19-4032; Rev 1; 7/09

EVALUATION KIT AVAILABLE

High-Voltage, 100mA/200mA Adjustable Linear High-Brightness LED Drivers with PWM Dimming

General Description

The MAX16815/MAX16828 current regulators operate from a 6.5V to 40V input voltage range and deliver up to 100mA (MAX16815) or 200mA (MAX16828) to high-brightness LED (HB LED) loads. The output current is adjusted by using an external current-sense resistor in series with the LEDs. The MAX16815/MAX16828's dimming input allows wide-range "pulsed" PWM operation. An on-board pass element minimizes external components while providing ±3.5% output-current accuracy.

The MAX16815/MAX16828 are available in a thermally enhanced, 3mm x 3mm, 6-pin TDFN package with exposed pad and in an 8-pin SO package with exposed pad; they are specified over the automotive -40°C to +125°C temperature range.

Applications

Automotive Interior: Map, Courtesy, and Cluster Lighting

Automotive Exterior: Rear Combination Lights (RCLs)

Emergency Vehicle Warning Lights

Signage and Indicators

Ambient and Architectural Lighting

LED Bulbs

Display Backlighting

Pin Configurations appear at end of data sheet.

Features

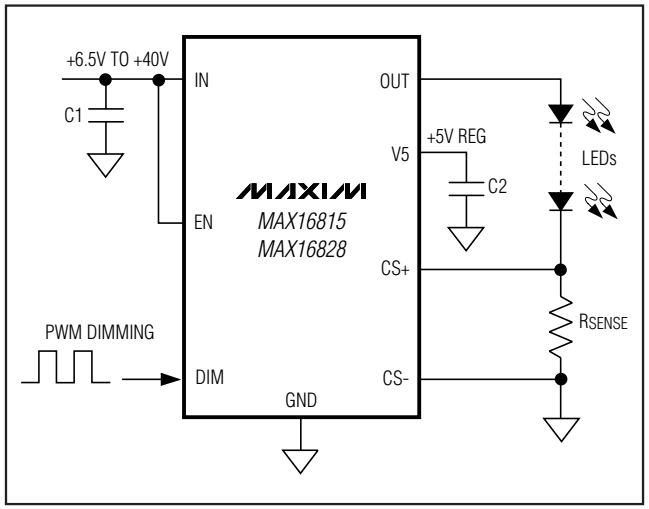
- **6.5V to 40V Operating Range**
- **Adjustable LED Current**
  MAX16815: 35mA to 100mA
  MAX16828: 35mA to 200mA
- **±3.5% LED Current Accuracy**
- **High-Voltage DIM Input for Dimming Interface**
- **Integrated Pass Element with Low-Dropout Voltage (0.4V typ)**
- **5V Regulated Output with 4mA Source Capability**
- **Thermal Shutdown**
- **Output Short-Circuit Protection**
- **Available in Small, Thermally Enhanced, 3mm x 3mm, 6-Pin TDFN and 8-Pin SO with Exposed Pad Packages**
- **-40°C to +125°C Operating Temperature Range**

Ordering Information

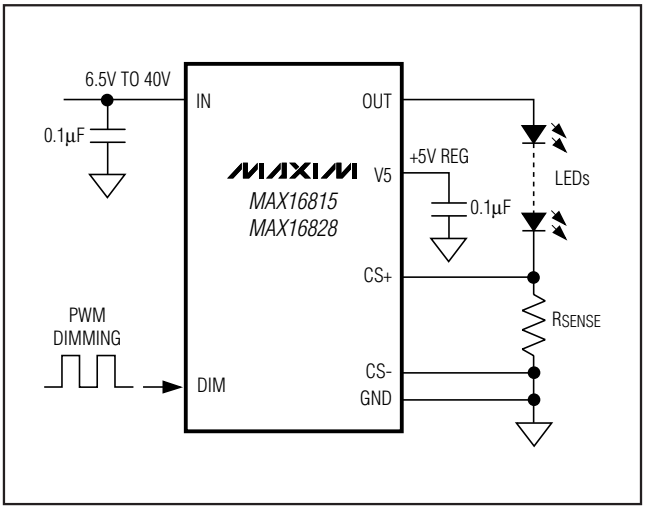
PART	TEMP RANGE	PIN-PACKAGE
MAX16815ATT+	-40°C to +125°C	6 TDFN-EP*
MAX16815ASA+	-40°C to +125°C	8 SO-EP*
MAX16828ATT+	-40°C to +125°C	6 TDFN-EP*
MAX16828ASA+	-40°C to +125°C	8 SO-EP*

+Denotes a lead(Pb)-free/RoHS-compliant package.
**EP = Exposed pad.*

Typical Operating Circuit



Simplified Diagram



For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

High-Voltage, 100mA/200mA Adjustable Linear High-Brightness LED Drivers with PWM Dimming

ABSOLUTE MAXIMUM RATINGS

IN to GND .....-0.3V to +45V
CS+, CS-, V5 to GND .....-0.3V to +6V
DIM, EN to GND.....-0.3V to (V_{IN} + 0.3V)
OUT Short Circuited to GND Duration
(at V_{IN} = +16V) .....60 minutes
Maximum Current into Any Pin (except IN and OUT).....±20mA
Continuous Power Dissipation (T_A = +70°C)
6-Pin, 3mm x 3mm TDFN
(derate 18.2mW/°C above +70°C).....1454.5mW
8-Pin SO (derate 23.3mW/°C above +70°C).....1860.5mW
Operating Temperature Range .....-40°C to +125°C
Junction Temperature.....+150°C
Junction-to-Case Thermal Resistance (θ_{JC}) (Note 1)
6-Pin, 3mm x 3mm TDFN .....9°C/W
8-Pin SO .....7°C/W
Junction-to-Ambient Thermal Resistance (θ_{JA}) (Note 1)
6-Pin, 3mm x 3mm TDFN .....42°C/W
8-Pin SO .....43°C/W
Storage Temperature Range .....-60°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C

Note 1: Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to **www.maxim-ic.com/thermal-tutorial**.

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, V_{EN} = 12V (SO only), C_{V5} = 0.1µF to GND, I_{V5} = 0, V_{DIM} = 4V, V_{CS-} = 0V (SO only), connect R_{SENSE} = 2Ω (MAX16815) and R_{SENSE} = 1Ω (MAX16828) between CS+ and GND. T_A = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage Range	V_{IN}	(Note 3)	6.5		40.0	V
Ground Current	I_G	I_{LOAD} = 100mA		0.82	2	mA
		I_{LOAD} = 200mA		1	2	
Shutdown Supply Current	I_{SHDN}	$V_{EN} \leq$ 0.6V (SO only)		35	70	µA
Guaranteed Output Current	I_{OUT}	R_{SENSE} = 2Ω (MAX16815)	100			mA
		R_{SENSE} = 1Ω (MAX16828)	200			
Output Current Accuracy		35mA < I_{OUT} < 100mA (MAX16815)		±3.5		%
		35mA < I_{OUT} < 200mA (MAX16828)		±3.5		
Dropout Voltage	ΔVDO	I_{OUT} = 100mA (current pulsed), 12V < V_{IN} < 40V (MAX16815) (Note 4)		0.1	0.4	V
		I_{OUT} = 100mA (current pulsed), 6.5V < V_{IN} < 12V (MAX16815) (Note 4)		0.1	0.6	
		I_{OUT} = 200mA (current pulsed), 12V < V_{IN} < 40V (MAX16828) (Note 5)		0.27	0.55	
		I_{OUT} = 200mA (current pulsed), 6.5V < V_{IN} < 12V (MAX16828) (Note 5)		0.27	0.7	
Output Current Slew Rate		Current rising		9.7		mA/µs
		Current falling		9.7		
Short-Circuit Current		V_{OUT} = 0V, V_{IN} = 12V, MAX16815	130	200	270	mA
		V_{OUT} = 0V, V_{IN} = 12V, MAX16828	250	300	350	
EN INPUT (SO ONLY)						
EN Input Current	I_{EN}		-2.5	-1	-0.2	µA
EN Input-Voltage High	V_{IH}		2.8			V
EN Input-Voltage Low	V_{IL}				0.6	V

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 12V, V_{EN} = 12V (SO only), C_{V5} = 0.1µF to GND, I_{V5} = 0, V_{DIM} = 4V, V_{CS-} = 0V (SO only), connect R_{SENSE} = 2Ω (MAX16815) and R_{SENSE} = 1Ω (MAX16828) between CS+ and GND. T_A = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CURRENT SENSE						
Regulated R_{SENSE} Voltage	V_{RSNS}	V_{RSNS} = V_{CS+} for TDFN package; V_{RSNS} = V_{CS+} - V_{CS-} for SO package	193	200	207	mV
CS- Voltage Range		SO only	-0.3		+4.7	V
Input Current (CS+)		V_{CS+} = 220mV		2.7	7	µA
Input Current (CS-)		V_{CS+} = 220mV (SO only)	-50	17.2		µA
DIM Input Current		V_{DIM} = 0V	-2.5	-1.0	-0.2	µA
DIM Input-Voltage High	V_{IH}		2.8			V
DIM Input-Voltage Low	V_{IL}				0.6	V
Turn-On Time	t_{ON}	After V_{DIM} rising to 4V (Note 7)			100	µs
Turn-Off Time	t_{OFF}	After V_{DIM} falling to 0.6V (Note 7)			55	µs
THERMAL OVERLOAD						
Thermal-Shutdown Temperature				+159		°C
Thermal-Shutdown Hysteresis				24		°C
+5V REGULATOR						
Output-Voltage Load Regulation	V_{V5}	(Note 8)	4.8	5.0	5.2	V
Output Voltage	ΔV_{V5}	0 < I_{V5} < 4mA		12	20	mV/mA
V5 Short-Circuit Current		V_{V5} = 0 (Note 9)		15		mA

Note 2: All devices are 100% production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed by design.

Note 3: Resistors were added from OUT to CS+ to aid with power dissipation.

Note 4: Dropout is measured as follows:
Connect R_O from OUT to CS+. Connect R_{SENSE} = 2Ω (MAX16815) from CS+ to GND (for TDFN) or from CS+ to CS- (for SO). Set V_{IN} = 12V (record V_{OUT1} = V_{OUT}). For V_{IN} = 40V, use R_O = 360Ω; for V_{IN} = 6.5V, use R_O = 56Ω.
Reduce V_{IN} until V_{OUT} = 0.97 x V_{OUT1} (record as V_{IN2} and V_{OUT2}). ΔV_{DO} = V_{IN2} - V_{OUT2}.

Note 5: Dropout is measured as follows:
Connect R_O from OUT to CS+. Connect R_{SENSE} = 1Ω (MAX16828) from CS+ to GND (for TDFN) or from CS+ to CS- (for SO). Set V_{IN} = 12V (record V_{OUT1} = V_{OUT}). For V_{IN} = 40V, use R_O = 180Ω; for V_{IN} = 6.5V, use R_O = 27Ω.
Reduce V_{IN} until V_{OUT} = 0.97 x V_{OUT1} (record as V_{IN2} and V_{OUT2}). ΔV_{DO} = V_{IN2} - V_{OUT2}.

Note 6: I_{V5} = 0mA.

Note 7: t_{ON} time includes the delay and the rise time needed for I_{OUT} to reach 90% of its final value. t_{OFF} time is the time needed for I_{OUT} to drop below 10%. See the *Typical Operating Characteristics*. t_{ON} and t_{OFF} are tested with 100Ω (MAX16815) or 51Ω (MAX16828) from OUT to CS+.

Note 8: Current regulation varies with V5 load (see the *Typical Operating Characteristics*).

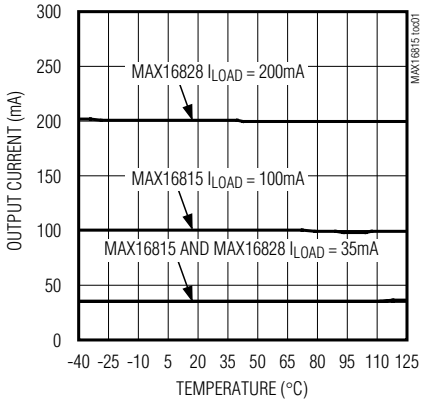
Note 9: Thermal shutdown does not function if V5 is shorted to ground.

High-Voltage, 100mA/200mA Adjustable Linear High-Brightness LED Drivers with PWM Dimming

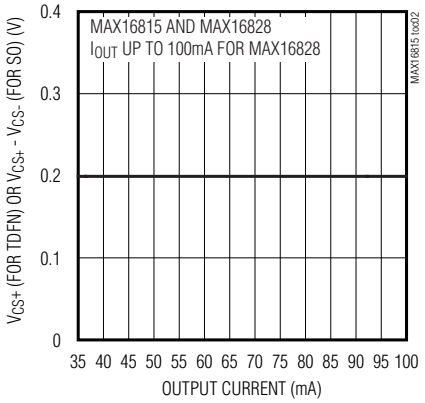
Typical Operating Characteristics

(V_{IN} = 12V, T_A = +25°C, unless otherwise noted.)

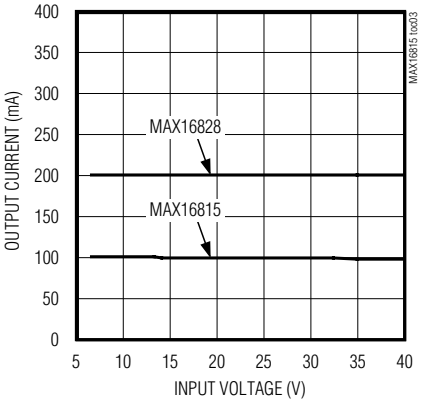
OUTPUT CURRENT vs. TEMPERATURE



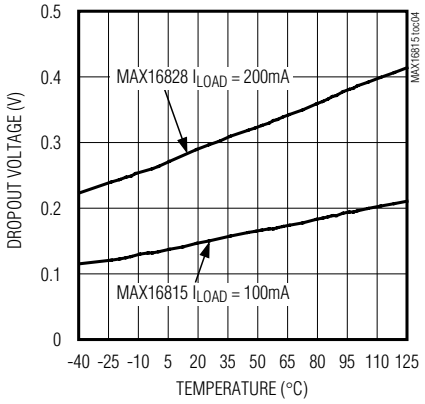
VCS+ (FOR TDFN) OR VCS+ - VCS- (FOR SO) vs. OUTPUT CURRENT



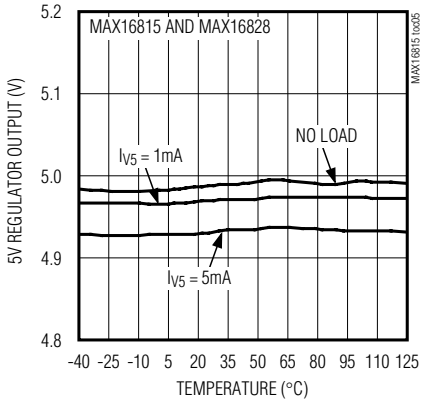
OUTPUT CURRENT vs. INPUT VOLTAGE



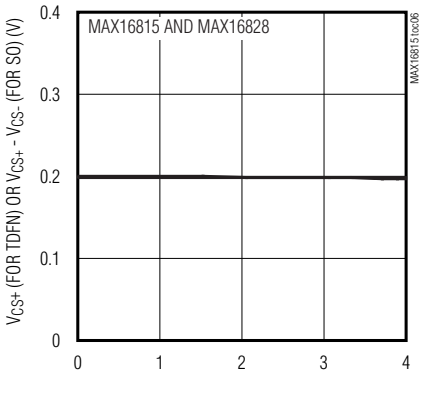
DROPOUT VOLTAGE vs. TEMPERATURE



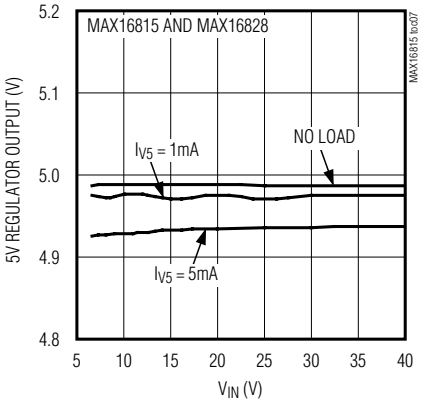
+5V REGULATOR OUTPUT vs. TEMPERATURE



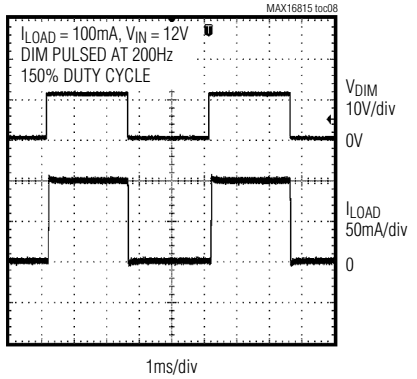
VCS+ (FOR TDFN) OR VCS+ - VCS- (FOR SO) vs. IV5



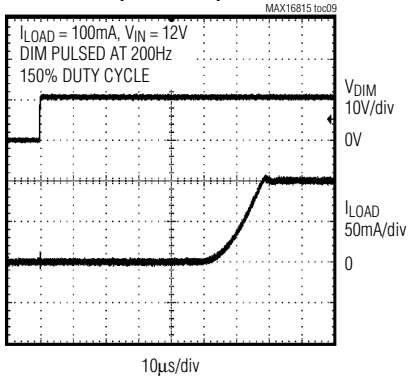
+5V REGULATOR OUTPUT vs. VIN



MAX16815 200Hz DIMMED OPERATION



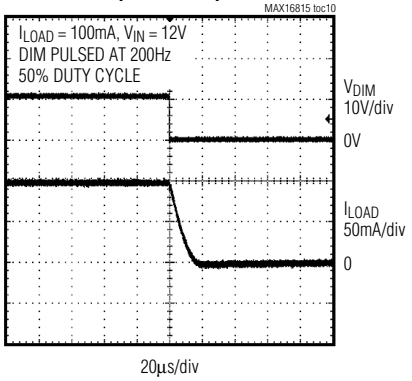
MAX16815 200Hz DIMMED OPERATION (EXPANDED)



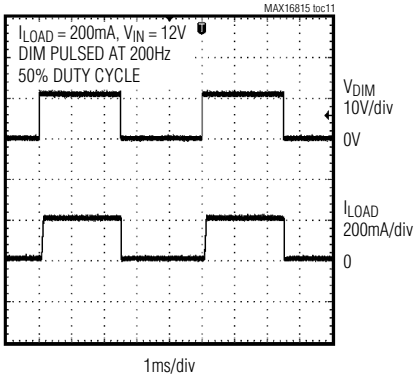
Typical Operating Characteristics (continued)

(V_{IN} = 12V, T_A = +25°C, unless otherwise noted.)

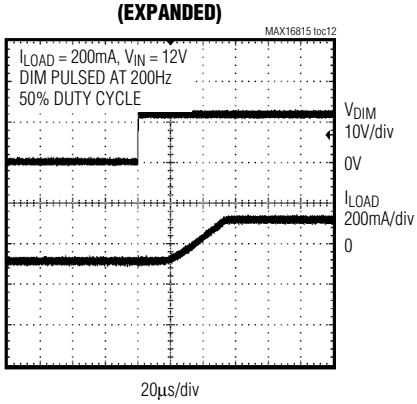
MAX16815 200Hz DIMMED OPERATION (EXPANDED)



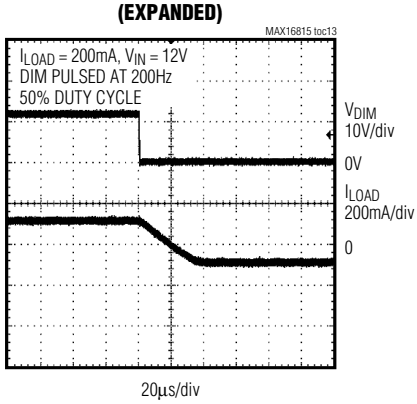
MAX16828 200Hz DIMMED OPERATION



MAX16828 200Hz DIMMED OPERATION (EXPANDED)



MAX16828 200Hz DIMMED OPERATION (EXPANDED)

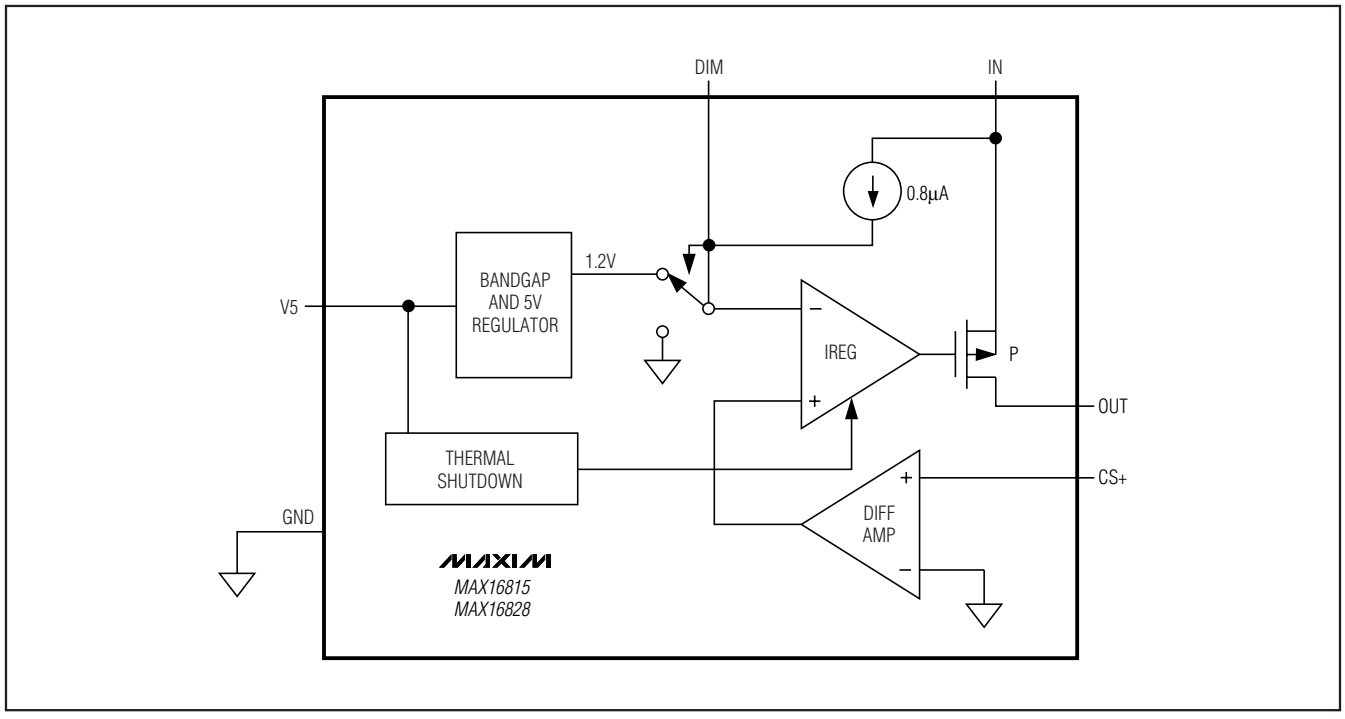


High-Voltage, 100mA/200mA Adjustable Linear High-Brightness LED Drivers with PWM Dimming

Pin Description

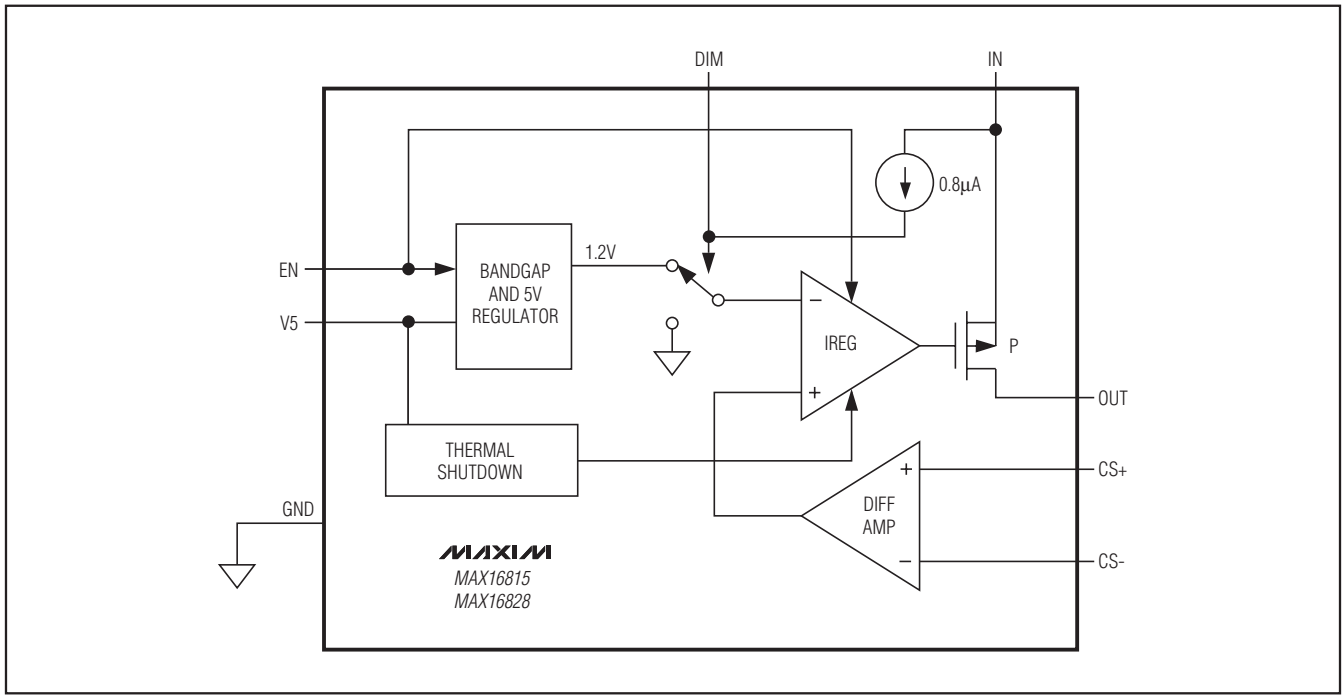
PIN		NAME	FUNCTION
TDFN	SO		
1	6	DIM	Pulsed Dimming Input. Drive DIM low to turn off output current (LED current). Drive DIM high to turn on the output current (LED current). DIM is pulled high to V_{IN} when left unconnected.
—	7	EN	Enable Input. Drive EN high to enable the output. For the TDFN package, this input is not accessible and always high.
2	8	OUT	Current-Regulated Output
3	1	IN	Positive Input Supply. Bypass IN with a 0.1µF (min) capacitor to GND.
4	2	CS+	LED Current-Sense Amplifier Positive Input. For the SO package version, connect the current-sense resistor between this pin and CS-; for the TDFN version, connect it between this pin and ground.
—	3	CS-	LED Current-Sense Amplifier Negative Input. Connect to ground.
5	4	V5	+5V Regulated Output. Connect a 0.1µF (min) capacitor from V5 to GND.
6	5	GND	Ground
—	—	EP	Exposed Pad. Connect to a large ground plane for effective power dissipation. Do not use as the only ground connection.

TDFN Functional Diagram



High-Voltage, 100mA/200mA Adjustable Linear High-Brightness LED Drivers with PWM Dimming

SO Functional Diagram



Detailed Description

+5V Regulator

The MAX16815/MAX16828 include a fixed +5V output regulator that delivers up to 4mA of load current throughout the 6.5V to 40V input voltage range. Connect a 0.1µF compensation capacitor from V5 to ground. Shorting V5 to ground disables the thermal shutdown. V5 stays on during PWM dimming.

Thermal Protection

The MAX16815/MAX16828 enter a thermal-shutdown mode in the event of overheating. This typically occurs in overload or output short-circuit conditions. If the junction temperature exceeds T_J = +159°C (typ), the internal thermal-protection circuitry turns off the series pass device. The MAX16815/MAX16828 recover from thermal-shutdown mode once the junction temperature drops by 24°C (typ). The devices therefore protect themselves by thermal cycling in the event of a short-circuit or overload condition. Shorting V5 to ground disables the thermal shutdown.

Applications Information

Programming the LED Current

The MAX16815/MAX16828 use a sense resistor across CS+ and GND for the TDFN package or across CS+ and CS- for the SO package, to set the LED current. The LED current is given by $I_{LED} = V_{RSNS}/R_{SENSE}$.

Input-Voltage Considerations

For proper operation, the minimum input voltage must always be:

$$V_{IN(MIN)} \geq V_{RSNS(MAX)} + V_{FT(MAX)} + \Delta V_{DO}(MAX)$$

where $V_{FT(MAX)}$ is the total forward voltage of all series connected LEDs. The minimum operating voltage of the device is +6.5V. The device operates below +6.5V; however, output current may not meet the full regulation specification (see the *Typical Operating Characteristics*) and the V5 regulator will drop below 5V.

Low-Frequency PWM Dimming at the Output

Provide a pulse to the dimming input (DIM) of the MAX16815/MAX16828 to produce a PWM output. Alternatively, connect DIM to IN and pulse IN.

High-Voltage, 100mA/200mA Adjustable Linear High-Brightness LED Drivers with PWM Dimming

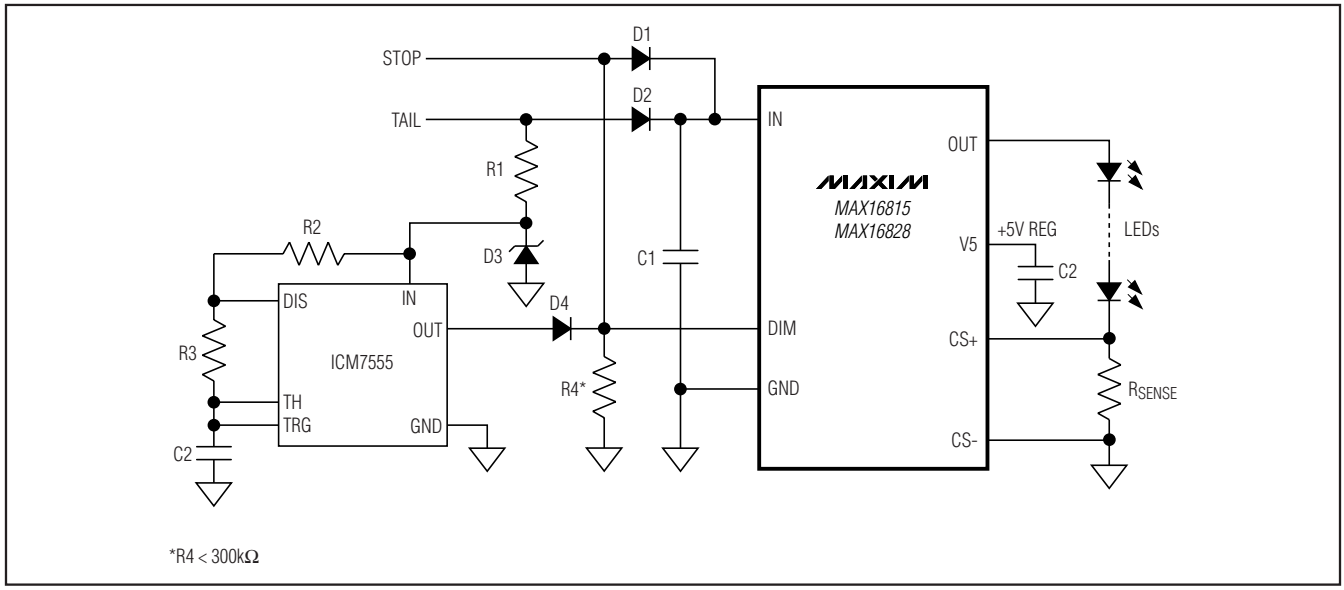


Figure 1. PWM Dimming Operation with ICM7555 Timer

Two Brightness Levels for TAIL/STOP Lights

Figure 1 shows PWM dimming operation for the MAX16815/MAX16828 with an ICM7555 timer. The ICM7555 provides adjustable duty cycle using two external resistors and a capacitor. In TAIL operation, the output of the ICM7555 feeds into DIM and lights up the LEDs. The LED's brightness depends on the duty cycle of the ICM7555. When V_{STOP} is present, DIM is pulled up to V_{STOP}. The PWM dimming operation is disabled and the LEDs light up to full brightness. See the ICM7555 data sheet for formulas to calculate the dimming frequency and the duty cycle.

LED Current Thermal Foldback

With a minimum number of external components, the MAX16815/MAX16828 provide LED current thermal foldback using a negative temperature coefficient (NTC) thermistor. Figure 2 shows a thermistor connected to V5 and the CS+ of the MAX16815/MAX16828. As the temperature increases, the voltage drop across R2 increases, causing the LED current to decrease.

$$I_{LED} = [V_{RSNS} - (R2 / R_T) (V_{V5} - V_{RSNS})]/R1$$

Other Applications

The application circuit in Figure 3 implements a two-level brightness current for TAIL/STOP lights. In TAIL operation, Q1 is off and R1 sets the output current. In STOP operation, Q1 turns on and the output current is set by a parallel combination of R1 and R2. Figure 4 shows an application circuit with the MAX16815/MAX16828 using a single BJT to provide high output current. For proper operation:

$$V_{IN(MIN)} > V_{CESAT(MAX)} + V_{FT(MAX)} + V_{RSNS}$$

where $V_{CESAT(MAX)}$ is the maximum saturation voltage of the external BJT and $V_{FT(MAX)}$ is the total forward voltage of all series connected LEDs.

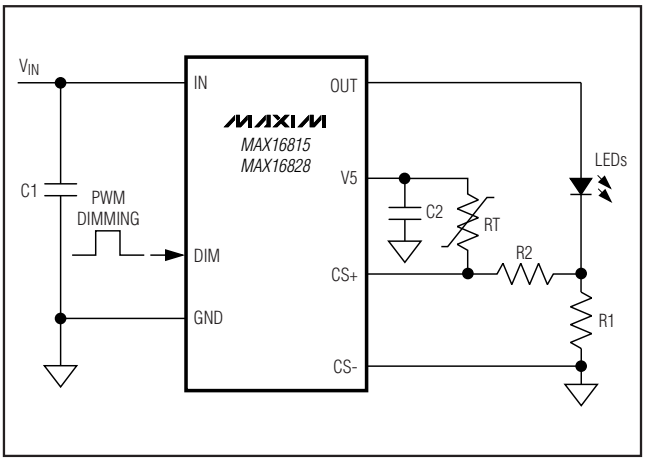


Figure 2. LED Current Thermal Foldback with an NTC Thermistor

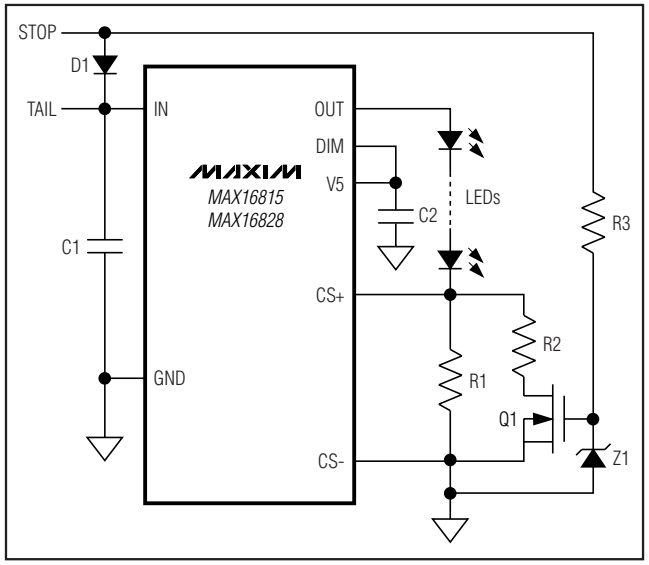


Figure 3. Two-Level Brightness with Current Level Switch for TAIL/STOP Lights

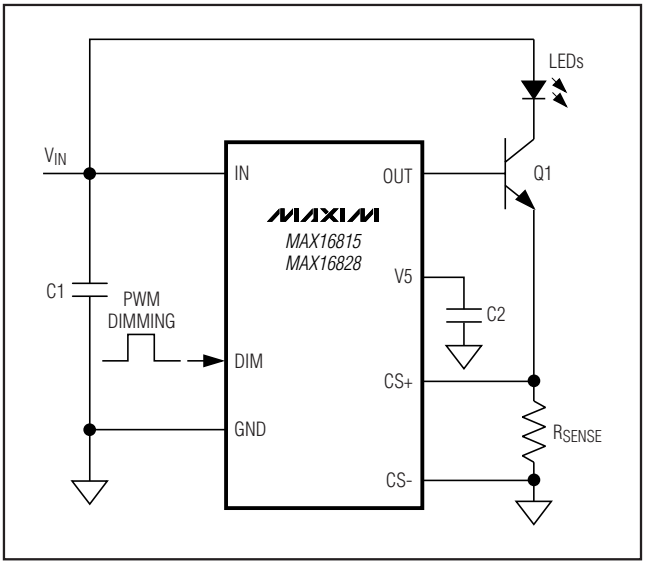


Figure 4. Increased LED Current (Ampere Range) with a Single BJT

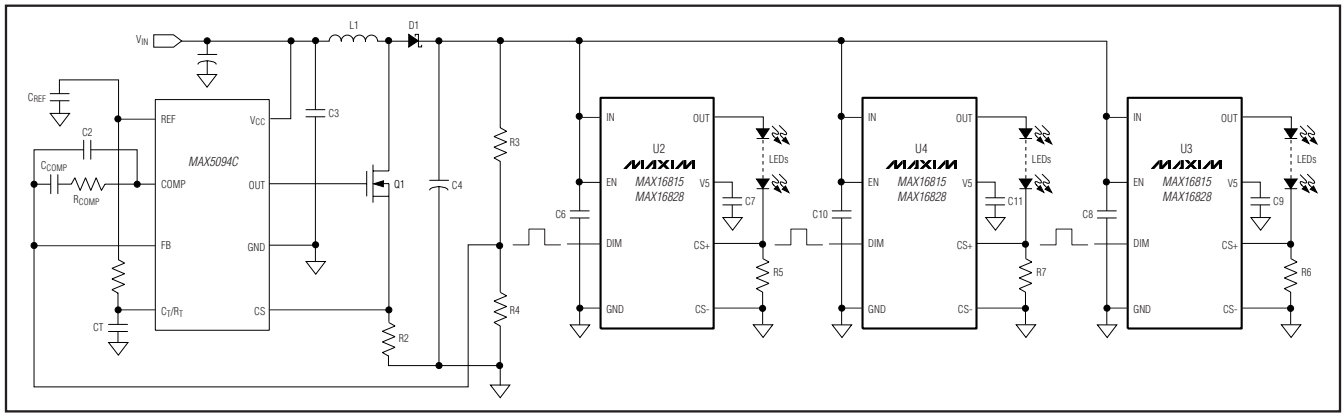


Figure 5. Multichannel HB LED Drivers for LCD Backlight

Multichannel HB LED Driver

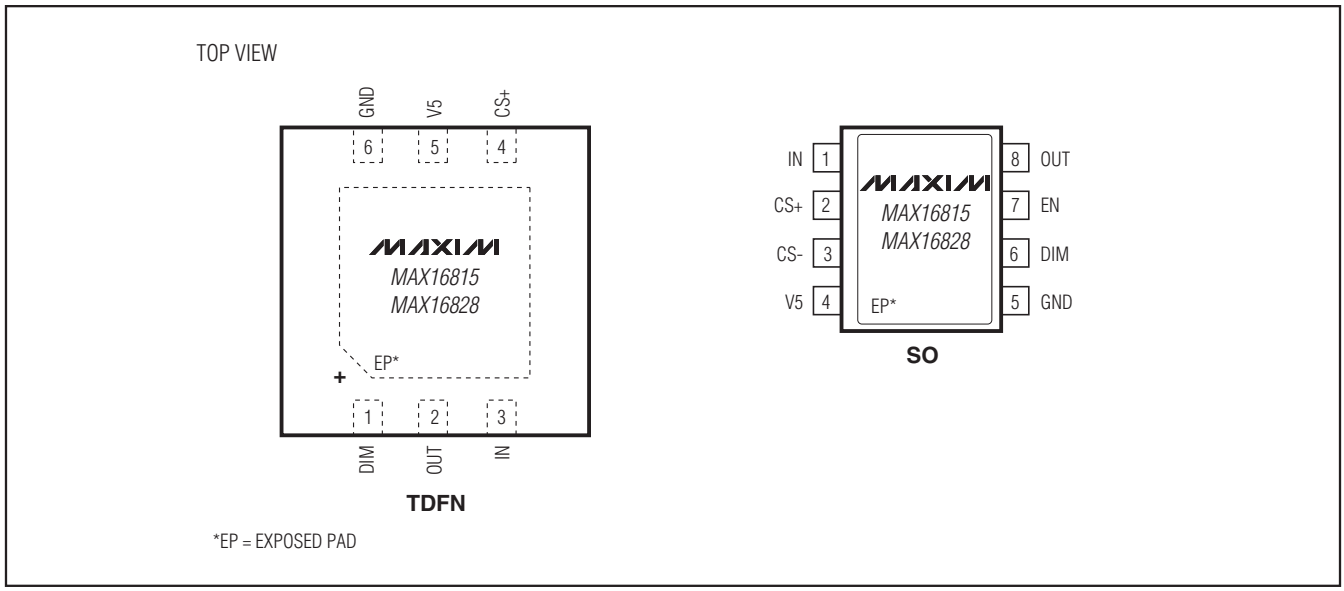
Figure 5 shows an array of MAX16815/MAX16828s with independent DIM control. The MAX5094C, a current-mode PWM controller, provides the input power to each LED driver preregulated voltage to multiple MAX16815/MAX16828 drivers.

Chip Information

PROCESS: BiCMOS

High-Voltage, 100mA/200mA Adjustable Linear High-Brightness LED Drivers with PWM Dimming

Pin Configurations



Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
8 SO-EP	S8E-12	21-0111
6 TDFN-EP	T633-2	21-0137

High-Voltage, 100mA/200mA Adjustable Linear High-Brightness LED Drivers with PWM Dimming

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	2/08	Initial release.	—
1	7/09	• Added the SO package to the *Ordering Information* table, *Electrical Characteristics*, *TOC 2* and *6*, *Pin Description* table, and *Functional Diagrams*. • Modified the *Simplified Diagram* and *Figures 1–4* to include the CS- pin. • Added the SO-EP *Pin Configuration*.	1–4, 6–10

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