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RV4141A

低功率，接地故障中断器

特性

- 由交流线路供电
- 内置整流器
- 直接连接至 SCR
- 500µA 静态电流
- 精密感应放大器
- 可调延时
- 最少的外部组件
- 满足 UL 943 要求
- 兼容 110V 或 220V 系统
- 提供 8 引脚 SOIC 封装

说明

RV4141A 是交流电插座接地故障电路中断器的低功率控制器。此类器件检测接地线和零线之间故障的危险电流路径。在发生有害致命冲击前，电路中断器将负载从线路上断开。

RV4141A 内部包含一个二极管整流器、电压调节器、精密感应放大器、参考电流、延时电路和 SCR 驱动器。

两个感应变压器、SCR、电磁阀、三个电阻和四个电容完成了基本电路中断器的设计。简单布局和最少的元件数目确保了应用简便和长期可靠。其他 GFCI 控制器所没有的功能包括一个低失调电压感应放大器，无需在感应变压器和感应放大器间增加一个耦合电容，还包含一个内部整流器来消除对高压整流二极管的需求。

RV4141A 仅在线路电压的正向半个期间供电，但始终能够感应电流默认值，与其相对于线路电压的相位无关。SCR 的栅极仅在线路电压的正半周期期间驱动。

订购信息

器件编号	工作温度范围	封装	包装方法
RV4141AN	-35 至 +80°C	8 引线，塑料双列直插封装 (DIP)	轨道
RV4141AMT	-35 至 +80°C	8 引线，塑料小外形集成电路 (SOIC)	卷带

框图

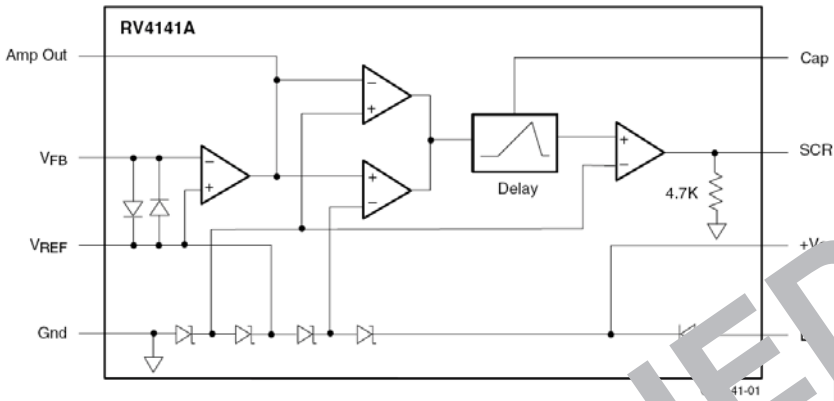


图 1. 框图

引脚布局

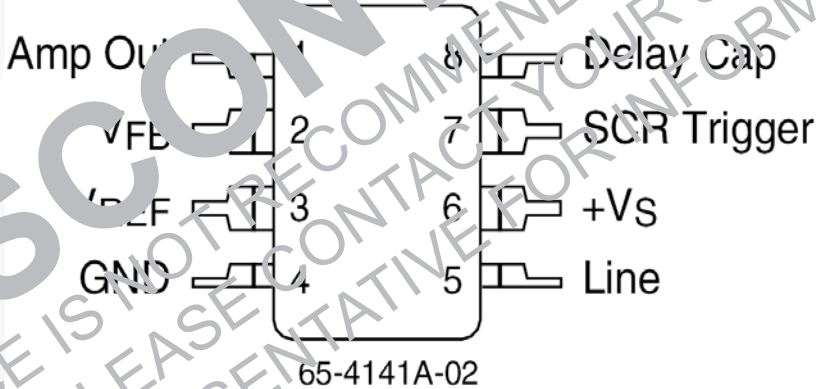


图 2. 引脚分配

引脚定义

引脚号	名称	说明
1	放大器输出	感测放大器输出— 到 V_{FB} 的外部电阻设置 I_{FAULT} 阈值
2	V_{FB}	感测放大器反向输入
3	V_{REF}	感测放大器同向输入 – $+V_S/2$ 内部偏置
4	GND	接地
5	Line	内部二极管阳极连接到电源电压
6	$+V_S$	RV4141A 电路的电源输入
7	SCR 触发	检测到故障时触发外部 SCR 的输出
8	延迟电容	一种连接到接地的外部电容，设置触发 SCR 前出现接地故障的延迟时间

绝对最大额定值

应力超过绝对最大额定值，可能会损坏器件。在超出推荐的工作条件的情况下，该器件可能无法正常工作，所以不建议让器件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应力规格值。

符号	参数		最小值	最大值	单位
V_{CC}	电源			10	mA
P_D	内部功耗			500	mW
T_{STG}	存储温度范围		-65	+150	°C
T_A	工作温度范围		-35	+80	°C
T_J	结温			125	°C
T_L	引脚焊接温度	10 秒, SOIC		+30	°C
		60 秒, DIP		+300	

热性能

符号	参数		典型值	最大值	单位
Θ_{JA}	热阻	SOIC	240		°C/W
		DIP	160		

电气特性

 $I_{\text{LINE}} = 1.5\text{mA}$ 且 $T_A = +25^\circ\text{C}$, $R_{\text{SET}} = 650\text{k}\Omega$ 。

符号	参数	工作条件	最小值	典型值	最大值	单位
电压调节器 (引脚 5 至 4)						
V_{REG}	调节后电压	$I_{2-3} = 11\mu\text{A}$	25	27	29	V
		$I_{\text{LINE}} = 750\mu\text{A}$, $I_{2-3} = 9\mu\text{A}$	25	27	29	
I_Q	静态电流	$V_{5-4} = 24\text{V}$		500		μA
感测放大器 (引脚 2 至 3)						
V_{OFF}	失调电压		-200	0	200	μV
GBW	增益带宽	设计值		3		MHz
t_{SK}	压摆率	设计值		1		V/ μS
I_{BIAS}	输入偏置电流	设计值		5	100	nA
SCR 触发 (引脚 7 至 4)						
R_{OUT}	输出电阻	$V_{7-4} = \text{开}$, $I_{2-3} = \mu\text{A}$	3	4.7	5.6	$\text{k}\Omega$
V_{OUT}	输出电压	$I_{2-3} = 9\mu\text{A}$	0	0.1	10.0	mV
		$I_{2-3} = 11\mu\text{A}$	3.0	3.8	4.5	V
I_{OUT}	输出电流	$V_{7-4} = 0\text{V}$, $I_{2-3} = 11\mu\text{A}$	400	600		μA
参考电压 (引脚 3 至 4)						
V_{REF}	参考电压	$I_{\text{LINE}} = 1.5\text{mA}$	12	13	14	V
延迟定时器 (引脚 8 至 4)						
	放电/充电比率	$I_{2-3} = 0/11\mu\text{A}$	1.8	2.5	3.0	$\mu\text{A}/\mu\text{A}$
t_{DLY}	延迟时间 ⁽¹⁾	$C_{8-4} = 12\text{nF}$		2		ms
I_{DLY}	延迟电流	$I_{2-3} = 11\mu\text{A}$	30	40	50	μA

注意:

1. 延迟时间定义为当瞬时感测电流 (I_{2-3}) 超过 $6.5\text{V}/R_{\text{SET}}$ 到 SCR 触发电压 V_{7-6} 升到高电平的时间。

电路工作

(请参阅图 1 和图 3。)

连接到引脚 1 到 3 的精度运算放大器检测到感测变压器的次级中的故障电流流动，将其转换为引脚 1 处的电压。次级电流与输出电压的比率与反馈电阻成正比， R_{SET} 。

R_{SET} 将感测变压器次级电流转换为引脚 1 处的电压。由于虚拟接地是由其负反馈环在感测放大器输入端创建的，所以感测变压器的负担等于 R_{IN} 的值。从变压器角度来看， R_{IN} 的理想值是 0Ω 。这使它像一个电流互感器，误差极小。然而，使 R_{IN} 等于零会在引脚 1 处形成较大的失调电压，因为感测放大器的直流增益非常高。应将 R_{IN} 选择得尽可能高，以便变压器的运行保持得像真正的电流互感器。 R_{IN} 的典型值在 200 和 1000Ω 之间。

如等式 (1) 所示，最大化 R_{IN} 将使感测放大器输出端处的直流失调误差最小。引脚 1 处的直流失调电压对跳变电流误差有直接影响。引脚 1 处的失调电压为：

$$V_{OS} \times R_{SET} / (R_{IN} + R_{SEC}) \quad (1)$$

其中：

V_{OS} = 感测放大器的输入失调电压；

R_{SET} = 反馈电阻；

R_{IN} = 输入电阻；

R_{SEC} = 变压器次级绕组电阻。

感测放大器有 $200\mu V$ 的指定最大失调电压，以最小化跳变电流误差。连接到感测放大器输出端的一个比较器配置为窗口检测器，其参考值为 $-6.5V$ 到 $6.5V$ ，以引脚 3 为参考。当感测变压器次级 RMS 电流超过 $4.6/R_{SET}$ 时，窗口检测器的输出启动延迟电路。如果次级电流超出预先确定的跳变电流，则会在延迟时间后，则会在引脚 7 处出现电流脉冲，触发 SCR。

SCR 阳极直接连接到电磁阀或继电器线圈。SCR 只能在其阳极比其阴极电压大时触发。

电源电流要求

RV4141A 通过一个串联限流电阻（称为 R_{LINE} ）从线路直接获得电源；其值在 $24k\Omega$ 和 $91k\Omega$ 之间。

控制器 IC 有内置的二极管整流器，因此无需外部功率二极管。 R_{LINE} 的推荐值是 $24k\Omega$ 到 $47k\Omega$ 对于 110V 系统，以及 $47k\Omega$ 到 $91k\Omega$ ，对于 220V 系统。当 R_{LINE} 是 $47k\Omega$ 时，电压调节器电流限定为 $3.6mA$ 。推荐的最大峰值线路电流（通过 R_{LINE} ）是 $10mA$ 。

GFCI 应用

(请参阅图 3)

GFCI 通过感测火线和零线中电流的差异来检测接地故障。电流中的差异被假定为故障电流，它会形成从火线到地的潜在危险路径。因为火线和零线通过感测变压器的中央，所以仅有差模初级端电流被传输到次级。假定匝数比是 1:1000，则次级电流为故障电流的 $1/1000$ 。RV4141A 的感测放大器将次级电流转换为电压，与两个窗口检测器中任何一个的参考电压相比。如果故障电流超出了编程时间延迟期间的设计值，则 RV4141A 的 SCR 的栅极发送电流脉冲。

检测地线与零线间故障更为困难。表示正常接地故障电阻。 R_N 是负荷/零线/接地之间电路的导线电阻。 R_G 表示地线与零线间故障电阻。根据 UL 943，当 $R_N = 0.4\Omega$ ， $R_G = 1\Omega$ 时，GFCI 必须跳变，且正常接地故障为 $6mA$ 。

假定故障电流为 $5mA$ ，则 $1mA$ 和 $4mA$ 分别通过 R_N 和 R_G ，导致有效的 $1mA$ 故障电流。此电流被感测变压器检测，并被感测放大器放大。地线与零线和感测变压器 R_G 、 R_N ，以及零线接地环路相互耦合，在感测放大器周围产生正反馈环路。这个新建立的反馈回路导致感测放大器以一定频率震荡，该频率由地线/零线变压器次级电感和 $C4$ 决定，在 $8kHz$ 时发生。

$C2$ 用于编程在 SCR 被触发前，显示故障要经过的时间。有关如何计算 $C2$ 值，请参阅等式 (2)。对于 $2ms$ 延迟，其典型值是 $12nF$ 。 R_{SET} 用于设置 GFCI 跳变时的故障电流。与 1:1000 感测变压器一同使用时，对于设计为在 $5mA$ 时跳变的 GFCI，其典型值是 $1M\Omega$ 。

R_{IN} 应该是可能的最高值，以确保从感测变压器流出的可预测的次级电流。如果 R_{IN} 设置得过高，则变压器磁导率的正常生产变差会导致次级电流出现器件间的变差。如果它太低，则在引脚 1 处会出现较大的失调电压误差。此电压反过来会形成与感测放大器的输入偏置电压成比例的跳变电流误差。例如，如果 R_{IN} 为 500Ω ， R_{SET} 为 $1M\Omega$ ， R_{SEC} 为 45Ω ，且感测放大器的 V_{OS} 为其最大值 $200\mu V$ ；跳变电流误差为 $\pm 5.6\%$ 。

SCR 阳极直接连接到电磁阀或继电器线圈。它仅能在其阳极比其阴极更正时跳变。它必须有较高的 dV/dt 额定值，以确保线路噪音（由会发出电噪音的设备产生）不会错误触发它。SCR 还必须小于 $200\mu A$ 的栅极驱动要求。C3 是一种噪声滤波器，它可防止高频线路脉冲触发 SCR。继电器电磁阀的响应时间应小于等于 $3ms$ ，以满足 UL 943 的定时要求。

感测变压器和磁芯

感测和接地/零线变压器磁芯通常使用高磁导率的层叠钢环制造。它们的单圈初级由通过其磁芯中心的火线和零线产生。次级线圈通常是 200 到 1500 圈。可以使用 Magnetic Metals, Inc. 生产的变压器，(www.magmet.com)。

计算 R_{SET} 和 C2 的值

确定标称接地故障跳变电流要求。在北美通常为 $5mA$ ，($117V_{AC}$) 在英国和欧洲通常为 $22mA$ ($220V_{AC}$)。确定防止误触发所需的最小延迟，一般是 1 到 $2ms$ 。提供所需延迟时间所必需的 C2 的值：

$$C2 = 6 \times t \quad (2)$$

其中：

C2 单位为 Nf，而 t 是所需的延迟时间，单位 ms。

满足标称接地故障跳变电流规格的 R_{SET} 的值是：

$$R_{SET} = \frac{4.6 \times N}{I_{FAULT} \times \cos 180(t/P)} \quad (3)$$

其中：

R_{SET} 以 k

为单位，t 是延迟时间，单位 ms；

P 是线路频率的时间，单位 ms；

I_{FAULT} 是所需的接地故障跳变电流，单位 mA RMS；

N 是感测变压器初级圈的数量。

1. 此公式假定使用的是理想感测变压器。使用非理想变压器时， R_{SET} 的计算值可能需要改变，最多达 30%

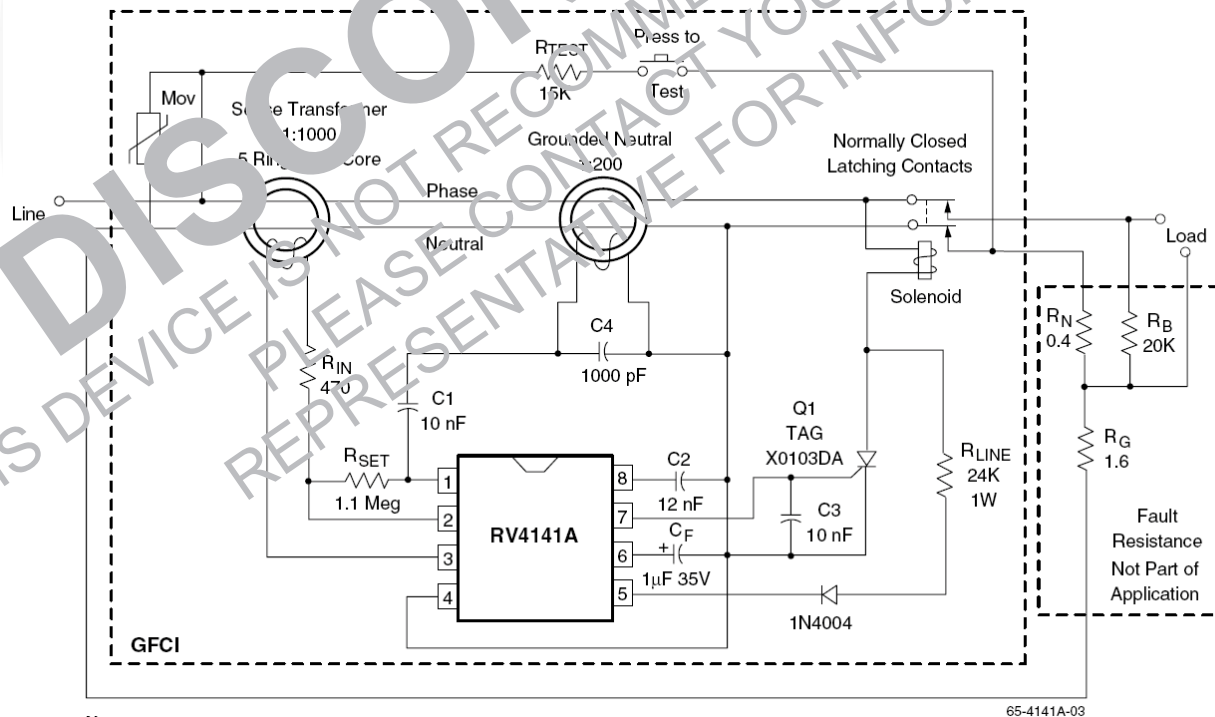
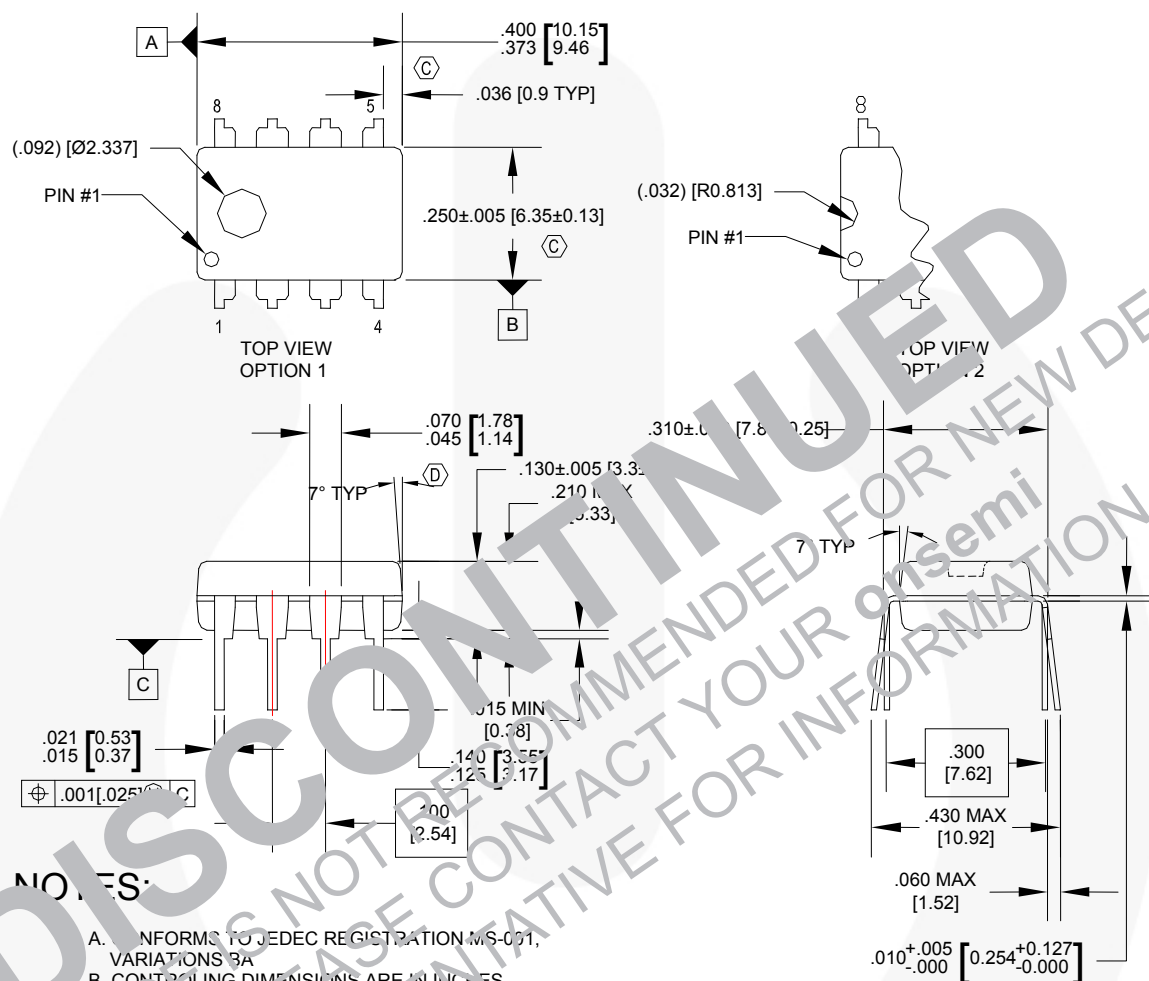


图 3. GFI 应用电路

物理尺寸



NOTES:

- CONFORMS TO JEDEC REGISTRATION MS-001, VARIATIONS BA.
- CONTROLLING DIMENSIONS ARE IN INCHES. REFERENCE DIMENSIONS ARE IN MILLIMETERS.
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N08EREVG

图 4. 8 引线，塑料双列直插封装 (DIP)

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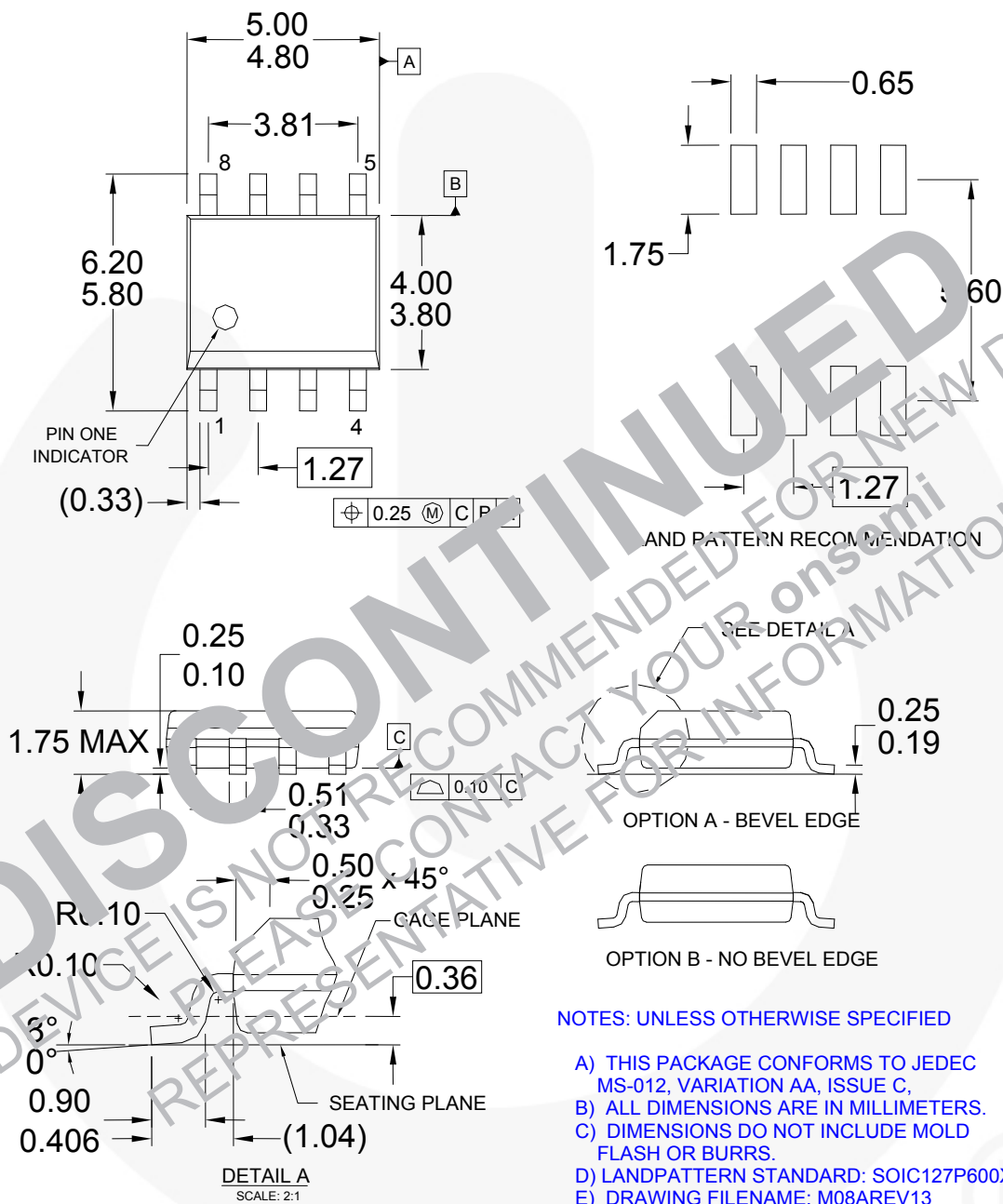


图 5. 8 引线，塑料小外形集成电路 (SOIC)

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