LT3466-1 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 ±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.

References

LT and LTC are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.
**ABSOLUTE MAXIMUM RATINGS**

(Note 1)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
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<tr>
<td>Input Voltage ($V_{IN}$)</td>
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<td>SW1, SW2 Voltages</td>
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<td>$V_{OUT1}$, $V_{OUT2}$ Voltages</td>
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<td></td>
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<tr>
<td>CTRL1, CTRL2 Voltages</td>
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<td></td>
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<tr>
<td>FB1, FB2 Voltages</td>
<td>2V</td>
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Operating Temperature Range (Note 2) ... $-40^\circ$C to $85^\circ$C

Storage Temperature Range ............... $-65^\circ$C to $125^\circ$C

Junction Temperature ...................... 125°C

**PACKAGE/ORDER INFORMATION**

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<thead>
<tr>
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<tbody>
<tr>
<td>LT3466EDD-1</td>
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<table>
<thead>
<tr>
<th>TOP VIEW</th>
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<tr>
<td>DD PACKAGE</td>
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<td>ORDER PART NUMBER</td>
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<tr>
<td>LT3466EDD-1</td>
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<tr>
<td>DD PART MARKING</td>
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<td>LBRX</td>
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**ELECTRICAL CHARACTERISTICS**

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

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

**Order Options**

- Tape and Reel: Add #TR
- Lead Free: Add #PBF
- Lead Free Tape and Reel: Add #TRPBF

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 \( T_A = 25^\circ C \). \( V_{IN} = 3V \), \( V_{CTRL1} = 3V \), \( V_{CTRL2} = 3V \), unless otherwise specified.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{OUT1} ) Overvoltage Threshold</td>
<td></td>
<td>39.5</td>
<td>V</td>
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<tr>
<td>( V_{OUT2} ) Overvoltage Threshold</td>
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<td>39.5</td>
<td>V</td>
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<tr>
<td>Schottky 1 Forward Drop</td>
<td>( I_{SCHOTTKY1} = 300mA )</td>
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<tr>
<td>Schottky 2 Forward Drop</td>
<td>( I_{SCHOTTKY2} = 300mA )</td>
<td></td>
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<tr>
<td>Schottky 1 Reverse Leakage</td>
<td>( V_{OUT1} = 20V )</td>
<td>5</td>
<td>( \mu A )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schottky 2 Reverse Leakage</td>
<td>( V_{OUT2} = 20V )</td>
<td>5</td>
<td>( \mu A )</td>
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<td>Soft-Start Time (Switcher 1)</td>
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<td>600</td>
<td>( \mu s )</td>
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<td></td>
</tr>
<tr>
<td>Soft-Start Time (Switcher 2)</td>
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<td>600</td>
<td>( \mu s )</td>
<td></td>
<td></td>
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</tbody>
</table>

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°C to 70°C. Specifications over the –40°C to 85°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

\( T_A = 25^\circ C \) unless otherwise specified

Switching Waveforms (LED Driver)

Switching Waveforms (Boost Converter)

\( V_{FB1} \) vs \( V_{CTRL1} \)

\( V_{FB2} \) vs \( V_{CTRL2} \)
TYPICAL PERFORMANCE CHARACTERISTICS \( T_A = 25^\circ C \) unless otherwise specified

- **Switch Current Limit vs Duty Cycle**
  - \( T_A = -50^\circ C \)
  - \( T_A = 25^\circ C \)
  - \( T_A = 85^\circ C \)

- **Quiescent Current** (CTRL1 = CTRL2 = 3V)
  - UVLO

- **Shutdown Current** (CTRL1 = CTRL2 = 0V)
  - \( T_A = -50^\circ C \)
  - \( T_A = 22^\circ C \)
  - \( T_A = 100^\circ C \)

- **Open-Circuit Output Clamp Voltage**
  - \( R_T = 63.4k \Omega \)

- **Open-Circuit Output Clamp Voltage**
  - \( R_T = 63.4k \)

- **Input Current with Output 1 and Output 2 Open Circuit**
  - \( R_T = 63.4k \)

- **RT vs Oscillator Frequency**
  - \( R_T \) \( \Omega \)
  - Oscillator Frequency (kHz)

- **Oscillator Frequency vs \( V_{IN} \)**
  - \( R_T = 48.7k \)
  - Oscillator Frequency (kHz)
  - \( V_{IN} \) (V)
TYPICAL PERFORMANCE CHARACTERISTICS  $T_A = 25^\circ C$ unless otherwise specified

Oscillator Frequency vs Temperature

CTRL Voltages to Shut Down the IC

Schottky Forward Voltage Drop

Schottky Leakage Current

FB2 Pin Voltage vs Temperature

FB2 Pin Load Regulation
**PIN FUNCTIONS**

**VOUT1 (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.

**VIN (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.

**VOUT2 (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:

\[ V_{FB2} = V_{CTRL2}, \text{ when } V_{CTRL2} < 0.8V \]
\[ V_{FB2} = 0.8V, \text{ when } V_{CTRL2} > 1V \]

**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.

**RT (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 \( I_{LED1} (= 200mV/R_{FB1}) \). 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:

\[ I_{LED1} = (V_{CTRL1}/5 \cdot R_{FB1}), \text{ when } V_{CTRL1} < 1V \]
\[ I_{LED1} = (200mV/R_{FB1}), \text{ when } V_{CTRL1} > 1.8V \]

**Exposed Pad (Pin 11):** The Exposed Pad must be soldered to the PCB system ground.
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 200mV. 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.

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.
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.

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

Figure 4b. Output 1 Open-Circuit Waveforms

Figure 5. Start-Up Waveforms
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 (RT). RT is chosen so as to run the converters at 800kHz (RT = 63.4k), 1.25MHz (RT = 38.3k) and 2MHz (RT = 20.5k). The efficiency comparison for different RT values is shown in Figure 7.

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 RT pin to ground. The nominal voltage on the RT 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 RT for a given operating frequency is shown in the Figure 6.

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.

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.
APPLICATIONS INFORMATION

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

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

where:

- $L$ = Inductor
- $f$ = Operating frequency
- $V_{\text{IN(MIN)}}$ = Minimum input voltage
- $V_{\text{OUT(MAX)}}$ = 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 10µH to 68µH.

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

<table>
<thead>
<tr>
<th>PART</th>
<th>L (µH)</th>
<th>MAX DCR (Ω)</th>
<th>CURRENT RATING (mA)</th>
<th>VENDOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LQH32CN100</td>
<td>10</td>
<td>0.44</td>
<td>300</td>
<td>Murata (814) 237-1431 <a href="http://www.murata.com">www.murata.com</a></td>
</tr>
<tr>
<td>LQH32CN150</td>
<td>15</td>
<td>0.58</td>
<td>300</td>
<td><a href="http://www.murata.com">www.murata.com</a></td>
</tr>
<tr>
<td>LQH43CN330</td>
<td>33</td>
<td>1.00</td>
<td>310</td>
<td></td>
</tr>
<tr>
<td>ELL6RH330M</td>
<td>33</td>
<td>0.38</td>
<td>600</td>
<td>Panasonic (714) 373-7939 <a href="http://www.panasonic.com">www.panasonic.com</a></td>
</tr>
<tr>
<td>ELL6SH680M</td>
<td>68</td>
<td>0.52</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>A914BYW330M</td>
<td>33</td>
<td>0.45</td>
<td>440</td>
<td>Toko <a href="http://www.toko.com">www.toko.com</a></td>
</tr>
<tr>
<td>A914BYW470M</td>
<td>47</td>
<td>0.73</td>
<td>360</td>
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<tr>
<td>A920CY680M</td>
<td>68</td>
<td>0.40</td>
<td>400</td>
<td></td>
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<tr>
<td>CDRH2D18150NC</td>
<td>15</td>
<td>0.22</td>
<td>0.35A</td>
<td>Sumida (847) 956-0666 <a href="http://www.sumida.com">www.sumida.com</a></td>
</tr>
<tr>
<td>CDRH4D18-330</td>
<td>33</td>
<td>0.51</td>
<td>0.31A</td>
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<tr>
<td>CDRH5D18-680</td>
<td>68</td>
<td>0.84</td>
<td>0.43A</td>
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</tr>
</tbody>
</table>

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 1µF 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

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PHONE</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiyo Yuden</td>
<td>(408) 573-4150</td>
<td><a href="http://www.t-yuden.com">www.t-yuden.com</a></td>
</tr>
<tr>
<td>AVX</td>
<td>(803) 448-9411</td>
<td><a href="http://www.avxcorp.com">www.avxcorp.com</a></td>
</tr>
<tr>
<td>Murata</td>
<td>(714) 852-2001</td>
<td><a href="http://www.murata.com">www.murata.com</a></td>
</tr>
</tbody>
</table>

INRUSH CURRENT

The LT3466-1 has built-in Schottky diodes. When supply voltage is applied to the VIN 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

<table>
<thead>
<tr>
<th>$V_{IN}$ (V)</th>
<th>L (µH)</th>
<th>$C_{OUT}$ (µF)</th>
<th>$I_{PK}$ (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>15</td>
<td>0.47</td>
<td>0.78</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>1.00</td>
<td>0.77</td>
</tr>
<tr>
<td>5</td>
<td>47</td>
<td>2.2</td>
<td>0.95</td>
</tr>
<tr>
<td>5</td>
<td>68</td>
<td>1.00</td>
<td>0.53</td>
</tr>
<tr>
<td>9</td>
<td>47</td>
<td>0.47</td>
<td>0.84</td>
</tr>
<tr>
<td>12</td>
<td>33</td>
<td>0.22</td>
<td>0.93</td>
</tr>
</tbody>
</table>

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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

<table>
<thead>
<tr>
<th>I_{LED1} (mA)</th>
<th>R_{FB1} (\Omega)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>40.2</td>
</tr>
<tr>
<td>10</td>
<td>20.0</td>
</tr>
<tr>
<td>15</td>
<td>13.3</td>
</tr>
<tr>
<td>20</td>
<td>10.0</td>
</tr>
<tr>
<td>25</td>
<td>8.06</td>
</tr>
</tbody>
</table>

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:

\[ I_{LED1} = \frac{(V_{CTRL1}/5 \cdot R_{FB1})}{2}, \text{ when } V_{CTRL1} < 1\text{V} \]
\[ I_{LED1} = (200\text{mV}/R_{FB1}), \text{ when } V_{CTRL1} > 1.8\text{V} \]

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 100kΩ.

![Figure 8. Dimming Control Using a Filtered PWM Signal](image)

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:

\[ V_{OUT2} = 0.8V \left(1 + \frac{R_1}{R_2}\right) \]

Choose 1% resistors for better accuracy. The FB2 input bias current is quite low, on the order of 10nA (typ). Large resistor values (R1 ~ 1M\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:

\[ V_{FB2} = V_{CTRL2}, \text{ when } V_{CTRL2} < 0.8\text{V} \]
\[ V_{FB2} = 0.8\text{V}, \text{ when } V_{CTRL2} > 1\text{V} \]
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.

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.

The \( R_{BASE} \) resistor can be calculated as:

\[
I_{LOAD} = 30\text{mA} \\
I_{BASE} = \frac{I_{LOAD}}{0.4h_{FE(MIN)}}
\]

\( I_{BASE} \) 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:

\[ h_{FE(MIN)} = 100 \]

This yields worst case \( I_{BASE} \) as:

\[
I_{BASE} = \frac{30\text{mA}}{0.4(100)} = 0.75\text{mA}
\]

\( R_{BASE} \) is given by:

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

Thus, \( R_{BASE} = \frac{V_{OUT2} - V_{IN(MAX)} + V_{CE(Q1)} - V_{BE(Q1)}}{I_{BASE}} \)
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.
Li-Ion Powered 4 White LEDs Driver and 12V Boost Converter

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

Efficiency vs Load Current

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

Conversion Efficiency

$V_{IN} = 3.8V$
$V_{OUT2} = 16V$

$V_{OUT1}$

$20V/DIV$

$I_L2$

$200mA/DIV$

CTRL2

$5V/DIV$

$V_{IN} = 3.6V$
$V_{OUT2} = 16V$

$2ms/DIV$

$L2$

$33\mu F$

$Q1$

PHILIPS BC807

$L1, L2$: 33$\mu H$ TDK D52LC

$C_{IN}$: TAIYO YUDEN JMK107BJ105

$C_{OUT1}$: TAIYO YUDEN GMK316BJ105

$C_{OUT2}$, $C_{OUT3}$: TAIYO YUDEN TMK316BJ474
TYPICAL APPLICATIONS

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

NOTE: ENSURE THAT VOUT2 > VIN(MAX) + 5V

Conversion Efficiency

VOUT2 = 16V
VIN = 3.6V

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Li-Ion to 10 White LEDs and LCD Bias (±8V) with Output Disconnect

Conversion Efficiency

Vin = 3.6V
10 LEDs
+8V/10mA
–8V/10mA
PACKAGE DESCRIPTION

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

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

RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS
## TYPICAL APPLICATION

Li-Ion to 8 White LEDs and ±15V TFT LCD Bias Supply

**Diagram:**

- **SW1, SW2:** V_IN, V_OUT1, V_OUT2
- **FB1, FB2:** CTRL1, CTRL2
- **L1:** 33µH
- **L2:** 33µH
- **C1:** 0.1µF
- **D1:** 10µA
- **CONVECTION EFFICIENCY:**
  - **Vin = 3.6V, 8 LEDs**: 74%
  - **±15V/10mA**: 78%

### RELATED PARTS

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT1618</td>
<td>Constant Current, Constant Voltage 1.4MHz, High Efficiency Boost Regulator</td>
<td>V_IN: 1.6V to 18V, V_OUT(MAX) = 34V, I_D = 1.8mA, I_SD &lt; 1µA, MS/EDD Packages</td>
</tr>
<tr>
<td>LT1932</td>
<td>Constant Current, 1.2MHz, High Efficiency White LED Boost Regulator</td>
<td>V_IN: 1V to 10V, V_OUT(MAX) = 34V, I_D = 1.2mA, I_SD &lt; 1µA, ThinSOT™ Package</td>
</tr>
<tr>
<td>LT1937</td>
<td>Constant Current, 1.2MHz, High Efficiency White LED Boost Regulator</td>
<td>V_IN: 2.5V to 10V, V_OUT(MAX) = 34V, I_D = 1.9mA, I_SD &lt; 1µA, ThinSOT, SC70 Packages</td>
</tr>
<tr>
<td>LTC3200-5</td>
<td>Low Noise, 2MHz, Regulated Charge Pump White LED Driver</td>
<td>V_IN: 2.7V to 4.5V, V_OUT(MAX) = 5V, I_D = 8mA, I_SD &lt; 1µA, ThinSOT Package</td>
</tr>
<tr>
<td>LTC3202</td>
<td>Low Noise, 1.5MHz, Regulated Charge Pump White LED Driver</td>
<td>V_IN: 2.7V to 4.5V, V_OUT(MAX) = 5.5V, I_D = 5mA, I_SD &lt; 1µA, MS/EDD Packages</td>
</tr>
<tr>
<td>LTC3205</td>
<td>High Efficiency, Multidisplay LED Controller</td>
<td>V_IN: 2.8V to 4.5V, V_OUT(MAX) = 6V, I_D = 50µA, I_SD &lt; 1µA, QFN-24 Package</td>
</tr>
<tr>
<td>LTC3216</td>
<td>1A Low Noise High Current LED Charge Pump with Independent Flash/Torch Current Control</td>
<td>V_IN: 2.9V to 4.4V, V_OUT(MAX) = 5.5V, I_D = 300µA, I_SD &lt; 2.5µA, QFN Package</td>
</tr>
<tr>
<td>LTC3453</td>
<td>500mA Synchronous Buck-Boost High Current LED Driver in QFN</td>
<td>V_IN: 2.7V to 5.5V, V_OUT(MAX) = 5.5V, I_D = 0.6mA, I_SD &lt; 6µA, QFN Package</td>
</tr>
<tr>
<td>LT3465/LT3465A</td>
<td>Constant Current, 1.2MHz/2.7MHz, High Efficiency White LED Boost Regulator with Integrated Schottky Diode</td>
<td>V_IN: 2.7V to 16V, V_OUT(MAX) = 34V, I_D = 1.9mA, I_SD &lt; 1µA, ThinSOT Package</td>
</tr>
<tr>
<td>LT3466</td>
<td>Dual Constant Current, 2MHz High Efficiency White LED Boost Regulator with Integrated Schottky Diode</td>
<td>V_IN: 2.7V to 24V, V_OUT(MAX) = 40V, I_D = 5mA, I_SD &lt; 16µA, QFN Package</td>
</tr>
<tr>
<td>LT3479</td>
<td>3A, Full Featured DC/DC Converter with Soft-Start and Inrush Current Protection</td>
<td>V_IN: 2.5V to 24V, V_OUT(MAX) = 40V, I_D = 6.5mA, I_SD &lt; 1µA, QFN/TSSOP Packages</td>
</tr>
</tbody>
</table>

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**Table:**

<table>
<thead>
<tr>
<th>LED CURRENT (mA)</th>
<th>EFFICIENCY (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>74</td>
</tr>
<tr>
<td>2.5</td>
<td>76</td>
</tr>
<tr>
<td>5</td>
<td>78</td>
</tr>
<tr>
<td>7.5</td>
<td>80</td>
</tr>
<tr>
<td>10</td>
<td>82</td>
</tr>
<tr>
<td>12.5</td>
<td>84</td>
</tr>
<tr>
<td>15</td>
<td>86</td>
</tr>
</tbody>
</table>

**Graph:**

- Conversion Efficiency
- Efficiency (%) vs. LED CURRENT (mA)

---

**Notes:**

- **CTRL1, CTRL2:** RTC
- **SW1, SW2:** VIN, VOUT1, VOUT2
- **FB1, FB2:** CTRL1, CTRL2
- **L1:** 33µH
- **L2:** 33µH
- **C1:** 0.1µF
- **D1:** 10µA

---

**Device:**

- **LT3466-1**
- **V_IN:** 3V to 5V
- **VOUT1:** –15V/10mA
- **VOUT2:** +15V/10mA

---

**Components:**

- **CIN:** TAIYO YUDEN JMK107BJ105
- **COUT1, COUT2, COUT3:** TAIYO YUDEN GMK316BJ105
- **C1:** TAIYO YUDEN UM212BJ104
- **L1, L2:** 33µH TOKO D52LC
- **D1:** PHILIPS BAT54S

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**Linear Technology Corporation**

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