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EVALUATION KIT AVAILABLE

MAX77387

Dual-Phase Adaptive DC-DC Step-Up Converter With 2x 1000mA High-Side Current Regulators

General Description

The MAX77387 provides a high-efficiency solution for smartphone camera flash applications by integrating a dual-phase 2A PWM DC-DC step-up converter and two programmable 1A high side, low-dropout LED current regulators for flash and torch functions. An I²C interface provides flexible control of the step-up converter, torch, flash mode selection, and torch/flash safety timer duration settings.

The IC operates down to 2.5V, making it futureproof for new battery technologies. The step-up converter features an internal switching MOSFET and synchronous rectifier to improve efficiency and minimize external component count. Dual-phase operation ensures low output ripple and provides smallest possible solution size. The IC also includes dual high-side high-current regulators for supporting torch and flash modes. The high-current regulators can source up to 1A each in flash mode and up to 250mA each in torch mode. The high-current regulators can be combined to drive a single LED up to 2A in flash mode and up to 500mA in torch mode. The output voltage can be adaptively controlled, boosting only as high as necessary to support the required LED forward voltage. Adaptive mode can be used in either flash or torch mode and works with both DAC and/or PWM dimming control schemes. This approach reduces IC power dissipation by optimizing the boost ratio and by minimizing the losses in the current regulators.

The IC includes control for external NTC, dual Tx mask, flash strobe, and torch enable functions. This allows for flexible control of the IC.

Additionally, the IC includes MAXFLASH 2.0 function that adaptively reduces flash current during low battery conditions to help prevent system undervoltage lockup.

Other features include shorted LED detection, overvoltage and thermal shutdown protection, and low-power standby and shutdown modes. The IC is available in a 20-bump, 0.4mm pitch WLP package (2.1mm x 1.73mm).

Applications

Cell Phones and Smartphones

Tablets

**Patent protected PCT/US2008/075643.*

Benefits and Features

- **Input Supply of 2.5V to 5.5V with Full Functionality**
- **Dual-Phase Interleave Step-Up DC-DC Converter**
  - **True Shutdown Output**
  - **2A Guaranteed Output Current for V_{IN} > 2.7V and $V_{OUT} \leq$ 4.0V**
  - **Adaptive Output Voltage Regulation to Ensure Industry's Highest System Efficiency**
  - **Over 90% Peak Efficiency**
  - **3.125% Minimum Duty Cycle**
  - **Skip Mode Capable**
  - **On-Chip Power MOSFET and Synchronous Rectifier**
  - **Up to 4MHz PWM Switching Frequency per Phase**
  - **Small 0.47µH Inductor per Phase**
- **High-Side Torch/Flash LED Current Regulator**
  - **I²C Programmable Flash Output Current (15.625mA to 1000mA in 15.625mA Steps)**
  - **I²C Programmable Torch Output Current (3.91mA to 250mA in 3.91mA Steps for Non-PWM dimming) (125mA to 1000mA in 125mA Steps for PWM Dimming with Programmable Duty Cycle from 3.125% to 25% in 3.125% steps)**
  - **Low-Dropout Voltage (80mV typ) at 1000mA**
- **I²C-Programmable Flash Safety Timer**
- **I²C-Programmable Torch Safety Timer and Optional Disabled Torch Timer**
- **Dual Independent TX_MASK Inputs for Limiting Flash Current During Tx Events**
- **Open/Shorted LED Detection**
- **NTC Monitoring for LED Protection**
- **Overvoltage Protection**
- **MAXFLASH 2.0 Preventing System Undervoltage Lockup**
- **Thermal Shutdown Protection**
- **< 1µA Shutdown Current**
- **20-Bump, 0.4mm Pitch 2.1mm x 1.73mm WLP**

***Ordering Information* appears at end of data sheet.**

***Simplified Block Diagram* appears at end of data sheet.**

For related parts and recommended products to use with this part, refer to www.maximintegrated.com/MAX77387.related.

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

19-6282; Rev 0; 7/12

MAX77387

Dual-Phase Adaptive DC-DC Step-Up Converter With 2x 1000mA High-Side Current Regulators

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LX_B to PGND_B ..... -0.3V to V_{OUT} + 0.3V
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TX1_MASK, TX2_MASK, TORCH_EN, NTC to AGND ..... -0.3V to V_{IN} + 0.3V
SDA, SCL, FLASH_STB to AGND ..... -0.3V to V_{IN} + 0.3V
AGND to PGND_A, PGND_B ..... -0.3V to +0.3V
I_{LX_A}, I_{LX_B} Current (rms) per Phase 2.0A
Continuous Power Dissipation (T_A = +70°C) (derate 21.7mW/°C above +70°C) 1736mW
Operating Temperature ..... -40°C to +85°C
Junction Temperature ..... +150°C
Storage Temperature Range ..... -65°C to +150°C
Soldering Temperature (reflow) (Note 1) ..... +260°C

Note 1: This device is constructed using a unique set of packaging techniques that impose a limit on the thermal profile the device can be exposed to during board level solder attach and rework. This limit permits only the use of the solder profiles recommended in the industry-standard specification, JEDEC 020A, paragraph 7.6, Table 3 for IR/VPR and Convection reflow. Preheating is required. Hand or wave soldering is not allowed.

PACKAGE THERMAL CHARACTERISTICS (Note 2)

WLP
Junction to Ambient Thermal Resistance (θ_{JA}) ..... 46°C/W

Note 2: 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.maximintegrated.com/thermal-tutorial**.

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

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, V_{DD} = 1.8V, V_{PGND_A} = V_{PGND_B} = V_{AGND} = 0V, V_{TX1_MASK} = V_{TX2_MASK} = V_{TORCH_EN} = V_{FLASH_STB} = 0V, f_{SW} = 4MHz, T_A = -40°C to +85°C**,** unless otherwise noted. Typical values are at T_A = +25°C. See Figure 1.) (Note 3)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
GENERAL						
IN Operating Voltage Range			2.5		5.5	V
V_{DD} Operating Voltage Range			1.62		3.6	V
IN Undervoltage Lockout (IN_UVLO) Threshold	V_{IN} falling, 60mV (typ) hysteresis		2.10	2.20	2.30	V
V_{DD} Under voltage Lockout (VDD_UVLO) Threshold	V_{DD} falling		0.65	0.9	1.0	V
IN Shutdown Supply Current	V_{IN} = 5.5V, V_{DD} = 0V	T_A = +25°C		0.01	1	µA
		T_A = +85°C		0.1		
V_{DD} Standby Supply Current	V_{IN} = 5.5V, V_{DD} = V_{SDA} = V_{SCL} = 3.6V, DCDC_MODE = 00	T_A = +25°C		0.01	1	µA
		T_A = +85°C		0.1		
IN Standby Supply Current	V_{IN} = 5.5V, V_{DD} = V_{SCL} = V_{SDA} = 3.6V, DCDC_MODE = 00, DC-DC converter and current regulators are off	T_A = -40°C to +85°C		1.5	5	µA

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{DD} = 1.8V, V_{PGND_A} = V_{PGND_B} = V_{AGND} = 0V, V_{TX1_MASK} = V_{TX2_MASK} = V_{TORCH_EN} = V_{FLASH_STB} = 0V, f_{SW} = 4MHz, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C. See Figure 1.) (Note 3)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
LOGIC INTERFACE						
Logic Input High Voltage	V_{DD} = 1.62V to 3.6V	SDA, SCL, FLASH_STB	0.7 x V_{DD}		V_{DD} + 0.3V	V
	V_{IN} = 2.5V to 5.5V	TORCH_EN, TX1_MASK, TX2_MASK	1.25		V_{IN} + 0.3V	V
Logic Input Low Voltage	V_{DD} = 1.62V to 3.6V	SDA, SCL, FLASH_STB			0.4	V
	V_{IN} = 2.5V to 5.5V	TORCH_EN, TX1_MASK, TX2_MASK			0.4	
Pulldown Resistor	V_{DD} = 1.62V to 3.6V FLASH_STB_PD = 1	FLASH_STB	400	800	1600	kΩ
	V_{IN} = 2.5V to 5.5V TORCH_EN_PD = 1, TX1_MASK_PD = 1, TX2_MASK_PD = 1	TORCH_EN, TX1_MASK, TX2_MASK	400	800	1600	
Logic Input Current	V_{DD} = 1.62V to 3.6V, FLASH_STB_PD = 0	T_A = +25°C	-1	0.01	+1	µA
		T_A = +85°C		0.1		
	V_{IN} = 2.5V to 5.5V TORCH_EN_PD = 0, TX1_MASK_PD = 0, TX2_MASK_PD = 0	T_A = +25°C	-1	0.01	+1	
		T_A = +85°C		0.1		
LOGIC INTERFACE TIMING						
FLASH_STB Enable Delay in Active Mode ($t_{FLASH\_EN\_ACTIV}$)	See Figure 4, from FLASH_STB rising edge until start of current regulator ramp up (Note 4)			5		µs
TORCH_EN Enable Delay in Active Mode ($t_{TORCH\_EN\_ACTIV}$)	See Figure 4, from TORCH_EN rising edge until start of current regulator ramp up (Note 4)			5		µs
FLASH_STB Enable Delay in Standby Mode ($t_{FLASH\_STB\_STDBY}$)	See Figure 3, from FLASH_STB rising edge until start of precharge of the output (Note 4)			30		µs
TORCH_EN Enable Delay in Standby Mode ($t_{TORCH\_EN\_STDBY}$)	See Figure 3, from TORCH_EN rising edge until start of precharge of the output (Note 4)			30		µs
Precharging of Output (t_{OUT_PCHG})	See Figures 3–6, V_{IN} = 3.6, C_{OUT} = 10µF, charging the output from 0V until LX starts switching (Note 4)			600		µs

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{DD} = 1.8V, V_{PGND_A} = V_{PGND_B} = V_{AGND} = 0V, V_{TX1_MASK} = V_{TX2_MASK} = V_{TORCH_EN} = V_{FLASH_STB} = 0V, f_{SW} = 4MHz, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C. See Figure 1.) (Note 3)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Soft-Start Time Duration, (t_{DCDC_SS})	See Figures 3, 4, and 5 (Note 4)			DCDC_SS x 8		µs
TX_MASK Trigger to Reduced Output Current ($t_{TX\_MASK\_EN}$)	See Figures 9 and 10 From TX1_MASK, TX2_MASK triggered until output current is at reduced output current (Note 4)			7		µs
Standby to Active Mode ($t_{STDBY2ACTIV}$)	See Figures 5 and 6 Time to transition from standby to active mode (Note 4)			25		µs
I²C INTERFACE (Note 4)						
SDA Output Low Voltage	I_{SDA} = 3mA			0.03	0.4	V
I²C Clock Frequency					400	kHz
Bus-Free Time Between START and STOP	t_{BUF}		1.3			µs
Hold Time Repeated START Condition	t_{HD_STA}		0.6	0.1		µs
SCL Low Period	t_{LOW}		1.3	0.2		µs
SCL High Period	t_{HIGH}		0.6	0.2		µs
Setup Time Repeated START Condition	t_{SU_STA}		0.6	0.1		µs
SDA Hold Time	t_{HD_DAT}		0	-0.01		µs
SDA Setup Time	t_{SU_DAT}		100	50		ns
Setup Time for STOP Condition	t_{SU_STO}		0.6	0.1		µs
STEP-UP DC-DC CONVERTER						
OUT Voltage Range	Adaptive controlled		2.3		5.2	V
Output Adaptive Regulation Step Size	Smallest step size when output voltage is in adaptive regulation $V_{ADPT\_REG\_STEP}$			6.25		mV
Digital Overvoltage Protection (OVP_D)	When operating in adaptive mode	OVP_TH = 00		0x140h (4.3V)		9-bit digital code
		OVP_TH = 01		0x170h (4.6V)		
		OVP_TH = 10		0x1A0h (4.9V)		
		OVP_TH = 11		0x1D0h (5.2V)		
Analog Overvoltage Protection	OVP_TH = 00		4.35	4.5	4.65	V
	OVP_TH = 01		4.65	4.8	4.95	
	OVP_TH = 10		4.95	5.1	5.25	
	OVP_TH = 11		5.25	5.4	5.55	
Output Threshold for Minimum Duty Cycle to Bypass Mode	V_{OUT_MIND} Output voltage where the DC-DC converter goes from operating at minimum duty cycle to dropout operation, during a disabling of the DC-DC converter, DCDC_MODE = 00			V_{IN} + 200mV		V

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{DD} = 1.8V, V_{PGND_A} = V_{PGND_B} = V_{AGND} = 0V, V_{TX1_MASK} = V_{TX2_MASK} = V_{TORCH_EN} = V_{FLASH_STB} = 0V, f_{SW} = 4MHz, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C. See Figure 1.) (Note 3)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Output Threshold for Dropout Operation to OFF Mode	V_{OUT_OFF} Output voltage where the DC-DC converter goes from operating in dropout mode to true shutdown, during a disabling of the DC-DC converter, DCDC_MODE = 00			V_{IN} + 150mV		V
Charge Mode Comparator Threshold	Output voltage where the DC-DC converter goes from operating at minimum duty cycle to soft start.			V_{IN} - 300mV		V
Adaptive Output Step Time	Time between sampling of adaptive regulation during soft-start (Note 5)			1		µs
	Time between sampling of adaptive regulation (Note 5)			8		
IN Supply Current	V_{OUT} = 4.5V, I_{OUT} = 0mA, switching 4MHz PWM mode dual-phase operation (Note 2)			14		mA
	V_{OUT} = 4.5V, I_{OUT} = 0mA, switching 2MHz PWM mode dual-phase operation (Note 2)			15		
	V_{OUT} = 4.5V, I_{OUT} = 0mA, no switching (skip mode)			450		µA
Low-Side Current Limit (Static Limits) (Phases A and B)	DCDC_ILIM = 00		1.11	1.25	1.37	A
	DCDC_ILIM = 01		1.35	1.5	1.65	
	DCDC_ILIM = 10		1.57	1.75	1.93	
	DCDC_ILIM = 11		1.80	2.0	2.20	
Current Sharing	Delta current between phase A and phase B (Note 4), excluding external components			0		%
Phase A Zero-Crossing Threshold (Static, Phases A and B)				120		mA
LX_ High-Side On-Resistance (Phases A and B)	LX_ to OUT_, $I_{LX\_}$ = -200mA, V_{OUT} = 3.6V			130	185	mΩ
LX_ Low-Side On-Resistance (Phases A and B)	LX_ to PGND_, $I_{LX\_}$ = 200mA, V_{OUT} = 3.6V			100	160	mΩ
Load Regulation	V_{IN} = 3.4V, V_{OUT} = 4.5V, enhanced mode (DCDC_GAIN = 1) (for adaptive mode only) (Note 4)			50		mV/A
	V_{IN} = 3.4V, V_{OUT} = 4.5V, enhanced mode (DCDC_GAIN = 1) (for program mode only) (Note 4)			100		mV/A
LX_ Leakage (Phase A, Phase B)	$V_{LX\_}$ = 5.5V	T_A = +25°C		0.1	2	µA
		T_A = +85°C		0.1		
Operating Frequency (Phase A, Phase B)	DCDC_OPERATION[2:0] = 010	T_A = -40°C to +85°C	3.90	4.0	4.10	MHz
Maximum Duty Cycle (Phase A, Phase B)	DCDC_OPERATION[2:0] = 011		70			%
Minimum Duty Cycle	During non-skip mode (DCDC_OPERATION[2:0] = 011)			3.3		%
	During skip mode (Note 4)			0		%

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{DD} = 1.8V, V_{PGND_A} = V_{PGND_B} = V_{AGND} = 0V, V_{TX1_MASK} = V_{TX2_MASK} = V_{TORCH_EN} = V_{FLASH_STB} = 0V, f_{SW} = 4MHz, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C. See Figure 1.) (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
LED CURRENT SOURCE DRIVERS					
REG_IN Supply Current (FLED1, FLED2)	FLED_ enabled in torch mode with PWM dimming set to maximum current setting, supply current measured during off period of PWM cycle		100		µA
IN Supply Current (FLED1, FLED2)	FLED_ enabled in torch mode with PWM dimming set to maximum current setting, supply current measured during off period of PWM cycle		25		µA
LED Current Setting Range (FLED1, FLED2)	FLED_ enabled in flash mode, current range in 15.625mA steps	15.625		1000	mA
	FLED_ enabled in torch mode, with DAC mode active, current range in 3.91mA steps	3.91		250	
	FLED_ enabled in torch mode with PWM dimming active, current range in 125mA steps	125.0		1000	
PWM Dimming Duty Cycle Setting Range	FLED_ enabled in torch mode with PWM dimming active, duty cycle range in 3.125% steps (Note 5)	3.125		25	%
PWM Dimming Frequency Setting Range	FREQ_PWM[1:0] = 00 (Note 5)		7.8		kHz
	FREQ_PWM[1:0] = 01 (Note 5)		1.9		
	FREQ_PWM[1:0] = 10 (Note 5)		0.488		
	FREQ_PWM[1:0] = 11 (Note 5)		0.122		
LED Peak Current Overshoot	FLED_ enabled in torch mode with PWM dimming set to maximum current setting, maximum LED current overshoot during initial ramping up (Note 4)		10		%
LED Current Settling Time	FLED_ enabled in torch mode with PWM dimming set to maximum current setting. Time for LED current to settle to less than 10% from nominal setting (not including ramp time) (Note 4)		6		µs
LED Current Accuracy Flash Mode or Torch Mode with PWM Dimming (FLED1, FLED2)	625mA to 1000mA	-5		+5	%
	218.75mA to 609.375mA	-7		+7	
	62.5mA to 203.125mA	-10		+10	
	31.25mA to 46.875mA	-12		+12	
	15.625mA	-14		+14	
LED Current Accuracy Torch Mode (FLED1, FLED2)	156.25 to 250mA	-5		+5	%
	54.6875mA to 152.34375mA	-7		+7	
	15.625mA to 50.78125mA	-10		+10	
	7.8125mA to 11.71875mA	-12		+12	
	3.91mA	-14		+14	

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{DD} = 1.8V, V_{PGND_A} = V_{PGND_B} = V_{AGND} = 0V, V_{TX1_MASK} = V_{TX2_MASK} = V_{TORCH_EN} = V_{FLASH_STB} = 0V, f_{SW} = 4MHz, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C. See Figure 1.) (Note 3)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
LED Current Dropout Voltage Flash Mode or Torch Mode with PWM Dimming (FLED1, FLED2)	1000mA setting at -10%			80		mV
	1000mA setting at -1% (Note 4)			100		
LED Current Dropout Voltage Torch Mode (FLED1, FLED2)	250mA setting at -10%			80		mV
	250mA setting at -1% (Note 4)			100		
LED Adaptive Mode Threshold Voltage Setting Range (FLED1, FLED2)	FLED_ enabled in flash mode or torch mode	DCDC_ADPT_REG = 00		120		mV
		DCDC_ADPT_REG = 01		150		
		DCDC_ADPT_REG = 10		180		
		DCDC_ADPT_REG = 11		210		
LED Leakage Current	REG_IN = 5.5V, FLED_ = 0V	T_A = +25°C		0.1	2	µA
		T_A = +85°C		1		
REG_IN UVLO Voltage	Minimum voltage on REG_IN required before FLED_ current regulators are enabled		2.2	2.3	2.4	V
TIMERS						
Flash Duration Timer Range	In 0.256ms steps (Note 5)		0.128		0.896	ms
	In 0.512ms steps (Note 5)		0.896		2.944	
	In 1.024ms steps (Note 5)		2.944		11.136	
	In 2.048ms steps (Note 5)		11.136		43.904	
	In 4.096ms steps (Note 5)		43.904		437.12	
	In 8.192ms steps (Note 5)		437.12		699.264	
Torch Duration Timer Range TORCH_TMR0	In 131.072ms steps (Note 5)		122.88		561.1	ms
	In 262.144ms steps (Note 5)		561.1		1564.67	
	In 524.288ms steps (Note 5)		1564.67		5767.17	
	In 1048.576ms steps (Note 5)		5767.17		22536.19	
Torch and Flash Duration Timer Accuracy	T_A = 0°C to +85°C (Note 4)		-2.5	0	+2.5	ms
	T_A = -40°C to +85°C (Note 4)		-3	0	+3	
Flash Mode Ramp Rate Settings	LED current ramp-up time (Note 5)	Time it takes for current regulator to ramp from 0mA to full scale current	384		32896	µs
	LED current ramp-down time. (Note 5)	Time it takes for current regulator to ramp from full scale current to 0mA	384		32896	µs
Torch Mode Ramp Rate Settings	LED current ramp-up time (Note 5)	Time it takes for current regulator to ramp from 0mA to full scale current	16.392		2097	ms
	LED current ramp-down time (Note 5)	Time it takes for current regulator to ramp from full scale current to 0mA	16.392		2097	ms

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{DD} = 1.8V, V_{PGND_A} = V_{PGND_B} = V_{AGND} = 0V, V_{TX1_MASK} = V_{TX2_MASK} = V_{TORCH_EN} = V_{FLASH_STB} = 0V, f_{SW} = 4MHz, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C. See Figure 1.) (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DIE PROTECTION					
Shorted LED detection Threshold FLED1, FLED2				1	V
Short Debounce timer FLED1, FLED2	From LED short detected until LED current regulator is disabled (Note 5)		1.024		ms
OVP_A Debounce Timer	Time where adaptive regulation threshold is set at OVP_A threshold until current regulator is disabled (Note 5)		1.024		ms
OVP_D Debounce Timer	Time where adaptive regulation threshold is set at OVP_D threshold until current regulator is disabled (Note 5)		384		µs
IN_UVLO/THERM Debounce Timer	Either time where V_{IN} is less than IN_UVLO threshold or thermal threshold is exceeded until the current regulator is disabled (Note 5)		0.512		ms
Thermal Shutdown Hysteresis	(Note 4)		20		°C
Thermal Shutdown	T_J = rising (Note 4)		+160		°C
NTC THERMAL PROTECTION					
NTC Bias	NTC_BIAS_25C T_A = +25°C	194	200	206	µA
NTC Bias Temperature Coefficient	NTC_T_COMP (Note 4)		0.020		µA/°C
NTC Bias On-Time ($t_{NTC\_TORCH\_ON}$)	Time NTC bias is enabled before temperature measurement is performed in torch mode (Note 5)		0.512		ms
NTC Bias On Interval ($_{NTC\_TORCH\_OFF}$)	Time between enabling of NTC bias in torch mode (Note 5)		131		ms
NTC Over Temperature Detection Threshold Range	In 50mV steps, NTC falling	200		550	mV
NTC Over Temperature Threshold Hysteresis			50		mV
NTC Over Temperature Threshold Accuracy	For NTC_TH at the 200mV setting	-2		+2	%
NTC Short Detection Threshold		55	70	120	mV
MAXFLASH					
Low Battery Detect Threshold Range	In 33mV steps, V_{IN} falling	2.4		3.4	V
Low Battery Voltage Threshold Accuracy			±2.5		%
Low Battery Voltage Hysteresis Programmable Range	In 50mV steps	50		350	mV

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{DD} = 1.8V, V_{PGND_A} = V_{PGND_B} = V_{AGND} = 0V, V_{TX1_MASK} = V_{TX2_MASK} = V_{TORCH_EN} = V_{FLASH_STB} = 0V, f_{SW} = 4MHz, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C. See Figure 1.) (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Low Battery Inhibit Timer	Falling in 256µs steps (Note 5)	256		2048	µs
	Rising in 256µs steps (Note 5)	256		2048	
Low Battery Inhibit Time Accuracy	(Note 4)	-3		+3	%

Note 3: All devices are 100% production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed by design.

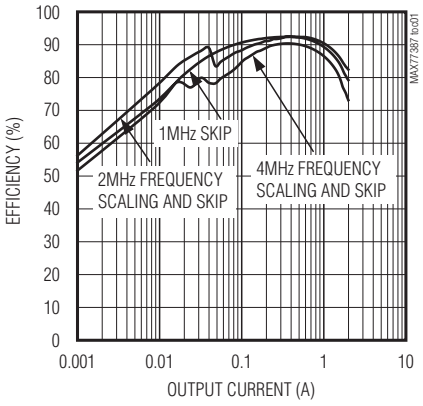
Note 4: Parameter not production tested. Parameter guaranteed by design through characterization.

Note 5: Parameter production tested through scan. Parameter guaranteed by design through characterization.

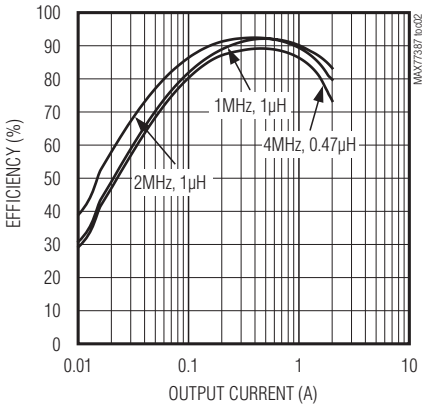
Typical Operating Characteristics

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

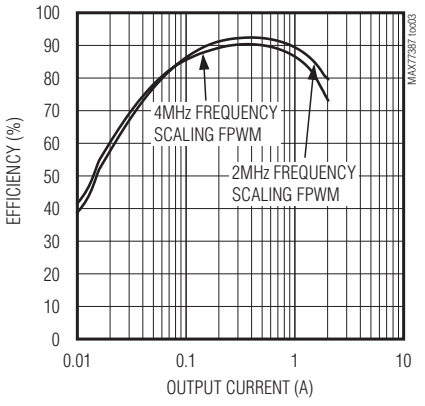
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 2.5V, V_{OUT} = 4V) 1µH



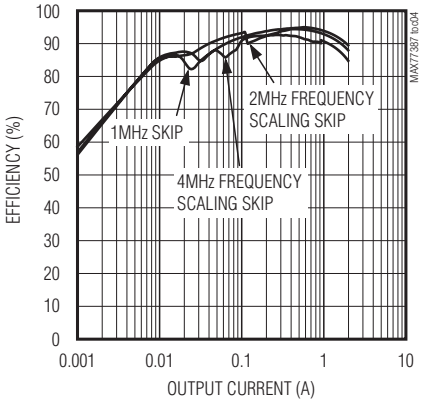
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 2.5V, V_{OUT} = 4V, FPWM)



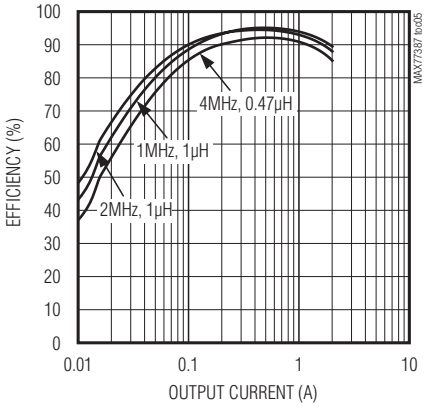
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 2.5V, V_{OUT} = 4V) 1µH



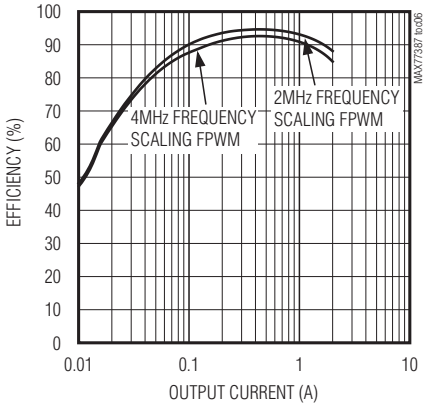
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 3.2V, V_{OUT} = 4V) 1µH



DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 3.2V, V_{OUT} = 4V, FPWM)



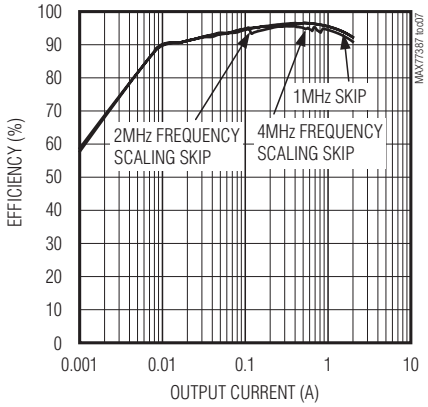
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 3.2V, V_{OUT} = 4V) 1µH



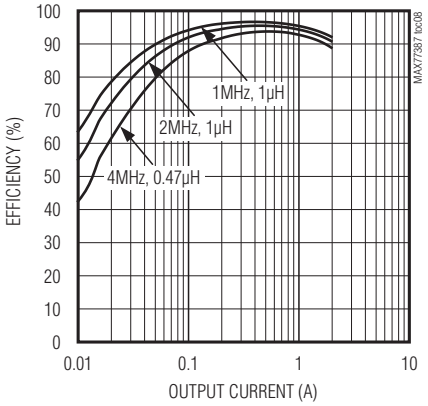
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

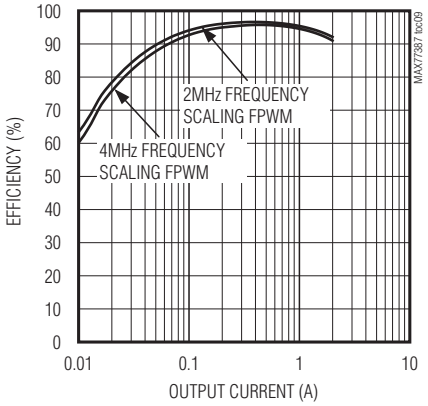
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 3.7V, V_{OUT} = 4V) 1µH



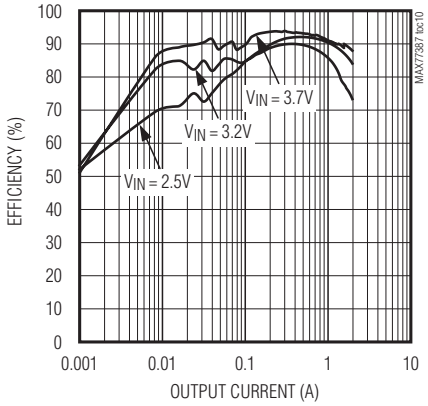
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 3.7V, V_{OUT} = 4V, FPWM)



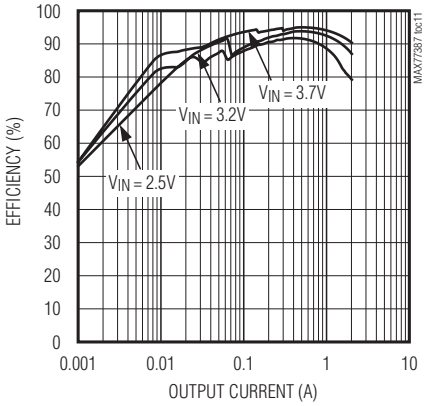
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{IN} = 3.7V, V_{OUT} = 4V) 1µH



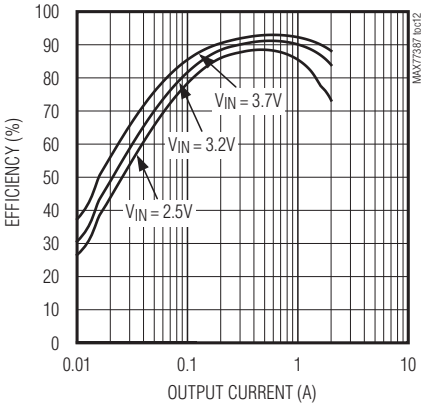
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT, V_{OUT} = 4.5V 4MHz FREQUENCY SCALING AND SKIP 1µH



DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT, V_{OUT} = 4.5V 2MHz FREQUENCY SCALING AND SKIP 1µH



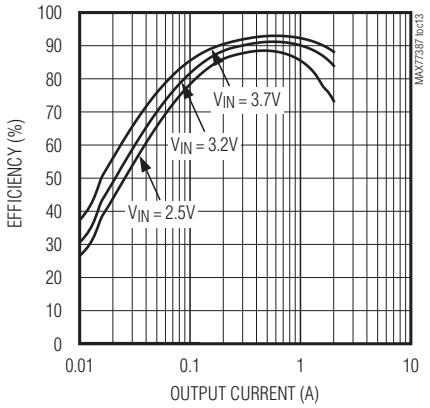
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{OUT} = 4V, 4MHz FPWM, 0.47µH)



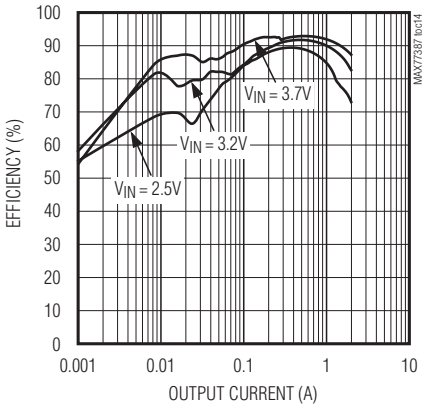
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

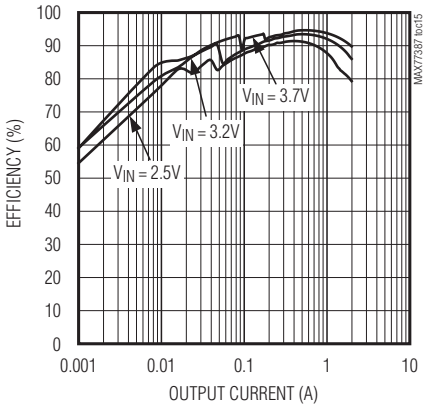
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT, V_{OUT} = 4.5V 2MHz FPWM 1µH



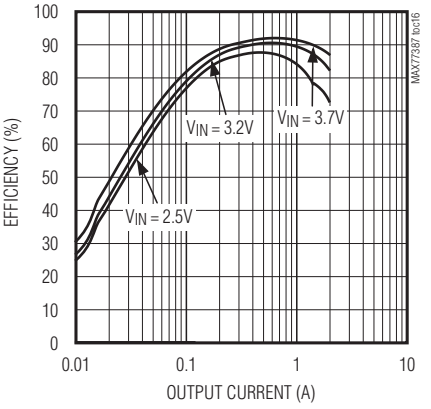
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRRENT, V_{OUT} = 5V 4MHz FREQUENCY SCALING AND SKIP 1µH



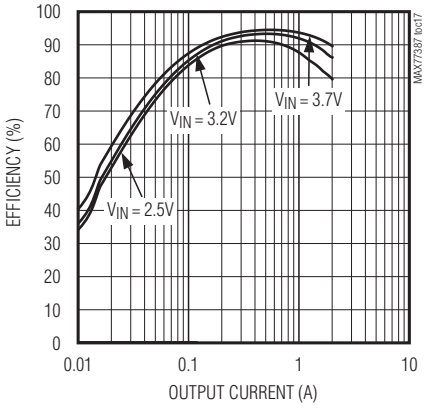
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRRENT, V_{OUT} = 5V 2MHz FREQUENCY SCALING AND SKIP 1µH



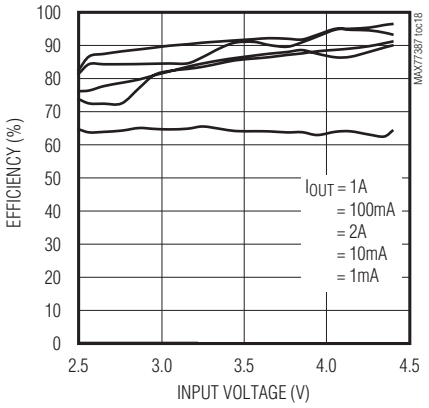
DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT (V_{OUT} = 5V, 4MHz FPWM, 0.47µH)



DC-DC CONVERTER EFFICIENCY vs. LOAD CURRENT, V_{OUT} = 5V 2MHz FPWM 1µH



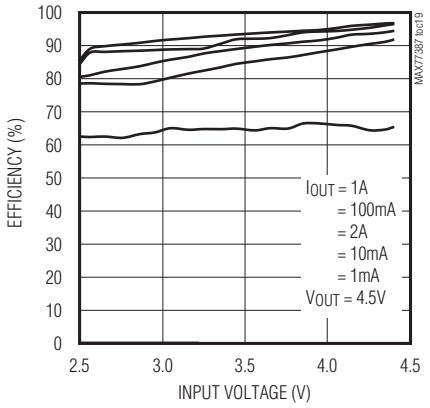
DC-DC CONVERTER EFFICIENCY vs. V_{IN}, V_{OUT} = 4.5V, 4MHz FREQUENCY SCALING AND SKIP 1µH



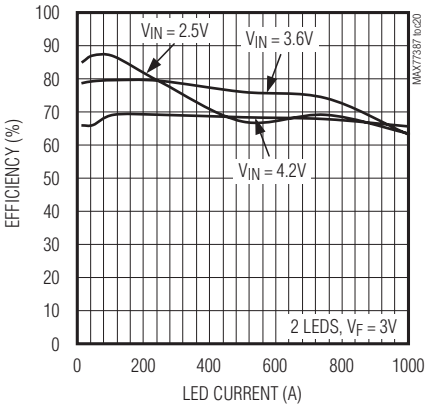
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

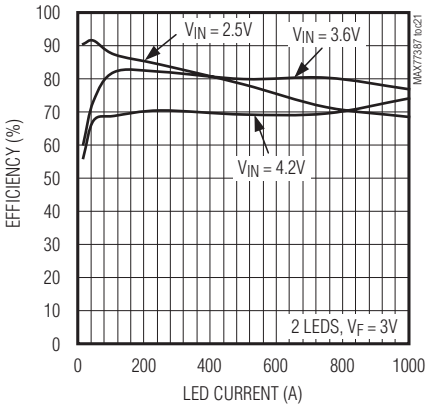
DC-DC CONVERTER EFFICIENCY vs. V_{IN}, 2MHz FREQUENCY SCALING AND SKIP 1µH



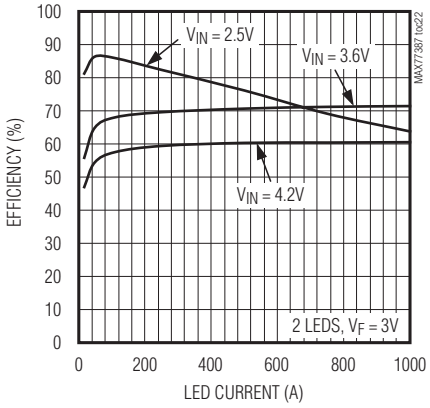
LED EFFICIENCY vs. LED CURRENT (4MHz, FREQUENCY SCALING, SKIP ALLOWED)



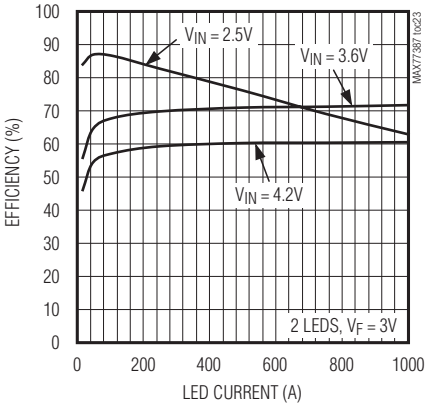
LED EFFICIENCY vs. LED CURRENT (2MHz, FREQUENCY SCALING, SKIP ALLOWED)



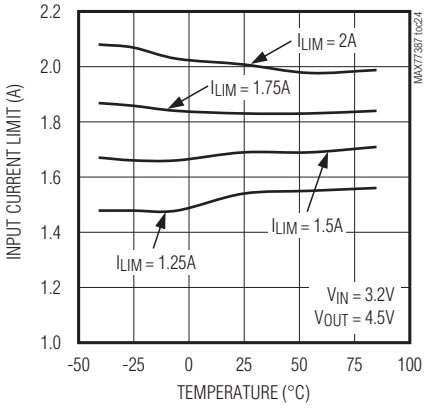
LED EFFICIENCY vs. LED CURRENT (4MHz, FPWM)



LED EFFICIENCY vs. LED CURRENT (2MHz, FPWM)



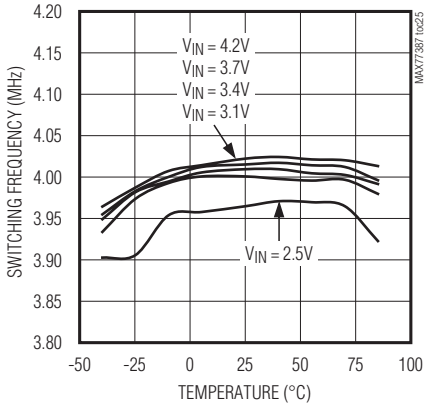
INPUT CURRENT LIMIT vs. TEMPERATURE



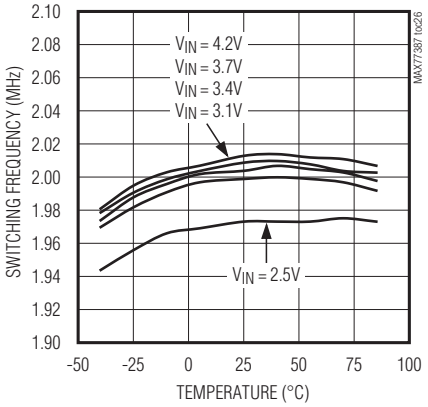
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

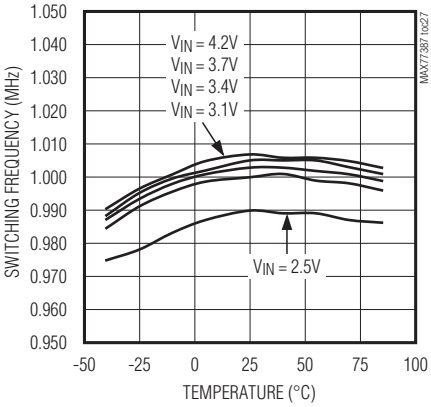
SWITCHING FREQUENCY vs. TEMPERATURE (4MHz FPWM)



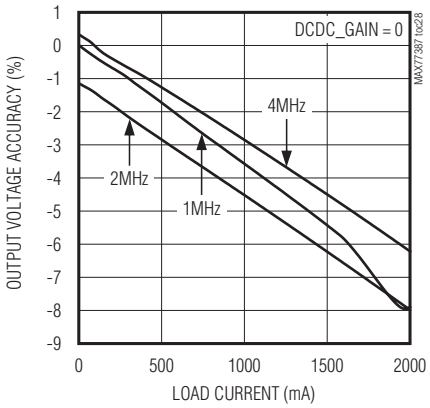
SWITCHING FREQUENCY vs. TEMPERATURE (2MHz FPWM)



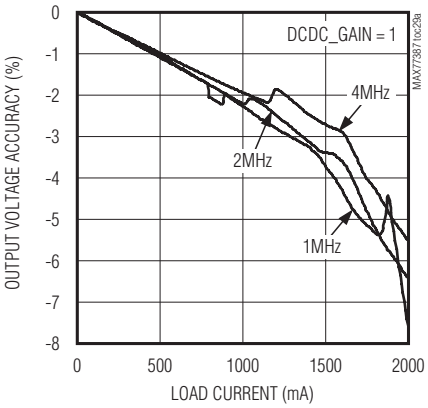
SWITCHING FREQUENCY vs. TEMPERATURE (1MHz FPWM)



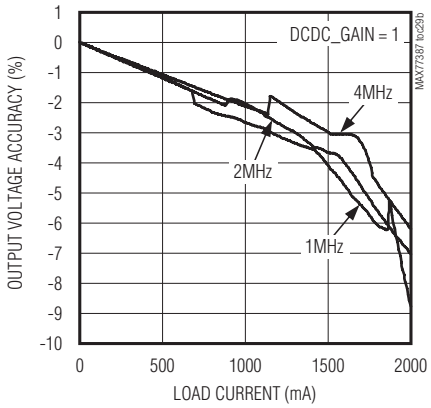
OUTPUT VOLTAGE ACCURACY vs. LOAD CURRENT (V_{IN} = 3.6V V_{OUT} = 5V FPWM)



OUTPUT VOLTAGE ACCURACY vs. LOAD CURRENT (V_{IN} = 3.6V, V_{OUT} = 5V FPWM)



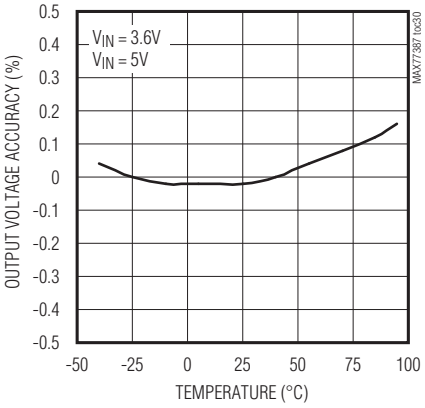
OUTPUT VOLTAGE ACCURACY vs. LOAD CURRENT (V_{IN} = 3.6V, V_{OUT} = 5V FPWM)



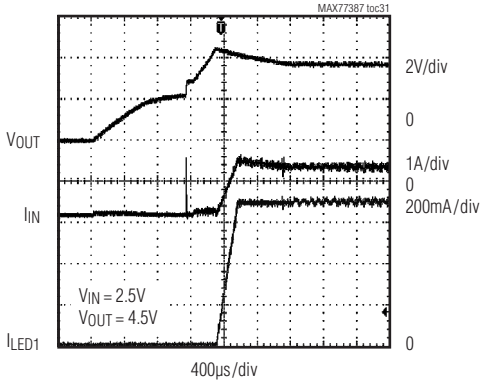
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

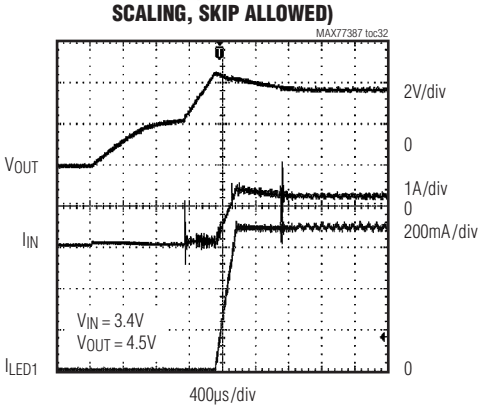
OUTPUT VOLTAGE ACCURACY vs. TEMPERATURE



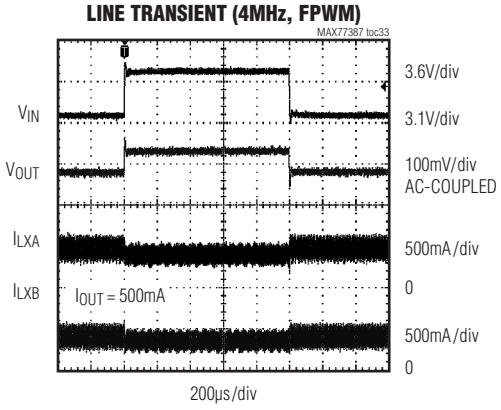
SOFT-START (4MHz, FPWM)



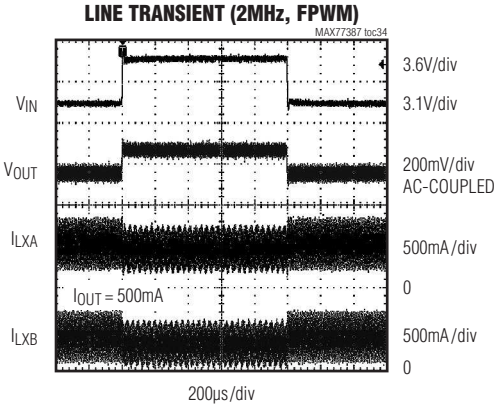
SOFT-START (4MHz, FREQUENCY SCALING, SKIP ALLOWED)



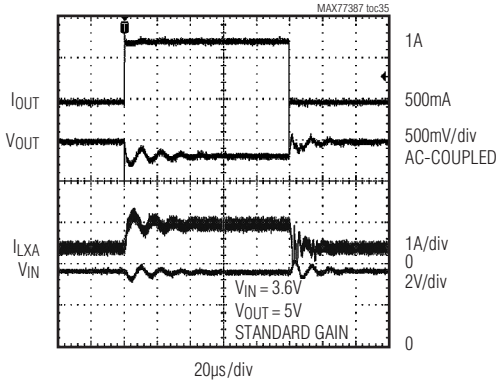
LINE TRANSIENT (4MHz, FPWM)



LINE TRANSIENT (2MHz, FPWM)



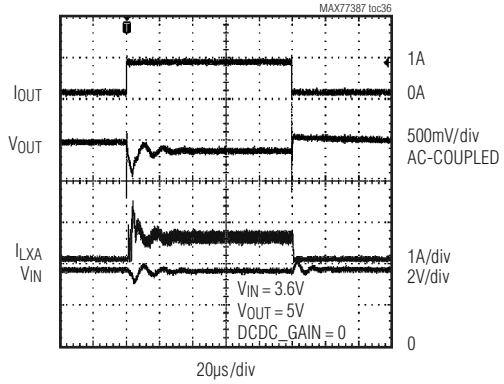
LOAD TRANSIENT (500mA-1A-500mA) 4MHz, FREQUENCY SCALING, SKIP ALLOWED



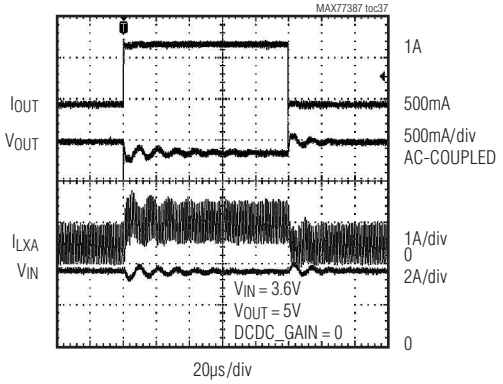
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

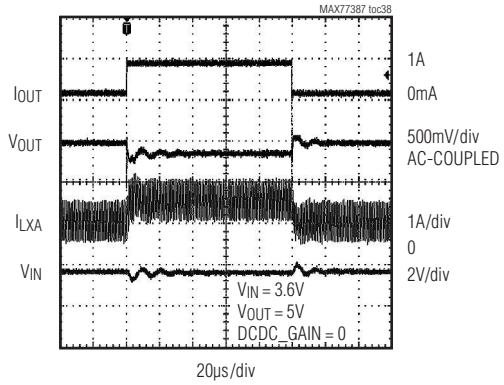
LOAD TRANSIENT (0A-1A-0A) 4MHz, FREQUENCY SCALING, SKIP ALLOWED



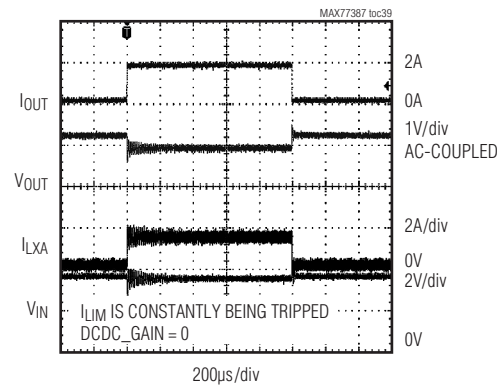
LOAD TRANSIENT (500mA-1A-500mA) 2MHz FPWM



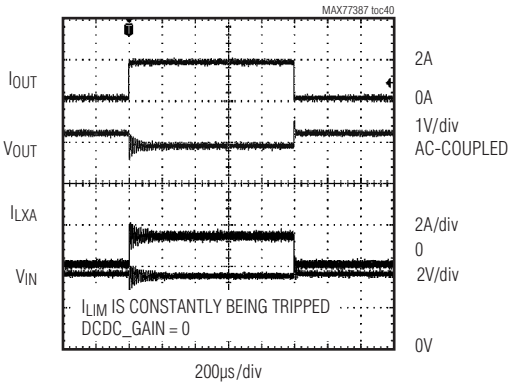
LOAD TRANSIENT (1mA-1A-1mA) 2MHz FPWM



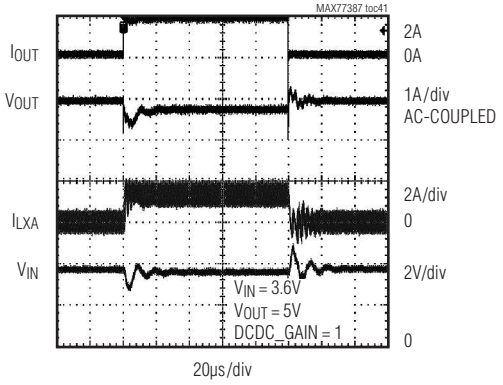
LOAD TRANSIENT (1mA-2A-1mA) 2MHz FPWM



LOAD TRANSIENT (1mA-2A-1mA) 4MHz FPWM



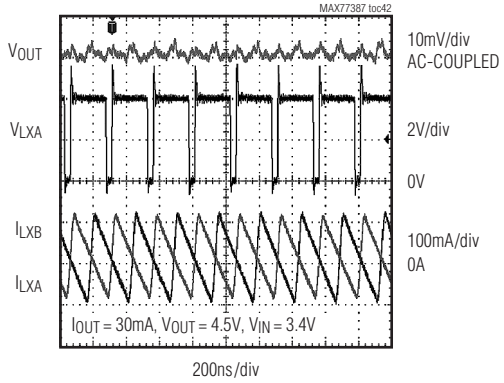
LOAD TRANSIENT (1mA-2A-1mA) 2MHz FPWM



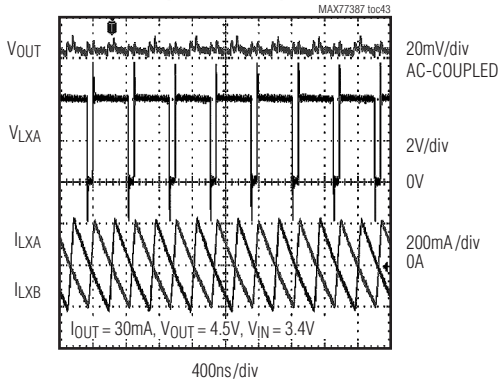
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

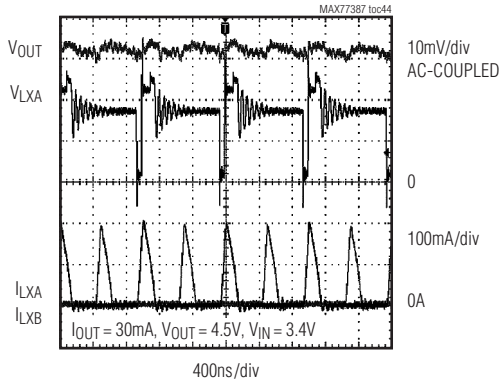
LIGHT-LOAD SWITCHING WAVEFORMS (4MHz FPWM)



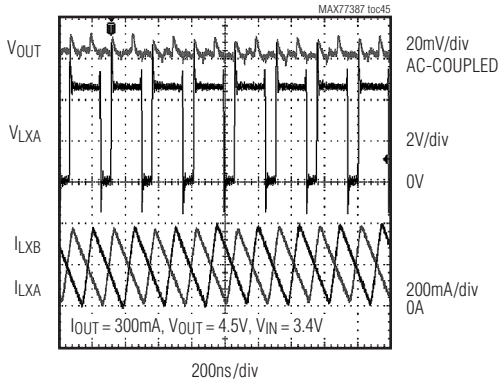
LIGHT-LOAD SWITCHING WAVEFORMS (2MHz FPWM)



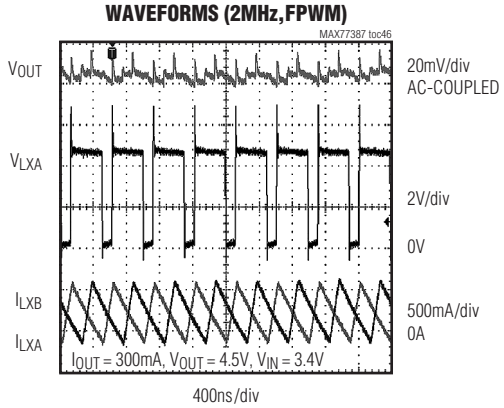
LIGHT-LOAD SWITCHING WAVEFORMS (4MHz, FREQUENCY SCALING, SKIP ALLOWED)



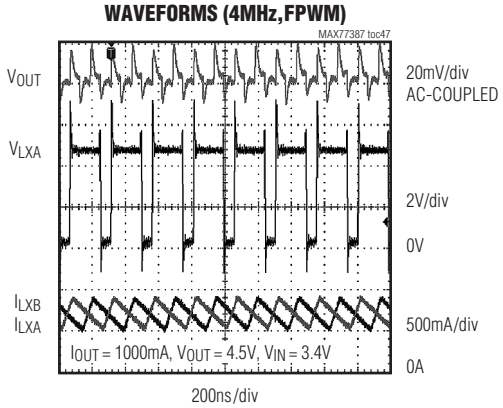
MODERATE-LOAD SWITCHING WAVEFORMS (4MHz,FPWM)



MODERATE-LOAD SWITCHING WAVEFORMS (2MHz,FPWM)



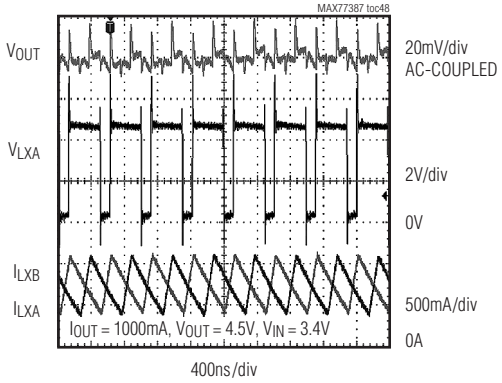
HEAVY-LOAD SWITCHING WAVEFORMS (4MHz,FPWM)



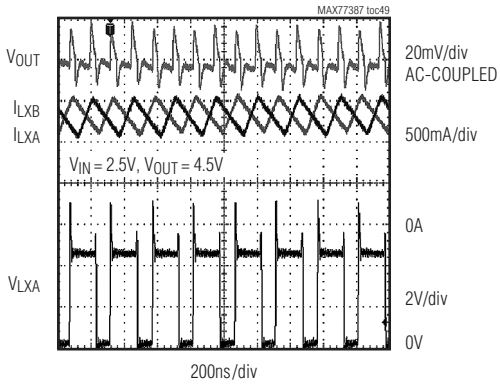
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

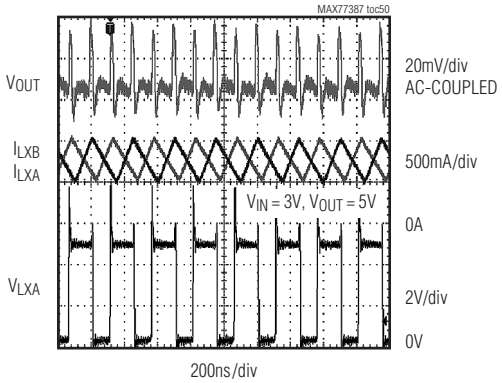
HEAVY-LOAD SWITCHING WAVEFORMS (2MHz,FPWM)



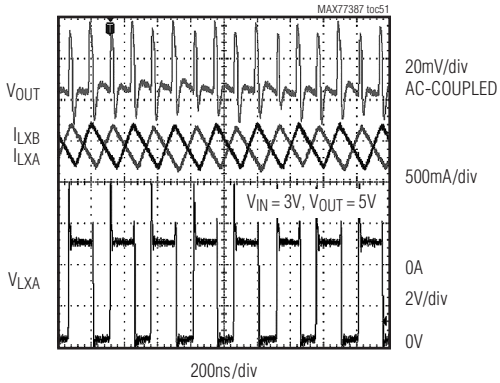
1.25A CURRENT LIMIT



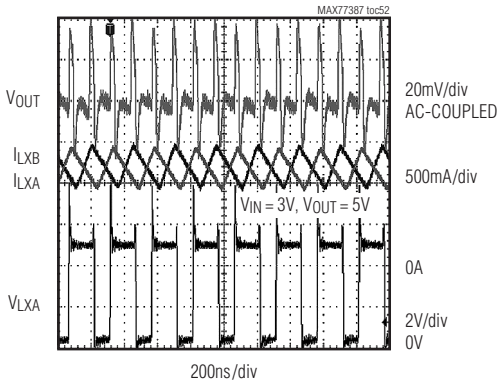
1.5A CURRENT LIMIT



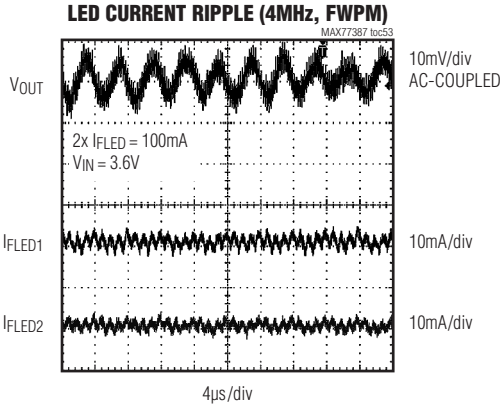
1.75A CURRENT LIMIT



2A CURRENT LIMIT



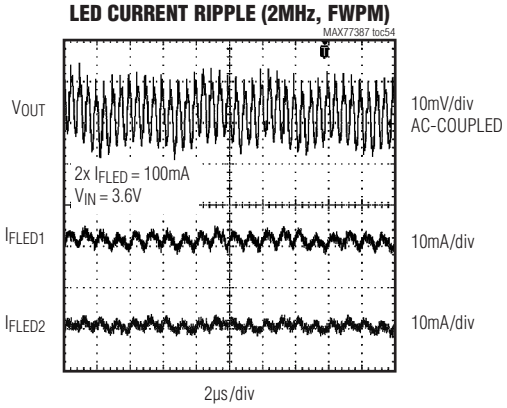
LED CURRENT RIPPLE (4MHz, FWPM)



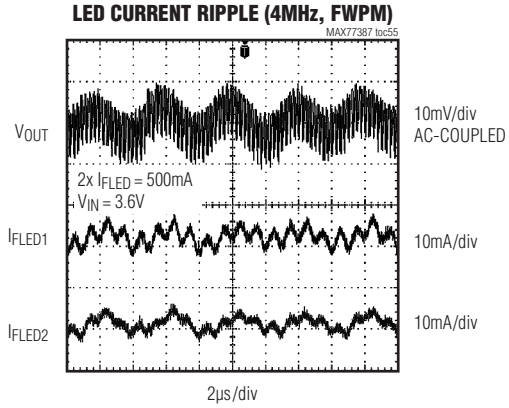
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

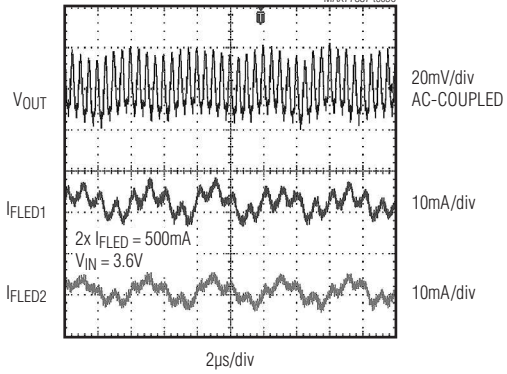
LED CURRENT RIPPLE (2MHz, FWPM)



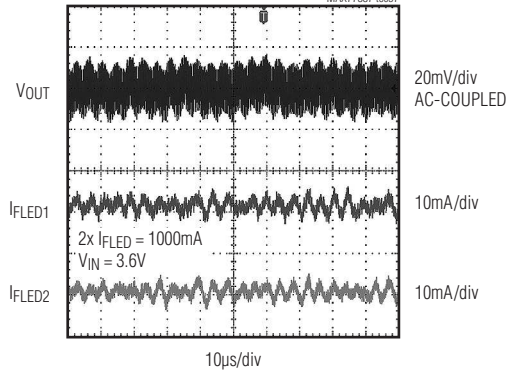
LED CURRENT RIPPLE (4MHz, FWPM)



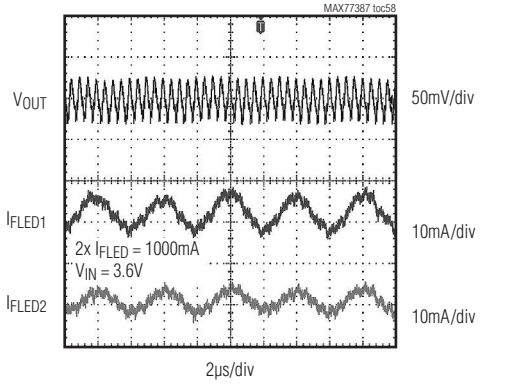
LED CURRENT RIPPLE (2MHz, FWPM)



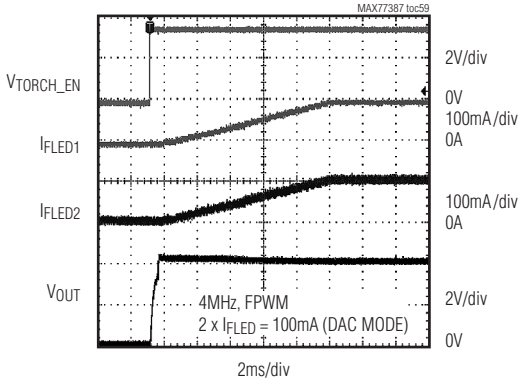
LED CURRENT RIPPLE (4MHz, FWPM)



LED CURRENT RIPPLE (2MHz, FWPM)



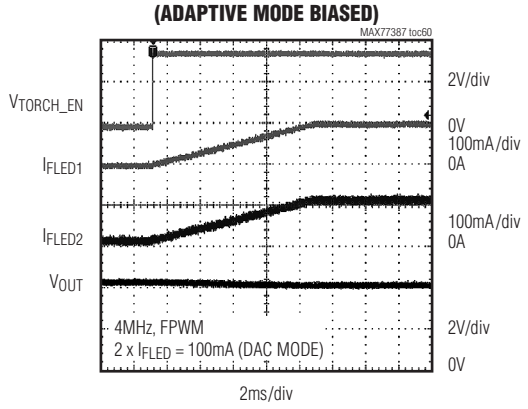
TORCH ENABLED BY TORCH_EN (ADAPTIVE MODE NO PREBIAS)



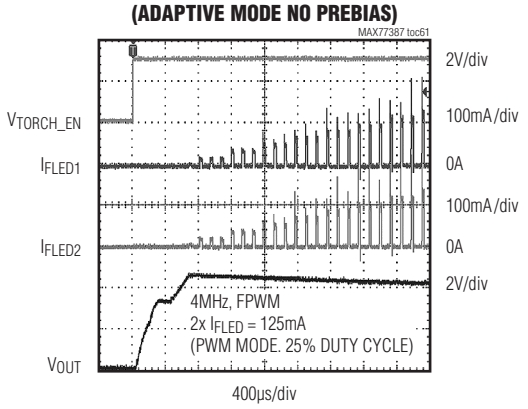
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

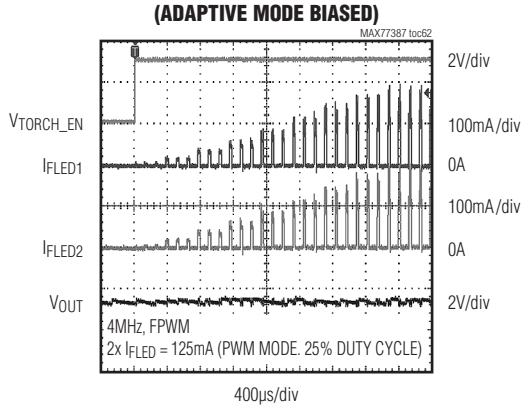
TORCH ENABLED BY TORCH_EN (ADAPTIVE MODE BIASED)



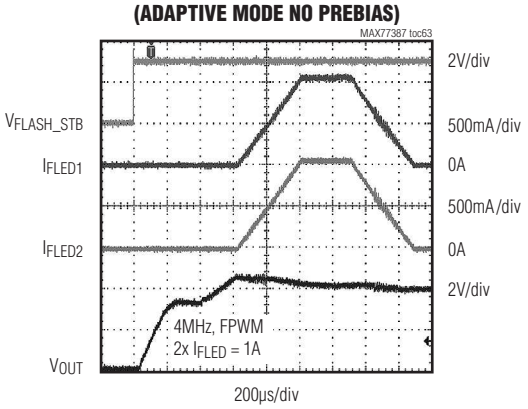
TORCH ENABLED BY TORCH_EN (ADAPTIVE MODE NO PREBIAS)



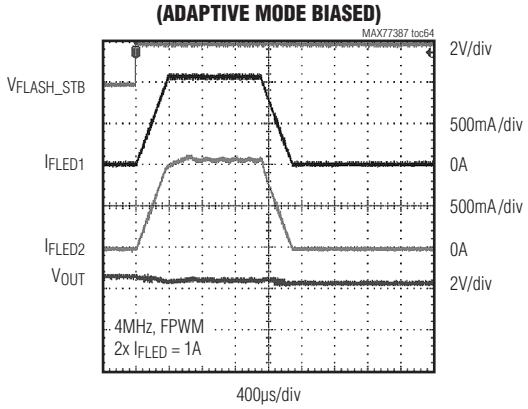
TORCH ENABLED BY TORCH_EN (ADAPTIVE MODE BIASED)



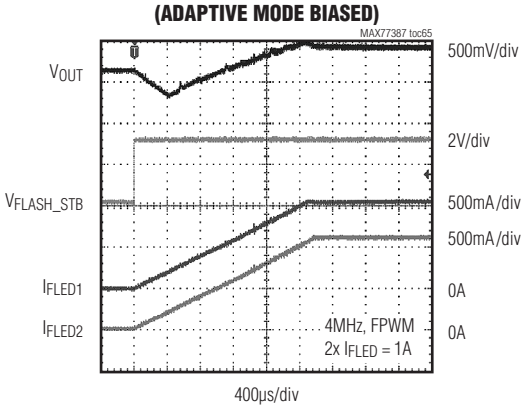
FLASH ENABLED BY FLASH_STB (ADAPTIVE MODE NO PREBIAS)



FLASH ENABLED BY FLASH_STB (ADAPTIVE MODE BIASED)



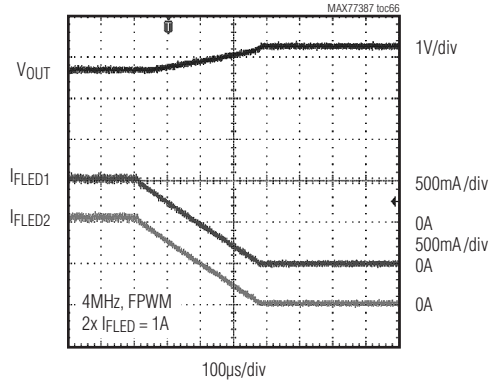
FLASH ENABLED BY FLASH_STB (ADAPTIVE MODE BIASED)



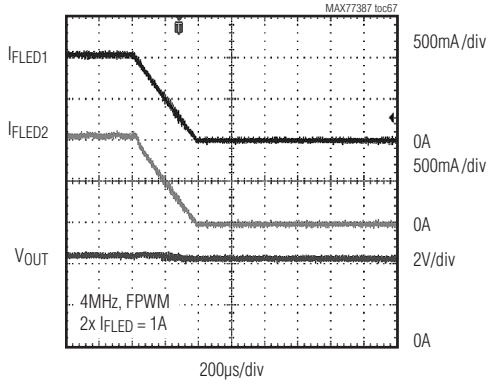
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

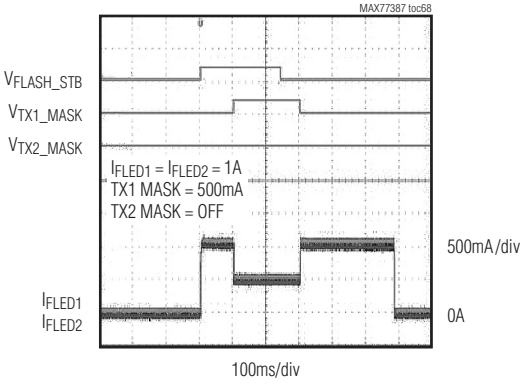
FLASH RAMP DOWN



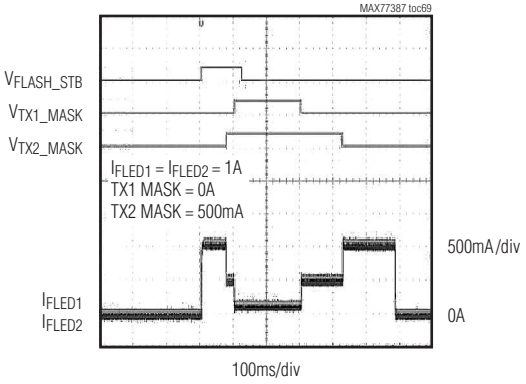
FLASH RAMP DOWN



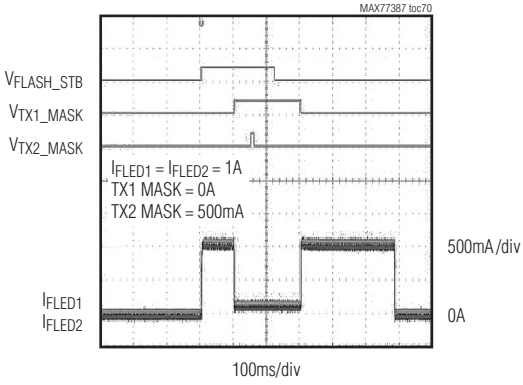
TX1 MASK (RISING EDGE)



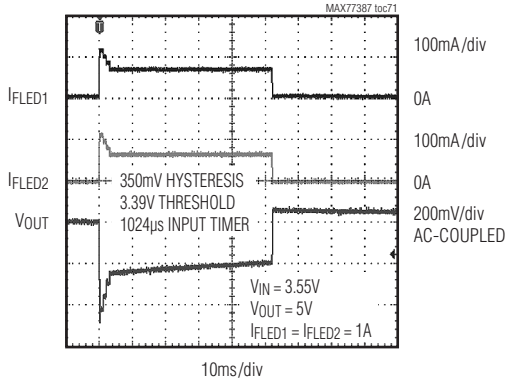
TX1 AND TX2 MASKS



TX1 AND TX2 MASKS



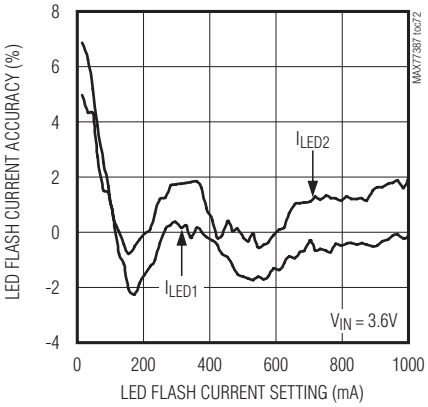
MAXFLASH



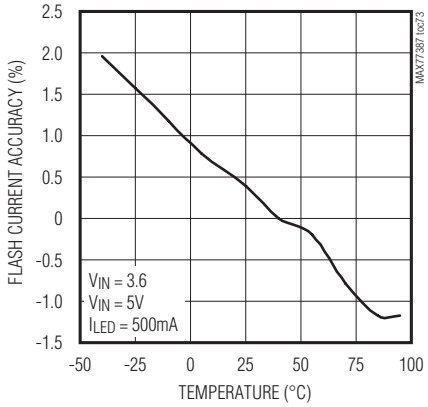
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = 3.6V, T_A = +25°C, unless otherwise noted.

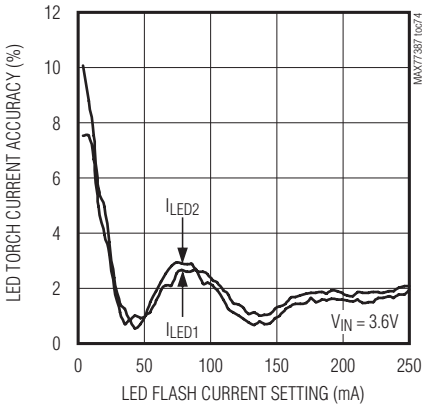
LED FLASH CURRENT ACCURACY vs. LOAD CURRENT



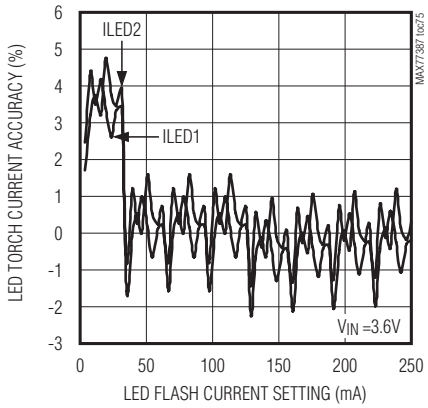
FLASH CURRENT ACCURACY vs. TEMPERATURE



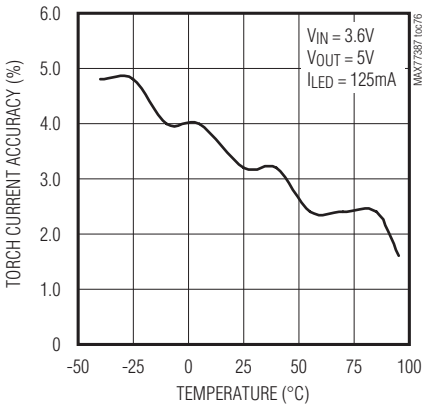
LED TORCH CURRENT ACCURACY vs. LOAD CURRENT (DAC MODE)



LED TORCH CURRENT ACCURACY vs. LOAD CURRENT (PWM MODE)



TORCH CURRENT ACCURACY vs. TEMPERATURE (DAC MODE)



SHUTDOWN CURRENT vs. TEMPERATURE