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2013 年 11 月

FSL136HR
绿色模式飞兆功率开关 (FPS™)

特性

- 耐雪崩的内部 SenseFET (650 V)
- 在 265 V_{AC}、空载条件并处于间歇模式时，待机功耗低于 50 mW
- 精确的固定工作频率，可提供频率调节来实现 EMI 衰减
- 内部启动电路
- 内置软启动：20 ms
- 逐脉冲限流
- 提供各种保护：过压保护 (OVP)、过载保护 (OLP)、输出短路保护 (OSP)、异常过流保护 (AOCP) 和带滞回的内部热关断功能 (TSD)
- 自动重启模式
- 欠压锁定 (UVLO)
- 低工作电流：1.8 mA
- 可调节峰值限流

应用

- 适用于 VCR、STB、DVD 和 DVCD 播放器的 SMPS
- 适用于家用电器的 SMPS
- 适配器

相关资源

- AN-4137-采用 FPS™ 的离线反激式转换器的设计准则
- AN-4141-飞兆电源开关 (FPS™) 反激式应用的故障排除和设计提示
- AN-4147-反激式转换器 RCD 缓冲器的设计指南

说明

FSL136HR 集成脉宽调制解调器 (PWM) 和 SenseFET，专为采用最少外部组件的高性能离线式开关电源 (SMPS) 而设计。FSL136HR 包括集成式高压电源开关调节器，这些调节器将雪崩耐用 SenseFET 与电流模式的 PWM 控制模块完美结合。

集成的 PWM 控制器包括：提供欠压锁定 (UVLO) 保护、前沿消隐 (LEB)、实现 EMI 衰减的频率生成器、优化的栅极开/关驱动器、热关断 (TSD) 保护以及用于环路补偿和故障保护电路的温度补偿精确电流源。FSL136HR 提供了出色的软启动性能。与分立式 MOSFET 和控制器或 RCC 开关转换器解决方案相比，FSL136HR 减少了总的组件数量、设计大小和重量；同时提高了效率、生产率和系统的可靠性。该器件为经济高效的反激式转换器设计提供了一个最佳的基础平台。

最大输出功率[1]			
230 V_{AC} ± 15%[2]		**85-265 V_{AC}**	
适配器[3]	**开架式电源 (Open Frame)**	**适配器[3]**	**开架式电源 (Open Frame)**
19 W	**26 W**	**14 W**	**20 W**

注意：
1. 结温可限制最大输出功率。
2. 230 V_{AC} 或 100/115 V_{AC}（带倍增器）。
3. 在 50°C 环境温度下测量的非通风封闭适配器中的典型持续功率。

订购信息

器件编号	工作温度范围	顶标	封装	包装方法
FSL136HR	-40 至 105°C	FSL136HR	8 引脚、双列直插封装 (DIP)	电轨
FSL136HRL			8 引脚、表面贴装封装 (LSOP)	电轨
FSL136HRLX				卷带和卷盘

典型应用框图

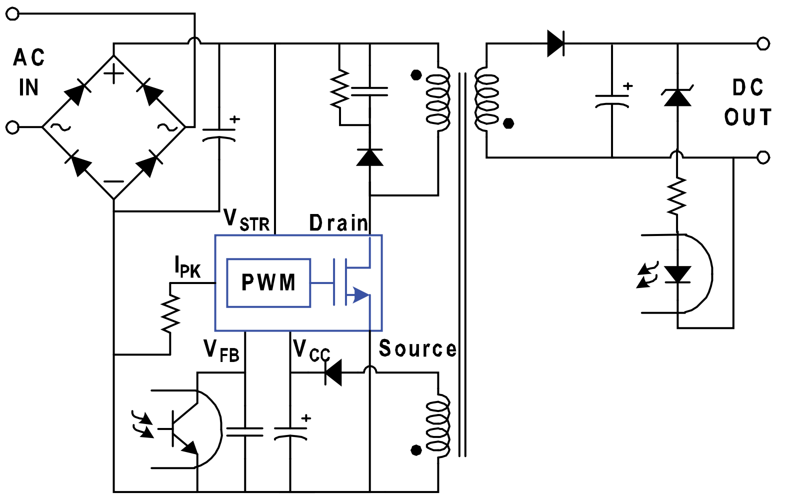

图 1. 典型应用

内部框图

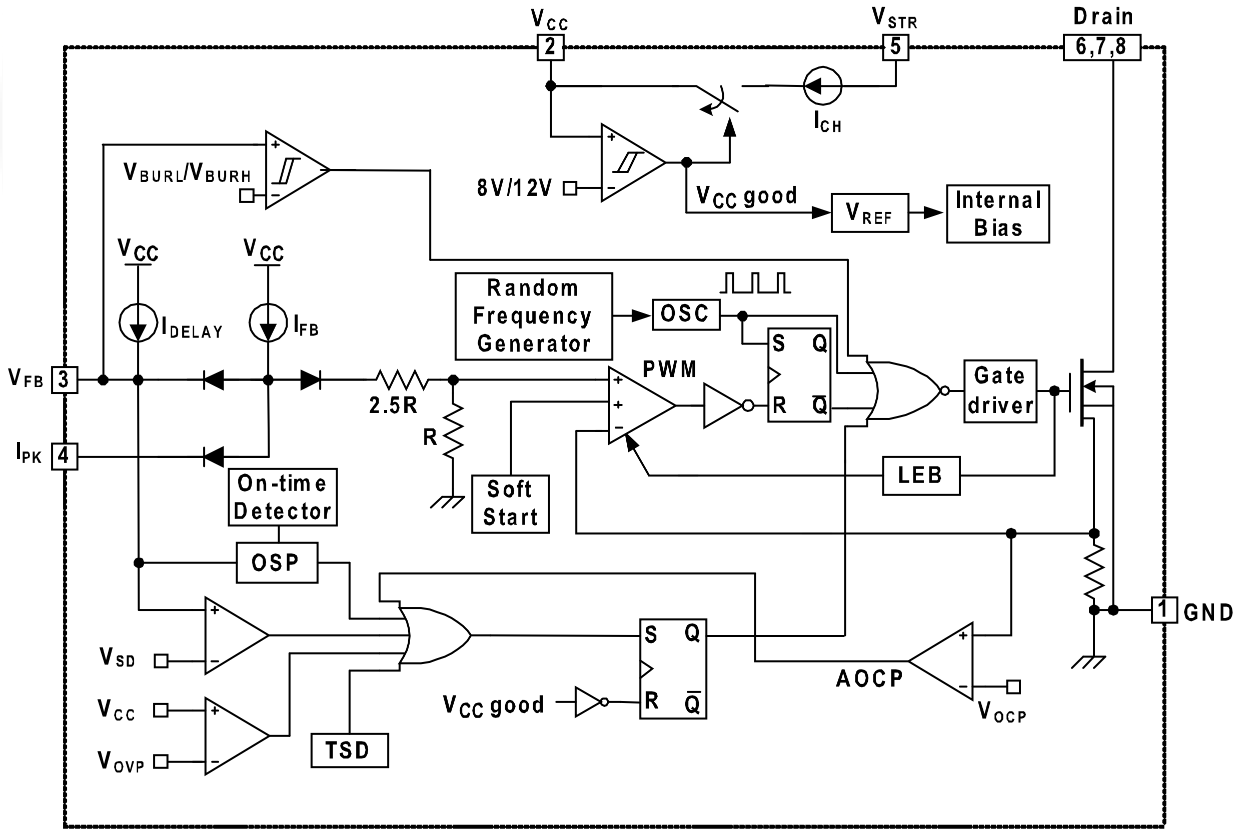

图 2. 内部框图

引脚布局

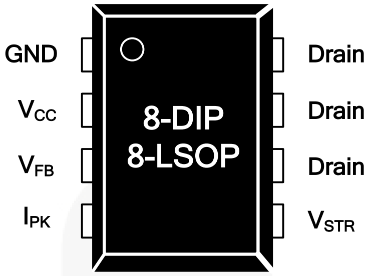

图 3. 引脚布局

引脚定义

引脚号	名称	说明
1	GND	**接地**。初级端和内部控制地上的 SenseFET 源极端。
2	V_{CC}	**正极电源电压输入**。尽管连接到变压器辅助绕组，启动期间电流仍通过内部开关从引脚 5 (V_{STR}) 提供（请参阅内部框图部分）。一旦 V_{CC} 达到 UVLO 上限 (12 V)，内部启动开关即断开，器件电源通过变压器辅助绕组提供。
3	V_{FB}	**反馈电压**。同相输入至 PWM 比较器，其具有内部连接的 0.4 mA 电流源，而电容和光电耦合器通常从外部连接。使用内部 5 µA 电流源将外部电容 C_{FB} 从 2.4 V 充电至 6 V 时有一个延迟。此延迟可防止瞬态情况下出现误触发，但仍允许保护机制在真正过载条件下工作。
4	I_{PK}	**峰值限流**。调节 SenseFET 的峰值限流。反馈 0.4 mA 电流源流过内部 6 kΩ 电阻和此引脚上任何接地外部电阻的并联组合，以确定峰值限流。
5	V_{STR}	**启动**。连接至整流后的 AC 线路电压源。启动时，内部开关提供内部偏压并对位于 V_{CC} 引脚和接地间的外部存储电容进行充电。一旦 V_{CC} 达到 12 V，即断开内部开关。
6, 7, 8	漏极	**漏极**。设计用于直接连接至变压器的初级引脚，开关电压最大为 650 V。最大程度地缩短这些引脚与变压器的连接走线长度，以减小漏电感。

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。除非另有规定，否则 T_J=25°C。

符号	参数	最小值	最大值	单位
V_{STR}	V_{STR} 引脚电压	-0.3	650.0	V
V_{DS}	漏极引脚电压	-0.3	650.0	V
V_{CC}	电源电压		26	V
V_{FB}	反馈电压范围	-0.3	12.0	V
I_D	连续漏极电流		3	A
I_{DM}	脉冲漏电流(4)		12	A
E_{AS}	单脉冲雪崩能量(5)		230	mJ
P_D	总功耗		1.5	W
T_J	工作结温	内部限制		°C
T_A	工作环境温度	-40	+105	°C
T_{STG}	存储温度	-55	+150	°C
ESD	人体模型，JESD22-A114(6)	5.0		KV
	元件充电模型，JESD22-C101(6)	1.5		
Θ_{JA}	结至环境热阻(7)(8)		80	°C/W
Θ_{JC}	结至外壳热阻(7)(9)		19	°C/W
Θ_{JT}	结至顶端热阻(7)(10)		33.7	°C/W

注意：

4. 重复额定值：脉冲宽度受限于最大结温。
5. L=51 mH，启动 T_J=25°C。
6. 符合 JEDEC 标准 JESD 22-A114 和 JESD 22-C101。
7. 所有项目均遵循标准 JESD 51-2 和 JESD 51-10（DIP 封装）测试。
8. Θ_{JA} 独立，不带散热片，在自然对流条件下。
9. JA$\Theta_{测试条件下}$, Θ_{JC} 结至引脚热特性。T_C 在源极 #7 引脚上测量，其靠近焊接安装 Θ_{JA} 热电偶的塑料接口。
10. JA$\Theta_{测试条件下}$, Θ_{JT} 结至顶端热特性。T_t 在封装顶部测量。热电偶使用环氧胶安装。

电气特性

除非另有规定，否则 T_A = 25°C。

符号	参数	条件	最小值	典型值	最大值	单位
SenseFET 部分						
BV_{DSS}	漏源极击穿电压	V_{CC} = 0 V, I_D = 250 µA	650			V
I_{DSS}	零栅极电压漏极电流	V_{DS} = 650 V, V_{GS} = 0 V			250	µA
$R_{DS(ON)}$	漏源极导通电阻	V_{GS} = 10 V, V_{GS} = 0 V, T_C = 25°C		3.5	4.0	Ω
C_{ISS}	输入电容	V_{GS} = 0 V, V_{DS} = 25 V, f = 1 MHz		290		pF
C_{OSS}	输出电容	V_{GS} = 0 V, V_{DS} = 25 V, f = 1 MHz		45		pF
C_{RSS}	反向传输电容	V_{GS} = 0 V, V_{DS} = 25 V, f = 1MHz		5.5		pF
$t_{d(ON)}$	导通延迟	V_{DD} = 350 V, I_D = 3.5 A		12		ns
t_r	上升时间	V_{DD} = 350 V, I_D = 3.5 A		22		ns
$t_{d(OFF)}$	关断延迟	V_{DD} = 350 V, I_D = 3.5 A		20		ns
t_f	下降时间	V_{DD} = 350 V, I_D = 3.5 A		19		ns
控制部分						
f_{OSC}	开关频率	V_{DS} = 650 V, V_{GS} = 0 V	90	100	110	KHz
Δf_{OSC}	开关频率变化	V_{GS} = 10 V, V_{GS} = 0 V, T_C = 125°C		±5	±10	%
f_{FM}	频率调制			±3		KHz
D_{MAX}	最大占空比	V_{FB} = 4 V	71	77	83	%
D_{MIN}	最小占空比	V_{FB} = 0 V	0	0	0	%
V_{START}	UVLO 阈值电压		11	12	13	V
V_{STOP}		导通后	7	8	9	V
I_{FB}	反馈源电流	V_{FB} = 0 V	320	400	480	µA
$t_{S/S}$	内部软启动时间	V_{FB} = 4 V	15	20	25	ms
间歇模式部分						
V_{BURH}	间歇模式电压	T_J = 25°C	0.4	0.5	0.6	V
V_{BURL}			0.25	0.35	0.45	V
$V_{BUR(HYS)}$				150		mV
保护部分						
I_{LIM}	峰值限流	T_J = 25°C, di/dt = 300 mA/µs	1.89	2.15	2.41	A
t_{CLD}	电流限制延迟时间(11)		200			ns
V_{SD}	关断反馈电压	V_{CC} = 15 V	5.5	6.0	6.5	V
I_{DELAY}	关断延迟电流	V_{FB} = 5 V	3.5	5.0	6.5	µA
V_{OVP}	过压保护阈值	V_{FB} = 2 V	22.5	24.0	25.5	V
t_{OSP}	输出短路保护(11) 阈值时间	T_J = 25°C OSP Triggered When t_{ON}<t_{OSP}, V_{FB}>V_{OSP} and Lasts Longer than t_{OSP_FB}		1.00	1.35	µs
V_{OSP}	阈值反馈电压		1.44	1.60		V
t_{OSP_FB}	反馈消隐时间		2.0	2.5		µs
V_{AOCP}	AOCP电压**(11)**	T_J = 25°C	0.85	1.00	1.15	V
TSD	热关断(11) 关断温度		125	137	150	°C
HYS_{TSD}	滞回			60		°C
t_{LEB}	前沿消隐时间(11)		300			ns

接下页

电气特性（续）

除非另有规定，否则 $T_A = 25°C$。

符号	参数	条件	最小值	典型值	最大值	单位
总器件部分						
I_{OP1}	工作电源电流(11)（开关时）	$V_{CC} = 14\ V$, $V_{FB} > V_{BURH}$		2.5	3.5	mA
I_{OP2}	工作电源电流（仅限控制部件）	$V_{CC} = 14\ V$, $V_{FB} < V_{BURL}$		1.8	2.5	mA
I_{CH}	启动充电电流	$V_{CC} = 0\ V$	0.90	1.10	1.30	mA
V_{STR}	最小 V_{STR} 电源电压	$V_{CC} = V_{FB} = 0\ V$, V_{STR} Increase	35			V

注：

11. 尽管由设计保证，但并非 100% 经生产测试。

典型性能特征

这些特性图在 T_A=25 时标准化。

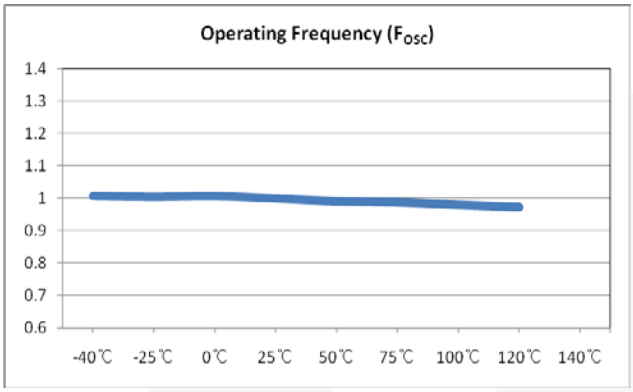

图 4. 工作频率与温度的关系

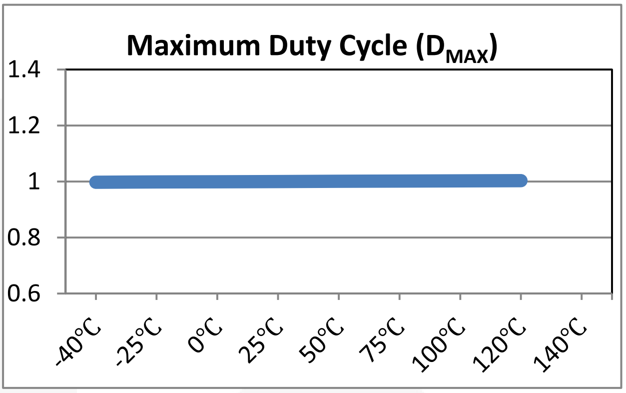

图 5. 最大占空比与温度的关系

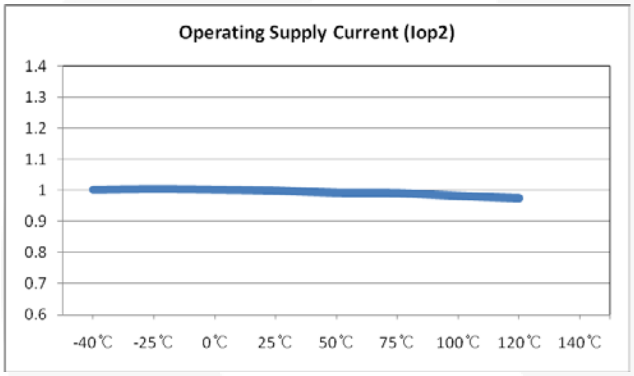

图 6. 工作电源电流与温度的关系

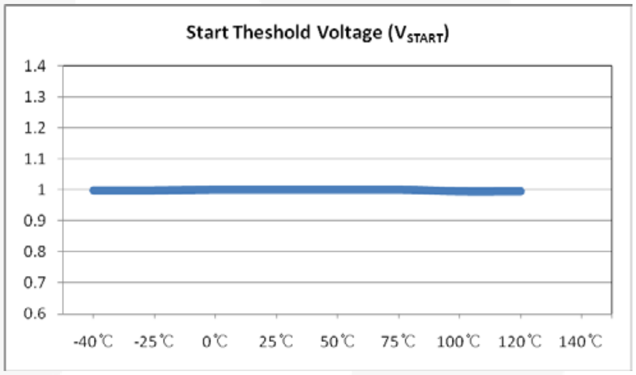

图 7. 启动阈值电压 vs. 温度

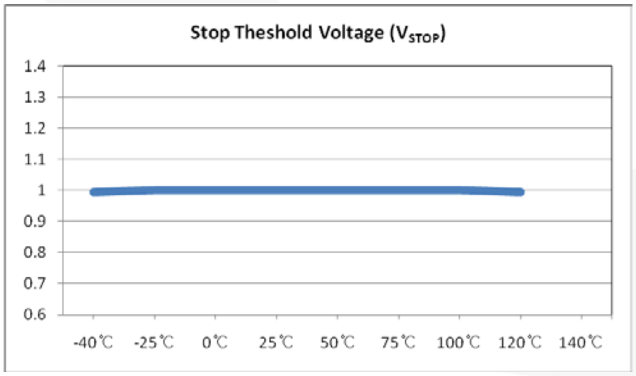

图 8. 停止阈值电压与温度的关系

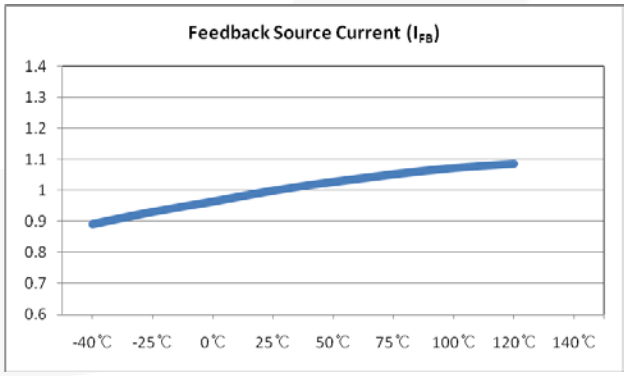

图 9. 反馈源电流与温度的关系

典型性能特征（接上页）

这些特性图在 T_A=25 时标准化。

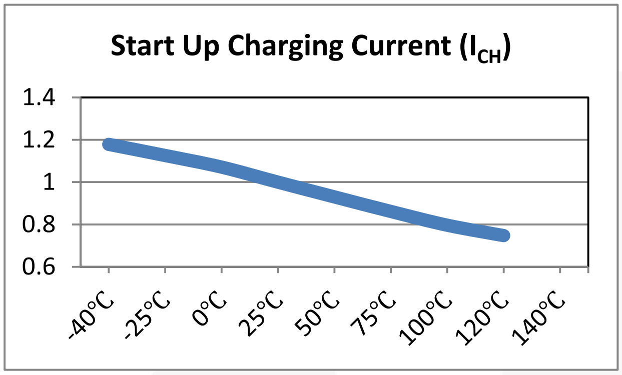

图 10. 启动充电电流与温度的关系

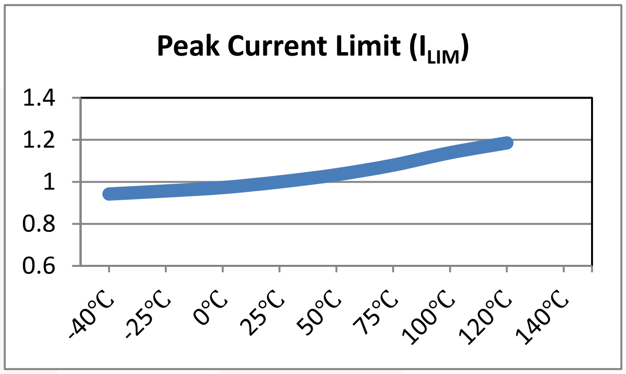

图 11. 峰值限流与温度的关系

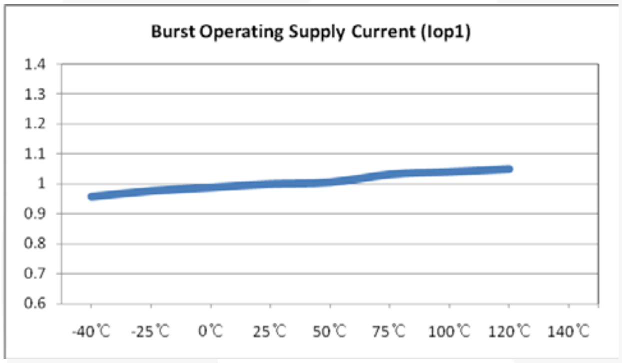

图 12. 间歇工作电源电流与温度的关系

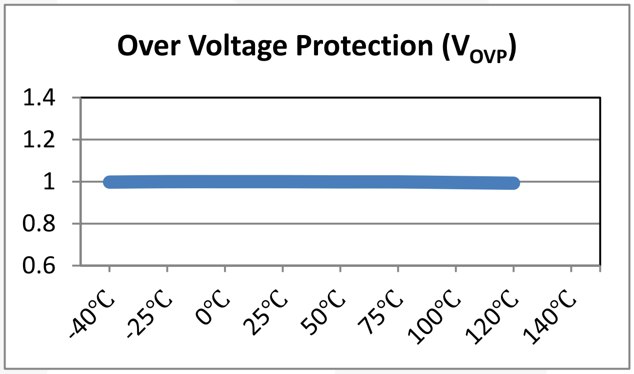

图 13. 过压保护与温度的关系

功能说明

启动

启动时，内部高压电流源提供内部偏置并对与 V_{CC} 引脚连接的外部电容 (C_A) 充电，如图 14 中所示。当 V_{CC} 达到 12 V 启动电压时，FPS™ 开始开关操作并且内部高压电流源被禁用。FPS 继续正常开关操作，除非 V_{CC} 低于 8 V 的停止电压，否则电源通过变压器辅助绕组提供。

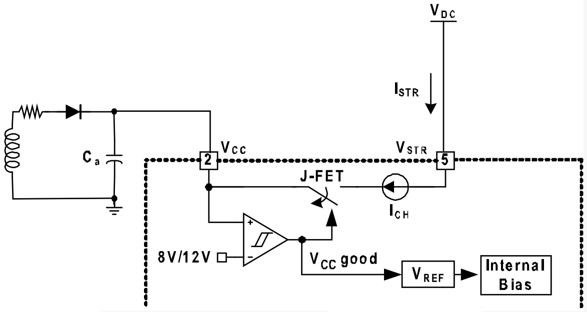

图 14. 启动电路

振荡器模块

振荡器频率在内部设置，并且 FPS 具有随机频率波动功能。开关电源的开关频率波动可将电能分布在比由 EMI 测试设备测量的带宽更宽的频率范围内，从而降低 EMI。EMI 降低量直接与频率变化范围相关。频率变化范围在内部是固定的；但通过外部反馈电压和内部自由运行的振荡器的组合来随机选择。此随机选择的开关频率有效地将 EMI 噪声分布在开关频率附近，并允许使用经济高效的电感代替 AC 输入电源滤波器来满足全球EMI要求。

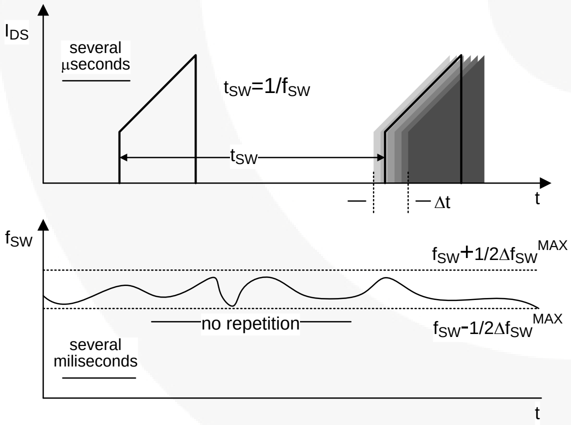

图 15. 频率波动波形

反馈控制

FSL136HR 采用电流模式控制，如图 16 中所示。通常用光电耦合器（如 FOD817A）和电压调节器（如 KA431）组成反馈网络。将反馈电压与 R_{SENSE} 电阻两端的电压进行比较，可实现开关占空比的控制。当电压调节器参考引脚电压超出 2.5 V 的内部参考电压时，光电耦合器 LED 电流增加，反馈电压 V_{FB} 被拉低，并且占空比减小。这种情况通常在输入电压提高或输出负载降低时发生。

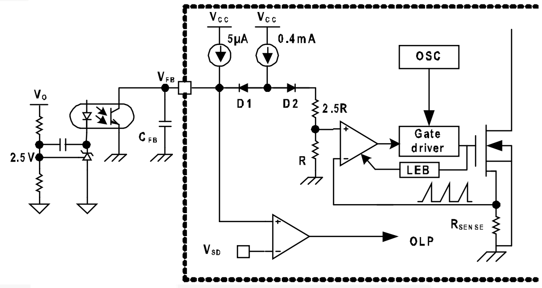

图 16. 脉宽调制电路

前沿消隐 (LEB)

内部 SenseFET 导通的那一刻，初级端电容放电和次级端整流器二极管的反向恢复通常导致高电流尖峰通过 SenseFET。R_{SENSE} 电阻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，FPS 采用了前沿消隐 (LEB) 电路（请参见图 16）。SenseFET 导通后，此电路将在短时间内抑制 PWM 比较器 (t_{LEB})。

保护电路

FPS 具有多个保护功能，如过载保护 (OLP)、过压保护 (OVP)、输出短路保护 (OSP)、欠压锁定 (UVLO)、异常过流保护 (AOCP) 和热关断 (TSD)。由于各种这些保护电路都完全集成在 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。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} 下降。当 V_{CC} 达到 UVLO 停止电压 V_{STOP} (8 V) 时，将复位保护功能，内部高压电流源通过 V_{STR} 引脚向 V_{CC} 电容提供电荷。当 V_{CC} 达到 UVLO 启动电压 V_{START} (12 V) 时，FPS 恢复正常操作。通过这种方式，自动重启功能可以交替使能和禁用功率 SenseFET 的开关，直到消除故障条件。

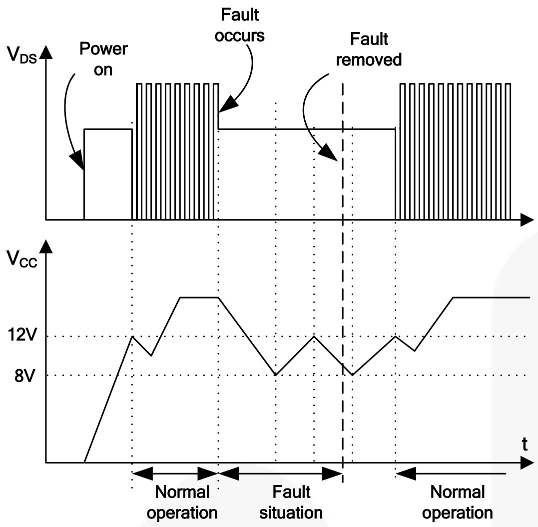

图 17. 自动重启保护波形

过载保护 (OLP)

过载定义为负载电流因意外事件而超过设定值。这种情况下，应该激活保护电路，从而保护 SMPS。但是，即使在 SMPS 正常工作时，过载保护 (OLP) 电路也可能在负载转换或启动期间激活。为了避免出现这种不必要的工作状况，OLP 电路设计为在一定时间后激活，以确定这是瞬态情况还是真正的过载情况。

与 I_{PK} 限流引脚（如果使用）相结合，在达到最大 PWM 占空比时，电流模式反馈路径会限制 SenseFET 中的电流。如果输出功耗大于此最大功率，输出电压 (V_O) 将降至此额定电压以下。这减小了通过光电耦合器 LED 的电流，也减小了光电耦合器电阻电流，从而提高了反馈电压 (V_{FB})。如果 V_{FB} 超过 2.4 V，反馈输入二极管受阻并且 5 µA 电流源 (I_{DELAY}) 缓慢启动以对 C_{FB} 充电。在这种情况下，当开关操作终止时，V_{FB} 一直增大至 6 V，如图 18 中所示。关断延迟是在电流源为 5 µA 时将 C_{FB} 从 2.4 V 供应电荷至 6 V 所需的时间 。

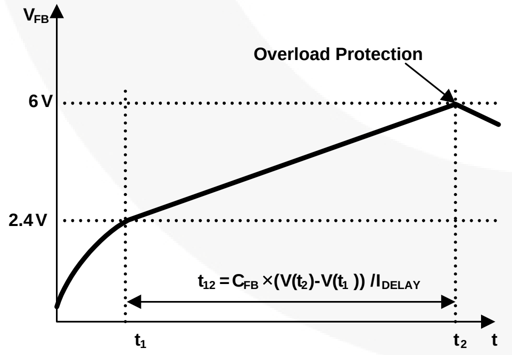

图 18. 过载保护 (OLP)

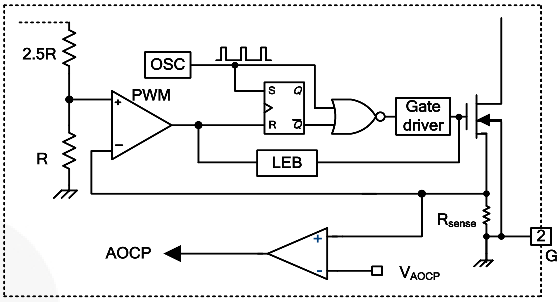

图 19. 异常过流保护

异常过流保护 (AOCP)

当次级整流二极管或变压器引脚短路时，具有极高 di/dt 的陡坡电流可在 LEB 时间期间流经 SenseFET。即使 FPS 具有 OLP（过载保护），在这种异常情况下，也不足以保护 FPS，因为在触发 OLP 之前，SenseFET 一直受到严重的电流应力。FPS 包括内部 AOCP（异常过流保护）电路，如图 19 中所示。当向功率 SenseFET 应用栅极导通信号时，将启用 AOCP 块，并监控通过感测电阻的电流。电阻两端的电压与预设 AOCP 电平进行比较。如果感测电阻电压大于 AOCP 电平，将向锁存器应用设定信号，导致 SMPS 关断。

热关断 (TSD)

SenseFET 和控制 IC 相集成，使控制 IC 可更轻松地检测 SenseFET 的温度。温度超过 137°C 左右时，将激活热关断。

过压保护 (OVP)

如果出现次级端反馈电路故障或因焊接缺陷而导致的反馈开环，通过光电耦合器电阻的电流几乎变为零。然后，V_{FB} 将以类似于过载情况的方式攀升，从而强制向 SMPS 提供预设最大电流，直到激活过载保护。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，V_{CC} 与输出电压成正比，并且 FPS 使用 V_{CC} 而非直接监控输出电压。如果 V_{CC} 超过 24 V，将激活 OVP 电路，导致开关操作终止。为避免在正常工作期间不必要地激活 OVP，V_{CC} 应设计为低于 24 V。

输出短路保护 (OSP)

如果输出短路，具有极高 di/dt 的陡坡电流可在 LEB 时间流经 SenseFET。关断时，这种陡坡电流对 SenseFET 的漏极带来高压应力。为避免器件出现此类异常情况，

OSP 检测 V_{FB} 和 SenseFET 导通时间。当 V_{FB} 高于 1.6 V 且 SenseFET 导通时间小于 1.2 µs 时，FPS 视此情况为异常错误并关断 PWM 开关，直至 V_{CC} 再次达到 V_{START}。异常情况输出如图 20 中所示。

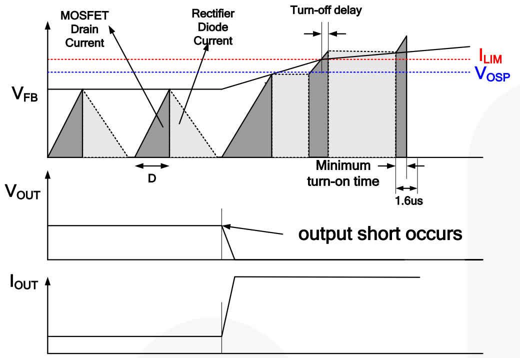

图 20. 输出短路波形 (OSP)

软启动

FPS 具有缓慢增大反馈电压的内部软启动电路，以及启动后的 SenseFET 电流。典型软启动时间为 20 ms，如图 21 中所示，启动阶段过程中允许 SenseFET 电流逐渐递增。输入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。输出电容器上的电压逐渐增加，从而能够顺畅地建立所需的输出电压。软启动有助于防止变压器饱和，并减少次级二极管上的应力。

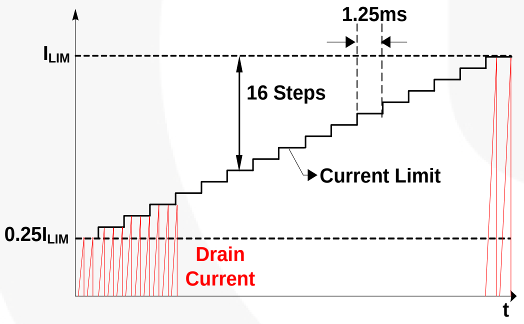

图 21. 内部软启动

间歇运行

为最大程度地降低待机模式下的功耗，FPS 会进入间歇模式。随着负载降低，反馈电压也会降低。如图 22 所示，反馈电压降至 V_{BURH} 以下时，器件自动进入间歇模式。开关操作继续直到反馈电压降低低于 V_{BURL}。此时，开关操作将停止，输出电压降低，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}，开关操作将恢复。反馈电压然后又降低，接着重复上述过程。间歇模式会交替使能和禁用 SenseFET 的开关操作，并降低待机模式下的开关损耗。

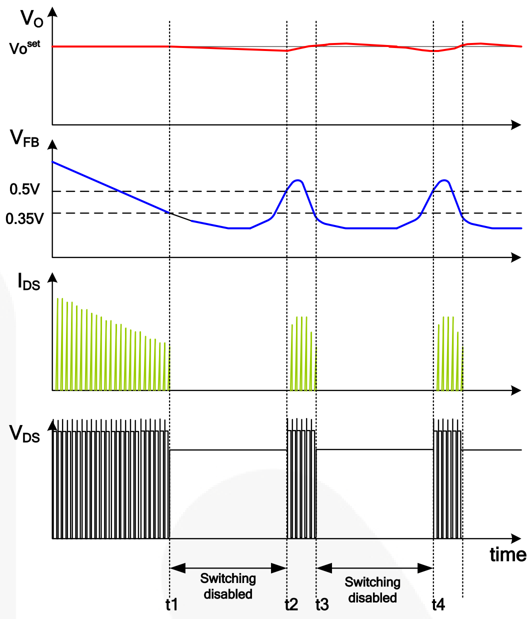

图 22. 间歇模式操作

调节峰值限流

如图 23 所示，PWM 比较器的同相引脚上连接了一个组合式 6 kΩ 内部电阻。当内部二极管由 400 µA 的主电流源偏置时，限流引脚上的 Rx 的外部电阻形成了与 6 kΩ 并联的电阻。例如，FSL136HR 具有 2.15 A 的典型 SenseFET 峰值限流 (I_{LIM})。在 I_{PK} 引脚和接地之间插入 Rx，可将 ILIM 调节为 1.5 A。Rx 的值可通过下式估算：

$$2.15A : 1.5A = 6k\Omega : Xk\Omega \tag{1}$$

$$X = Rx \,||\, 6k\Omega \tag{2}$$

其中 X 是并联网络的电阻。

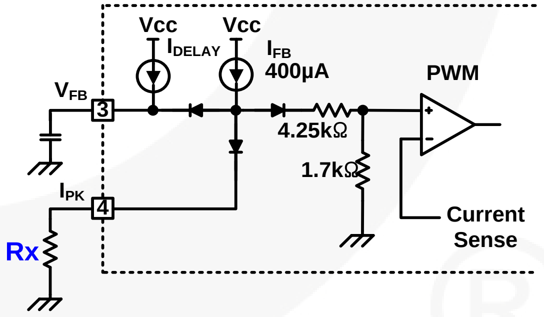

图 23. 峰值限流调节

物理尺寸

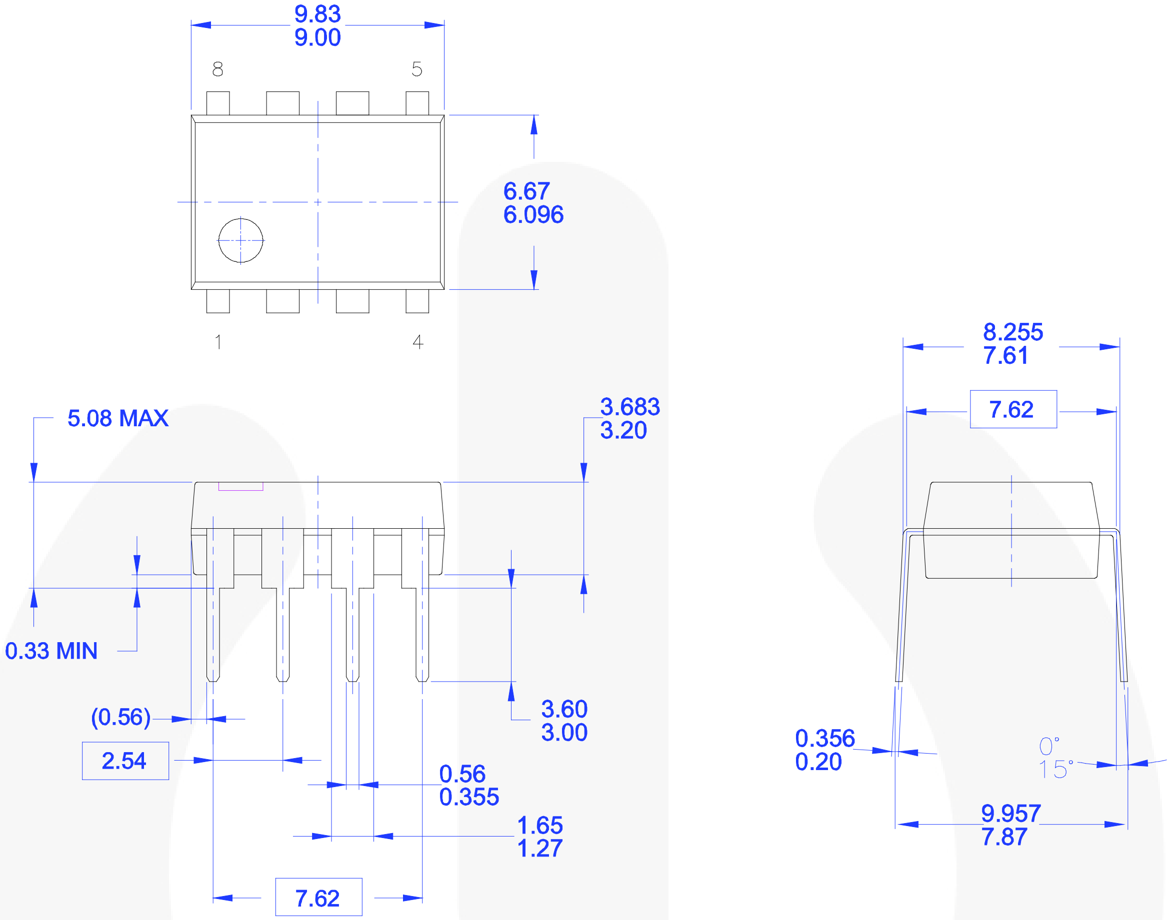

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图 24. 8 引脚、双列直插封装 (DIP)

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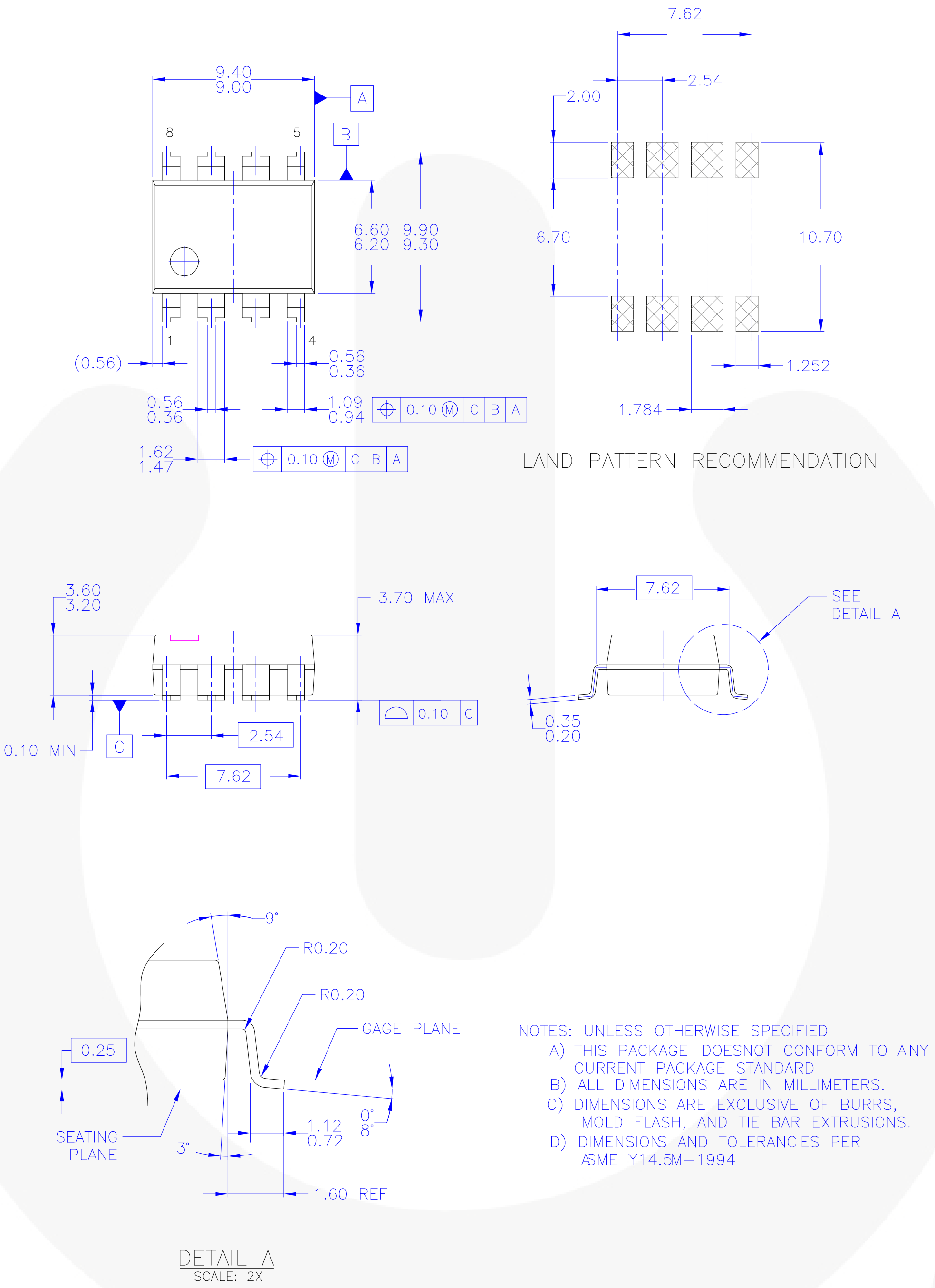

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图 25. 8 引脚、300" 宽、表面贴装封装 (LSOP)

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