MAX17651

60V, 100mA, Ultra-Low Quiescent Current, Linear Regulator

General Description

The MAX17651 ultra-low quiescent current, high-voltage linear regulator is ideal for use in industrial and battery-operated systems. The device operates from a 4V to 60V input voltage, delivers up to 100mA of load current, and consumes only 8μA of quiescent current at no load. The device consumes only 0.9μA current when in shutdown. Output voltage is adjustable in the 0.6V to 59V voltage range. Feedback voltage accuracy is ±2% over temperature.

An open-drain, active-low PGOOD pin provides a power-good signal to the system upon achieving successful regulation of the output voltage. The device also incorporates an enable pin (EN) that allows the user to turn the part on or off. The device has a thermal shutdown feature that shuts down the part when the die temperature exceeds 165°C. The MAX17651 operates over the -40°C to +125°C industrial temperature range and is available in a 6 lead, compact TSOT package.

Applications

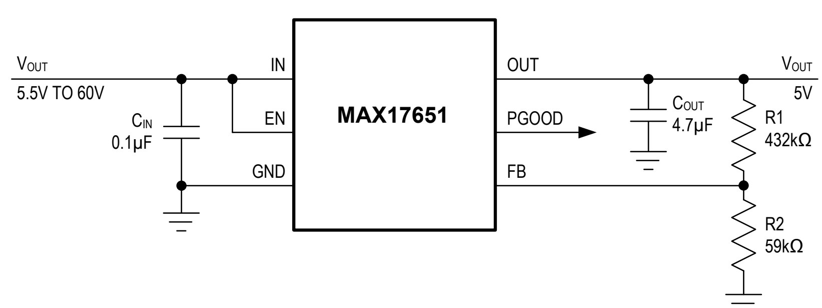
- Low-Current Industrial Power Supplies
- Battery-Powered Equipment
- Post Regulator for Switching Power Supplies
- Utility Meters
- Remote Sensors

Benefits and Features

- Extremely Easy to Use
  - Only 4 External Components Required
  - Stable with Tiny 4.7μF, 0805 Output Capacitor
  - All Ceramic Capacitors, Compact Layout
- Reduces Number of Linear Regulators to Stock
  - Wide 4V to 60V Input Voltage Range
  - Adjustable 0.6V to 59V Output
  - Up to 100mA Load Current Capability
- Operates Reliably in Adverse Industrial Environments
  - Built-In Output Voltage Monitoring with PGOOD Pin
  - High-Voltage ENABLE Input
  - Low 8μA Quiescent Current
  - Low Dropout Voltage of 300mV at 100mA
  - Overload Protection
  - Overtemperature Protection
  - -40°C to +125°C Operation

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

Application Circuit for 5V Output



19-7454; Rev 1; 3/16

Absolute Maximum Ratings

IN to GND..-0.3V to +70V
EN, OUT to GND...-0.3V to IN + 0.3V
FB, PGOOD to GND ....-0.3V to +6V
Output Short-Circuit Duration...................................Continuous
Operating Temperature Range........................ -40°C to +125°C
Junction Temperature..+150°C
Storage Temperature Range........................... -65°C to +160°C
Continuous Power Dissipation (T_A = +70°C) (multilayer board)
TSOT (derate 9.1mW/°C above +70°C)......................727mW
Lead Temperature (soldering 10s) ....+300°C

Package Thermal Characteristics (Note 1)

TSOT
Junction-to-Ambient Thermal Resistance (θ_{JA}) ....110°C/W
Junction-to-Case Thermal Resistance (θ_{JC})..............50°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

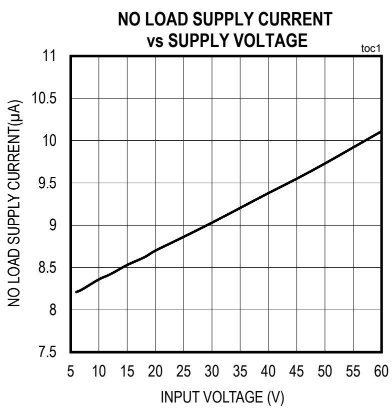
(V_{IN} = 12V, C_{OUT} = 4.7µF T_A = T_J = -40°C to +125°C, unless otherwise noted. Typical values are at T_A = +25°C. All voltages are referenced to GND, unless otherwise noted.) (Note 2)

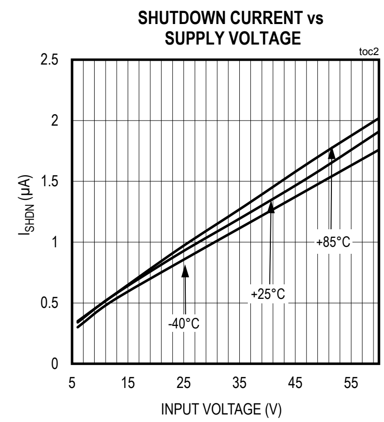
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
INPUT SUPPLY (V_{IN})						
Input Voltage Range	V_{IN}		4		60	V
Input Supply Current	I_{IN-SH}	V_{EN} = 0V, shutdown mode		0.9	1.8	µA
	I_{IN-Q}	V_{EN} = V_{IN}, I_{LOAD} = 0mA		8	15	µA
ENABLE(EN)						
EN Threshold	V_{ENR}	V_{EN} rising	2			V
	V_{ENF}	V_{EN} falling			0.6	V
EN Leakage Current	I_{EN}	T_A = +25°C	-100		+100	nA
FEEDBACK (FB)						
FB Regulation Voltage	V_{FB-REG}		0.588	0.6	0.612	V
FB Input Leakage Current	I_{FB}	V_{FB} = 0.6V, T_A = 25°C	-25		+25	nA
CURRENT LIMIT						
Current Limit Threshold	I_{LIMIT}	V_{IN} = 5.5V, V_{OUT} = 4.5V	101	140	165	mA
PGOOD						
PGOOD Rising Threshold	$V_{PGOOD-RISE}$	V_{FB} rising	89.5	92	94.5	%
PGOOD Falling Threshold	$V_{PGOOD-FALL}$	V_{FB} falling	87	89.5	92	%
PGOOD Output Level Low		I_{PGOOD} = 1mA			0.2	V
PGOOD Output leakage Current		V_{PGOOD} = 5.5V, T_A = +25°C			1	µA
OUTPUT VOLTAGE						
Dropout Voltage	V_{DO}	V_{IN} = 4.5V, I_{LOAD} = 100mA		280	550	mV
Line Regulation		V_{IN} = 4V to 60V, V_{OUT} = FB, I_{LOAD} = 1mA		0.1		%
Load Regulation		0.1mA < I_{LOAD} < 100mA, V_{OUT} = FB		0.5	1.2	%
THERMAL SHUTDOWN						
Thermal-Shutdown Threshold		Temperature rising		165		°C
Thermal-Shutdown Hysteresis				15		°C

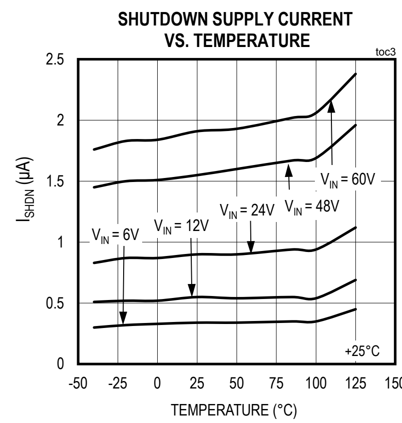
Note 2: All the limits are 100% tested at +25°C. Limits over temperature are guaranteed by design.

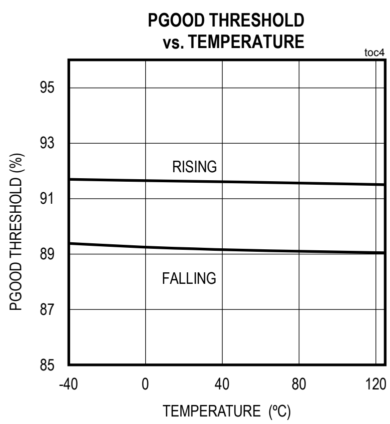
Typical Operating Characteristics

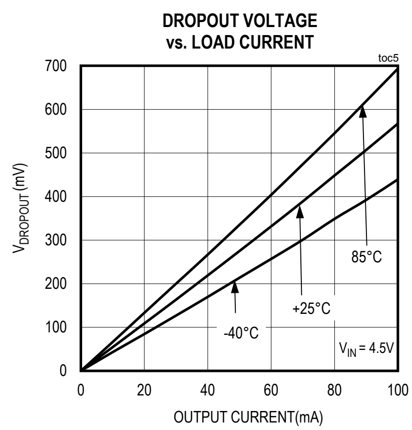
(V_{IN} = 6V, V_{OUT} = 5V, C_{OUT} = 4.7µF T_A= +25°C, unless otherwise noted.

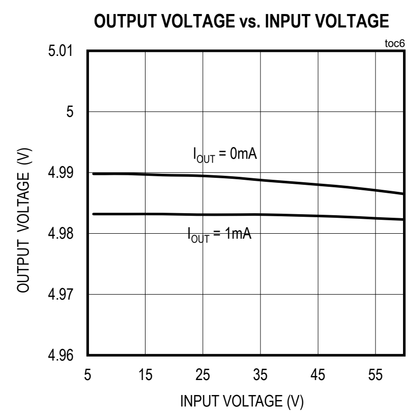


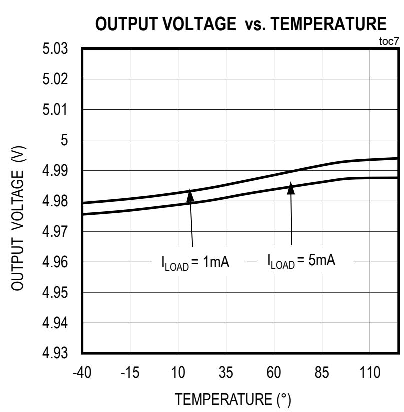


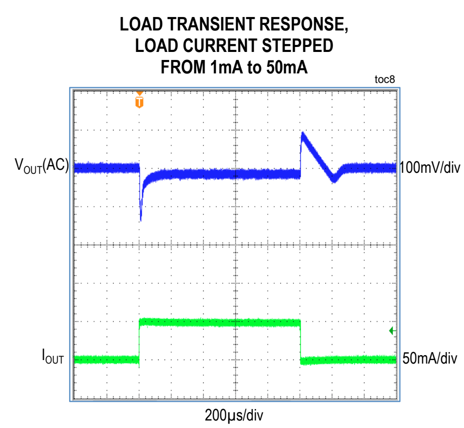








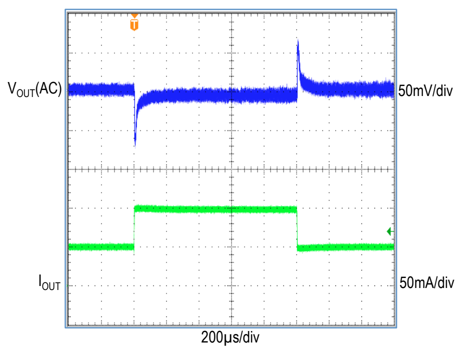




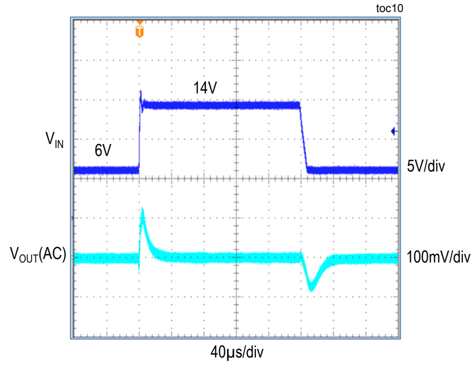
Typical Operating Characteristics (continued)

(V_{IN} = 6V, V_{OUT} = 5V, C_{OUT} = 4.7μF T_A= +25°C, unless otherwise noted.

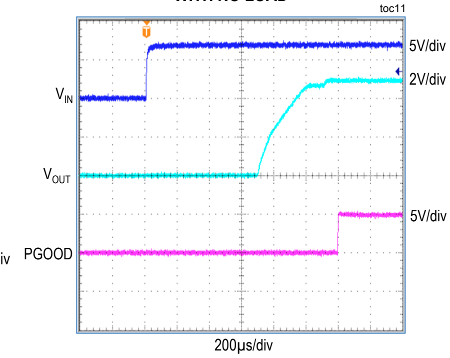
LOAD TRANSIENT RESPONSE, LOAD CURRENT STEPPED FROM 50mA to 100mA



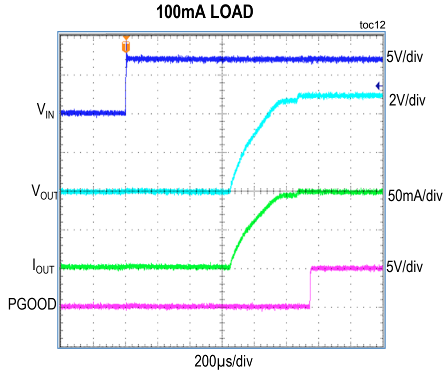
INPUT-VOLTAGE STEP RESPONSE WITH 100mA LOAD CURRENT



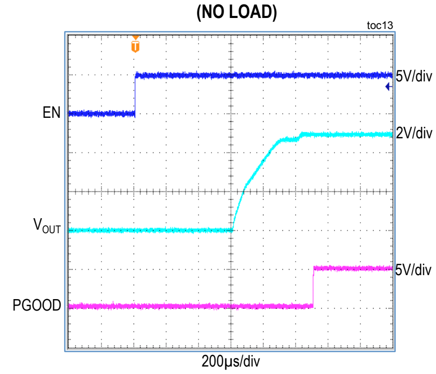
STARTUP RESPONSE WITH NO LOAD



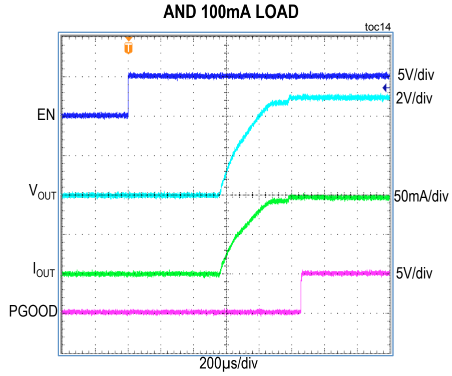
START UP RESPONSE WITH 100mA LOAD



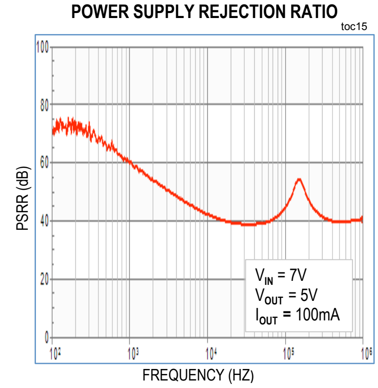
STARTUP RESPONSE WITH ENABLE (NO LOAD)



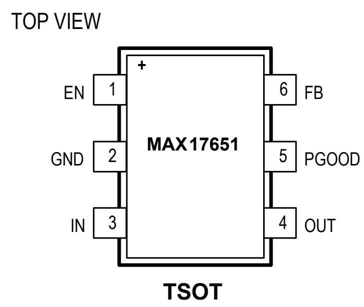
STARTUP RESPONSE WITH ENABLE AND 100mA LOAD



POWER SUPPLY REJECTION RATIO



Pin Configuration



Pin Description

PIN	NAME	FUNCTION
1	EN	Active-High, Enable Input. Force EN high (or connect to IN) to turn the regulator on. Pull EN to GND to place the device in a low-power shutdown mode.
2	GND	Ground. Connect GND to the ground plane.
3	IN	Power-Supply Input. Decouple to GND with a 0.1µF capacitor; place the capacitor close to the IN and GND pins.
4	OUT	Regulator Output. Connect at least 4.7µF, 0805 capacitor from OUT to GND.
5	PGOOD	Open-Drain PGOOD Output. Pull up PGOOD to an external power supply. PGOOD pulls low if FB drops below 89% of its set value. PGOOD goes high after FB rises above 92% of its set value. The PGOOD pin can be left floating if not used.
6	FB	Output Feedback Connection. Connect FB to a resistor divider between V_{OUT} and GND to adjust the output voltage from 0.6V to 59V.

Functional Diagram

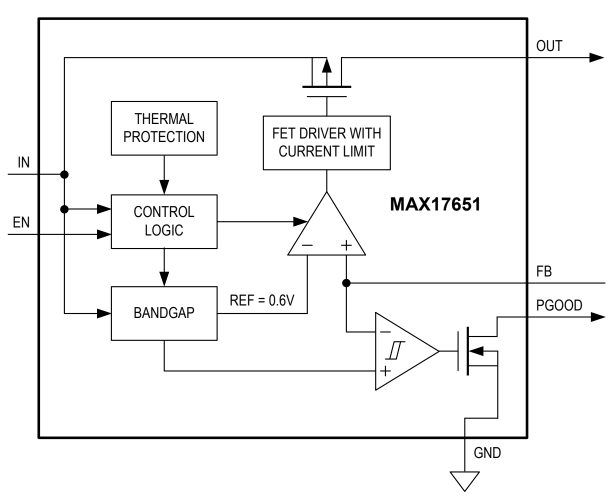


Figure 1. Block Diagram

Detailed Description

The MAX17651 ultra-low quiescent current, high-voltage linear regulator is ideal for use in industrial and battery-operated systems. The device operates from a 4V to 60V input voltage, delivers up to 100mA of load current and consumes only 8μA of quiescent current at no load. The device consumes only 0.9μA current when in shutdown. Output voltage is adjustable from 0.6V to 59V voltage range. Feedback voltage accuracy is ±2% over temperature.

An open-drain, active-low PGOOD pin provides a power-good signal to the system upon achieving successful regulation of the output voltage. The device also incorporates an enable pin (EN) that allows the user to turn the part on or off. The device has a thermal shutdown feature that shuts down the part when the die temperature exceeds 165°C. The MAX17651 operates over the -40°C to +125°C industrial temperature range and is available in a compact, 6-lead TSOT package.

EN Input

EN is an active-high, logic-level enable input that turns the device on or off. Drive EN high to turn the device on. While in shutdown, the device consumes only 0.9μA (typ). EN withstands voltages up to V_{IN} + 0.3V, allowing it to be driven by high input-level voltages, or be connected to IN for always-on operation.

Thermal Protection

When the junction temperature exceeds +165°C, an internal thermal sensor turns the pass transistor off, allowing the device to cool. The thermal sensor turns the pass transistor on again after the junction temperature cools by 15°C. This results in a cycled output during continuous thermal-overload conditions. Thermal protection protects the MAX17651 in the event of fault conditions.

Output Short-Circuit Current Limit

The MAX17651 features a 140mA (typ) current limit. The output can be shorted to GND for an indefinite period without damage to the device. During a short-circuit event, the power dissipated across the internal pass transistor can quickly heat the device. When the die temperature reaches +165°C, the MAX17651 shuts down and automatically restarts once the die temperature cools by 15°C.

Applications Information

Output Voltage Setting

The output voltage can be programmed from 0.6V to 59V. Set the output voltage by connecting a resistor divider from output to FB to GND. Choose R2 = 59kΩ, then calculate R1 with the following equation:

$$R1 = 98.3 \times (V_{OUT} - 0.6)k\Omega$$

Output Capacitor Selection

If the output voltage is less than 1.8V, use a low-ESR 10μF(min) 0805 ceramic output capacitor for good load transient response. If the output voltage is greater than or equal to 1.8V, use a low-ESR 4.7μF(min) 0805 ceramic output capacitor.

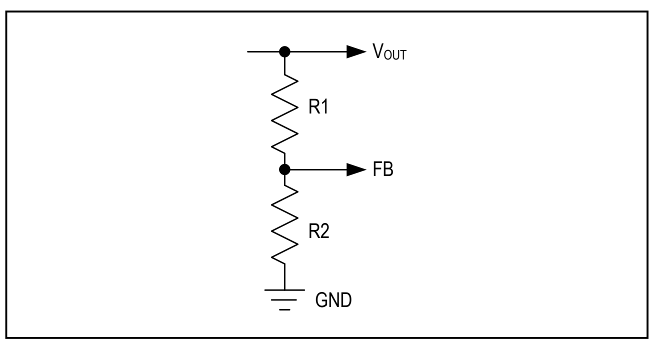


Figure 2. Setting the Output Voltage

Available Output Current Calculation

Ensure that the junction temperature of the MAX17651 does not exceed +125°C under the operating conditions specified for the power supply.

At a particular operating condition, the power loss that leads to the temperature rise of the part is estimated as follows:

$$P_{LOSS} = (V_{IN} - V_{OUT}) \times I_{LOAD}$$

where V_{IN} is the input voltage, V_{OUT} is the output voltage, and I_{LOAD} is the load current.

For a multilayer board, the thermal performance metrics for the package are given below:

$$\theta_{JA} = 110°C/W$$

The junction temperature of the MAX17651 can be estimated at any given maximum ambient temperature (T_{A_MAX}) from the equation below:

$$T_J = T_{A\_MAX} + (\theta_{JA} \times P_{LOSS})$$

Calculate the maximum allowable output current, using the following formula:

$$I_{LOAD(MAX)} = \frac{(125 - T_{A\_MAX})}{110 \times (V_{IN} - V_{OUT})}$$

Example: T_{A_MAX} = +70°C, V_{IN} = 24V, V_{OUT} = 5V

$$I_{LOAD(MAX)} = \frac{(125 - 70)}{110 \times (24 - 5)} \cong 26mA$$

Typical Application Circuit

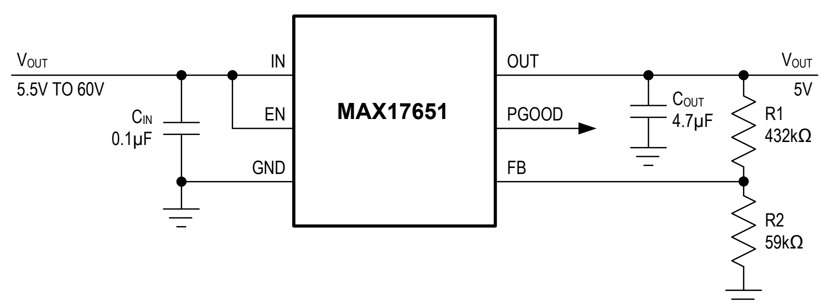


Figure 3. Application Circuit for 5V output

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX17651AZT+	-40°C to +125°C	6 pin TSOT

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.
6 TSOT	Z6+1	21-0114	90-0242

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	11/14	Initial release	—
1	3/16	Updated *Electrical Characteristics* table and *Typical Operating Characteristics* section	1–4, 6, 7

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

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