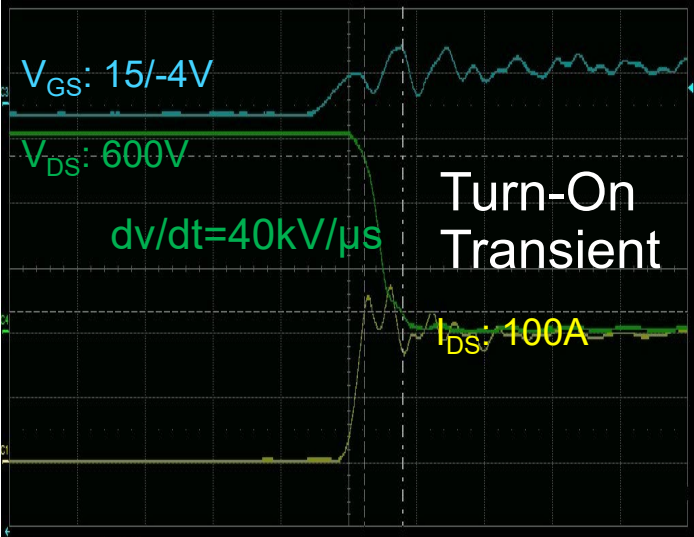
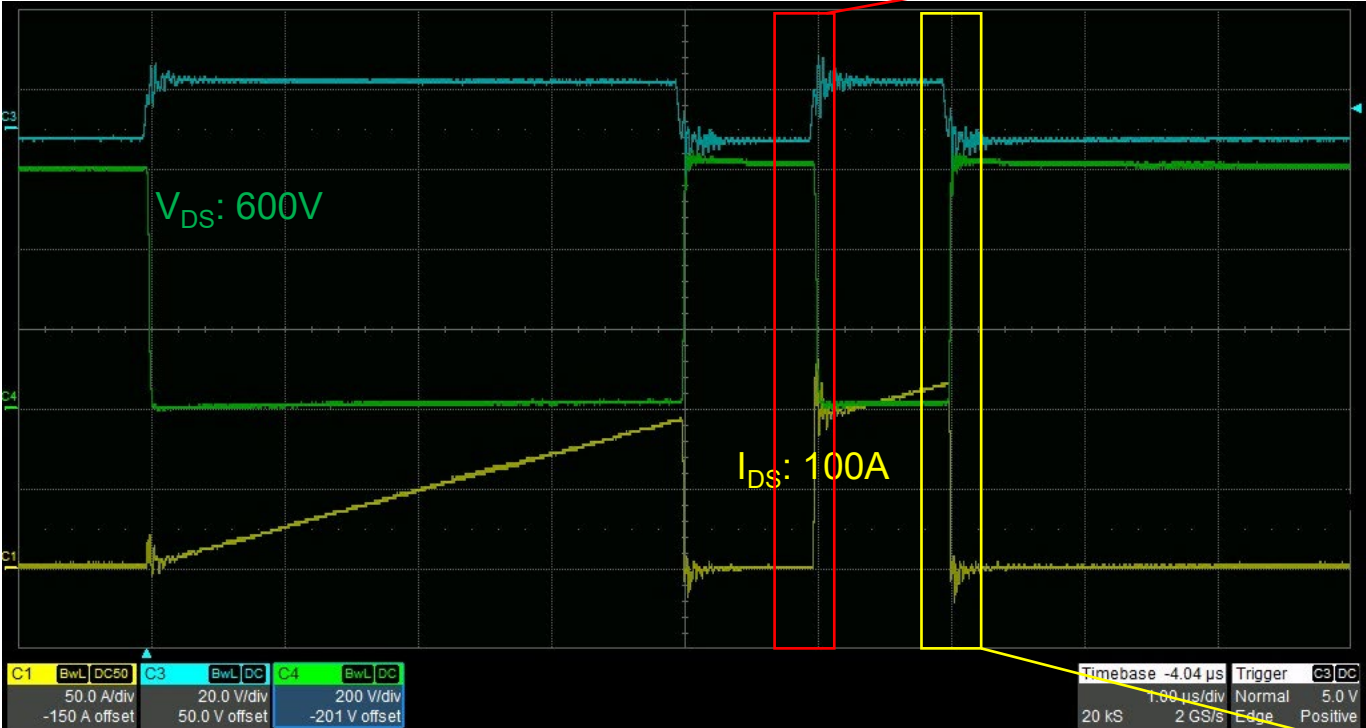


FM3驱动器评估板功能框图

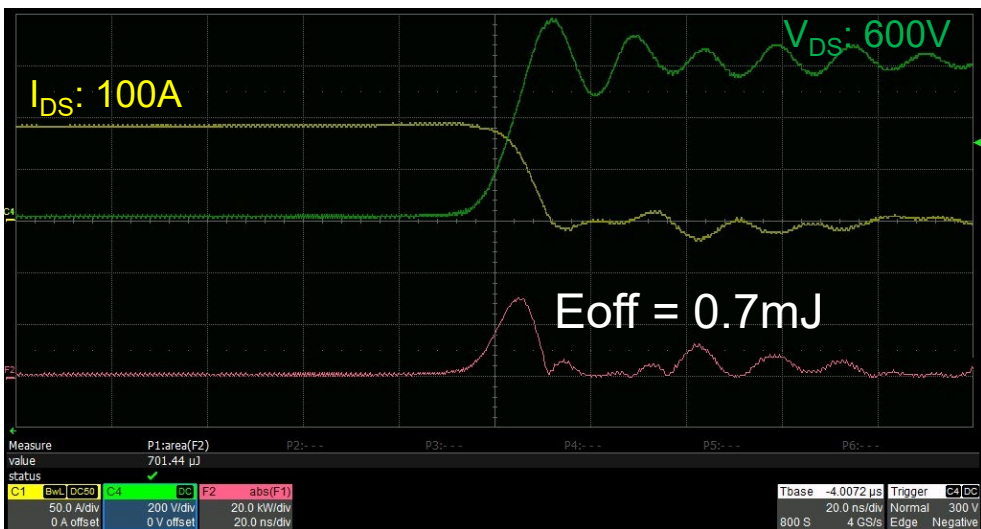
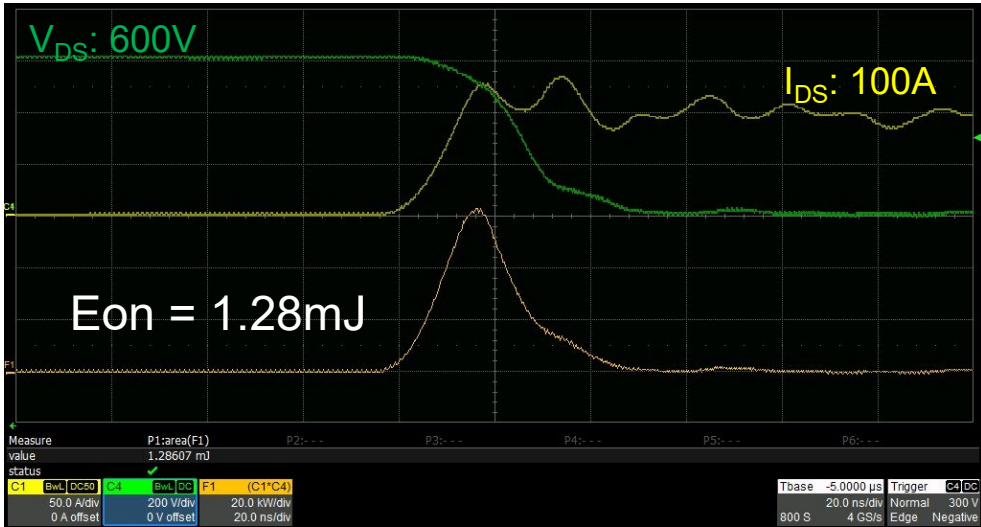


SiC 驱动板 – SiC开关性能

Double Pulse Test



SiC 驱动板 – SiC开关性能



SiC Datasheet

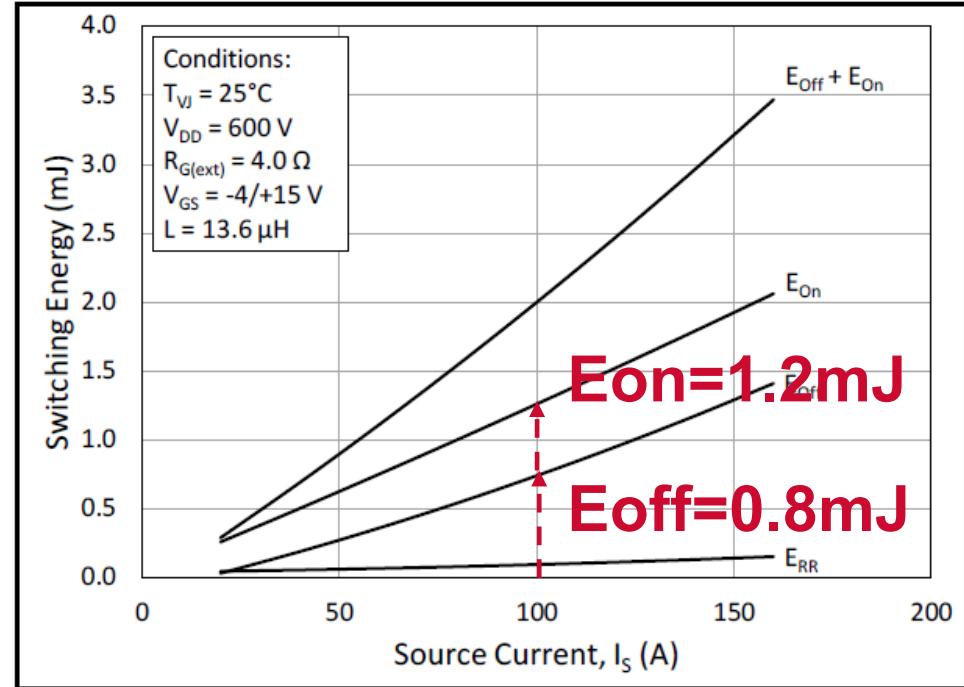
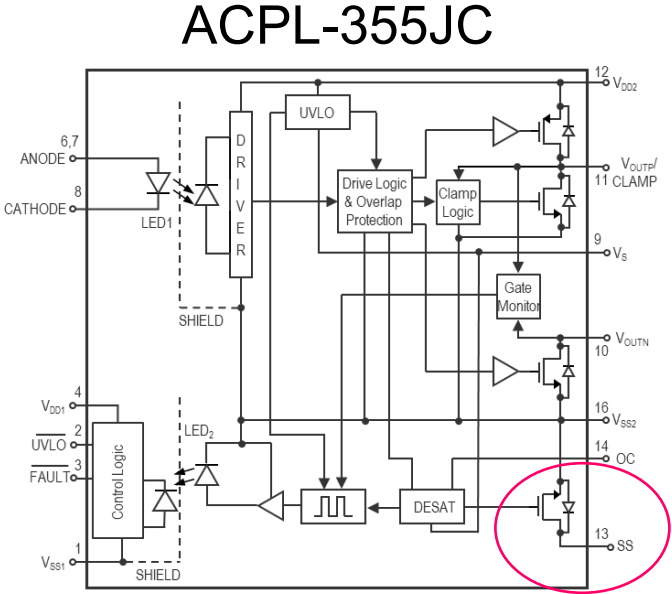


Figure 11. Switching Energy vs. Drain Current ($V_{DS} = 600 V$)

CAB016M12FM3
Datasheet 1200V/78A



SiC 驱动板 – SiC 短路测试



软关断引脚



SiC Power MOSFET –半桥评估板



ACFL-3161
10A Single Channel
Gate Drive Optocouplers

SCTWA70N120G2V4
1200V, 90A, 21m Ω SiC MOSFET

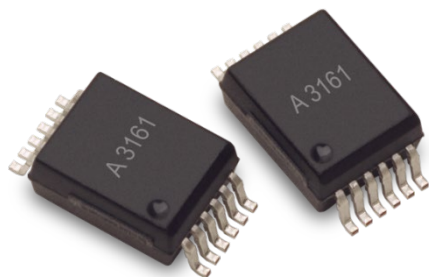
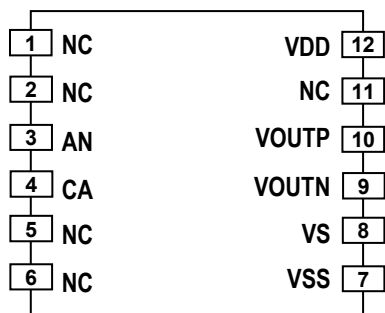


SiC MOSFET 评估板

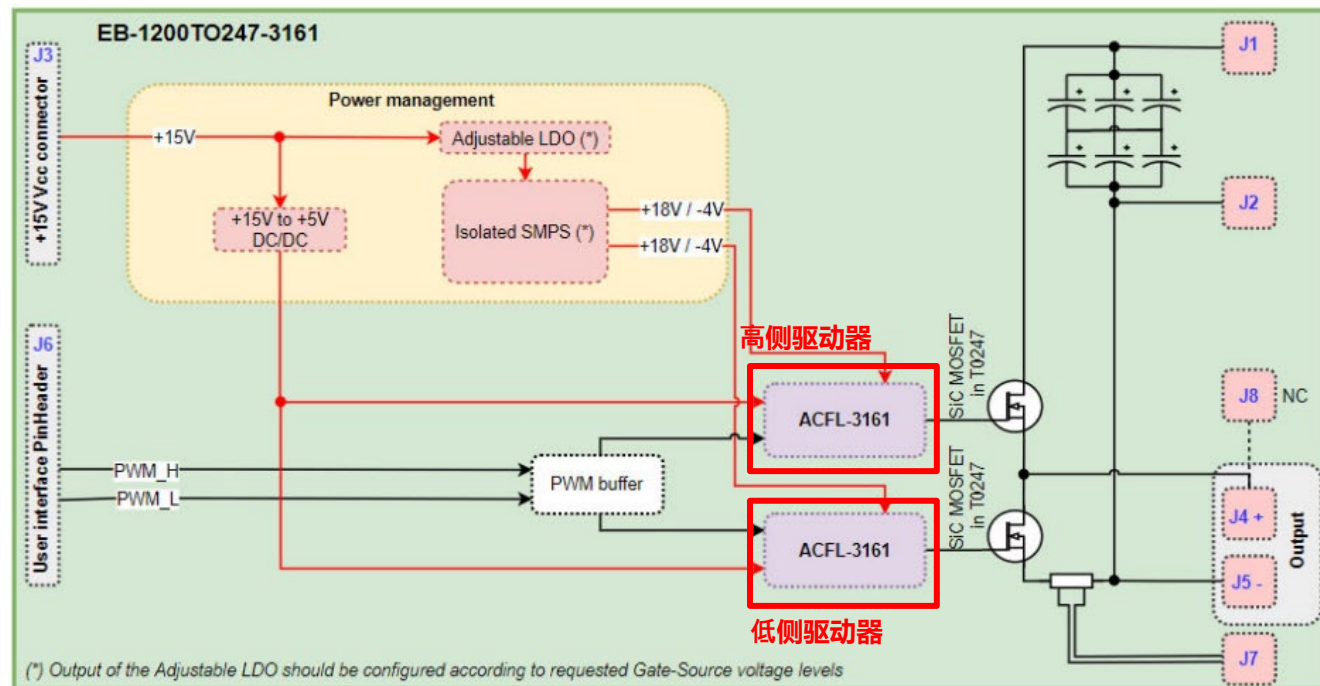
ACFL-3161基本栅极驱动器

特性

- **10A**峰值输出电流
- 小于**95ns**的传播延迟
- 抗扰度, $dv/dt > 100kV/\mu s$
- 安全认证
 - UL认证5000 VRMS@1分钟
 - CSA
 - IEC/EN/DIN EN 60747-5-5 $V_{IORM} = 1230 V_{PEAK}$

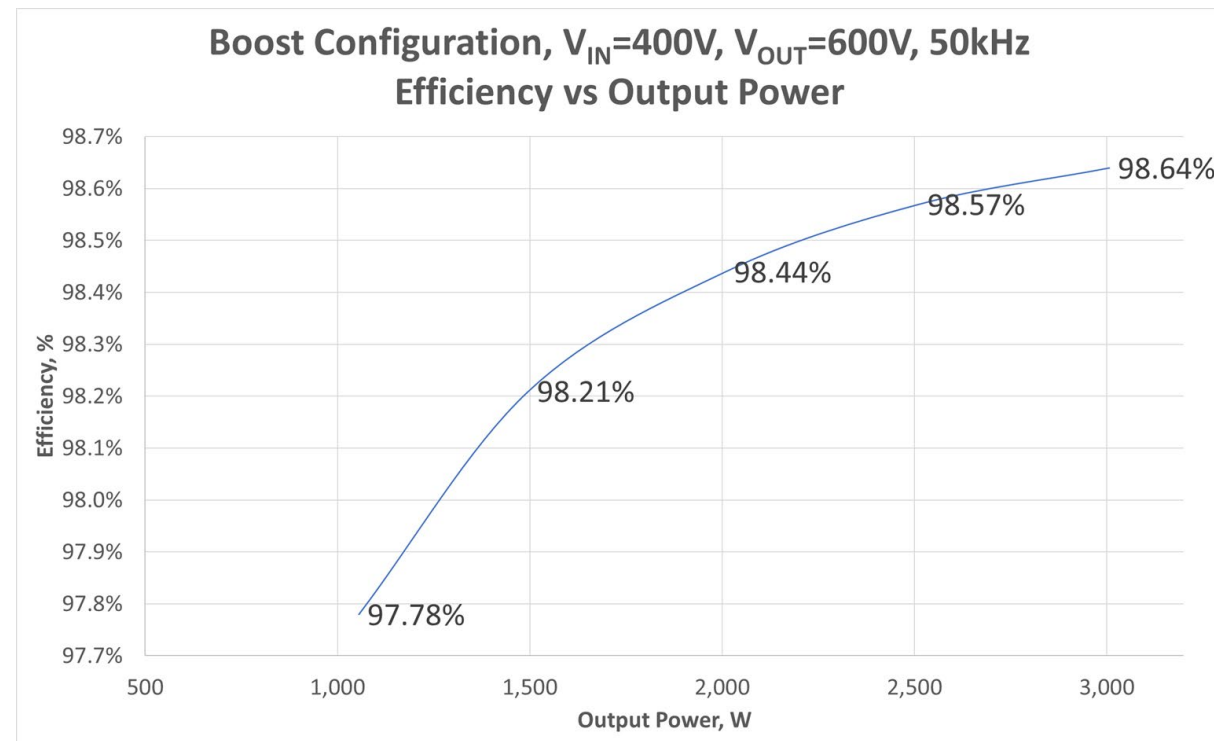
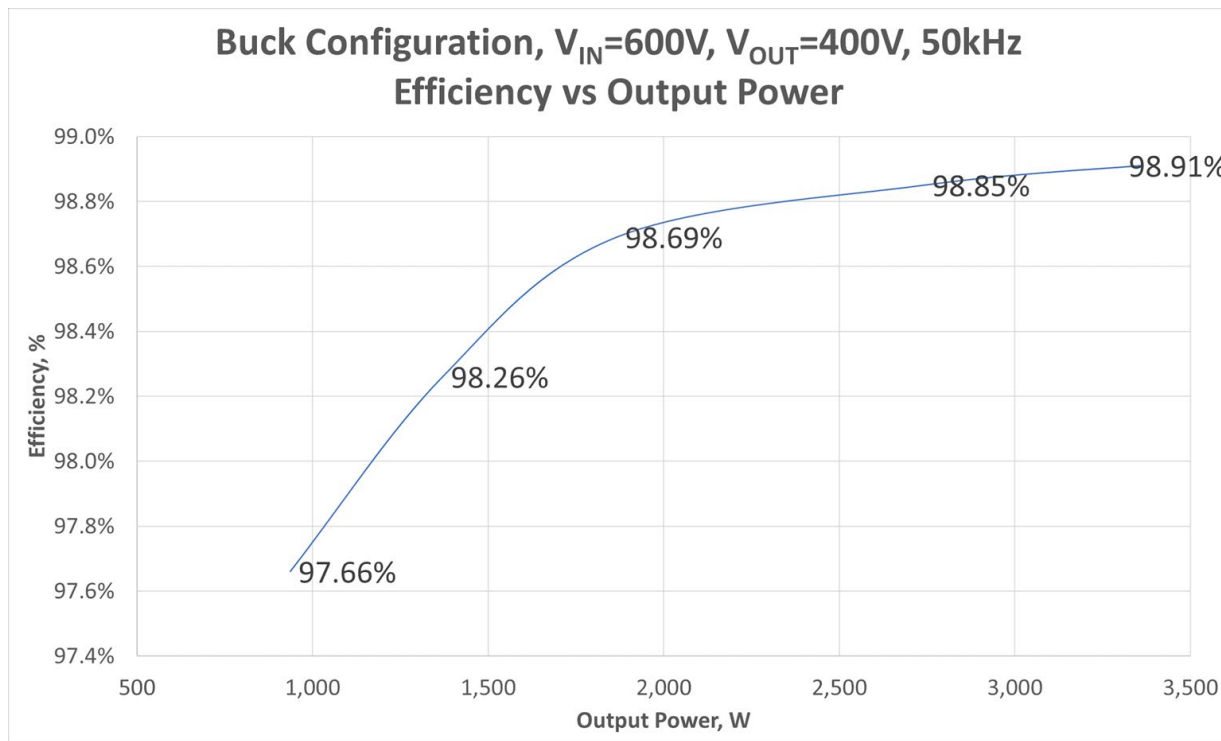


已量产发布!

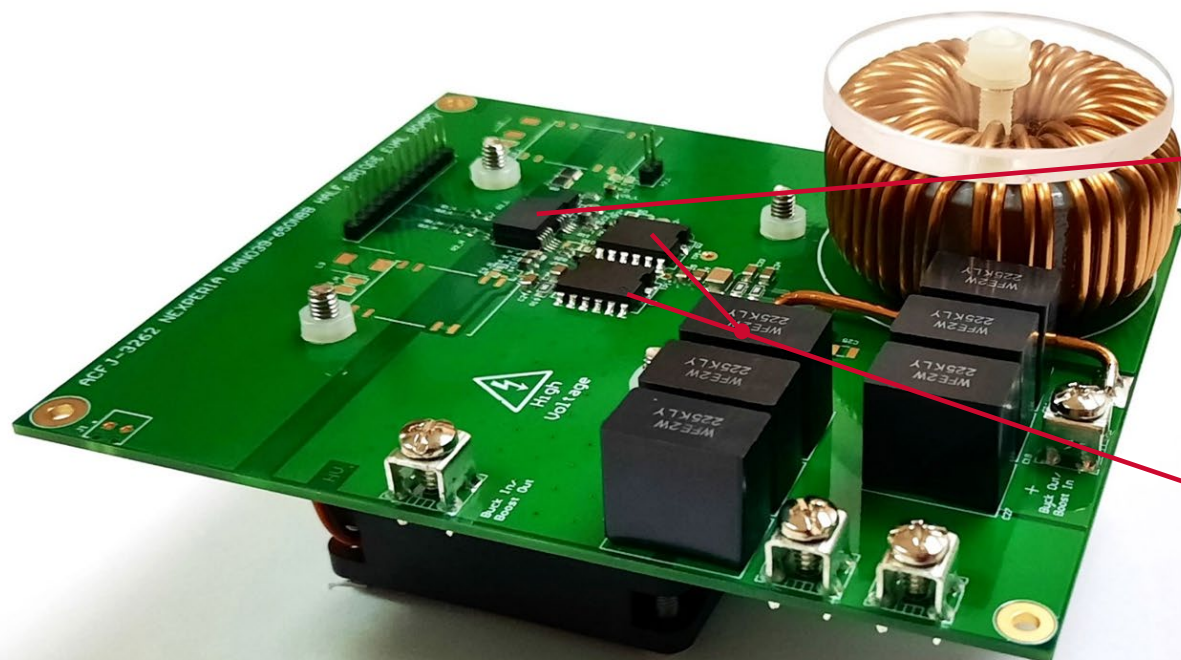


STM评估板功能框图

SiC MOSFET 评估板-效率性能



GaN FET-半桥评估板



ACFJ-3262
10A双通道
栅极驱动光耦

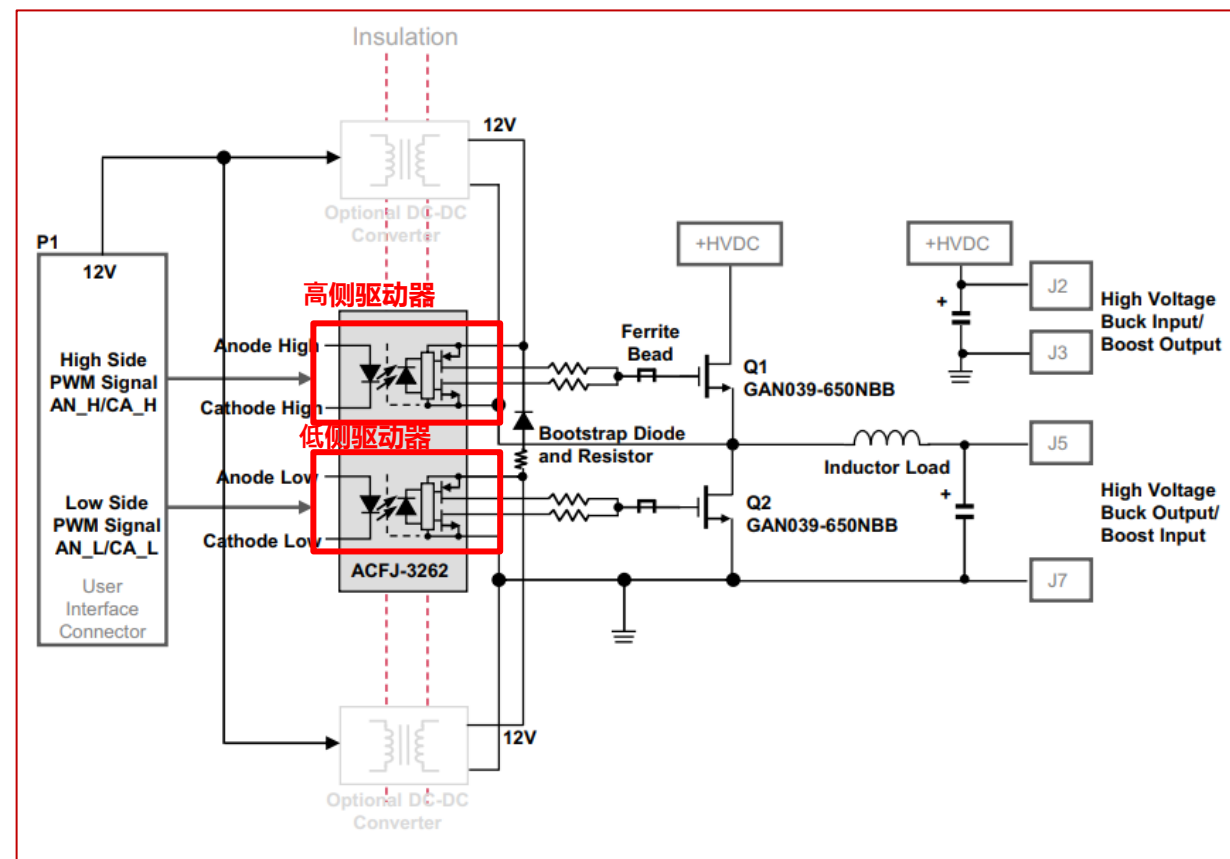
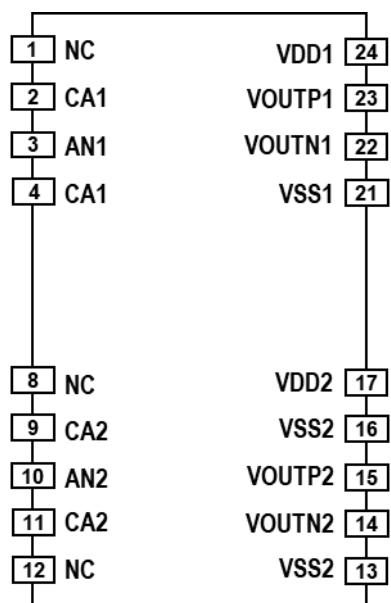
GAN039-650NBB
650V 33m Ω GaN FET



GaN FET评估板 – ACFJ-3262 双通道栅极驱动光耦

特性

- **10A**峰值输出电流
- 8.6V UVLO, 适用于**10-25V**电源范围
- 小于**95ns**的传播延迟
- 抗扰度, $dv/dt > 100kV/\mu s$

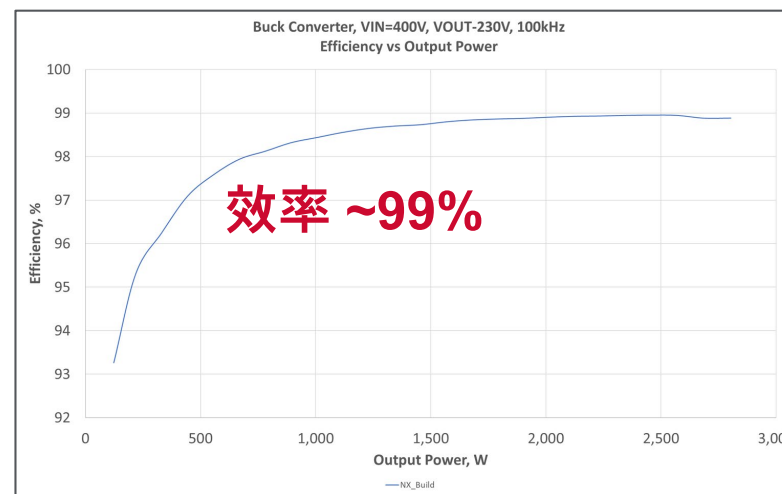
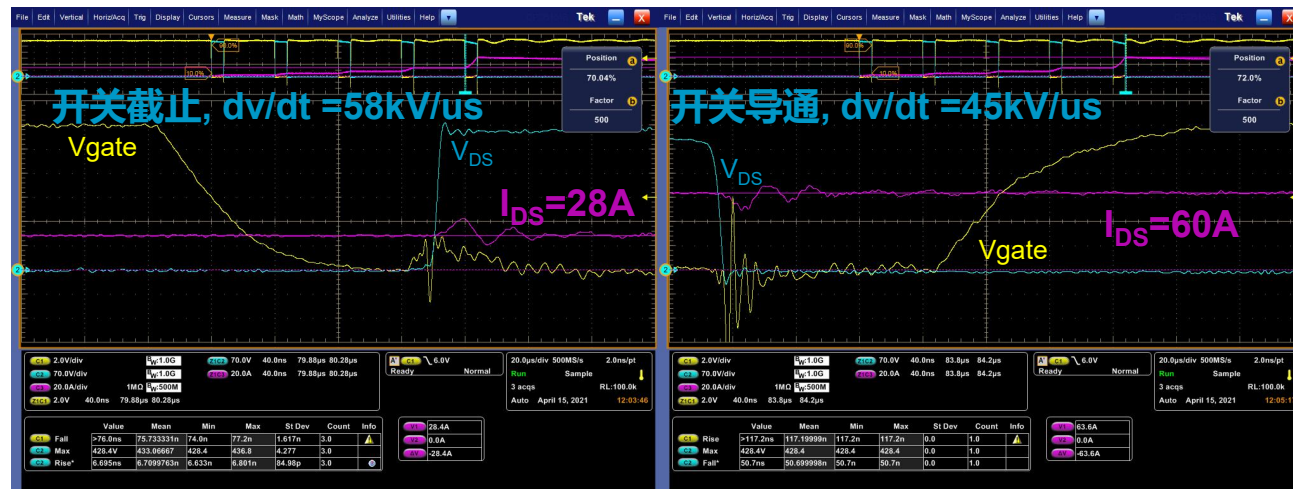
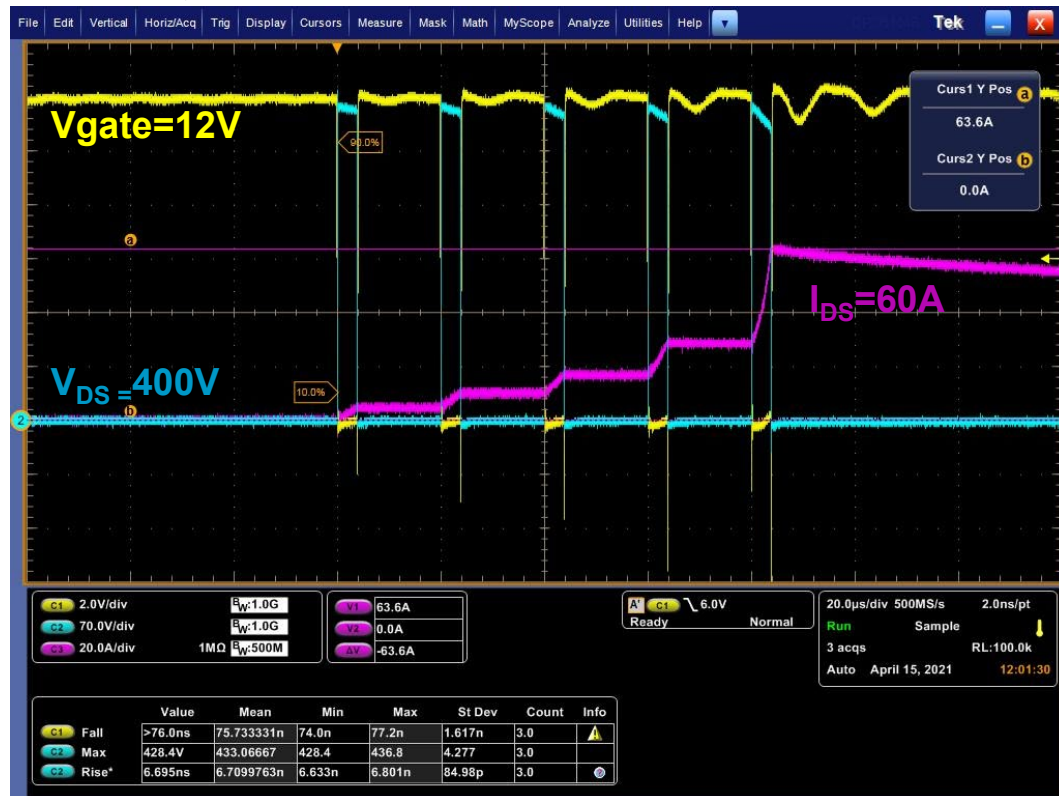


ACFJ-3262 + GAN039-650NBB 评估板功能框图



GaN FET评估板——开关性能

双脉冲测试

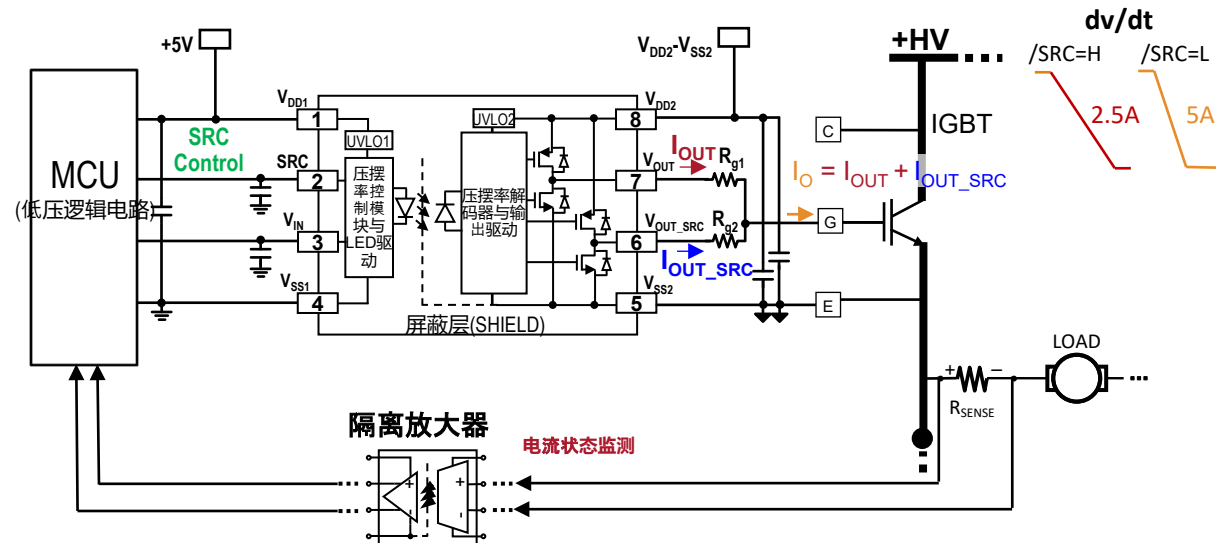


新品介绍...

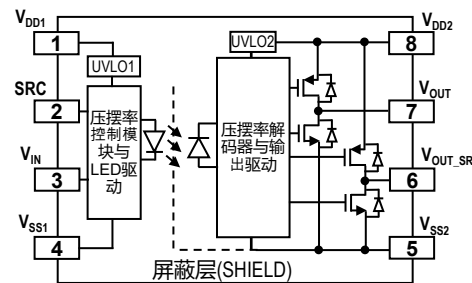
ACPL-C361/C362 *: 5A双模式SRC栅极驱动器

关键特性：

- 最高**5A**双模式压摆率控制
- 双重输出驱动强度可优化dv/dt抑制性能，降低开关过程中的导通量(Eon)
 - 第一级: I_{OUT} (最大2.5A)
 - 第二级: $I_{OUT} + I_{OUT_SRC}$ (最大5.0A)
- 提供两款型号:
 - **ACPL-C361**: 双模式SRC栅极驱动器
 - **ACPL-C362**: 带米勒钳位的双模式SRC栅极驱动
- 高共模抑制能力 最小值100kV/ μ s
- 紧凑型SSO-8封装，爬电/电气间隙距离>8mm
- **宽工作结温范围** (-40°C~+125°C)
- **相对漏电起痕指数 (CTI) >400V**
- 监管认证待审批
 - UL/cUL 1577 (5kVRMS 1min)
 - IEC 60747-5-5 ($V_{IORM} = 1,414V_{PEAK}$)



ACPL-C361
(2-L SRC)



* ACPL-C361/C362: Advance information, subject to change.

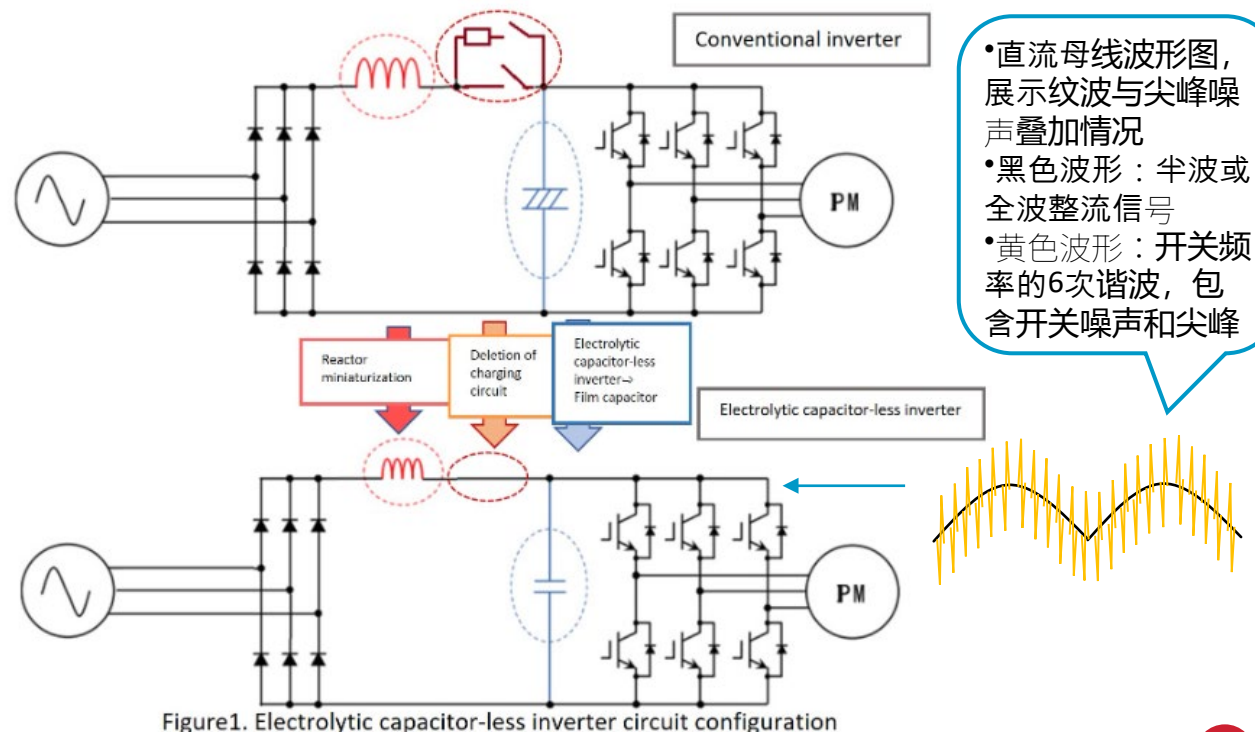


SRC技术助力降低HVAC逆变器开关噪声

- HVAC逆变器新设计将直流母线电容由**电解电容**替换为**薄膜电容**，具有以下优势：
 - 缩小系统尺寸，降低总体成本
 - 使用寿命长，ESR低，纹波电流耐受能力强
 - 在温度和时间变化下具有更好的稳定性
- 挑战：
 - **直流母线纹波和尖峰噪声增加，导致电机振动、运行噪声增大及使用寿命缩短。**



电解电容（左图）与薄膜电容（右图）
直流母线电容器

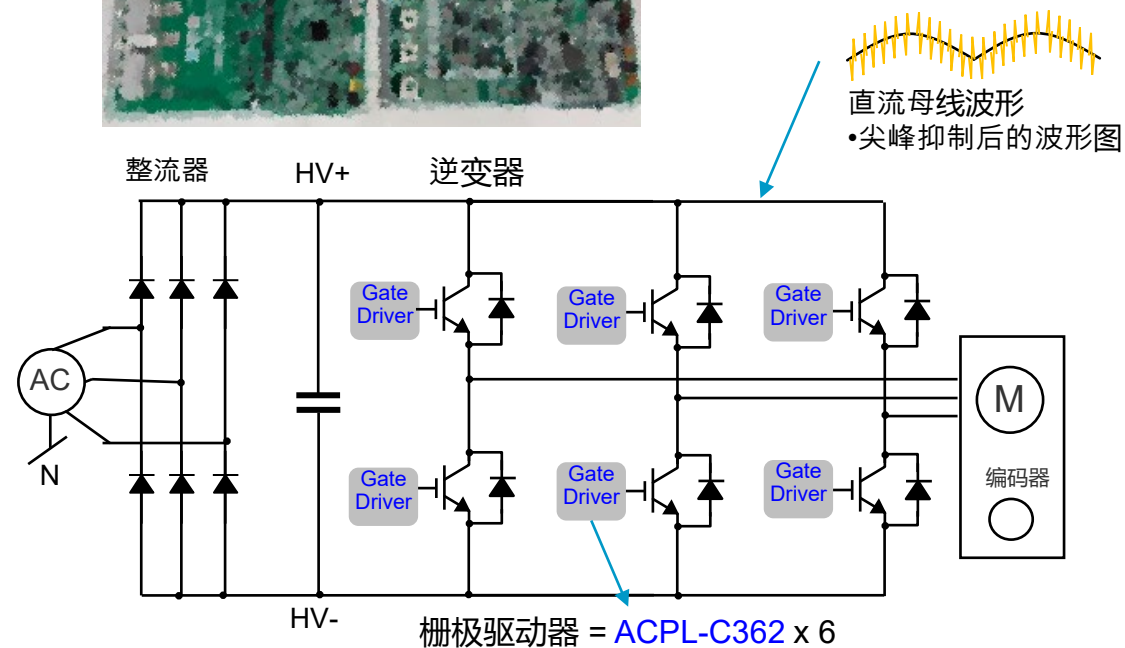
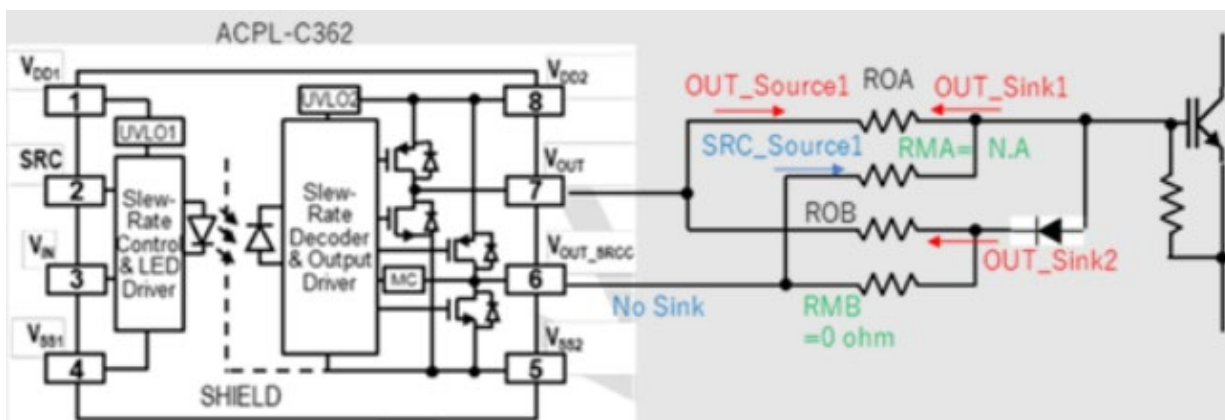


• 直流母线波形图，展示纹波与尖峰噪声叠加情况
• 黑色波形：半波或全波整流信号
• 黄色波形：开关频率的6次谐波，包含开关噪声和尖峰



SRC技术助力降低HVAC逆变器开关噪声 (续)

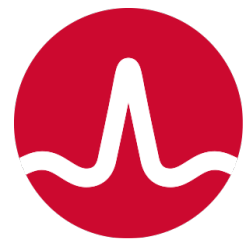
- 解决方案：
 - 在逆变器与电机之间加装外部滤波装置（成本较高）；
 - 建议客户**评估采用ACPL-C362* SRC栅极驱动器**，以抑制逆变器输出相的dv/dt开关噪声。
 - 客户已验证SRC功能对噪声的抑制效果，并确认新产品的应用优势。



* ACPL-C361/C362: Advance information, subject to change.



问与答



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