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FL7730 PFC 和 LED 调光驱动用单级初级端调节PWM 控制器

特性

- 兼容传统 TRIAC 控制（无需改变现有灯管结构：墙开关&线路）
- 兼容非照明灯设计
- 无输入降压电容和反馈电路的高性价比解决方案
- 功率因数校正 (PFC)
- 精确恒定电流 (CC) 控制、独立在线电压、输出电压及磁化电导变化
- 用于 CC 控制的线路电压补偿
- 具有更高效率和更简单设计的线性频率控制
- 开路 LED 保护
- 短路 LED 保护
- 逐周期限流
- 过温保护（带自动重启）
- 低启动电流：20 μ A
- 低工作电流：5 mA
- 采用 SOP-8 封装
- 应用电压范围：80 V_{AC} ~ 308 V_{AC}

应用

- LED 照明系统

说明

FL7730 是高度集成的 PWM 控制器，提供多种功能来增强单级反激式转换器的性能。专有拓扑 TRUECURRENT® 简化了 LED 照明应用的电路设计。

TRIAC 照明可通过照明亮度控制实现平滑管理，不会出现抖动。通过使用初级端调节单级拓扑，LED 照明电路板能采用更少的外部元件，从而将成本降至最低。它不需要输入降压电容或反馈电路。为了实施更好的功率因数和更低的总谐波失真，采用一个连接至 COM1 引脚的外部电容进行恒定导通控制。

与输入输出电压的变化相比，精密的恒定电流控制可精确控制输出电流。工作频率与输出电压成比例改变，以保证非连续导通模式 (DCM) 能够更加高效低运行，其设计也更为简单。FL7730 提供保护功能，例如开路 LED、短路 LED 和过温保护。电流限制电平自动降低以将输出电流降至最低，在短路 LED 情况下保护外部元件。

FL7730 控制器采用 8 引脚小尺寸封装 (SOP)。

相关资源

评测板：FEBFL7730_L20L008A

评测板：FEBFL7730_L20H008A

订购信息

部件编号	工作温度范围	封装	包装方法
FL7730MY_F116	-40° C 至 125° C	8-引脚小尺寸封装 (SOP-8)	卷带和卷盘

应用框图

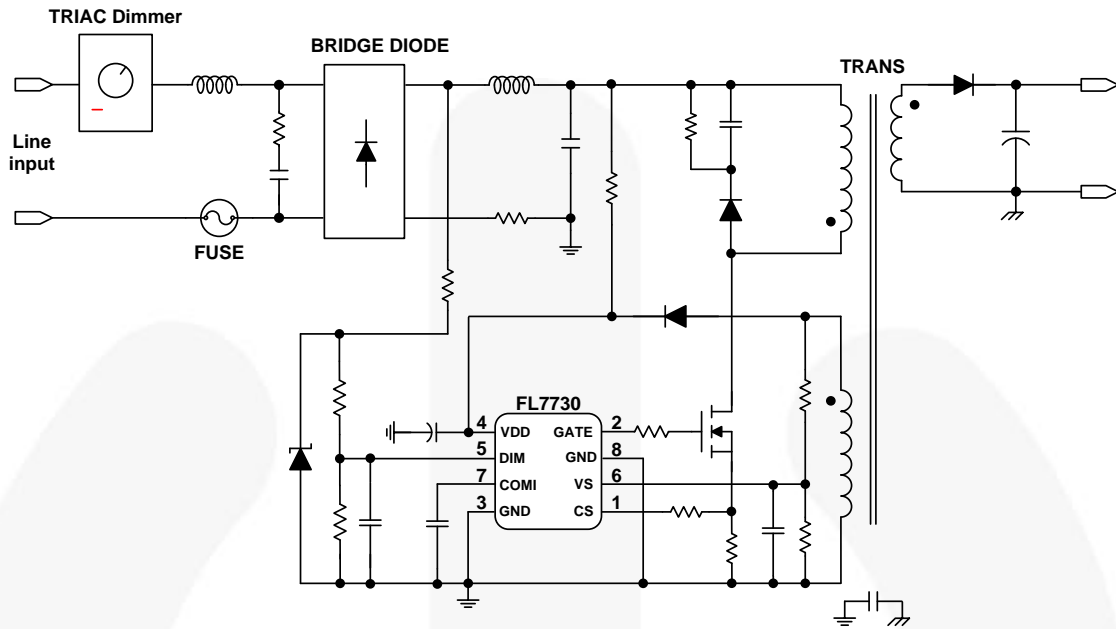


图 1. 典型应用

内部框图

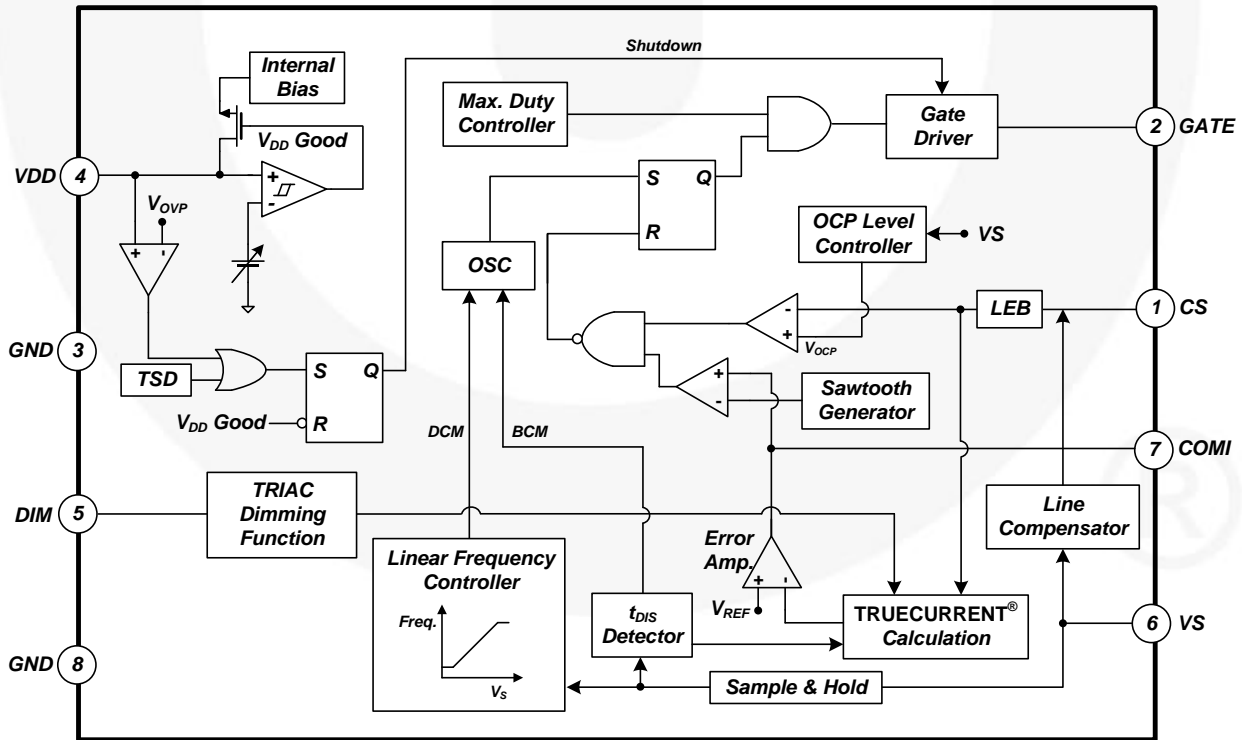
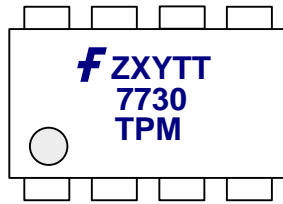


图 2. 功能框图

标识信息



F: 飞兆徽标
 Z: 工厂编码
 X: 一位数字年份代码
 Y: 一位数字周代码
 TT: 两位数字模具运行代码
 T: 封装类型 (M-SOP)

图 3. 顶标

引脚布局

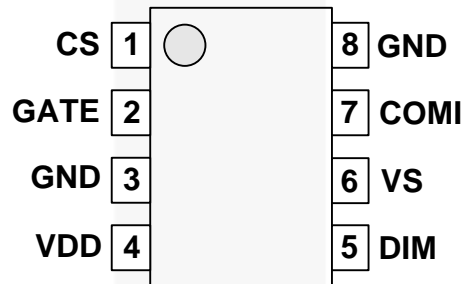


图 4. 引脚布局

引脚说明

引脚号	名称	说明
1	CS	电流检测。 此引脚连接电流检测电阻，用来检测 MOSFET 电流，进行恒流调节中的输出电流调节。
2	栅极	PWM 信号输出。 此引脚采用内部图腾柱输出驱动器，用于驱动功率 MOSFET。
3	GND	接地
4	VDD	电源。 集成电路工作电流和 MOSFET 驱动电流通过此引脚提供。
5	DIM	调光。 该引脚控制 LED 照明的调光工作。
6	VS	电压检测。 该引脚检测输出电压信息和放电时间，用于线性频率控制和恒流调节。该引脚需要连接到与辅助绕组相连的分压电阻。
7	COMI	恒流环路补偿。 该引脚为跨导误差放大器的输出。
8	GND	接地

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；不建议让器件工作在这种条件下。

此外，让器件在超过推荐条件下工作，可能会影响器件的可靠性。绝对最大额定值仅仅是应力额定值。

符号	参数	最小值	最大值	单位
V_{VDD}	直流电源电压 ^(1, 22)		30	V
V_{VS}	VS 引脚输入电压	-0.3	7.0	V
V_{CS}	CS 引脚输入电压	-0.3	7.0	V
V_{DIM}	DIM 引脚输入电压	-0.3	7.0	V
V_{COM1}	COM1 引脚输入电压	-0.3	7.0	V
V_{GATE}	GATE 引脚输入电压	-0.3	30.0	V
P_D	功率耗散 ($T_A < 50^\circ\text{C}$)		633	mW
θ_{JA}	热阻 (结至空气)		158	$^\circ\text{C}/\text{W}$
θ_{JC}	热阻 (结至壳体)		39	$^\circ\text{C}/\text{W}$
T_J	最大结温		150	$^\circ\text{C}$
T_{STG}	存储温度范围	-55	150	$^\circ\text{C}$
T_L	引脚温度 (焊接, 10 秒)		260	$^\circ\text{C}$

注意：

1. 若压力超过绝对最大额定值中所列的数值，可能会给器件造成不可修复的损坏。
2. 测得的所有电压，除差模电压之外，都参照 GND 引脚。

推荐工作条件

推荐的操作条件表定义了器件的真实工作条件。指定推荐的工作条件，以确保器件的最佳性能达到数据表中的规格。飞兆半导体建议不要超过推荐工作条件，也不能按照绝对最大额定值进行设计。

符号	参数	最小值	最大值	单位
T_A	操作环境温度	-40	125	$^\circ\text{C}$

电气特性

若无其他说明, $V_{DD}=20\text{ V}$ 且 $T_A=25^\circ\text{ C}$ 。

符号	参数	条件	最小值	典型值	最大值	单位
VDD 部分						
V_{DD-ON}	导通阈值电压		14.5	16.0	17.5	V
V_{DD-OFF}	关断阈值电压		6.75	7.75	8.75	V
I_{DD-OP}	工作电流	最大频率, $C_{LOAD} = 1\text{ nF}$	3	4	5	mA
I_{DD-ST}	启动电流	$V_{DD} = V_{DD-ON} - 0.16\text{ V}$		2	20	$\mu\text{ A}$
V_{OVP}	V_{DD} 过电压保护		22.0	23.5	25.0	V
栅极部分						
V_{OL}	输出低电平	$V_{DD}=20\text{ V}$, $I_{GATE}=-1\text{ mA}$			1.5	V
V_{OH}	输出高电平	$V_{DD}=10\text{ V}$, $I_{GATE}=+1\text{ mA}$	5			V
I_{SOURCE}	峰值源电流	$V_{DD} = 10 \sim 20\text{ V}$		60		mA
I_{SINK}	峰值灌电流	$V_{DD} = 10 \sim 20\text{ V}$		180		mA
t_r	上升时间	$C_{LOAD} = 1\text{ nF}$	100	150	200	ns
t_f	下降时间	$C_{LOAD} = 1\text{ nF}$	20	60	100	ns
V_{CLAMP}	输出钳位电压		12	15	18	V
振荡器部分						
f_{MAX-CC}	恒流最大频率		60	65	70	kHz
f_{MIN-CC}	恒流最小频率		21.0	23.5	26.0	kHz
VS_{MAX-CC}	恒流最大频率电压检测	$f = f_{MAX} - 2\text{ kHz}$	2.25	2.35	2.45	V
VS_{MIN-CC}	恒流最小频率电压检测	$f = f_{MIN} + 2\text{ kHz}$	0.55	0.85	1.15	V
$t_{ON(MAX)}$	Maximum Turn-On Time		12	14	16	μs
电流感测部分						
V_{RV}	参考电压		2.475	2.500	2.525	V
V_{CCR}	恒流调节的 EMI 电压	$V_{CS} = 0.44\text{ V}$	2.38	2.43	2.48	V
t_{LEB}	前沿消隐时间			300		ns
t_{MIN}	恒流模式下的最小导通时间	$V_{COMI} = 0\text{ V}$		600		ns
t_{PD}	至栅极的传输延迟		50	100	150	ns
$t_{DIS-BNK}$	t_{DIS} 电压检测消隐时间			1.5		μs
$I_{COMI-BNK}$	用于 COMI 消隐的 VS 电流			100		μA
电流误差放大器部分						
G_m	跨导			85		μmho
$I_{COMI-SINK}$	COMI 灌电流	$V_{EAI}=3\text{ V}$, $V_{COMI}=5\text{ V}$	28		38	μA
$I_{COMI-SOURCE}$	COMI 拉电流	$V_{EAI}=2\text{ V}$, $V_{COMI}=0\text{ V}$	28		38	μA
$V_{COMI-HGH}$	COMI 高压	$V_{EAI}=2\text{ V}$	4.9			V
$V_{COMI-LOW}$	COMI 低压	$V_{EAI}=3\text{ V}$			0.1	V

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电气特性

如无其他说明, $V_{DD}=15\text{ V}$ 且 $T_A=25^\circ\text{ C}$ 。

符号	参数	条件	最小值	典型值	最大值	单位
过流保护部分						
V_{OCP}	V_{CS} 过流保护阈值电压		0.60	0.67	0.74	V
V_{LowOCP}	V_{CS} 低过流保护阈值电压		0.13	0.18	0.23	V
$t_{startup}$	启动时间			13		ms
$V_{LowOCP-EN}$	开启低过流保护水平的电压检测阈值电压			0.40		V
$V_{LowOCP-DIS}$	禁止低过流保护水平的VS检测阈值电压			0.60		V
过温保护部分						
T_{OTP}	过温保护阈值温度 ⁽³⁾		140	150	160	$^\circ\text{C}$
$T_{OTP-HYS}$	重新启动结温滞回			10		$^\circ\text{C}$
调光部分						
$V_{DIM-LOW}$	小调光角度范围中的最大 V_{DIM}		2.45	2.50	2.55	V
$V_{DIM-HIGH}$	大调光角度范围中的最大 V_{DIM}		3.43	3.50	3.57	V
DS_{LOW}	小调光角度范围中的 V_{DIM} 与 $V_{cs,offset}$ 斜率			0.19		V/V
DS_{HIGH}	大调光角度范围中的 V_{DIM} 与 $V_{cs,offset}$ 斜率			0.58		V/V

注意:

3. 如果过温保护激活, 供电系统进入自动恢复模式, 输出被禁止。在超过最大结温时, 器件工作不受保障。

典型性能特征

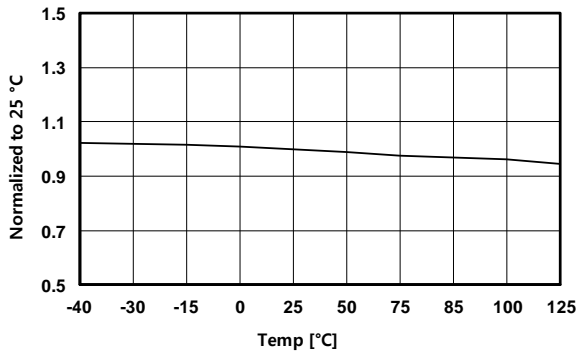


图 5. V_{DD-ON} 与温度的关系

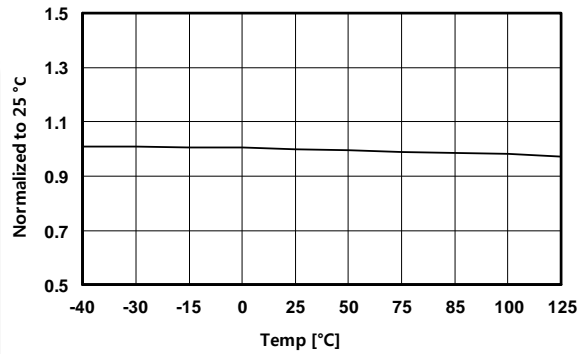


图 6. V_{DD-OFF} 与温度的关系

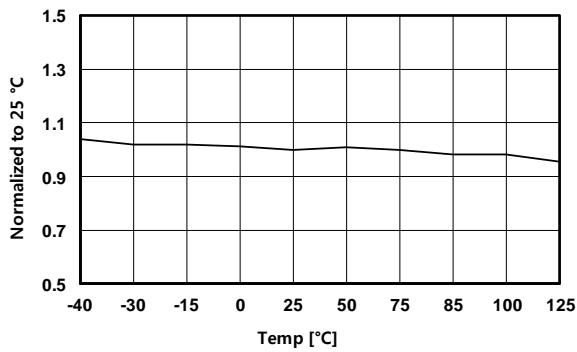


图 7. I_{DO-OP} 与温度的关系

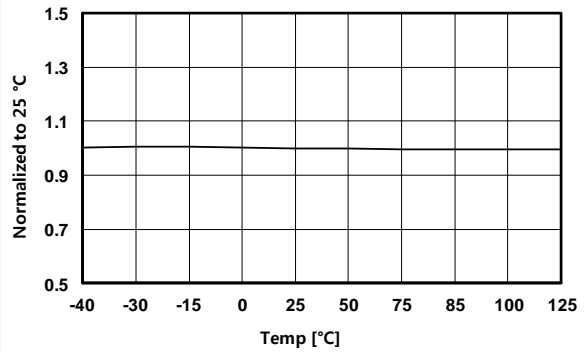


图 8. V_{OVp} 与温度的关系

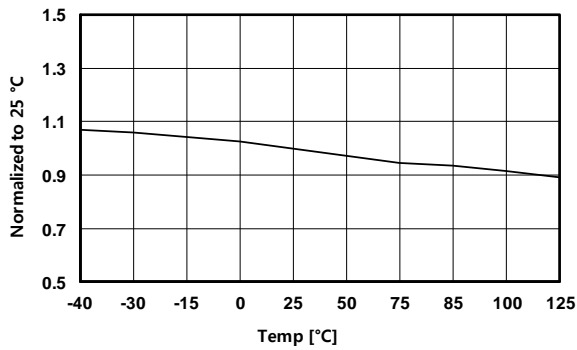


图 9. f_{MAX-OC} 与温度的关系

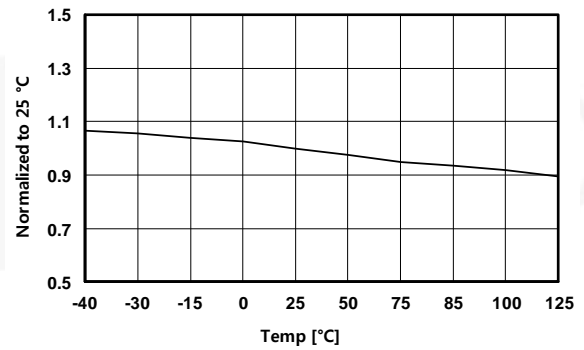


图 10. f_{MIN-OC} 与温度的关系

典型性能特征

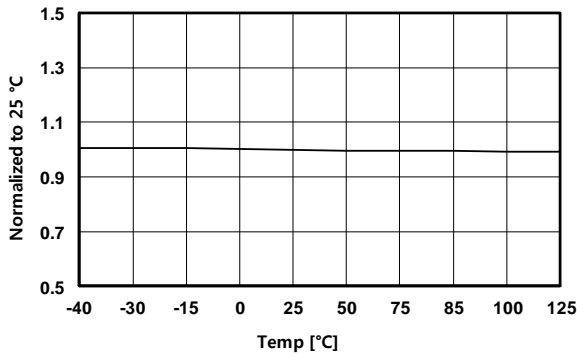


图 11. V_{RV} 与温度的关系

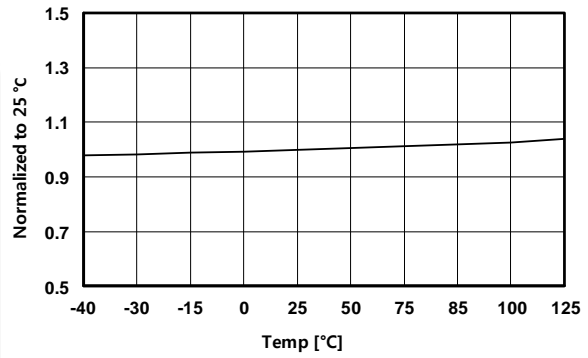


图 12. V_{OR} 与温度的关系

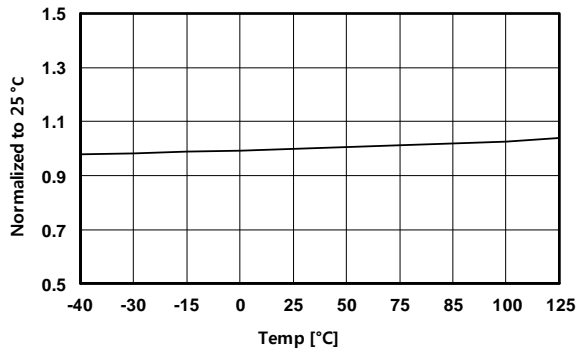


图 13. V_{OP} 与温度的关系

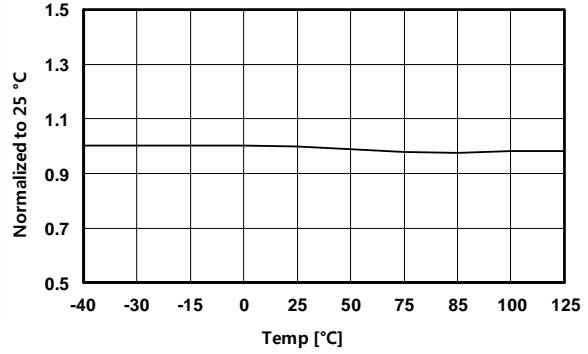


图 14. V_{OP-Low} 与温度的关系

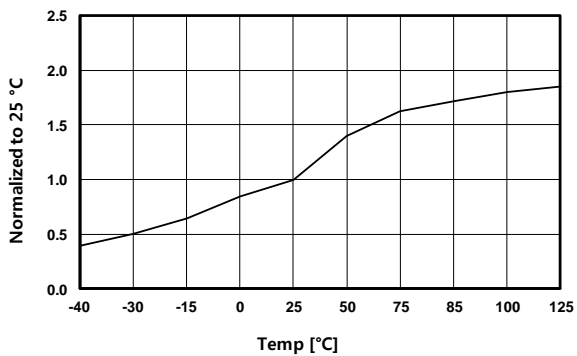


图 15. DS_{Low} 与温度的关系

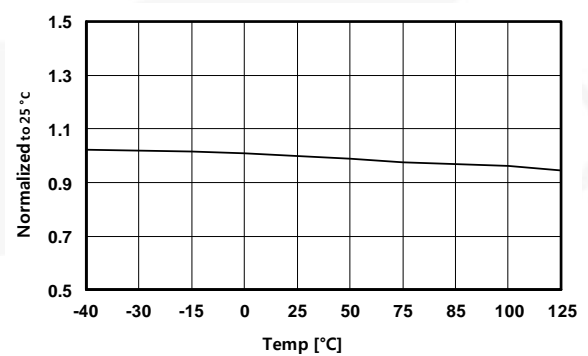


图 16. DS_{High} 与温度的关系

功能说明

FL7730 属于交流-直流调光 PWM 控制器，可用于 LED 照明应用。TRUECURRENT®

技术和内部线路补偿技术，能够精确地调节 LED 电流，克服输入电压、输出电压以及磁化电感的波动。

TRIAC

调光功能模块能够提供平滑的亮度调节控制，并兼容传统 TRIAC 调光器。

振荡器中的线性频率控制能够减少导通损耗，保持 DCM 模式在宽范围输出电压下运行，在单级反激式拓扑结构下实现高功率因数校正。诸如 LED 短路保护、LED 开路保护、过温保护、逐周期限流等一系列保护措施，能够使系统稳定运行，保护外部元件。

启动

由于功率因数校正转换器中的反馈回路带宽较低，启动阶段的供能较为缓慢。

为了加快启动阶段的供能，内部振荡器计时 12 ms 作为启动模式。

在启动模式下，开通时间由电流模式控制确定，具有 0.2 V_{CS} 电压限制并且跨导增大 14 倍，如图 17 所示。启动模式后，采用 COM1 电压，开通时间由电压模式控制并且误差放大器跨导减少到 85 欧姆。

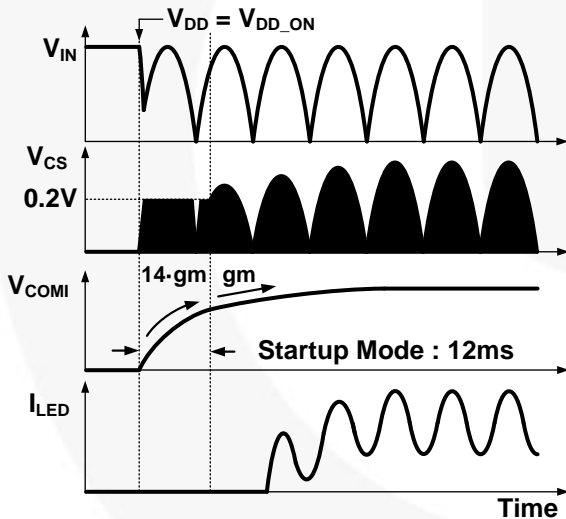


图 17. 启动顺序

恒流调节

由于输出电流与稳定状态时二极管电流的平均值相等，因此可以通过峰值漏极电流和电感电流放电时间来估计输出电流。漏极电流峰值取决于 CS 引脚。电感放电时间 (t_{DIS}) 由 t_{DIS} 探测器检测。

通过使用三种信息（峰值漏极电流、电感放电时间和工作切换周期），TRUECURRENT® 模块能够估算输出电流。

计算所得输出与内部精确基准进行比较，能够生成误差电压 (V_{COM1})，它可以决定电压模式控制中的导通时间。

凭借飞兆公司创新型 TRUECURRENT® 技术，恒流输出可以实现精确控制。

PFC 与 THD

在传统升压变换器中，临界导通模式 (BCM) 通常用于保持输入电流与输入电压同相，以控制功率因数 (PF) 和总体谐波失真 (THD)。

然而，在反激/降压升压拓扑中，采用恒定导通时间和恒定频率的断续导通模式 (DCM)，可以提高 PF 并降低 THD，如图 18 所示。

恒定接通时间通过内部误差放大器和 COM1 引脚的大容量外部电容（通常超过 1 μ F）来维持。恒定频率和 DCM 运行由线性频率控制来管理。

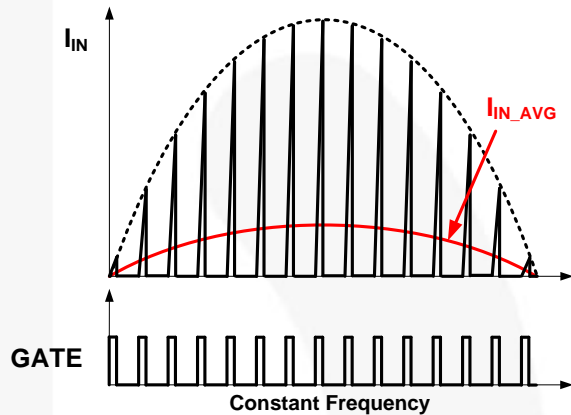


图 18. 输入电流和切换

线性频率控制

在反激式拓扑中，应当确保工作于 DCM 模式以保证达到高功率因数。为了在宽输出电压范围内维持 DCM，在线性频率控制下，频率需要根据输出电压进行线性调节。输出电压由辅助绕组和连接 VS 引脚的分压电阻检测，如图 19 所示。

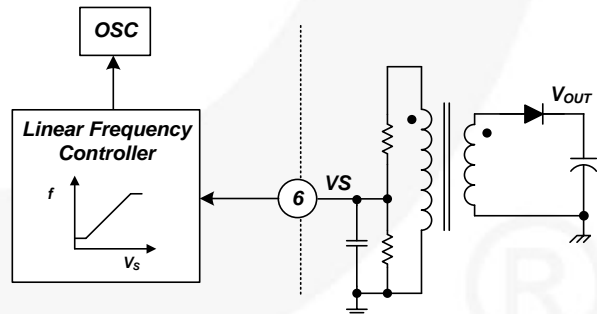


图 19. 线性频率控制

当输出电压降低时，次级二极管传导时间增加并且线性频率控制延长开关周期，这样即可在宽输出电压范围内保持 DCM 工作模式，如图 20 所示。

在满载条件下，频率控制还会调低初级 RMS 电流，获得更佳功率效率。

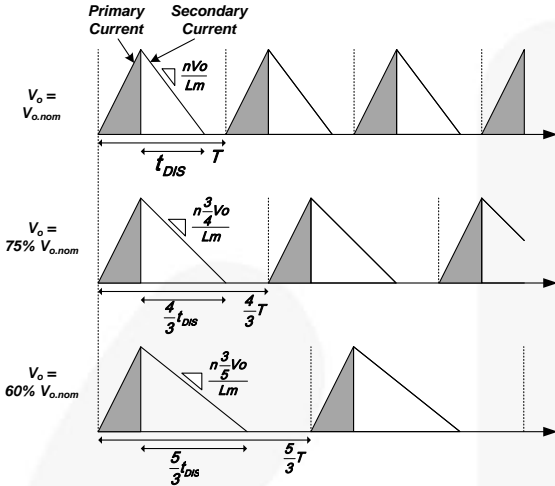


图 20. 初级电流和次级电流

BCM 控制

次级二极管传导时间末尾可能超过线性频率控制设定的切换时间。在这种情况下，FL7730 不会允许 CCM，工作模式会从 DCM 转为 BCM。因此如果 PF 和 THD

性能满足规范并且还有足够的余量，可以设计较大的磁化电感，以便添加 BCM，获得更佳效率。

调光控制

TRIAC

调光控制由一些简单和抑噪的外部无源器件以及内部调光功能模块实现。图

21 给出了调光角检测和内部调光控制模块。

调光角经由齐纳二极管检测，齐纳二极管电压经过两个电阻 (R_{D1} 与 R_{D2}) 分压，得到电压适合 DIM

引脚的测压范围。检测信号经过电容

C_D 滤波，得到直流电压，连接到 DIM 引脚。

内部调光控制将 CS_{offset} 迭加到电流峰值上，作为 TRUECURRENT® 计算模块的输入。当调光角较小时，DIM 电压降低， CS_{offset} 增加，导致计算所得的输出电流增加，从而减少了导通时间，调暗了 LED 亮度。

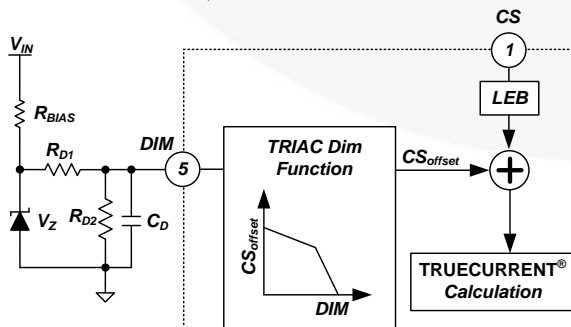


图 21. 调光控制原理

如需禁用调光功能，可以在 DIM 引脚增加一个 1 nF 滤波电容。DIM 引脚上的内部电流源 (~7.5 μ A) 将该滤波电容充电至 4 V。当 DIM 电压高于 6 V 时，FL7730 进入 IC 测试模式。因此最大 DIM 电压应该限制在 5 V 以内。

短路 LED 保护

当发生 LED 短路时，开关 MOSFET

和次级二极管通常会承受较大的电流应力。但是，在 LED 短路时，FL7730 改变 OCP 值。当 V_S 电压低于 0.4 V 时，OCP 限值由 0.7 V 变为 0.2 V，如图 22 所示，以限制供电强度，并减轻外部器件承受的电流应力。

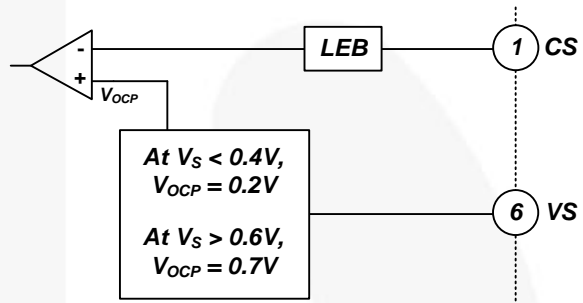


图 22. 内部过流保护模块

图 23 图中显示了 LED 短路时的工作波形。发生 LED 短路时，输出电压迅速降至 0 V。反射的辅助电压也为 0 V，使得 V_S 低于 0.4 V。0.2 V OCP 值限制了初级端电流并且 V_{DD} 进入“上下波动”状态，在 UVLO 滞环内重复上升和下降。

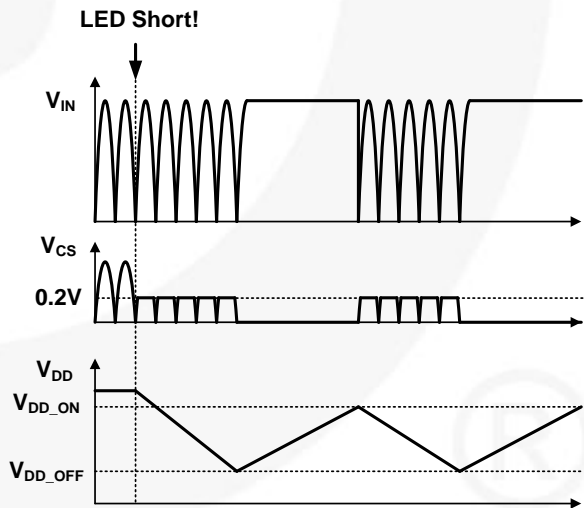


图 23. LED 短路时的波形

开路 LED 保护

当发生 LED 开路时，FL7730 可以保护次级端外部器件，例如二极管和电容。开关断开期间， V_{DD} 电容充电至辅助线圈电压，作为反射输出电压。由于 V_{DD} 电压具有输出电压信息，VDD 引脚的内部电压比较器可以触发输出过压保护 (OVP)，如图所示图 24。当至少一个 LED 发生开路时，输出负载阻抗会变得非常高，输出电容快速充电至 $V_{OVP} \times N_s/N_a$ 。接着，开关过程中断， V_{DD} 模块进入“上下波动”模式，直到 LED 开路条件解除为止，如图 25 所示。

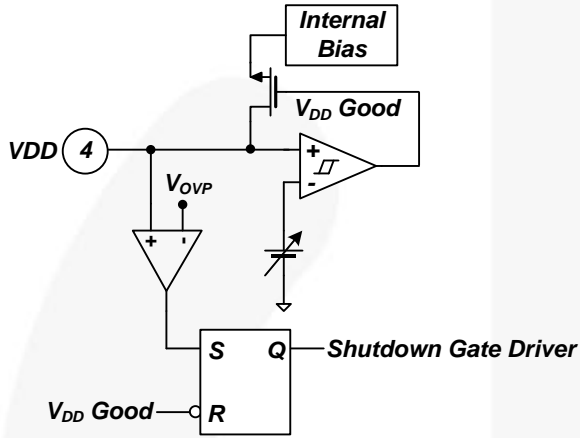


图 24. 内部过压保护模块

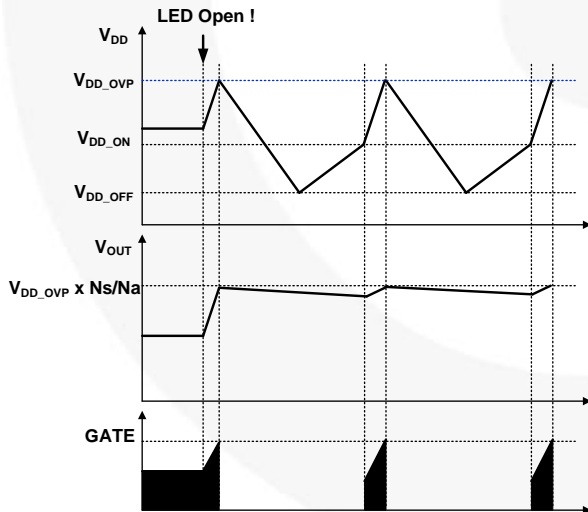


图 25. LED 开路时的波形

欠压锁定 (UVLO)

在器件内部，开通和关断阈值分别固定为 16 V 和 7.5 V。在启动过程中， V_{DD} 电容必须经由启动电阻充电至 16 V，方可启用 FL7730。 V_{DD} 电容持续为 V_{DD} 供电，直至器件改由主变压器的辅助绕组供电。在启动过程中， V_{DD} 不能低于 7.5 V。在启动过程中，UVLO 滞环窗口确保 V_{DD} 电容足够为 V_{DD} 供电。

过温保护 (OTP)

当结温超过 150°C 时，内置温度检测电路会关闭脉宽调制输出。当脉宽调制输出关闭时， V_{DD} 电压逐渐降至 UVLO 电压。部分内部电路关闭后， V_{DD} 又逐渐升高。当 V_{DD} 升至 16 V 时，所有内部电路开始工作。如果结温仍然高于 140°C，脉宽调制控制器会立即关闭。

物理尺寸测试

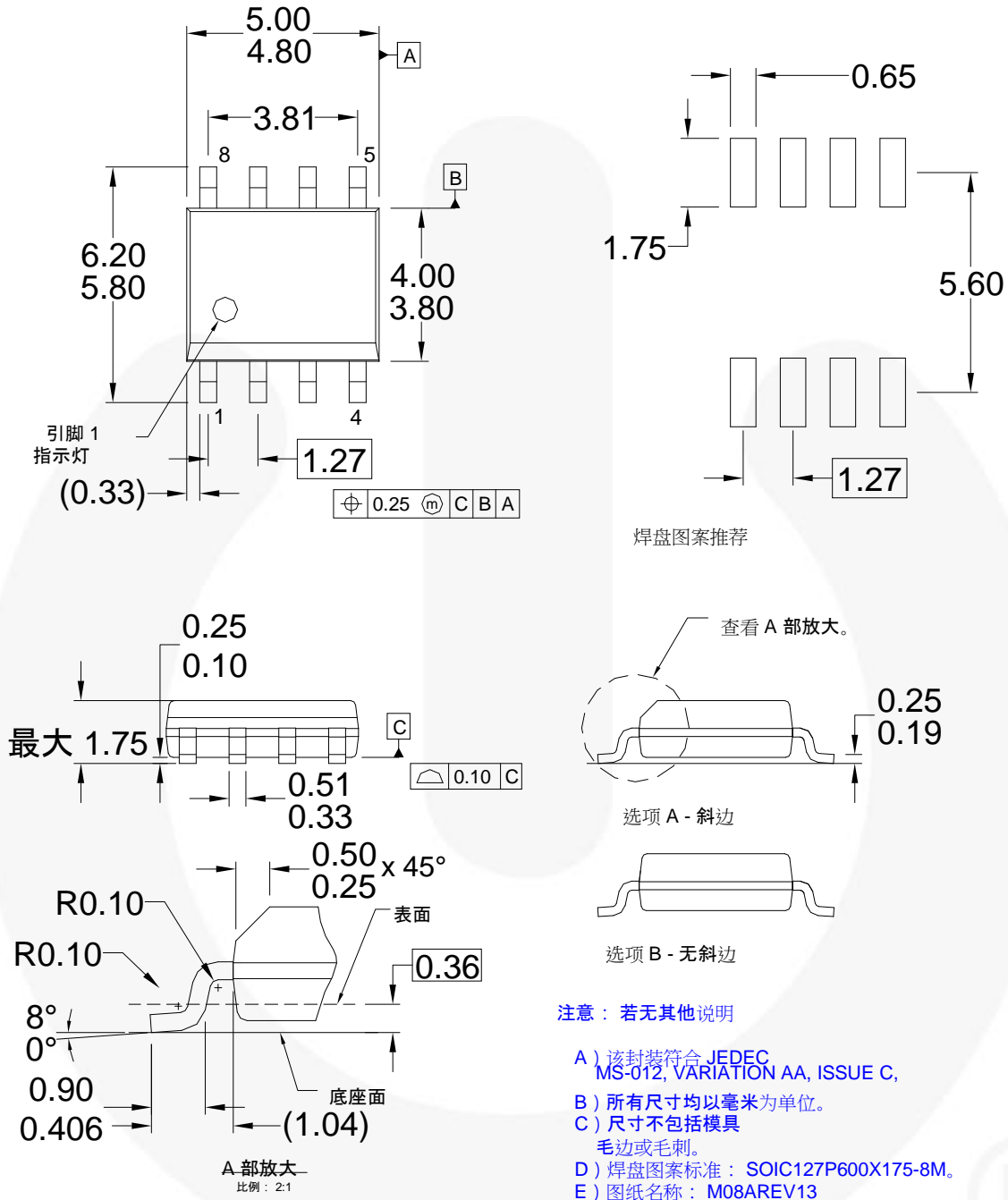


图 26. 8-引脚, SOIC, JEDEC MS-012, .150" 窄型

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