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2013 年 11 月

FSL137MRIN
绿色模式飞兆电源开关 (FPS™)

特性

- 用于低待机功率和低声频噪声的先进软间歇模式
- 电磁干扰小的随机频率波动 (RFF)
- 在 265 V_{AC}、空载条件并处于间歇模式时，待机功耗低于 50 mW
- 逐脉冲限流
- 过载保护 OLP)、过压保护 (OVP)、异常过流保护 (AOCP)、带滞回的内部热关断 (TSD)、输出短路保护 (OSP)、带滞回的欠压锁定 (UVLO) 及线路过压保护 (LOVP)
- 间歇模式下具有低工作电流 (0.4 mA)
- 内部启动电路
- 内部高压 SenseFET：700 V
- 内置软启动：15 ms
- 自动重启模式

应用

- 适用于家用电器、LCD 监控器、STB 和 DVD 播放器的电源

说明

FSL137MRIN 是集成式 PWM 控制器和 SenseFET，专门设计用于外部元件最少的离线开关电源 (SMPS)。PWM控制器包括集成式固定频率振荡器、线路过压保护 (LOVP)、欠压锁定 (UVLO)、前沿消隐 (LEB)、优化的栅极驱动器、内部软启动、用于环路补偿的温度补偿精密电流源和自保护电路。

与分立式 MOSFET和 PWM 控制器解决方案相比，FSL137MRIN 可在降低总成本、元件数、尺寸以及重量的同时提高效率、生产率和系统可靠性。此器件为经济高效的反激式转换器设计提供了一个基础平台。

订购信息

器件编号	封装(1)	工作结温	电流限制（典型值）	$R_{DS(ON)}$（最大值）	输出功率表(2)			
					230 V_{AC}±15%		85-265 V_{AC}	
					适配器(3)	开架式(4)	适配器(3)	开架式(4)
FSL137MRIN	8-DIP	−40°C~ +125°C	1.3 A	4.75 Ω	25 W	30 W	15 W	20 W

注意：

1. 符合 JEDEC J-STD-020B 标准的无铅封装。
2. 结温可以限制最大输出功率。
3. 50°C 环境温度下不通风封闭适配器中测得的典型持续功率。
4. 50°C 环境温度下开架式设计中的最大实际持续功率。

应用电路

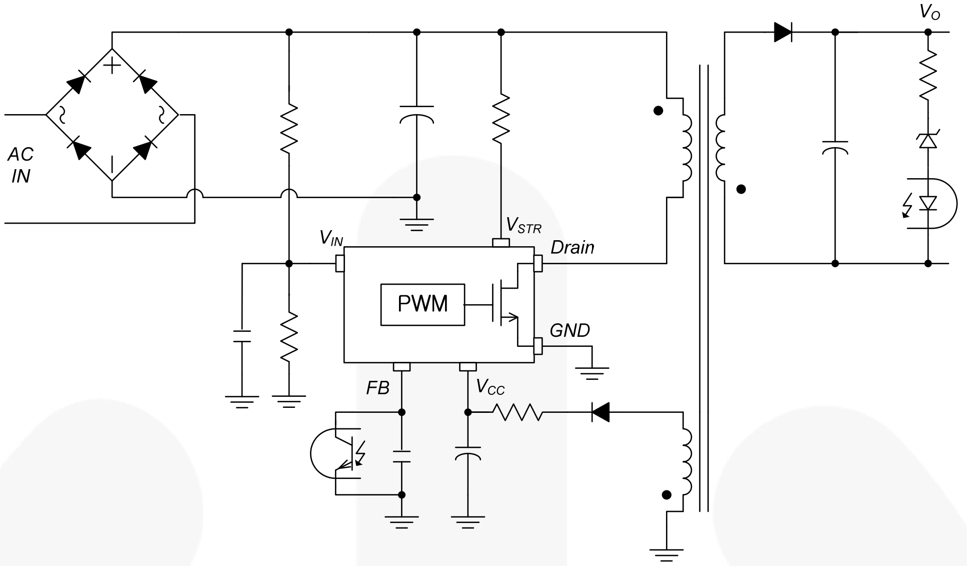

图 1. 典型应用电路

内部框图

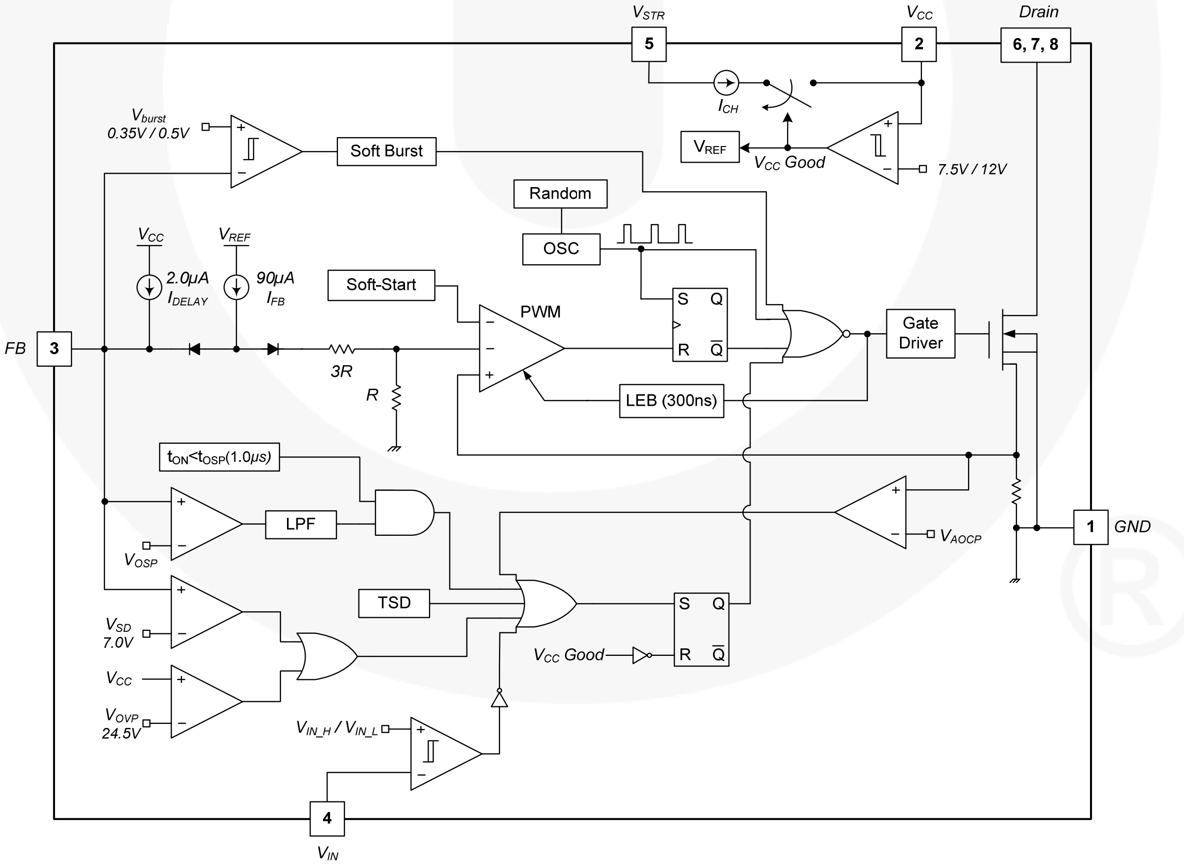

图 2. 内部框图

引脚布局

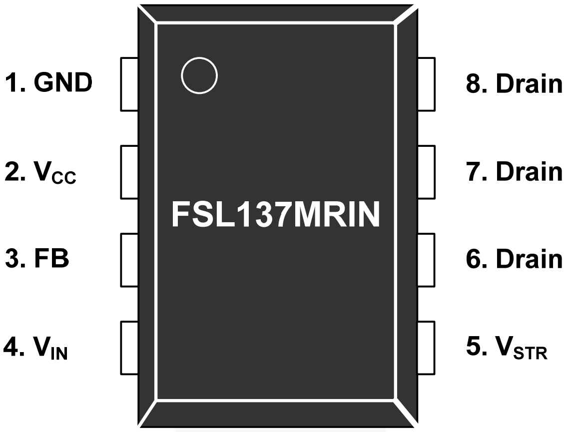

图 3. 引脚分配（顶视图/俯视图）

引脚定义

引脚号	名称	说明
1	GND	**接地**。该引脚为控制地和 SenseFET 源极。
2	V_{CC}	**电源**。该引脚为电源正输入，为启动和稳态运行提供内部工作电流。
3	FB	**反馈**。该引脚在内部连接至 PWM 比较器的反相输入。光电耦合器的集电极通常连接至该引脚。为了保持稳定运行，应当在该引脚和 GND 之间放置一个电容器。若该引脚电压达到 7V，会触发过载保护，即关断 FPS。
4	V_{IN}	**线路过压输入**。这是线路电压输入引脚。通过电阻分压的电压为该引脚的输入。如果该引脚电压高于 V_{INH} 电压，会触发 LOVP，即会关断 FPS。该引脚不得悬浮。如果未使用 LOVP，该引脚应该直连到 GND。
5	V_{STR}	**启动**。该引脚直连到或通过电阻连接到高压直流母线。启动时，内部高压电流源提供内部偏压并为连接到 V_{CC} 引脚的外部电容器充电。一旦 V_{CC} 达到 12 V，内部电流源 (I_{CH}) 将被禁用。
6	漏极	**SenseFET 漏极**。高压功率 SenseFET 漏极连接。
7		
8		

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_{STR}	V_{STR} 引脚电压			700	V
V_{DS}	漏极引脚电压			700	V
V_{CC}	V_{CC} 引脚电压			26	V
V_{FB}	反馈引脚电压		−0.3	10.0	V
V_{IN}	V_{IN} 引脚电压		−0.3	10.0	V
I_{DM}	漏极电流脉冲			12	A
I_D	持续开关漏极电流(5)			3	A
E_{AS}	单脉冲雪崩能量(6)			230	mJ
P_D	总功率损耗 (T_C= 25°C)(7)			1.5	W
T_J	最大结温			150	°C
	工作结温(8)		−40	+125	°C
T_{STG}	存储温度		−55	+150	°C
ESD	静电放电能力	人体模式，JESD22-A114		4.5	kV
		元件充电模式，JESD22-C101		2.0	

注意：

5. 假定感性负载时，最大重复漏极峰值电流受限于 最大占空比 (D_{MAX}=0.73) 和结温（见图 4）。
6. L = 45 mH，开始 T_J= 25°C。
7. 无限冷却条件（参考 SEMI G30-88）。
8. 尽管该参数保证 IC 运行，但不能保证所有电气特征。

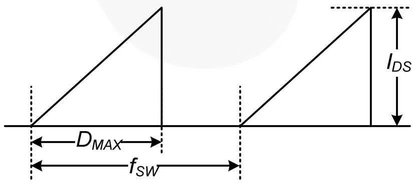

图 4. 重复峰值开关电流

热阻测试

除非另有说明，T_A= 25°C。

符号	参数	数值	单位
θ_{JA}	结至环境热阻(9)	85	°C/W
Ψ_{JL}	结至引脚热阻(10)	11	°C/W

注意：

9. JEDEC 推荐环境，JESD51-2 和测试板 JESD51-10 具有最小焊盘布局。
10. 在漏极引脚 #7 测得，接近于 Rthja 测试条件下的塑料接口。

电气特征

除非另有说明，T_J = 25°C。

符号	参数	工作条件	最小值	典型值	最大值	单位
SenseFET 部分						
BV_{DSS}	漏极－源极击穿电压	V_{CC}=0 V, I_D=250 µA	700			V
I_{DSS}	零栅极电压漏极电流	V_{DS}=560 V, T_A=125°C			250	µA
$R_{DS(ON)}$	漏源极导通电阻	V_{GS}=10 V, I_D=1 A		4.00	4.75	Ω
C_{ISS}	输入电容(11)	V_{DS}=25 V, V_{GS}=0 V, f=1 MHz		315		pF
C_{OSS}	输出电容(11)	V_{DS}=25 V, V_{GS}=0 V, f=1 MHz		47		pF
t_r	上升时间	V_{DS}=325 V, I_D=4 A, R_G=25 Ω		34		ns
t_f	下降时间	V_{DS}=325 V, I_D=4 A, R_G=25 Ω		32		ns
$t_{d(on)}$	导通延迟	V_{DS}=325 V, I_D=4 A, R_G=25 Ω		11.2		ns
$t_{d(off)}$	关断延迟	V_{DS} =325 V, I_D=4 A, R_G=25 Ω		28.2		ns
控制部分						
f_S	开关频率(11)	V_{CC} =14 V, V_{FB}=4 V	61	67	73	kHz
Δf_S	开关频率变化(11)	−25°C < T_J <125°C		±5	±10	%
D_{MAX}	最大占空比	V_{CC}=14 V, V_{FB}=4 V	61	67	73	%
D_{MIN}	最小占空比	V_{CC}=14 V, V_{FB}=0 V			0	%
I_{FB}	反馈源电流	V_{FB}=0 V	65	90	115	µA
V_{START}	UVLO 阈值电压	V_{FB}=0 V 时，V_{CC} 扫描	11	12	13	V
V_{STOP}		导通后，V_{FB} =0 V	7.0	7.5	8.0	
t_{SS}	内部软启动时间	V_{STR}=40 V 时，V_{CC} 扫描		15		ms
V_{RECOMM}	推荐 V_{CC} 范围		13		23	V
间歇模式部分						
V_{BURH}	间歇模式电压	V_{CC}=14 V 时，V_{FB} 扫描	0.45	0.50	0.55	V
V_{BURL}			0.30	0.35	0.40	V
Hys				150		mV
保护部分						
I_{LIM}	峰值漏极电流限制	di/dt=300 mA/µs	1.1	1.3	1.5	A
V_{SD}	关断反馈电压	V_{CC}=4 V 时，V_{FB} 扫描	6.45	7.00	7.55	V
I_{DELAY}	关断延迟电流	V_{CC}=14 V, V_{FB} =4 V	1.2	2.0	2.8	µA
t_{LEB}	前沿消隐时间(10,12)			300		ns
V_{OVP}	过压保护	V_{CC} 扫描	23.0	24.5	26.0	V
V_{INH}	线路过压保护阀值电压	V_{CC} =14 V 时，V_{IN} 扫描	1.885	1.950	2.015	V
V_{INHYS}	线路过压保护滞回	V_{CC} =14 V 时，V_{IN} 扫描		0.06		V
t_{OSP}	输出短路保护(11) 阈值时间	当 t_{ON}< t_{OSP}& V_{FB}> V_{OSP} 时，触发 OSP（持续时间大于 t_{OSP_FB}）	0.7	1.0	1.3	µs
V_{OSP}	阈值 V_{FB}		1.8	2.0	2.2	V
t_{OSP_FB}	V_{FB} 消隐时间		2.0	2.5	3.0	µs
TSD	热关闭温度(11)	关断温度	125	135	145	°C
T_{HYS}		滞回		60		°C

接下页

电气特征（接上页）

除非另有说明，$T_J = 25°C$。

符号	参数	工作条件	最小值	典型值	最大值	单位
整机部分						
I_{OP}	工作电源电流， （间歇模式下控制部分）	V_{CC}=14 V, V_{FB} =0 V	0.3	0.4	0.5	mA
I_{OPS}	工作开关电流， （控制部分和 SenseFET 部分）	V_{CC}=14 V, V_{FB} =2 V		1.2	1.5	mA
I_{START}	启动电流	V_{CC}=11 V（V_{CC} 达到 V_{START} 前）	85	120	155	µA
I_{CH}	启动充电电流	V_{CC}=V_{FB} =0 V, V_{STR} =40 V	0.7	1.0	1.3	mA
V_{STR}	最小电源电压 V_{STR}	V_{CC}=V_{FB} =0 V 时，V_{STR} 扫描		26		V

注意：

11. 这些参数由设计保证；未经 100% 产品测试。
12. t_{LEB} 包括栅极导通时间。

典型性能特征

这些测得的特征图在 T_A= 25°C下都被归一化。

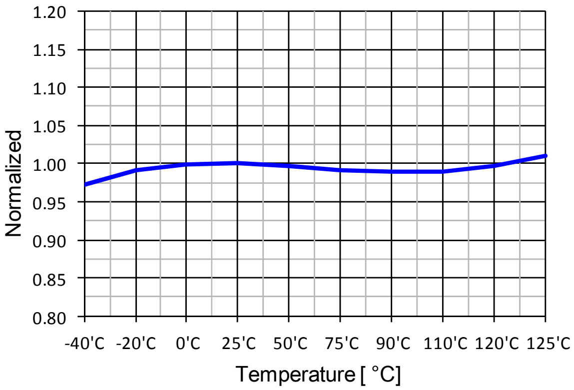

图 5.　工作电源电流 (I_{OP}) 与 T_A 的关系

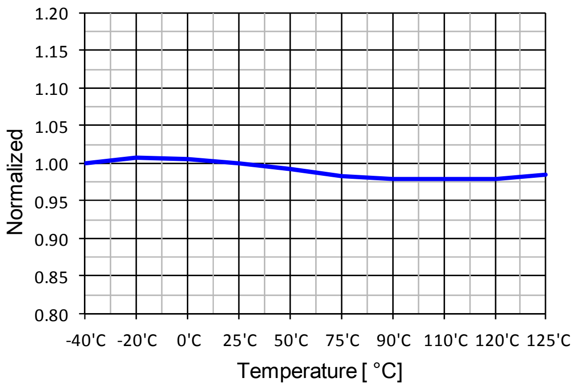

图 6.　工作开关电流 (I_{OPS}) 与 T_A 的关系

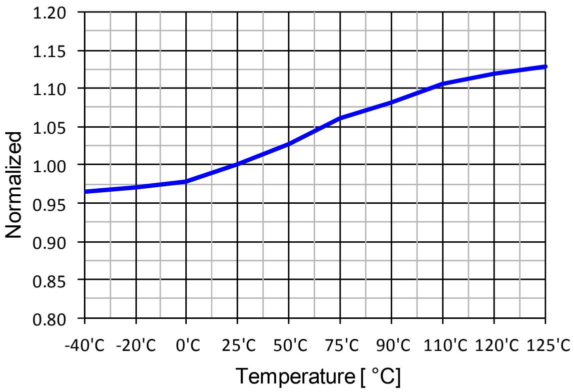

图 7.　启动充电电流 (I_{CH}) 与 T_A 的关系

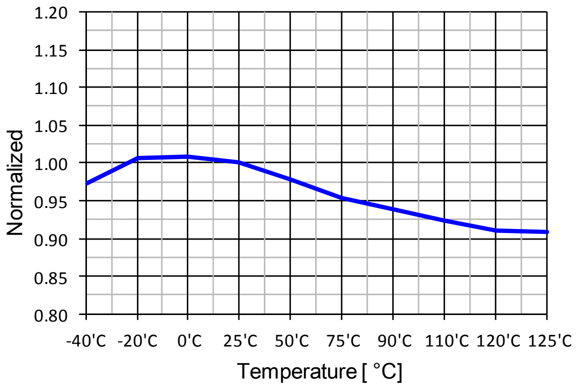

图 8.　峰值漏极电流限制 (I_{LIM}) 与 T_A 的关系

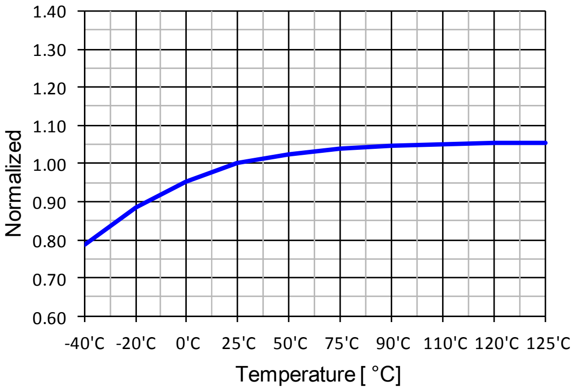

图 9.　反馈源电流 (I_{FB}) 与 T_A 的关系

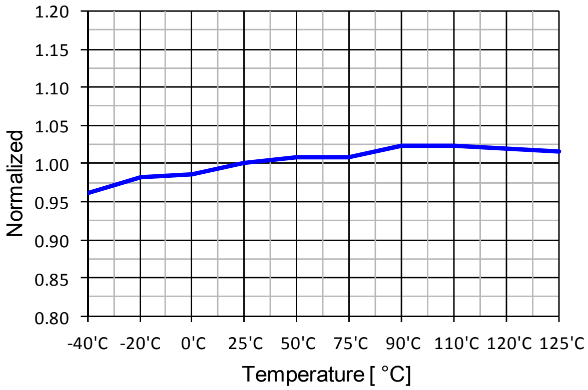

图 10.　关断延迟电流 (I_{DELAY}) 与 T_A 的关系

典型性能特征

这些测得的特征图在 T_A= 25°C下都被归一化。

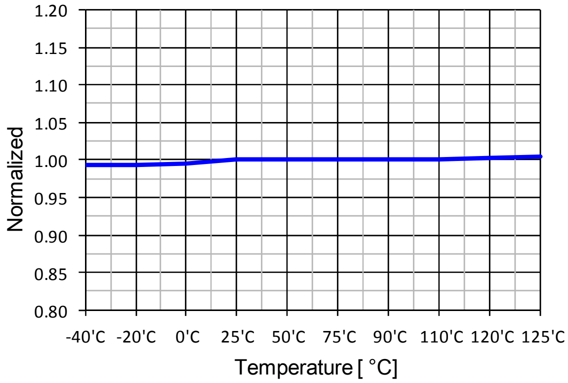

图 11. UVLO 阈值电压 (V_{START}) 与 T_A 的关系

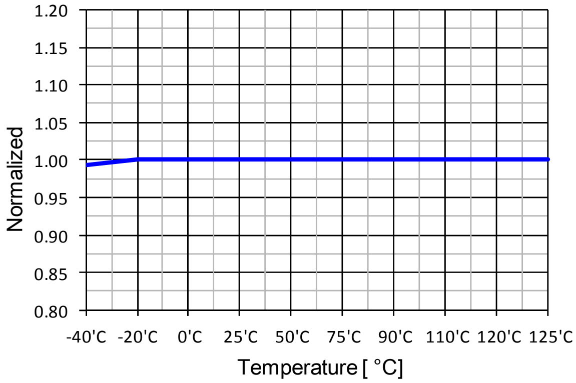

图 12. UVLO 阈值电压 (V_{STOP}) 与 T_A 的关系

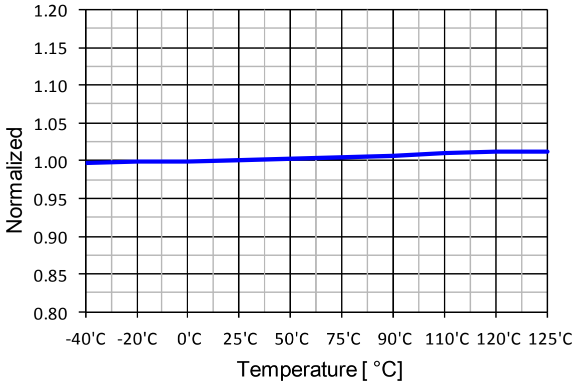

图 13. 关断反馈电压 (V_{SD}) 与 T_A 的关系

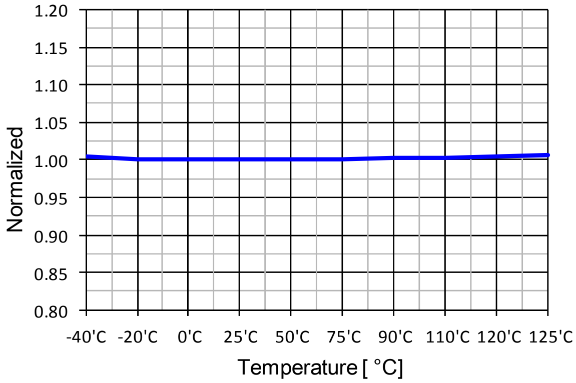

图 14. 过压保护 (V_{OVP}) 与 T_A 的关系

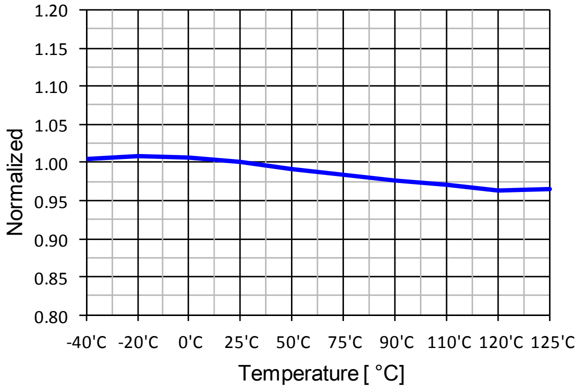

图 15. 开关频率 (f_S) 与 T_A 的关系

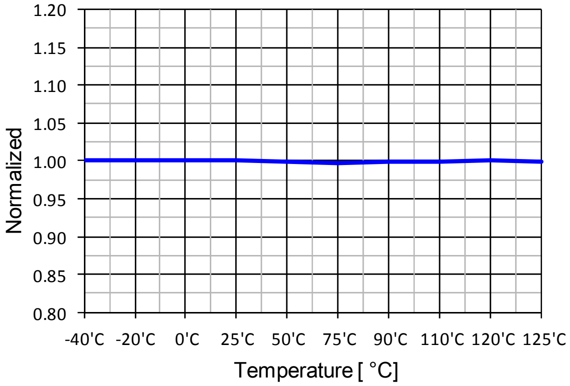

图 16. 最大占空比 (D_{MAX}) 与 T_A 的关系

典型性能特征

这些测得的特征图在 T_A= 25°C下都被归一化。

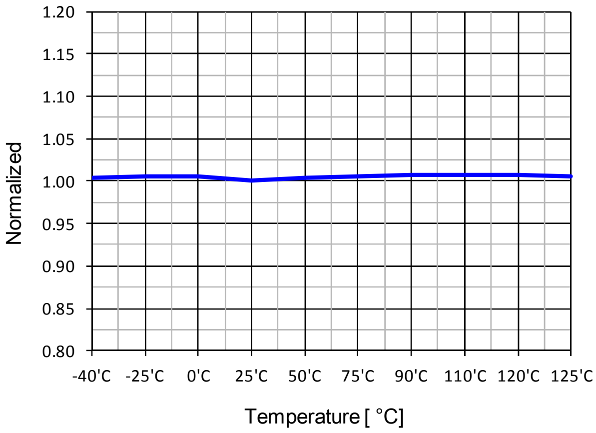

图 17. 线路 OVP (V_{INH}) 与 T_A 的关系

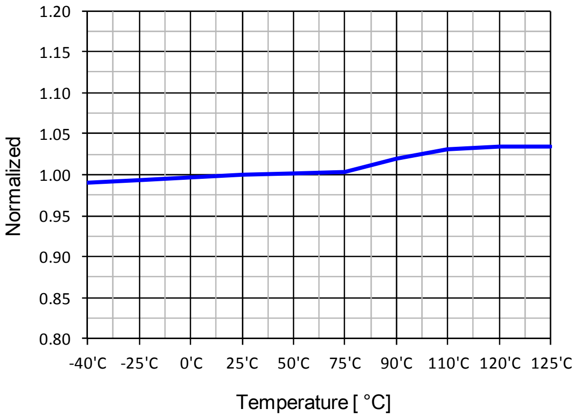

图 18. LOVP 滞回 (V_{INHYS}) 与 T_A 的关系

功能说明

1. 启动：启动时，内部高压电流源提供内部偏压并为连接至 V_{CC} 引脚的外部电容器 (C_{VCC}) 充电，如图 19 所示。 当 V_{CC} 达到 12 V 时，FSL137MRIN 开始开关过程，内部高压电流源被禁用。除非 V_{CC} 低于停止电压 7.5 V，正常的开关操作持续进行，电源由变压器辅助绕组提供。

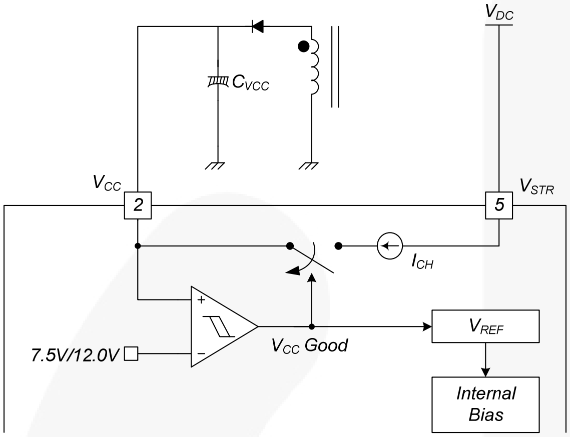

图 19. 启动框图

2. 软启动：启动后，内部软启动电路缓慢增大 PWM 比较器反相输入电压以及 SenseFET 电流。典型软启动时间为 15 ms。功率开关器件的脉宽逐渐增加，从而建立适合变压器、电感器和电容器的正确工作条件。输出电容上的电压逐渐增加，从而顺畅地建立所需的输出电压。这有助于防止变压器饱和，降低启动过程中次级二极管承受的应力。

3. 反馈控制：该器件采用电流模式控制，如图 20 所示。通常用光电耦合器（如 FOD817）和电压调节器（如 KA431）实现反馈网络。通过比较反馈电压与 R_{SENSE} 电阻两端的电压，可实现开关占空比的控制。当电压调节器的参考引脚电压超过内部参考电压 2.5 V 时，光电耦合器 LED 电流增大，拉低反馈电压，并减小漏电流。这种情况通常在输入电压提高或输出负载降低时发生。

3.1 逐脉冲限流：由于采用电流模式控制，因此通过 PWM 比较器的反相输入 (V_{FB}*) 限制了流经 SenseFET 的峰值电流，如图 20 所示。假设 90 µA 的源电流只流经内部电阻 (3R + R = 25 kΩ)，则二极管 D2 的阴极电压约为 2.8V。由于 (V_{FB}) 超过 2.84 V 时 D1 受阻，所以 D2 的最大阴极电压将箝位在此电压值。因此，通过 SenseFET 的电流峰值将受到限制。

3.2 前沿消隐 (LEB)：在内部 SenseFET 导通瞬间，SenseFET 通常会出现高电流尖峰，是由初级端电容放电和次级端整流器反向恢复导致的。感测电阻 R_{SENSE} 两端的过大电压会导致电流模式 PWM 控制中出现不正确的反馈运行状况。为了抵消这种效应，在 SenseFET 导通后，LEB 电路抑制 PWM 比较器一段时间 t_{LEB} (300 ns)。

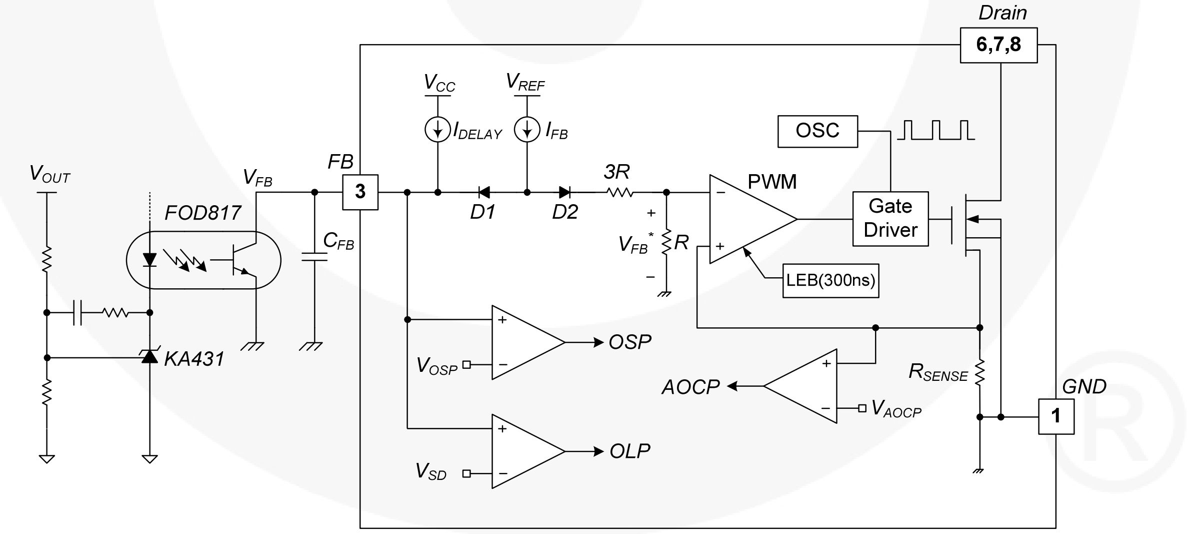

图 20. 脉宽调制 (PWM) 电路

4. 保护电路：FSL137MRIN 具有若干自我保护功能，如过载保护 (OLP)、异常过流保护 (AOCP)、输出短路保护 (OSP)、过压保护 (OVP) 和热关断 (TSD)。所有保护功能都在自动重启模式下实现。如果出现故障情况，开关将终止，且 SenseFET 保持关断。这会导致 V_{CC} 开始下降。当 V_{CC} 降至欠压锁定 (UVLO) 停止电压 7.5 V 时，保护功能被重置，启动电路向 V_{CC} 电容器充电。当 V_{CC} 达到 12.0 V 的启动电压时，恢复正常运行。如果故障情况仍未解除，SenseFET 保持关断并且 V_{CC} 再次跌至停止电压。通过这种方式，自重启功能可以交替使能和禁用功率 SenseFET 的开关过程，直到消除故障状况。由于这些保护电路完全集成在 IC 中，无需任何外部元件，因此能够在不增加成本的情况下提高可靠性。

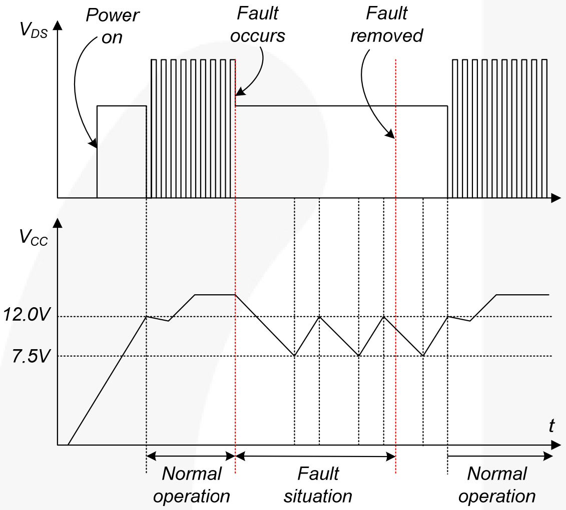

图 21. 自重启保护波形

4.1 过载保护 (OLP)：过载定义为负载电流因意外异常事件而超过正常值。这种情况下，应当触发保护电路，从而保护 SMPS。然而，即使 SMPS 正常运行，在负载过渡过程中也可能触发过载保护电路。为了避免出现这种不必要的工作状况，特定时间后触发过载保护电路确定这是瞬态情况还是真正的过载情况。由于逐脉冲限流能力，通过 SenseFET 的最大峰值电流受限，因此，通过特定的输入电压限制最大输入功率。如果输出消耗的功率超过最大功率，输出电压 (V_{OUT}) 降低至设定电压以下。这样会降低通过光电耦合器 LED 的电流，同时减少光电耦合器晶体管电流，进而增大反馈电压 (V_{FB})。如果 V_{FB} 超过 2.5 V，D1 受阻，并且 2.0 μA 的电流源开始缓慢向 C_{FB} 充电。在这种状况下，V_{FB} 持续增加直至达到 7.0 V，此时开关操作终止，如图 22 所示。关断延迟时间为通过 2.0 μA 的电流将 C_{FB} 从 2.5 V 充电至 7.0 V 所需的时间。通常多数应用延时时间为 25 ~ 50 ms。该保护功能在自动重启模式下实现。

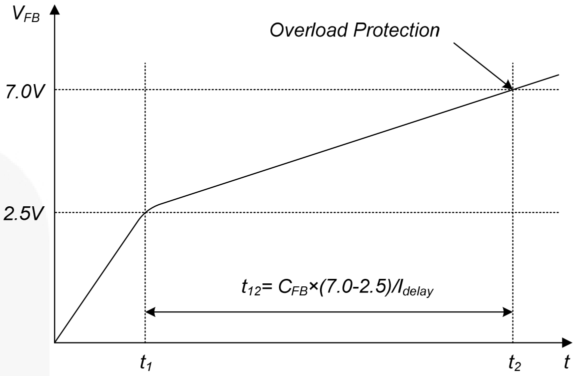

图 22. 过载保护

4.2 异常过流保护 (AOCP)：当次级整流二极管或变压器引脚短路时，在最小导通时间内有一个具有极高 di/dt 的陡波电流流过 SenseFET。虽然 FSL137MRIN 具有过载保护功能，在那种异常情况下仍不足以保护 FSL137MRIN，这是因为触发 OLP 前有很大的电流应力施加在 SenseFET 上。内部 AOCP 电路如图 23 所示。当栅极导通信号被施加到功率 SenseFET 时，AOCP 模块被启用并通过感测电阻监控电流。电阻两端的电压与预置 AOCP 电平进行比较。如果感测电阻电压大于 AOCP 电平，设置信号被施加到 S–R 锁存，导致 SMPS 关断。

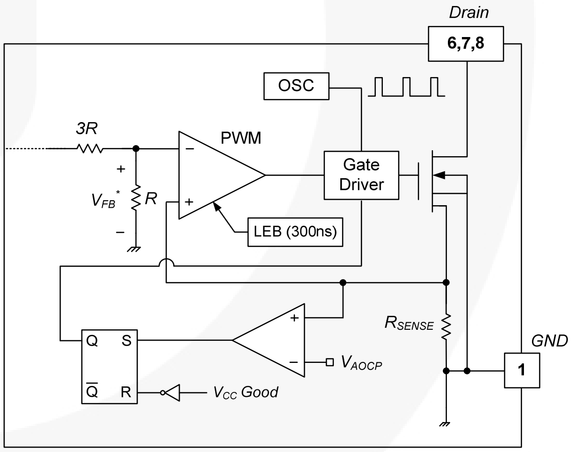

图 23. 异常过流保护

4.3. 输出短路保护 (OSP)：如果输出短路，在最小导通时间内有一个具有极高 di/dt 的陡波电流流过 SenseFET。关断时，该陡波电流会在 SenseFET 漏极上产生高压应力。为了防止器件发生异常情况，需包含 OSP。包括检测 V_{FB} 和 SenseFET 导通时间。当 V_{FB} 高于 2.0 V 且 SenseFET 导通时间小于 1.0 μs，这种情况被认为发生异常错误，PWM 开关停止直至 V_{CC} 再次达到 V_{START}。异常状态输出短路如图 24 所示。

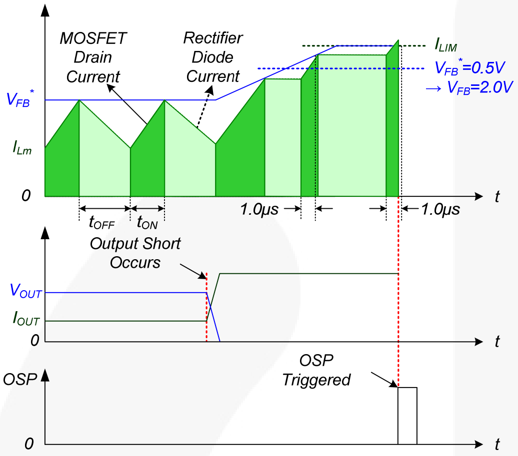

图 24. 输出短路保护

4.4 过压保护 (OVP)：若次级端反馈电路出现功能故障或焊接故障导致反馈路径开环，通过光电耦合器晶体管的电流几乎变为零。然后，V_{FB} 将以类似于过载情况的方式攀升，从而导致强制向 SMPS 提供预置最大电流，直到触发过载保护。由于向输出端提供了过大能量，在激活过载保护之前，输出电压可能就超出了额定电压，从而导致次级端器件击穿。为防止出现这种现象，采用了过压保护 (OVP) 电路。通常来说，V_{CC} 与输出电压成正比，FSL137MRIN 采用 V_{CC}，而不是直接监控输出电压。如果 V_{CC} 超过 24.5 V，触发过压保护电路，导致开关操作终止。 为避免在正常工作期间激活 OVP，V_{CC} 应该设计为低于 24.5 V。

4.5 热关断 (TSD)：SenseFET 和控制 IC 位于同一封装的同一裸片上，方便了控制 IC 检测 SenseFET 的温度。如果温度超过 ~135°C，就会触发热关断，停止运行。FSL137MRIN 运行于自动重启模式，直至温度降至约 75°C，恢复正常运行。

4.6 线路过压保护 (LOVP)：如果线路输入电压增加过高，高线路输入电压会对整个系统产生高压应力。为了防止出现这种异常情况，需包含 LOVP。包括采用分压电阻检测 V_{IN}。当 V_{IN} 高于 1.95 V，这种情况被认为出现异常错误，PWM 开关停止，直至 V_{IN} 降至约 1.89 V（60 mV 滞回）。

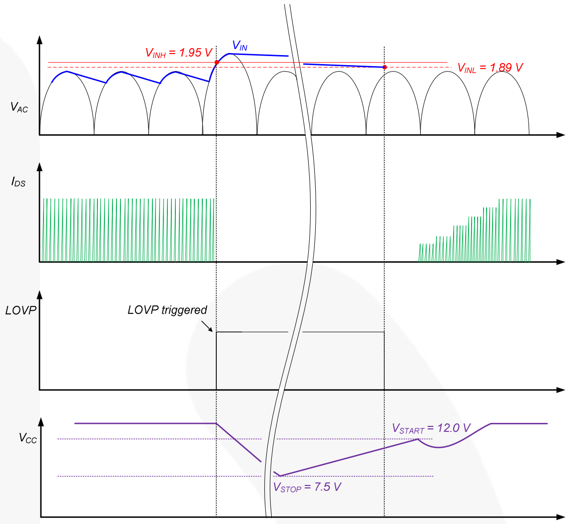

图 25. 线路过压保护

与以前的 FPS 产品系列不同，FSL137MRIN 的 V_{IN} 引脚能够检测交流线路过压保护功能。当线路输入电压超过 V_{IN} 引脚预置电平，控制器发起故障信号并关断 PWM 输出。为了防止错误激活 LOVP，当线路过压持续超过特定时间后才会触发 LOVP 功能。线路过压保护功能的另一个重要特性是自动恢复。即使在故障条件下，控制器也可持续监控线路输入电压，并在过压条件消失时开启PWM输出。方程式 (1) 计算输入过压电平 RMS 值：

$$V_{IN\_ovp} = 1.95 \times \left(\frac{(R1 + R2)}{R1} \right) \tag{1}$$

可根据需要调整分压电阻阻值。轻载情况下，较小的阻值会导致相对较大的待机功耗。为了避免这种情况，推荐使用一个几 MΩ 的电阻器。为了保持稳定运行，使用阻值为几 MΩ 的电阻器时，应该同时在 V_{IN} 引脚与 GND 之间连接一个容值为几百 pF 的电容器。

5. 软间歇模式：为最大程度地降低待机模式下的功耗，FSL137MRIN 会进入间歇运行模式。随着负载减小，反馈电压也随之减小。如图 26 所示，反馈电压降至 V_{BURL} (350 mV) 以下时，器件自动进入间歇模式。此时，开关过程停止，输出电压开始降低，降低的速率取决于待机电流负载。这会导致反馈电压上升。一旦此值超过 V_{BURH}(500 mV)，开关操作将恢复。反馈电压则随之降低，此过程重复进行。间歇模式交替启用和禁用 SenseFET 开关过程，从而减少待机模式下的开关损耗。

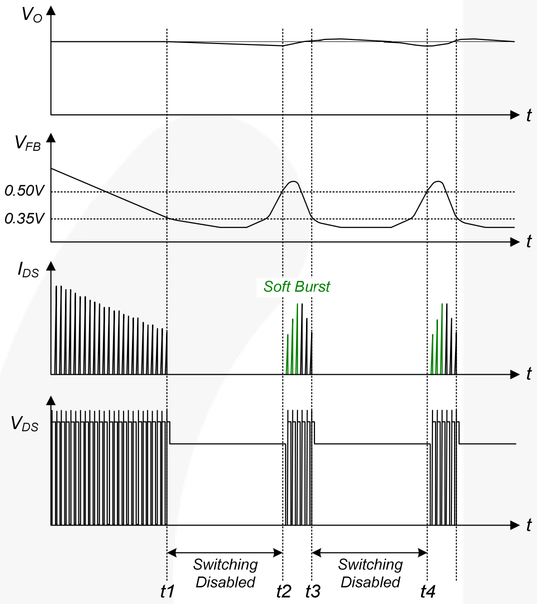

图 26. 间歇模式运行

6. 随机频率波动 (RFF)：SMPS 的波动开关频率能够将能量分布在较宽的频率范围内，从而减少 EMI。EMI 的减少量与在内部限制的开关频率变化有直接关系。开关频率由外部反馈电压和内部自激振荡器在每次开关时随机确定。RFF 将 EMI 噪声有效地分布在典型开关频率 (67 kHz) 附近，能够减少包含的输入滤波器的成本，因而满足 EMI 要求（如 EN55022）。

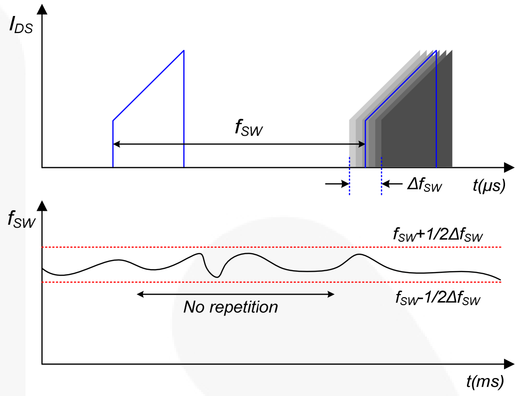

图 27. 随机频率波动

封装尺寸

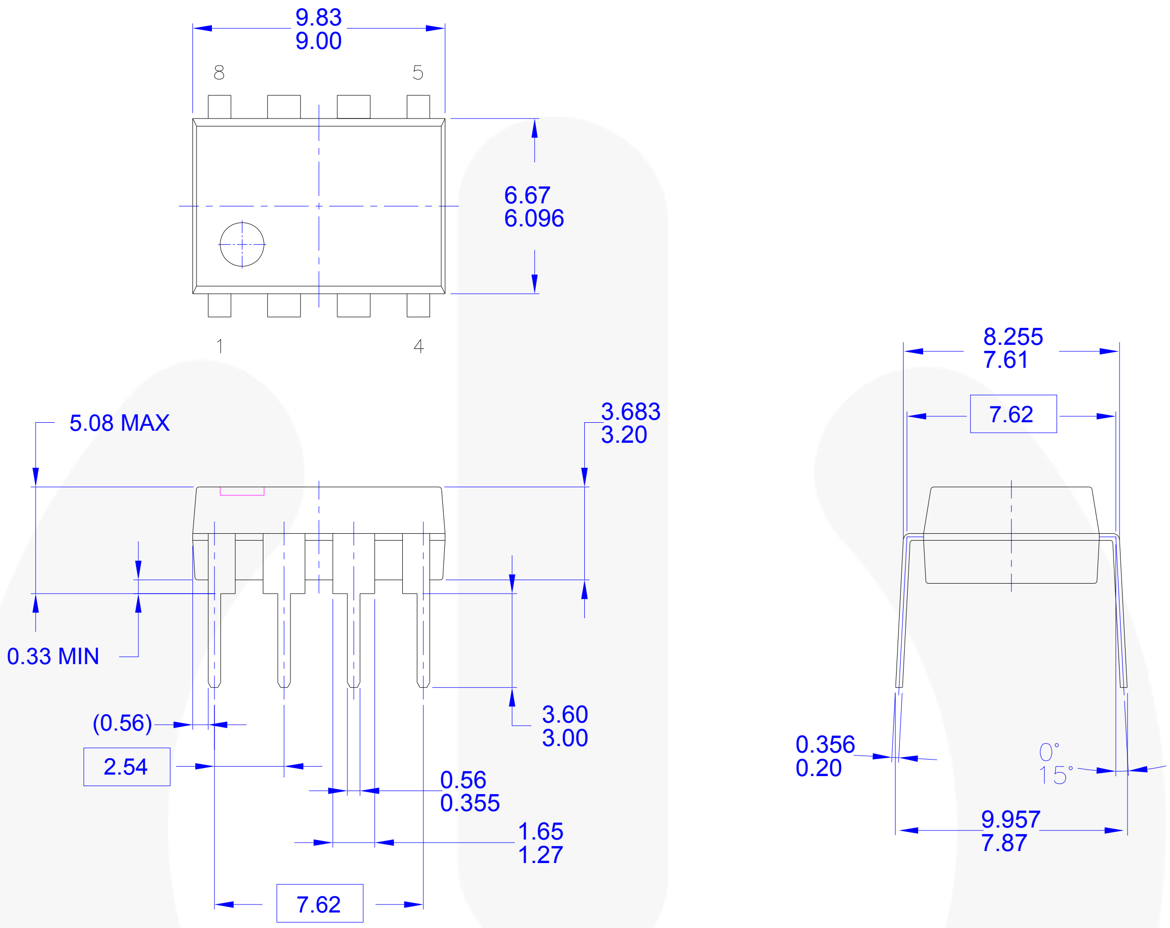

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图 28. 8 引脚，MDIP，JEDEC MS-001，.300"宽

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