MAX16804

High-Voltage, 350mA LED Driver with Analog and PWM Dimming Control

General Description

The MAX16804 current regulator operates from a 5.5V to 40V input voltage range and delivers 35mA to 350mA to one or more strings of high-brightness LEDs (HB LEDs). The output current of the MAX16804 is set by using an external current-sense resistor in series with the LEDs. A dual-mode DIM pin and on-board 200Hz ramp generator allow PWM dimming with an analog or PWM input signal. The analog control signal at dimming input DIM allows for a theater-dimming effect to be implemented. Fast turn-on and turn-off times ensure a wide-range PWM operation, while wave-shaping circuitry minimizes EMI. The differential current-sense input increases LED current accuracy and noise immunity. The MAX16804 is well suited for applications requiring high-voltage input and is able to withstand load-dump events up to 45V. An on-board pass element minimizes external components while providing 3% output-current accuracy. Additional features include a 5V regulated output and short-circuit and thermal protection.

The MAX16804 is available in a thermally enhanced, 5mm x 5mm, 20-pin TQFN package and is specified over the automotive -40°C to +125°C temperature range.

Applications

- Warning Lights for Emergency Vehicles
- Navigation and Marine Indicators
- Signage, Canopies, and Beacons

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX16804ATP+	-40°C to +125°C	20 TQFN-EP*

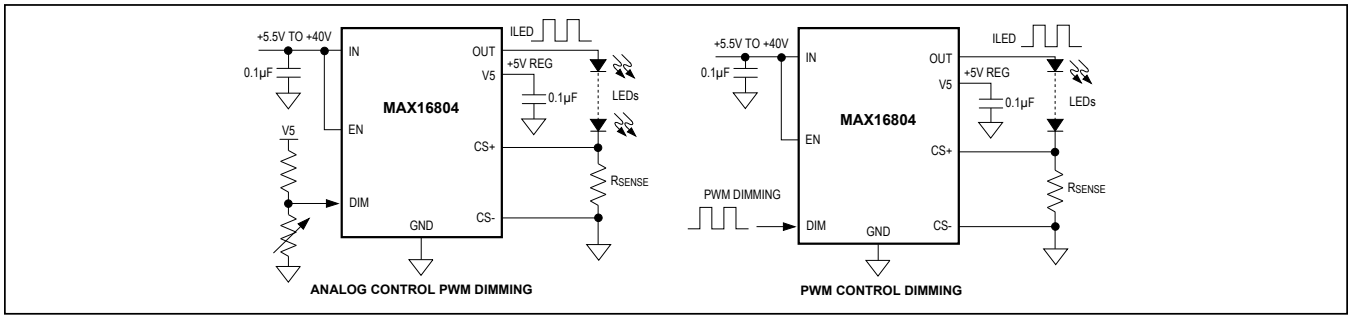
+Denotes lead(Pb)-free/RoHS-compliant package.
**EP = Exposed pad.*

Benefits and Features

- Flexible Dimming Control Simplifies Lighting System Design
  - Analog or PWM Control Signal for PWM and Theater Dimming
  - 200Hz On-Board Ramp Generator
  - High-Voltage (Up to 40V) DIM Pin
  - Additional +5V On-Board Regulator with 2mA Capability
- External Synchronization and Pulse Shaping Reduce Radio Interference
  - Wave-Shaped Edges Minimize EMI During PWM Dimming
  - Syncs to External PWM Signal (Up to 2kHz)
- Powers High-Power, High-Brightness LEDs
  - 35mA to 350mA Adjustable LED Current
  - 3% LED Current Accuracy
  - Differential LED Current Sense
- Enables High-Efficiency Designs to Minimize Heat Dissipation
  - Integrated Pass Element with Low-Dropout Voltage (0.5V typ)
  - 200mV Current-Sense Reference Reduces Power Losses
- Thermal Shutdown and Output Short-Circuit Protection Provide Additional Safety
  - 5.5V to 40V Operating Range
  - -40°C to +125°C Operating Temperature Range

Pin Configuration appears at end of data sheet.

Simplified Diagrams



maxim integrated™

Absolute Maximum Ratings

IN to GND.....-0.3V to +45V
DIM, OUT, EN to GND.....-0.3V to (V_{IN} + 0.3V)
IN Slew Rate (20V < V_{IN} < 45V).....250mV/µs
CS+, V5 to GND.....-0.3V to +6V
CS- to GND.....-0.3V to +0.3V
OUT Short Circuited to GND Duration
(at V_{IN} < +16V).....1hour
Maximum Current Into Any Pin (except IN and OUT).....±20mA
Continuous Power Dissipation (T_A = +70°C)
20-Pin TQFN (derate 34.5mW/°C above +70°C)....2758.6mW
Operating Temperature Range.....-40°C to +125°C
Junction Temperature.....+150°C
Storage Temperature Range.....-65°C to +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} = V_{EN} = 12V, C_{V5} = 0.1µF, I_{V5} = 0, CS- = GND, R_{SENSE} = 0.56Ω (see the *Typical Operating Circuit*), V_{DIM} = 4V, T_A = T_J = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = T_J = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage Range	V_{IN}	(Note 2)	5.5		40.0	V
Ground Current	I_G	I_{LOAD} = 350mA		2.5	4.5	mA
Shutdown Supply Current	I_{SHDN}	V_{EN} ≤ 0.3V		12	40	µA
Guaranteed Output Current	I_{OUT}	R_{SENSE} = 0.55Ω	350			mA
Output Current Accuracy		35mA < I_{OUT} < 350mA, not including R_{SENSE} tolerance			3	%
Dropout Voltage (Note 3)	ΔV_{DO}	I_{OUT} = 350mA, 12V < V_{IN} < 40V		0.4	1.2	V
		I_{OUT} = 350mA, 6.5V < V_{IN} < 12V		0.5	1.5	
Output Current Slew Rate (External PWM Signal at DIM)		Current rising, DIM rising to 4V		17		mA/µs
		Current falling, DIM falling to 0.6V		17		
Short-Circuit Current		V_{OUT} = 0V		600		mA
ENABLE INPUT						
EN Input Current	I_{EN}				100	nA
EN Input-Voltage High	V_{IH}		2.8			V
EN Input-Voltage Low	V_{IL}				0.6	V
Enable Turn–On Time	t_{ON}	EN rising edge to 90% of OUT		250		µs
CURRENT SENSE (Note 4)						
Regulated R_{SENSE} Voltage	V_{RSENSE}	V_{SENSE} = V_{CS+} - V_{CS-}	192	198	204	mV
Input Current (CS+)		V_{CS+} = 220mV			+14	µA
Input Current (CS-)		V_{CS+} = 220mV	-75			µA
INTERNAL RAMP GENERATOR						
Internal Ramp Frequency	f_{RAMP}		180	200	220	Hz
External Sync Frequency Range	f_{DIM}		80		2000	Hz
External Sync Voltage Low					0.4	V
External Sync Voltage High			2.8			V
EXTERNAL PWM DIMMING INPUT						
DIM Input Current					1	µA
Turn-On Time	t_{ON}	After DIM rising to 4V (Note 5)		28	52	µs
Turn-Off Time	t_{OFF}	After DIM falling to 0.6V (Note 5)		19	38	µs

Electrical Characteristics (continued)

(V_{IN} = V_{EN} = 12V, C_{V5} = 0.1µF, I_{V5} = 0, CS- = GND, R_{SENSE} = 0.56Ω (see the *Typical Operating Circuit*), V_{DIM} = 4V, T_A = T_J = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = T_J = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
THERMAL PROTECTION						
Thermal-Shutdown Temperature	$T_{J(SHDN)}$			+155		°C
Thermal-Shutdown Hysteresis				23		°C
+5V REGULATOR						
Output Voltage Regulation	V5	0 ≤ I_{V5} ≤ 2mA	4.8	5.1	5.4	V
V5 Short-Circuit Current		V5 = 0V (Note 6)		12		mA

Note 1: All devices are 100% production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed by design.

Note 2: Resistors were added from OUT to CS+ to aid with the power dissipation during testing.

Note 3: Dropout is measured as follows:
Connect a resistor from OUT to CS+. Connect R_{SENSE} = 0.56Ω from CS+ to CS-. Set V_{IN} = V_{OUT} +3V (record V_{OUT} as V_{OUT1}). 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 4: I_{V5} = 0mA.

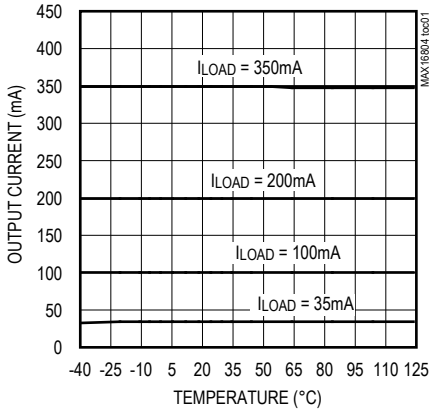
Note 5: t_{ON} time includes the delay and the rise time needed for I_{OUT} to reach 90% of its final value. t_{OFF} time is the time needed for I_{OUT} to drop below 10%. See the *Typical Operating Characteristics*. t_{ON} and t_{OFF} are tested with 13Ω from OUT to CS+.

Note 6: Thermal shutdown does not function if the output of the 5V reference is shorted to ground. Shorting V5 to GND disables the output.

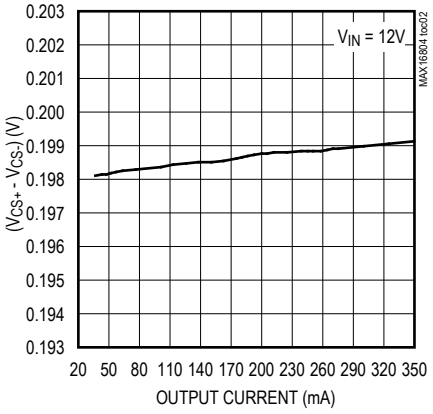
Typical Operating Characteristics

(V_{IN} = 12V, V_{EN} = V_{IN}, C_{V5} = 0.1µF, I_{V5} = 0, CS- = GND, R_{SENSE} = 0.56Ω, connect OUT to CS+, V_{DIM} = 4V, T_A = +25°C, unless otherwise noted.)

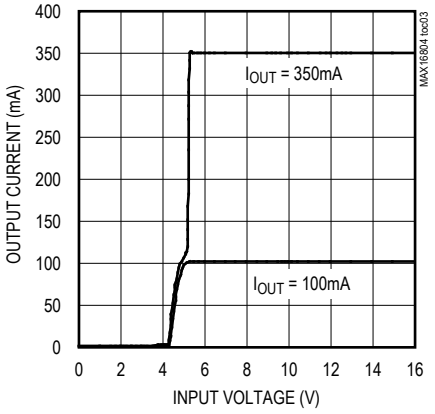
OUTPUT CURRENT vs. TEMPERATURE



(V_{CS+} - V_{CS-}) vs. OUTPUT CURRENT



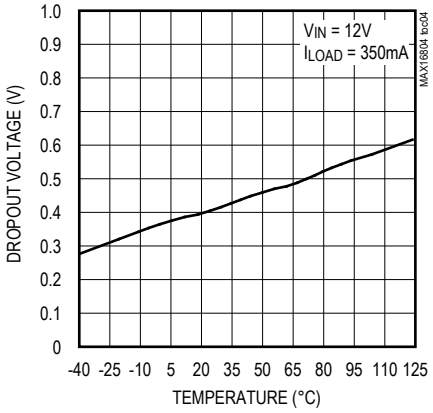
OUTPUT CURRENT vs. INPUT VOLTAGE



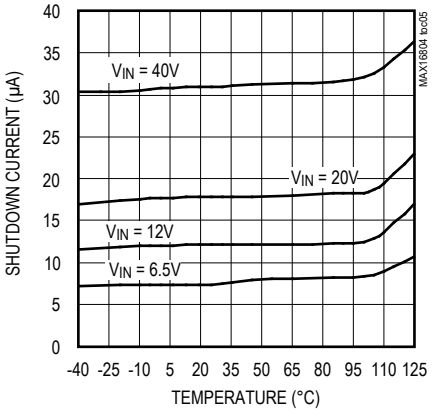
Typical Operating Characteristics (continued)

(V_{IN} = 12V, V_{EN} = V_{IN}, C_{V5} = 0.1µF, I_{V5} = 0, CS- = GND, R_{SENSE} = 0.56Ω, connect OUT to CS+, V_{DIM} = 4V, T_A = +25°C, unless otherwise noted.)

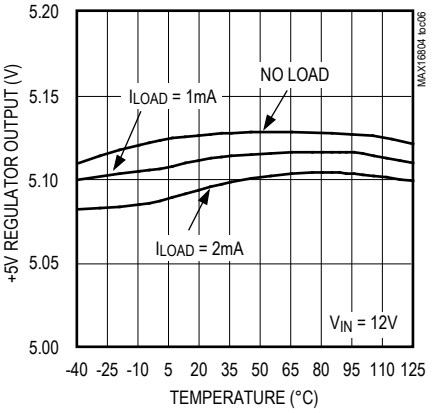
DROPOUT VOLTAGE vs. TEMPERATURE



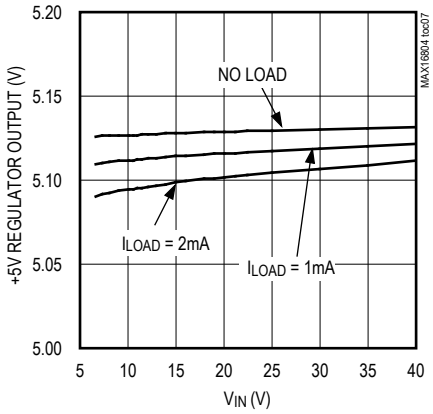
SHUTDOWN CURRENT vs. TEMPERATURE



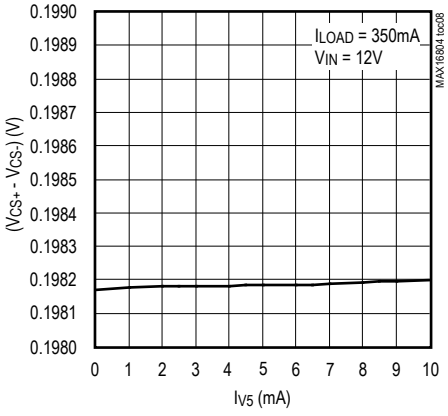
+5V REGULATOR OUTPUT vs. TEMPERATURE



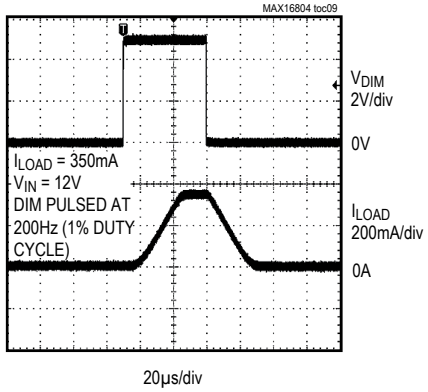
+5V REGULATOR OUTPUT vs. V_{IN}



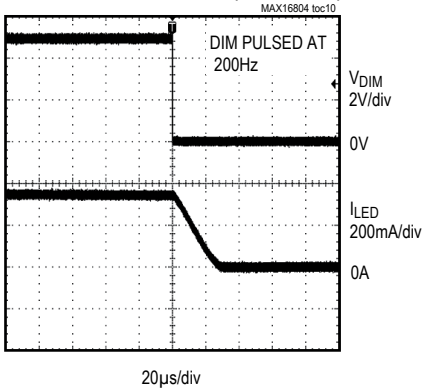
(V_{CS+} - V_{CS-}) vs. I_{V5}



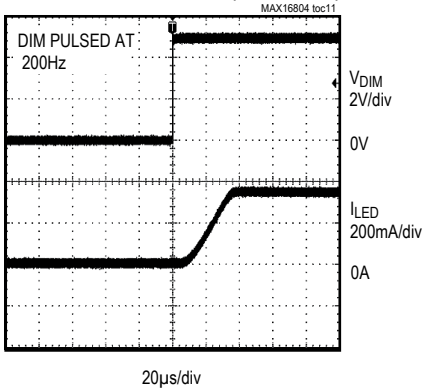
200Hz DIMMED OPERATION



LED CURRENT FALL TIME (EXPANDED)

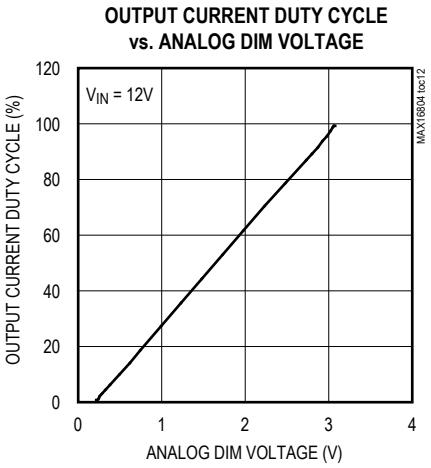


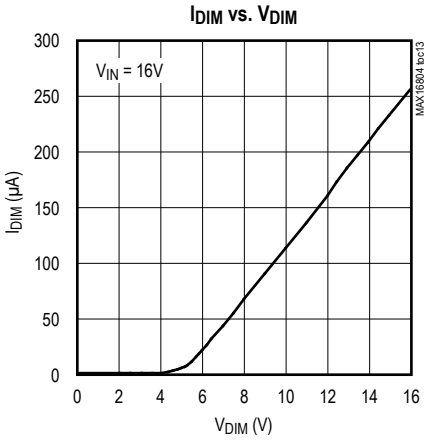
LED CURRENT RISE TIME (EXPANDED)



Typical Operating Characteristics (continued)

(V_{IN} = 12V, V_{EN} = V_{IN}, C_{V5} = 0.1µF, I_{V5} = 0, CS- = GND, R_{SENSE} = 0.56Ω, connect OUT to CS+, V_{DIM} = 4V, T_A = +25°C, unless otherwise noted.)

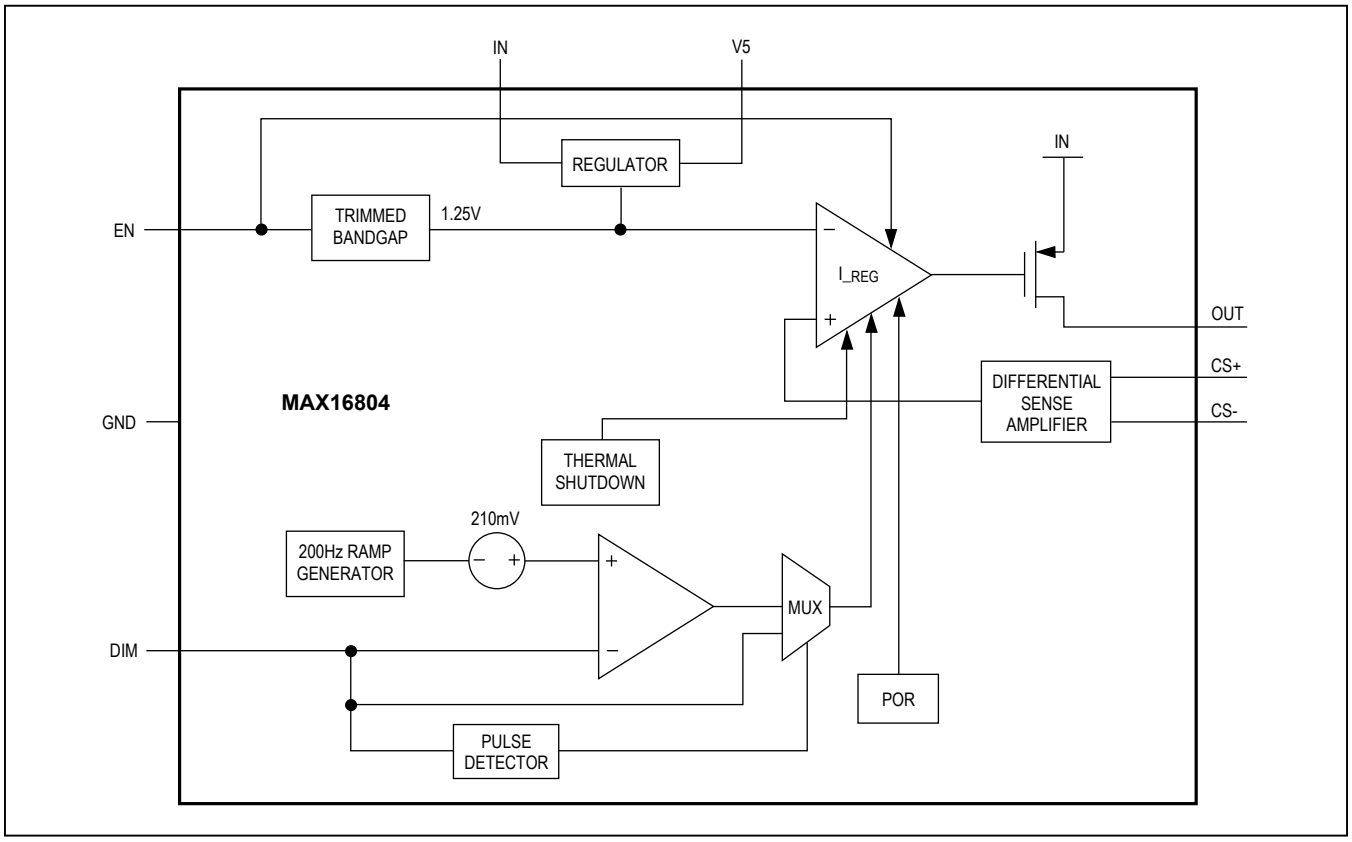




Pin Description

PIN	NAME	FUNCTION
1, 20	OUT	Current-Regulated Output. Connect pin 1 to pin 20.
2, 3	IN	Input Supply. Bypass IN with a 0.1µF (min) capacitor to GND. Connect pin 2 to pin 3.
4, 9, 11, 18	N.C.	No Connection. Leave unconnected (internal connection).
5–8, 10, 16	GND	Ground
12, 15	V5	+5V Regulated Output. Connect a 0.1µF capacitor from V5 to GND.
13	CS+	Positive Input of the Internal Differential Amplifier. Connect the current-sense resistor between CS+ and CS- to program the output current level.
14	CS-	Negative Input of the Internal Differential Amplifier. Connect the current-sense resistor between CS- and CS+ to program the output current level.
17	DIM	Dimming Input. See the *Dimming Input (DIM)* section.
19	EN	Enable Input. Drive EN high to enable the output and the 5V LDO.
—	EP	Exposed Pad. Connect to the ground plane for effective power dissipation. Do not use as the only ground connection.

Functional Diagram



Detailed Description

The MAX16804 is a high-current regulator that operates from a wide input voltage range of 5.5V to 40V and is capable of providing up to 350mA of current to one or more strings of HB LEDs. A +5V regulated output provides up to 2mA of current to power external circuitry. In addition, the MAX16804 features thermal and output short-circuit protection. The wide operating voltage range helps protect the MAX16804 against large transients such as those found in load-dump situations up to 45V.

The MAX16804 uses a feedback loop to control the output current. The differential voltage across the sense resistor is compared to a fixed reference voltage, and the error is amplified to serve as the drive to the internal pass device (see the *Functional Diagram*). The regulation point is factory-set at (V_{CS+} - V_{CS-}) = 198 ±6mV. The regulated current is user-defined by the value of R_{SENSE}.

The MAX16804 is a current controller internally optimized for driving the impedance range expected from one to ten or more HB LEDs.

Dimming Input (DIM)

The MAX16804's dimming input functions with either an analog or PWM control signal. If the pulse detector detects three edges of a PWM signal with a frequency range between 80Hz and 2kHz, the MAX16804 synchronizes to external PWM input signal and pulse-width modulates the LED current. If an analog control signal is applied to DIM, the MAX16804 compares the DC input to an internally generated 200Hz ramp to pulse-width modulate the LED current.

The output current duty cycle is adjustable from 0% to 100% (0.21V < V_{DIM} < 3.1V).

Use the following formula to calculate the output current duty cycle:

$$\text{Duty cycle} = (V_{DIM} - 0.21V)/(2.895V) \quad (1)$$

The dimming feature can be used for LED brightness adjustment (see the *Simplified Diagrams*) and theater dimming. If an external PWM signal is used, the theater-dimming effect can be achieved by varying the PWM duty cycle. Figure 1 shows a simple circuit that implements theater dimming with a DC input signal.

+5V Regulator

The MAX16804 includes a fixed +5V output regulator that delivers up to 2mA 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. When EN is low, V5 is off. V5 stays on during PWM dimming.

Thermal Protection

The MAX16804 enters a thermal-shutdown mode in the event of overheating. This typically occurs in overload or short-circuit conditions on the output. If the junction temperature exceeds T_J = +155°C (typ), the internal thermal-protection circuitry turns off the series pass device. The MAX16804 recovers from thermal-shutdown mode once the junction temperature drops by 23°C (typ). The part therefore protects itself by thermally cycling in the event of a short-circuit or overload condition.

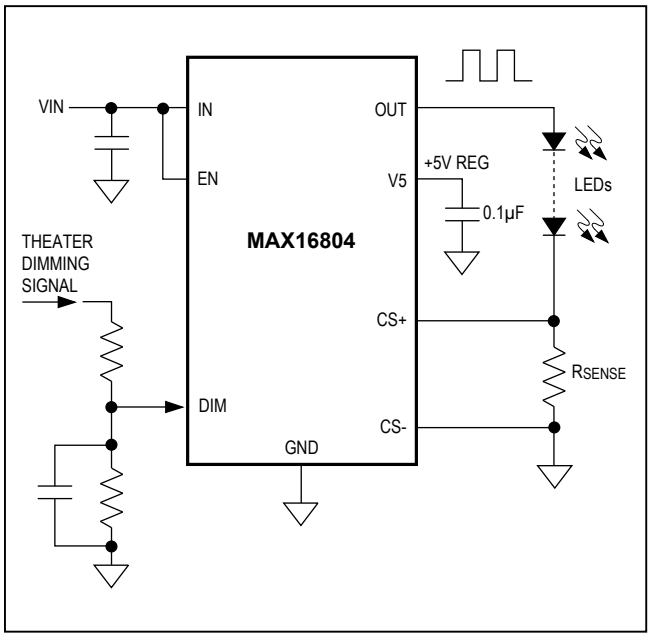


Figure 1. Theater Dimming

Applications Information

Programming the LED Current

The MAX16804 uses a sense resistor across CS+ and CS- to set the LED current. The differential sense amplifier connected across R_{SENSE} provides ground-loop immunity and low-frequency noise rejection. The LED current is given by:

$$I_{LED} = V_{SENSE}/R_{SENSE} \quad (2)$$

Input-Voltage Considerations

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

$$V_{IN(MIN)} \geq V_{RSENSE(MAX)} + V_{FT(MAX)} + \Delta V_{DO(MAX)} \quad (3)$$

where $V_{FT(MAX)}$ is the maximum forward voltage of all series connected LEDs and $\Delta V_{DO(MAX)}$ is the maximum drop output voltage. The minimum operating voltage of the device is +5.5V.

Two Brightness Levels for TAIL/STOP Lights

Figure 2 shows two-level brightness adjustment using the MAX16804 with minimum external components. Set the dimming level with a resistive divider connected to DIM. See Equation 1 for details.

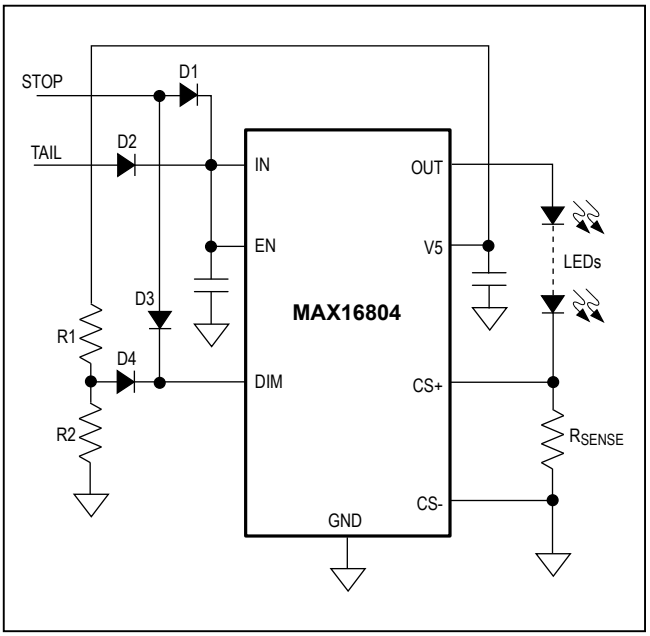


Figure 2. Two-Level Brightness Operation

LED Current Thermal Foldback

With a minimum number of external components, the MAX16804 provides LED current thermal foldback using a negative temperature coefficient (NTC) thermistor. Figure 3 shows a thermistor connected to V5 and the CS+ of the MAX16804. As the temperature increases, the voltage drop across R2 increases causing the LED current to decrease.

$$I_{LED} = [V_{SENSE} - [R2/(R2 + RT)] \times V5]/R1 \quad (4)$$

Other Applications

Figure 4 shows an application circuit with the MAX16804 using a single BJT to provide high output current. For proper operation:

$$V_{IN(MIN)} > V_{CESAT(MAX)} + V_{FT(MAX)} + V_{RSENSE} \quad (5)$$

where $V_{CESAT(MAX)}$ is the maximum saturation voltage of the external BJT.

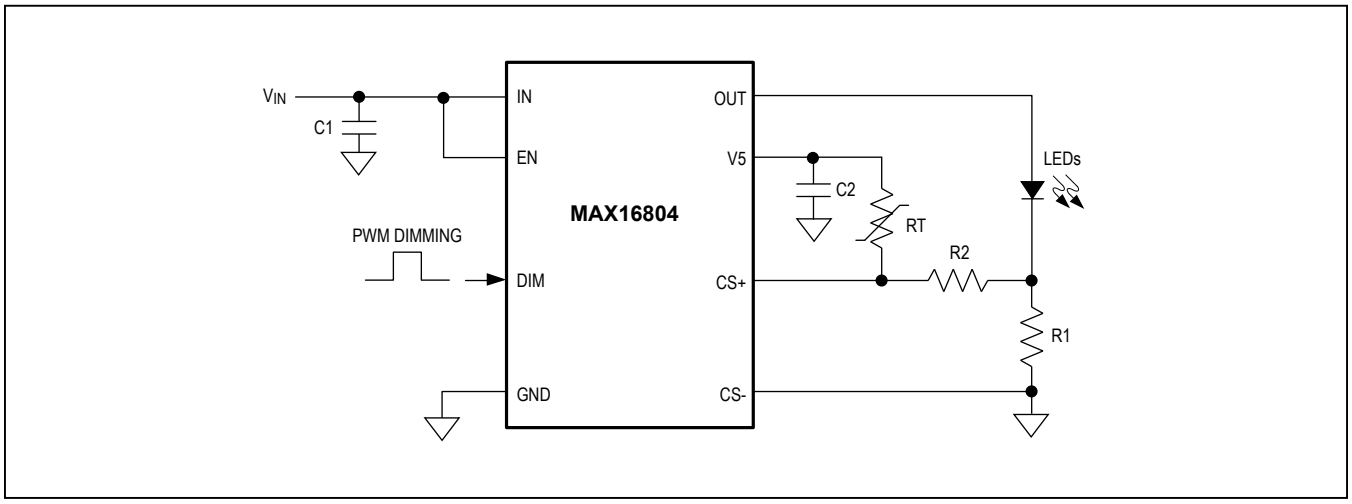


Figure 3. LED Current Thermal Foldback Operation with an NTC Thermistor

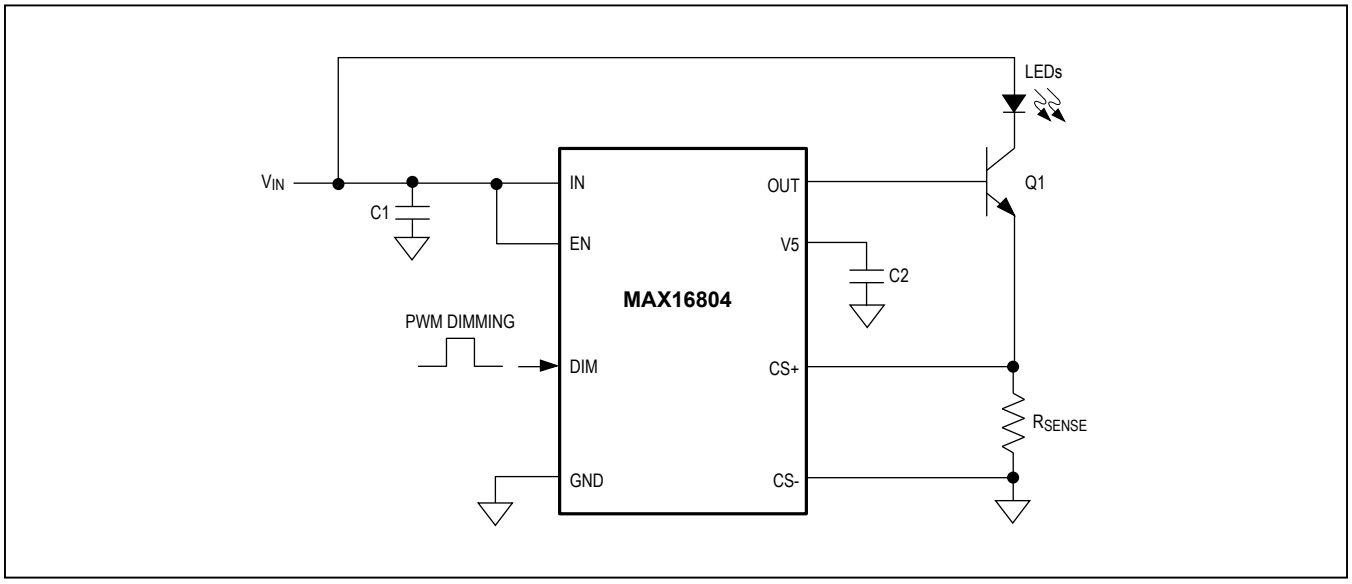
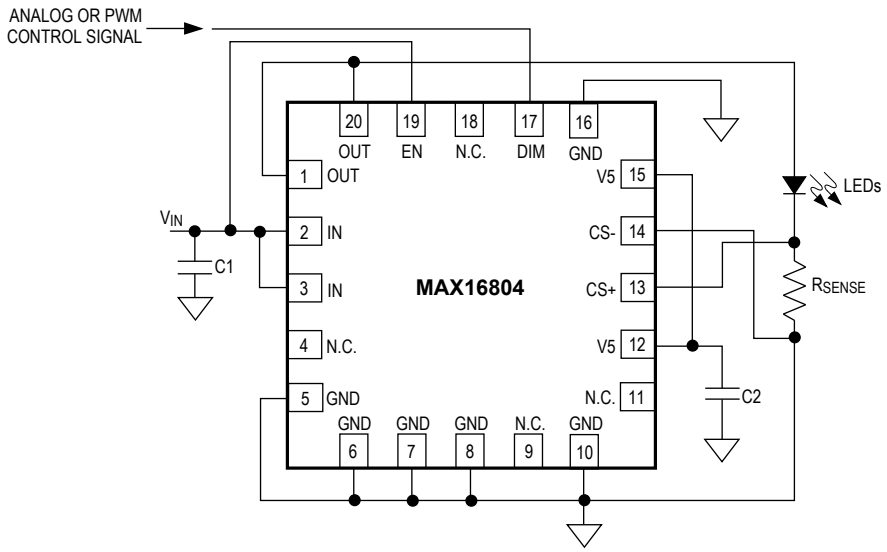
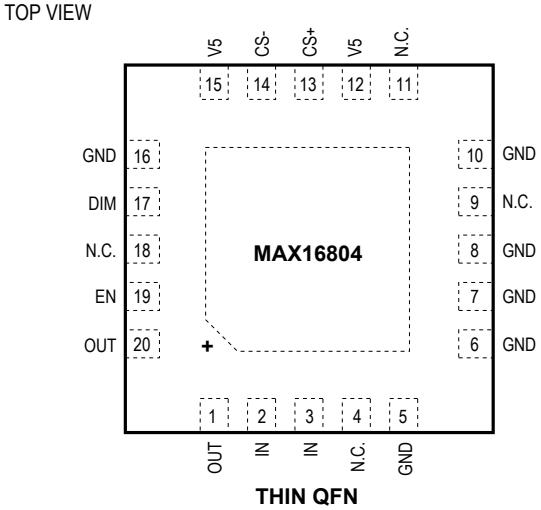


Figure 4. Increased Output Current (Ampere Range) with a Single BJT

Typical Operating Circuit



Pin Configuration



THIN QFN

Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.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.
20 TQFN	T2055MN-5	21-0140

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	7/06	Initial release	—
1	5/08	Corrected Figure 2.	7
2	1/15	Updated *Benefits and Features* section	1
3	4/15	Deleted automotive references in *General Description*, *Applications*, and *Detailed Description* sections	1, 6

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

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