

# 90V Boost DC/DC Converter with APD Current Monitor

## FEATURES

- **High Output Voltage: Up to 90V**
- **Integrated Schottky Diodes**
- **48V, 280mA Internal Switch**
- **High Side APD Current Monitor**
- Adjustable Switching Frequency: 650kHz or 1.1MHz
- Wide  $V_{IN}$  Range: 2.5V to 16V
- Surface Mount Components
- Low Shutdown Current:  $<1\mu A$
- Soft-Start
- Internal Compensation
- CTRL Pin Allows Output Adjustment with No Polarity Inversion
- 3mm  $\times$  3mm 16-Lead QFN Package

## APPLICATIONS

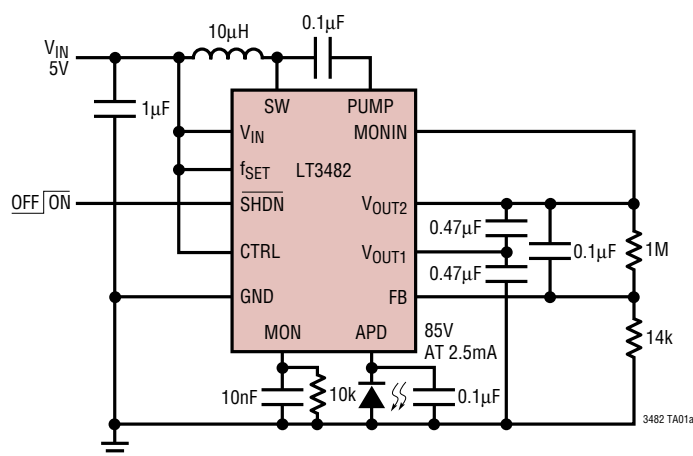
- APD Bias
- PIN Diode Bias
- Optical Receivers and Modules
- Fiber Optic Network Equipment

## DESCRIPTION

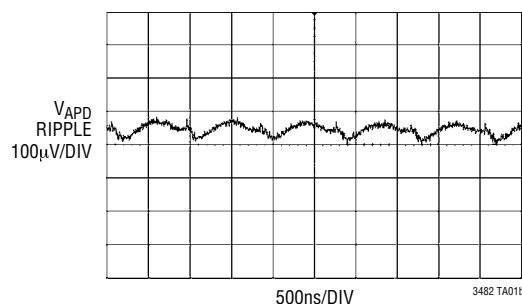
The LT<sup>®</sup>3482 is a fixed frequency current mode step-up DC/DC converter with voltage doubler designed to bias avalanche photodiodes (APDs) in optical receivers. It can provide up to 90V output. The LT3482 features high side APD current monitoring with better than 10% relative accuracy over the entire temperature range. The integrated power switch, Schottky diodes and APD current monitor allow a small converter footprint and low solution cost. Constant switching frequency results in predictable output noise that is easy to filter. The inductor-based topology ensures an input free from switching noise. An integrated high side current monitor produces a current proportional to APD current with better than 10% relative accuracy over four decades of dynamic range in the input range of 250nA to 2.5mA. This current can be used as a reference to provide a digitally programmed output voltage via the CTRL pin. The LT3482 is available in the tiny footprint (3mm  $\times$  3mm) 16-lead QFN package.

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## TYPICAL APPLICATION



Output Voltage Ripple



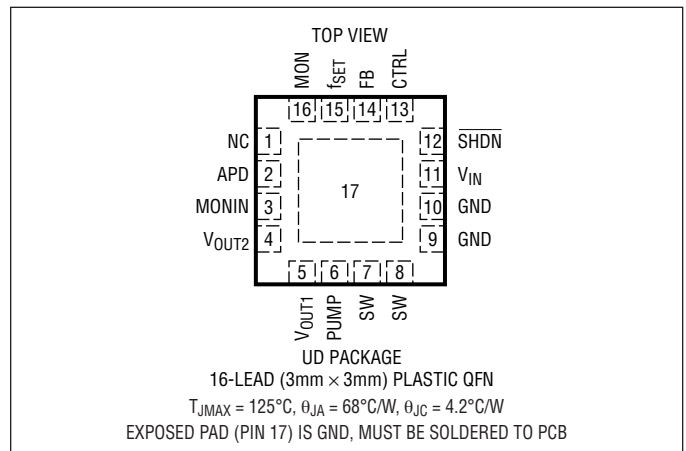
# LT3482

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

|                                       |                |
|---------------------------------------|----------------|
| Input Voltage ( $V_{IN}$ )            | 16V            |
| $V_{OUT1}$ , SW Voltage               | 48V            |
| $V_{OUT2}$ , PUMP, MONIN, APD Voltage | 90V            |
| FB Voltage                            | 5V             |
| SHDN, $f_{SET}$ , CTRL Voltage        | 16V            |
| MON Voltage                           | 12V            |
| Operating Temperature Range           |                |
| (Note 2)                              | –40°C to 85°C  |
| Maximum Junction Temperature          | 125°C          |
| Storage Temperature Range             | –65°C to 125°C |

## PIN CONFIGURATION



## ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL   | PART MARKING* | PACKAGE DESCRIPTION             | TEMPERATURE RANGE |
|------------------|-----------------|---------------|---------------------------------|-------------------|
| LT3482EUD#PBF    | LT3482EUD#TRPBF | LCFG          | 16-Lead (3mm x 3mm) Plastic QFN | 0°C to 85°C       |
| LT3482IUD#PBF    | LT3482IUD#TRPBF | LCFG          | 16-Lead (3mm x 3mm) Plastic QFN | –40°C to 125°C    |

Consult LTC Marketing for parts specified with wider operating temperature ranges. \*The temperature grade is identified by a label on the shipping container.

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

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

## 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                                     | MIN            | TYP        | MAX            | UNITS      |
|---------------------------|--|----------------|------------|----------------|------------|
| Minimum Operating Voltage |  | 2.5            |            |                | V          |
| Maximum Operating Voltage |  |                |            | 16             | V          |
| Feedback Voltage          | CTRL = 1.5V                                    | 1.215<br>1.200 | 1.235      | 1.255<br>1.260 | V<br>V     |
| Feedback Line Regulation  |  |                | 0.025      | 0.07           | %/V        |
| FB Pin Bias Current       |  | ●              | 30         | 100            | nA         |
| Supply Current            | FB = 1.3V, Not Switching<br>$V_{SHDN} = 0$     |                | 3.3<br>0.1 | 4.0<br>0.5     | mA<br>μA   |
| Switching Frequency       | $f_{SET} = 0\text{V}$<br>$f_{SET} = 2\text{V}$ | 580<br>1.0     | 650<br>1.1 | 750<br>1.3     | kHz<br>MHz |
| Maximum Duty Cycle        | $f_{SET} = 0\text{V}$                          | 95             |            |                | %          |
| Switch Current Limit      |  | 280            | 360        | 420            | mA         |
| Switch $V_{CESAT}$        | $I_{SW} = 150\text{mA}$                        |                | 130        | 220            | mV         |
| Switch Leakage Current    | SW = 5V  |                |            | 2              | μA         |
| Schottky Forward Voltage  | $I_{SCHOTTKY} = 150\text{mA}$                  |                | 880        |                | mV         |
| Schottky Reverse Leakage  | $V_{OUT1} - \text{SW} = 50\text{V}$            |                |            | 5              | μA         |
| SHDN Voltage High         |  | 1.5            |            |                | V          |

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## 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.

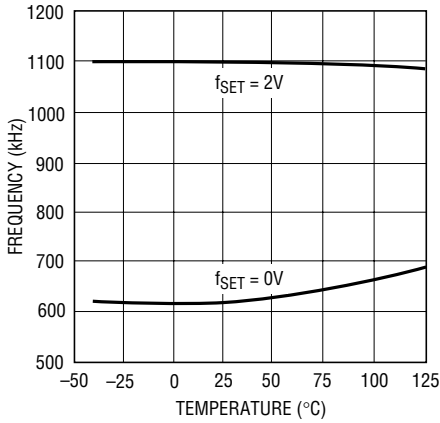
| PARAMETER                    | CONDITIONS  |   | MIN       | TYP    | MAX      | UNITS         |
|------------------------------|---|---|-----------|--------|----------|---------------|
| SHDN Voltage Low             |   |   |           |        | 0.4      | V             |
| SHDN Pin Bias Current        |   |   |           | 35     | 50       | $\mu\text{A}$ |
| $f_{SET}$ Voltage High       |   |   | 1.5       |        |          | V             |
| $f_{SET}$ Voltage Low        |   |   |           |        | 0.4      | V             |
| $f_{SET}$ Bias Current       | $f_{SET} = 2\text{V}$   |   |           | 22     | 40       | $\mu\text{A}$ |
| CTRL to FB Offset            | CTRL = 0.5V   | ● | -5<br>-10 | 2<br>2 | 10<br>15 | mV<br>mV      |
| APD Current Monitor Gain     | $I_{APD} = 250\text{nA}$ , $10\text{V} \leq \text{MONIN} \leq 90\text{V}$ | ● | 0.180     | 0.20   | 0.215    |               |
|                              | $I_{APD} = 2.5\text{mA}$ , $20\text{V} \leq \text{MONIN} \leq 90\text{V}$ | ● | 0.185     | 0.20   | 0.215    |               |
| Monitor Output Voltage Clamp |   |   |           | 11.5   |          | V             |
| APD Monitor Voltage Drop     | MONIN – APD at $I_{APD} = 1\text{mA}$ , MONIN = 90V                       |   |           |        | 5        | V             |
| MONIN Pin Current Limit      | APD = 0V, MONIN = 40V   |   |           | 15     |          | mA            |

**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.

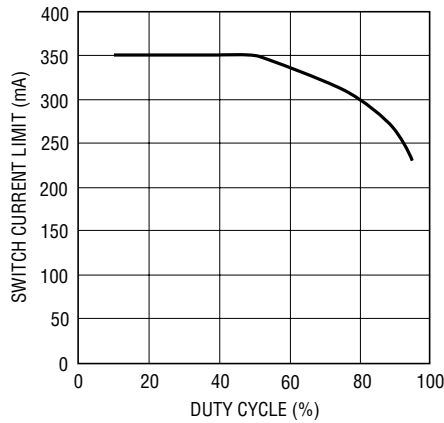
**Note 2:** The LT3482E is guaranteed to meet specified performance from  $0^\circ\text{C}$  to  $85^\circ\text{C}$ . Specifications over the  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  operating temperature range are assured by design, characterization and correlation with statistical process controls. The LT3482I is guaranteed to meet performance specifications over the  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  operating temperature range.

# TYPICAL PERFORMANCE CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ unless otherwise specified)

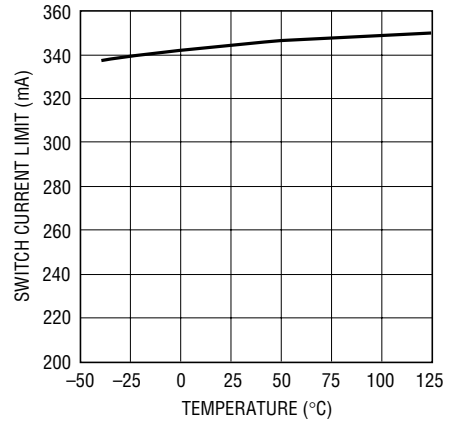
**Oscillator Frequency vs Temperature**



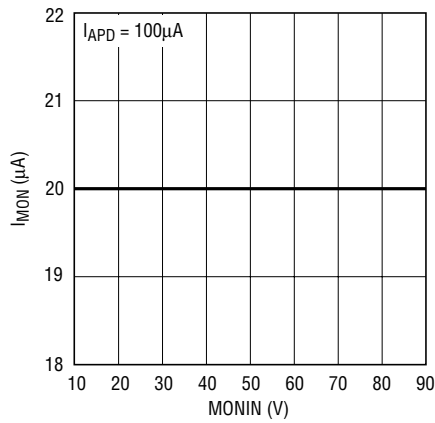
**Switch Current Limit vs Duty Cycle**



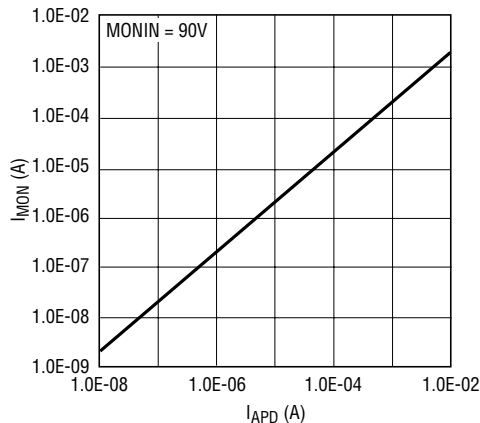
**Switch Current Limit vs Temperature**



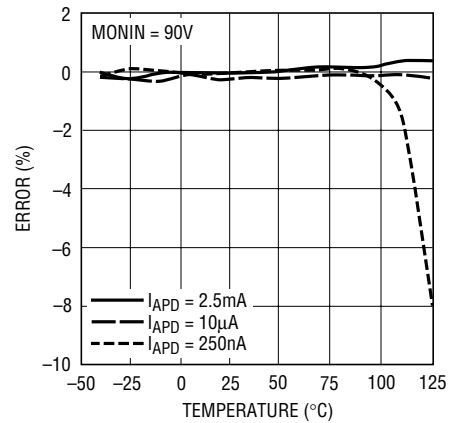
**Current Monitor Output vs MONIN**



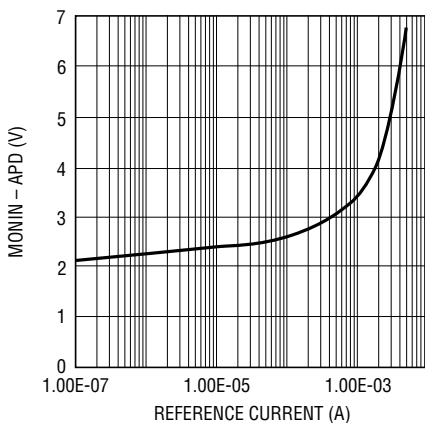
**APD Current Monitor Accuracy**



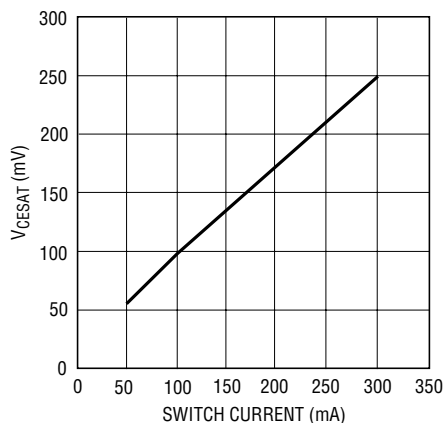
**APD Current Monitor Accuracy vs Temperature**



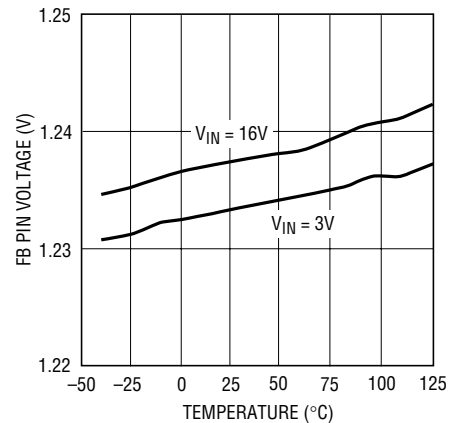
**Current Monitor Voltage Drop vs Reference Current**



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



**FB Pin Voltage vs Temperature**



## PIN FUNCTIONS

**APD (Pin 2):** Connect APD cathode to this pin.

**MONIN (Pin 3):** Current Monitor Power Supply Pin. An external lowpass filter can be included here to further reduce supply voltage ripple.

**V<sub>OUT2</sub> (Pin 4):** Voltage Doubler Output Pin. Put a 50V rated capacitor between this pin and V<sub>OUT1</sub>. Tie a resistor divider to the FB pin and GND.

**V<sub>OUT1</sub> (Pin 5):** Boost Output Pin. Put a capacitor between this pin and the GND plane. Minimize the length of the trace to the capacitor.

**PUMP (Pin 6):** Charge Pump Pin. Put a 50V rating bypass capacitor between SW and PUMP to form a complete voltage doubler with the internal integrated Schottky diodes. Minimize trace length to the capacitor.

**SW (Pins 7, 8):** Switch Pin. Minimize the trace length on this pin to reduce EMI.

**GND (Pins 9, 10):** Ground. Pins connected internally. For best performance, connect both pins to board ground.

**V<sub>IN</sub> (Pin 11):** Input Supply Pin. This pin must be locally bypassed.

**SHDN (Pin 12):** Shutdown Pin. Tie to 1.5V or higher to enable device; 0.4V or less to disable device. This pin also functions as soft-start between 1.5V and 2V.

**CTRL (Pin 13):** Internal Reference Override Pin. This allows the FB voltage to be externally set between 0V and 1.2V. Tie this pin higher than 1.5V to use the internal reference of 1.235V.

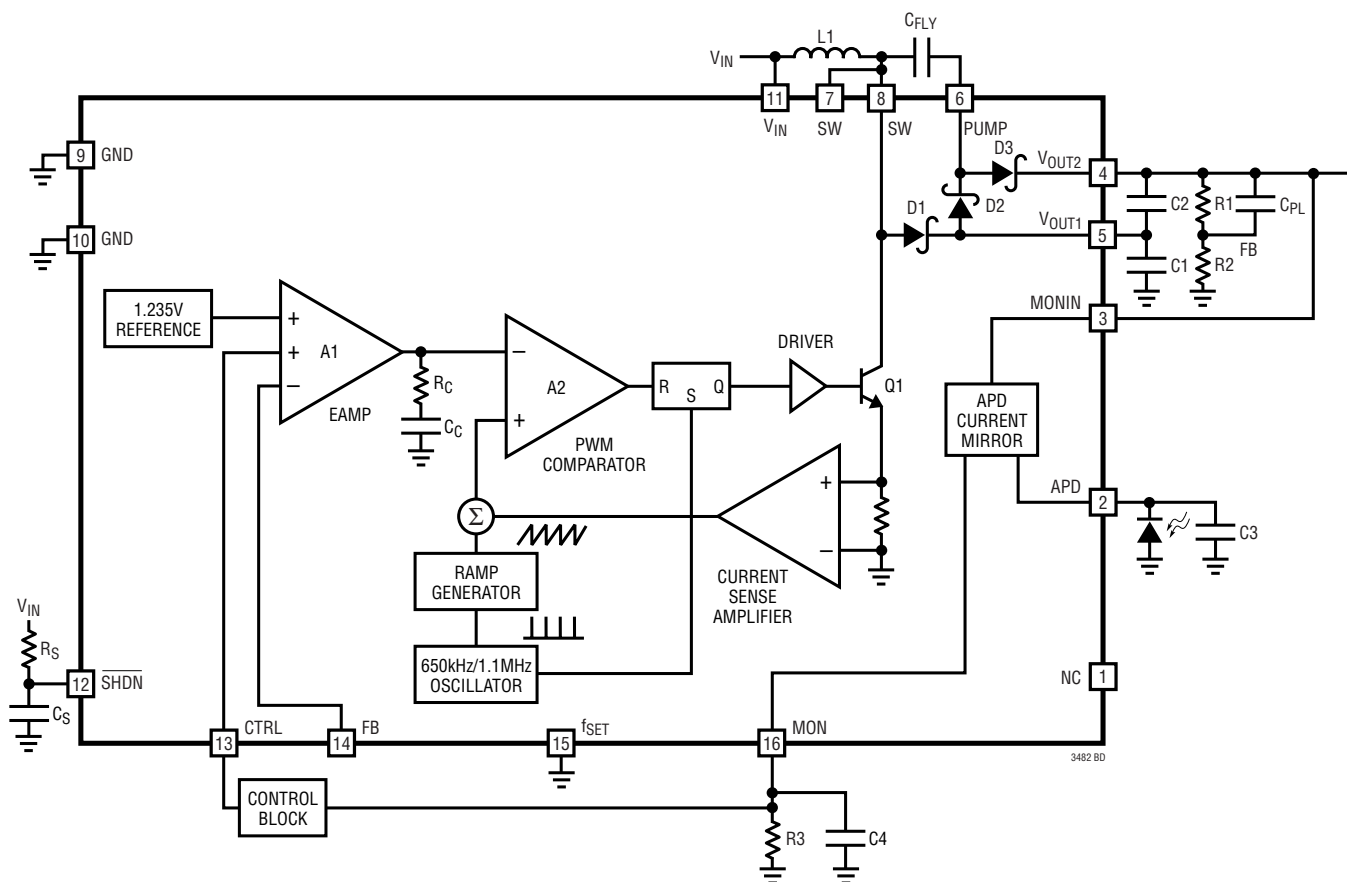
**FB (Pin 14):** Feedback Pin. Connect the output resistor divider tap here.

**f<sub>SET</sub> (Pin 15):** Oscillator Frequency Selection Pin. Tie this pin to above 1.5V or higher to select the higher switching frequency of 1.1MHz. For lower switching frequency, tie to GND.

**MON (Pin 16):** Current Monitor Output Pin. It sources a current equal to 20% of the APD current and converts to a reference voltage through an external resistor.

**Exposed Pad (Pin 17):** GND. This pin must be soldered to the PCB.

## FUNCTIONAL DIAGRAM



## OPERATION

The LT3842 boost converter uses a constant frequency current mode control scheme to provide excellent line and load regulation. Operation can be best understood by referring to the Functional Diagram. 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 1.235V, or externally provided CTRL voltage. 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.

The LT3482 has an integrated high side APD current monitor with a 5:1 ratio. The MONIN pin can accept a supply voltage up to 90V, which is suitable for APD photodiode applications. The MON pin has an open-circuit protection feature and is internally clamped to 11.5V.

If an APD is tied to the APD pin, the current will be mirrored to the MON pin and converted to a voltage signal by the resistor R3. This voltage signal can be used to drive an external control block to adjust the APD voltage by adjusting the feedback threshold of EAMP A1 through the CTRL input.

## APPLICATIONS INFORMATION

### Switching Frequency

The LT3482 can operate at either 650kHz nominal or 1.1MHz nominal; the voltage at the  $f_{SET}$  pin selects which frequency is used. At 1.1MHz, a physically smaller inductor and capacitor can be used in a given application, but higher frequencies will slightly decrease efficiency and maximum duty cycle. Generally if efficiency and maximum duty cycle are crucial, the lower switching frequency should be selected by connecting  $f_{SET}$  to GND. If application size and cost are more important, connect  $f_{SET}$  to  $V_{IN}$  to select the higher switching frequency.

### Inrush Current

The LT3482 has built-in Schottky diodes for the boost and charge pump. When supply voltage is applied to the  $V_{IN}$  pin, the voltage difference between  $V_{IN}$  and  $V_{OUT1}$  generates inrush current flowing from input through the inductor and the Schottky diode (D1 in the Functional Diagram) to charge the output capacitor. The selection of inductor and capacitor value should ensure the peak of the inrush current to be below 1A. In addition, the LT3482 turn-on should be delayed until the inrush current is less than the maximum current limit. The peak inrush current can be estimated as follows:

$$I_P = \frac{V_{IN} - 0.6}{\sqrt{\frac{L}{C}} - 1} \cdot \exp\left(-\frac{\pi}{2\sqrt{\frac{L}{C}} - 1}\right)$$

where L is the inductance and C is the output capacitance. Table 1 gives inrush peak currents for some component selections.

Table 1. Inrush Peak Current

| $V_{IN}$ (V) | L ( $\mu$ H) | C ( $\mu$ F) | $I_P$ (A) |
|--------------|--------------|--------------|-----------|
| 5            | 10           | 1            | 0.87      |
| 5            | 22           | 1            | 0.68      |

### Setting Output Voltage

The LT3482 is equipped with both an internal 1.235V reference and an auxiliary reference input (the CTRL pin). This allows users to select between using the built-in reference and supplying an external reference voltage. The voltage at the CTRL pin can be adjusted while the chip is operating to alter the output voltage of LT3482 for purposes such as APD's bias voltage adjustment. To use the internal 1.235V reference, the CTRL pin should be held higher than 1.5V, which can be done by tying it to  $V_{IN}$ . When the CTRL pin is between 0V and 1.2V, the LT3482 will regulate the output such that the FB pin voltage is equal to the CTRL pin voltage.

To set the output voltage, select the values of R1 and R2 (see Figure 1) according to the following equation:

$$R1 = R2 \left( \frac{V_{OUT2}}{V_{REF}} - 1 \right)$$

where  $V_{REF} = 1.235V$  if the internal reference is used or  $V_{REF} = CTRL$  if CTRL is between 0V and 1.2V. R2 can be selected to load the output to maintain a constant switching frequency when the APD load is very low. Preventing entry into pulse skipping mode is an important consideration for post filtering the regulator output.

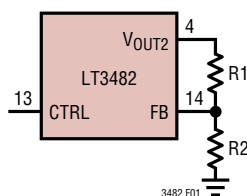


Figure 1. Output Voltage Feedback Connection

## APPLICATIONS INFORMATION

### Inductor Selection

The inductors used with the LT3482 should have a saturation current rating of 0.3A or greater. If the device is used in an application where the input supply will be hot-plugged, the saturation current rating should be equal to or greater than the peak inrush current. For best loop stability, the inductor value selected should provide a ripple current of 60mA or more. For a given  $V_{IN}$  and  $V_{OUT1}$ , the inductor value to use in continuous conduction mode (CCM) is estimated by the formula:

$$L = \frac{D \cdot V_{IN}}{f \cdot 60\text{mA}}$$

where:

$$D = \frac{V_{OUT1} + 1 - V_{IN}}{V_{OUT1} + 1}$$

and  $f$  is the switching frequency.

To achieve low output voltage ripple, a small value inductor should be selected to force the LT3482 work in discontinuous conduction mode (DCM). The inequality is true when the LT3482 is operating in discontinuous condition mode.

$$L < \frac{D \cdot V_{IN}}{f \cdot I_{LIMIT}}$$

where  $I_{LIMIT}$  is the switch current limit. Operating in DCM reduces the maximum load current and the conversion efficiency.

### Capacitor Selection

Low ESR capacitors should be used at the output to minimize the output voltage ripple. Use only X5R and X7R types because they retain their capacitance over wider voltage and temperature ranges than other types. High output voltages typically require less capacitance for loop stability. For applications with out voltage less than 45V, intermediate output pin  $V_{OUT1}$  can directly serve as the output pin. Typically use a 2 $\mu$ F capacitor for output voltage less than 25V and 1 $\mu$ F capacitor for output voltage between 25V and 45V. When output voltage goes beyond 45V, a charge pump must be formed with cascaded 0.47 $\mu$ F

capacitors C1 and C2 at the output nodes. A typical 0.1 $\mu$ F capacitor is used as the flying capacitor  $C_{FLY}$  to form the charge pump. Always use a capacitor with sufficient voltage rating.

Either ceramic or solid tantalum capacitors may be used for the input decoupling capacitor, which should be placed as close as possible to the LT3482. A 1 $\mu$ F capacitor is sufficient for most applications.

### Phase Lead Capacitor

A small value capacitor (i.e., 10pF to 22pF) can be added in parallel with the resistor between the output and the FB pin to reduce output perturbation due to a load step and to improve transient response. This phase lead capacitor introduces a pole-zero pair to the feedback that boosts phase margin near the crossover frequency.

The APD is very sensitive to a noisy bias supply. To lowpass filter noise from the internal reference and error amplifier, a 0.1 $\mu$ F phase lead capacitor can be used. The corner frequency of the noise filter is  $R1 \cdot C_{PL}$ .

### APD Current Monitor

The power supply switching noise associated with a switching power supply can interfere with the photodiode DC measurement. To suppress this noise, a 0.1 $\mu$ F capacitor is recommended at APD pin. An additional output lowpass filter, a 10k resistor and a 10nF capacitor in parallel at MON pin, can further reduce the power supply noise and other wide band noise, which might limit the measurement accuracy of low level signals. For applications requiring fast current monitor response time, a RC lowpass filter at MONIN pin is used to replace the 0.1 $\mu$ F capacitor at APD pin, as illustrated in Figure 2.

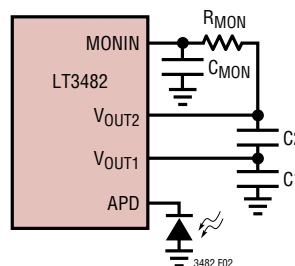
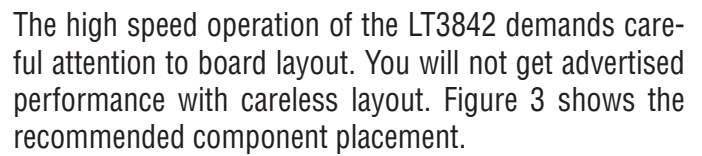


Figure 2

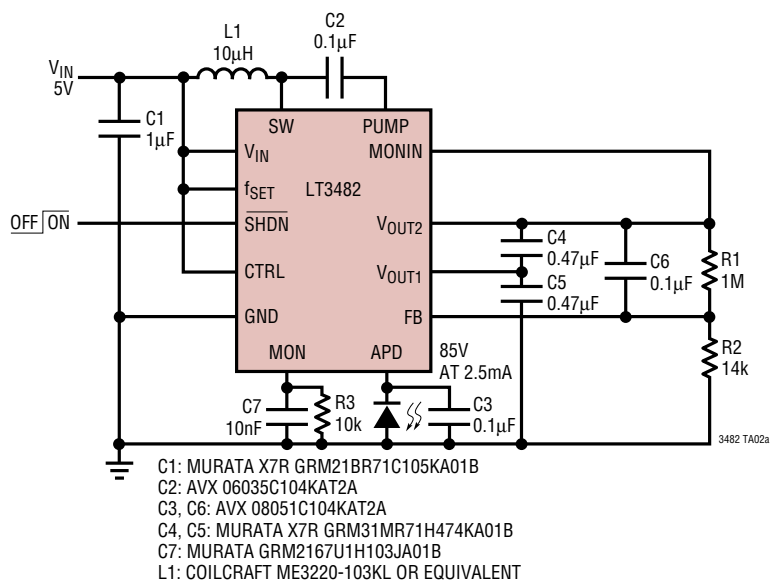


## Layout Hints

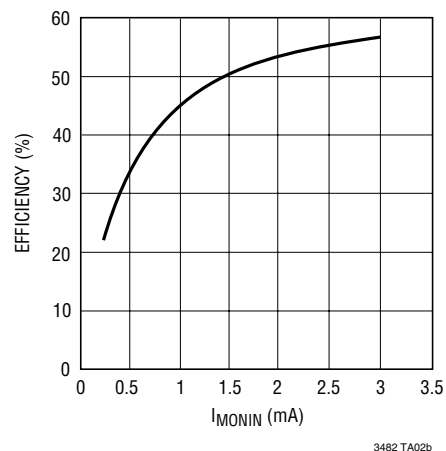


## TYPICAL APPLICATIONS

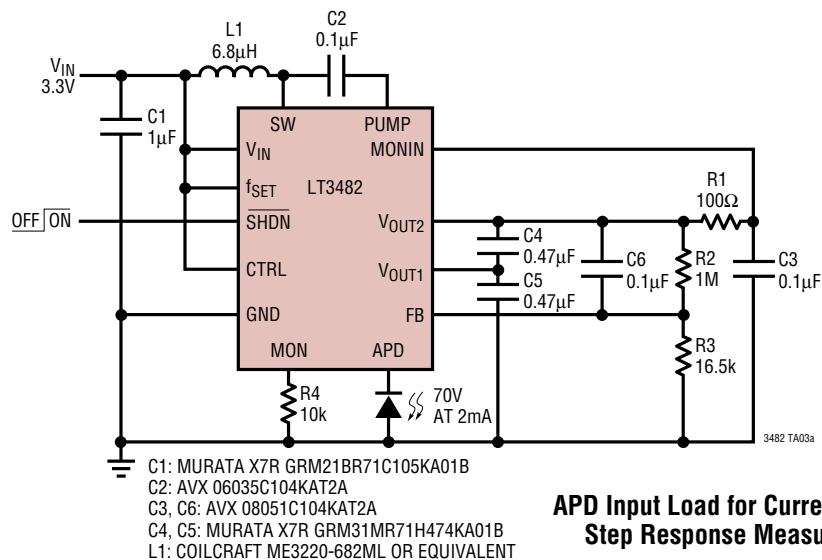
### 5V to 85V APD Bias Power Supply



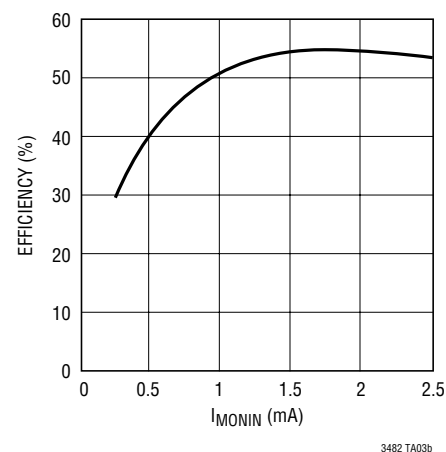
### Efficiency



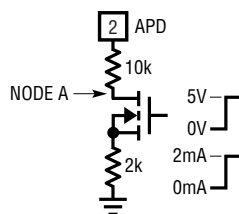
### 3.3V to 70V APD Bias Power Supply with Fast Current Monitor Response



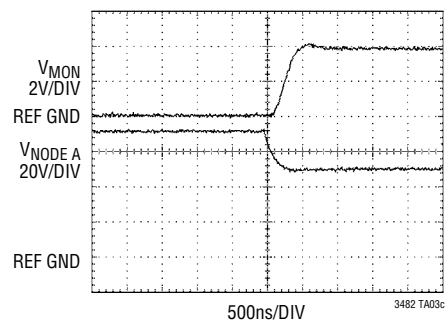
### Efficiency



### APD Input Load for Current Monitor Step Response Measurement



### Current Monitor Step Response

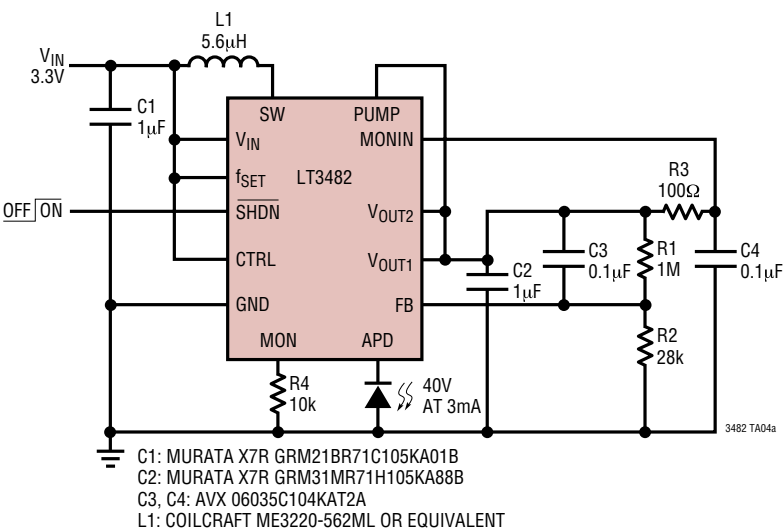


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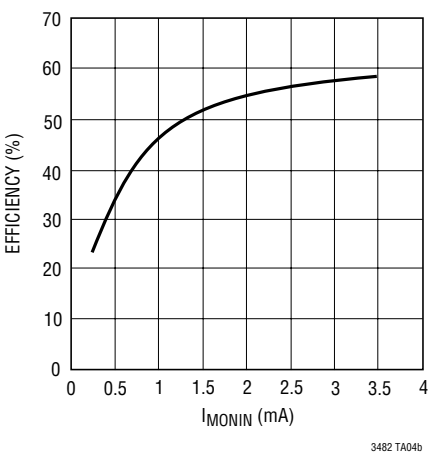


TYPICAL APPLICATION

3.3V to 40V APD Bias Power Supply



Efficiency



RELATED PARTS

| PART NUMBER    | DESCRIPTION  | COMMENTS  |
|----------------|--|---|
| LT1930/LT1930A | 1A (I <sub>SW</sub> ), 1.2MHz/2.2MHz High Efficiency Step-Up DC/DC Converters                          | V <sub>IN</sub> : 2.6V to 16V, V <sub>OUT(MAX)</sub> = 34V, I <sub>Q</sub> = 4.2mA/5.5mA, I <sub>SD</sub> < 1µA, ThinSOT™ Package   |
| LT3460         | 0.3A (I <sub>SW</sub> ), 1.3MHz High Efficiency Step-Up DC/DC Converter                                | V <sub>IN</sub> : 2.5V to 16V, V <sub>OUT(MAX)</sub> = 38V, I <sub>Q</sub> = 2mA, I <sub>SD</sub> < 1µA, ThinSOT Package            |
| LT3461/LT3461A | 0.3A (I <sub>SW</sub> ), 1.3MHz/3MHz High Efficiency Step-Up DC/DC Converters with Integrated Schottky | V <sub>IN</sub> : 2.5V to 16V, V <sub>OUT(MAX)</sub> = 38V, I <sub>Q</sub> = 2.8mA, I <sub>SD</sub> < 1µA, SC70 and ThinSOT Package |
| LT3465/LT3465A | Constant Current, 1.2MHz/2.7MHz High Efficiency White LED Boost Regulator with Integrated Schottky     | V <sub>IN</sub> : 2.7V to 16V, V <sub>OUT(MAX)</sub> = 34V, I <sub>Q</sub> = 1.9mA, I <sub>SD</sub> < 1µA, ThinSOT Package          |

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