MIC2870

1.5A Synchronous Boost Flash LED Driver with I²C Interface

Features

- Up to 1.5A Flash LED Driving Current
- 2.7V to 5.0V Input Voltage Range
- High-Efficiency 2 MHz V_F Adaptive Boost Driver
- Configurable 1 or 2 Channel(s) WLED Driver
- LED Driving Current Soft-Start
- Control through I²C Interface or External Pins
- Flash Inhibit Function for GSM Pulse Synchronization
- True Load Disconnect
- Flash Time-Out Protection
- 1 µA Shutdown Current
- Available in 16-Pin 2 mm x 2 mm TQFN Package

Applications

- Camera Phones/Mobile Handsets
- Cellular Phones/Smartphones
- LED Light for Image Capture/Auto-Focus/ White Balance
- Handset Video Light (Torch Light)
- Digital Cameras
- Portable Applications

General Description

The MIC2870 is a high-current, high-efficiency flash LED driver for one or two high-brightness camera flash LEDs.

The LED drive current is generated by an integrated inductive boost converter with 2 MHz switching frequency, which allows the use of a very small inductor and output capacitor. These features make the MIC2870 an ideal solution for high-resolution camera phone LED flashlight driver applications.

MIC2870 supports two 750 mA white LEDs (WLEDs) or a single 1.5A WLED configuration. When two WLEDs are connected, their currents are matched automatically.

MIC2870 operates in either Flash or Torch mode that can be controlled through either an I²C interface or external pins. The brightness in the Flash and Torch mode can be adjusted via two external resistors individually. The high-speed mode I²C interface provides a simple control at a clock speed up to 3.4 MHz to support most camera functions, such as auto-focus, white balance, and image capture (Flash mode).

The MIC2870 is available in 16-pin, 2 mm x 2 mm TQFN package with a junction temperature range of –40°C to +125°C.

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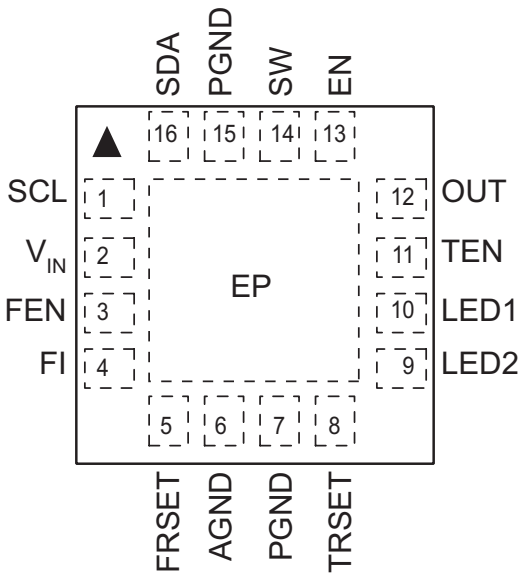
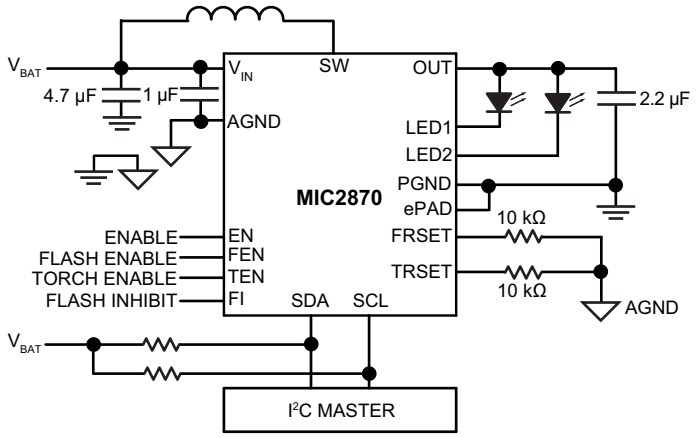
Package Type

MIC2870
16-Pin 2 mm x 2 mm TQFN
(Top View)



Note: Thin QFN Pin 1 identifier = "▲".

Typical Application Schematic



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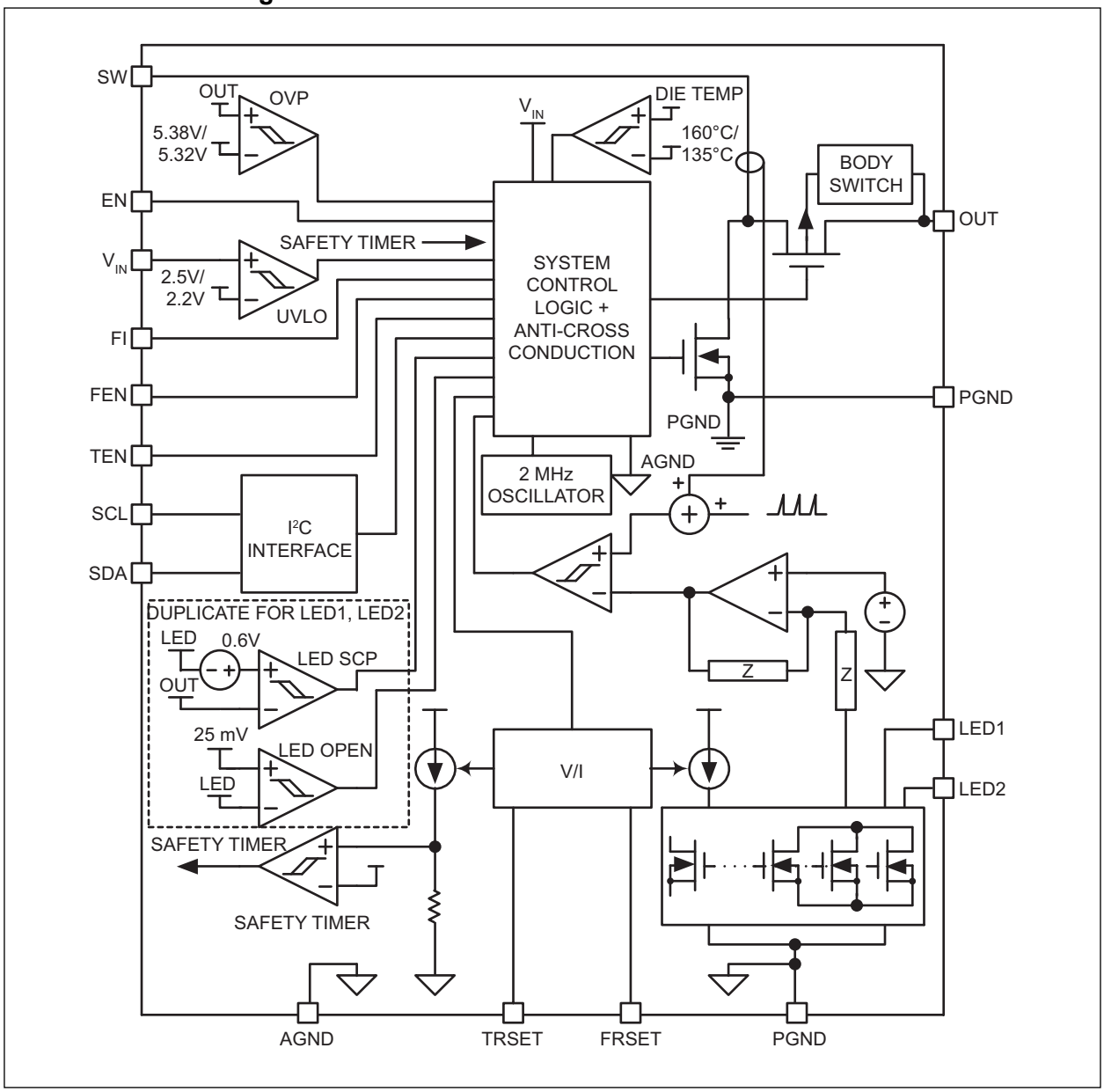
Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings†

Supply Voltage (V_{IN}) ..... -0.3V to +6.0V
Enable Input Voltage (V_{EN}, V_{FEN}, V_{FI}, V_{TEN}) ..... -0.3V to V_{IN} + 0.3V
V_{OUT}, V_{LED1}, and V_{LED2} ..... -0.3V to +6.0V
I^2C I/O (V_{SCL}, V_{SDA}) ..... -0.3V to V_{IN} + 0.3V
V_{FRSET} and V_{TRSET} ..... -0.3V to V_{IN} + 0.3V
V_{SW} ..... -0.3V to +6.0V
Power Dissipation(1) (P_{DISS}) ..... Internally Limited
ESD Rating(2) ..... 2 kV HBM and 150V MM

† **Notice:** Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

Note 1: The maximum allowable power dissipation at any T_A (ambient temperature) is $P_{DISS(max)} = (T_{J(max)} - T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature and the regulator will go into thermal shutdown.

2: Devices are ESD-sensitive. Handling precautions are recommended. Human body model, 1.5 kΩ in series with 100 pF.

Operating Ratings(1)

Supply Voltage (V_{IN}) ..... +2.7V to +5.0V
Enable Input Voltage (V_{EN}, V_{FEN}, V_{FI}, V_{TEN}) ..... 0V to V_{IN}
I^2C I/O (V_{SCL}, V_{SDA}) ..... 0V to V_{IN}

Note 1: The device is not ensured to function outside the operating range.

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TABLE 1-1: ELECTRICAL CHARACTERISTICS[1]

Electrical Specifications: unless otherwise specified, V_{IN} = 3.6V; L = 1 µH; C_{OUT} = 2.2 µF; R_{FRSET} = 10 kΩ; R_{TRSET} = 10 kΩ; I_{LED} = 100 mA; $T_A = T_J$ = +25°C. **Boldface** values indicate -40°C ≤ T_J ≤ +125°C.						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Test Conditions**
Power Supply						
Input Voltage	V_{IN}	**2.7**	—	**5.0**	V	—
Quiescent Current	I_{VIN}	—	0.9	—	mA	$V_{LED1} = V_{LED2}$ > 200 mV, not switching **(Note 2)**
		—	4.2	—		$V_{LED1} = V_{LED2}$ = 70 mV, boost keeps switching **(Note 2)**
Shutdown Current	$I_{VIN(SD)}$	—	0.6	—	µA	V_{EN} = 0V **(Note 2)**
SW Pin Shutdown Current	$I_{SW(SD)}$	—	1	**5**	µA	V_{EN} = 0V
UVLO Threshold (Rising)	UVLO_Rise	2.35	2.5	2.65	V	—
UVLO Hysteresis	UVLO_Hyst	—	300	—	mV	**(Note 2)**
Output Voltage	V_{OUT}	—	—	V_{IN}	V	$V_{IN} \geq V_{OUT}$
		—	—	5.2		$V_{OUT} > V_{IN}$
Overvoltage Protection Threshold	V_{OVP}	**5.26**	5.38	**5.6**	V	$V_{OUT} > V_{IN}$
Overvoltage Protection Hysteresis	V_{OVP_HYS}	—	60	—	mV	**(Note 2)**
OVP Blanking Time	T_{BLANK_OVP}	—	24	—	µs	**(Note 2)**
Maximum Duty Cycle	D_{MAX}	80	85	90	%	—
Minimum Duty Cycle	D_{MIN}	—	5.5	—	%	**(Note 2)**
Switch Current Limit	I_{SW_OC}	**3.35**	4.5	**5.65**	A	$V_{IN} = V_{OUT}$ = 2.7V
Oscillator Frequency	F_{SW}	1.8	2.0	2.2	MHz	—
Switch-on Resistance	$R_{ON(N)}$	—	80	—	mΩ	V_{VIN} = 2.7V, I_{SW} = 750 mA **(Note 2)**
	$R_{ON(P)}$	—	80	—		V_{SW} = 2.7V, I_{OUT} = 750 mA **(Note 2)**
NMOS Switch Leakage Current	$I_{LK(N)}$	—	1	**5**	µA	V_{EN} = 0V, $V_{IN} = V_{SW} = V_{OUT}$ = 5V
PMOS Switch Leakage Current	$I_{LK(P)}$	—	1	**5**	µA	V_{EN} = 0V, $V_{IN} = V_{OUT}$ = 5V, V_{SW} = 0V
Auto-Discharge NMOS Resistance	R_{DCHG}	—	160	—	Ω	V_{EN} = 0V, I_{OUT} = -1 mA **(Note 2)**
Overtemperature Shutdown Threshold	T_{SD}	—	160	—	°C	**(Note 2)**
Overtemperature Shutdown Hysteresis	T_{SD_HYST}	—	25	—	°C	**(Note 2)**
Flash Safety Time-out Shutdown	$T_{FLASH_TIMEOUT}$	—	1.25	—	s	Maximum time-out setting **(Note 2)**
Current Sink Channels						
Channel Current Accuracy	$Accu_{LED_Ch}$	-10	—	10	%	$V_{LED1} = V_{LED2}$ = 890 mV, $I_{LED1} = I_{LED2}$ = 750 mA
Channel Current Matching	$Match_{LED_Ch}$	-5	—	5	%	$V_{LED1} = V_{LED2}$ = 890 mV, $I_{LED1} = I_{LED2}$ = 750 mA
Current Sink Dropout	$V_{DROPOUT}$	—	100	—	mV	Boost is in regulation **(Note 2)**

Note 1: Specification for packaged product only.

2: Specifications are obtained by design and characterization; not 100% tested in production.

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TABLE 1-1: ELECTRICAL CHARACTERISTICS[1] (CONTINUED)

Electrical Specifications: unless otherwise specified, V_{IN} = 3.6V; L = 1 µH; C_{OUT} = 2.2 µF; R_{FRSET} = 10 kΩ; R_{TRSET} = 10 kΩ; I_{LED} = 100 mA; $T_A = T_J$ = +25°C. **Boldface** values indicate -40°C ≤ T_J ≤ +125°C.						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Test Conditions**
LED1 Leakage Current	I_{LK_LED1}	—	0.05	—	µA	V_{IN} = 3.6V, V_{EN} = 0V, V_{LED1} = 3.6V **(Note 2)**
LED2 Leakage Current	I_{LK_LED2}	—	0.05	—	µA	V_{IN} = 3.6V, V_{EN} = 0V, V_{LED2} = 3.6V **(Note 2)**
FRSET Pin Voltage	V_{FRSET}	**0.970**	1.00	**1.030**	V	R_{FRSET} = 10 kΩ, Flash mode
FRSET Current Sourcing	I_{FRSET}	**90**	100	**110**	µA	F_{RSET} pin is shorted to ground, Flash mode
TRSET Pin Voltage	V_{TRSET}	**0.970**	1.00	**1.030**	V	R_{TRSET} = 10 kΩ, Torch mode
TRSET Current Sourcing	I_{TRSET}	**90**	100	**110**	µA	T_{RSET} pin is shorted to ground, Torch mode
EN/FEN/TEN/FI Control Pins						
EN High-Level Voltage	V_{EN_ON}	**1.5**	—	—	V	Boost converter and chip logic on
EN Low-Level Voltage	V_{EN_OFF}	—	—	**0.4**	V	Boost converter and chip logic off
FEN High-Level Voltage	V_{FEN_ON}	**1.5**	—	—	V	Flash on
FEN Low-Level Voltage	V_{FEN_OFF}	—	—	**0.4**	V	Flash off
TEN High-Level Voltage	V_{TEN_ON}	**1.5**	—	**—**	V	Torch on
TEN Low-Level Voltage	V_{TEN_OFF}	—	—	**0.4**	V	Torch off
FI High-Level Voltage	V_{FI_ON}	**1.5**	—	**—**	V	Flash inhibit on
FI Low-Level Voltage	V_{FI_OFF}	—	—	**0.4**	V	Flash inhibit off
EN Pin Current	—	—	2	5	µA	V_{EN} = 5V
FEN/TEN/FI Pin Current	—	—	1	5	µA	$V_{FEN} = V_{TEN} = V_{FI}$ = 5V
EN Off Blanking Time	$t_{Blank_EN_Off}$	0.90	1.10	1.30	s	EN pin should be driven low for more than this time before the IC enters Sleep mode
I^2C Interface – SCL/SDA Pins (Ensured by Design)						
Maximum Operating Frequency	f_{SCL}	—	—	**3.4**	MHz	—
Low-Level Input Voltage	V_{IL}	—	—	**0.4**	V	—
High-Level Input Voltage	V_{IH}	**1.5**	—	—	V	—
SDA Pull-Down Resistance	R_{SDA_DN}	—	20	—	Ω	**(Note 2)**

Note 1: Specification for packaged product only.

2: Specifications are obtained by design and characterization; not 100% tested in production.

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TABLE 1-1: ELECTRICAL CHARACTERISTICS[1] (CONTINUED)

Electrical Specifications: unless otherwise specified, V_{IN} = 3.6V; L = 1 µH; C_{OUT} = 2.2 µF; R_{FRSET} = 10 kΩ; R_{TRSET} = 10 kΩ; I_{LED} = 100 mA; $T_A = T_J$ = +25°C. **Boldface** values indicate -40°C ≤ T_J ≤ +125°C.						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Test Conditions**
Additional Protection Features						
LED1/LED2 Open Detect Threshold	$V_{TH_LEDOPEN}$	15	25	40	mV	—
Open Detect Blanking Time	T_{BLANK_OPEN}	—	65	—	µs	**(Note 2)**
Open Retry Time-out	T_{RETRY_OPEN}	—	100	—	ms	**(Note 2)**
Short Trigger Threshold	$V_{TH_LEDSHORT}$	400	600	800	mV	V_{OUT} – MAX[V_{LED1},V_{LED2}], V_{OUT} = 3.6V
Short Trigger Hysteresis	$V_{HYST_LED-SHORT}$	—	200	—	mV	**(Note 2)**
Short Trigger Blanking Time	T_{BLANK_SHORT}	—	30	—	µs	**(Note 2)**
Short Retry Time-out	T_{RETRY_SHORT}	—	100	—	ms	**(Note 2)**

Note 1: Specification for packaged product only.

2: Specifications are obtained by design and characterization; not 100% tested in production.

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TEMPERATURE SPECIFICATIONS (Note 1)

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Maximum Junction Temperature Range	T_J	–40	—	150	°C	—
Operating Junction Temperature Range	T_J	–40	—	125	°C	—
Storage Temperature	T_S	–40	—	150	°C	—
Lead Temperature	—	—	—	260	°C	Soldering, 10s
Package Thermal Resistance						
Thermal Resistance 2 mm x 2 mm TQFN-16LD	θ_{JA}	—	+80	—	°C/W	—

Note 1: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e., T_A, T_J, θ_{JA}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +150°C rating. Sustained junction temperatures above +150°C can impact the device reliability.

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2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

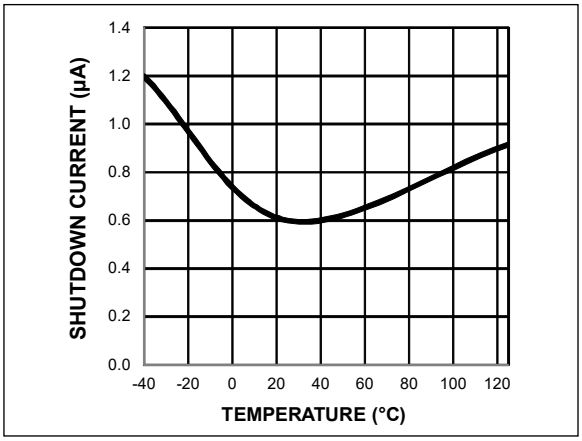

FIGURE 2-1: *Shutdown Current vs. Temperature.*

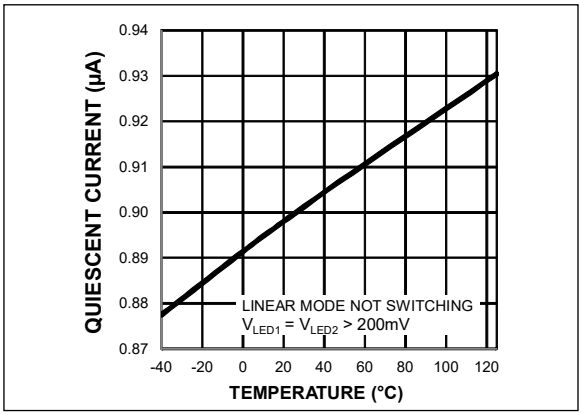

FIGURE 2-2: *Quiescent Current (Linear Mode) vs. Temperature.*

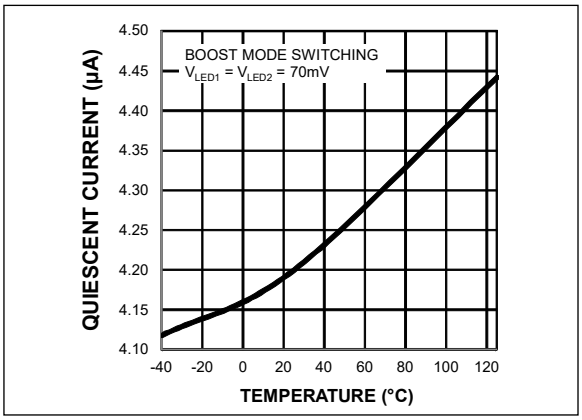

FIGURE 2-3: *Quiescent Current (Boost Mode) vs. Temperature.*

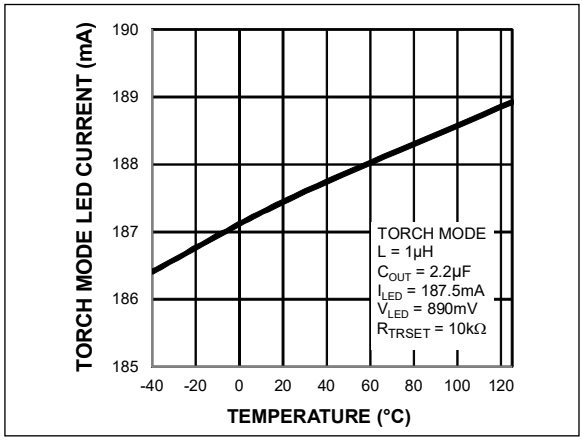

FIGURE 2-4: *Torch Mode LED1 and LED2 Current vs. Temperature.*

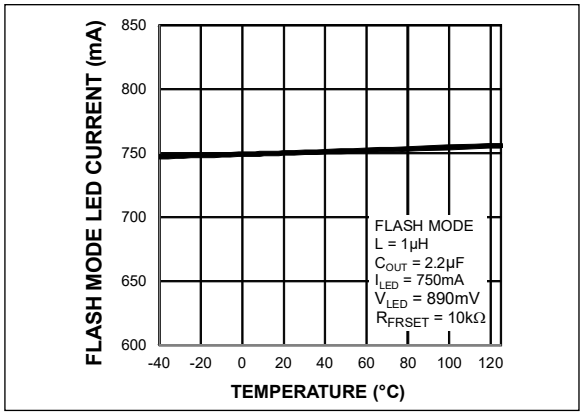

FIGURE 2-5: *Flash Mode LED1 and LED2 Current vs. Temperature.*

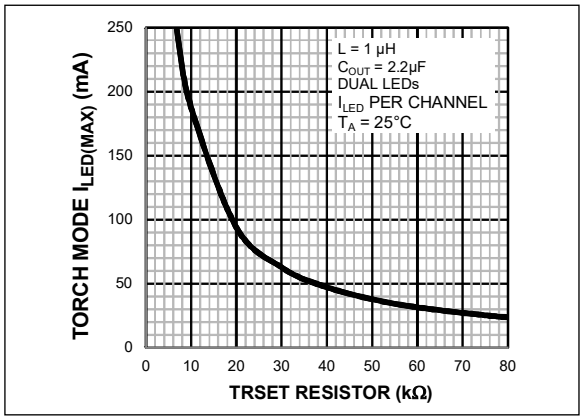

FIGURE 2-6: *Torch Mode $I_{LED(MAX)}$ (Dual LEDs) vs. TRSET Resistor.*

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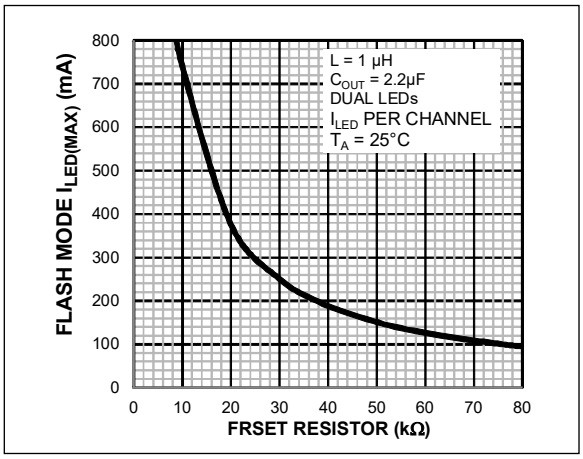

FIGURE 2-7: *Flash Mode $I_{LED(MAX)}$ (Dual LEDs) vs. FRSET Resistor.*

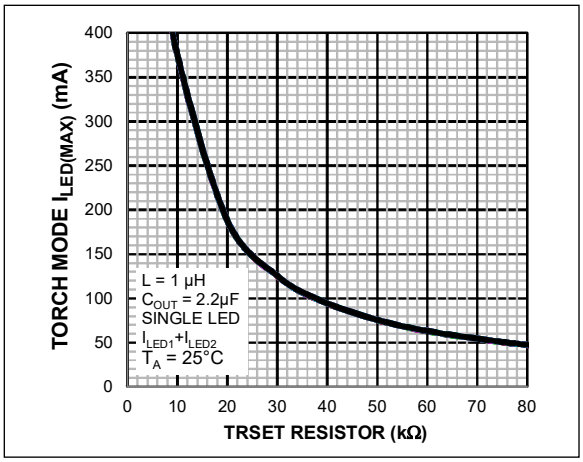

FIGURE 2-8: *Torch Mode $I_{LED(MAX)}$ (Single LED) vs. TRSET Resistor.*

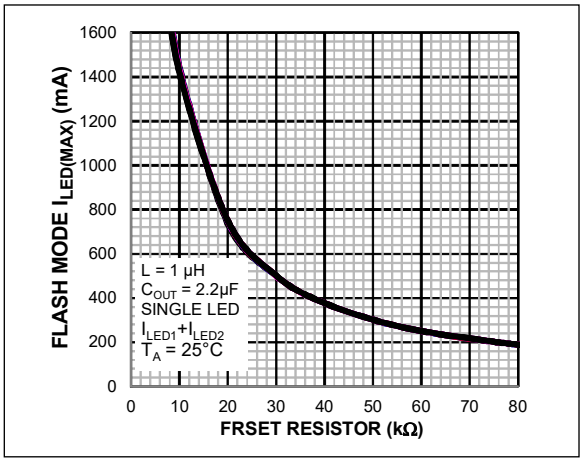

FIGURE 2-9: *Flash Mode $I_{LED(MAX)}$ (Single LED) vs. FRSET Resistor.*

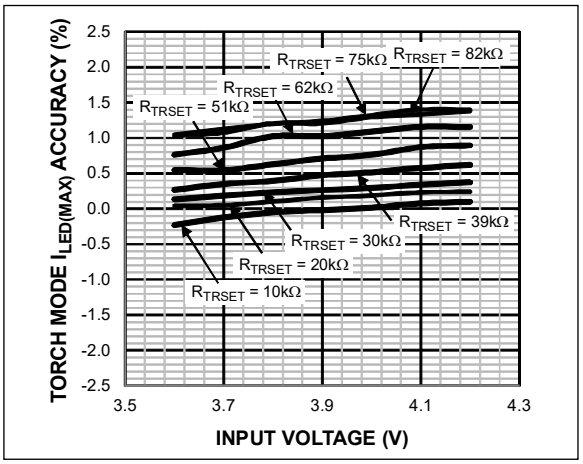

FIGURE 2-10: *Torch Mode $I_{LED(MAX)}$ Accuracy vs. Input Voltage.*

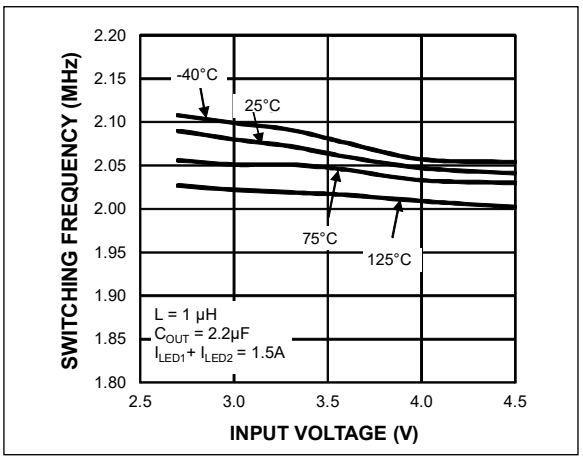

FIGURE 2-11: *Boost Switching Frequency vs. Input Voltage.*

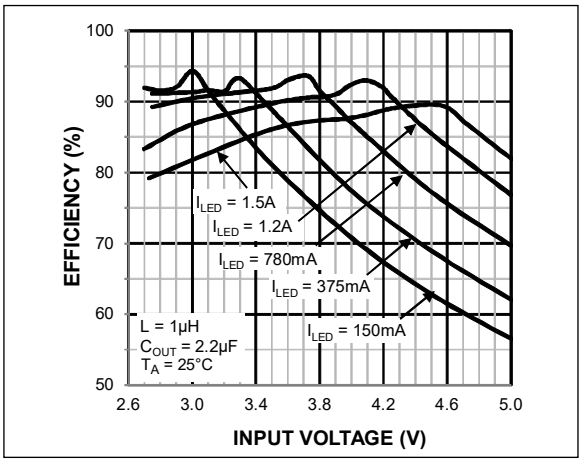

FIGURE 2-12: *WLED Output Power Efficiency vs. Input Voltage.*

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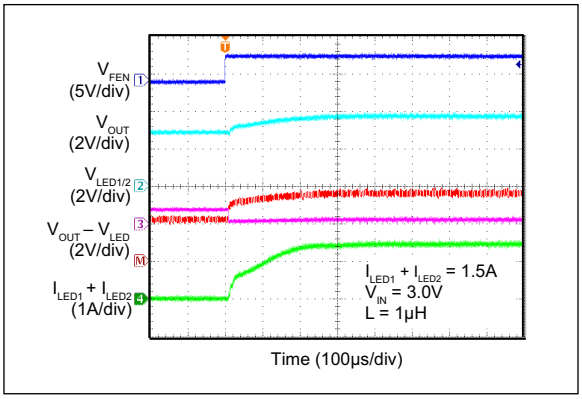

FIGURE 2-13: *Flash Mode Turn-On Sequence (Boost Mode).*

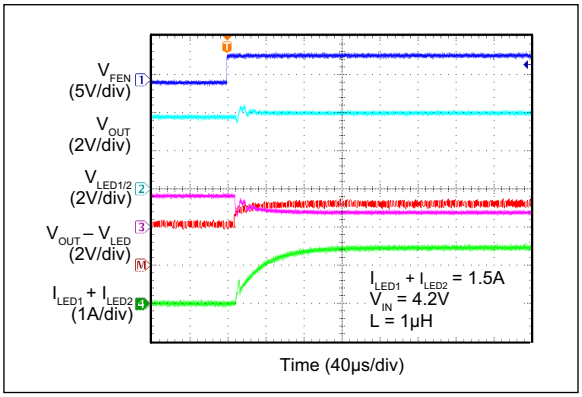

FIGURE 2-14: *Flash Mode Turn-On Sequence (Linear Mode).*

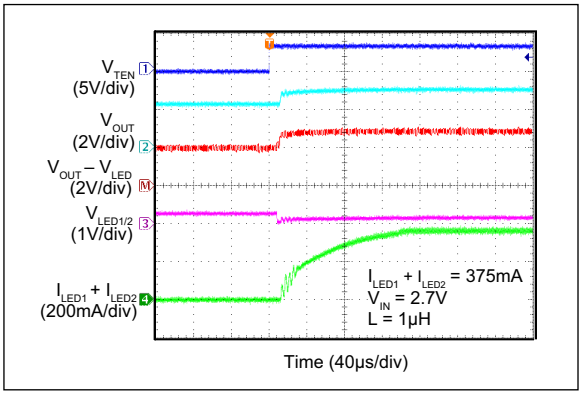

FIGURE 2-15: *Torch Mode Turn-On Sequence (Boost Mode).*

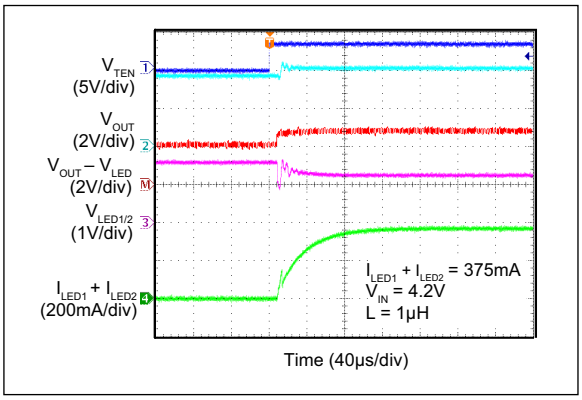

FIGURE 2-16: *Torch Mode Turn-On Sequence (Linear Mode).*

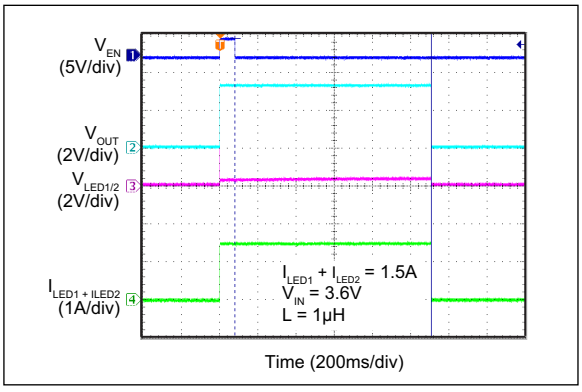

FIGURE 2-17: *Flash Mode Load Disconnect and Enable Off Blanking Time.*

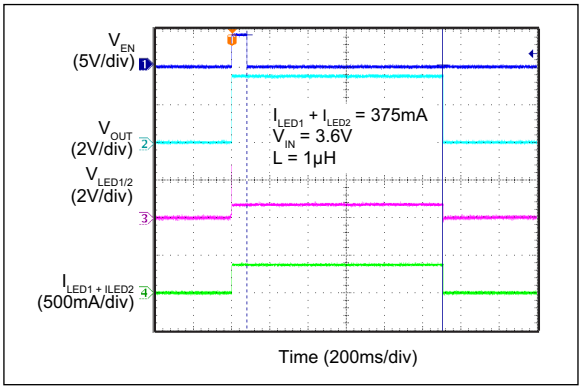

FIGURE 2-18: *Torch Mode Load Disconnect and Enable Off Blanking Time.*

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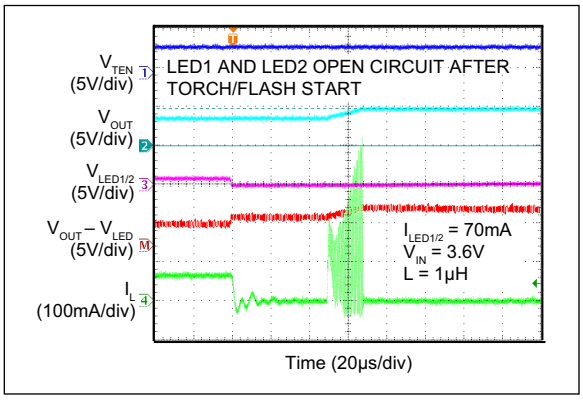

FIGURE 2-19: *LED Open-Circuit Protection.*

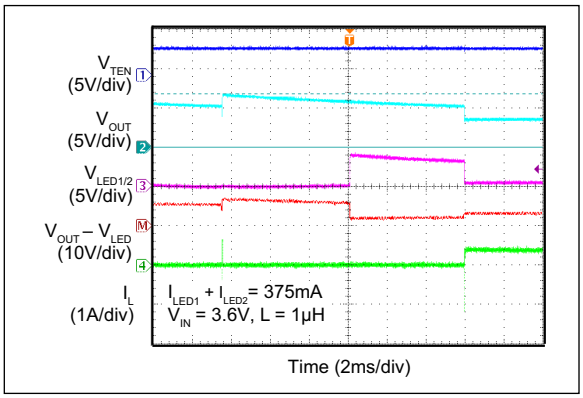

FIGURE 2-20: *LED Open-Circuit Protection Recovery.*

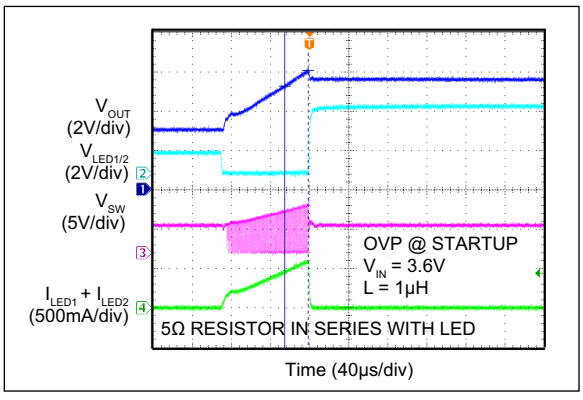

FIGURE 2-21: *Overvoltage Protection.*

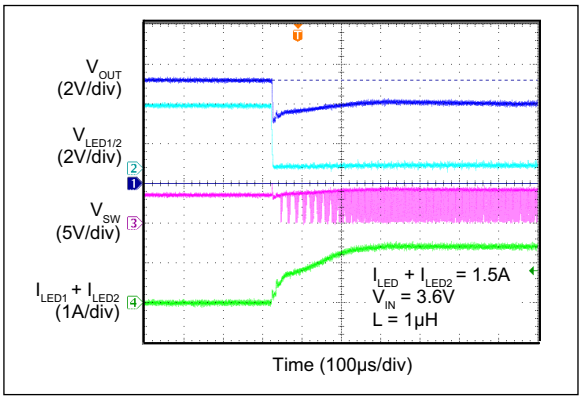

FIGURE 2-22: *Overvoltage Protection Recovery.*

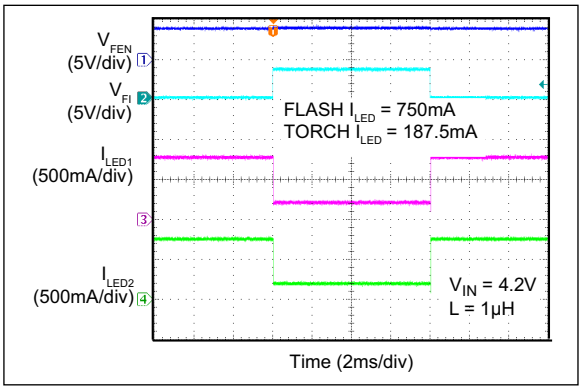

FIGURE 2-23: *Flash Inhibit and Recovery.*

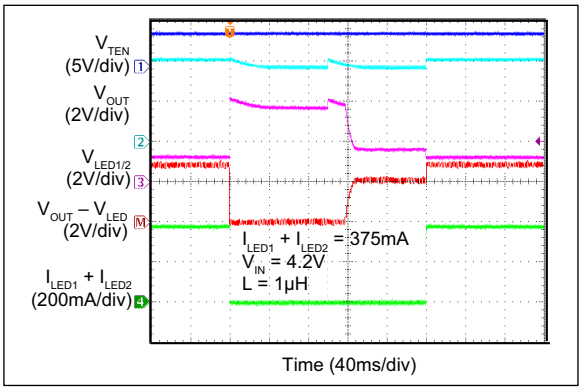

FIGURE 2-24: *LED Short-Circuit Protection, Retry and Recovery.*

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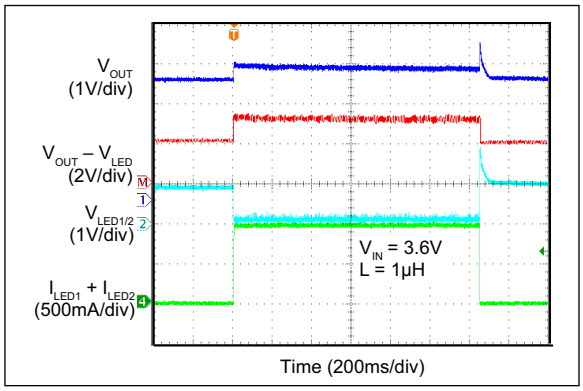

FIGURE 2-25: *Flash Safety Timer @ 1250 ms.*

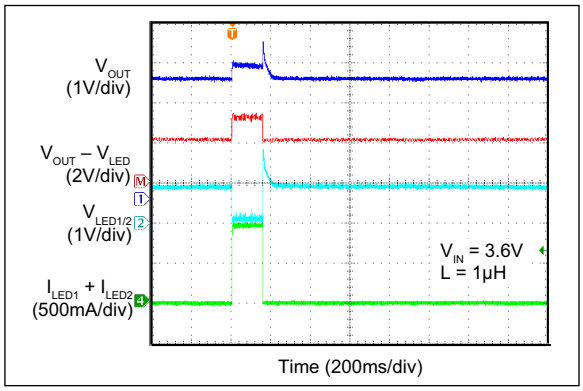

FIGURE 2-26: *Flash Safety Timer @ 156 ms.*

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3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

MIC2870 Pin Number	Pin Name	Pin Function
1	SCL	High-Speed Mode (3.4 MHz) I^2C Clock Input.
2	V_{IN}	Supply Input: Connect a low-ESR ceramic capacitor of at least 4.7 µF to PGND. A small capacitor of 100 nF between V_{IN} and AGND is highly recommended.
3	FEN	Flash Mode Enable Pin: A low-to-high transition initiates the Flash mode and Flash mode timer. If FEN is left floating, it is pulled-down internally by a built-in 1 µA current source when the device is enabled.
4	FI	Flash Inhibit: When FI is pulled high, both LED currents are changed from the Flash mode current level to the Torch mode current level. If FI is left floating, it is pulled down internally by a built-in 1 µA current source when the device is enabled. This function is generally used to reduce instantaneous battery load current by synchronizing with the handset's GSM pulse off-time.
5	FRSET	Flash Mode Current-Level Programming: Connect a resistor from FRSET to AGND to set the maximum current in the Flash mode. For example, a 10 kΩ resistor sets the LED sink current to its maximum value of 750 mA per channel. FRSET can be grounded if the default maximum Flash mode current (750 mA) is desired. FRSET, however, cannot be left floating and the maximum resistance is limited to 80 kΩ.
6	AGND	Analog Ground: Reference ground for the FRSET and TRSET pins.
7, 15	PGND	Power Ground: PGND is used for the switching NMOS and PMOS of boost converter and Power Ground for LED current sinks.
8	TRSET	Torch Mode Current Level Programming: Connect a resistor from TRSET to AGND to set the maximum current in the Torch mode. For example, a 10 kΩ resistor sets the LED sink current to its maximum value of 187.5 mA per channel. TRSET can be grounded if the default maximum Torch mode current (187.5 mA) is desired. TRSET, however, cannot be left floating and the maximum resistance is limited to 80 kΩ.
9	LED2	Channel 2 LED Current Sink: Connect the LED anode to OUT and the cathode to LED2.
10	LED1	Channel 1 LED Current Sink: Connect the LED anode to OUT and the cathode to LED1.
11	TEN	Torch Mode Enable: Initiates Torch mode when TEN is high. If TEN is left floating, it is pulled down internally by a built-in 1 µA current source when the device is enabled.
12	OUT	Boost Converter Output.
13	EN	Enable (IC): The MIC2870 is in Standby mode when EN is asserted high. If EN is driven low for more than 1s, the IC is shut down. Alternatively, the I^2C interface can be used for enabling/disabling the IC through the Master Control/Status register. EN is pulled down by an internal resistor.
14	SW	Inductor Connection: It is connected to the internal power MOSFETs.
16	SDA	High-Speed Mode (3.4 MHz) I^2C Data Input/Output.
EP	ePAD	Exposed Heat Sink Pad: Connect to PGND ground plane for best thermal performance. This pin is internally connected to PGND.

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4.0 FUNCTIONAL DESCRIPTION

4.1 V_{IN}

The input supply provides power to the internal MOSFETs' gate drive and controls circuitry for the switch mode regulator. The operating input voltage range is from 2.7V to 5.0V. A 4.7 µF low-ESR ceramic input capacitor should be connected from V_{IN} to AGND, as close to MIC2870 as possible to ensure a clean supply voltage for the device. The minimum voltage rating of 10V is recommended for the input capacitor.

4.2 SW

The MIC2870 has internal low-side and synchronous MOSFET switches. The switch node (SW), between the internal MOSFET switches, connects directly to one end of the inductor and provides the current paths during switching cycles. The other end of the inductor is connected to the input supply voltage. Due to the high-speed switching on this pin, the switch node should be routed away from sensitive nodes wherever possible.

4.3 AGND

This is the ground path for the internal biasing and control circuitry. The current loop of the Analog Ground should be separated from that of the Power Ground (PGND). AGND should be connected to PGND at a single point.

4.4 PGND

The Power Ground pin is the ground path for the high current in the boost switch and the ground path of the LED current sinks. The current loop for the Power Ground should be as small as possible and separate from the AGND loop as applicable.

4.5 OUT

OUT is the boost converter output pin, which is connected to the anode of the LED. A low-ESR ceramic capacitor of 2.2 µF or larger should be connected from OUT to PGND, as close as possible to the MIC2870. The minimum voltage rating of 10V is recommended for the output capacitor.

4.6 LED1/LED2

These are the current sink pins for the LED(s). The LED anode is connected to the OUT pin and the LED cathode is connected to the LED1/LED2 pin(s).

4.7 EN

This is the enable pin of the MIC2870. The MIC2870 is in Standby mode when the EN pin is asserted high. If this pin is driven low for more than one second, the IC is shut down. Alternatively, the I^2C interface can be used for enabling/disabling the IC through the Master Control/Status register. EN is pulled down by an internal resistor.

4.8 FEN

FEN is the hardware enable pin for Flash mode. A logic low-to-high transition on the FEN pin initiates the Flash mode. If the FEN pin is left floating, it is pulled down internally by a built-in 1 µA current source when the device is enabled. Flash mode is terminated when FEN is pulled low or left floating, and the Flash Control register is cleared.

4.9 TEN

TEN is the hardware enable pin for Torch mode. A logic low-to-high transition on the TEN pin initiates the Torch mode. If the TEN pin is left floating, it is pulled down internally by a built-in 1 µA current source when the device is enabled. Torch mode is terminated when TEN is pulled low or left floating, and the Torch Control register is cleared.

4.10 FI

FI is the Flash Inhibit pin. When this pin is high in Flash mode, both the LED1 and LED2 currents are changed from the Flash mode current level to the Torch mode current level. When this pin is low, both the LED1 and LED2 currents are changed from the Torch mode current level back to the original Flash mode current level.

4.11 FRSET

The Flash mode maximum LED current level is programmed through the FRSET pin. A resistor connected from FRSET to AGND sets the maximum current in the Flash mode. FRSET can be grounded for the default Flash mode current of 0.75A. For best current accuracy, a 0.1% tolerance resistor is recommended. FRSET cannot be left floating and the maximum resistance is limited to 80 kΩ.

4.12 TRSET

The Torch mode maximum LED current level is programmed through the TRSET pin. A resistor connected from the TRSET pin to AGND sets the maximum current in the Torch mode. TRSET can be grounded for the default torch mode current of 187.5 mA. For best current accuracy, a 0.1% tolerance resistor is recommended. TRSET cannot be left floating and the maximum resistance is limited to 80 kΩ.

4.13 SCL

The I^2C clock input pin provides a reference clock for clocking in the data signal. This is a high-speed mode, up to 3.4 MHz, input pin and requires a 4.7 kΩ pull-up resistor.

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4.14 SDA

The I^2C data input/output pin allows for data to be written to and read from the MIC2870. This is a high-speed mode, up to 3.4 MHz, I^2C pin and requires a 4.7 kΩ pull-up resistor.

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5.0 APPLICATION INFORMATION

The MIC2870 can drive one or two high-current Flash WLEDs in either Flash mode or Torch mode. Two WLEDs can be used to optimize the light output and beam shaping through the optical lens/reflector assembly. In this case, the two channels, up to 750 mA each, are matched to within 10% for optimal Flash illumination. When the two channels are combined to drive a single high-brightness WLED, the maximum current is 1.5A. If one of the channels is left floating, MIC2870 senses the circuit condition automatically and allows the other channel to operate.

5.1 Flash Mode

The maximum current level in the Flash mode is 750 mA per channel. This current level can be adjusted through an external resistor connected to FRSET, according to the following equation:

EQUATION 5-1: ADJUSTING FLASH MODE CURRENT LEVEL

$$I_{LED(MAX)} = \frac{7500}{R_{FRSET}}$$

Alternatively, the default maximum value of 750 mA per channel is used when FRSET is grounded.

The Flash mode current can be initiated at the preset FRSET brightness level by asserting FEN high or by setting the I^2C Flash Control register (address: 01h) for the desired Flash duration, subjected to the Flash safety time-out setting. The Flash mode current is terminated when FEN is brought low and the I^2C Flash register is cleared.

The Flash Inhibit (FI) pin can be used to synchronize the Flash current to a handset GSM pulse event to prevent excessive battery droop. When the FEN and FI pins are both high, the Flash mode current is limited to the Torch mode current setting. The FI pin is also functional when the Flash mode current is enabled through the I^2C Flash register.

Flash mode current can be adjusted to a fraction of the maximum Flash mode level (either default or set by the FRSET resistor) by selecting the desired Flash current level percentage in the Flash Control register (address: 01h) through the I^2C interface. The Flash current is the product of the maximum Flash current setting and the percentage selected in the Flash register.

The Flash safety time-out feature automatically shuts down the Flash current if the Flash mode is enabled for an extended period of time. Refer to the Flash safety timer setting in Table 5-4.

5.2 Torch Mode

The maximum Torch mode current level can be adjusted through an external resistor connected to the TRSET pin, according to Equation 5-2:

EQUATION 5-2: ADJUSTING TORCH MODE CURRENT LEVEL

$$I_{LED(MAX)} = \frac{7500}{4R_{TRSET}}$$

Alternatively, the default maximum value of 187.5 mA per channel is used when the TRSET pin is grounded. The Torch mode operation is activated by asserting TEN high or by setting the I^2C Torch register (address: 02h) for the desired duration. The Torch mode current is terminated when TEN is brought low and the I^2C Torch register is cleared.

Like the Flash mode current, the Torch mode current can be set to a fraction of the maximum Torch mode level (either default or set by the TRSET resistor) by selecting the desired torch current level percentage in the Torch register (address: 02h) through the I^2C interface. The torch current is the product of the maximum torch current setting and the percentage selected in the Torch register.

5.3 Overvoltage Protection

When the output voltage rises above the overvoltage protection (OVP) threshold, MIC2870 is shutdown. The boost regulator and LED current regulator are turned off automatically to avoid permanent damage to the IC. When the OV condition is removed or when the output drops below the OVP threshold (minus the hysteresis), the MIC2870 resumes operation.

5.4 Open-Circuit Detection

The Open-Circuit Detector (OCD) is active only when the LED current regulator is turned on. When either one external LED is missing or fails open, LED 1 or LED 2 pin voltage is pulled to near ground potential by the internal current sink. If both LEDs are open or missing, the OCD triggers MIC2870 into an OPEN state and initiates the Open Retry timer. At the same time, bit D1 (LED_OP bit) of register 00h is set to 1.

But in most cases, OPEN state causes the boost regulator to drive the output higher with the LEDs open and forces the voltage to rise above OVP threshold triggering MIC2870 into an OVP state. OVP state overrides an OPEN state and forces MIC2870 to shutdown. When MIC2870 is shutdown, the boost regulator and LED current regulator are turned off. In this case, bit D1 in register 00h remains unchanged at 0. If the OV condition is not removed, the output could enter a hiccup mode where the output voltage bounces around the OVP threshold.

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5.5 Short-Circuit Detection

Like the OCD, the short-circuit detector is active only when the current regulator is turned on. If either one or both of the external LEDs fail a short, the short-circuit detector would force the MIC2870 to turn off. The MIC2870 will try to turn on the boost regulator and LED current regulator again after a 100 ms time-out. If the short condition persists, the whole cycle repeats again. Prolonged operation in short-circuit condition is not recommended as it can damage the device.

5.6 I²C Interface

Figure 5-1 shows the communications required for write and read operations via the I²C interface. The black lines show master communications and the red lines show the slave communications. During a write operation, the master must drive SDA and SCL for all stages, except the Acknowledgment (A) shown in red, which is provided by the slave (MIC2870):

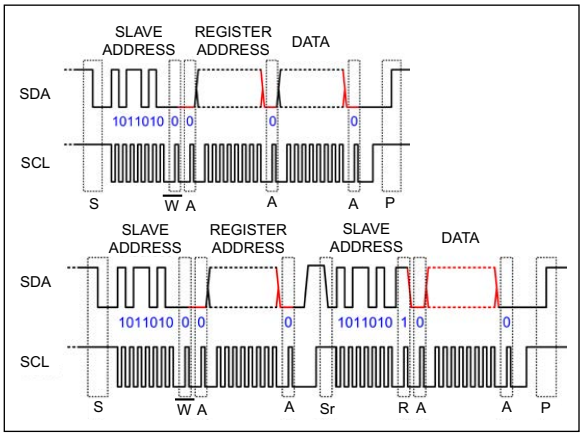

FIGURE 5-1: *I²C Timing Example.*

The read operation begins with a dataless write to select the register address from which to read. Then, a restart sequence is issued and then a read command followed by the data read.

The MIC2870 responds to a slave address of Hex: 0xB4 and 0xB5 for write and read operations, respectively, or binary '1011010x' (where 'x' is the read/write bit).

The register address is eight bits wide and carries the address of the MIC2870 register to be operated upon. Only the lower three bits are used.

5.7 I²C Registers

MIC2870 contains three 8-bit Read/Write registers, having an address from 00h to 02h for operation control, as shown in Table 5-1. These registers are reset to their default values in a Power-on Reset (POR) event. In other words, they hold their previous contents when the chip is shut down as long as supply voltage is above 1.5V (typical).

TABLE 5-1: MIC2870 REGISTER MAP

Register Address	Register Name	Description
00h	Master Control/Status	Chip Enable Control and Status register
01h	Flash Control	Flash Mode Current, Flash Mode Enable and Flash Time-out Control register
02h	Torch Control	Torch Mode Current and Torch Mode Enable Control register

5.8 Master Control/Status Register (00h)

The Master Control/Status register allows the MIC2870 to be enabled by the I²C interface – setting the ON[ ] bit high has the same effect as asserting the EN pin. The LED Short bit, LED_SHT[ ], is set if any or both of the LEDs is shorted to OUT, while the LED Open bit, LED_OP[ ], is asserted only when both LEDs are open circuit. The Thermal Shutdown bit, TSD[ ], is set when the junction temperature of the MIC2870 is higher than +160°C.

5.9 Flash Control Register (01h)

The Flash safety timer and Flash mode current are configurable via the Flash Control register. Refer to the Flash time-out duration setting and Flash mode current setting in Table 5-4 and Table 5-5.

5.10 Torch Control Register (02h)

The Torch mode current is configurable via the Torch Control register. Refer to the Torch mode current setting in Table 5-7. The FI[ ] bit has the same function as the FI pin. When the FI[ ] bit is set, the Flash mode current is reduced to the Torch mode current setting.

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TABLE 5-2: MASTER CONTROL/STATUS REGISTER (00h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	Reserved				ON	LED_SHT	LED_OP	TSD
Access	R				R/W	R		
Default Value	0							

TABLE 5-3: FLASH CONTROL REGISTER (01h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	FTMR			FEN	FCUR			
Access	R/W							
Default Value	111			0	0000			

TABLE 5-4: FLASH SAFETY TIMER SETTING (FTMR)

Register Value (D<7:5>)	Flash Time-out Duration (ms)
111	1250
110	1093.75
101	937.5
100	781.25
011	625
010	468.75
001	312.5
000	156.25

TABLE 5-5: FLASH MODE CURRENT SETTING (FCUR)

Percentage of Maximum Current (%)	Register Value (D<3:0>) of 01h	Current per Channel (mA) (R_{FRSET} = 0Ω)	Combined Current (mA) (R_{FRSET} = 0Ω)
100	0000	750.0	1500.0
90	0001	675.0	1350.0
80	0010	600.0	1200.0
70	0011	525.0	1050.0
63	0100	472.5	945.0
56	0101	420.0	840.0
50	0110	375.0	750.0
44.7	0111	335.3	670.5
39.8	1000	298.5	597.0
35.5	1001	266.3	532.5
31.6	1010	237.0	474.0
28.2	1011	211.5	423.0
25.1	1100	188.3	376.5
22.4	1101	168.0	336.0
20	1110	150.0	300.0
18	1111	135.0	270.0

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TABLE 5-6: TORCH CONTROL REGISTER (02h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	Reserved		FI	TEN	TCUR			
Access	RO		R/W					
Default Value	0		0000					

TABLE 5-7: TORCH MODE CURRENT SETTING (TCUR)

Percentage of Maximum Current (%)	Register Value (D<3:0>) of 02h	Current per Channel (mA) (R_{TRSET} = 0Ω)	Combined Current (mA) (R_{TRSET} = 0Ω)
100	0000	187.5	375.0
90	0001	168.8	337.5
80	0010	150.0	300.0
70	0011	131.3	262.5
63	0100	118.1	236.3
56	0101	105.0	210.0
50	0110	93.8	187.5
44.7	0111	83.8	167.6
39.8	1000	74.6	149.3
35.5	1001	66.6	133.1
31.6	1010	59.3	118.5
28.2	1011	52.9	105.8
25.1	1100	47.1	94.1
22.4	1101	42.0	84.0
20	1110	37.5	75.0
18	1111	33.8	67.5

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6.0 COMPONENT SELECTION

6.1 Inductor

Inductor selection is a balance between efficiency, stability, cost, size, and rated current. Because the boost converter is compensated internally, the recommended inductance of L is limited from 1 µH to 2.2 µH to ensure system stability. It is usually a good balance between these considerations.

A large inductance value reduces the peak-to-peak inductor ripple current; hence, the output ripple voltage and the LED ripple current. This also reduces both the DC loss and the transition loss at the same inductor's DC Resistance (DCR). However, the DCR of an inductor usually increases with the inductance in the same package size. This is due to the longer windings required for an increase in inductance. Because the majority of the input current passes through the inductor, the higher the DCR, the lower the efficiency is, and more significantly, at higher load currents. On the other hand, an inductor with smaller DCR, but the same inductance, usually has a larger size. The saturation current rating of the selected inductor must be higher than the maximum peak inductor current to be encountered and should be at least 20% to 30% higher than the average inductor current at maximum output current.

6.2 Input Capacitor

A ceramic capacitor of 4.7 µF or larger with low-ESR is recommended to reduce the input voltage ripple to ensure a clean supply voltage for the device. The input capacitor should be placed as close as possible to the MIC2870 V_{IN} pin, with a short trace for good noise performance. X5R or X7R type ceramic capacitors are recommended for better tolerance over temperature. The Y5V and Z5U type temperature rating ceramic capacitors are not recommended due to their large reduction in capacitance over temperature and increased resistance at high frequencies. These reduce their ability to filter out high-frequency noise. The rated voltage of the input capacitor should be at least 20% higher than the maximum operating input voltage over the operating temperature range.

6.3 Output Capacitor

Output capacitor selection is also a trade-off between performance, size and cost. Increasing the output capacitor will lead to an improved transient response, however, the size and cost will also increase. The output capacitor is preferred in the range of 2.2 µF to 10 µF with ESR from 10 mΩ to 50 mΩ. X5R or X7R type ceramic capacitors are recommended for better tolerance over temperature.

The Y5V and Z5U type ceramic capacitors are not recommended due to their wide variation in capacitance over temperature and increased resistance at high frequencies. The rated voltage of the output capacitor should be at least 20% higher than the maximum operating output voltage over the operating temperature range.

6.4 FRSET/TRSET Resistor

Because the FRSET/TRSET resistor is used for setting the maximum LED current in Flash mode and Torch mode, respectively, a resistor type with 0.1% tolerance is recommended for more accurate LED current setting.

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7.0 POWER DISSIPATION CONSIDERATION

As with all power devices, the ultimate current rating of the output is limited by the thermal properties of the device package and the PCB on which the device is mounted. There is a simple, Ohm's law type relationship between thermal resistance, power dissipation and temperature, which are analogous to an electrical circuit:

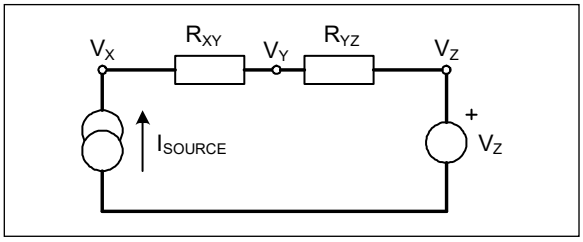

FIGURE 7-1: *Series Electrical Resistance Circuit.*

From this simple circuit, we can calculate V_X if we know the I_{SOURCE}, V_Z and the resistor values, R_{XY} and R_{YZ}, using Equation 7-1:

EQUATION 7-1: CALCULATING V_X

$$V_X = I_{SOURCE} \times (R_{XY} + R_{YZ}) + V_Z$$

Thermal circuits can be considered using this same rule and can be drawn similarly by replacing current sources with power dissipation (in watts), resistance with thermal resistance (in °C/W) and voltage sources with temperature (in °C).

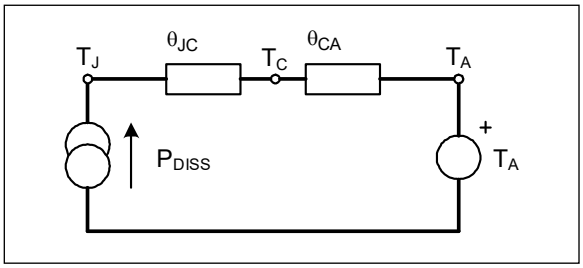

FIGURE 7-2: *Series Thermal Resistance Circuit.*

Now replacing the variables in the equation for V_X, we can find the Junction Temperature (T_J) from the power dissipation, ambient temperature, and the known thermal resistance of the PCB (θ_{CA}) and the package (θ_{JC}).

EQUATION 7-2: JUNCTION TEMPERATURE

$$T_J = P_{DISS} \times (\theta_{JC} + \theta_{CA}) + T_A$$

As can be seen in the diagram, the total thermal resistance: $\theta_{JA} = \theta_{JC} + \theta_{CA}$. Hence, this can also be written as in Equation 7-3:

EQUATION 7-3:

$$T_J = P_{DISS} \times (\theta_{JA}) + T_A$$

Where:

θ_{JA} = Thermal resistance between junction and ambient, which is typically 80°C/W for 2 x 2 TQFN package

Because all of the power losses (minus the inductor losses) in the converter are dissipated within the MIC2870 package, P_{DISS} can be calculated thus:

EQUATION 7-4: CALCULATING P_{DISS}

$$\text{Linear Mode: } P_{DISS} = [P_{OUT} \times \left(\frac{1}{\eta} - 1\right)] - I_{OUT}^2 \times DCR$$

$$\text{Boost Mode: } P_{DISS} = [P_{OUT} \times \left(\frac{1}{\eta} - 1\right)] - \left(\frac{I_{OUT}}{1 - D}\right)^2 \times DCR$$

$$\text{Duty Cycle in Boost Mode: } D = \frac{V_{OUT} - V_{IN}}{V_{OUT}}$$

Where:

η = Efficiency taken from efficiency curves

DCR = Inductor DCR

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Where the real board area differs from 1" square, θ_{CA} (the PCB thermal resistance) values for various PCB copper areas can be taken from Figure 7-3. Figure 7-3 is taken from *"Designing with Low Dropout Voltage Regulators"* available from the Microchip web site (www.microchip.com).

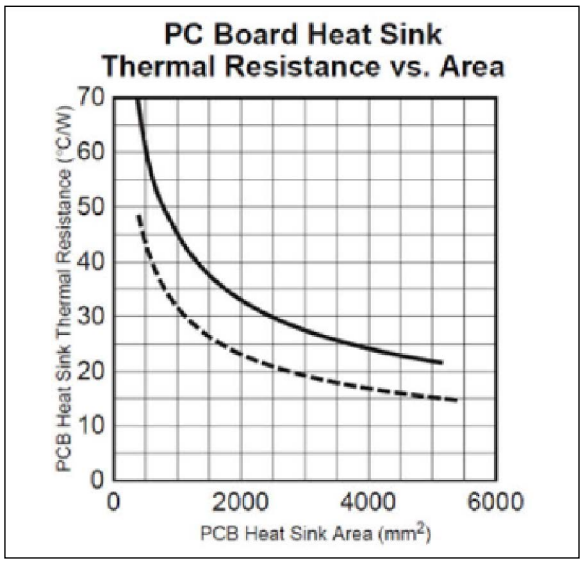

FIGURE 7-3: *Graph to Determine PC Board Area for a Given PCB Thermal Resistance.*

Figure 7-3 shows the total area of a round or square pad, centered on the device. The solid trace represents the area of a square single-sided, horizontal, solder masked, copper PC board trace heat sink, measured in square millimeters. No airflow is assumed. The dashed line shows the PC board's trace heat sink, covered in black oil-based paint, and with 1.3m/sec (250 feet per minute) airflow. This approaches a "best case" pad heat sink. Conservative design dictates using the solid trace data, which indicates that a maximum pad size of 5000 mm^2 is needed. This is a pad that is 71 mm x 71 mm (2.8 inches per side).

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8.0 PCB LAYOUT GUIDELINES

PCB layout is critical to achieve reliable, stable and efficient performance. A ground plane is required to control EMI and minimize the inductance in power and signal return paths. The following guidelines should be followed to ensure proper operation of the device:

8.1 IC (Integrated Circuit)

- Place the IC close to the point-of-load (in this case, the flash LED).
- Use fat traces to route the input and output power lines.
- Analog ground (AGND) and power ground (PGND) should be kept separate and connected at a single location.
- The exposed pad (ePad) on the bottom of the IC must be connected to the PGND ground plane of the PCB.
- 4 to 6 thermal vias must be placed on the PCB pad for exposed pad and connected it to the PGND ground plane to ensure a good PCB thermal resistance can be achieved.

8.2 VIN Decoupling Capacitor

- The VIN decoupling capacitor must be placed close to the VIN pin of the IC and preferably connected directly to the pin and not through any via. The capacitor must be located right at the IC.
- The VIN decoupling capacitor should be connected to analog ground (AGND).
- The VIN terminal is noise sensitive and the placement of capacitor is very critical.

8.3 Inductor

- Keep both the inductor connections to the switch node (SW) and input power line short and wide enough to handle the switching current. Keep the areas of the switching current loops small to minimize the EMI problem.
- Do not route any digital lines underneath or close to the inductor.
- Keep the switch node (SW) away from the noise sensitive pins.
- To minimize noise, place a ground plane underneath the inductor.

8.4 Output Capacitor

- Use wide and short traces to connect the output capacitor to the OUT and PGND pins.
- Place several vias to the ground plane close to the output capacitor ground terminal.
- Use either X5R or X7R temperature rating ceramic capacitors. Do not use Y5V or Z5U type ceramic capacitors.

8.5 Flash LED

- Use wide and short trace to connect the LED anode to the OUT pin.
- Use wide and short trace to connect the LED cathode to the LED1/LED2 pins.
- Make sure that the LED's PCB land pattern can provide sufficient PCB pad heat sink to the flash LED.

8.6 FRSET/TRSET Resistor

- The FRSET/TRSET resistor should be placed close to the FRSET/TRSET pin and connected to AGND.

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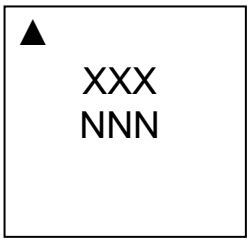
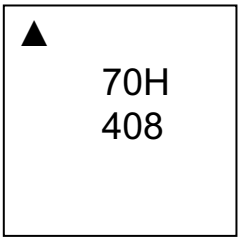
9.0 PACKAGING INFORMATION

9.1 Package Marking Information

16-Lead TQFN*



Example



Legend:	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.
	●, ▲, ▼	Pin one index is identified by a dot, delta up or delta down (triangle mark).

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

Underbar (_) and/or Overbar (¯) symbol may not be to scale.

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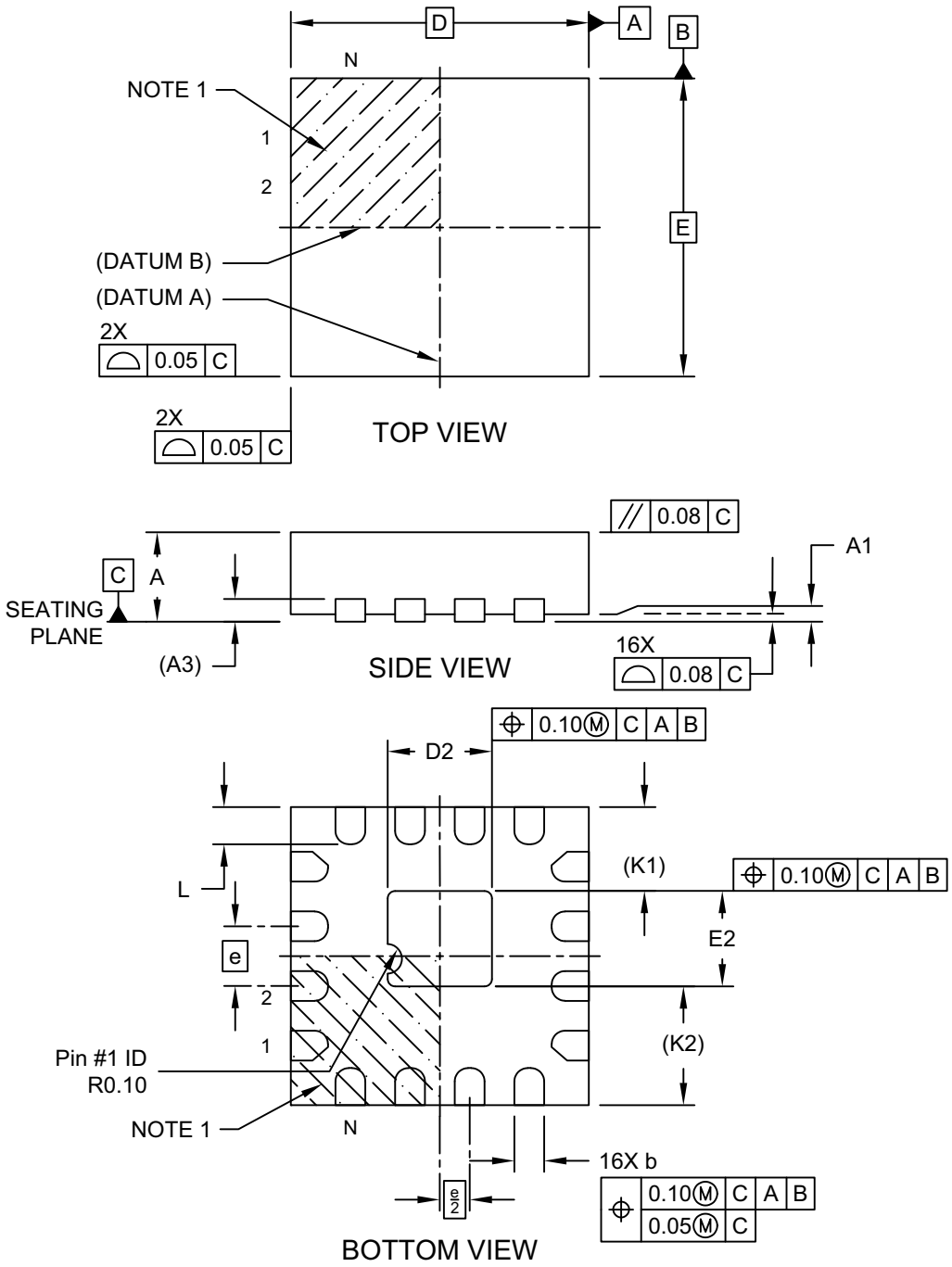
9.2 Package Details

The following sections give the technical details of the packages.

16-Lead Ultra Thin Plastic Quad Flat, No Lead Package (MJA) - 2x2x0.6 mm Body [UQFN] With 0.70x0.64 mm Exposed Pad

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



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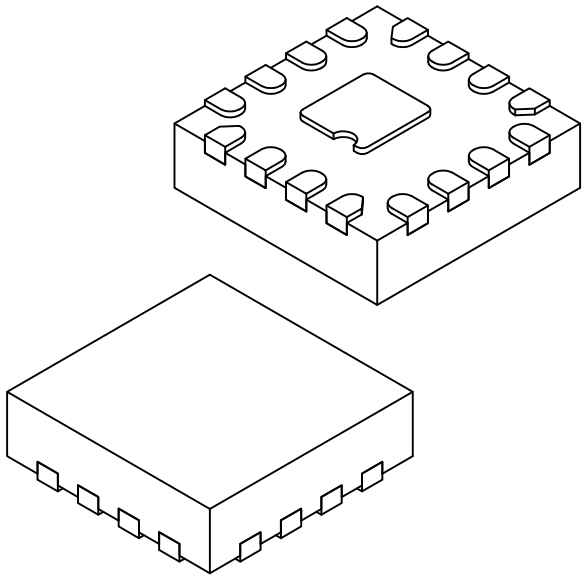
16-Lead Ultra Thin Plastic Quad Flat, No Lead Package (MJA) - 2x2x0.6 mm Body [UQFN] With 0.70x0.64 mm Exposed Pad

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N		16	
Pitch	e		0.40 BSC	
Overall Height	A	0.50	0.55	0.60
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.152 REF	
Overall Length	D		2.00 BSC	
Exposed Pad Length	D2	0.65	0.70	0.75
Overall Width	E		2.00 BSC	
Exposed Pad Width	E2	0.59	0.64	0.69
Terminal Width	b	0.15	0.20	0.25
Terminal Length	L	0.20	0.25	0.30
Body Edge-to-Exposed-Pad	K1		0.56 REF	
Body Edge-to-Exposed-Pad	K2		0.67 REF	

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

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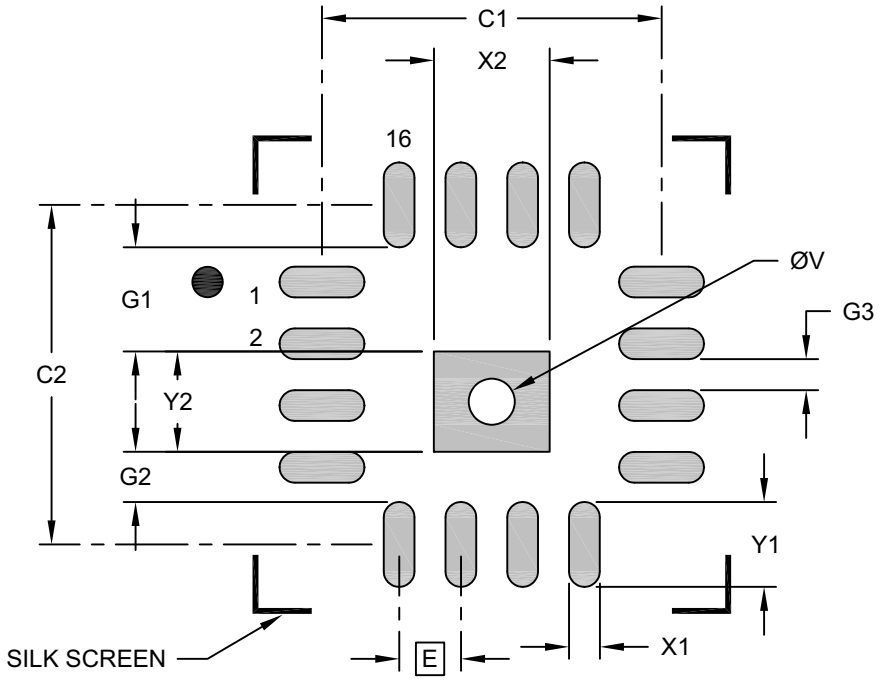
16-Lead Ultra Thin Plastic Quad Flat, No Lead Package (MJA) - 2x2x0.6 mm Body [UQFN] With 0.70x0.64 mm Exposed Pad

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.40 BSC	
Center Pad Width	X2			0.75
Center Pad Length	Y2			0.69
Contact Pad Spacing	C1		2.20	
Contact Pad Spacing	C2		2.20	
Contact Pad Width (X16)	X1			0.20
Contact Pad Length (X16)	Y1			0.55
Contact Pad to Center Pad	G1	0.547		
Contact Pad to Center Pad	G2	0.313		
Contact Pad to Contact Pad (X12)	G3	0.20		
Thermal Via Diameter	V		0.30	

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

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APPENDIX A: REVISION HISTORY

Revision B (June 2023)

- Updated Table 5-2 title.
- Updated Section 5.3, Overvoltage Protection, Section 5.4, Open-Circuit Detection and Section 9.2, Package Details.

Revision A (October 2018)

- Converted Micrel document MIC2870 to Microchip data sheet DS20006078A.
- Minor text changes throughout document.

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NOTES:

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PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

PART NO.	X	XX	-	XX
Device	Temperature	Package		Media Type

Device:	MIC2870:		1.5A Synchronous Boost Flash LED Driver with I^2C Interface
Temperature:	Y	=	-40°C to +125°C
Package:	FT	=	16-Pin 2 mm x 2 mm TQFN
Media Type:	T5	=	500/Reel
	TR	=	5,000/Reel

Examples:

a) MIC2870YFT-T5: MIC2870, -40°C to +125°C Temp. Range, 16-Pin TQFN, 500/Reel

b) MIC2870YFT-TR: MIC2870, -40°C to +125°C Temp. Range, 16-Pin TQFN, 5,000/Reel

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

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ISBN: 978-1-6683-2639-8

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