MH1683A/MH1683C

2MHz, High-Brightness LED Drivers with Integrated MOSFET and High-Side Current Sense

General Description

The MH1683A/MH1683C step-down constant-current high-brightness LED (HB LED) drivers provide a cost-effective design solution for automotive interior/exterior lighting, architectural and ambient lighting, LED bulbs, and other LED illumination applications.

The MH1683A/MH1683C operate from a +6.5V to +65V input voltage range and can provide an output current up to 700mA, if operated up to a temperature of +125°C, or up to a 1A if operated up to a temperature of +105°C. A high-side current-sense resistor adjusts the output current, and a dedicated pulse-width modulation (PWM) input enables pulsed LED dimming over a wide range of brightness levels.

These devices are well suited for applications requiring a wide input voltage range. The high-side current sensing and an integrated current-setting circuitry minimize the number of external components while delivering an average output current with ±3% accuracy. A hysteretic control method ensures excellent input supply rejection and fast response during load transients and PWM dimming. The MH1683A allows 10% current ripple, and the MH1683C allows 30% current ripple. Both devices operate up to a 2MHz switching frequency, thus allowing the use of small-sized components.

The MH1683A/MH1683C offer an analog dimming feature that reduces the output current by applying an external DC voltage below the internal 2V threshold voltage from TEMP_I to GND. TEMP_I also sources 25µA to a negative temperature coefficient (NTC) thermistor connected between TEMP_I and GND, thus providing an analog thermal-foldback feature that reduces the LED current when the temperature of the LED string exceeds a specified temperature point. Additional features include thermal-shutdown protection.

The MH1683A/MH1683C operate over the -40°C to +125°C automotive temperature range and are available in a thermally enhanced 8-pin SO package.

Applications

- Architectural, Industrial, and Ambient Lighting
- Automotive RCL, DRL, and Fog Lights
- Heads-Up Displays
- Indicator and Emergency Lighting
- PoE Powered Lighting

Benefits and Features

- Cost-Effective Solution for a Wide Range of LED Lighting Applications
  - 6.5V to 65V Input Voltage Range
  - Output Current Up to 1A
  - ±3% LED Current Accuracy
  - Selectable Dimming Options: Linear or PWM
- Minimal Component Count Saves Cost and Space
  - On-Board 65V, 0.45Ω Power MOSFET
  - Resistor-Programmable Constant LED Current
  - Integrated High-Side Current Sense with 200mV Current-Sense Reference
  - Hysteretic Control: Up to 2MHz Switching Frequency
- Protection Features and Wide Operating Temperature Range Improves Lighting Fixture Reliability
  - Thermal-Foldback Protection Dims LEDs to Minimize Overheating
  - Thermal-Shutdown Protection
  - Available in a Thermally Enhanced 8-Pin SO Package
  - Operation over -40°C to +125°C Temperature Range

Ordering Information and Pin Configuration appear at end of data sheet.

Typical Application Circuit
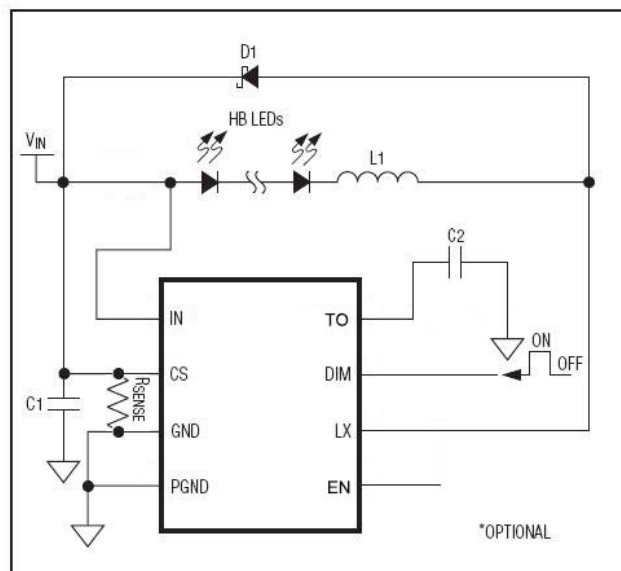
MH1683A/MH1683C

Absolute Maximum Ratings

IN, CS, LX, DIM to GND ....-0.3V to +70V
TEMP_I to GND ....-0.3V to +6V
PGND to GND ....-0.3V to +0.3V
CS to IN ....-0.3V to +0.3V
Maximum Current into Any Pin
  (except IN, LX, and PGND)..20mA
Continuous Power Dissipation (T$_A$ = +70°C)
  8-Pin SO (derate 18.9mW/°C above +70°C)...........1509.4mW

Operating Temperature Range
  700mA (max) Output Current ....-40°C to +125°C
  1A (max) Output Current ....-40°C to +105°C
Junction Temperature...+150°C
Storage Temperature Range ....-65°C to +150°C
Soldering (reflow)...+260°C
Lead Temperature (soldering, 10s) ....+300°C
Pin-to-Pin ESD Ratings..±2.5kV

Package Thermal Characteristics (Note 1)

SO-EP
  Junction-to-Ambient Thermal Resistance (θ$_{JA}$)...............+53°C/W
  Junction-to-Case Thermal Resistance (θ$_{JC}$).....................+5°C/W

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.led-ics.com**

*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$_{IN}$ = +24V, V$_{DIM}$ = V$_{IN}$, T$_A$ = T$_J$ = -40°C to +125°C, unless otherwise noted. Typical values are at T$_A$ = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range	V$_{IN}$		6.5		65	V
Ground Current		No switching		1.5		mA
Supply Current		V$_{DIM}$ < 0.6V, V$_{IN}$ = 12V		350		µA
UNDERVOLTAGE LOCKOUT (UVLO)						
Undervoltage Lockout	UVLO	V$_{CS}$ = V$_{IN}$ - 100mV, V$_{IN}$ rising until V$_{LX}$ < 0.5V$_{IN}$		6.25	6.5	V
		V$_{CS}$ = V$_{IN}$ - 100mV, V$_{IN}$ falling until V$_{LX}$ > 0.5V$_{IN}$			6.0	
Undervoltage-Lockout Hysteresis				0.5		V
SENSE COMPARATOR						
Sense Voltage Threshold High	V$_{SNSHI}$	**MH1683A**, V$_{IN}$ - V$_{CS}$ rising from 140mV until V$_{LX}$ > 0.5V$_{IN}$, V$_{DIM}$ = 5V	197	205	213	mV
		MH1683C, V$_{IN}$ - V$_{CS}$ rising from 140mV until V$_{LX}$ > 0.5V$_{IN}$, V$_{DIM}$ = 5V	218	230	236	
Sense Voltage Threshold Low	V$_{SNSLO}$	**MH1683A**, V$_{IN}$ - V$_{CS}$ falling from 260mV until V$_{LX}$ < 0.5V$_{IN}$, V$_{DIM}$ = 5V	185	190	198	mV
		MH1683C, V$_{IN}$ - V$_{CS}$ falling from 260mV until V$_{LX}$ < 0.5V$_{IN}$, V$_{DIM}$ = 5V	166	170	180	
Propagation Delay to Output High	t$_{DPDH}$	Falling edge of V$_{IN}$ - V$_{CS}$ from 140mV to 260mV to V$_{LX}$ > 0.5V$_{IN}$		50		ns
Propagation Delay to Output Low	t$_{DPDL}$	Rising edge of V$_{CS}$ - V$_{IN}$ from 260mV to 140mV to V$_{LX}$ < 0.5V$_{IN}$		50		ns
CS Input Current	I$_{CSIN}$	V$_{IN}$ - V$_{CS}$ = 200mV, V$_{IN}$ = V$_{CS}$			3.5	µA

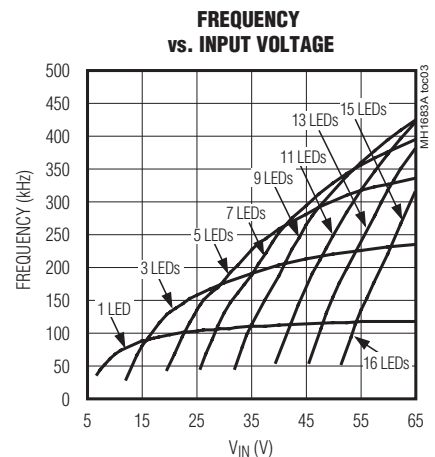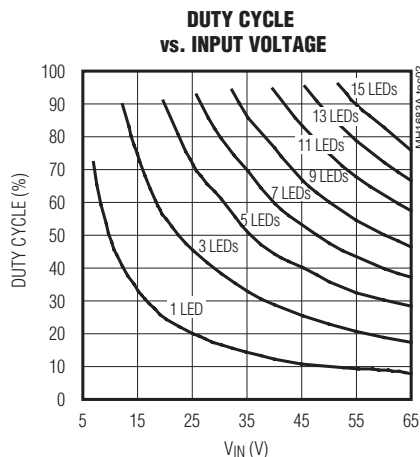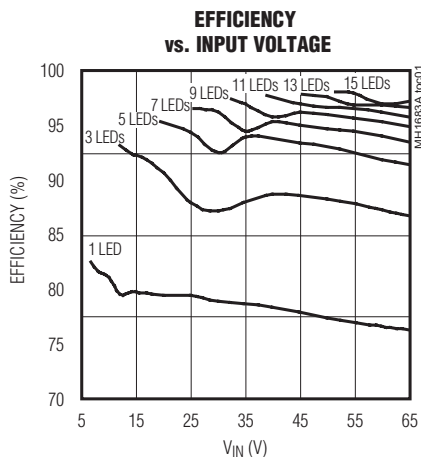## Electrical Characteristics (continued)

(V_{IN} = +24V, V_{DIM} = V_{IN}, T_A = T_J = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
INTERNAL MOSFET						
Drain-to-Source Resistance	R_{DSON}	V_{IN} = V_{DIM} = 24V, V_{CS} = 23.9V, I_{LX} = 700mA		0.45	0.9	Ω
		V_{IN} = V_{DIM} = 6.0V, V_{CS} = 5.9V, I_{LX} = 700mA		1	2	
LX Leakage Current	I_{LX_LEAK}	V_{DIM} = 0V, V_{LX} = 65V			10	µA
DIM INPUT						
DIM Input-Voltage High	V_{IH}	V_{IN} - V_{CS} = 100mV	2.8			V
DIM Input-Voltage Low	V_{IL}	V_{CS} - V_{IN} = 100mV			0.6	V
DIM Turn-On Time	t_{DIM_ON}	V_{DIM} rising edge to V_{LX} < 0.5V_{IN}		60		ns
DIM Input Leakage High		V_{DIM} = V_{IN}		8	15	µA
DIM Input Leakage Low		V_{DIM} = 0V	-3	-1.5	0	µA
THERMAL SHUTDOWN						
Thermal-Shutdown Threshold		Temperature rising		+165		°C
Thermal-Shutdown Threshold Hysteresis				10		°C
THERMAL FOLDBACK						
Thermal-Foldback Enable Threshold Voltage	V_{TFB_ON}	V_{DIM} = 5V	1.9	2.0	2.12	V
Thermal-Foldback Slope	FB_{SLOPE}	V_{DIM} = 5V		0.75		1/V
TEMP_I Output Bias Current	I_{TEMP_I}	T_A = +25°C	25	26.5	28	µA

Typical Operating Characteristics

(V_{IN} = V_{DIM} = 48V, R_{SENSE} = 0.3Ω, L = 220µH (connected between IN and CS). Typical values are at T_A = +25°C, unless otherwise noted.)
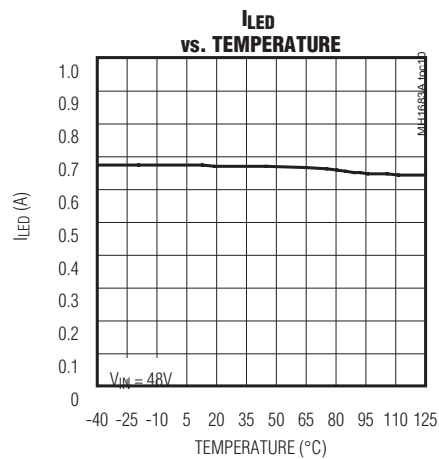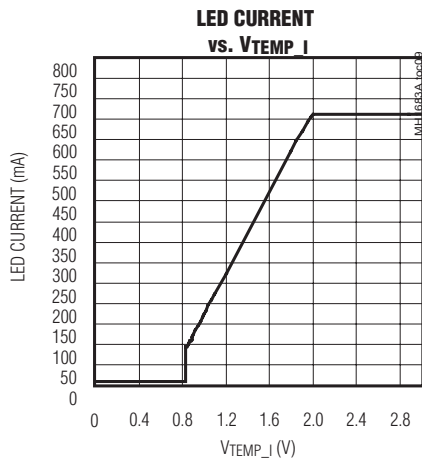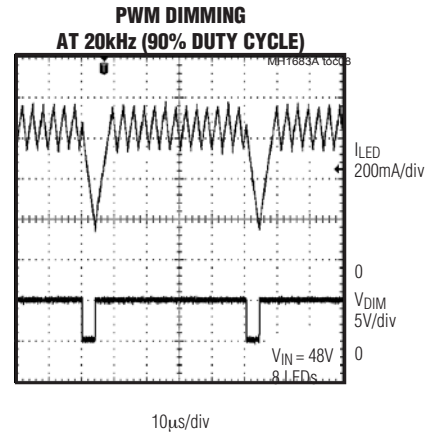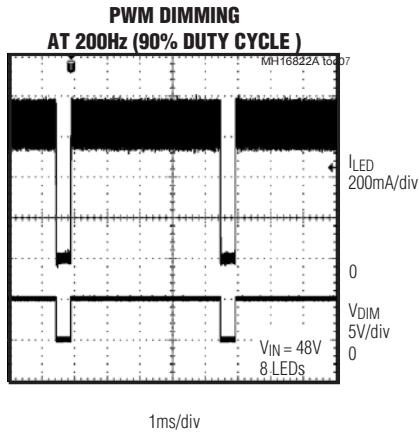

EFFICIENCY vs. INPUT VOLTAGE

DUTY CYCLE vs. INPUT VOLTAGE

FREQUENCY vs. INPUT VOLTAGE
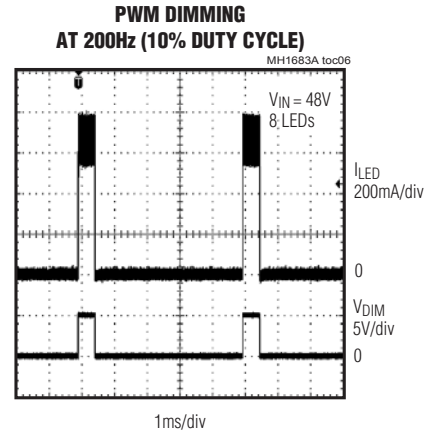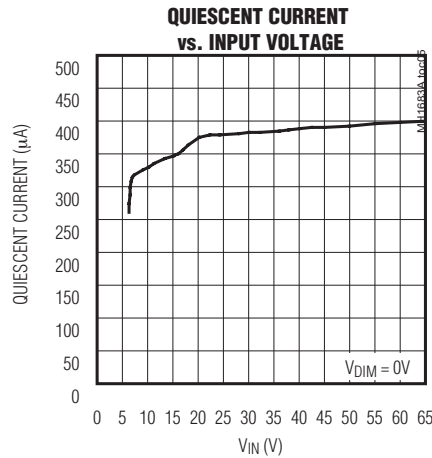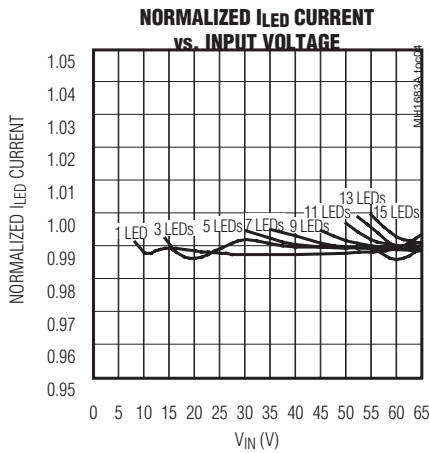
2MHz, High-Brightness LED Drivers
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Typical Operating Characteristics (continued)

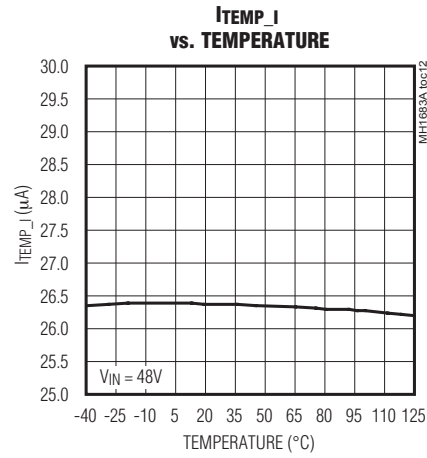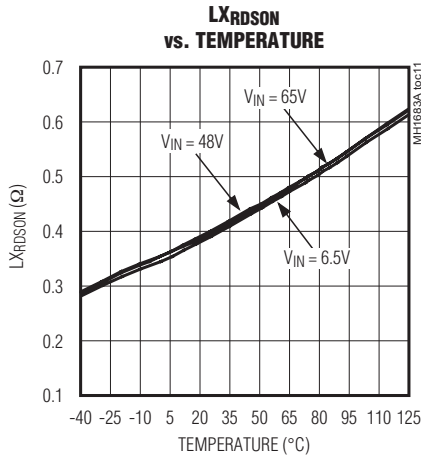(V_{IN} = V_{DIM} = 48V, R_{SENSE} = 0.3Ω, L = 220µH (connected between IN and CS). Typical values are at T_A = +25°C, unless otherwise noted.)

NORMALIZED I_{LED} CURRENT vs. INPUT VOLTAGE

QUIESCENT CURRENT vs. INPUT VOLTAGE

PWM DIMMING AT 200Hz (10% DUTY CYCLE)

PWM DIMMING AT 200Hz (90% DUTY CYCLE)

PWM DIMMING AT 20kHz (90% DUTY CYCLE)

LED CURRENT vs. V_{TEMP_I}

I_{LED} vs. TEMPERATURE

Typical Operating Characteristics (continued)

(V_{IN} = V_{DIM} = 48V, R_{SENSE} = 0.3Ω, L = 220µH (connected between IN and CS). Typical values are at T_A = +25°C, unless otherwise noted.)

Pin Description

PIN	NAME	FUNCTION
1	CS	Current-Sense Input. Connect a resistor between IN and CS to program the LED current.
2	IN	Positive Supply Voltage Input. Bypass with a 1µF or higher value capacitor to GND.
3	GND	Ground
4	PGND	Power Ground
5, 6	LX	Switching Node
7	DIM	Logic-Level Dimming Input. Drive DIM low to turn off the current regulator. Drive DIM high to enable the current regulator.
8	TEMP_I	Thermal Foldback Control and Linear Dimming Input. Bypass with a 0.01µF capacitor to GND if thermal foldback or analog dimming is used. See the *Thermal Foldback* section.
—	EP	Exposed Pad. Connect EP to a large-area ground plane for effective power dissipation. Do not use as the IC ground connection.

Detailed Description

The **MH1683A/MH1683C** are step-down, constant-current, HB LED drivers. These devices operate from a +6.5V to +65V input voltage range. The maximum output is 1A, if the part is used at temperatures up to T_A = +105°C, or 700mA, if it is used up to T_A = +125°C. A high-side current-sense resistor sets the output current and a dedicated PWM dimming input enables pulsed LED dimming over a wide range of brightness levels.

A high-side current-sensing scheme and an on-board current-setting circuitry minimize the number of external components while delivering LED current with ±3% accuracy, using a 1% sense resistor. See Figure 1 for a functional diagram.

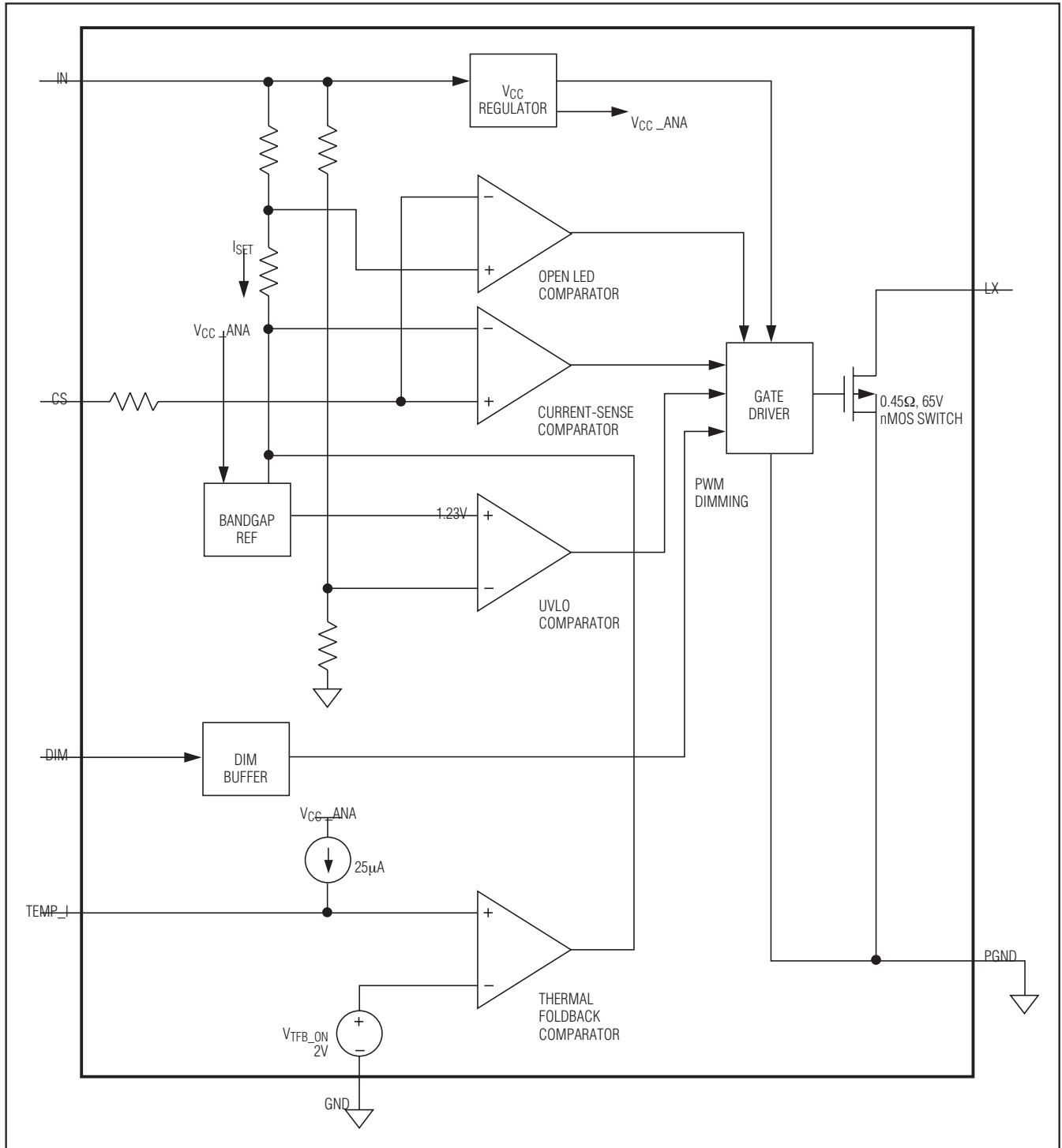# 2MHz, High-Brightness LED Drivers with Integrated MOSFET and High-Side Current Sense

Figure 1. Functional Diagram

Undervoltage Lockout (UVLO)

The MH1683A/MH1683C include a UVLO with 500mV hysteresis. The internal MOSFET turns off when V_{IN} falls below 5.5V to 6.0V.

DIM Input

LED dimming is achieved by applying a PWM signal at DIM. A logic level below 0.6V at DIM forces the MH1683A/MH1683Cs' output low, thus turning off the LED current. To turn the LED current on, the logic level at DIM must be greater than 2.8V.

Thermal Shutdown

The MH1683A/MH1683C thermal-shutdown feature turns off the LX driver when the junction temperature exceeds +165°C. The LX driver turns back on when the junction temperature drops 10°C below the shutdown temperature threshold.

Analog Dimming

The MH1683A/MH1683C offer an analog-dimming feature that reduces the output current when the voltage at TEMP_I is below the internal 2V threshold voltage. The MH1683A/MH1683C achieve analog dimming by either an external DC voltage source connected between TEMP_I and ground or by a voltage on a resistor connected across TEMP_I and ground induced by an internal current source of 25µA. When the voltage at TEMP_I is below the internal 2V threshold limit, the MH1683A/MH1683C reduce the LED current. Use the following formula to set the analog dimming current:

$$I_{TF}(A) = I_{LED}(A) \times \left[1 - FB_{SLOPE}\left(\frac{1}{V}\right) \times \left(V_{TFB\_ON} - V_{AD}\right)(V) \right]$$

where $V_{TFB\_ON} = 2V$ and $FB_{SLOPE} = 0.75$ are obtained from the *Electrical Characteristics* table and V_{AD} is the voltage at TEMP_I.

Thermal Foldback

The MH1683A/MH1683C include a thermal-foldback feature that reduces the output current when the temperature of the LED string exceeds a specified temperature point. These devices enter thermal-foldback mode when the voltage drop on the NTC thermistor, thermally attached to the LEDs and electrically connected between TEMP_I and ground, drops below the internal 2V threshold limit.

Applications Information

Selecting R_{SENSE} to Set LED Current

The LED current is programmed with a current-sense resistor connected between IN and CS. Use the following equation to calculate the value of this resistor:

$$R_{SENSE}(\Omega) = \frac{1}{2}\frac{(V_{SNSHI} + V_{SNSLO})(V)}{I_{LED}(A)}$$

where V_{SNSHI} is the sense voltage threshold high and V_{SNSLO} is the sense voltage threshold low (see the *Electrical Characteristics* table for values).

Current-Regulator Operation

The MH1683A/MH1683C regulate the LED current using a comparator with hysteresis (see Figure 2). As the current through the inductor ramps up and the voltage across the sense resistor reaches the upper threshold, the internal MOSFET turns off. The internal MOSFET turns on again when the inductor current ramps down through the freewheeling diode until the voltage across the sense resistor equals the lower threshold. Use the following equation to determine the operating frequency:

$$f_{SW} = \frac{(V_{IN} - nV_{LED}) \times nV_{LED} \times R_{SENSE}}{V_{IN} \times \Delta V \times L}$$

where n is the number of LEDs, V_{LED} is the forward voltage drop of 1 LED, and $\Delta V = (V_{SNSHI} - V_{SNSLO})$.

Inductor Selection

The MH1683A/MH1683C operate up to a switching frequency of 2MHz. For space-sensitive applications, the high switching frequency allows the size of the inductor to be reduced. Use the following formula to calculate an approximate inductor value and use the closest standard value:

$$L(approx.) = \frac{(V_{IN} - nV_{LED}) \times nV_{LED} \times R_{SENSE}}{V_{IN} \times \Delta V \times f_{SW}}$$

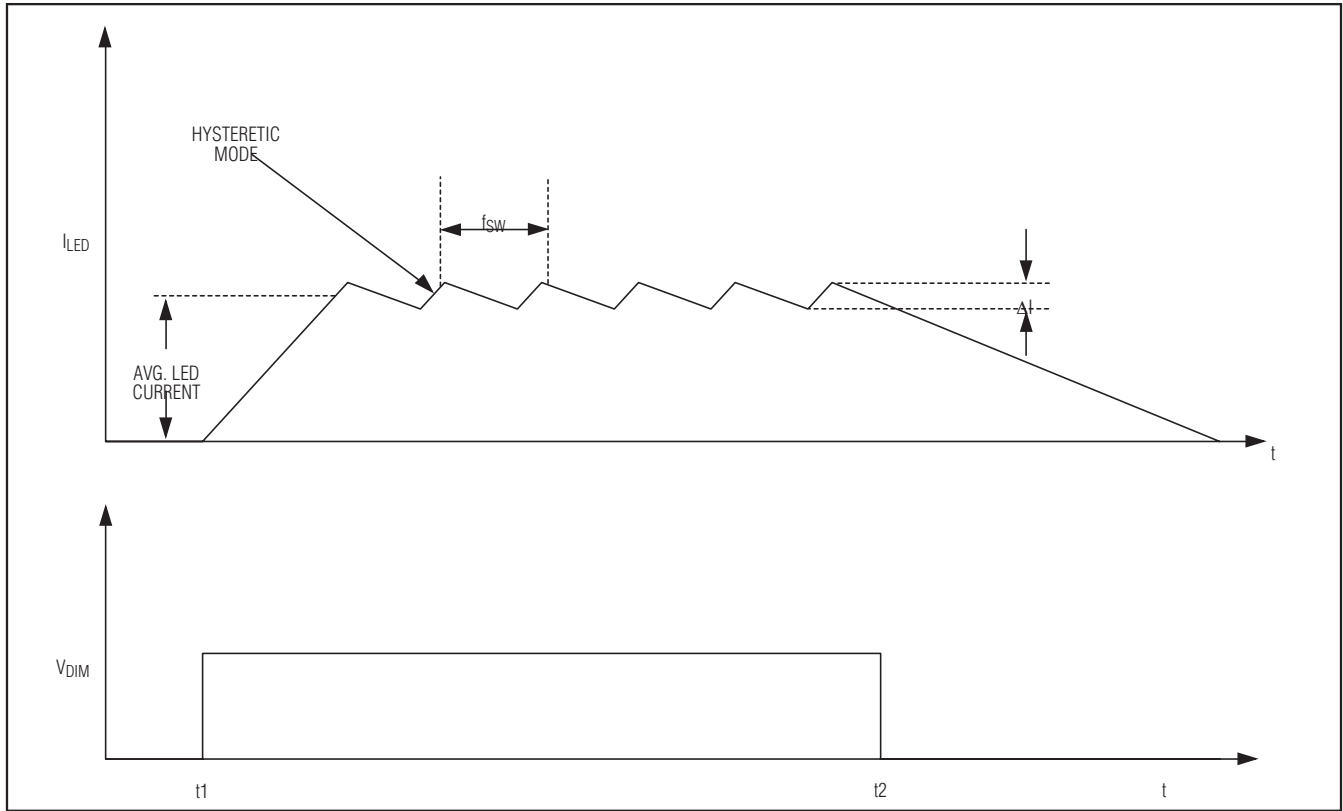For component selection, use the MH1683A/C Design Tool available at: **www.led-ics.com**

Figure 2. Current-Regulator Operation

Freewheeling-Diode Selection

For stability and best efficiency, a low forward-voltage drop diode with fast reverse-recovery time and low capacitance is recommended. A Schottky diode is a good choice as long as its breakdown voltage is high enough to withstand the maximum operating voltage.

PCB Layout Guidelines

Careful PCB layout is critical to achieve low switching losses and stable operation. In normal operation, there are two power loops. One is formed when the internal MOSFET is on and the high current flows from ground through the input cap, R_{SENSE}, the LED load, the inductor, and the internal MOSFET back to ground. The second loop is formed when the internal MOSFET is off and the high current circulates from the input cap positive terminal through R_{SENSE}, the LED load, the inductor, and the freewheeling diode and back to the input cap positive terminal. Note that the current through R_{SENSE}, the LED load, and the inductor is basically DC with some triangular ripple (low noise). The high-noise, large signal, fast transition switching currents only flow through the freewheeling diode to the input cap positive

terminal, or through the MOSFET to ground and then to the input cap positive terminal. Without a proper PCB layout, these square-wave switching currents can create problems in a hysteretic LED driver.

The current control depends solely on the voltage across R_{SENSE}. Any noise pickup on this node induces erratic switching of the internal MOSFET (the IC will operate at a much higher frequency). To help prevent this, place R_{SENSE} as close as possible to CS and IN and keep the sense traces short. It is especially important to keep the square-wave switching currents in the freewheeling diode away from R_{SENSE}. To minimize interference, place the freewheeling diode on the opposite side of the IC as R_{SENSE} and position the input capacitor near the diode so it can return the high frequency currents to ground. The layout in Figure 3 should be used as a guideline. The dashed line shows the path of the high frequency components that cause disruption in operation. For a good thermal design, the exposed pad on the IC should solder to a large pad with many vias to the backside ground plane.
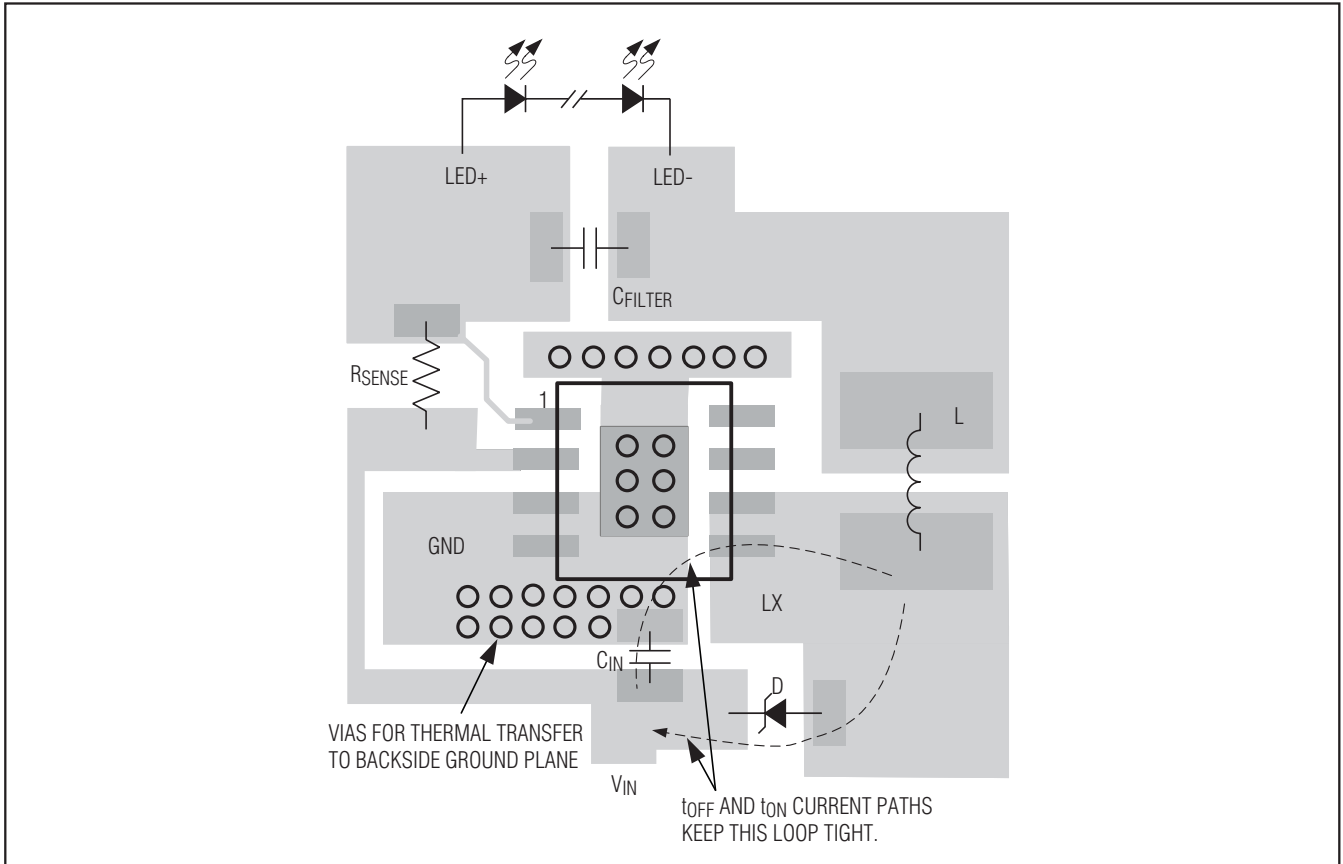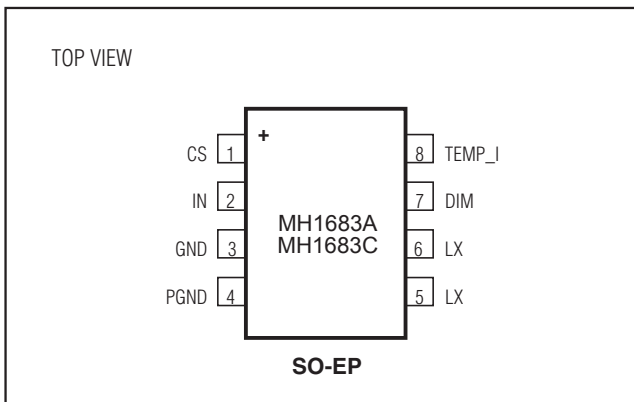
2MHz, High-Brightness LED Drivers
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Figure 3. PCB Layout

Pin Configuration

Chip Information
PROCESS: BiCMOS