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FAN4147

接地故障断路器

产品特性

- 应用于GFCI和RCD
- 精密感应放大器与带隙基准
- 内置交流整流器
- 内置噪声滤波器
- 低压晶闸管禁用
- 直接直流耦合至感应线圈
- 晶闸管门极驱动器
- 可调敏感度
- 400µA静态电流
- 最少外部器件
- 满足UL 943B要求
- 适合120V 或 220V系统
- 空间节省的SuperSOT™6引脚封装

适用范围

- GFCI输出接口
- GFCI电路断路器
- 便携式GFCI线路

说明

FAN4147为低功率接地故障断路器（GFI）控制器，用于检测危险的接地路径以及接地对零线故障。FAN4147的应用电路可以在危险的电击前断开负载。

FAN4147内部包含一个二极管整流器、高精度12V带隙并联稳压器、精密的低 V_{OS} 失调感应放大器、延时噪声滤波器、窗口检测比较器和一个晶闸管驱动器。通过最少数目的外部器件，FAN4147侦测并防护火线对地故障和零线对负载短路。器件数量最少以及小型SuperSOT™封装，使得FAN4147成为超小型、低成本的应用解决方案。

FAN4147电路包含一个内置整流器和并联稳压器，只需较低的静态电流，允许使用高值、低功率系列电阻。内置温度补偿的并联稳压器、感应放大器以及偏置电路提供高精度对地故障检测。低 V_{OS} 失调感应放大器允许感应线圈直接耦合到放大器的反馈信号端，无需大容量的50/60Hz交流耦合电容。内置的延时滤波器能够滤除感性负载中的高频噪声尖峰，减少了虚假有害触发。内置的晶闸管驱动器具有温度补偿，该设计可以满足在宽范围内选择外部晶闸管的电流要求。

外部元件数量最少以及6引脚SuperSOT™封装带来了低成本、紧凑设计和布局。

订购信息

器件型号	工作温度范围	封装	包装方法
FAN4147SX	-35°C至85°C	6-Lead SUPERSOT6, JEDEC MO-193, 1.6mm	卷带

框图

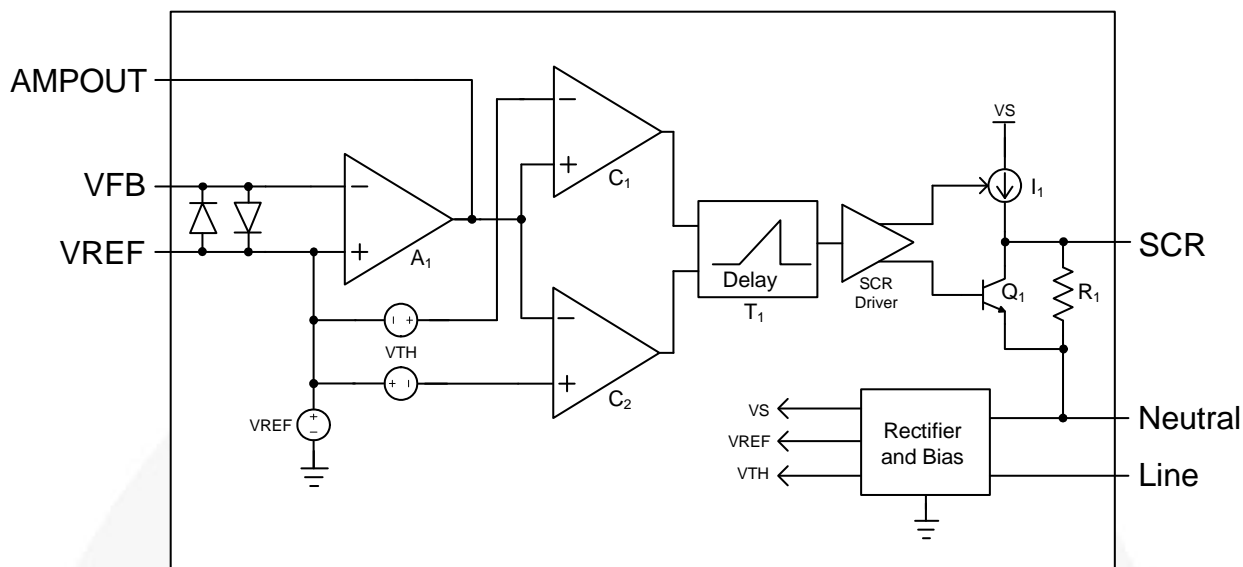


图1. 框图

典型应用

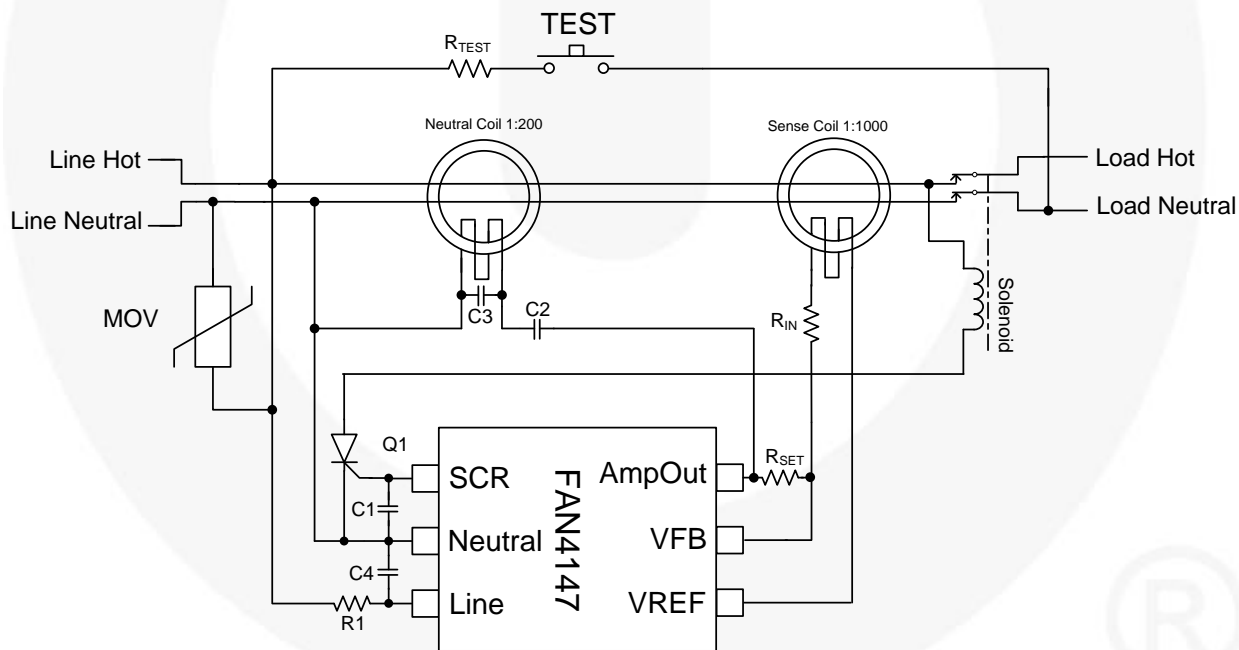


图2. 典型应用⁽¹⁾

典型值

R1: 91K Ω	R _{SET} : 511K Ω ⁽²⁾	C1: 22nF	C3=1nF
R _{TEST} : 15K Ω	R _{IN} : 470 Ω	C2: 10nF	C4=10nF

注意:

1. 联系飞兆半导体，了解最佳应用实践，抑制有害触发。
2. 精确值取决于感应线圈特性和应用。

引脚布局

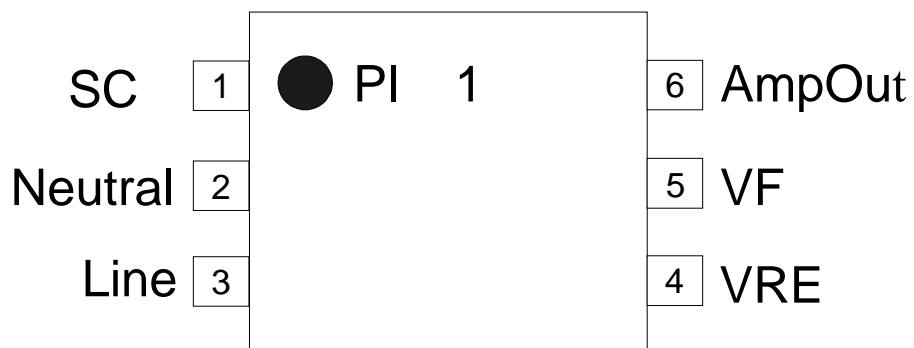


图3. 引脚布局

引脚说明

引脚号	名称	说明
1	SCR	外部晶闸管的门极驱动
2	Neutral	FAN4147电路的电源零线输入
3	Line	FAN4147电路的电源火线输入
4	VREF	电流感应放大器的非反相输入
5	VFB	电流感应放大器的反相输入
6	AmpOut	VFB引脚上连接一个外部电阻，设置 I_{fault} 灵敏度阈值

绝对最大额定值

如果应力超过绝对最大额定值，设备就会毁损。在推荐的工作条件之上，该设备可能无法正常运行或操作，且不建议让设备在这些条件下长期工作。此外，过度暴露在高于推荐的工作条件下，会影响器件的可靠性。绝对最大额定值仅是额定应力值。

符号	参数	最小值	最大值	单位	
I_{CC}	连续电流，火线到零线		15	mA	
V_{CC}	连续电压，火线到零线	-1.2	16	V	
	连续电压到零线，所有其他引脚	-0.8	15	V	
T_{STG}	存储温度范围	-65	+150	°C	
ESD	静电放电防护等级	人体模式，JESD22-A114		2.5	kV
		带电设备模式，JESD22-C101		1.0	
		机械模式，JESD22-A115		0.2	

推荐工作条件

推荐的操作条件表定义了真实设备的工作条件。指定推荐的工作条件，以确保设备的最佳性能达到数据表中的规格。飞兆半导体建议不超过推荐的工作条件，或将绝对最大额定值设计为工作条件。（若无其他指定要求，请参考图2。）

符号	参数	工作条件	最小值	典型值	最大值	单位
直流电气特性 ($T_A=25^{\circ}\text{C}$, $I_{shunt}=1\text{mA}$)						
V_{REG}	电源并联稳压器电压	电源到零线	12.2	12.7	13.2	V
		电源到零线, $I_{shunt}=-2\text{mA}$	-0.9	-0.7		V
I_Q	静态电流	电源到零线=10V	350	400	450	μA
V_{REF}	参考电压	V_{REF} 到零线	5.8	6.0	6.2	V
V_{TH}	触发阈值	AmpOut 到 V_{REF}	3.4	3.5	3.6	V
V_{OS}	放大器偏置	$R_{SET}=511\text{K}\Omega$, $R_{IN}=500\Omega$	-450	0	450	μV
I_{OS}	放大器输入偏置 ⁽⁰⁾	设计值	-50	0	50	nA
G	放大器直流增益 ⁽⁰⁾	设计值		100		dB
f_{GBW}	放大器增益带宽 ⁽⁰⁾	设计值		1.5		MHz
V_{SW+}	放大器正电压摆幅	AmpOut 到 V_{REF} , $I_{FAULT}=10\mu\text{A}$	4.0			V
V_{SW-}	放大器负电压摆幅	V_{REF} 到AmpOut, $I_{FAULT}=10\mu\text{A}$	4.0			V
I_{SINK}	放大器电流槽	AmpOut= $V_{REF} + 3\text{V}$, $V_{FB}=V_{REF} + 100\text{mV}$	400			μA
I_{SRL}	放大器电流源	AmpOut= $V_{REF} - 3\text{V}$, $V_{FB}=V_{REF} - 100\text{mV}$	400			μA
t_d	延时滤波器	从 C_1 触发到晶闸管的时延从低到高	0.7	1.0	1.3	ms
R_{OUT}	SCR输出电阻	SCR—零线=250mV, AmpOut= V_{REF}		0.5	1.0	$\text{K}\Omega$
V_{OUT}	SCR输出电压	SCR—零线, AmpOut= V_{REF}		1	10	mV
		SCR—零线, AmpOut= $V_{REF}+4\text{V}$	2.5			V
I_{OUT}	SCR输出电流	SCR—零线=1V AmpOut= $V_{REF} + 4\text{V}$	350	500		μA

说明：

3. 由设计保证；未经产品测试。

功能说明

(参考图 1 和图 2)。

FAN4147 为 GFCI 控制器，专门用于交流接地故障断路器。在交流电源的正半周，内置整流器整流。内置 12V 并联稳压器采用了精密温度补偿带隙基准。精密的基准电路与精密的感应放大器的组合，提供了精确的接地故障容差。使外部元件的参数选择范围更广泛和更低廉。由于所需静态电流较低，可以采用高值的外部串联电阻 (R_1)，大大降低功耗。12V 并联稳压器为感应放大器 (A_1) 的非反相输入端 (AC 接地参考) 提供参考电压，并且给延时定时器 (T_1)、比较器 (C_1 & C_2) 和晶闸管驱动器提供偏压。

感应变压器的次级绕组连接至引脚 4 (V_{REF})，电阻 R_{IN} 直接直流耦合到感应放大器的反相输入端引脚 5 (V_{FB})。反馈电阻 R_{SET} 将感应变压器的次级绕组电流在引脚 6 (AmpOut) 处转换成电压。该电压与内置窗口比较器 (C_1 和 C_2) 进行比较，如果 AmpOut 的电压超过阈值电压 $\pm V_{TH}$ ，窗口比较器就会触发内部延时定时器。窗口比较器的输出必须在定时器 t_1 时段保持高电平。如果窗口比较器的输出为低电平，内置延时定时器将开始复位。如果在 t_1 脉冲结束时，窗口比较器输出一直为高电平，则晶闸管驱动器启动电流源 I_1 ，禁止 Q_1 。然后电流源 I_1 开启外部晶闸管，给电磁阀通电，打开连接负载的接触开关，从而消除有害接地故障。窗口比较器允许检测正的或负的 I_{FAULT} 信号，不依赖于电源电压的相位。

感应变压器通常都有一个由复合钢环或者固体铁氧体制成的环形磁芯。一般情况下，变压器次级要求由 40# 线在该环形磁芯上绕 800 匝至 1500 匝。变压器初级通常为一到两匝，交流火线和零线穿过该环形磁芯中央。当接地故障出现时，流入火线与零线的电流出现偏差。通过将初级差动电流除以初级与次级之间的匝比就可得到了变压器的次级电流。

零线在零线负载侧接地时出现接地零线故障。

根据接地零线的阻抗，该故障令感应线圈侦测到更低的接地故障电流。地对负载对零线故障的侦测应根据正向反馈原理。出现这种情况时，感应和零线圈双向耦合，可以在感应放大器周围产生正向反馈路径。这种正向反馈使得感应放大器出现共振。峰值共振电压超过晶闸管触发阈值时，将启用内置延时定时器。由于放大器输出信号跨越窗口比较器的触发阈值的典型值为 6kHz，延迟定时器将在故障/无故障侦测之间转换。如果启用了晶闸管驱动器，可确定故障/无故障侦测时间延迟。

接地零线侦测的灵敏度随零线圈匝数和 C_2 , C_3 值而变化。

R_{SET} 电阻的计算

AmpOut 的信号必须超过窗口比较器的阈值电压 V_{TH} ，持续时间超过延时定时器时间。因此：

$$V_{TH} = I_{FAULT} \times 1.41 \times R_{SET} \times C_{OS} (2\pi \times (t/2P)) / N \quad (1)$$

$$R_{SET} = (V_{TH} \times N) / (1.41 \times I_{FAULT} \times C_{OS} (\pi \times t/P)) \quad (2)$$

其中：

$$V_{TH} = 3.5V;$$

$$I_{FAULT} = 5mA \text{ (UL943)};$$

T

$$t = 1ms \text{ (定时器延时)};$$

$$P = \text{交流电源周期 (1/60Hz)};$$

$$N = \text{次级与初级匝比 (1000:1)}$$

$$R_{SET} = 505K\Omega \text{ (511K}\Omega \text{ 标准 1\%)}^{(4)}$$

说明：

4. 在实际中，由于变压器不理想，需要调节 R_{SET} ，范围高达 30%，才能获得所需的 I_{fault} 触发阈值

V_{OS} 触发阈值误差的计算

由于感应线圈直接连接到感应放大器的反馈端， V_{OS} 偏置会引入一个 I_{fault} 阈值误差。误差的计算方法为：

%Error=

$$100 \times (V_{OS} \times R_{SET}) / (R_{IN} + R_{LDC} + R_{LAC}) / V_{TH} \quad (3)$$

where:

$$V_{OS} = \pm 450\mu V \text{ (最坏情况)};$$

$$= \pm 150\mu V \text{ (典型值)};$$

$$R_{SET} = 511K\Omega;$$

$$R_{IN} = 470\Omega \text{ (典型值)};$$

$$R_{LDC} = 75\Omega \text{ (感性线圈次级直流电阻)};$$

$$R_{LAC} = 1.5 K\Omega \text{ (AC}_{(j\omega L)} \text{ 感应线圈阻抗)} \\ (L = 4H, f = 60Hz);$$

$$V_{TH} = 3.5V;$$

$$\%Error = \pm 3.2\% \text{ (最差情况)}; \pm 1.1\% \\ \text{ (典型值)}$$

典型性能特征

若无其他说明，所有值都是在 $T_A=25^{\circ}\text{C}$ ，晶闸管断开（根据图2）情况下得到。

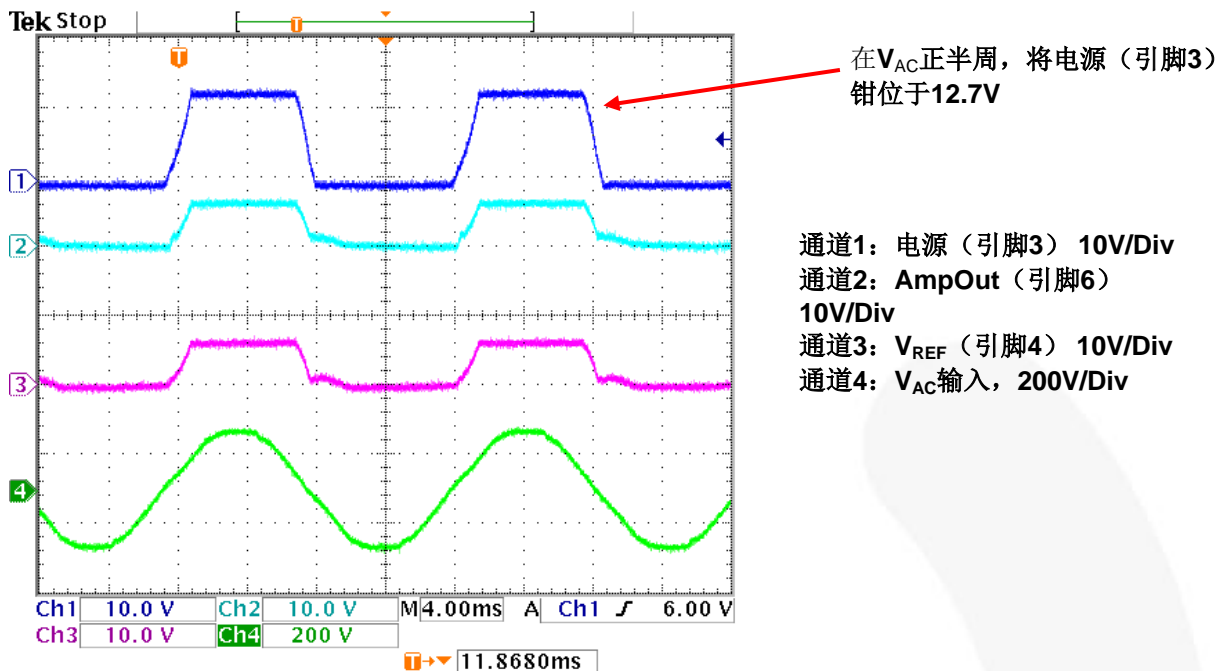


图4. 无接地故障时典型波形

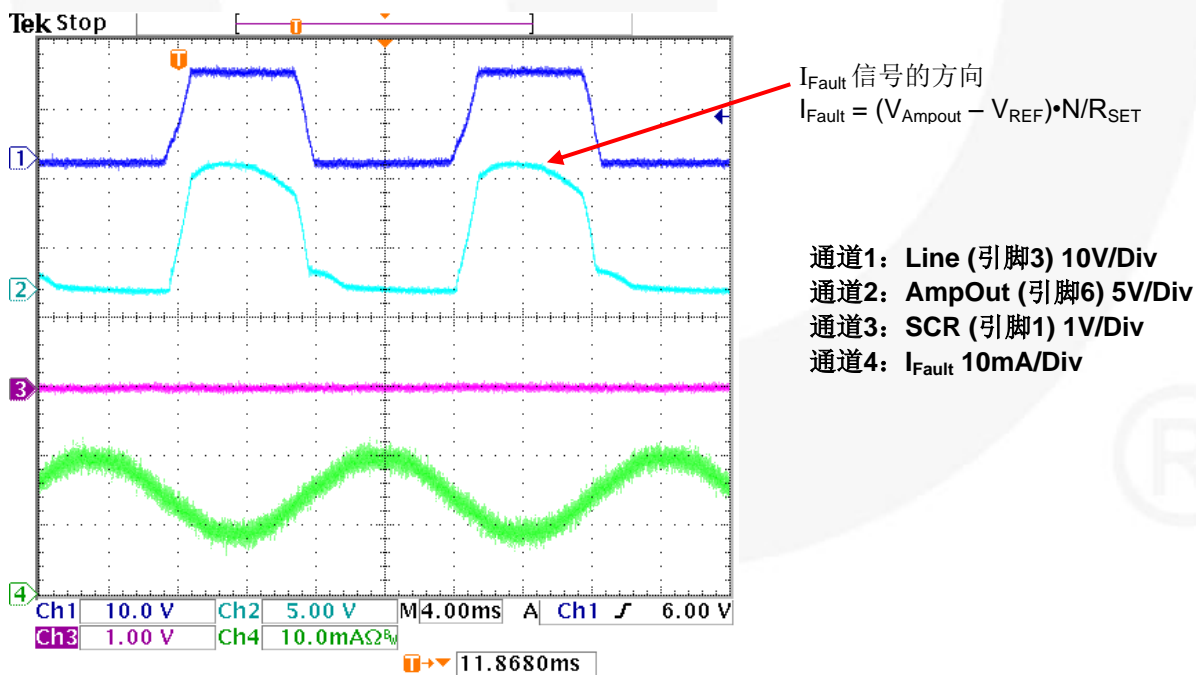


图5. 4mA接地故障时典型波形

典型性能特征

若无其他说明, 所有值都是在 $T_A=25^{\circ}\text{C}$, 晶闸管断开 (根据图2) 情况下得到。

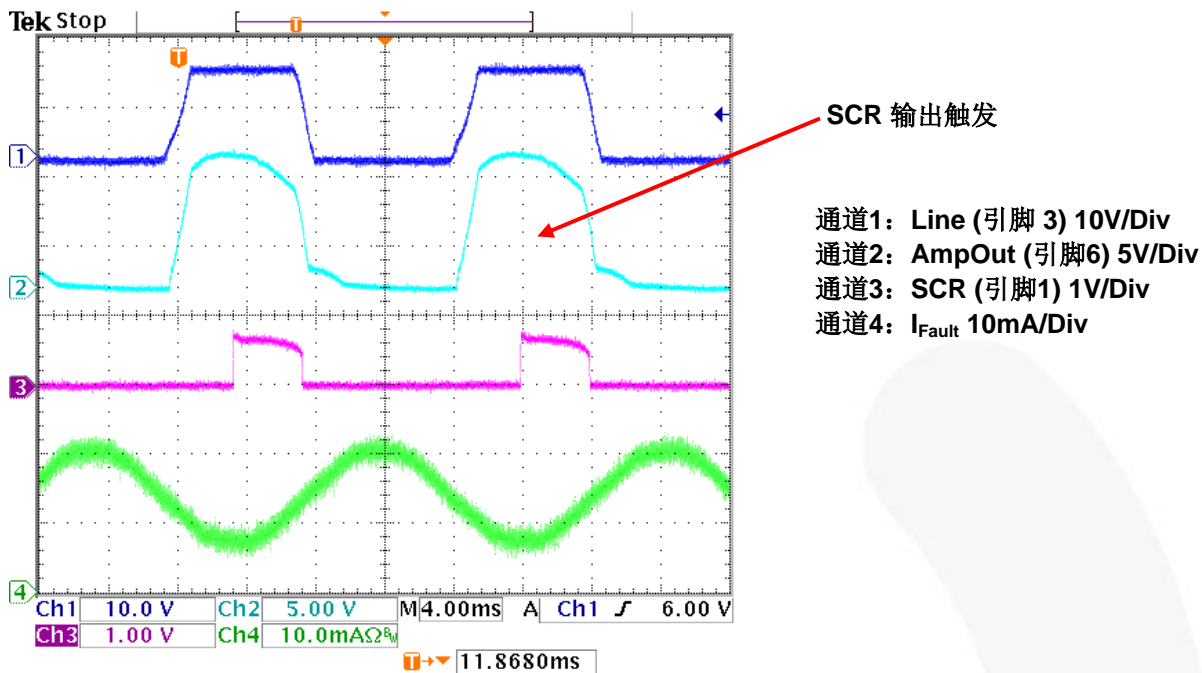


图6. 5mA接地故障时典型波形

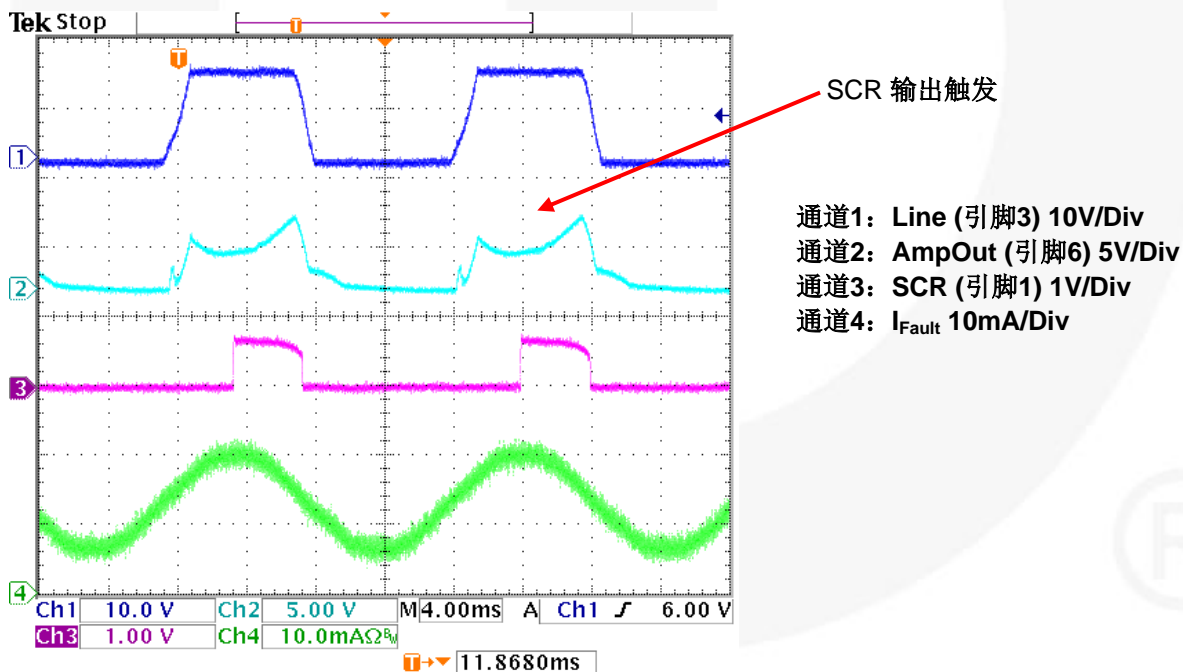


图7. 5mA接地故障时典型波形 (线路极性反转)

典型性能特征

若无其他说明，所有值都是在 $T_A=25^{\circ}\text{C}$ ，晶闸管断开（根据图2）情况下得到。

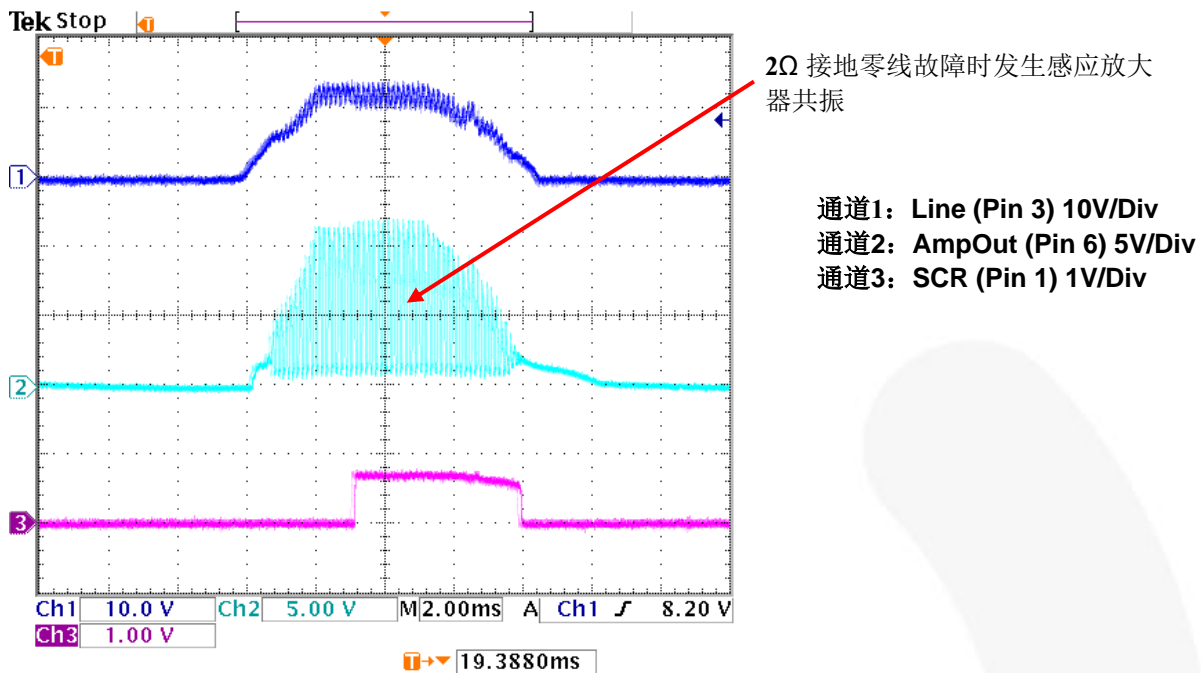


图8. 接地火线检测的典型波形

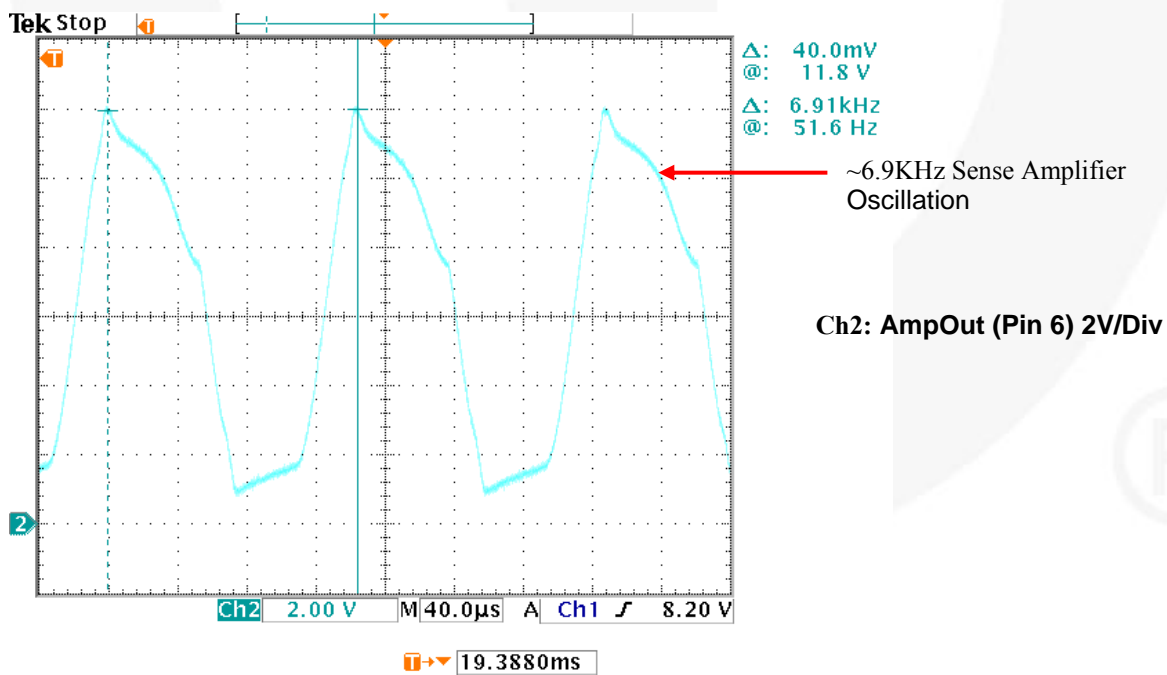
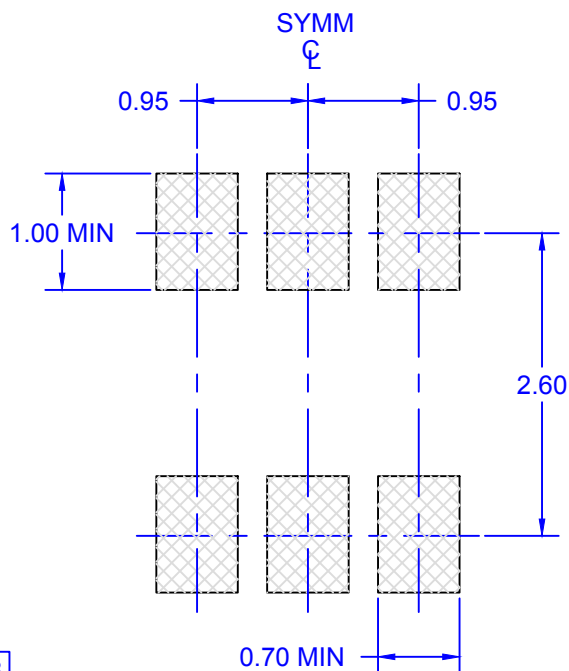
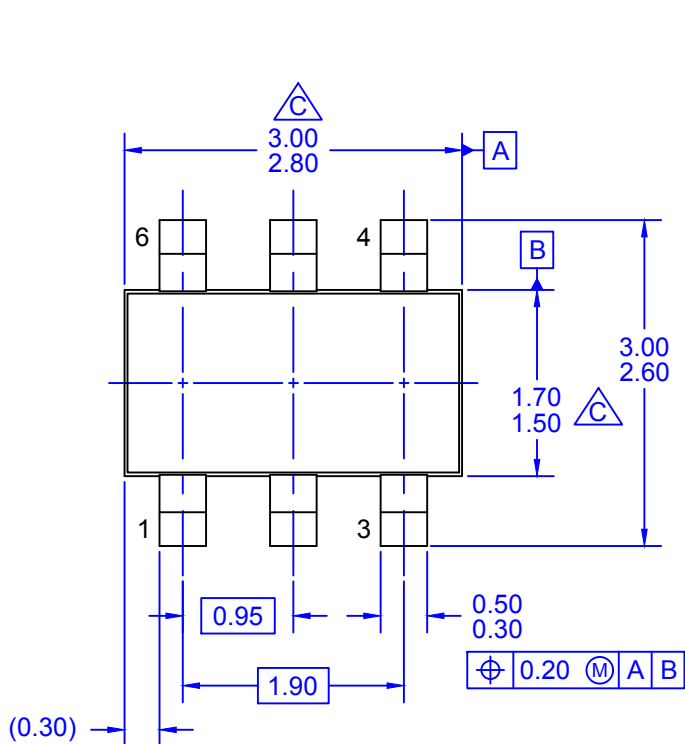
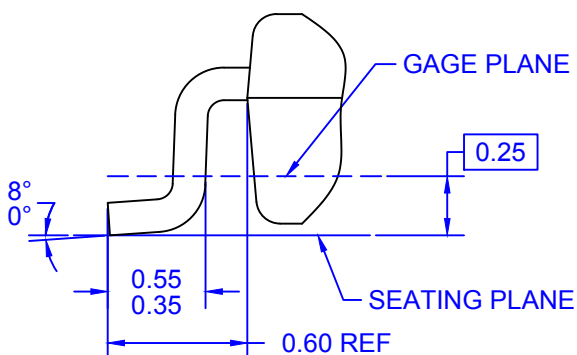
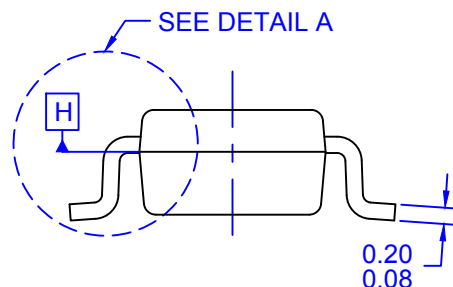
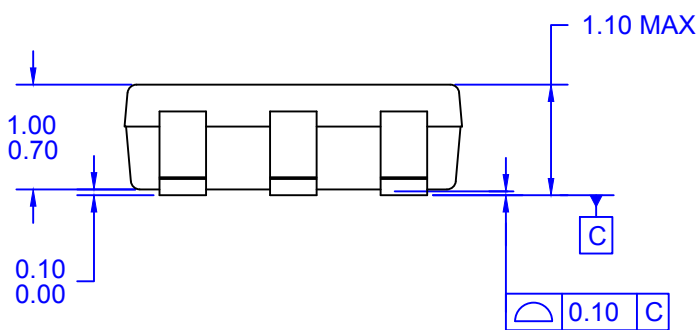


图9. 接地火线检测的典型波形



LAND PATTERN RECOMMENDATION



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 - C) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.25mm PER END. PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25mm PER SIDE. PACKAGE LENGTH AND WIDTH DIMENSIONS ARE DETERMINED AT DATUM H.
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