# LINEAR TECHNOLOGY

## LT1170/LT1171/LT1172

### 100kHz, 5A, 2.5A and 1.25A
### High Efficiency Switching Regulators

## FEATURES

- **Wide Input Voltage Range: 3V to 60V**
- **Low Quiescent Current: 6mA**
- **Internal 5A Switch (2.5A for LT1171, 1.25A for LT1172)**
- **Shutdown Mode Draws Only 50µA Supply Current**
- Very Few External Parts Required
- Self-Protected Against Overloads
- Operates in Nearly All Switching Topologies
- Flyback-Regulated Mode Has Fully Floating Outputs
- Comes in Standard 5-Pin Packages
- LT1172 Available in 8-Pin MiniDIP and Surface Mount Packages
- Can Be Externally Synchronized

## APPLICATIONS

- Logic Supply 5V at 10A
- 5V Logic to ±15V Op Amp Supply
- Battery Upconverter
- Power Inverter (+ to –) or (– to +)
- Fully Floating Multiple Outputs

**USER NOTE:**

This data sheet is only intended to provide specifications, graphs, and a general functional description of the LT1170/LT1171/LT1172. Application circuits are included to show the capability of the LT1170/LT1171/LT1172. A complete design manual (AN19) should be obtained to assist in developing new designs. This manual contains a comprehensive discussion of both the LT1070 and the external components used with it, as well as complete formulas for calculating the values of these components. The manual can also be used for the LT1170/LT1171/LT1172 by factoring in the higher frequency. A CAD design program called SwitcherCAD™ is also available.

## DESCRIPTION

The LT®1170/LT1171/LT1172 are monolithic high power switching regulators. They can be operated in all standard switching configurations including buck, boost, flyback, forward, inverting and "Cuk." A high current, high efficiency switch is included on the die along with all oscillator, control and protection circuitry. Integration of all functions allows the LT1170/LT1171/LT1172 to be built in a standard 5-pin TO-3 or TO-220 power package as well as the 8-pin packages (LT1172). This makes them extremely easy to use and provides "bust proof" operation similar to that obtained with 3-pin linear regulators.

The LT1170/LT1171/LT1172 operate with supply voltages from 3V to 60V, and draw only 6mA quiescent current. They can deliver load power up to 100W with no external power devices. By utilizing current-mode switching techniques, they provide excellent AC and DC load and line regulation.

The LT1170/LT1171/LT1172 have many unique features not found even on the vastly more difficult to use low power control chips presently available. They use adaptive antisat switch drive to allow very wide ranging load currents with no loss in efficiency. An externally activated shutdown mode reduces total supply current to 50µA typically for standby operation.
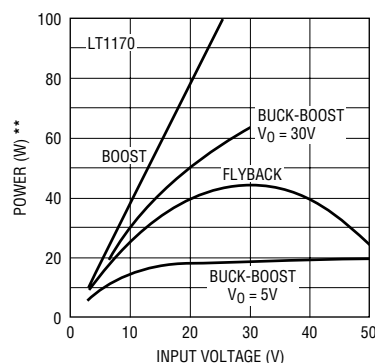
## TYPICAL APPLICATION

### Boost Converter (5V to 12V)



*REQUIRED IF INPUT LEADS ≥ 2"
** COILTRONICS 50-2-52
PULSE ENGINEERING 92114
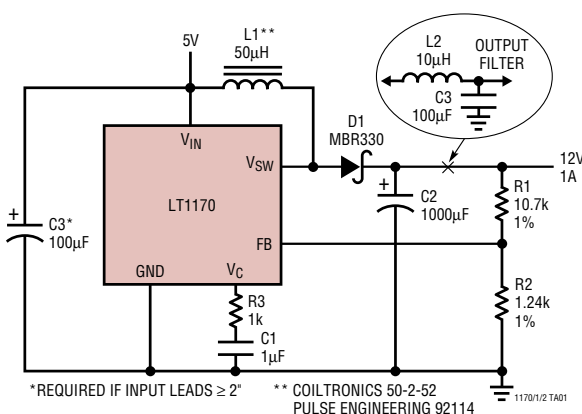
1170/1/2 TA01

### Maximum Output Power*



* ROUGH GUIDE ONLY. BUCK MODE $P_{OUT} = (5A)(V_{OUT})$ SPECIAL TOPOLOGIES DELIVER MORE POWER.
** **DIVIDE VERTICAL POWER SCALE BY TWO FOR LT1171, BY FOUR FOR LT1172.**

LT1170/1/2 TA02

# LT1170/LT1171/LT1172

# ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage
    LT1170/71/72HV (Note 2) .................................. 60V
    LT1170/71/72 (Note 2) ...................................... 40V
Switch Output Voltage
    LT1170/71/72HV ............................................. 75V
    LT1170/71/72 ................................................. 65V
    LT1172S8 ...................................................... 60V
Feedback Pin Voltage (Transient, 1ms) ............... ±15V
Storage Temperature Range ............... −65°C to 150°C
Lead Temperature (Soldering, 10 sec)................ 300°C

Operating Junction Temperature Range
    LT1170/71/72M......................... −55°C to 150°C
    LT1170/71/72HVC,
        LT1170/71/72C (Oper.) .............. 0°C to 100°C ⎫
    LT1170/71/72HVC                                        ⎬ C
        LT1170/71/72C (Sh. Ckt.) .......... 0°C to 125°C  ⎭
    LT1170/71/72HVI,
        LT1170/71/72I (Oper.) .......... −40°C to 100°C   ⎫
    LT1170/71/72HVI,                                      ⎬ I
        LT1170/71/72I (Sh. Ckt.) ...... −40°C to 125°C    ⎭

# PACKAGE/ORDER INFORMATION

TOP VIEW

| | | | |
|---|---|---|---|
| GND | 1 | 8 | E2 |
| $V_C$ | 2 | 7 | $V_{SW}$ |
| FB | 3 | 6 | E1 |
| NC* | 4 | 5 | $V_{IN}$ |

J8 PACKAGE    N8 PACKAGE
8-LEAD CERDIP  8-LEAD PDIP
S8 PACKAGE
8-LEAD PLASTIC SO

* Do not connect Pin 4 of the LT1172 DIP or SO to external circuitry. This pin may be active in future revisions.

$T_{JMAX}$ = 150°C, $\theta_{JA}$ = 100°C/W (J)
$T_{JMAX}$ = 100°C, $\theta_{JA}$ = 100°C/W (N)
$T_{JMAX}$ = 100°C, $\theta_{JA}$ = 120°C/W to 150°C/W depending on board layout (S)

ORDER PART NUMBER

LT1172MJ8
LT1172CJ8
LT1172CN8
LT1172IN8
LT1172CS8
LT1172IS8

S8 PART MARKING

1172    1172I

TOP VIEW

| | | | |
|---|---|---|---|
| NC | 1 | 16 | NC |
| NC | 2 | 15 | NC |
| GND | 3 | 14 | E2 |
| $V_C$ | 4 | 13 | $V_{SW}$ |
| FB | 5 | 12 | E1 |
| NC | 6 | 11 | $V_{IN}$ |
| NC | 7 | 10 | NC |
| NC | 8 | 9 | NC |

SW PACKAGE
16-LEAD PLASTIC SO WIDE

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

Based on continuous operation.
$T_{JMAX}$ = 125°C for intermittent fault conditions.

ORDER PART NUMBER

LT1172CSW

BOTTOM VIEW

$V_{SW}$ — 1
$V_C$ — 2
CASE IS GND
4
3 — FB
$V_{IN}$ — 

K PACKAGE
4-LEAD TO-3 METAL CAN

| | $T_{JMAX}$ | $\theta_{JC}$ | $\theta_{JA}$ |
|---|---|---|---|
| LT1170MK | 150°C | 2°C/W | 35°C/W |
| LT1170CK | 100°C | 2°C/W | 35°C/W |
| LT1171MK | 150°C | 4°C/W | 35°C/W |
| LT1171CK | 100°C | 4°C/W | 35°C/W |
| LT1172MK | 150°C | 8°C/W | 35°C/W |
| LT1172CK | 150°C | 8°C/W | 35°C/W |

Based on continuous operation.
$T_{JMAX}$ = 125°C for intermittent fault conditions.

ORDER PART NUMBER

LT1170MK
LT1170CK
LT1171MK
LT1171CK
LT1172MK
LT1172CK

FRONT VIEW

| | |
|---|---|
| 5 | $V_{IN}$ |
| 4 | $V_{SW}$ |
| 3 | GND |
| 2 | FB |
| 1 | $V_C$ |

T PACKAGE
5-LEAD PLASTIC TO-220

| | $T_{JMAX}$ | $\theta_{JC}$ | $\theta_{JA}$ |
|---|---|---|---|
| LT1170CT/LT1170HVCT | 100°C | 2°C/W | 75°C/W |
| LT1171CT/LT1171HVCT | 100°C | 4°C/W | 75°C/W |
| LT1172CT/LT1172HVCT | 100°C | 8°C/W | 75°C/W |

Based on continuous operation.
$T_{JMAX}$ = 125°C for intermittent fault conditions.

ORDER PART NUMBER

LT1170CT
LT1170IT
LT1170HVCT
LT1170HVIT
LT1171CT
LT1171IT
LT1171HVCT
LT1172CT
LT1172HVCT

FRONT VIEW

| | |
|---|---|
| 5 | $V_{IN}$ |
| 4 | $V_{SW}$ |
| 3 | GND |
| 2 | FB |
| 1 | $V_C$ |

Q PACKAGE
5-LEAD DD

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

*θ will vary from approximately 25°C/W with 2.8 sq. in. of 1oz. copper to 45°C/W with 0.20 sq. in. of 1oz. copper. Somewhat lower values can be obtained with additional copper layers in multilayer boards.

ORDER PART NUMBER

LT1170CQ   LT1171HVCQ
LT1170IQ   LT1172CQ
LT1171CQ   LT1172HVIQ
LT1171IQ

LINEAR TECHNOLOGY

# ELECTRICAL CHARACTERISTICS
The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25°C$. $V_{IN} = 15V$, $V_C = 0.5V$, $V_{FB} = V_{REF}$, output pin open, unless otherwise noted.

| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| $V_{REF}$ | Reference Voltage | Measured at Feedback Pin | | 1.224 | 1.244 | 1.264 | V |
| | | $V_C = 0.8V$ | ● | 1.214 | 1.244 | 1.274 | V |
| $I_B$ | Feedback Input Current | $V_{FB} = V_{REF}$ | | | 350 | 750 | nA |
| | | | ● | | | 1100 | nA |
| $g_m$ | Error Amplifier Transconductance | $\Delta I_C = \pm25\mu A$ | | 3000 | 4400 | 6000 | μmho |
| | | | ● | 2400 | | 7000 | μmho |
| | Error Amplifier Source or Sink Current | $V_C = 1.5V$ | | 150 | 200 | 350 | μA |
| | | | ● | 120 | | 400 | μA |
| | Error Amplifier Clamp Voltage | Hi Clamp, $V_{FB} = 1V$ | | 1.80 | | 2.30 | V |
| | | Lo Clamp, $V_{FB} = 1.5V$ | | 0.25 | 0.38 | 0.52 | V |
| | Reference Voltage Line Regulation | $3V \leq V_{IN} \leq V_{MAX}$ $V_C = 0.8V$ | ● | | | 0.03 | %/V |
| $A_V$ | Error Amplifier Voltage Gain | $0.9V \leq V_C \leq 1.4V$ | | 500 | 800 | | V/V |
| | Minimum Input Voltage (Note 5) | | ● | | 2.6 | 3.0 | V |
| $I_Q$ | Supply Current | $3V \leq V_{IN} \leq V_{MAX}$, $V_C = 0.6V$ | | | 6 | 9 | mA |
| | Control Pin Threshold | Duty Cycle = 0 | | 0.8 | 0.9 | 1.08 | V |
| | | | ● | 0.6 | | 1.25 | V |
| | Normal/Flyback Threshold on Feedback Pin | | | 0.4 | 0.45 | 0.54 | V |
| $V_{FB}$ | Flyback Reference Voltage (Note 5) | $I_{FB} = 50\mu A$ | | 15.0 | 16.3 | 17.6 | V |
| | | | ● | 14.0 | | 18.0 | V |
| | Change in Flyback Reference Voltage | $0.05 \leq I_{FB} \leq 1mA$ | | 4.5 | 6.8 | 9 | V |
| | Flyback Reference Voltage Line Regulation (Note 5) | $I_{FB} = 50\mu A$ $7V \leq V_{IN} \leq V_{MAX}$ | | | 0.01 | 0.03 | %/V |
| | Flyback Amplifier Transconductance ($g_m$) | $\Delta I_C = \pm10\mu A$ | | 150 | 300 | 650 | μmho |
| | Flyback Amplifier Source and Sink Current | $V_C = 0.6V$ Source | ● | 15 | 32 | 70 | μA |
| | | $I_{FB} = 50\mu A$ Sink | ● | 25 | 40 | 70 | μA |
| BV | Output Switch Breakdown Voltage | $3V \leq V_{IN} \leq V_{MAX}$, LT1170/LT1171/LT1172 | ● | 65 | 90 | | V |
| | | $I_{SW} = 1.5mA$ LT1170HV/LT1171HV/LT1172HV | ● | 75 | 90 | | V |
| | | LT1172S8 | ● | 60 | 80 | | V |
| $V_{SAT}$ | Output Switch "On" Resistance (Note 3) | LT1170 | ● | | 0.15 | 0.24 | Ω |
| | | LT1171 | ● | | 0.30 | 0.50 | Ω |
| | | LT1172 | ● | | 0.60 | 1.00 | Ω |
| | Control Voltage to Switch Current Transconductance | LT1170 | | | 8 | | A/V |
| | | LT1171 | | | 4 | | A/V |
| | | LT1172 | | | 2 | | A/V |
| $I_{LIM}$ | Switch Current Limit (LT1170) | Duty Cycle = 50% $T_J \geq 25°C$ | ● | 5 | | 10 | A |
| | | Duty Cycle = 50% $T_J < 25°C$ | ● | 5 | | 11 | A |
| | | Duty Cycle = 80% (Note 4) | ● | 4 | | 10 | A |
| | (LT1171) | Duty Cycle = 50% $T_J \geq 25°C$ | ● | 2.5 | | 5.0 | A |
| | | Duty Cycle = 50% $T_J < 25°C$ | ● | 2.5 | | 5.5 | A |
| | | Duty Cycle = 80% (Note 4) | ● | 2.0 | | 5.0 | A |
| | (LT1172) | Duty Cycle = 50% $T_J \geq 25°C$ | ● | 1.25 | | 3.0 | A |
| | | Duty Cycle = 50% $T_J < 25°C$ | ● | 1.25 | | 3.5 | A |
| | | Duty Cycle = 80% (Note 4) | ● | 1.00 | | 2.5 | A |

# ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $V_{IN}$ = 15V, $V_C$ = 0.5V, $V_{FB}$ = $V_{REF}$, output pin open, unless otherwise noted.

| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| $\frac{\Delta I_{IN}}{\Delta I_{SW}}$ | Supply Current Increase During Switch On-Time | | | | 25 | 35 | mA/A |
| f | Switching Frequency | | ● | 88<br>85 | 100 | 112<br>115 | kHz<br>kHz |
| $DC_{MAX}$ | Maximum Switch Duty Cycle | | ● | 85 | 92 | 97 | % |
| | Shutdown Mode Supply Current | $3V \leq V_{IN} \leq V_{MAX}$<br>$V_C$ = 0.05V | | | 100 | 250 | μA |
| | Shutdown Mode Threshold Voltage | $3V \leq V_{IN} \leq V_{MAX}$ | ● | 100<br>50 | 150 | 250<br>300 | mV<br>mV |
| | Flyback Sense Delay Time (Note 5) | | | | 1.5 | | μs |

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

**Note 2:** Minimum effective switch "on" time for the LT1170/71/72 (in current limit only) is ≈ 0.6μs. This limits the maximum safe input voltage during an output shorted condition. Buck mode and inverting mode input voltage during an output shorted condition is limited to:

$$V_{IN} \text{ (max, output shorted)} = 15V + \frac{(R)(I_L) + Vf}{(t)(f)}$$
buck and inverting mode

R = Inductor DC resistance

$I_L$ = 10A for LT1170, 5A for LT1171, and 2.5A for LT1172

Vf = Output catch diode forward voltage at $I_L$

t = 0.6μs, f = 100kHz switching frequency

Maximum input voltage can be increased by increasing R or Vf.

External current limiting such as that shown in AN19, Figure 39, will provide protection up to the full supply voltage rating. C1 in Figure 39 should be reduced to 200pF.

Transformer designs will tolerate much higher input voltages because leakage inductance limits rate of rise of current in the switch. These designs must be evaluated individually to assure that current limit is well controlled up to maximum input voltage.
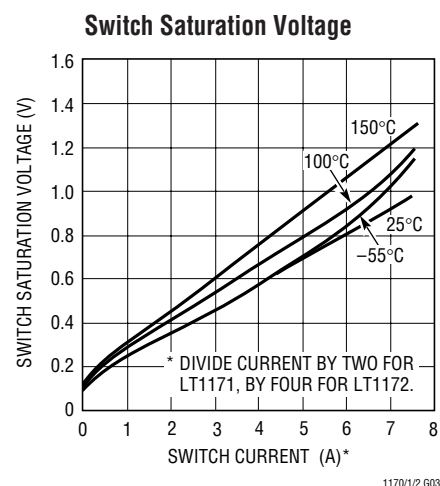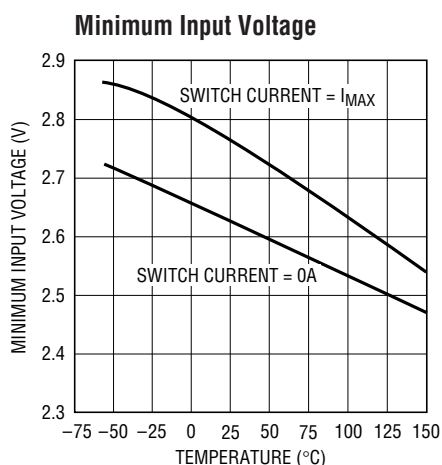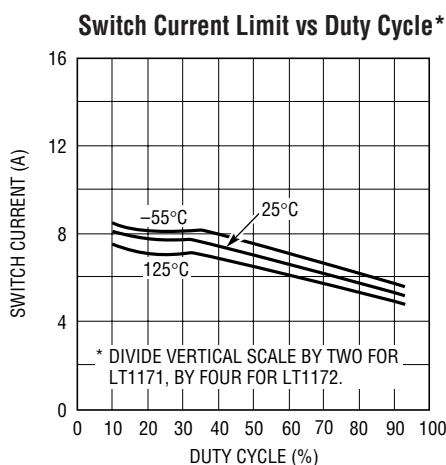
Boost mode designs are never protected against output shorts because the external catch diode and inductor connect input to output.

**Note 3:** Measured with $V_C$ in hi clamp, $V_{FB}$ = 0.8V. $I_{SW}$ = 4A for LT1170, 2A for LT1171, and 1A for LT1172.

**Note 4:** For duty cycles (DC) between 50% and 80%, minimum guaranteed switch current is given by $I_{LIM}$ = 3.33 (2 – DC) for the LT1170, $I_{LIM}$ = 1.67 (2 – DC) for the LT1171, and $I_{LIM}$ = 0.833 (2 – DC) for the LT1172.
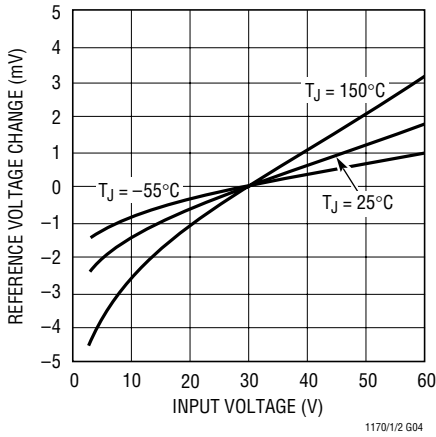
**Note 5:** Minimum input voltage for isolated flyback mode is 7V. $V_{MAX}$ = 55V for HV grade in fully isolated mode to avoid switch breakdown.

# TYPICAL PERFORMANCE CHARACTERISTICS

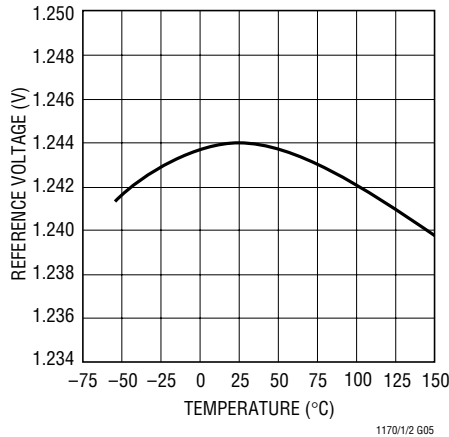**Switch Current Limit vs Duty Cycle***



1170/1/2 G01

**Minimum Input Voltage**



1170/1/2 G02

**Switch Saturation Voltage**
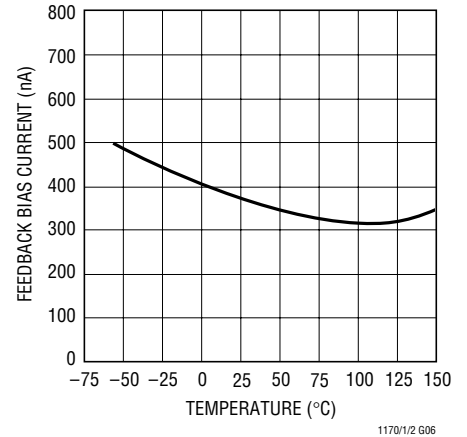


1170/1/2 G03

# TYPICAL PERFORMANCE CHARACTERISTICS
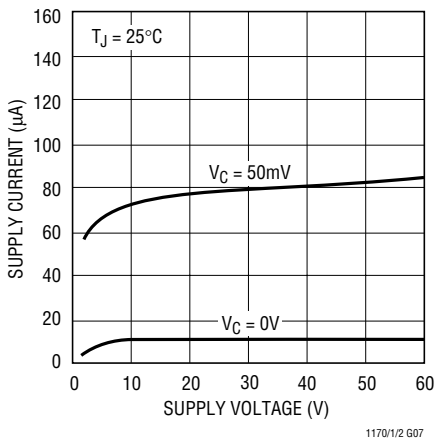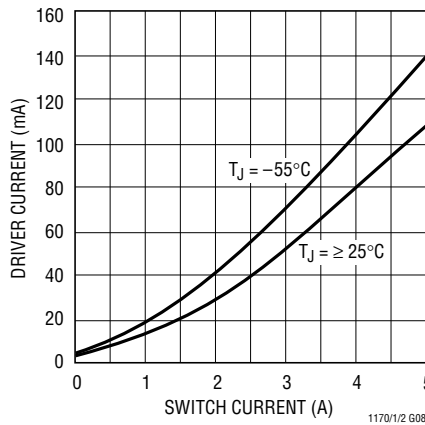
**Line Regulation**



**Reference Voltage vs Temperature**



**Feedback Bias Current vs Temperature**



**Supply Current vs Supply Voltage (Shutdown Mode)**



**Driver Current* vs Switch Current**



* AVERAGE LT1170 POWER SUPPLY CURRENT IS FOUND BY MULTIPLYING DRIVER CURRENT BY DUTY CYCLE, THEN ADDING QUIESCENT CURRENT.

**Supply Current vs Input Voltage***



* UNDER VERY LOW OUTPUT CURRENT CONDITIONS, DUTY CYCLE FOR MOST CIRCUITS WILL APPROACH 10% OR LESS.

**Shutdown Mode Supply Current**



**Error Amplifier Transconductance**

$$g_m = \frac{\Delta I \ (V_C \ PIN)}{\Delta V \ (FB \ PIN)}$$
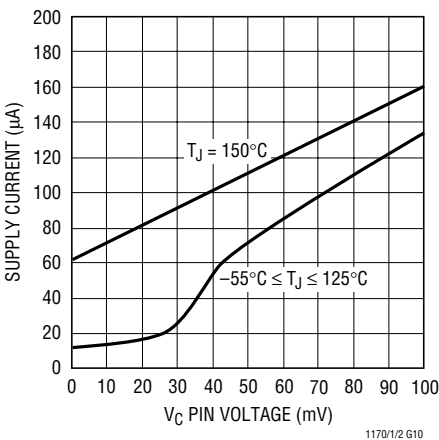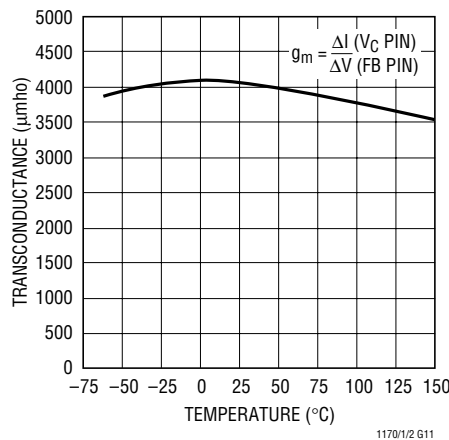


**$V_C$ Pin Characteristics**
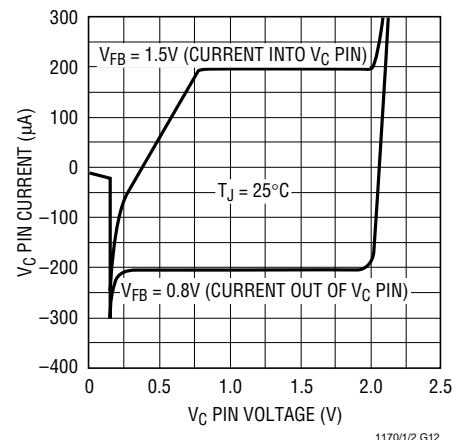
# TYPICAL PERFORMANCE CHARACTERISTICS

**Idle Supply Current vs Temperature**



1170/1/2 G13
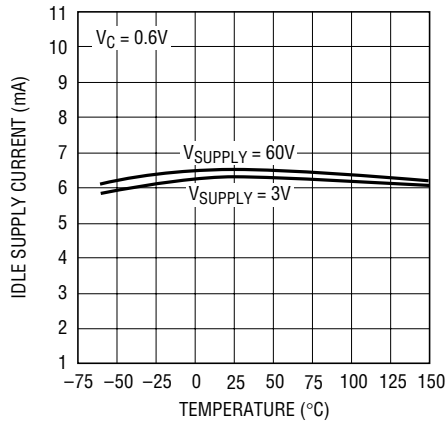
**Feedback Pin Clamp Voltage**



1170/1/2 G14
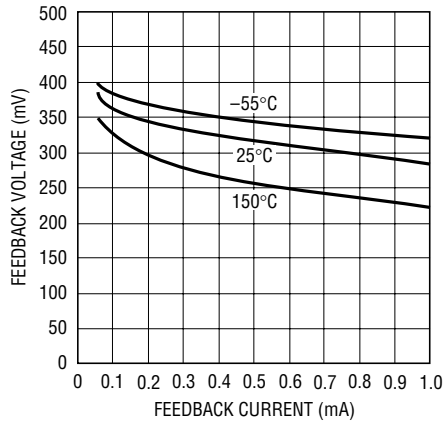
**Switch "Off" Characteristics**



1170/1/2 G15
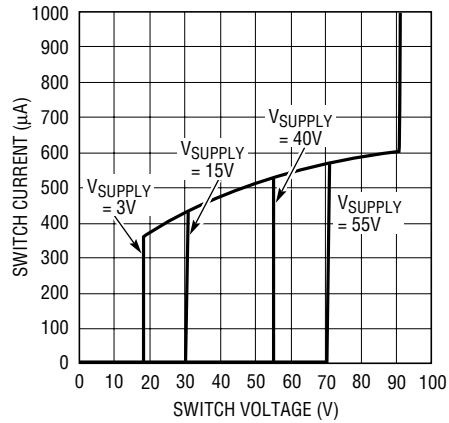
**Shutdown Thresholds**



1170/1/2 G16
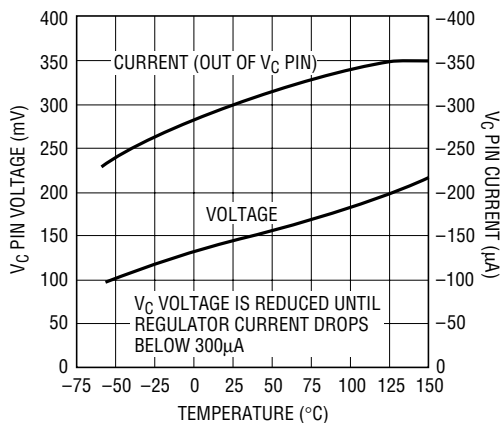
**Flyback Blanking Time**



1170/1/2 G17
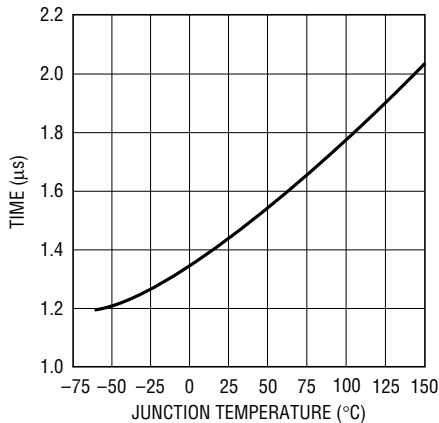
**Isolated Mode Flyback Reference Voltage**



1170/1/2 G18
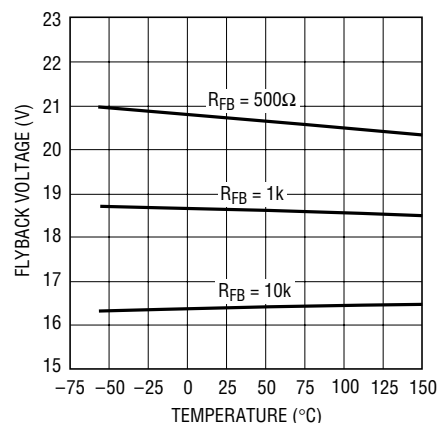
**Transconductance of Error Amplifier**



1170/1/2 G19
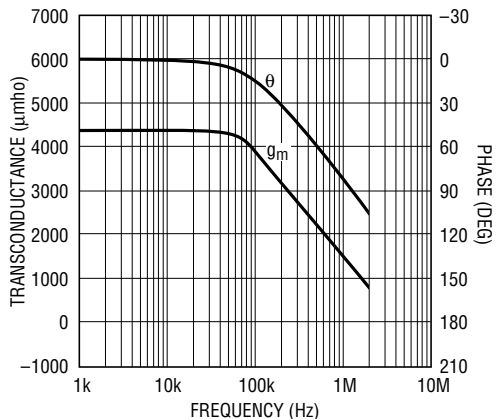
**Normal/Flyback Mode Threshold on Feedback Pin**



1170/1/2 G20
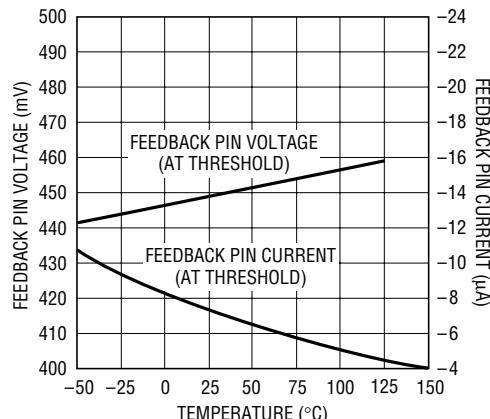
# BLOCK DIAGRAM
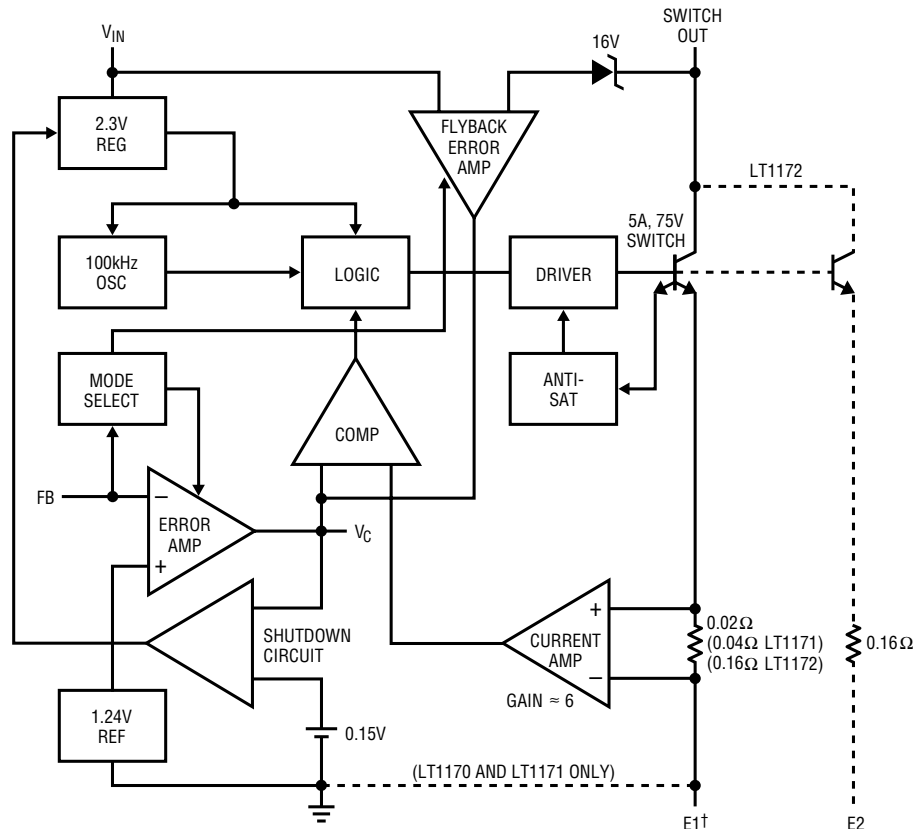


† ALWAYS CONNECT E1 TO THE GROUND PIN ON MINIDIP, 8- AND 16-PIN SURFACE MOUNT PACKAGES.
E1 AND E2 INTERNALLY TIED TO GROUND ON TO-3 AND TO-220 PACKAGES.

1170/1/2 BD

# OPERATION

The LT1170/LT1171/LT1172 are current mode switchers. This means that switch duty cycle is directly controlled by switch current rather than by output voltage. Referring to the block diagram, the switch is turned "on" at the start of each oscillator cycle. It is turned "off" when switch current reaches a predetermined level. Control of output voltage is obtained by using the output of a voltage sensing error amplifier to set current trip level. This technique has several advantages. First, it has immediate response to input voltage variations, unlike ordinary switchers which have notoriously poor line transient response. Second, it reduces the 90° phase shift at midfrequencies in the energy storage inductor. This greatly simplifies closed-loop frequency compensation under widely varying input voltage or output load conditions. Finally, it allows simple pulse-by-pulse current limiting to provide maximum switch

protection under output overload or short conditions. A low dropout internal regulator provides a 2.3V supply for all internal circuitry on the LT1170/LT1171/LT1172. This low dropout design allows input voltage to vary from 3V to 60V with virtually no change in device performance. A 100kHz oscillator is the basic clock for all internal timing. It turns "on" the output switch via the logic and driver circuitry. Special adaptive anti-sat circuitry detects onset of saturation in the power switch and adjusts driver current instantaneously to limit switch saturation. This minimizes driver dissipation and provides very rapid turn-off of the switch.

A 1.2V bandgap reference biases the positive input of the error amplifier. The negative input is brought out for output voltage sensing. This feedback pin has a second

## OPERATION

function; when pulled low with an external resistor, it programs the LT1170/LT1171/LT1172 to disconnect the main error amplifier output and connects the output of the flyback amplifier to the comparator input. The LT1170/LT1171/LT1172 will then regulate the value of the flyback pulse with respect to the supply voltage.* This flyback pulse is directly proportional to output voltage in the traditional transformer coupled flyback topology regulator. By regulating the amplitude of the flyback pulse, the output voltage can be regulated with no direct connection between input and output. The output is fully floating up to the breakdown voltage of the transformer windings. Multiple floating outputs are easily obtained with additional windings. A special delay network inside the LT1170/LT1171/LT1172 ignores the leakage inductance spike at the leading edge of the flyback pulse to improve output regulation.

The error signal developed at the comparator input is brought out externally. This pin ($V_C$) has four different functions. It is used for frequency compensation, current limit adjustment, soft starting, and total regulator shutdown. During normal regulator operation this pin sits at a voltage between 0.9V (low output current) and 2.0V (high output current). The error amplifiers are current output ($g_m$) types, so this voltage can be externally clamped for adjusting current limit. Likewise, a capacitor coupled external clamp will provide soft start. Switch duty cycle goes to zero if the $V_C$ pin is pulled to ground through a diode, placing the LT1170/LT1171/LT1172 in an idle mode. Pulling the $V_C$ pin below 0.15V causes total regulator shutdown, with only 50µA supply current for shutdown circuitry biasing. See AN19 for full application details.

### Extra Pins on the MiniDIP and Surface Mount Packages

The 8- and 16-pin versions of the LT1172 have the emitters of the power transistor brought out separately from the ground pin. This eliminates errors due to ground pin voltage drops and allows the user to reduce switch current limit 2:1 by leaving the second emitter (E2) disconnected. The first emitter (E1) should always be connected to the ground pin. Note that switch "on" resistance doubles when E2 is left open, so efficiency will suffer somewhat

when switch currents exceed 300mA. Also, note that chip dissipation will actually *increase* with E2 open during normal load operation, even though dissipation in current limit mode will *decrease*. See "Thermal Considerations" next.

### Thermal Considerations When Using the MiniDIP and SW Packages

The low supply current and high switch efficiency of the LT1172 allow it to be used without a heat sink in most applications when the TO-220 or TO-3 package is selected. These packages are rated at 50°C/W and 35°C/W respectively. The miniDIPs, however, are rated at 100°C/W in ceramic (J) and 130°C/W in plastic (N).

Care should be taken for miniDIP applications to ensure that the worst case input voltage and load current conditions do not cause excessive die temperatures. The following formulas can be used as a rough guide to calculate LT1172 power dissipation. For more details, the reader is referred to Application Note 19 (AN19), "Efficiency Calculations" section.

Average supply current (including driver current) is:

$$I_{IN} \approx 6mA + I_{SW}(0.004 + DC/40)$$

$I_{SW}$ = switch current
DC = switch duty cycle

Switch power dissipation is given by:

$$P_{SW} = (I_{SW})^2 \bullet (R_{SW})(DC)$$

$R_{SW}$ = LT1172 switch "on" resistance (1Ω maximum)

Total power dissipation is the sum of supply current times input voltage plus switch power:

$$P_{D(TOT)} = (I_{IN})(V_{IN}) + P_{SW}$$

In a typical example, using a boost converter to generate 12V at 0.12A from a 5V input, duty cycle is approximately 60%, and switch current is about 0.65A, yielding:

$$I_{IN} = 6mA + 0.65(0.004 + DC/40) = 18mA$$

$$P_{SW} = (0.65)^2 \bullet (1Ω)(0.6) = 0.25W$$

$$P_{D(TOT)} = (5V)(0.018A) + 0.25 = 0.34W$$

---

*See note under block diagram.

LINEAR
TECHNOLOGY

# OPERATION

Temperature rise in a plastic miniDIP would be 130°C/W times 0.34W, or approximately 44°C. The maximum ambient temperature would be limited to 100°C (commercial temperature limit) minus 44°C, or 56°C.

In most applications, full load current is used to calculate die temperature. However, if overload conditions must also be accounted for, four approaches are possible. First, if loss of regulated output is acceptable under overload conditions, the internal *thermal limit* of the LT1172 will protect the die in most applications by shutting off switch current. *Thermal limit is not a tested parameter*, however, and should be considered only for noncritical applications with temporary overloads. A second approach is to use the larger TO-220 (T) or TO-3 (K) package which, even without a heat sink, may limit die temperatures to safe levels under overload conditions. In critical situations, heat sinking of these packages is required; especially if overload conditions must be tolerated for extended periods of time.

The third approach for lower current applications is to leave the second switch emitter (miniDIP only) open. This increases switch "on" resistance by 2:1, but reduces switch current limit by 2:1 also, resulting in a net 2:1 reduction in $I^2R$ switch dissipation under current limit conditions.

The fourth approach is to clamp the $V_C$ pin to a voltage less than its internal clamp level of 2V. The LT1172 switch current limit is zero at approximately 1V on the $V_C$ pin and 2A at 2V on the $V_C$ pin. Peak switch current can be externally clamped between these two levels with a diode. See AN19 for details.

## LT1170/LT1171/LT1172 Synchronizing

The LT1170/LT1171/LT1172 can be externally synchronized in the frequency range of 120kHz to 160kHz. This is accomplished as shown in the accompanying figures. Synchronizing occurs when the $V_C$ pin is pulled to ground with an external transistor. To avoid disturbing the DC characteristics of the internal error amplifier, the width of the synchronizing pulse should be under 0.3µs. C2 sets the pulse width at $\cong$ 0.2µs. The effect of a synchronizing pulse on the LT1170/LT1171/LT1172 amplifier offset can be calculated from:

$$\Delta V_{OS} = \frac{\left(\dfrac{KT}{q}\right)(t_S)(f_S)\left(I_C + \dfrac{V_C}{R3}\right)}{I_C}$$

$\dfrac{KT}{q}$ = 26mV at 25°C

$t_S$ = pulse width
$f_S$ = pulse frequency
$I_C$ = $V_C$ source current ($\approx$ 200µA)
$V_C$ = operating $V_C$ voltage (1V to 2V)
R3 = resistor used to set mid-frequency "zero" in frequency compensation network.

With $t_S$ = 0.2µs, $f_S$ = 150kHz, $V_C$ = 1.5V, and R3 = 2k, offset voltage shift is $\approx$ 3.8mV. This is not particularly bothersome, but note that high offsets could result if R3 were reduced to a much lower value. Also, the synchronizing transistor must sink higher currents with low values of R3, so larger drives may have to be used. The transistor must be capable of pulling the $V_C$ pin to within 200mV of ground to ensure synchronizing.

**Synchronizing with Bipolar Transistor**
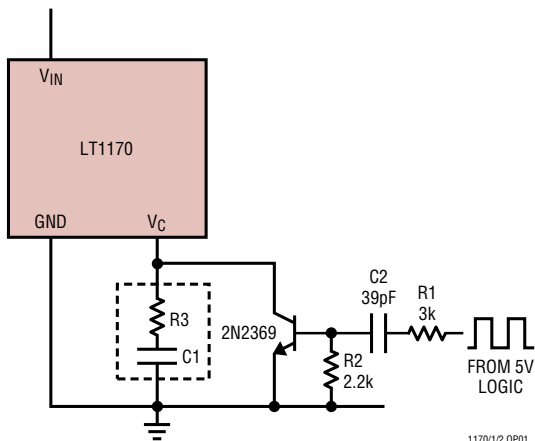


**Synchronizing with MOS Transistor**
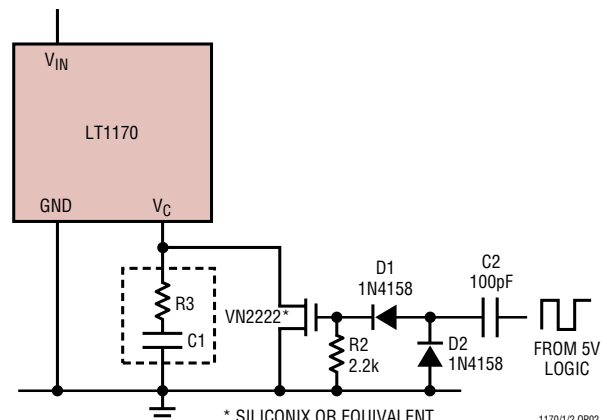
# TYPICAL APPLICATIONS

## Flyback Converter



PRIMARY FLYBACK VOLTAGE $= \dfrac{V_{OUT} + V_f}{N}$

LT1170 SWITCH VOLTAGE
AREA "a" = AREA "b" TO MAINTAIN
ZERO DC VOLTS ACROSS PRIMARY

SECONDARY VOLTAGE
AREA "c" = AREA "d" TO MAINTAIN
ZERO DC VOLTS ACROSS SECONDARY

PRIMARY CURRENT

SECONDARY CURRENT

LT1170 SWITCH CURRENT

SNUBBER DIODE CURRENT

$t = \dfrac{(I_{PRI})(L_L)}{V_{SNUB}}$

*REQUIRED IF INPUT LEADS ≥ 2"
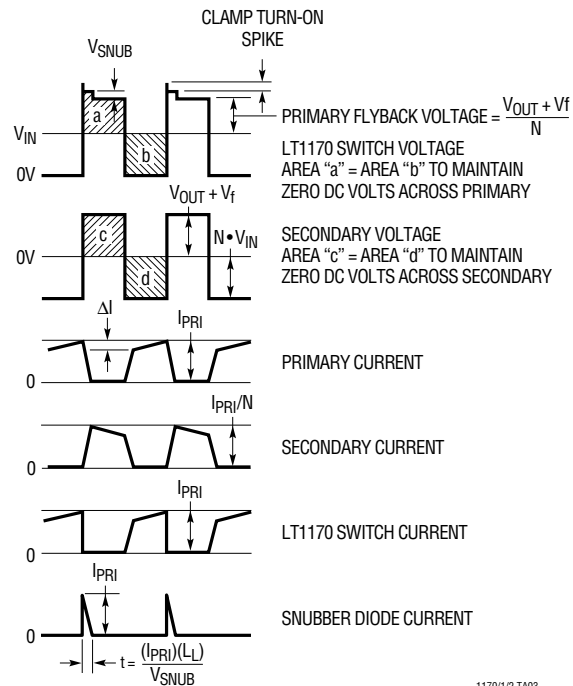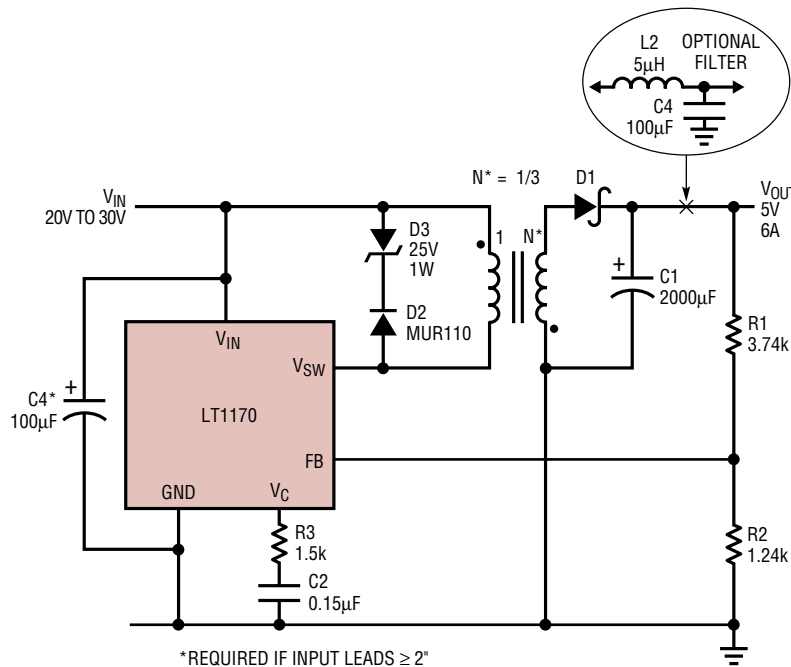
1170/1/2 TA03

## LCD Contrast Supply
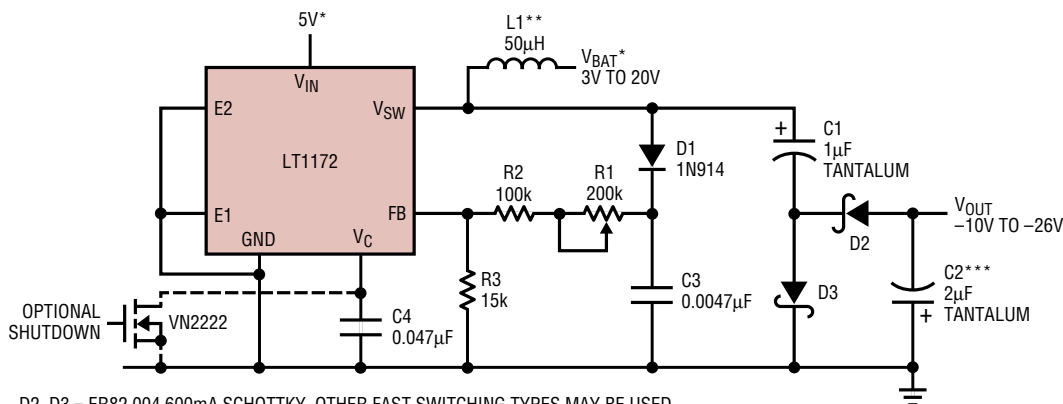


D2, D3 = ER82.004 600mA SCHOTTKY. OTHER FAST SWITCHING TYPES MAY BE USED.

* $V_{IN}$ AND BATTERY MAY BE TIED TOGETHER. MAXIMUM VALUE FOR $V_{BAT}$ IS EQUAL TO THE |NEGATIVE OUTPUT| + 1V. WITH HIGHER BATTERY VOLTAGES, HIGHEST EFFICIENCY IS OBTAINED BY RUNNING THE LT1172 $V_{IN}$ PIN FROM 5V. SHUTTING OFF THE 5V SUPPLY WILL AUTOMATICALLY TURN OFF THE LT1172. EFFICIENCY IS ABOUT 80% AT $I_{OUT} = 25mA$.

R1, R2, R3 ARE MADE LARGE TO MINIMIZE BATTERY DRAIN IN SHUTDOWN, WHICH IS APPROXIMATELY $V_{BAT}$/(R1 + R2 + R3).

** FOR HIGH EFFICIENCY, L1 SHOULD BE MADE ON A FERRITE OR MOLYPERMALLOY CORE. PEAK INDUCTOR CURRENTS ARE ABOUT 600mA AT $P_{OUT} = 0.7Ω$. INDUCTOR SERIES RESISTANCE SHOULD BE LESS THAN 0.4Ω FOR HIGH EFFICIENCY.

*** OUTPUT RIPPLE IS ABOUT 200mV$_{P-P}$ TO 400mV$_{P-P}$ WITH C2 = 2μF TANTALUM. IF LOWER RIPPLE IS DESIRED, INCREASE C2, OR ADD A 10Ω , 1μF TANTALUM OUTPUT FILTER.

1170/1/2 TA04

# TYPICAL APPLICATIONS (Note that maximum output currents are divided by 2 for LT1171, by 4 for LT1172.)

### Driving High Voltage FET
### (for Off-Line Applications, See AN25)

1170/1/2 TA05

### External Current Limit

1170/1/2 TA06
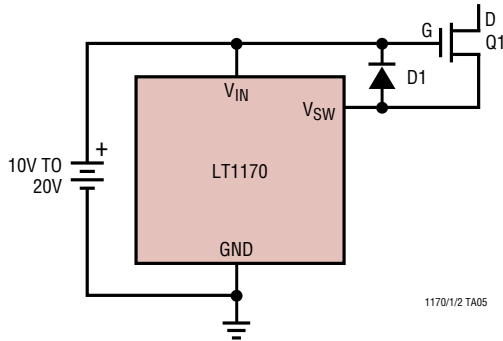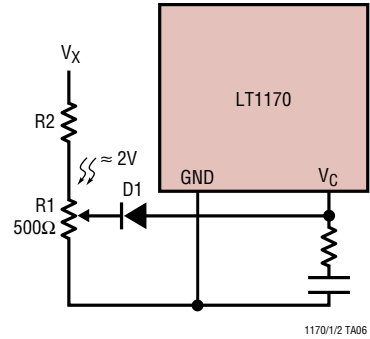
### Negative-to-Positive Buck-Boost Converter†
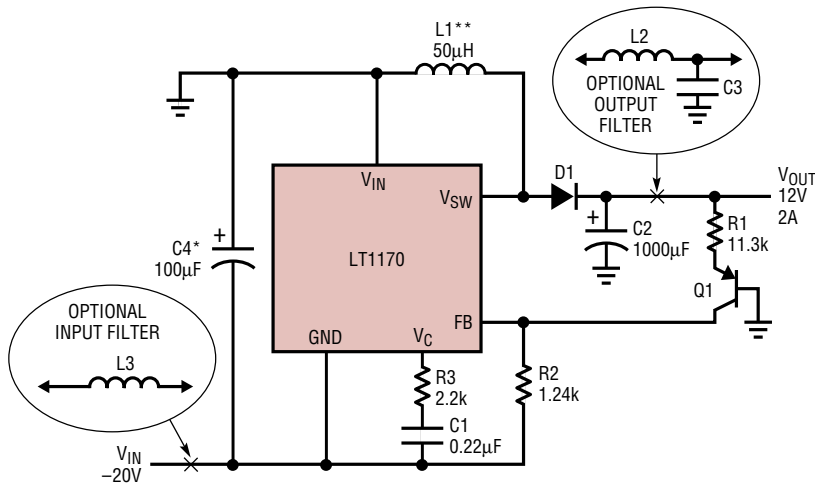
* REQUIRED IF INPUT LEADS ≥ 2"
** PULSE ENGINEERING 92114, COILTRONICS 50-2-52
† THIS CIRCUIT IS OFTEN USED TO CONVERT –48V TO 5V. TO GUARANTEE
FULL SHORT-CIRCUIT PROTECTION, THE CURRENT LIMIT CIRCUIT SHOWN
IN AN19, FIGURE 39, SHOULD BE ADDED WITH C1 REDUCED TO 200pF.

1170/1/2 TA07

### External Current Limit

NOTE THAT THE LT1170
GND PIN IS NO LONGER
COMMON TO $V_{IN}^-$.

1170/1/2 TA08

### Negative Buck Converter

* REQUIRED IF INPUT LEADS ≥ 2"
** PULSE ENGINEERING 92114
COILTRONICS 50-2-52
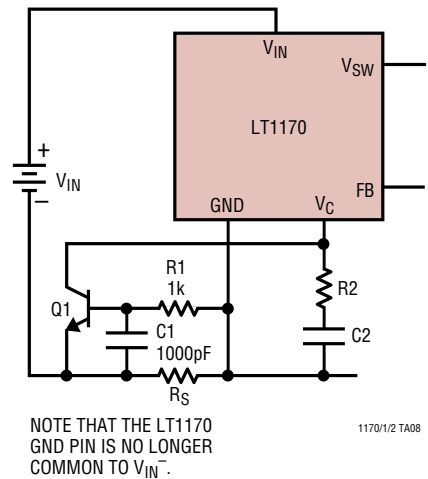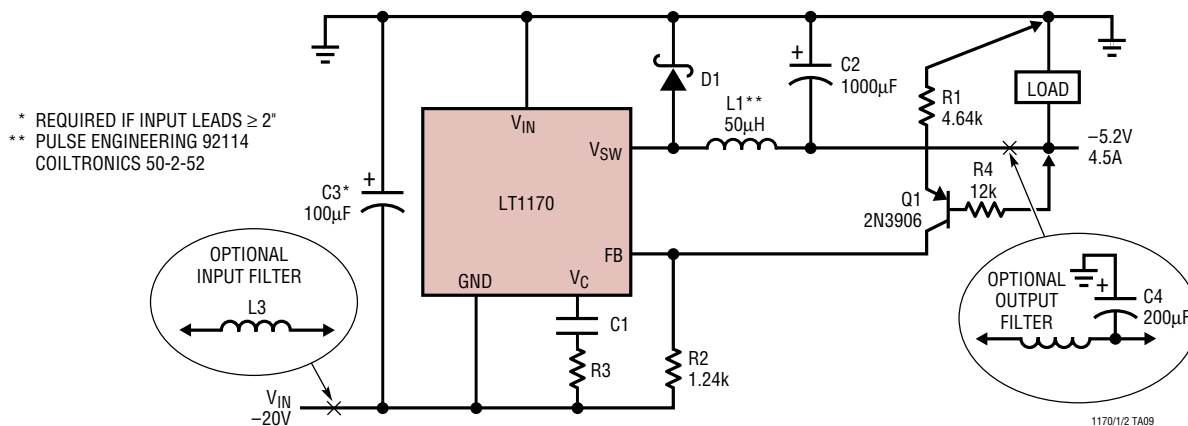
1170/1/2 TA09

# TYPICAL APPLICATIONS

**Positive-to-Negative Buck-Boost Converter**



* REQUIRED IF INPUT LEADS ≥ 2"
** PULSE ENGINEERING 92114, COILTRONICS 50-2-52
† TO AVOID STARTUP PROBLEMS FOR INPUT VOLTAGES
  BELOW 10V, CONNECT ANODE OF D3 TO $V_{IN}$, AND
  REMOVE R5. C1 MAY BE REDUCED FOR LOWER OUTPUT
  CURRENTS. C1 ≈ (500µF)($I_{OUT}$).
  FOR 5V OUTPUTS, REDUCE R3 TO 1.5k, INCREASE C2 TO
  0.3µF, AND REDUCE R6 TO 100Ω.
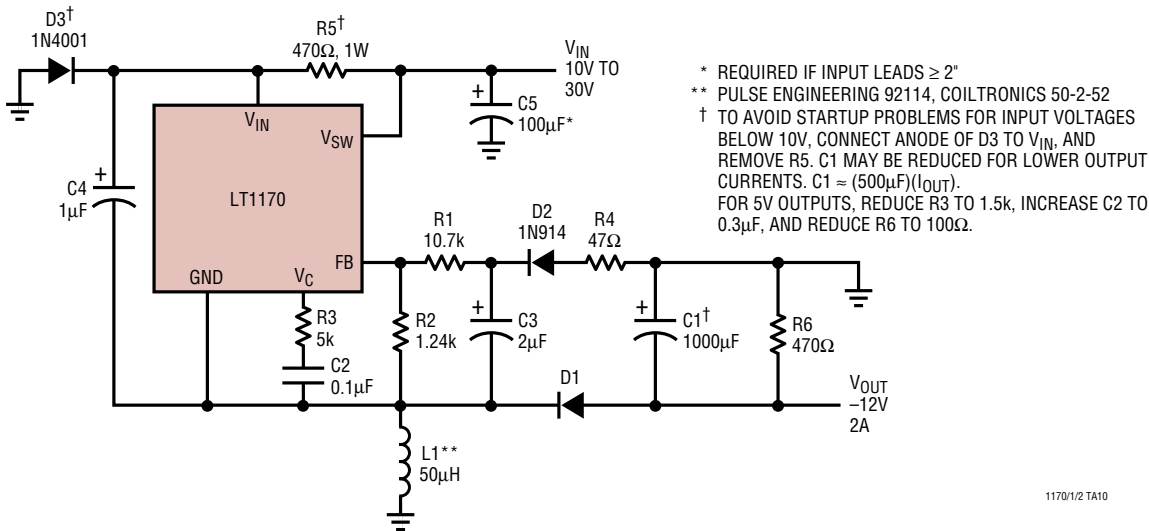
1170/1/2 TA10

**High Efficiency Constant Current Charger**



$$I_{CHRG} = \frac{1.244V \cdot R4}{R3 \cdot R5} = 1A \text{ AS SHOWN}$$

* L2 REDUCES RIPPLE CURRENT INTO
  THE BATTERY BY ABOUT 20:1.
  IT MAY BE OMITTED IF DESIRED.
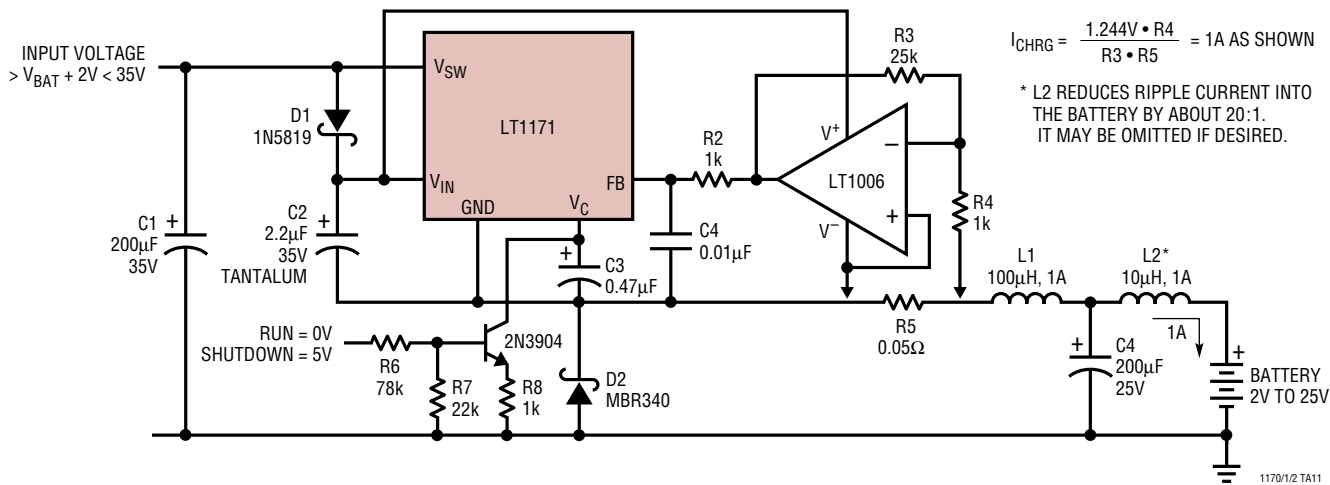
1170/1/2 TA11

**Backlight CCFL Supply (see AN45 for details)**



* Q1,Q2 = BCP56 OR MPS650/561
** COILTRONICS CTX300-4
*** SUMIDA 6345-020 OR COILTRONICS 110092-1
† A MODIFICATION WILL ALLOW OPERATION DOWN TO 4.5V. CONSULT FACTORY.
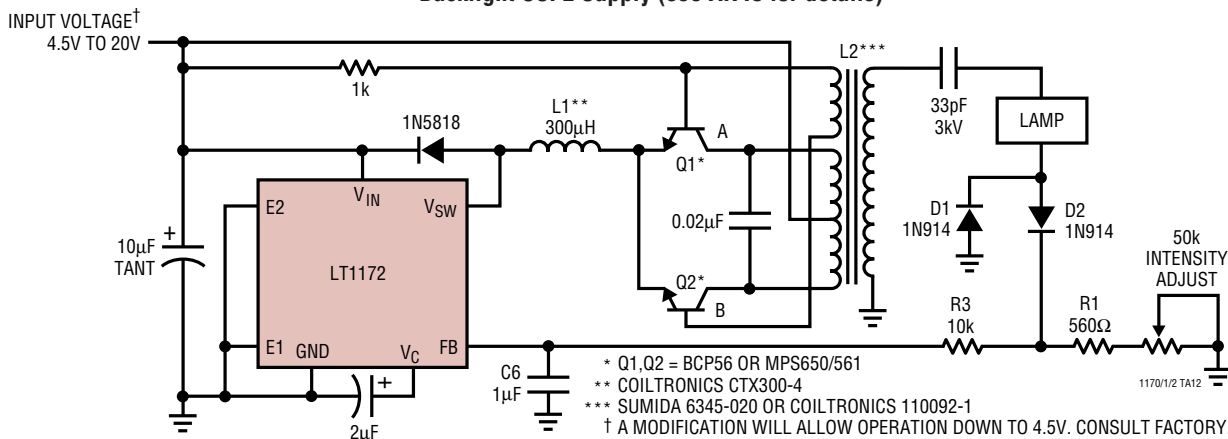
1170/1/2 TA12

# TYPICAL APPLICATIONS

**Positive Buck Converter**



```
*   REQUIRED IF INPUT LEADS ≥ 2"
**  PULSE ENGINEERING 92114
    COILTRONICS 50-2-52
```

1170/1/2 TA13
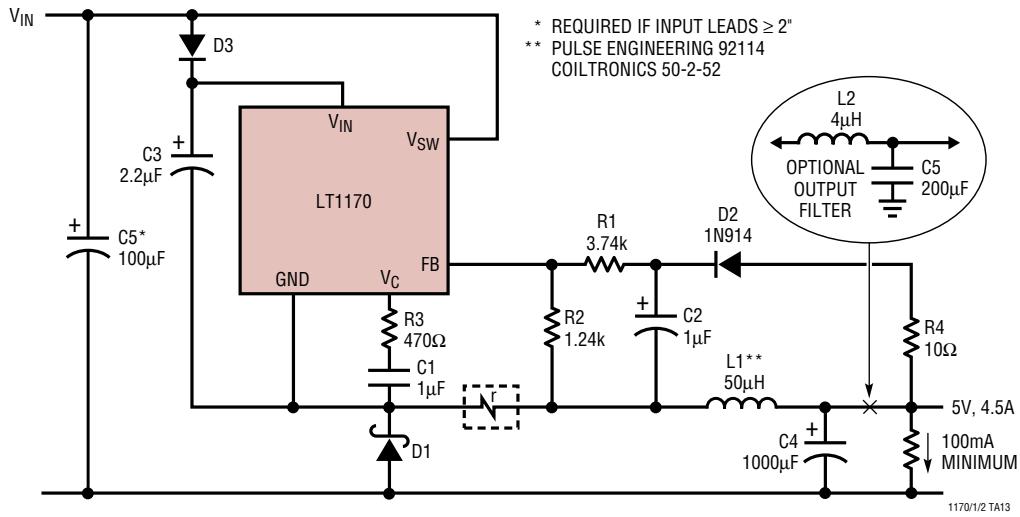
**Negative Boost Regulator**



* REQUIRED IF INPUT LEADS ≥ 2"

1170/1/2 TA14

**Driving High Voltage NPN**



```
*   SETS I_B (ON)
**  SETS I_B (OFF)
```

1170/1/2 TA15
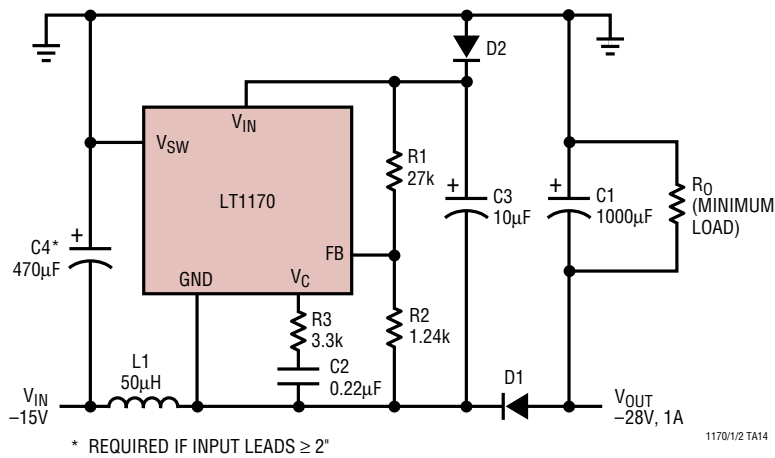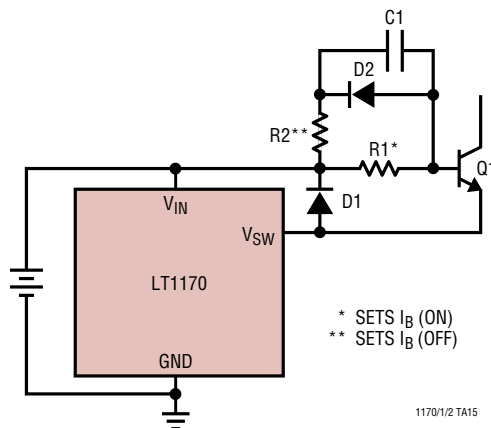
# TYPICAL APPLICATIONS

**Forward Converter**



1170/1/2 TA16
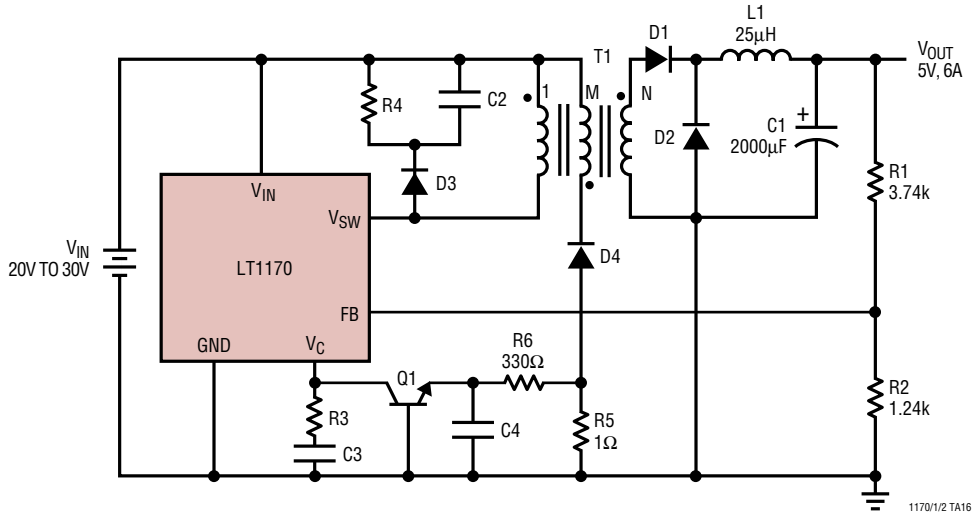
**High Efficiency 5V Buck Converter**



MODE LOGIC
220pF

<0.3V = NORMAL MODE
>2.5V = SHUTDOWN
OPEN = BURST MODE

* R2 IS MADE FROM PC BOARD
  COPPER TRACES.
** MAXIMUM CURRENT IS DETERMINED
   BY THE CHOICE OF LT1070 FAMILY.
   SEE APPLICATION SECTION.

1170/1/2 TA17
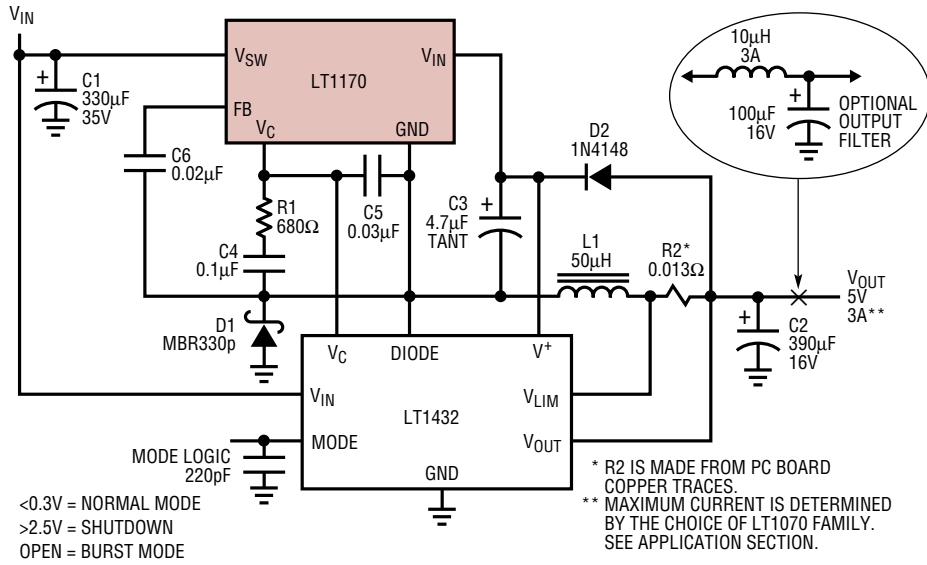
# PACKAGE DESCRIPTION  Dimensions in inches (millimeters) unless otherwise noted.

**J8 Package**
**8-Lead CERDIP (Narrow 0.300, Hermetic)**
(LTC DWG # 05-08-1110)

CORNER LEADS OPTION
(4 PLCS)

0.023 – 0.045
(0.584 – 1.143)
HALF LEAD
OPTION

0.045 – 0.068
(1.143 – 1.727)
FULL LEAD
OPTION

0.300 BSC
(0.762 BSC)

0.008 – 0.018
(0.203 – 0.457)

0° – 15°

NOTE: LEAD DIMENSIONS APPLY TO SOLDER DIP/PLATE
OR TIN PLATE LEADS

0.405
(10.287)
MAX

0.005
(0.127)
MIN

8 7 6 5

0.025
(0.635)
RAD TYP

0.220 – 0.310
(5.588 – 7.874)

1 2 3 4

0.200
(5.080)
MAX

0.015 – 0.060
(0.381 – 1.524)

0.045 – 0.065
(1.143 – 1.651)

0.014 – 0.026
(0.360 – 0.660)

0.100
(2.54)
BSC

0.125
3.175
MIN

J8 1298

15
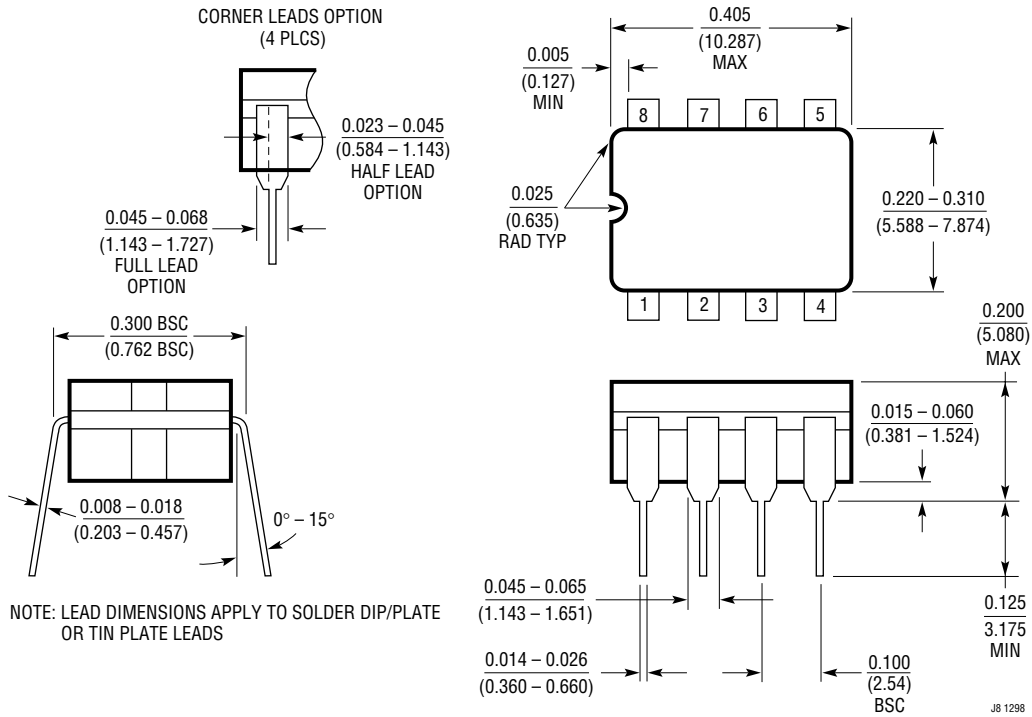
# PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

**K Package**
**4-Lead TO-3 Metal Can**
(LTC DWG # 05-08-1311)

0.320 – 0.350
(8.13 – 8.89)

0.760 – 0.775
(19.30 – 19.69)

0.060 – 0.135
(1.524 – 3.429)

0.420 – 0.480
(10.67 – 12.19)

0.038 – 0.043
(0.965 – 1.09)

1.177 – 1.197
(29.90 – 30.40)

0.470 TP
P.C.D.

0.655 – 0.675
(16.64 – 19.05)

0.151 – 0.161
(3.84 – 4.09)
DIA 2 PLC

0.167 – 0.177
(4.24 – 4.49)
R

0.490 – 0.510
(12.45 – 12.95)
R

72°

18°

K4(TO-3) 1098
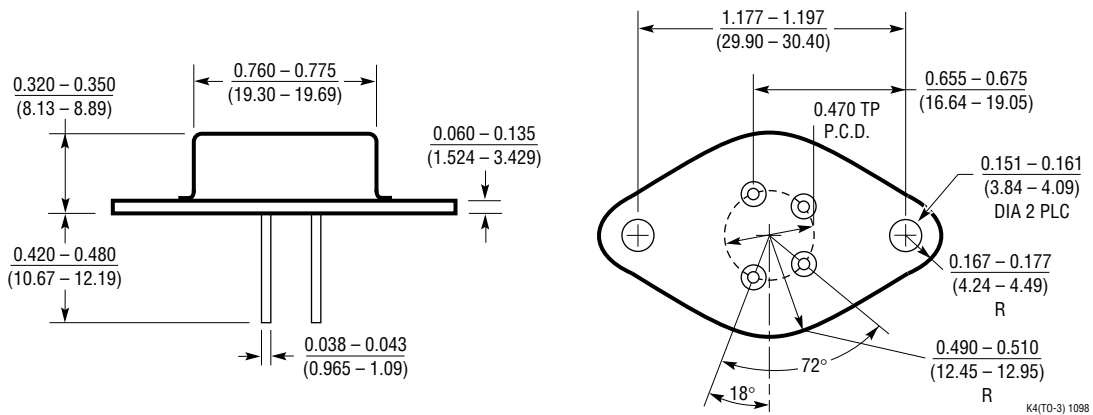
**N8 Package**
**8-Lead PDIP (Narrow 0.300)**
(LTC DWG # 05-08-1510)

0.400*
(10.160)
MAX

0.255 ± 0.015*
(6.477 ± 0.381)

0.300 – 0.325
(7.620 – 8.255)

0.009 – 0.015
(0.229 – 0.381)

$0.325 \begin{smallmatrix} +0.035 \\ -0.015 \end{smallmatrix}$

$\left( 8.255 \begin{smallmatrix} +0.889 \\ -0.381 \end{smallmatrix} \right)$

0.045 – 0.065
(1.143 – 1.651)

0.130 ± 0.005
(3.302 ± 0.127)

0.065
(1.651)
TYP

0.125
(3.175)
MIN

0.020
(0.508)
MIN

0.100
(2.54)
BSC

0.018 ± 0.003
(0.457 ± 0.076)

N8 1098

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

LINEAR
TECHNOLOGY

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

**Q Package**
**5-Lead Plastic DD Pak**
(LTC DWG # 05-08-1461)

0.256
(6.502)

0.060
(1.524)

0.060
(1.524)

0.183
(4.648)

0.075
(1.905)

0.300
(7.620)

BOTTOM VIEW OF DD PAK
HATCHED AREA IS SOLDER PLATED
COPPER HEAT SINK

0.060
(1.524)
TYP

0.390 – 0.415
(9.906 – 10.541)

15° TYP

0.330 – 0.370
(8.382 – 9.398)

$0.143^{+0.012}_{-0.020}$

$\left(3.632^{+0.305}_{-0.508}\right)$

0.028 – 0.038
(0.711 – 0.965)

0.067
(1.70)
BSC

0.165 – 0.180
(4.191 – 4.572)

0.045 – 0.055
(1.143 – 1.397)

0.059
(1.499)
TYP

$0.004^{+0.008}_{-0.004}$

$\left(0.102^{+0.203}_{-0.102}\right)$

0.095 – 0.115
(2.413 – 2.921)

0.013 – 0.023
(0.330 – 0.584)

0.050 ± 0.012
(1.270 ± 0.305)

Q(DD5) 1098

**S8 Package**
**8-Lead Plastic Small Outline (Narrow 0.150)**
(LTC DWG # 05-08-1610)
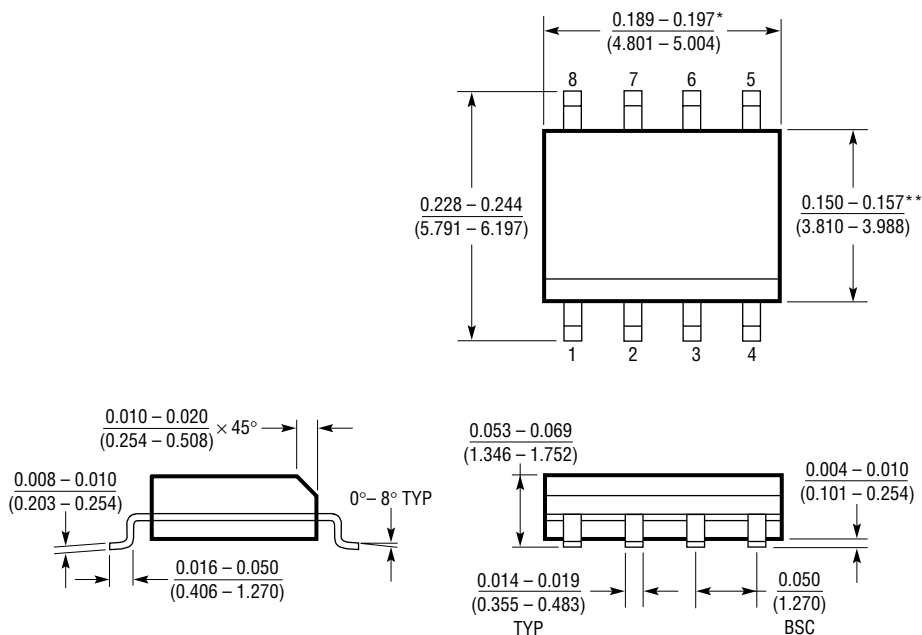
0.189 – 0.197*
(4.801 – 5.004)

8  7  6  5

0.228 – 0.244
(5.791 – 6.197)

0.150 – 0.157**
(3.810 – 3.988)

1  2  3  4

0.010 – 0.020
(0.254 – 0.508) × 45°

0.008 – 0.010
(0.203 – 0.254)

0° – 8° TYP

0.016 – 0.050
(0.406 – 1.270)

0.053 – 0.069
(1.346 – 1.752)

0.004 – 0.010
(0.101 – 0.254)

0.014 – 0.019
(0.355 – 0.483)
TYP

0.050
(1.270)
BSC

*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

SO8 1298

*LT* LINEAR
TECHNOLOGY

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

**SW Package**
**16-Lead Plastic Small Outline (Wide 0.300)**
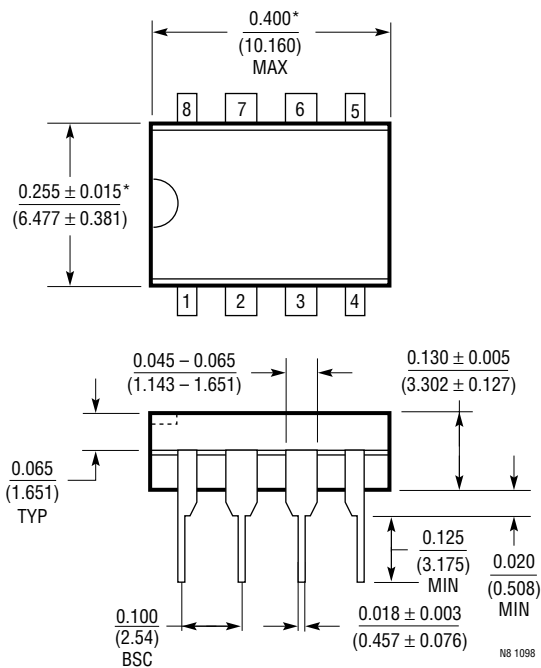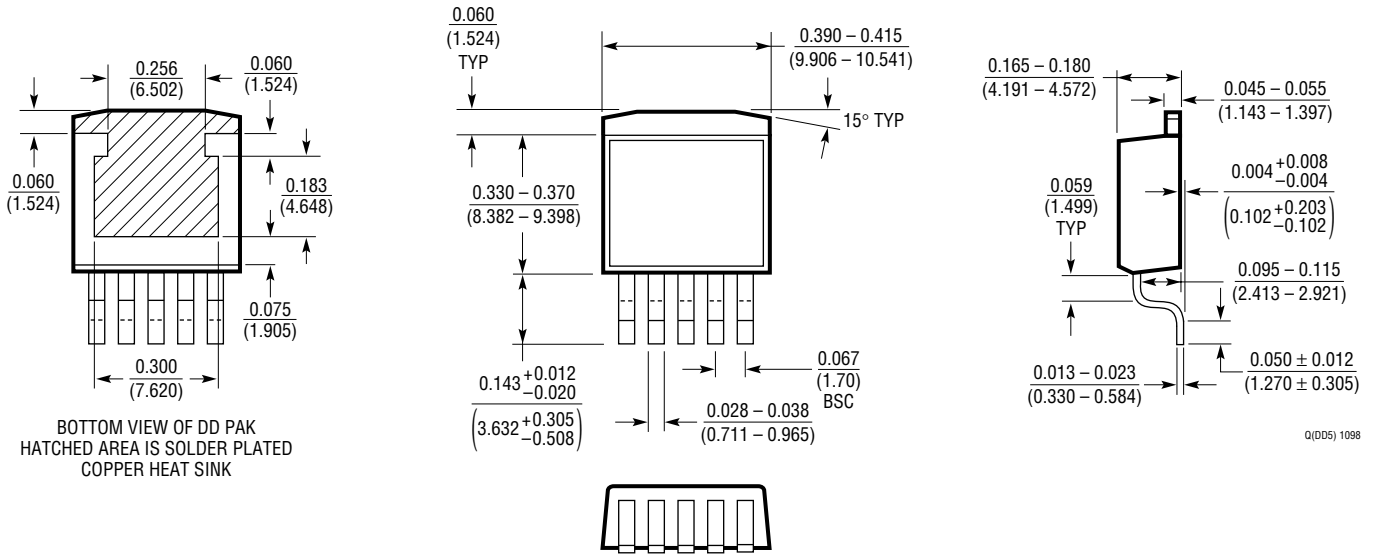(LTC DWG # 05-08-1620)

0.398 – 0.413*
(10.109 – 10.490)

16 15 14 13 12 11 10 9

NOTE 1

0.394 – 0.419
(10.007 – 10.643)

1 2 3 4 5 6 7 8

0.291 – 0.299**
(7.391 – 7.595)

0.010 – 0.029
(0.254 – 0.737) × 45°

0° – 8° TYP

0.009 – 0.013
(0.229 – 0.330)

NOTE 1

0.016 – 0.050
(0.406 – 1.270)

0.093 – 0.104
(2.362 – 2.642)

0.037 – 0.045
(0.940 – 1.143)

0.050
(1.270)
BSC

0.014 – 0.019
(0.356 – 0.482)
TYP

0.004 – 0.012
(0.102 – 0.305)

NOTE:
1. PIN 1 IDENT, NOTCH ON TOP AND CAVITIES ON THE BOTTOM OF PACKAGES ARE THE MANUFACTURING OPTIONS.
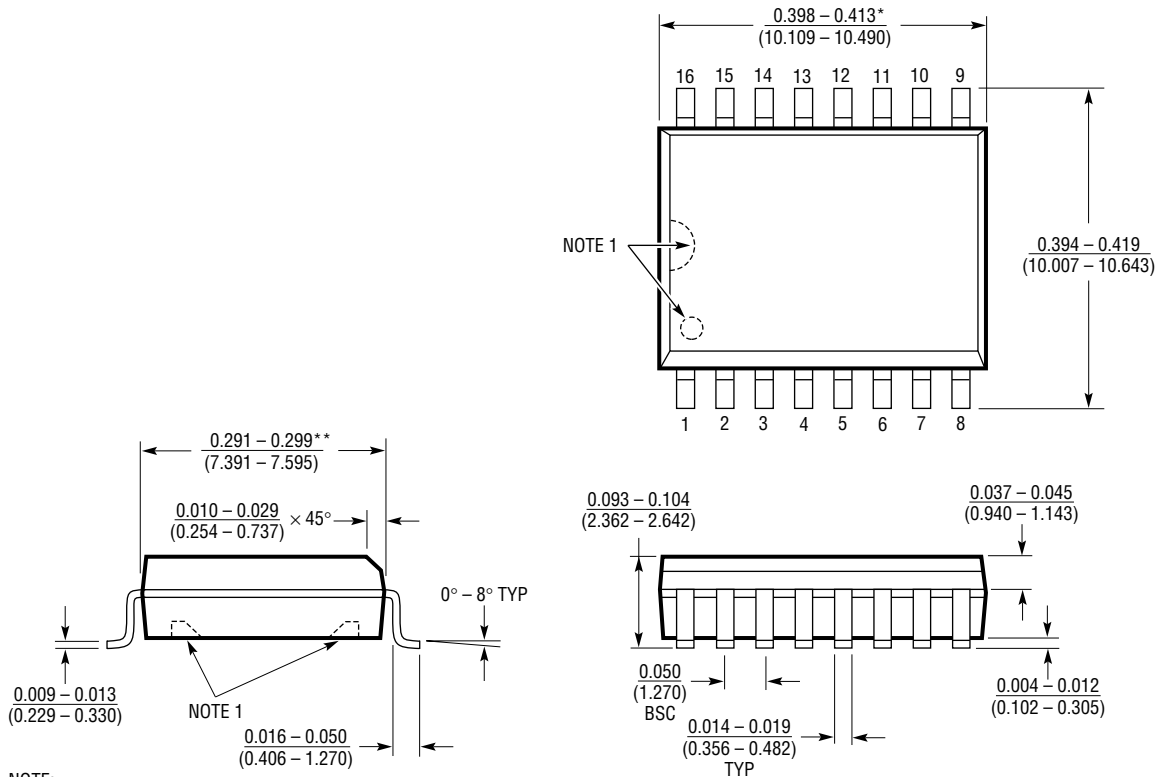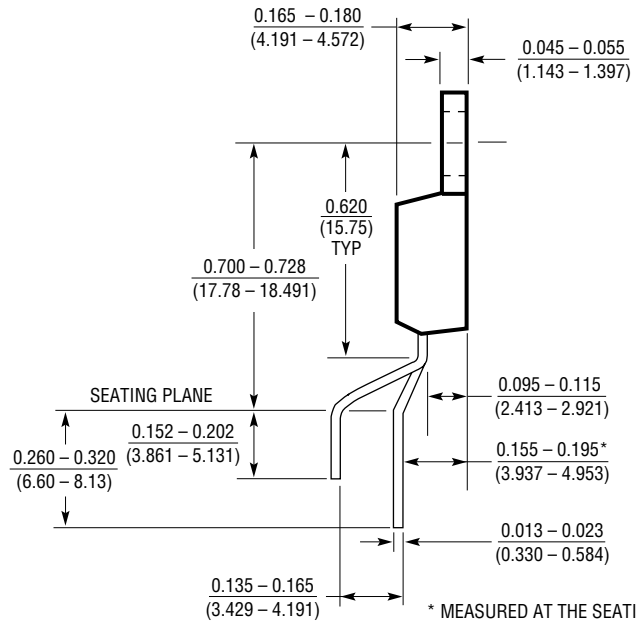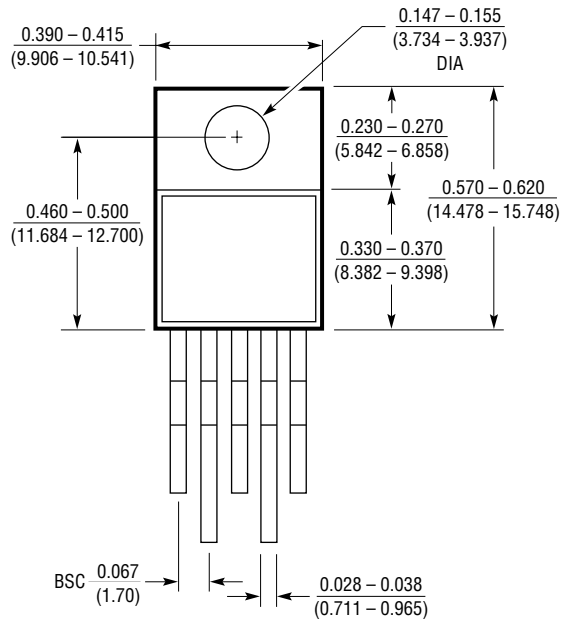   THE PART MAY BE SUPPLIED WITH OR WITHOUT ANY OF THE OPTIONS

\*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

S16 (WIDE) 1098

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TECHNOLOGY

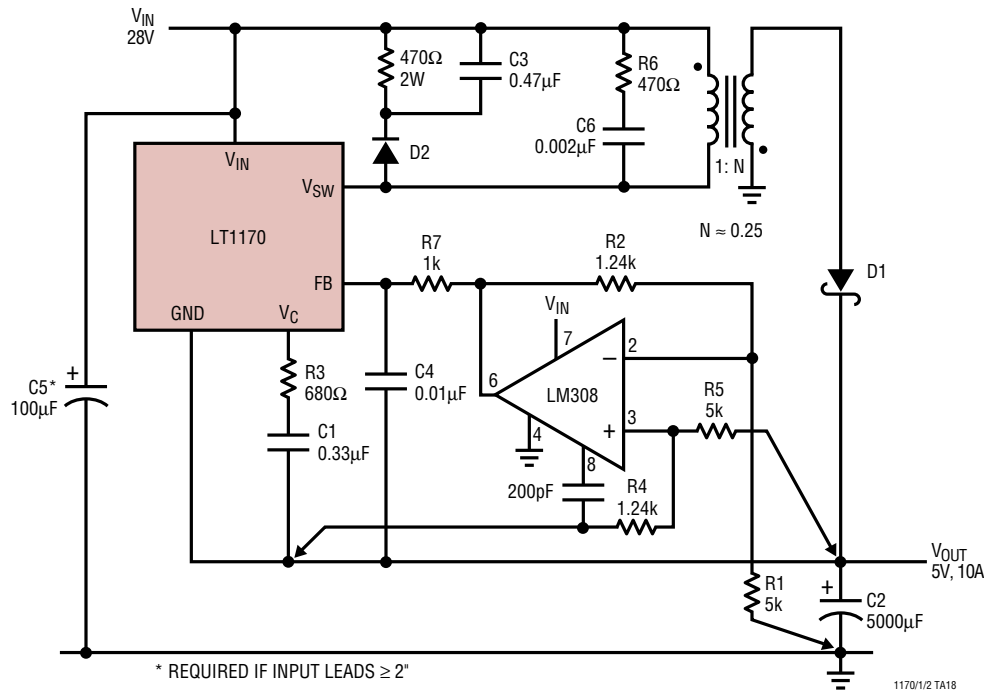# PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

**T Package**
**5-Lead Plastic TO-220 (Standard)**
(LTC DWG # 05-08-1421)

0.390 – 0.415
(9.906 – 10.541)

0.147 – 0.155
(3.734 – 3.937)
DIA

0.230 – 0.270
(5.842 – 6.858)

0.570 – 0.620
(14.478 – 15.748)

0.460 – 0.500
(11.684 – 12.700)

0.330 – 0.370
(8.382 – 9.398)

BSC 0.067
(1.70)

0.028 – 0.038
(0.711 – 0.965)

0.165 – 0.180
(4.191 – 4.572)

0.045 – 0.055
(1.143 – 1.397)

0.620
(15.75)
TYP

0.700 – 0.728
(17.78 – 18.491)

SEATING PLANE

0.152 – 0.202
(3.861 – 5.131)

0.260 – 0.320
(6.60 – 8.13)

0.095 – 0.115
(2.413 – 2.921)

0.155 – 0.195*
(3.937 – 4.953)

0.013 – 0.023
(0.330 – 0.584)

0.135 – 0.165
(3.429 – 4.191)

* MEASURED AT THE SEATING PLANE
T5 (TO-220) 0399

# TYPICAL APPLICATION

**Positive Current Boosted Buck Converter**



* REQUIRED IF INPUT LEADS ≥ 2"

1170/1/2 TA18

# RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|---|---|---|
| LT1070/LT1071/LT1072 | 5A/2.5A/1.25A High Efficiency Switching Regulators | 40kHz, $V_{IN}$ to 60V, $V_{SW}$ to 75V |
| LT1074/LT1076 | 5.5A/2A Step-Down Switching Regulators | 100kHz, Also for Positive-to-Negative Conversion |
| LT1082 | 1A, High Voltage, High Efficiency Switching Regulator | $V_{IN}$ to 75V, $V_{SW}$ to 100V, Telecom |
| LT1268/LT1268B | 7.5A, 150kHz Switching Regulators | $V_{IN}$ to 30V, $V_{SW}$ to 60V |
| LT1269/LT1271 | 4A High Efficiency Switching Regulators | 100kHz/60kHz, $V_{IN}$ to 30V, $V_{SW}$ to 60V |
| LT1270/LT1270A | 8A and 10A High Efficiency Switching Regulators | 60kHz, $V_{IN}$ to 30V, $V_{SW}$ to 60V |
| LT1370 | 500kHz High Efficiency 6A Switching Regulator | High Power Boost, Flyback, SEPIC |
| LT1371 | 500kHz High Efficiency 3A Switching Regulator | Good for Boost, Flyback, Inverting, SEPIC |
| LT1372/LT1377 | 500kHz and 1MHz High Efficiency 1.5A Switching Regulators | Directly Regulates $\pm V_{OUT}$ |
| LT1373 | 250kHz Low Supply Current High Efficiency 1.5A Switching Regulator | Low 1mA Quiescent Current |
| LT1374 | 4A, 500kHz Step-Down Switching Regulator | Synchronizable, $V_{IN}$ to 25V |
| LT1375/LT1376 | 1.5A, 500kHz Step-Down Switching Regulators | Up to 1.25A Out from an SO-8 |
| LT1425 | Isolated Flyback Switching Regulator | 6W Output, ±5% Regulation, No Optocoupler Needed |
| LT1507 | 500kHz Monolithic Buck Mode Switching Regulator | 1.5A Switch, Good for 5V to 3.3V |
| LT1533 | Ultralow Noise 1A Switching Regulator | Push-Pull, <100μV$_{P-P}$ Output Noise |