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2013 年 11 月

FSL126HR
绿色模式飞兆电源开关 (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，可提供频率调制来实现 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

- VCR、STB、DVD、DVCD 播放器的开关电源
- 家用电器的开关电源
- 适配器

相关资源

- AN-4137 —采用 FPS™ 的离线反激式转换器设计指南
- AN-4141 —飞兆电源开关 (FPS™) 反激式应用的排错与设计技巧
- AN-4147 —-反激式 RCD 缓冲电路设计指南

说明

FSL126HR 集成脉宽调制解调器 (PWM) 和 SenseFET，专为采用最少外部元件的高性能离线式开关电源 (SMPS) 而设计。FSL126HR 包括集成式高压电源开关调节器，这些调节器将耐雪崩的 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。FSL126HR 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，FSL126HR 减少了总的元件数量、设计大小和重量；同时提高了效率、生产力和系统的可靠性。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**	**适配器**(3)	**开架式**
15 W	**21 W**	**12 W**	**17 W**

注意：

1. 结温可以限制最大输出功率。
2. 2304 V_{AC}，或者带有倍压器时为 100/115 V_{AC}。
3. 在 50°C 环境温度下且不通风的封闭适配器中测得的典型持续功率。

订购信息

器件编号	工作温度范围	顶标	封装	包装方法
FSL126HR	-40 至 105°C	FSL126HR	8 引脚双列直插式封装 (DIP)	电轨

典型应用图

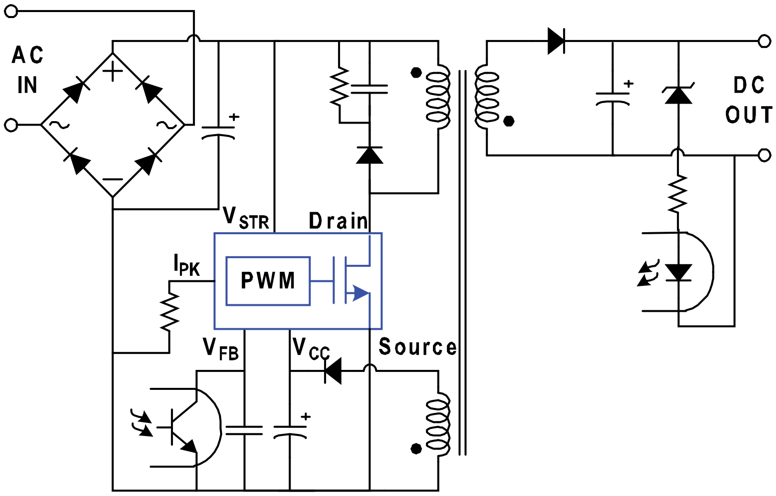

图 1. 典型应用

内部框图

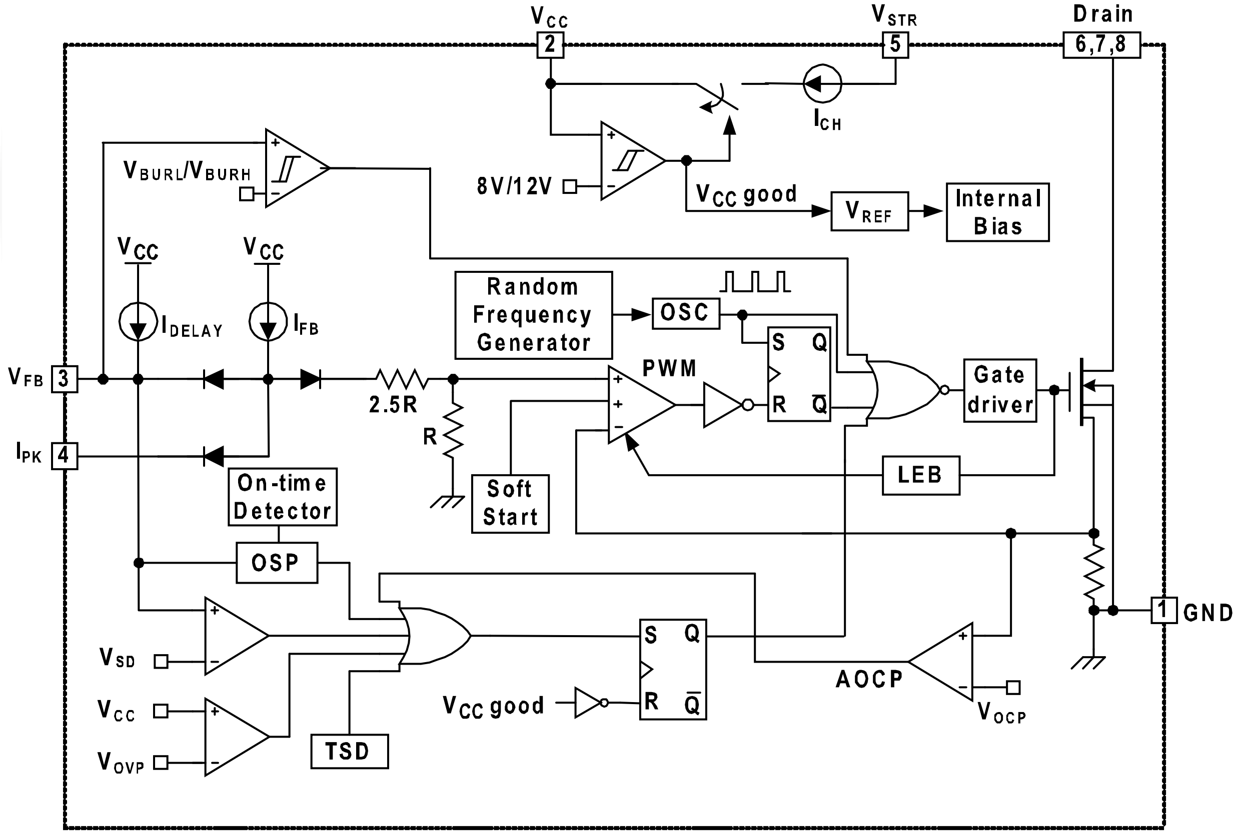

图 2. 内部框图

引脚布局

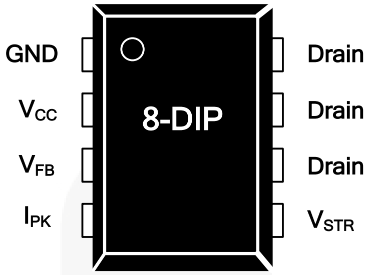

图 3. 引脚布局

引脚定义

引脚号	名称	说明
1	GND	**接地**。初级端和内部控制地的 SenseFET 源极端子。
2	V_{CC}	**电源电压正输入**。尽管连接至变压器辅助绕组，启动期间电流仍通过内部开关由引脚 5 (V_{STR}) 提供（见图 2）。一旦 V_{CC}达到 UVLO 上阀值 (12 V)，内部启动开关开启并且器件电源由变压器辅助绕组提供。
3	V_{FB}	**反馈电压**。PWM 比较器的同相输入在内部连接 0.4 mA 的电流源，同时通常在外部连接电容器和光电耦合器。采用 5µA 的内部电流源将外部电容器 C_{FB} 从 2.4 V 充电至 6 V 时存在延时。该延时用于防止瞬态状况下的错误触发，同时允许真实过载状况下运行保护机制。
4	I_{PK}	**峰值电流限制**。调整 SenseFET 的峰值电流限制。0.4 mA 的反馈电流源被传输到该引脚到 GND 的任意外部电阻和内部 6 kΩ 电阻的并联组合，以确定峰值电流限制。
5	V_{STR}	**启动**。连接至经过整流的交流线路电压源。启动期间，内部开关提供内部偏压并为放置在 V_{CC} 引脚和地之间的外部存储电容器充电。一旦 V_{CC} 达到 12 V，内部开关打开。
6, 7, 8	漏极	**漏极**。设计用于直连到变压器的初级引脚，最大能够实现 650 V 开关。最大限度地缩短连接这些引脚到变压器的引线长度，能够减小漏电感。

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。除非另有说明，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		2	A
I_{DM}	漏极电流脉冲(4)		8	A
E_{AS}	单脉冲雪崩能量(5)		73	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		KV
	元件充电模型，JESD22-C101(6)	2		
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}	结至顶部热阻(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 = 30 mH，启动 T_J = 25°C。
6. 符合 JEDEC 标准 JESD 22-A114 和 JESD 22-C101。
7. 经测试，所有项目都符合标准 JESD 51-2 和 JESD 51-10。
8. Θ_{JA} 独立式、无散热器、自然对流。
9. Θ_{JC} 结至引脚热阻特性是在 Θ_{JA} 条件下测得。T_C 是在接近于塑料接口的源极 #7 引脚测得，用于 Θ_{JA} 热电偶焊接。
10. Θ_{JT} 结至顶部热阻特性是在 Θ_{JA} 条件下测得的。T_t 是在封装顶部测得的。热电偶用环氧树脂胶安装。

电气特征

除非另有说明，T_A= 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}	漏极一源极击穿电压	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		4.9	6.2	Ω
C_{ISS}	输入电容	V_{GS} = 0 V, V_{DS} = 25 V, f = 1 MHz		210		pF
C_{OSS}	输出电容	V_{GS} = 0 V, V_{DS} = 25 V, f = 1 MHz		33.3		pF
C_{RSS}	反向传输电容	V_{GS} = 0 V, V_{DS} = 25 V, f = 1 MHz		4.1		pF
$t_{d(ON)}$	导通延迟	V_{DD} = 350 V, I_D = 2 A		23		ns
t_r	上升时间	V_{DD} = 350 V, I_D = 2 A		16.4		ns
$t_{d(OFF)}$	关断延迟	V_{DD} = 350 V, I_D = 2 A		17.2		ns
t_f	下降时间	V_{DD} = 350 V, I_D = 2 A		23		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	0.48	0.60	0.72	V
V_{BURL}			0.32	0.45	0.58	V
$V_{BUR(HYS)}$				150		mV
保护部分						
I_{LIM}	峰值电流限制	T_J = 25°C, di/dt = 300 mA/µs	1.32	1.50	1.68	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 的触发条件是 $t_{ON} < t_{OSP}$ 且 $V_{FB} > V_{OSP}$，持续时间比 t_{OSP_FB} 长		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

电气特征（接上页）

除非另有说明，$T_A = 25°C$。

符号	参数	工作条件	最小值	典型值	最大值	单位
整机部分						
I_{OP1}	工作电源电流$^{(11)}$ （开关过程中）	$V_{CC} = 14$ V, $V_{FB} > V_{BURH}$		2.5	3.5	mA
I_{OP2}	工作电源电流 （仅控制部分）	$V_{CC} = 14$ V, $V_{FB} < V_{BURL}$		1.8	2.5	mA
I_{CH}	启动充电电流	$V_{CC} = 0$ V	0.9	1.1	1.3	mA
V_{STR}	最小电源电压 V_{STR}	$V_{CC} = V_{FB} = 0$ V 时，V_{STR} 增大	35			V

注：

11. 虽然有设计保证，但未经 100% 产品测试。

典型性能特征

这些测得的特征图在 T_A=25°C 条件下的都被归一化。

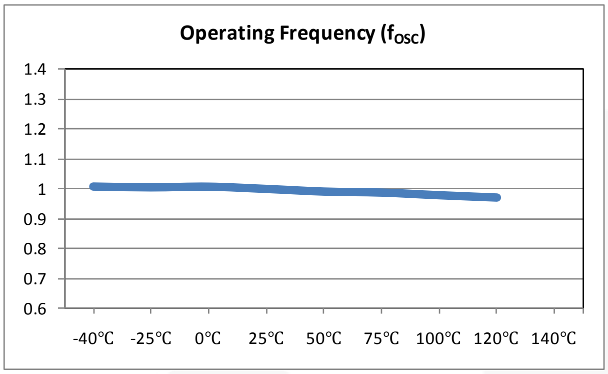

图 4. 工作频率与温度的关系

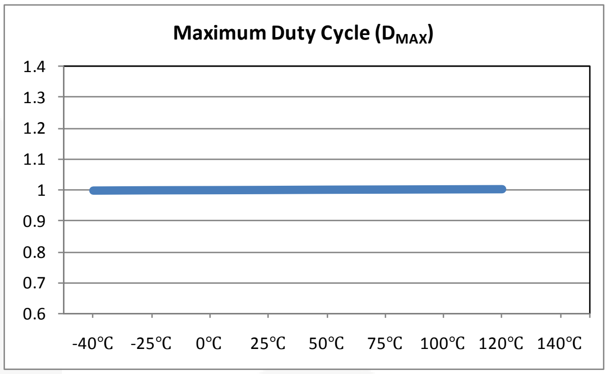

图 5. 最大占空比与温度的关系

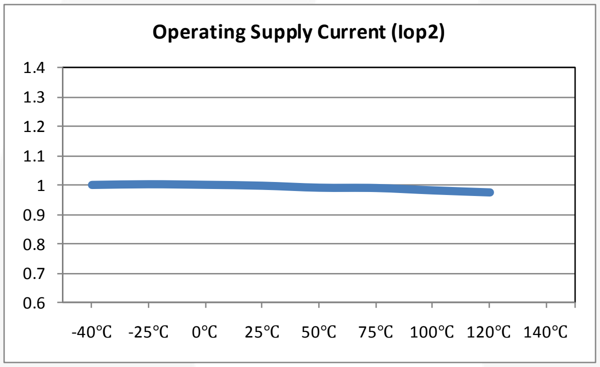

图 6. 工作电源电流与温度的关系

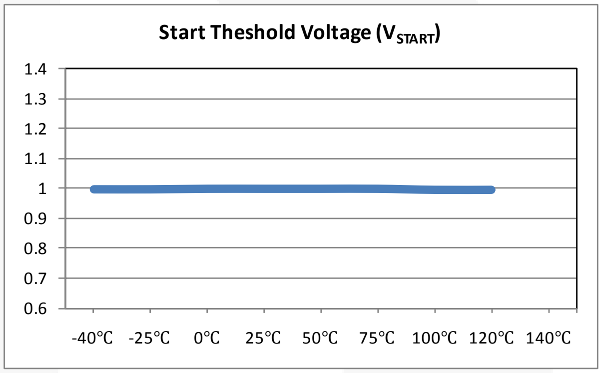

图 7. 开始阀值电压与温度的关系

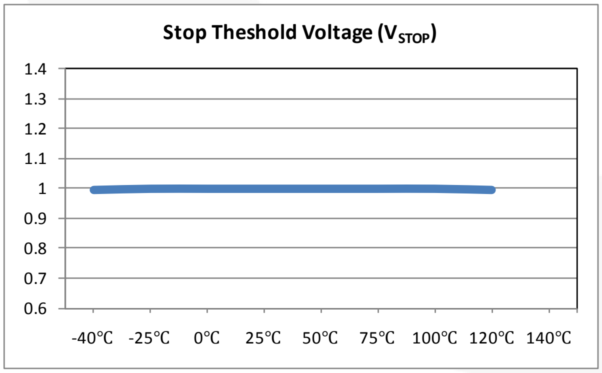

图 8. 停止阀值电压与温度的关系

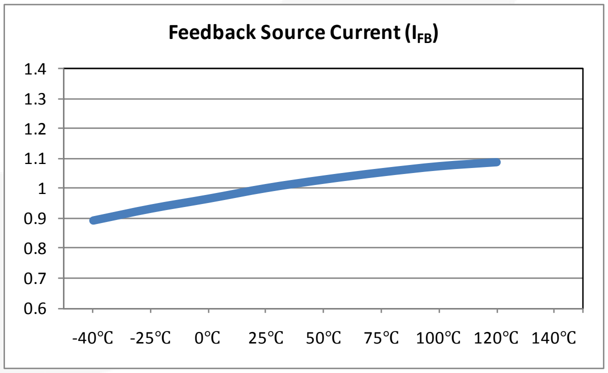

图 9. 反馈源电流与温度的关系

典型性能特征（接上页）

这些测得的特征图在 T_A=25°C 条件下的都被归一化。

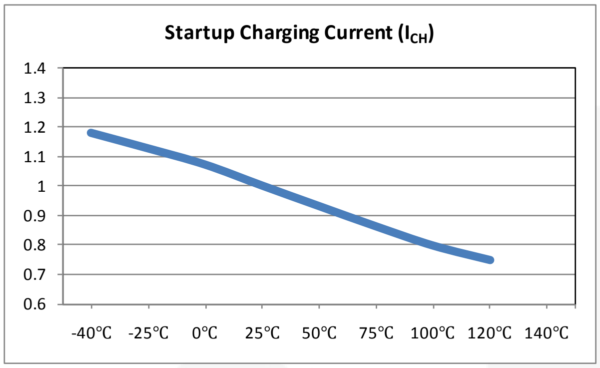

图 10.　启动充电电流与温度的关系

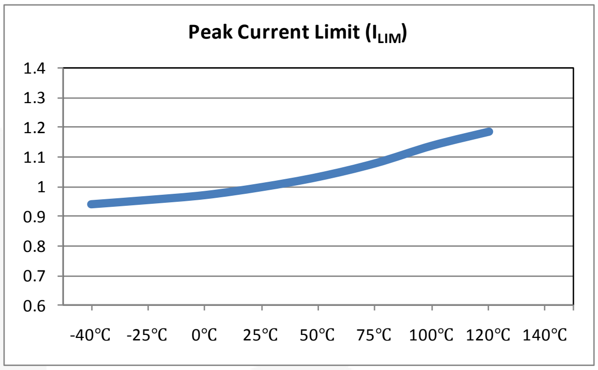

图 11.　峰值电流限制与温度的关系

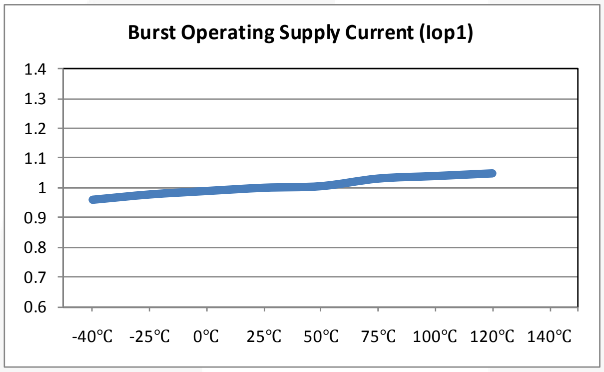

图 12.　间歇工作电源电流与温度的关系

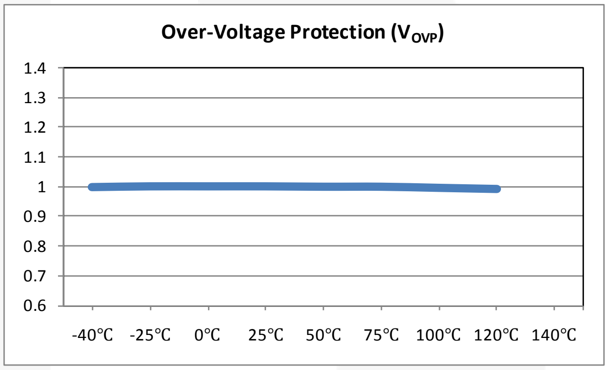

图 13.　过压保护与温度的关系

功能说明

启动

启动期间，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_A) 充电，如图 14 所示。当 V_{CC} 达到开始电压 12 V，FPS™ 开始开关过程，并且内部高压电流源被禁用。FPS 继续正常开关操作，电源由变压器辅助绕组提供，直至 V_{CC} 低于停止电压 8 V。

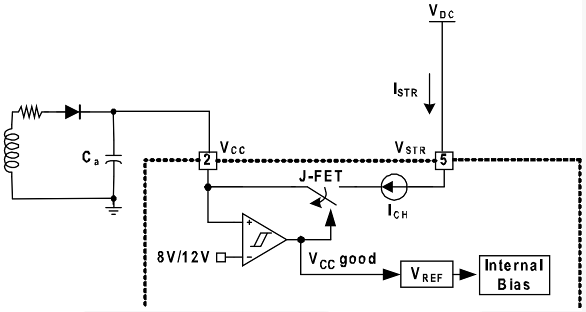

图 14. 启动电路

振荡器模块

振荡器频率在内部设定，FPS 具有随机频率波动功能。开关电源的开关频率波动将能量分布在比 EMI 测试设备测得的带宽更宽的频率范围内，因而能够减少 EMI。EMI 的减少量与频率变化范围有直接的关系。频率变化范围内部固定；然而，频率范围的选择由外部反馈电压和内部自激振荡器共同随机决定。随机选择的开关频率将 EMI 噪声有效地分布在开关频率附近，并允许使用具有成本效益的电感器，而不是交流电源滤波器，来满足全球 EMI 要求。

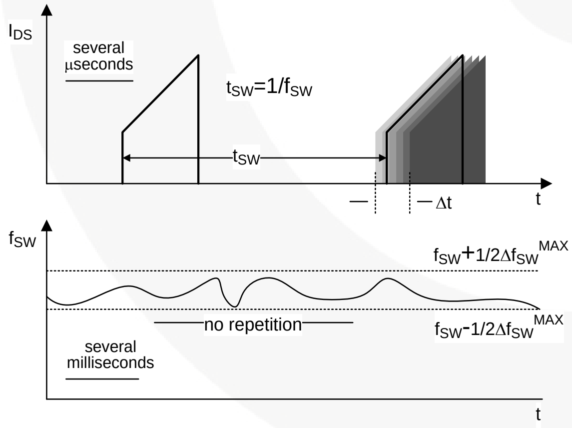

图 15. 频率波动波形

反馈控制

FSL126HR 采用电流模式控制，如图 16 所示。通常用光电耦合器（如 FOD817A）和电压调节器（如 KA431）来实现反馈网络。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。当分流调节器参考引脚电压超过内部参考电压 2.5 V 时，光电耦合器 LED 电流会增大，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。

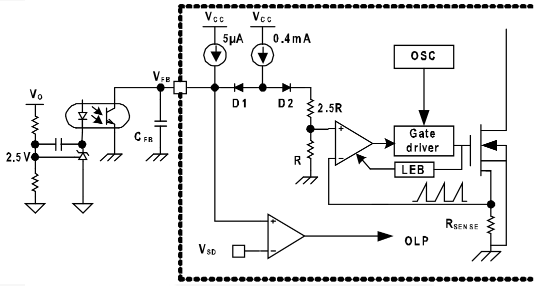

图 16. 脉宽调制 (PWM) 电路

前沿消隐时间 (LEB)

内部 SenseFET 导通瞬间，初级端电容放电和次级端整流二极管反向恢复通常会导致 SenseFET 上通过一个高电流尖峰。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，FPS 采用了前沿消隐 (LEB) 电路（见图 16）。SenseFET 导通后，此电路将在短时间 (t_{LEB}) 内抑制 PWM 比较器。

保护电路

FPS 具有若干项保护功能，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) 以及热关断 (TSD)。由于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} 开始下降。当 V_{CC} 达到 UVLO 停止电压 V_{STOP}(8 V)，保护功能被复位，并且内部高压电流源通过 V_{STR} 引脚向 V_{CC} 电容器充电。当 V_{CC} 达到 UVLO 开始电压 V_{START}(12 V)，FPS 恢复正常运行。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。

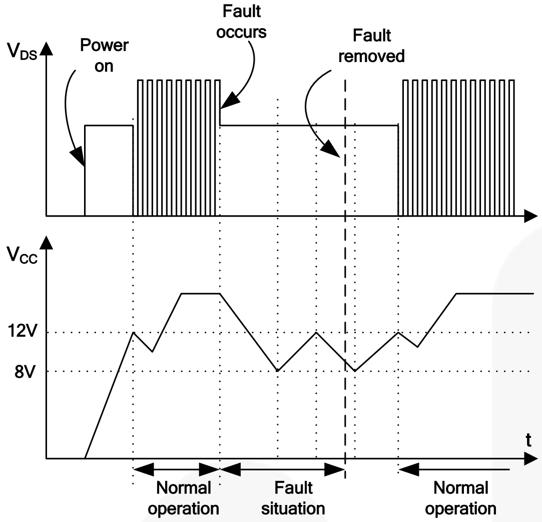

图 17.　自重启保护波形

过载保护 (OLP)

过载定义为负载电流因意外事件而超过预设值。这种情况下，应该激活保护电路，从而保护SMPS。然而，即使SMPS 正常工作，过载保护 (OLP) 电路也会在负载变化或启动期间被激活。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。

结合 I_{PK} 电流限制引脚（若使用），当达到最大 PWM 占空比时，电流模式反馈路径限制 SenseFET 中的电流。如果输出消耗的功率超过最大功率，输出电压 (V_O) 降至低于该额定电压。这会减小通过光电耦合器 LED 的电流，同时减小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 2.4 V，反馈输入二极管受阻，并且 5 µA 的电流源 (I_{DELAY}) 开始缓慢将 C_{FB} 充电至 V_{CC}。在这种状况下，V_{FB} 增大直至达到 6 V，此时开关操作终止，如图 18 所示。关断延时是指通过 5 µA 的电流源将 C_{FB} 从 2.4 V 充电至 6 V 所需的时间。

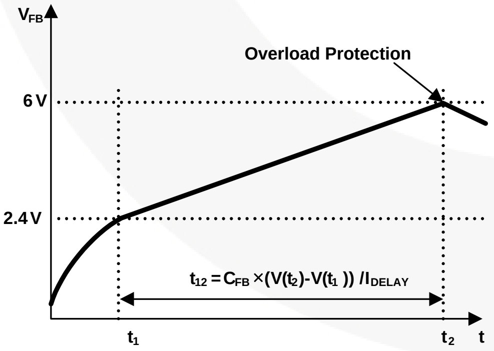

图 18.　过载保护 (OLP)

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 LEB 时间内有一个具有极高 di/dt 的陡波电流流过 SenseFET。虽然 FPS 具有过载保护 (OLP) 功能，在那种异常情况下仍不足以保护 FPS，这是因为触发 OLP 前有很大的电流应力施加在 SenseFET 上。FPS 包含内部异常过流保护 (AOCP) 电路，如图 19 所示。当栅极导通信号被施加到功率 SenseFET，AOCP 模块被启用并且监控通过检测电阻的电流。电阻两端的电压与预置 AOCP 电平进行比较。如果检测电阻电压大于 AOCP 电平，设置信号被施加到锁存，导致 SMPS 关断。

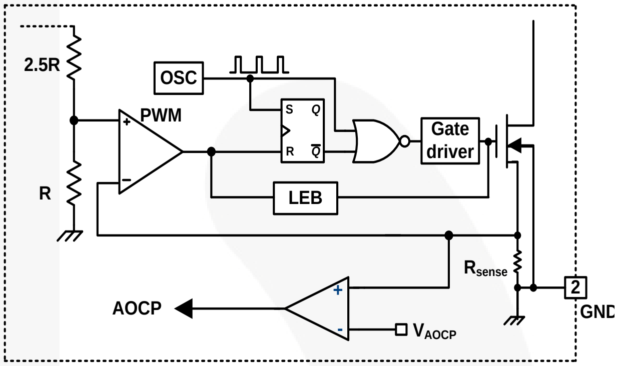

图 19.　异常过流保护

热关断 (TSD)

SenseFET 和控制 IC 集成在同一封装中使 SenseFET 的温度检测更简便。温度超过大约 137°C 时，热关断被激活。

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，V_{CC} 与输出电压成正比，FPS 采用 V_{CC}，而不是直接监控输出电压。如果 V_{CC} 超过 24 V，便会激活 OVP 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 V。

输出短路保护 (OSP)

如果输出短路，在 LEB 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。为了防止器件出现这种异常状况，采用 OSP 检测 V_{FB} 和 SenseFET 导通时间。当 V_{FB} 高于 1.6 V 且 SenseFET 导通时间少于 1.2 µs 时，FPS 认为出现异常错误，会关断 PWM 开关直至 V_{CC} 再次达到 V_{START}。异常状况输出如图 20 所示。

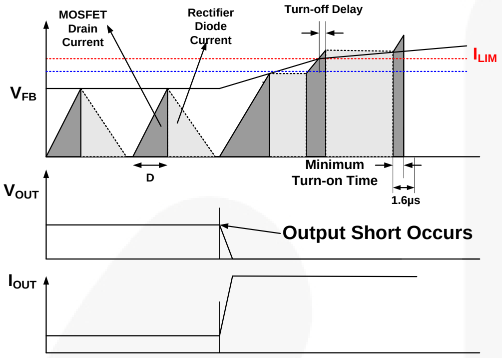

图 20. 输出短路波形 (OSP)

软启动

FPS 具有内部软启动电路，启动后，它缓慢增大反馈电压以及 SenseFET 电流。典型软启动时间为 20 ms，如图 21 所示，启动过程中允许 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，旨在顺畅地建立所需的输出电压。软启动还有助于防止变压器饱和，并减少次级二极管上的应力。

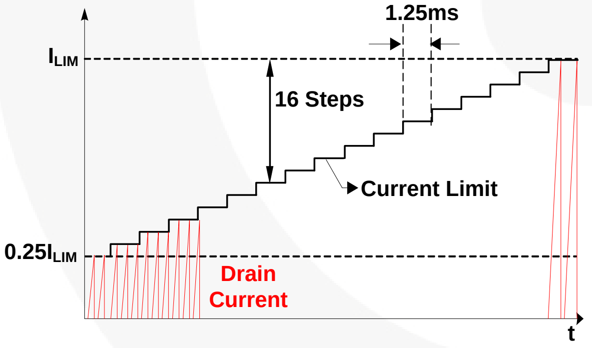

图 21. 内部软启动

间歇运行

为最大限度地降低待机模式下的功耗，FPS 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 22 所示，反馈电压降至 V_{BURH} 以下时，器件自动进入间歇运行模式。

开关过程持续进行，直至反馈电压降至低于 V_{BURL}。此时，开关操作将停止，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}，开关操作将恢复。反馈电压则随之降低，此过程重复进行。间歇运行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。

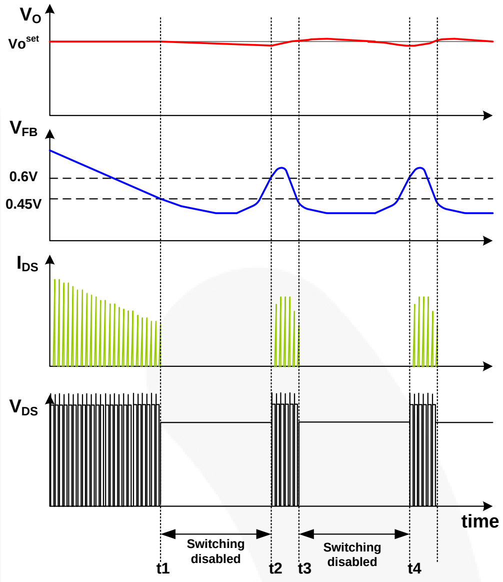

图 22. 间歇模式运行

调整峰值电流限制

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。内部二极管由 400 µA 的主电流源偏置时，电流限制引脚上的外部电阻 Rx 形成了与 6 kΩ 电阻并联的电阻 例如，FSL126HR 具有 1.5 A 的典型 SenseFET 峰值电流限制 (I_{LIM})。通过在 I_{PK} 引脚和地之间插入 Rx，可以将 I_{LIM} 调整为 1 A。根据以下方程式可估算 Rx 的值：

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

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

其中，X 是指并联网络的电阻。

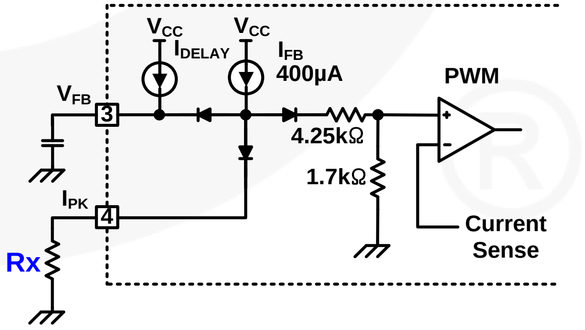

图 23. 峰值电流限制调整

物理尺寸

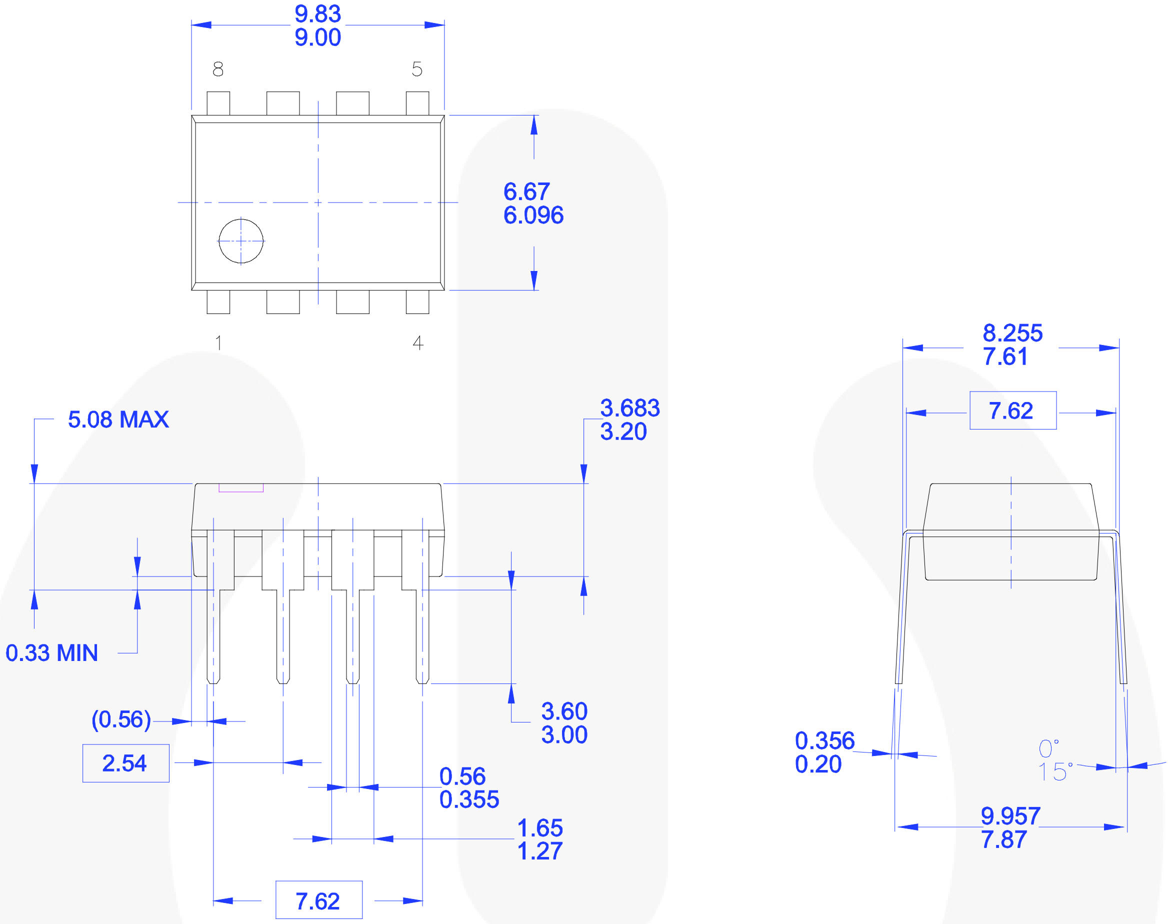

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图 24. 8 引脚双列直插式封装 (DIP)

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