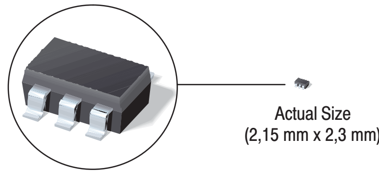


SLVS338F − MAY 2001 − REVISED JANUARY 2004

HIGH INPUT VOLTAGE, MICROPOWER SC70/SOT-323 PACKAGED 50-mA LDO LINEAR REGULATORS

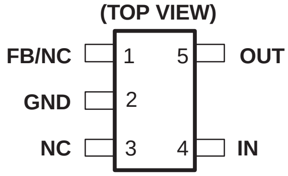
FEATURES

- **50mA Low-Dropout Regulator**
- **Available in 2.5V, 3.0V, 3.3V, 5.0V, and Adjustable**
- **24V Maximum Input Voltage**
- **Low 3.2μA Quiescent Current at 50mA**
- **Stable With Any Capacitor (>0.47μF)**
- **Over Current Limitation**
- **5-Pin SC70/SOT-323 (DCK) Package**
- **−40°C to +125°C Operating Junction Temperature Range**

APPLICATIONS

- **Battery Management**
- **Microcontroller**
- **PDAs and Notebooks**

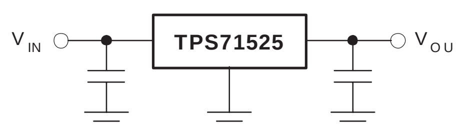
DCK PACKAGE
(TOP VIEW)



DESCRIPTION

The TPS715xx low-dropout (LDO) voltage regulators offer the benefits of high input voltage, low-dropout voltage, low-power operation, and miniaturized packaging. The devices, which operate over an input range of 2.5V to 24V, are stable with any capacitor (>0.47μF). The low dropout voltage and low quiescent current allow operations at extremely low power levels. Therefore, the devices are ideal for powering battery management ICs. Specifically, since the devices are enabled as soon as the applied voltage reaches the minimum input voltage, the output is quickly available to power continuously operating battery charging ICs.

The usual PNP pass transistor has been replaced by a PMOS pass element. Because the PMOS pass element behaves as a low-value resistor, the low dropout voltage, typically 415mV at 50mA of load current, is directly proportional to the load current. The low quiescent current (3.2μA typically) is stable over the entire range of output load current (0mA to 50mA).



TEXAS INSTRUMENTS
www.ti.com

AVAILABLE OPTIONS(1)

T_J	VOLTAGE	PACKAGE	PART NUMBER	SYMBOL
−40°C to 125°C	2.5V	SC70/SOT-323 (DCK)	TPS71525DCKR	AQL
			bq71525DCKR	
	3.0V	SC70/SOT-323 (DCK)	TPS71530DCKR	AQM
			bq71530DCKR	
	3.3V	SC70/SOT-323 (DCK)	TPS71533DCKR	AQI
			bq71533DCKR	
	5.0V	SC70/SOT-323 (DCK)	TPS71550DCKR	T48
			bq71550DCKR	
	(Adjustable) 1.2V−15V	SC70/SOT-323 (DCK)	TPS71501DCKR	ARB
			bq71501DCKR	

(1) Contact the factory for other voltage options between 1.25V and 5.85V.

ABSOLUTE MAXIMUM RATINGS OVER OPERATING FREE-AIR TEMPERATURE RANGE (UNLESS OTHERWISE NOTED)(1)

Input voltage range(2) . . . . −0.3V to 24V
Peak output current . . . . Internally limited
ESD rating, HBM 2kV
ESD rating, CDM 500V
Continuous total power dissipation . . . . See Dissipation Rating Table
Operating junction temperature range, T_J . . . . −40°C to 125°C
Operating ambient temperature range, T_A . . . . −40°C to 85°C
Storage temperature range, T_{stg} . . . . −65°C to 150°C

(1) 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 under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

BOARD	PACKAGE	$R_{\theta JC}$ °C/W	$R_{\theta JA}$ °C/W	DERATING FACTOR ABOVE T_A = 25°C	$T_A \le$ 25°C POWER RATING	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING
Low K(1)	DCK	165	395	2.52mW/°C	250mW	140mW	100mW
High K(2)	DCK	165	315	3.18mW/°C	320mW	175mW	130mW

(1) The JEDEC Low K (1s) board design used to derive this data was a 3-inch x 3-inch, two layer board with 2ounce copper traces on top of the board.
(2) The JEDEC High K (2s2p) board design used to derive this data was a 3-inch x 3-inch, multilayer board with 1ounce internal power and ground planes and 2ounce copper traces on top and bottom of the board.

RECOMMENDED OPERATING CONDITIONS

		MIN	NOM	MAX	UNIT
Input voltage, $V_{(IN)}$(1)	I_O = 10mA	2.5		24	V
	I_O = 50mA	3		24	
Continuous output current, $I_{(OUT)}$		0		50	mA
Operating junction temperature, T_J		−40		125	°C

(1) To calculate the minimum input voltage for your maximum output current, use the following formula:
$V_I(min) = V_O(max) + V_{DO}$ (max load)

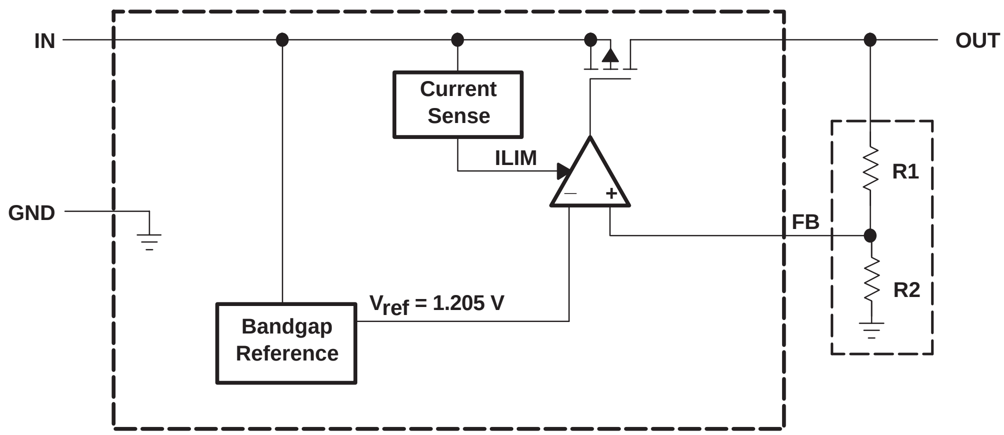
ELECTRICAL CHARACTERISTICS

over operating free-air temperature range (T_J = −40°C to 125°C), $V_{(IN)} = V_{(OUT)}$ typical + 1V, $I_{(OUT)}$ = 1mA, $C_{(OUT)}$ = 1μF unless otherwise noted

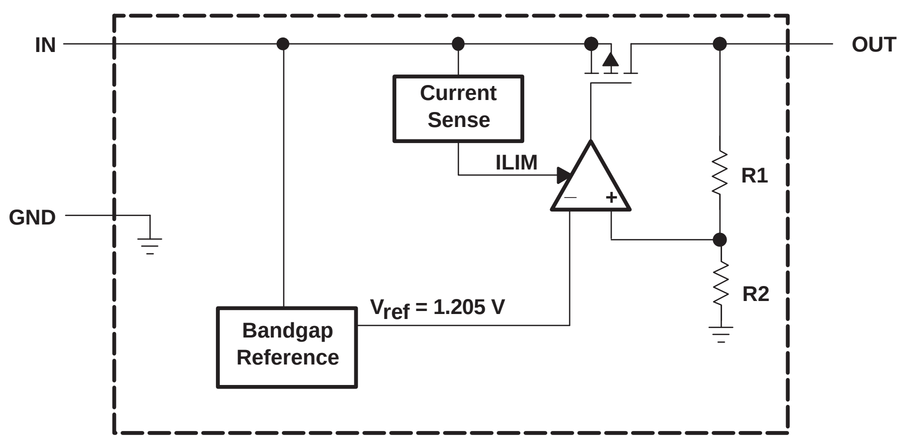
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Output voltage (100μA to 50 mA Load)(1)	TPS71501	T_J = 25°C,	1.2V ≤ V_O ≤ 15V				V
			1.2V ≤ V_O ≤ 15V	0.96 V_O		1.04 V_O	
	TPS71525	T_J = 25°C,	3.5V < V_I < 24V		2.5		
			3.5V < V_I < 24V	2.4		2.6	
	TPS71530	T_J = 25°C,	4V < V_O < 24V		3		
			4V < V_O < 24V	2.88		3.12	
	TPS71533	T_J = 25°C,	4.3V < V_I < 24V		3.3		
			4.3V < V_I < 24V	3.168		3.432	
	TPS71550	T_J = 25°C,	6V < V_O < 24V		5		
			6V < V_O < 24V	4.8		5.2	
Quiescent current (GND current)		T_J = 25°C,	0 < I_O < 50mA		3.2		μA
		T_J = −40°C to 85°C,	I_O = 50mA			4.5	
			I_O = 50mA			5.2	
			I_O = 50mA, V_I = 24V			6.2	
Load regulation		T_J = 25°C,	I_O = 100μA to 50mA		22		mV
Output voltage line regulation ($\Delta V_O/V_O$)(1)		T_J = 25°C,	V_O + 1V < V_I ≤ 24V		20		mV
			V_O + 1V < V_I ≤ 24V			60	
Output noise voltage		T_J = 25°C, C_O = 10μF,	BW = 200Hz to 100kHz, I_O = 50mA		575		μVrms
Output current limit		V_O = 0V,	See Note 1	125		750	mA
Power supply ripple rejection		T_J = 25°C,	f = 100kHz, C_O = 10 μF		60		dB
Dropout voltage(2)		T_J = 25°C,	I_O = 50mA		415		mV
			I_O = 50mA			750	

(1) The maximum IN voltage is 24V. There is no minimum output current and the maximum output current is 50mA.
(2) IN voltage equals $V_{(OUT)}$ typical −100mV; The TPS71533 input voltage is set to 3.2V.

FUNCTIONAL BLOCK DIAGRAM − ADJUSTABLE VERSION



FUNCTIONAL BLOCK DIAGRAM − FIXED VERSION



Terminal Functions

TERMINAL			DESCRIPTION
NAME	NO.		
	FIXED	ADJ.	
FB		1	Adjustable version. This terminal is the feedback input voltage.
NC	1		Fixed voltage version. No connection.
GND	2	2	Ground
NC	3	3	No connection.
IN	4	4	Unregulated input to the device.
OUT	5	5	Output of the regulator.

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE vs OUTPUT CURRENT

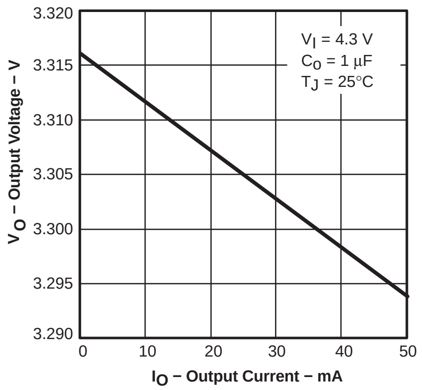


Figure 1

OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

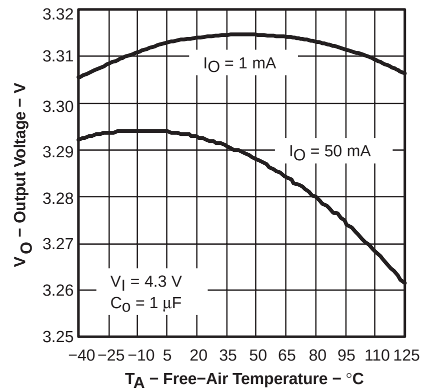


Figure 2

QUIESCENT CURRENT vs FREE-AIR TEMPERATURE

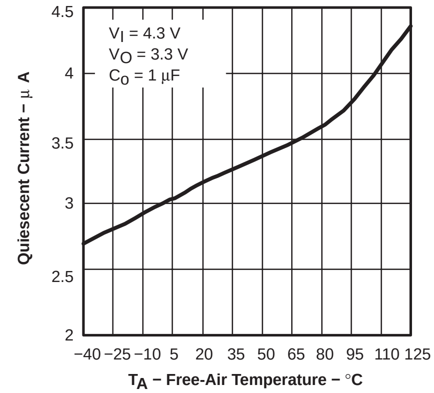


Figure 3

OUTPUT SPECTRAL NOISE DENSITY vs FREQUENCY

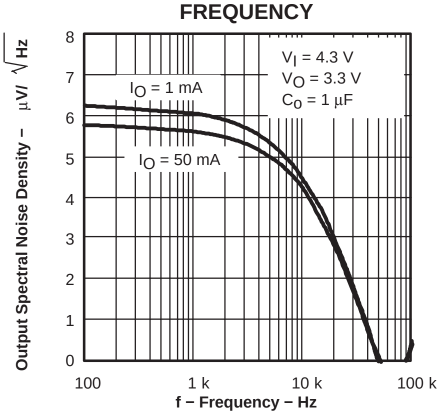


Figure 4

OUTPUT IMPEDANCE vs FREQUENCY

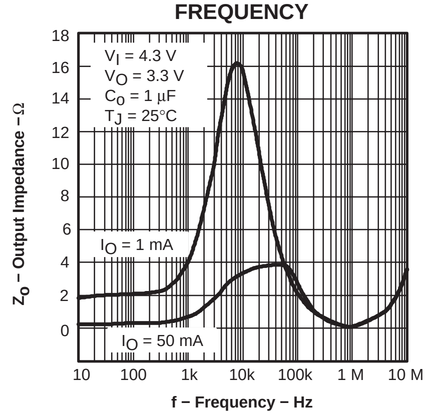


Figure 5

DROPOUT VOLTAGE vs OUTPUT CURRENT

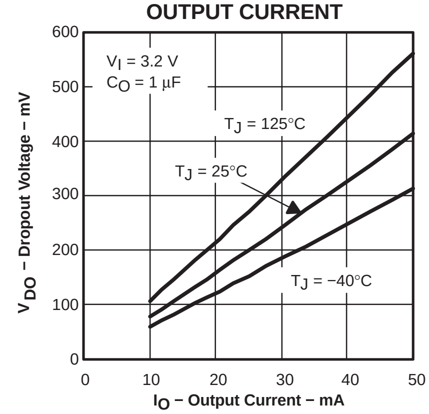


Figure 6

TPS791501
DROPOUT VOLTAGE vs INPUT VOLTAGE

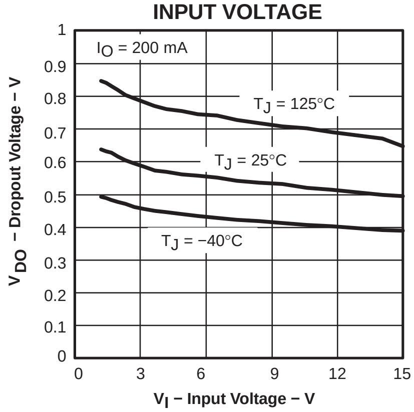


Figure 7

DROPOUT VOLTAGE vs FREE-AIR TEMPERATURE

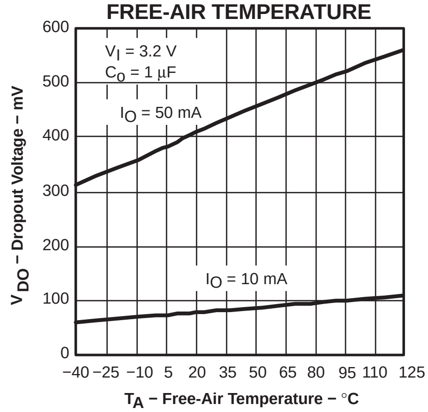


Figure 8

POWER SUPPLY RIPPLE REJECTION vs FREQUENCY

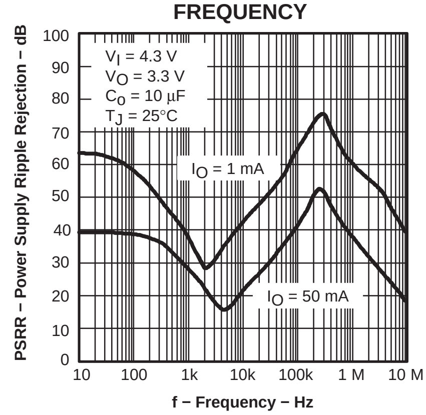


Figure 9

TYPICAL CHARACTERISTICS

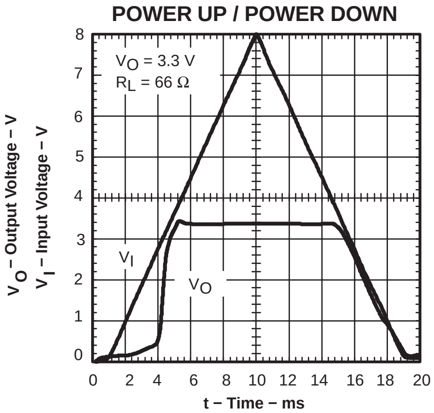


Figure 10

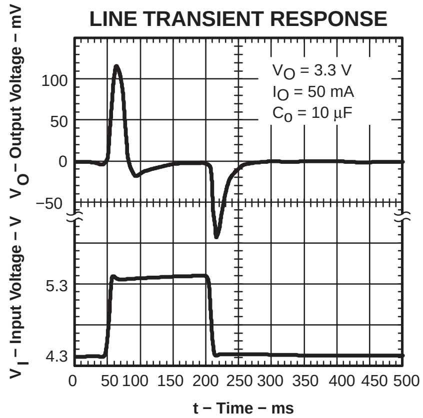


Figure 11

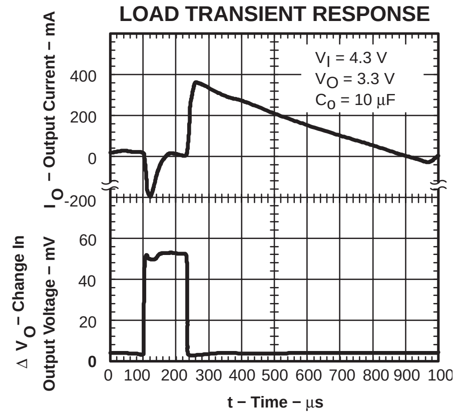


Figure 12

APPLICATION INFORMATION

The TPS715xx family of LDO regulators has been optimized for use with battery management ICs. After the minimum input voltage requirement is met, it is always enabled. The device’s maximum input voltage is 24V. It has a dropout voltage of 415mV at 50mA, and its quiescent current is 3.2μA typically. A typical application circuit is shown in Figure 13.

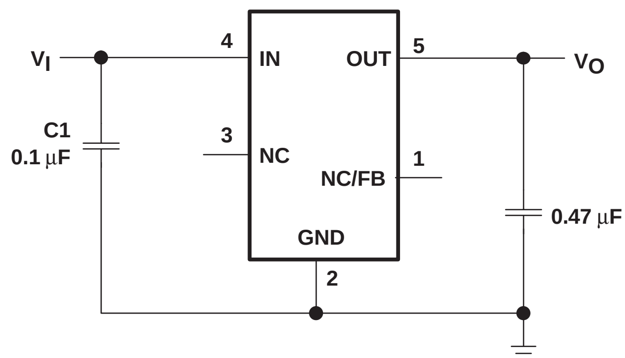


Figure 13. Typical Application Circuit (Fixed Voltage Version)

EXTERNAL CAPACITOR REQUIREMENTS

Although not required, a 0.047μF or larger input bypass capacitor, connected between IN and GND and located close to the device, is recommended to improve transient response and noise rejection. A higher-value electrolytic input capacitor may be necessary if large, fast-rise-time load transients are anticipated and the device is located several inches from the power source.

The TPS715xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. Any capacitor ≥ 0.47μF properly stabilizes this loop.

APPLICATION INFORMATION

POWER DISSIPATION AND JUNCTION TEMPERATURE

Specified regulator operation is assured to a junction temperature of 125°C; restrict the maximum junction temperature to 125°C under normal operating conditions. This restriction limits the power dissipation the regulator can handle in any given application. To ensure the junction temperature is within acceptable limits, calculate the maximum allowable dissipation, $P_{D(max)}$, and the actual dissipation, P_D, which must be less than or equal to $P_{D(max)}$.

The maximum-power-dissipation limit is determined using the following equation:

$$P_{D(max)} = \frac{T_J max - T_A}{R_{\theta JA}}$$

where:

$T_J max$ is the maximum allowable junction temperature.

$R_{\theta JA}$ is the thermal resistance junction-to-ambient for the package (see the Dissipation Rating Table).

T_A is the ambient temperature.

The regulator dissipation is calculated using:

$$P_D = \left(V_I - V_O\right) \times I_O$$

Power dissipation resulting from quiescent current is negligible.

REGULATOR PROTECTION

The TPS715xx PMOS-pass transistor has a built-in back diode that conducts reverse current when the input voltage drops below the output voltage (e.g., during power down). Current is conducted from the output to the input and is not internally limited. If extended reverse voltage operation is anticipated, external limiting might be appropriate.

The TPS715xx features internal current limiting. During normal operation, the TPS715xx limits output current to approximately 500mA. When current limiting engages, the output voltage scales back linearly until the overcurrent condition ends. Take care not to exceed the power dissipation ratings of the package.

PROGRAMMING THE TPS71501 ADJUSTABLE LDO REGULATOR

The output voltage of the TPS71501 adjustable regulator is programmed using an external resistor divider as shown in Figure 14. The output voltage is calculated using:

$$V_O = V_{ref} \times \left(1 + \frac{R1}{R2}\right) \tag{3}$$

where

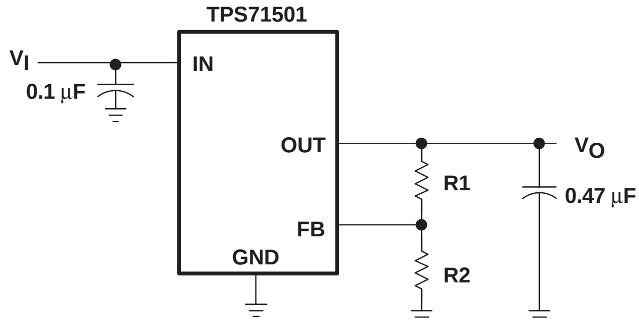
V_{ref} = 1.205V typ (the internal reference voltage)

APPLICATION INFORMATION

PROGRAMMING THE TPS71501 ADJUSTABLE LDO REGULATOR (continued)

Resistors R1 and R2 should be chosen for approximately 1.5µA divider current. Lower value resistors can be used for improved noise performance, but the solution consumes more power. Higher resistor values should be avoided as leakage current into/out of FB across R1/R2 creates an offset voltage that artificially increases/decreases the feedback voltage and thus erroneously decreases/increases V_O. The recommended design procedure is to choose R2 = 1MΩ to set the divider current at 1.5µA, and then calculate R1 using:

$$R1 = \left(\frac{V_O}{V_{ref}} - 1\right) \times R2 \tag{4}$$



OUTPUT VOLTAGE PROGRAMMING GUIDE

OUTPUT VOLTAGE	R1	R2
1.8 V	0.499 MΩ	1 MΩ
2.8 V	1.33 MΩ	1 MΩ
5.0 V	3.16 MΩ	1 MΩ

Figure 14. TPS71501 Adjustable LDO Regulator Programming

BATTERY MANAGEMENT APPLICATION

One application for which this device is particularly suited is providing a regulated voltage from a much larger input voltage, as is often the case of ICs used in portable battery-powered devices. Many of the battery management ICs currently on the market monitor battery voltages above 20V. However, the IC’s internal circuitry and peripheral equipment, like an LED’s, generally need a lower power bus for operation. Some of the battery management ICs have internal LDO regulator controllers that require five or more external components in order to provide a regulated output voltage. The TPS715xx family has a maximum input voltage rating of 24V, provides up to 50mA of output current, and requires only one external component. Therefore, using one of the TPS715xx regulators to power battery management ICs is a much simpler, more compact, and less expensive solution than using onboard LDO regulator controllers. In addition, the TPS715xx family uses only 3.2µA of quiescent current and does not significantly decrease battery life while the device is inactive.

TI’s bq2060 gas gauge IC was chosen to demonstrate the use of the TPS71533. The bq2060 battery management IC requires a regulated 3.3V for normal operation. The bq2060 has a regulator controller output (REG) that, when used in conjunction with an external JFET (Q2), a bipolar transistor (Q1), two capacitors (C1 and C2), and one resistor (R1), forms a 3.3V output linear regulator as shown in Figure 15.

APPLICATION INFORMATION

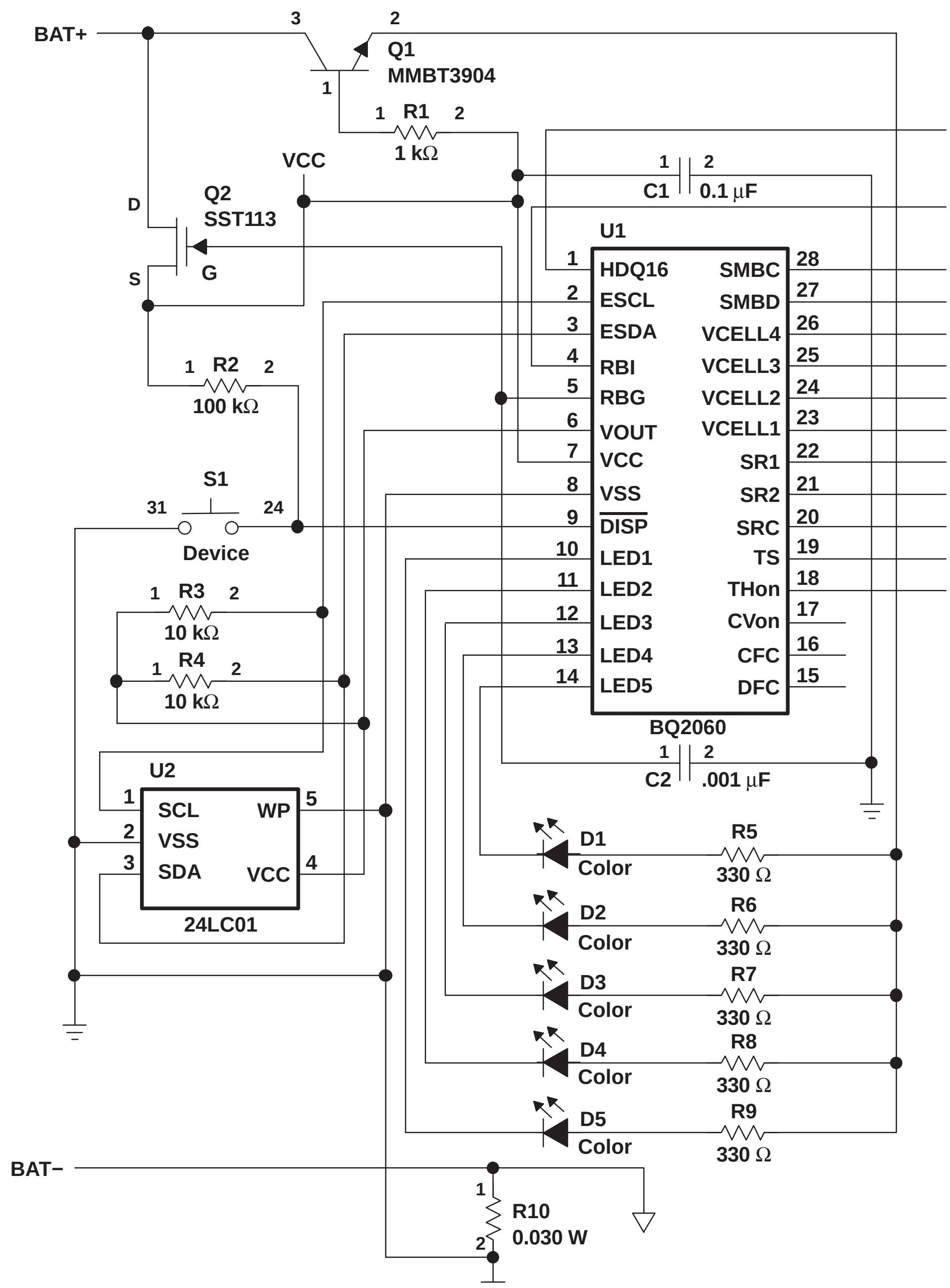


Figure 15. bq2060 Powered With Internal LDO Controller

APPLICATION INFORMATION

However, with five external components, this regulator is more complex and costly than using a separate LDO regulator. Figure 16 shows the TPS71533 and its external output capacitor (C1) providing the regulated 3.3V to the bq2060.

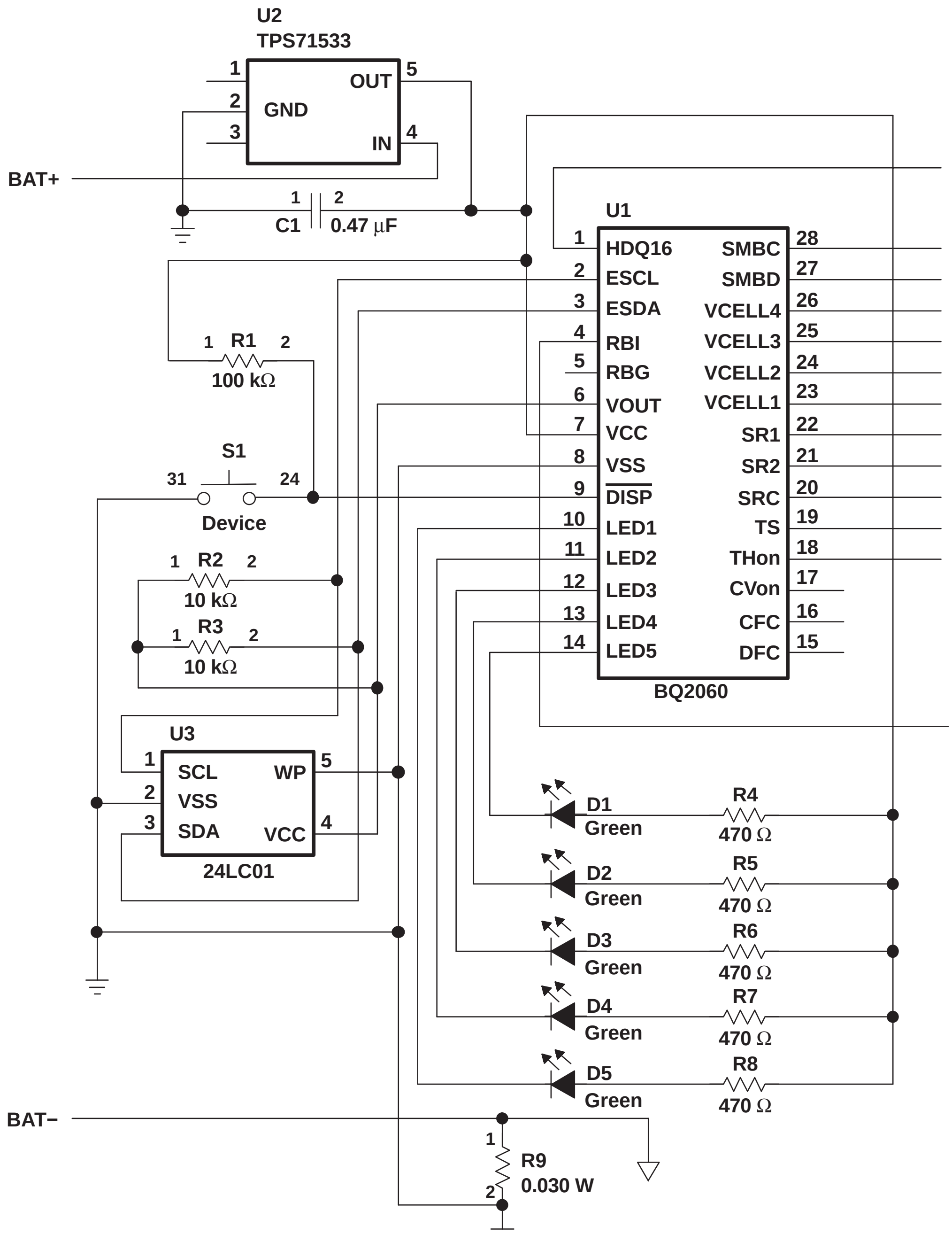


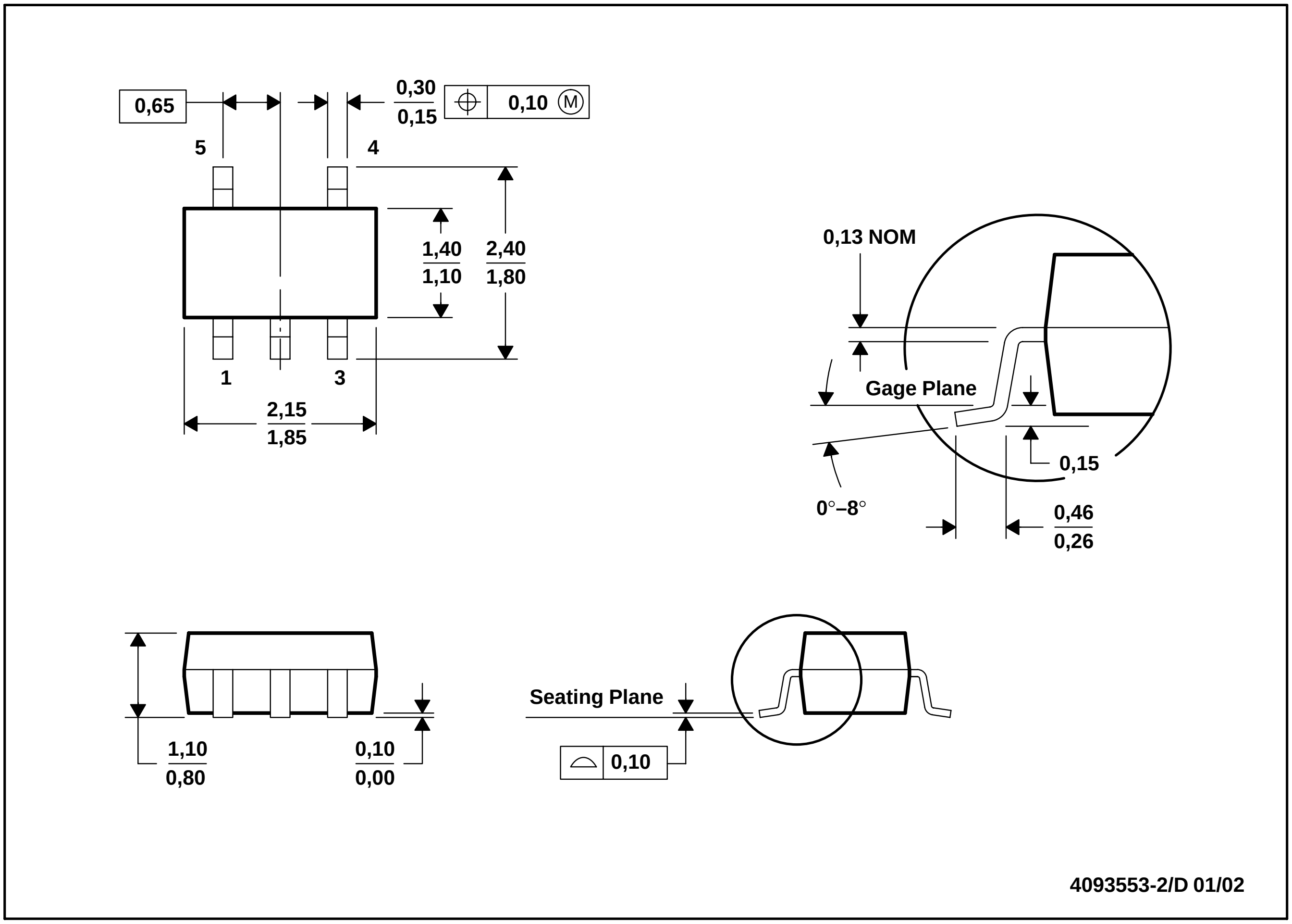
Figure 16. bq2060 Powered With TPS71533

APPLICATION INFORMATION

In Figure 16, the bq2060 is configured to monitor 4 Li-Ion batteries in series totaling 16.8V. During either battery charging or discharging, the maximum current that the bq2060 requires from the TPS71533 occurs when the user presses the push button (S1) and potentially activates all five LEDs, indicating a fully charged battery. The LEDs require 3mA each and remain on for 4 seconds. Therefore, the bq2060 LED requires a total of 15mA with a maximum power dissipated by the TPS71533 of 203mW [(16.8V – 3.3V) x 15mA for the 4-second interval]. The LEDs remain active for 4 seconds even if the push button remains depressed. When the LEDs are not activated, the bq2060 only requires approximately 200µA quiescent current.

For more information on the operation of the bq2060, refer to the data sheet (TI literature number SLUS035). An evaluation module with a similar configuration to the one shown in Figure 16 is also available (TI literature number SLUU063).

DCK (R-PDSO-G5) **PLASTIC SMALL-OUTLINE PACKAGE**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO-203

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