

# 1.3 MHz/650kHz Step-Up DC/DC Converter in SC70, ThinSOT and DFN

## FEATURES

- **1.3MHz (LT3460) Switching Frequency**
- **650kHz (LT3460-1) Switching Frequency**
- **High Output Voltage: Up to 36V**
- **300mA Integrated Switch (LT3460)**
- **180mA Integrated Switch (LT3460-1)**
- **Wide Input Range: 2.5V to 16V**
- **Uses Small Surface Mount Components**
- **Low Shutdown Current: <1μA**
- **Low Profile (1mm) SC70 (LT3460 and LT3460-1), SOT-23 (ThinSOT™) (LT3460) and 2mm × 2mm DFN (LT3460-1) 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/LT3460-1 are general purpose step-up DC/DC converters. The LT3460/LT3460-1 switch at 1.3MHz/650kHz, 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.

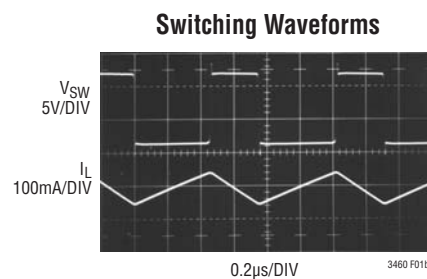
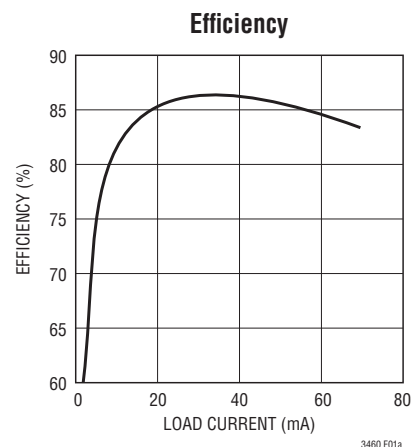
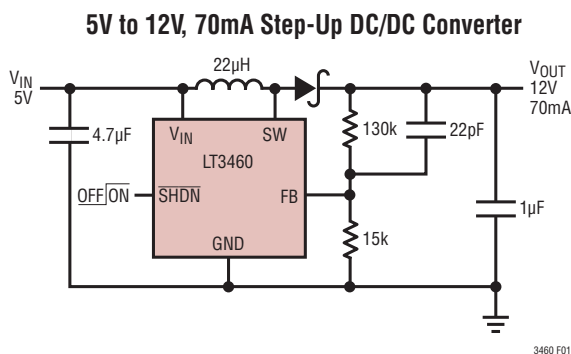
The high voltage switches in the LT3460/LT3460-1 are rated at 38V, making the device ideal for boost converters up to 36V. The LT3460 can generate 12V at up to 70mA from a 5V supply.

The low 1mA quiescent current and 650kHz switching frequency of LT3460-1 make it ideal for lower current applications.

The LT3460 is available in SC70 and SOT-23 packages. The LT3460-1 is available in SC70 and 2mm × 2mm DFN packages.

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## TYPICAL APPLICATION

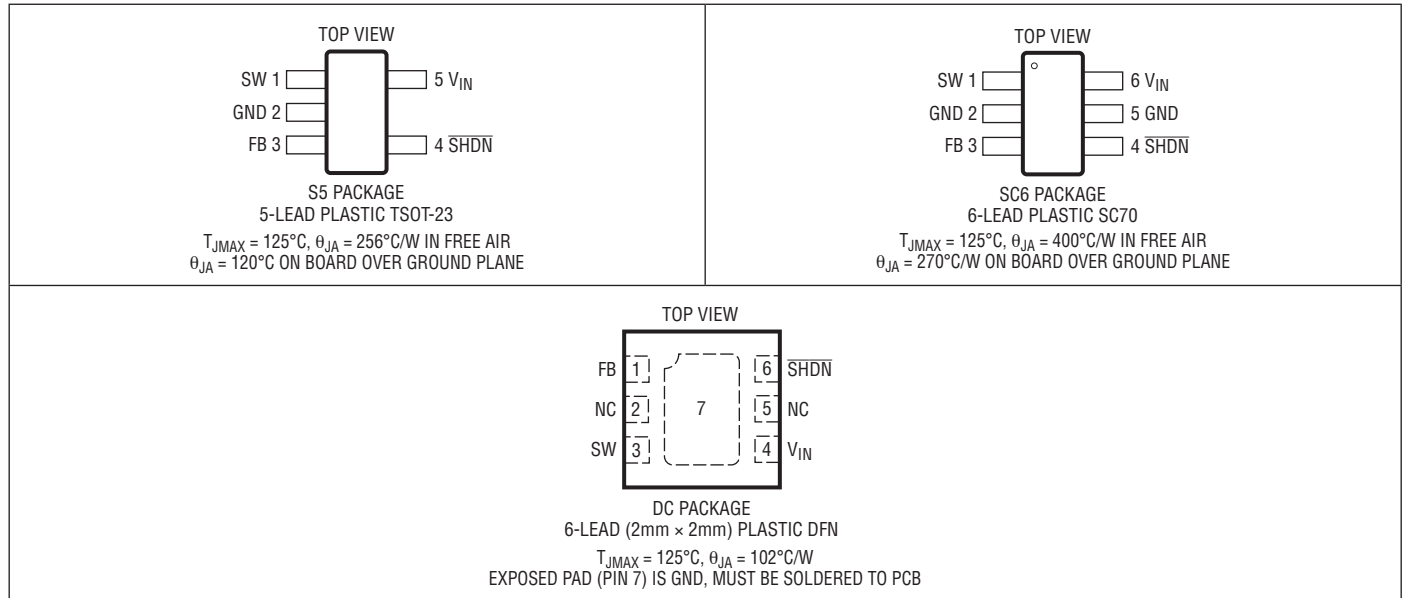


# LT3460/LT3460-1

## ABSOLUTE MAXIMUM RATINGS (Note 1)

|                                 |     |                                            |                |
|---------------------------------|-----|--------------------------------------------|----------------|
| Input Voltage ( $V_{IN}$ )..... | 16V | Operating Ambient                          |                |
| SW Voltage .....                | 38V | Temperature Range (Note 2).....            | –40°C to 85°C  |
| FB Voltage.....                 | 5V  | Maximum Junction Temperature.....          | 125°C          |
| SHDN Voltage .....              | 16V | Storage Temperature Range.....             | –65°C to 150°C |
|                                 |     | Lead Temperature (Soldering, 10 sec) ..... | 300°C          |

## PIN CONFIGURATION



## ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL      | PART MARKING | PACKAGE DESCRIPTION            | TEMPERATURE RANGE |
|------------------|--------------------|--------------|--------------------------------|-------------------|
| LT3460ES5#PBF    | LT3460ES5#TRPBF    | LTB1         | 5-Lead Plastic TSOT-23         | –40°C to 85°C     |
| LT3460ESC6#PBF   | LT3460ESC6#TRPBF   | LAAF         | 6-Lead Plastic SC70            | –40°C to 85°C     |
| LT3460ESC6-1#PBF | LT3460ESC6-1#TRPBF | LDJV         | 6-Lead Plastic SC70            | –40°C to 85°C     |
| LT3460EDC-1#PBF  | LT3460EDC-1#TRPBF  | LDNB         | 6-Lead (2mm × 2mm) Plastic DFN | –40°C to 85°C     |

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

Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreel/>

## ELECTRICAL CHARACTERISTICS

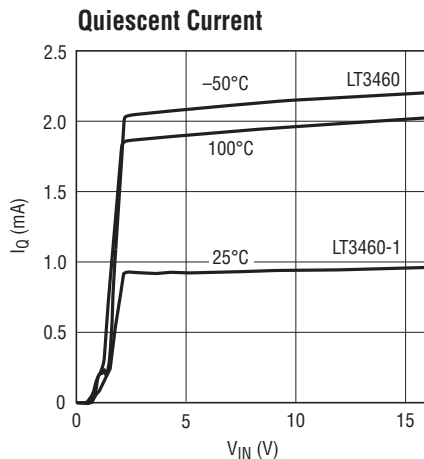
The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 3\text{V}$ ,  $V_{SHDN} = 3\text{V}$ , unless otherwise noted.

| PARAMETER                                 | CONDITIONS                                                           | LT3460           |       |                | LT3460-1       |       |                | UNITS         |
|-------------------------------------------|----------------------------------------------------------------------|------------------|-------|----------------|----------------|-------|----------------|---------------|
|                                           |                                                                      | MIN              | TYP   | MAX            | MIN            | TYP   | MAX            |               |
| Minimum Operating Voltage                 |                                                                      | 2.5              |       |                | 2.5            |       |                | V             |
| Maximum Operating Voltage                 |                                                                      |                  |       | 16             |                |       | 16             | V             |
| Feedback Voltage                          |                                                                      | ● 1.235<br>1.225 | 1.255 | 1.275<br>1.280 | 1.235<br>1.225 | 1.255 | 1.275<br>1.280 | V<br>V        |
| Feedback Line Regulation                  | $2.5\text{V} < V_{IN} < 16\text{V}$                                  |                  | 0.015 |                |                | 0.015 |                | %/V           |
| FB Pin Bias Current                       |                                                                      | ● 5              | 25    | 80             | 0              | 25    | 80             | nA            |
| Supply Current                            | $\overline{\text{SHDN}} = 0\text{V}$                                 |                  | 2.0   | 3.0            |                | 1.0   | 1.5            | mA            |
|                                           |                                                                      |                  | 0.1   | 0.5            |                | 0.1   | 0.5            | $\mu\text{A}$ |
| Switching Frequency                       |                                                                      | 1.0              | 1.3   | 1.7            | 0.35           | 0.65  | 1.0            | MHz           |
| Maximum Duty Cycle                        |                                                                      | 85               | 90    |                | 80             | 90    |                | %             |
| Switch Current Limit                      |                                                                      | 300              | 420   | 600            | 180            | 260   | 380            | mA            |
| Switch $V_{CESAT}$                        | $I_{SW} = 250\text{mA}$ (LT3460), $I_{SW} = 100\text{mA}$ (LT3460-1) |                  | 320   | 450            |                | 220   | 350            | mV            |
| Switch Leakage Current                    | $V_{SW} = 5\text{V}$                                                 |                  | 0.01  | 1              |                | 0.01  | 1              | $\mu\text{A}$ |
| $\overline{\text{SHDN}}$ Voltage High     |                                                                      | 1.5              |       |                | 1.5            |       |                | V             |
| $\overline{\text{SHDN}}$ Voltage Low      |                                                                      |                  |       | 0.4            |                |       | 0.4            | V             |
| $\overline{\text{SHDN}}$ Pin Bias Current |                                                                      |                  | 40    |                |                | 15    |                | $\mu\text{A}$ |

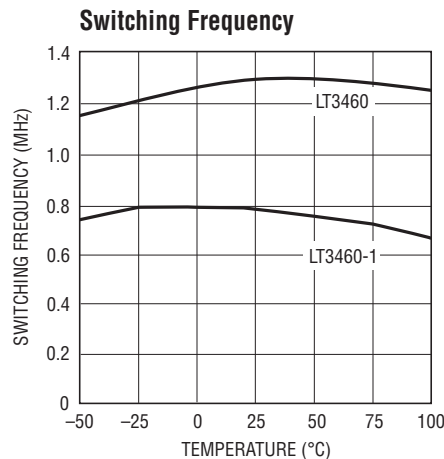
**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** The LT3460E/LT3460-1E is guaranteed to meet specifications from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ . Specifications over the  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  operating temperature range are assured by design, characterization and correlation with statistical process controls.

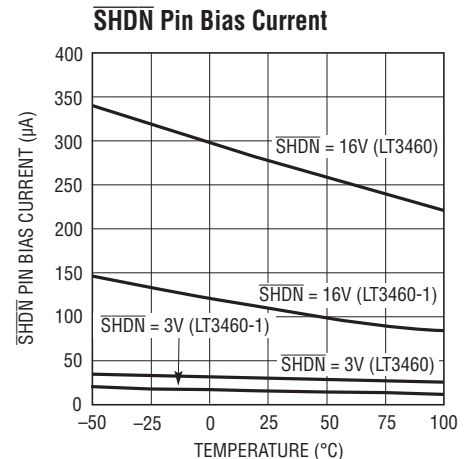
## TYPICAL PERFORMANCE CHARACTERISTICS



3460 G01



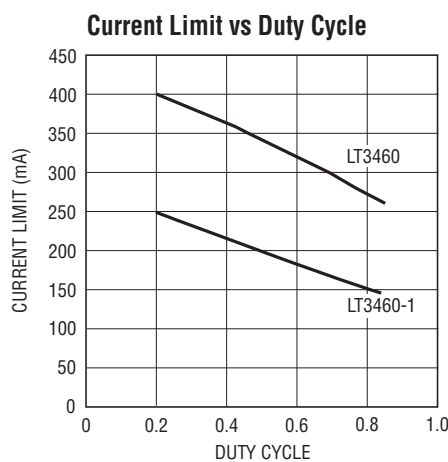
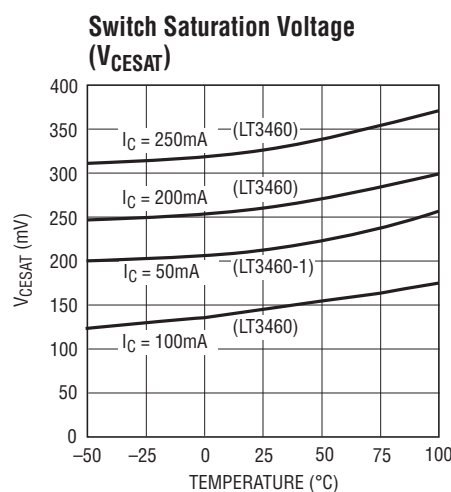
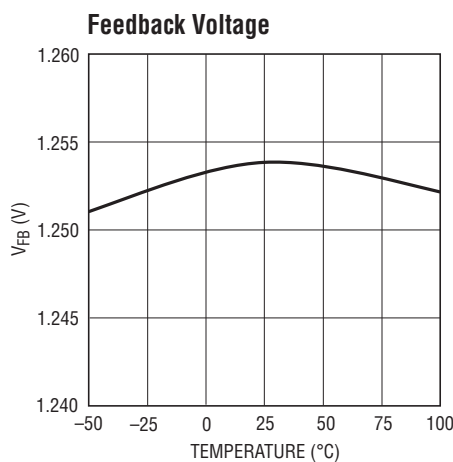
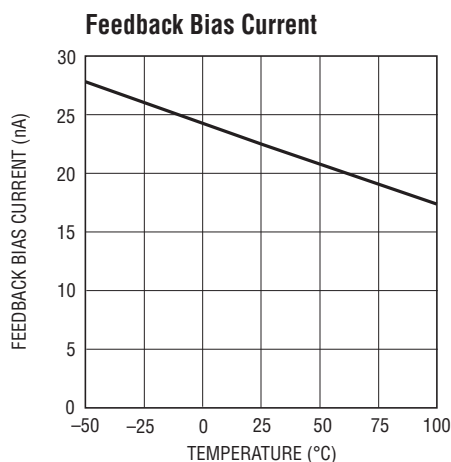
3460 G02



3460 G03

3460fb

## TYPICAL PERFORMANCE CHARACTERISTICS



## PIN FUNCTIONS (ThinSOT/SC70/DFN Packages)

**SW (Pin 1/Pin 1/Pin 3):** Switch Pin. Connect inductor/diode here. Minimize trace at this pin to reduce EMI.

**GND (Pin 2/Pins 2 and 5/Exposed Pad Pin 7):** Ground Pin. Tie directly to local ground plane.

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

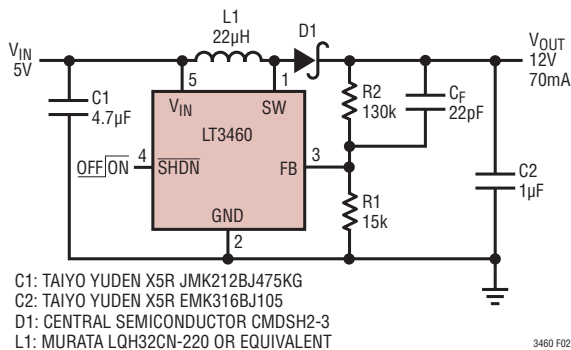
**SHDN (Pin 4/Pin 4/Pin 6):** Shutdown Pin. Tie to 1.5V or higher to enable device; 0.4V or less to disable device. Also functions as soft-start. Use RC filter (47k, 47nF typ) as shown in Figure 1.

**V<sub>IN</sub> (Pin 5/Pin 6/Pin 4):** Input Supply Pin. Must be locally bypassed.

**NC (NA/NA/Pins 2, 5):** No-Connects. These pins are not connected to internal circuitry. They should be tied to ground to improve thermal and electrical performance.



## OPERATION



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

The feedback loop gain  $T(s) = K3 \cdot G_P(s) \cdot G_C(s)$ . 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.

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:

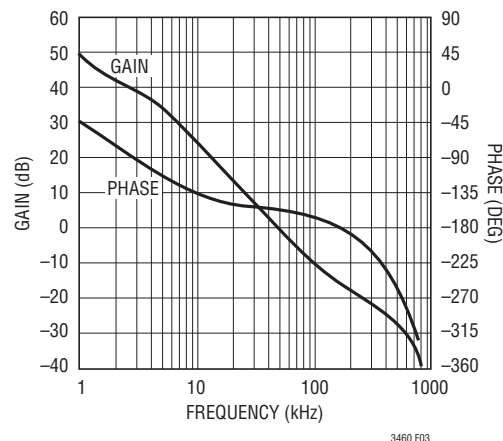
$$\frac{FB}{V_{OUT}} = \frac{R1}{R1+R2}$$

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

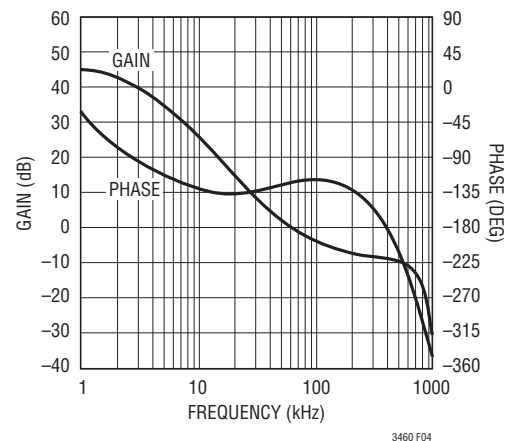
$$\frac{FB}{V_{OUT}} = \frac{R1}{R1+R2} \cdot \frac{s \cdot R2 \cdot C_F + 1}{s \cdot \frac{R1 \cdot R2}{R1+R2} \cdot C_F + 1}$$

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 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 3**



**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/LT3460-1, 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.

## OPERATION

### Layout Hints

The high speed operation of the LT3460/LT3460-1 demands careful attention to board layout. You will not get advertised performance with careless layout. Figure 5 shows the recommended component placement.

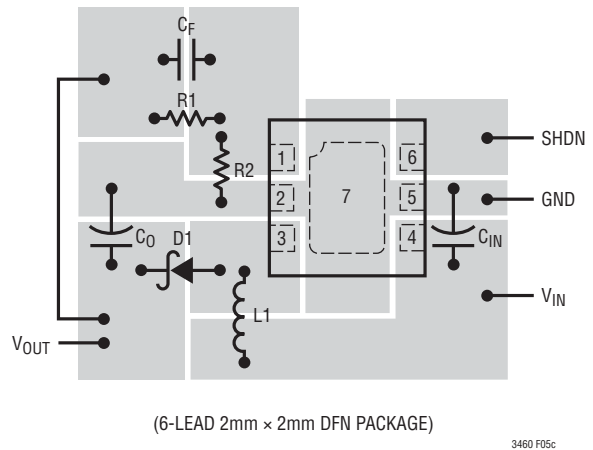
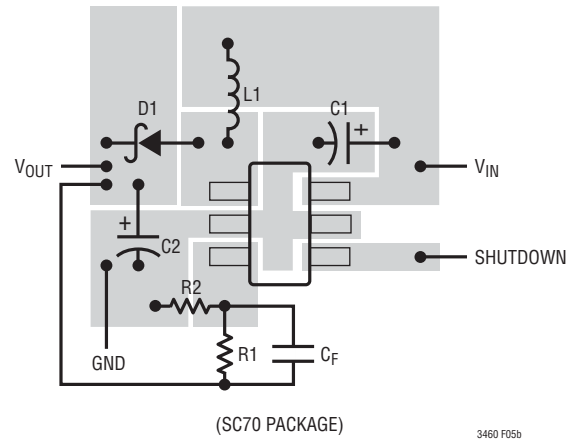
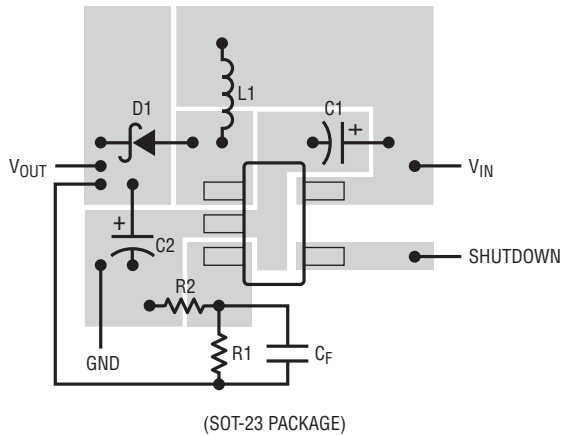
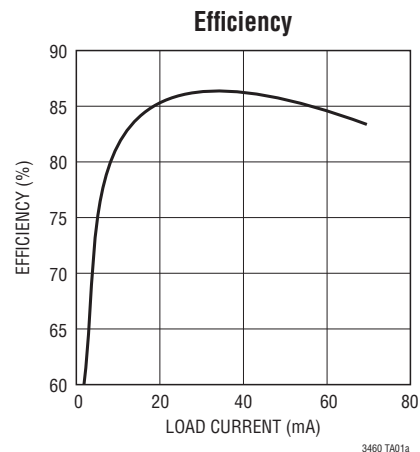
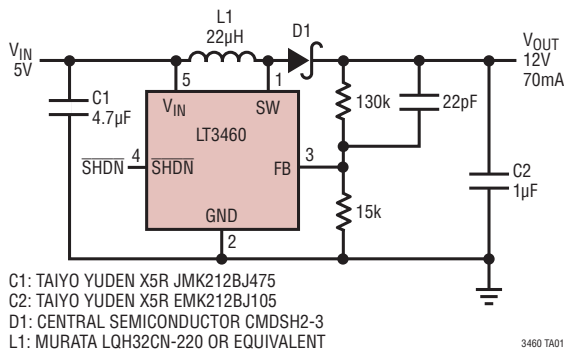


Figure 5

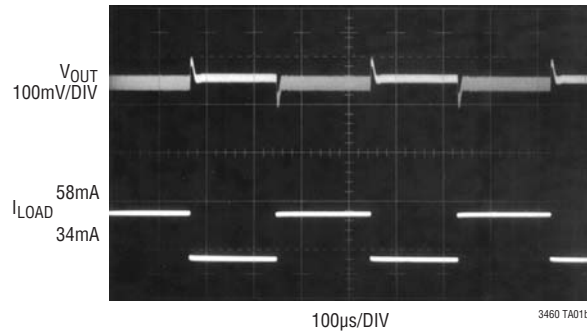
## TYPICAL APPLICATIONS

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

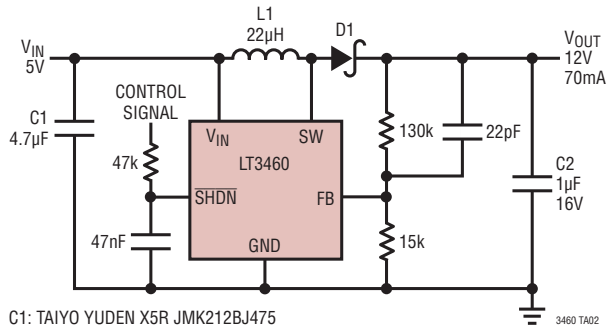


## TYPICAL APPLICATIONS

Load Step Response

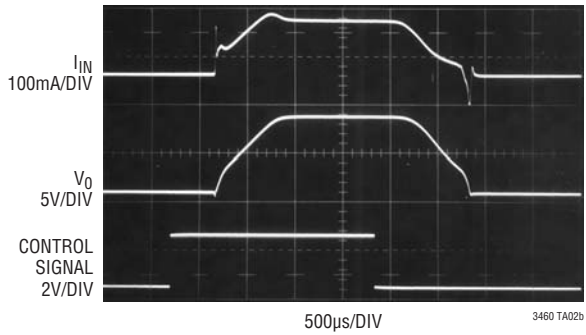


5V to 12V with Soft-Start Circuit

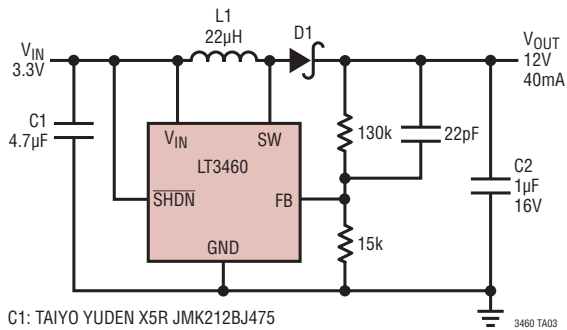


C1: TAIYO YUDEN X5R JMK212BJ475  
C2: TAIYO YUDEN X5R EMK212BJ105  
D1: CENTRAL SEMICONDUCTOR CMDSH2-3  
L1: MURATA LQH32CN-220 OR EQUIVALENT

Input Current and Output Voltage

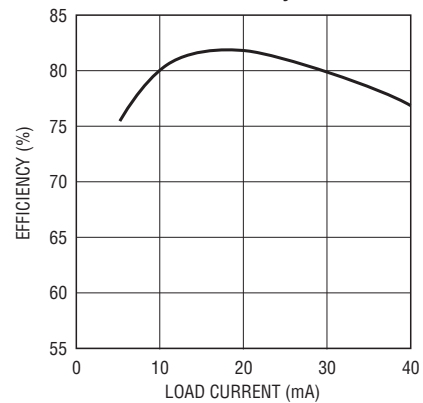


5V to 12V Step-Up Converter



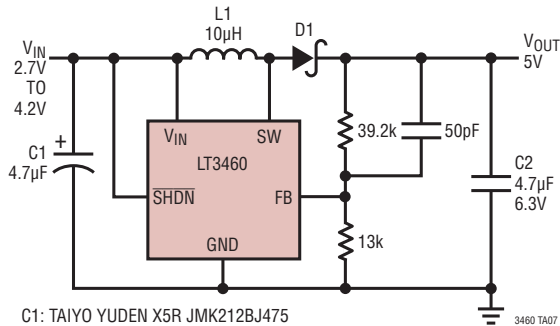
C1: TAIYO YUDEN X5R JMK212BJ475  
C2: TAIYO YUDEN X5R EMK212BJ105  
D1: CENTRAL SEMICONDUCTOR CMDSH2-3  
L1: MURATA LQH32CN-220 OR EQUIVALENT

Efficiency



# TYPICAL APPLICATIONS

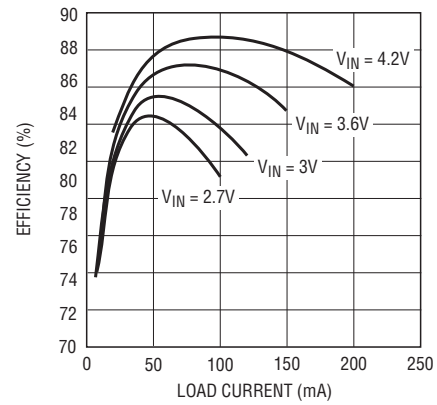
## 5V to 12V Step-Up Converter



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

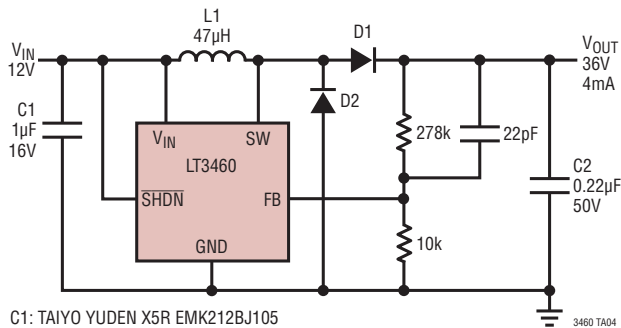
3460 TA07

## Efficiency



3460 TA07a

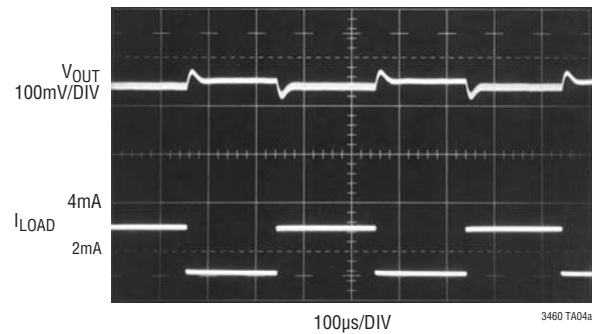
## 12V to 36V Step-Up Converter



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

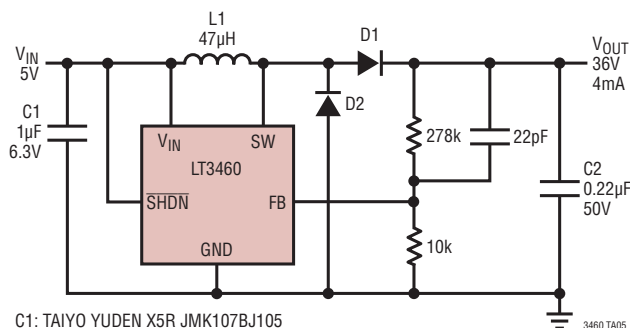
3460 TA04

## Load Step Response



3460 TA04a

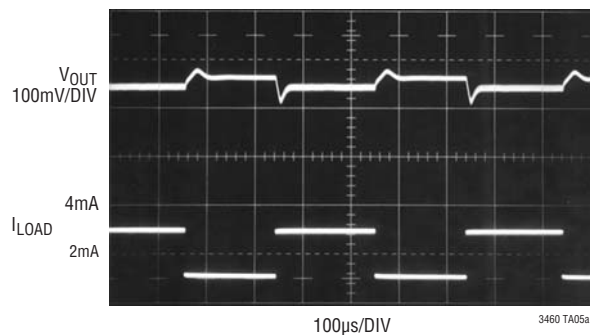
## 5V to 36V Step-Up Converter



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

3460 TA05

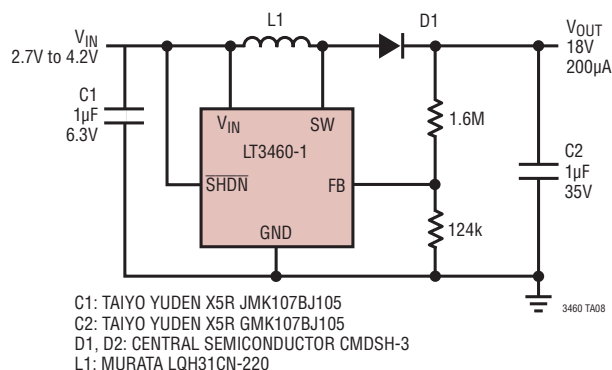
## Load Step Response



3460 TA05a

## APPLICATIONS INFORMATION

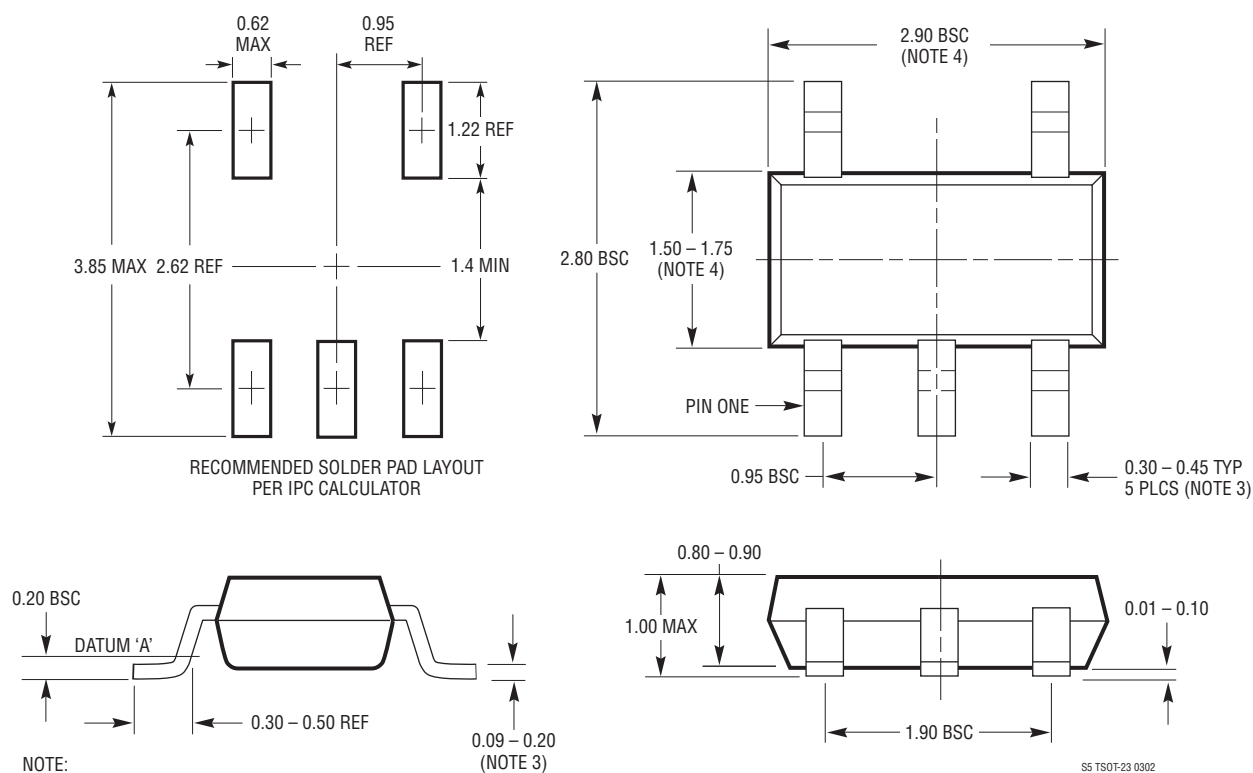
### Li-Ion to 18V Step-Up Converter



## PACKAGE DESCRIPTION

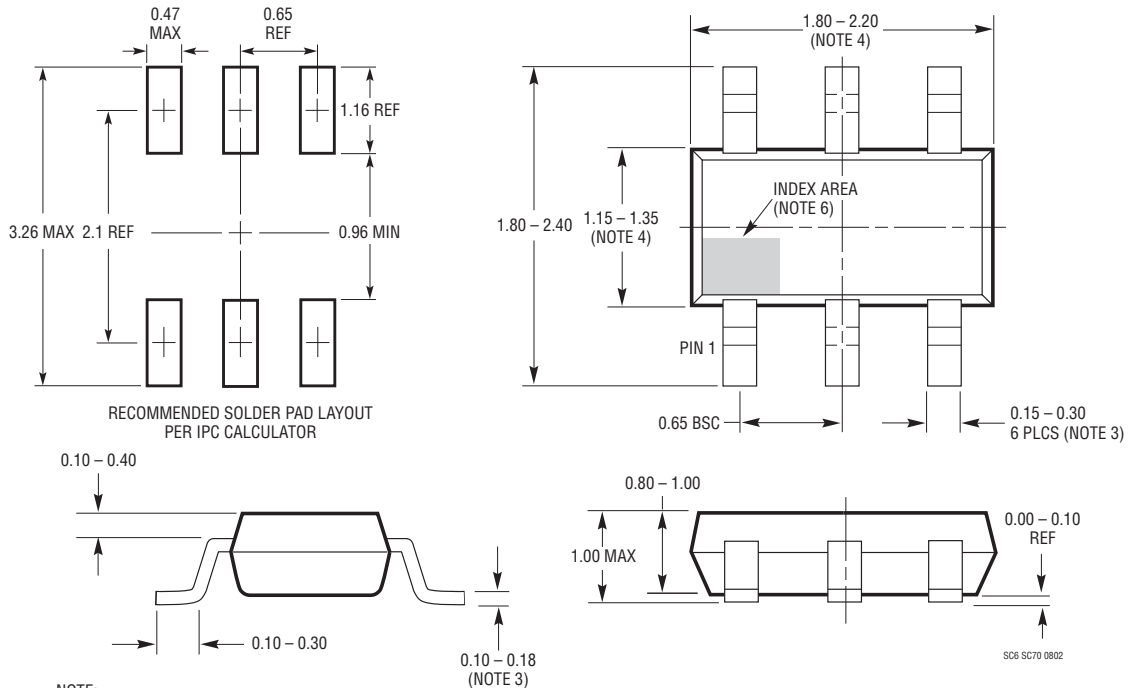
### S5 Package 5-Lead Plastic TSOT-23

(Reference LTC DWG # 05-08-1635)



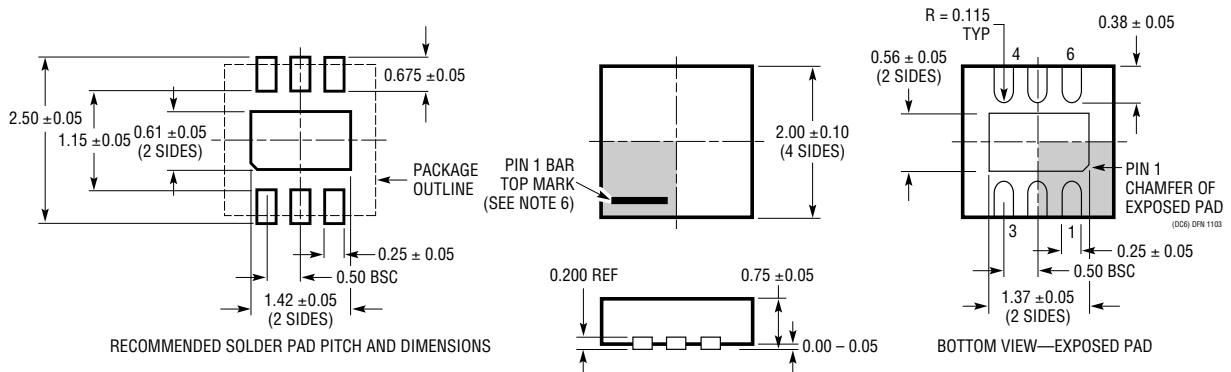
# PACKAGE DESCRIPTION

## 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 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE INDEX AREA
  7. EIAJ PACKAGE REFERENCE IS EIAJ SC-70

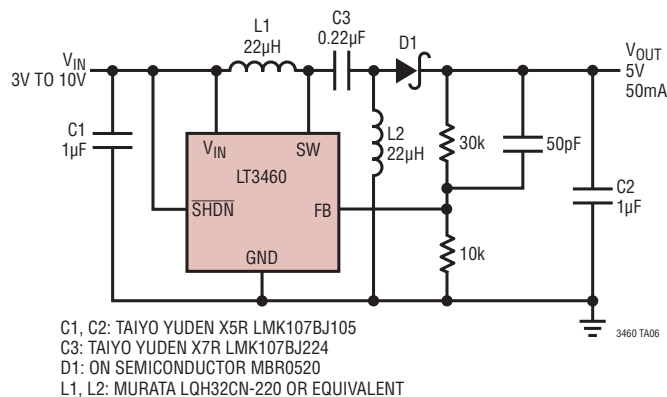
## DC Package 6-Lead Plastic DFN (2mm x 2mm) (Reference LTC DWG # 05-08-1703)



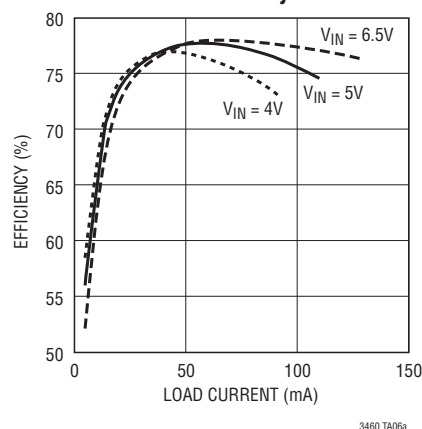
- NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WCCD-2)
  2. DRAWING NOT TO SCALE
  3. ALL DIMENSIONS ARE IN MILLIMETERS
  4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
  5. EXPOSED PAD SHALL BE SOLDER PLATED
  6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE TOP AND BOTTOM OF PACKAGE

## TYPICAL APPLICATIONS

### 5V to 5V SEPIC



### 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        |