# Inverting Micropower DC/DC Converters with Schottky

## FEATURES

- **Internal 40V Schottky Diode**
- **One Resistor Feedback (Other Resistor Inside)**
- **Internal 40V, 200mA/400mA Power Switch**
- **Generates Regulated Negative Outputs to –38V**
- Low Quiescent Current:
  40μA in Active Mode
  <1μA in Shutdown Mode
- Low $V_{CESAT}$ Switch: 200mV at 150mA
- Wide Input Range: 2.5V to 16V
- Uses Small Surface Mount Components
- Output Short-Circuit Protected
- Available in a 6-Lead SOT-23 (LT3483 Only) and Low Profile 8-Lead DFN (2mm × 2mm × 0.75mm) Packages

## APPLICATIONS

- LCD Bias
- Handheld Computers
- Battery Backup
- Digital Cameras
- OLED Bias

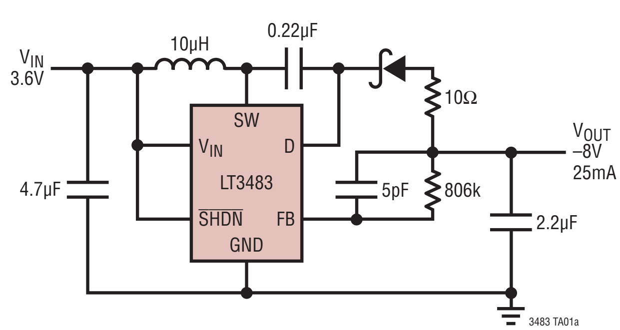
## DESCRIPTION

The LT®3483/LT3483A are micropower inverting DC/DC converters with integrated Schottky and one resistor feedback. The small package size, high level of integration and use of tiny surface mount components yield a solution size as small as 40mm$^2$. The devices feature a quiescent current of only 40μA at no load, which further reduces to 0.1μA in shutdown. A current limited, fixed off-time control scheme conserves operating current, resulting in high efficiency over a broad range of load current. A precisely trimmed 10μA feedback current enables one resistor feedback and virtually eliminates feedback loading of the output. The 40V switch enables voltage outputs up to –38V to be generated without the use of costly transformers. The LT3483/LT3483A's low 300ns off-time permits the use of tiny low profile inductors and capacitors to minimize footprint and cost in space-conscious portable applications.

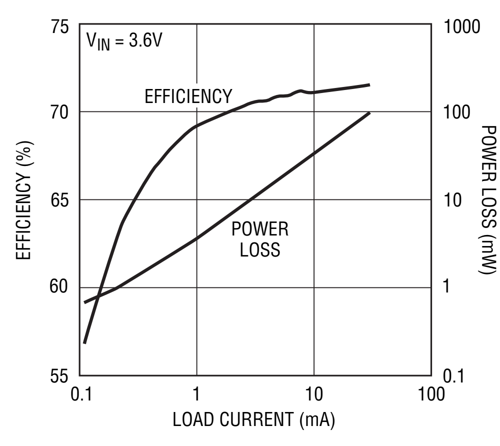


## TYPICAL APPLICATION

**3.6V to –8V DC/DC Converter**




**Efficiency and Power Loss**



## ABSOLUTE MAXIMUM RATINGS

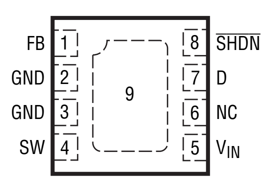
**(Note 1)**

$V_{IN}$ Voltage ............................................................ 16V
SW Voltage ............................................................ 40V
D Voltage ............................................................ –40V
FB Voltage ............................................................ 2.5V
$\overline{SHDN}$ Voltage ............................................................ 16V

Operating Ambient Temperature Range (Note 2)
LT3483E/LT3483AE ............................ –40°C to 85°C
LT3483I/LT3483AI ............................ –40°C to 125°C
Junction Temperature ...................................... 125°C
Storage Temperature Range.................. –65°C to 150°C
Lead Temperature (Soldering, 10 sec)
(TSOT-23 Package Only)................................. 300°C

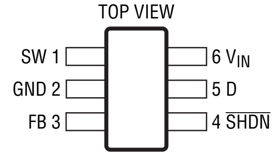
## PIN CONFIGURATION

TOP VIEW




DC PACKAGE
8-LEAD (2mm × 2mm) PLASTIC DFN
$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 88.5°C/W
EXPOSED PAD (PIN 9) IS GND

TOP VIEW




S6 PACKAGE
6-LEAD PLASTIC TSOT-23
$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 192°C/W

## ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL | PART MARKING* | PACKAGE DESCRIPTION | TEMPERATURE RANGE |
|---|---|---|---|---|
| LT3483EDC#PBF | LT3483EDC#TRPBF | LCYT | 8-Lead (2mm  2mm) Plastic DFN | –40°C to 85°C |
| LT3483ES6#PBF | LT3483ES6#TRPBF | LTBKX | 6-Lead Plastic TSOT-23 | –40°C to 85°C |
| LT3483AEDC#PBF | LT3483AEDC#TRPBF | LFXD | 8-Lead (2mm  2mm) Plastic DFN | –40°C to 85°C |
| LT3483IDC#PBF | LT3483IDC#TRPBF | LCYT | 8-Lead (2mm  2mm) Plastic DFN | –40°C to 125°C |
| LT3483IS6#PBF | LT3483IS6#TRPBF | LTBKX | 6-Lead Plastic TSOT-23 | –40°C to 125°C |
| LT3483AIDC#PBF | LT3483AIDC#TRPBF | LFXD | 8-Lead (2mm  2mm) Plastic DFN | –40°C to 125°C |
| **LEAD BASED FINISH** | **TAPE AND REEL** | **PART MARKING** | **PACKAGE DESCRIPTION** | **TEMPERATURE RANGE** |
| LT3483EDC | LT3483EDC#TR | LCYT | 8-Lead (2mm  2mm) Plastic DFN | –40°C to 85°C |
| LT3483ES6 | LT3483ES6#TR | LTBKX | 6-Lead Plastic TSOT-23 | –40°C to 85°C |

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container. 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°C. $V_{IN}$ = 3.6V, $V_{\overline{SHDN}}$ = 3.6V unless otherwise specified.**

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| $V_{IN}$ Operating Range | | | 2.5 | | 16 | V |
| $V_{IN}$ Undervoltage Lockout | | | | 2 | 2.4 | V |
| FB Comparator Trip Voltage to GND ($V_{FB}$) | FB Falling | ● | 0 | 5 | 12 | mV |
| FB Output Current (Note 3) | FB = $V_{FB}$ – 5mV | ● | –10.2 | –10 | –9.7 | µA |
| FB Comparator Hysteresis | FB Rising | | | 10 | | mV |
| Quiescent Current in Shutdown | $V_{\overline{SHDN}}$ = GND | | | | 1 | µA |
| Quiescent Current (Not Switching) | FB = –0.05V | | | 40 | 50 | µA |
| $I_{FB}$ Line Regulation | 2.5V ≤ $V_{IN}$ ≤ 16V | | | | 0.07 | %/V |
| Switch Off-Time | | | | 300 | | ns |
| Switch Current Limit | LT3483<br>LT3483A | | 170<br>340 | 200<br>400 | 230<br>460 | mA<br>mA |
| Switch $V_{CESAT}$ | $I_{SW}$ = 150mA to GND | | | 200 | | mV |
| Switch Leakage Current | SW = 40V | | | | 1 | µA |
| D Pin Current Limit | | | | 350 | | mA |
| Rectifier Leakage Current | D = –40V | | | | 4 | µA |
| Rectifier Forward Drop | $I_D$ = 150mA to GND | | | 0.64 | | V |
| SHDN Input Low Voltage | | | | | 0.4 | V |
| SHDN Input High Voltage | | | 1.5 | | | V |
| SHDN Pin Current | | | | 6 | 10 | µA |

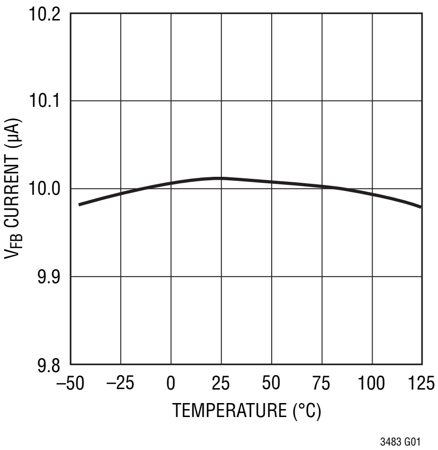
**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** The LT3483E/LT3483AE are guaranteed to meet specifications from 0°C to 85°C. Specifications over the –40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls. The LT3483I/LT3483AI are guaranteed to meet specifications over the –40°C to 125°C operating temperature range.

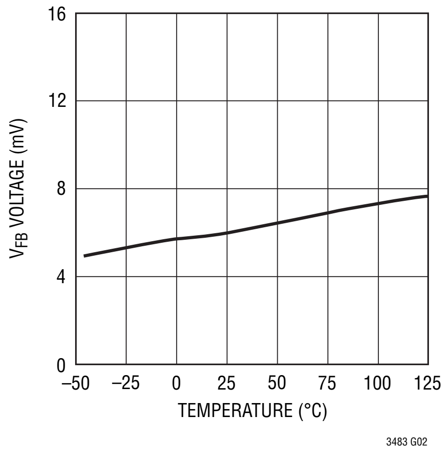
**Note 3:** Current flows out of the pin.

## TYPICAL PERFORMANCE CHARACTERISTICS

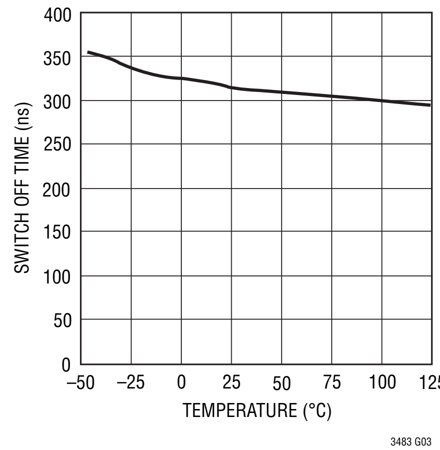
### $V_{FB}$ Current



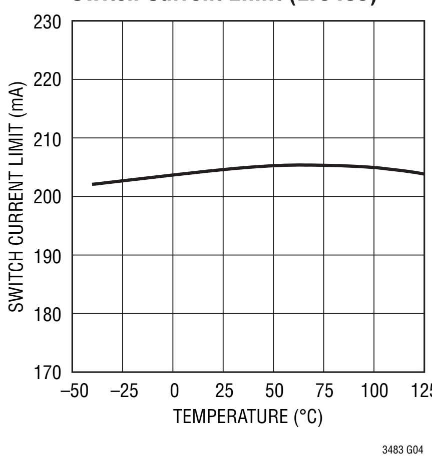

### $V_{FB}$ Voltage



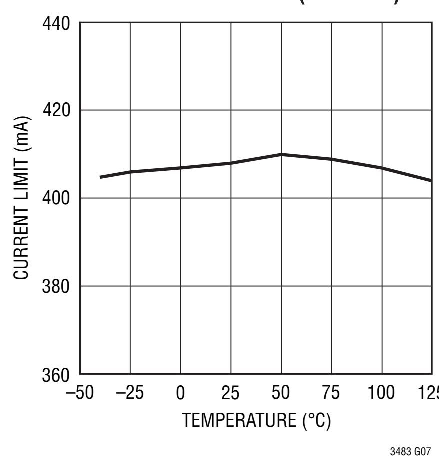

### Switch Off Time



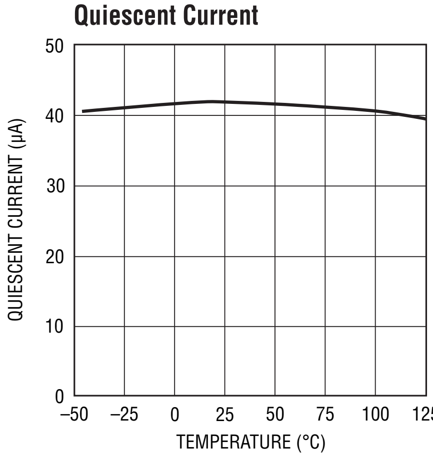

### Switch Current Limit (LT3483)



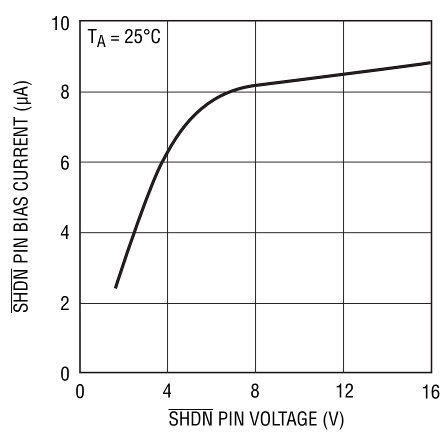

### Switch Current Limit (LT3483A)




### Quiescent Current




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



## PIN FUNCTIONS (DFN/TSOT-23)

**FB (Pin 1/Pin 3):** Feedback. Place resistor to negative output here. Set resistor value R1 = $V_{OUT}$/10µA.

**GND (Pins 2, 3/Pin 2):** Ground. For DFN package, tie both pin 2 and pin 3 together to ground.

**SW (Pin 4/Pin 1):** Switch. Connect to external inductor L1 and positive terminal of transfer capacitor.

**$V_{IN}$ (Pin 5/Pin 6):** Input Supply. Must be locally bypassed with 1µF or greater.

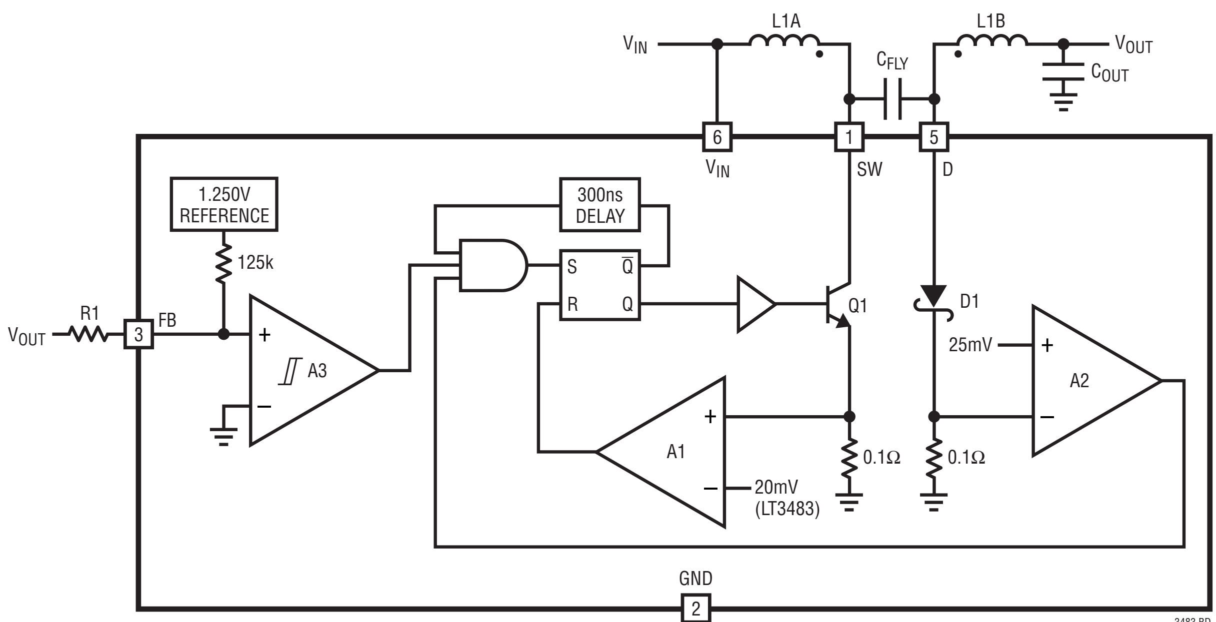
**NC (Pin 6/NA):** No Internal Connection.

**D (Pin 7/Pin 5):** Anode Terminal of Integrated Schottky Diode. Connect to negative terminal of transfer capacitor and external inductor L2 (flyback configuration) or to cathode of external Schottky diode (inverting charge pump configuration).

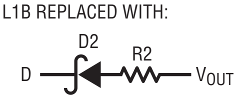
**$\overline{SHDN}$ (Pin 8/Pin 4):** Shutdown. Connect to GND to turn device off. Connect to supply to turn device on.

**Exposed Pad (Pin 9/NA):** GND. The exposed pad should be soldered to the PCB ground to achieve the rated thermal performance.

## BLOCK DIAGRAM




OPTIONAL CHARGE PUMP CONFIGURATION.
L1B REPLACED WITH:




PIN NUMBERS CORRESPOND TO THE 6-PIN TSOT-23 PACKAGE

# OPERATION

The LT3483/LT3483A use a constant off-time control scheme to provide high efficiency over a wide range of output currents. Operation can be best understood by referring to the Block Diagram. When the voltage at the FB pin is approximately 0V, comparator A3 disables most of the internal circuitry. Output current is then provided by external capacitor $C_{OUT}$, which slowly discharges until the voltage at the FB pin goes above the hysteresis point of A3. Typical hysteresis at the FB pin is 10mV. A3 then enables the internal circuitry, turns on power switch Q1, and the currents in external inductors L1A and L1B begin to ramp up. Once the switch current reaches 200mA (LT3483) or 400mA (LT3483A), comparator A1 resets the latch, which turns off Q1 after about 80ns. Inductor current flows through the internal Schottky D1 to GND, charging the flying capacitor. Once the 300ns off-time has elapsed, and internal diode current drops below 250mA (as detected by comparator A2), Q1 turns on again and ramps up to the switch current limit. This switching action continues until the output capacitor charge is replenished (until the FB pin decreases to 0V), then A3 turns off the internal circuitry and the cycle repeats. The inverting charge pump topology replaces L1B with the series combination D2 and R2.

# APPLICATIONS INFORMATION

## CHOOSING A REGULATOR TOPOLOGY

### Inverting Charge Pump

The inverting charge pump regulator combines an inductor-based step-up with an inverting charge pump. This configuration usually provides the best size, efficiency and output ripple and is applicable where the magnitude of $V_{OUT}$ is greater than $V_{IN}$. Negative outputs to –38V can be produced with the LT3483/LT3483A in this configuration. For cases where the magnitude of $V_{OUT}$ is less than or equal to $V_{IN}$, use a 2-inductor or transformer configuration such as the inverting flyback.

In the inverting charge pump configuration, a resistor is added in series with the Schottky diode between the negative output and the D pin of the LT3483/LT3483A. The purpose of this resistor is to smooth/reduce the current spike in the flying capacitor when the switch turns on. A 10Ω resistor works well for a $Li^+$ to –8V application, and the impact to converter efficiency is less than 3%. The resistor values recommended in the applications circuits also limit the switch current during a short-circuit condition at the output.

### Inverting Flyback

The inverting flyback regulator, shown in the –5V application circuit, uses a coupled inductor and is an excellent choice where the magnitude of the output is less than or equal to the supply voltage. The inverting flyback also performs well in a step-up/invert application, but it occupies more board space compared with the inverting charge pump. Also, the maximum $|V_{OUT}|$ using the flyback is less than can be obtained with the charge pump—it is reduced from 38V by the magnitudes of $V_{IN}$ and ringing at the switch node. Under a short-circuit condition at the output, a proprietary technique limits the switch current and prevents damage to the LT3483/LT3483A even with supply voltage as high as 16V. As an option, a 0.47µF capacitor may be added between terminals D and SW of LT3483/LT3483A to suppress ringing at SW.

### Inductor Selection

Several recommended inductors that work well with the LT3483/LT3483A are listed in Table 1, although there are many other manufacturers and devices that can be used. Consult each manufacturer for more detailed information and for their entire selection of related parts. Many different sizes and shapes are available. For inverting charge pump regulators with input and output voltages below 7V, a 4.7µH or 6.8µH inductor is usually the best choice. For flyback regulators or for inverting charge pump regulators where the input or output voltage is greater than 7V, a 10µH inductor is usually the best choice. A larger value inductor can be used to slightly increase the available output current, but limit it to around twice the

## APPLICATIONS INFORMATION

value recommended, as too large of an inductance will increase the output voltage ripple without providing much additional output current.

**Table 1. Recommended Inductors**

| PART | L (µH) | MAX $I_{DC}$ (mA) | DCR (Ω) | HEIGHT (mm) | MANUFACTURER |
|---|---|---|---|---|---|
| LQH2MCN4R7M02L<br>LQH2MCN6R8M02L<br>LQH2MCN100M02L | 4.7<br>6.8<br>10 | 300<br>255<br>225 | 0.84<br>1.0<br>1.2 | 0.95 | Murata<br>www.murata.com |
| SDQ12<br>Coupled<br>Inductor | 4.7<br>10<br>15 | 1.45<br>980<br>780 | 0.40<br>0.72<br>1.15 | 1.2 | Cooper Electronics<br>Tech<br>www.cooperet.com |
| LPD3015<br>Coupled<br>Inductor | 4.7<br>10 | 860<br>580 | 0.52<br>1.0 | 1.4 | Coilcraft<br>www.coilcraft.com |

### Capacitor Selection

The small size and low ESR of ceramic capacitors make them ideal for LT3483/LT3483A applications. Use of X5R and X7R types is recommended because they retain their capacitance over wider voltage and temperature ranges than other dielectric types. Always verify the proper voltage rating. Table 2 shows a list of several ceramic capacitor manufacturers. Consult the manufacturers for more detailed information on their entire selection of ceramic capacitors.

A 4.7µF ceramic bypass capacitor on the $V_{IN}$ pin is recommended where the distance to the power supply or battery could be more than a couple inches. Otherwise, a 1µF is adequate.

A capacitor in parallel with feedback resistor R1 is recommended to reduce the output voltage ripple. Use a 5pF capacitor for the inverting charge pump, and a 22pF value for the inverting flyback or other dual inductor configurations. Output voltage ripple can be reduced to 20mV in some cases using this capacitor in combination with an appropriately selected output capacitor.

The output capacitor is selected based on desired output voltage ripple. For low output voltage ripple in the inverting flyback configuration, use a 4.7µF to 10µF capacitor. The inverting charge pump utilizes values ranging from 0.22µF to 4.7µF. The following formula is useful to estimate the output capacitor value needed:

$$C_{OUT} = \frac{L \bullet I_{SW}^2}{-V_{OUT} \bullet \Delta V_{OUT}}$$

where $I_{SW}$ = 0.25A (LT3483) or $I_{SW}$ = 0.5A (LT3483A) and $\Delta V_{OUT}$ = 30mV. The flying capacitor in the inverting charge pump configuration ranges from 0.1µF to 0.47µF. Multiply the value predicted by the above equation for $C_{OUT}$ by 1/10 to determine the value needed for the flying capacitor.

**Table 2. Recommended Ceramic Capacitor Manufacturers**

| MANUFACTURER | URL |
|---|---|
| AVX | www.avxcorp.com |
| Kemet | www.kemet.com |
| Murata | www.murata.com |
| Taiyo Yuden | www.tyuden.com |

### Setting the Output Voltage

The output voltage is programmed using one feedback resistor according to the following formula:

$$R1 = -\frac{V_{OUT}}{10\mu A}$$

### Inrush Current

When $V_{IN}$ is increased from ground to operating voltage, an inrush current will flow through the input inductor and integrated Schottky diode to charge the flying capacitor. Conditions that increase inrush current include a larger, more abrupt voltage step at $V_{IN}$, a larger flying capacitor, and an inductor with a low saturation current.

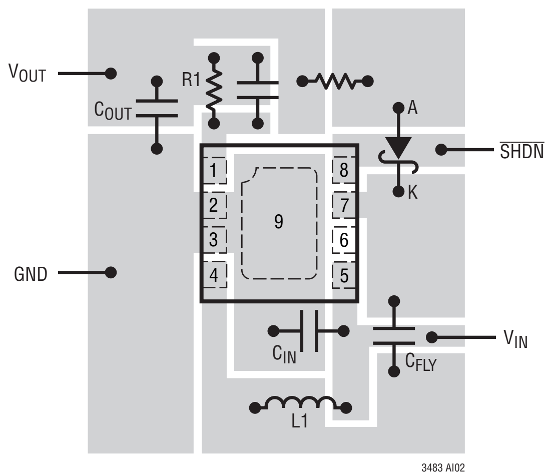
While the internal diode is designed to handle such events, the inrush current should not be allowed to exceed 1.5A. For circuits that use flying capacitors within the recommended range and have input voltages less than 5V, inrush current remains low, posing no hazard to the device. In cases where there are large steps at $V_{IN}$, inrush current should be measured to ensure operation within the limits of the device.

# APPLICATIONS INFORMATION

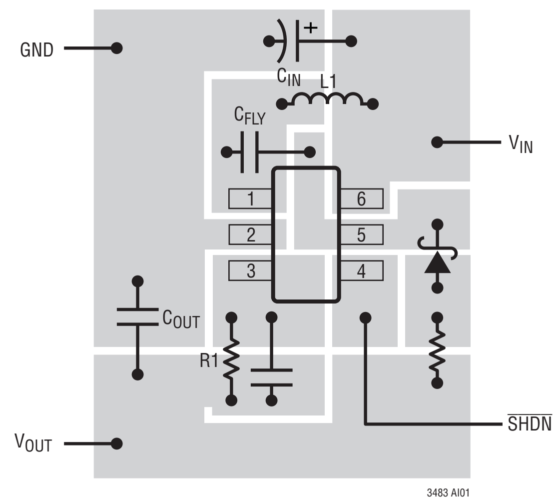
## Board Layout Considerations

As with all switching regulators, careful attention must be given to the PCB board layout and component placement. Proper layout of the high frequency switching path is essential. The voltage signals of the SW and D pins have sharp rising and falling edges. Minimize the length and area of all traces connected to the SW and D pins. In particular, it is desirable to minimize the trace length to and from the flying capacitor, since current in this capacitor switches directions within a cycle. Always use a ground plane under the switching regulator to minimize interplane coupling.

**Suggested Layout (DFN) for Inverting Charge Pump**

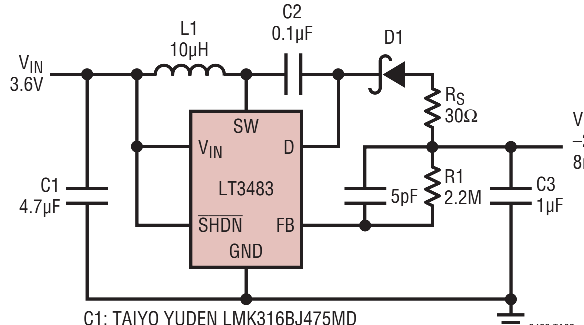



**Suggested Layout (SOT-23) for Inverting Charge Pump**



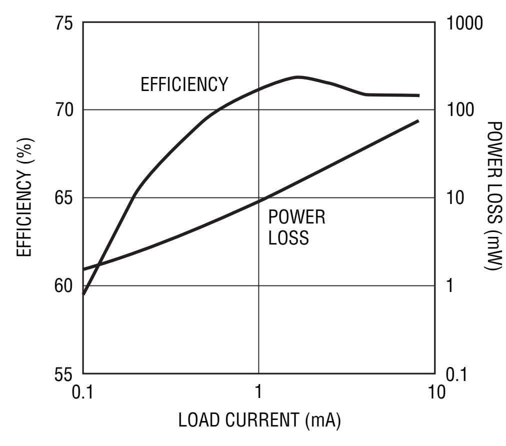

# TYPICAL APPLICATIONS

**3.6V to –22V DC/DC Converter**



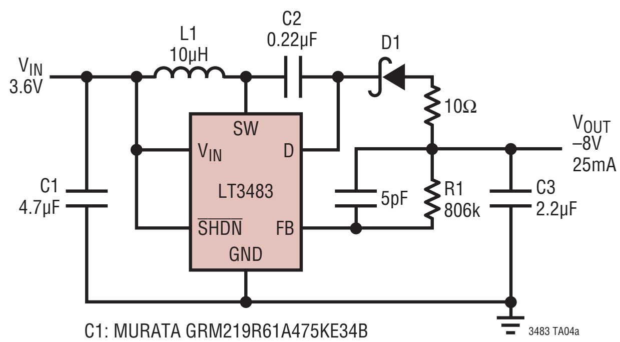

C1: TAIYO YUDEN LMK316BJ475MD
C2: TAIYO YUDEN TMK107BJ104 (X5R)
C3: TAIYO YUDEN TMK316BJ105MD
D1: PHILIPS PMEG3002AEB
L1: MURATA LQH2MCN100K02L

**3.6V to –22V Converter Efficiency and Power Loss**



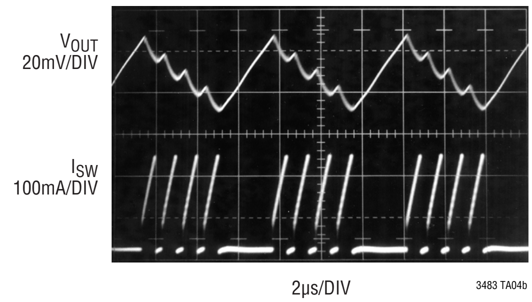
# TYPICAL APPLICATIONS

**3.6V to –8V DC/DC Converter**
**Low Profile, Small Footprint**



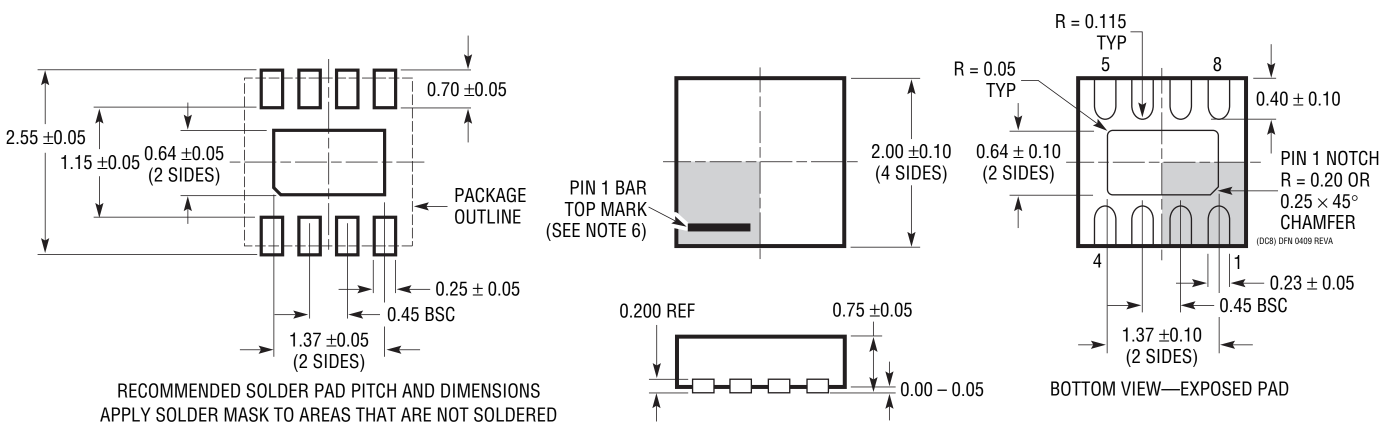

C1: MURATA GRM219R61A475KE34B
C2: TAIYO YUDEN LMK107BJ224
C3: MURATA GRM219R61C225KA88B
D1: PHILIPS PMEG2005EB
L1: MURATA LQH2MCN100K02L

**Switching Waveform**




# PACKAGE DESCRIPTION

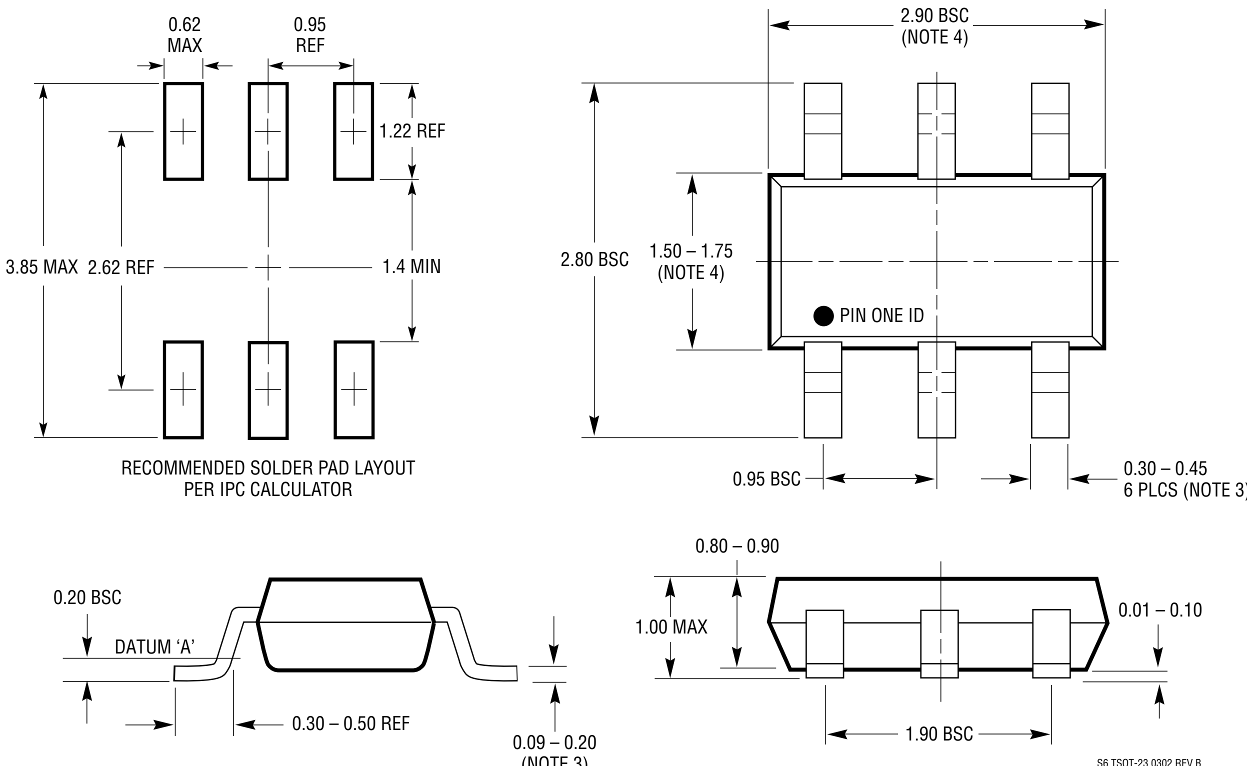
**DC Package**
**8-Lead Plastic DFN (2mm × 2mm)**
(Reference LTC DWG # 05-08-1719 Rev A)




NOTE:
1. DRAWING IS NOT A JEDEC PACKAGE OUTLINE
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

# PACKAGE DESCRIPTION

**S6 Package**
**6-Lead Plastic TSOT-23**
(Reference LTC DWG # 05-08-1636 Rev B)



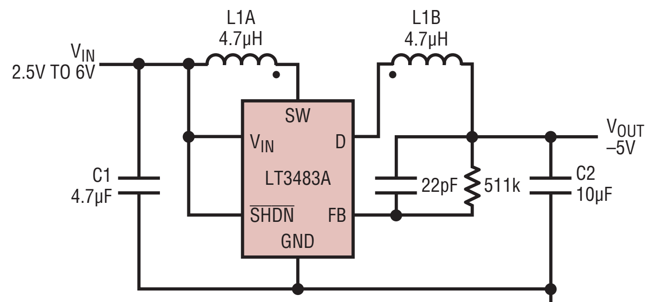

NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DRAWING NOT TO SCALE
3. DIMENSIONS ARE INCLUSIVE OF PLATING
4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
5. MOLD FLASH SHALL NOT EXCEED 0.254mm
6. JEDEC PACKAGE REFERENCE IS MO-193

## REVISION HISTORY (Revision history begins at Rev C)

| REV | DATE | DESCRIPTION | PAGE NUMBER |
|---|---|---|---|
| C | 09/10 | Revised entire data sheet to add LTC3483A | 1-12 |

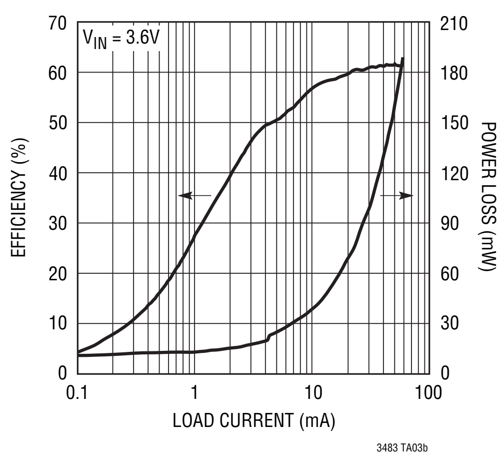
## TYPICAL APPLICATION

**–5V Step-Up/Step-Down Converter**

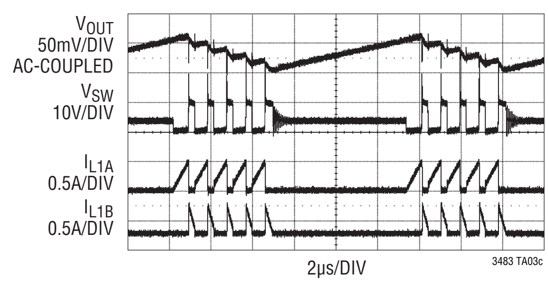



C1: TAIYO YUDEN EMK316BJ475ML
C2: TAIYO YUDEN JMK316BJ106ML
L1A, L1B: COILTRONICS SDQ12-4R7 OR
COILCRAFT LPD3015-472

**Efficiency and Power Loss vs Load Current**




**Switching Waveforms**




## RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|---|---|---|
| LT1617/LT1617-1 | 350mA/100mA ($I_{SW}$) High Efficiency Micropower Inverting DC/DC Converter | $V_{IN}$: 1.2V to 15V, $V_{OUT(MAX)}$ = –34V, $I_Q$ = 20µA, $I_{SD}$ < 1µA ThinSOT Package |
| LT1931/LT1931A | 1A ($I_{SW}$), 1.2MHz/2.2MHz, High Efficiency Micropower Inverting DC/DC Converter | $V_{IN}$: 2.6V to 16V, $V_{OUT(MAX)}$ = –34V, $I_Q$ = 5.8mA, $I_{SD}$ < 1µA ThinSOT Package |
| LT1945 | Dual Output, Boost/Inverter, 350mA ($I_{SW}$), Constant Off-Time, High Efficiency Step-Up DC/DC Converter | $V_{IN}$: 1.2V to 15V, $V_{OUT(MAX)}$ = ±34V, $I_Q$ = 40µA, $I_{SD}$ < 1µA, MS10 Package |
| LT3463 | Dual Output, Boost/Inverter, 250mA ($I_{SW}$), Constant Off-Time, High Efficiency Step-Up DC/DC Converter with Integrated Schottky Diodes | $V_{IN}$: 2.3V to 15V, $V_{OUT(MAX)}$ = ±40V, $I_Q$ = 40µA, $I_{SD}$ < 1µA DFN Package |
| LT3464 | 85mA ($I_{SW}$), High Efficiency Step-Up DC/DC Converter with Integrated Schottky and PNP Disconnect | $V_{IN}$: 2.3V to 10V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 25µA, $I_{SD}$ < 1µA ThinSOT Package |
| LT3472 | Boost (350mA) and Inverting (400mA) DC/DC Converter for CCD Bias with Integrated Schottkys | $V_{IN}$: 2.3V to 15V, $V_{OUT(MAX)}$ = ±40V, $I_Q$ = 2.8mA, $I_{SD}$ < 1µA DFN Package |




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

LT 0910 REV C • PRINTED IN USA