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 0.9Ω Power Switch: V_{IN} = 9V
- Only Four External Components Required
- 130µA 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®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 0.9Ω 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 130µA. In shutdown, it draws a mere 1µA 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.

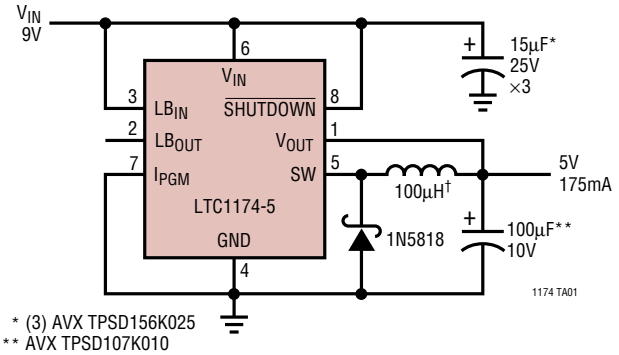
The maximum inductor current of the LTC1174 family is pin selectable to either 340mA or 600mA, optimizing efficiency for a wide range of applications. Operation up to 200kHz permits the use of small surface mount inductors and capacitors.

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

and LTC are registered trademarks and LT is a trademark of Linear Technology Corporation.

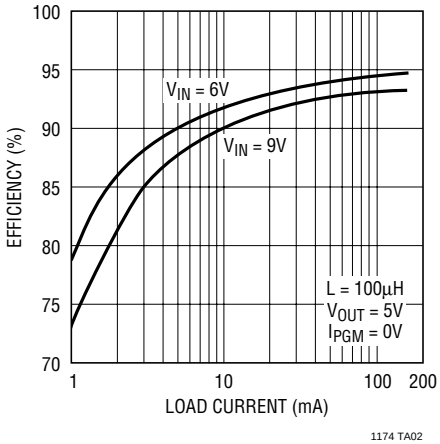
TYPICAL APPLICATION

High Efficiency Step-Down Converter



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

LTC1174-5 Efficiency

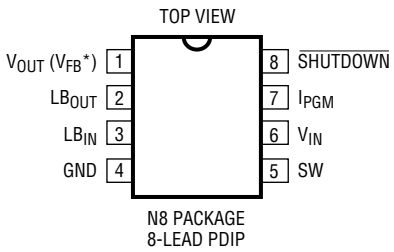


ABSOLUTE MAXIMUM RATINGS (Note 1)

(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

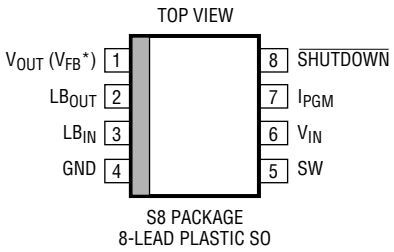


N8 PACKAGE
8-LEAD PDIP

* ADJUSTABLE OUTPUT VERSION

T_{JMAX} = 125°C, θ_{JA} = 110°C/W

ORDER PART NUMBER
LTC1174CN8
LTC1174CN8-3.3
LTC1174CN8-5
LTC1174IN8
LTC1174HVCN8
LTC1174HVCN8-3.3
LTC1174HVCN8-5



S8 PACKAGE
8-LEAD PLASTIC SO

* ADJUSTABLE OUTPUT VERSION

T_{JMAX} = 125°C, θ_{JA} = 150°C/W

ORDER PART NUMBER
LTC1174CS8
LTC1174CS8-3.3
LTC1174CS8-5
LTC1174IS8
LTC1174HVCS8
LTC1174HVCS8-3.3
LTC1174HVCS8-5
LTC1174HVIS8

S8 PART MARKING	
1174	1174HV
117433	1174H3
117450	1174H5
1174I	1174HI

Consult factor for Military grade parts.

ELECTRICAL CHARACTERISTICS

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

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
I_{FB}	Feedback Current	LTC1174/LTC1174HV				1	µA
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
ΔV_{OUT}	Output Voltage Line Regulation	V_{IN} = 6V to 12V, I_{LOAD} = 100mA, I_{PGM} = V_{IN} (Note 3)			10	70	mV
	Output Voltage Load Regulation	LTC1174-3.3 (Note 3)					
		20mA < I_{LOAD} < 175mA, I_{PGM} = 0V			–5	–70	mV
		20mA < I_{LOAD} < 400mA, I_{PGM} = V_{IN}			–45	–70	mV
		LTC1174-5 (Note 3)					
		20mA < I_{LOAD} < 175mA, I_{PGM} = 0V			–5	–70	mV
		20mA < I_{LOAD} < 400mA, I_{PGM} = V_{IN}			–50	–70	mV

ELECTRICAL CHARACTERISTICS

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

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

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at –40°C ≤ T_A ≤ 85°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} = 0.4V (LTC1174I)	●	0.75	1.2	2.0	mA
		V_{LBOUT} = 0.4V (LTC1174HVI)	●	0.50	0.8	1.6	mA
I_{PEAK}	Current Limit	I_{PGM} = V_{IN}, V_{OUT} = 0V (LTC1174I)	●	0.54	0.60	0.84	A
		I_{PGM} = 0V, V_{OUT} = 0V (LTC1174I)			0.34		A
		I_{PGM} = V_{IN}, V_{OUT} = 0V (LTC1174HVI)	●	0.5	0.60	0.86	A
		I_{PGM} = 0V, V_{OUT} = 0V (LTC1174HVI)			0.34		A
t_{OFF}	Switch Off-Time (Note 6)	V_{OUT} at Regulated Value (LTC1174I)	●	2.0	4	6.0	µs
		V_{OUT} at Regulated Value (LTC1174HVI)	●	1.8	4	6.2	µs
R_{ON}	Switch On Resistance	LTC1174I/LTC1174HVI	●		0.9	1.7	Ω

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

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:

$T_J = T_A + (P_D \times 110°C/W)$

LTC1174CS8, LTC1174CS8-3.3, LTC1174CS8-5:

$T_J = T_A + (P_D \times 150°C/W)$

Note 3: Guaranteed by design.

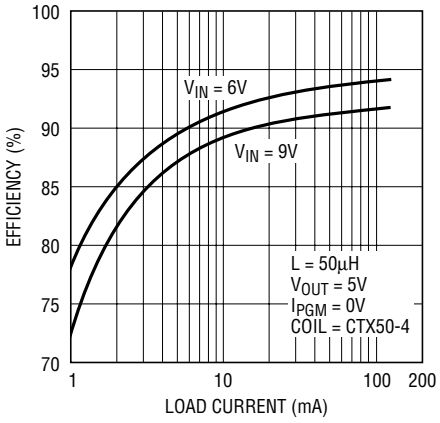
Note 4: Dynamic supply current is higher due to the gate charge being delivered at the switching frequency.

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

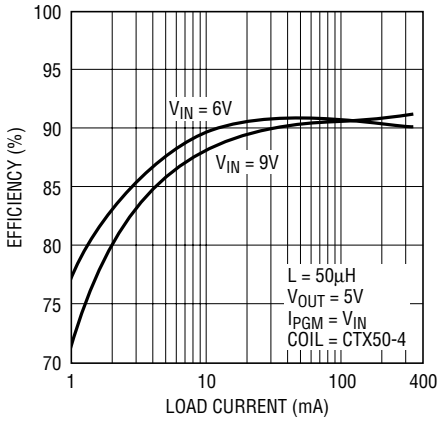
Note 6: The off-time is wafer-sort trimmed.

TYPICAL PERFORMANCE CHARACTERISTICS

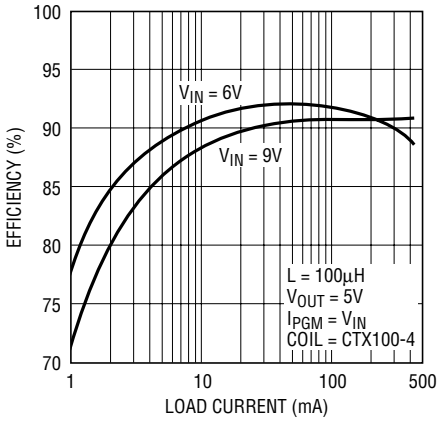
Efficiency vs Load Current



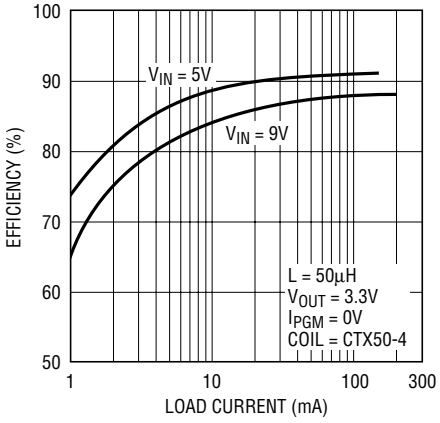
Efficiency vs Load Current



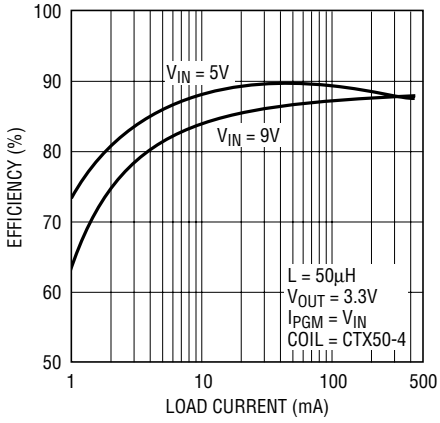
Efficiency vs Load Current



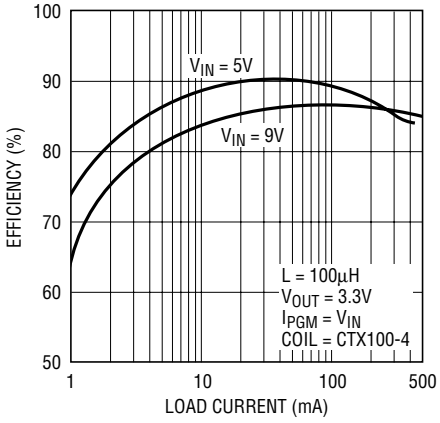
Efficiency vs Load Current



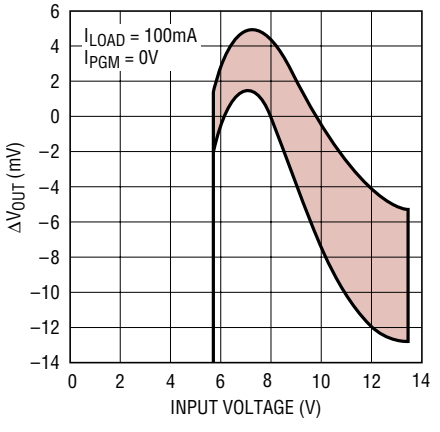
Efficiency vs Load Current



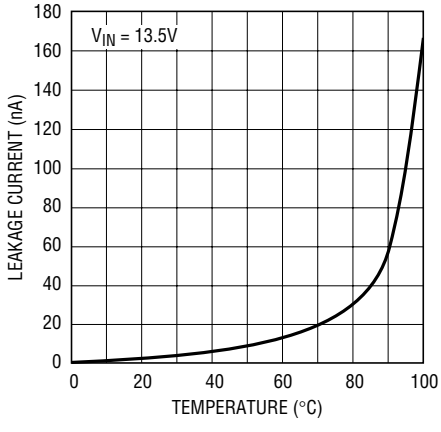
Efficiency vs Load Current



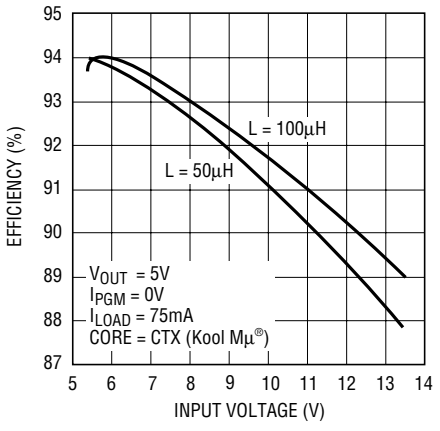
Line Regulation



Switch Leakage Current vs Temperature



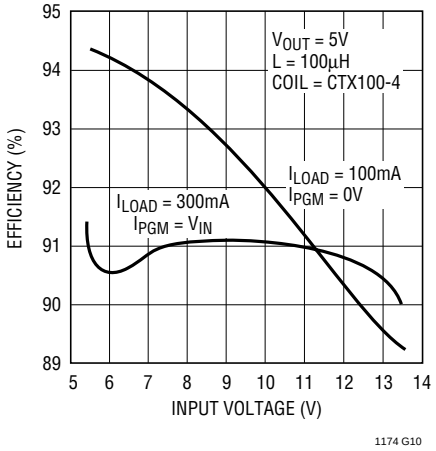
Efficiency vs Input Voltage



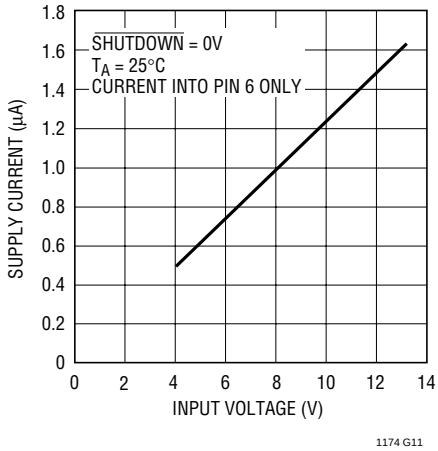
Kool Mµ is a registered trademark of Magnetics, Inc.

TYPICAL PERFORMANCE CHARACTERISTICS

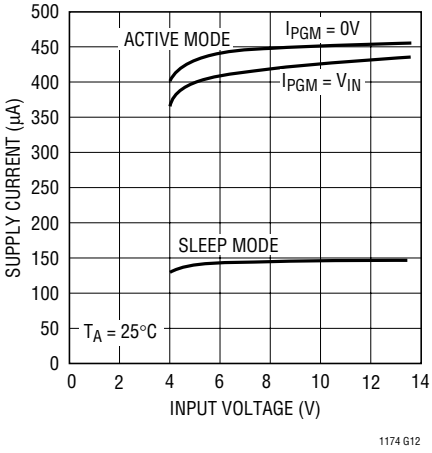
Efficiency vs Input Voltage



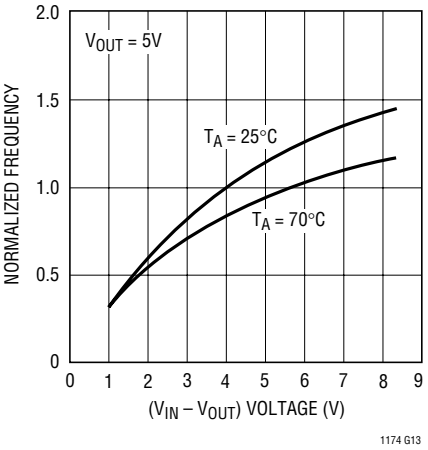
Supply Current in Shutdown



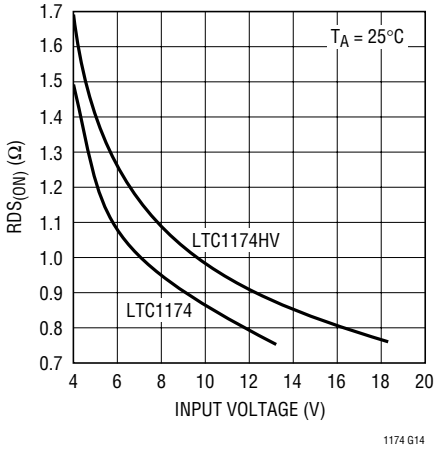
DC Supply Current



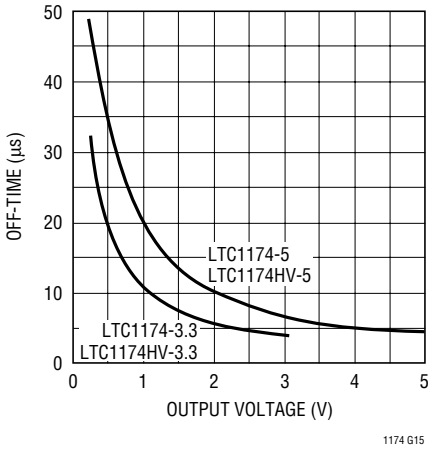
Operating Frequency vs $V_{IN} - V_{OUT}$



Switch Resistance vs Input Voltage



Off-Time vs Output Voltage



PIN FUNCTIONS

V_{OUT} (V_{FB}) (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_{OUT} (Pin 2): Open Drain of an N-Channel Pull-Down. This pin will sink current when Pin 3 (LB_{IN}) goes below 1.25V. During shutdown the state of this pin is indeterminate.

LB_{IN} (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.

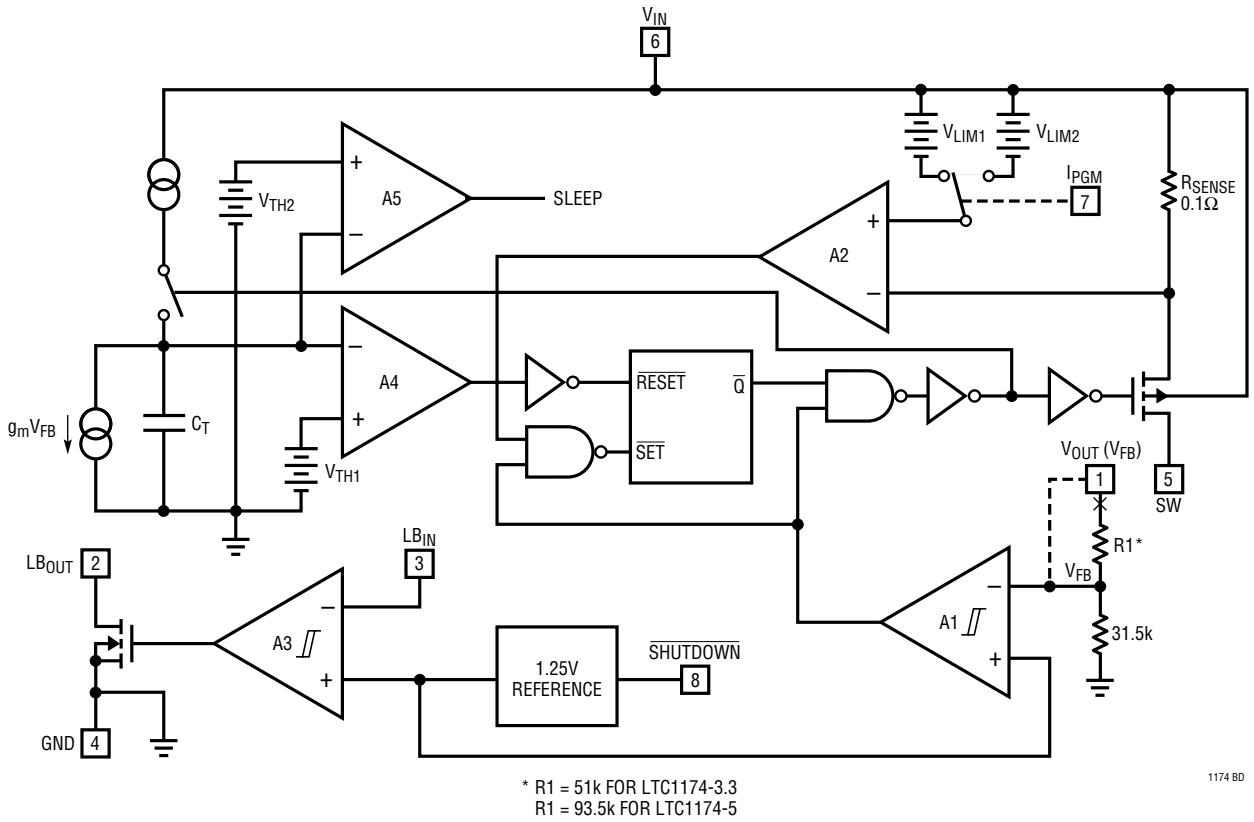
SW(Pin5): Drain of the P-Channel MOSFET Switch. Cathode of Schottky diode must be closely connected to this pin.

V_{IN} (Pin 6): Input Supply Voltage. It must be decoupled close to ground Pin 4.

I_{PGM} (Pin 7): Selects the Current Limit of the P-Channel Switch. With $I_{PGM} = V_{IN}$, the current trip point is 600mA and with $I_{PGM} = 0V$, the current trip value is reduced to 340mA.

$\overline{\text{SHUTDOWN}}$ (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

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™ 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 0.1Ω 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

Burst Mode is a trademark of Linear Technology Corporation.

OPERATION (Refer to Functional Diagram)

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:

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

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

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

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.

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 Mμ 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 Mμ and the CTXP 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_{IN}

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

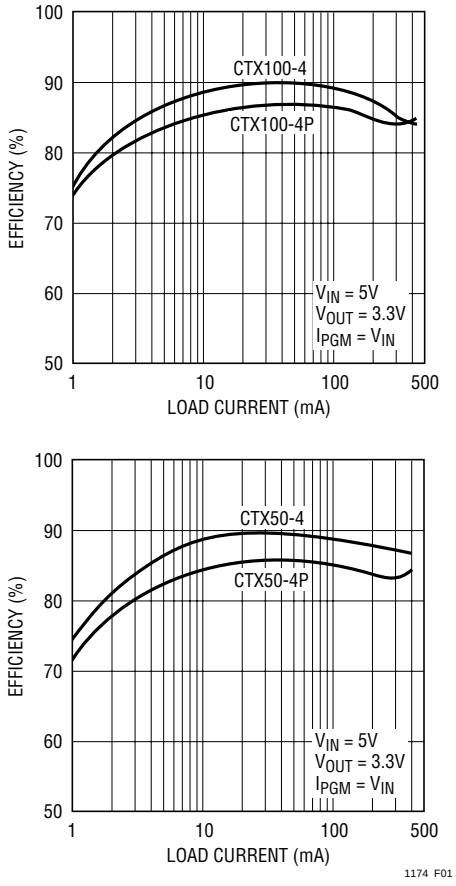


Figure 1. Efficiency Using Different Types of Inductor Core Material

APPLICATIONS INFORMATION

the maximum RMS current must be used. The C_{IN} RMS current is given by:

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

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 0.1µF ceramic capacitor is also required on V_{IN} for high frequency decoupling.

C_{OUT}

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.

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 MBRS140T3 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).

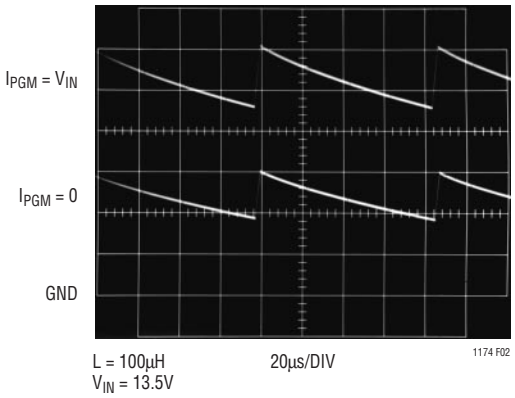


Figure 2. Inductor's Current with Output Shorted

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.

APPLICATIONS INFORMATION

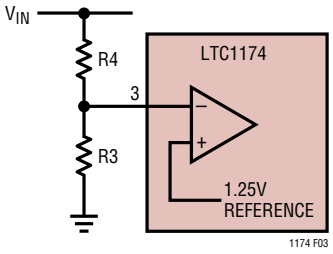


Figure 3. Low-Battery Comparator

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.

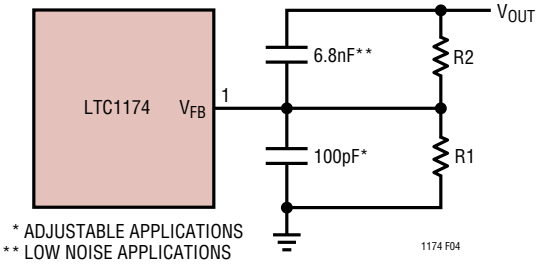


Figure 4. LTC1174 Adjustable Configuration

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 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.

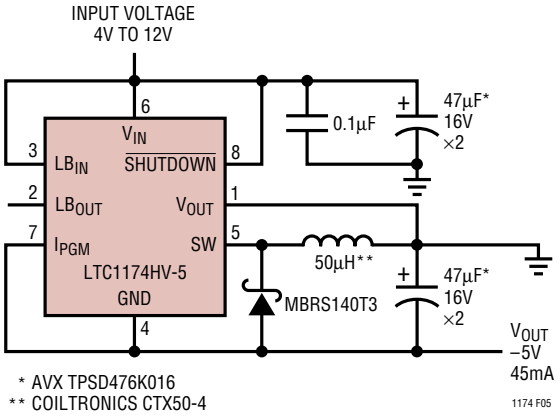


Figure 5. Positive-to-Negative 5V Converter

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.

APPLICATIONS INFORMATION

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 occuring, a resistor must be connected between V_{OUT} and ground with a value low enough to sink the maximum possible leakage current.

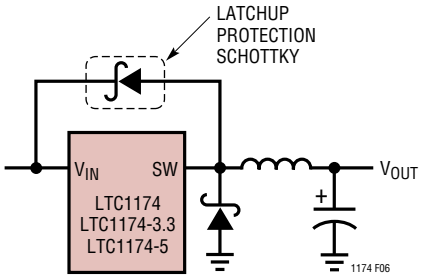


Figure 6. Preventing Absolute Maximum Ratings from Being Exceeded

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 0.1µF V_{IN} decoupling capacitor *closely* conected between V_{IN} (Pin 6) and ground (Pin 4)? This capacitor carries the high frequency peak currents.
4. Is the $\overline{\text{SHUTDOWN}}$ (Pin 8) actively pulled to V_{IN} during normal operation? The $\overline{\text{SHUTDOWN}}$ 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.

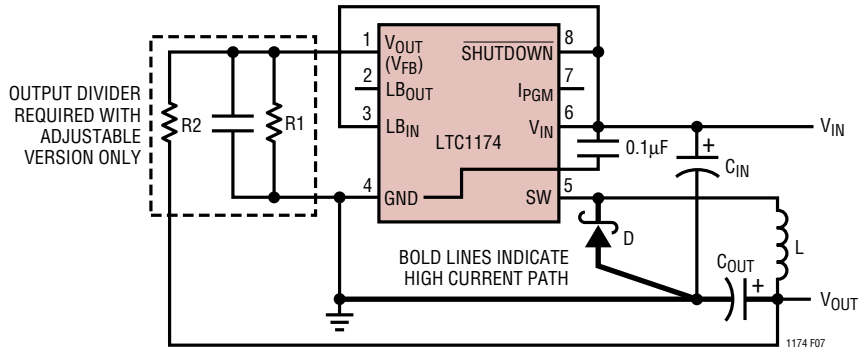


Figure 7. LTC1174 Layout Diagram (See Board Layout Checklist)

APPLICATIONS INFORMATION

DESIGN EXAMPLE

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

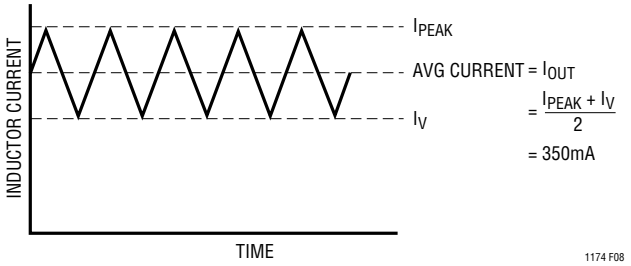


Figure 8. Continuous Inductor Current

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

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

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

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

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:

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

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

Table 2. Capacitor Manufacturers

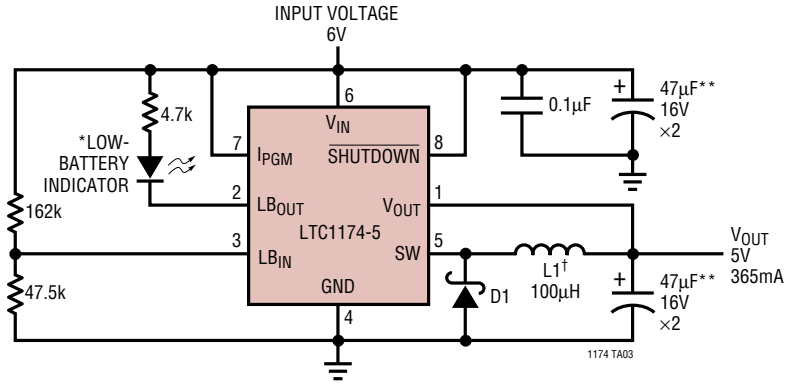
MANUFACTURER	PART NUMBER
AVX Corporation P.O. Box 887 Myrtle Beach, SC 29578 (803) 448-9411	TPS Series TAJ Series
Nichicon America Corporation 927 East State Parkway Schaberg, IL 60173 (708) 843-7500	PL Series
Sanyo Video Components 2001 Sanyo Avenue San Diego, CA 92173 (619) 661-6385 Attn: Sales Dept.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

TYPICAL APPLICATIONS

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

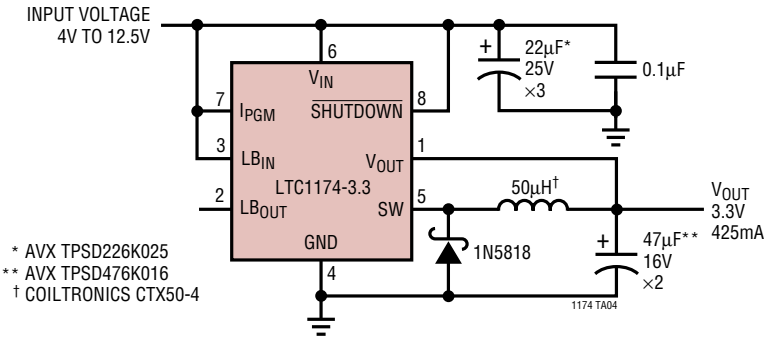
* LOW-BATTERY INDICATOR
IS SET TO TRIP AT V_{IN} = 5.5V
** AVX TPSD476K016
D1 = MBRS140T3 (SURFACE MOUNT)
1N5818
† L1 SELECTION

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



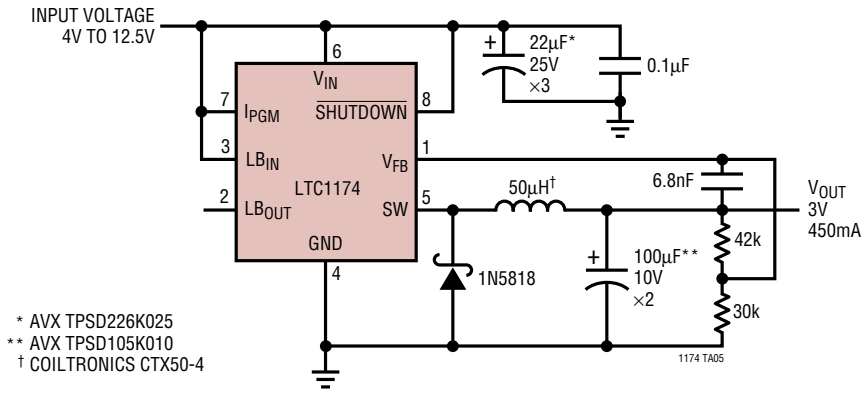
High Efficiency 3.3V Regulator

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



TYPICAL APPLICATIONS

Low Noise 3V Regulator

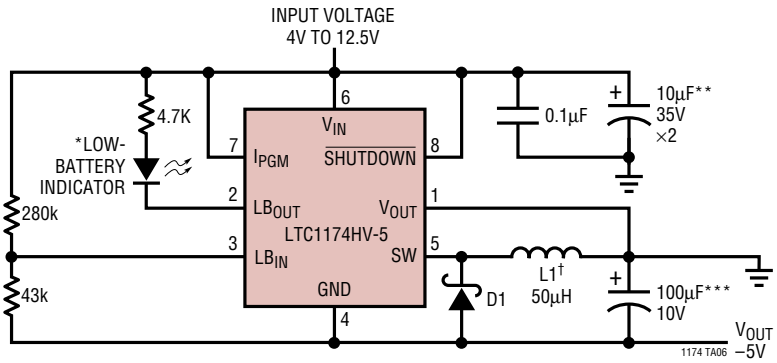


Positive-to-Negative (–5V) Converter

* LOW-BATTERY INDICATOR IS SET TO TRIP AT V_{IN} = 4.4V
** AVX TPSD106K035
*** AVX TPSD105K010
D1 = MBRS130LT3 (SURFACE MOUNT) 1N5818
† L1 SELECTION

V_{IN}(V)	$I_{OUT\ MAX}$(mA)
4	110
6	140
8	170
10	200
12.5	235

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



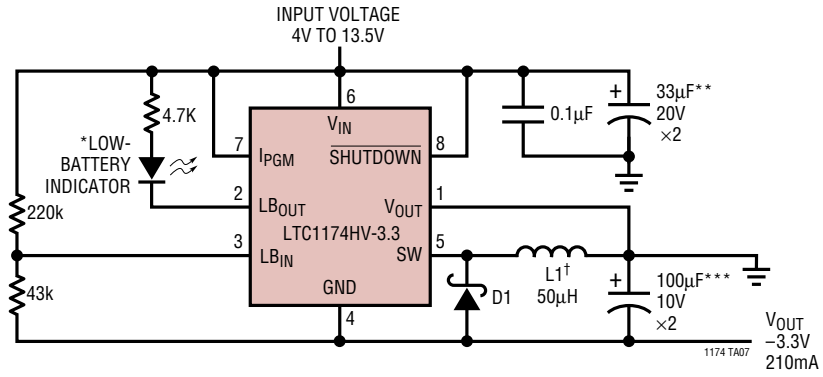
TYPICAL APPLICATIONS

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

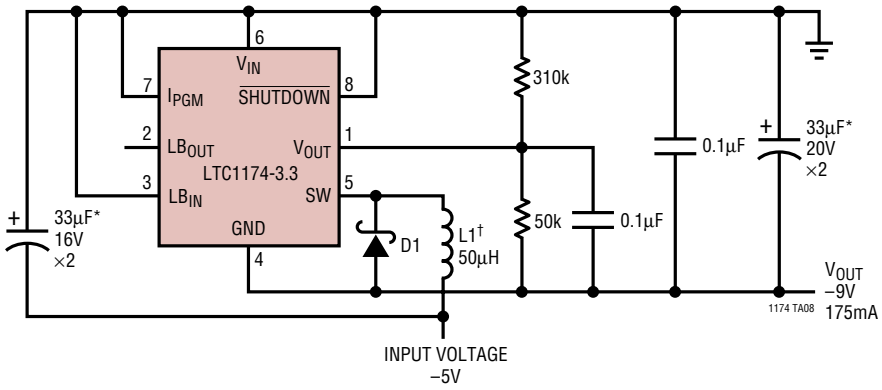
MANUFACTURER	PART NO.	TYPE
COILTRONICS	CTX50-3	SURFACE MOUNT
COILCRAFT	DT3316-473	SURFACE MOUNT
SUMIDA	CD54-470	SURFACE MOUNT
GOWANDA	GA10-472K	THROUGH HOLE



Negative Boost Converter

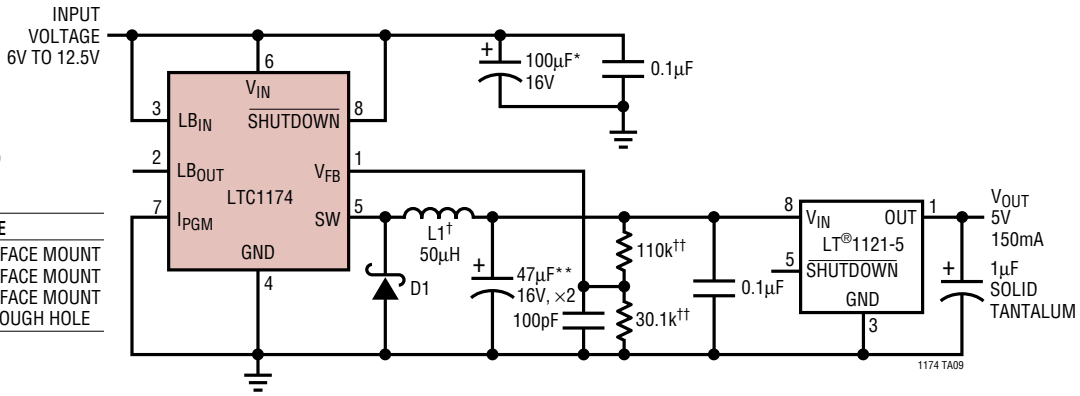
* AVX TPSD336K020
D1 = MBRS140T3 (SURFACE MOUNT)
1N5818
† L1 SELECTION

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



TYPICAL APPLICATIONS

9V to 5V Pre-Post Regulator

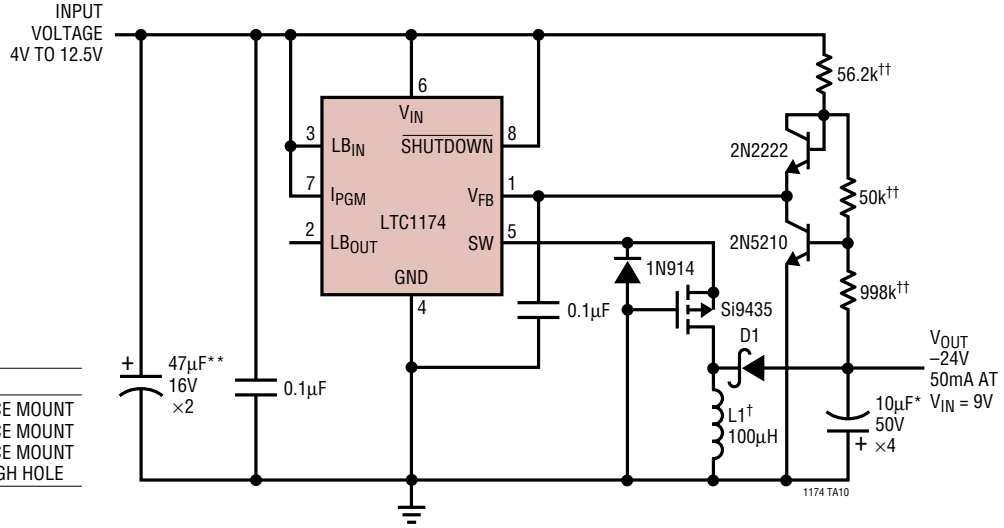


* SANYO OS-CON
** AVX TPSD476K016
D1 = MBRS140T3 (SURFACE MOUNT)
1N5818
† L1 SELECTION

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_{IN}(V)	$I_{OUT\ MAX}$(mA)
4	20
5	25
6	30
7	35
8	43
9	50
10	55
11	60
12	65

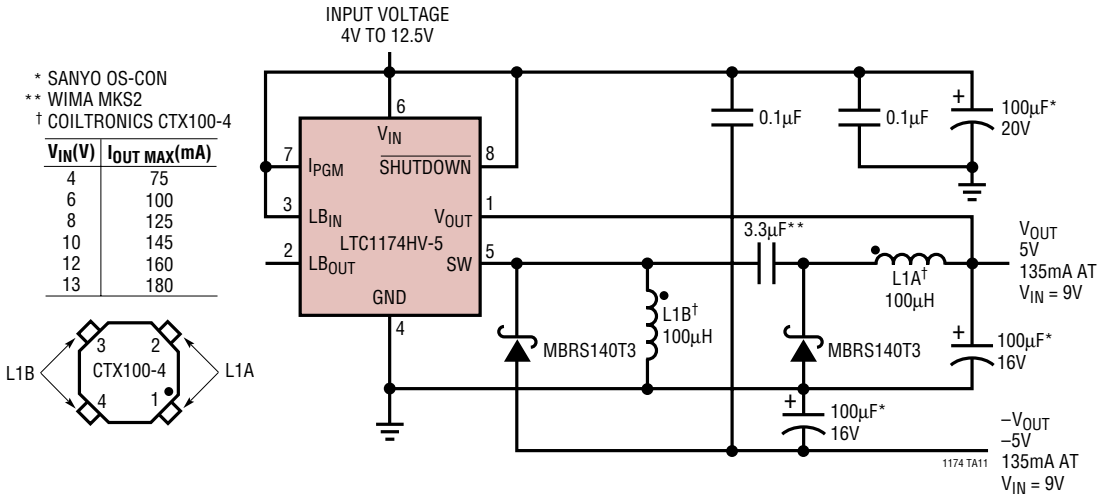
* AVX TAJE106K050
** AVX TPSD476K016
D1 = MBRS140T3 (SURFACE MOUNT)
1N5818
† L1 SELECTION

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

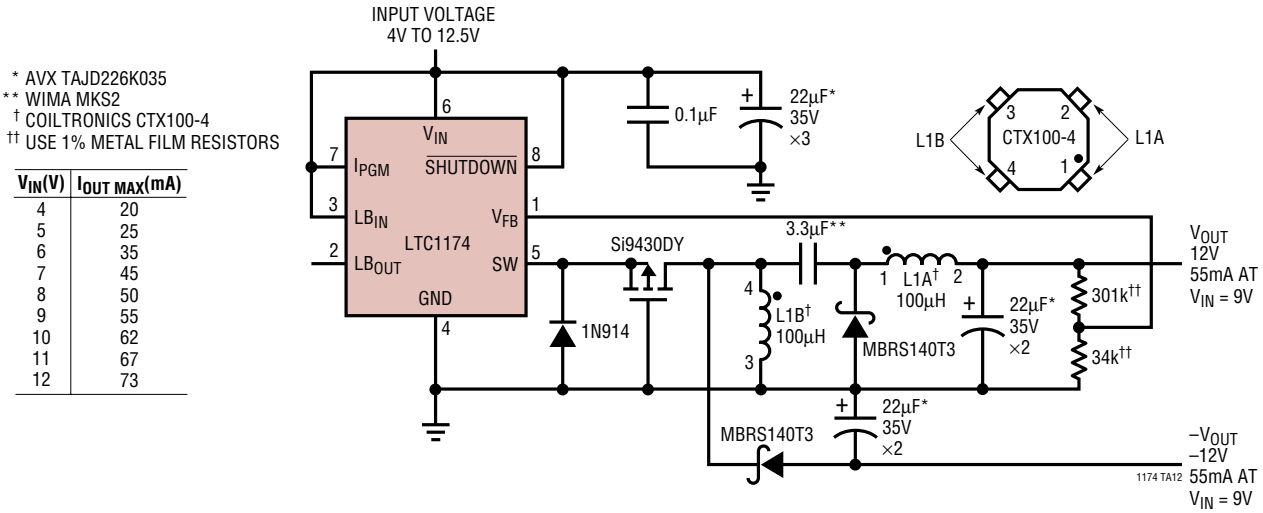
†† USE 1% METAL FILM RESISTORS

TYPICAL APPLICATIONS

9V to 5V, –5V Outputs

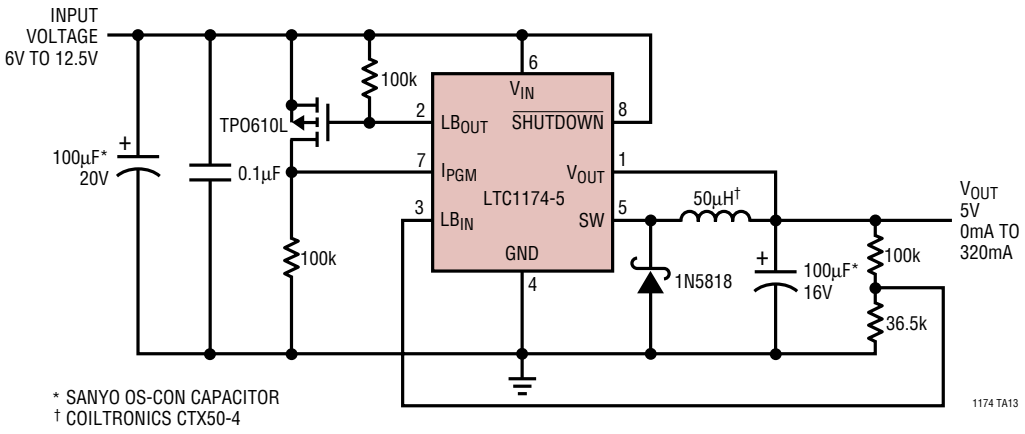


9V to 12V, –12V Outputs

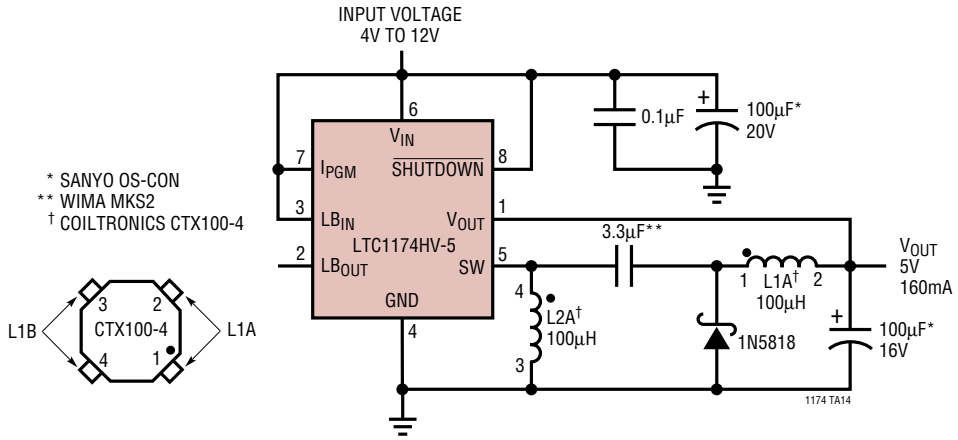


TYPICAL APPLICATIONS

Automatic Current Selection



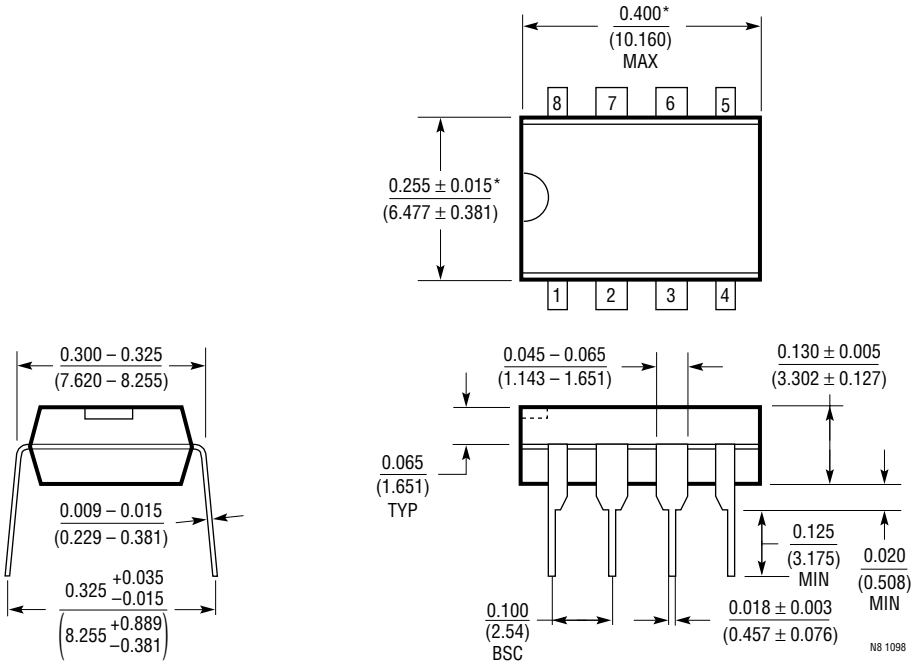
Buck-Boost Converter



PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

N8 Package
8-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)

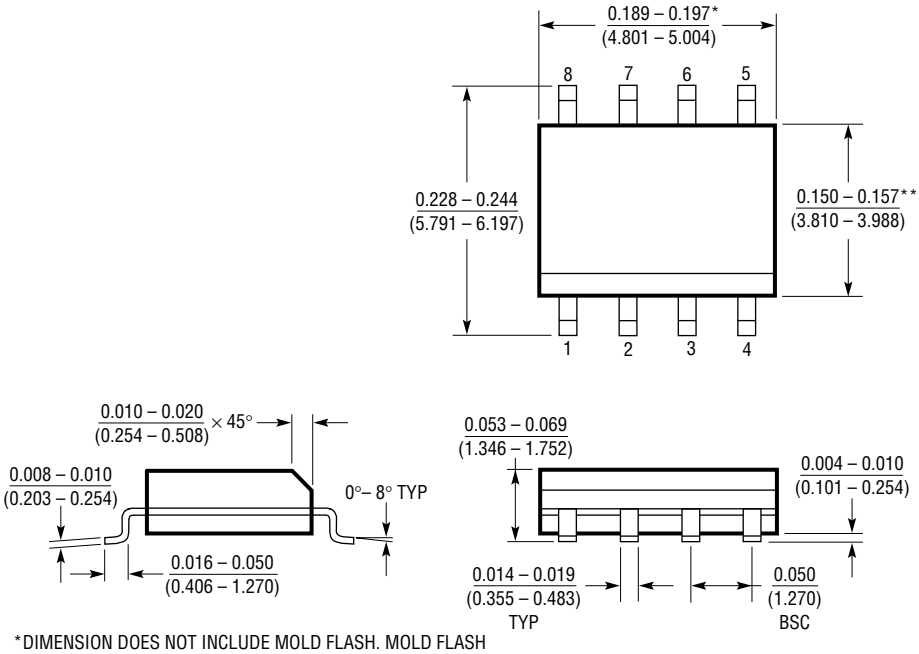


*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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

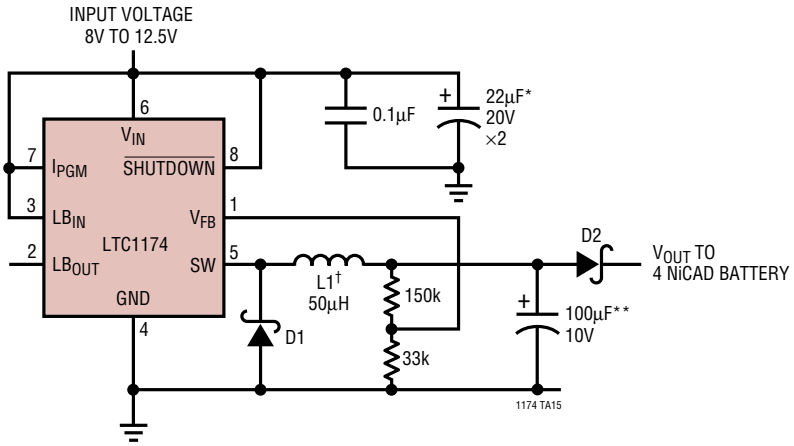
**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

S08 1298

Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

TYPICAL APPLICATION

Battery Charger



* AVX TAJD226K020
** AVX TAJD107K010
D1, D2 = MBRS140T3
(SURFACE MOUNT)
1N5818
† L1 SELECTION

V_{IN}(V)	$I_{OUT\ MAX}$(mA)
8	320
9	325
10	330
11	335
12	335

MANUFACTURER	PART NO.	TYPE
COILTRONICS	CTX50-2P	SURFACE MOUNT
COILCRAFT	DT3316-473	SURFACE MOUNT
SUMIDA	CD54-470	SURFACE MOUNT
GOWANDA	GA10-472K	THROUGH HOLE

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT®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_{P-P} Output Ripple, SOT-23 Package
LTC1701	1MHz Step-Down DC/DC Converter in SOT-23	V_{IN} = 2.5V to 5.5V, I_Q = 135µA, V_{OUT} = 5V to 1.25V
LTC1707	High Efficiency Synchronous Step-Down Regulator	V_{IN} = 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_{IN} = 5V, 2.65V to 10V = V_{IN}, I_Q = 10µA

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