

# White LED Driver and Boost Converter in 3mm × 3mm DFN Package

## FEATURES

- Drives Up to 10 White LEDs from a 3.6V Supply
- Two Independent Step-Up DC/DC Converters
- Independent Dimming and Shutdown Control of the Outputs
- $\pm 1.5\%$  Output Voltage Accuracy (Boost Converter)
- $\pm 4\%$  LED Current Programming Accuracy
- Internal Schottky Diodes
- Internal Soft-Start Eliminates Inrush Current
- Output Overvoltage Protection (39.5V Max  $V_{OUT}$ )
- Fixed Frequency Operation Up to 2MHz
- 83% Efficiency Driving 8 White LEDs at 15mA from a 3.6V Supply
- Wide Input Voltage Range: 2.7V to 24V
- Tiny (3mm × 3mm) 10-Lead DFN Package

## APPLICATIONS

- White LED and OLED Displays
- Digital Cameras, Sub-Notebook PCs
- PDAs, Handheld Computers
- TFT - LCD Bias Supply
- Automotive

## DESCRIPTION

LT<sup>®</sup>3466-1 is a dual switching regulator that combines a white LED driver and a boost converter in a low profile, small footprint (3mm × 3mm × 0.75mm) DFN package. The LED driver can be configured to drive up to 10 White LEDs in series and the boost converter can be used for generating the LCD bias voltages or driving a secondary OLED display. Series connection of the LEDs provides identical LED currents resulting in uniform brightness and eliminating the need for ballast resistors and expensive factory calibration.

The LT3466-1 provides independent dimming and shutdown control of the two converters. The operating frequency can be set with an external resistor over a 200kHz to 2MHz range. The white LED driver features a low 200mV reference, thereby minimizing power loss in the current setting resistor for better efficiency. The boost converter achieves  $\pm 1.5\%$  output voltage accuracy by the use of a precision 0.8V reference. Protection features include output overvoltage protection and internal soft-start. Wide input supply range allows operation from 2.7V to 24V.

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## TYPICAL APPLICATION

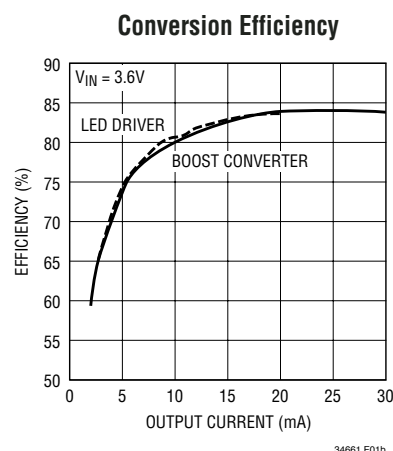
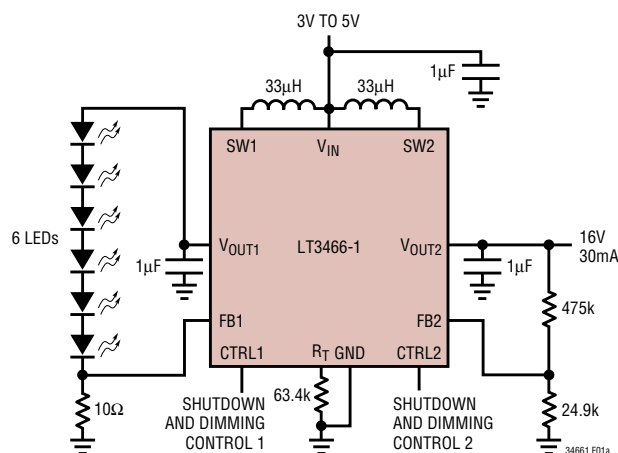


Figure 1. Li-Ion Powered Driver for 6 White LEDs and OLED Display

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

|                                          |                |
|------------------------------------------|----------------|
| Input Voltage ( $V_{IN}$ )               | 24V            |
| SW1, SW2 Voltages                        | 44V            |
| $V_{OUT1}$ , $V_{OUT2}$ Voltages         | 44V            |
| CTRL1, CTRL2 Voltages                    | 24V            |
| FB1, FB2 Voltages                        | 2V             |
| Operating Temperature Range (Note 2) ... | -40°C to 85°C  |
| Storage Temperature Range                | -65°C to 125°C |
| Junction Temperature                     | 125°C          |

## PACKAGE/ORDER INFORMATION

|                                                                                                                                                                                                                                                                    |                   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| <p>DD PACKAGE<br/>10-LEAD (3mm × 3mm) PLASTIC DFN<br/><math>T_{JMAX} = 125^{\circ}\text{C}</math>, <math>\theta_{JA} = 43^{\circ}\text{C/W}</math>, <math>\theta_{JC} = 3^{\circ}\text{C/W}</math><br/>EXPOSED PAD (PIN 11) IS GND<br/>MUST BE SOLDERED TO PCB</p> | ORDER PART NUMBER |
|                                                                                                                                                                                                                                                                    | LT3466EDD-1       |
|                                                                                                                                                                                                                                                                    | DD PART MARKING   |
|                                                                                                                                                                                                                                                                    | LBRX              |

**Order Options** Tape and Reel: Add #TR  
Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF  
Lead Free Part Marking: <http://www.linear.com/leadfree/>

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

## ELECTRICAL CHARACTERISTICS

The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^{\circ}\text{C}$ .  $V_{IN} = 3\text{V}$ ,  $V_{CTRL1} = 3\text{V}$ ,  $V_{CTRL2} = 3\text{V}$ , unless otherwise specified.

| PARAMETER                                  | CONDITIONS                                                          | MIN   | TYP            | MAX       | UNITS       |
|--------------------------------------------|---------------------------------------------------------------------|-------|----------------|-----------|-------------|
| Minimum Operating Voltage                  |                                                                     | 2.7   |                |           | V           |
| Maximum Operating Voltage                  |                                                                     |       |                | 22        | V           |
| FB1 Voltage                                |                                                                     | ● 192 | 200            | 208       | mV          |
| FB2 Voltage                                |                                                                     | ● 788 | 800            | 812       | mV          |
| FB1 Pin Bias Current                       | $V_{FB1} = 0.2\text{V}$ (Note 3)                                    |       | 10             | 50        | nA          |
| FB2 Pin Bias Current                       | $V_{FB2} = 0.8\text{V}$ (Note 3)                                    |       | 10             | 50        | nA          |
| Quiescent Current                          | $V_{FB1} = V_{FB2} = 1\text{V}$<br>$CTRL1 = CTRL2 = 0\text{V}$      |       | 5<br>16        | 7.5<br>25 | mA<br>μA    |
| Switching Frequency                        | $R_T = 48.7\text{k}$                                                | 0.75  | 1              | 1.25      | MHz         |
| Oscillator Frequency Range                 | (Note 4)                                                            | 200   |                | 2000      | kHz         |
| Nominal $R_T$ Pin Voltage                  | $R_T = 48.7\text{k}$                                                |       | 0.54           |           | V           |
| Maximum Duty Cycle                         | $R_T = 48.7\text{k}$<br>$R_T = 20.5\text{k}$<br>$R_T = 267\text{k}$ | ● 90  | 96<br>92<br>99 |           | %<br>%<br>% |
| Converter 1 Current Limit                  |                                                                     | ● 310 | 400            |           | mA          |
| Converter 2 Current Limit                  |                                                                     | ● 310 | 400            |           | mA          |
| Converter 1 $V_{CESAT}$                    | $I_{SW1} = 300\text{mA}$                                            |       | 320            |           | mV          |
| Converter 2 $V_{CESAT}$                    | $I_{SW2} = 300\text{mA}$                                            |       | 320            |           | mV          |
| Switch 1 Leakage Current                   | $V_{SW1} = 10\text{V}$                                              |       | 0.01           | 5         | μA          |
| Switch 2 Leakage Current                   | $V_{SW2} = 10\text{V}$                                              |       | 0.01           | 5         | μA          |
| CTRL1 Voltage for Full LED Current         |                                                                     | ● 1.8 |                |           | V           |
| CTRL2 Voltage for Full Feedback Voltage    |                                                                     | ● 1   |                |           | V           |
| CTRL1 or CTRL2 Voltage to Turn On the IC   |                                                                     | 150   |                |           | mV          |
| CTRL1 and CTRL2 Voltages to Shut Down Chip |                                                                     |       |                | 70        | mV          |
| CTRL1 Pin Bias Current                     | $V_{CTRL1} = 1\text{V}$                                             | ● 6   | 9              | 12.5      | μA          |
| CTRL2 Pin Bias Current                     | $V_{CTRL2} = 1\text{V}$ (Note 3)                                    | ●     | 10             | 120       | nA          |

## ELECTRICAL CHARACTERISTICS

The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_{IN} = 3\text{V}$ ,  $V_{CTRL1} = 3\text{V}$ ,  $V_{CTRL2} = 3\text{V}$ , unless otherwise specified.

| PARAMETER                        | CONDITIONS                     | MIN | TYP  | MAX | UNITS         |
|----------------------------------|--------------------------------|-----|------|-----|---------------|
| $V_{OUT1}$ Overvoltage Threshold |                                |     | 39.5 |     | V             |
| $V_{OUT2}$ Overvoltage Threshold |                                |     | 39.5 |     | V             |
| Schottky 1 Forward Drop          | $I_{SCHOTTKY1} = 300\text{mA}$ |     | 0.85 |     | V             |
| Schottky 2 Forward Drop          | $I_{SCHOTTKY2} = 300\text{mA}$ |     | 0.85 |     | V             |
| Schottky 1 Reverse Leakage       | $V_{OUT1} = 20\text{V}$        |     |      | 5   | $\mu\text{A}$ |
| Schottky 2 Reverse Leakage       | $V_{OUT2} = 20\text{V}$        |     |      | 5   | $\mu\text{A}$ |
| Soft-Start Time (Switcher 1)     |                                |     | 600  |     | $\mu\text{s}$ |
| Soft-Start Time (Switcher 2)     |                                |     | 600  |     | $\mu\text{s}$ |

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

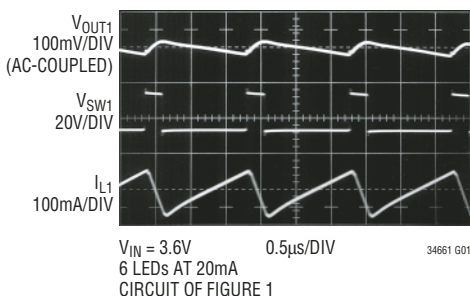
**Note 2:** The LTC3466-1E is guaranteed to meet specified performance from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ . Specifications over the  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  operating range are assured by design, characterization and correlation with statistical process controls.

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

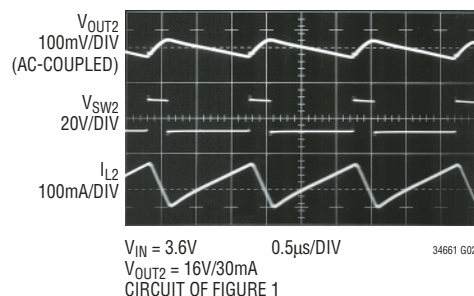
**Note 4:** Guaranteed by design and test correlation, not production tested.

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

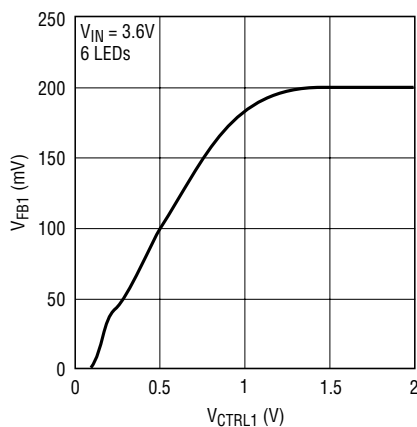
Switching Waveforms  
(LED Driver)



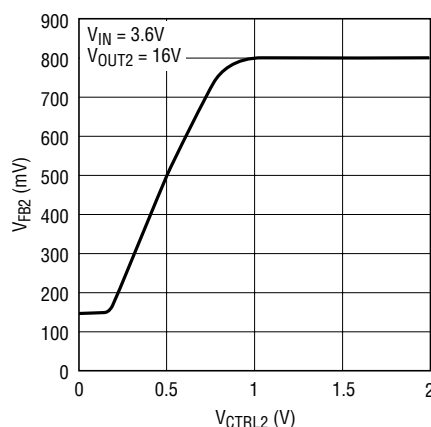
Switching Waveforms  
(Boost Converter)



$V_{FB1}$  vs  $V_{CTRL1}$

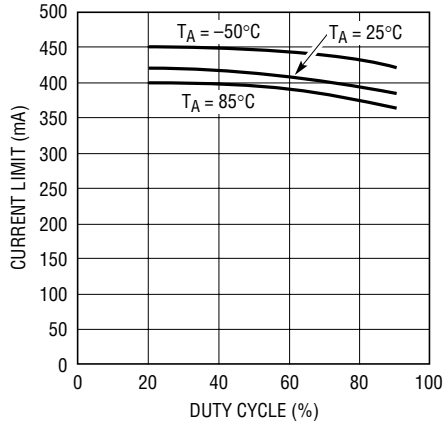


$V_{FB2}$  vs  $V_{CTRL2}$



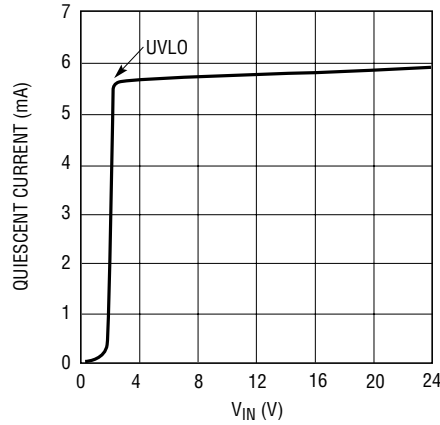
# TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$ unless otherwise specified

Switch Current Limit vs Duty Cycle



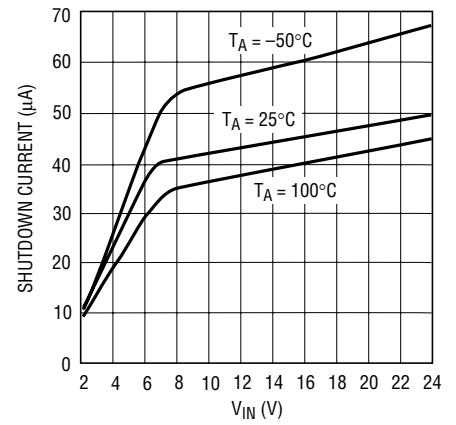
34661 G05

Quiescent Current  
(CTRL1 = CTRL2 = 3V)



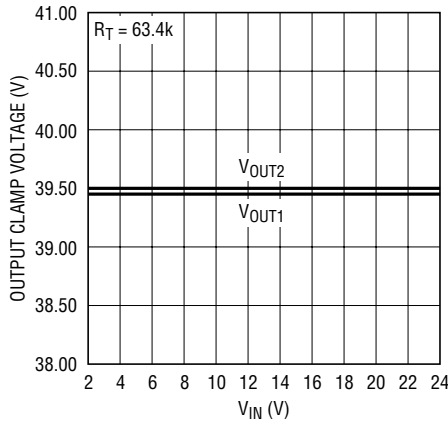
34661 G04

Shutdown Current  
(CTRL1 = CTRL2 = 0V)



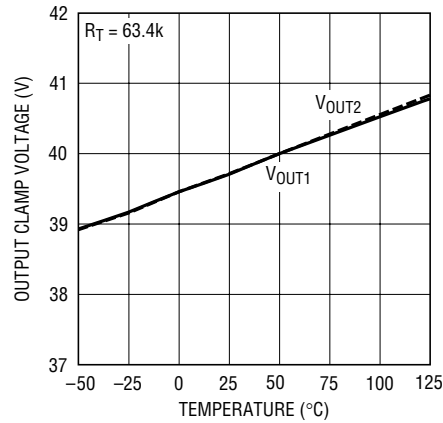
34661 G06

Open-Circuit Output Clamp  
Voltage



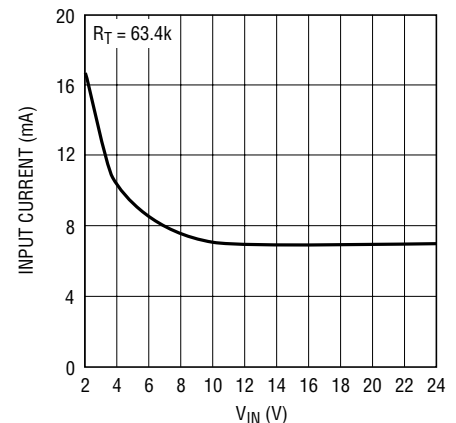
34661 G07

Open-Circuit Output Clamp  
Voltage



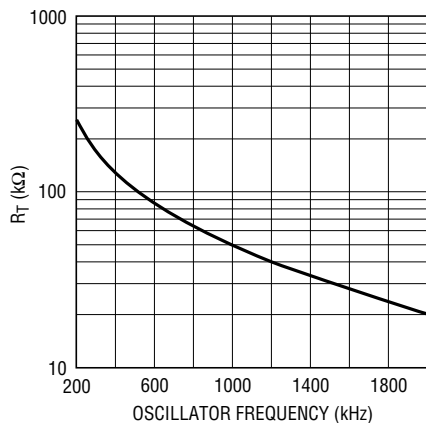
34661 G08

Input Current with Output 1 and  
Output 2 Open Circuit



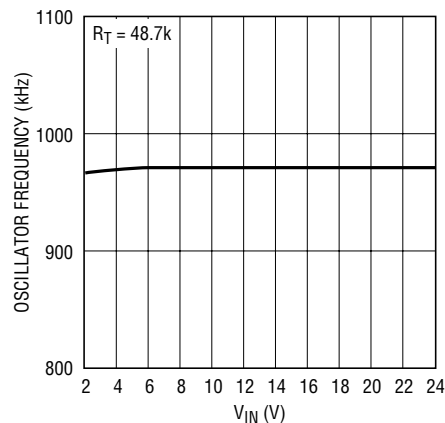
34661 G09

$R_T$  vs Oscillator Frequency



34661 G10

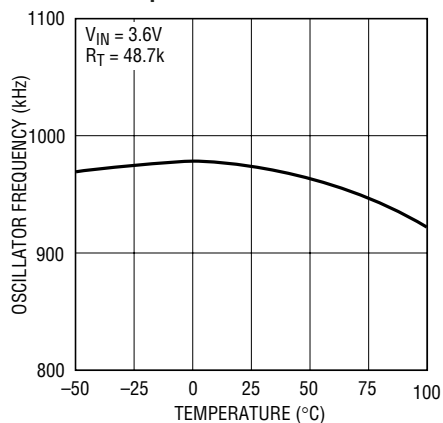
Oscillator Frequency vs  $V_{IN}$



34661 G11

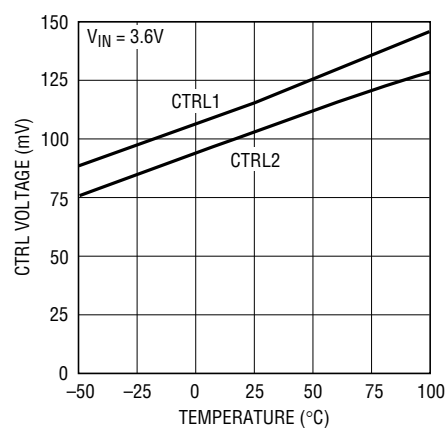
# TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$ unless otherwise specified

### Oscillator Frequency vs Temperature



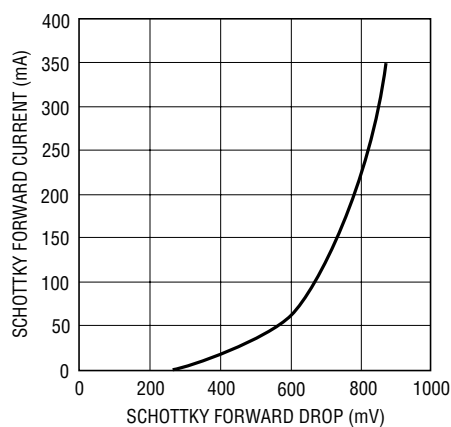
34661 G12

### CTRL Voltages to Shut Down the IC



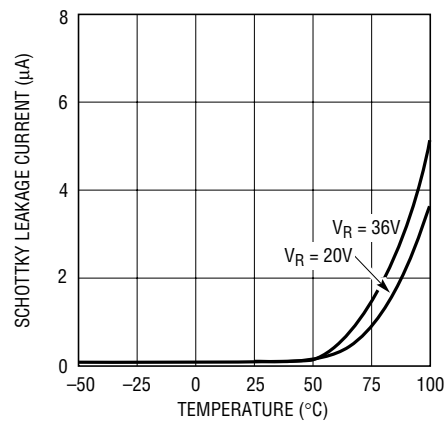
34661 G13

### Schottky Forward Voltage Drop



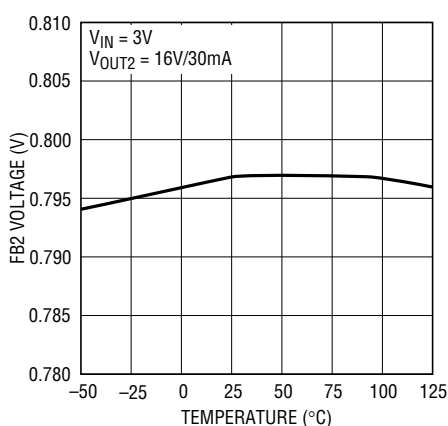
34661 G14

### Schottky Leakage Current



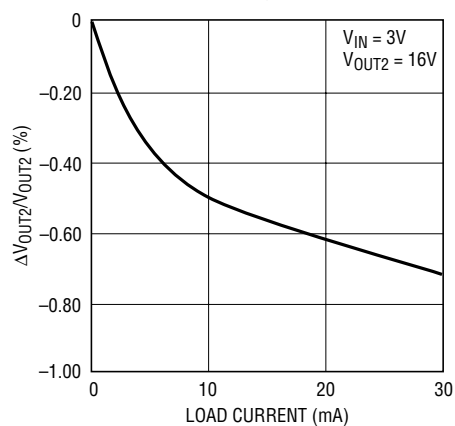
34661 G015

### FB2 Pin Voltage vs Temperature



34661 G17

### FB2 Pin Load Regulation



34661 G18

## PIN FUNCTIONS

**V<sub>OUT1</sub> (Pin 1):** Output of Converter 1. This pin is connected to the cathode of the internal Schottky diode. Connect an output capacitor from this pin to ground.

**SW1 (Pin 2):** Switch Pin for Converter 1. Connect the inductor at this pin.

**V<sub>IN</sub> (Pin 3):** Input Supply Pin. Must be locally bypassed with a 1μF, X5R or X7R type ceramic capacitor.

**SW2 (Pin 4):** Switch Pin for Converter 2. Connect the inductor at this pin.

**V<sub>OUT2</sub> (Pin 5):** Output of Converter 2. This pin is connected to the cathode of the internal Schottky diode. Connect an output capacitor from this pin to ground.

**FB2 (Pin 6):** Feedback Pin for Converter 2. The nominal voltage at this pin is 800mV. Connect the resistor divider to this pin. The feedback voltage can be programmed as:

$$V_{FB2} \approx V_{CTRL2}, \text{ when } V_{CTRL2} < 0.8V$$

$$V_{FB2} = 0.8V, \text{ when } V_{CTRL2} > 1V$$

**CTRL2 (Pin 7):** Dimming and Shutdown Pin for Converter 2. As the pin voltage is ramped from 0V to 1V, the FB2 pin voltage tracks the CTRL2 voltage and ramps up to 0.8V. Any voltage above 1V does not affect the feedback voltage. Do not leave the pin floating. It must be connected to ground to disable converter 2.

**R<sub>T</sub> (Pin 8):** Timing Resistor to Program the Switching Frequency. The switching frequency can be programmed from 200KHz to 2MHz.

**CTRL1 (Pin 9):** Dimming and Shutdown Pin for Converter 1. Connect this pin to ground to disable the converter. As the pin voltage is ramped from 0V to 1.8V, the LED current ramps from 0 to I<sub>LED1</sub> (= 200mV/R<sub>FB1</sub>). Any voltage above 1.8V does not affect the LED current.

**FB1 (Pin 10):** Feedback Pin for Converter 1. The nominal voltage at this pin is 200mV. Connect cathode of the lowest LED and the feedback resistor at this pin. The LED current can be programmed by :

$$I_{LED1} \approx (V_{CTRL1}/5 \cdot R_{FB1}), \text{ when } V_{CTRL1} < 1V$$

$$I_{LED1} \approx (200mV/R_{FB1}), \text{ when } V_{CTRL1} > 1.8V$$

**Exposed Pad (Pin 11):** The Exposed Pad must be soldered to the PCB system ground.

# BLOCK DIAGRAM

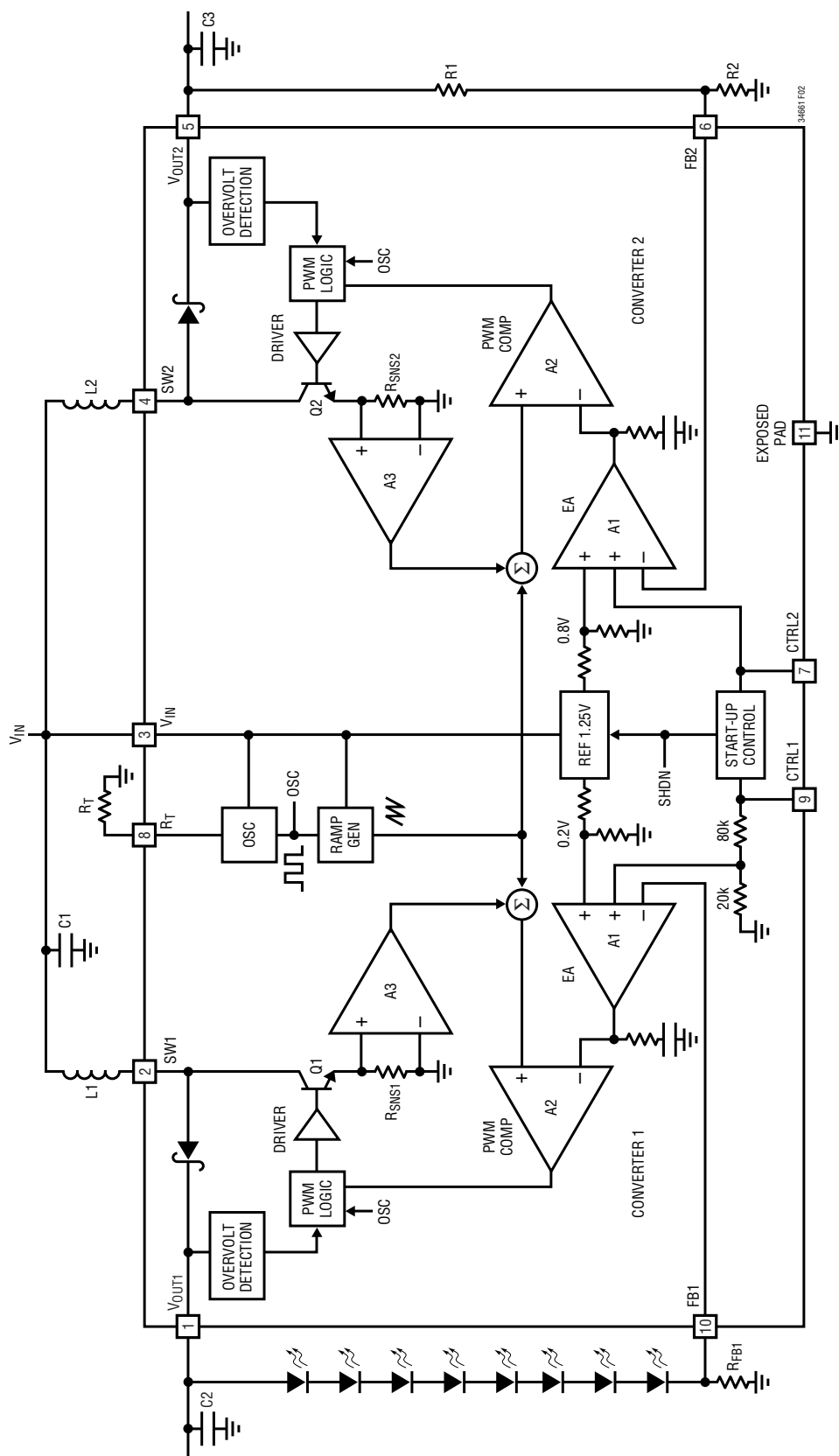


Figure 2. Block Diagram

## OPERATION

### Main Control Loop

The LT3466-1 uses a constant frequency, current mode control scheme to provide excellent line and load regulation. It incorporates two similar, but fully independent PWM converters. Operation can be best understood by referring to the Block Diagram in Figure 2. The oscillator, start-up bias and the bandgap reference are shared between the two converters. The control circuitry, power switch, Schottky diode etc., are similar for both converters.

At power-up, the output voltages  $V_{OUT1}$  and  $V_{OUT2}$  are charged up to  $V_{IN}$  (input supply voltage) via their respective inductor and the internal Schottky diode. If either CTRL1 and CTRL2 or both are pulled high, the bandgap reference, start-up bias and the oscillator are turned on.

Working of the main control loop can be understood by following the operation of converter 1. At the start of each oscillator cycle, the power switch Q1 is turned on. 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 PWM logic turns 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 200mV reference voltage. In this manner, the error amplifier A1 regulates the voltage at the FB1 pin to 200mV. The output of the error amplifier A1 sets the correct peak current level in inductor L1 to keep the output in regulation. The CTRL1 pin voltage is used to adjust the feedback voltage.

The working of converter 2 is similar to converter 1 with the exception that the feedback 2 reference voltage is 800mV. The error amplifier A1 in converter 2 regulates the voltage at the FB2 pin to 800mV. If only one of the converters is turned on, the other converter will stay off and its output will remain charged up to  $V_{IN}$  (input supply voltage). The LT3466-1 enters into shutdown, when both CTRL1 and CTRL2 are pulled lower than 70mV. The CTRL1 and CTRL2 pins perform independent dimming and shutdown control for the two converters.

### Minimum Output Current

The LT3466-1 can drive a 6-LED string at 3mA LED current without pulse skipping. As current is further reduced, the device may begin skipping pulses. This will result in some low frequency ripple, although the LED current remains regulated on an average basis down to zero. The photo in Figure 3 shows circuit operation with 6 white LEDs at 3mA current driven from 3.6V supply. Peak inductor current is less than 50mA and the regulator operates in discontinuous mode implying that the inductor current reached zero during the discharge phase. After the inductor current reaches zero, the switch pin exhibits ringing due to the LC tank circuit formed by the inductor in combination with switch and diode capacitance. This ringing is not harmful; far less spectral energy is contained in the ringing than in the switch transitions. The ringing can be damped by application of a 300Ω resistor across the inductors, although this will degrade efficiency.

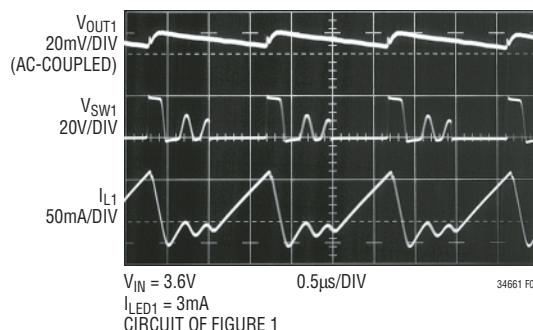


Figure 3. Switching Waveforms

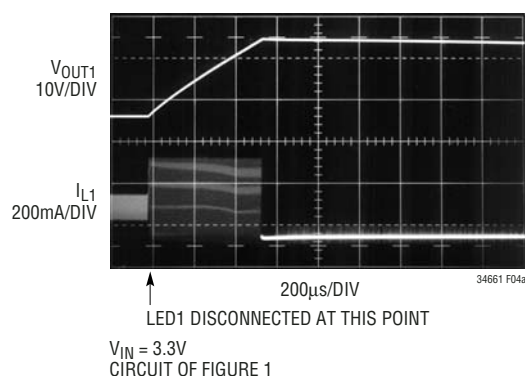
### Overvoltage Protection

The LT3466-1 has internal overvoltage protection for both converters. In the event the white LEDs are disconnected from the circuit or fail open, the converter 1 output voltage is clamped at 39.5V (typ). Figure 4(a) shows the transient response of the circuit in Figure 1 with LED1 disconnected. With the white LEDs disconnected, the converter 1 starts switching at the peak current limit. The output of converter 1 starts ramping up and finally gets clamped at 39.5V (typ). The converter 1 will then switch at low inductor current to regulate the output voltage. Output voltage and input current during output open circuit are shown in the Typical Performance Characteristics graphs.

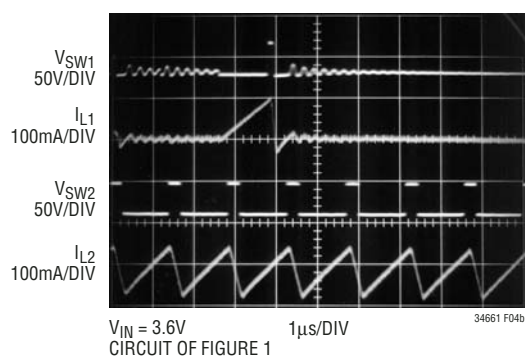


## OPERATION

In the event one of the converters has an output open-circuit, its output voltage will be clamped at 39.5V. However, the other converter will continue functioning properly. The photo in Figure 4b shows circuit operation with converter 1 output open-circuit and converter 2 driving the OLED display. Converter 1 starts switching at a lower inductor current and begins skipping pulses, thereby reducing its input current. Converter 2 continues functioning properly.



**Figure 4a. Transient Response of Switcher 1 with LED1 Disconnected from the Output**



**Figure 4b. Output 1 Open-Circuit Waveforms**

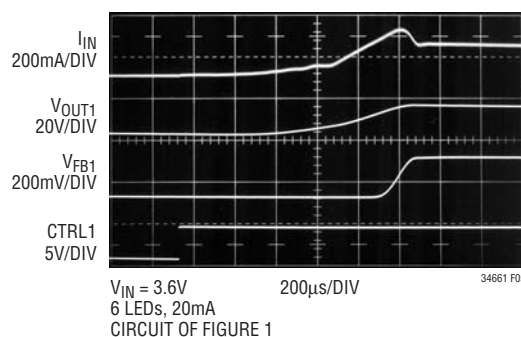
## Soft-Start

The LT3466-1 has a separate internal soft-start circuitry for each converter. Soft-start helps to limit the inrush current during start-up. Soft-start is achieved by clamping the output of the error amplifier during the soft-start period. This limits the peak inductor current and ramps up the output voltage in a controlled manner.

The converter enters into soft-start mode whenever the respective CTRL pin is pulled from low to high. Figure 5 shows the start-up waveforms with converter 1 driving six LEDs at 20mA. The filtered input current, as shown in Figure 5, is well controlled. The soft-start circuitry is less effective when driving a higher number of LEDs.

## Undervoltage Lockout

The LT3466-1 has an undervoltage lockout circuit which shuts down both converters when the input voltage drops below 2.1V (typ). This prevents the converter from switching in an erratic mode when powered from low supply voltages.



**Figure 5. Start-Up Waveforms**

## APPLICATIONS INFORMATION

### DUTY CYCLE

The duty cycle for a step-up converter is given by:

$$D = \frac{V_{OUT} + V_D - V_{IN}}{V_{OUT} + V_D - V_{CESAT}}$$

where:

$V_{OUT}$  = Output voltage

$V_D$  = Schottky forward voltage drop

$V_{CESAT}$  = Saturation voltage of the switch

$V_{IN}$  = Input battery voltage

The maximum duty cycle achievable for LT3466-1 is 96% (typ) when running at 1MHz switching frequency. It increases to 99% (typ) when run at 200kHz and drops to 92% (typ) at 2MHz. Always ensure that the converter is not duty-cycle limited when powering the LEDs or OLED at a given switching frequency.

### SETTING THE SWITCHING FREQUENCY

The LT3466-1 uses a constant frequency architecture that can be programmed over a 200kHz to 2MHz range with a single external timing resistor from the  $R_T$  pin to ground. The nominal voltage on the  $R_T$  pin is 0.54V, and the current that flows into the timing resistor is used to charge and discharge an internal oscillator capacitor. A graph for selecting the value of  $R_T$  for a given operating frequency is shown in the Figure 6.

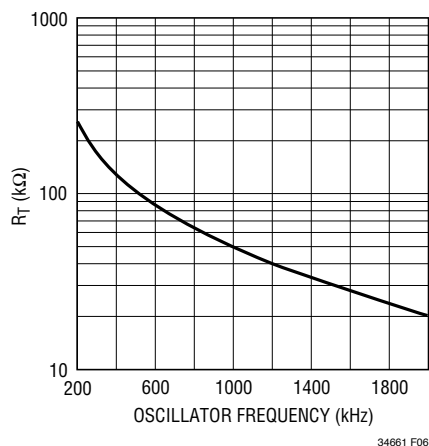


Figure 6. Timing Resistor ( $R_T$ ) Value

### OPERATING FREQUENCY SELECTION

The choice of operating frequency is determined by several factors. There is a tradeoff between efficiency and component size. Higher switching frequency allows the use of smaller inductors albeit at the cost of increased switching losses and decreased efficiency.

Another consideration is the maximum duty cycle achievable. In certain applications, the converter needs to operate at the maximum duty cycle in order to light up the maximum number of LEDs. The LT3466-1 has a fixed oscillator off-time and a variable on-time. As a result, the maximum duty cycle increases as the switching frequency is decreased.

The circuit of Figure 1 is operated with different values of timing resistor ( $R_T$ ).  $R_T$  is chosen so as to run the converters at 800kHz ( $R_T = 63.4k$ ), 1.25MHz ( $R_T = 38.3k$ ) and 2MHz ( $R_T = 20.5k$ ). The efficiency comparison for different  $R_T$  values is shown in Figure 7.

### INDUCTOR SELECTION

The choice of the inductor will depend on the selection of switching frequency of LT3466-1. The switching frequency can be programmed from 200kHz to 2MHz. Higher switching frequency allows the use of smaller inductors albeit at the cost of increased switching losses.

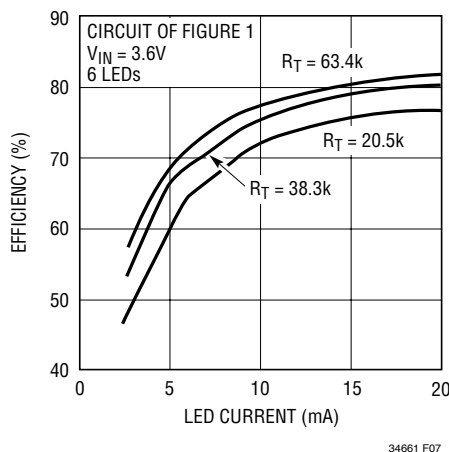


Figure 7. Efficiency Comparison for Different  $R_T$  Resistors

## APPLICATIONS INFORMATION

The inductor current ripple ( $\Delta I_L$ ), neglecting the drop across the Schottky diode and the switch, is given by :

$$\Delta I_L = \frac{V_{IN(MIN)} \cdot (V_{OUT(MAX)} - V_{IN(MIN)})}{V_{OUT(MAX)} \cdot f \cdot L}$$

where:

L = Inductor

f = Operating frequency

$V_{IN(MIN)}$  = Minimum input voltage

$V_{OUT(MAX)}$  = Maximum output voltage

The  $\Delta I_L$  is typically set to 20% to 40% of the maximum inductor current.

The inductor should have a saturation current rating greater than the peak inductor current required for the application. Also, ensure that the inductor has a low DCR (copper wire resistance) to minimize  $I^2R$  power losses. Recommended inductor values range from 10 $\mu$ H to 68 $\mu$ H.

Several inductors that work well with the LT3466-1 are listed in Table 1. Consult each manufacturer for more detailed information and for their entire selection of related parts.

**Table 1. Recommended Inductors**

| PART          | L ( $\mu$ H) | MAX DCR ( $\Omega$ ) | CURRENT RATING (mA) | VENDOR                                           |
|---------------|--------------|----------------------|---------------------|--------------------------------------------------|
| LQH32CN100    | 10           | 0.44                 | 300                 | Murata<br>(814) 237-1431<br>www.murata.com       |
| LQH32CN150    | 15           | 0.58                 | 300                 |                                                  |
| LQH43CN330    | 33           | 1.00                 | 310                 |                                                  |
| ELL6RH330M    | 33           | 0.38                 | 600                 | Panasonic<br>(714) 373-7939<br>www.panasonic.com |
| ELL6SH680M    | 68           | 0.52                 | 500                 |                                                  |
| A914BYW330M   | 33           | 0.45                 | 440                 | Toko<br>www.toko.com                             |
| A914BYW470M   | 47           | 0.73                 | 360                 |                                                  |
| A920CY680M    | 68           | 0.40                 | 400                 |                                                  |
| CDRH2D18150NC | 15           | 0.22                 | 0.35A               | Sumida<br>(847) 956-0666<br>www.sumida.com       |
| CDRH4D18-330  | 33           | 0.51                 | 0.31A               |                                                  |
| CDRH5D18-680  | 68           | 0.84                 | 0.43A               |                                                  |

## CAPACITOR SELECTION

The small size of ceramic capacitors make them ideal for LT3466-1 applications. Use only X5R and X7R types because they retain their capacitance over wider voltage and temperature ranges than other types such as Y5V or

Z5U. A 1 $\mu$ F input capacitor is sufficient for most applications. Always use a capacitor with sufficient voltage rating.

Table 2 shows a list of several ceramic capacitor manufacturers. Consult the manufacturers for detailed information on their entire selection of ceramic parts.

**Table 2. Ceramic Capacitor Manufacturers**

|             |                                   |
|-------------|-----------------------------------|
| Taiyo Yuden | (408) 573-4150<br>www.t-yuden.com |
| AVX         | (803) 448-9411<br>www.avxcorp.com |
| Murata      | (714) 852-2001<br>www.murata.com  |

## INRUSH CURRENT

The LT3466-1 has built-in Schottky diodes. When supply voltage is applied to the  $V_{IN}$  pin, an inrush current flows through the inductor and the Schottky diode and charges up the output capacitor. Both Schottky diodes in the LT3466-1 can sustain a maximum of 1A current. The selection of inductor and capacitor value should ensure the peak of the inrush current to be below 1A.

For low DCR inductors, which is usually the case for this application, the peak inrush current can be simplified as follows:

$$I_{PK} = \frac{V_{IN} - 0.6}{\omega L}$$

where:

$$\omega = \frac{1}{\sqrt{LC_{OUT}}}$$

Table 3 gives inrush peak current for some component selections.

**Table 3. Inrush Peak Current**

| $V_{IN}$ (V) | L ( $\mu$ H) | $C_{OUT}$ ( $\mu$ F) | $I_P$ (A) |
|--------------|--------------|----------------------|-----------|
| 5            | 15           | 0.47                 | 0.78      |
| 5            | 33           | 1.00                 | 0.77      |
| 5            | 47           | 2.2                  | 0.95      |
| 5            | 68           | 1.00                 | 0.53      |
| 9            | 47           | 0.47                 | 0.84      |
| 12           | 33           | 0.22                 | 0.93      |

## APPLICATIONS INFORMATION

Typically peak inrush current will be less than the value calculated above. This is due to the fact that the DC resistance in the inductor provides some damping resulting in a lower peak inrush current.

### SETTING THE LED CURRENT

The current in the LED string can be set by the choice of the resistor  $R_{FB1}$  (Figure 1). The feedback reference is 200mV. In order to have accurate LED current, precision resistors are preferred (1% is recommended).

$$R_{FB1} = \frac{200\text{mV}}{I_{LED1}}$$

Table 4.  $R_{FB1}$  Value Selection

| $I_{LED1}$ (mA) | $R_{FB1}$ ( $\Omega$ ) |
|-----------------|------------------------|
| 5               | 40.2                   |
| 10              | 20.0                   |
| 15              | 13.3                   |
| 20              | 10.0                   |
| 25              | 8.06                   |

Most White LEDs are driven at maximum currents of 15mA to 20mA.

### DIMMING WHITE LEDS

The LED current in the driver can be set by modulating the CTRL1 pin. There are two different ways to control the intensity of white LEDs.

#### Using a DC Voltage

For some applications, the preferred method of brightness control is a variable DC voltage to adjust the LED current. The CTRL1 pin voltage can be modulated to set the dimming of the LED string. As the voltage on the CTRL1 pin increases from 0V to 1.8V, the LED current increases from 0 to  $I_{LED1}$ . As the CTRL1 pin voltage increases beyond 1.8V, it has no effect on the LED current.

The LED current can be set by:

$$I_{LED1} \approx (V_{CTRL1}/5 \cdot R_{FB1}), \text{ when } V_{CTRL1} < 1\text{V}$$

$$I_{LED1} \approx (200\text{mV}/R_{FB1}), \text{ when } V_{CTRL1} > 1.8\text{V}$$

Feedback voltage variation versus control voltage is given in the Typical Performance Characteristics graphs.

#### Using a Filtered PWM Signal

A variable duty cycle PWM can be used to control the brightness of the LED string. The PWM signal is filtered (Figure 8) by an RC network and fed to the CTRL1 pin.

The corner frequency of R1, C1 should be much lower than the frequency of the PWM signal. R1 needs to be much smaller than the internal impedance in the CTRL pin, which is 100k $\Omega$ .

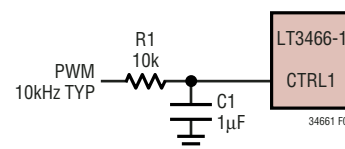


Figure 8. Dimming Control Using a Filtered PWM Signal

### SETTING THE BOOST OUTPUT VOLTAGE

The LT3466-1 regulates the voltage at the FB2 pin to 0.8V. The output voltage of the boost converter ( $V_{OUT2}$ ) is set by a resistor divider according to the formula:

$$V_{OUT2} = 0.8\text{V} \left( 1 + \frac{R1}{R2} \right)$$

Choose 1% resistors for better accuracy. The FB2 input bias current is quite low, on the order of 10nA (typ). Large resistor values ( $R1 \sim 1\text{M}\Omega$ ) can be used in the divider network maximizing efficiency.

### PROGRAMMING THE BOOST OUTPUT VOLTAGE

The output voltage of the boost converter can be modulated by applying a variable DC voltage at the CTRL2 pin. The nominal voltage at the FB2 pin is 800mV. As the voltage on the CTRL2 pin is ramped from 0V to 1V, the FB2 pin voltage ramps up to 0.8V. The feedback voltage can be programmed as:

$$V_{FB2} \approx V_{CTRL2}, \text{ when } V_{CTRL2} < 0.8\text{V}$$

$$V_{FB2} \approx 0.8\text{V}, \text{ when } V_{CTRL2} > 1\text{V}$$

## APPLICATIONS INFORMATION

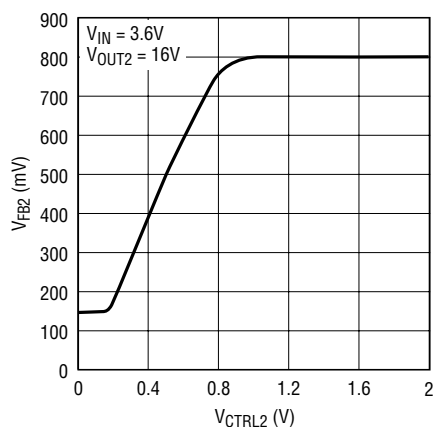
Figure 9 shows the feedback voltage variation versus the control voltage. As seen in Figure 9, the linearity of the graph allows the feedback voltage to be set accurately via the control voltage.

The boost converter output voltage ( $V_{OUT2}$ ) is given by:

$$V_{OUT2} = V_{FB2} \left( 1 + \frac{R_1}{R_2} \right)$$

Thus a linear change in the feedback (FB2) voltage results in a linear change in the boost output voltage ( $V_{OUT2}$ ).

Connect the CTRL2 pin to ground to disable converter 2. Do not leave the pin floating. Unlike the CTRL1 pin, which has an internal 100k pull-down resistor, the CTRL2 pin input impedance is very high ( $>100M\Omega$ ). A small amount of board leakage current is sufficient to turn on the converter 2.



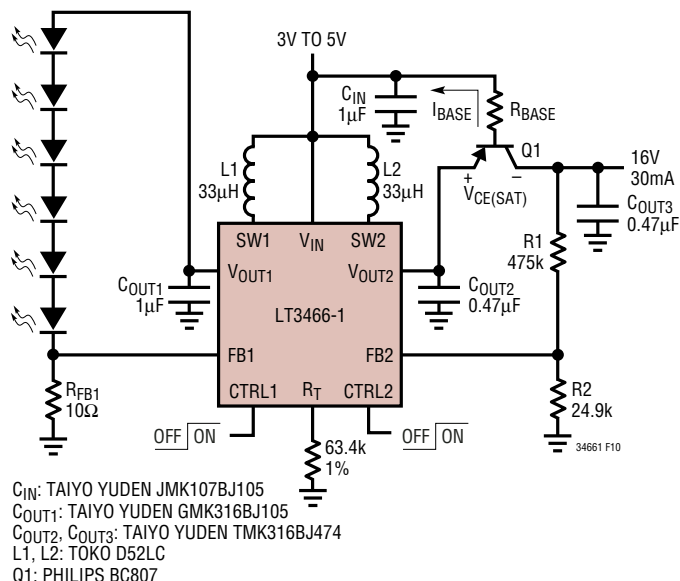
34661 F09

Figure 9.  $V_{FB2}$  vs  $V_{CTRL2}$

### OUTPUT DISCONNECT

The LT3466-1 can be used for powering white LEDs (Channel 1) and an OLED display or, LCD bias (Channel 2). Some OLED displays require load isolation in order to reduce the current drained from the battery in shutdown. The LT3466-1 output can be configured to provide output disconnect by the use of only one resistor,  $R_{BASE}$ , and a PNP transistor, Q1, as shown in Figure 10.

As a design example, we target a Li-Ion powered driver for 6 white LEDs and an OLED display (16V at 30mA). We can choose a general purpose PNP switching transistor like Philips BC807 (Q1) to provide isolation.



C<sub>IN</sub>: TAIYO YUDEN JMK107BJ105  
C<sub>OUT1</sub>: TAIYO YUDEN GMK316BJ105  
C<sub>OUT2</sub>, C<sub>OUT3</sub>: TAIYO YUDEN TMK316BJ474  
L1, L2: TOKO D52LC  
Q1: PHILIPS BC807

Figure 10. Li-Ion Powered Driver for 6 White LEDs and a Secondary OLED Display with Output Disconnect

The  $R_{BASE}$  resistor can be calculated as:

$$I_{LOAD} = 30mA$$

$$I_{BASE} = \frac{I_{LOAD}}{0.4h_{FE(MIN)}}$$

$I_{BASE}$  must be chosen such that Q1 is in saturation under all conditions. The  $h_{FE(MIN)}$  can be obtained from the Philips BC807 data sheet as:

$$h_{FE(MIN)} \cong 100$$

This yields worst case  $I_{BASE}$  as:

$$I_{BASE} = \frac{30mA}{0.4(100)} \cong 0.75mA$$

$R_{BASE}$  is given by:

$$V_{IN(MAX)} + I_{BASE} \cdot R_{BASE} + V_{BE(Q1)} = V_{OUT2} + V_{CE(Q1)}$$

$$\text{Thus; } R_{BASE} = \frac{V_{OUT2} - V_{IN(MAX)} + V_{CE(Q1)} - V_{BE(Q1)}}{I_{BASE}}$$

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## APPLICATIONS INFORMATION

The  $V_{CE(SAT)}$  and  $V_{BE(SAT)}$  values for the transistor Q1 can be obtained from the Philips BC807 data sheet:

$$R_{BASE} = \frac{16V - 5V + 0.1 - 0.9}{0.75mA}$$

$$R_{BASE} = 13.6k$$

Picking the closest 1% resistor value yields:

$$R_{BASE} = 14k$$

### BOARD LAYOUT CONSIDERATION

As with all switching regulators, careful attention must be paid to the PCB board layout and component placement. To prevent electromagnetic interference (EMI) problems, proper layout of high frequency switching paths is essential. Minimize the length and area of all traces connected to the switching node pins (SW1 and SW2). Keep the feedback pins (FB1 and FB2) away from the switching nodes.

The DFN package has an exposed paddle that must be connected to the system ground. The ground connection for the feedback resistors should be tied directly to the

ground plane and not shared with any other component, except the  $R_T$  resistor, ensuring a clean, noise-free connection. Recommended component placement is shown in the Figure 11.

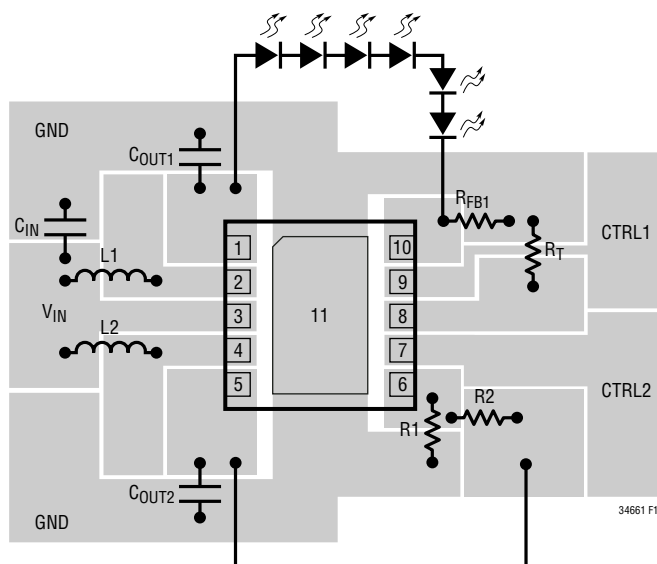
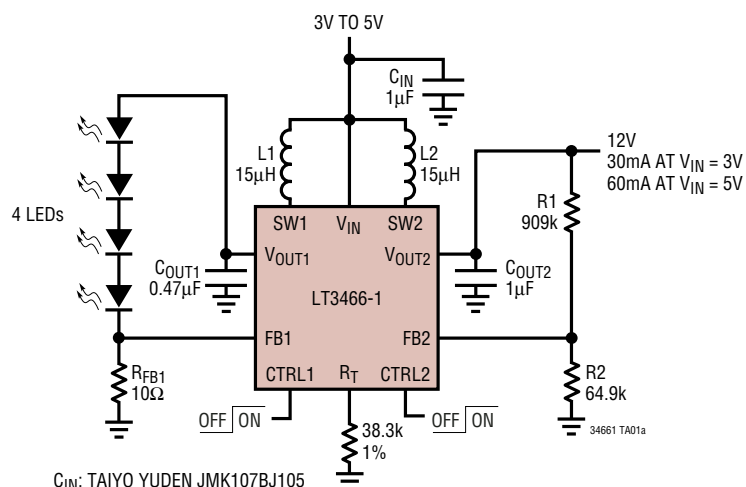


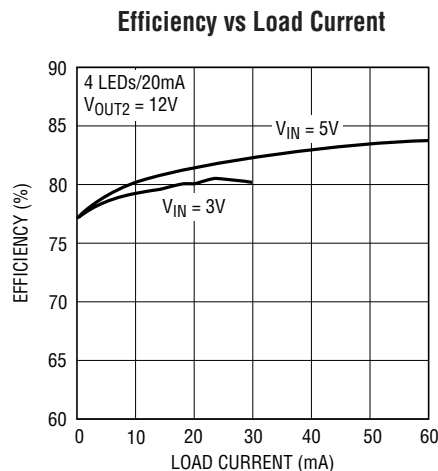
Figure 11. Recommended Component Placement

## TYPICAL APPLICATIONS

### Li-Ion Powered 4 White LEDs Driver and 12V Boost Converter

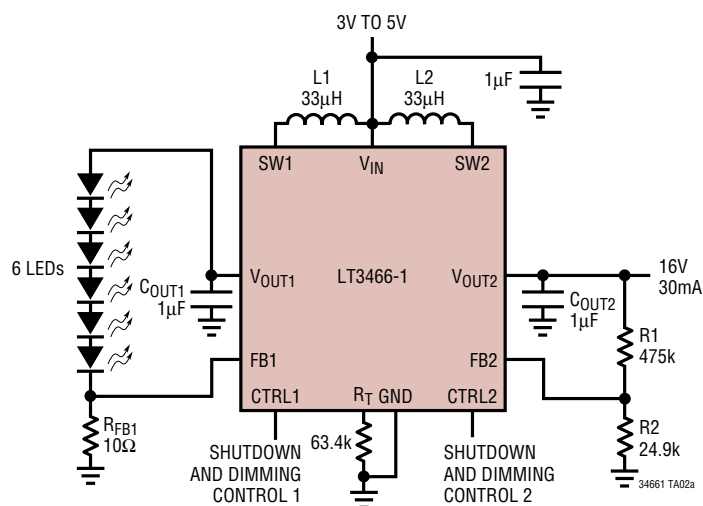


$C_{IN}$ : TAIYO YUDEN JMK107BJ105  
 $C_{OUT1}$ : TAIYO YUDEN EMK212BJ474  
 $C_{OUT2}$ : TAIYO YUDEN EMK212BJ105  
 $L1, L2$ : MURATA LQH32CN150K53

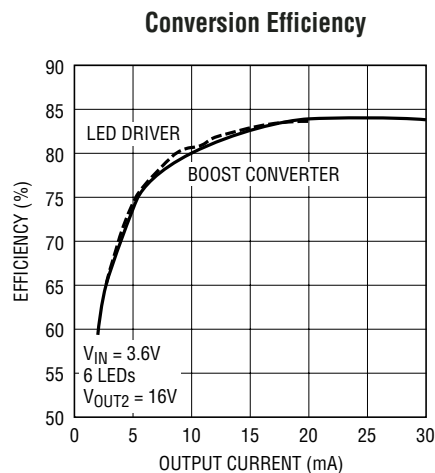


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### Li-Ion Powered Driver for 6 White LEDs and OLED Display



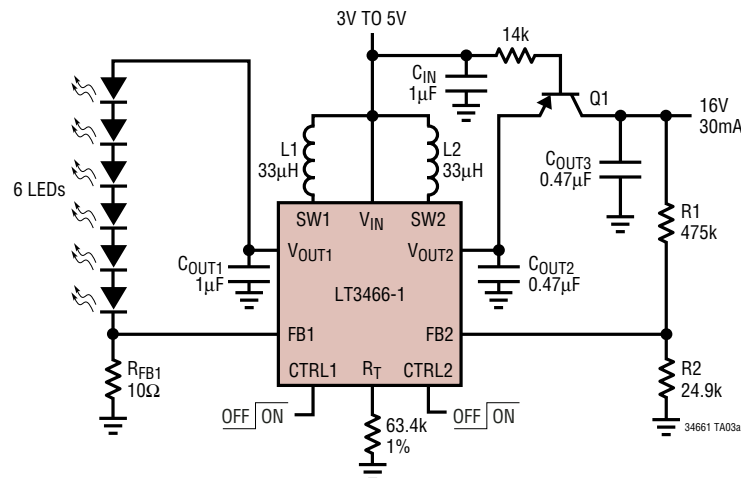
$C_{IN}$ : TAIYO YUDEN JMK107BJ105  
 $C_{OUT1}, C_{OUT2}$ : TAIYO YUDEN GMK316BJ105  
 $L1, L2$ : 33μH TOKO D52LC



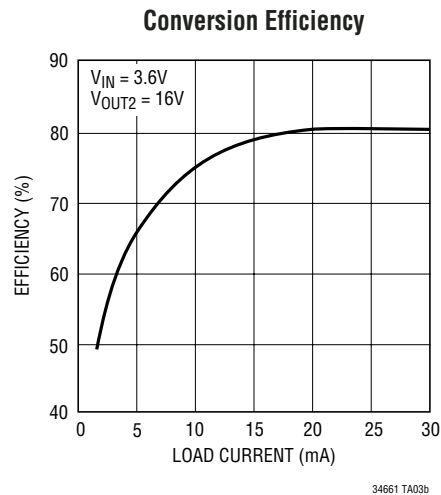
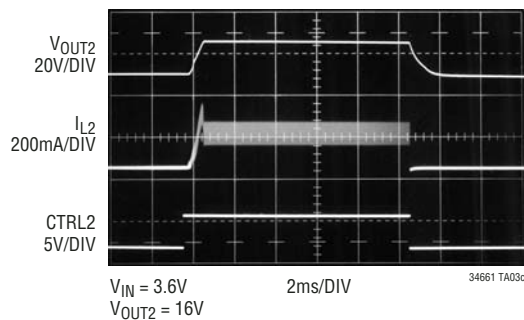
34661 TA02b

TYPICAL APPLICATIONS

Li-Ion Powered Driver for 6 White LEDs and OLED with Output Disconnect

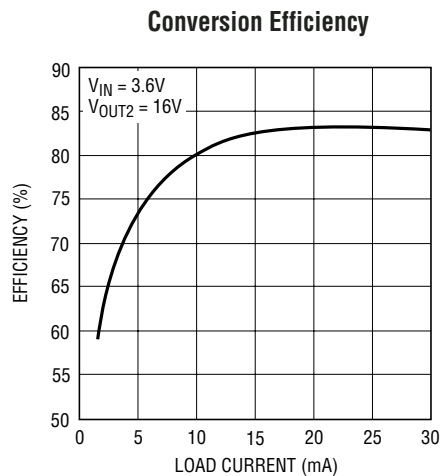


C<sub>IN</sub>: TAIYO YUDEN JMK107BJ105  
C<sub>OUT1</sub>: TAIYO YUDEN GMK316BJ105  
C<sub>OUT2</sub>, C<sub>OUT3</sub>: TAIYO YUDEN TMK316BJ474  
L1, L2: 33μH TOKO D52LC  
Q1: PHILIPS BC807

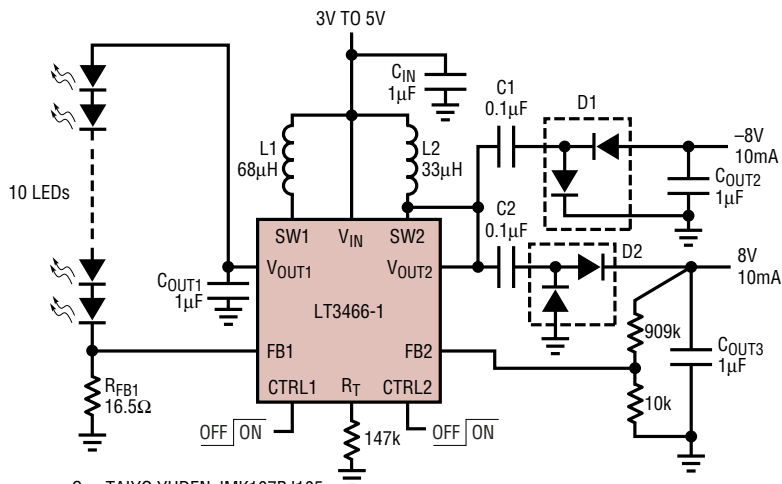




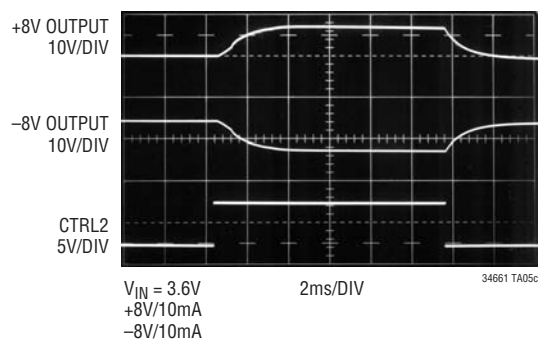
**NOTE: ENSURE THAT  $V_{OUT2} > V_{IN(MAX)} + 5V$**



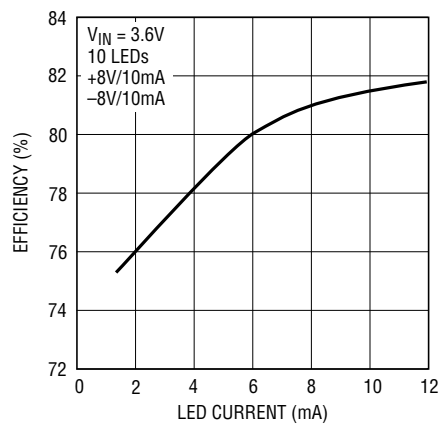
### Li-Ion to 10 White LEDs and LCD Bias ( $\pm 8V$ ) with Output Disconnect



**C<sub>IN</sub>:** TAIYO YUDEN JMK107BJ105  
**C<sub>OUT1</sub>:** TAIYO YUDEN UMK325BJ105  
**C<sub>OUT2</sub>, C<sub>OUT3</sub>:** TAIYO YUDEN GMK316BJ105  
**C1, C2:** TAIYO YUDEN UMK212BJ104  
**D1, D2:** PHILIPS BAT54S  
**L1:** 68μH TOKO D52LC  
**L2:** 33μF TOKO D52LC

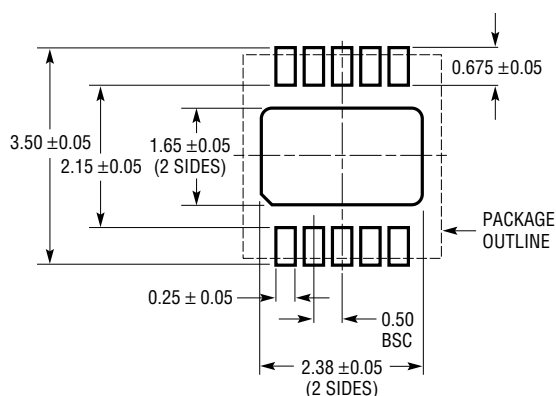


### Conversion Efficiency

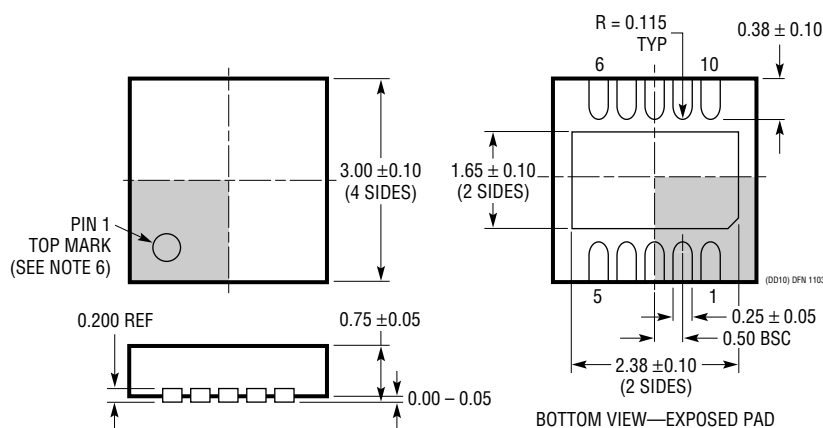


## PACKAGE DESCRIPTION

**DD Package**  
**10-Lead Plastic DFN (3mm × 3mm)**  
 (Reference LTC DWG # 05-08-1699)



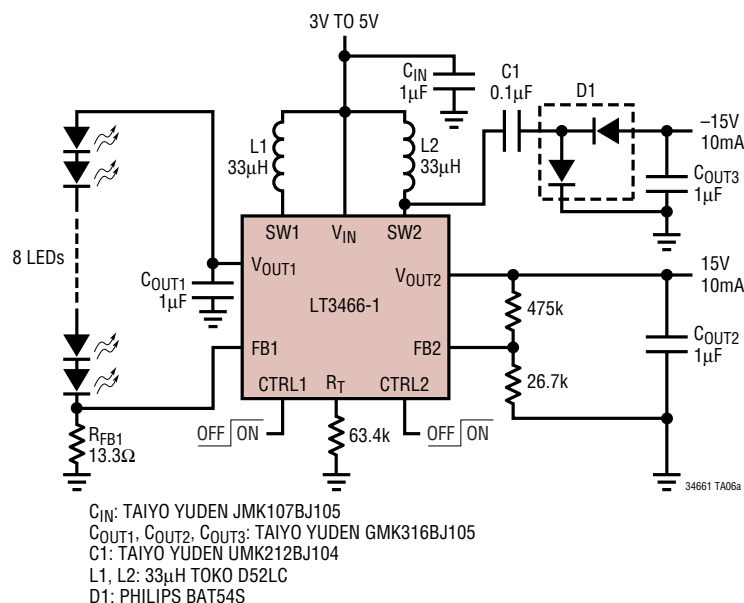
## RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS



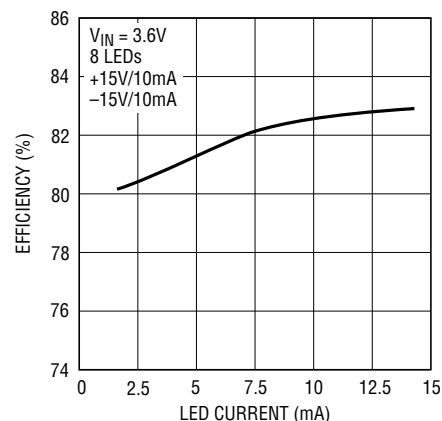
NOTE:

1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-2).  
CHECK THE LTC WEBSITE DATA SHEET FOR CURRENT STATUS OF VARIATION ASSIGNMENT
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 APPLICATION

Li-Ion to 8 White LEDs and  $\pm 15\text{V}$  TFT LCD Bias Supply

## Conversion Efficiency



## RELATED PARTS

| PART NUMBER    | DESCRIPTION                                                                                               | COMMENTS                                                                                            |
|----------------|-----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| LT1618         | Constant Current, Constant Voltage 1.4MHz, High Efficiency Boost Regulator                                | $V_{IN}$ : 1.6V to 18V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 1.8mA, $I_{SD}$ < 1µA, MS/EDD Packages        |
| LT1932         | Constant Current, 1.2MHz, High Efficiency White LED Boost Regulator                                       | $V_{IN}$ : 1V to 10V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 1.2mA, $I_{SD}$ < 1µA, ThinSOT™ Package         |
| LT1937         | Constant Current, 1.2MHz, High Efficiency White LED Boost Regulator                                       | $V_{IN}$ : 2.5V to 10V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 1.9mA, $I_{SD}$ < 1µA, ThinSOT, SC70 Packages |
| LTC®3200-5     | Low Noise, 2MHz, Regulated Charge Pump White LED Driver                                                   | $V_{IN}$ : 2.7V to 4.5V, $V_{OUT(MAX)}$ = 5V, $I_Q$ = 8mA, $I_{SD}$ < 1µA, ThinSOT Package          |
| LTC3202        | Low Noise, 1.5MHz, Regulated Charge Pump White LED Driver                                                 | $V_{IN}$ : 2.7V to 4.5V, $V_{OUT(MAX)}$ = 5.5V, $I_Q$ = 5mA, $I_{SD}$ < 1µA, MS/EDD Packages        |
| LTC3205        | High Efficiency, Multidisplay LED Controller                                                              | $V_{IN}$ : 2.8V to 4.5V, $V_{OUT(MAX)}$ = 6V, $I_Q$ = 50µA, $I_{SD}$ < 1µA, QFN-24 Package          |
| LTC3216        | 1A Low Noise High Current LED Charge Pump with Independent Flash/Torch Current Control                    | $V_{IN}$ : 2.9V to 4.4V, $V_{OUT(MAX)}$ = 5.5V, $I_Q$ = 300µA, $I_{SD}$ < 2.5µA, DFN Package        |
| LTC3453        | 500mA Synchronous Buck-Boost High Current LED Driver in Q FN                                              | $V_{IN}$ : 2.7V to 5.5V, $V_{OUT(MAX)}$ = 5.5V, $I_Q$ = 0.6mA, $I_{SD}$ < 6µA, QFN 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, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 1.9mA, $I_{SD}$ < 1µA, ThinSOT Package        |
| LT3466         | Dual Constant Current, 2MHz High Efficiency White LED Boost Regulator with Integrated Schottky Diode      | $V_{IN}$ : 2.7V to 24V, $V_{OUT(MAX)}$ = 40V, $I_Q$ = 5mA, $I_{SD}$ < 16µA, DFN Package             |
| LT3479         | 3A, Full Featured DC/DC Converter with Soft-Start and Inrush Current Protection                           | $V_{IN}$ : 2.5V to 24V, $V_{OUT(MAX)}$ = 40V, $I_Q$ = 6.5mA, $I_{SD}$ < 1µA, DFN/TSSOP Packages     |

ThinSOT is a trademark of Linear Technology Corporation.

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