100mA, Low Noise, Low Dropout Micropower Regulator

March 1999

FEATURES

- **Quiescent Current: 20μA (Typ)**
- **Dropout Voltage: 300mV (Typ)**
- **Output Current: 100mA**
- **Low Noise: 20μV$_{RMS}$ (10Hz to 100kHz) (Typ)**
- No Protection Diodes Needed
- Adjustable Output from 1.22V to 20V
- Stable with 1μF Output Capacitor
- Stable with Aluminum, Tantalum or Ceramic Capacitors
- Reverse Battery Protection
- No Reverse Current
- Thermal Limiting

APPLICATIONS

- Low Current Regulator
- Regulator for Battery-Powered Systems
- Low Noise Regulator

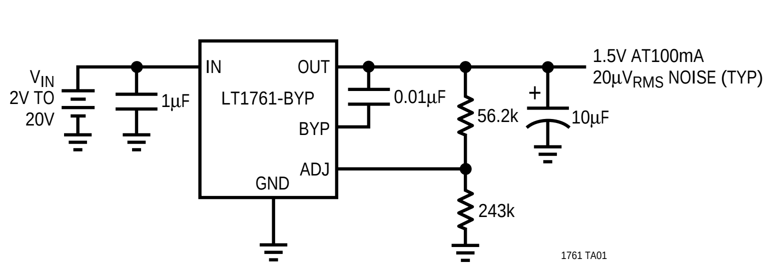
DESCRIPTION

The LT®1761 is a micropower, low noise, low dropout regulator. The device is capable of supplying 100mA of output current with a dropout voltage of 300mV. Designed for use in battery-powered systems, the low 20μA operating quiescent current makes it an ideal choice. Quiescent current is well controlled; it does not rise in dropout as it does with many other regulators.

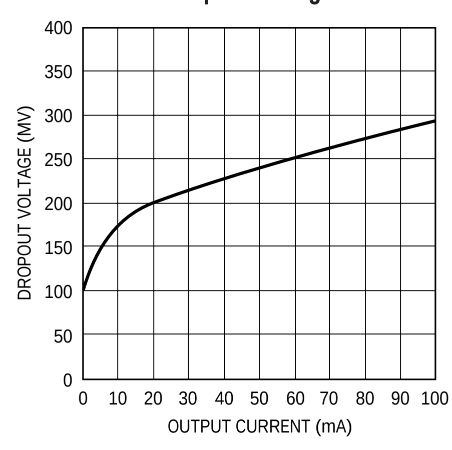
Other features of the LT1761 include low output noise. With the addition of an external 0.01μF bypass capacitor, output noise is dropped to 20μV$_{RMS}$ over a 10Hz to 100kHz bandwidth. The LT1761 regulator is capable of operating with small capacitors and is stable with output capacitors as low as 1μF. Small ceramic capacitors can be used without the necessary addition of ESR as is common with other regulators. Internal protection circuitry includes reverse battery protection, current limiting, thermal limiting and reverse current protection. The device is available as an adjustable device with a 1.22V reference voltage. The LT1761 regulator is available in the 5-lead SOT-23 package.

TYPICAL APPLICATION

1.5V Low Noise Supply



Dropout Voltage

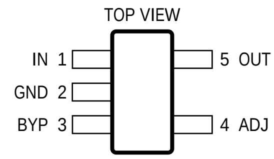


ABSOLUTE MAXIMUM RATINGS

(Note 1)

IN Pin Voltage .... ±20V
OUT Pin Voltage .... ±20V
OUT Pin Reverse Current 5mA
Input to Output Differential Voltage .... ±20V
ADJ Pin Voltage .... ±7V
ADJ Pin Current 5mA
BYP Pin Voltage .... ±0.6V
BYP Pin Current 5mA
Output Short-Circut Duration .... Indefinite
Operating Junction Temperature Range .... 0°C to 125°C
Storage Temperature Range .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER
 S5 PACKAGE 5-LEAD PLASTIC SOT-23 T_{JMAX} = 125°C, θ_{JA} = 250°C/ W SEE THE APPLICATIONS INFORMATION SECTION.	LT1761S5-BYP

Consult factory for Industrial and Military grade parts.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are T_A = 25°C. (Note 2)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
ADJ Pin Voltage (Note 3, 4)	LT1761 V_{IN} = 2V, I_{LOAD} = 1mA, T_J = 25°C		1.205	1.220	1.235	V
	2V < V_{IN} < 20V, 1mA < I_{LOAD} < 50mA	●	1.190	1.220	1.250	V
	2V < V_{IN} < 20V, 1mA < I_{LOAD} < 100mA	●	1.170	1.220	1.260	V
Line Regulation	LT1761(Note 3) ΔV_{IN} = 2V to 20V, I_{LOAD} = 1mA	●		1	10	mV
Load Regulation	LT1761(Note 3) V_{IN} = 2V, ΔI_{LOAD} = 1mA to 50mA, T_J = 25°C			1	6	mV
	V_{IN} = 2V, ΔI_{LOAD} = 1mA to 50mA	●			12	mV
	V_{IN} = 2V, ΔI_{LOAD} = 1mA to 100mA, T_J = 25°C			1	12	mV
	V_{IN} = 2V, ΔI_{LOAD} = 1mA to 100mA	●			50	mV
Dropout Voltage $V_{IN} = V_{OUT(NOMINAL)}$ (Notes 5, 6)	I_{LOAD} = 1mA, T_J = 25°C			0.10	0.15	V
	I_{LOAD} = 1mA	●			0.19	V
	I_{LOAD} = 10mA, T_J = 25°C			0.17	0.22	V
	I_{LOAD} = 10mA	●			0.29	V
	I_{LOAD} = 50mA, T_J = 25°C			0.24	0.31	V
	I_{LOAD} = 50mA	●			0.40	V
	I_{LOAD} = 100mA, T_J = 25°C			0.30	0.35	V
	I_{LOAD} = 100mA	●			0.45	V
GND Pin Current $V_{IN} = V_{OUT(NOMINAL)}$ (Notes 5, 7)	I_{LOAD} = 0mA	●		20	45	µA
	I_{LOAD} = 1mA	●		55	90	µA
	I_{LOAD} = 10mA	●		230	400	µA
	I_{LOAD} = 50mA	●		1	2	mA
	I_{LOAD} = 100mA	●		2.2	4	mA
Output Voltage Noise	C_{OUT} = 10µF, C_{BYP} = 0.01µF, I_{LOAD} = 100mA, BW = 10Hz to 100kHz			20		μV_{RMS}
ADJ Pin Bias Current	T_J = 25°C (Notes 3, 8)			30	100	nA
Minimum Input Voltage	LT1761 I_{LOAD} = 100mA	●		1.8	2.3	V
Ripple Rejection	$V_{IN} - V_{OUT}$ = 1V (Avg), V_{RIPPLE} = 0.5V_{P-P}, f_{RIPPLE} = 120Hz, I_{LOAD} = 50mA		55	65		dB

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are T_A = 25°C. (Note 2)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Current Limit	V_{IN} = 7V, V_{OUT} = 0V, T_J = 25°C, $V_{IN} = V_{OUT(NOMINAL)}$ + 1V, ΔV_{OUT} = –0.1V	 ●	 110	200		mA mA
Input Reverse Leakage Current	V_{IN} = –20V, V_{OUT} = 0V	●			1.0	mA
Reverse Output Current (Note 9)	LT1761 (Note 2) V_{OUT} = 1.22V, V_{IN} < 1.22V			5	10	µA

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: The LT1761 is tested and specified under pulse load conditions such that $T_J \approx T_A$.

Note 3: The LT1761 (adjustable version) is tested and specified for these conditions with the ADJ pin connected to the OUT pin.

Note 4: 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 5: To satisfy requirements for minimum input voltage, the LT1761 (adjustable version) is tested and specified for these conditions with an external resistor divider (two 250k resistors) for an output voltage of 2.44V. The external resistor divider will add a 5µA DC load on the otuput.

Note 6: Dropout voltage is the 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: GND pin current is tested with $V_{IN} = V_{OUT(NOMINAL)}$ and a current source load. This means the device is tested while operating in its dropout region. This is the worst-case GND pin current. The GND pin current will decrease slightly at higher input voltages.

Note 8: ADJ pin bias current flows into the ADJ pin.

Note 9: Reverse output current is tested with the IN pin grounded and the OUT pin forced to the rated output voltage. This current flows into the OUT pin and out the GND pin.

PIN FUNCTIONS

IN (Pin 1): Input. Power is supplied to the device through the IN pin. A bypass capacitor is required on this pin if the device is more than six inches away from the main input filter capacitor. In general, the output impedance of a battery rises with frequency, so it is advisable to include a bypass capacitor in battery-powered circuits. A bypass capacitor in the range of 1µF to 10µF is sufficient. The LT1761 is designed to withstand reverse voltages on the IN pin with respect to ground and the OUT pin. In the case of a reverse input, which can happen if a battery is plugged in backwards, the LT1761 will act as if there is a diode in series with its input. There will be no reverse current flow into the LT1761 and no reverse voltage will appear at the load. The device will protect both itself and the load.

GND (Pin 2): Ground.

BYP (Pin 3): Bypass. The BYP pin is used to bypass the reference of the LT1761 to achieve low noise performance from the regulator. The BYP pin is clamped internally to ±0.6V (one V_{BE}) from ground. A small capacitor from the output to this pin will bypass the reference to lower the output voltage noise. A maximum value of 0.01µF can be used for reducing output voltage noise to a typical 20µV_{RMS} over a 10Hz to 100kHz bandwidth. If not used, this pin must be left unconnected.

ADJ (Pin 4): Adjust Pin. This is the input to the error amplifier. This pin is internally clamped to ±7V. It has a bias current of 30nA which flows into the pin. The ADJ pin voltage is 1.22V referenced to ground and the output voltage range is 1.22V to 20V.

OUT (Pin 5): Output. The output supplies power to the load. A minimum output capacitor of 1µF is required to prevent oscillations. Larger output capacitors will be required for applications with large transient loads to limit peak voltage transients. See the Applications Information section for more information on output capacitance and reverse output characteristics.

APPLICATIONS INFORMATION

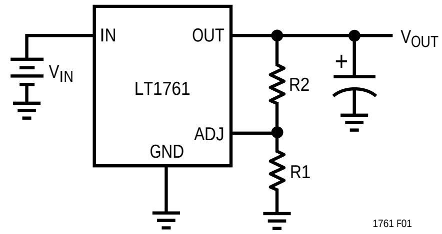
The LT1761 is a 100mA low dropout regulator with micropower quiescent current and shutdown. The device is capable of supplying 100mA at a dropout voltage of 300mV. Output voltage noise can be lowered to $20\mu V_{RMS}$ over a 10Hz to 100kHz bandwidth with the addition of a 0.01µF reference bypass capacitor. Additionally, the reference bypass capacitor will improve transient response of the regulator, lowering the settling time for transient load conditions. Quiescent operating current is a low 20µA. In addition to the low quiescent current, the LT1761 incorporates several protection features which make it ideal for use in battery-powered systems. The device is protected against both reverse input and reverse output voltages. In battery backup applications where the output can be held up by a backup battery when the input is pulled to ground, the LT1761 acts like it has a diode in series with its output and prevents reverse current flow. Additionally, in dual supply applications where the regulator load is returned to a negative supply, the output can be pulled below ground by as much as 20V and still allow the device to start and operate.

Adjustable Operation

The adjustable version of the LT1761 has an output voltage range of 1.22V to 20V. The output voltage is set by the ratio of two external resistors as shown in Figure 1. The device servos the output to maintain the voltage at the ADJ pin at 1.22V referenced to ground. The current in R1 is then equal to 1.22V/R1 and the current in R2 is the current in R1 plus the ADJ pin bias current. The ADJ pin bias current, 30nA at 25°C, flows through R2 into the ADJ pin. The output voltage can be calculated using the formula in Figure 1. The value of R1 should be less than 250k to minimize errors in the output voltage caused by the ADJ pin bias current.

The adjustable device is tested and specified with the ADJ pin tied to the OUT pin for an output voltage of 1.22V. Specifications for output voltages greater than 1.22V will be proportional to the ratio of the desired output voltage to 1.22V: V_{OUT}/1.22V. For example, load regulation for an output current change of 1mA to 100mA is –1mV typical at V_{OUT} = 1.22V. At V_{OUT} = 12V, load regulation is:

(12V/1.22V)(–1mV) = –9.8mV



$$V_{OUT} = 1.22V\left(1 + \frac{R2}{R1}\right) + \left(I_{ADJ}\right)\left(R2\right)$$

$$V_{ADJ} = 1.22V$$

$$I_{ADJ} = 30nA\ AT\ 25°C$$

OUTPUT RANGE = 1.22V TO 20V

Figure 1. Adjustable Operation

Bypass Capacitance and Low Noise Performance

The LT1761 may be used with the addition of a bypass capacitor from V_{OUT} to the BYP pin to lower output voltage noise. A good quality low leakage capacitor is recommended. This capacitor will bypass the reference of the LT1761, providing a low frequency noise pole. The noise pole provided by this bypass capacitor will lower the output voltage noise to as low as $20\mu V_{RMS}$ with the addition of a 0.01µF bypass capacitor. Using a bypass capacitor has the added benefit of improving transient response. With no bypass capacitor and a 3.3µF output capacitor, a 1mA to 50mA load step will settle to within 5% of its final value in less than 50µs. With the addition of a 0.01µF bypass capacitor, settling time is reduced to less than 5µs. However, regulator start-up time is inversely proportional to the size of the bypass capacitor, slowing to 15ms with a 0.01µF bypass capacitor and 10µF output capacitor.

Output Capacitance and Transient Response

The LT1761 is designed to be stable with a wide range of 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 3Ω or less is recommended to prevent oscillations. The LT1761 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

APPLICATIONS INFORMATION

improved transient response for larger load current changes. Bypass capacitors, used to decouple individual components powered by the LT1761, will increase the effective output capacitor value. With larger capacitors used to bypass the reference (for low noise operation), larger values of output capacitors are needed. For 100pF of bypass capacitance, 2.2µF of output capacitor is recommended. With a 330pF bypass capacitor or larger, a 3.3µF output capacitor is recommended.

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 made up of two components:

1. Output current multiplied by the input/output voltage differential: $(I_{OUT})(V_{IN} – V_{OUT})$, and
2. GND pin current multiplied by the input voltage: $(I_{GND})(V_{IN})$.

The GND pin current can be estimated using the GND Pin Current specification in the Electrical Characteristics table. Power dissipation will be equal to the sum of the two components listed above.

The LT1761 series regulators have internal thermal limiting designed to protect the device during 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 following table lists thermal resistance for several different board sizes and copper areas. All measurements were taken in still air on 3/32" FR-4 board with one ounce copper.

Table 1. Measured Thermal Resistance

COPPER AREA			THERMAL RESISTANCE
TOPSIDE*	BACKSIDE	BOARD AREA	(JUNCTION-TO-AMBIENT)
$2500mm^2$	$2500mm^2$	$2500mm^2$	125°C/W
$1000mm^2$	$2500mm^2$	$2500mm^2$	125°C/W
$225mm^2$	$2500mm^2$	$2500mm^2$	130°C/W
$100mm^2$	$2500mm^2$	$2500mm^2$	135°C/W
$50mm^2$	$2500mm^2$	$2500mm^2$	150°C/W

*Device is mounted on topside.

Calculating Junction Temperature

Example: Given an output voltage of 3.3V, an input voltage range of 4V to 6V, an output current range of 0mA to 50mA 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:

$$I_{OUT(MAX)}(V_{IN(MAX)} – V_{OUT}) + I_{GND}(V_{IN(MAX)})$$

where,

$I_{OUT(MAX)} = 50mA$
$V_{IN(MAX)} = 6V$
I_{GND} at $(I_{OUT} = 50mA, V_{IN} = 6V) = 1mA$

so,

$$P = 50mA(6V – 3.3V) + 1mA(6V) = 0.14W$$

The thermal resistance will be in the range of 125°C/W to 150°C/W depending on the copper area. So the junction temperature rise above ambient will be approximately equal to:

$$0.14W(150°C/W) = 21.2°C$$

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

$$T_{JMAX} = 50°C + 21.2°C = 71.2°C$$

APPLICATIONS INFORMATION

Protection Features

The LT1761 incorporates several protection features which make it ideal for use in battery-powered circuits. In addition to the normal protection features associated with monolithic regulators, such as current limiting and thermal limiting, the device is protected against reverse input voltages, reverse output voltages and reverse voltages from output to input.

Current limit protection and thermal overload protection are intended to protect the device against current overload conditions at the output of the device. For normal operation, the junction temperature should not exceed 125°C.

The input of the device will withstand reverse voltages of 20V. Current flow into the device will be limited to less than 1mA (typically less than 100μA) and no negative voltage will appear at the output. The device will protect both itself and the load. This provides protection against batteries which can be plugged in backward.

The output of the LT1761 can be pulled below ground without damaging the device. If the input is left open circuit or grounded, the output can be pulled below ground by 20V. For adjustable versions, the output will act like an open circuit; no current will flow out of the pin. If the input is powered by a voltage source, the output will source the short-circuit current of the device and will protect itself by thermal limiting.

The ADJ pin of the adjustable device can be pulled above or below ground by as much as 7V without damaging the device. If the input is left open circuit or grounded, the ADJ pin will act like an open circuit when pulled below ground and like a large resistor (typically 100k) in series with a diode when pulled above ground.

In situations where the ADJ pin is connected to a resistor divider that would pull the ADJ pin above its 7V clamp voltage if the output is pulled high, the ADJ pin input current must be limited to less than 5mA. For example, a resistor divider is used to provide a regulated 1.5V output from the 1.22V reference when the output is forced to 20V. The top resistor of the resistor divider must be chosen to limit the current into the ADJ pin to less than 5mA when the ADJ pin is at 7V. The 13V difference between output and ADJ pin divided by the 5mA maximum current into the ADJ pin yields a minimum top resistor value of 2.6k.

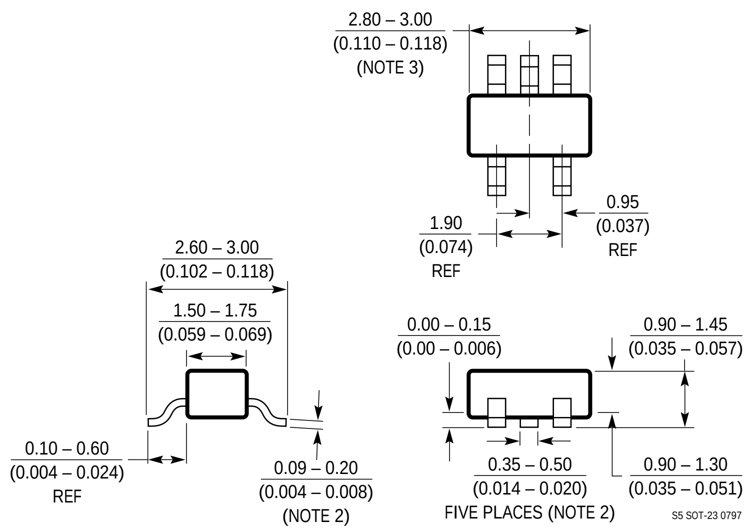
In circuits where a backup battery is required, several different input/output conditions can occur. The output voltage may be held up while the input is either pulled to ground, pulled to some intermediate voltage or is left open circuit. Current flow back into the output will be less than 15μA.

When the IN pin of the LT1761 is forced below the OUT pin or the OUT pin is pulled above the IN pin, input current will typically drop to less than 2μA. This can happen if the input of the LT1761 is connected to a discharged (low voltage) battery and the output is held up by either a backup battery or a second regulator circuit.

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

S5 Package
5-Lead Plastic SOT-23
(LTC DWG # 05-08-1633)



NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DIMENSIONS ARE INCLUSIVE OF PLATING
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
4. MOLD FLASH SHALL NOT EXCEED 0.254mm
5. PACKAGE EIAJ REFERENCE IS SC-74A (EIAJ)

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1120	125mA Low Dropout Regulator with 20µA I_Q	Includes 2.5V Reference and Comparator
LT1121	150mA Micropower Low Dropout Regulator	30µA I_Q, SOT-223 Package
LT1129	700mA Micropower Low Dropout Regulator	50µA Quiescent Current
LT1521	300mA Low Dropout Micropower Regulator with Shutdown	15µA I_Q, Reverse Battery Protection
LT1529	3A Low Dropout Regulator with 50µA I_Q	500mV Dropout Voltage
LT1611	Inverting 1.4MHz Switching Regulator	5V to –5V at 150mA, Low Output Noise, SOT-23 Package
LT1613	1.4MHz Single-Cell Micropower DC/DC Converter	SOT-23 Package, Internally Compensated
LTC1627	High Efficiency Synchronous Step-Down Switching Regulator	Burst Mode™ Operation, Monolithic, 100% Duty Cycle

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