19-3880; Rev 2; 1/10

可提供评估板

用于高亮度LED驱动器的离线式、DC-DC PWM控制器

MAX16801A/B/MAX16802A/B

概述

MAX16801A/B/MAX16802A/B是高亮度(HB) LED驱动器控制IC，内部包含了设计一个宽输入范围LED驱动器所需的全部电路，适合通用照明和显示应用。MAX16801非常适合通用输入(85VAC至265VAC整流电压输入) LED驱动器，MAX16802适用于低输入电压(10.8VDC至24VDC) LED驱动器。

需要精密调节LED电流时，可利用片上的误差放大器以及精度为1%的基准。通过低频PWM亮度调节可实现较宽的亮度调节范围。

MAX16801/MAX16802具有输入欠压锁定(UVLO)特性，可设置输入启动电压，并可确保在电源跌落时正常工作。MAX16801具有较高滞回电压的内部自举欠压锁定电路，从而简化了离线式LED驱动器的设计。MAX16802内部没有这个自举电路，可直接由+12V电压提供偏置电源。

内部微调的262kHz固定开关频率允许优化选择磁性元件和滤波元件，从而实现紧凑、高性价比的LED驱动器。MAX16801A/MAX16802A的最大占空比为50%，MAX16801B/MAX16802B的最大占空比为75%。这些器件均采用8引脚µMAX®封装，可工作在-40°C至+85°C温度范围。

应用

离线式DC-DC LED驱动器

RGB背光，用于LCD TV和监视器

商业与工业照明

装饰与建筑照明

µMAX是Maxim Integrated Products, Inc.的注册商标。

特性

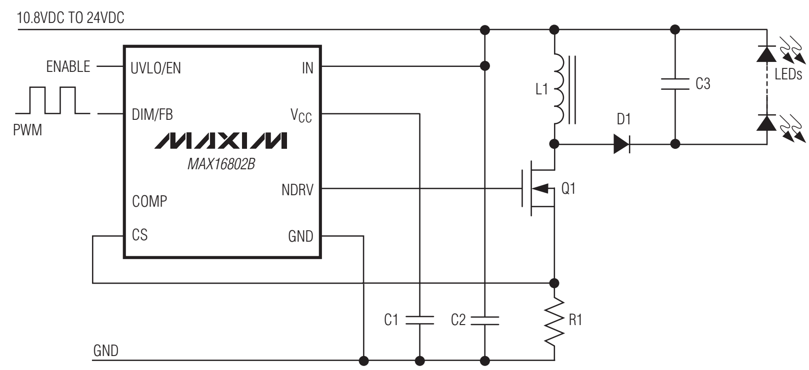
- 适合buck、boost、flyback、SEPIC和其它拓扑
- 高达50W或更高的输出功率
- 通用离线输入电压范围：整流后的85VAC至265VAC (MAX16801)
- IN引脚直接由10.8VDC至24VDC输入驱动(MAX16802)
- 内部带有误差放大器和1%精度的基准，可实现精密的LED电流调节
- PWM或线性亮度调节
- 262kHz ±12%的固定开关频率
- 热关断
- 数字软启动
- 可编程输入启动电压
- 具有较高滞回电压的内部自举UVLO (MAX16801)
- 45µA (典型值)启动电源电流，1.4mA (典型值)工作电源电流
- 50% (MAX16801A/MAX16802A)或75% (MAX16801B/MAX16802B)最大占空比
- 采用微型8引脚µMAX封装

定购信息

PART	TEMP RANGE	PIN-PACKAGE
MAX16801AEUA+	-40°C to +85°C	8 µMAX
MAX16801BEUA+	-40°C to +85°C	8 µMAX
MAX16802AEUA+	-40°C to +85°C	8 µMAX
MAX16802BEUA+	-40°C to +85°C	8 µMAX

+表示无铅封装。

典型工作电路



警告：*MAX16801/MAX16802设计工作于高压下，注意小心操作。*

用于高亮度LED驱动器的离线式、DC-DC PWM控制器

ABSOLUTE MAXIMUM RATINGS

IN to GND .... -0.3V to +30V
V_{CC} to GND .... -0.3V to +13V
DIM/FB, COMP, UVLO/EN, CS to GND .... -0.3V to +6V
NDRV to GND .... -0.3V to (V_{CC} + 0.3V)
Continuous Power Dissipation (T_A = +70°C)
8-Pin µMAX (derate 4.5mW/°C above +70°C) 362mW
Operating Temperature Range .... -40°C to +85°C
Storage Temperature Range .... -65°C to +150°C
Junction Temperature .... +150°C
Lead Temperature (soldering, 10s) .... +300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{IN} = +12V (MAX16801: V_{IN} must first be brought up to +23.6V for startup), 10nF bypass capacitors at IN and V_{CC}, C_{NDRV} = 0µF, $V_{UVLO/EN}$ = +1.4V, $V_{DIM/FB}$ = +1.0V, COMP = unconnected, V_{CS} = 0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
UNDERVOLTAGE LOCKOUT/STARTUP						
Bootstrap UVLO Wake-Up Level	V_{SUVR}	V_{IN} rising (MAX16801 only)	19.68	21.6	23.60	V
Bootstrap UVLO Shutdown Level	V_{SUVF}	V_{IN} falling (MAX16801 only)	9.05	9.74	10.43	V
UVLO/EN Wake-Up Threshold	V_{ULR2}	UVLO/EN rising	1.188	1.28	1.371	V
UVLO/EN Shutdown Threshold	V_{ULF2}	UVLO/EN falling	1.168	1.23	1.291	V
UVLO/EN Input Current	I_{UVLO}	T_J = +125°C		25		nA
UVLO/EN Hysteresis				50		mV
IN Supply Current In Undervoltage Lockout	I_{START}	V_{IN} = +19V, for MAX16801 only when in bootstrap UVLO		45	90	µA
IN Voltage Range	V_{IN}		10.8		24	V
UVLO/EN Propagation Delay	t_{EXTR}	UVLO/EN steps up from +1.1V to +1.4V		12		µs
	t_{EXTF}	UVLO/EN steps down from +1.4V to +1.1V		1.8		
Bootstrap UVLO Propagation Delay	t_{BUVR}	V_{IN} steps up from +9V to +24V		5		µs
	t_{BUVF}	V_{IN} steps down from +24V to +9V		1		
INTERNAL SUPPLY						
V_{CC} Regulator Set Point	V_{CCSP}	V_{IN} = +10.8V to +24V, sinking 1µA to 20mA from V_{CC}	7		10.5	V
IN Supply Current After Startup	I_{IN}	V_{IN} = +24V		1.4	2.5	mA
Shutdown Supply Current		UVLO/EN = low			90	µA
GATE DRIVER						
Driver Output Impedance	$R_{ON(LOW)}$	Measured at NDRV sinking, 100mA		2	4	Ω
	$R_{ON(HIGH)}$	Measured at NDRV sourcing, 20mA		4	12	
Driver Peak Sink Current				1		A
Driver Peak Source Current				0.65		A
PWM COMPARATOR						
Comparator Offset Voltage	V_{OPWM}	V_{COMP} - V_{CS}	1.15	1.38	1.70	V
CS Input Bias Current	I_{CS}	V_{CS} = 0V	-2		+2	µA
Comparator Propagation Delay	t_{PWM}	V_{CS} = +0.1V		60		ns
Minimum On-Time	$t_{ON(MIN)}$			150		ns

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = +12V (MAX16801: V_{IN} must first be brought up to +23.6V for startup), 10nF bypass capacitors at IN and V_{CC}, C_{NDRV} = 0µF, $V_{UVLO/EN}$ = +1.4V, $V_{DIM/FB}$ = +1.0V, COMP = unconnected, V_{CS} = 0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

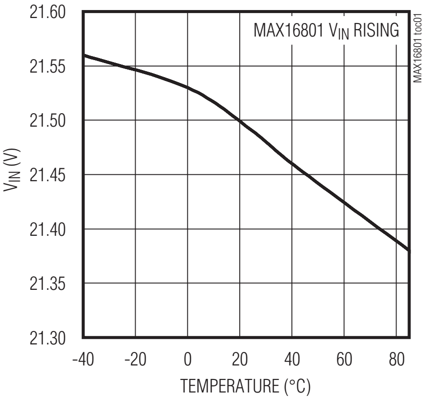
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CURRENT-SENSE COMPARATOR						
Current-Sense Trip Threshold	V_{CS}		262	291	320	mV
CS Input Bias Current	I_{CS}	V_{CS} = 0V	-2		+2	µA
Propagation Delay From Comparator Input to NDRV	t_{PWM}	50mV overdrive		60		ns
Switching Frequency	f_{SW}		230	262	290	kHz
Maximum Duty Cycle	D_{MAX}	MAX1680_A		50	50.5	%
		MAX1680_B		75	76	
IN CLAMP VOLTAGE						
IN Clamp Voltage	V_{INC}	2mA sink current, MAX16801 only (Note 3)	24.1	26.1	29.0	V
ERROR AMPLIFIER						
Voltage Gain		R_{LOAD} = 100kΩ		80		dB
Unity-Gain Bandwidth		R_{LOAD} = 100kΩ, C_{LOAD} = 200pF		2		MHz
Phase Margin		R_{LOAD} = 100kΩ, C_{LOAD} = 200pF		65		Degrees
DIM/FB Input Offset Voltage					3	mV
COMP Clamp Voltage		High	2.2		3.5	V
		Low	0.4		1.1	
Source Current			0.5			mA
Sink Current			0.5			mA
Reference Voltage	V_{REF}	(Note 2)	1.218	1.230	1.242	V
Input Bias Current					50	nA
COMP Short-Circuit Current				8		mA
THERMAL SHUTDOWN						
Thermal-Shutdown Temperature				130		°C
Thermal Hysteresis				25		°C
DIGITAL SOFT-START						
Soft-Start Duration				15,872		Clock cycles
Reference Voltage Steps During Soft-Start				31		Steps
Reference Voltage Step				40		mV

Note 1: All devices are 100% tested at T_A = +85°C. All limits over temperature are guaranteed by characterization.
Note 2: V_{REF} is measured with DIM/FB connected to the COMP pin (see the *Functional Diagram*).
Note 3: The MAX16801 is intended for use in universal input offline drivers. The internal clamp circuit is used to prevent the bootstrap capacitor (C1 in Figure 5) from charging to a voltage beyond the absolute maximum rating of the device when UVLO/EN is low. The maximum current to IN (hence to clamp) when UVLO/EN is low (device in shutdown), must be externally limited to 2mA (max). Clamp currents higher than 2mA may result in clamp voltage higher than +30V, thus exceeding the absolute maximum rating for IN. For the MAX16802, do not exceed the +24V maximum operating voltage of the device.

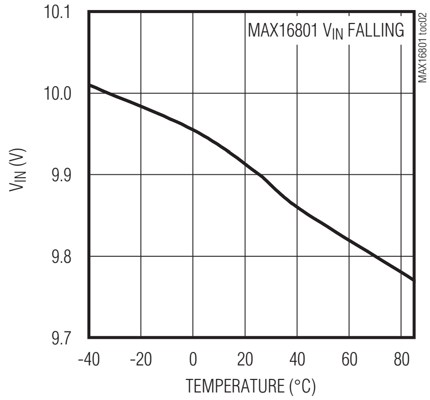
典型工作特性

($V_{UVLO/EN}$ = +1.4V, $V_{DIM/FB}$ = +1V, COMP = unconnected, V_{CS} = 0V, T_A = +25°C, unless otherwise noted.)

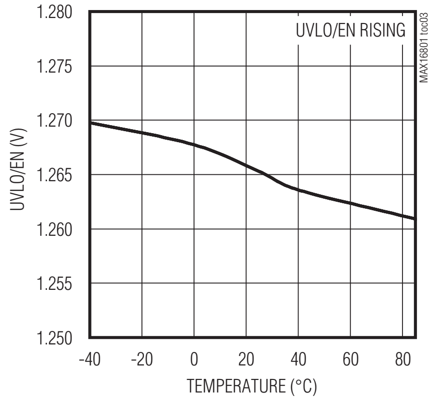
BOOTSTRAP UVLO WAKE-UP LEVEL vs. TEMPERATURE



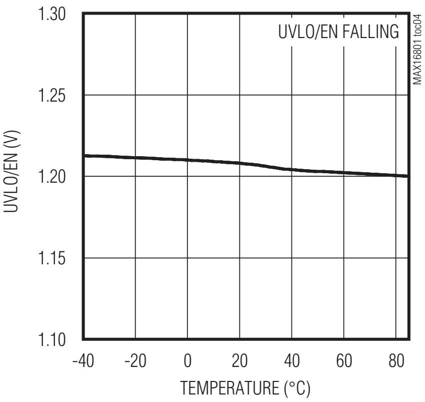
BOOTSTRAP UVLO SHUTDOWN LEVEL vs. TEMPERATURE



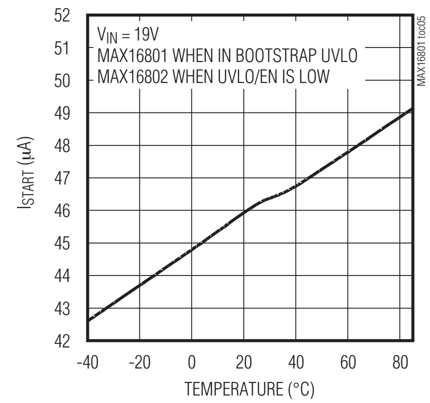
UVLO/EN WAKE-UP THRESHOLD vs. TEMPERATURE



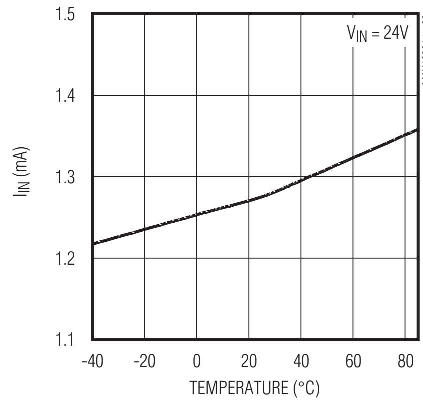
UVLO/EN SHUTDOWN THRESHOLD vs. TEMPERATURE



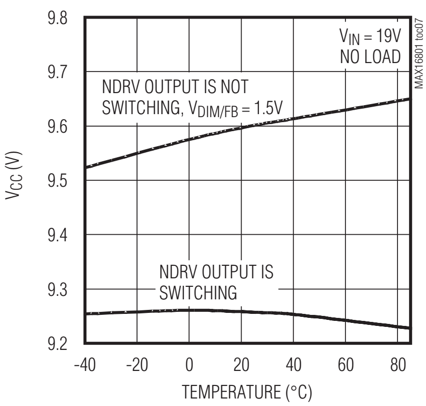
V_{IN} SUPPLY CURRENT IN UNDERVOLTAGE LOCKOUT vs. TEMPERATURE



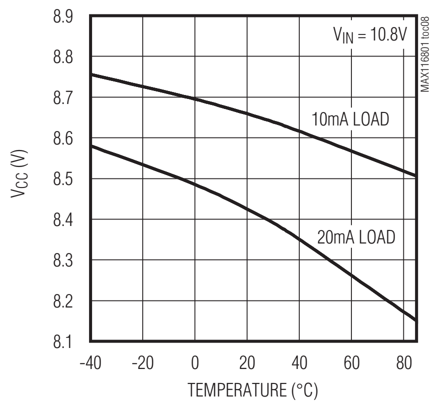
V_{IN} SUPPLY CURRENT AFTER STARTUP vs. TEMPERATURE



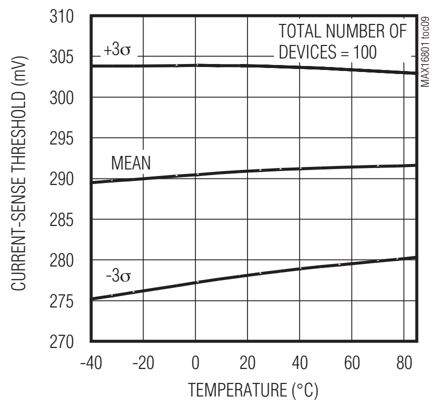
V_{CC} REGULATOR SET POINT vs. TEMPERATURE



V_{CC} REGULATOR SET POINT vs. TEMPERATURE



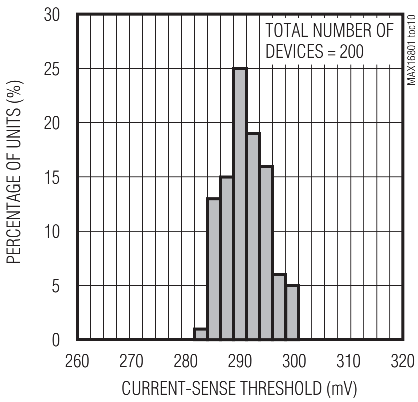
CURRENT-SENSE THRESHOLD vs. TEMPERATURE



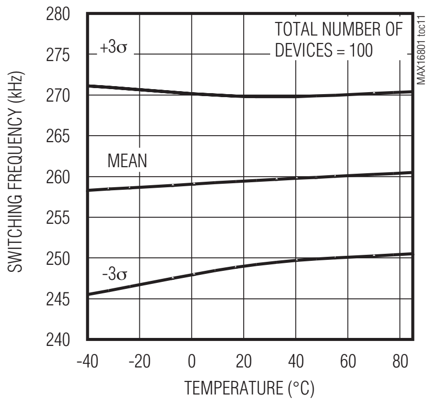
典型工作特性(续)

($V_{UVLO/EN}$ = +1.4V, $V_{DIM/FB}$ = +1V, COMP = unconnected, V_{CS} = 0V, T_A = +25°C, unless otherwise noted.)

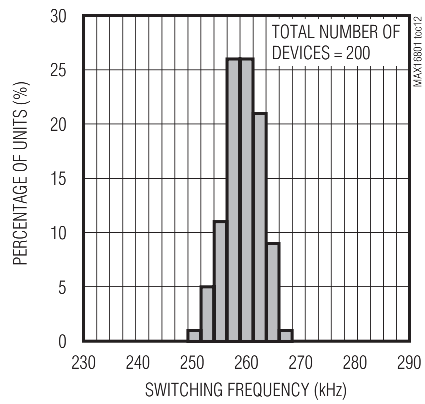
CURRENT-SENSE THRESHOLD



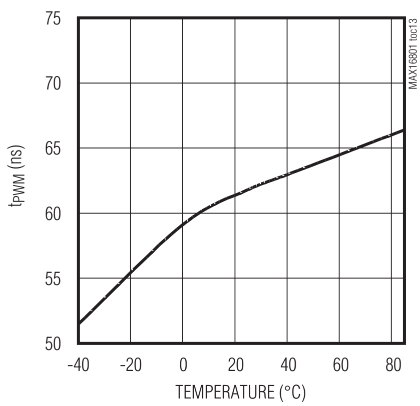
SWITCHING FREQUENCY vs. TEMPERATURE



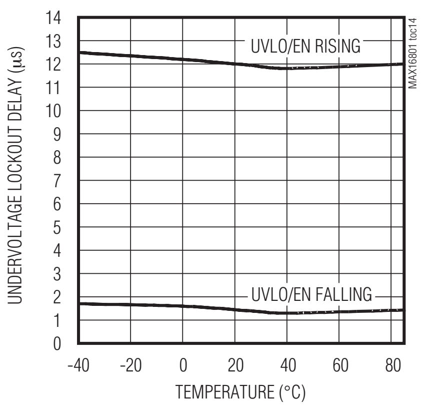
SWITCHING FREQUENCY



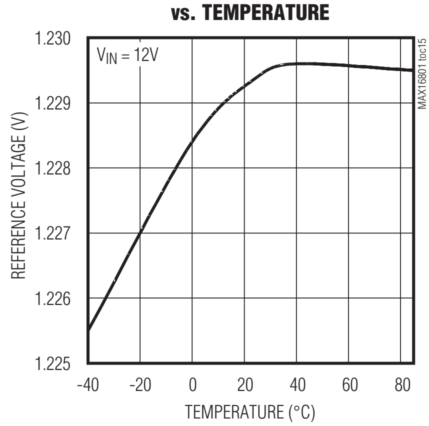
PROPAGATION DELAY FROM CURRENT-SENSE COMPARATOR INPUT TO NDRV vs. TEMPERATURE



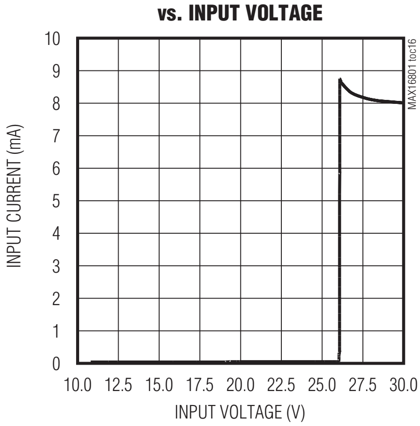
UVLO/EN PROPAGATION DELAY vs. TEMPERATURE



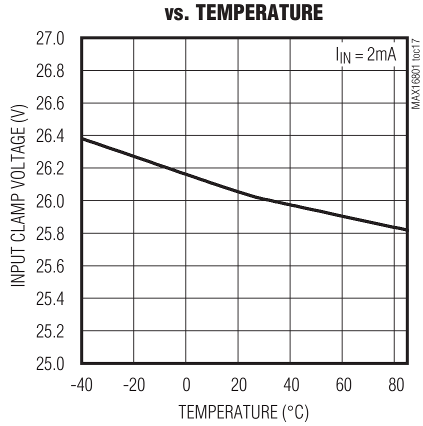
REFERENCE VOLTAGE vs. TEMPERATURE



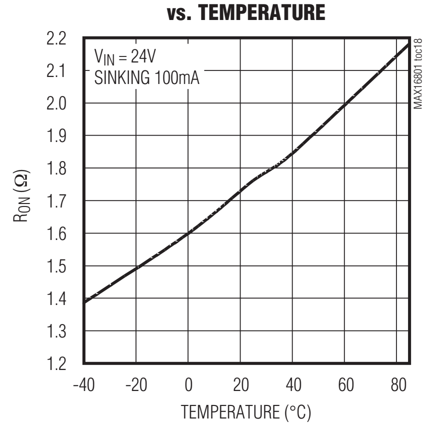
INPUT CURRENT vs. INPUT VOLTAGE



INPUT CLAMP VOLTAGE vs. TEMPERATURE



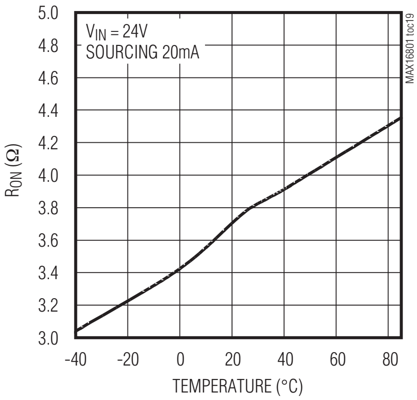
NDRV OUTPUT IMPEDANCE vs. TEMPERATURE

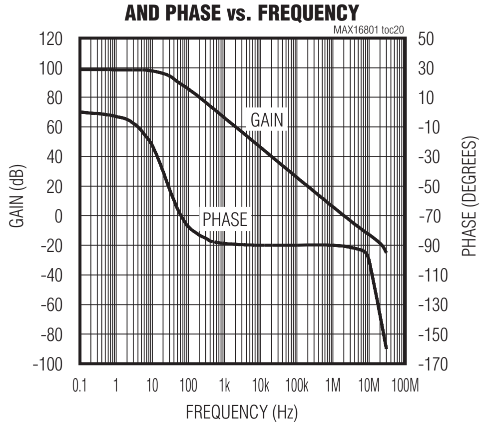


用于高亮度LED驱动器的离线式、DC-DC PWM控制器

典型工作特性(续)

($V_{UVLO/EN}$ = +1.4V, $V_{DIM/FB}$ = +1V, COMP = unconnected, V_{CS} = 0V, T_A = +25°C, unless otherwise noted.)





引脚说明

引脚	名称	功能
1	UVLO/EN	外部可编程欠压锁定。UVLO设置输入启动电压。将UVLO连接至GND可禁止器件工作。
2	DIM/FB	低频PWM亮度调节输入/误差放大器反相输入端。
3	COMP	误差放大器输出。在高精度LED电流调节应用中，将补偿元件连接在DIM/FB和COMP之间。
4	CS	电流感应信号连接端，用于电流调节。接至检流电阻高端。可以用RC滤波器除去前沿上的毛刺。
5	GND	电源地。
6	NDRV	外部n沟道MOSFET栅极连接端。
7	V_{CC}	栅极驱动电源。内部由IN降压得到。V_{CC}与GND间接一只10nF或容值更高的去耦电容器。
8	IN	IC电源。IN与GND间接一只10nF或容值更高的去耦电容器。自举工作模式(MAX16801)下，可在输入电源和IN之间接一个启动电阻。偏置绕组电源连接至该点(参见图5)。对于MAX16802，IN直接接+10.8V至+24V电源。

详细说明

MAX16801/MAX16802系列器件用于高亮度(HB) LED的恒流驱动，适合通用照明和显示应用。该系列器件专为隔离和非隔离电路拓扑设计，如buck、boost、flyback和SEPIC等，工作在连续或非连续模式。开关频率在内部微调为262kHz固定值，可实现电流模式控制。具有较高滞回电压(11.9V)的自举UVLO电路、超低启动电流以及低工作电流特性，可实现高效的通用输入LED驱动器。该系列器件除内置自举UVLO外，还能通过UVLO/EN引脚对输入启动电压进行编程设置。MAX16801非常适合通用交流输入(85VAC至265VAC整流电压输入)驱动器。MAX16802非常适合低输入电压(10.8VDC至24VDC)应用。

MAX16801/MAX16802逐周期监视流过外部MOSFET的电流，从而实现对LED电流的调节。

当工作在带有变压器的自举模式时(图5)，该电路还可提供大多数短路故障保护。当出现短路故障时，第三绕组电压降至+10V以下，致使UVLO电路关闭供给外部MOSFET的栅极驱动信号。这会重新触发一次软启动过程。

若需要精密调节LED电流，可利用片上误差放大器以及精度为1%的基准(图9)。这一额外反馈可大大降低由于无源元件变化和偏差所产生的影响，并且只需最少的外围元件即可实现。

将低频PWM亮度调节信号直接馈入DIM/FB引脚可实现宽范围的亮度调节。

基于MAX16801设计的LED驱动电路采用一个高值启动电阻R1为储能电容C1充电(图5或图9)。在初始阶段，充电电压低于内部自举UVLO门限电压，器件消耗的静态电流仅为45μA (典型值)。低启动电流和较高滞回电压的自举UVLO可大大降低R1的功耗，即便是在通用交流输入电压位于高端时功耗也很小。

当芯片结温超过+130°C (典型值)时，内置的关断电路可启动保护功能。

亮度调节

线性亮度调节是通过在CS上的一个求和节点来实现的，如图6和图7所示。

低频PWM (电流斩波)亮度调节则通过在器件的DIM/FB引脚上施加一个反相逻辑PWM信号来实现(图8)。这种方法对于那些要求调节亮度时严格保持光谱不变的应用场合也许会是首选方案。它是通过对恒定幅度的LED电流进行斩波实现调光的。

MAX16801/MAX16802的偏置

当变压器存在时，由变压器实现自举(图5)。采用非隔离式拓扑时也可直接由LED产生偏置(图1)。

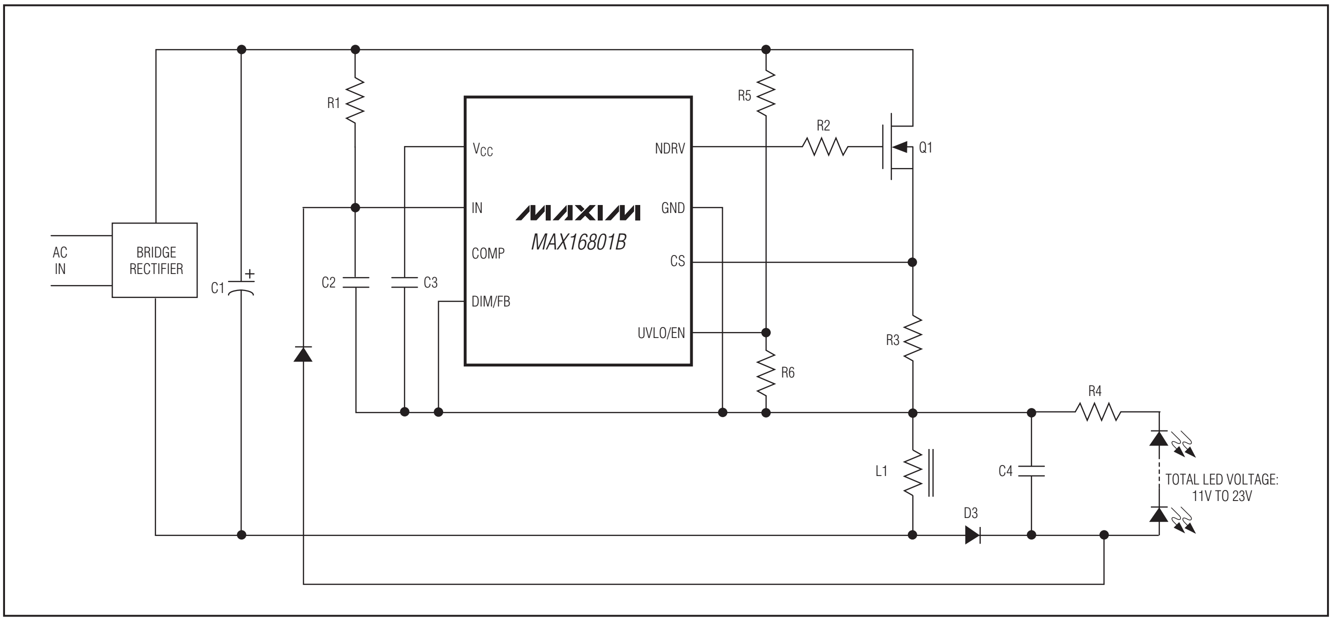


图1. 在非隔离型flyback驱动器中利用LED为IC提供偏置

用于高亮度LED驱动器的离线式、DC-DC PWM控制器

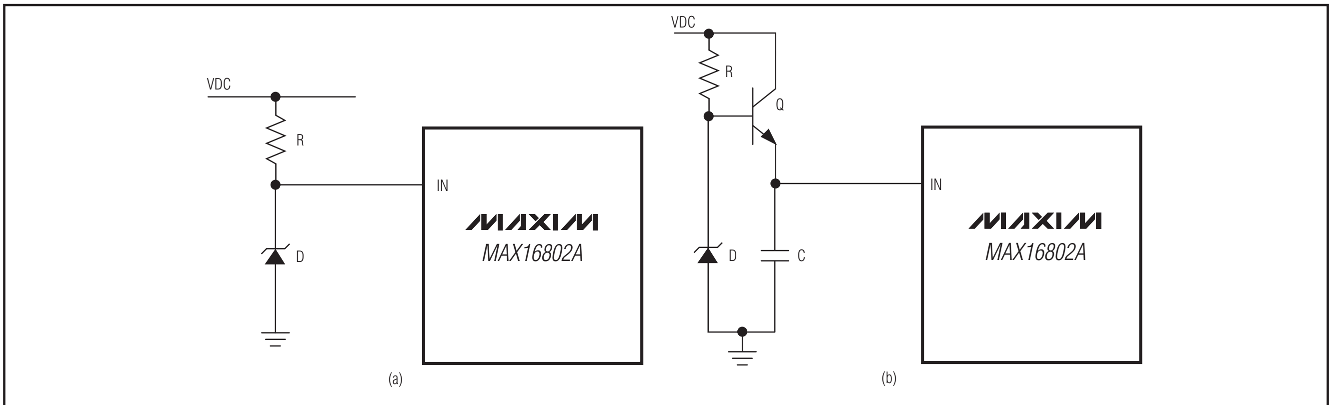


图2. (a)电阻-齐纳二极管和(b)晶体管-齐纳二极管-电阻偏置电路

MAX16802可直接由10.8VDC至24VDC输入电压进行偏置。利用电阻器-齐纳二极管(图2a)或晶体管-齐纳二极管-电阻器偏置电路(图2b)，MAX16802也可用在更高直流输入电压的场合。

MAX16801/MAX16802欠压锁定

MAX16801/MAX16802具有一个输入电压UVLO/EN引脚。UVLO门限电压为+1.28V。只有在该引脚电压大于+1.28V后电路才开始工作。UVLO电路可使CPWM比较器、ILIM比较器、振荡器以及输出驱动器处于关断状态，以减少电流消耗(参见*功能框图*)。利用该UVLO功能可设置输入启动电压。分压电阻R2和R3 (图5)阻值的计算公式如下：

$$R3 \cong \frac{V_{ULR2} \times V_{IN}}{500 \times I_{UVLO}\left(V_{IN} - V_{ULR2}\right)}$$

选择R3阻值时，应使UVLO/EN输入偏置电流在R2上的压降所产生的误差最低。V_{ULR2} = +1.28V，I_{UVLO} = 50nA (最大值)，V_{IN}是电源启动时的输入电源电压值。

$$R2 = \frac{V_{IN} - V_{ULR2}}{V_{ULR2}} \times R3$$

其中I_{UVLO}是UVLO/EN引脚的输入电流，V_{ULR2}是UVLO/EN唤醒门限。

MAX16801自举欠压锁定

除了MAX16801/MAX16802均具有的外部可编程UVLO外，MAX16801还内置一个额外的自举UVLO，在设计高压LED驱动器时非常有用(参见*功能框图*)。这样允许器件在初始上电时自行启动。当V_{IN}高于自举UVLO门限电压+23.6V时，MAX16801开始启动。启动期间，UVLO电路保持CPWM比较器、ILIM比较器、振荡器以及输出驱动器处于关断状态，以减小电流消耗。一旦V_{IN}达到+23.6V，UVLO电路启动CPWM比较器、ILIM比较器和振荡器，并允许输出驱动器开始开关操作。如果V_{IN}降至+9.7V以下，UVLO电路则关断CPWM比较器、ILIM比较器、振荡器以及输出驱动器，从而使MAX16801返回至启动模式。

MAX16801启动工作模式

在隔离式LED驱动器应用中，V_{IN}取自变压器的第三绕组。然而，启动时变压器中没有电能提供。因此，需要特定的自举过程。图3所示为启动时IN和V_{CC}引脚上的电压。开始，V_{IN}和V_{CC}均为0V。施加电源电压之后，启动电阻R1将C1充至某个中间电压。此时，内部稳压器开始向C2充电(参见图5)。在由R1提供的电流当中，MAX16801仅用45μA，其余输入电流则为C1和C2充电。当V_{CC}电压近似为+9.5V时，停止对C2充电，而C1两端的电压继续上升，直到该电容上的电压达到唤醒电压+23.6V为止。一旦V_{IN}大于自举UVLO门限电压，NDRV开始开关MOSFET，并

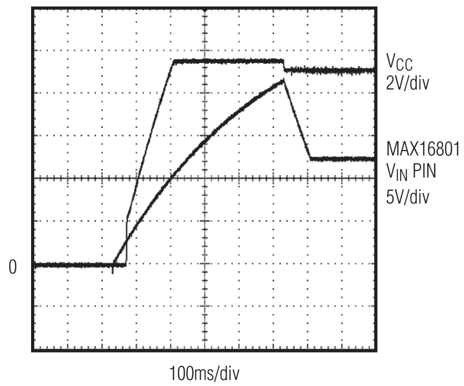


图3. 当MAX16801处于自举模式下，启动时的V_{IN}和V_{CC}

向第二绕组和第三绕组传输电能。如果第三绕组输出建立电压高于+9.7V (自举UVLO低端门限)，则启动过程完成，开始连续工作。

如果在启动完成之前V_{IN}降至+9.7V以下，则器件返回至低电流UVLO状态。这种情况下，可增大C1来存储足够的电能，以便第三绕组上建立起足够的电压。

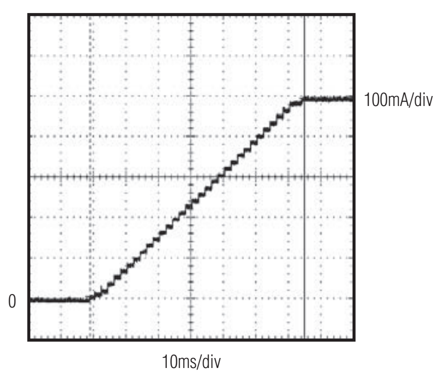


图4. 初始启动时的典型软启动电流

软启动

MAX16801/MAX16802的软启动特性可使LED电流在受控模式下沿斜坡上升。当脱离UVLO状态后开始软启动过程。加至放大器同相节点的电压在60ms的软启动时间内从0直线上升至+1.23V。图4显示了0.5A的典型输出电流在启动过程中的变化情况。可注意到LED电流以阶梯方式升高。这是由于采用了数字软启动技术。与其它器件不同的是，内置放大器的基准电压是软启动的。这种方法能较好地控制LED电流。

n沟道MOSFET开关驱动器

NDRV引脚能驱动外部n沟道MOSFET。NDRV输出由内部稳压器(V_{CC})供电，该内部稳压器在内部设置为约+9.5V。对于通用输入电压和带有变压器的应用而言，所采用的MOSFET必须能承受电源电压最高时的直流电平与变压器初级的反射电压之和。对于大多数采用非连续flyback拓扑的离线式应用而言，需要额定电压为600V的MOSFET。NDRV能源出/吸入超过650mA/1000mA峰值电流。所选择的MOSFET产生的导通损耗和开关损耗必须在可接受的范围内。

内部误差放大器

MAX16801/MAX16802包括一个内部误差放大器，可用来非常精确地调节LED电流。例如，图5所示的非隔离式电源。LED电流的计算公式如下：

$$I_{LED} = \frac{V_{REF}}{R7}$$

其中V_{REF} = +1.23V。放大器的同相输入端由内部连接至数字软启动电路，确保启动过程中基准电压缓慢上升，并将该基准电压施加至该引脚。这样可强制LED电流在所有状态下都按照预定的方式有序地升高。

应用信息

MAX16801用于高亮度LED驱动器的启动时间考虑

IN旁路电容C1用于在电路刚刚唤醒时迅速提供工作电流(图5)。C1的尺寸和第三绕组的连接方式决定了可用于启动的周期数。大容值C1延长了启动时间，但能在初始启动阶段提供更多电荷以支持更多的开关周期。如果C1的容值太小，那么NDRV将没有足够的时间开关MOSFET，从而不能在第三绕组上建立足够的电压为器件提供电源，致使V_{IN}降至+9.7V以下。器件返回UVLO状态而不能启动。C1和C2需采用低泄漏电容。

假定在低电源电压状态下(85VAC输入的通用离线式应用)离线式LED驱动器仍要维持小于500ms的启动时间，启动电阻R1应能同时提供器件所需的最大启动偏置电流(最差状态下90µA)和为C1、C2充电所需的电流。在预期的500ms启动时间内，旁路电容C2必须被充电到+9.5V，而C1必须充电到+24V。

由于MAX16801内部有60ms的软启动时间，C1必须存储足够的电荷，以便至少在这段时间内向器件供应电流。用以下公式近似计算所需的电容值：

$$I_g = Q_{gtot} \times f_{SW}$$

$$C1 = \frac{\left(I_{IN} + I_g\right)\left(t_{SS}\right)}{V_{HYST}}$$

其中I_{IN}是启动后MAX16801的内部电源电流(1.4mA)，Q_{gtot}是Q1的总栅极电荷，f_{SW}是MAX16801的开关频率(262kHz)，V_{HYST}是自举UVLO滞回电压(11.9V)，t_{SS}是内部软启动时间(60ms)。

例如：

$$I_g = (8nC) \times (262kHz) = 2.1mA$$

$$C1 = \frac{\left(1.4mA + 2.1mA\right) \times \left(60ms\right)}{\left(12V\right)} = 17.5\mu F$$

电容值取标准值15µF。

假设C1 > C2，则按以下公式计算R1：

$$I_{C1} = \frac{V_{SUVR} \times C1}{\left(500ms\right)}$$

$$R1 = \frac{V_{IN(MIN)} - V_{SUVR}}{I_{C1} + I_{START}}$$

其中$V_{IN(MIN)}$是应用中的最小输入电压，V_{SUVR}是自举UVLO唤醒电平(最大值+23.6V)，I_{START}是启动时IN上的电源电流(最大值90µA)。

例如，交流输入电压取最小值85V时，有：

$$I_{C1} = \frac{\left(24V\right) \times \left(15\mu F\right)}{\left(500ms\right)} = 0.72mA$$

$$R1 = \frac{120V - 24V}{\left(0.72mA + (90\mu A)\right)} = 119k\Omega$$

电阻取标准值120kΩ。

如果允许更长的启动时间，则R1阻值可选取得比上述计算值更大一些，这样可以降低该电阻的功耗。

上述启动方案可用于类似于图5的电路。该电路中第三绕组与输出绕组同相。因而任何时间第三绕组的电压与输出电压总成正比，并和输出电压经历相同的软启动过程。C1从+22V放电至+10V的最短放电时间必须大于60ms的软启动时间。

实现自举的另一个方法是在调节输出电压的绕组之外采用一个独立的偏置绕组，并使偏置绕组与MOSFET导通时间同相(参见图9)。在此情况下，所需的电容值就小多了。

然而，在这种方式下，输入电压范围必须小于2:1。在决定偏置绕组是否与输出同相时，还有另一个需要考虑的问题。如果同相，则LED驱动电路会在输出短路状态下打嗝和软启动。但是，如果偏置绕组与MOSFET导通时间同相，就不具有该特性。

应用电路

图5给出了一个基于MAX16801的离线式HB LED驱动器应用电路。变压器T1可大大提高设计的灵活性。内部误差放大器可实现非常精确的LED电流控制。

图6给出了一个具有线性亮度调节功能的非连续flyback LED驱动器。LED总电压可低于或高于输入电压。

图7给出了一个连续导通模式的HB LED buck驱动器，具有线性调光，只需少量的外部元件。

图8给出了一个基于MAX16801、采用低频PWM方式调光的离线式隔离flyback HB LED驱动器。PWM信号需要反相(参见*功能框图*)。变压器T1提供安全隔离，工作于通用交流电源(85VAC至265VAC)。

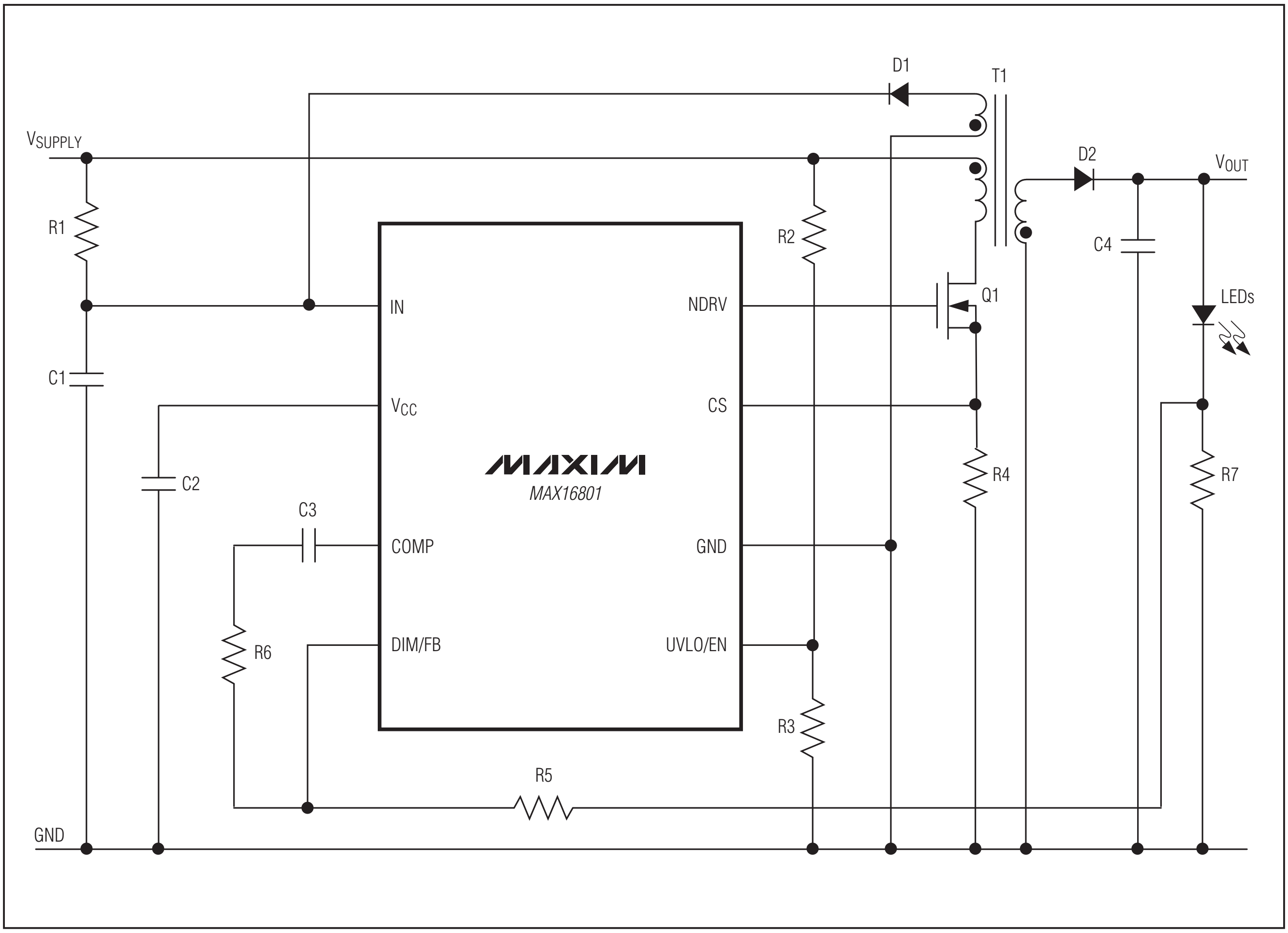


图5. 离线式、非隔离、flyback LED驱动器，具有可编程输入启动电压

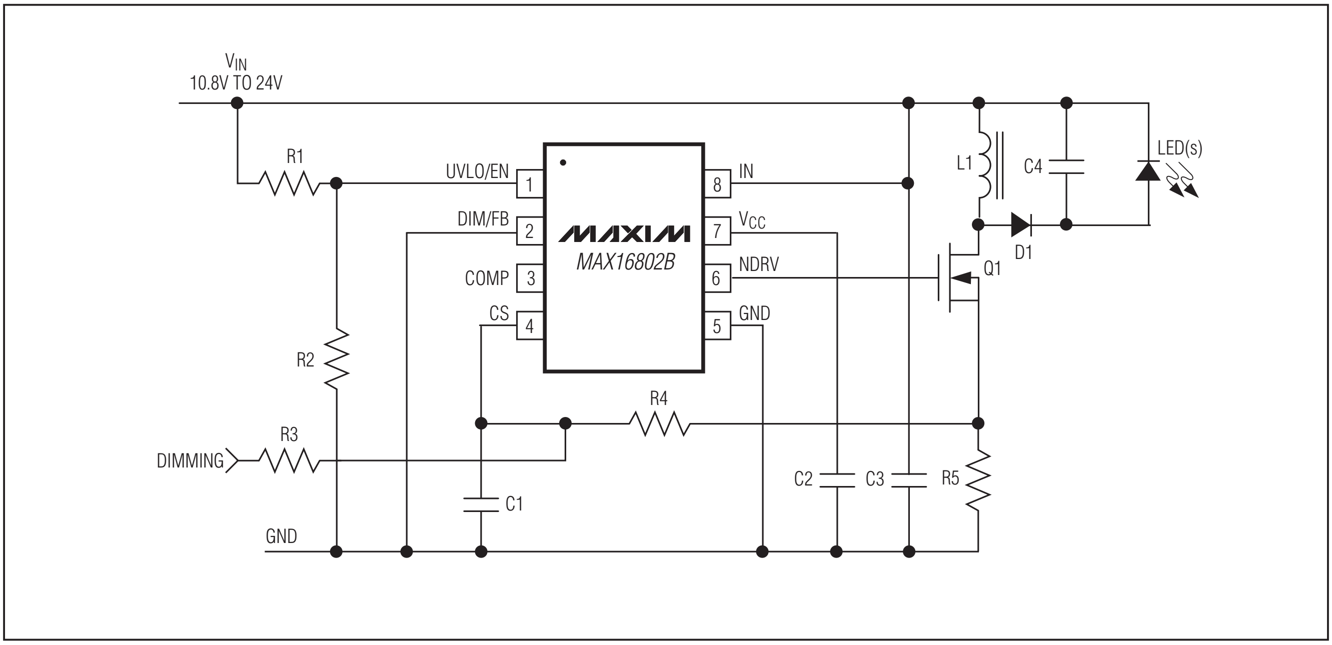


图6. 具有亮度调节功能的MAX16802 flyback HB LED驱动器，输入电压范围10.8V至24V

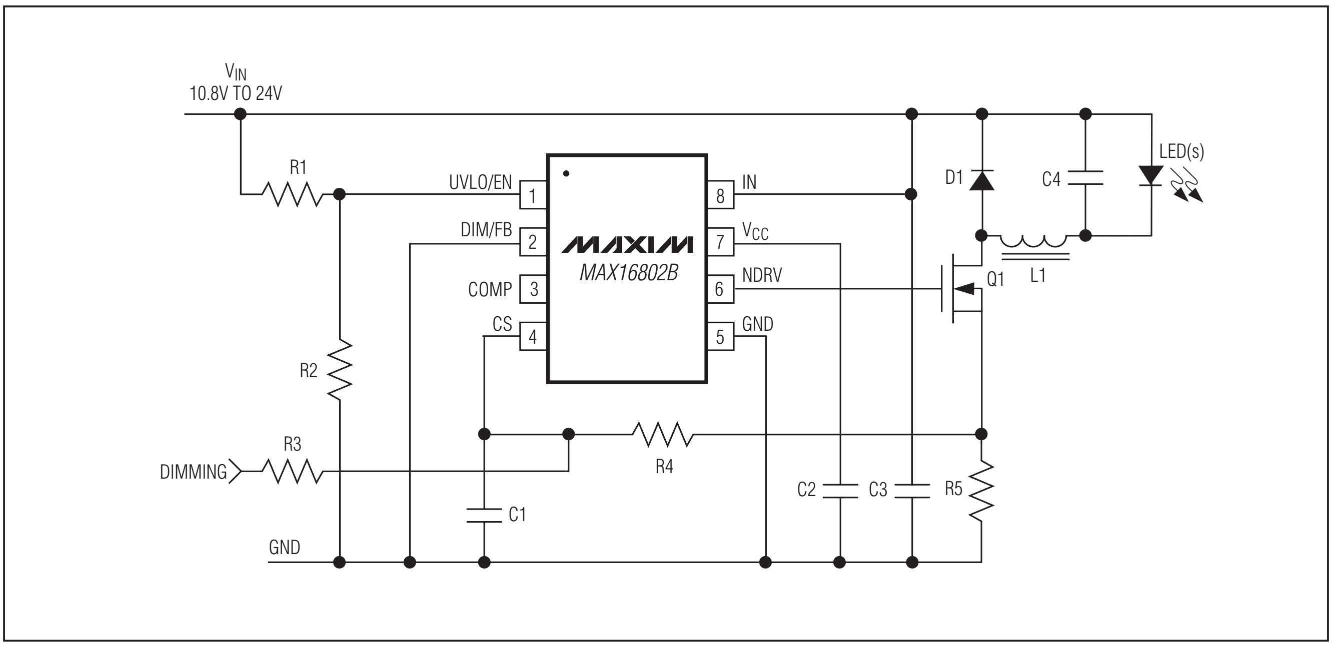


图7. 具有亮度调节功能的MAX16802 buck HB LED驱动器，输入电压范围10.8V至24V

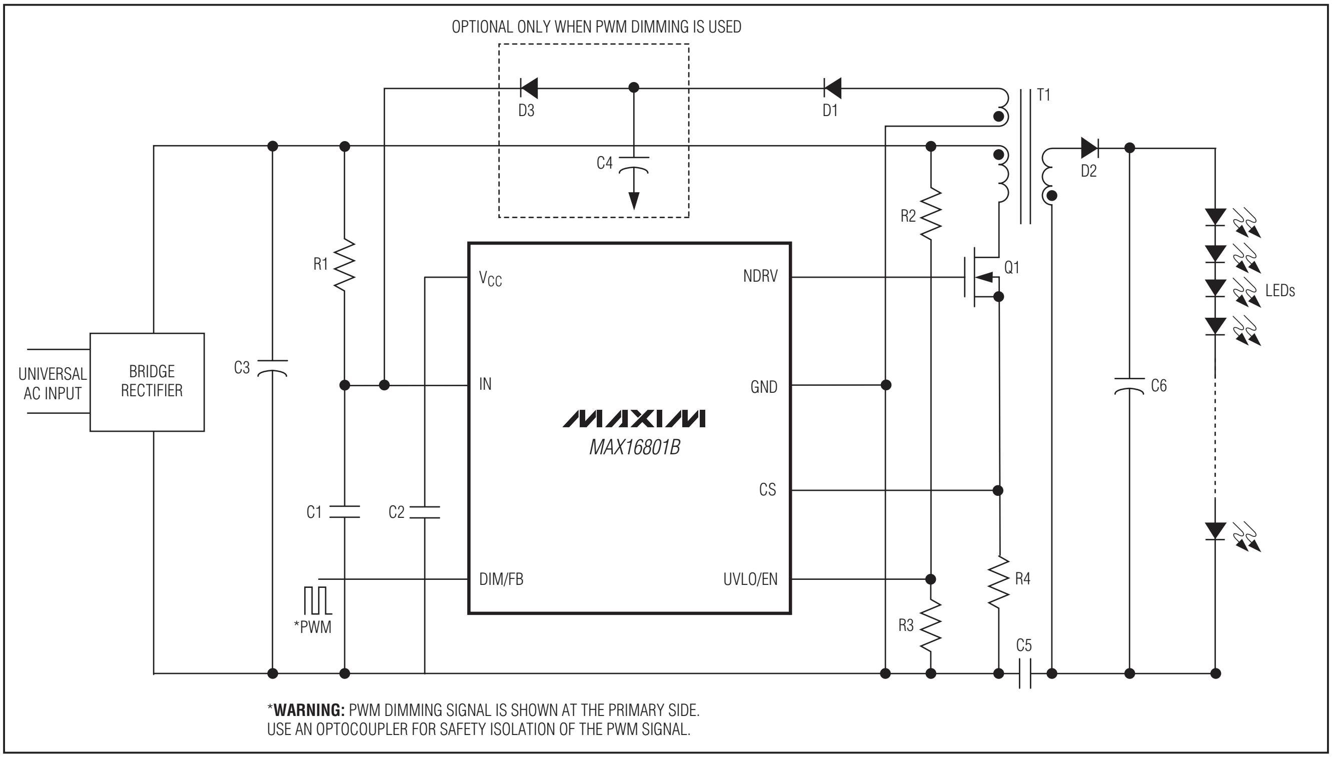


图8. 通用交流输入、离线式、隔离型flyback HB LED驱动器，采用低频PWM调光

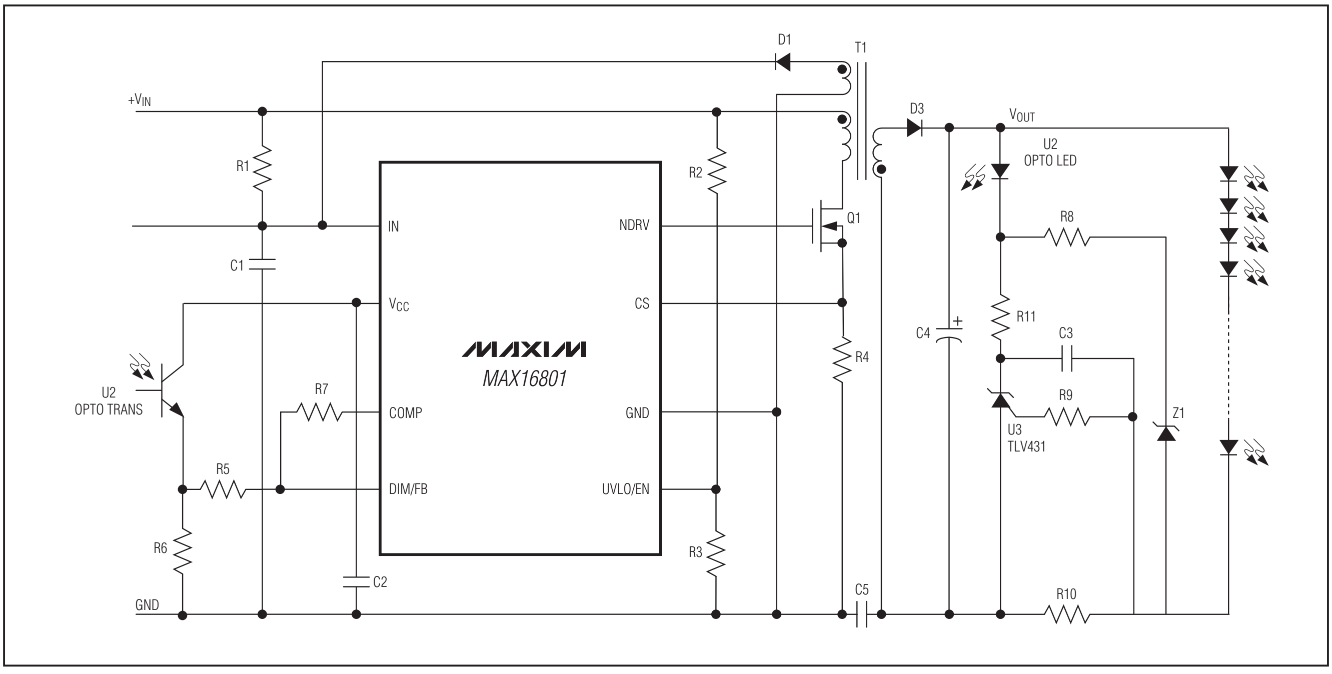
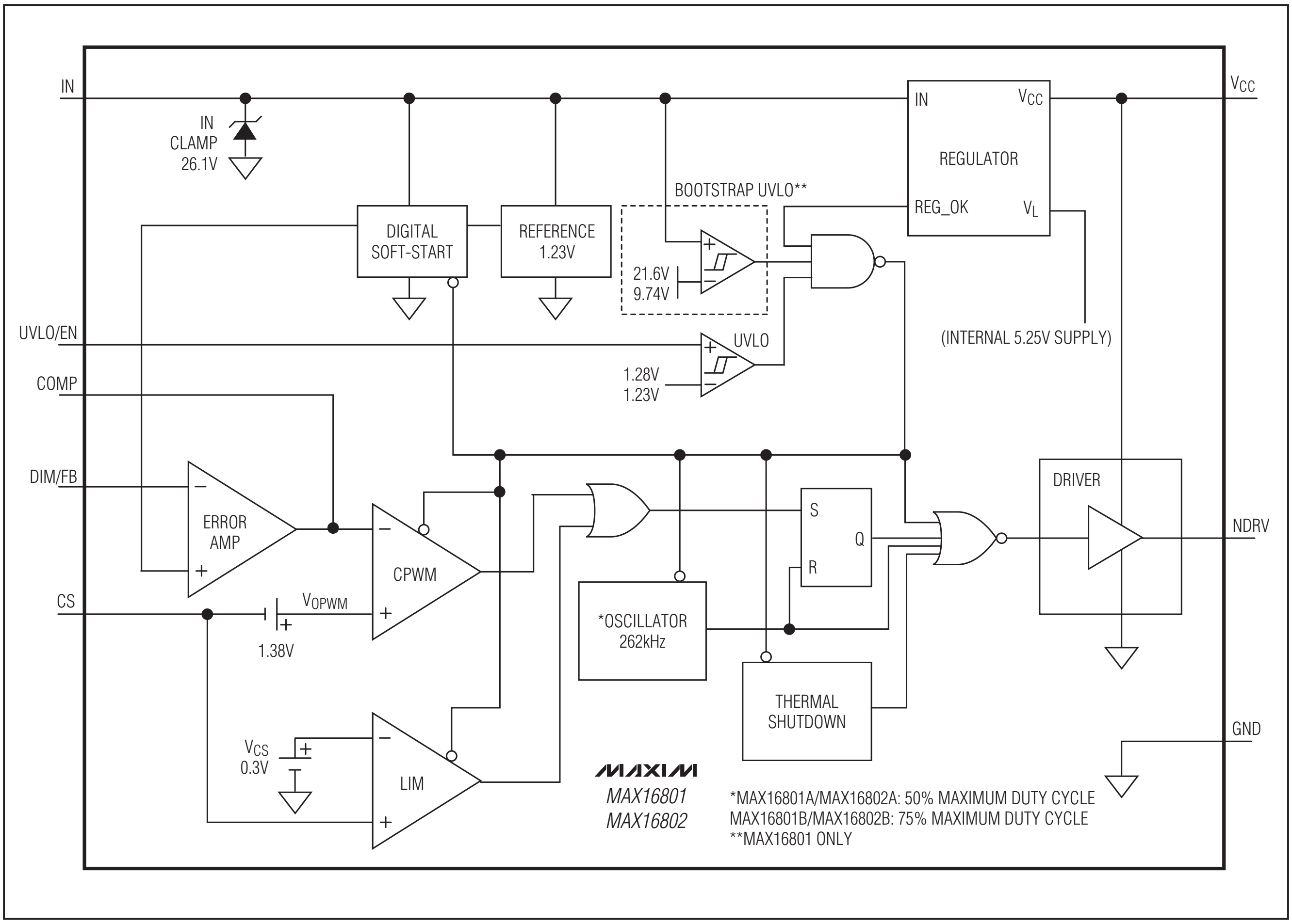


图9. 通用输入、离线式、隔离型flyback HB LED驱动器，具有高精度电流调节特性

用于高亮度LED驱动器的离线式、DC-DC PWM控制器

功能框图

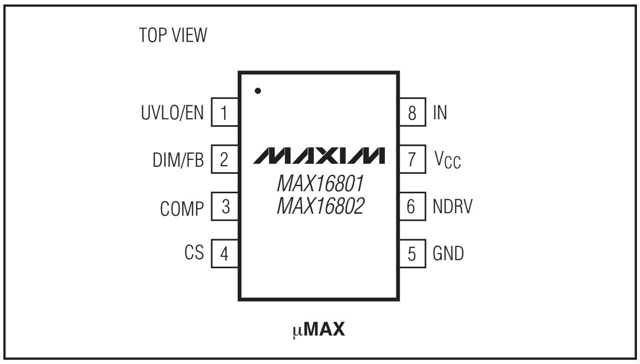


选型指南

PART	BOOTSTRAP UVLO	STARTUP VOLTAGE (V)	MAX DUTY CYCLE (%)
MAX16801A	Yes	22	50
MAX16801B	Yes	22	75
MAX16802A	No	10.8*	50
MAX16802B	No	10.8*	75

*MAX16802没有内部自举UVLO。
V_{CC}引脚电压高于+7V (IN引脚电压为+10.8V时的保证输出)，并且UVLO/EN引脚为高电平时MAX16802开始工作。

引脚配置



封装信息

如需最近的封装外形信息和焊盘布局，请查询 **china.maxim-ic.com/packages**。请注意，封装编码中的"+"、"#"或"-"仅表示RoHS状态。封装图中可能包含不同的尾缀字符，但封装图只与封装有关，与RoHS状态无关。

封装类型	封装编码	文档编号
8 μMAX	—	21-0036

用于高亮度LED驱动器的 离线式、DC-DC PWM控制器

修订历史

修订号	修订日期	说明	修改页
0	10/05	最初版本。	—
1	1/06	增加了MAX16802AEUA+器件。	1
2	1/10	更正了计算公式，更新了下标，并删除了封装图。	1, 2, 3, 6–15

Maxim北京办事处

北京 8328信箱 邮政编码 100083
免费电话：800 810 0310
电话：010-6211 5199
传真：010-6211 5299

MAX16801, MAX16801A, MAX16801B, MAX16802, MAX16802A, MAX16802B

离线式、DC-DC PWM控制器，用于高亮度LED驱动器

具有宽工作范围、高电流精度的**LED**驱动方案

状况

状况：生产中。

概述

完整的数据资料
英文 下载 Rev. 2 (PDF, 212kB)
中文 下载 Rev. 2 (PDF, 700kB)

MAX16801A/B/MAX16802A/B高亮度(HB) LED驱动控制器IC含有设计宽输入电压范围LED驱动器所需的全部电路，适用于通用照明和显示器应用。MAX16801非常适用于通用输入(85VAC至265VAC整流电压输入) LED驱动器，MAX16802适用于低输入电压(10.8VDC至24VDC) LED驱动器。

需要精密调节LED电流时，可利用板上误差放大器以及精度为1%的基准。通过低频PWM亮度调节可实现较宽的亮度调节范围。

MAX16801/MAX16802具有输入欠压锁定(UVLO)特性，可设置输入启动电压，并可确保在电源跌落时正常工作。MAX16801具有大滞回的内部自举欠压锁定电路，从而简化了离线LED驱动器的设计。MAX16802没有这个内部自举电路，可直接由+12V电压偏置。

内部微调的262kHz固定开关频率允许优化选择磁性元件和滤波元件，从而实现紧凑、高性价比的LED驱动器。MAX16801A/MAX16802A的最大占空比为50%，MAX16801B/MAX16802B的最大占空比为75%。这些器件均采用8引脚µMAX®封装，可工作在-40°C至+85°C温度范围内。

现备有评估板：MAX16802BEVKIT

关键特性

- 适合buck、boost、flyback、SEPIC和其它拓扑
- 高达50W或更高的输出功率
- 通用离线输入电压范围：85VAC至265VAC整流电压(MAX16801)
- IN引脚直接由10.8V至24V直流输入驱动(MAX16802)
- 内部带有误差放大器和1%精度的基准，可实现精密的LED电流调节
- PWM或线性亮度调节
- 262kHz ±12%固定开关频率
- 热关断
- 数字软启动
- 可编程输入启动电压
- 大滞回内部自举UVLO (MAX16801)
- 45µA (典型值)启动电源电流，1.4mA (典型值)工作电源电流
- 50% (MAX16801A/MAX16802A)或75% (MAX16801B/MAX16802B)最大占空比
- 采用微型8引脚µMAX封装

应用/使用

- 商用与工业照明
- 装饰灯与建筑照明
- 离线式DC-DC LED驱动器
- RGB背光，用于LCD TV和监视器

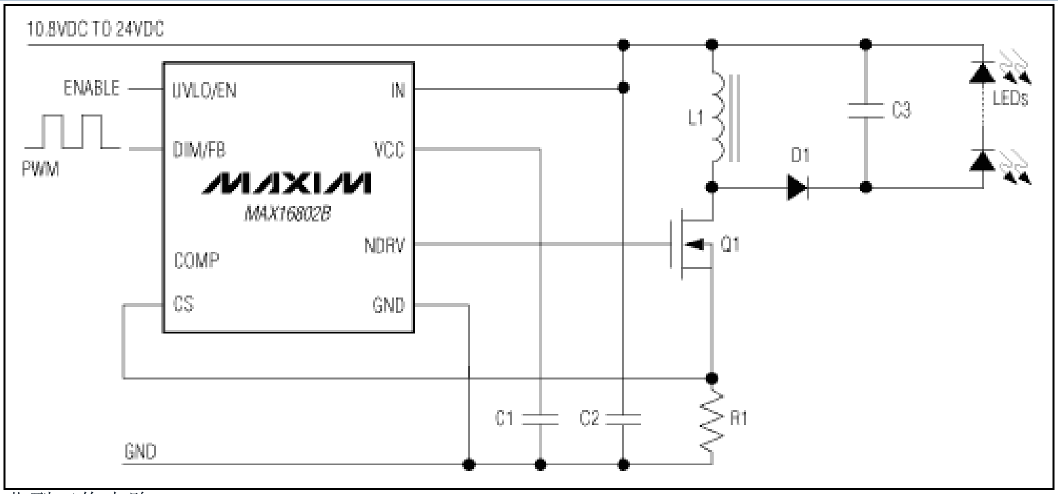
Key Specifications: High Brightness LED Drivers

Part	Topology	Device V_{IN} (V)	Device V_{IN} (V)	Application V_{IN} (V)	LED	I_{LED} per Channel (A)	LED String Volt.	Internal Pwr.	Freq. (kHz)	PWM Dimming Freq.	PWM Dimming Ratio	EV	Price

Number					Channels		(V)	MOSFETs		(kHz)		Kit	
		max	min	max		max	max		max	max	max		*See Notes*
MAX16801	Boost/SEPIC Flyback	24	10.8	400	1	3	250	No	262	2	3000	No	$0.66 @1k
MAX16802	Boost/SEPIC Buck Flyback			24	1							Yes	$0.66 @1k

查看所有**High Brightness LED Drivers (23)**

图表



典型工作电路

相关产品

MAX16802BEVKIT MAX16802B评估板

类似产品：浏览其它类似产品线

- 查看所有High Brightness LED Drivers (25产品)

更多信息

新品发布 [2005-11-14]

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- 应用工程师帮助选型，下个工作日回复
- 参数搜索
- 应用帮助

参考文献： 19-3880 Rev. 2; 2010-04-01
本页最后一次更新: 2010-04-01

19-0560; Rev 0; 5/06

MAX16802B评估板

概述

MAX16802B评估板(EV kit)用来演示基于MAX16802B的电流控制、大电流输出LED驱动器。评估板可提供稳定的750mA输出电流，工作在10.8V至30V电源电压之间，工作温度范围为-40°C至+85°C。

MAX16802B评估板具有两种不同类型的亮度控制方式：利用模拟输入电压或PWM输入信号控制LED亮度。该评估板还具有UVLO功能，在输入电源电压过低时关闭评估板，并且可以在LED开路时为评估板提供过压保护。MAX16802B评估板是完全安装并经过测试的电路板。

警告：当出现严重故障或失效状态时，本评估板可能消耗巨大能量，造成元件或元件碎片的高速溅射。请谨慎操作本评估板，以避免可能的人身伤害。

特性

- ♦ 10.8V至30V宽电源电压范围
- ♦ 电流控制输出
- ♦ 12V输出时电流可达750mA
- ♦ 线性或PWM亮度控制
- ♦ 满载时效率高达80%
- ♦ 电源电压欠压锁定
- ♦ 输出过压保护

定购信息

PART	TEMP RANGE	IC PACKAGE
MAX16802BEVKIT	-40°C to +85°C	8 µMAX®

µMAX是Maxim Integrated Products, Inc.的注册商标。

元件列表

DESIGNATION	QTY	DESCRIPTION
C1, C2, C5, C6	4	4.7µF, 50V X7R ceramic capacitors Murata GRM32ER71H475KA88L
C3, C4, C7	3	0.1µF, 50V X7R SMD ceramic capacitors Murata GRM188R71H104KA93D or TDK C1608X7R1H104K
C8	1	470pF, 50V X7R ceramic capacitor Murata GRM188R71H471KA01D or TDK C1608X7R1H471K
C9	1	1nF, 50V X7R ceramic capacitor Murata GRM188R71H102KA01D or TDK C1608X7R1H102K
D1	1	22V, 1.5W zener diode Vishay SMZG3797B
D2	1	60V, 1A Schottky diode Central Semiconductor CMSH1-60M or Diodes Inc. B160
D3	1	20V, small-signal Schottky diode Vishay SD103CWS or Diodes Inc. SD103CWS
J1, J2	2	0.1in, 2-pin hole headers (through hole)

DESIGNATION	QTY	DESCRIPTION
L1	1	4.7µH, 4.2A peak SMD inductor Coilcraft DO3308P-472ML
Q1	1	60V, 3.2A n-channel MOSFET Vishay Si3458DV
R1	1	392kΩ ±1%, 1/8W resistor (0603)
R2	1	11kΩ ±1%, 1/8W resistor (0603)
R3	1	499kΩ ±1%, 1/8W resistor (0603)
R4	1	73.2kΩ ±1%, 1/8W resistor (0603)
R5, R7	2	1kΩ ±1%, 1/8W resistors (0603)
R6	1	330Ω ±1%, 1/4W resistor (1206)
R8	1	220Ω ±1%, 1/8W resistor (0603)
R9	1	0.10Ω ±1%, 1/2W resistor (1206) Susumu RL1632R-R100-F
R10	1	1Ω ±5%, 1/8W resistor (0603)
U1	1	MAX16802B (8-pin µMAX)
VIN, VLED, PWM_IN, LIN_IN	4	0.1in, 2-pin male connectors (through hole)
—	1	MAX16802B PC board

MAX16802B评估板

快速入门

MAX16802B评估板是完全装配并经过测试的电路板。按照下列步骤验证其工作情况。**在完成所有连接之前，不要接通电源。**

1) 将直流电源(0至30V或更高，1A)连接至+VIN和GND。
2) 将电压表或示波器和LED阵列(串行连接，750mA正向电流下压降约为12V)连接至+VLED和-VLED端；阳极接+VLED，阴极接-VLED。
3) 接通跳线J1和J2以禁止亮度调节。
4) 打开电源，并将输入电压增加到10.8V以上。输出电压将增大到LED阵列正向偏置电压，并提供大约750mA稳定的LED平均电流。将输入电压增至30V，平均输出电流在整个电源电压范围内保持稳定。
5) 断开短路器J1，并在PWM_IN上加载PWM信号(频率为200Hz, 幅度为0至2V)。从0至100%改变占空比，LED亮度随之变化，相应地从100%变化至0%。当PWM信号占空比为0%时，LED亮度为100%。
6) 接通J1并将断开J2。连接一个可变电压源至LIN_IN，在0至1.6V之间调节电压。LED亮度将在100%与0%之间变化。输入LIN_IN电压为0V时，LED亮度为100%。

警告：不接负载时请勿给评估板上电。

详细说明

MAX16802B评估板(EV kit)是电流控制型、大电流输出LED驱动器，可提供高达750mA的稳定电流，且不受电源电压变化影响。

该评估板基于工作在262kHz、非连续电流模式(DCM)的buck-boost转换器，每个周期为输出提供一定能量，具体的能量值主要取决于电感和用户可编程的峰值电感电流，与输入电压无关。按照这一配置，评估板的输出电压和在给定LED工作电压下供给LED的输出电流与电源电压无关。

该评估板设计用于驱动LED负载，12V工作电压下可提供高达750mA的最大电流。如果LED的工作电压较低，那么最大输出电流将按比例增加，可保持稳定的输出功率。为驱动不同工作电压的LED阵列，需要改变检流电阻。下面给出了不同工作电压下检流电阻计算方法的详细说明。

输入电源UVLO

输入电源UVLO电路由R3、R4组成的电阻网络实现。该电阻网络检测输入电源电压，并在输入电压高于10.8V时通过EN引脚启动电路。当EN引脚的电压升高时，其唤醒电压门限为1.23V，具有50mV滞回。器件一旦开始工作，它只在输入电源电压低于10.4V (考虑到滞回电压)时才会关断。

UVLO门限可按照下列公式通过电阻R1和R2进行调节：

$$R3 = \left(\frac{V_{UVLO}}{1.23} - 1\right) \times R4$$

其中，V_{UVLO}为所要求的UVLO门限。为保持门限精度，R4应小于100kΩ。

元件供应商

SUPPLIER	PHONE	FAX	WEBSITE
Central Semiconductor	631-435-1110	631-435-3388	www.centralsemi.com
Coilcraft	847-639-6400	847-639-1469	www.coilcraft.com
Diodes Inc.	805-446-4800	805-446-4850	www.diodes.com
Murata	770-436-1300	770-436-3030	www.murata.com
Susumu Co Ltd.	208-328-0307	208-328-0308	www.susumu-usa.com
TDK	847-390-4373	847-390-4428	www.component.tdk.com
Vishay	402-563-6866	402-563-6296	www.vishay.com

注：与上述元器件供应商联系时，请说明您正在使用的是MAX16802B。

输出过压保护

VLED正极引脚相对于GND的最大电压由R1、R2组成的反馈网络限制在45V，该网络连接至MAX16802B的FB引脚。如果评估板在没有接负载时开启或LED开路，则VLED正极电压可能会上升到不安全的电压。内部误差放大器会检测这种情况，从而降低电感的峰值电流，将VLED正极引脚的电压限制在45V以内。即便使用了这种保护，仍建议在给评估板上电之前接上指定的负载。

PWM亮度调节

通过调节连接在PWN_IN输入端的PWM信号占空比来控制LED亮度。PWM_IN输入为高电平时关断LED电流；输入为低电平时开启LED电流。信号峰值在1.5V至5.0V、频率为100Hz至1000Hz，通过改变占空比调节LED亮度。频率低于100Hz的信号可能会导致输出闪烁。增大占空比时，LED亮度减弱，反之亦然。PWM占空比为0%时，LED亮度达到100%。

线性亮度调节

线性亮度调节是通过改变LIN_IN输入电压的幅度来控制LED亮度。LIN_IN输入调制检流信号，在不同的电流下触发MOSFET。这一过程会进一步控制输出电流，从而达到控制LED亮度的目的。因为在任何亮度等级LED始终保持导通状态，线性亮度调节不会产生闪烁现象。在0至1.6V范围内调节LIN_IN电压，可使LED亮度在100%至0%间变化。LIN_IN电压增大时，LED亮度减弱，反之亦然。LIN_IN电压为0V时，LED亮度为100%。

调节输出功率

根据下列公式调节检流电阻R9，可以改变评估板的最大输出功率：12V、750mA。注意：评估板最大输出电流限制在750mA、最大输出电压限制在15V，且最大输出功率限制在8.25W。

首先计算最小输入电压下的最佳导通占空比：

$$D_{ON} = \frac{V_{LED} + V_D}{V_{INMIN} + V_{LED} + V_D}$$

其中，V_{INMIN}为最小输入电压，V_{LED}为LED工作电压，I_{LED}为所要求的LED电流，V_D为D2的正向电压。

计算所要求的峰值电感电流：

$$I_P = \frac{k_f \times 2 \times I_{LED}}{1 - D_{ON}}$$

其中，k_f为“修正因子” (非临界系数)，该电路中将其设置为1.1。

计算所需的电感值，并选择最接近标准值但小于计算值的电感：

$$L = \frac{D_{ON} \times V_{INMIN}}{f_{SW} \times I_P}$$

其中，L为电感L1的电感值；f_{SW}为开关频率，等于262kHz。

通过反激模式提供给输出电路的功率为：

$$P_{IN} = \frac{1}{2} \times L \times I_P^2 \times f_{SW}$$

输出电路消耗的功率为：

$$P_{OUT} = V_{LED} \times I_{LED} + V_D \times I_{LED}$$

根据能量守恒定律，上述两个等式相等，从而求出一个更精确的峰值电感电流：

$$I_P = \sqrt{\left(\frac{2 \times (V_{LED} + V_D) \times I_{LED}}{f_{SW} \times L}\right)}$$

根据求得的I_{PEAK}，利用下式计算检流电阻R9：

$$R9 = \frac{0.292 \times (R8 + R7)}{I_{PEAK} \times R7}$$

其中，0.292V为检流门限电压。R7、R8组成一个电阻分压器，能够在器件检流引脚之前按比例降低检流电阻上的压降。

跳线选择

不使用PWM亮度调节时将跳线J1接通；不使用线性亮度调节时将跳线J2接通。

MAX16802B评估板

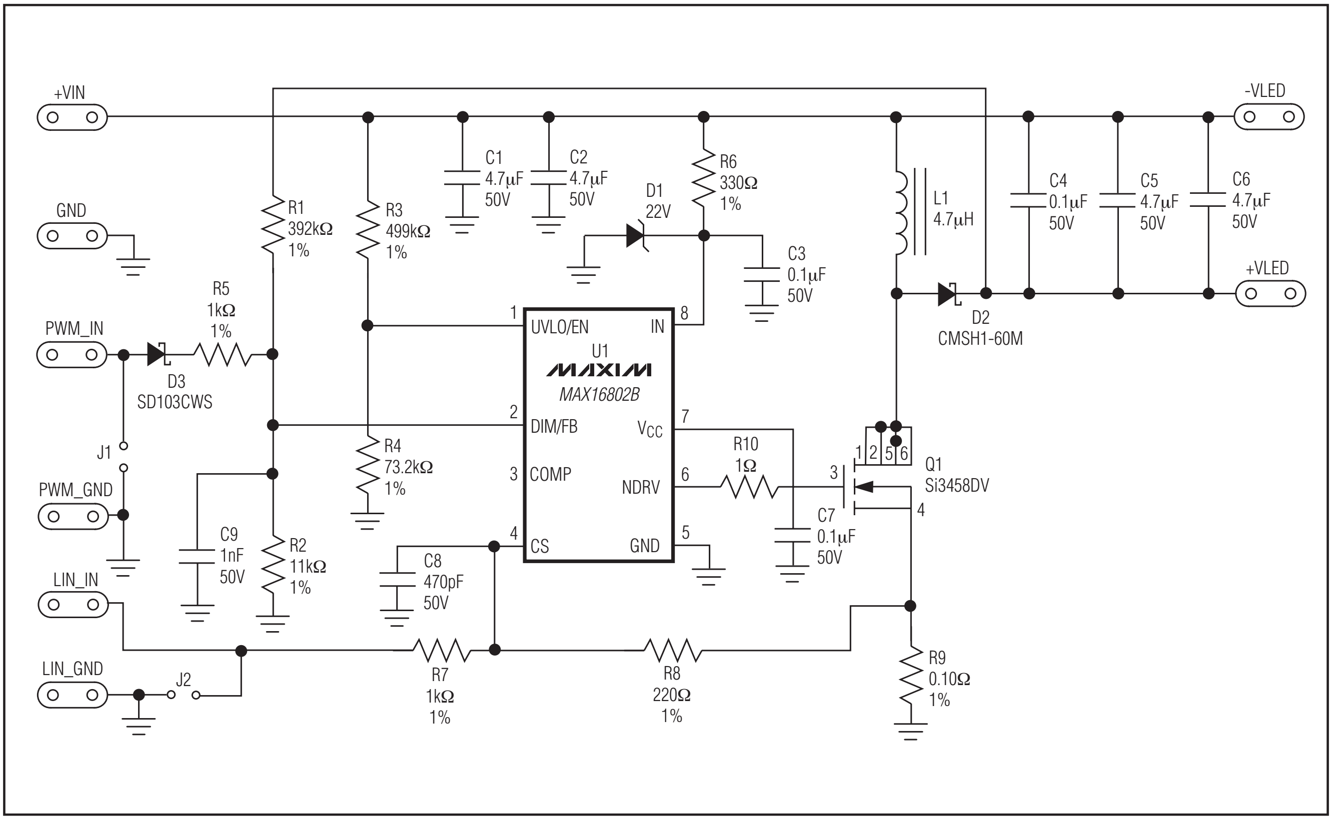

图1. MAX16802B评估板原理图

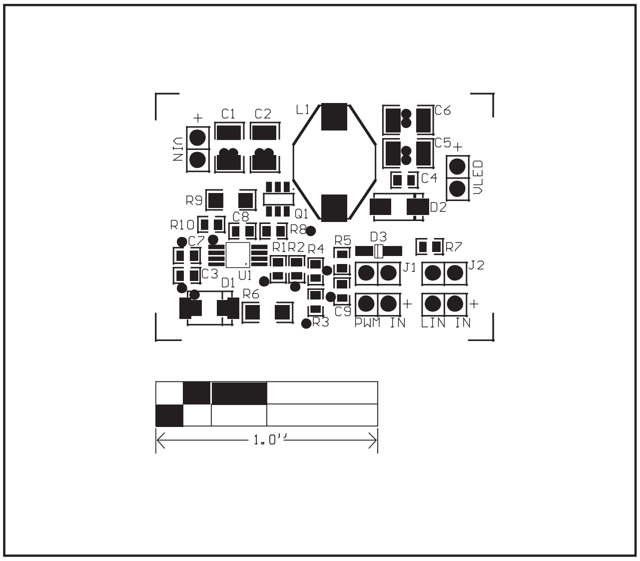

图2. MAX16802B评估板元件布局——元件层

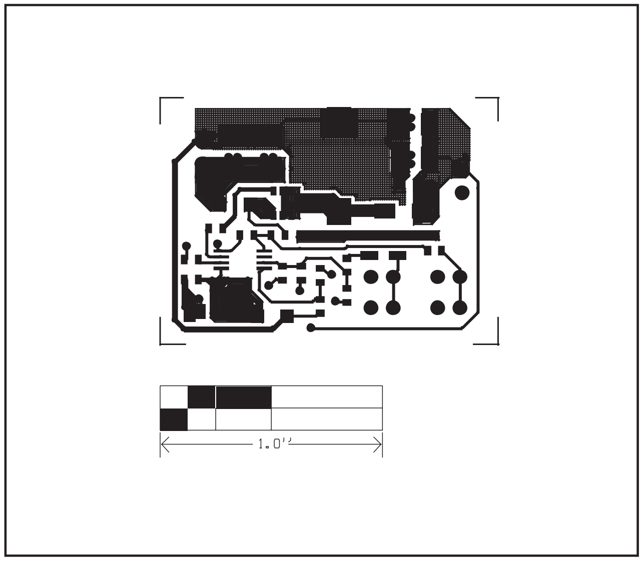

图3. MAX16802B评估板PCB布局——元件层

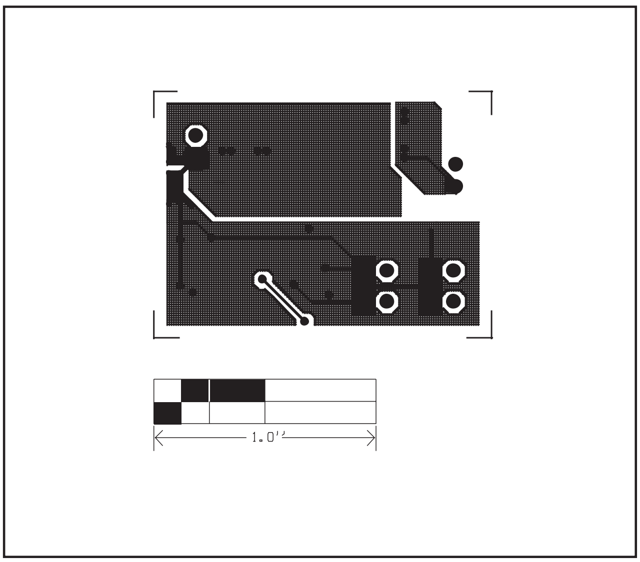

图4. MAX16802B评估板PCB布局——焊接层

MAX16802BEVKIT

MAX16802B评估板

概述 | 技术文档 | 定购信息 | 用户说明 (0) | 所有内容

状况

状况：生产中。

概述

MAX16802B评估板(EV kit)用来演示基于MAX16802B的电流控制型、大电流LED驱动器。该评估板具备高达750mA的稳定电流供给能力，并可运行在10.8V至30V电源电压之间，工作温度范围为-40°C至+85°C。

MAX16802B评估板具有两种不同类型的亮度控制方式：使用模拟输入电压或PWM输入信号来控制LED亮度。该评估板还具有UVLO功能，可以在输入电源电压过低时关闭评估板，并且可以在LED开路时为评估板提供过压保护。MAX16802B评估板是一块经过完全安装与测试的电路板。

完整的数据资料

英文 下载 Rev. 0 (PDF, 132kB)
中文 下载 Rev. 0 (PDF, 640kB)

警告：当出现严重故障或失效状态时，本评估板有巨大能量耗散，可能会造成元件或元件碎片的高速溅射。请小心操作本评估板，以避免可能的人身伤害。

关键特性

- 10.8V至30V电源电压范围
- 电流控制型输出
- 12V输出时，电流可高达750mA
- 线性或PWM亮度控制
- 满载时效率高达80%
- 电源电压欠压锁定
- 输出过压保护

应用/使用

- 商用与工业照明
- 装饰灯与建筑照明
- 离线式DC-DC LED驱动器
- RGB背光，用于LCD TV和监视器

相关产品

MAX16801, MAX16801A, MAX16801B, MAX16802, MAX16802A, MAX16802B	离线式、DC-DC PWM控制器，用于高亮度LED驱动器

没有找到你需要的产品吗？

- 应用工程师帮助选型，下个工作日回复
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数据资料
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关键特性
应用/使用
关键指标
图表
注释、注解
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应用笔记
评估板
设计指南
可靠性报告
软件/模型

样品
在线订购
封装信息
无铅信息

参考文献： 19-0560 Rev. 0; 2006-05-30
本页最后一次更新：2006-07-20

19-0560; Rev 0; 5/06

MAX16802B Evaluation Kit

General Description

The MAX16802B evaluation kit (EV kit) demonstrates a current-controlled, high-output-current LED driver based on the MAX16802B. This EV kit is capable of supplying stable output currents of up to 750mA, can run at supply voltages between 10.8V and 30V, and can operate at temperatures ranging from -40°C to +85°C.

The MAX16802B EV kit features two different types of dimming controls using either a linear input voltage or a PWM input signal to control the LED brightness. This EV kit also has a UVLO feature to turn off the EV kit operation during low input supply voltage and an overvoltage protection to protect the EV kit under an open-LED condition. The MAX16802B EV kit is a fully assembled and tested board.

Warning: Under severe fault or failure conditions, this EV kit may dissipate large amounts of power, which could result in the mechanical ejection of a component or of component debris at high velocity. Operate this EV kit with care to avoid possible personal injury.

Features

- ♦ **10.8V to 30V Wide Supply Voltage Range**
- ♦ **Current-Controlled Output**
- ♦ **Up to 750mA LED Current at 12V Output**
- ♦ **Linear and PWM Dimming Control**
- ♦ **Over 80% Efficiency at Full Load**
- ♦ **Supply Undervoltage Lockout**
- ♦ **Output Overvoltage Protection**

Ordering Information

PART	TEMP RANGE	IC PACKAGE
MAX16802BEVKIT	-40°C to +85°C	8 µMAX®

µMAX is a registered trademark of Maxim Integrated Products, Inc.

Component List

DESIGNATION	QTY	DESCRIPTION
C1, C2, C5, C6	4	4.7µF, 50V X7R ceramic capacitors Murata GRM32ER71H475KA88L
C3, C4, C7	3	0.1µF, 50V X7R SMD ceramic capacitors Murata GRM188R71H104KA93D or TDK C1608X7R1H104K
C8	1	470pF, 50V X7R ceramic capacitor Murata GRM188R71H471KA01D or TDK C1608X7R1H471K
C9	1	1nF, 50V X7R ceramic capacitor Murata GRM188R71H102KA01D or TDK C1608X7R1H102K
D1	1	22V, 1.5W zener diode Vishay SMZG3797B
D2	1	60V, 1A Schottky diode Central Semiconductor CMSH1-60M or Diodes Inc. B160
D3	1	20V, small-signal Schottky diode Vishay SD103CWS or Diodes Inc. SD103CWS
J1, J2	2	0.1in, 2-pin hole headers (through hole)

DESIGNATION	QTY	DESCRIPTION
L1	1	4.7µH, 4.2A peak SMD inductor Coilcraft DO3308P-472ML
Q1	1	60V, 3.2A n-channel MOSFET Vishay Si3458DV
R1	1	392kΩ ±1%, 1/8W resistor (0603)
R2	1	11kΩ ±1%, 1/8W resistor (0603)
R3	1	499kΩ ±1%, 1/8W resistor (0603)
R4	1	73.2kΩ ±1%, 1/8W resistor (0603)
R5, R7	2	1kΩ ±1%, 1/8W resistors (0603)
R6	1	330Ω ±1%, 1/4W resistor (1206)
R8	1	220Ω ±1%, 1/8W resistor (0603)
R9	1	0.10Ω ±1%, 1/2W resistor (1206) Susumu RL1632R-R100-F
R10	1	1Ω ±5%, 1/8W resistor (0603)
U1	1	MAX16802B (8-pin µMAX)
VIN, VLED, PWM_IN, LIN_IN	4	0.1in, 2-pin male connectors (through hole)
—	1	MAX16802B PC board

MAX16802B Evaluation Kit

Quick Start

The MAX16802B EV kit is fully assembled and tested. Follow these steps to verify operation. **Do not turn on the power supply until all connections are completed.**

1) Connect a DC power supply (0 to 30V or above, 1A) to +VIN and GND.
2) Connect a voltmeter or oscilloscope and the LED array (connected in series to drop about 12V at 750mA forward current) to +VLED and -VLED with anode connected to +VLED and cathode to -VLED.
3) Close the jumpers J1 and J2 to disable dimming.
4) Turn on the power supply and increase the input voltage to above 10.8V. The output voltage increases to forward bias the LED array and delivers approximately 750mA regulated average LED current. Increase the supply further up to 30V and the output average current will be regulated throughout the range.
5) Open shunt J1 and apply a PWM signal to PWM_IN with a frequency of 200Hz and 0 to 2V amplitude. Vary the duty cycle from 0 to 100% and the LED brightness varies from 100% to 0%. When the PWM duty cycle is 0%, the LED brightness is 100%.
6) Close J1, and then open J2. Connect a variable voltage source to LIN_IN and vary the voltage between 0 and 1.6V. The LED brightness varies from 100% to 0%. When the voltage input at LIN_IN is 0V, the LED brightness is 100%.

Caution: Avoid powering up the EV kit without connecting load.

Detailed Description

The MAX16802B evaluation kit is a current-controlled, high-output-current LED driver capable of supplying constant currents up to 750mA, irrespective of supply voltage variations.

This EV kit is based on a discontinuous current mode (DCM) buck-boost converter operating at 262kHz to deliver a finite amount of energy to the output every cycle. The amount of this energy depends primarily on the value of the inductor and the user-programmable peak inductor current and does not depend on the supply voltage. Due to this configuration, the power output of the EV kit, and thus the output current supplied to the LED at a given LED operating voltage, becomes independent of the supply voltage.

This EV kit is designed to drive LED loads capable of taking up to 750mA of maximum current at a 12V operating voltage. If an LED load with lower operating voltage is used, then the maximum output current will increase by the same ratio to maintain the output power constant. To drive an LED array with a different operating voltage, the value of the current-sense resistor needs to be adjusted. Calculation of the current-sense resistor for a different output operating voltage is explained in later sections.

Input Supply UVLO

Input supply UVLO is implemented by using a resistor network that combines R3 and R4, which senses the input supply voltage and uses the EN pin to turn on the circuit when the input supply voltage goes above 10.8V. The wake-up threshold of EN is 1.23V when the voltage at EN is rising, and it has a hysteresis of 50mV. Once the device is turned on, due to the hysteresis, the device turns off only if the input supply voltage goes below 10.4V.

The UVLO threshold can be adjusted by varying R1 or R2 using the equation below:

$$R3 = \left(\frac{V_{UVLO}}{1.23} - 1\right) \times R4$$

where V_{UVLO} is the desired UVLO threshold. To maintain threshold accuracy, keep the value of R4 less than 100kΩ.

Component Suppliers

SUPPLIER	PHONE	FAX	WEBSITE
Central Semiconductor	631-435-1110	631-435-3388	www.centralsemi.com
Coilcraft	847-639-6400	847-639-1469	www.coilcraft.com
Diodes Inc.	805-446-4800	805-446-4850	www.diodes.com
Murata	770-436-1300	770-436-3030	www.murata.com
Susumu Co Ltd.	208-328-0307	208-328-0308	www.susumu-usa.com
TDK	847-390-4373	847-390-4428	www.component.tdk.com
Vishay	402-563-6866	402-563-6296	www.vishay.com

Note: *Indicate you are using the MAX16802B when contacting these manufacturers.*

Output Overvoltage Protection

The maximum voltage at the positive pin of VLED with respect to GND is limited to 45V by a feedback network formed by R1 and R2, which is connected to the FB pin of the MAX16802B. If the EV kit is turned on with no load or if the LED connection opens, the voltage at the positive pin of VLED may rise to unsafe levels. This condition is sensed by the internal error amplifier, which reduces the peak inductor current to limit the voltage at the positive pin of VLED to 45V. Even if this protection is present, it is recommended to connect the specified load before powering up the EV kit.

PWM Dimming

The PWM dimming is for controlling the LED brightness by adjusting the duty cycle of the PWM input signal connected to the PWM_IN input. A HIGH at PWM_IN input turns off the LED current and LOW turns on the LED current. Connect a signal with peak amplitude between 1.5V to 5.0V and with frequency between 100Hz to 1000Hz and vary the duty cycle to adjust the LED brightness. Frequencies lower than 100Hz can introduce flickering in the light output. LED brightness reduces when duty cycle is increased and vice-versa. When the PWM duty cycle is 0%, the LED brightness will be 100%.

Linear Dimming

The linear dimming is for controlling the LED brightness by varying the amplitude of the voltage connected to the LIN_IN input. The voltage at the LIN_IN input modulates the current-sense signal and makes the MOSFET trip at a different current level. This process, in turn, changes the output current and thus controls the LED brightness. Since the LED is continuously on at all brightness levels, flickering effect is not present with linear dimming. Vary the LIN_IN voltage between 0 and 1.6V to adjust LED brightness from 100% to 0%. LED brightness reduces when the voltage at LIN_IN is increased and vice-versa. When the voltage at LIN_IN is 0V the LED brightness is 100%.

Adjusting the Output Power

To change the maximum output power of the EV kit from 12V at 750mA to a different level, adjust the value of the current-sense resistor, R9, using the following equations. Note that the maximum output current of the EV kit is limited to 750mA, the maximum output voltage is limited to 15V, and the maximum output power is limited to 8.25W.

Initially calculate the approximate optimum ON duty cycle required at the minimum input voltage:

$$D_{ON} = \frac{V_{LED} + V_D}{V_{INMIN} + V_{LED} + V_D}$$

where V_{INMIN} is the minimum input supply voltage, V_{LED} is the LED operating voltage, I_{LED} is the desired LED current and V_D is the forward voltage of D2.

Calculate the approximate required peak inductor current:

$$I_P = \frac{k_f \times 2 \times I_{LED}}{1 - D_{ON}}$$

where k_f is a noncritical "fudge factor" set equal to 1.1 for this circuit.

Calculate the approximate required inductor value and choose the closest standard value smaller than the calculated value:

$$L = \frac{D_{ON} \times V_{INMIN}}{f_{SW} \times I_P}$$

where L is the inductance value of inductor L1, and f_{SW} is the switching frequency equal to 262kHz.

Power transferred to the output circuit by the flyback process is:

$$P_{IN} = \frac{1}{2} \times L \times I_P^2 \times f_{SW}$$

Power consumed by the output circuit is:

$$P_{OUT} = V_{LED} \times I_{LED} + V_D \times I_{LED}$$

Conservation of power requires that the above two equations can be equated and solved for a more precise value of the required peak inductor current.

$$I_P = \sqrt{\left(\frac{2 \times (V_{LED} + V_D) \times I_{LED}}{f_{SW} \times L}\right)}$$

Set the value of the current-sense resistor, R9, based on the I_{PEAK} value using the following equation:

$$R9 = \frac{0.292 \times (R8 + R7)}{I_{PEAK} \times R7}$$

where 0.292V is the current-sense trip threshold voltage. R7 and R8 form a voltage-divider, which scales down the voltage across the current-sense resistor before reaching the current-sense pin of the device.

Jumper Selection

Keep jumper J1 closed when PWM dimming is not used. Keep jumper J2 closed when linear dimming is not used.

MAX16802B Evaluation Kit

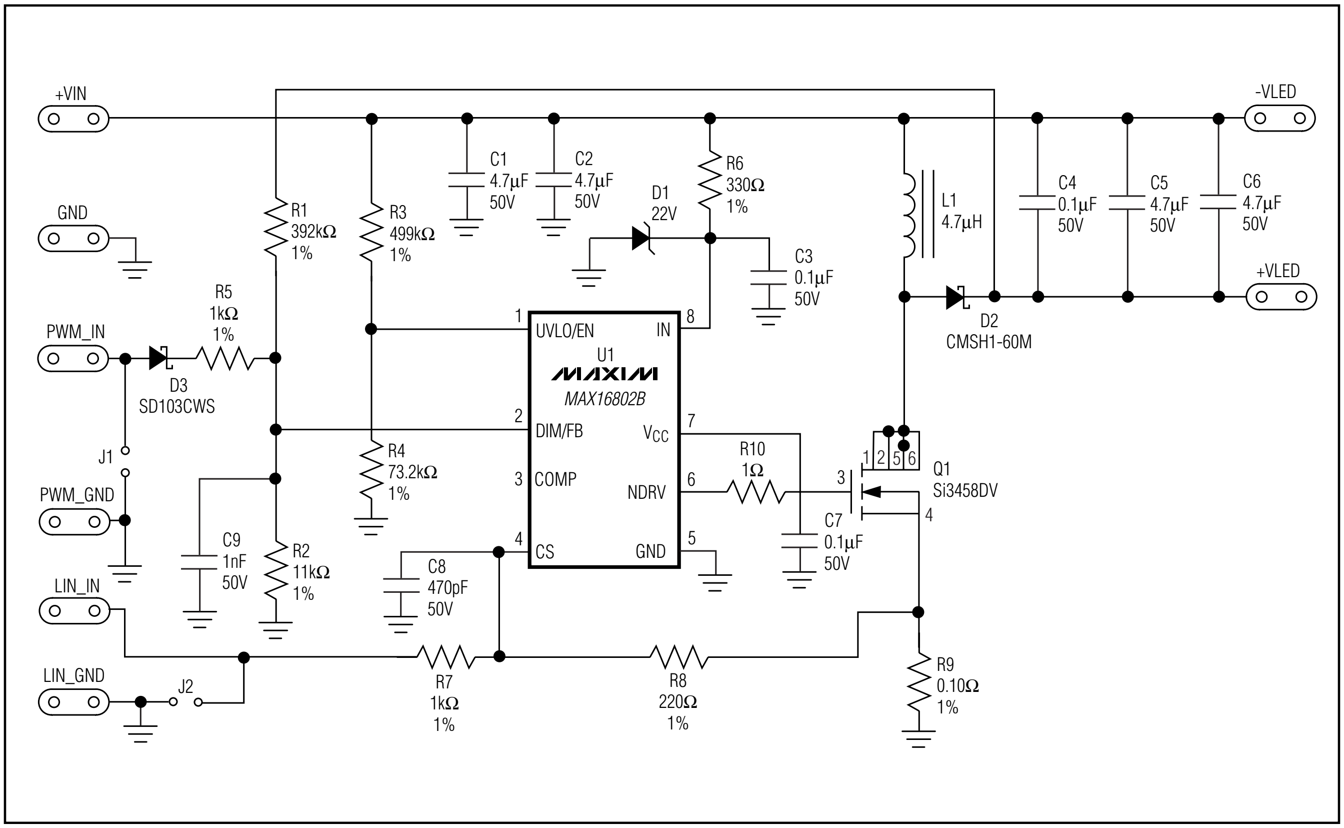


Figure 1. MAX16802B EV Kit Schematic

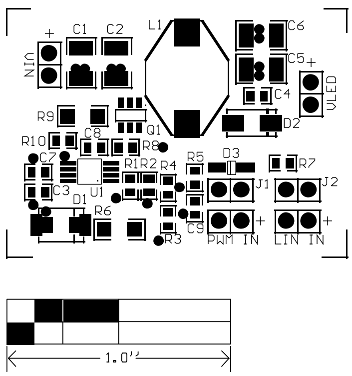


Figure 2. MAX16802B EV Kit Component Placement Guide—Component Side

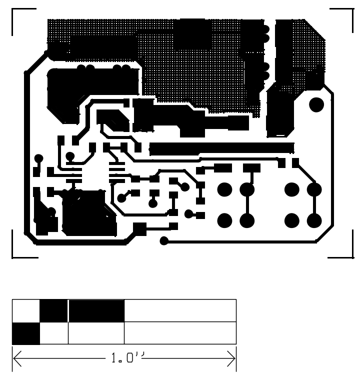


Figure 3. MAX16802B EV Kit PC Board Layout—Component Side

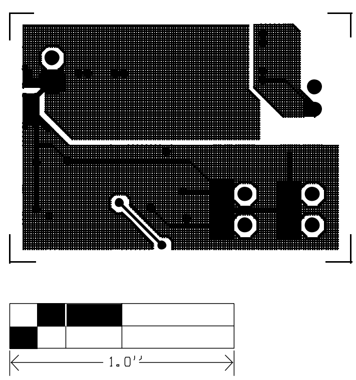


Figure 4. MAX16802B EV Kit PC Board Layout—Solder Side

19-3880; Rev 2; 1/10

EVALUATION KIT AVAILABLE

Offline and DC-DC PWM Controllers for High-Brightness LED Drivers

General Description

The MAX16801A/B/MAX16802A/B high-brightness (HB) LED driver-control ICs contain all the circuitry required for the design of wide-input-voltage-range LED drivers for general lighting and display applications. The MAX16801 is well suited for universal input (rectified 85VAC to 265VAC) LED drivers, while the MAX16802 is intended for low-input-voltage (10.8VDC to 24VDC) LED drivers.

When the LED current needs to be tightly regulated, an additional on-board error amplifier with 1% accurate reference can be utilized. A wide dimming range can be implemented by using low-frequency PWM dimming.

The MAX16801/MAX16802 feature an input undervoltage lockout (UVLO) for programming the input-supply start voltage, and to ensure proper operation during brownout conditions. The MAX16801 has an internal-bootstrap undervoltage lockout circuit with a large hysteresis that simplifies offline LED driver designs. The MAX16802 does not have this internal bootstrap circuit and can be biased directly from a +12V rail.

The 262kHz fixed switching frequency is internally trimmed, allowing for optimization of the magnetic and filter components, resulting in a compact, cost-effective LED driver. The MAX16801A/MAX16802A are offered with 50% maximum duty cycle. The MAX16801B/MAX16802B are offered with 75% maximum duty cycle. These devices are available in an 8-pin µMAX® package and operate over the -40°C to +85°C temperature range.

Applications

- Offline and DC-DC LED Drivers
- RGB Back Light for LCD TVs and Monitors
- Commercial and Industrial Lighting
- Decorative and Architectural Lighting

Features

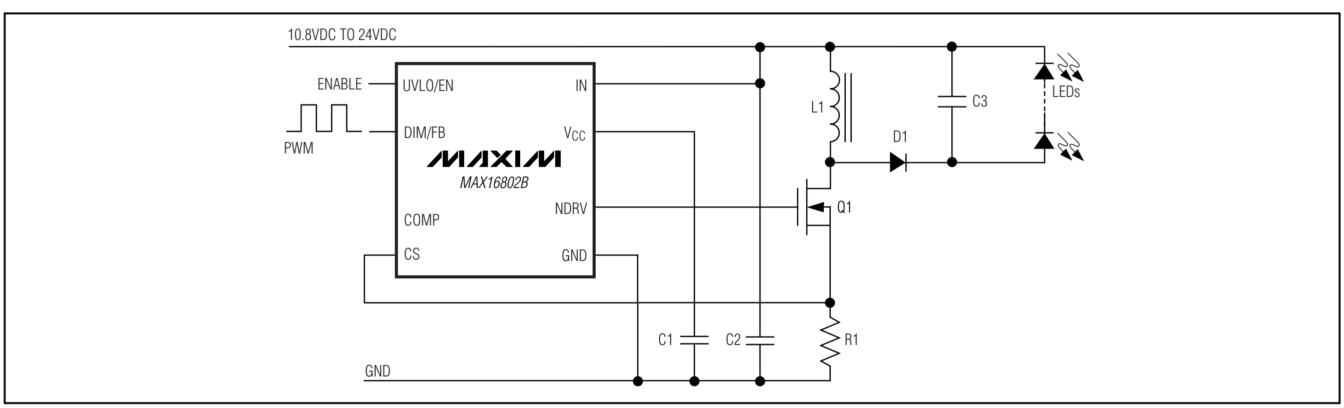
- ♦ **Suitable for Buck, Boost, Flyback, SEPIC, and Other Topologies**
- ♦ **Up to 50W or Higher Output Power**
- ♦ **Universal Offline Input Voltage Range: Rectified 85VAC to 265VAC (MAX16801)**
- ♦ **IN Pin Directly Driven From 10.8VDC to 24VDC Input (MAX16802)**
- ♦ **Internal Error Amplifier with 1% Accurate Reference for Precise LED Current Regulation**
- ♦ **PWM or Linear Dimming**
- ♦ **Fixed Switching Frequency of 262kHz ±12%**
- ♦ **Thermal Shutdown**
- ♦ **Digital Soft-Start**
- ♦ **Programmable Input Startup Voltage**
- ♦ **Internal Bootstrap UVLO with Large Hysteresis (MAX16801)**
- ♦ **45µA (typ) Startup Supply Current, 1.4mA (typ) Operating Supply Current**
- ♦ **50% (MAX16801A/MAX16802A) or 75% (MAX16801B/MAX16802B) Maximum Duty Cycle**
- ♦ **Available in a Tiny 8-Pin µMAX Package**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX16801AEUA+	-40°C to +85°C	8 µMAX
MAX16801BEUA+	-40°C to +85°C	8 µMAX
MAX16802AEUA+	-40°C to +85°C	8 µMAX
MAX16802BEUA+	-40°C to +85°C	8 µMAX

+Denotes lead-free package.

Typical Operating Circuit



Warning: *The MAX16801/MAX16802 are designed to work with high voltages. Exercise caution.*

Offline and DC-DC PWM Controllers for High-Brightness LED Drivers

ABSOLUTE MAXIMUM RATINGS

IN to GND..-0.3V to +30V
V_{CC} to GND..-0.3V to +13V
DIM/FB, COMP, UVLO, CS to GND..........................-0.3V to +6V
NDRV to GND..-0.3V to (V_{CC} + 0.3V)
Continuous Power Dissipation (T_A = +70°C)
8-Pin μMAX (derate 4.5mW/°C above +70°C).............362mW
Operating Temperature Range ....-40°C to +85°C
Storage Temperature Range ....-65°C to +150°C
Junction Temperature...+150°C
Lead Temperature (soldering, 10s) ....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{IN} = +12V (MAX16801: V_{IN} must first be brought up to +23.6V for startup), 10nF bypass capacitors at IN and V_{CC}, C_{NDRV} = 0μF, V_{UVLO} = +1.4V, $V_{DIM/FB}$ = +1.0V, COMP = unconnected, V_{CS} = 0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
UNDERVOLTAGE LOCKOUT/STARTUP						
Bootstrap UVLO Wake-Up Level	V_{SUVR}	V_{IN} rising (MAX16801 only)	19.68	21.6	23.60	V
Bootstrap UVLO Shutdown Level	V_{SUVF}	V_{IN} falling (MAX16801 only)	9.05	9.74	10.43	V
UVLO/EN Wake-Up Threshold	V_{ULR2}	UVLO/EN rising	1.188	1.28	1.371	V
UVLO/EN Shutdown Threshold	V_{ULF2}	UVLO/EN falling	1.168	1.23	1.291	V
UVLO/EN Input Current	I_{UVLO}	T_J = +125°C		25		nA
UVLO/EN Hysteresis				50		mV
IN Supply Current In Undervoltage Lockout	I_{START}	V_{IN} = +19V, for MAX16801 only when in bootstrap UVLO		45	90	μA
IN Voltage Range	V_{IN}		10.8		24	V
UVLO/EN Propagation Delay	t_{EXTR}	UVLO/EN steps up from +1.1V to +1.4V		12		μs
	t_{EXTF}	UVLO/EN steps down from +1.4V to +1.1V		1.8		
Bootstrap UVLO Propagation Delay	t_{BUVR}	V_{IN} steps up from +9V to +24V		5		μs
	t_{BUVF}	V_{IN} steps down from +24V to +9V		1		
INTERNAL SUPPLY						
V_{CC} Regulator Set Point	V_{CCSP}	V_{IN} = +10.8V to +24V, sinking 1μA to 20mA from V_{CC}	7		10.5	V
IN Supply Current After Startup	I_{IN}	V_{IN} = +24V		1.4	2.5	mA
Shutdown Supply Current		UVLO/EN = low			90	μA
GATE DRIVER						
Driver Output Impedance	$R_{ON(LOW)}$	Measured at NDRV sinking, 100mA		2	4	Ω
	$R_{ON(HIGH)}$	Measured at NDRV sourcing, 20mA		4	12	
Driver Peak Sink Current				1		A
Driver Peak Source Current				0.65		A
PWM COMPARATOR						
Comparator Offset Voltage	VO_{PWM}	V_{COMP} - V_{CS}	1.15	1.38	1.70	V
CS Input Bias Current	I_{CS}	V_{CS} = 0V	-2		+2	μA
Comparator Propagation Delay	t_{PWM}	V_{CS} = +0.1V		60		ns
Minimum On-Time	$t_{ON(MIN)}$			150		ns

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = +12V (MAX16801: V_{IN} must first be brought up to +23.6V for startup), 10nF bypass capacitors at IN and V_{CC}, C_{NDRV} = 0µF, V_{UVLO} = +1.4V, $V_{DIM/FB}$ = +1.0V, COMP = unconnected, V_{CS} = 0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CURRENT-SENSE COMPARATOR						
Current-Sense Trip Threshold	V_{CS}		262	291	320	mV
CS Input Bias Current	I_{CS}	V_{CS} = 0V	-2		+2	µA
Propagation Delay From Comparator Input to NDRV	t_{PWM}	50mV overdrive		60		ns
Switching Frequency	f_{SW}		230	262	290	kHz
Maximum Duty Cycle	D_{MAX}	MAX1680_A		50	50.5	%
		MAX1680_B		75	76	
IN CLAMP VOLTAGE						
IN Clamp Voltage	V_{INC}	2mA sink current, MAX16801 only (Note 3)	24.1	26.1	29.0	V
ERROR AMPLIFIER						
Voltage Gain		R_{LOAD} = 100kΩ		80		dB
Unity-Gain Bandwidth		R_{LOAD} = 100kΩ, C_{LOAD} = 200pF		2		MHz
Phase Margin		R_{LOAD} = 100kΩ, C_{LOAD} = 200pF		65		Degrees
DIM/FB Input Offset Voltage					3	mV
COMP Clamp Voltage		High	2.2		3.5	V
		Low	0.4		1.1	
Source Current			0.5			mA
Sink Current			0.5			mA
Reference Voltage	V_{REF}	(Note 2)	1.218	1.230	1.242	V
Input Bias Current					50	nA
COMP Short-Circuit Current				8		mA
THERMAL SHUTDOWN						
Thermal-Shutdown Temperature				130		°C
Thermal Hysteresis				25		°C
DIGITAL SOFT-START						
Soft-Start Duration				15,872		Clock cycles
Reference Voltage Steps During Soft-Start				31		Steps
Reference Voltage Step				40		mV

Note 1: All devices are 100% tested at T_A = +85°C. All limits over temperature are guaranteed by characterization.

Note 2: V_{REF} is measured with DIM/FB connected to the COMP pin (see the *Functional Diagram*).

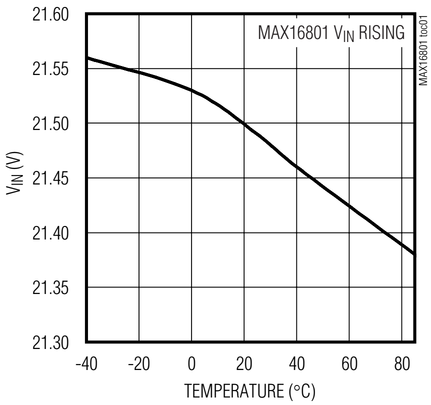
Note 3: The MAX16801 is intended for use in universal input offline drivers. The internal clamp circuit is used to prevent the bootstrap capacitor (C1 in Figure 5) from charging to a voltage beyond the absolute maximum rating of the device when EN/UVLO is low. The maximum current to IN (hence to clamp) when UVLO is low (device in shutdown), must be externally limited to 2mA (max). Clamp currents higher than 2mA may result in clamp voltage higher than +30V, thus exceeding the absolute maximum rating for IN. For the MAX16802, do not exceed the +24V maximum operating voltage of the device.

Offline and DC-DC PWM Controllers for High-Brightness LED Drivers

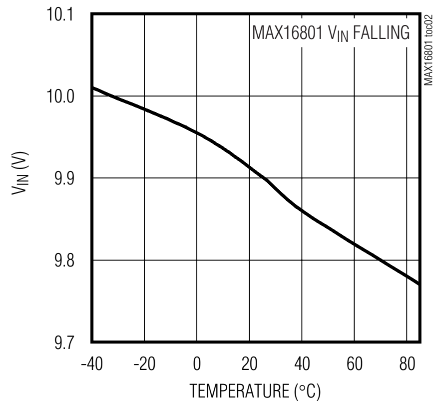
Typical Operating Characteristics

($V_{UVLO/EN}$ = +1.4V, V_{FB} = +1V, COMP = unconnected, V_{CS} = 0V, T_A = +25°C, unless otherwise noted.)

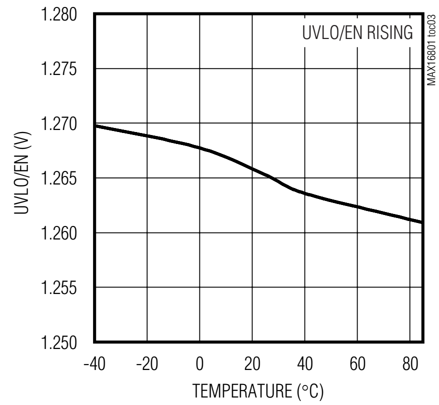
BOOTSTRAP UVLO WAKE-UP LEVEL vs. TEMPERATURE



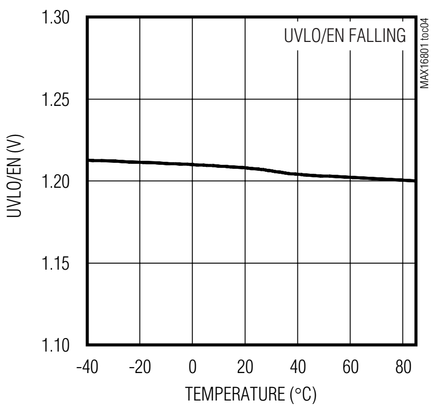
BOOTSTRAP UVLO SHUTDOWN LEVEL vs. TEMPERATURE



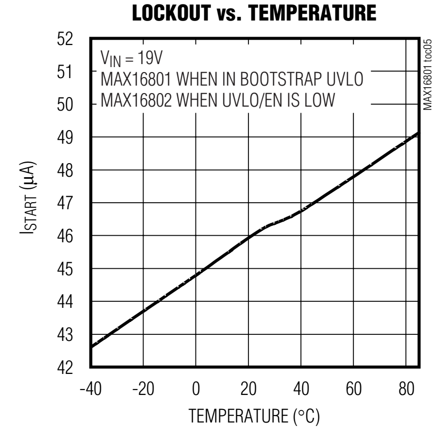
UVLO/EN WAKE-UP THRESHOLD vs. TEMPERATURE



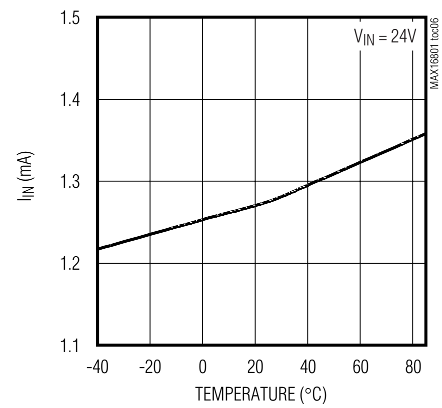
UVLO/EN SHUTDOWN THRESHOLD vs. TEMPERATURE



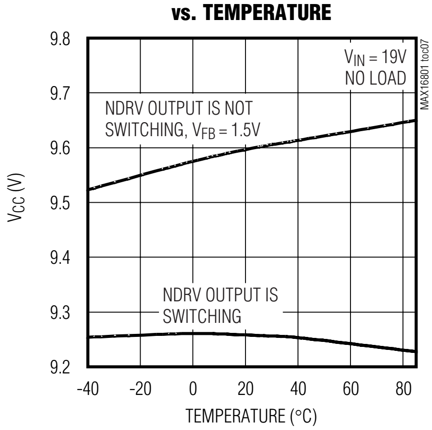
V_{IN} SUPPLY CURRENT IN UNDERVOLTAGE LOCKOUT vs. TEMPERATURE



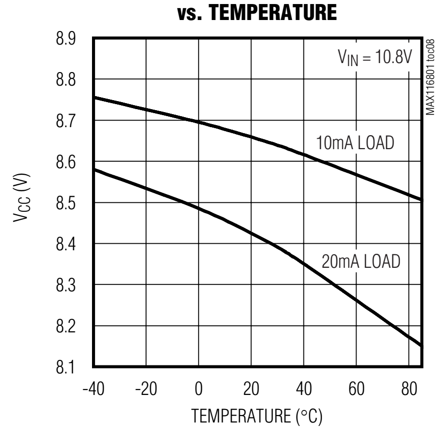
V_{IN} SUPPLY CURRENT AFTER STARTUP vs. TEMPERATURE



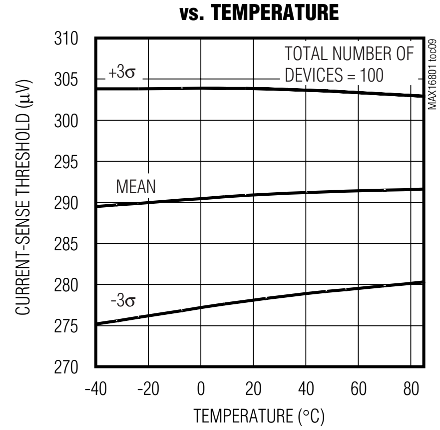
V_{CC} REGULATOR SET POINT vs. TEMPERATURE



V_{CC} REGULATOR SET POINT vs. TEMPERATURE



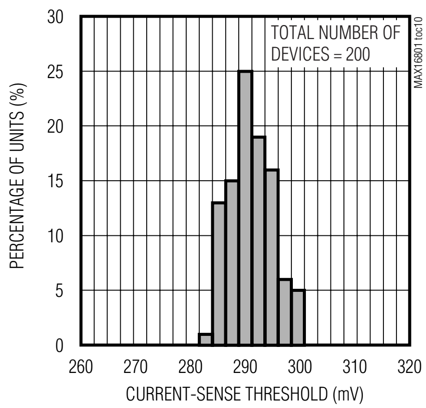
CURRENT-SENSE THRESHOLD vs. TEMPERATURE



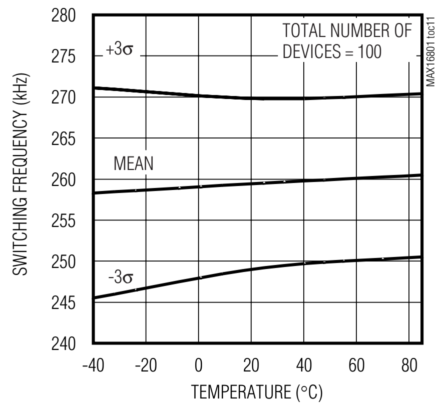
Typical Operating Characteristics (continued)

($V_{UVLO/EN}$ = +1.4V, V_{FB} = +1V, COMP = unconnected, V_{CS} = 0V, T_A = +25°C, unless otherwise noted.)

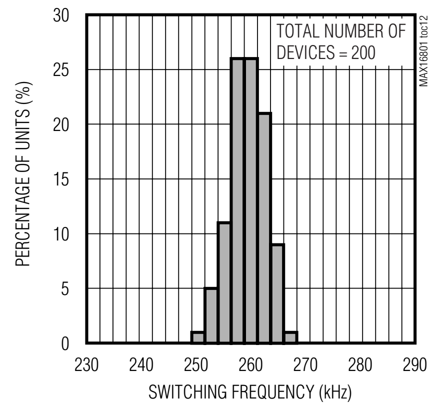
CURRENT-SENSE THRESHOLD



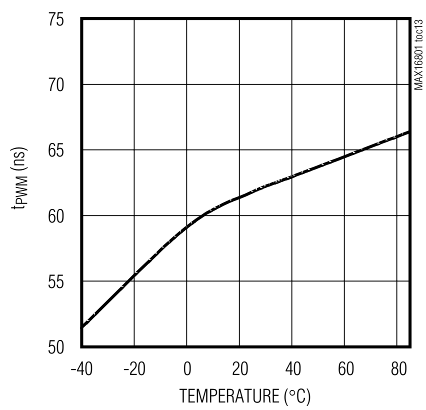
SWITCHING FREQUENCY vs. TEMPERATURE



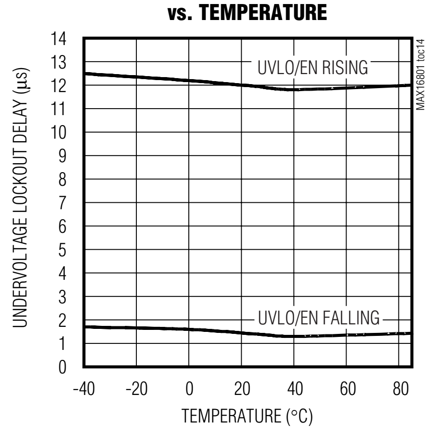
SWITCHING FREQUENCY



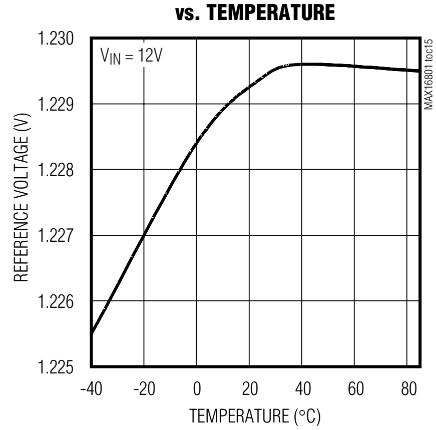
PROPAGATION DELAY FROM CURRENT-SENSE COMPARATOR INPUT TO NDRV vs. TEMPERATURE



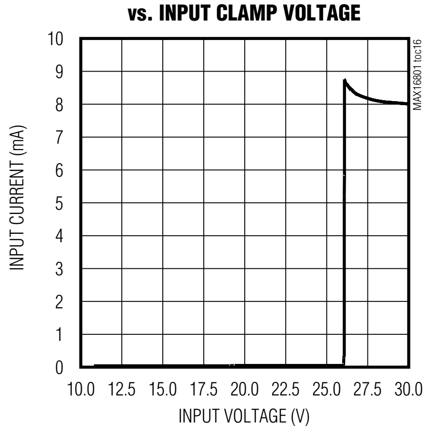
UVLO/EN PROPAGATION DELAY vs. TEMPERATURE



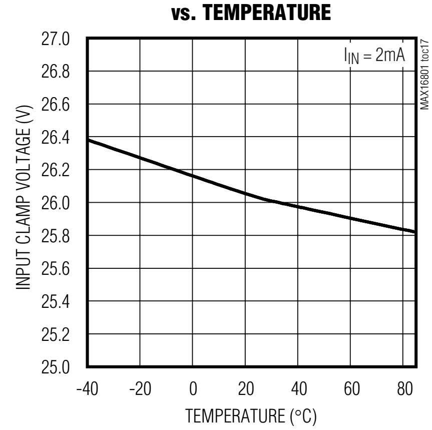
REFERENCE VOLTAGE vs. TEMPERATURE



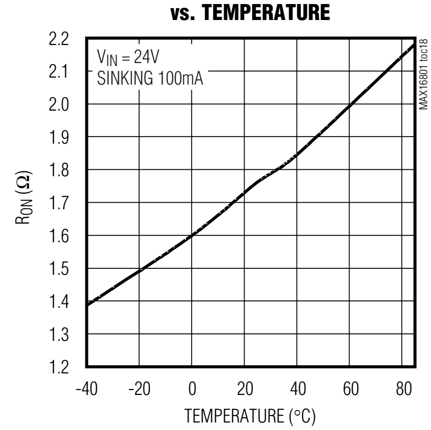
INPUT CURRENT vs. INPUT CLAMP VOLTAGE



INPUT CLAMP VOLTAGE vs. TEMPERATURE

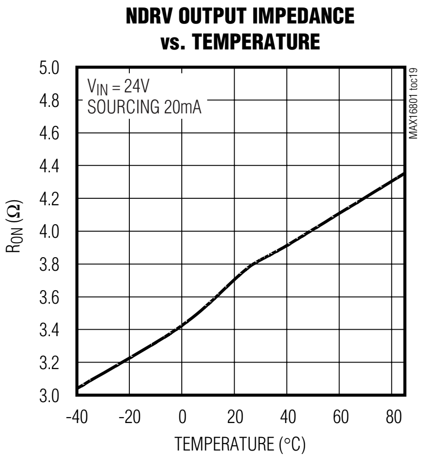


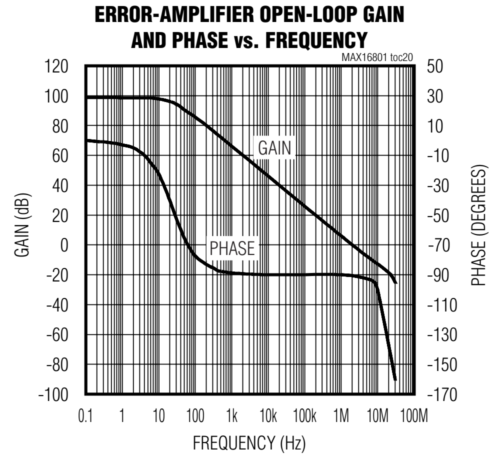
NDRV OUTPUT IMPEDANCE vs. TEMPERATURE



Typical Operating Characteristics (continued)

($V_{UVLO/EN}$ = +1.4V, V_{FB} = +1V, COMP = unconnected, V_{CS} = 0V, T_A = +25°C, unless otherwise noted.)





Pin Description

PIN	NAME	FUNCTION
1	UVLO/EN	Externally Programmable Undervoltage Lockout. UVLO programs the input start voltage. Connect UVLO to GND to disable the device.
2	DIM/FB	Low-Frequency PWM Dimming Input/Error-Amplifier Inverting Input
3	COMP	Error-Amplifier Output. Connect the compensation components between DIM/FB and COMP in high-accuracy LED current regulation.
4	CS	Current-Sense Connection for Current Regulation. Connect to high side of sense resistor. An RC filter may be necessary to eliminate leading-edge spikes.
5	GND	Power-Supply Ground
6	NDRV	External n-Channel MOSFET Gate Connection
7	V_{CC}	Gate-Drive Supply. Internally regulated down from IN. Decouple with a 10nF or larger capacitor to GND.
8	IN	IC Supply. Decouple with a 10nF or larger capacitor to GND. For bootstrapped operation (MAX16801), connect a startup resistor from the input supply line to IN. Connect the bias winding supply to this point (see Figure 5). For the MAX16802, connect IN directly to a +10.8V to +24V supply.

Detailed Description

The MAX16801/MAX16802 family of devices is intended for constant current drive of high-brightness (HB) LEDs used in general lighting and display applications. They are specifically designed for use in isolated and nonisolated circuit topologies such as buck, boost, flyback, and SEPIC, operating in continuous or discontinuous mode. Current mode control is implemented with an internally trimmed, fixed 262kHz switching frequency. A bootstrap UVLO with a large hysteresis (11.9V), very low startup current, and low operating current result in an efficient universal-input LED driver. In addition to the internal bootstrap UVLO, these devices also offer programmable input startup voltage programmed through the UVLO/EN pin. The MAX16801 is well suited for universal AC input (rectified 85VAC to 265VAC) drivers. The MAX16802 is well suited for low input voltage (10.8VDC to 24VDC) applications.

The MAX16801/MAX16802 regulate the LED current by monitoring current through the external MOSFET cycle by cycle.

When in the bootstrapped mode with a transformer (Figure 5), the circuit is protected against most output short-circuit faults when the tertiary voltage drops below +10V, causing the UVLO to turn off the gate drive of the external MOSFET. This re-initiates a startup sequence with soft-start.

When the LED current needs to be tightly regulated, an internal error amplifier with 1% accurate reference can be used (Figure 9). This additional feedback minimizes the impact of passive circuit component variations and tolerances, and can be implemented with a minimum number of additional external components.

A wide dimming range can be implemented using a low-frequency PWM dimming signal fed directly to the DIM/FB pin.

LED driver circuits designed with the MAX16801 use a high-value startup resistor R1 that charges a reservoir capacitor C1 (Figure 5 or Figure 9). During this initial period, while the voltage is less than the internal bootstrap UVLO threshold, the device typically consumes only 45µA of quiescent current. This low startup current and the large bootstrap UVLO hysteresis help minimize the power dissipation across R1, even at the high end of the universal AC input voltage.

An internal shutdown circuit protects the device whenever the junction temperature exceeds +130°C (typ).

Dimming

Linear dimming can be implemented by creating a summing node at CS, as shown in Figures 6 and 7.

Low-frequency PWM (chopped-current) dimming is possible by applying an inverted-logic PWM signal to the DIM/FB pin of the IC (Figure 8). This might be a preferred way of dimming in situations where it is critical to retain the light spectrum unchanged. It is accomplished by keeping constant the amplitude of the chopped LED current.

MAX16801/MAX16802 Biasing

Implement bootstrapping from the transformer when it is present (Figure 5). Biasing can also be realized directly from the LEDs in non-isolated topologies (Figure 1).

Bias the MAX16802 directly from the input voltage of 10.8VDC to 24VDC. The MAX16802 can also be used

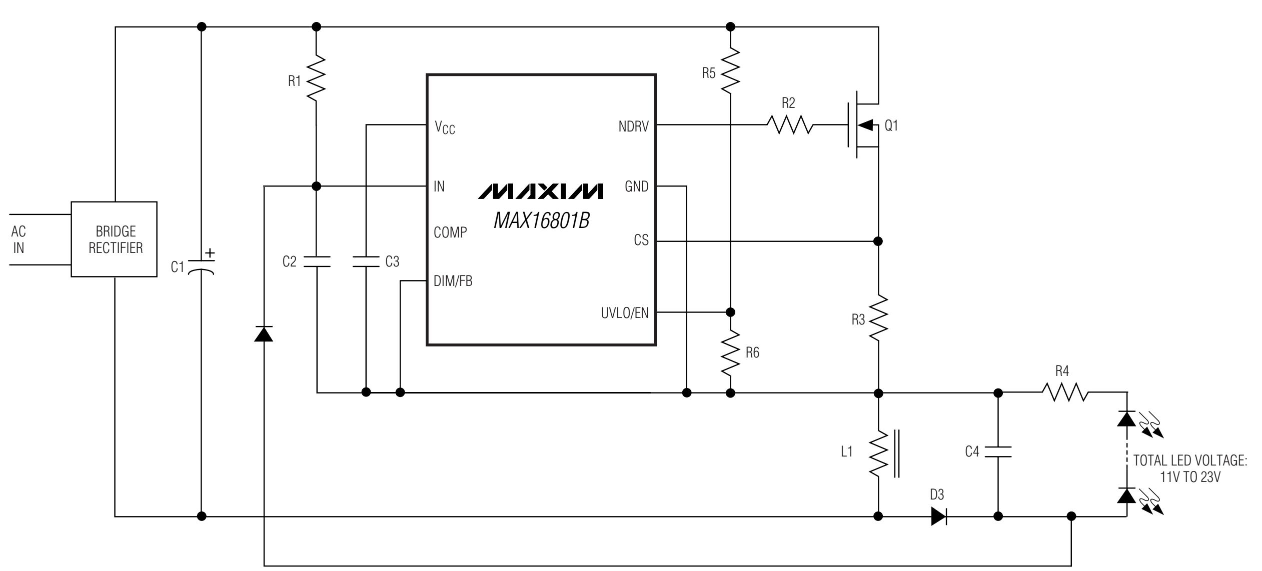


Figure 1. Biasing the IC using LEDs in Nonisolated Flyback Driver

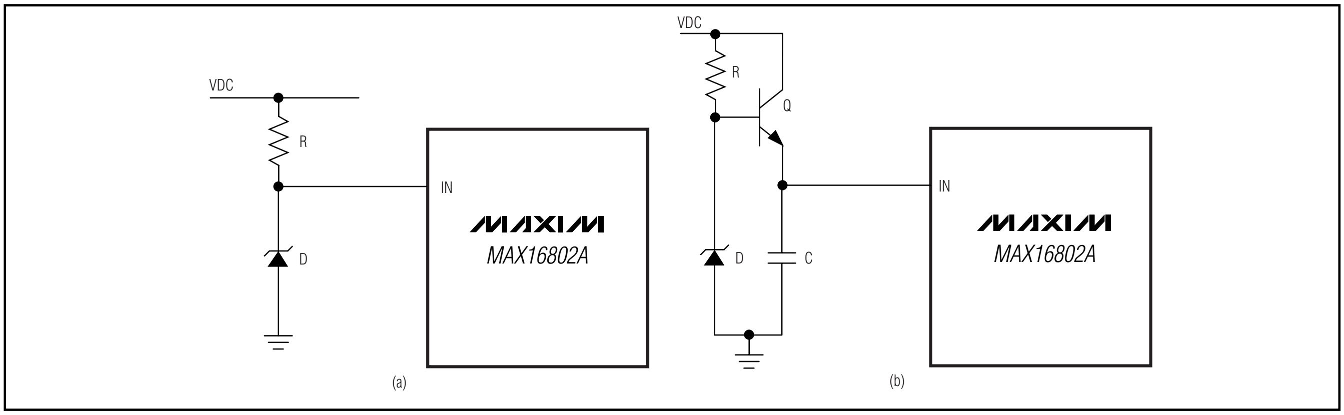


Figure 2. (a) Resistor-Zener and (b) Transistor-Zener-Resistor Bias Arrangements

in applications with higher input DC voltages by implementing resistor-Zener bias (Figure 2a) or transistor-Zener-resistor bias (Figure 2b).

MAX16801/MAX16802 Undervoltage Lockout

The MAX16801/MAX16802 have an input voltage UVLO/EN pin. The threshold of this UVLO is +1.28V. Before any operation can commence, the voltage on this pin has to exceed +1.28V. The UVLO circuit keeps the CPWM comparator, ILIM comparator, oscillator, and output driver in shutdown to reduce current consumption (see the *Functional Diagram*). Use this UVLO function to program the input start voltage. Calculate the divider resistor values, R2 and R3 (Figure 5), by using the following formulas:

$$R3 \cong \frac{V_{ULR2} \times V_{IN}}{500 \times I_{UVLO}\left(V_{IN} - V_{ULR2}\right)}$$

The value of R3 is calculated to minimize the voltage-drop error across R2 as a result of the input bias current of the UVLO/EN pin. V_{ULR2} = +1.28V, I_{UVLO} = 50nA (max), V_{IN} is the value of the input-supply voltage where the power supply must start.

$$R2 = \frac{V_{IN} - V_{ULR2}}{V_{ULR2}} \times R3$$

where I_{UVLO} is the UVLO/EN pin input current, and V_{ULR2} is the UVLO/EN wake-up threshold.

MAX16801 Bootstrap Undervoltage Lockout

In addition to the externally programmable UVLO function offered in both the MAX16801/MAX16802, the MAX16801 has an additional internal bootstrap UVLO that is very useful when designing high-voltage LED drivers (see the *Functional Diagram*). This allows the device to bootstrap itself during initial power-up. The MAX16801 attempts to start when V_{IN} exceeds the bootstrap UVLO threshold of +23.6V. During startup, the UVLO circuit keeps the CPWM comparator, ILIM comparator, oscillator, and output driver shut down to reduce current consumption. Once V_{IN} reaches +23.6V, the UVLO circuit turns on both the CPWM and ILIM comparators, as well as the oscillator, and allows the output driver to switch. If V_{IN} drops below +9.7V, the UVLO circuit will shut down the CPWM comparator, ILIM comparator, oscillator, and output driver thereby returning the MAX16801 to the startup mode.

MAX16801 Startup Operation

In isolated LED driver applications, V_{IN} can be derived from a tertiary winding of a transformer. However, at startup there is no energy delivered through the transformer. Therefore, a special bootstrap sequence is required. Figure 3 shows the voltages on IN and V_{CC} during startup. Initially, both V_{IN} and V_{CC} are 0V. After the line voltage is applied, C1 charges through the startup resistor R1 to an intermediate voltage. At this point, the internal regulator begins charging C2 (see Figure 5). The MAX16801 uses only 45µA of the current supplied by R1, and the remaining input current charges C1 and C2. The charging of C2 stops when the V_{CC} voltage reaches approximately +9.5V, while the voltage across C1 continues rising until it reaches

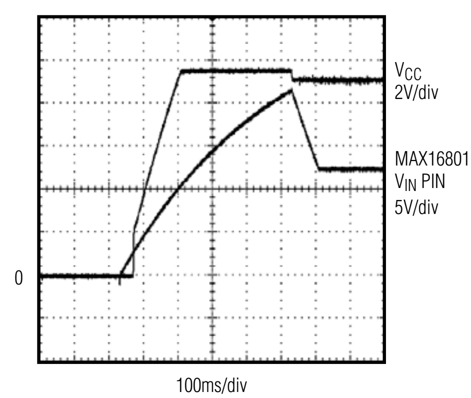


Figure 3. V_{IN} and V_{CC} During Startup when Using the MAX16801 in Bootstrapped Mode

the wake-up level of +23.6V. Once V_{IN} exceeds the bootstrap UVLO threshold, NDRV begins switching the MOSFET and transfers energy to the secondary and tertiary outputs. If the voltage on the tertiary output builds to a value higher than +9.7V (the bootstrap UVLO lower threshold), then startup has been accomplished and sustained operation commences.

If V_{IN} drops below +9.7V before startup is complete, the device goes back to low-current UVLO. In this case, increase C1 in order to store enough energy to allow for the voltage at the tertiary winding to build up.

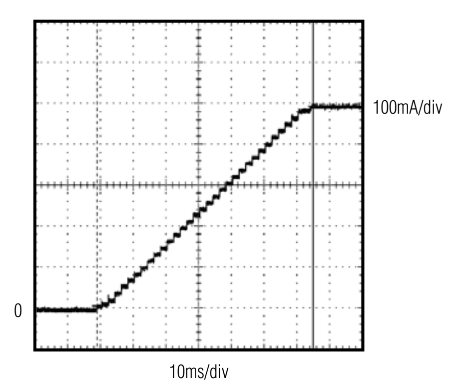


Figure 4. Typical Current Soft-Start During Initial Startup

Soft-Start

The MAX16801/MAX16802 soft-start feature allows the LED current to ramp up in a controlled manner. Soft-start begins after UVLO deasserts. The voltage applied to the noninverting node of the amplifier ramps from 0 to +1.23V over a 60ms soft-start timeout period. Figure 4 shows a typical 0.5A output current during startup. Note the staircase increase of the LED current. This is a result of the digital soft-starting technique used. Unlike other devices, the reference voltage to the internal amplifier is soft-started. This method results in superior control of the LED current.

n-Channel MOSFET Switch Driver

The NDRV pin drives an external n-channel MOSFET. The NDRV output is supplied by the internal regulator (V_{CC}), which is internally set to approximately +9.5V. For the universal input voltage and applications with a transformer, the MOSFET used must be able to withstand the DC level of the high-line input voltage plus the reflected voltage at the primary of the transformer. For most offline applications that use the discontinuous flyback topology, this requires a MOSFET rated at 600V. NDRV can source/sink in excess of the 650mA/1000mA peak current. Select a MOSFET that yields acceptable conduction and switching losses.

Internal Error Amplifier

The MAX16801/MAX16802 include an internal error amplifier that can be used to regulate the LED current very accurately. For example, see the nonisolated power supply in Figure 5. Calculate the LED current using the following equation:

$$I_{LED} = \frac{V_{REF}}{R7}$$

where V_{REF} = +1.23V. The amplifier's noninverting input is internally connected to a digital soft-start circuit that gradually increases the reference voltage during startup and is applied to this pin. This forces the LED current to come up in an orderly and well-defined manner under all conditions.

Offline and DC-DC PWM Controllers for High-Brightness LED Drivers

Applications Information

Startup Time Considerations for High-Brightness LED Drivers Using MAX16801

The IN bypass capacitor C1 supplies current immediately after wake-up (Figure 5). The size of C1 and the connection configuration of the tertiary winding determine the number of cycles available for startup. Large values of C1 increase the startup time but also supply gate charge for more cycles during initial startup. If the value of C1 is too small, V_{IN} drops below +9.7V because NDRV does not have enough time to switch and build up sufficient voltage across the tertiary winding that powers the device. The device goes back into UVLO and does not start. Use low-leakage capacitors for C1 and C2.

Assuming that offline LED drivers keep typical startup times to less than 500ms even in low-line conditions (85VAC input for universal offline applications), size the startup resistor R1 to supply both the maximum startup bias of the device (90µA, worst case) and the charging current for C1 and C2. The bypass capacitor C2 must charge to +9.5V and C1 to +24V, all within the desired time period of 500ms.

Because of the internal 60ms soft-start time of the MAX16801, C1 must store enough charge to deliver current to the device for at least this much time. To calculate the approximate amount of capacitance required, use the following formula:

$$I_g = Q_{gtot} \times f_{SW}$$

$$C1 = \frac{(I_{IN} + I_g)(t_{SS})}{V_{HYST}}$$

where I_{IN} is the MAX16801's internal supply current after startup (1.4mA), Q_{gtot} is the total gate charge for Q1, f_{SW} is the MAX16801's switching frequency (262kHz), V_{HYST} is the bootstrap UVLO hysteresis (11.9V) and t_{SS} is the internal soft-start time (60ms).

For example:

$$Ig = (8nC) \times (262kHz) = 2.1mA$$

$$C1 = \frac{(1.4mA + 2.1mA) \times (60ms)}{(12V)} = 17.5\mu F$$

Choose the 15µF standard value.

Assuming C1 > C2, calculate the value of R1 as follows:

$$I_{C1} = \frac{V_{SUVR} \times C1}{(500ms)}$$

$$R1 = \frac{V_{IN(MIN)} - V_{SUVR}}{I_{C1} + I_{START}}$$

where $V_{IN(MIN)}$ is the minimum input supply voltage for the application, V_{SUVR} is the bootstrap UVLO wake-up level (+23.6V, max), and I_{START} is the IN supply current at startup (90µA, max).

For example, for the minimum AC input of 85V:

$$I_{C1} = \frac{(24V) \times (15\mu F)}{(500ms)} = 0.72mA$$

$$R1 = \frac{120V - 24V}{(0.72mA + (90\mu A))} = 119k\Omega$$

Choose the 120kΩ standard value.

Choose a higher value for R1 than the one calculated above if longer startup time can be tolerated in order to minimize power loss on this resistor.

The above startup method is applicable to a circuit similar to the one shown in Figure 5. In this circuit, the tertiary winding has the same phase as the output windings. Thus, the voltage on the tertiary winding at any given time is proportional to the output voltage and goes through the same soft-start period as the output voltage. The minimum discharge voltage of C1 from +22V to +10V must be greater than the soft-start time of 60ms.

Another method of bootstrapping the circuit is to have a separate bias winding than the one used for regulating the output voltage and to connect the bias winding so that it is in phase with the MOSFET ON time (see Figure 9). In this case, the amount of capacitance required is much smaller.

However, in this mode, the input voltage range has to be less than 2:1. Another consideration is whether the bias winding is in phase with the output. If so, the LED driver circuit hiccups and soft-starts under output short-circuit conditions. However, this property is lost if the bias winding is in phase with the MOSFET ON time.

Application Circuits

Figure 5 shows an offline application of an HB LED driver using the MAX16801. The use of transformer T1 allows significant design flexibility. Use the internal error amplifier for a very accurate LED current control.

Figure 6 shows a discontinuous flyback LED driver with linear dimming capability. The total LED voltage can be lower or higher than the input voltage.

Figure 7 shows a continuous-conduction-mode HB LED buck driver with linear dimming and just a few external components.

Figure 8 shows an offline isolated flyback HB LED driver with low-frequency PWM using MAX16801. The PWM signal needs to be inverted (see the *Functional Diagram*). Transformer T1 provides full safety isolation and operation from universal AC line (85VAC to 265VAC).

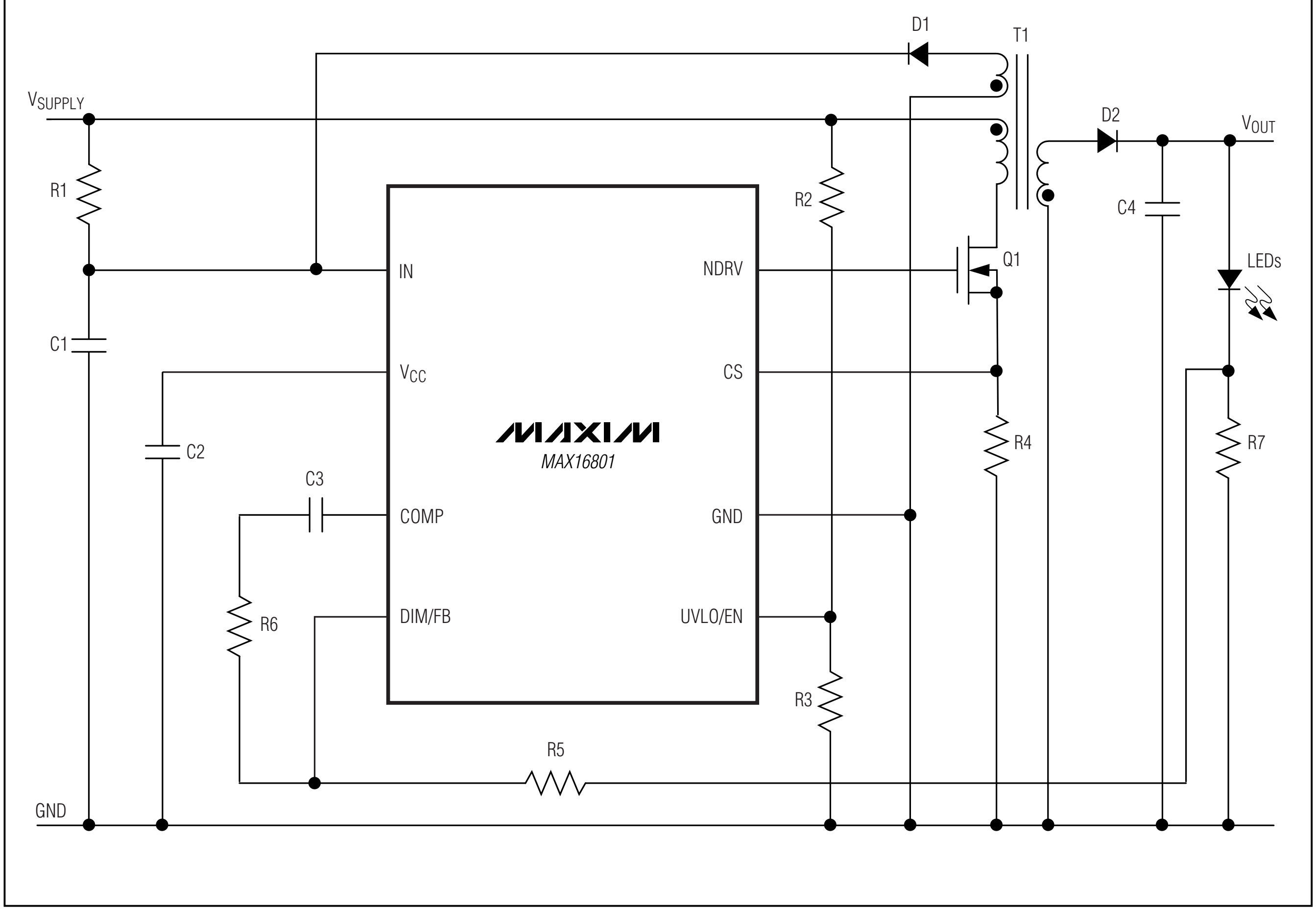


Figure 5. Offline, Nonisolated, Flyback LED Driver with Programmable Input-Supply Start Voltage

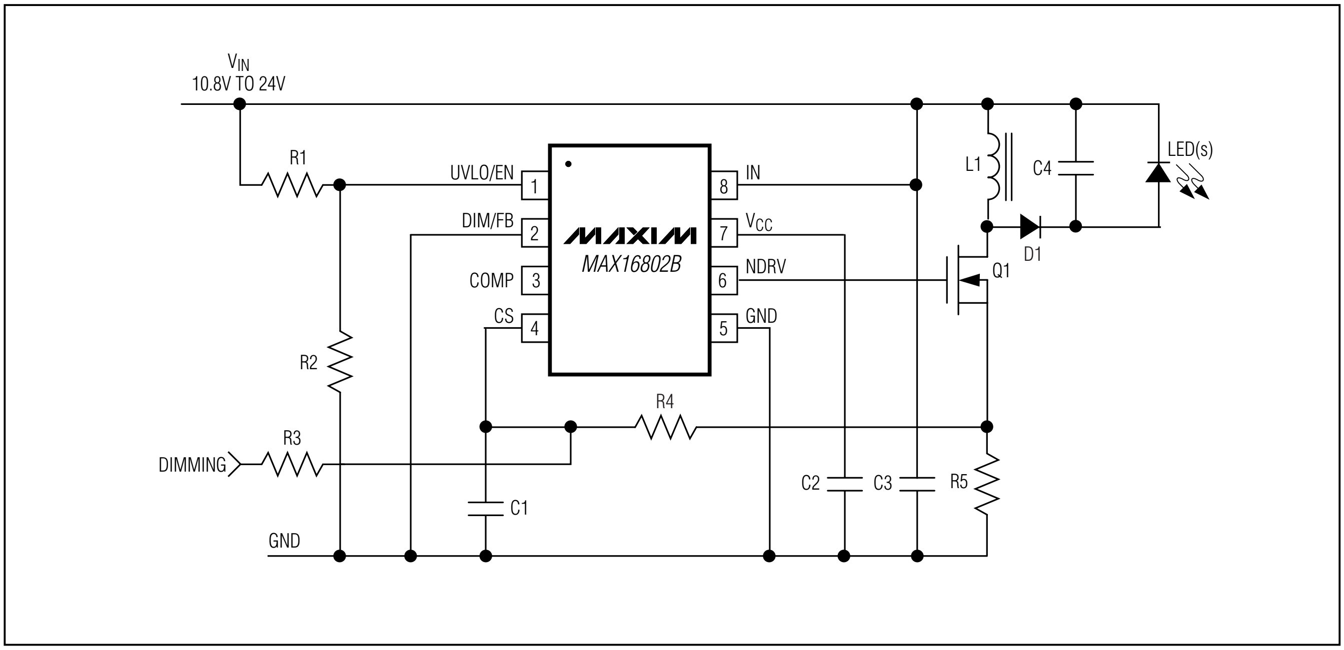


Figure 6. MAX16802 Flyback HB LED Driver with Dimming Capability, 10.8V to 24V Input Voltage Range

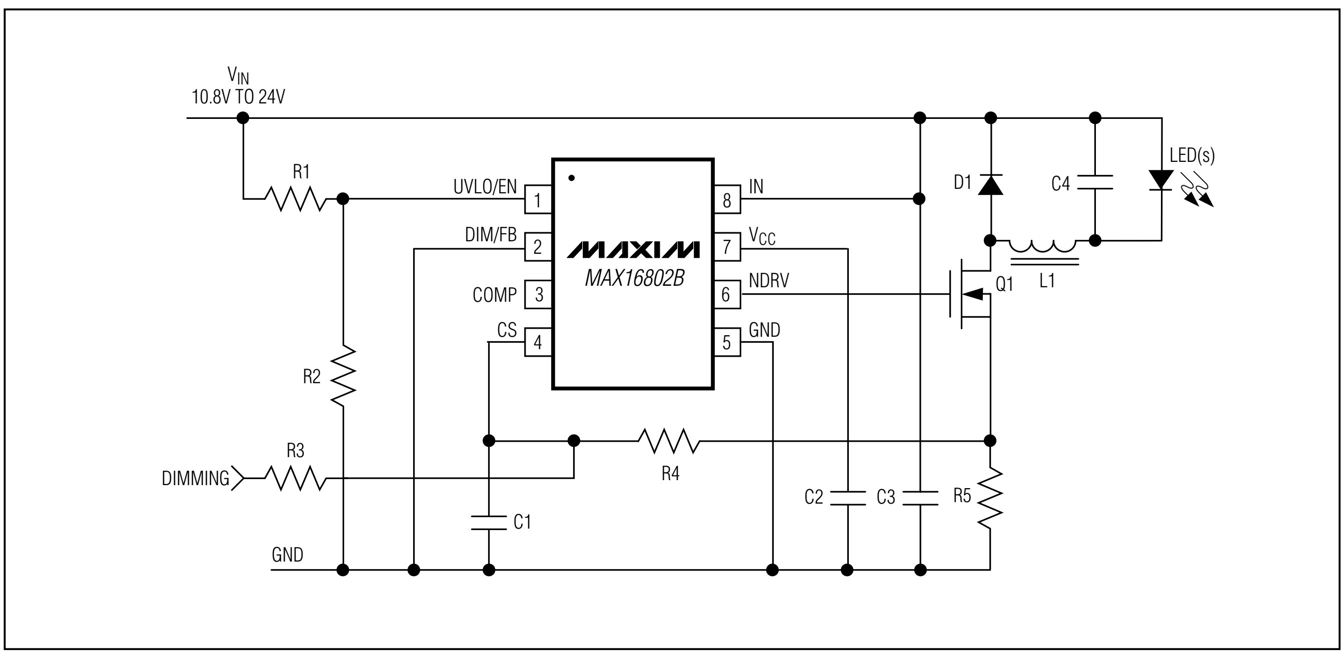


Figure 7. MAX16802 Buck HB LED Driver with Dimming Capability, 10.8V to 24V Input Voltage Range

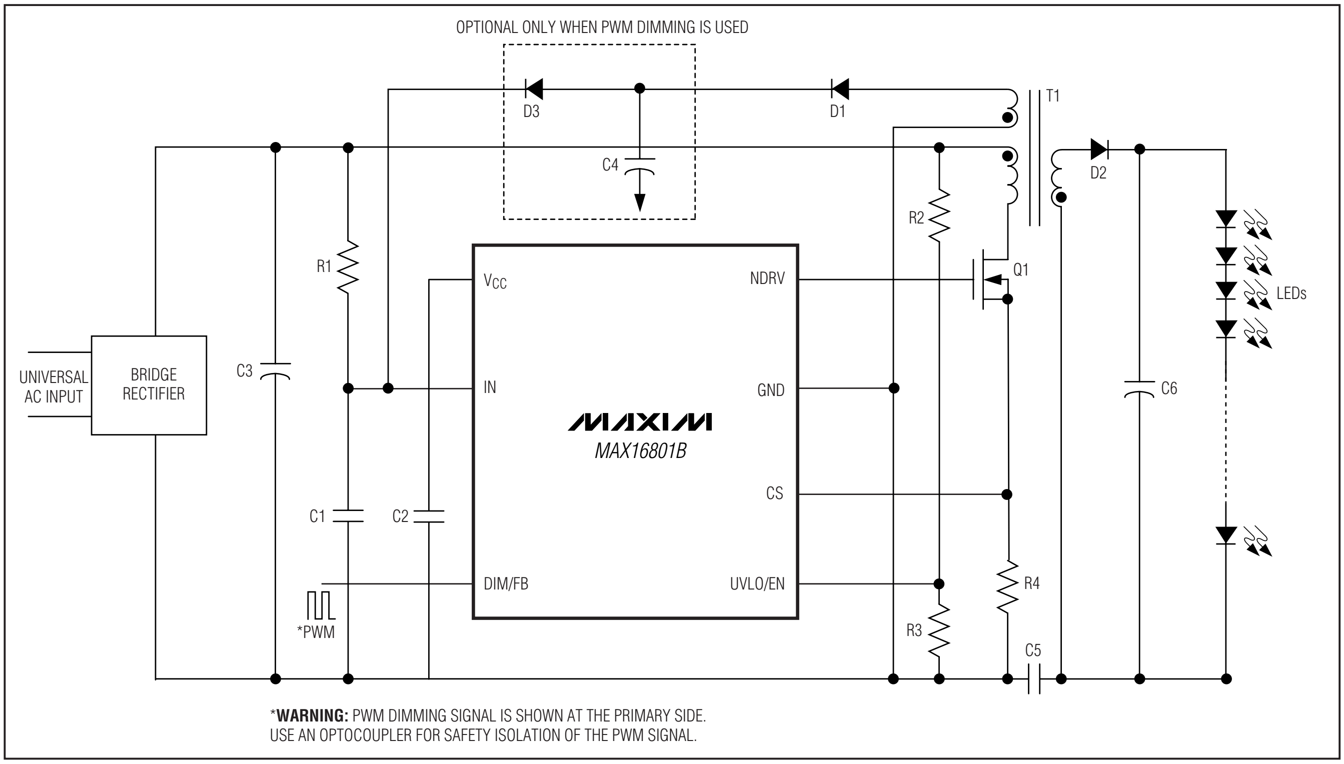


Figure 8. Universal AC Input, Offline, Isolated Flyback HB LED Driver with Low-Frequency PWM Dimming

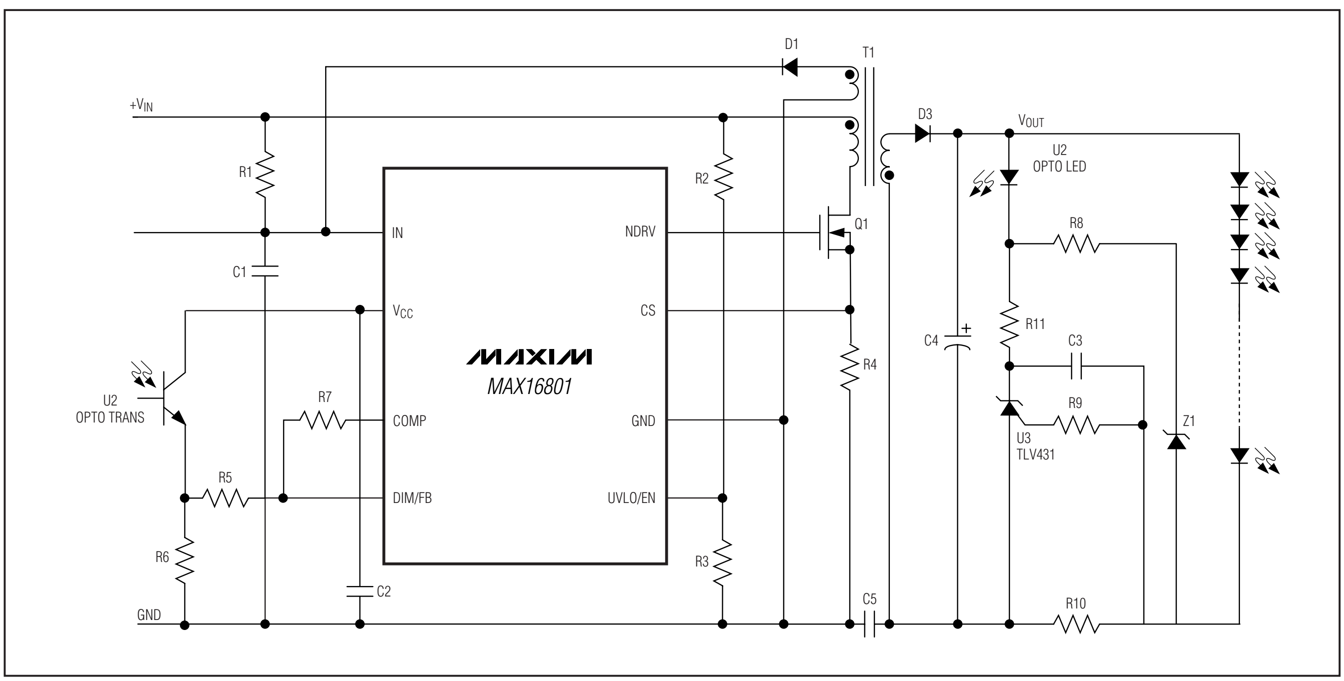
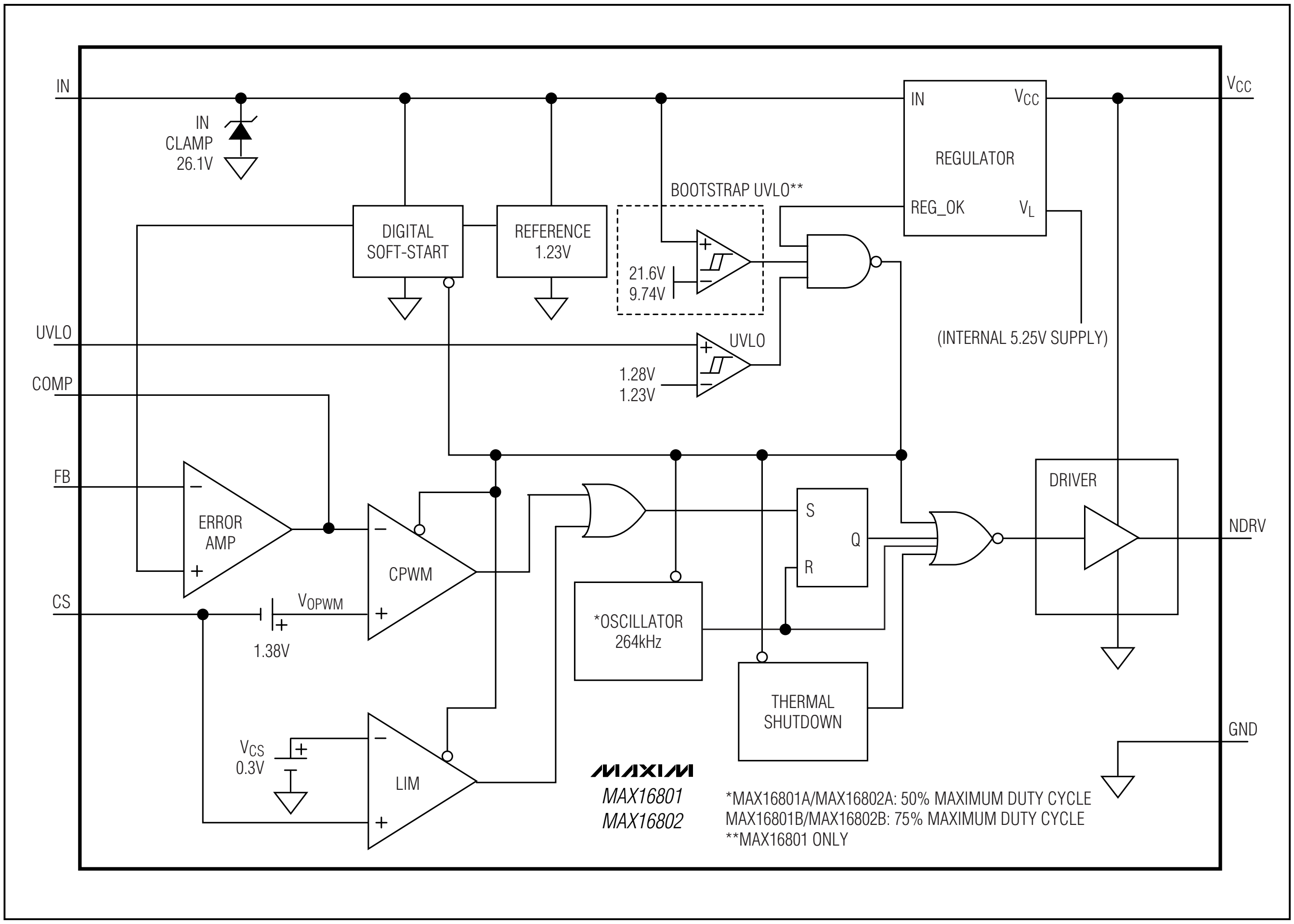


Figure 9. Universal Input, Offline, High-Accuracy Current Regulation in an Isolated Flyback HB LED Driver

Offline and DC-DC PWM Controllers for High-Brightness LED Drivers

Functional Diagram

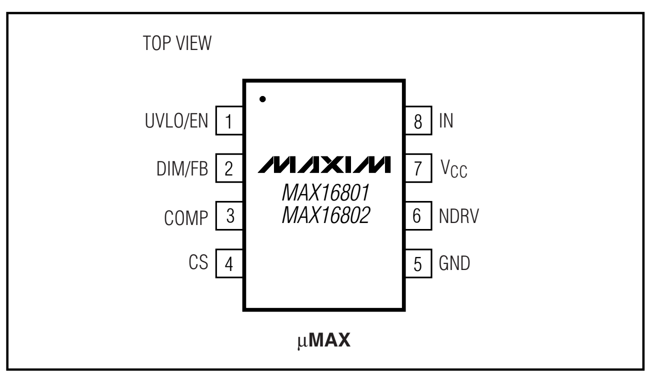


Selector Guide

PART	BOOTSTRAP UVLO	STARTUP VOLTAGE (V)	MAX DUTY CYCLE (%)
MAX16801A	Yes	22	50
MAX16801B	Yes	22	75
MAX16802A	No	10.8*	50
MAX16802B	No	10.8*	75

**The MAX16802 does not have an internal bootstrap UVLO. The MAX16802 starts operation as long as the V_{CC} pin is higher than +7V, (the guaranteed output with an IN pin voltage of +10.8V), and the UVLO/EN pin is high.*

Pin Configuration



Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**. Note that a “+”, “#”, or “-” in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
8 µMAX	—	21-0036

Offline and DC-DC PWM Controllers for High-Brightness LED Drivers

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/05	Initial release	—
1	1/06	MAX16802AEUA+ parts are available	1
2	1/10	Corrected formulas, updated subscripts, and removed package outline	1, 2, 3, 6–14