3A Step-Down Voltage Regulator LM2575

DESCRIPITION

The LM2575 is amonolithic integrated circuit that provides all the active functions for a step-down(buck) switching regulator, capable of driving 3A load with excellent line and load regulation. The LM2575 available in fixed output voltages of 3.3V, 5V, and an adjustable output version.

Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation and a fixed-frequency oscillator.

The LM2575 offers a high-efficiencyreplacement for popular three-terminal linear regulators. It substantially reduces the size of the heat sink, and in some cases no heat sink is required.

A standard of inductors optimized for use with the 2575 are available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies.

Other features include a guaranteed ±4% tolerance on output voltage within specified input voltages and output load conditions, and ±10% on the oscillator frequency. External shutdown is included, featuring 50 µA (typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.

FEATURES

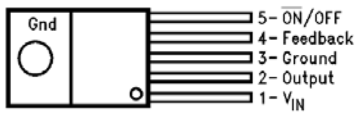
- 3.3V, 5V, and adjustable output versions
- Guaranteed 3A output current
- Requires only 4 external components
- 52 kHz fixed frequency internal oscillator
- TTL shutdown capability, low power standby mode
- High efficiency
- Uses readily available standard inductors
- Thermal shutdown and current limit protection
- P+ Product Enhancement tested

APPLICATIONS

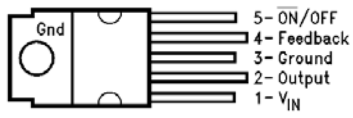
- Simple high-efficiency step-down (buck) regulator
- Efficient pre-regulator for linear regulators
- On-card switching regulators
- Positive to negative converter (Buck-Boost)

CONNECTION DIAGRAMS

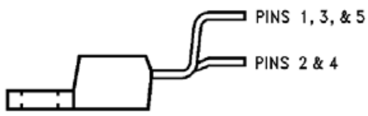
Straight Leads
5-Lead TO-220 (T)
Top View



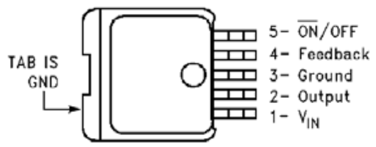
Bent, Staggered Leads
5-Lead TO-220 (B)
Top View



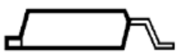
Side View



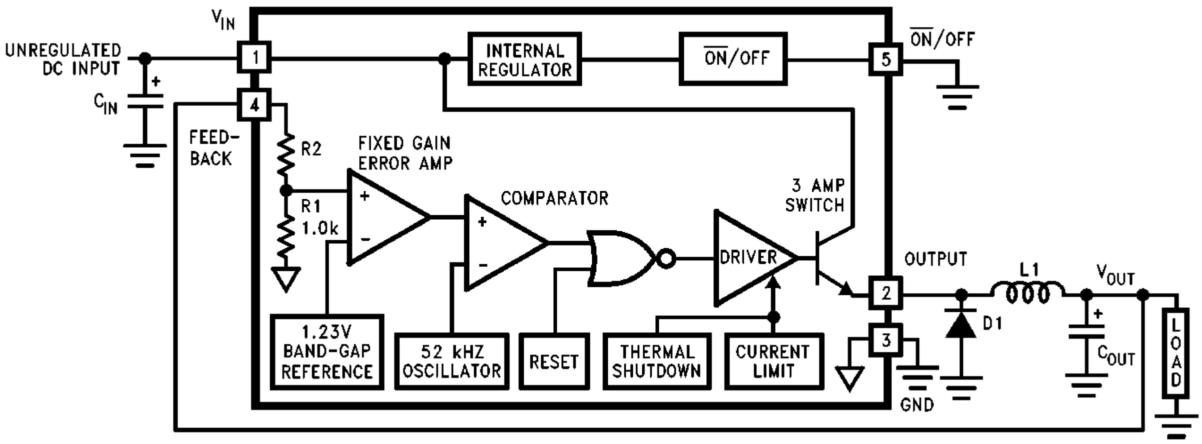
TO-263 (S)
5-Lead Surface-Mount Package
Top View



Side View



BLOCK DIAGRAM



R2=3.1K

ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

Characteristic	Value	Unit
Maximum supply voltage	45	V
$\overline{ON}$ /OFF pin inpur voltage	$-0.3V \le V \le +V_{IN}$	V
Output voltage to ground(steady state)	-1	V
Power dissipation	Internally limited	
Operating temperature range	-40~+125	°C
Storage temperature range	-65~+150	°C
Maximum junction temperature	150	°C
Minimum ESD Rating(C=100pF,R=1.5kΩ)	2	kV
Lead Temperature(soldering,10seconds)	260	°C

RECOMMENDED OPERATING CONDITIONS

Characteristic	Symbol	Value	Unit
Supply Voltage	V_{CC}	40	V

LM2575-3.3 ELECTRICAL CHARACTERISTICS

(Unless otherwise specified: T_J = 25°C, and those with boldface type apply over full Operating Temperature Range.)

Symbol	Parameter	Conditions	2576-3.3		Units (Limits)
			Typ	Limit	
SYSTEM PARAMETERS					
V_{OUT}	Output Voltage	V_{IN} = 12V, I_{LOAD} = 0.5A	3.3	 3.234 3.366	V V(Min) V(Max)
V_{OUT}	Output Voltage 257	6V ≤ V_{IN} ≤ 40V, 0.5A ≤ I_{LOAD} ≤ 3A	3.3	 3.168/**3.135** 3.432/**3.465**	V V(Min) V(Max)
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A	75		%

LM2575-5.0 ELECTRICAL CHARACTERISTICS

(Unless otherwise specified: T_J = 25°C, and those with boldface type apply over full Operating Temperature Range.)

Symbol	Parameter	Conditions	2576-5.0		Units (Limits)
			Typ	Limit	
SYSTEM PARAMETERS					
V_{OUT}	Output Voltage	V_{IN} = 12V, I_{LOAD} = 0.5A	5.0	 4.900 5.100	V V(Min) V(Max)
V_{OUT}	Output Voltage 2576	0.5A ≤ I_{LOAD} ≤ 3A, 8V ≤ V_{IN} ≤ 40V	5.0	 4.800/**4.750** 5.200/**5.250**	V V(Min) V(Max)
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A	77		%

LM2575-ADJ ELECTRICAL CHARACTERISTICS

Symbol	Parameter	Conditions	2576-ADJ		Units (Limits)
			Typ	Limit	
SYSTEM PARAMETERS					
V_{OUT}	Feedback Voltage	V_{IN} = 12V, I_{LOAD} = 0.5A V_{OUT} = 5V,	1.230	 1.217 1.243	V V(Min) V(Max)
V_{OUT}	Feedback Voltage 257	0.5A ≤ I_{LOAD} ≤ 3A, 8V ≤ V_{IN} ≤ 40V V_{OUT} = 5V	1.230	 1.193/**1.180** 1.267/**1.280**	V V(Min) V(Max)
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 3A, V_{OUT} = 5V	77		%

ELECTRICAL CHARACTERISTICS

(Unless otherwise specified: T_J = 25°C, and those with boldface type apply over full Operating Temperature Range. Unless otherwise specified, V_{IN} = 12V, I_{LOAD} = 500 mA.)

Symbol	Parameter	Conditions	257 XX		Units (Limits)
			Typ	Limit (Note 2)	
DEVICE PARAMETERS					
I_b	Feedback Bias Current	V_{OUT} = 5V (Adjustable Version Only)	50	100/**500**	nA
f_O	Oscillator Frequency	(Note 11)	52	 47/**42** 58/**63**	kHz kHz (Min) kHz (Max)
V_{SAT}	Saturation Voltage	I_{OUT} = 3A (Note 4)	1.4	 1.8/**2.0**	V V(Max)
DC	Max Duty Cycle (ON)	(Note 5)	98	 93	% %(Min)
I_{CL}	Current Limit	(Notes 4 and 11)	5.8	 4.2/**3.5** 6.9/**7.5**	A A(Min) A(Max)
I_L	Output Leakage Current	(Notes 6 and 7) Output = 0V Output = −1V Output = −1V	 7.5	2 30	mA(Max) mA mA(Max)
I_Q	Quiescent Current	(Note 6)	5	 10	mA mA(Max)
I_{STBY}	Standby Quiescent Current	$\overline{\text{ON}}$/OFF Pin = 5V (OFF)	50	 200	μA μA(Max)
θ_{JA} θ_{JA} θ_{JC} θ_{JA}	Thermal Resistance	T Package, Junction to Ambient (Note 8) T Package, Junction to Ambient (Note 9) T Package, Junction to Case S Package, Junction to Ambient (Note 10)	65 45 2 50		°C/W
$\overline{\text{ON}}$/OFF CONTROL					
V_{IH}	$\overline{\text{ON}}$/OFF Pin Logic Input Level	V_{OUT} = 0V	1.4	2.2/**2.4**	V(Min)
V_{IL}		V_{OUT} = Nominal Output Voltage	1.2	1.0/**0.8**	V(Max)
I_{IH}	$\overline{\text{ON}}$/OFF Pin Input Current	$\overline{\text{ON}}$/OFF Pin = 5V (OFF)	12	 30	μA μA(Max)
I_{IL}		$\overline{\text{ON}}$/OFF Pin = 0V (ON)	0	 10	μA μA(Max)

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.

Note 2: All limits guaranteed at room temperature (standard type face) and at **temperature extremes (bold type face)**. All room temperature limits are 100% production tested. All limits at **temperature extremes** are guaranteed via correlation using standard Statistical Quality Control (SQC) methods.

Note 3: External components such as the catch diode, inductor, input and output capacitors can affect switching regulator system performance. When the D2576 is used as shown in the test circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

Note 4: Output pin sourcing current. No diode, inductor or capacitor connected to output.

Note 5: Feedback pin removed from output and connected to 0V.

Note 6: Feedback pin removed from output and connected to +12V for the Adjustable, 3.3V, and 5V versions, to force the output transistor OFF.

Note 7: V_{IN} = 40V (60V for high voltage version).

Note 8: Junction to ambient thermal resistance (no external heat sink) for the 5 lead TO-220 package mounted vertically, with ½ inch leads in a socket, or on a PC board with minimum copper area.

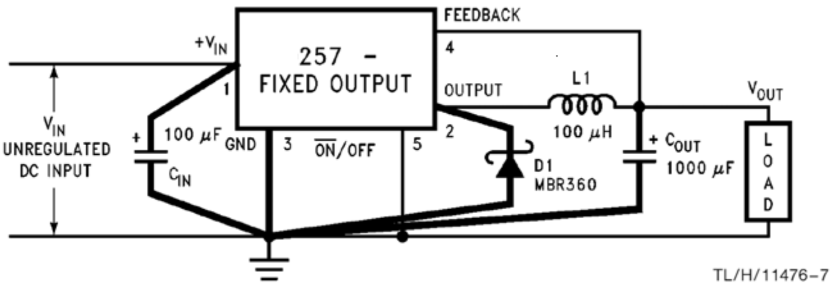
Note 9: Junction to ambient thermal resistance (no external heat sink) for the 5 lead TO-220 package mounted vertically, with ¼ inch leads soldered to a PC board containing approximately 4 square inches of copper area surrounding the leads.

Note 10: If the TO-263 package is used, the thermal resistance can be reduced by increasing the PC board copper area thermally connected to the package. Using 0.5 square inches of copper area, θ_{JA} is 50°C/W, with 1 square inch of copper area, θ_{JA} is 37°C/W, and with 1.6 or more square inches of copper area, θ_{JA} is 32°C/W.

Note 11: The oscillator frequency reduces to approximately 11 kHz in the event of an output short or an overload which causes the regulated output voltage to drop approximately 40% from the nominal output voltage. This self protection feature lowers the average power dissipation of the IC by lowering the minimum duty cycle from 5% down to approximately 2%.

TEST CIRCUIT

Fixed Output Voltage Versions



C_{IN} — 100 µF, 75V, Aluminum Electrolytic

C_{OUT} — 1000 µF, 25V, Aluminum Electrolytic

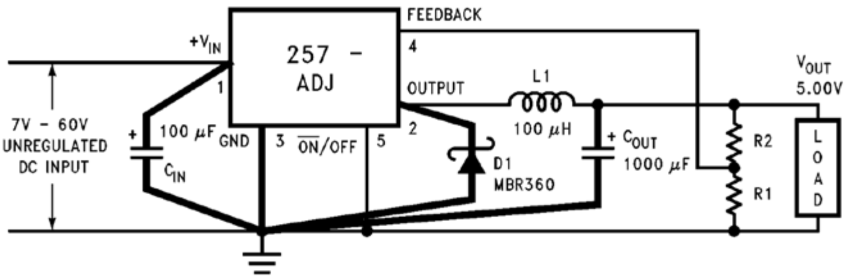
D_1 — Schottky, MBR360

L_1 — 100 µH, Pulse Eng. PE-92108

R_1 — 2k, 0.1%

R_2 — 6.12k, 0.1%

Adjustable Output Voltage Version



$$V_{OUT} = V_{REF}\left(1 + \frac{R_2}{R_1}\right)$$

$$R_2 = R_1\left(\frac{V_{OUT}}{V_{REF}} - 1\right)$$

where V_{REF} = 1.23V, R1 between 1k and 5k.

APPLICATION CIRCUIT

APPLICATION INFORMATION

INPUT CAPACITOR (C_{IN})

To maintain stability, the regulator input pin must be bypassed with at least a 100 µF electrolytic capacitor. The capacitor's leads must be kept short, and located near the regulator.

If the operating temperature range includes temperatures below -25°C, the input capacitor value may need to be larger. With most electrolytic capacitors, the capacitance value decreases and the ESR increases with lower temperatures and age. Paralleling a ceramic or solid tantalum capacitor will increase the regulator stability at cold temperatures.

INDUCTOR SELECTION

All switching regulators have two basic modes of operation: continuous and discontinuous. The difference between the two types relates to the inductor current, whether it is flowing continuously, or if it drops to zero for a period of time in the normal switching cycle. Each mode has distinctively different operating characteristics, which can affect the regulator performance and requirements.

The 2576 (or any of the SIMPLE SWITCHER family) can be used for both continuous and discontinuous modes of operation.

When using inductor values shown in the inductor selection guide, the peak-to-peak inductor ripple current will be approximately 20% to 30% of the maximum DC current. With relatively heavy load currents, the circuit operates in the continuous mode (inductor current always flowing), but under light load conditions, the circuit will be forced to the discontinuous mode (inductor current falls to zero for a period of time). This discontinuous mode of operation is perfectly acceptable. For light loads(less than approximately 300 mA) it may be desirable to operate the regulator in the discontinuous mode, primarily because of the lower inductor values required for the discontinuous mode.

The selection guide chooses inductor values suitable for continuous mode operation, but if the inductor value chosen is prohibitively high, the designer should investigate the possibility of discontinuous operation. The computer design software Switchers Made Simple will provide all component values for discontinuous (as well as continuous) mode of operation.

Inductors are available in different styles such as pot core, toriod, E-frame, bobbin core, etc., as well as different core materials, such as ferrites and powdered iron. The least expensive, the bobbin core type, consists of wire wrapped on a ferrite rod core. This type of construction makes for an inexpensive inductor, but since the magnetic flux is not completely contained within the core, it generates more electromagnetic interference (EMI). This EMI can cause problems in sensitive circuits, or can give incorrect scope readings because of induced voltages in the scope probe.

The inductors listed in the selection chart include ferrite pot core construction for AIE, powdered iron toroid for Pulse Engineering, and ferrite bobbin core for Renco.
An inductor should not be operated beyond its maximum rated current because it may saturate. When an inductor begins to saturate, the inductance decreases rapidly and the inductor begins to look mainly resistive (the DC resistance of the winding). This will cause the switch current to rise very rapidly. Different inductor types have different saturation characteristics, and this should be kept in mind when selecting an inductor.

The inductor manufacturer’s data sheets include current and energy limits to avoid inductor saturation.

INDUCTOR RIPPLE CURRENT

When the switcher is operating in the continuous mode, the inductor current waveform ranges from a triangular to a sawtooth type of waveform (depending on the input voltage). For a given input voltage and output voltage, the peak-topeak amplitude of this inductor current waveform remains constant. As the load current rises or falls, the entire sawtooth current waveform also rises or falls. The average DC value of this waveform is equal to the DC load current (in the buck regulator configuration).

If the load current drops to a low enough level, the bottom of the sawtooth current waveform will reach zero, and the switcher will change to a discontinuous mode of operation. This is a perfectly acceptable mode of operation. Any buck switching regulator (no matter how large the inductor value is) will be forced to run discontinuous if the load current is light enough.

OUTPUT CAPACITOR

An output capacitor is required to filter the output voltage and is needed for loop stability. The capacitor should be located near the D2576 using short pc board traces. Standard aluminum electrolytics are usually adequate, but low ESR types are recommended for low output ripple voltage and good stability. The ESR of a capacitor depends on many factors, some which are: the value, the voltage rating, physical size and the type of construction. In general, low value or low voltage (less than 12V) electrolytic capacitors usually have higher ESR numbers.

The amount of output ripple voltage is primarily a function of the ESR (Equivalent Series Resistance) of the output capacitor and the amplitude of the inductor ripple current (ΔI_{IND}). See the section on inductor ripple current in Application Hints.

The lower capacitor values (220 μF–1000 μF) will allow typically 50 mV to 150 mV of output ripple voltage, while larger-value capacitors will reduce the ripple to approximately 20 mV to 50 mV.

Output Ripple Voltage = (ΔI_{IND}) (ESR of C_{OUT})

To further reduce the output ripple voltage, several standard electrolytic capacitors may be paralleled, or a higher-grade capacitor may be used. Such capacitors are often called "high-frequency," "low-inductance," or "low-ESR." These will reduce the output ripple to 10 mV or 20 mV. However, when operating in the continuous mode, reducing the ESR below 0.03Ω can cause instability in the regulator.

Tantalum capacitors can have a very low ESR, and should be carefully evaluated if it is the only output capacitor. Because of their good low temperature characteristics, a tantalum can be used in parallel with aluminum electrolytics, with the tantalum making up 10% or 20% of the total capacitance.

The capacitor's ripple current rating at 52 kHz should be at least 50% higher than the peak-to-peak inductor ripple current.

CATCH DIODE

Buck regulators require a diode to provide a return path for the inductor current when the switch is off. This diode should be located close to the D2576 using short leads and short printed circuit traces.

Because of their fast switching speed and low forward voltage drop, Schottky diodes provide the best efficiency, especially in low output voltage switching regulators (less than 5V). Fast-Recovery, High-Efficiency, or Ultra-Fast Recovery diodes are also suitable, but some types with an abrupt turn-off characteristic may cause instability and EMI problems. A fast-recovery diode with soft recovery characteristics is a better choice. Standard 60 Hz diodes (e.g., 1N4001 or1N5400, etc.) are also not suitable.

OUTPUT VOLTAGE RIPPLE AND TRANSIENTS

The output voltage of a switching power supply will contain a sawtooth ripple voltage at the switcher frequency, typically about 1% of the output voltage, and may also contain short voltage spikes at the peaks of the sawtooth waveform.

The output ripple voltage is due mainly to the inductor sawtooth ripple current multiplied by the ESR of the output capacitor. (See the inductor selection in the application hints.)

The voltage spikes are present because of the the fast switching action of the output switch, and the parasitic inductance of the output filter capacitor. To minimize these voltage spikes, special low inductance capacitors can be used, and their lead lengths must be kept short. Wiring inductance, stray capacitance, as well as the scope probe used to evaluate these transients, all contribute to the amplitude of these spikes.

An additional small LC filter (20 μH & 100 μF) can be added to the output to further reduce theamount of output ripple and transients. A 10 x reduction in output ripple voltage and transients is possible with this filter.

FEEDBACK CONNECTION

The 2575 (fixed voltage versions) feedback pin must be wired to the output voltage point of the switching power supply. When using the adjustable version, physically locate both output voltage programming resistors near the 2575 to avoid picking up unwanted noise. Avoid using resistors greater than 100 k. because of the increased chance of noise pickup.

$\overline{ON}$ /OFF INPUT

For normal operation, the $\overline{ON}$ /OFF pin should be grounded or driven with a low-level TTL voltage (typically below 1.6V). To put the regulator into standby mode, drive this pin with a high-level TTL or CMOS signal. The $\overline{ON}$ /OFF pin can be safely pulled up to $+V_{IN}$ without a resistor in series with it. The $\overline{ON}$ /OFF pin should not be left open.

GROUNDING

To maintain output voltage stability, the power ground connections must be low-impedance. For the5-lead TO-220 astyle package, both the tab and pin 3 are ground and either connection may be used, as they are both part of the same copper lead frame.

HEAT SINK/THERMAL CONSIDERATIONS

temperature within the allowed operating range. For each application, to determine whether or not a heat sink will be required, the following must be identified:

1. Maximum ambient temperature (in the application).
2. Maximum regulator power dissipation (in application).
3. Maximum allowed junction temperature (125°C for the 2575). For a safe, conservative design, a temperature approximately 15°C cooler than the maximum temperatures should be selected.
4. 2575 package thermal resistances θ_{JA} and θ_{JC}.

Total power dissipated by the 2575 can be estimated as follows:

$P_D = (V_{IN})(I_Q) + (V_O/V_{IN})(I_{LOAD})(V_{SAT})$

where I_Q (quiescent current) and VSAT can be found in the Characteristic Curves shown previously, V_{IN} is the applied minimum input voltage, V_O is the regulated output voltage,

and I_{LOAD} is the load current. The dynamic losses during turn-on and turn-off are negligible if a Schottky type catch diode is used.

When no heat sink is used, the junction temperature rise can be determined by the following: $\Delta T_J = (P_D)(\theta_{JA})$

To arrive at the actual operating junction temperature, add the junction temperature rise to the maximum ambient temperature. $T_J = \Delta T_J + T_A$

If the actual operating junction temperature is greater than the selected safe operating junction temperature determined in step 3, then a heat sink is required.

When using a heat sink, the junction temperature rise can be determined by the following: $\Delta T_J = (P_D)(\theta_{JC} + \theta\ \text{interface} + \theta\ \text{Heat sink})$

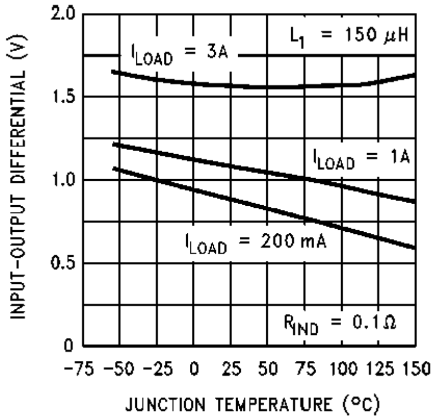
The operating junction temperature will be: $T_J = T_A + \Delta T_J$

As above, if the actual operating junction temperature is greater than the selected safe operating junction temperature, then a larger heat sink is required (one that has a lower thermal resistance).

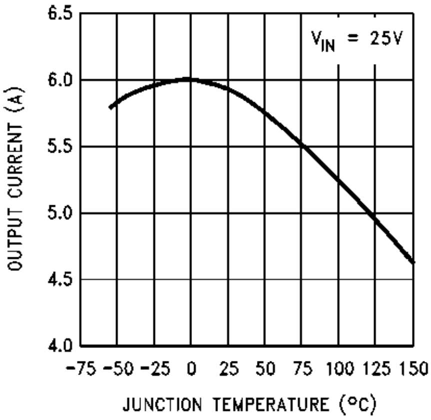
Included on the Switcher Made Simple design software is a more precise (non-linear) thermal model that can be used to determine junction temperature with different input-output parameters or different component values. It can also calculate the heat sink thermal resistance required to maintain the regulators junction temperature below the maximum operating temperature.

CHARACTERISTIC CURVES

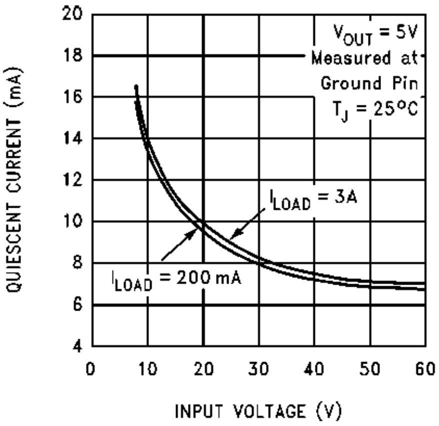
Dropout Voltage



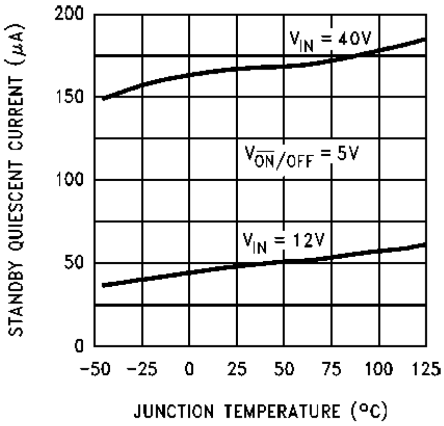
Current Limit



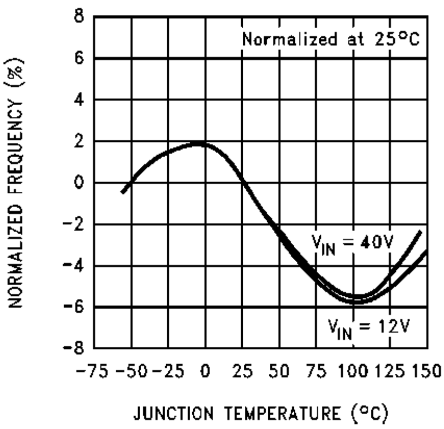
Quiescent Current



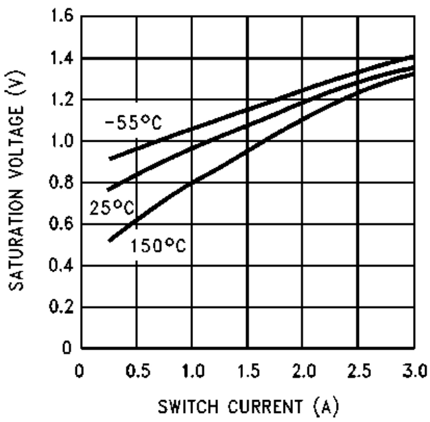
Standby Quiescent Current



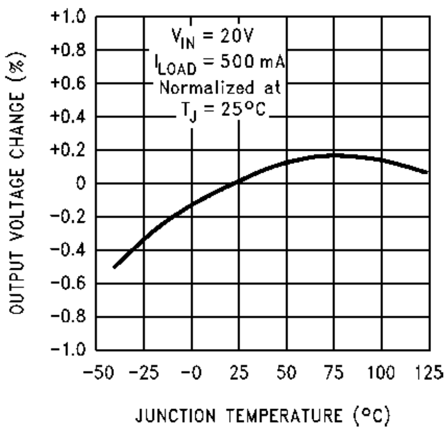
Oscillator Frequency



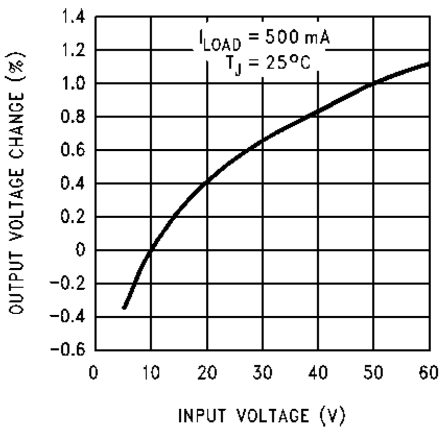
Switch Saturation Voltage



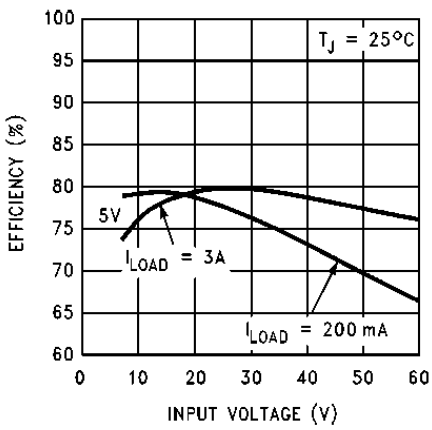
Normalized Output Voltage



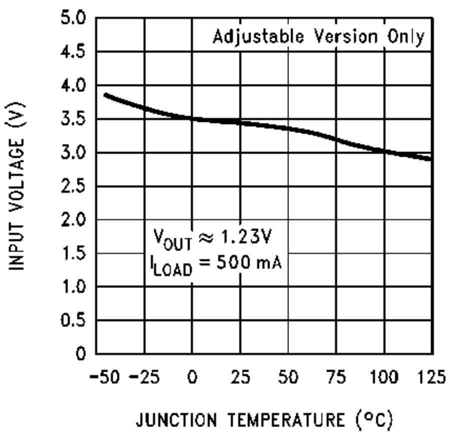
Line Regulation



Efficiency



Minimum Operating Voltage



OUTLINE DRAWING

TO-220(T)