

# High Efficiency Step-Down and Inverting DC/DC Converter

## FEATURES

- **High Efficiency: Up to 94%**
- Peak Inductor Current Independent of Inductor Value
- Short-Circuit Protection
- Optimized for 5V to -5V Applications
- Wide  $V_{IN}$  Range: 4V to 18.5V
- Low Dropout Operation
- Low-Battery Detector
- Pin Selectable Current Limit
- Internal  $0.9\Omega$  Power Switch:  $V_{IN} = 9V$
- Only Four External Components Required
- 130 $\mu$ A Standby Current
- Active Low Micropower Shutdown

## APPLICATIONS

- Distributed Power Systems
- Step-Down Converters
- Inverting Converters
- Memory Backup Supply
- Portable Instruments
- Battery-Powered Equipment

## DESCRIPTION

The LTC<sup>®</sup>1174 is a simple current mode DC/DC converter ideally suited for 9V to 5V, 5V to 3.3V or 5V to -5V operation. With an internal  $0.9\Omega$  switch (at a supply voltage of 9V), the LTC1174 requires only four external components to construct a complete high efficiency DC/DC converter.

Under a no load condition the LTC1174 draws only 130 $\mu$ A. In shutdown, it draws a mere 1 $\mu$ A making this converter ideal for current sensitive applications. In dropout, the internal P-channel MOSFET switch is turned on continuously allowing the user to maximize the life of the battery source.

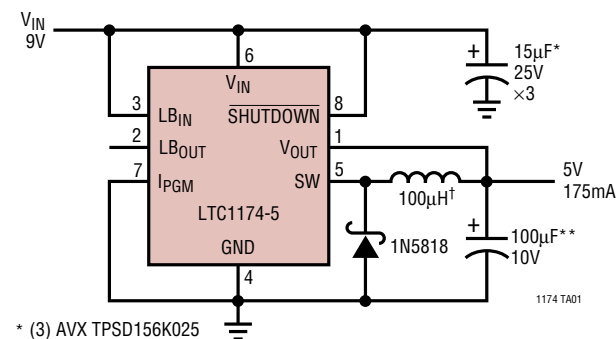
The maximum inductor current of the LTC1174 family is pin selectable to either 340mA or 600mA, optimizing efficiency for a wide range of applications. Operation up to 200kHz permits the use of small surface mount inductors and capacitors.

For applications requiring higher output current or ultra-high efficiency, see the LTC1148 data sheet.

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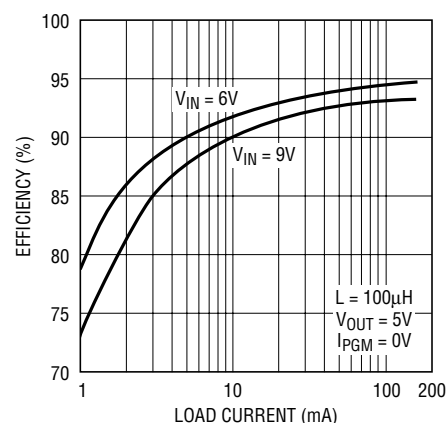
## TYPICAL APPLICATION

High Efficiency Step-Down Converter



\* (3) AVX TPSD156K025  
 \*\* AVX TPSD107K010  
 † COILTRONICS CTX100-4

LTC1174-5 Efficiency



1174 TA02

1174fe

# LTC1174

## LTC1174-3.3/LTC1174-5

### ABSOLUTE MAXIMUM RATINGS (Note 1)

(Voltage Referred to GND Pin)

Input Supply Voltage (Pin 6)

LTC1174 ..... -0.3V to 13.5V

LTC1174HV ..... -0.3V to 18.5V

Switch Current (Pin 5) ..... 1A

Switch Voltage (Pin 5)

LTC1174 .....  $V_{IN} - 13.5V$

LTC1174HV .....  $V_{IN} - 18.5V$

Operating Temperature Range

LTC1174CX ..... 0°C to 70°C

LTC1174IX ..... -40°C to 85°C

Junction Temperature (Note 2) ..... 125°C

Storage Temperature Range ..... -65°C to 150°C

Lead Temperature (Soldering, 10 sec) ..... 300°C

### PACKAGE/ORDER INFORMATION

| <p>TOP VIEW</p> <p>N8 PACKAGE<br/>8-LEAD PDIP</p> <p>* ADJUSTABLE OUTPUT VERSION</p> <p><math>T_{JMAX} = 125^{\circ}C</math>, <math>\theta_{JA} = 110^{\circ}C/W</math></p>                                              | <p>TOP VIEW</p> <p>S8 PACKAGE<br/>8-LEAD PLASTIC SO</p> <p>* ADJUSTABLE OUTPUT VERSION</p> <p><math>T_{JMAX} = 125^{\circ}C</math>, <math>\theta_{JA} = 150^{\circ}C/W</math></p> |                                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| ORDER PART NUMBER                                                                                                                                                                                                        | ORDER PART NUMBER                                                                                                                                                                 | S8 PART MARKING                                                          |
| LTC1174CN8<br>LTC1174CN8-3.3<br>LTC1174CN8-5<br>LTC1174IN8<br>LTC1174HVCN8<br>LTC1174HVCN8-3.3<br>LTC1174HVCN8-5                                                                                                         | LTC1174CS8<br>LTC1174CS8-3.3<br>LTC1174CS8-5<br>LTC1174IS8<br>LTC1174HVCS8<br>LTC1174HVCS8-3.3<br>LTC1174HVCS8-5<br>LTC1174HVIS8                                                  | 1174<br>117433<br>117450<br>1174I<br>1174H<br>1174H3<br>1174H5<br>1174HI |
| <p><b>Order Options</b> Tape and Reel: Add #TR<br/>Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF<br/>Lead Free Part Marking: <a href="http://www.linear.com/leadfree/">http://www.linear.com/leadfree/</a></p> |                                                                                                                                                                                   |                                                                          |

Consult LTC Marketing for parts specified with wider operating temperature ranges.

### ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^{\circ}C$ .  $V_{IN} = 9V$ ,  $V_{SHUTDOWN} = V_{IN}$ ,  $I_{PGM} = 0V$ , unless otherwise noted.

| SYMBOL           | PARAMETER                      | CONDITIONS                                                                | MIN  | TYP  | MAX  | UNITS   |
|------------------|--------------------------------|---------------------------------------------------------------------------|------|------|------|---------|
| $I_{FB}$         | Feedback Current               | LTC1174/LTC1174HV                                                         |      |      | 1    | $\mu A$ |
| $V_{FB}$         | Feedback Voltage               | LTC1174/LTC1174HV ●                                                       | 1.20 | 1.25 | 1.30 | V       |
| $V_{OUT}$        | Regulated Output Voltage       | LTC1174-3.3/LTC1174HV-3.3 ●                                               | 3.14 | 3.30 | 3.46 | V       |
|                  |                                | LTC1174-5/LTC1174V-5 ●                                                    | 4.75 | 5.00 | 5.25 | V       |
| $\Delta V_{OUT}$ | Output Voltage Line Regulation | $V_{IN} = 6V$ to $12V$ , $I_{LOAD} = 100mA$ , $I_{PGM} = V_{IN}$ (Note 3) |      | 10   | 70   | mV      |

1174fe

## ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_{IN} = 9\text{V}$ ,  $V_{SHUTDOWN} = V_{IN}$ ,  $I_{PGM} = 0\text{V}$ , unless otherwise noted.

| SYMBOL       | PARAMETER                        | CONDITIONS                                                                | MIN    | TYP  | MAX  | UNITS         |
|--------------|----------------------------------|---------------------------------------------------------------------------|--------|------|------|---------------|
|              | Output Voltage Load Regulation   | LTC1174-3.3 (Note 3)                                                      |        |      |      |               |
|              |                                  | $20\text{mA} < I_{LOAD} < 175\text{mA}$ , $I_{PGM} = 0\text{V}$           |        | -5   | -70  | mV            |
|              |                                  | $20\text{mA} < I_{LOAD} < 400\text{mA}$ , $I_{PGM} = V_{IN}$              |        | -45  | -70  | mV            |
|              |                                  | LTC1174-5 (Note 3)                                                        |        |      |      |               |
| $I_Q$        | Input DC Supply Current (Note 4) | $20\text{mA} < I_{LOAD} < 175\text{mA}$ , $I_{PGM} = 0\text{V}$           |        | -5   | -70  | mV            |
|              |                                  | $20\text{mA} < I_{LOAD} < 400\text{mA}$ , $I_{PGM} = V_{IN}$              |        | -50  | -70  | mV            |
|              |                                  | Active Mode                                                               |        |      |      |               |
|              |                                  | LTC1174: $4\text{V} < V_{IN} < 12\text{V}$ , $I_{PGM} = 0\text{V}$        |        | 450  | 600  | $\mu\text{A}$ |
|              | Sleep Mode                       | LTC1174HV: $4\text{V} < V_{IN} < 16\text{V}$ , $I_{PGM} = 0\text{V}$      |        | 450  | 600  | $\mu\text{A}$ |
|              |                                  | LTC1174: $4\text{V} < V_{IN} < 12\text{V}$                                |        | 130  | 180  | $\mu\text{A}$ |
|              |                                  | LTC1174HV: $4\text{V} < V_{IN} < 16\text{V}$                              |        | 130  | 180  | $\mu\text{A}$ |
|              |                                  | SHUTDOWN (Note 4)                                                         |        |      |      |               |
|              | Low-Battery Trip Point           | LTC1174: $V_{SHUTDOWN} = 0\text{V}$ , $4\text{V} < V_{IN} < 12\text{V}$   |        | 1    | 10   | $\mu\text{A}$ |
|              |                                  | LTC1174HV: $V_{SHUTDOWN} = 0\text{V}$ , $4\text{V} < V_{IN} < 16\text{V}$ |        | 2    | 25   | $\mu\text{A}$ |
| $V_{LBTRIP}$ | Low-Battery Trip Point           |                                                                           |        | 1.25 | 1.4  | V             |
| $I_{LBIN}$   | Current into Pin 3               |                                                                           |        |      | 0.5  | $\mu\text{A}$ |
| $I_{LBOUT}$  | Current Sunk by Pin 2            | LTC1174: $V_{LBOUT} = 0.4\text{V}$                                        | 1.0    | 1.2  | 1.5  | $\text{mA}$   |
|              |                                  | LTC1174HV: $V_{LBOUT} = 0.4\text{V}$                                      | 0.6    | 0.8  | 1.5  | $\text{mA}$   |
| $V_{HYST}$   | Comparator Hysteresis            | LTC1174/LTC1174HV                                                         | 7.5    | 15   | 30   | mV            |
| $I_{PEAK}$   | Current Limit                    | $I_{PGM} = V_{IN}$ , $V_{OUT} = 0\text{V}$                                | ● 0.54 | 0.60 | 0.83 | A             |
|              |                                  | $I_{PGM} = 0\text{V}$ , $V_{OUT} = 0\text{V}$                             | ● 0.27 | 0.34 | 0.53 | A             |
| $R_{ON}$     | ON Resistance of Switch          | LTC1174                                                                   | ●      | 0.75 | 1.30 | $\Omega$      |
|              |                                  | LTC1174HV                                                                 | ●      | 0.90 | 1.55 | $\Omega$      |
| $t_{OFF}$    | Switch Off-Time (Note 6)         | $V_{OUT}$ at Regulated Value                                              | 3      | 4    | 5    | $\mu\text{s}$ |
| $V_{IH}$     | SHUTDOWN Pin High                | Minimum Voltage at Pin 8 for Device to Be Active                          | 1.2    |      |      | V             |
| $V_{IL}$     | SHUTDOWN Pin Low                 | Maximum Voltage at Pin 8 for Device to Be in Shutdown                     |        |      | 0.75 | V             |
| $I_{IH}$     | SHUTDOWN Pin Input Current       | LTC1174: $V_{SHUTDOWN} = 12\text{V}$                                      |        |      | 0.5  | $\mu\text{A}$ |
|              |                                  | LTC1174HV: $V_{SHUTDOWN} = 16\text{V}$                                    |        |      | 2.0  | $\mu\text{A}$ |
| $I_{IL}$     | SHUTDOWN Pin Input Current       | $0 \leq V_{SHUTDOWN} \leq 0.8\text{V}$                                    |        |      | 0.5  | $\mu\text{A}$ |

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at  $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ . LTC1174I and LTC1174HVI Only.

| SYMBOL      | PARAMETER                | CONDITIONS                                                 | MIN    | TYP  | MAX  | UNITS         |
|-------------|--------------------------|------------------------------------------------------------|--------|------|------|---------------|
| $V_{FB}$    | Feedback Voltage         | LTC1174I/LTC1174HVI                                        | ● 1.18 | 1.25 | 1.31 | V             |
| $I_{LBOUT}$ | Current Sunk by Pin 2    | $V_{LBOUT} = 0.4\text{V}$ (LTC1174I)                       | ● 0.75 | 1.2  | 2.0  | $\text{mA}$   |
|             |                          | $V_{LBOUT} = 0.4\text{V}$ (LTC1174HVI)                     | ● 0.50 | 0.8  | 1.6  | $\text{mA}$   |
| $I_{PEAK}$  | Current Limit            | $I_{PGM} = V_{IN}$ , $V_{OUT} = 0\text{V}$ (LTC1174I)      | ● 0.54 | 0.60 | 0.84 | A             |
|             |                          | $I_{PGM} = 0\text{V}$ , $V_{OUT} = 0\text{V}$ (LTC1174I)   |        | 0.34 |      | A             |
|             |                          | $I_{PGM} = V_{IN}$ , $V_{OUT} = 0\text{V}$ (LTC1174HVI)    | ● 0.5  | 0.60 | 0.86 | A             |
|             |                          | $I_{PGM} = 0\text{V}$ , $V_{OUT} = 0\text{V}$ (LTC1174HVI) |        | 0.34 |      | A             |
| $t_{OFF}$   | Switch Off-Time (Note 6) | $V_{OUT}$ at Regulated Value (LTC1174I)                    | ● 2.0  | 4    | 6.0  | $\mu\text{s}$ |
|             |                          | $V_{OUT}$ at Regulated Value (LTC1174HVI)                  | ● 1.8  | 4    | 6.2  | $\mu\text{s}$ |
| $R_{ON}$    | Switch On Resistance     | LTC1174I/LTC1174HVI                                        | ●      | 0.9  | 1.7  | $\Omega$      |

**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:**  $T_J$  is calculated from the ambient temperature  $T_A$  and power dissipation  $P_D$  according to the following formulas:

LTC1174CN8, LTC1174CN8-3.3, LTC1174CN8-5:

$$T_J = T_A + (P_D \times 110^\circ\text{C/W})$$

LTC1174CS8, LTC1174CS8-3.3, LTC1174CS8-5:

$$T_J = T_A + (P_D \times 150^\circ\text{C/W})$$

### ELECTRICAL CHARACTERISTICS

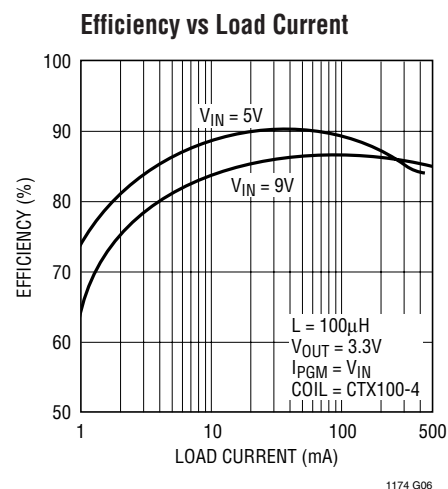
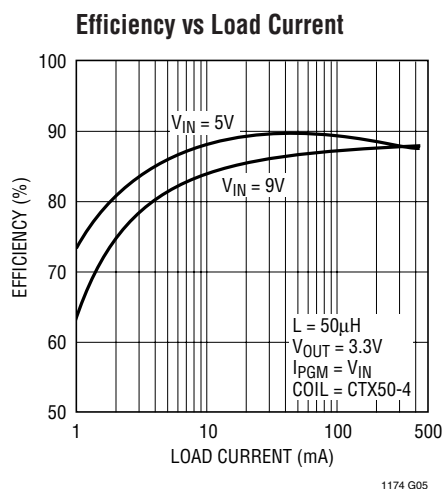
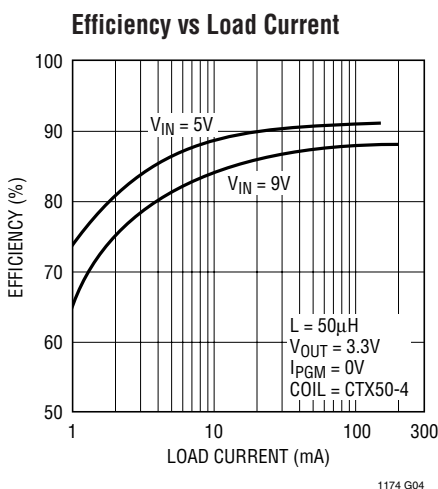
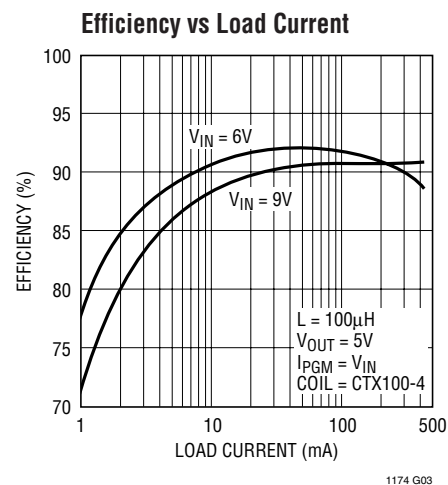
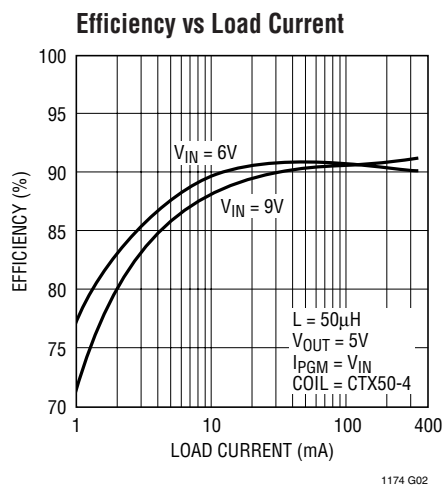
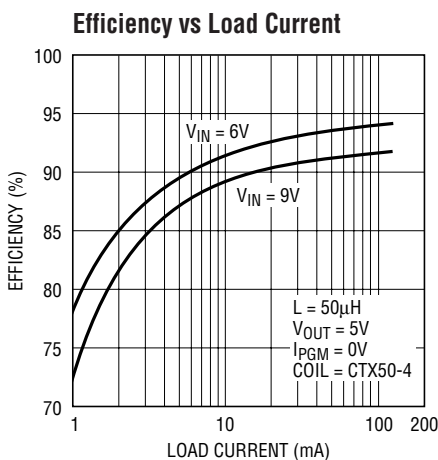
**Note 3:** Guaranteed by design.

**Note 4:** Dynamic supply current is higher due to the gate charge being delivered at the switching frequency.

**Note 5:** Current into Pin 6 only, measured without electrolytic input capacitor.

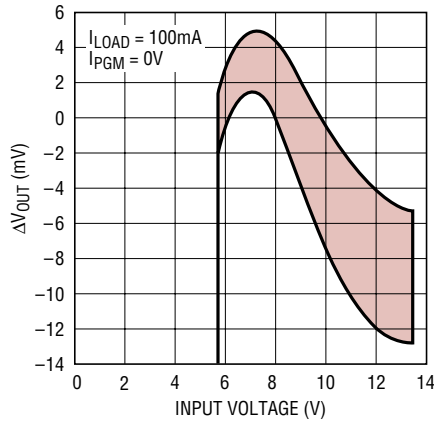
**Note 6:** The off-time is wafer-sort trimmed.

### TYPICAL PERFORMANCE CHARACTERISTICS



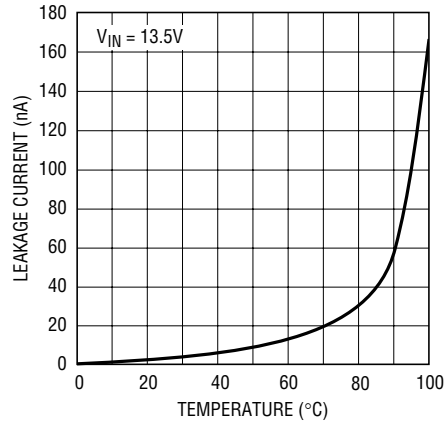
## TYPICAL PERFORMANCE CHARACTERISTICS

Line Regulation



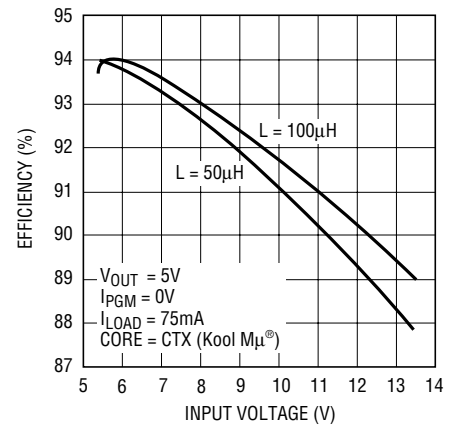
1174 G07

Switch Leakage Current vs Temperature



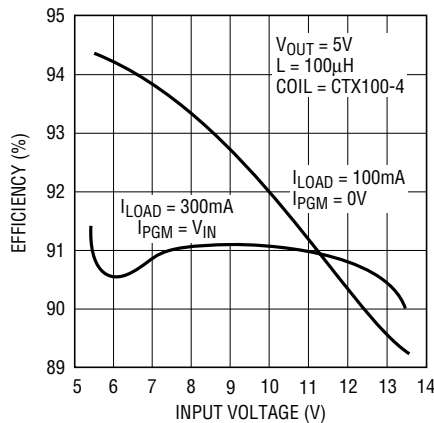
1174 G08

Efficiency vs Input Voltage



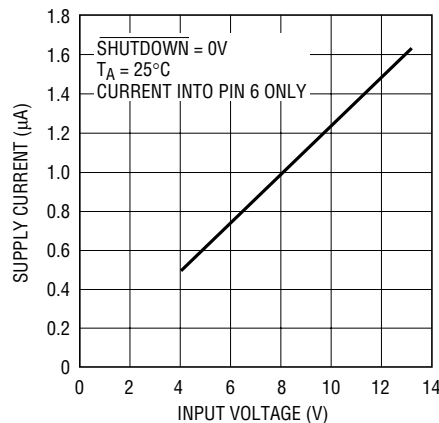
1174 G09

Efficiency vs Input Voltage



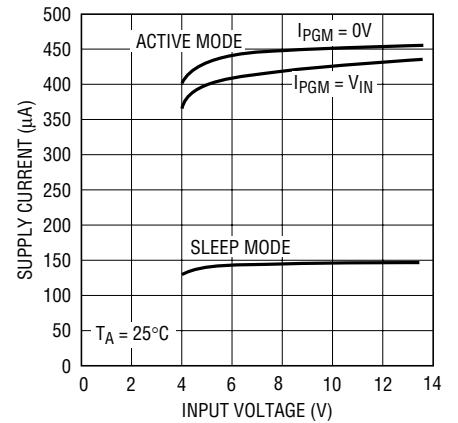
1174 G10

Supply Current in Shutdown



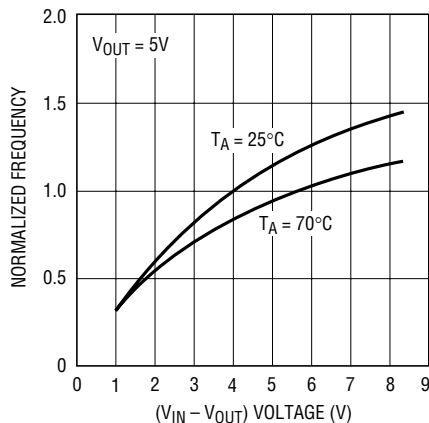
1174 G11

DC Supply Current



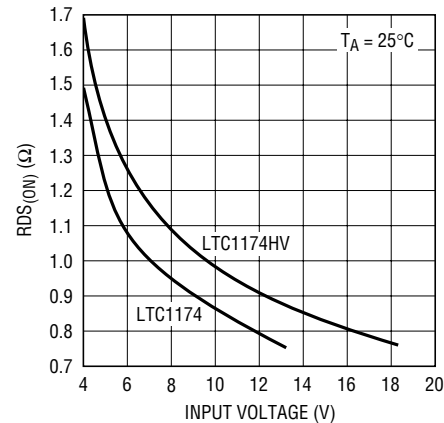
1174 G12

Operating Frequency vs  $V_{IN} - V_{OUT}$



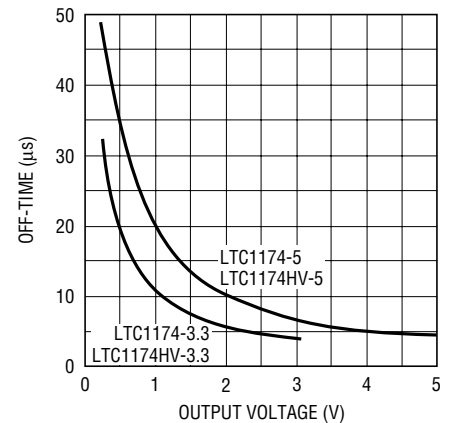
1174 G13

Switch Resistance vs Input Voltage



1174 G14

Off-Time vs Output Voltage



1174 G15

# LTC1174

## LTC1174-3.3/LTC1174-5

### PIN FUNCTIONS

**V<sub>OUT</sub> (V<sub>FB</sub>) (Pin 1):** For the LTC1174, this pin connects to the main voltage comparator's input. On the LTC1174-3.3 and LTC1174-5 this pin goes to an internal resistive divider which sets the output voltage.

**LB<sub>OUT</sub> (Pin 2):** Open Drain of an N-Channel Pull-Down. This pin will sink current when Pin 3 (LB<sub>IN</sub>) goes below 1.25V. During shutdown the state of this pin is indeterminate.

**LB<sub>IN</sub> (Pin 3):** The “-” Input of the Low-Battery Voltage Comparator. The “+” input is connected to a reference voltage of 1.25V.

**GND (Pin 4):** Ground Pin.

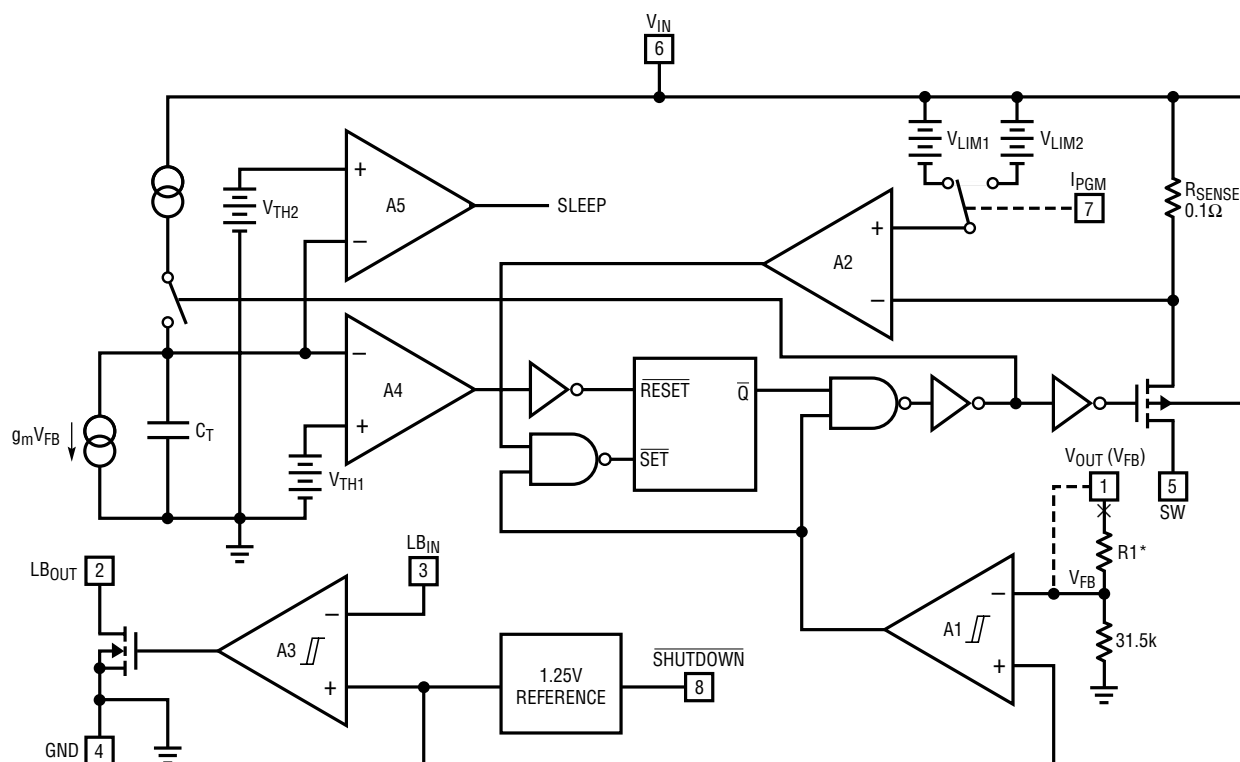
**SW (Pin 5):** Drain of the P-Channel MOSFET Switch. Cathode of Schottky diode must be closely connected to this pin.

**V<sub>IN</sub> (Pin 6):** Input Supply Voltage. It must be decoupled close to ground Pin 4.

**I<sub>PGM</sub> (Pin 7):** Selects the Current Limit of the P-Channel Switch. With I<sub>PGM</sub> = V<sub>IN</sub>, the current trip point is 600mA and with I<sub>PGM</sub> = 0V, the current trip value is reduced to 340mA.

**SHUTDOWN (Pin 8):** Pulling this pin to ground keeps the internal switch off and puts the LTC1174 in micropower shutdown.

### FUNCTIONAL DIAGRAM (Pin 1 connection shown for LTC1174-3.3 and LTC1174-5, changes create LTC1174)



\* R1 = 51k FOR LTC1174-3.3  
R1 = 93.5k FOR LTC1174-5

1174 BD

## OPERATION (Refer to Functional Diagram)

The LTC1174 uses a constant off-time architecture to switch its internal P-channel power MOSFET. The off-time is set by an internal timing capacitor and the operating frequency is a function of  $V_{IN}$ .

The output voltage is set by an internal resistive divider (LTC1174-3.3 and LTC1174-5) or an external divider returned to  $V_{FB}$  Pin 1 (LTC1174). A voltage comparator A1 compares the divided output voltage to a reference voltage of 1.25V.

To optimize efficiency, the LTC1174 automatically switches between continuous and Burst Mode<sup>®</sup> operation. The voltage comparator is the primary control element when the device is in Burst Mode operation, while the current comparator controls the output voltage in continuous mode.

During the switch "ON" time, switch current flows through the  $0.1\Omega$  sense resistor. When this current reaches the threshold of the current comparator A2, its output signal will change state, setting the flip-flop and turning the switch off. The timing capacitor,  $C_T$ , begins to discharge until its voltage goes below  $V_{TH1}$ . Comparator A4 will then trip, which resets the flip-flop and causes the switch to turn on again. Also, the timing capacitor is recharged. The inductor current will again ramp up until the current comparator A2 trips. The cycle then repeats.

When the load is relatively light, the LTC1174 automatically goes into Burst Mode operation. The current mode loop is interrupted when the output voltage reaches the desired regulated value. The hysteretic voltage comparator A1 trips when  $V_{OUT}$  is above the desired output voltage, shutting off the switch and causing the timing capacitor to discharge. This capacitor discharges past  $V_{TH1}$  until its voltage drops below  $V_{TH2}$ . Comparator A5 then trips and a sleep signal is generated.

In sleep mode, the LTC1174 is in standby and the load current is supplied by the output capacitor. All unused circuitry is shut off, reducing quiescent current from 0.45mA to 0.13mA. When the output capacitor discharges by the amount of the hysteresis of the comparator A1, the P-channel switch turns on again and the process repeats itself.

### Operating Frequency and Inductor

Since the LTC1174 utilizes a constant off-time architecture, its operating frequency is dependent on the value of  $V_{IN}$ . The frequency of operation can be expressed as:

$$f = \frac{1}{t_{OFF}} \left( \frac{V_{IN} - V_{OUT}}{V_{IN} + V_D} \right) \quad (\text{Hz})$$

where  $t_{OFF} = 4\mu\text{s}$  and  $V_D$  is the voltage drop across the diode. Note that the operating frequency is a function of the input and output voltage.

Although the size of the inductor does not affect the frequency, it does affect the ripple current. The peak-to-peak ripple current is given by:

$$I_{RIPPLE} = 4 \cdot 10^{-6} \left( \frac{V_{OUT} + V_D}{L} \right) \quad (A_{P-P})$$

By choosing a smaller inductor, a low ESR output filter capacitor has to be used (see  $C_{IN}$  and  $C_{OUT}$ ). Moreover, core loss will also increase (see Inductor Core Selection section) due to higher ripple current.

Burst Mode is a registered trademark of Linear Technology Corporation.

## APPLICATIONS INFORMATION

### Inductor Core Selection

With the value of L selected, the type of inductor must be chosen. Basically there are two kinds of losses in an inductor, core and copper

Core losses are dependent on the peak-to-peak ripple current and the core material. However it is independent of the physical size of the core. By increasing the inductance the inductor's peak-to-peak ripple current will decrease, therefore reducing core loss. Utilizing low core loss material, such as molypermalloy or Kool M $\mu$  will allow users to concentrate on reducing copper loss and preventing saturation. Figure 1 shows the effect of different core material on the efficiency of the LTC1174. The CTX core is Kool M $\mu$  and the CTP core is powdered iron (material 52).

Although higher inductance reduces core loss, it increases copper loss as it requires more windings. When space is not

a premium larger gauge wire can be used to reduce the wire resistance. This also prevents excessive heat dissipation.

### C<sub>IN</sub>

In continuous mode the source current of the P-channel MOSFET is a square wave of duty cycle  $V_{OUT}/V_{IN}$ . To prevent large voltage transients, a low ESR input capacitor sized for the maximum RMS current must be used. The  $C_{IN}$  RMS current is given by:

$$I_{RMS} \approx \frac{I_{OUT} [V_{OUT}(V_{IN} - V_{OUT})]^{1/2}}{V_{IN}} \quad (A_{RMS})$$

This formula has a maximum at  $V_{IN} = 2V_{OUT}$ , where  $I_{RMS} = I_{OUT}/2$ . This simple worst case is commonly used for design because even significant deviations do not offer much relief. Note that ripple current directly affects capacitor's lifetime. **DO NOT UNDERSPECIFY THIS COMPONENT.** An additional 0.1 $\mu$ F ceramic capacitor is also required on  $V_{IN}$  for high frequency decoupling.

### C<sub>OUT</sub>

To avoid overheating, the output capacitor must be sized to handle the ripple current generated by the inductor. The worst case RMS ripple current in the output capacitor is given by:

$$I_{RMS} \approx \frac{I_{PEAK}}{2} \quad (A_{RMS})$$

$$= 170mA \text{ or } 300mA$$

Although the output voltage ripple is determined by the hysteresis of the voltage comparator, ESR of the output capacitor is also a concern. Too high of an ESR will create a higher ripple output voltage and at the same time cause the LTC1174 to sleep less often. This will affect the efficiency of the LTC1174. For a given technology, ESR is a direct function of the volume of the capacitor. Several small-sized capacitors can also be paralleled to obtain the same ESR as one large can. Manufacturers such as Nichicon, Chemicon and Sprague should be considered for high performance capacitors. The OS-CON semiconductor dielectric capacitor available from Sanyo has the lowest ESR for its size, at a higher price.

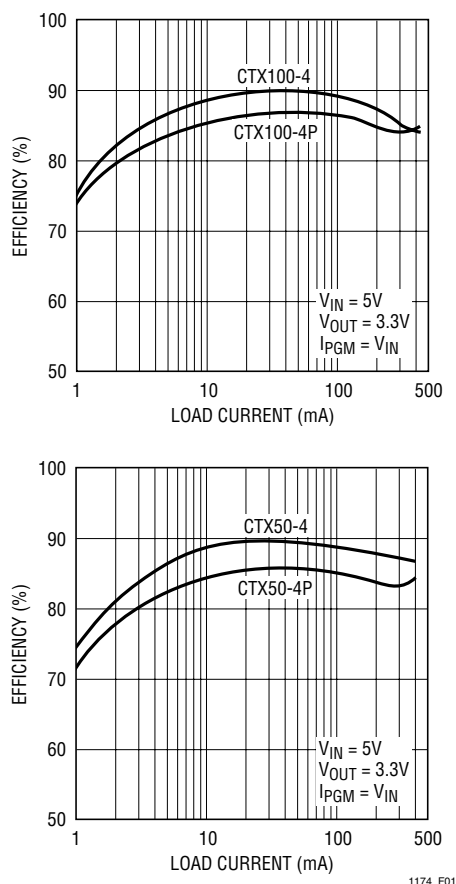


Figure 1. Efficiency Using Different Types of Inductor Core Material

## APPLICATIONS INFORMATION

### Catch Diode Selection

The catch diode carries load current during the off-time. The average diode current is therefore dependent on the P-channel switch duty cycle. At high input voltages the diode conducts most of the time. As  $V_{IN}$  approaches  $V_{OUT}$  the diode conducts only a small fraction of the time. The most stressful condition for the diode is when the output is short-circuited. Under this condition the diode must safely handle  $I_{PEAK}$  at close to 100% duty cycle. A fast switching diode must also be used to optimize efficiency. Schottky diodes are a good choice for low forward drop and fast switching times. Most LTC1174 circuits will be well served by either a 1N5818, a MBR140T3 or a MBR0520L Schottky diode.

### Short-Circuit Protection

The LTC1174 is protected from output short by its internal current limit. Depending on the condition of  $I_{PGM}$  pin, the limit is either set to 340mA or 600mA. In addition, the off-time of the switch is increased to allow the inductor's current to decay far enough to prevent any current build-up (see Figure 2).

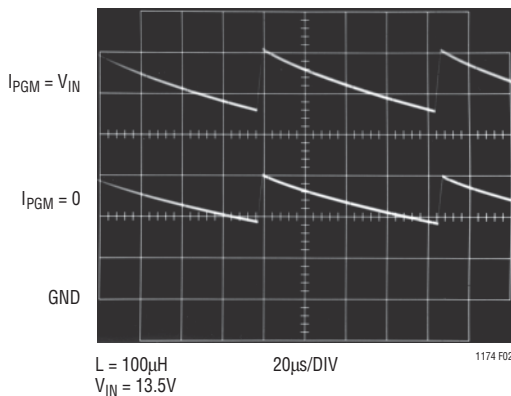


Figure 2. Inductor's Current with Output Shorted

### Low-Battery Detector

The low-battery indicator senses the input voltage through an external resistive divider. This divided voltage connects to the “-” input of a voltage comparator (Pin 3) which is

compared with a 1.25V reference voltage. With the current going into Pin 3 being negligible, the following expression is used for setting the trip limit:

$$V_{LBTRIP} = 1.25 \left( 1 + \frac{R4}{R3} \right)$$

When the LTC1174 is shut down, the low-battery detector is inactive.

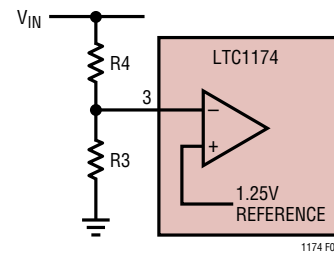


Figure 3. Low-Battery Comparator

### LTC1174 Adjustable/Low Noise Applications

The LTC1174 develops a 1.25V reference voltage between the feedback (Pin 1) terminal and ground (see Figure 4). By selecting resistor R1, a constant current is caused to flow through R1 and R2 to set the overall output voltage. The regulated output voltage is determined by:

$$V_{OUT} = 1.25 \left( 1 + \frac{R2}{R1} \right)$$

For most applications, a 30k resistor is suggested for R1. To prevent stray pickup, a 100pF capacitor is suggested across R1 located close to the LTC1174. Alternatively, a capacitor across R2 can be used to increase the switching frequency for low noise operation.

### Inverting Applications

The LTC1174 can easily be set up for a negative output voltage. If -5V is desired, the LTC1174-5 is ideal for this application as it requires the least components. Figure 5 shows the schematic for this application. Note that the

## APPLICATIONS INFORMATION

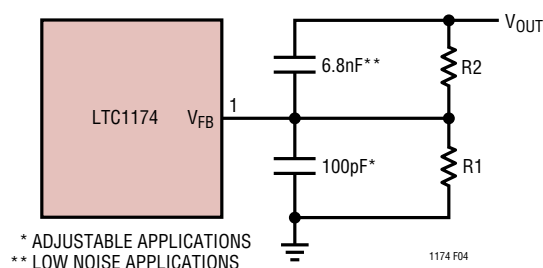


Figure 4. LTC1174 Adjustable Configuration

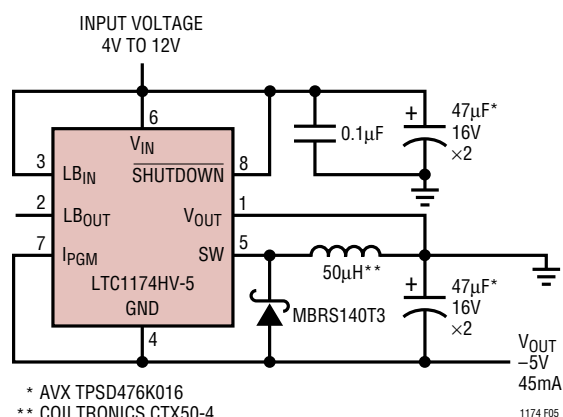


Figure 5. Positive-to-Negative 5V Converter

output voltage is now taken off the GND pin. Therefore, the maximum input voltage is now determined by the difference between the absolute maximum voltage rating and the output voltage. A maximum of 12V is specified in Figure 5, giving the circuit a 1.5V of headroom for  $V_{IN}$ . Note that the circuit can operate from a minimum of 4V, making it ideal for a 4 NiCad cell application. For a higher output current circuit, please refer to the Typical Applications section.

### Absolute Maximum Ratings and Latchup Prevention

The absolute maximum ratings specify that SW (Pin 5) can never exceed  $V_{IN}$  (Pin 6) by more than 0.3V. Normally this situation should never occur. It could, however, if the output is held up while the supply is pulled down. A condition where this could potentially occur is when a battery is supplying power to an LTC1174/LTC1174-3.3/

LTC1174-5 regulator and also to one or more loads in parallel with the the regulator's  $V_{IN}$ . If the battery is disconnected while the LTC1174/LTC1174-3.3/LTC1174-5 regulator is supplying a light load and one of the parallel circuits is a heavy load, the input capacitor of the LTC1174/LTC1174-3.3/LTC1174-5 regulator could be pulled down faster than the output capacitor, causing the absolute maximum ratings to be exceeded. The result is often a latchup which can be destructive if  $V_{IN}$  is reapplied. Battery disconnect is possible as a result of mechanical stress, bad battery contacts or use of a lithium-ion battery with a built-in internal disconnect. The user needs to assess his/her application to determine whether this situation could occur. If so, additional protection is necessary.

Prevention against latchup can be accomplished by simply connecting a Schottky diode across the SW and  $V_{IN}$  pins as shown in Figure 6. The diode will normally be reverse biased unless  $V_{IN}$  is pulled below  $V_{OUT}$  at which time the diode will clamp the  $(V_{OUT} - V_{IN})$  potential to less than the 0.6V required for latchup. Note that a low leakage Schottky should be used to minimize the effect on no-load supply current. Schottky diodes such as MBR0530, BAS85 and BAT84 work well. Another more serious effect of the protection diode leakage is that at no load with nothing to provide a sink for this leakage current, the output voltage can potentially float above the maximum allowable tolerance. To prevent this from occurring, a resistor must be connected between  $V_{OUT}$  and ground with a value low enough to sink the maximum possible leakage current.

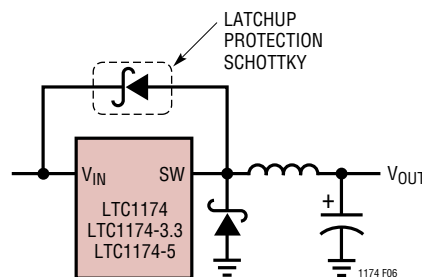


Figure 6. Preventing Absolute Maximum Ratings from Being Exceeded

## APPLICATIONS INFORMATION

### Board Layout Checklist

When laying out the printed circuit board, the following checklist should be used to ensure proper operation of the LTC1174. These items are also illustrated graphically in the layout diagram in Figure 7. Check the following in your layout:

1. Is the Schottky catch diode *closely* connected between ground (Pin 4) and switch (Pin 5)?
2. Is the “+” plate of  $C_{IN}$  *closely* connected to  $V_{IN}$  (Pin 6)? This capacitor provides the AC current to the internal P-channel MOSFET.
3. Is the  $0.1\mu\text{F}$   $V_{IN}$  decoupling capacitor *closely* connected between  $V_{IN}$  (Pin 6) and ground (Pin 4)? This capacitor carries the high frequency peak currents.
4. Is the  $\text{SHUTDOWN}$  (Pin 8) actively pulled to  $V_{IN}$  during normal operation? The  $\text{SHUTDOWN}$  pin is high impedance and must not be allowed to float.
5. Is the  $I_{PGM}$  (Pin 7) pulled either to  $V_{IN}$  or ground? The  $I_{PGM}$  pin is high impedance and must not be allowed to float.

### DESIGN EXAMPLE

As a design example, assume  $V_{IN} = 9\text{V}$  (nominal),  $V_{OUT} = 5\text{V}$ , and  $I_{OUT} = 350\text{mA}$  maximum. The LTC1174-5 is used for this application, with  $I_{PGM}$  (Pin 7) connected to  $V_{IN}$ . The minimum value of  $L$  is determined by assuming the LTC1174-5 is operating in continuous mode.

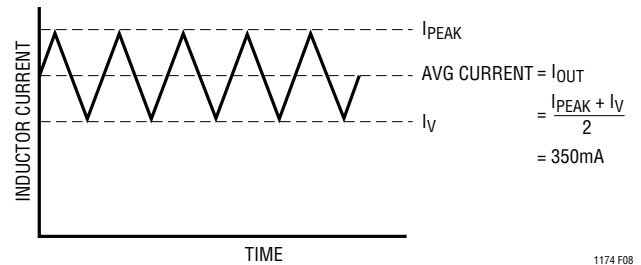


Figure 8. Continuous Inductor Current

With  $I_{OUT} = 350\text{mA}$  and  $I_{PEAK} = 0.6\text{A}$  ( $I_{PGM} = V_{IN}$ ),  $I_V = 0.1\text{A}$ . The peak-to-peak ripple inductor current,  $I_{RIPPLE}$ , is  $0.5\text{A}$  and is also equal to:

$$I_{RIPPLE} = 4 \cdot 10^{-6} \left( \frac{V_{OUT} + V_D}{L} \right) (A_{P-P})$$

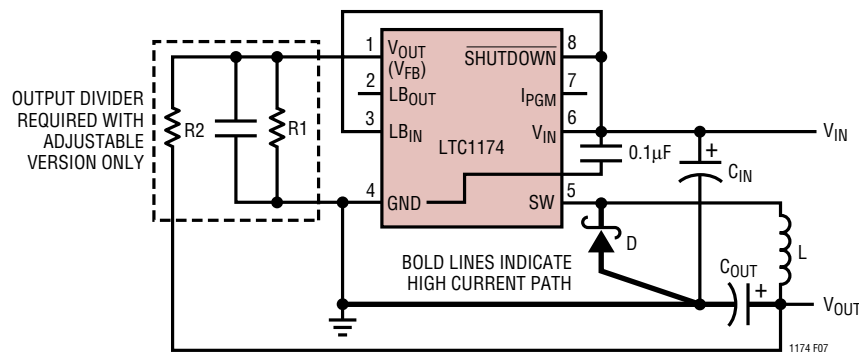


Figure 7. LTC1174 Layout Diagram (See Board Layout Checklist)

## APPLICATIONS INFORMATION

Solving for L in the above equation and with  $V_D = 0.6V$ ,  $L = 44.8\mu H$ . The next higher standard value of L is  $50\mu H$  (example: Coiltronics CTX50-4). The operating frequency, neglecting voltage across diode  $V_D$  is:

$$f \approx 2.5 \cdot 10^5 \left( 1 - \frac{V_{OUT}}{V_{IN}} \right) \\ = 111kHz$$

With the value of L determined, the requirements for  $C_{IN}$  and  $C_{OUT}$  are calculated. For  $C_{IN}$ , its RMS current rating should be at least:

$$I_{RMS} = \frac{I_{OUT} [V_{OUT}(V_{IN} - V_{OUT})]^{1/2}}{V_{IN}} \quad (A_{RMS}) \\ = 174mA$$

For  $C_{OUT}$ , the RMS current rating should be at least:

$$I_{RMS} \approx \frac{I_{PEAK}}{2} \quad (A_{RMS}) \\ = 300mA$$

Now allow  $V_{IN}$  to drop to 6V. At this minimum input voltage the operating frequency will decrease. The new frequency is 42kHz.

**Table 1. Inductor Manufacturers**

| MANUFACTURER                                                                                               | PART NUMBER                  |
|------------------------------------------------------------------------------------------------------------|------------------------------|
| Coilcraft<br>1102 Silver Lake Road<br>Cary, IL 60013<br>(708) 639-2361                                     | DT3316 Series                |
| Coiltronics Inc.<br>6000 Park of Commerce Blvd.<br>Boca Raton, FL 33487<br>(407) 241-7876                  | Econo-Pac<br>Octa-Pac        |
| Gowanda Electronics Corporation<br>1 Industrial Place<br>Gowanda, NY 14070<br>(716) 532-2234               | GA10 Series                  |
| Sumida Electric Co. Ltd.<br>637 E. Golf Road, Suite 209<br>Arlington Heights, IL 60005<br>(708) 956-0666/7 | CD 54 Series<br>CD 75 Series |

**Table 2. Capacitor Manufacturers**

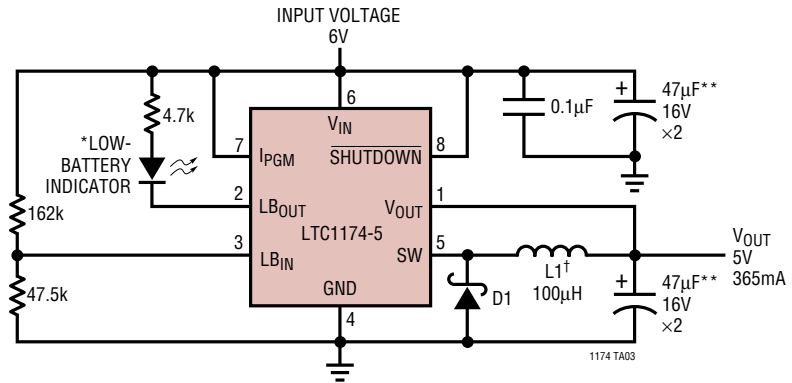
| MANUFACTURER                                                                                              | PART NUMBER              |
|-----------------------------------------------------------------------------------------------------------|--------------------------|
| AVX Corporation<br>P.O. Box 887<br>Myrtle Beach, SC 29578<br>(803) 448-9411                               | TPS Series<br>TAJ Series |
| Nichicon America Corporation<br>927 East State Parkway<br>Schaberg, IL 60173<br>(708) 843-7500            | PL Series                |
| Sanyo Video Components<br>2001 Sanyo Avenue<br>San Diego, CA 92173<br>(619) 661-6385<br>Attn: Sales Dept. | OS-CON Series            |

## TYPICAL APPLICATIONS

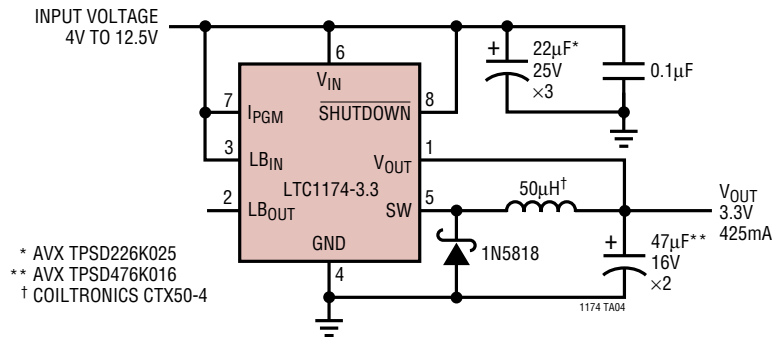
### 6V to 5V Step-Down Regulator with Low-Battery Detection

\* LOW-BATTERY INDICATOR  
IS SET TO TRIP AT  $V_{IN} = 5.5V$   
\*\* AVX TPSD476K016  
D1 = MBRS140T3 (SURFACE MOUNT)  
1N5818  
† L1 SELECTION

| MANUFACTURER | PART NO.  | TYPE          |
|--------------|-----------|---------------|
| COILTRONICS  | CTX100-4  | SURFACE MOUNT |
| SUMIDA       | CD75-101  | SURFACE MOUNT |
| GOWANDA      | GA10-103K | THROUGH HOLE  |



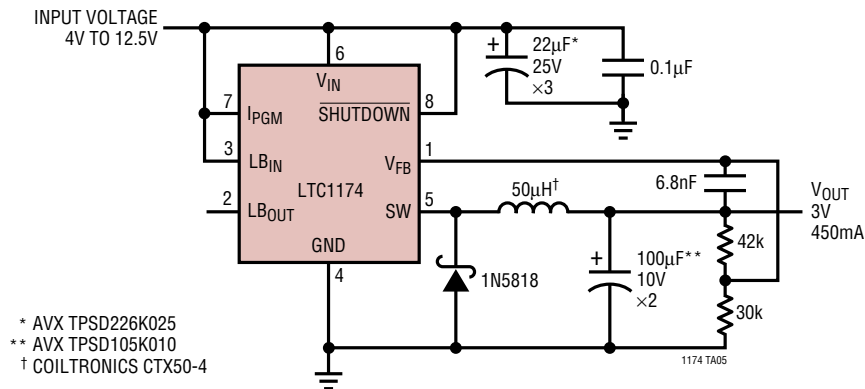
### High Efficiency 3.3V Regulator



\* AVX TPSD226K025  
\*\* AVX TPSD476K016  
† COILTRONICS CTX50-4

TYPICAL APPLICATIONS

Low Noise 3V Regulator



Positive-to-Negative (–5V) Converter

\* LOW-BATTERY INDICATOR  
IS SET TO TRIP AT  $V_{IN} = 4.4V$

\*\* AVX TPSD106K035

\*\*\* AVX TPSD105K010

D1 = MBR5130LT3 (SURFACE MOUNT)

† L1 SELECTION

1N5818

12.5

235

280k

43k

4.7K

10µF\*\*

35V

×2

0.1µF

100µF\*\*\*

10V

50µH

D1

L1†

SW

V<sub>OUT</sub>

–5V

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

1174 TA06

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1174 TA06

1174 TA06

1174 TA06

## TYPICAL APPLICATIONS

### Positive-to-Negative (–3.3V) Converter

\* LOW-BATTERY INDICATOR  
IS SET TO TRIP AT  $V_{IN} = 4.4V$

\*\* AVX TPSD336K020

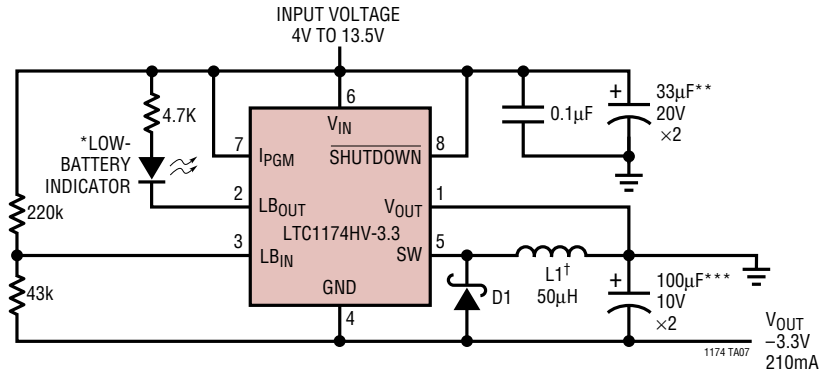
\*\*\* AVX TPSD105K010  
D1 = MBRS140T3 (SURFACE MOUNT)

† 1N5818

‡ L1 SELECTION

| $V_{IN}(V)$ | $I_{OUT MAX}(mA)$ |
|-------------|-------------------|
| 4           | 175               |
| 5           | 205               |
| 6           | 230               |
| 7           | 255               |

| MANUFACTURER | PART NO.   | TYPE          |
|--------------|------------|---------------|
| COILTRONICS  | CTX50-3    | SURFACE MOUNT |
| COILCRAFT    | DT3316-473 | SURFACE MOUNT |
| SUMIDA       | CD54-470   | SURFACE MOUNT |
| GOWANDA      | GA10-472K  | THROUGH HOLE  |



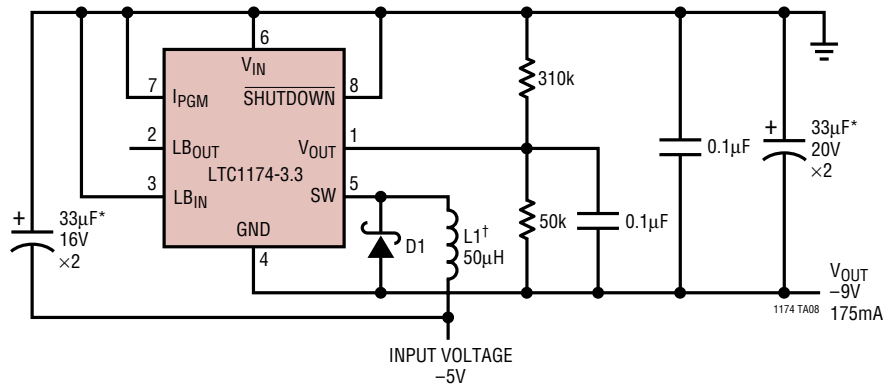
### Negative Boost Converter

\* AVX TPSD336K020

D1 = MBRS140T3 (SURFACE MOUNT)  
1N5818

† L1 SELECTION

| MANUFACTURER | PART NO.   | TYPE          |
|--------------|------------|---------------|
| COILTRONICS  | CTX50-3    | SURFACE MOUNT |
| COILCRAFT    | DT3316-473 | SURFACE MOUNT |
| SUMIDA       | CD54-470   | SURFACE MOUNT |
| GOWANDA      | GA10-472K  | THROUGH HOLE  |



# LTC1174

## LTC1174-3.3/LTC1174-5

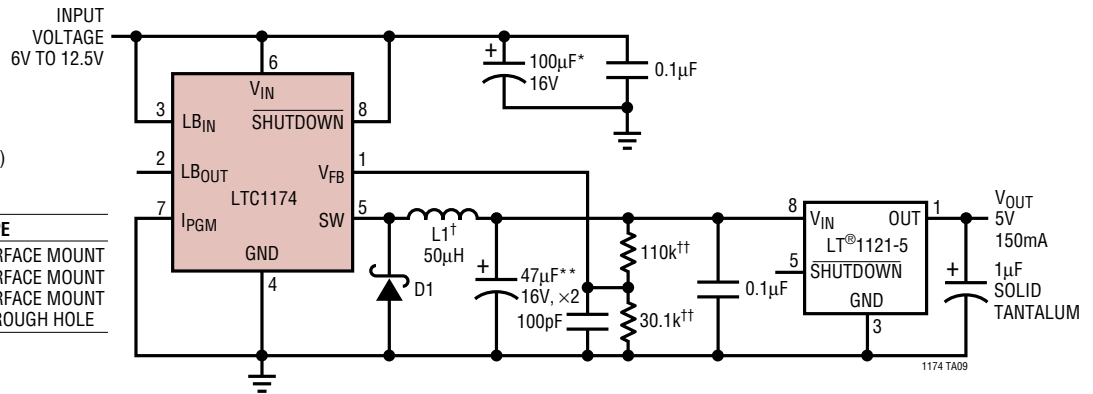
### TYPICAL APPLICATIONS

#### 9V to 5V Pre-Post Regulator

\* SANYO OS-CON  
 \*\* AVX TPSD476K016  
 D1 = MBRS140T3 (SURFACE MOUNT)  
 1N5818  
 † L1 SELECTION

| MANUFACTURER | PART NO.   | TYPE          |
|--------------|------------|---------------|
| COILTRONICS  | CTX50-3    | SURFACE MOUNT |
| COILCRAFT    | DT3316-473 | SURFACE MOUNT |
| SUMIDA       | CD54-470   | SURFACE MOUNT |
| GOWANDA      | GA10-472K  | THROUGH HOLE  |

†† USE 1% METAL FILM RESISTORS



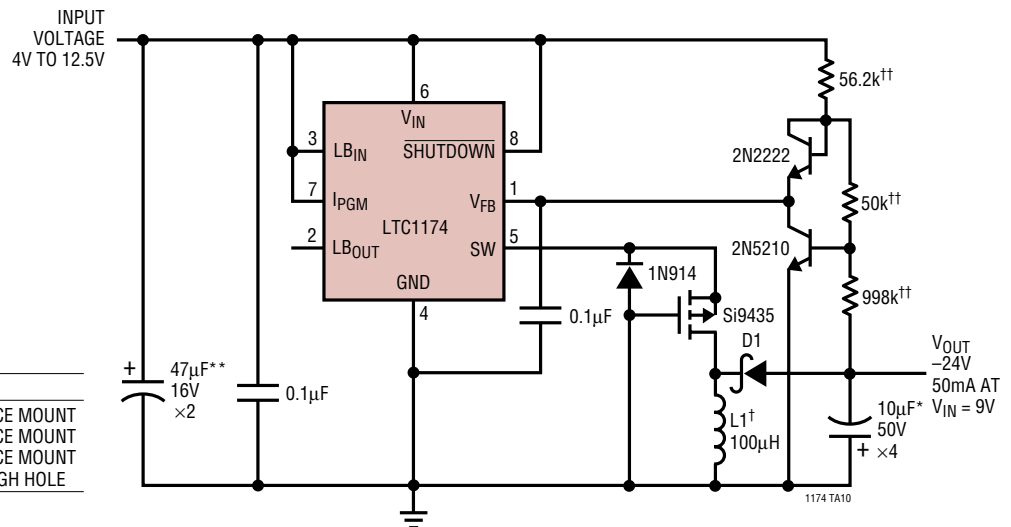
#### LCD Display Power Supply

| V <sub>IN</sub> (V) | I <sub>OUT</sub> MAX(mA) |
|---------------------|--------------------------|
| 4                   | 20                       |
| 5                   | 25                       |
| 6                   | 30                       |
| 7                   | 35                       |
| 8                   | 43                       |
| 9                   | 50                       |
| 10                  | 55                       |
| 11                  | 60                       |
| 12                  | 65                       |

\* AVX TAJE106K050  
 \*\* AVX TPSD476K016  
 D1 = MBRS140T3 (SURFACE MOUNT)  
 1N5818  
 † L1 SELECTION

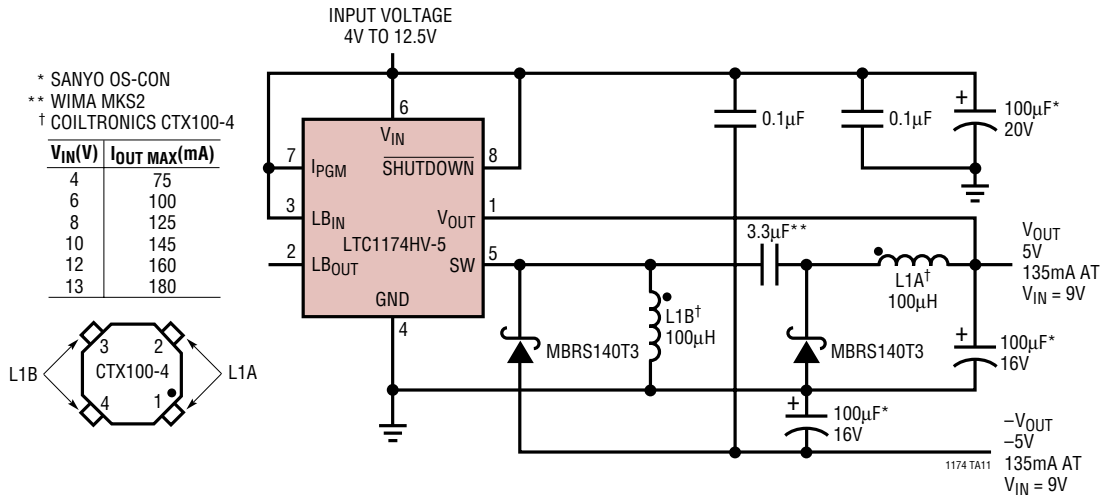
| MANUFACTURER | PART NO.   | TYPE          |
|--------------|------------|---------------|
| COILTRONICS  | CTX100-3   | SURFACE MOUNT |
| COILCRAFT    | DT3316-104 | SURFACE MOUNT |
| SUMIDA       | CD75-101   | SURFACE MOUNT |
| GOWANDA      | GA10-103K  | THROUGH HOLE  |

†† USE 1% METAL FILM RESISTORS

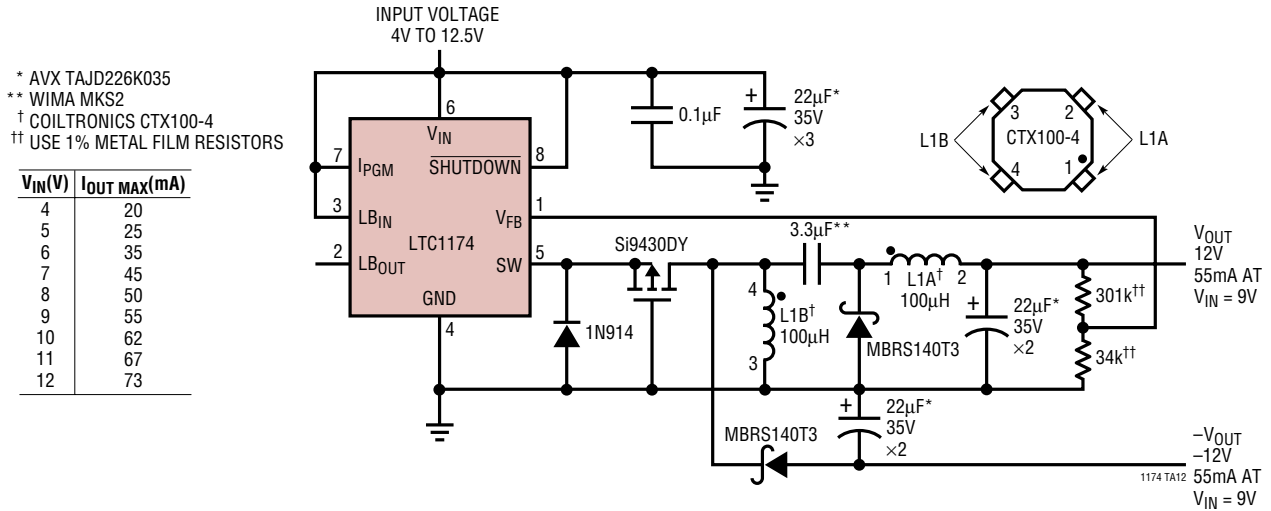


## TYPICAL APPLICATIONS

### 9V to 5V, -5V Outputs

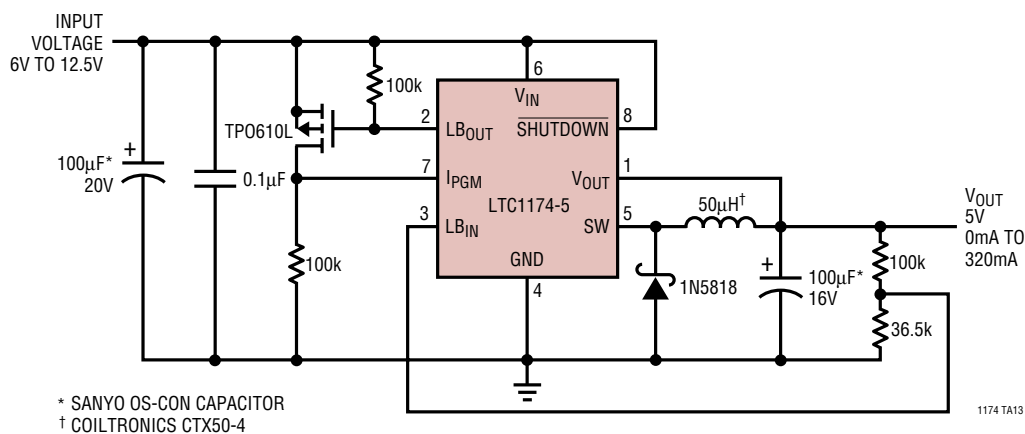


### 9V to 12V, -12V Outputs

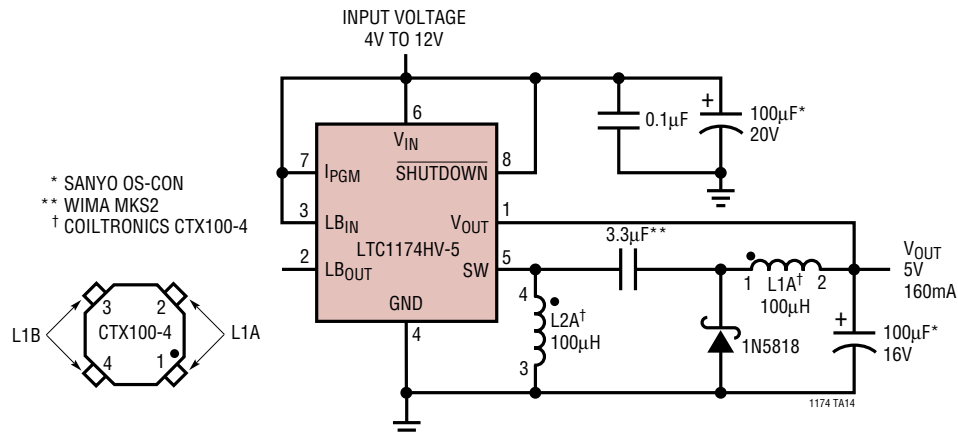


### TYPICAL APPLICATIONS

#### Automatic Current Selection

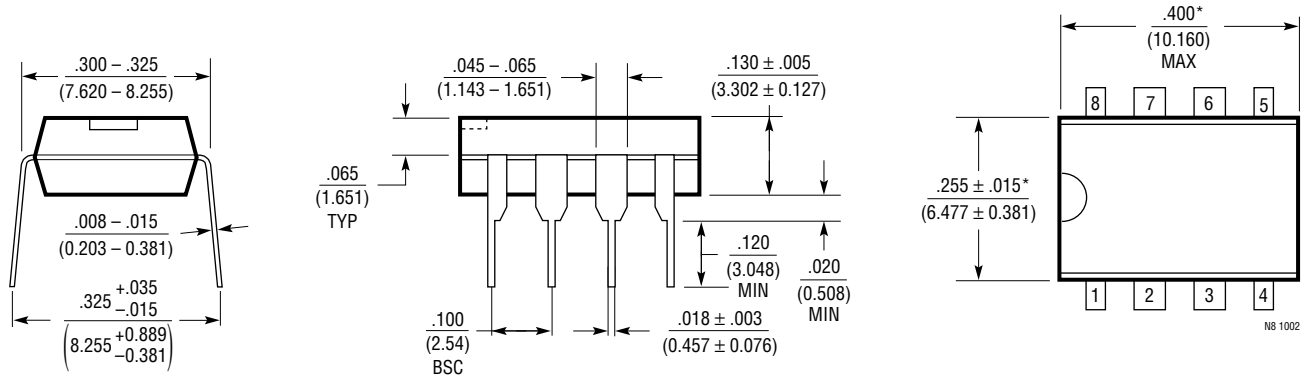


#### Buck-Boost Converter



## PACKAGE DESCRIPTION

### N8 Package 8-Lead PDIP (Narrow .300 Inch) (Reference LTC DWG # 05-08-1510)

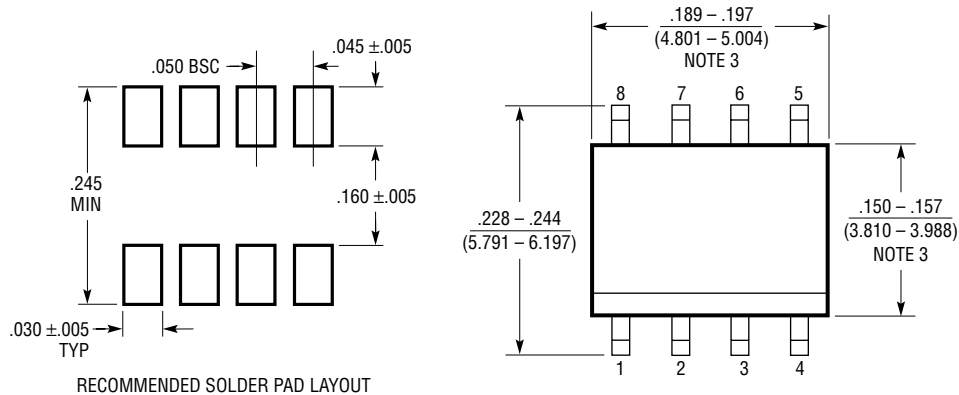


NOTE:

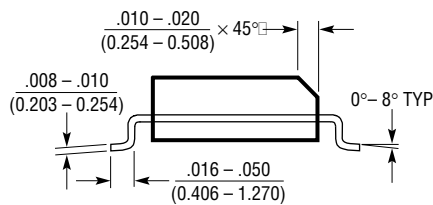
1. DIMENSIONS ARE  $\frac{\text{INCHES}}{\text{MILLIMETERS}}$

\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

### S8 Package 8-Lead Plastic Small Outline (Narrow .150 Inch) (Reference LTC DWG # 05-08-1610)



RECOMMENDED SOLDER PAD LAYOUT



NOTE:

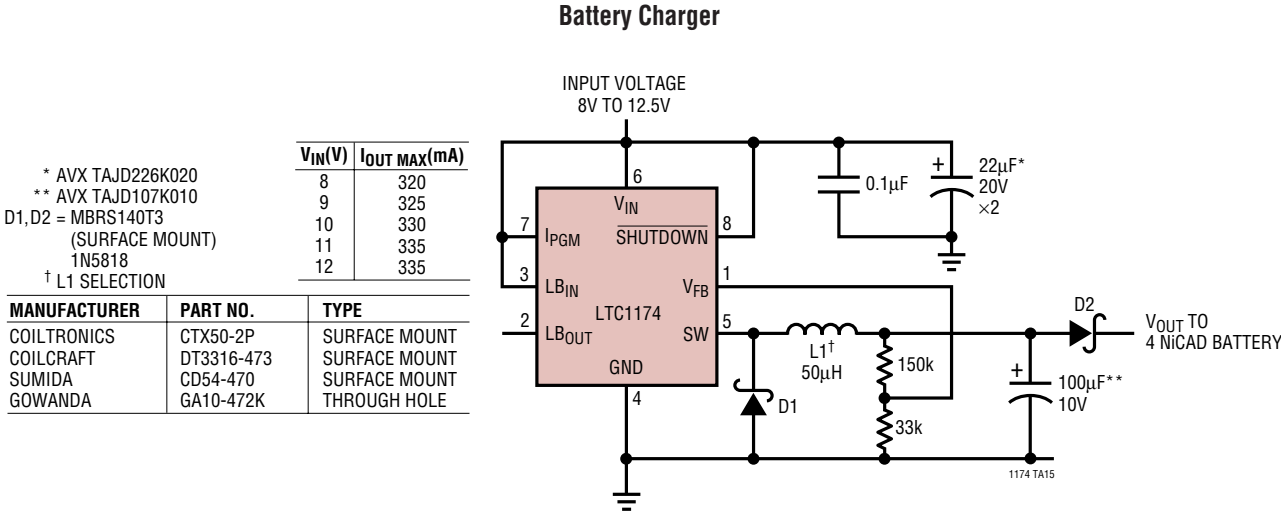
1. DIMENSIONS IN  $\frac{\text{INCHES}}{\text{MILLIMETERS}}$

2. DRAWING NOT TO SCALE

3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

S08 0303

TYPICAL APPLICATION



RELATED PARTS

| PART NUMBER                 | DESCRIPTION                                     | COMMENTS                                                                                            |
|-----------------------------|-------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| LT <sup>®</sup> 1074/LT1076 | Step-Down Switching Regulator                   | 100kHz, 5A (LT1074) or 2A (LT1076) Monolithic                                                       |
| LTC1147                     | High Efficiency Step-Down DC/DC Controller      | 8-Pin Controller                                                                                    |
| LTC1265                     | 1.2A High Efficiency Step-Down DC/DC Regulator  | Burst Mode Operation, Monolithic                                                                    |
| LT1375/LT1376               | 1.5A 500kHz Step-Down Switching Regulator       | High Frequency Small Inductor                                                                       |
| LTC1574                     | High Efficiency Step-Down DC/DC Regulator       | LTC1174 with Internal Schottky Diode                                                                |
| LT1611                      | Inverting 1.4MHz Switching Regulator in SOT-23  | –5V at 150mA from 5V Input, 1mV <sub>P-P</sub> Output Ripple, SOT-23 Package                        |
| LTC1701                     | 1MHz Step-Down DC/DC Converter in SOT-23        | V <sub>IN</sub> = 2.5V to 5.5V, I <sub>Q</sub> = 135µA, V <sub>OUT</sub> = 5V to 1.25V              |
| LTC1707                     | High Efficiency Synchronous Step-Down Regulator | V <sub>IN</sub> = 2.85 to 8.5V, Selectable Burst Mode Operation, 600mA Output Current, SO-8 Package |
| LTC1877                     | High Efficiency Synchronous Step-Down Regulator | 600mA at V <sub>IN</sub> = 5V, 2.65V to 10V = V <sub>IN</sub> , I <sub>Q</sub> = 10µA               |