General Description

The AAT3159 is a low noise, constant frequency charge pump DC/DC converter that uses a tri-mode load switch (1X), fractional (1.5X), and doubling (2X) conversion to maximize efficiency for white LED applications. The device is capable of driving up to four channels of LEDs at up to 40mA per channel from a 2.7V to 5.5V input supply voltage. The current sinks may be operated individually or in parallel for driving higher-current LEDs. A low external parts count (two 1µF flying capacitors [C1 and C2] and two small 1µF capacitors [C_IN and C_OUT]) makes this part ideally suited for small battery-powered applications.

Skyworks' patented single-wire Simple Serial Control (S2Cwire™) serial digital interface is used to enable, disable, and set the current for each LED with 16 levels from a maximum of 40mA down to 50µA. The maximum current level is programmable via an external resistor. To save power, low-current mode supply current will be as low as 50µA.

Each output of the AAT3159 is equipped with built-in protection for V_OUT short-circuit operation and auto-disable functionality for LED open-circuit conditions. Built-in soft-start circuitry prevents excessive inrush current during start-up. A low-current shutdown feature disconnects the load from IN and reduces quiescent current to less than 1µA.

The AAT3159 is available in a Pb-free, space-saving 2.85x3x1mm TSOPJW-14 package.

Features

- Input Supply Voltage Range: 2.7V to 5.5V
- Tri-Mode (1X/1.5X/2X) Charge Pump
- Maximizes Efficiency
- 1MHz Constant Switching Frequency
- No Inductors, Low Noise Operation
- Drives Four Channels of LEDs up to 40mA/Channel
- User-Programmable LED Current
- Excellent LED Channel-to-Channel Current Matching
- Digitally Programmable LED Current with Single-Wire S2Cwire Interface
- 16 Current Levels From 40mA to 50µA
- Low I_Q (50µA) for Low Current Mode Operation
- True Load Disconnect in Shutdown; I_Q < 1µA
- Built-In Thermal Protection
- Built-In Auto-Disable for Open LED Circuit
- Automatic Soft-Start Minimizes Inrush Startup Current
- 2.85x3x1mm TSOPJW-14 Package

Applications

- Cellphones, DSC, Handheld Devices
- LED Photo Flash
- Programmable Current Sinks
- White LED Backlighting

Typical Application

```
C1+ 1µF
C1-
V_BATTERY 3.6V
C_IN 1µF
EN/SET
S2Cwire Serial Control
R_SET 26.1kΩ
AAT3159
EN/SET
GND
C2+ 1µF
C2-
C_OUT
WLEDs
OSRAM LW M67C or equivalent
D1
D2
D3
D4
```

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## Pin Descriptions

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Symbol</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D4</td>
<td>Current sink input #4. Connect to the cathode of LED4. If not used, connect D4 to the OUT pin.</td>
</tr>
<tr>
<td>2</td>
<td>SET</td>
<td>LED current setting resistor input/connection.</td>
</tr>
<tr>
<td>3</td>
<td>EN/SET</td>
<td>Serial wire serial interface control input for LED current magnitude control.</td>
</tr>
<tr>
<td>4</td>
<td>C1+</td>
<td>Positive terminal of charge pump capacitor 1.</td>
</tr>
<tr>
<td>5</td>
<td>C1-</td>
<td>Negative terminal of charge pump capacitor 1.</td>
</tr>
<tr>
<td>6</td>
<td>OUT</td>
<td>Charge pump output. Connect all LED anodes to OUT.</td>
</tr>
<tr>
<td>7</td>
<td>C2+</td>
<td>Positive terminal of charge pump capacitor 2.</td>
</tr>
<tr>
<td>8</td>
<td>C2-</td>
<td>Negative terminal of charge pump capacitor 2.</td>
</tr>
<tr>
<td>9, 11</td>
<td>GND</td>
<td>Ground.</td>
</tr>
<tr>
<td>10</td>
<td>IN</td>
<td>Input power supply connection.</td>
</tr>
<tr>
<td>12</td>
<td>D1</td>
<td>Current sink input #1. Connect to the cathode of LED1. If not used, connect D1 to the OUT pin.</td>
</tr>
<tr>
<td>13</td>
<td>D2</td>
<td>Current sink input #2. Connect to the cathode of LED2. If not used, connect D2 to the OUT pin.</td>
</tr>
<tr>
<td>14</td>
<td>D3</td>
<td>Current sink input #3. Connect to the cathode of LED3. If not used, connect D3 to the OUT pin.</td>
</tr>
</tbody>
</table>

## Pin Configuration

```
TSOPJW-14
(Top View)

D4  1  14  D3
SET  2  13  D2
EN/SET  3  12  D1
C1+  4  11  GND
C1-  5  10  IN
OUT  6  9   GND
C2+  7  8   C2-
```
## Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_N$</td>
<td>[IN, OUT, D1, D2, D3, D4] to GND</td>
<td>-0.3 to 6</td>
<td>V</td>
</tr>
<tr>
<td>$V_N$</td>
<td>[C1-, C2-, EN/SET, SET] to GND</td>
<td>-0.3 to $V_{IN} + 0.3$</td>
<td>V</td>
</tr>
<tr>
<td>$V_N$</td>
<td>[C1+, C2+] to GND</td>
<td>-0.3 to $V_{OUT} + 0.3$</td>
<td>V</td>
</tr>
<tr>
<td>$T_J$</td>
<td>Operating Junction Temperature Range</td>
<td>-40 to 150</td>
<td>°C</td>
</tr>
<tr>
<td>$T_{LEAD}$</td>
<td>Maximum Soldering Temperature (at leads, 10 sec)</td>
<td>300</td>
<td>°C</td>
</tr>
</tbody>
</table>

## Thermal Information

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_D$</td>
<td>Maximum Power Dissipation</td>
<td>0.625</td>
<td>W</td>
</tr>
<tr>
<td>$\theta_{JA}$</td>
<td>Maximum Thermal Resistance</td>
<td>160</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum Rating should be applied at any one time.
2. Mounted on a FR4 board.
3. Derate 6.25mW/°C above 25°C.
AAT3159 High Efficiency 1X/1.5X/2X Charge Pump for White LED Applications

Electrical Characteristics¹

\[ V_{IN} = 3.6\text{V} \]; \( C_{IN} = C_{OUT} = C1 = C2 = 1.0\mu\text{F} \); \( T_A = -40^\circ\text{C} \) to \( +85^\circ\text{C} \), unless otherwise noted. Typical values are \( T_A = 25^\circ\text{C} \).

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{IN} )</td>
<td>Input Supply Voltage Range</td>
<td>1X Mode, ( 3.0 \leq V_{IN} \leq 5.5 ), Active, No Load Current</td>
<td>2.7</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( I_{CC} )</td>
<td>Operating Input Current</td>
<td>1X Mode, ( 3.0 \leq V_{IN} \leq 5.5 ), Active, No Load Current</td>
<td>0.3</td>
<td>1</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5X Mode, ( 3.0 \leq V_{IN} \leq 5.5 ), Active, No Load Current</td>
<td>1</td>
<td>3</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2X Mode, ( 3.0 \leq V_{IN} \leq 5.5 ), Active, No Load Current</td>
<td>1</td>
<td></td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>50\mu A Setting, 1X Mode</td>
<td>50</td>
<td></td>
<td>\mu A</td>
<td></td>
</tr>
<tr>
<td>( I_{SHDN} )</td>
<td>Shutdown Current</td>
<td>EN/SET = 0</td>
<td>1</td>
<td></td>
<td>\mu A</td>
<td></td>
</tr>
<tr>
<td>( I_{DX} )</td>
<td>DX Pin Current</td>
<td>1X to 1.5X or 1.5X to 2X Transition Threshold at Any DX Pin</td>
<td>18</td>
<td>20</td>
<td>22 mA</td>
<td></td>
</tr>
<tr>
<td>( I_{(D-Match)} )</td>
<td>Current Matching²</td>
<td>( V_i:D1:D4 = 3.6\text{V} )</td>
<td>0.5</td>
<td></td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>( V_{TH} )</td>
<td>SET Pin Voltage</td>
<td>0.6\text{V}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{SET} )</td>
<td>SET Pin Voltage</td>
<td>870\text{A/A}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{EN/SET} )</td>
<td>EN/SET Input Leakage</td>
<td>-1\text{A/A}</td>
<td></td>
<td></td>
<td>\mu A</td>
<td></td>
</tr>
</tbody>
</table>

1. The AAT3159 is guaranteed to meet performance specifications over the -40°C to +85°C operating temperature range and is assured by design, characterization, and correlation with statistical process controls.

2. Current matching is defined as the deviation of any sink current from the average of all active channels.
**Typical Characteristics**

$V_{IN} = 3.6V; \quad C_{IN} = C_{OUT} = C1 = C2 = 1.0\mu F; \quad T_A = -40^\circ C \text{ to } +85^\circ C$, unless otherwise noted. Typical values are $T_A = 25^\circ C$.

### Efficiency vs. Input Voltage

<table>
<thead>
<tr>
<th>Input Voltage (V)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.7</td>
<td>30</td>
</tr>
<tr>
<td>2.9</td>
<td>40</td>
</tr>
<tr>
<td>3.1</td>
<td>50</td>
</tr>
<tr>
<td>3.3</td>
<td>60</td>
</tr>
<tr>
<td>3.5</td>
<td>70</td>
</tr>
<tr>
<td>3.7</td>
<td>80</td>
</tr>
<tr>
<td>3.9</td>
<td>90</td>
</tr>
<tr>
<td>4.1</td>
<td>100</td>
</tr>
</tbody>
</table>

### Turn-On to 1X Mode

(V$_{IN}$ = 4.2V; 20mA/Channel Load)

- $V_{EN/SET}$ (1V/div)
- $V_{OUT}$ (2V/div)
- $V_{DX}$ (1V/div)
- $I_{IN}$ (100mA/div)

### Turn-On to 1.5X Mode

(V$_{IN}$ = 3.5V; 20mA/Channel Load)

- $V_{EN/SET}$ (1V/div)
- $V_{OUT}$ (4V/div)
- $V_{DX}$ (1V/div)
- $I_{IN}$ (200mA/div)

### Turn-On to 2X Mode

(V$_{IN}$ = 2.8V; 20mA/Channel Load)

- $V_{EN/SET}$ (1V/div)
- $V_{OUT}$ (4V/div)
- $V_{DX}$ (1V/div)
- $I_{IN}$ (500mA/div)

### Turn-Off from 1.5X Mode

(V$_{IN}$ = 3.5V; 20mA/Channel Load)

- $V_{EN/SET}$ (1V/div)
- $V_F$ (4V/div)
- $I_{IN}$ (100mA/div)

### LED Current vs. Temperature

(20mA/Channel)

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>LED Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40</td>
<td>$I_{D1}$</td>
</tr>
<tr>
<td>-15</td>
<td>$I_{D2}$</td>
</tr>
<tr>
<td>10</td>
<td>$I_{D3}$</td>
</tr>
<tr>
<td>35</td>
<td>$I_{D4}$</td>
</tr>
<tr>
<td>60</td>
<td>$I_{D5}$</td>
</tr>
<tr>
<td>85</td>
<td>$I_{D6}$</td>
</tr>
</tbody>
</table>

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**Typical Characteristics**

$V_{IN} = 3.6V$; $C_{IN} = C_{OUT} = C1 = C2 = 1.0\mu F$; $T_A = -40^\circ C$ to $+85^\circ C$, unless otherwise noted. Typical values are $T_A = 25^\circ C$.

---

### Operating Characteristics

(V$_{IN}$ = 3.7V; 1.5X Mode; 20mA/Channel Load; AC Coupled)

- $V_{IN}$ (20mV/div)
- $V_{OUT}$ (40mV/div)
- $V_{DX}$ (20mV/div)

Time (500ns/div)

### Operating Characteristics

(V$_{IN}$ = 3.5V; 1.5X Mode; 14mA/Channel Load; AC Coupled)

- $V_{IN}$ (20mV/div)
- $V_{OUT}$ (40mV/div)
- $V_{DX}$ (20mV/div)

Time (500ns/div)

### Operating Characteristics

(V$_{IN}$ = 2.9V; 2X Mode; 20mA/Channel Load; AC Coupled)

- $V_{IN}$ (20mV/div)
- $V_{OUT}$ (40mV/div)
- $V_{DX}$ (40mV/div)

Time (500ns/div)

### Operating Characteristics

(V$_{IN}$ = 2.9V; 2X Mode; 14mA/Channel Load; AC Coupled)

- $V_{IN}$ (20mV/div)
- $V_{OUT}$ (40mV/div)
- $V_{DX}$ (40mV/div)

Time (500ns/div)

---

### Input Ripple vs. Input Voltage

- 20mA/channel
- 14mA/channel
- 10mA/channel

---

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Typical Characteristics

$V_{IN} = 3.6 \text{V}; \ C_{IN} = C_{OUT} = C1 = C2 = 1.0 \mu \text{F}; \ T_A = -40\degree \text{C} \text{ to } +85\degree \text{C}$, unless otherwise noted. Typical values are $T_A = 25\degree \text{C}$.

**EN/SET Latch Timeout vs. Input Voltage**

![Graph showing EN/SET Latch Timeout vs. Input Voltage](image)

**EN/SET Off Timeout vs. Input Voltage**

![Graph showing EN/SET Off Timeout vs. Input Voltage](image)

**EN/SET High Threshold Voltage vs. Input Voltage**

![Graph showing EN/SET High Threshold Voltage vs. Input Voltage](image)

**EN/SET Low Threshold Voltage vs. Input Voltage**

![Graph showing EN/SET Low Threshold Voltage vs. Input Voltage](image)
**Functional Description**

The AAT3159 is a tri-mode load switch (1X) and high efficiency (1.5X or 2X) charge pump device intended for white LED backlight applications. To maximize power conversion efficiency, an internal sensing circuit monitors the voltage required on each constant current sink input and sets the load switch and charge pump modes based on the input battery voltage and the current sink input voltage. As the battery discharges over time, the AAT3159 charge pump is enabled when any of the four current sink inputs nears dropout. The charge pump initially starts in 1.5X mode. If the charge pump output droops enough for any current source output to become close to dropout, the charge pump will automatically transition to 2X mode. The AAT3159 requires only four external components: two 1µF ceramic capacitors for the charge pump flying capacitors (C1 and C2), one 1µF ceramic input capacitor (C_in), and one 0.33µF to 1µF ceramic output capacitor (C_out).

The four constant current sink inputs (D1 to D4) can drive four individual LEDs with a maximum current of 40mA each. The unused sink inputs must be connected to V_OUT; otherwise, the part will operate only in 2X charge pump mode. The S²Cwire serial interface enables the AAT3159 and sets the LED current magnitudes.

**Constant Current Output Level Settings**

The LED current magnitude is controlled by Skyworks’ S²Cwire serial digital interface. The maximum current is programmed by an external resistor at the SET pin. Since the current sinks are programmable, no PWM (pulse width modulation) or additional control circuitry is needed to control LED brightness. This feature greatly
reduces the burden on a microcontroller or system IC to manage LED or display brightness, allowing the user to "set it and forget it." With its high-speed serial interface (1MHz data rate), the LED current can be changed successively to brighten or dim LEDs in smooth transitions (e.g., to fade-out) or in abrupt steps, giving the user complete programmability and real-time control of LED brightness. The code settings for the AAT3159 are listed in Table 1.

**S²Cwire Serial Interface**

The current level magnitude is controlled by Skyworks' Simple Serial Control (S²Cwire) serial interface. The interface records rising edges of the EN/SET pin and decodes them into 16 different states. The 16 current level settings available are indicated in Table 1.

<table>
<thead>
<tr>
<th>Data</th>
<th>All LED Outputs D1 - D4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>90%</td>
</tr>
<tr>
<td>3</td>
<td>79%</td>
</tr>
<tr>
<td>4</td>
<td>70%</td>
</tr>
<tr>
<td>5</td>
<td>62%</td>
</tr>
<tr>
<td>6</td>
<td>55%</td>
</tr>
<tr>
<td>7</td>
<td>48%</td>
</tr>
<tr>
<td>8</td>
<td>40%</td>
</tr>
<tr>
<td>9</td>
<td>31%</td>
</tr>
<tr>
<td>10</td>
<td>21%</td>
</tr>
<tr>
<td>11</td>
<td>15%</td>
</tr>
<tr>
<td>12</td>
<td>11%</td>
</tr>
<tr>
<td>13</td>
<td>1mA</td>
</tr>
<tr>
<td>14</td>
<td>500µA</td>
</tr>
<tr>
<td>15</td>
<td>100µA</td>
</tr>
<tr>
<td>16</td>
<td>50µA</td>
</tr>
</tbody>
</table>

Table 1: AAT3159 LED Current Levels as a Percentage of the Maximum Level Set by \( R_{SET} \).

The S²Cwire serial interface has flexible timing. Data can be clocked-in at speeds greater than 1MHz, or much slower, such as 15kHz. After data is submitted, EN/SET is held high to latch the data. Once EN/SET has been held in the logic high state longer than \( T_{LAT} \) (500µs), the programmed current becomes active. For subsequent current level programming, the number of rising edges corresponding to the desired code must be entered on the EN/SET pin.

When EN/SET is held logic low longer than \( T_{OFF} \) (500µs), the AAT3159 enters into shutdown mode and draws less than 1µA from IN. The internal data register is reset to zero during shutdown.

**Auto-Disable Feature**

The AAT3159 is equipped with an auto-disable feature for each LED channel. After the IC is enabled and started up, a test current of 100µA (typical) is forced through each sink channel. The channel will be disabled if the voltage of that particular current sink (DX pin) does not drop to a specific threshold. This feature is very convenient for disabling an unused channel or during an LED fail short event.

**Thermal Protection**

The AAT3159 has built-in thermal protection circuit that will shut down the charge pump if the die temperature rises above the thermal limit, as is the case during a short-circuit event with the OUT pin.
Applications Information

LED Selection

Although the AAT3159 is specifically intended for driving white LEDs, the device can also be used to drive most types of LEDs with forward voltage specifications ranging from 2.0V to 4.7V. LED applications may include main and sub-LCD display backlighting, camera photo-flash applications, color (RGB) LEDs, infrared (IR) diodes for remotes, and other loads benefiting from a controlled output current generated from a varying input voltage. Since the D1 to D4 input current sinks are matched with negligible voltage dependence, the LED brightness will be matched regardless of the specific LED forward voltage ($V_f$) levels. In some instances (e.g., in high-luminous-output applications such as photo flash), it may be necessary to drive high-$V_f$ type LEDs. The low dropout current sinks in the AAT3159 make it capable of driving LEDs with forward voltages as high as 4.7V at full current from an input supply as low as 3.0V. Outputs can be paralleled to drive high-current LEDs without complication.

Determining the Maximum LED Current Level

The value of $R_{SET}$ determines the maximum LED current level. In the typical application, selecting $R_{SET} = 26.1k\Omega$ results in 20mA/channel LED current. From this reference point, the $R_{SET}$ value required for other current levels can be calculated as:

$$R_{SET} = \frac{20\text{mA} \cdot 26.1k\Omega}{I_{LED(\text{MAX})}}$$

A visual representation of the maximum LED current per channel versus $R_{SET}$ value is shown in Figure 1. Since the AAT3159’s LED current control circuits were optimized for full-scale current settings higher than 15mA, $R_{SET}$ values smaller than or equal to 33.2kΩ are recommended.

Brightness Control Using the SET Pin

Additional methods of brightness control can be achieved with the SET pin. For example, using an additional resistor to connect the SET pin with a digital output provides a HI/LO control. Figure 2 illustrates a configuration of the SET pin utilizing two resistors.

$$I_{LED(LO)} = I_{SET}\left(\frac{0.6V}{R_1 // R_2} - \frac{V_{DAC}}{R_2}\right)$$

When the digital output is asserted high, the resulting brightness level is HI and the individual LED currents are:

$$I_{LED(HI)} = I_{SET}\left(\frac{0.6V}{R_1 // R_2}\right)$$

Figure 1: Maximum LED Current vs. $R_{SET}$.

Figure 2: SET Pin Configuration Using Two Resistors.
Additionally, a digital-to-analog converter can be used with the SET pin to control the brightness level. The result is like the equation above, where $V_{IO}$ is replaced with $V_{DAC}$:

$$I_{LED(LO)} = \frac{0.6V}{R_1 // R_2} \cdot V_{DAC}$$

For cases where PWM dimming is preferred, the PWM signal can be applied directly to the SET resistor, as shown in Figure 3. In order for the LED current to go to zero, the voltage level of the PWM signal must be higher than the SET pin voltage of 0.6V.

![Figure 3: SET Pin Configuration for PWM Dimming Control.](image)

**Device Power Efficiency**

The AAT3159’s power conversion efficiency depends on the charge pump mode of operation. By definition, device efficiency is expressed as the output power delivered to the LEDs divided by the total input power consumed.

$$\eta = \frac{P_{LEDs}}{P_{IN}} = \frac{V_{LED1} \cdot I_{LED1} + \ldots + V_{LED4} \cdot I_{LED4}}{V_{IN} \cdot I_{IN}}$$

When the input voltage is sufficiently greater than the LED forward voltages, the device optimizes efficiency by operating in 1X mode. In 1X mode, the device is working as a bypass switch and passing the input supply directly to the output. By simplifying the conditions such that the LEDs have uniform $V_F$, the power conversion efficiency can be approximated by:

$$\eta = \frac{4 \cdot V_{LEDX} \cdot I_{LEDX}}{V_{IN} \cdot I_{IN}}$$

Due to the very low 1X mode quiescent current, the input current nearly equals the total output current delivered to the LEDs. Further, the low resistance bypass switch introduces a negligible voltage drop from input to output.

The AAT3159 further maintains optimized performance and efficiency by detecting when the input voltage is not sufficient to sustain the LED bias current. The device automatically switches to 1.5X mode when the input voltage drops too low in relation to the LED forward voltages.

In 1.5X mode, the output voltage can be boosted to 1.5X the input voltage. The 1.5X conversion ratio introduces a corresponding 0.5X increase in input current. For ideal conversion, the 1.5X mode efficiency is given by:

$$\eta = \frac{4 \cdot V_{LEDX} \cdot I_{LEDX}}{V_{IN} \cdot I_{IN}}$$

Similarly, when the input falls further, such that 1.5X mode can no longer sustain the LED bias currents, the AAT3159 will automatically switch to 2X mode. In 2X mode, the output voltage can be boosted to 2X the input voltage. The 2X conversion ratio introduces a corresponding 1X increase in input current. For ideal conversion, the 2X mode efficiency is given by:

$$\eta = \frac{4 \cdot V_{LEDX} \cdot I_{LEDX}}{V_{IN} \cdot I_{IN}}$$
Device Switching Noise Performance

The AAT3159 operates at a fixed frequency of approximately 1MHz to control noise and limit harmonics that can interfere with the RF operation of cellular telephone handsets or other communication devices. Back-injected noise appearing on the input pin of the charge pump is 20mV peak-to-peak, typically ten times less than inductor-based DC/DC boost converter white LED backlight solutions. The AAT3159 soft-start feature prevents noise transient effects associated with inrush currents during start-up of the charge pump circuit.

Capacitor Selection

Careful selection of the four external capacitors (C\text{IN}, C1, C2, C\text{OUT}) is important because they will affect turn-on time, output ripple, and transient performance. Optimum performance will be obtained when low Equivalent Series Resistance (ESR) ceramic capacitors are used; in general, low ESR may be defined as less than 100mΩ. A value of 1µF for all four capacitors is a good starting point when choosing capacitors. If the LED current sources are only programmed for light current levels, then the capacitor size may be decreased.

Capacitor Characteristics

Ceramic composition capacitors are highly recommended over all other types of capacitors for use with the AAT3159. Ceramic capacitors offer many advantages over their tantalum and aluminum electrolytic counterparts. A ceramic capacitor typically has very low ESR, is lowest cost, has a smaller PCB footprint, and is non-polarized. Low ESR ceramic capacitors help maximize charge pump transient response. Since ceramic capacitors are non-polarized, they are not prone to incorrect connection damage.

Equivalent Series Resistance

ESR is an important characteristic to consider when selecting a capacitor. ESR is a resistance internal to a capacitor that is caused by the leads, internal connections, size or area, material composition, and ambient temperature. Capacitor ESR is typically measured in milliohms for ceramic capacitors and can range to more than several ohms for tantalum or aluminum electrolytic capacitors.

Ceramic Capacitor Materials

Ceramic capacitors less than 0.1µF are typically made from NPO or C0G materials. NPO and C0G materials typically have tight tolerance and are stable over temperature. Larger capacitor values are typically composed of X7R, X5R, Z5U, or Y5V dielectric materials. Large ceramic capacitors, typically greater than 2.2µF, are often available in low-cost Y5V and Z5U dielectrics, but capacitors greater than 1µF are typically not required for AAT3159 applications. Capacitor area is another contributor to ESR. Capacitors that are physically large will have a lower ESR when compared to an equivalent material smaller capacitor. These larger devices can improve circuit transient response when compared to an equal value capacitor in a smaller package size.

PCB Layout

To achieve adequate electrical and thermal performance, careful attention must be given to the printed circuit board (PCB) layout of the AAT3159. Figures 5 and 6 illustrate an example PCB layout for the AAT3159 (evaluation board). The flying capacitors (C1 and C2), input capacitor (C4), and output capacitor (C3) should be connected as close as possible to the IC. In addition to the external passive components being placed as close as possible to the IC, all traces connecting the AAT3159 should be as short and wide as possible to minimize path resistance and potential coupling.
AAT3159 High Efficiency 1X/1.5X/2X Charge Pump for White LED Applications

Evaluation Board Schematic

Figure 4: AAT3159 Evaluation Board Schematic.

Evaluation Board Layout

Figure 5: AAT3159 Evaluation Board Top Side Layout.

Figure 6: AAT3159 Evaluation Board Bottom Side Layout.
**Ordering Information**

<table>
<thead>
<tr>
<th>Package</th>
<th>Marking¹</th>
<th>Part Number (Tape and Reel)²</th>
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<tbody>
<tr>
<td>TSOPJW-14</td>
<td>TLXYY</td>
<td>AAT3159ITO-T1</td>
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</table>

Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to Skyworks *Definition of Green™*, document number SQ04-0074.

**Package Information**

**TSOPJW-14**

All dimensions in millimeters.

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1. XYY = assembly and date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.