# 1.3MHz Step-Up DC/DC Converter in SC70 and ThinSOT

## FEATURES

- **1.3MHz Switching Frequency**
- **High Output Voltage: Up to 36V**
- **300mA Integrated Switch**
- 12V at 70mA from 5V Input
- 5V at 60mA from 3.3V Input
- Wide Input Range: 2.5V to 16V
- Uses Small Surface Mount Components
- Low Shutdown Current: <1µA
- Low Profile (1mm) SC70 and SOT-23 (ThinSOT™) Packages

## APPLICATIONS

- Digital Cameras
- CCD Bias Supply
- XDSL Power Supply
- TFT-LCD Bias Supply
- Local 5V or 12V Supply
- Medical Diagnostic Equipment
- Battery Backup

## DESCRIPTION

The LT®3460 is a general purpose step-up DC/DC converter. The LT3460 switches at 1.3MHz, allowing the use of tiny, low cost and low height capacitors and inductors. The constant frequency results in low, predictable output noise that is easy to filter.

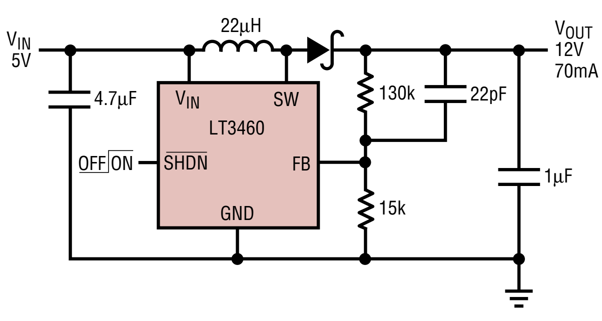
The high voltage switch in the LT3460 is rated at 38V, making the device ideal for boost converters up to 36V. The LT3460 can generate 12V at up to 70mA from a 5V supply.

The LT3460 is available in SC70 and SOT-23 packages.

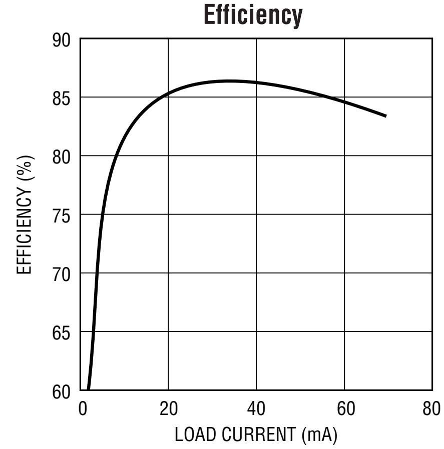


## TYPICAL APPLICATION

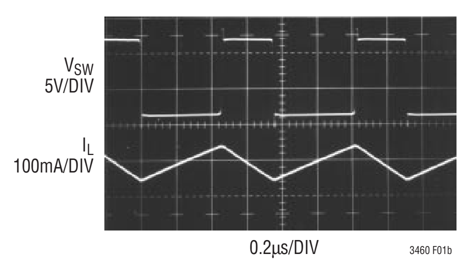
5V to 12V, 70mA Step-Up DC/DC Converter




Efficiency




Switching Waveforms

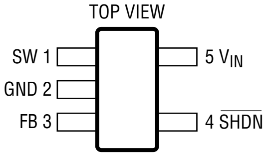
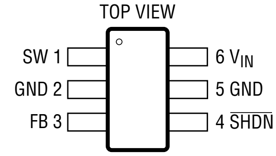


## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage ($V_{IN}$) .................................................. 16V
SW Voltage ............................................................ 38V
FB Voltage ............................................................... 5V
SHDN Voltage ......................................................... 16V

Operating Ambient
Temperature Range (Note 2) .................. –40°C to 85°C
Maximum Junction Temperature .......................... 125°C
Storage Temperature Range ................. –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .................. 300°C

## PACKAGE/ORDER INFORMATION

| | ORDER PART NUMBER | | ORDER PART NUMBER |
|---|---|---|---|
| TOP VIEW   S5 PACKAGE<br>5-LEAD PLASTIC TSOT-23<br>$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 256°C/W IN FREE AIR<br>$\theta_{JA}$ = 120°C ON BOARD OVER GROUND PLANE | LT3460ES5<br>**S5 PART MARKING**<br>LTB1 | TOP VIEW   SC6 PACKAGE<br>6-LEAD PLASTIC SC70<br>$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 400°C/W IN FREE AIR<br>$\theta_{JA}$ = 270°C/W ON BOARD OVER GROUND PLANE | LT3460ESC6<br>**SC6 PART MARKING**<br>LAAF |

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

## ELECTRICAL CHARACTERISTICS

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C, $V_{IN}$ = 3V, $V_{\overline{SHDN}}$ = 3V, unless otherwise noted.**

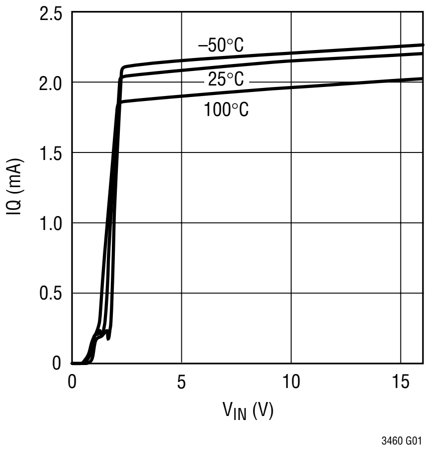
| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Minimum Operating Voltage | | | 2.5 | | | V |
| Maximum Operating Voltage | | | | | 16 | V |
| Feedback Voltage | | | 1.235 | 1.255 | 1.275 | V |
| | | ● | 1.225 | | 1.280 | V |
| Feedback Line Regulation | 2.5V < $V_{IN}$ < 16V | | | 0.015 | | %/V |
| FB Pin Bias Current | | ● | 5 | 25 | 80 | nA |
| Supply Current | | | | 2.0 | 3.0 | mA |
| | SHDN = 0V | | | 0.1 | 0.5 | µA |
| Switching Frequency | | | 1.0 | 1.3 | 1.7 | MHz |
| Maximum Duty Cycle | | | 85 | 90 | | % |
| Switch Current Limit | | | 300 | 420 | 600 | mA |
| Switch $V_{CESAT}$ | $I_{SW}$ = 250mA | | | 320 | 450 | mV |
| Switch Leakage Current | $V_{SW}$ = 5V | | | 0.01 | 1 | µA |
| SHDN Voltage High | | | 1.5 | | | V |
| SHDN Voltage Low | | | | | 0.4 | V |
| SHDN Pin Bias Current | | | | 40 | | µA |

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

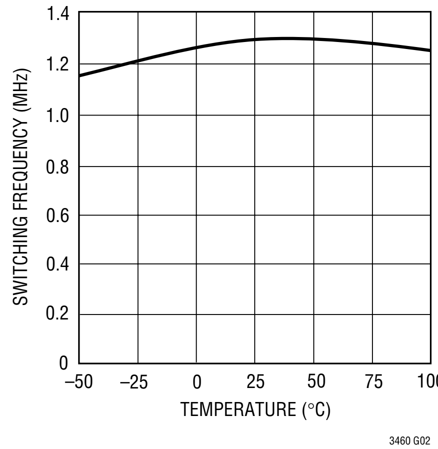
**Note 2:** The LT3460E is guaranteed to meet specifications from 0°C to 70°C. Specifications over the –40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

## TYPICAL PERFORMANCE CHARACTERISTICS

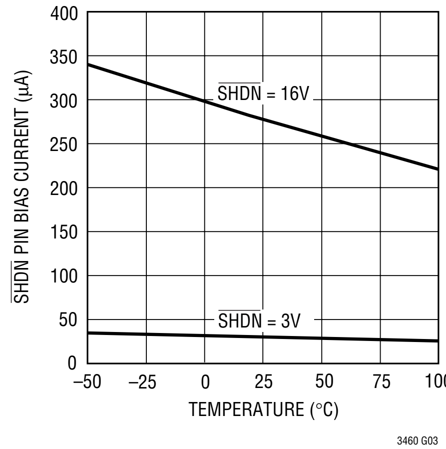
### Quiescent Current



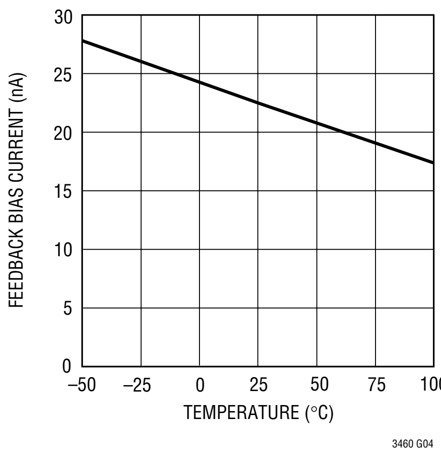

### Switching Frequency



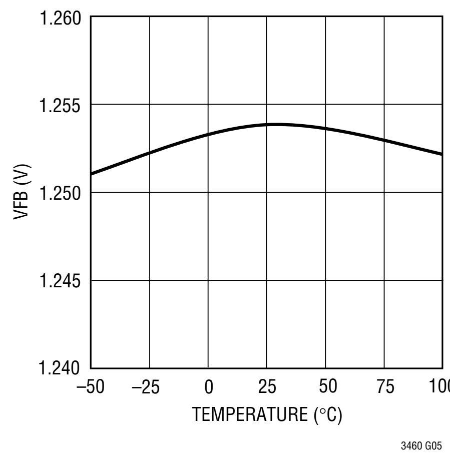

### $\overline{SHDN}$ Pin Bias Current



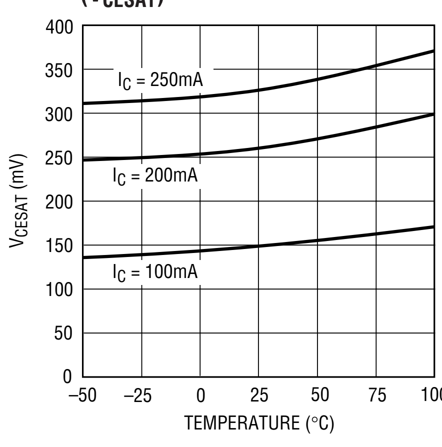

### Feedback Bias Current



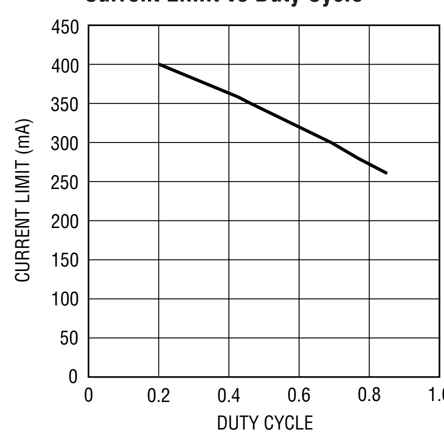

### Feedback Voltage




### Switch Saturation Voltage ($V_{CESAT}$)




### Current Limit vs Duty Cycle



## PIN FUNCTIONS (ThinSOT/SC70 Packages)

**SW (Pin 1/Pin 1):** Switch Pin. Connect inductor/diode here. Minimize trace at this pin to reduce EMI.

**GND (Pin 2/Pins 2 and 5):** Ground Pin. Tie directly to local ground plane.

**FB (Pin 3/Pin 3):** Feedback Pin. Reference voltage is 1.255V. Connect resistor divider tap here. Minimize trace area at FB. Set $V_{OUT}$ according to $V_{OUT} = 1.255V (1 + R1/R2)$.

**$\overline{SHDN}$ (Pin 4/Pin 4):** Shutdown Pin. Tie to 1.5V or higher to enable device; 0.4V or less to disable device. Also functions as soft-start. Use RC filter (47k, 47nF typ) as shown in Figure 1.

**$V_{IN}$ (Pin 5/Pin 6):** Input Supply Pin. Must be locally bypassed.

## BLOCK DIAGRAM

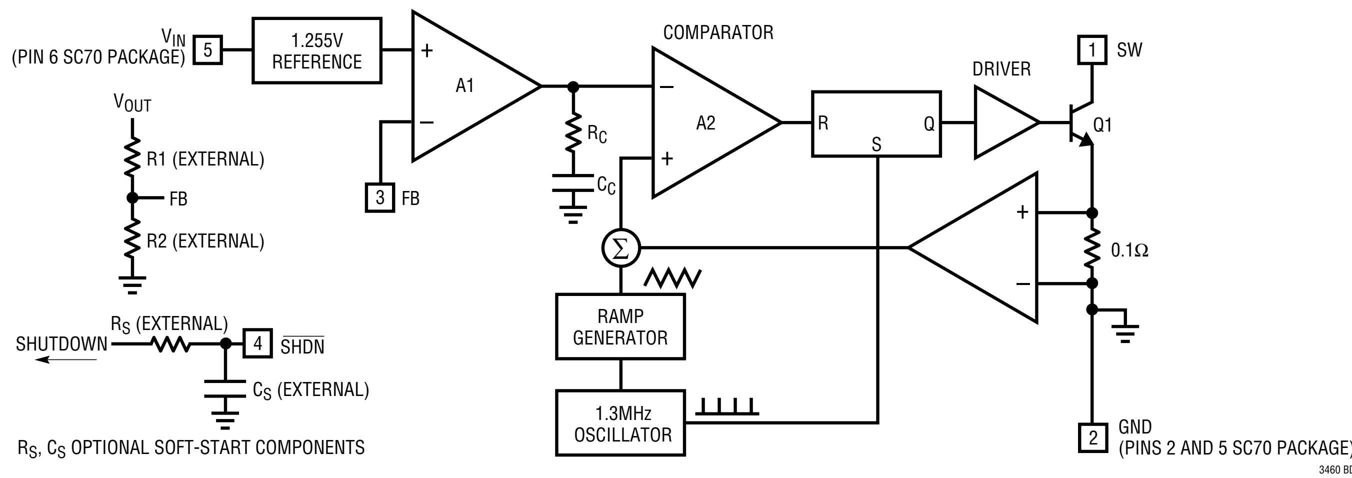



**Figure 1. Block Diagram**

## OPERATION

The LT3460 uses a constant frequency, current mode control scheme to provide excellent line and load regulation. Operation can be best understood by referring to the block diagram in Figure 1. At the start of each oscillator cycle, the SR latch is set, which turns on the power switch Q1. A voltage proportional to the switch current is added to a stabilizing ramp and the resulting sum is fed into the positive terminal of the PWM comparator A2. When this voltage exceeds the level at the negative input of A2, the SR latch is reset turning off the power switch. The level at the negative input of A2 is set by the error amplifier A1, and is simply an amplified version of the difference between the feedback voltage and the reference voltage of 1.255V. In this manner, the error amplifier sets the correct peak current level to keep the output in regulation. If the error amplifier's output increases, more current is delivered to the output; if it decreases, less current is delivered.

# OPERATION

### Feedback Loop Compensation

The LT3460 has an internal feedback compensation network as shown in Figure 1 ($R_C$ and $C_C$). However, because the small signal characteristics of a boost converter change with operation conditions, the internal compensation network cannot satisfy all applications. A properly designed external feed forward capacitor from $V_{OUT}$ to FB ($C_F$ in Figure 2) will correct the loop compensation for most applications.

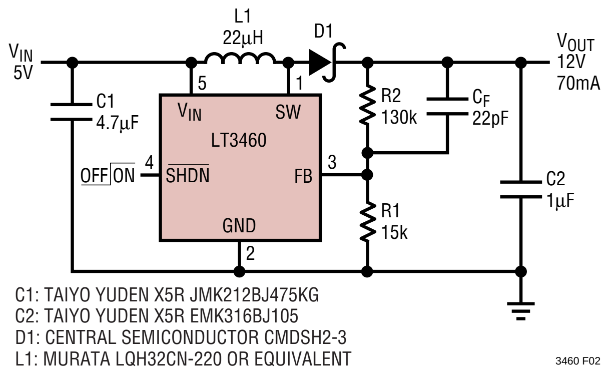



**Figure 2. 5V to 12V Step-Up Converter**

The LT3460 uses peak current mode control. The current feedback makes the inductor very similar to a current source in the medium frequency range. The power stage transfer function in the medium frequency range can be approximated as:

$$G_{P(s)} = \frac{K1}{s \bullet C2},$$

where C2 is the output capacitance, and K1 is a constant based on the operating point of the converter. In continuous current mode, K1 increases as the duty cycle decreases.

The internal compensation network $R_C$, $C_C$ can be approximated as follows in medium frequency range:

$$G_{C(s)} = K2 \bullet \frac{s \bullet R_C \bullet C_C + 1}{s \bullet C_C}$$

The zero

$$f_Z = \frac{1}{2 \bullet \pi \bullet R_C \bullet C_C}$$

is about 70kHz.

The feedback loop gain T(s) = K3 • $G_P$(s) • $G_C$(s). If it crosses over 0dB far before $f_Z$, the phase margin will be small. Figure 3 is the Bode plot of the feedback loop gain measured from the converter shown in Figure 2 without the feedforward capacitor $C_F$. The result agrees with the previous discussion: Phase margin of about 20° is insufficient.

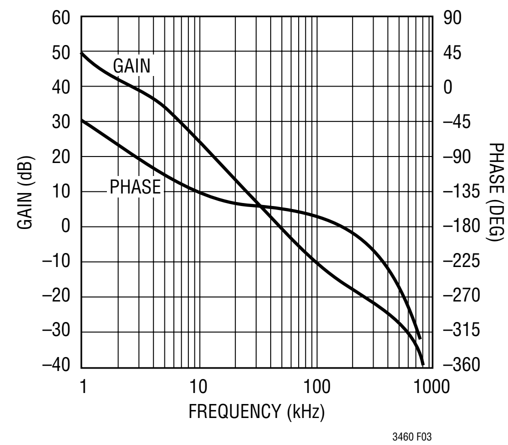



**Figure 3**

In order to improve the phase margin, a feed-forward capacitor $C_F$ in Figure 2 can be used.

Without the feed-forward capacitor, the transfer function from $V_{OUT}$ to FB is:

$$\frac{FB}{V_{OUT}} = \frac{R1}{R1 + R2}$$

With the feed-forward capacitor $C_F$, the transfer function becomes:

$$\frac{FB}{V_{OUT}} = \frac{R1}{R1 + R2} \bullet \frac{s \bullet R2 \bullet C_F + 1}{s \bullet \frac{R1 \bullet R2}{R1 + R2} \bullet C_F + 1}$$

The feed-forward capacitor $C_F$ generates a zero and a pole. The zero always appears before the pole. The frequency distance between the zero and the pole is determined only by the ratio between $V_{OUT}$ and FB. To give maximum phase

## OPERATION

margin, $C_F$ should be chosen so that the midpoint frequency between the zero and the pole is at the cross over frequency.

With $C_F$ = 20pF, the feedback loop Bode plot is reshaped as shown in Figure 4. The phase margin is about 60°.

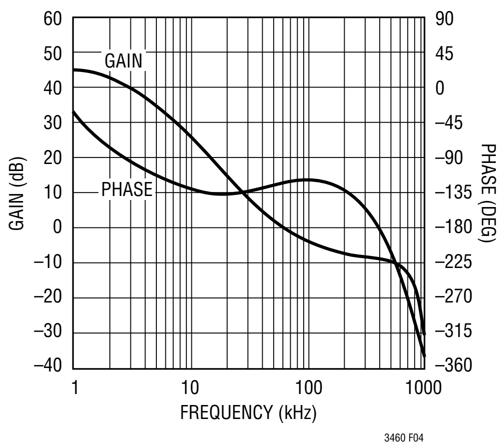



**Figure 4.**

The feed-forward capacitor increases the gain at high frequency. The feedback loop therefore needs to have enough attenuation at the switching frequency to reject the switching noise. Additional internal compensation components have taken this into consideration.

For most of the applications of LT3460, the output capacitor ESR zero is at very high frequency and can be ignored. If a low frequency ESR zero exists, for example, when a high-ESR Tantalum capacitor is used at the output, the phase margin may be enough even without a feed-forward capacitor. In these cases, the feed-forward capacitor should not be added because it may cause the feedback loop to not have enough attenuation at the switching frequency.

### Layout Hints

The high speed operation of the LT3460 demands careful attention to board layout. You will not get advertised performance with careless layout. Figure 5 shows the recommended component placement.

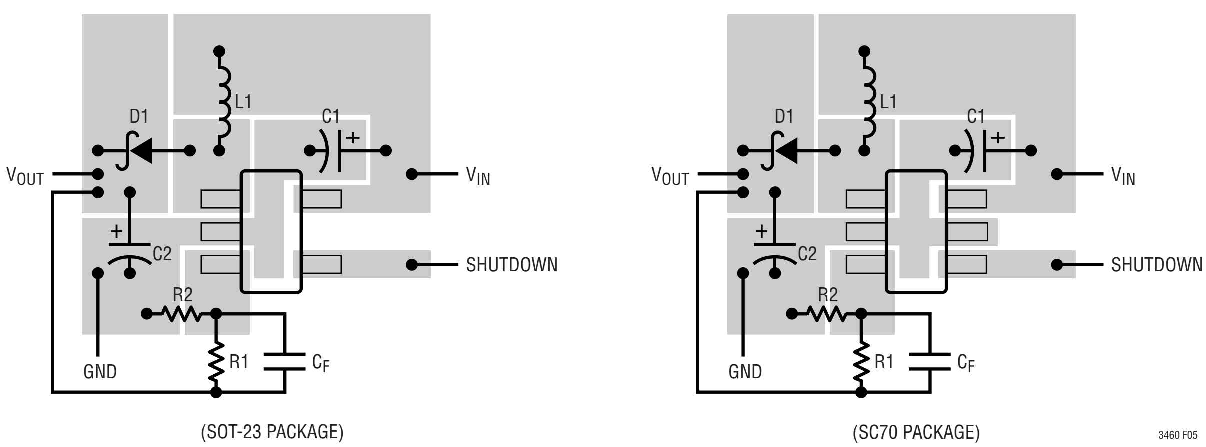
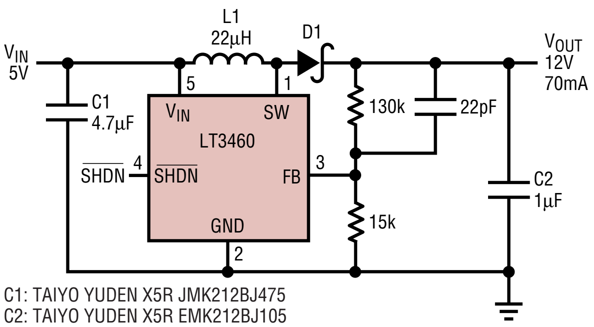



**Figure 5. Suggested Layout**

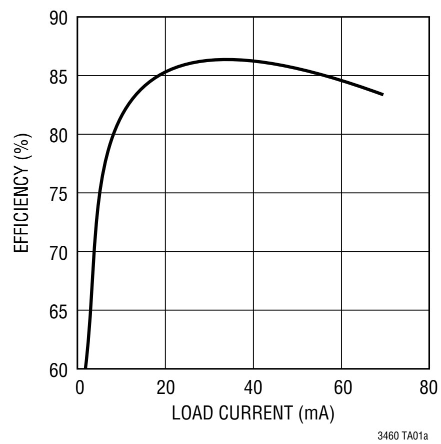
## TYPICAL APPLICATIONS

**5V to 12V Step-Up Converter**

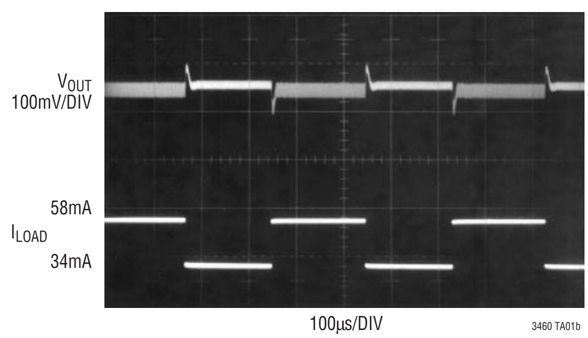



C1: TAIYO YUDEN X5R JMK212BJ475
C2: TAIYO YUDEN X5R EMK212BJ105
D1: CENTRAL SEMICONDUCTOR CMDSH2-3
L1: MURATA LQH32CN-220 OR EQUIVALENT

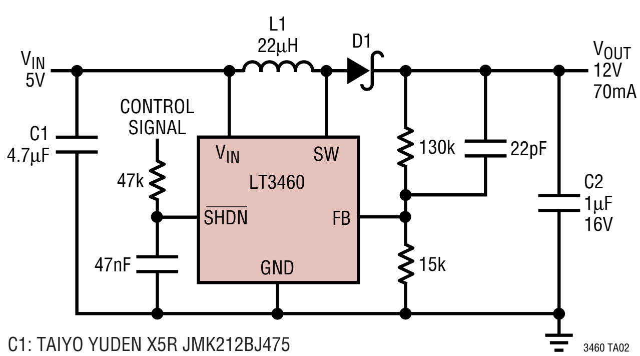
**Efficiency**




**Load Step Response**

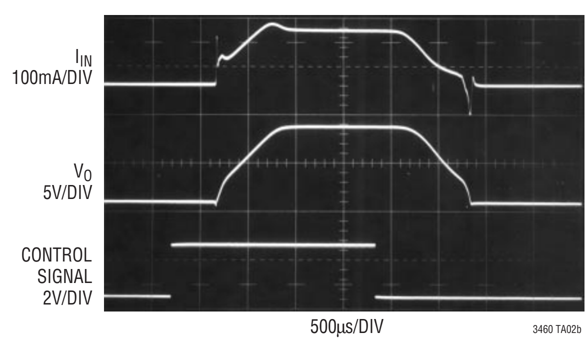



**5V to 12V with Soft-Start Circuit**



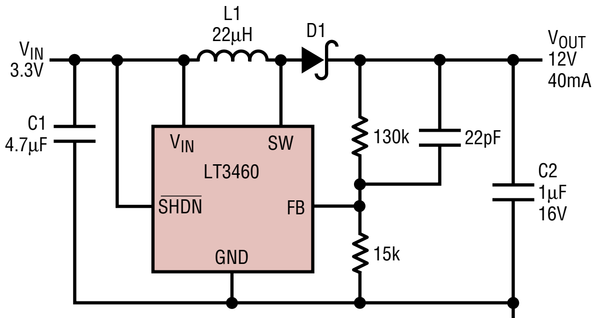

C1: TAIYO YUDEN X5R JMK212BJ475
C2: TAIYO YUDEN X5R EMK212BJ105
D1: CENTRAL SEMICONDUCTOR CMDSH2-3
L1: MURATA LQH32CN-220 OR EQUIVALENT

**Input Current and Output Voltage**



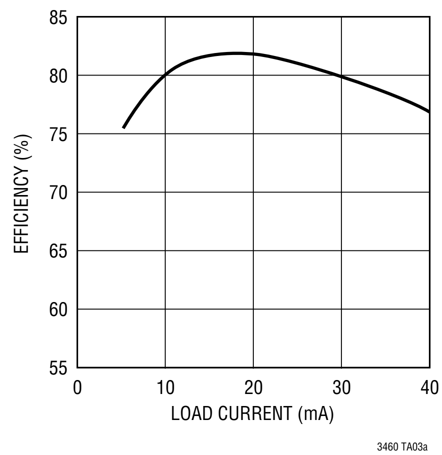
## TYPICAL APPLICATIONS

**3.3V to 12V Step-Up Converter**

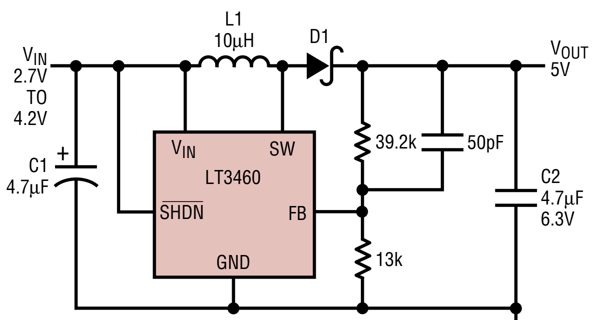



C1: TAIYO YUDEN X5R JMK212BJ475
C2: TAIYO YUDEN X5R EMK212BJ105
D1: CENTRAL SEMICONDUCTOR CMDSH2-3
L1: MURATA LQH32CN-220 OR EQUIVALENT

**Efficiency**

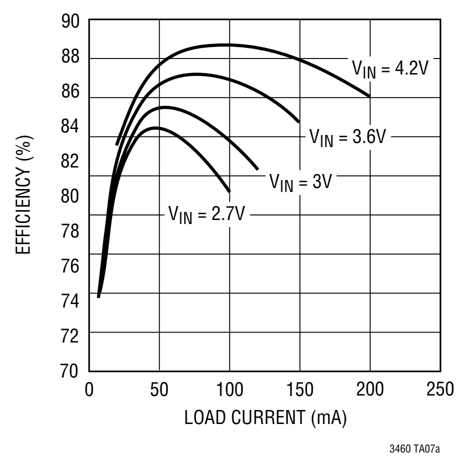



**Li-Ion to 5V Step-Up Converter**



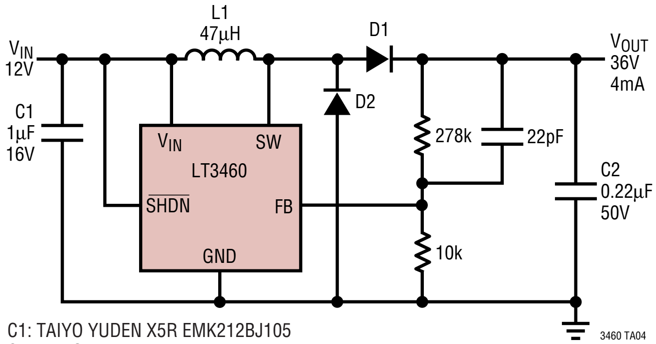

C1: TAIYO YUDEN X5R JMK212BJ475
C2: TAIYO YUDEN X5R JMK212BJ475
D1: PHILIPS PMEG2010
L1: MURATA LQH32CN-100 OR EQUIVALENT

**Efficiency**



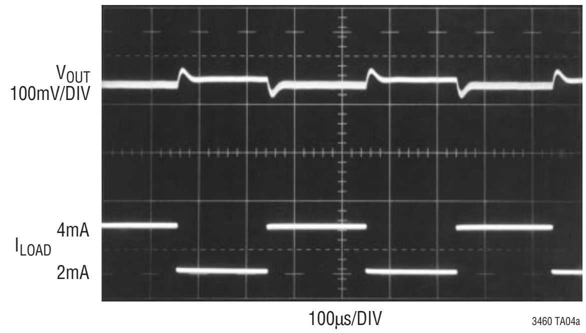
## TYPICAL APPLICATIONS

**12V to 36V Step-Up Converter**

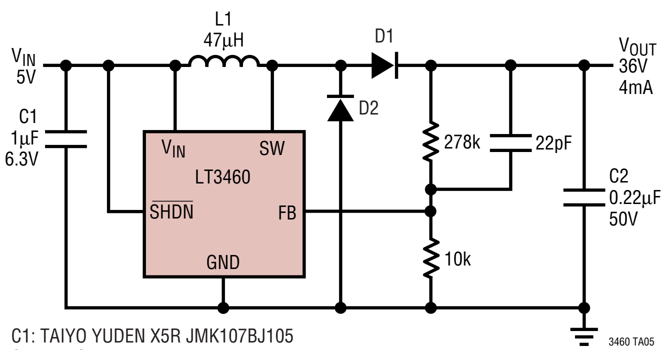



C1: TAIYO YUDEN X5R EMK212BJ105
C2: TAIYO YUDEN X7R UMK212BJ224
D1, D2: CENTRAL SEMICONDUCTOR CMOD4448
L1: TAIYO YUDEN LB2012

**Load Step Response**

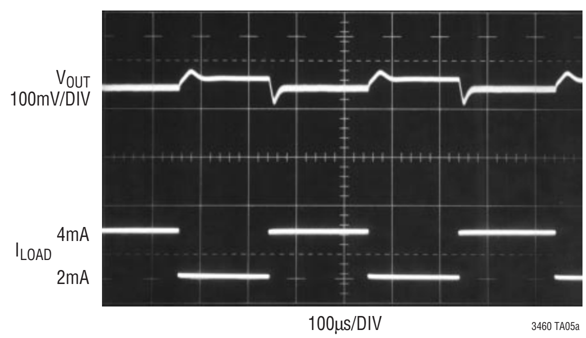



**5V to 36V Step-Up Converter**



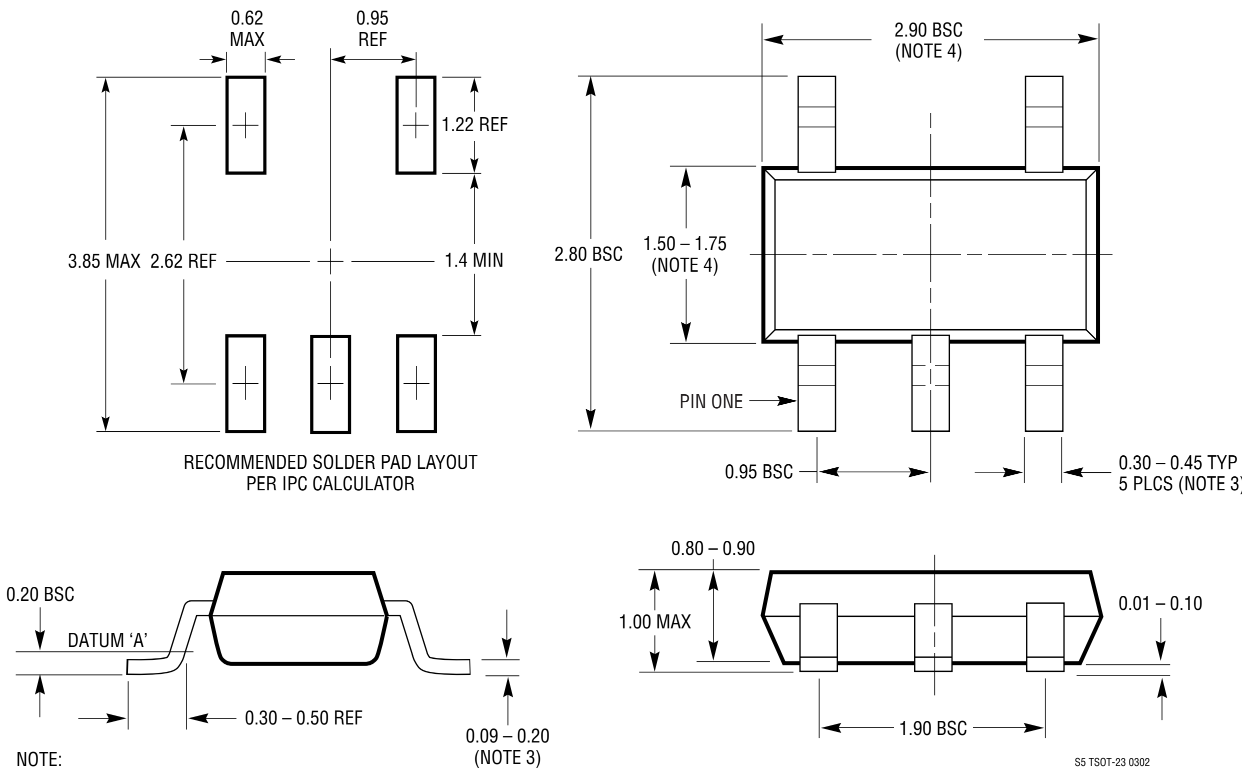

C1: TAIYO YUDEN X5R JMK107BJ105
C2: TAIYO YUDEN X7R UMK212BJ224
D1, D2: CENTRAL SEMICONDUCTOR CMOD4448
L1: TAIYO YUDEN LB2012

**Load Step Response**



# PACKAGE DESCRIPTION

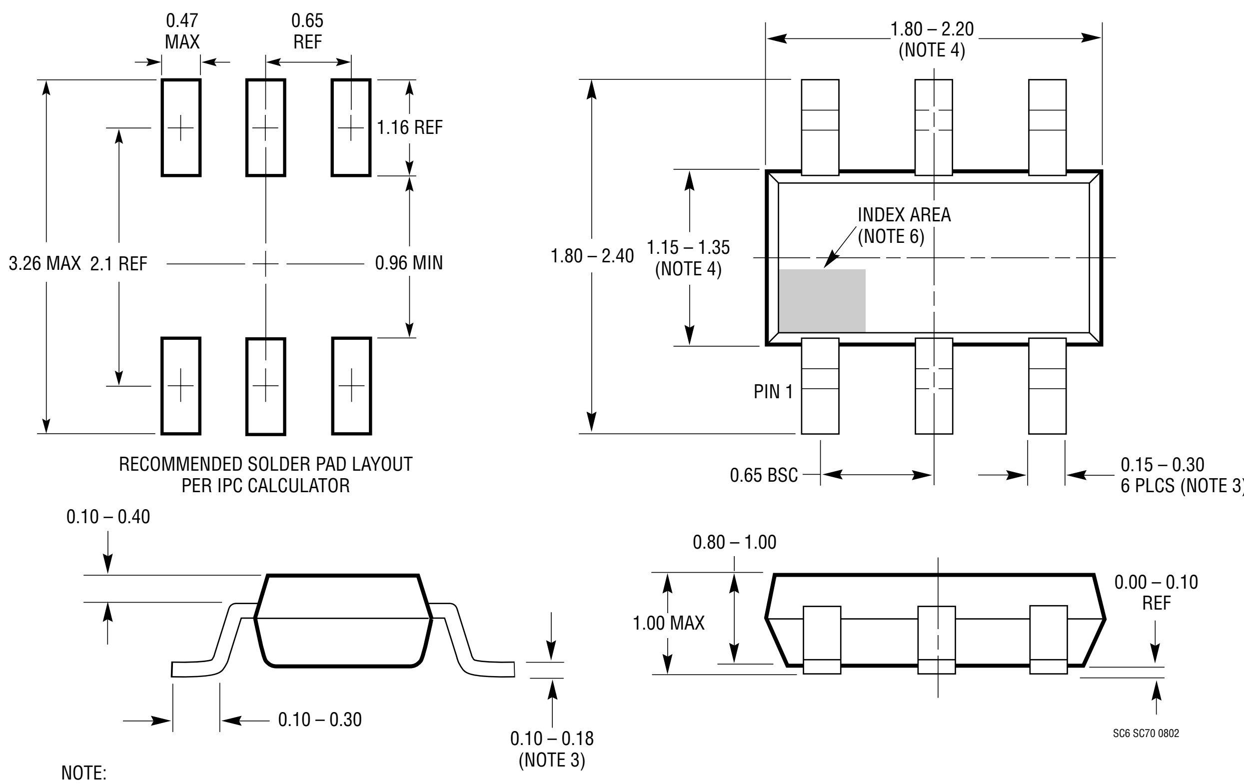
**S5 Package**
**5-Lead Plastic TSOT-23**
(Reference LTC DWG # 05-08-1635)




NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DRAWING NOT TO SCALE
3. DIMENSIONS ARE INCLUSIVE OF PLATING
4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
5. MOLD FLASH SHALL NOT EXCEED 0.254mm
6. JEDEC PACKAGE REFERENCE IS MO-193

# PACKAGE DESCRIPTION

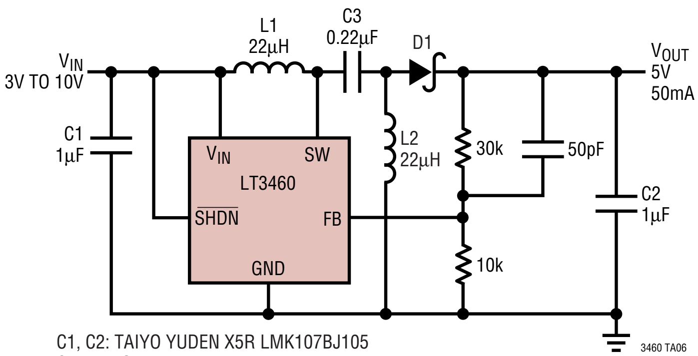
**SC6 Package**
**6-Lead Plastic SC70**
(Reference LTC DWG # 05-08-1638)




NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DRAWING NOT TO SCALE
3. DIMENSIONS ARE INCLUSIVE OF PLATING
4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
5. MOLD FLASH SHALL NOT EXCEED 0.254mm
6. DETAILS OF THE PIN 1 INDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE INDEX AREA
7. EIAJ PACKAGE REFERENCE IS EIAJ SC-70

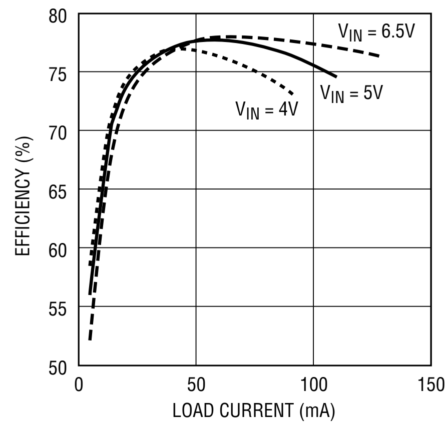
## TYPICAL APPLICATIONS

5V to 5V SEPIC




C1, C2: TAIYO YUDEN X5R LMK107BJ105
C3: TAIYO YUDEN X7R LMK107BJ224
D1: ON SEMICONDUCTOR MBR0520
L1, L2: MURATA LQH32CN-220 OR EQUIVALENT

Efficiency




## RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|---|---|---|
| LT1613 | 550mA ($I_{SW}$), 1.4MHz, High Efficiency Step-Up DC/DC Converter | $V_{IN}$: 0.9V to 10V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 3mA, $I_{SD}$ <1μA, ThinSOT Package |
| LT1615/LT1615-1 | 300mA/80mA ($I_{SW}$), Constant Off-Time, High Efficiency Step-Up DC/DC Converter | $V_{IN}$: 1.2V to 15V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 20μA, $I_{SD}$ <1μA, ThinSOT Package |
| LT1944/LT1944-1 | Dual Output 350mA/100mA ($I_{SW}$), Constant Off-Time, High Efficiency Step-Up DC/DC Converter | $V_{IN}$: 1.2V to 15V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 20μA, $I_{SD}$ <1μA, MS Package |
| LT1945 | Dual Output, Pos/Neg, 350mA ($I_{SW}$), Constant Off-Time, High Efficiency Step-Up DC/DC Converter | $V_{IN}$: 1.2V to 15V, $V_{OUT(MAX)}$ = ±34V, $I_Q$ = 20μA, $I_{SD}$ <1μA, MS Package |
| LT1961 | 1.5A ($I_{SW}$), 1.25MHz, High Efficiency Step-Up DC/DC Converter | $V_{IN}$: 3V to 25V, $V_{OUT(MAX)}$ = 35V, $I_Q$ = 0.9mA, $I_{SD}$ <6μA, MS8E Package |
| LTC3400/LTC3400B | 600mA ($I_{SW}$), 1.2MHz, Synchronous Step-Up DC/DC Converter | $V_{IN}$: 0.85V to 5V, $V_{OUT(MAX)}$ = 5V, $I_Q$ = 19μA/300μA, $I_{SD}$ <1μA, ThinSOT Package |
| LTC3401/LTC3402 | 1A/2A ($I_{SW}$), 3MHz, Synchronous Step-Up DC/DC Converter | $V_{IN}$: 0.5V to 5V, $V_{OUT(MAX)}$ = 6V, $I_Q$ = 38μA, $I_{SD}$ <1μA, MS Package |
| LT3461/LT3461A | 0.3A ($I_{SW}$), 1.3MHz/3MHz, High Efficiency Step-Up DC/DC Converter with Integrated Schottky | $V_{IN}$: 2.5V to 16V, $V_{OUT(MAX)}$ = 38V, $I_Q$ = 2.8mA, $I_{SD}$ <1μA, SC70, ThinSOT Packages |
| LT3464 | 0.08A ($I_{SW}$), High Efficiency Step-Up DC/DC Converter with Integrated Schottky, Output Disconnect | $V_{IN}$: 2.3V to 10V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 25μA, $I_{SD}$ <1μA, ThinSOT Package |
| LT3465/LT3465A | Constant Current, 1.2MHz/2.7MHz, High Efficiency White LED Boost Regulator with Integrated Schottky Diode | $V_{IN}$: 2.7V to 16V, $V_{OUT(MAX)}$ = 30V, $I_Q$ = 1.9mA, $I_{SD}$ <1μA, ThinSOT Package |




Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com

LT/TP 0204 1K • PRINTED IN USA