# Inverting 600kHz Switching Regulator

July 1998

## FEATURES

- **Better Regulation Than a Charge Pump**
- **0.1Ω Effective Output Impedance**
- **–5V at 200mA from a 5V Input**
- 600kHz Fixed Frequency Operation
- Operates with $V_{IN}$ as Low as 1V
- 1mA Quiescent Current
- Low Shutdown Current: 10µA
- Low-Battery Detector
- Low $V_{CESAT}$ Switch: 295mV at 500mA

## APPLICATIONS

- MR Head Bias
- LCD Bias
- GaAs FET Bias
- Positive-to-Negative Conversion

## DESCRIPTION

The LT®1614 is a fixed frequency, inverting mode switching reglator that operates from an input voltage as low as 1V. Utilizing a low noise topology, the LT1614 can generate a negative output down to –24V from a 1V to 5V input. Fixed frequency switching ensures a clean output free from low frequency noise. The device contains a low-battery detector with a 200mV reference and shuts down to less than 10µA. No load quiescent current of the LT1614 is 1mA and the internal NPN power switch handles a 500mA current with a voltage drop of just 295mV.

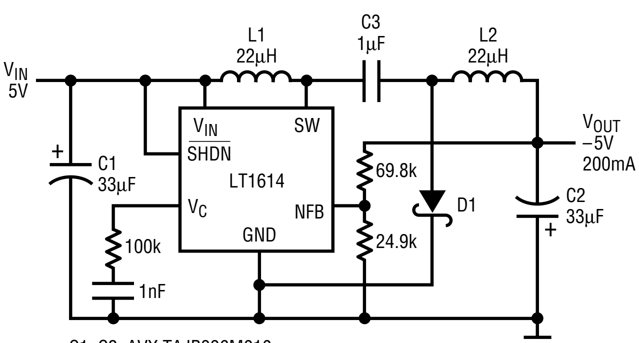
High frequency switching enables the use of small inductors and capacitors. Ceramic capacitors can be used in many applications, eliminating the need for bulky tantalum types.

The LT1614 is available in 8-lead MSOP or SO packages.



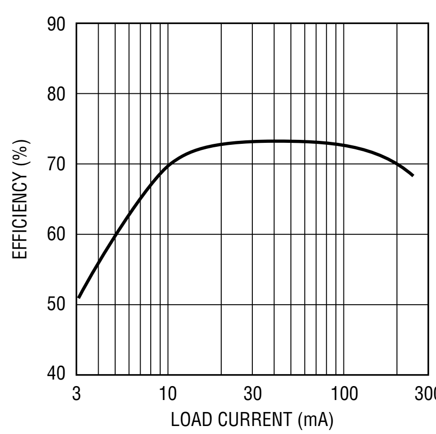
## TYPICAL APPLICATION

**5V to –5V Converter**




C1, C2: AVX TAJB336M010
C3: AVX 1206CY106
D1: MBR0520
L1, L2: MURATA LQH3C220

**5V to –5V Converter Efficiency**

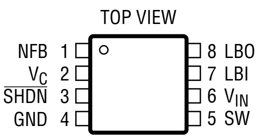


## ABSOLUTE MAXIMUM RATINGS

$V_{IN}$, $\overline{SHDN}$, LBO Voltage ........ 12V
SW Voltage ........ −0.4V to 30V
NFB Voltage ........ −3V
$V_C$ Voltage ........ 2V
LBI Voltage ........ $0V \leq V_{LBI} \leq 1V$
Current into FB Pin ........ ±1mA
Junction Temperature ........ 125°C

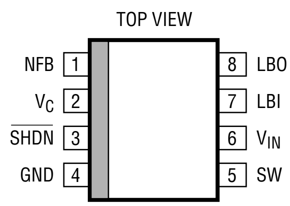
Operating Temperature Range
LT1614C ........ 0°C to 70°C
LT1614I ........ −40°C to 85°C
Extended Commercial
Temperature Range (Note 1) ........ −40°C to 85°C
Storage Temperature Range ........ −65°C to 150°C
Lead Temperature (Soldering, 10 sec) ........ 300°C

## PACKAGE/ORDER INFORMATION



MS8 PACKAGE
8-LEAD PLASTIC MSOP
$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 160°C/W

| ORDER PART NUMBER |
|---|
| LT1614CMS8 |
| **MS8 PART MARKING** |
| LTEJ |



S8 PACKAGE
8-LEAD PLASTIC SO
$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 120°C/W

| ORDER PART NUMBER |
|---|
| LT1614CS8<br>LT1614IS8 |
| **S8 PART MARKING** |
| 1614<br>1614I |

Consult factory for Military grade parts.

## ELECTRICAL CHARACTERISTICS

**Commercial Grade 0°C to 70°C. $V_{IN}$ = 1.5V, $V_{\overline{SHDN}}$ = $V_{IN}$, $T_A$ = 25°C unless otherwise noted.**

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Quiescent Current | <br>$V_{\overline{SHDN}}$ = 0V | | | 1<br>5 | 2<br>10 | mA<br>µA |
| Feedback Voltage | | ● | −1.21 | −1.24 | −1.27 | V |
| NFB Pin Bias Current (Note 2) | $V_{NFB}$ = −1.24V | ● | −2.5 | −4.5 | −7 | µA |
| Reference Line Regulation | $1V \leq V_{IN} \leq 2V$<br>$2V \leq V_{IN} \leq 6V$ | | | 0.6<br>0.3 | 1.1<br>0.8 | %/V<br>%/V |
| Minimum Input Voltage | | | | 0.92 | 1 | V |
| Maximum Input Voltage | | ● | | | 6 | V |
| Error Amp Transconductance | ΔI = 5µA | | | 16 | | µmhos |
| Error Amp Voltage Gain | | | | 100 | | V/V |
| Switching Frequency | | ● | 500 | 600 | 750 | kHz |
| Maximum Duty Cycle | | <br>● | 73<br>70 | 80<br>80 | | %<br>% |
| Switch Current Limit (Note 3) | | | 0.75 | 1.2 | | A |

## ELECTRICAL CHARACTERISTICS

**Commercial Grade 0°C to 70°C. $V_{IN}$ = 1.5V, $V_{\overline{SHDN}}$ = $V_{IN}$, $T_A$ = 25°C unless otherwise noted.**

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Switch $V_{CESAT}$ | $I_{SW}$ = 500mA (25°C, 0°C)<br>$I_{SW}$ = 500mA (70°C) | | | 295 | 350<br>400 | mV<br>mV |
| Shutdown Pin Current | $V_{\overline{SHDN}}$ = $V_{IN}$<br>$V_{\overline{SHDN}}$ = 0V | | | 10<br>−5 | 20<br>−10 | µA<br>µA |
| LBI Threshold Voltage | | <br>● | 190<br>185 | 200 | 210<br>215 | mV<br>mV |
| LBO Output Low | $I_{SINK}$ = 10µA | | | 0.1 | 0.25 | V |
| LBO Leakage Current | $V_{LBI}$ = 250mV, $V_{LBO}$ = 5V | | | 0.01 | 0.1 | µA |
| LBI Input Bias Current (Note 4) | $V_{LBI}$ = 150mV | | | 10 | 50 | nA |
| Low-Battery Detector Gain | 1MΩ Load | | | 1000 | | V/V |
| Switch Leakage Current | $V_{SW}$ = 5V | | | 0.01 | 3 | µA |

**Industrial Grade −40°C to 85°C. $V_{IN}$ = 1.5V, $V_{\overline{SHDN}}$ = $V_{IN}$ unless otherwise noted.**

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Quiescent Current | <br>$V_{\overline{SHDN}}$ = 0V | | | 1<br>5 | 2<br>10 | mA<br>µA |
| Feedback Voltage | | ● | −1.21 | −1.24 | −1.27 | V |
| NFB Pin Bias Current (Note 2) | $V_{NFB}$ = −1.24V | ● | −2 | −4.5 | −7.5 | µA |
| Reference Line Regulation | 1V ≤ $V_{IN}$ ≤ 2V<br>2V ≤ $V_{IN}$ ≤ 6V | | | 0.6<br>0.3 | 1.1<br>0.8 | %/V<br>%/V |
| Minimum Input Voltage | −40°C<br>85°C | | | 1.1<br>0.8 | 1.25<br>1.0 | V<br>V |
| Maximum Input Voltage | | ● | | | 6 | V |
| Error Amp Transconductance | ΔI = 5µA | | | 16 | | µmhos |
| Error Amp Voltage Gain | | | | 100 | | V/V |
| Switching Frequency | | ● | 500 | 600 | 750 | kHz |
| Maximum Duty Cycle | | ● | 70 | 80 | | % |
| Switch Current Limit (Note 3) | | | 0.75 | 1.2 | | A |
| Switch $V_{CESAT}$ | $I_{SW}$ = 500mA (−40°C)<br>$I_{SW}$ = 500mA (85°C) | | | 250<br>330 | 350<br>400 | mV<br>mV |
| Shutdown Pin Current | $V_{\overline{SHDN}}$ = $V_{IN}$<br>$V_{\overline{SHDN}}$ = 0V | | | 10<br>−5 | 20<br>−10 | µA<br>µA |
| LBI Threshold Voltage | | ● | 180 | 200 | 220 | mV |
| LBO Output Low | $I_{SINK}$ = 10µA | | | 0.1 | 0.25 | V |
| LBO Leakage Current | $V_{LBI}$ = 250mV, $V_{LBO}$ = 5V | | | 0.1 | 0.3 | µA |
| LBI Input Bias Current (Note 4) | $V_{LBI}$ = 150mV | | | 5 | 30 | nA |
| Low-Battery Detector Gain | 1MΩ Load | | | 1000 | | V/V |
| Switch Leakage Current | $V_{SW}$ = 5V | | | 0.01 | 3 | µA |

The ● denotes specifications which apply over the full operating temperature range.

**Note 1:** The LT1614C is guaranteed to meet specified performance from 0°C to 70°C and is designed, characterized and expected to meet these extended temperature limits, but is not tested at −40°C and 85°C. The LT1614I is guaranteed to meet the extended temperature limits.

**Note 2:** Bias current flows out of NFB pin.

**Note 3:** Switch current limit guaranteed by design and/or correlation to static tests. Duty cycle affects current limit due to ramp generator.

**Note 4:** Bias current flows out of LBI pin.

## PIN FUNCTIONS

**NFB (Pin 1):** Negative Feedback Pin. Reference voltage is –1.24V. Connect resistive divider tap here. The suggested value for R2 is 24.9k. Set R1 and R2 according to:

$$R1 = \frac{|V_{OUT}| - 1.24}{\frac{1.24}{R2} + \left(4.5 \bullet 10^{-6}\right)}$$

**$V_C$ (Pin 2):** Compensation Pin for Error Amplifier. Connect a series RC from this pin to ground. Typical values are 100kΩ and 1nF. Minimize trace area at $V_C$.

**$\overline{\text{SHDN}}$ (Pin 3):** Shutdown. Ground this pin to turn off switcher. Must be tied to $V_{IN}$ (or higher voltage) to enable switcher. Do not float the $\overline{\text{SHDN}}$ pin.

**GND (Pin 4):** Ground. Connect directly to local ground plane.

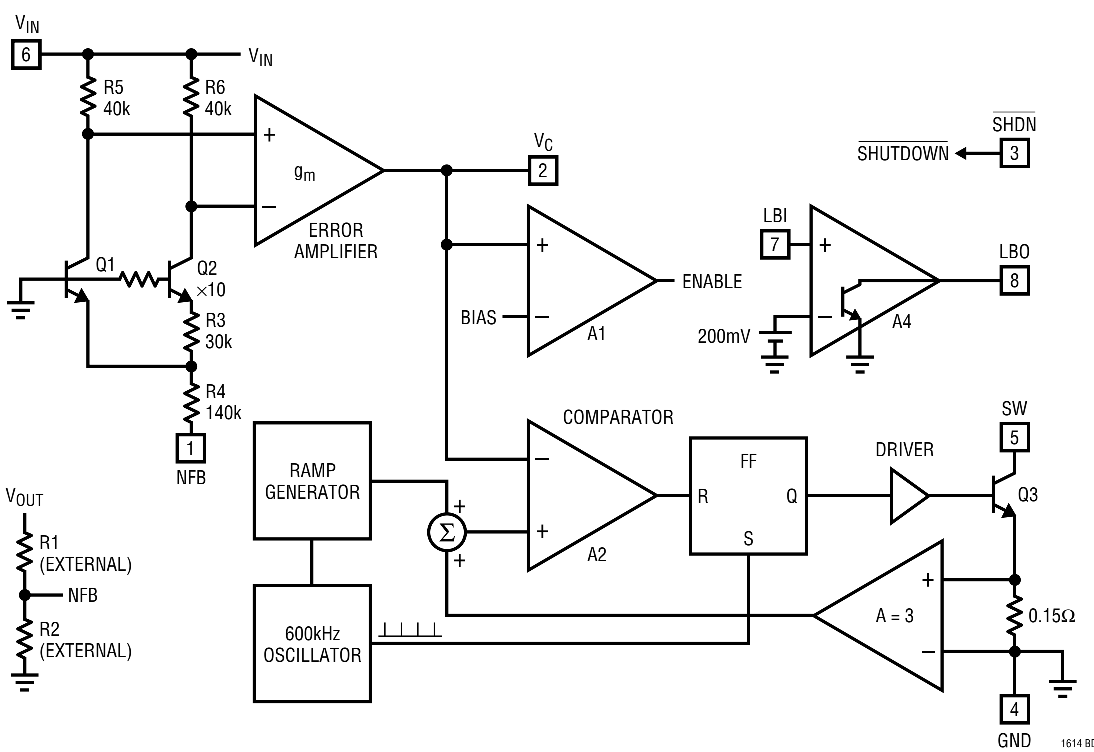
**SW (Pin 5):** Switch Pin. Minimize trace area at this pin to keep EMI down.

**$V_{IN}$ (Pin 6):** Supply Pin. Must have 1μF ceramic bypass capacitor right at the pin, connected directly to ground.

**LBI (Pin 7):** Low-Battery Detector Input. 200mV reference. Voltage on LBI must stay between ground and 700mV. Float this pin if not used.

**LBO (Pin 8):** Low-Battery Detector Output. Open collector, can sink 10μA. A 1MΩ pull-up is recommended. Float this pin if not used.

## BLOCK DIAGRAM



## APPLICATIONS INFORMATION

### Shutdown Pin

The LT1614 has a Shutdown pin ($\overline{SHDN}$) that must be grounded to shut the device down or tied to a voltage equal or greater than $V_{IN}$ to operate. The shutdown circuit is shown in Figure 1.

Note that allowing $\overline{SHDN}$ to float turns on both the start-up current (Q2) and the shutdown current (Q3) for $V_{IN}$ > $2V_{BE}$. The LT1614 doesn't know what to do in this situation and behaves erratically. $\overline{SHDN}$ voltage above $V_{IN}$ is allowed. This merely reverse-biases Q3's base emitter junction, a benign condition.

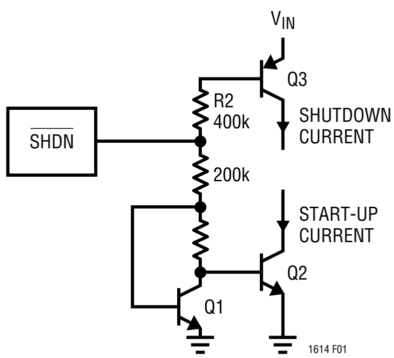



**Figure 1. Shutdown Circuit**

### Low-Battery Detector

The LT1614's low-battery detector is a simple PNP input gain stage with an open collector NPN output. The negative input of the gain stage is tied internally to a 200mV reference. The positive input is the LBI pin. Arrangement as a low-battery detector is straightforward. Figure 2 details hookup. R1 and R2 need only be low enough in value so that the bias current of the LBI pin doesn't cause large errors. For R2, 100k is adequate. The 200mV reference can also be accessed as shown in Figure 3.

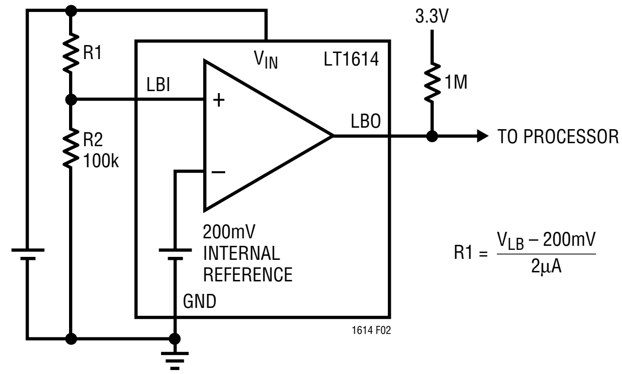



**Figure 2. Setting Low-Battery Detector Trip Point**

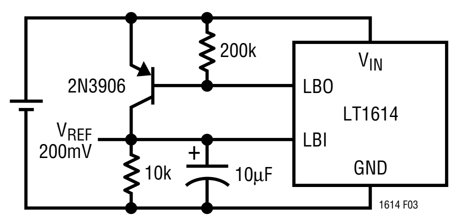



**Figure 3. Accessing 200mV Reference**

### Coupled Inductors

The applications shown in this data sheet use two uncoupled inductors because the Murata units specified are small and inexpensive. This topology can also be used with a coupled inductor as shown in Figure 4. Be sure to get the phasing right.

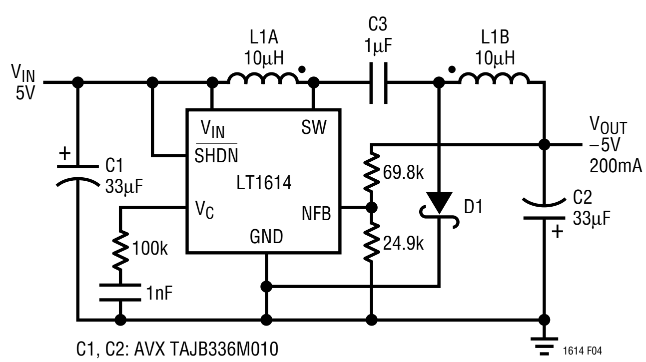
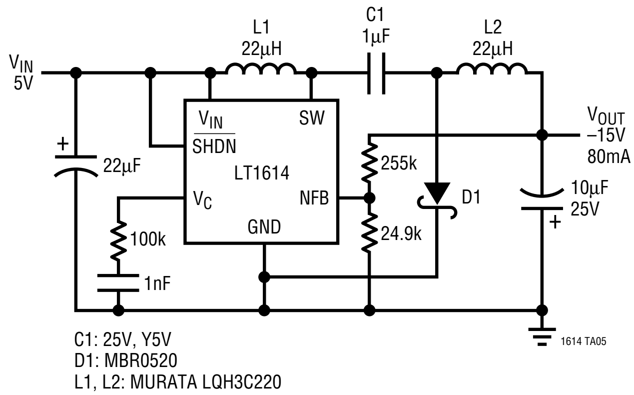


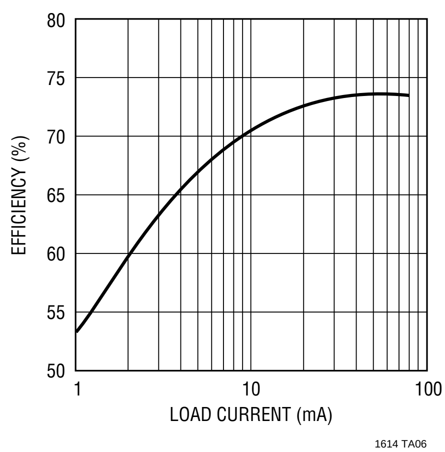

**Figure 4. 5V to –5V Converter with Coupled Inductor**

# TYPICAL APPLICATION

**5V to –15V/80mA DC/DC Converter**

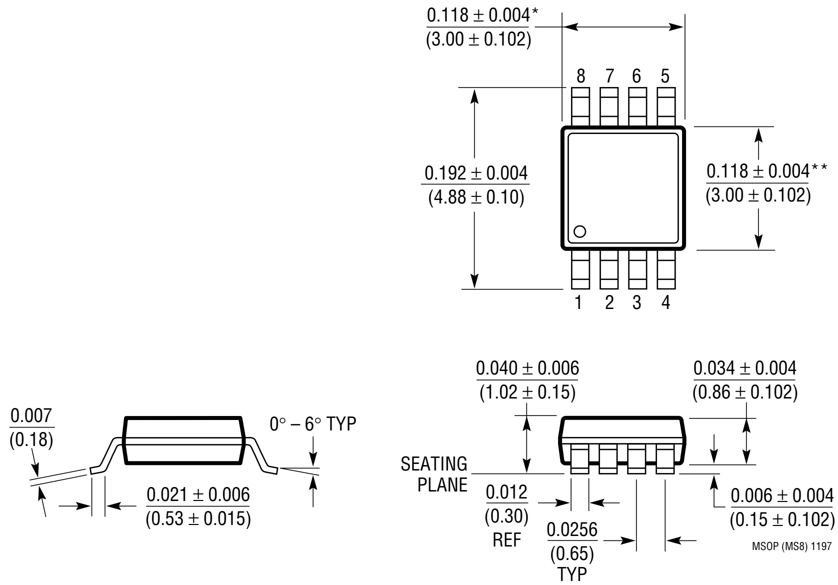



**5V to –15V Converter Efficiency**



# PACKAGE DESCRIPTION **Dimensions in inches (millimeters) unless otherwise noted.**

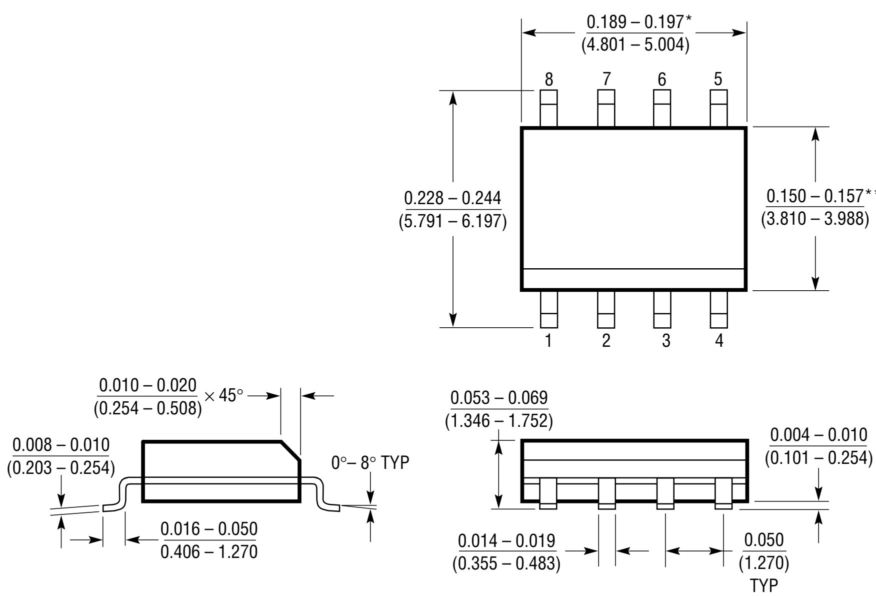
**MS8 Package**
**8-Lead Plastic MSOP**
(LTC DWG # 05-08-1660)




* DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

** DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS. INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**S8 Package**
**8-Lead Plastic Small Outline (Narrow 0.150)**
(LTC DWG # 05-08-1610)

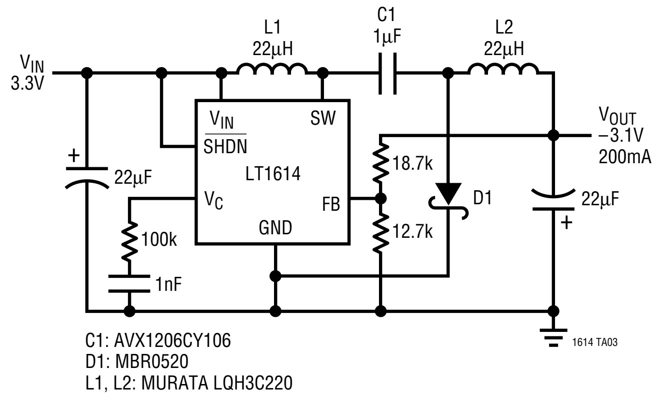



*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

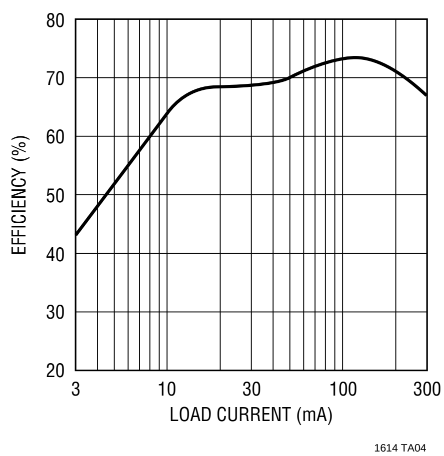
**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

# TYPICAL APPLICATION

**3.3V to –3.1V/200mA DC/DC Converter**




**3.3V to –3.1V Converter Efficiency**




# RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|---|---|---|
| LTC®1174 | High Efficiency Step-Down and Inverting DC/DC Converter | Selectable $I_{PEAK}$ = 300mA or 600mA |
| LT1307 | Single Cell Micropower 600kHz PWM DC/DC Converter | 3.3V at 75mA from 1 Cell, MSOP Package |
| LT1308 | Single Cell High Current Micropower 600kHz Boost Converter | 5V at 1A from a Single Li-Ion Cell, SO-8 Package |
| LT1316 | Micropower Boost DC/DC Converter | Programmable Peak Current Limit, MSOP Package |
| LT1317 | Micropower 600kHz PWM DC/DC Converter | 2 Cells to 3.3V at 200mA, MSOP Package |
| LTC1474 | Low Quiescent Current High Efficiency DC/DC Converter | $I_Q$ = 10µA, Programmable Peak Current Limit, MSOP |
| LT1610 | 1.7MHz Single Cell Micropower DC/DC Converter | 5V at 200mA from 3.3V, MSOP Package |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