MAX5087

45V, 400mA, Low-Quiescent-Current Linear Regulator with Adjustable Reset Delay

General Description

The MAX5087 high-voltage linear regulator operates from an input voltage of 6.5V to 45V and delivers up to 400mA of output current. The device consumes only 70µA of quiescent current with no load and 11µA in shutdown. The device includes a SET input, that when connected to ground, selects a preset output voltage of 3.3V (MAX5087A) or 5.0V (MAX5087B). Alternatively, the output voltage can be adjusted from 2.5V to 11V by simply connecting SET to the regulator's output through a resistive divider network. The MAX5087 also provides an open-drain, active-low microprocessor (µP) reset output that asserts when the regulator output drops below the preset output voltage threshold. An external capacitor programs the reset timeout period. Other features include an enable input, thermal shutdown, and short-circuit protection.

The MAX5087 operates over the automotive temperature range of -40°C to +125°C and is available in a 16-pin TQFN thermally enhanced package.

Applications

- Industrial
- Home Security/Safety
- Networking

Features

- Wide Operating Input Voltage Range (6.5V to 45V)
- Thermally Enhanced Package Dissipates 2.6W at T_A = +70°C (16-Pin TQFN)
- Guaranteed 400mA Output Current
- 70µA Quiescent Supply Current
- Preset 3.3V, 5.0V, or Adjustable 2.5V to 11V Output Voltage
- Remote Load Sense Capability
- Enable Input
- Integrated µP Reset Circuit with Programmable Timeout Period
- Thermal and Short-Circuit Protection
- -40°C to +125°C Operating Temperature Range

Ordering Information

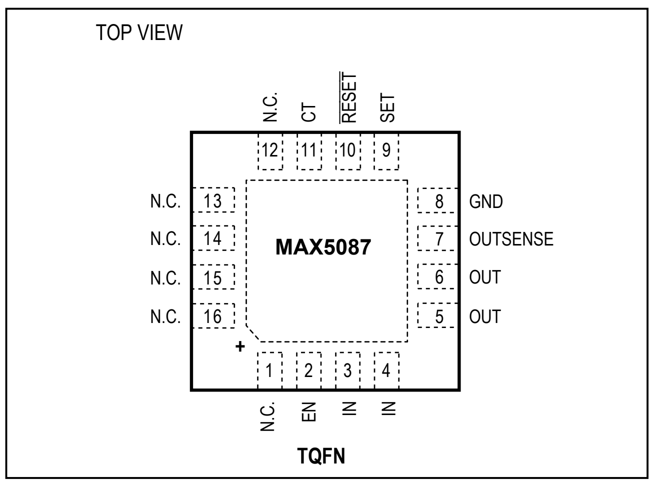
PART	PIN-PACKAGE	OUTPUT VOLTAGE (V)
MAX5087AATE+	16 TQFN-EP*	3.3
MAX5087BATE+	16 TQFN-EP*	5.0
MAX5087BATE/V+	16 TQFN-EP*	5.0

***Note:** All devices are specified over the -40°C to +125°C operating temperature range.*

**EP = Exposed paddle.*

+Denotes lead-free package.

Pin Configuration



Absolute Maximum Ratings

IN to GND (do not exceed package power dissipation)....................-0.3V to +50V
IN to GND (T ≤ 300ms, I_{OUT} ≤ 250mA)....................-0.3V to +42V
EN to GND....................-0.3V to +50V
$\overline{RESET}$, OUT, OUTSENSE to GND....................-0.3V to +12V
IN to OUT....................-0.3V to +50V
CT, SET TO GND....................-0.3V to +35V
Short-Circuit Duration (V_{IN} ≤ 14V)....................Continuous
Maximum Current into Any Pin (Except IN, OUT)....................±20mA
Continuous Power Dissipation (T_A = +70°C)
16-Pin TQFN (derate 33.3mW/°C above +70°C).......2666mW
Operating Temperature Range....................-40°C to +125°C
Junction Temperature....................+150°C
Storage Temperature Range....................-60°C to +150°C
Lead Temperature (soldering, 10s)....................+300°C

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

Package Thermal Characteristics (Note 1)

TQFN
Junction-to-Ambient Thermal Resistance (θ_{JA})........30.0°C/W
Junction-to-Case Thermal Resistance (θ_{JC})..................2°C/W

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

Electrical Characteristics

(V_{IN} = 14V, I_{OUT} = 1mA, C_{IN} = 47μF (low ESR), C_{OUT} = 15μF, V_{EN} = 2.4V, 10kΩ from $\overline{RESET}$ to OUT, T_A = T_J = -40°C to +125°C, unless otherwise noted. Typical specifications are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}	V_{IN} ≥ V_{OUT} + 1.5V		6.5		45.0	V
Supply Current	I_Q	Measured at GND, SET = GND	I_{OUT} = 0		70	150	μA
			I_{OUT} = 400mA		5300		
Shutdown Supply Current	I_{SHDN}	V_{EN} P 0.4V			11	21	μA
REGULATOR							
Guaranteed Output Current	I_{OUT}	V_{IN} = 6.5V, V_{OUT} = 5.0V		400			mA
Output Voltage (Note 3)	V_{OUT}	SET = GND, 5V version	6.5V P V_{IN} ≤ 25V, 5mA P I_{OUT} ≤ 400mA	4.87	5	5.13	V
			6.5V P V_{IN} ≤ 45V, 5mA P I_{OUT} ≤ 100mA	4.850	5	5.150	
		SET = GND, 3.3V version	6.5V P V_{IN} ≤ 25V, 5mA P I_{OUT} ≤ 400mA	3.208	3.3	3.392	
			6.5V P V_{IN} ≤ 45V, 5mA P I_{OUT} ≤ 100mA	3.208	3.3	3.392	
		I_{OUT} = 5mA, adjustable range		2.5		11.0	
Dropout Voltage	ΔV_{DO}	I_{OUT} = 400mA, V_{OUT} = 5V (Note 4)			0.9	2.2	V
Startup Response Time		Rising edge of V_{IN} to V_{OUT}, R_L = 500Ω, SET = GND (Note 5)			400		μs
Line Regulation	ΔV_{OUT} / ΔV_{IN}	8V ≤ V_{IN} ≤ 45V	5V version	-1		+1	mV/V
			3.3V version	-0.5		+0.5	
Enable Voltage	V_{EN}	V_{EN} = high, regulator on		2.4			V
		V_{EN} = low, regulator off				0.4	

Electrical Characteristics (continued)

(V_{IN} = 14V, I_{OUT} = 1mA, C_{IN} = 47µF (low ESR), C_{OUT} = 15µF, V_{EN} = 2.4V, 10kΩ from $\overline{RESET}$ to OUT, $T_A = T_J$ = -40°C to +125°C, unless otherwise noted. Typical specifications are at T_A = +25°C.) (Note 2)

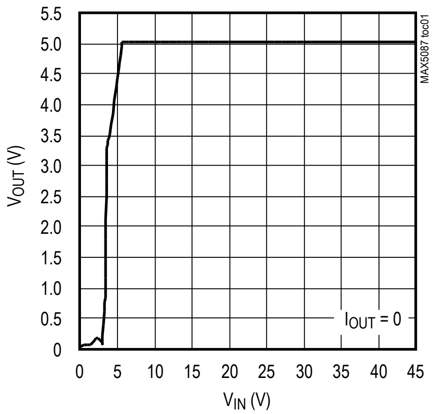
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Enable Input Current	I_{EN}	V_{EN} = 2.4V		0.35		µA
		V_{EN} = 14V		3.4		
SET Reference Voltage	V_{SET}		1.200	1.235	1.260	V
SET Input Leakage Current	I_{SET}		-100	+0.5	+100	nA
Load Regulation	ΔV_{OUT} / ΔI_{OUT}	I_{OUT} = 1mA to 400mA (Note 3)		0.1	0.35	Ω
Power-Supply Rejection Ratio	PSRR	I_{OUT} = 10mA, f = 100Hz, 500mV_{P-P}, V_{OUT} = 5V		70		dB
Short-Circuit Current	I_{SC}	V_{IN} < 14V (Note 6)		640		mA
Thermal Shutdown Temperature	$T_{J(SHDN)}$			175		°C
Thermal Shutdown Hysteresis	$\Delta T_{J(SHDN)}$			25		°C
$\overline{RESET}$ Voltage Threshold	$V_{\overline{RESET}}$		89	92	94	% V_{OUT}
$\overline{RESET}$ Threshold Hysteresis	V_{RHYST}			2		% V_{OUT}
$\overline{RESET}$ Output Low Voltage	V_{RL}	I_{SINK} = 1mA			0.4	V
$\overline{RESET}$ Output Leakage Current	I_{RH}	V_{RESET} = 5V			1	µA
$\overline{RESET}$ Output Minimum Timeout Period		When V_{OUT} reaches $\overline{RESET}$ threshold, C_{CT} = Open		15		µs
ENABLE to $\overline{RESET}$ Minimum Timeout Period		When EN goes high, C_{CT} = open		170		µs
Delay Comparator Threshold (Rising)			1.196	1.230	1.264	V
Delay Comparator Threshold Hysteresis				100		mV
CT Charge Current			1	2	4	µA
CT Discharge Current				5		mA

Note 2: Limits at T_A = -40°C are guaranteed by design.
Note 3: Output voltage is tested using a pulsed load current of less than 50ms duration.
Note 4: Dropout voltage is defined as (V_{IN} - V_{OUT}) when V_{OUT} is 100mV below the value of V_{OUT} for V_{IN} = V_{OUT} + 3V.
Note 5: Startup time measured from 50% of V_{IN} to 90% of V_{OUT}.
Note 6: Continuous short-circuit protection for V_{IN} > 14V not guaranteed.

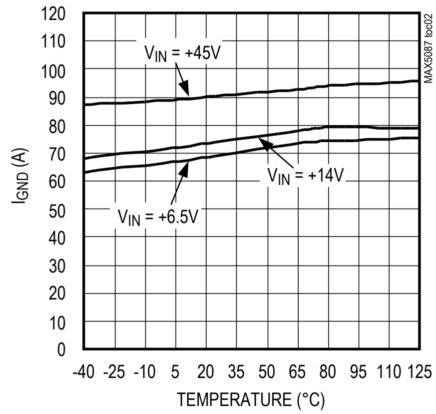
Typical Operating Characteristics

(V_{IN} = V_{EN} = 14V, C_{IN} = 47µF (low ESR), C_{OUT} = 15µF, V_{OUT} = 5V, SET = GND, T_A = +25°C, unless otherwise specified.)

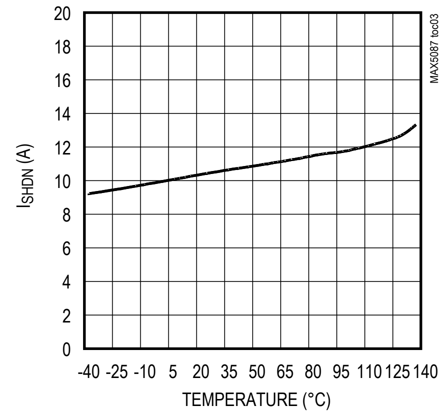
OUTPUT VOLTAGE vs. INPUT VOLTAGE



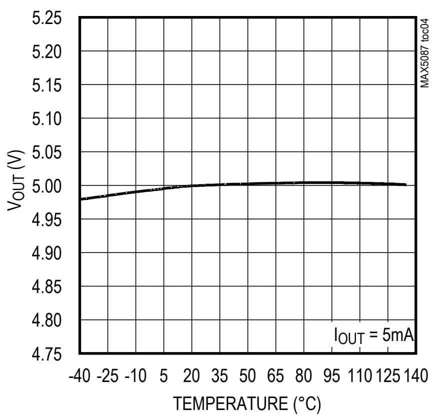
NO-LOAD SUPPLY CURRENT vs. TEMPERATURE



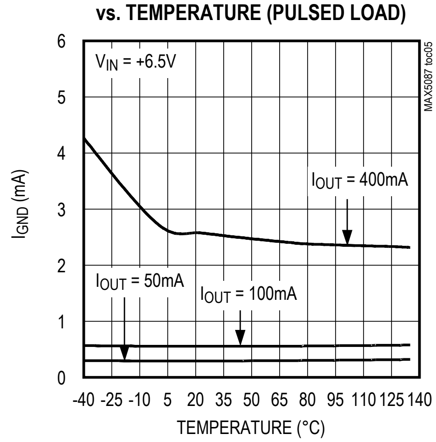
SHUTDOWN SUPPLY CURRENT vs. TEMPERATURE



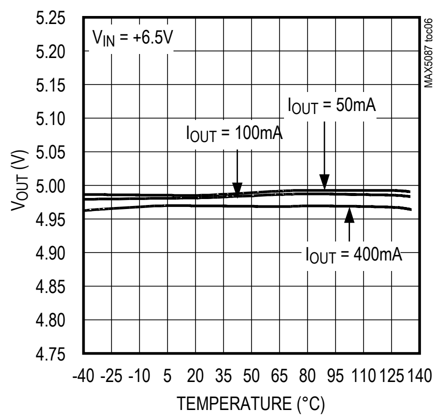
OUTPUT VOLTAGE vs. TEMPERATURE



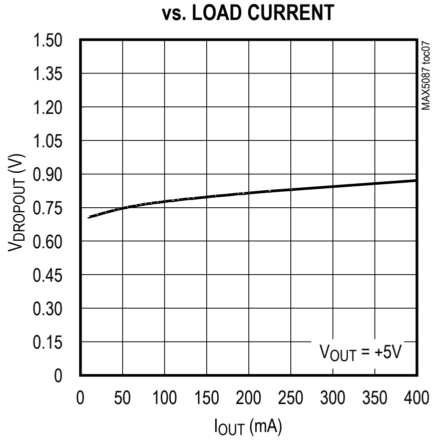
GROUND CURRENT vs. TEMPERATURE (PULSED LOAD)



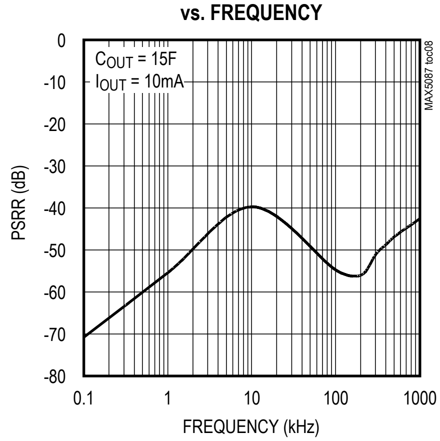
OUTPUT VOLTAGE vs. LOAD CURRENT AND TEMPERATURE



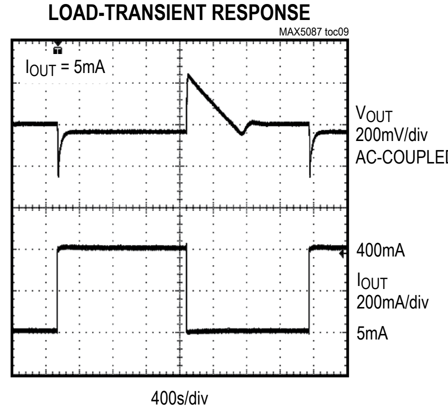
DROPOUT VOLTAGE vs. LOAD CURRENT



POWER-SUPPLY REJECTION RATIO vs. FREQUENCY



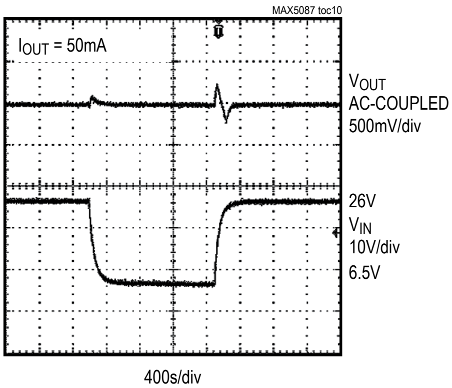
LOAD-TRANSIENT RESPONSE



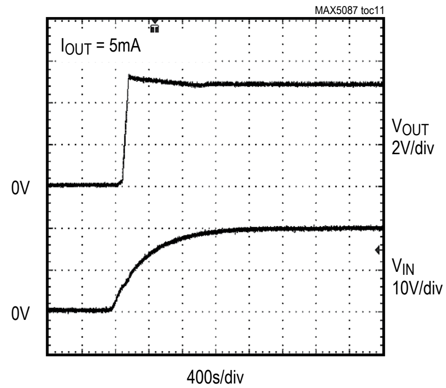
Typical Operating Characteristics (continued)

(V_{IN} = V_{EN} = 14V, C_{IN} = 47µF (low ESR), C_{OUT} = 15µF, V_{OUT} = 5V, SET = GND, T_A = +25°C, unless otherwise specified.)

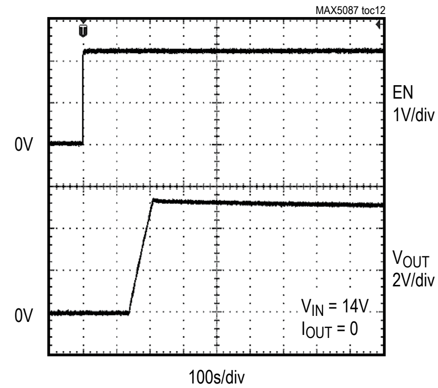
INPUT VOLTAGE STEP RESPONSE



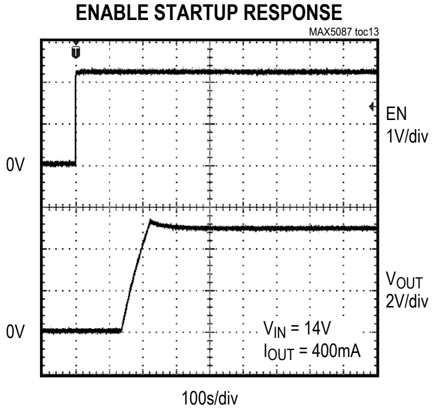
STARTUP RESPONSE



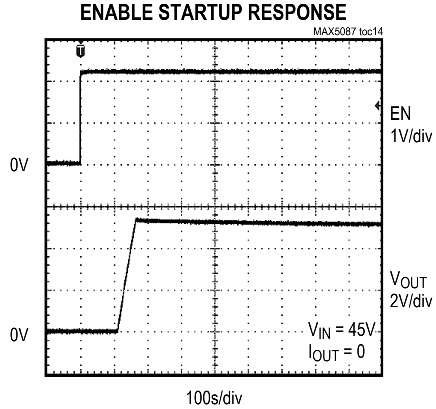
ENABLE STARTUP RESPONSE



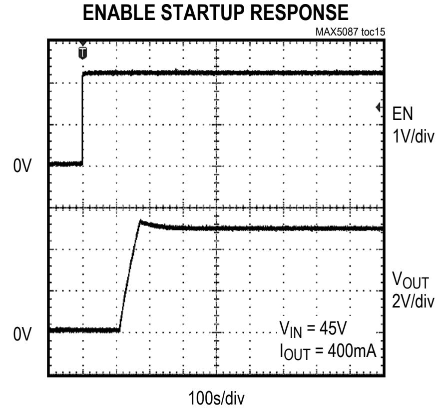
ENABLE STARTUP RESPONSE



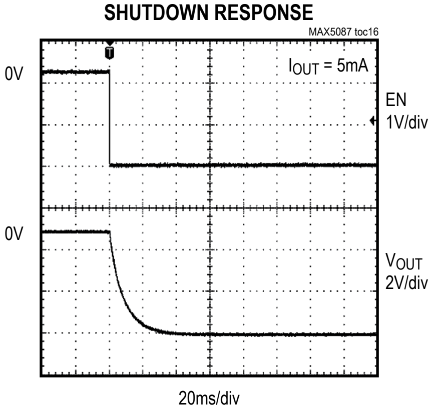
ENABLE STARTUP RESPONSE



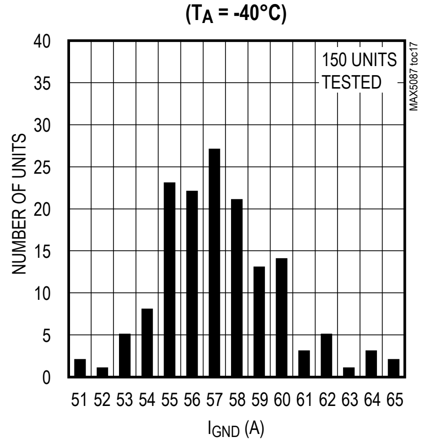
ENABLE STARTUP RESPONSE



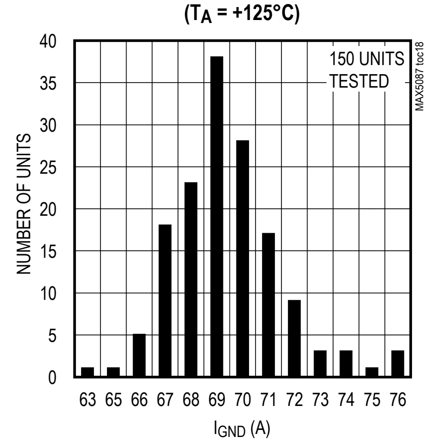
SHUTDOWN RESPONSE



GROUND CURRENT DISTRIBUTION (T_A = -40°C)



GROUND CURRENT DISTRIBUTION (T_A = +125°C)



Pin Description

PIN	NAME	FUNCTION
1, 12–16	N.C.	No Connection. Not internally connected.
2	EN	Enable Input. Drive EN high to turn on the regulator. Force EN low to place the device in shutdown mode.
3, 4	IN	Regulator Input. Supply voltage ranges from 6.5V to 45V. Bypass IN to GND with a low-ESR 47μF electrolytic capacitor.
5, 6	OUT	Regulator Output. Connect at least a 15μF low-ESR capacitor from OUT to GND.
7	OUTSENSE	Regulator Output Feedback Point. OUTSENSE must be connected to OUT for fixed output voltage versions. Leave OUTSENSE open for adjustable output voltage version.
8	GND	Ground
9	SET	Feedback Regulation Set Point. Connect SET to GND for a fixed 3.3V output (MAX5087A) or 5.0V output (MAX5087B). Connect an external resistive divider network from OUTSENSE to SET to GND to adjust the output voltage from 2.5V to 11V.
10	$\overline{\text{RESET}}$	Open-Drain Active-Low Reset Output. Connect a 10kΩ pullup resistor from $\overline{\text{RESET}}$ to any supply voltage up to 11V to create a logic output.
11	CT	Reset Timeout Setting Connection. A 2μA charging current is available at CT. Connect a capacitor from CT to GND to set the reset timeout period (see the *Adjustable Reset Timeout Period (CT)* section).
—	EP	Exposed Paddle. Connect externally to a large ground plane to aid heat dissipation. Do not use EP as a ground connection.

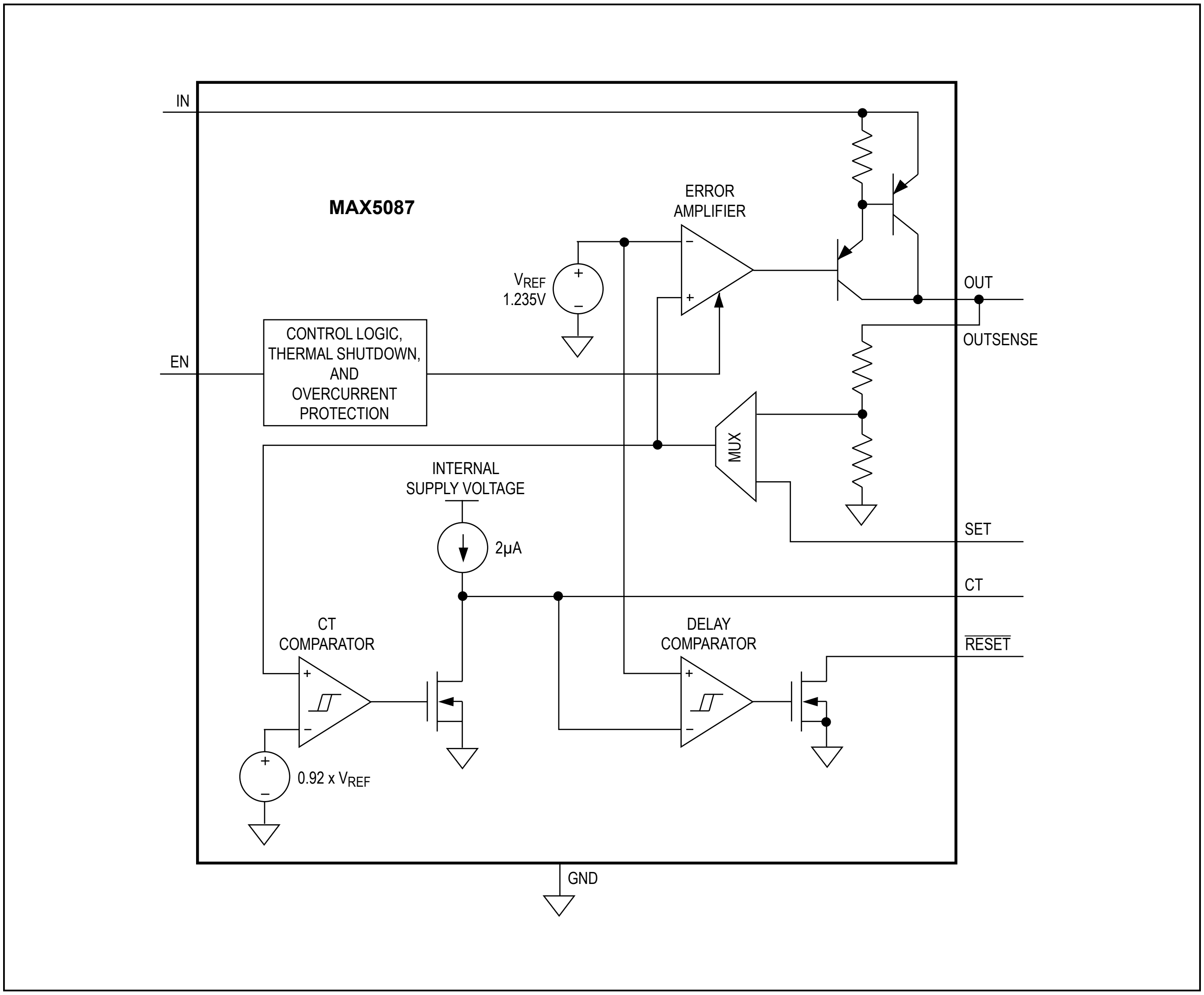


Figure 1. Functional Diagram

Detailed Description

The MAX5087 high-voltage linear regulator includes an integrated µP reset circuit with an adjustable reset timeout period (see the *Adjustable Reset Timeout Period (CT)* section). The device guarantees a 400mA load current and is available with a preset output voltage of 3.3V (MAX5087A) or 5V (MAX5087B). Both devices can be configured to provide an adjustable output voltage from 2.5V to 11V. The internal reset circuit monitors the regulator output voltage and asserts $\overline{\text{RESET}}$ low when the regulator output falls below the reset threshold voltage. Other features include an enable (regulator control input), 21µA (max) shutdown current, short-circuit protection (see the *Output Short-Circuit Current Limit* section), and thermal shutdown (see the *Thermal Protection* section).

Regulator

The MAX5087 accepts an input voltage range from 6.5V to 45V and offers a fixed output voltage of 3.3V or 5V. For an adjustable output voltage operation, use an external resistive divider network connected between OUT, SET, and GND (see Figure 2).

Enable Input (EN)

EN is a logic-level enable input that turns the device on/off. Drive EN high to turn on the device and drive EN low to place the device in shutdown. The MAX5087 draws 11µA (typ) of supply current when in shutdown. EN withstands voltages up to +45V, allowing EN to be connected to IN for an always-on operation.

Remote Sensing (OUTSENSE)

The 3.3V (MAX5087A) and 5V (MAX5087B) output voltage versions connect OUTSENSE for load voltage sensing. Leave OUTSENSE open when using adjustable output voltage version.

Reset Output ($\overline{\text{RESET}}$)

A supervisor circuit is fully integrated in the MAX5087 and uses the same reference voltage as the regulator. $\overline{\text{RESET}}$ goes low if V_{OUT} drops below the preset output voltage threshold, and remains low at least for the timeout period after V_{OUT} rises above the reset voltage threshold.

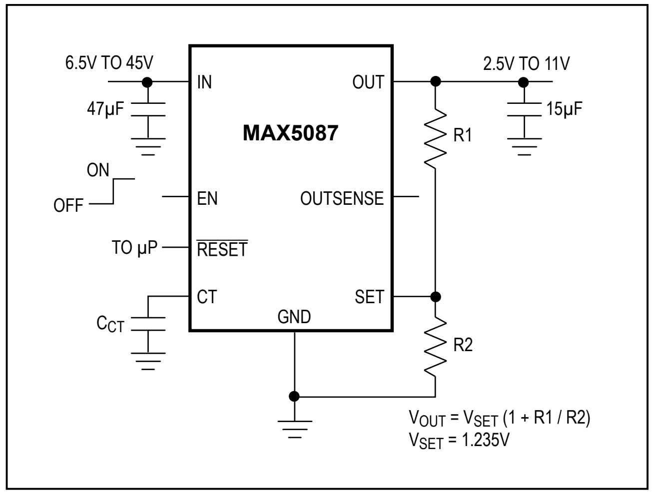


Figure 2. Setting the Adjustable Output Voltage

Adjustable Reset Timeout Period (CT)

The MAX5087 features a user-adjustable reset timeout. Connect a capacitor from CT to GND to set the reset timeout period (see Figure 2) and use the following equation to calculate the timeout period:

$$t_{RP} = C_{CT} \times 0.6175 \times 10^6 \text{ (s)}$$

where C_{CT} is the value of the external capacitor connected from CT to GND.

Thermal Protection

When the junction temperature exceeds T_J = +175°C, an internal thermal sensor signals the shutdown logic, which turns off the pass transistor, allowing the IC to cool. The thermal sensor turns the pass transistor on again after the IC's junction temperature cools by 25°C, resulting in a cycled output during continuous thermaloverload conditions. Thermal protection protects the MAX5087 in the event of fault conditions. During continuous operation, do not exceed the absolute maximum junction temperature rating of T_J = +150°C.

Output Short-Circuit Current Limit

The MAX5087 features a current limit. The output can be shorted to GND for an indefinite period of time (for V_{IN} < 14V) without damage to the device. Continuous output short-circuit protection is only guaranteed for V_{IN} < 14V.

Applications Information

Output-Voltage Selection

The MAX5087 features a Dual ModeTM operation, in either a preset-voltage mode or an adjustable mode. In preset-voltage mode, internal feedback resistors set the MAX5087's output voltage to +3.3V or +5V. Select preset-voltage mode by connecting SET to ground. In adjustable mode, select an output between +2.5V and +11V using two external resistors connected as a voltage-divider to SET (Figure 2). Set the output voltage using the following equation:

$$V_{OUT} = V_{SET} \times \left(1 + \frac{R1}{R2}\right)$$

where V_{SET} = 1.235V and R2 is chosen to be < 100kΩ.

Available Output-Current Calculation

The MAX5087 high-voltage regulator provides up to 400mA of output current. The input voltage extends to +45V. Package power dissipation limits the amount of output current available for a given input/output voltage and ambient temperature. Figure 3 shows the maximum power dissipation curve for these devices. The graph assumes that the exposed paddle of the MAX5087 package is set up per JEDEC 51 (multilayer board) specifications.

Use Figure 3 to determine the allowable package dissipation (P_D) for a given ambient temperature. Alternately, use the following formulas to calculate the allowable package dissipation. Note that for the examples shown below, the electrical characteristic limits are guaranteed up to T_J = +125°C (max).

$$P_D = \begin{cases} 2.666W \text{ for } T_A \le +70°C \\ 2.666W - 0.0333\frac{W}{°C} \times (T_A - 70°C) \\ \text{for } +70°C < T_A \le +125°C \end{cases}$$

After determining the allowable package dissipation calculate the maximum output current using the following formula:

$$I_{OUT(MAX)} \cong \frac{P_D}{V_{IN} - V_{OUT}} \le 400mA$$

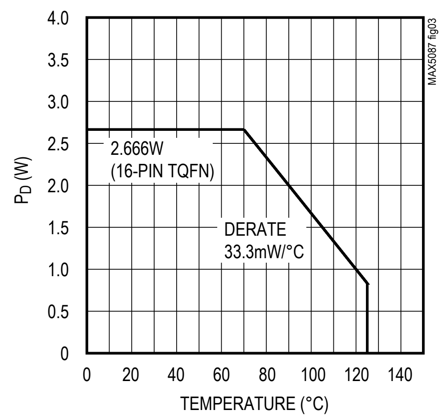


Figure 3. Calculated Maximum Power Dissipation vs. Temperature

The above equations do not include the negligible power dissipation from self-heating due to the IC ground current.

Example 1:

T_A = +95°C

V_{IN} = +14V

V_{OUT} = +5V

Find the maximum allowable output current. First calculate package dissipation at the given temperature as follows:

$$P_D = 2.666W - 0.0333\frac{W}{°C}(95°C - 70°C) = 1.8335W$$

Then determine the maximum output current:

$$I_{OUT(MAX)} = \frac{(1.8335W)}{(14V) - (5V)} = 203mA$$

Example 2:

T_A = +125°C

V_{IN} = +14V

V_{OUT} = +5V

Dual Mode is a trademark of Maxim Integrated Products, Inc.

Calculate package dissipation at the given temperature as follows:

$$P = 2.666W - 0.0333\frac{}{^{\circ}}(125^{\circ}C - 70^{\circ}C) = 0.8345W$$

And establish the maximum current:

$$I_{OUT(MAX)} = \frac{(1.191W)}{(14V) - (5V)} = 92.7mA$$

Example 3:

T_A = +50°C

V_{IN} = +14V

V_{OUT} = +10V

Calculate package dissipation at the given temperature as follows:

$$P_D = 2.666W$$

And find the maximum output current:

$$I_{OUT(MAX)} = \frac{(2.666W)}{(14V) - (10V)} = 666mA \Rightarrow I_{OUT(MAX)} = 400mA$$

In example 3 the maximum output current is calculated as 666mA, however, the maximum output current cannot exceed 400mA.

Use Figure 4 to quickly determine maximum allowable output current for selected ambient temperatures.

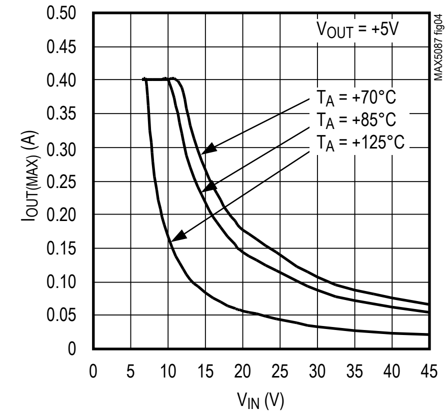


Figure 4. Maximum Output Current vs. Input Voltage (16-Pin TQFN)

Output-Capacitor Selection and Regulator Stability

For stable operation over the full temperature range and with load currents up to 400mA, use a 15µF (min) output capacitor with an ESR < 0.25Ω. To reduce noise and improve load-transient response, stability, and power-supply rejection use larger output capacitor values such as 22µF.

Some ceramic capacitor dielectrics exhibit large capacitance and ESR variation with temperature. For capacitor dielectrics such as Y5V, use 22µF or more to ensure stability at temperatures below -10°C. With X7R or X5R dielectrics, 15µF should be sufficient at all operating temperatures. To improve power supply rejection and transient response, use a minimum 47µF low-ESR capacitor from IN to GND.

Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
16 TQFN-EP	T1655+3	**21-0140**	**90-0073**

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	2/06	Initial release	—
1	4/06	Updated *Ordering Information* and *Electrical Characteristics* tables.	1–3
2	7/06	Updated *Electrical Characteristics* table.	2
3	2/08	Corrected errors in data sheet, reduced operating range, and removed products from *Ordering Information* table.	1–13
4	4/13	Added /V variant to *Ordering Information*	1
5	7/13	Changed package code to T1655+3	11
6	5/14	Updated *Applications*.	1

