# Micropower High Efficiency 5V/12V Step-Up DC/DC Converter for Flash Memory

## FEATURES

- **12V at 120mA from 5V or 3.3V Supply**
- Supply Voltage as Low as 1.8V
- Better High Current Efficiency Than CMOS
- Up to 89% Efficiency
- **120μA Quiescent Current**
- Shutdown to 10μA
- Programmable 5V or 12V Output
- Low $V_{CESAT}$ Switch: 170mV at 1A Typical
- $I_{LIM}$ Pin Programs Peak Switch Current
- Uses Inexpensive Surface Mount Inductors
- 8-Lead DIP or SOIC Package

## APPLICATIONS

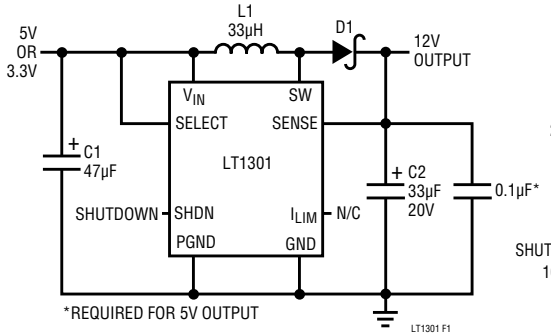
- Flash Memory $V_{PP}$ Generator
- Palmtop Computers
- Portable Instruments
- Bar-Code Scanners
- Personal Digital Assistants
- PCMCIA Cards

## DESCRIPTION

The LT1301 is a micropower step-up DC/DC converter that utilizes Burst Mode™ operation. The device can deliver 5V or 12V from a two-cell battery input. It features programmable 5V or 12V output via a logic-controlled input, no-load quiescent current of 120μA and a shutdown pin which reduces supply current to 10μA. The on-chip power switch has a low 170mV saturation voltage at a switch current of 1A, a four-fold reduction over prior designs. A 155kHz internal oscillator allows the use of extremely small surface mount inductors and capacitors. Operation is guaranteed at 1.8V input. This allows more energy to be extracted from the battery, increasing operating life. The $I_{LIM}$ pin can be used for soft start or to program peak switch current with a single resistor allowing the use of even smaller inductors in lighter load applications. The LT1301 is available in an 8-lead SOIC package, minimizing board space requirements. For a selectable 3.3V/5V step-up converter, please see the LT1300. For higher output power, see the LT1302.

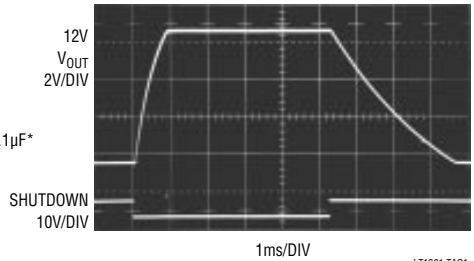
Burst Mode is a trademark of Linear Technology Corporation.

## TYPICAL APPLICATIONS




L1 = COILCRAFT DO3316-333
OR SUMIDA CD73-330KC
D1 = 1N5817 OR MOTOROLA
MBRS130LT3
C1 = AVX TPSD476M016R0100
OR SANYO OS-CON 165A47M
C2 = AVX TPSD336M020R0100
OR SANYO OS-CON 205A33M

**Output Voltage**




$V_{IN}$ = 5V, $V_{OUT}$ = 12V
LOAD = 100Ω

**Efficiency**

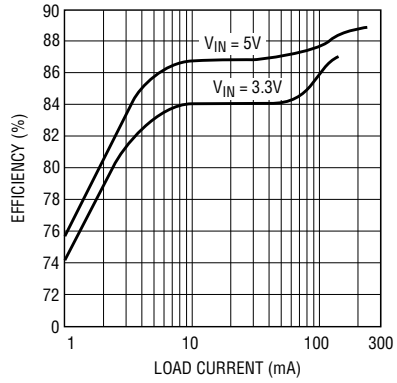


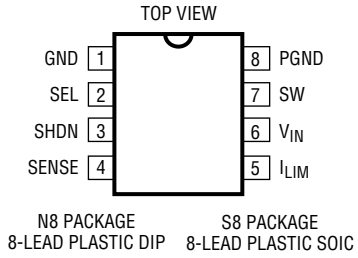

**Figure 1. 3.3V/5V to 12V Step-Up Converter**

LT1300 F2

## ABSOLUTE MAXIMUM RATINGS

$V_{IN}$ Voltage ..... 10V
SW1 Voltage ..... 20V
Sense Voltage ..... 20V
Shutdown Voltage ..... 10V
Select Voltage ..... 10V
$I_{LIM}$ Voltage ..... 0.5V
Maximum Power Dissipation ..... 500mW
Operating Temperature Range
LT1301C ..... 0°C to 70°C
LT1301I ..... 40°C to 85°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

## PACKAGE/ORDER INFORMATION




N8 PACKAGE
8-LEAD PLASTIC DIP

S8 PACKAGE
8-LEAD PLASTIC SOIC

$T_{JMAX}$ = 100°C, $\theta_{JA}$ = 150°C/W

| ORDER PART NUMBER |
|---|
| LT1301CN8<br>LT1301CS8<br>LT1301IS8 |
| **S8 PART MARKING** |
| 1301<br>1301I |

## ELECTRICAL CHARACTERISTICS

**$T_A$ = 25°C, $V_{IN}$ = 2V unless otherwise noted.**

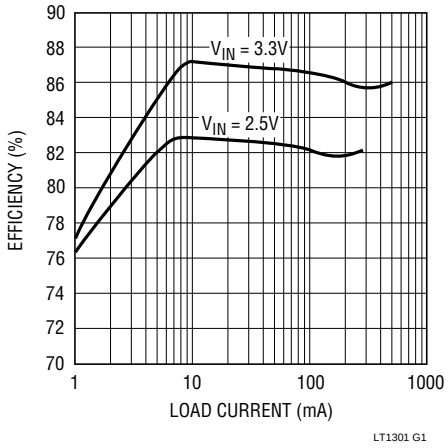
| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| $I_Q$ | Quiescent Current | $V_{SHDN}$ = 0.5V, $V_{SEL}$ = 5V, $V_{SENSE}$ = 5.5V | ● | | 120 | 200 | µA |
| | | $V_{SHDN}$ = 1.8V | ● | | 7 | 15 | µA |
| $V_{IN}$ | Input Voltage Range | | | 1.8 | | | V |
| | | | ● | 2.0 | | | V |
| $V_{OUT}$ | Output Sense Voltage | $V_{SEL}$ = 5V | ● | 11.52 | 12.00 | 12.48 | V |
| | | $V_{SEL}$ = 0V | ● | 4.75 | 5.00 | 5.25 | V |
| | Output Referred Comparator Hysteresis | $V_{SEL}$ = 5V (Note 1) | ● | | 50 | 100 | mV |
| | | $V_{SEL}$ = 0V (Note 1) | ● | | 22 | 50 | mV |
| | Oscillator Frequency | Current Limit not Asserted. | | 120 | 155 | 185 | kHz |
| | Oscillator TC | | | | 0.2 | | %/°C |
| DC | Maximum Duty Cycle | | | 75 | 86 | 95 | % |
| $t_{ON}$ | Switch On-Time | Current Limit not Asserted. | | | 5.6 | | µs |
| | Output Line Regulation | 1.8V < $V_{IN}$ < 6V | ● | | 0.06 | 0.15 | %/V |
| $V_{CESAT}$ | Switch Saturation Voltage | $I_{SW}$ = 700mA | ● | | 130 | 200 | mV |
| | Switch Leakage Current | $V_{SW}$ = 5V, Switch Off | ● | | 0.1 | 10 | µA |
| | Peak Switch Current (Internal Trip Point) | $I_{LIM}$ Floating (See Typical Application) | | 0.75 | 1.0 | 1.25 | A |
| | | $I_{LIM}$ Grounded | | | 0.4 | | A |
| $V_{SHDNH}$ | Shutdown Pin High | | ● | 1.8 | | | V |
| $V_{SHDNL}$ | Shutdown Pin Low | | | | | 0.5 | V |
| $V_{SELH}$ | Select Pin High | | ● | 1.5 | | | V |
| $V_{SELL}$ | Select Pin Low | | ● | | | 0.8 | V |
| $I_{SHDN}$ | Shutdown Pin Bias Current | $V_{SHDN}$ = 5V | ● | | 8 | 20 | µA |
| | | $V_{SHDN}$ = 2V | ● | | 3 | | µA |
| | | $V_{SHDN}$ = 0V | ● | | 0.1 | 1 | µA |
| $I_{SEL}$ | Select Pin Bias Current | 0V < $V_{SEL}$ < 5V | ● | | 1 | 3 | µA |

The ● denotes specifications which apply over the 0°C to 70°C temperature range.

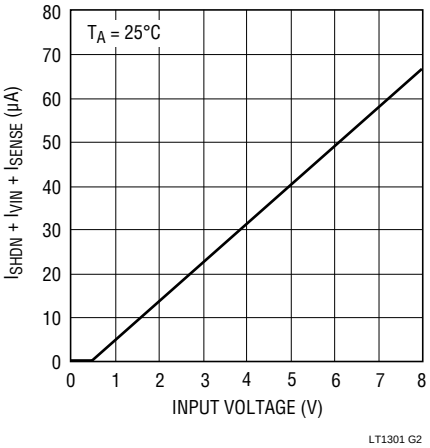
**Note 1:** Hysteresis specified is DC. Output ripple may be higher if output capacitance is insufficient or capacitor ESR is excessive. See operation section.

# TYPICAL PERFORMANCE CHARACTERISTICS

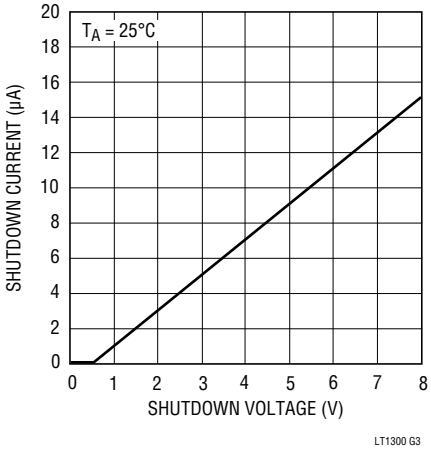
### 5V Output Efficiency



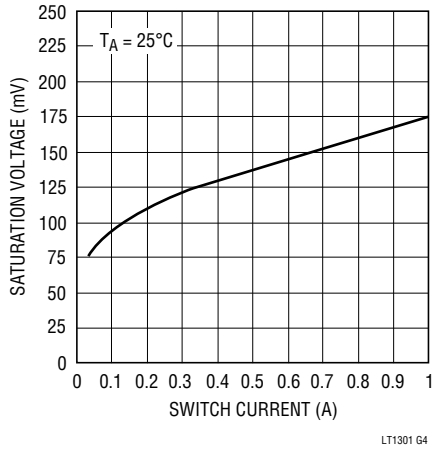

### Total Quiescent Current in Shutdown



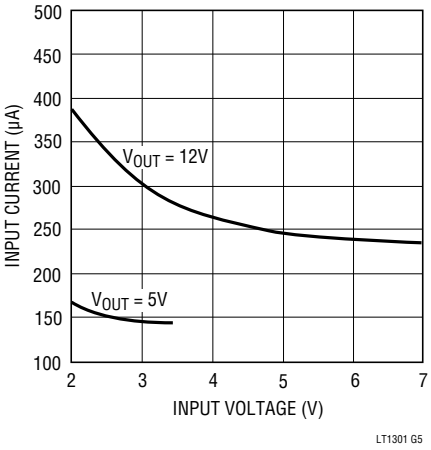

### Shutdown Pin Bias Current



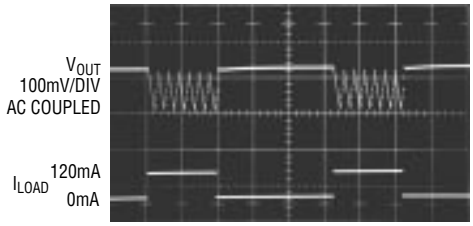

### Saturation Voltage vs Switch Current



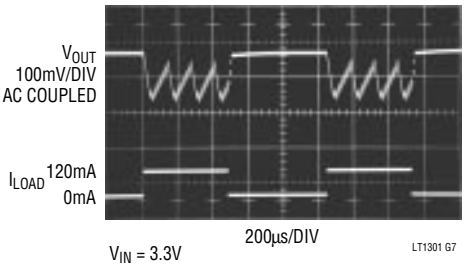

### No-Load Input Current



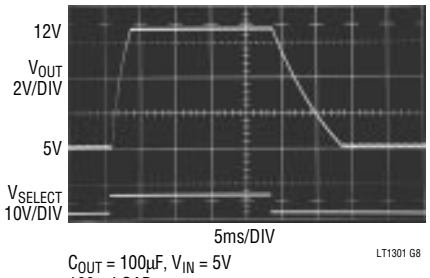

### Load Transient Response of Figure 1 Circuit



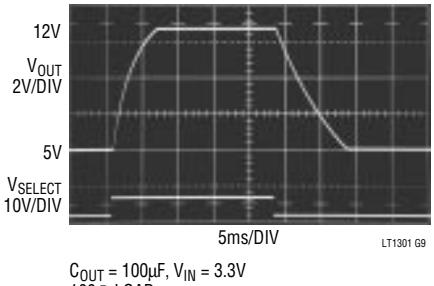

### Load Transient Response of Figure 1 Circuit




### Select Pin Transient Response




### Select Pin Transient Response



## PIN FUNCTIONS

**GND (Pin 1):** Signal Ground. Tie to PGND under the package.

**Sel (Pin 2):** Output Select. When tied to $V_{IN}$ converter regulates at 12V. When grounded or floating converter regulates at 5V. May be driven under logic control.

**SHDN (Pin 3):** Shutdown. Pull high to shut down the LT1301. Ground for normal operation.

**Sense (Pin 4):** "Output" Pin. Goes to internal resistive divider. If operating at 5V output, a 0.1µF ceramic capacitor is required from Sense to Ground.

**$I_{LIM}$ (Pin 5):** Float for 1A switch current limit. Tie to ground for approximately 400mA. A resistor between $I_{LIM}$ and ground sets peak current to some intermediate value .

**$V_{IN}$ (Pin 6):** Supply Pin. Must be bypassed with a large value electrolytic to ground. Keep bypass within 0.2" of the device.

**SW (Pin 7):** Switch Pin. Connect inductor and diode here. Keep layout short and direct to minimize radio frequency interference.

**PGND (Pin 8):** Power Ground. Tie to signal ground (pin 1) under the package. Bypass capacitor from $V_{IN}$ should be tied directly to PGND within 0.2" of the device.

## BLOCK DIAGRAM

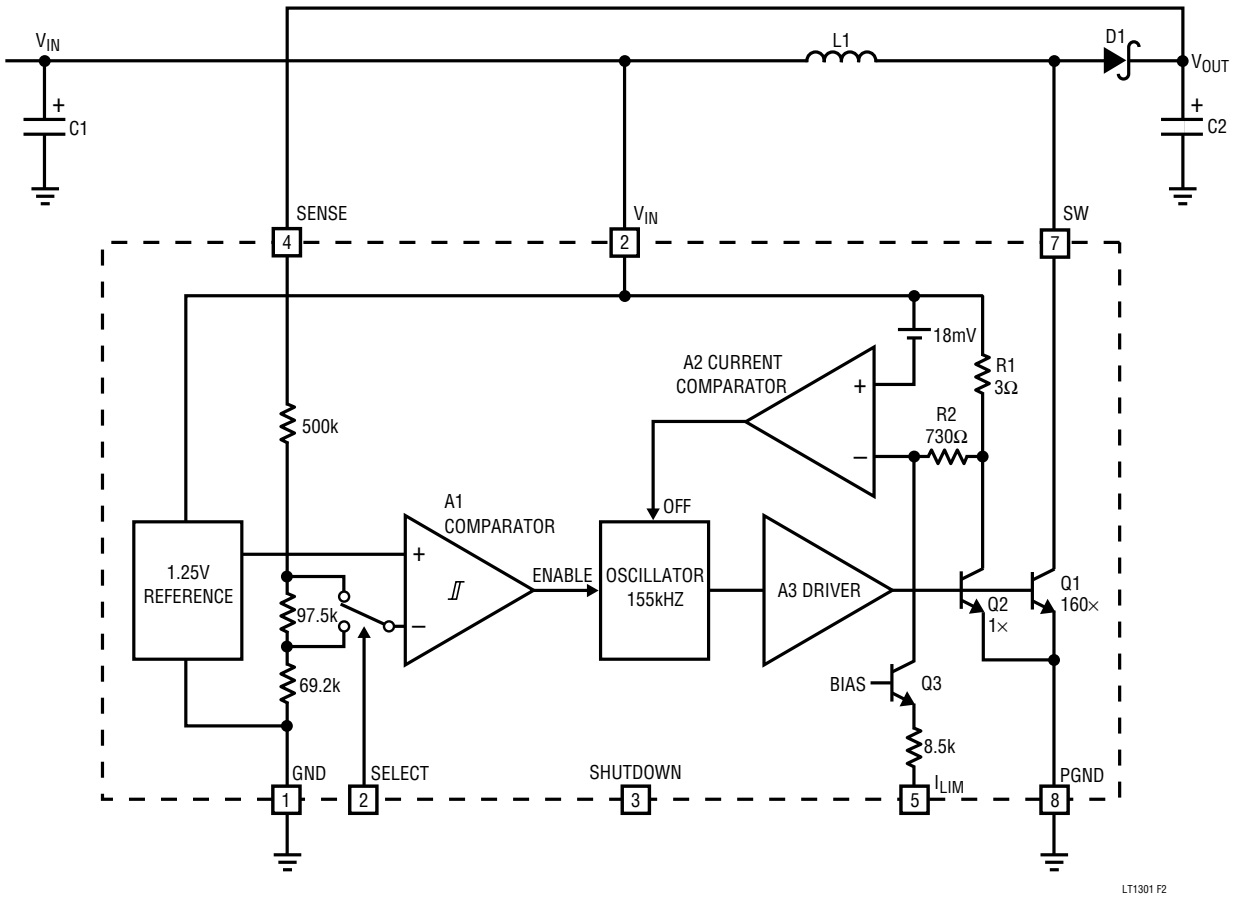
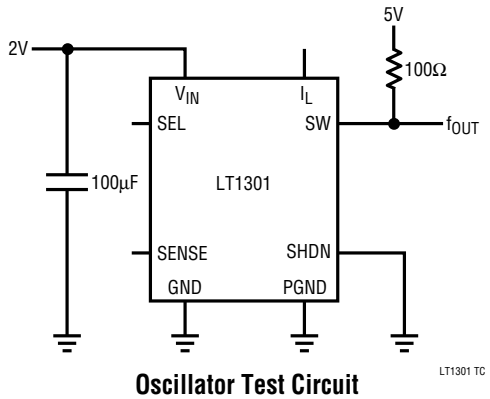



**Figure 2.**

## TEST CIRCUIT




**Oscillator Test Circuit**

## OPERATION

Operation of the LT1301 is best understood by referring to the Block Diagram in Figure 2. When A1's negative input, related to the Sense pin voltage by the appropriate resistor-divider ratio is higher that the 1.25V reference voltage, A1's output is low. A2, A3 and the oscillator are turned off, drawing no current. Only the reference and A1 consume current, typically 120µA. When A1's negative input drops below 1.25V, overcoming A1's 6mV hysteresis, A1's output goes high enabling the oscillator, current comparator A2, and driver A3. Quiescent current increases to 2mA as the device prepares for high current switching. Q1 then turns on in controlled saturation for (nominally) 5.3µs or until comparator A2 trips, whichever comes first. After a fixed off-time of (nominally) 1.2µs, Q1 turns on again. The LT1301's switching causes current to alternately build up in L1 and dump into output capacitor C2 via D1, increasing the output voltage. When the output is high enough to cause A1's output to go to low, switching action ceases. C2 is left to supply current to the load until $V_{OUT}$ decreases enough to force A1's output high, and the entire cycle repeats. Figure 4 details relevant waveforms. A1's cycling causes low-to-mid-frequency ripple voltage on the output. Ripple can be reduced by making the output capacitor large. The 33µF unit specified results in ripple of 100mV to 200mV on the 12V output. A 100µF capacitor will decrease ripple to 50mV. If operating at 5V ouput a 0.1µF ceramic capacitor is required at the Sense pin in addition to the electrolytic.

If switch current reaches 1A, causing A2 to trip, switch on-time is reduced and off-time increases slightly. This allows continuous mode operation during bursts. A2 monitors the voltage across 3Ω resistor R1 which is directly related to the switch current. Q2's collector current is set by the emitter-area ratio to 0.6% of Q1's collector current. When R1's voltage drop exceeds 18mV, corresponding to 1A switch current, A2's output goes high, truncating the on-time portion of the oscillator cycle and increasing off-time to about 2µs as shown in Figure 3, trace A. This programmed peak current can be reduced by tying the $I_{LIM}$ pin to ground, causing 15µA to flow through R2 into Q3's collector. Q3's current causes a 10.4mV drop in R2 so that only an additional 7.6mV is required across R1 to turn off the switch. This corresponds to a 400mA switch current as shown in Figure 3, trace B. The reduced peak switch current reduces $I^2R$ loses in Q1, L1, C1 and D1. Efficiency can be increased by doing this provided that the accompanying reduction in full load current is acceptable. Lower peak currents also extend alkaline battery life due to the alkaline cell's high internal impedance.

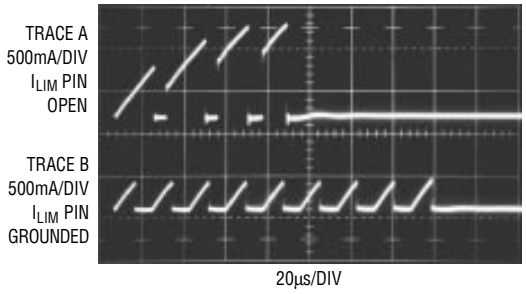
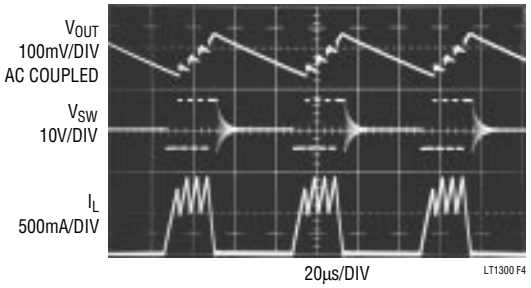



**Figure 3. Switch Pin Current With $I_{LIM}$ Floating or Grounded**

## APPLICATIONS INFORMATION




$V_{IN}$ = 5V, $V_{OUT}$ = 12V, L = 33µH
$C_{OUT}$ = 33µF, $I_{LOAD}$ = 90mA

**Figure 4. Burst Mode Operation in Action**

### Output Voltage Selection

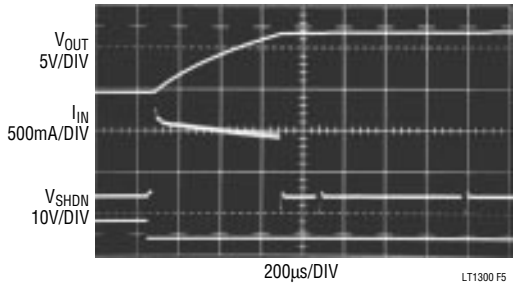
The LT1301 can be selected to 5V or 12V under logic control or fixed at either by tying Select to ground or $V_{IN}$ respectively. It is permissible to tie Select to a voltage higher than $V_{IN}$ as long as it does not exceed 10V. Efficiency in 5V mode will be slightly less that in 12V mode due to the fact that the diode drop is a greater percentage of 5V than 12V. Since the bipolar switch in the LT1301 gets its base drive from $V_{IN}$, no reduction in switch efficiency occurs when in 5V mode. When $V_{IN}$ exceeds the programmed output voltage the output will follow the input. This is characteristic of the simple step-up or "boost" converter topology. A circuit example that provides a regulated output with an input voltage above or below the output (known as a buck-boost or SEPIC) is shown in the Typical Applications section.

### Shutdown

The converter can be turned off by pulling SHDN (pin 3) high. Quiescent current drops to 10µA in this condition. Bias current of 8µA to 10µA flows into the pin (at 5V input). It is recommended that SHDN not be left floating. Tie the pin to ground if the feature is not used. SHDN can be driven high even if $V_{IN}$ is floating.

### $I_{LIM}$ Function

The LT1301's current limit ($I_{LIM}$) pin can be used for soft start. Upon start-up, the LT1301 will draw maximum current from the supply (about 1A) from the supply to charge the output capacitor. Figure 5 shows $V_{OUT}$ and $I_{IN}$ waveforms as the device is turned on. The high current flow can create IR drops along supply and ground lines or cause the input supply to drop out momentarily. By




$V_{IN}$ = 5V, $V_{OUT}$ = 12V

**Figure 5. Start-Up Response**

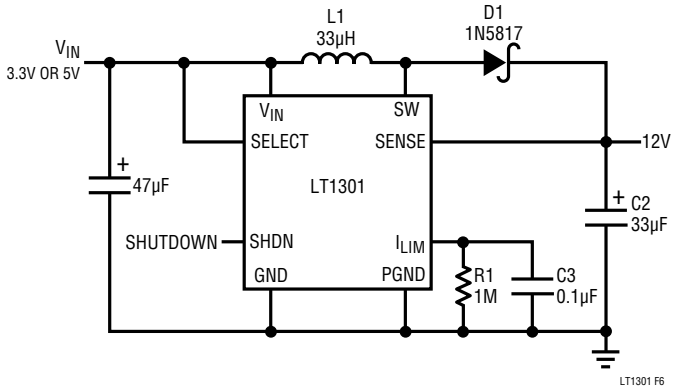
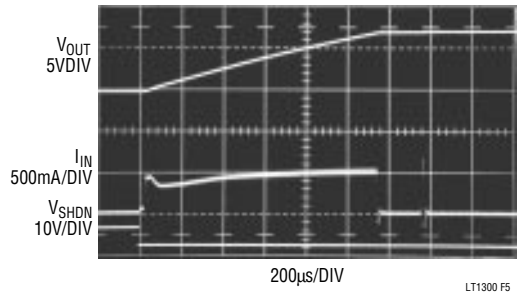



**Figure 6.**




$V_{IN}$ = 5V, $V_{OUT}$ = 12V

**Figure 7. Startup Response Soft-Start Circuitry Added**

adding R1 and C3 as shown in Figure 6, the switch current in the LT1301 is initially limited to 400mA until the 15µA flowing out of the $I_{LIM}$ pin charges up C3. Input current is held to under 500mA while the output voltage ramps up to 12V as shown in Figure 7. R1 provides a discharge path for the capacitor without appreciably decreasing peak switch current. When using the $I_{LIM}$ pin soft-start mode a minimum load of a few hundred microamperes is recommended to prevent C3 from discharging, as no current flows out of $I_{LIM}$ when the LT1301 is not

# APPLICATIONS INFORMATION

**Table 1. Recommended Inductors**

| PART NUMBER | VENDOR | L (μH) | DCR (Ω) | $V_{IN}$(V) | $I_{LIM}$ PIN | EFFICIENCY (%) 30mA | 60mA | 120mA | COMPONENT HEIGHT (mm) | PHONE NUMBER |
|---|---|---|---|---|---|---|---|---|---|---|
| DO3316-333 | Coilcraft | 33 | 0.088 | 3.3 | Open | 84 | 84 | 85 | 5.5 | (708) 639–6400 |
| | | | | 5 | Open | 89 | 89 | 90 | | |
| DO1608-223 | Coilcraft | 22 | .31 | 3.3 | Open | 82 | 82 | — | 3.5 | |
| | | | | 3.3 | Ground | 85 | — | — | | |
| | | | | 5 | 10k | 86 | 87 | — | | |
| | | | | 5 | Ground | 88 | — | — | | |
| DO1608-103 | Coilcraft | 10 | .11 | 2 | Open | 78 | — | — | 3.5 | |
| CTX20-1 | Coiltronics | 20 | .175 | 3.3 | Open | 84 | 84 | — | 4.2 | (407) 241-7876 |
| | | | | 5 | Open | 88 | 88 | 89 | | |
| GA10-332 | Gowanda | 33 | .077 | 3.3 | Open | 86 | 86 | 87 | Through-Hole | (716) 532-2234 |
| | | | | 5 | Open | 89 | 89 | 90 | | |
| LQH3G220K04M00 | Murata-Erie | 22 | 0.7 | 3.3 | Ground | 81 | — | — | 2.0 | (404) 436-1300 |
| | | | | 5 | Ground | 85 | — | — | | |
| CD73-330KC | Sumida | 33 | 0.131 | 3.3 | Open | 84 | 85 | 86 | 3.5 | (708) 956-0666 |
| | | | | 5 | Open | 88 | 88 | 89 | | |
| CDRH62-330MC | Sumida | 33 | 0.48 | 3.3 | Open | 80 | 80 | 81 | 3.0 | |
| | | | | | Ground | 85 | — | — | | |
| | | | | 5 | Open | 84 | 84 | 85 | | |
| | | | | | Ground | 83 | — | — | | |

switching. Zero load current causes the LT1301 to switch so infrequently that C3 can completely discharge reducing subsequent peak switch current to 400mA. If a load is suddenly applied, output voltage will sag until C3 can be recharged and peak switch current returns to 1A.

If the full capacity of the LT1301 is not required peak current can be reduced by changing the value of R3 as shown in Figure 8. With R3 = 0 switch current is limited to approximately 400mA. Smaller, less expensive inductors with lower saturation ratings can then be used.

## Inductor Selection

For full output power, the inductor should have a saturation current rating of 1.25A for worst-case current limit, although it is acceptable to bias an inductor 20% or more into saturation. Smaller inductors can be used in conjunction with the $I_{LIM}$ pin. Efficiency is significantly affected by inductor DCR. For best efficiency limit the DCR to 0.03Ω or less. Toroidal types are preferred in some cases due to their inherent flux containment and EMI/RFI superiority. Recommended inductors are listed in Table 1.

**Table 2. Recommended Capacitors**

| VENDOR | SERIES | TYPE | PHONE# |
|---|---|---|---|
| AVX | TPS | Surface Mount | (803)448–9411 |
| Sanyo | OS-CON | Through-Hole | (619) 661–6835 |
| Panasonic | HFQ | Through-Hole | (201) 348-5200 |

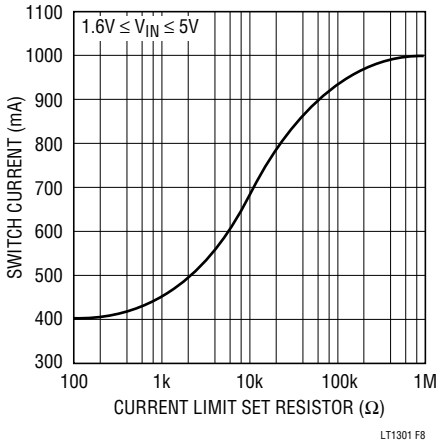



**Figure 8. Peak Switch Current vs. Current Limit Set Resistor**

## APPLICATIONS INFORMATION

### Capacitor Selection

Low ESR capacitors are required for both input and output of the LT1301. ESR directly affects ripple voltage and efficiency. For surface mount applications AVX TPS series tantalum capacitors are recommended. These have been specially designed for SMPS and have low ESR along with high surge current ratings. For through-hole applications Sanyo OS-CON capacitors offer extremely low ESR in a small size. Again, if peak switch current is reduced using the $I_{LIM}$ pin, capacitor requirements can be relaxed and smaller, higher ESR units can be used. Suggested capacitor sources are listed in Table 2.

### Diode Selection

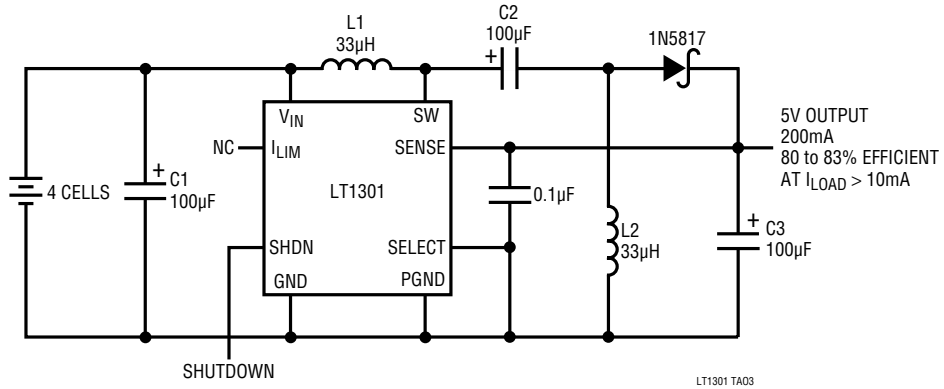
Best performance is obtained with a Schottky rectifier diode such as the 1N5817. Phillips Components makes this in surface mount as the PRLL5817. Motorola makes the MBRS130LT3 which is slightly better and also in surface mount. For lower output power a 1N4148 can be used although efficiency will suffer substantially.

### Layout Considerations

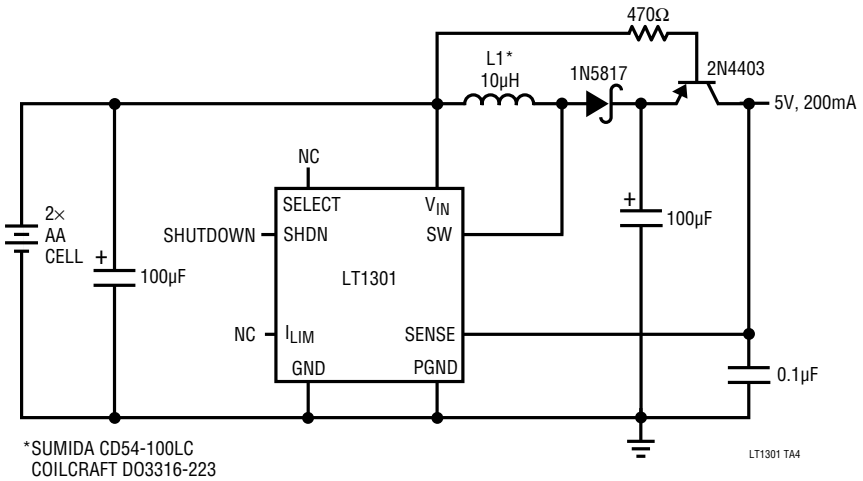
The LT1301 is a high speed, high current device. The input capacitor must be no more than 0.2″ from $V_{IN}$ (pin 6) and ground. Connect the PGND and GND (pins 8 and 1) together under the package. Place the inductor adjacent to SW (pin 7) and make the switch pin trace as short as possible. This keeps radiated noise to a minimum.

## TYPICAL APPLICATIONS

**Four-Cell to 5V Converter**

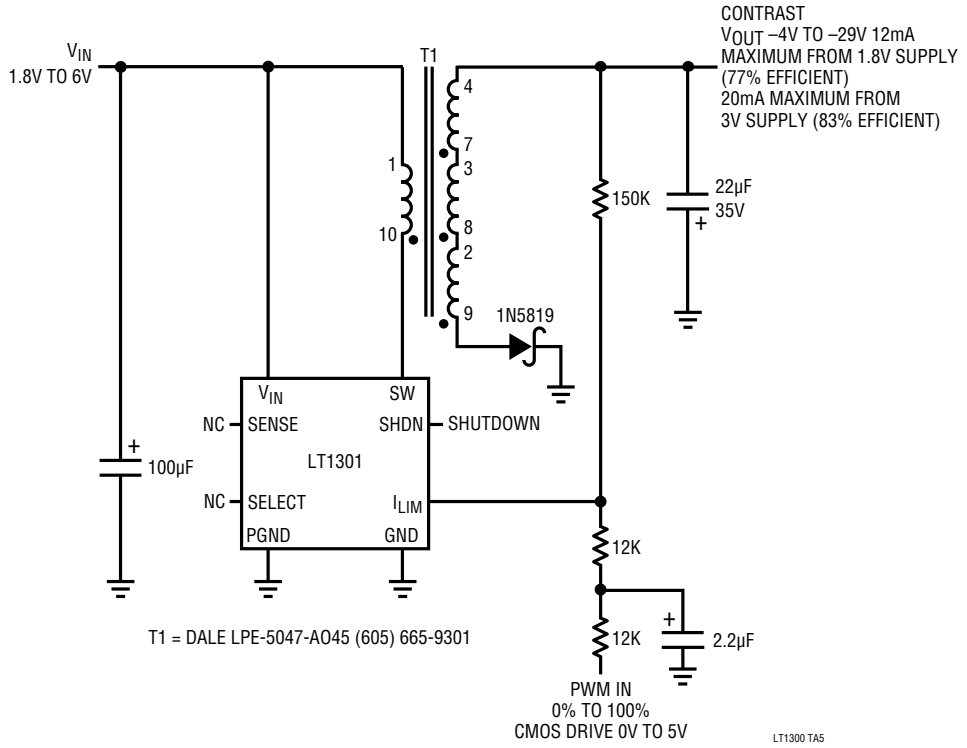



**Step-Up Converter with Automatic Output Disconnect**



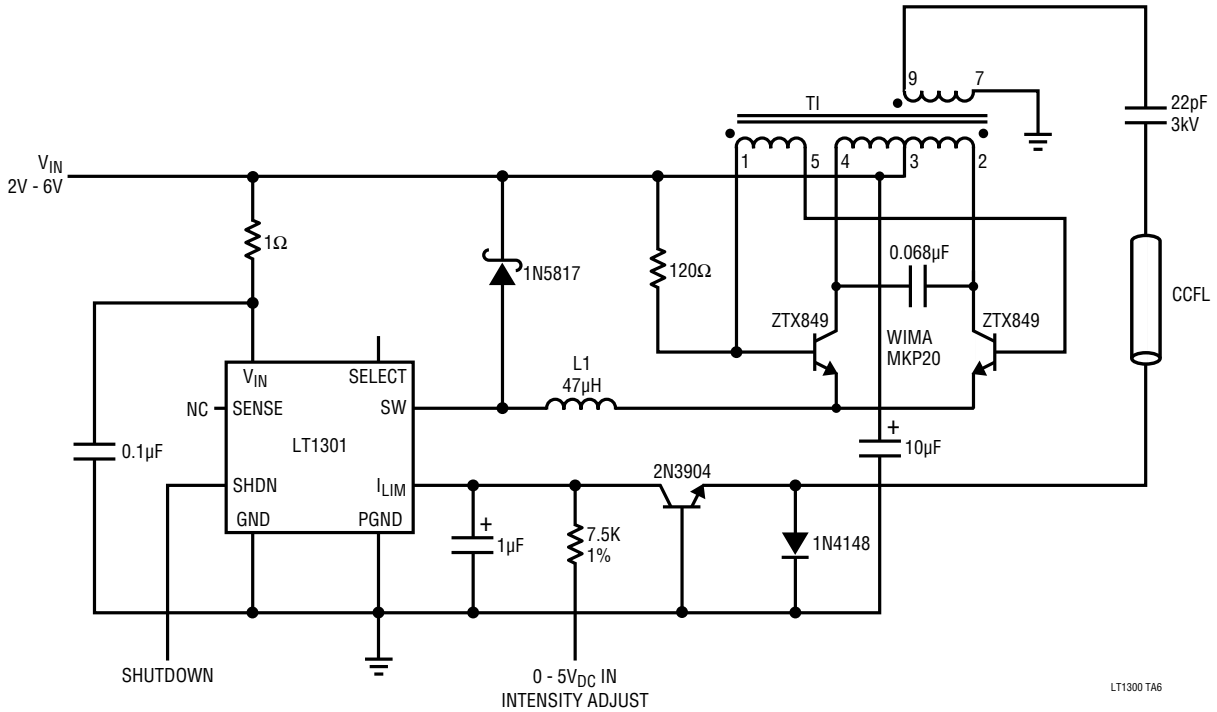
# TYPICAL APPLICATIONS

**LCD Contrast Supply**




T1 = DALE LPE-5047-AO45 (605) 665-9301

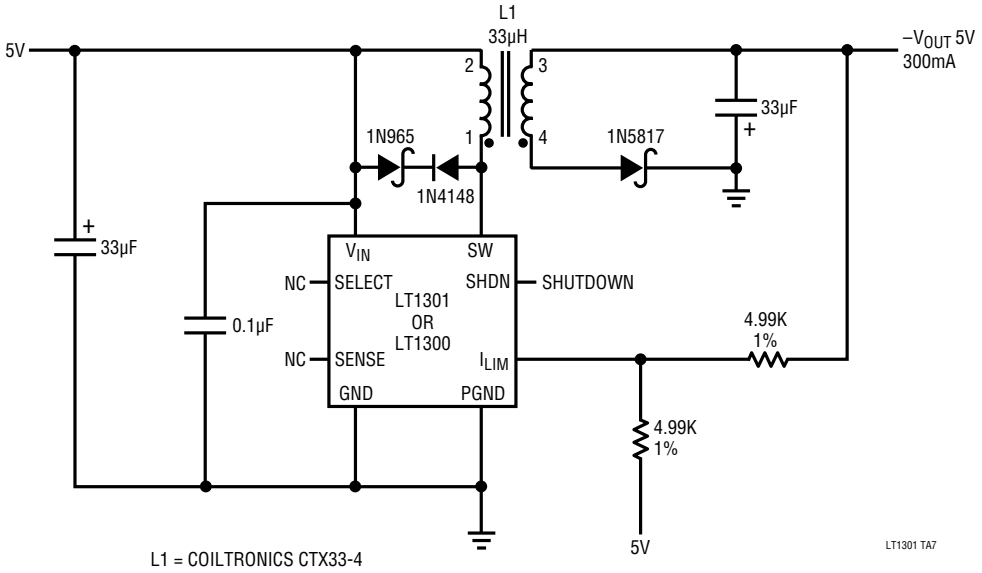
**Low-Voltage CCFL Power Supply**




T1 = COILTRONICS CTX110654-1
L1 = COILCRAFT D03316-473

# TYPICAL APPLICATIONS

**5V to –5V Converter**

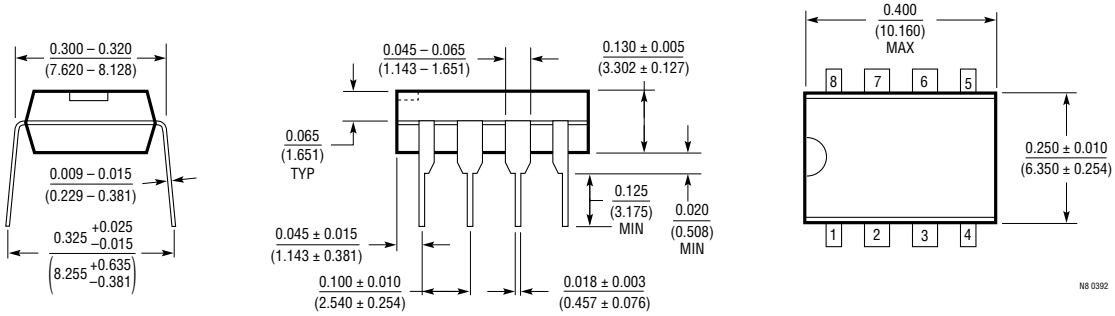



L1 = COILTRONICS CTX33-4

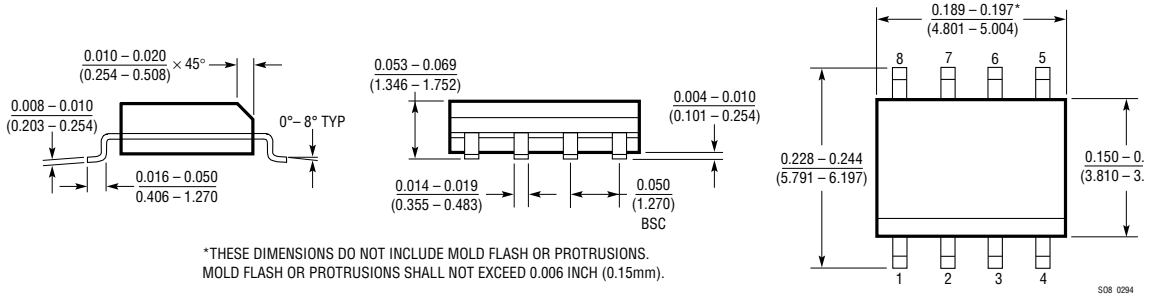
## PACKAGE DESCRIPTION

**Dimensions in inches (millimeters) unless otherwise noted.**

### N8 Package
### 8-Lead Plastic DIP




### S8 Package
### 8-Lead Plastic SOIC




*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 INCH (0.15mm).

LINEAR TECHNOLOGY

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