超低压差线性稳压器 LTC3025

方佩敏

LTC3025 是一种微功耗、超低压差(VLDO)、低工作电压的线性稳压器。其主要特点:宽的输入电压(0.9V 到 5.5V);输出仅需 1μF 多层陶瓷电容;很低的压差(在 300mA 输出时仅为 45mV);输出电压可设定(从 0.4V 到 3.6V);在工作温度范围及输出电流范围内输出电压精度为 ±2%;噪声电压低(在 10Hz 到 100kHz 范围为 80μV_{RMS});偏置电压范围 2.5V 到 5.5V);有关闭控制,在关闭状态时负载与 V_{IN} 及 V_{BIAS} 不连接,耗电小;I_{IN}=1μA,I_{BIAS}=0.01μA(典型值);工作电流低;I_{IN}=4μA,I_{BIAS}=50μA(典型值);内部有输出电流限制、过热保护;6 管脚 DFN(2mm×2mm)封装;工作温度范围(结温)-40℃~+125℃。

由该器件组成的稳压器主要应用于小功率手持式电子产品、低电压逻辑电源、DSP 电源、蜂窝电话、手持式医疗仪器、开关电源的后续电源等。

表 1

管脚	符号	功能
1	BIAS	偏置电压输入端。它提供器件内部电路的电源。此端需接一个 0.01~0.1μF 旁路电容到地
2	GND	地
3	IN	电源输入端,输出负载电流直接由 V_{IN} 提供。此端常接 0.1~1μF 旁路电旁到地
4	OUT	稳压的输出电压输出端.此端接一个 1μF(或更大)的多层陶瓷电容到地,以保证稳定性。采用更大的容量可改善输出动态特性
5	ADJ	输出电压设定端。外接一个电阻分压器,其输出电压与 R1、R2 的关系为;V_{OUT}=0.4V(1+R2/R1)
6	$\overline{SHDN}$	关闭控制端(低电平有效)。若不用此功的时必须接高电平(如接 BIAS 端),此端不能悬空。

注:1、底部金属片应接地,并用作散热。

2、$\overline{SHDN}$ 高电平≥0.9V;低电平≤0.3V。

管脚排列与功能

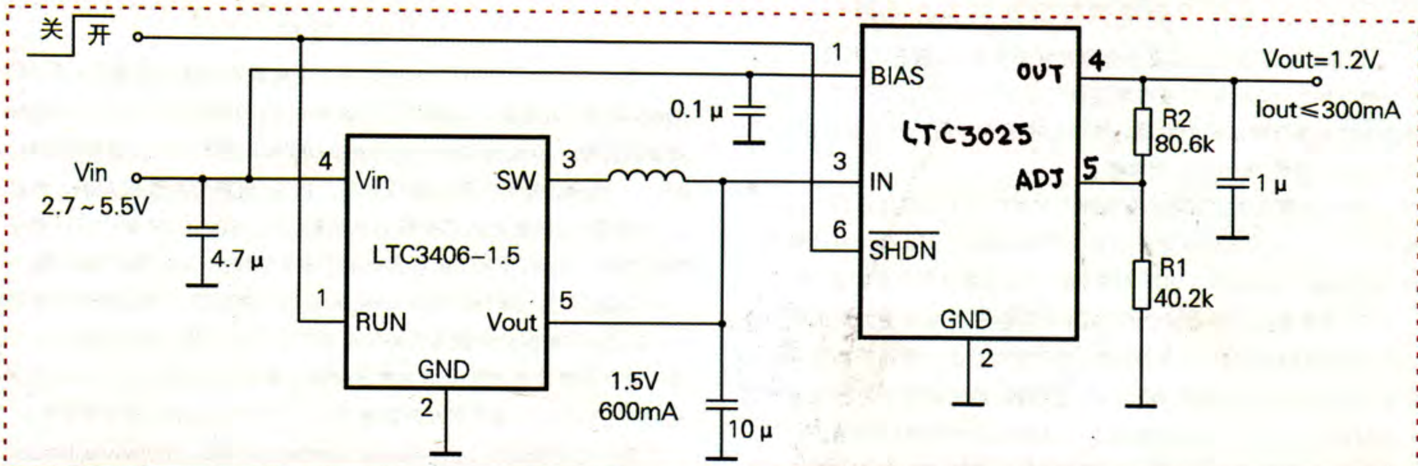
LTC3025 的管脚排列如图 1 所示,各管脚功能如表 1 所示。

典型应用电路

LTC3025 的典型电路如图 2 所示。图 2 中采用了 3 节镍氢电池或一节锂离子电池供电。LTC3025 的偏量电压 V_{BIAS} 由电池直接供电,而供负载的电源由另一个降压式 DC/DC 变换器提供(输出 1.5V/600mA 的 LTC3406-1.5 作为 LTC3025 的供电电源)。

输出电压由外接的 R1、R2 电阻分压器设定,其输出电压 V_{OUT}=0.4V(1+R2/R1)。

——图 1——



——图 2——

按图中 R1、R2 值代入 V_{OUT}=0.4V (1+80.6K/40.2K)=1.2V，式中的 0.4V 为内部的基准电压。

LTC3406-1.5 的 RUN 端及 LTC3025 的 $\overline{SHDN}$ 端由微控制器来控制，要关闭时加低电平，工作时加高电平即可。

输出电容应采用×5R 或×7R 介质的多层陶瓷电容器，它具有较 YSV 更好的性能，使电源工作更稳定。

这里要说明的是，LTC3025 本身是一个超低压差线性稳压器，其转换效率是较高的，若按简单的粗略计算，$\eta=V_{OUT}/V_{IN}$=1.2V/1.5V=80%，但它还需要 LTC3406-1.5 配合工作，它的实际效率会降低，若 LTC3406-1.5 的效率 η=90%，则实际效率 η 为两个效率的乘积，即 η=80%×90%=72%。

图 3 是 V_{OUT}=1.2V 在不同输出电流时效率曲线，在 I_{OUT}=5mA 到 300mA 时，效率约 70%.

另外，这个电源需要两个电源 IC，外围元件较多，成本稍高，占印制板的面积也比较大，LT3026 是另一种超低压差线性稳压器，电路简单，也无需另一电源供电，效率更高。

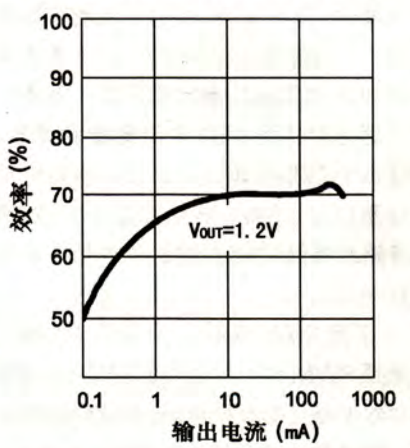


图 3

500mA Micropower VLDO Linear Regulators

FEATURES

- **Wide Input Voltage Range: 0.9V to 5.5V**
- **Stable with Ceramic Capacitors**
- **Very Low Dropout: 85mV at 500mA**
- **Adjustable Output Range: 0.4V to 3.6V (LTC3025-1)**
- **Fixed Output: 1.2V(LTC3025-2), 1.5V(LTC3025-3), 1.8V(LTC3025-4)**
- **±2% Voltage Accuracy over Temperature, Supply and Load**
- Low Noise: 80μV_{RMS} (10Hz to 100kHz)
- BIAS Voltage Range: 2.5V to 5.5V
- Fast Transient Recovery
- Shutdown Disconnects Load from V_{IN} and V_{BIAS}
- Low Operating Current: I_{IN} = 4μA, I_{BIAS} = 50μA Typ
- Low Shutdown Current: I_{IN} = 1μA, I_{BIAS} = 0.01μA Typ
- Output Current Limit
- Thermal Overload Protection
- Available in 6-Lead (2mm × 2mm) DFN Package

APPLICATIONS

- Low Power Handheld Devices
- Low Voltage Logic Supplies
- DSP Power Supplies
- Cellular Phones
- Portable Electronic Equipment
- Handheld Medical Instruments
- Post Regulator for Switching Supply Noise Rejection

DESCRIPTION

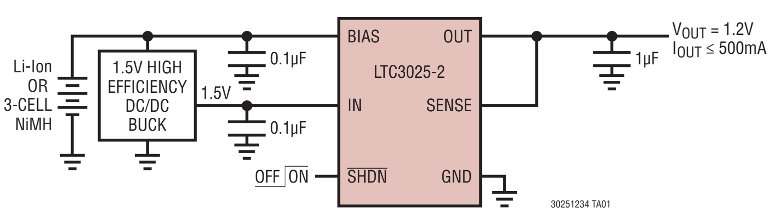
The LTC®3025-X is a micropower, VLDO™ (very low dropout) linear regulator which operates from input voltages as low as 0.9V. The device is capable of supplying 500mA of output current with a typical dropout voltage of only 85mV. A BIAS supply is required to run the internal reference and LDO circuitry while output current comes directly from the IN supply for high efficiency regulation. The LTC3025-1 features an adjustable output with a low 0.4V reference while the LTC3025-2, LTC3025-3, and LTC3025-4 have fixed 1.2V, 1.5V and 1.8V output voltages respectively.

The LTC3025-X's low quiescent current makes it an ideal choice for use in battery-powered systems. For 3-cell NiMH and single cell Li-Ion applications, the BIAS voltage can be supplied directly from the battery while the input can come from a high efficiency buck regulator, providing a high efficiency, low noise output.

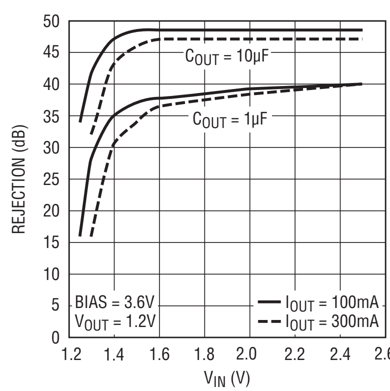
Other features include high output voltage accuracy, excellent transient response, stability with ultralow ESR ceramic capacitors as small as 1μF, short-circuit and thermal overload protection and output current limiting. The LTC3025-X is available in a tiny, low profile (0.75mm) 6-lead DFN (2mm × 2mm) package.

TYPICAL APPLICATION

1.2V Output Voltage from 1.5V Input Supply



1MHz V_{IN} Supply Rejection



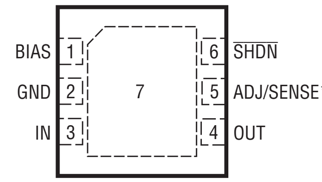
ABSOLUTE MAXIMUM RATINGS

(Notes 1, 2)

V_{BIAS}, V_{IN} to GND .... –0.3V to 6V
SHDN to GND .... –0.3V to 6V
SENSE, ADJ to GND .... –0.3V to 6V
V_{OUT} .... –0.3V to V_{IN} + 0.3V or 6V
Operating Junction Temperature Range
(Note 3) .... –40°C to 125°C
Storage Temperature Range .... –65°C to 125°C
Output Short-Circuit Duration .... Indefinite

PIN CONFIGURATION

TOP VIEW



DC6 PACKAGE
6-LEAD (2mm × 2mm) PLASTIC DFN
T_{JMAX} = 125°C, θ_{JA} = 102°C/W, θ_{JC} = 20°C/W
EXPOSED PAD (PIN 7) IS GND, MUST BE SOLDERED TO PCB
*ADJ FOR LTC3025-1, SENSE FOR LTC3025-2, LTC3025-3, LTC3025-4

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LTC3025EDC-1#PBF	LTC3025EDC-1#TRPBF	LDDW	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC-1#PBF	LTC3025IDC-1#TRPBF	LDDW	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025EDC-2#PBF	LTC3025EDC-2#TRPBF	LDMK	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC-2#PBF	LTC3025IDC-2#TRPBF	LDMK	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025EDC-3#PBF	LTC3025EDC-3#TRPBF	LDQS	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC-3#PBF	LTC3025IDC-3#TRPBF	LDQS	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025EDC-4#PBF	LTC3025EDC-4#TRPBF	LDPQ	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC-4#PBF	LTC3025IDC-4#TRPBF	LDPQ	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LEAD BASED FINISH	**TAPE AND REEL**	**PART MARKING***	**PACKAGE DESCRIPTION**	**TEMPERATURE RANGE**
LTC3025EDC-1	LTC3025EDC-1#TR	LDDW	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC-1	LTC3025IDC-1#TR	LDDW	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025EDC-2	LTC3025EDC-2#TR	LDMK	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC-2	LTC3025IDC-2#TR	LDMK	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025EDC-3	LTC3025EDC-3#TR	LDQS	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC-3	LTC3025IDC-3#TR	LDQS	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025EDC-4	LTC3025EDC-4#TR	LDPQ	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC-4	LTC3025IDC-4#TR	LDPQ	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container.
For more information on lead free part marking, go to: http://www.linear.com/leadfree/
For more information on tape and reel specifications, go to: http://www.linear.com/tapeandreel/

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.5V, V_{BIAS} = 3.6V, C_{OUT} = 1µF, C_{IN} = 0.1µF, C_{BIAS} = 0.1µF (all capacitors ceramic) unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{IN} Operating Voltage (Note 4)	LTC3025-1	●	0.9		5.5	V
	LTC3025-2	●	1.4		5.5	V
	LTC3025-3	●	1.7		5.5	V
	LTC3025-4	●	2.0		5.5	V

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.5V, V_{BIAS} = 3.6V, C_{OUT} = 1µF, C_{IN} = 0.1µF, C_{BIAS} = 0.1µF (all capacitors ceramic) unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{BIAS} Operating Voltage (Note 4)	LTC3025-1	●	2.5		5.5	V
	LTC3025-2	●	2.7		5.5	V
	LTC3025-3	●	3.0		5.5	V
	LTC3025-4	●	3.3		5.5	V
V_{BIAS} Undervoltage Lockout		●		2.2	2.5	V
V_{IN} Operating Current	I_{OUT} = 10µA, V_{OUT} = 1.2V, LTC3025-1	●		4	10	µA
V_{IN} Operating Current	I_{OUT} = 0µA, LTC3025-2/LTC3025-3/LTC3025-4	●		4	10	µA
V_{BIAS} Operating Current	I_{OUT} = 10µA, V_{OUT} = 1.2V, LTC3025-1	●		50	80	µA
V_{BIAS} Operating Current	I_{OUT} = 0µA, LTC3025-2/LTC3025-3/LTC3025-4	●		50	80	µA
V_{IN} Shutdown Current	$V_{\overline{SHDN}}$ = 0V			1	5	µA
V_{BIAS} Shutdown Current	$V_{\overline{SHDN}}$ = 0V			0.01	1	µA
V_{ADJ} Regulation Voltage (Note 5)	1mA ≤ I_{OUT} ≤ 500mA, V_{OUT} = 1.2V, 1.5V ≤ V_{IN} ≤ 5V, LTC3025-1 1mA ≤ I_{OUT} ≤ 500mA, V_{OUT} = 1.2V, 1.5V ≤ V_{IN} ≤ 5V, LTC3025-1	 ●	0.395 0.392	0.4 0.4	0.405 0.408	V V
V_{SENSE} Regulation Voltage (Note 5)	1mA ≤ I_{OUT} ≤ 500mA, 1.5V ≤ V_{IN} ≤ 5V, LTC3025-2 1mA ≤ I_{OUT} ≤ 500mA, 1.5V ≤ V_{IN} ≤ 5V, LTC3025-2	 ●	1.185 1.176	1.2 1.2	1.215 1.224	V V
V_{SENSE} Regulation Voltage (Note 5)	1mA ≤ I_{OUT} ≤ 500mA, 1.7V ≤ V_{IN} ≤ 5V, LTC3025-3 1mA ≤ I_{OUT} ≤ 500mA, 1.7V ≤ V_{IN} ≤ 5V, LTC3025-3	 ●	1.481 1.470	1.5 1.5	1.519 1.530	V V
V_{SENSE} Regulation Voltage (Note 5)	1mA ≤ I_{OUT} ≤ 500mA, 2.0V ≤ V_{IN} ≤ 5V, LTC3025-4 1mA ≤ I_{OUT} ≤ 500mA, 2.0V ≤ V_{IN} ≤ 5V, LTC3025-4	 ●	1.777 1.764	1.8 1.8	1.823 1.836	V V
I_{ADJ} ADJ Input Current	V_{ADJ} = 0.45V, LTC3025-1		–50	0	50	nA
OUT Load Regulation (Referred to ADJ Pin)	ΔI_{OUT} = 1mA to 500mA, LTC3025-1			–0.35		mV
OUT Load Regulation	ΔI_{OUT} = 1mA to 500mA, LTC3025-2 ΔI_{OUT} = 1mA to 500mA, LTC3025-3 ΔI_{OUT} = 1mA to 500mA, LTC3025-4			–1 –1.3 –1.5		mV mV mV
V_{IN} Line Regulation (Referred to ADJ Pin)	V_{IN} = 1.5V to 5V, V_{BIAS} = 3.6V, V_{OUT} = 1.2V, I_{OUT} = 1mA, LTC3025-1			0.07		mV
V_{IN} Line Regulation	V_{IN} = 1.5V to 5V, V_{BIAS} = 3.6V, I_{OUT} = 1mA, LTC3025-2 V_{IN} = 1.8V to 5V, V_{BIAS} = 3.6V, I_{OUT} = 1mA, LTC3025-3 V_{IN} = 2.1V to 5V, V_{BIAS} = 3.6V, I_{OUT} = 1mA, LTC3025-4			0.21 0.26 0.32		mV mV mV
V_{BIAS} Line Regulation	V_{IN} = 1.5V, V_{BIAS} = 2.7V to 5V, V_{OUT} = 1.2V, I_{OUT} = 1mA, LTC3025-1	●		4.5	16.5	mV
V_{BIAS} Line Regulation	V_{IN} = 1.5V, V_{BIAS} = 2.7V to 5V, I_{OUT} = 1mA, LTC3025-2 V_{IN} = 1.8V, V_{BIAS} = 3.0V to 5V, I_{OUT} = 1mA, LTC3025-3 V_{IN} = 2.1V, V_{BIAS} = 3.3V to 5V, I_{OUT} = 1mA, LTC3025-4	● ● ●		4.5 4.5 4.5	16.5 16.5 16.5	mV mV mV
V_{IN} to V_{OUT} Dropout Voltage (Notes 4, 6)	V_{BIAS} = 3V, V_{IN} = 1.5V, I_{OUT} = 500mA, V_{ADJ} = 0.37V(LTC3025-1), V_{SENSE} = 1.15V(LTC3025-2)	 ●		85	120 170	mV mV
V_{IN} to V_{OUT} Dropout Voltage (Notes 4, 6)	V_{BIAS} = 3.1V, V_{IN} = 1.7V, I_{OUT} = 500mA, V_{SENSE} = 1.45V(LTC3025-3)	 ●		90	130 185	mV mV
V_{IN} to V_{OUT} Dropout Voltage (Notes 4, 6)	V_{BIAS} = 3.4V, V_{IN} = 2.0V, I_{OUT} = 500mA, V_{SENSE} = 1.75V(LTC3025-4)	 ●		90	130 185	mV mV
V_{BIAS} to V_{OUT} Dropout Voltage (Note 4)	LTC3025-1	●			1.5	V
I_{OUT} Continuous Output Current		●	500			mA
I_{OUT} Current Limit	V_{ADJ} = 0V(LTC3025-1), V_{SENSE} = 0V(LTC3025-2/LTC3025-3/LTC3025-4)			1130		mA
e_n Output Voltage Noise	f = 10Hz to 100kHz, I_{OUT} = 300mA			80		$µV_{RMS}$

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.5V, V_{BIAS} = 3.6V, C_{OUT} = 1µF, C_{IN} = 0.1µF, C_{BIAS} = 0.1µF (all capacitors ceramic) unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{IH} $\overline{SHDN}$ Input High Voltage		●	0.9			V
V_{IL} $\overline{SHDN}$ Input Low Voltage		●			0.3	V
I_{IH} $\overline{SHDN}$ Input High Current	$\overline{SHDN}$ = 1.2V		–1		1	µA
I_L $\overline{SHDN}$ Input Low Current	$\overline{SHDN}$ = 0V		–1		1	µA

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: This IC includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperature will exceed 125°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

Note 3: The LTC3025-X regulators are tested and specified under pulse load conditions such that $T_J \approx T_A$. The LTC3025E-X are guaranteed to meet performance specifications from 0°C and 125°C. Specifications over the –40°C to 125°C operating junction temperature range are assured by design, characterization and correlation with statistical process controls. The LTC3025I-X are guaranteed to meet performance specifications over the full –40°C to 125°C operating junction temperature range.

Note 4: For the LTC3025-1, a regulated output voltage will only be available when the minimum IN and BIAS operating voltages as well as the IN to OUT and BIAS to OUT dropout voltages are all satisfied. For the LTC3025-2/LTC3025-3/LTC3025-4 the minimum IN operating voltage assumes I_{OUT} = 500mA. For correct regulation at I_{OUT} < 500mA the minimum IN operating voltage decreases to the maximum V_{SENSE} Regulation Voltage as I_{OUT} decreases to 0mA (i.e. V_{INMIN} = 1.312V at I_{OUT} = 250mA for the LTC3025-2).

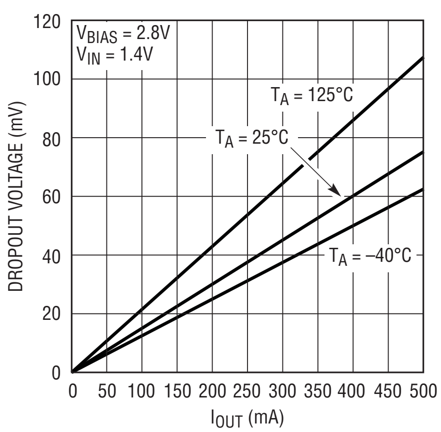
Note 5: Operating conditions are limited by maximum junction temperature. The regulated output voltage specification will not apply for all possible combinations of input voltage and output current. When operating at maximum input voltage, the output current range must be limited. When operating at maximum output current, the input voltage range must be limited.

Note 6: Dropout voltage is minimum input to output voltage differential needed to maintain regulation at a specified output current. In dropout, the output voltage will be equal to $V_{IN} – V_{DROPOUT}$.

TYPICAL PERFORMANCE CHARACTERISTICS

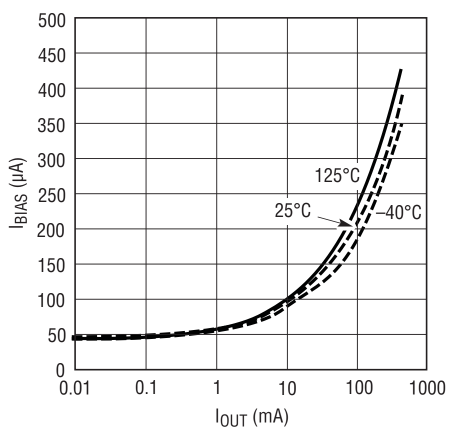
(T_A = 25°C unless otherwise noted)

V_{IN} to V_{OUT} Dropout Voltage vs I_{OUT}



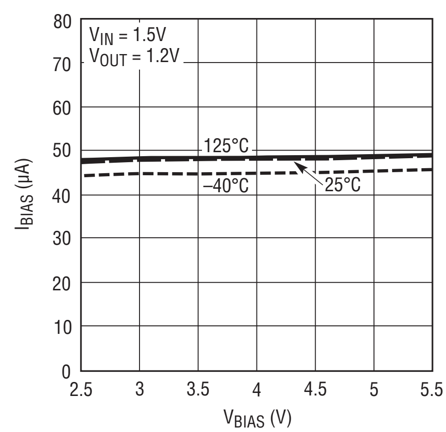
30251234 G01

Operating BIAS Current vs Output Current



30251234 G02

BIAS No Load Operating Current



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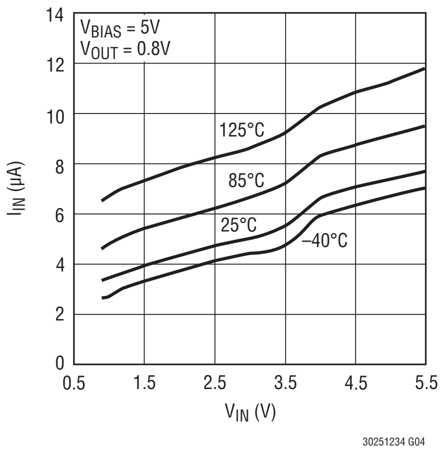
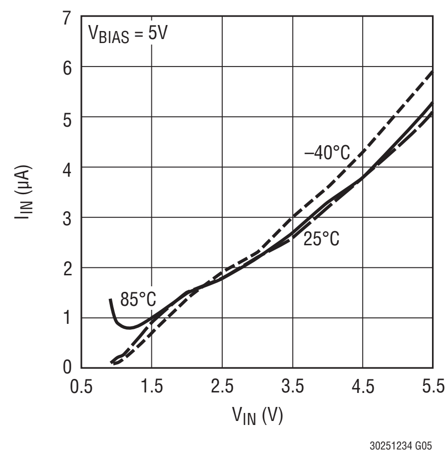
TYPICAL PERFORMANCE CHARACTERISTICS (T_A = 25°C unless otherwise noted)

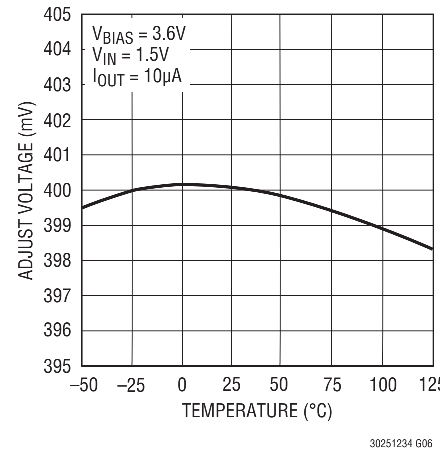
V_{IN} No Load Operating Current



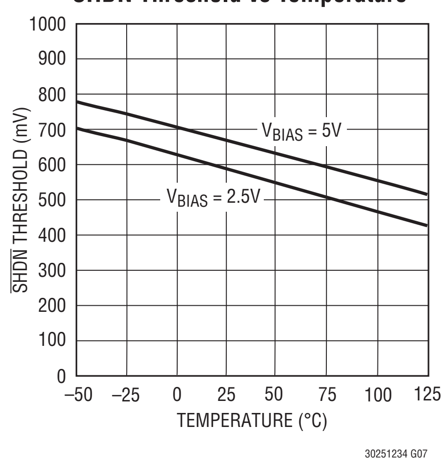
V_{IN} Shutdown Current



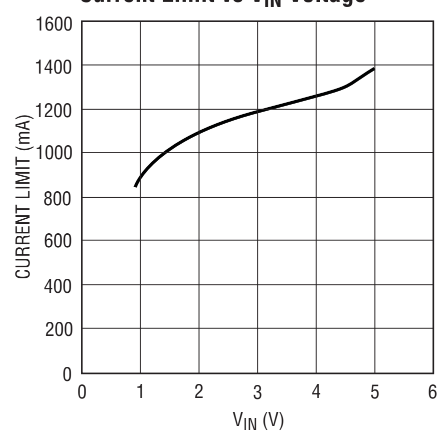
Adjust Voltage vs Temperature



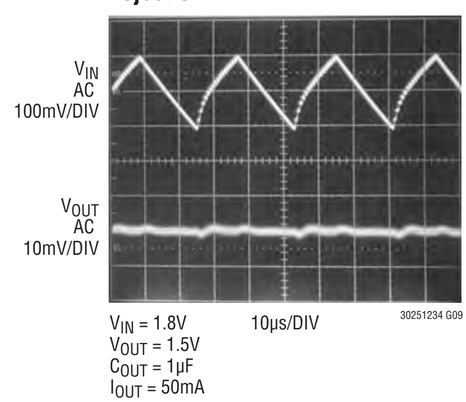
$\overline{SHDN}$ Threshold vs Temperature



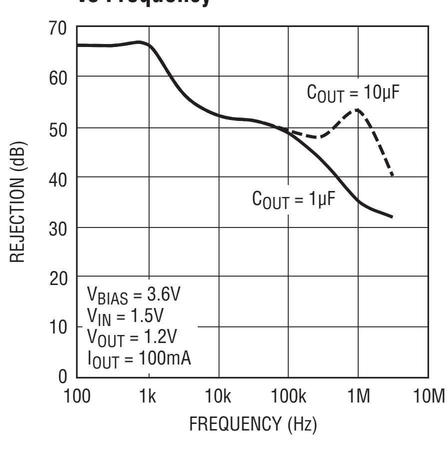
Current Limit vs V_{IN} Voltage



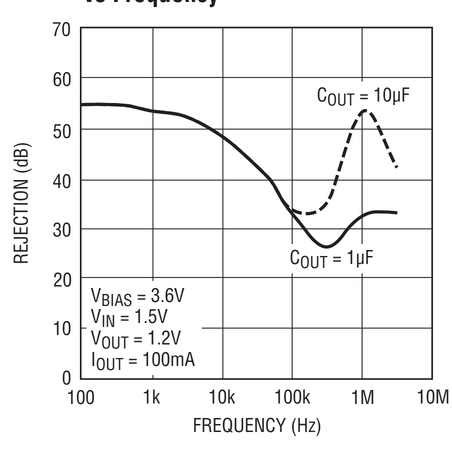
Burst Mode DC/DC Buck Ripple Rejection



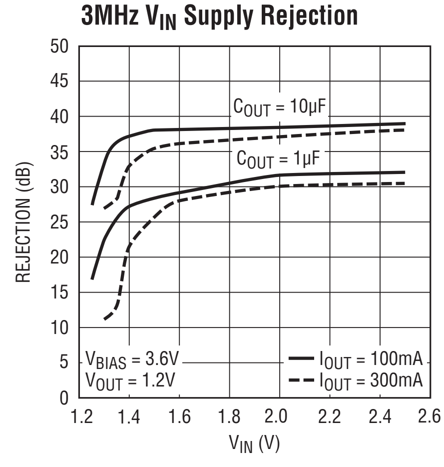
V_{IN} Ripple Rejection vs Frequency



BIAS Ripple Rejection vs Frequency

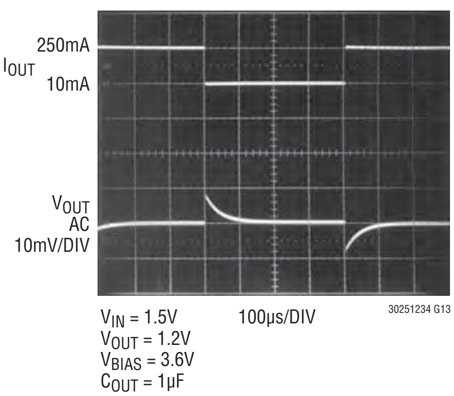


3MHz V_{IN} Supply Rejection

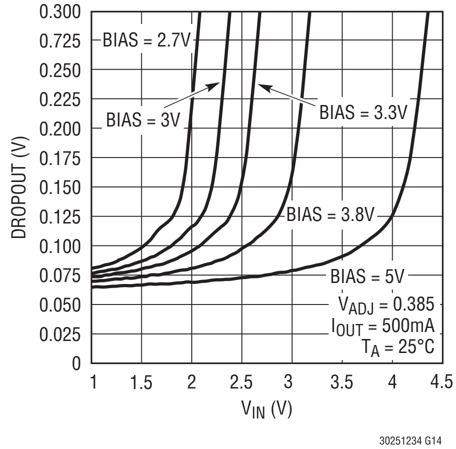


TYPICAL PERFORMANCE CHARACTERISTICS (T_A = 25°C unless otherwise noted)

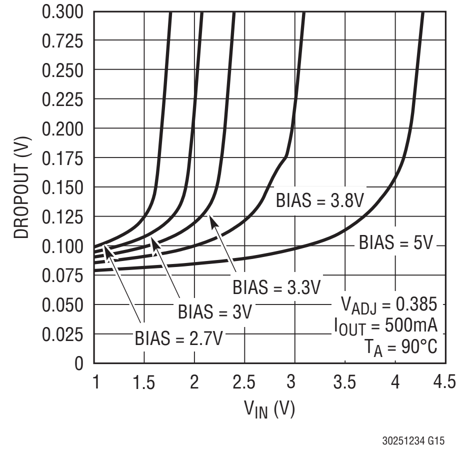
Transient Response



V_{IN} to V_{OUT} Dropout Voltage vs V_{IN} (25°C) LTC3025-1



V_{IN} to V_{OUT} Dropout Voltage vs V_{IN} (90°C) LTC3025-1



PIN FUNCTIONS

BIAS (Pin 1): BIAS Input Voltage. BIAS provides internal power for LTC3025-X circuitry. The BIAS pin should be locally bypassed to ground if the LTC3025-X is more than a few inches away from another source of bulk capacitance. In general, the output impedance of a battery rises with frequency, so it is usually advisable to include an input bypass capacitor in battery-powered circuits. A capacitor in the range of 0.01µF to 0.1µF is usually sufficient.

GND (Pin 2): Ground. Connect to a ground plane.

IN (Pin 3): Input Supply Voltage. The output load current is supplied directly from IN. The IN pin should be locally bypassed to ground if the LTC3025-X is more than a few inches away from another source of bulk capacitance. In general, the output impedance of a battery rises with frequency, so it is usually advisable to include an input bypass capacitor when supplying IN from a battery. A capacitor in the range of 0.1µF to 1µF is usually sufficient.

OUT (Pin 4): Regulated Output Voltage. The OUT pin supplies power to the load. A minimum ceramic output capacitor of at least 1µF is required to ensure stability. Larger output capacitors may be required for applications with large transient loads to limit peak voltage transients. See the Applications Information section for more information on output capacitance.

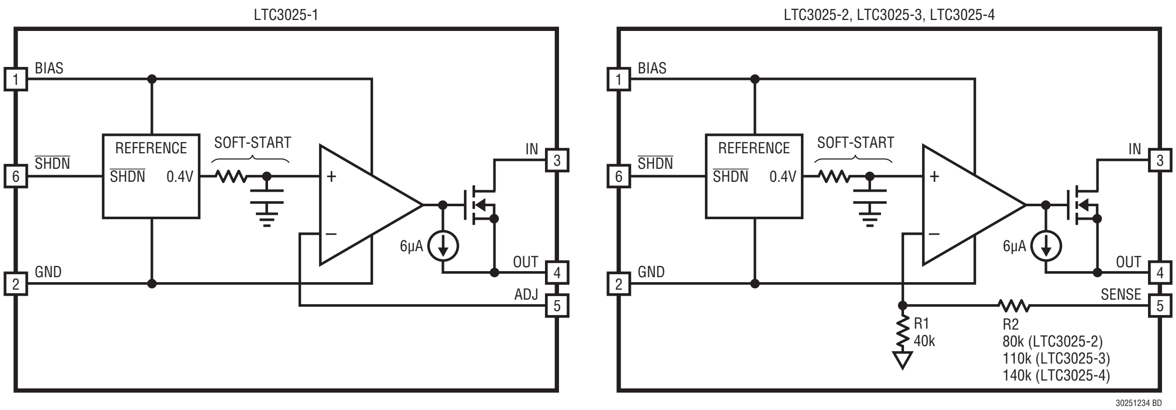
ADJ (Pin 5) LTC3025-1: Adjust Input. This is the input to the error amplifier. The ADJ pin reference voltage is 0.4V referenced to ground. The output voltage range is 0.4V to 3.6V and is typically set by connecting ADJ to a resistor divider from OUT to GND. See Figure 2.

SENSE (Pin 5) LTC3025-2, LTC3025-3, LTC3025-4: Output Sense. The sense is the input to the resistor divider driving the error amplifier. Optimum regulation will be obtained at the point where SENSE is connected to OUT. The SENSE pin bias current is 10µA at the nominal rated output voltage.

$\overline{SHDN}$ (Pin 6): Shutdown Input, Active Low. This pin is used to put the LTC3025-X into shutdown. The $\overline{SHDN}$ pin current is typically less than 10nA. The $\overline{SHDN}$ pin cannot be left floating and must be tied to a valid logic level (such as BIAS) if not used.

Exposed Pad (Pin 7): Ground and Heat Sink. Must be soldered to PCB ground plane or large pad for optimal thermal performance.

BLOCK DIAGRAM



APPLICATIONS INFORMATION

Operation (Refer to Block Diagram)

The LTC3025-X is a micropower, VLDO (very low dropout) linear regulator which operates from input voltages as low as 0.9V. The device provides a highly accurate output that is capable of supplying 500mA of output current with a typical dropout voltage of only 85mV. A single ceramic capacitor as small as 1μF is all that is required for output bypassing. A low reference voltage allows the LTC3025-1 output to be programmed to much lower voltages than available in common LDOs (range of 0.4V to 3. 6V). The LTC3025-2/LTC3025-3/LTC3025-4 have fixed outputs of 1.2V, 1.5V and 1.8V respectively, eliminating the need for an external resistor divider.

As shown in the Block Diagram, the BIAS input supplies the internal reference and LDO circuitry while all output current comes directly from the IN input for high efficiency regulation. The low quiescent supply currents I_{IN} = 4μA, I_{BIAS} = 50μA drop to I_{IN} = 1μA, I_{BIAS} = 0.01μA typical in shutdown making the LTC3025-X an ideal choice for use in battery-powered systems.

The device includes current limit and thermal overload protection. The fast transient response of the follower output stage overcomes the traditional tradeoff between dropout voltage, quiescent current and load transient response inherent in most LDO regulator architectures. The LTC3025-X also includes overshoot detection circuitry which brings the output back into regulation when going from heavy to light output loads (see Figure 1).

Adjustable Output Voltage (LTC3025-1)

The output voltage is set by the ratio of two external resistors as shown in Figure 2. The device servos the output to maintain the ADJ pin voltage at 0.4V (referenced to ground). Thus, the current in R1 is equal to 0.4V/R1. For good transient response, stability, and accuracy, the current

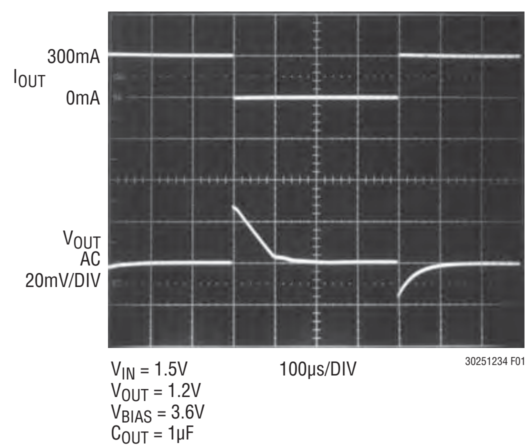


Figure 1. LTC3025-X Transient Response

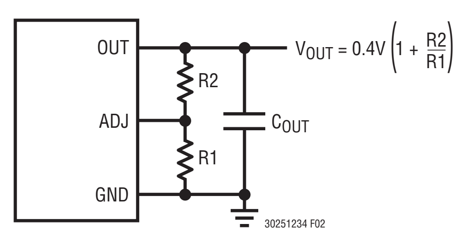


Figure 2. Programming the LTC3025-1

APPLICATIONS INFORMATION

in R1 should be at least 8μA, thus the value of R1 should be no greater than 50k. The current in R2 is the current in R1 plus the ADJ pin bias current. Since the ADJ pin bias current is typically <10nA, it can be ignored in the output voltage calculation. The output voltage can be calculated using the formula in Figure 2. Note that in shutdown the output is turned off and the divider current will be zero once C_{OUT} is discharged.

The LTC3025-1 operates at a relatively high gain of –0.7μV/mA referred to the ADJ input. Thus a load current change of 1mA to 500mA produces a –0.35mV drop at the ADJ input. To calculate the change referred to the output simply multiply by the gain of the feedback network (i. e. ,1 + R2/R1). For example, to program the output for 1.2V choose R2/R1 = 2. In this example, an output current change of 1mA to 500mA produces –0.35mV • (1 + 2) = 1.05mV drop at the output.

Because the ADJ pin is relatively high impedance (depending on the resistor divider used), stray capacitance at this pin should be minimized (<10pF) to prevent phase shift in the error amplifier loop. Additionally, special attention should be given to any stray capacitances that can couple external signals onto the ADJ pin producing undesirable output ripple. For optimum performance connect the ADJ pin to R1 and R2 with a short PCB trace and minimize all other stray capacitance to the ADJ pin.

Output Capacitance and Transient Response

The LTC3025-X is designed to be stable with a wide range of ceramic output capacitors. The ESR of the output capacitor affects stability, most notably with small capacitors. A minimum output capacitor of 1μF with an ESR of 0.05Ω or less is recommended to ensure stability. The LTC3025-X is a micropower device and output transient response will be a function of output capacitance. Larger values of output capacitance decrease the peak deviations and provide improved transient response for larger load current changes. Note that bypass capacitors used to decouple individual components powered by the LTC3025-X will increase the effective output capacitor value. High ESR tantalum and electrolytic capacitors may be used, but a low ESR ceramic capacitor must be in parallel at the output. There is no minimum ESR or maximum capacitor size requirements.

Extra consideration must be given to the use of ceramic capacitors. Ceramic capacitors are manufactured with a variety of dielectrics, each with different behavior across temperature and applied voltage. The most common dielectrics used are Z5U, Y5V, X5R and X7R. The Z5U and Y5V dielectrics are good for providing high capacitances in a small package, but exhibit large voltage and temperature coefficients as shown in Figures 3 and 4. When used with a 2V regulator, a 1μF Y5V capacitor can lose as

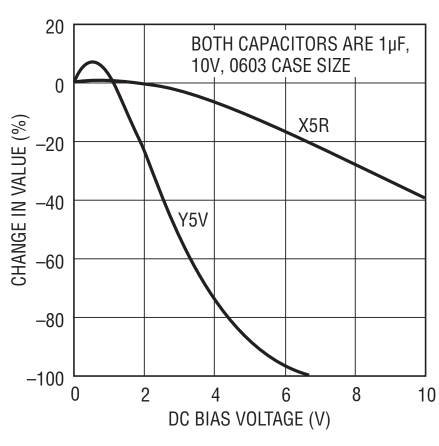


Figure 3. Ceramic Capacitor DC Bias Characteristics

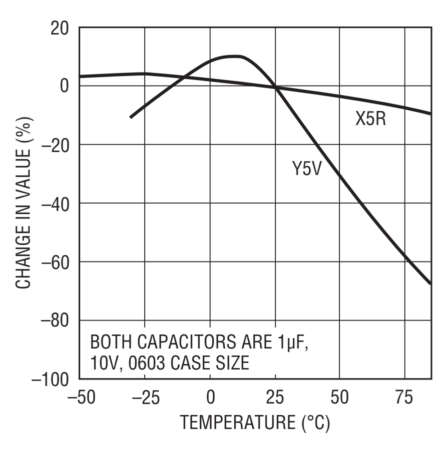


Figure 4. Ceramic Capacitor Temperature Characteristics

APPLICATIONS INFORMATION

much as 75% of its intial capacitance over the operating temperature range. The X5R and X7R dielectrics result in more stable characteristics and are usually more suitable for use as the output capacitor. The X7R type has better stability across temperature, while the X5R is less expensive and is available in higher values. In all cases, the output capacitance should never drop below 0.4µF, or instability or degraded performance may occur.

Thermal Considerations

The power handling capability of the device will be limited by the maximum rated junction temperature (125°C). The power dissipated by the device will be the output current multiplied by the input/output voltage differential:

$(I_{OUT})(V_{IN} – V_{OUT})$

Note that the BIAS current is less than 500µA even under heavy loads, so its power consumption can be ignored for thermal calculations.

The LTC3025-X has internal thermal limiting designed to protect the device during momentary overload conditions. For continuous normal conditions, the maximum junction temperature rating of 125°C must not be exceeded. It is important to give careful consideration to all sources of thermal resistance from junction to ambient. Additional heat sources mounted nearby must also be considered. For surface mount devices, heat sinking is accomplished by using the heat-spreading capabilities of the PC board and its copper traces. Copper board stiffeners and plated through holes can also be used to spread the heat generated by power devices.

The LTC3025-X 2mm × 2mm DFN package is specified as having a junction-to-ambient thermal resistance of 102°C/W, which assumes a minimal heat spreading copper plane. The actual thermal resistance can be reduced substantially by connecting the package directly to a good heat spreading ground plane. When soldered to 2500mm^2 double-sided 1 oz. copper plane, the actual junction-to-ambient thermal resistance can be less than 60°C/W.

Calculating Junction Temperature

Example: Given an output voltage of 1.2V, an input voltage of 1.8V to 3V, an output current range of 0mA to 100mA and a maximum ambient temperature of 50°C, what will the maximum junction temperature be?

The power dissipated by the device will be equal to:

$I_{OUT(MAX)}(V_{IN(MAX)} – V_{OUT})$

where:

$I_{OUT(MAX)} = 100mA$

$V_{IN(MAX)} = 3V$

So:

$P = 100mA(3V – 1.2V) = 0.18W$

Even under worst-case conditions, the LTC3025-X's BIAS pin power dissipation is only about 1mW, thus can be ignored. Assuming a junction-to-ambient thermal resistance of 102°C/W, the junction temperature rise above ambient will be approximately equal to:

$0.18W(102°C/W) = 18.4°C$

The maximum junction temperature will then be equal to the maximum junction temperature rise above ambient plus the maximum ambient temperature or:

$T_J = 50°C + 18.4°C = 68.4°C$

Short-Circuit/Thermal Protection

The LTC3025-X has built-in short-circuit current limiting as well as overtemperature protection. During short-circuit conditions, internal circuitry automatically limits the output current to approximately 1130mA. At higher temperatures, or in cases where internal power dissipation causes excessive self heating on chip, the thermal shutdown circuitry will shut down the LDO when the junction temperature exceeds approximately 150°C. It will re enable the LDO once the junction temperature drops back to approximately 140°C. The LTC3025-X will cycle in and out of thermal

APPLICATIONS INFORMATION

shutdown without latch-up or damage until the overstress condition is removed. Long term overstress ($T_J > 125°C$) should be avoided as it can degrade the performance or shorten the life of the part.

Soft-Start Operation

The LTC3025-X includes a soft-start feature to prevent excessive current flow during start-up. When the LDO is enabled, the soft-start circuitry gradually increases the LDO reference voltage from 0V to 0.4V over a period of about 600µs. There is a short 700µs delay from the time the part is enabled until the LDO output starts to rise. Figure 5 shows the start-up and shutdown output waveform.

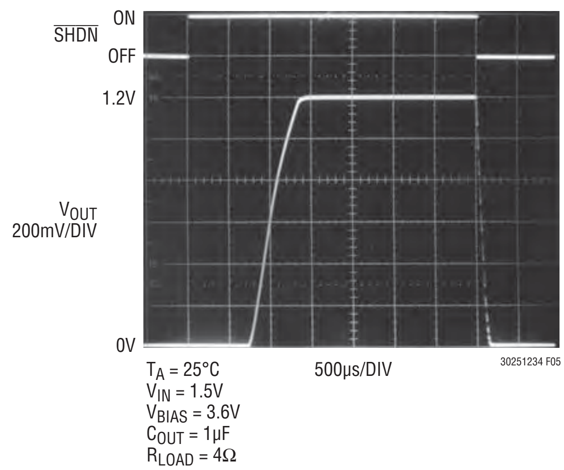
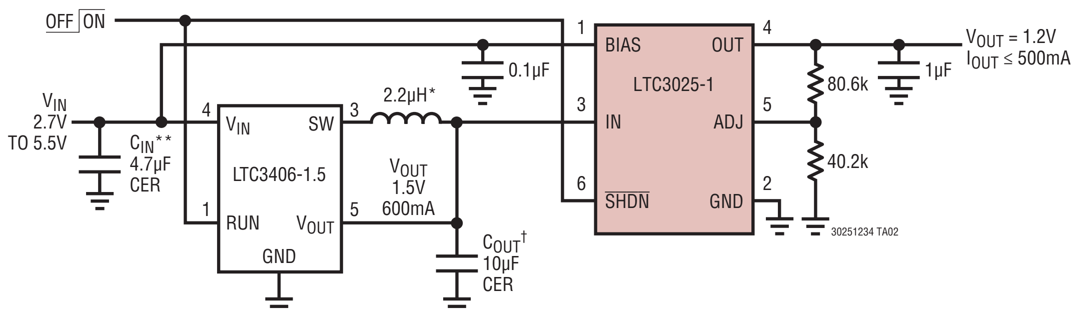


Figure 5. Output Start-Up and Shutdown

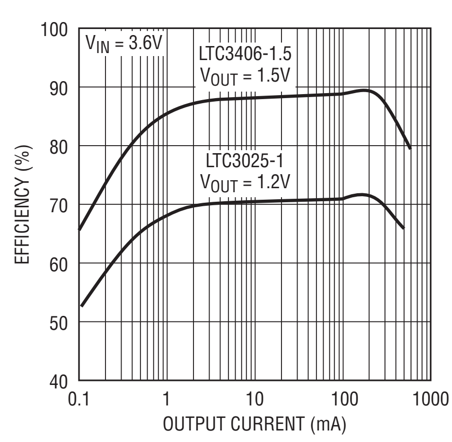
TYPICAL APPLICATION

High Efficiency 1.5V Step-Down Converter with Efficient 1.2V VLDO Output



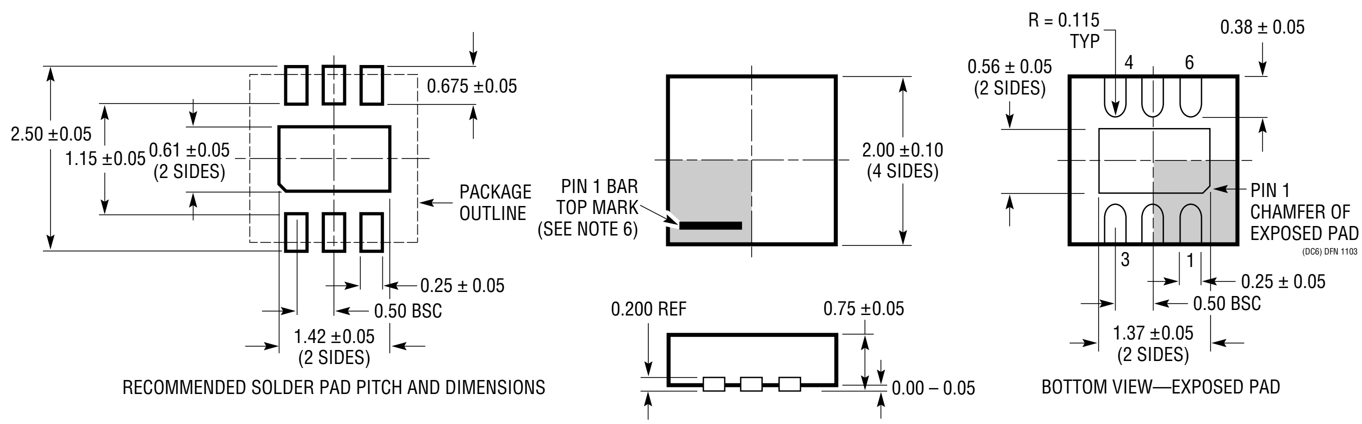
*MURATA LQH32CN2R2M33
**TAIYO YUDEN JMK212BJ475MG
†TAIYO YUDEN JMK316BJ106ML

Efficiency vs Output Current



PACKAGE DESCRIPTION

DC Package
6-Lead Plastic DFN (2mm × 2mm)
(Reference LTC DWG # 05-08-1703)



NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WCCD-2)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE TOP AND BOTTOM OF PACKAGE

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT®1129	700mA, Micropower, LDO	V_{IN}: 4.2V to 30V, $V_{OUT(MIN)}$ = 3.75V, V_{DO} = 0.40V, I_Q = 50µA, I_{SD} < 16µA, V_{OUT} = Adj, 3.3V, 5V, DD, SOT-223, S8, TO-220, TSSOP20 Packages
LT1175	500mA, Micropower, Negative LDO	V_{IN}: –20V to –4.3V, $V_{OUT(MIN)}$ = –3.8V, V_{DO} = 0.50V, I_Q = 45µA, I_{SD} < 10µA, V_{OUT} = Adj, –5V, DD, SOT-223, S8, N8 Packages. Guaranteed Voltage Tolerance and Line/Load Regulation
LT1185	3A, Negative LDO	V_{IN}: –35V to –4.2V, $V_{OUT(MIN)}$ = –2.40V, V_{DO} = 0.80V, I_Q = 2.5mA, I_{SD} < 1µA, V_{OUT} = Adj, TO-220 Package. Accurate Programmable Current Limit, Remote Sense
LT1761	100mA, Low Noise Micropower, LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 20µA, I_{SD} < 1µA, V_{OUT} = Adj, 1.5V, 1.8V, 2V, 2.5V, 2.8V, 3V, 3.3V, 5V, ThinSOT™ Package. Low Noise < 20µV_{RMSP-P}, Stable with 1µF Ceramic Capacitors
LT1762	150mA, Low Noise Micropower LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 25µA, I_{SD} < 1µA, V_{OUT} = Adj, 2.5V, 3V, 3.3V, 5V, MS8 Package. Low Noise < 20µV_{RMSP-P}
LT1763	500mA, Low Noise Micropower LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 30µA, I_{SD} < 1µA, V_{OUT} = 1.5, 1.8V, 2.5V, 3V, 3.3V, 5V, S8 Package. Low Noise < 20µV_{RMSP-P}
LT1764/LT1764A	3A, Low Noise, Fast Transient Response, LDO	V_{IN}: 2.7V to 20V, $V_{OUT(MIN)}$ = 1.21V, V_{DO} = 0.34V, I_Q = 1mA, I_{SD} < 1µA, V_{OUT} = 1.8V, 2.5V, 3.3V, DD, TO-220 Packages. Low Noise < 40µV_{RMSP-P}, "A" Version Stable with Ceramic Capacitors
LTC1844	150mA, Very Low Dropout LDO	V_{IN}: 1.6V to 6.5V, $V_{OUT(MIN)}$ = 1.25V, V_{DO} = 0.08V, I_Q = 40µA, I_{SD} < 1µA, V_{OUT} = Adj, 1.5V, 1.8V, 2.5V, 2.8V, 3.3V, ThinSOT Package. Low Noise < 30µV_{RMSP-P}, Stable with 1µF Ceramic Capacitors
LT1962	300mA, Low Noise Micropower LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.27V, I_Q = 30µA, I_{SD} < 1µA, V_{OUT} = 1.5, 1.8V, 2.5V, 3V, 3.3V, 5V, MS8 Package. Low Noise < 20µV_{RMSP-P}
LT1963/LT1963A	1.5A, Low Noise, Fast Transient Response, LDO	V_{IN}: 2.1V to 20V, $V_{OUT(MIN)}$ = 1.21V, V_{DO} = 0.34V, I_Q = 1mA, I_{SD} < 1µA, V_{OUT} = 1.5V, 1.8V, 2.5V, 3.3V, DD, SOT-223, S8, TO-220 Packages. Low Noise < 40µV_{RMSP-P}, "A"Version Stable with Ceramic Capacitors
LT1964	200mA, Low Noise Micropower, Negative LDO	V_{IN}: –0.9V to –20V, $V_{OUT(MIN)}$ = –1.21V, V_{DO} = 0.34V, I_Q = 30µA, I_{SD} < 3µA, V_{OUT} = Adj, –5V, ThinSOT Package. Low Noise < 30µV_{RMSP-P}, Stable with Ceramic Capacitors
LT1965	1.1A, Low Noise, Low Dropout Linear Regulator	290mV Dropout Voltage, Low Noise: 40µV_{RMS}, V_{IN}: 1.8V to 20V, V_{OUT}: 1.2V to 19.5V, Stable with Ceramic Caps, TO-220, DD, MSOP and 3 × 3 DFN Packages
LT3020	100mA, Low Voltage, VLDO	V_{IN}: 0.9V to 10V, $V_{OUT(MIN)}$ = 0.20V, V_{DO} = 0.15V, I_Q = 120µA, I_{SD} < 3µA, V_{OUT} = Adj, DFN, MS8 Package
LT3023	Dual, 2 × 100mA, Low Noise Micropower, LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 40µA, I_{SD} < 1µA, V_{OUT} = Adj, DFN, MS Packages. Low Noise < 20µV_{RMSP-P}, Stable with 1µF Ceramic Capacitors
LT3024	Dual 100mA/500mA, Low Noise Micropower, LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 60µA, I_{SD} < 1µA, V_{OUT} = Adj, DFN, TSSOP Packages. Low Noise < 20µV_{RMSP-P}, Stable with 1µF Ceramic Capacitors
LTC3025	300mA Micropower VLDO Linear Regulator	45mV Dropout Voltage, Low Noise: 80µV_{RMS}, V_{IN}: 0.9V to 5.5V, Low I_Q = 54µA, 2mm × 2mm 6-Lead DFN Package
LTC3026	1.5A, Low Input Voltage VLDO Regulator	V_{IN}: 1.14V to 3.5V (Boost Enabled), 1.14V to 5.5V (with External 5V Rail), V_{DO} = 0.1V, I_Q = 950µA, Stable with 10µF Ceramic Capacitors, DFN-10 and MSOP-10 Packages
LT3080/LT3080-1	1.1A, Parallelable, Low Noise, Low Dropout Linear Regulator	300mV Dropout Voltage (2-supply operation), Low Noise: 40µV_{RMS}, V_{IN}: 1.2V to 36V, V_{OUT}: 0V to 35.7V, Current-Based Reference with 1-Resistor V_{OUT} Set; Directly Parallelable (No Op Amp Required), Stable with Ceramic Caps, TO-220, SOT-223, MSOP and 3 × 3 DFN Packages; "–1" Version Has Integrated Internal Ballast Resistor

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300mA Micropower VLDO Linear Regulator

FEATURES

- **Wide Input Voltage Range: 0.9V to 5.5V**
- **Stable with Ceramic Capacitors**
- **Very Low Dropout: 45mV at 300mA**
- **Adjustable Output Range: 0.4V to 3.6V**
- **±2% Voltage Accuracy over Temperature Supply Load**
- Low Noise: $80\mu V_{RMS}$ (10Hz to 100kHz)
- BIAS Voltage Range: 2.5V to 5.5V
- Fast Transient Recovery
- Shutdown Disconnects Load from V_{IN} and V_{BIAS}
- Low Operating Current: I_{IN} = 4µA, I_{BIAS} = 50µA Typ
- Low Shutdown Current: I_{IN} = 1µA, I_{BIAS} = 0.01µA Typ
- Output Current Limit
- Thermal Overload Protection
- Available in 6-Lead (2mm × 2mm) DFN Package

APPLICATIONS

- Low Power Handheld Devices
- Low Voltage Logic Supplies
- DSP Power Supplies
- Cellular Phones
- Portable Electronic Equipment
- Handheld Medical Instruments
- Post Regulator for Switching Supply Noise Rejection

DESCRIPTION

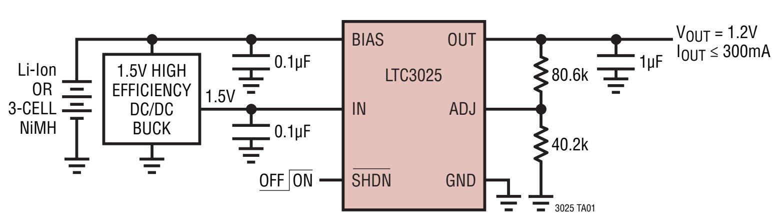
The LTC®3025 is a micropower, VLDO™ (very low dropout) linear regulator which operates from input voltages as low as 0.9V. The device is capable of supplying 300mA of output current with a typical dropout voltage of only 45mV. A BIAS supply is required to run the internal reference and LDO circuitry while output current comes directly from the IN supply for high efficiency regulation. The low 0.4V internal reference voltage allows the LTC3025 output to be programmed to much lower voltages than available in common LDOs (range of 0.4V to 3.6V). The output voltage is programmed via two ultrasmall SMD resistors.

The LTC3025's low quiescent current makes it an ideal choice for use in battery-powered systems. For 3-cell NiMH and single cell Li-Ion applications, the BIAS voltage can be supplied directly from the battery while the input can come from a high efficiency buck regulator, providing a high efficiency, low noise output.

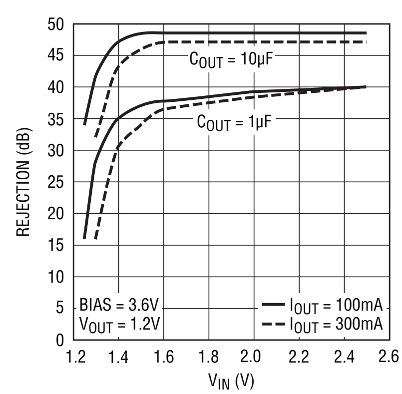
Other features include high output voltage accuracy, excellent transient response, stability with ultralow ESR ceramic capacitors as small as 1µF, short-circuit and thermal overload protection and output current limiting. The LTC3025 is available in a tiny, low profile (0.75mm) 6-lead DFN (2mm × 2mm) package.

TYPICAL APPLICATION

1.2V Output Voltage from 1.5V Input Supply



1MHz V_{IN} Supply Rejection

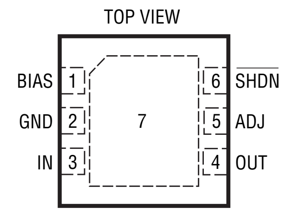


ABSOLUTE MAXIMUM RATINGS

(Notes 1, 2)

V_{BIAS}, V_{IN} to GND.. –0.3V to 6V
$\overline{SHDN}$ to GND.. –0.3V to 6V
ADJ to GND.. –0.3V to 6V
V_{OUT}......................................–0.3V to V_{IN} + 0.3V or 6V
Operating Junction Temperature Range
(Note 3).. –40°C to 125°C
Storage Temperature Range................... –65°C to 125°C
Output Short-Circuit Duration .... Indefinite

PIN CONFIGURATION



DC6 PACKAGE
6-LEAD (2mm × 2mm) PLASTIC DFN

T_{JMAX} = 125°C, θ_{JA} = 102°C/W, θ_{JC} = 20°C/W
EXPOSED PAD (PIN 7) IS GND, MUST BE SOLDERED TO PCB

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LTC3025EDC#PBF	LTC3025EDC#TRPBF	LBDY	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC#PBF	LTC3025IDC#TRPBF	LBDY	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LEAD BASED FINISH	**TAPE AND REEL**	**PART MARKING***	**PACKAGE DESCRIPTION**	**TEMPERATURE RANGE**
LTC3025EDC	LTC3025EDC#TR	LBDY	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C
LTC3025IDC	LTC3025IDC#TR	LBDY	6-Lead (2mm × 2mm) Plastic DFN	–40°C to 125°C

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container.

For more information on lead free part marking, go to: http://www.linear.com/leadfree/
For more information on tape and reel specifications, go to: http://www.linear.com/tapeandreel/

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.5V, V_{BIAS} = 3.6V, V_{OUT} = 1.2V, C_{OUT} = 1µF, C_{IN} = 0.1µF, C_{BIAS} = 0.1µF (all capacitors ceramic) unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{IN} Operating Voltage (Note 4)		●	0.9		5.5	V
V_{BIAS} Operating Voltage (Note 4)		●	2.5		5.5	V
V_{BIAS} Undervoltage Lockout		●		2.2	2.5	V
V_{IN} Operating Current	I_{OUT} = 10µA	●		4	10	µA
V_{BIAS} Operating Current	I_{OUT} = 10µA	●		50	80	µA
V_{IN} Shutdown Current	$V_{\overline{SHDN}}$ = 0V			1	5	µA
V_{BIAS} Shutdown Current	$V_{\overline{SHDN}}$ = 0V			0.01	1	µA
V_{ADJ} Regulation Voltage (Note 5)	1mA ≤ I_{OUT} ≤ 300mA, 1.5V ≤ V_{IN} ≤ 5V 1mA ≤ I_{OUT} ≤ 300mA, 1.5V ≤ V_{IN} ≤ 5V	 ●	0.395 0.392	0.4 0.4	0.405 0.408	V V
I_{ADJ} ADJ Input Current	V_{ADJ} = 0.45V		–50	0	50	nA
OUT Load Regulation (Referred to ADJ Pin)	ΔI_{OUT} = 1mA to 300mA			–0.2		mV
V_{IN} Line Regulation (Referred to ADJ Pin)	V_{IN} = 1.5V to 5V, V_{BIAS} = 3.6V, V_{OUT} = 1.2V, I_{OUT} = 1mA			0.07		mV

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.5V, V_{BIAS} = 3.6V, V_{OUT} = 1.2V, C_{OUT} = 1µF, C_{IN} = 0.1µF, C_{BIAS} = 0.1µF (all capacitors ceramic) unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
BIAS Line Regulation (Referred to ADJ Pin)	V_{IN} = 1.5V, V_{BIAS} = 2.6V to 5V, V_{OUT} = 1.2V I_{OUT} = 1mA	●		1.7	5.5	mV
V_{IN} to V_{OUT} Dropout Voltage (Notes 4, 6, 7)	V_{BIAS} = 2.8V, V_{IN} = 1.5V, V_{ADJ} = 0.37V, I_{OUT} = 300mA	●		45	100	mV
V_{BIAS} to V_{OUT} Dropout Voltage (Note 4)		●			1.4	V
I_{OUT} Continuous Output Current		●	300			mA
I_{OUT} Current Limit	V_{ADJ} = 0V			680		mA
e_n Output Voltage Noise	f = 10Hz to 100kHz, I_{OUT} = 300mA			80		μV_{RMS}
V_{IH} $\overline{SHDN}$ Input High Voltage		●	0.9			V
V_{IL} $\overline{SHDN}$ Input Low Voltage		●			0.3	V
I_{IH} $\overline{SHDN}$ Input High Current	$\overline{SHDN}$ = 1.2V		–1		1	µA
I_L $\overline{SHDN}$ Input Low Current	$\overline{SHDN}$ = 0V		–1		1	µA

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: This IC includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperature will exceed 125°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

Note 3: The LTC3025 regulator is tested and specified under pulse loadconditions such that $T_J \approx T_A$. The LTC3025 is 100% production tested at 25°C. Performance at –40°C and 125°C is assured by design, characterization and correlation with statistical process control. The LTC3025I is guaranteed to meet performance specifications over the full –40°C and 125°C temperature range.

Note 4: For the LTC3025, a regulated output voltage will only be available when the minimum IN and BIAS Operating Voltages as well as the IN to OUT and BIAS to OUT Dropout Voltages are all satisfied.

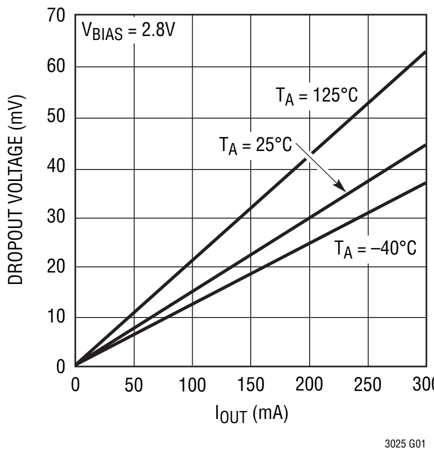
Note 5: Operating conditions are limited by maximum junction temperature. The regulated output voltage specification will not apply for all possible combinations of input voltage and output current. When operating at maximum input voltage, the output current range must be limited. When operating at maximum output current, the input voltage range must be limited.

Note 6: Dropout voltage is minimum input to output voltage differential needed to maintain regulation at a specified output current. In dropout, the output voltage will be equal to $V_{IN} - V_{DROPOUT}$.

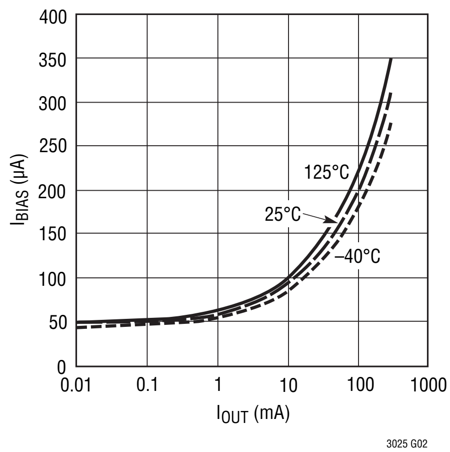
Note 7: The DFN output FET on-resistance in dropout is guaranteed by correlation to wafer level measurements.

TYPICAL PERFORMANCE CHARACTERISTICS

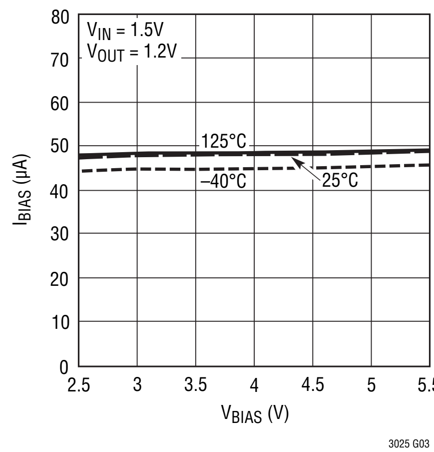
Dropout Voltage vs I_{OUT}



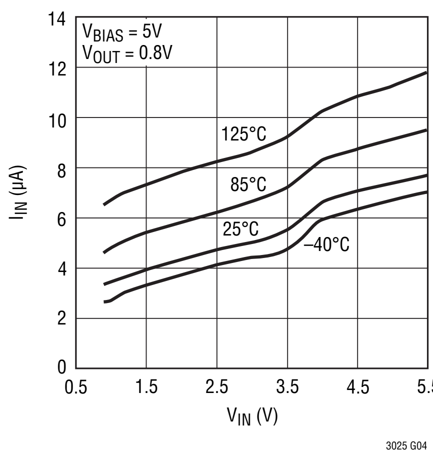
Operating BIAS Current vs Output Load



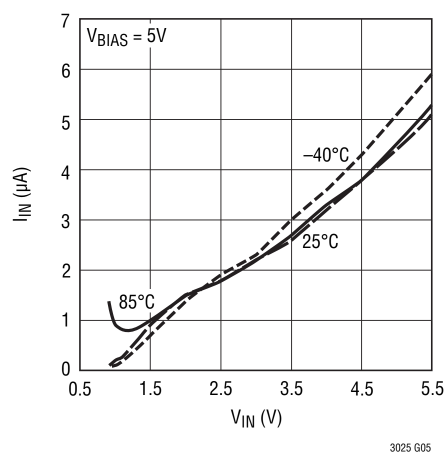
BIAS No Load Operating Current



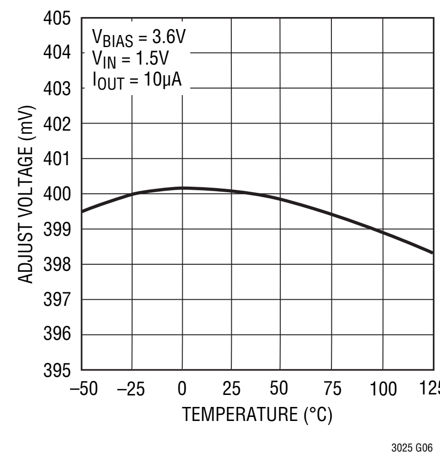
V_{IN} No Load Operating Current



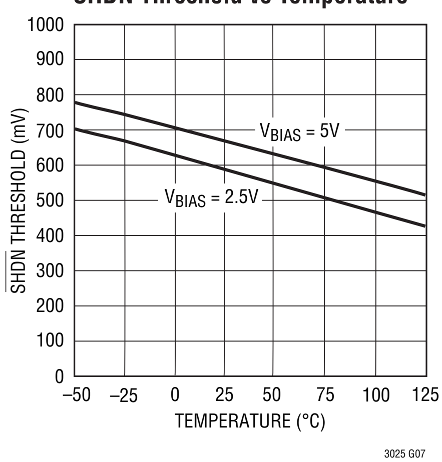
V_{IN} Shutdown Current



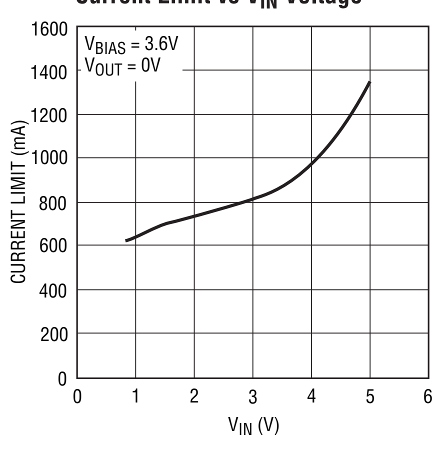
Adjust Voltage vs Temperature



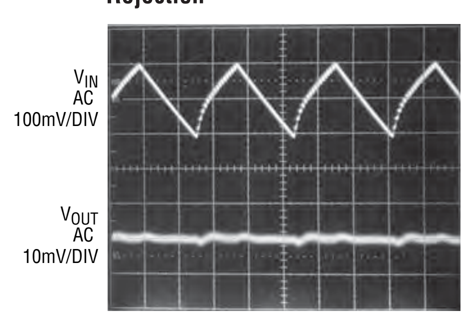
$\overline{SHDN}$ Threshold vs Temperature



Current Limit vs V_{IN} Voltage

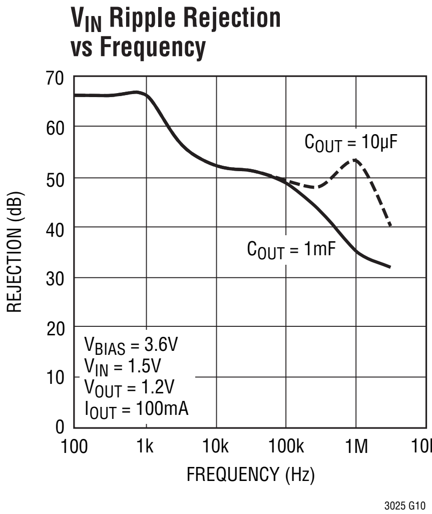


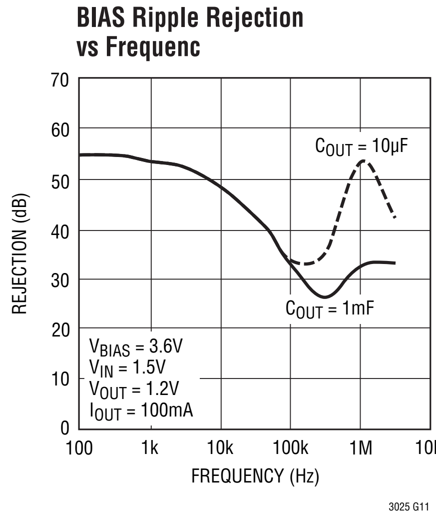
Burst Mode DC/DC Buck Ripple Rejection

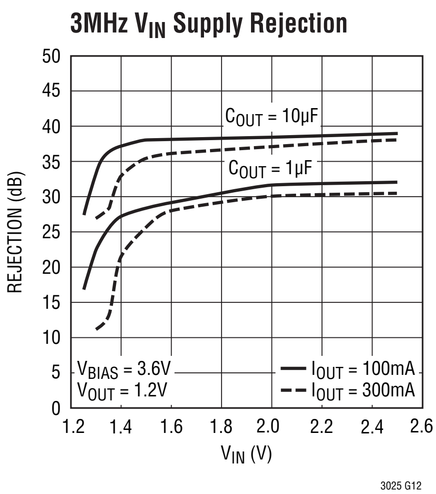


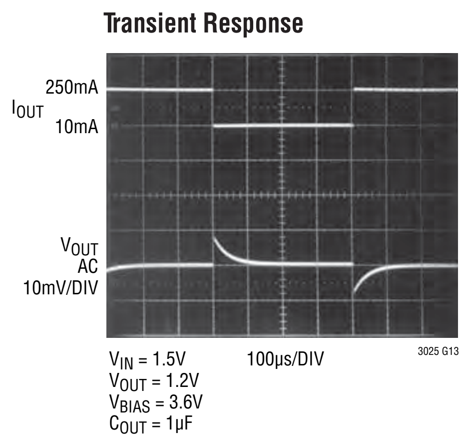
V_{IN} = 1.8V
V_{OUT} = 1.5V
C_{OUT} = 1µF
I_{OUT} = 50mA
10µs/DIV

TYPICAL PERFORMANCE CHARACTERISTICS









PIN FUNCTIONS

BIAS (Pin 1): BIAS Input Voltage. BIAS provides internal power for LTC3025 circuitry. The BIAS pin should be locally bypassed to ground if the LTC3025 is more than a few inches away from another source of bulk capacitance. In general, the output impedance of a battery rises with frequency, so it is usually advisable to include an input bypass capacitor in battery-powered circuits. A capacitor in the range of 0.01µF to 0.1µF is usually sufficient.

GND (Pin 2): Ground. Connect to a ground plane.

IN (Pin 3): Input Supply Voltage. The output load current is supplied directly from IN. The IN pin should be locally bypassed to ground if the LTC3025 is more than a few inches away from another source of bulk capacitance. In general, the output impedance of a battery rises with frequency, so it is usually advisable to include an input bypass capacitor when supplying IN from a battery. A capacitor in the range of 0.1µF to 1µF is usually sufficient.

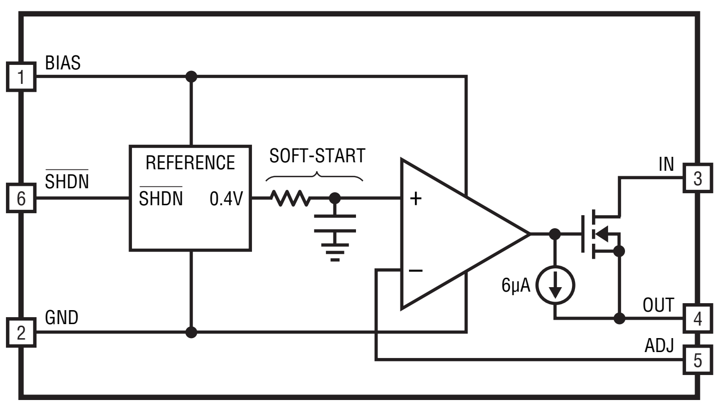
OUT (Pin 4): Regulated Output Voltage. The OUT pin supplies power to the load. A minimum ceramic output capacitor of at least 1µF is required to ensure stability. Larger output capacitors may be required for applications with large transient loads to limit peak voltage transients. See the Applications Information section for more information on output capacitance.

ADJ (Pin 5): Adjust Input. This is the input to the error amplifier. The ADJ pin reference voltage is 0.4V referenced to ground. The output voltage range is 0.4V to 3.6V and is typically set by connecting ADJ to a resistor divider from OUT to GND. See Figure 2.

$\overline{\text{SHDN}}$ (Pin 6): Shutdown Input, Active Low. This pin is used to put the LTC3025 into shutdown. The $\overline{\text{SHDN}}$ pin current is typically less than 10nA. The $\overline{\text{SHDN}}$ pin cannot be left floating and must be tied to a valid logic level (such as BIAS) if not used.

Exposed Pad (Pin 7): Ground and Heat Sink. Must be soldered to PCB ground plane or large pad for optimal thermal performance.

BLOCK DIAGRAM



APPLICATIONS INFORMATION

Operation (Refer to Block Diagram)

The LTC3025 is a micropower, VLDO (very low dropout) linear regulator which operates from input voltages as low as 0.9V. The device provides a high accuracy output that is capable of supplying 300mA of output current with a typical dropout voltage of only 45mV. A single ceramic capacitor as small as 1µF is all that is required for output bypassing. A low reference voltage allows the LTC3025 output to be programmed to much lower voltages than available in common LDOs (range of 0.4V to 3. 6V).

As shown in the Block Diagram, the BIAS input supplies the internal reference and LDO circuitry while all output current comes directly from the IN input for high efficiency regulation. The low quiescent supply currents I_{IN} = 4µA, I_{BIAS} = 50µA drop to I_{IN} = 1µA, I_{BIAS} = 0.01µA typical in shutdown making the LTC3025 an ideal choice for use in battery-powered systems.

The device includes current limit and thermal overload protection. The fast transient response of the follower output stage overcomes the traditional tradeoff between dropout voltage, quiescent current and load transient response inherent in most LDO regulator architectures. The LTC3025 also includes overshoot detection circuitry which brings the output back into regulation when going from heavy to light output loads (see Figure 1).

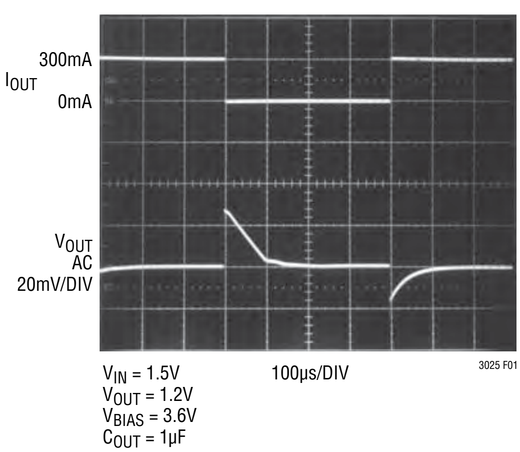


Figure 1. LTC3025 Transient Response

Adjustable Output Voltage

The output voltage is set by the ratio of two external resistors as shown in Figure 2. The device servos the output to maintain the ADJ pin voltage at 0.4V (referenced to ground). Thus the current in R1 is equal to 0.4V/R1. For good transient response, stability, and accuracy, the current in R1 should be at least 8µA, thus the value of R1 should be no greater than 50k. The current in R2 is the current in R1 plus the ADJ pin bias current. Since the ADJ pin bias current is typically <10nA, it can be ignored in the output voltage calculation. The output voltage can be calculated using the formula in Figure 2. Note that in shutdown the output is turned off and the divider current will be zero once C_{OUT} is discharged.

The LTC3025 operates at a relatively high gain of –0.7µV/mA referred to the ADJ input. Thus a load current change of 1mA to 300mA produces a –0.2mV drop at the ADJ input. To calculate the change referred to the output simply multiply by the gain of the feedback network (i. e. ,1 + R2/R1). For example, to program the output for 1.2V choose R2/R1 = 2. In this example, an output current change of 1mA to 300mA produces –0.2mV • (1 + 2) = 0.6mV drop at the output.

Because the ADJ pin is relatively high impedance (depending on the resistor divider used) , stray capacitance at this pin should be minimized (<10pF) to prevent phase shift in the error amplifier loop. Additionally, special attention should be given to any stray capacitances that can couple external signals onto the ADJ pin producing undesirable output ripple. For optimum performance connect the ADJ pin to R1 and R2 with a short PCB trace and minimize all other stray capacitance to the ADJ pin.

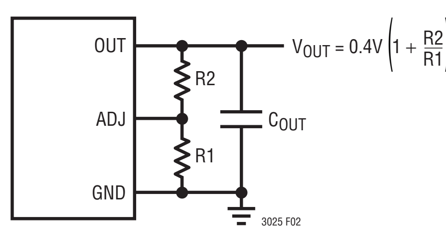


Figure 2. Programming the LTC3025

APPLICATIONS INFORMATION

Output Capacitance and Transient Response

The LTC3025 is designed to be stable with a wide range of ceramic output capacitors. The ESR of the output capacitor affects stability, most notably with small capacitors. A minimum output capacitor of 1μF with an ESR of 0.05Ω or less is recommended to ensure stability. The LTC3025 is a micropower device and output transient response will be a function of output capacitance. Larger values of output capacitance decrease the peak deviations and provide improved transient response for larger load current changes. Note that bypass capacitors used to decouple individual components powered by the LTC3025 will increase the effective output capacitor value. High ESR tantalum and electrolytic capacitors may be used, but a low ESR ceramic capacitor must be in parallel at the output. There is no minimum ESR or maximum capacitor size requirements.

Extra consideration must be given to the use of ceramic capacitors. Ceramic capacitors are manufactured with a variety of dielectrics, each with different behavior across temperature and applied voltage. The most common dielectrics used are Z5U, Y5V, X5R and X7R. The Z5U and Y5V dielectrics are good for providing high capacitances in a small package, but exhibit large voltage and temperature coefficients as shown in Figures 3 and 4. When used with a 2V regulator, a 1μF Y5V capacitor can lose as much as 75% of its intial capacitance over the operating temperature range. The X5R and X7R dielectrics result in more stable characteristics and are usually more suitable for use as the output capacitor. The X7R type has better stability across temperature, while the X5R is less expensive and is available in higher values. In all cases, the output capacitance should never drop below 0.4μF, or instability or degraded performance may occur.

Thermal Considerations

The power handling capability of the device will be limited by the maximum rated junction temperature (125°C). The power dissipated by the device will be the output current multiplied by the input/output voltage differential:

$$(I_{OUT})\,(V_{IN} - V_{OUT})$$

Note that the BIAS current is less than 300μA even under heavy loads, so its power consumption can be ignored for thermal calculations.

The LTC3025 has internal thermal limiting designed to protect the device during momentary overload conditions. For continuous normal conditions, the maximum junction temperature rating of 125°C must not be exceeded. It is important to give careful consideration to all sources of thermal resistance from junction to ambient. Additional heat sources mounted nearby must also be considered. For surface mount devices, heat sinking is accomplished by using the heat-spreading capabilities of the PC board and its copper traces. Copper board stiffeners and plated through holes can also be used to spread the heat generated by power devices.

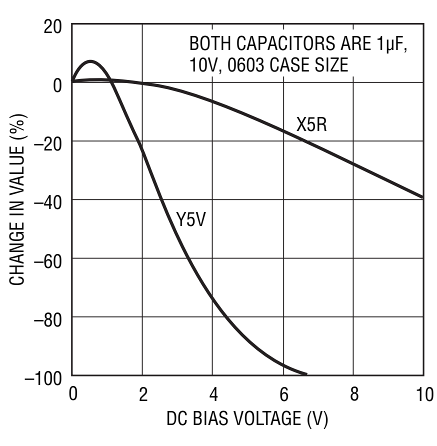


Figure 3. Ceramic Capacitor DC Bias Characteristics

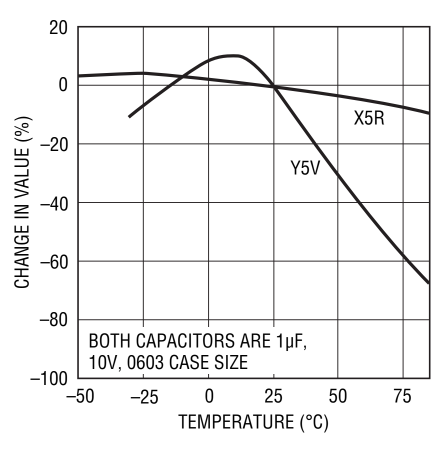


Figure 4. Ceramic Capacitor Temperature Characteristics

APPLICATIONS INFORMATION

The LTC3025 2mm × 2mm DFN package is specified as having a junction-to-ambient thermal resistance of 102°C/W, which assumes a minimal heat spreading copper plane. The actual thermal resistance can be reduced substantially by connecting the package directly to a good heat spreading ground plane. When soldered to 2500mm^2 double-sided 1 oz. copper plane, the actual junction-to-ambient thermal resistance can be less than 60°C/W.

Calculating Junction Temperature

Example: Given an output voltage of 1.2V, an input voltage of 1.8V to 3V, an output current range of 0mA to 100mA and a maximum ambient temperature of 50°C, what will the maximum junction temperature be?

The power dissipated by the device will be equal to:

$$I_{OUT(MAX)}\ (V_{IN(MAX)} - V_{OUT})$$

where:

$I_{OUT(MAX)} = 100mA$

$V_{IN(MAX)} = 3V$

So:

$$P = 100mA(3V - 1.2V) = 0.18W$$

Even under worst-case conditions, the LTC3025's BIAS pin power dissipation is only about 1mW, thus can be ignored. Assuming a junction-to-ambient thermal resistance of 102°C/W, the junction temperature rise above ambient will be approximately equal to:

$$0.18W(102°C/W) = 18.4°C$$

The maximum junction temperature will then be equal to the maximum junction temperature rise above ambient plus the maximum ambient temperature or:

$$T = 50°C + 18.4°C = 68.4°C$$

Short-Circuit/Thermal Protection

The LTC3025 has built-in short-circuit current limiting as well as overtemperature protection. During short-circuit conditions, internal circuitry automatically limits the output current to approximately 600mA. At higher temperatures, or in cases where internal power dissipation causes excessive self heating on chip, the thermal shutdown circuitry will shut down the LDO when the junction temperature exceeds approximately 150°C. It will re enable the LDO once the junction temperature drops back to approximately 140°C. The LTC3025 will cycle in and out of thermal shutdown without latch-up or damage until the overstress condition is removed. Long term overstress ($T_J > 125°C$) should be avoided as it can degrade the performance or shorten the life of the part.

Soft-Start Operation

The LTC3025 includes a soft-start feature to prevent excessive current flow during start-up. When the LDO is enabled, the soft-start circuitry gradually increases the LDO reference voltage from 0V to 0.4V over a period of about 600µs. There is a short 700µs delay from the time the part is enabled until the LDO output starts to rise. Figure 5 shows the start-up and shutdown output waveform.

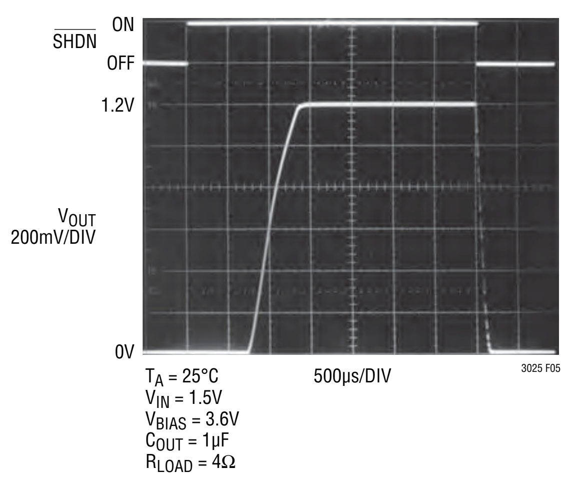
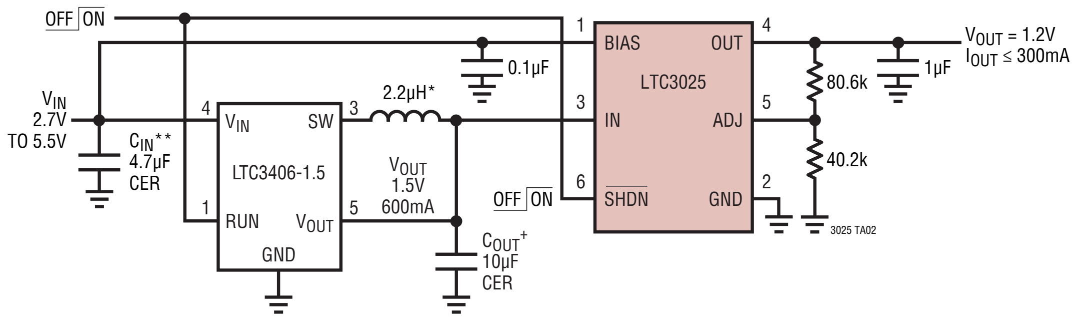


Figure 5. Output Start-Up and Shutdown

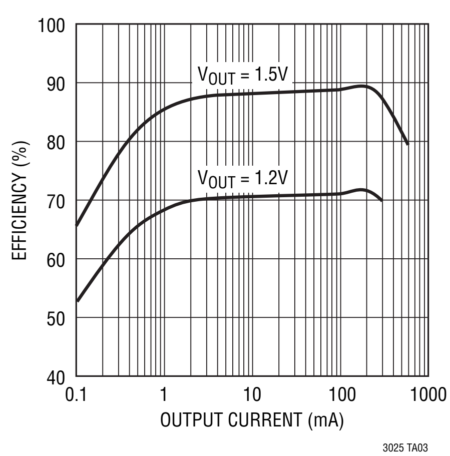
TYPICAL APPLICATION

High Efficiency 1.5V Step-Down Converter with Efficient 1.2V VLDO Output



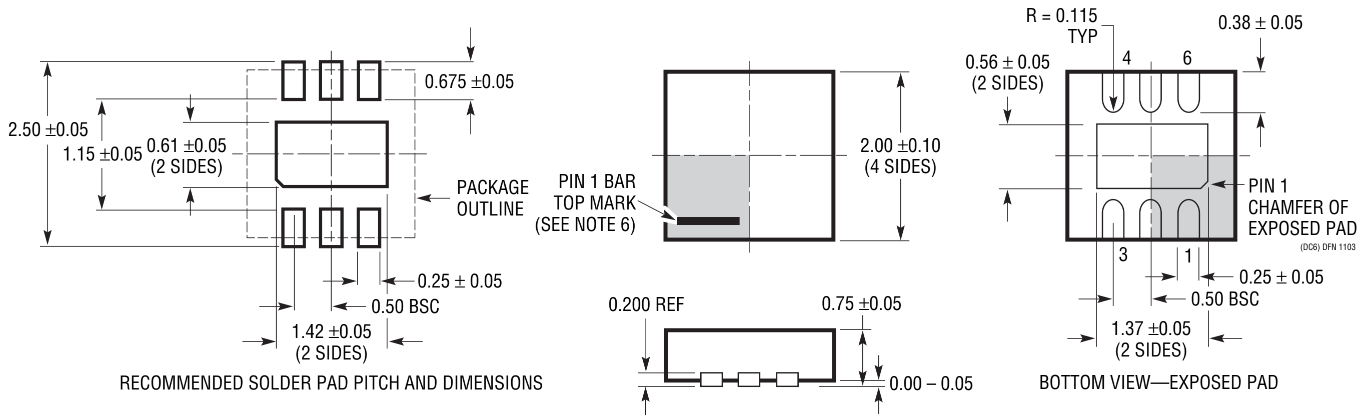
*MURATA LQH32CN2R2M33
**TAIYO YUDEN JMK212BJ475MG
†TAIYO YUDEN JMK316BJ106ML

Efficiency vs Output Current



PACKAGE DESCRIPTION

DC Package
6-Lead Plastic DFN (2mm × 2mm)
(Reference LTC DWG # 05-08-1703)



NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WCCD-2)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE TOP AND BOTTOM OF PACKAGE

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT®1129	700mA, Micropower, LDO	V_{IN}: 4.2V to 30V, $V_{OUT(MIN)}$ = 3.75V, V_{DO} = 0.40V, I_Q = 50µA, I_{SD} < 16µA, V_{OUT} = Adj, 3.3V, 5V, DD, SOT-223, S8, TO-220, TSSOP20 Packages
LT1175	500mA, Micropower, Negative LDO	V_{IN}: –20V to –4.3V, $V_{OUT(MIN)}$ = –3.8V, V_{DO} = 0.50V, I_Q = 45µA, I_{SD} < 10µA, V_{OUT} = Adj, –5V, DD, SOT-223, S8, N8 Packages. Guaranteed Voltage Tolerance and Line/Load Regulation
LT1185	3A, Negative LDO	V_{IN}: –35V to –4.2V, $V_{OUT(MIN)}$ = –2.40V, V_{DO} = 0.80V, I_Q = 2.5mA, I_{SD} < 1µA, V_{OUT} = Adj, TO-220 Package. Accurate Programmable Current Limit, Remote Sense
LT1761	100mA, Low Noise Micropower, LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 20µA, I_{SD} < 1µA, V_{OUT} = Adj, 1.5V, 1.8V, 2V, 2.5V, 2.8V, 3V, 3.3V, 5V, ThinSOT™ Package. Low Noise < 20µV_{RMSP-P} Stable with 1µF Ceramic Capacitors
LT1762	150mA, Low Noise Micropower LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 25µA, I_{SD} < 1µA, V_{OUT} = Adj, 2.5V, 3V, 3.3V, 5V, MS8 Package. Low Noise < 20µV_{RMSP-P}
LT1763	500mA, Low Noise Micropower LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 30µA, I_{SD} < 1µA, V_{OUT} = 1.5, 1.8V, 2.5V, 3V, 3.3V, 5V, S8 Package. Low Noise < 20µV_{RMSP-P}
LT1764/LT1764A	3A, Low Noise, Fast Transient Response, LDO	V_{IN}: 2.7V to 20V, $V_{OUT(MIN)}$ = 1.21V, V_{DO} = 0.34V, I_Q = 1mA, I_{SD} < 1µA, V_{OUT} = 1.8V, 2.5V, 3.3V, DD, TO-220 Packages. Low Noise < 40µV_{RMSP-P} "A" Version Stable with Ceramic Capacitors
LTC1844	150mA, Very Low Dropout LDO	V_{IN}: 1.6V to 6.5V, $V_{OUT(MIN)}$ = 1.25V, V_{DO} = 0.08V, I_Q = 40µA, I_{SD} < 1µA, V_{OUT} = Adj, 1.5V, 1.8V, 2.5V, 2.8V, 3.3V, ThinSOT Package. Low Noise < 30µV_{RMSP-P} Stable with 1µF Ceramic Capacitors
LT1962	300mA, Low Noise Micropower LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.27V, I_Q = 30µA, I_{SD} < 1µA, V_{OUT} = 1.5, 1.8V, 2.5V, 3V, 3.3V, 5V, MS8 Package. Low Noise < 20µV_{RMSP-P}
LT1963/LT1963A	1.5A, Low Noise, Fast Transient Response, LDO	V_{IN}: 2.1V to 20V, $V_{OUT(MIN)}$ = 1.21V, V_{DO} = 0.34V, I_Q = 1mA, I_{SD} < 1µA, V_{OUT} = 1.5V, 1.8V, 2.5V, 3.3V, DD, SOT-223, S8, TO-220 Packages. Low Noise < 40µV_{RMSP-P} "A"Version Stable with Ceramic Capacitors
LT1964	200mA, Low Noise Micropower, Negative LDO	V_{IN}: –0.9V to –20V, $V_{OUT(MIN)}$ = –1.21V, V_{DO} = 0.34V, I_Q = 30µA, I_{SD} < 3µA, V_{OUT} = Adj, –5V, ThinSOT Package. Low Noise < 30µV_{RMSP-P} Stable with Ceramic Capacitors
LT3020	100mA, Low Voltage, VLDO	V_{IN}: 0.9V to 10V, $V_{OUT(MIN)}$ = 0.20V, V_{DO} = 0.15V, I_Q = 120µA, I_{SD} < 3µA, V_{OUT} = Adj, DFN, MS8 Package
LT3023	Dual, 2 × 100mA, Low Noise Micropower, LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 40µA, I_{SD} < 1µA, V_{OUT} = Adj, DFN, MS Packages. Low Noise < 20µV_{RMSP-P} Stable with 1µF Ceramic Capacitors
LT3024	Dual 100mA/500mA, Low Noise Micropower, LDO	V_{IN}: 1.8V to 20V, $V_{OUT(MIN)}$ = 1.22V, V_{DO} = 0.30V, I_Q = 60µA, I_{SD} < 1µA, V_{OUT} = Adj, DFN, TSSOP Packages. Low Noise < 20µV_{RMSP-P} Stable with 1µF Ceramic Capacitors

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Power Supply Tracking for Linear Regulators

by Dan Eddleman

Introduction

The LTC2923 provides simple and versatile control over the power-up and power-down behavior of switching power supplies. It allows several supplies to track the voltage of a master supply, so that their relative voltages meet the stringent specifications for the power up of modern digital semiconductors, such as DSPs, microprocessors, FPGAs and ASICs. The LTC2923 is specifically designed to work with switching power supplies (see "Versatile Power Supply Tracking without MOSFETs" from *Linear Technology* Magazine, February, 2004) but it is easily adapted to linear regulators, including popular low-dropout (LDO) types. Summarized here are several techniques for controlling linear regulators with the LTC2923.

Monolithic Regulators

Table 1 lists three popular monolithic linear regulators that have been tested with the LTC2923. Using these three monolithic LDOs with the LTC2923 is generally very simple:

- ❑ The LTC3020 is a 100mA low dropout regulator (LDO) that operates with input supply voltages between 1V and 10V. Since its ADJ pin behaves like the feedback pin on most switching regulators, tracking the LTC3020's output using the LTC2923 is simple. The standard circuits and design procedures shown in the LTC2923 data sheet require no modification when used with the LTC3020 (Figures 1 and 2).
- ❑ The LTC3025 is a 300mA monolithic CMOS LDO that regulates input supplies between 0.9V and 5.5V, while a bias supply between 2.5V and 5.5V powers the part. Similar to the LT3020, the LTC3025's ADJ pin is operationally identical to common switchers. For that reason, the LTC3025 combined with an LTC2923 provides a simple supply tracking solution for loads less than 300mA (Figures 1 and 2).
- ❑ The LTC1844 CMOS LDO drives loads up to 150mA with input supply voltages between 1.6V and 6.5V. When used in conjunction with the LTC2923, a feedforward capacitor should be included as described in the "Adjustable Operation" section of the LTC1844 data sheet. Otherwise, no special considerations are necessary.

Table 1. New monolithic linear regulators

Regulator	$I_{OUT(MAX)}$ (V)	$V_{IN(MIN)}$ (V)	$V_{IN(MAX)}$ (V)	$V_{DROPOUT}$ (V)
LT3020	100mA	0.9	10	0.15
LTC1844	150mA	1.6	6.5	0.11
LTC3025	300mA	0.9	5.5	0.045

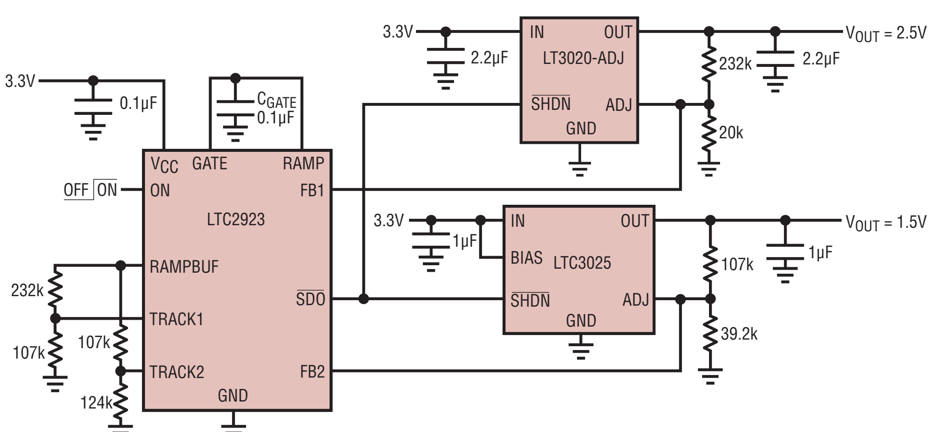

Figure 1. An LTC2923 causes the outputs of the LT3020 and LTC3025 to track during power-up and power-down.

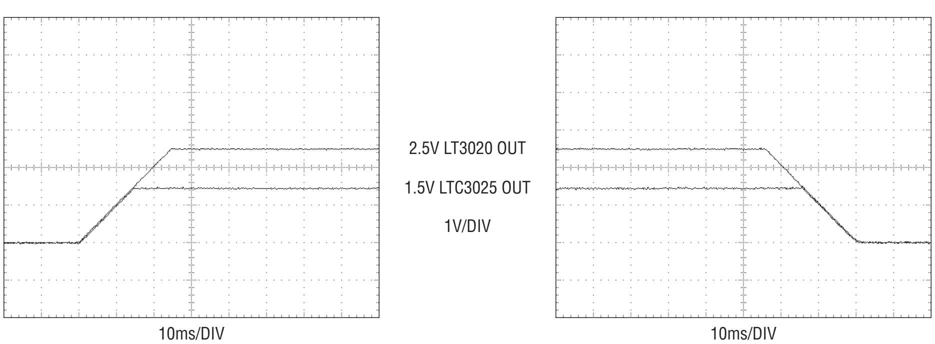

Figure 2. The outputs of the LT3020 and LTC3025 low-dropout linear regulators ramp-up and ramp-down together. (Output of circuit in Figure 1.)

The LTC1761 Family of Monolithic, Bipolar Regulators

Table 2 shows the LTC1761 family of monolithic, bipolar low dropout regulators. These regulators cover a wide range of load currents and offer outstanding transient response and low noise, making them a popular choice for applications with loads less than 3A.

In these regulators, the ADJ pin draws excess current when the OUT

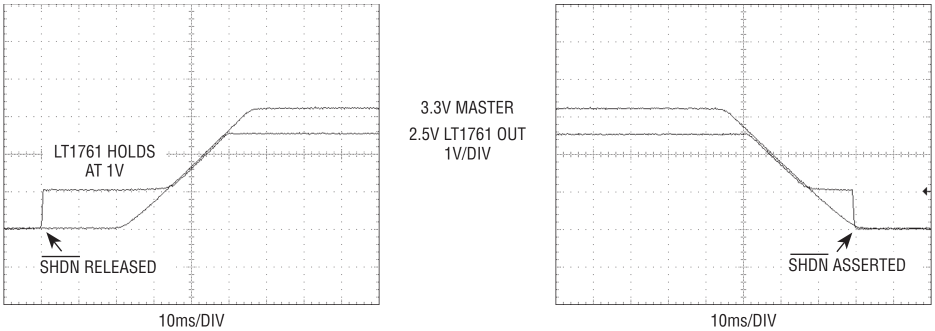

Figure 3. LT1761/LT1962/LT1762/LT1763/LT1963A/LT1764A with adjustable outputs only track above 1V unless modified as discussed in this article. The $\overline{SHDN}$ pin of the LDO is active before the ramp-up and after ramp-down.

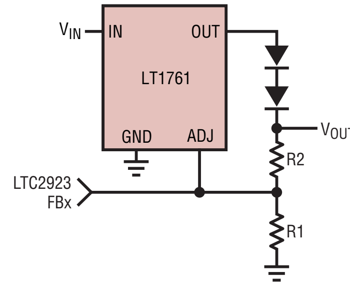

Figure 4. Diodes placed in series with the OUT pin allow the LT1761 to track down to 0V.

pin drops below about 1V, a region of operation that LDOs do not normally experience. Nevertheless, an LDO which tracks another supply, enters this region when the output tracks below 1V (Figure 3). If this excess current is not accounted for, the output of the LDO will be slightly higher than ideal when it tracks below 1V. Three techniques have been used to successfully track outputs of this LDO family below 1V.

If low dropout voltages are not necessary, simply connect two diodes in series with the OUT pin (Figure 4). In this configuration, the OUT pin remains two diode drops above the circuit's output. As a result, the LDO remains in its normal region of operation even when the output is driven near ground. Since the feedback resistors are connected to the output, the LDO regulates the voltage at the circuit output instead of the LDO's OUT pin. Diode voltage varies with both load current and temperature, so verify that the output is low enough at the minimum diode voltage. Likewise, the input voltage must be high enough to regulate the output when the diode drops are at their maximum. This solution effectively increases the dropout voltage of the linear regulator by two diode drops. Therefore, applications that require a low dropout voltage are better served by the solutions that follow.

Consider using the LTC1761, LT1962, LT1762, or LT1763 voltage regulators when the load is less than 500mA and a low dropout voltage is necessary. A fixed output part, (such as the LTC1763A-1.5) can be used as an adjustable LDO if the SENSE pin is treated like an ADJ pin with a feedback voltage of 1.5V (Figure 5). The SENSE pin on the fixed output parts draws about 10µA regardless of the OUT pin's voltage, unlike the ADJ pin on the adjustable parts. When choosing feedback resistors, minimize the output error by compensating for the extra 10µA of current that appears across the upper resistor. Also, use small valued resistors to minimize the error due to the 0µA to 20µA data sheet limits while avoiding values that are so small that the LTC2923's 1mA I_{FB} will be unable to drive the output to ground. To satisfy these constraints, ensure that the parallel combination of the two feedback resistors is slightly greater than 1.5kΩ. For most output voltages, this reduces the output error due to the SENSE pin current to about 1%.

For applications that require higher load currents and a low dropout voltage, the LT1963A and LT1764A may be appropriate. These parts are specified for 1.5A and 3A load currents respectively. Unfortunately, the SENSE pins on these fixed output parts draw about 600µA.

To use these parts, configure an operational amplifier to buffer the voltage from the feedback resistors to the SENSE pin of the 1.5V fixed output versions (Figure 6). If the op amp is configured with a voltage gain of 2, the 1.5V regulator in combination with the op amp behaves as an adjustable output regulator with a 0.75V reference voltage. The input to the op amp now serves as the ADJ input of the new regulator. This technique allows the use of the high current LT1963A/LT1764A where the voltage loss of series diodes would be unacceptable. It also works for the LT1761, LT1962, LT1762, and LT1763 in cases where the 10µA ADJ pin cur-

continued on page 35

Table 2. LT1761 family of low-dropout linear regulators

Regulator	$I_{OUT(MAX)}$ (V)	$V_{IN(MIN)}$ (V)	$V_{IN(MAX)}$ (V)	$V_{DROPOUT}$ (V)
LT1761	100mA	1.8	20	0.30
LT1762	150mA	1.8	20	0.30
LT1962	300mA	1.8	20	0.27
LT1763	500mA	1.8	20	0.30
LT1963A	1.5A	2.1	20	0.34
LT1764A	3A	2.7	20	0.34

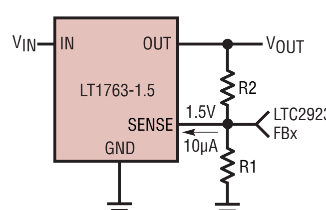

Figure 5. The fixed-output LT1763-1.5 can track down to 0V, has low dropout, and a resistive divider can be used for outputs greater than 1.5V.

Optimizing for Efficiency

While the LT3461A (boost) and LT3462A (inverting) are optimized for small size, the LT3461 (boost) and LT3462 (inverting) are intended for applications requiring higher efficiencies or high conversion ratios. The lower switching frequencies translate to higher efficiencies because of a reduction in switching losses.

The LT3461 (boost) is guaranteed to a maximum switch duty cycle of 92% in continuous conduction mode, and the LT3462 (inverting) is guaranteed to a maximum switch duty cycle of 90%, which enables high conversion ratios at relatively high output currents.

Although high conversion ratios can also be obtained using discontinuous conduction mode (DCM)—where current in the inductor is allowed to go to zero each cycle—the DCM technique requires higher switch currents and larger inductors/rectifiers than a system operating in continuous conduction mode at the same load current. Because the LT3461 can switch at 1.3MHz in continuous conduction mode with up to 92% switch duty cycle, and the LT3462 at 1.2Mhz, 90% duty, they are the most compact solutions available for outputs 5 to 10 times the supply voltage. For example, the LCD bias circuit of Figure 7 provides 18mA at 25V from a 3.3V supply and occupies as little as 50mm^2 of board space. Figure 8 shows that the efficiency of the 25V converter is quite good, peaking at 79% for a 4.2V supply. Figure 9 shows a 3.3V to –25V, 14mA inverter with efficiency above 70% (Figure 10).

Conclusion

The LT3461, LT3461A, LT3462 and LT3462A provide very compact boost and inverter solutions for a wide input voltage range of 2.5V to 16V, and outputs to ±38V, making these devices a good fit in a variety of applications.

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rent produces an unacceptable output voltage error.

Drivers for External, High Current Pass Devices

Table 3 summarizes the characteristics of the LT1575 and LT3150 low dropout regulators. These devices drive external N-channel MOSFET pass devices for high current/high power applications. The LTC3150 additionally includes a boost regulator that generates gate drive for the external FET.

The LTC2923 tracks the outputs of the LT1575 and LT3150 without any special modifications. Because these linear regulators only pull the FET's gate down to about 2.6V, low-threshold FETs may not allow the output to fall below a few hundred millivolts. This is acceptable for most applications.

Table 3. Drivers for external, high current pass devices

Regulator	$I_{OUT(MAX)}$ (V)	$V_{IN(MIN)}$ (V)	$V_{IN(MAX)}$ (V)	$V_{DROPOUT}$ (V)
LT3150	10A*	1.4	10	0.13
LT1575	*	N/A	22	*

*Depends on selection of external MOSFET

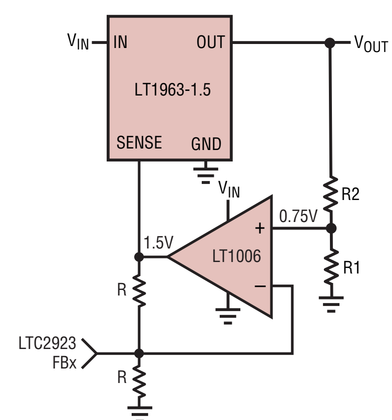

Figure 6. Using an op amp with the LT1963-1.5 allows lower output voltages and removes error due to the SENSE pin current.

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LT1990/91/95, continued from page 4

operating-point—and resistors to set gain. High quality resistors consume precious printed circuit board real estate, and test time. In contrast, the LT1995 provides on-chip resistors for voltage division and gain setting in a highly integrated video-speed op amp.

Figure 5 shows a simple way to drive AC-coupled composite video signals over 75Ω coaxial cable using minimum component count. In this circuit, the input resistors form a supply splitter for biasing and a net attenuation of 0.75. The feedback configuration provides an AC-coupled gain of 2.66, so that the overall gain of the stage is 2.0. The output is AC-coupled and series back-terminated with 75Ω to provide a match into terminated video cable and an overall unity gain from signal input to the destination load. An output shunt resistor (10kΩ in this example) is always good practice in AC-coupled circuits to assure nominal biasing of the output coupling capacitor.

Full Bridge Load Current Monitor

Many new motor-drive circuits employ an H-bridge transistor configuration to provide bidirectional control from a single-voltage supply. The difficulty with this topology is that both motor leads "fly," so current sensing becomes problematic. The LT1990 offers a simple solution to the problem by providing an integrated difference amp structure with an unusually high common-mode voltage rating, up to ±250VDC.