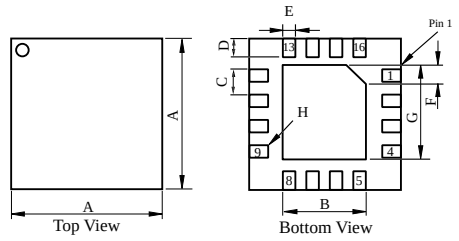
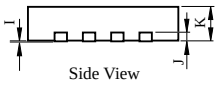
## 1X/1. 5X Fractional Charge Pump for White LED Driver with Dimming Control

The KAC3301 is low noise constant frequency charge pump DC/DC converter specially designed to drive up to four white LEDs with constant current from Li-ion cell. Dual (1x/1.5x) Modes and low dropout voltage of LED driver maximize efficiency for the white LED application over full Li-ion battery input range. The LED current is set by the external resistor. PWM(Pulse Width Modulation) signal can be used to control LED brightness over wide frequency range. Various kinds of protection circuits protect your system from every undesirable output condition.




| DIM | MILLIMETERS |
|---|---|
| A | 4.00 ± 0.05 |
| B | 2.30 ± 0.05 |
| C | 0.650BSC |
| D | 0.55 ± 0.05 |
| E | 0.33 ± 0.05 |
| F | 0.45 ± 0.05 |
| G | 2.40 ± 0.05 |
| H | R0.030 Max |
| I | 0.05 Max |
| J | 0.203 ± 0.008 |
| K | 0.9 ± 0.1 |




QFN16

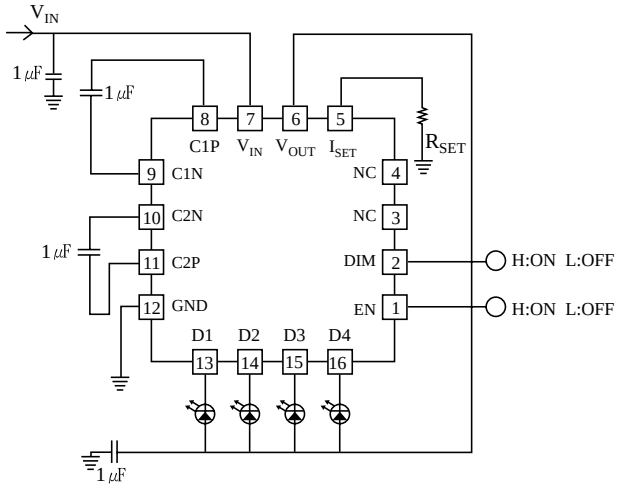
### Features

- 1x/1.5x dual charge pump modes with auto detection.
- Excellent Power Efficiency. (more than 92% of $P_{MAX}$)
- LED current matching of ±2%.
- Power-down current below 1uA.(max.)
- Up to 30mA/LED current capability. [$V_{IN}$ > 3.1V]
- Up to 20mA/LED current capability. [$V_{IN}$ > 2.7V]
- Strong to ESD. [MM:>200V, HBM:>2000V]
- Low input ripple and EMI.
- PWM or Analog dimming control.
- 2.7V to 5.5V input voltage range.
- Output over-voltage protection.
- Thermal shutdown protection.
- Output over-current protection.
- Soft start limits Inrush current.
- Automatic soft-start protects IC from output short.
- 1MHz switching frequency.
- QFN-16 package.

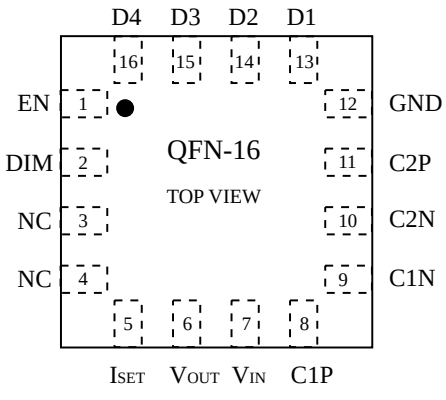
### Applications

- Cellular phones, Smart Phones, PDA, Digital Cameras, Camcorders.
- MP3 player and other handheld devices with color displays operating circuit.

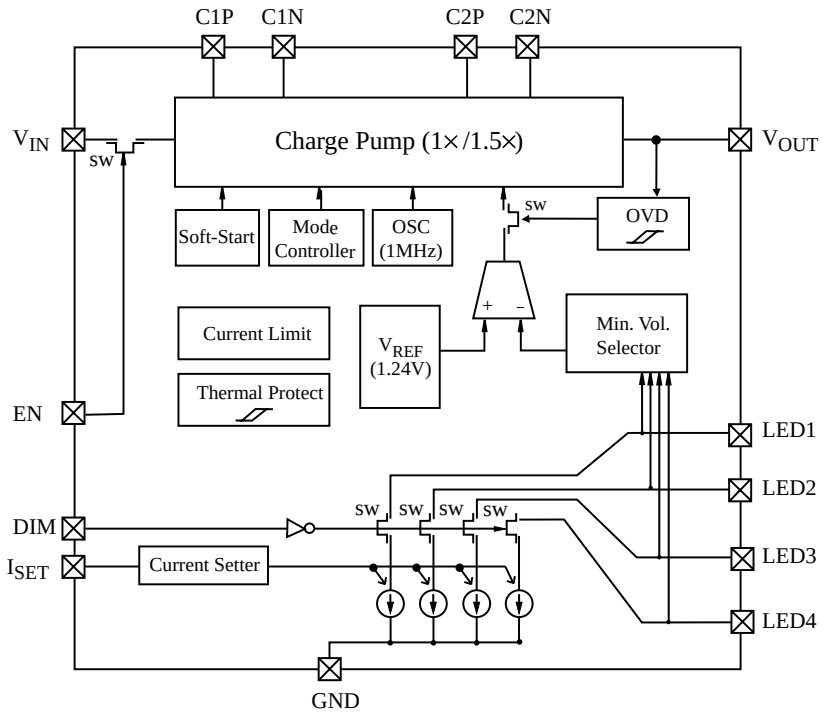
### Typical operating Circuit




### Pin Configuration



**Block Diagram**




**Pin Descriptions**

| Pin | Name | Function |
|---|---|---|
| 1 | EN | Chip enable input.(Shutdown at Low state) |
| 2 | DIM | PWM Dimming control input |
| 3 | NC | |
| 4 | NC | |
| 5 | $I_{SET}$ | Reference current set.(Connecting a resistor to gorund)<br>Analog Dimming Control |
| 6 | $V_{OUT}$ | Charge pump output |
| 7 | $V_{IN}$ | Power Supply Voltage Input |
| 8 | C1P | Positive terminal of switched capacitor1 |
| 9 | C1N | Negative terminal of switched capacitor1 |
| 10 | C2N | Negative terminal of switched capacitor2 |
| 11 | C2P | Positive terminal of switched capacitor2 |
| 12 | GND | Ground |
| 13 | D1 | Sinking current input for LED1 |
| 14 | D2 | Sinking current input for LED2 |
| 15 | D3 | Sinking current input for LED3 |
| 16 | D4 | Sinking current input for LED4 |

**Maximum Ratings**

| Characteristics | Symbol | Rating | Units |
|---|---|---|---|
| Input supply Voltage | $V_{IN}$ | -0.3 to +6.0 | V |
| Input Pin | DIM,EN | -0.3 to ($V_{IN}$+0.2) | V |
| Maximum Power Dissipation. (@Ta=25℃) | $P_D$ | 2.6 | W |
| Thermal Resistance | $\theta_{JA}$ | 48.22 | ℃/W |
| Operating Ambient | Ta | -40 to + 85 | ℃ |
| Junction Temperature | Tj | -40 to + 150 | ℃ |
| Storage Temperature | $T_{stg}$ | -65 to + 150 | ℃ |
| Lead Temperature | $T_{LEAD}$ | 300 | ℃ |

**Electrical Characteristics** (Ta=-40 to 85℃, 2.7V< $V_{IN}$ < 5.5V,C1 = C2 = 1.0㎌. unless otherwise noted.) (note 1)

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Input Supply Voltage | $V_{IN}$ | | 2.7 | - | 5.5 | V |
| Maximum LED sink current | $I_{LED}$ | 2.7V〈$V_{IN}$ ($I_{SET}$=50㎂) | - | 20 | - | mA |
| | | 3.1V〈$V_{IN}$ ($I_{SET}$=75㎂) | - | 30 | - | mA |
| Set bias Voltage | $V_{SET}$ | | 1.178 | 1.24 | 1.302 | V |
| Current Ratio | $I_{LED}/I_{SET}$ | | - | 400 | - | |
| Quiescent current | $I_Q$ | No load($V_{DIM}$=High). $I_{SET}$=12.5㎂ | - | 1.0 | 2.0 | mA |
| Power-down Current | $I_{PD}$ | $V_{EN}$=GND, Ta=25℃ | - | 0.1 | 1 | ㎂ |
| $I_{LED}$ Accuracy | $I_{LED\_ACC}$ | 2mA 〈$I_{LED}$〈30mA | - | 5 | - | % |
| $I_{LED}$ Matching between any other $I_{LED}$ | $I_{LED\_MAT}$ (Note 2) | 2mA 〈$I_{LED}$〈30mA | - | ±2 | - | % |
| LED regulation Voltage | $V_{LED}$ | | 50 | 120 | 200 | mV |
| Maximum Output Current | $I_{OUT}$ | $V_{IN}$〉3.1V, $V_{OUT}$≤3.8V | 120 | 140 | - | mA |
| | | $V_{IN}$〉2.7V, $V_{OUT}$≤3.5V | 80 | 90 | - | mA |
| Input Current Limit | $I_{LIMIT}$ | Short Condition in $V_{OUT}$ Without Softstart. (Note 3) | 160 | - | 850 | mA |
| Thermal Shutdown Threshold | $T_{SD}$ | 40 ℃ Hysteresis | - | 150 | - | ℃ |
| Over-Voltage Protect | $V_{OVP}$ | | - | 5.5 | 6.0 | V |
| Hysteresis of $V_{OVP}$ | $V_{HTY\_OVP}$ | | - | 0.4 | - | V |
| Switching frequency | $F_{SW}$ | | - | 1 | - | MHz |
| Input Logic High | $V_{IH}$ | | 1.3 | - | - | V |
| Input Logic Low | $V_{IL}$ | | - | - | 0.4 | V |

Note 1 : Specifications to -40℃ are guaranteed by design and not production tested.

Note 2 : $I_{LEAD\_MAT}[\%] = \pm \left( \frac{I_{MAX} - I_{MIN}}{I_{MAX} + I_{MIN}} \right) \times 100$

Note 3 : This is occurred when Pin of LED is shorted to GND, or there are ohmic short $V_{OUT}$ to GND

## Application Information

**• Output Regulation**

KAC3301 maintains constant LED brightness even at very low battery voltage. For example, at 2.7V of the battery voltage KAC3301 can maintain constant LED bright above 20mA. For better efficiency KAC3301 will be kept in 1x mode unless lowest voltage of the LED1~LED4 goes under the 50mV. Constant switching frequency & optimized duty make low input and output ripple at the 1.5x mode. Ofcourse, KAC3301 has almost no output ripple at the 1x mode.

**• LED Current Control**

The LED current is a multiple of the current flowing out of the $I_{SET}$ pin. Set the LED current as follows:

$$I_{LED} = K \times \frac{1.24V}{R_{SET}}, \quad K = 380$$

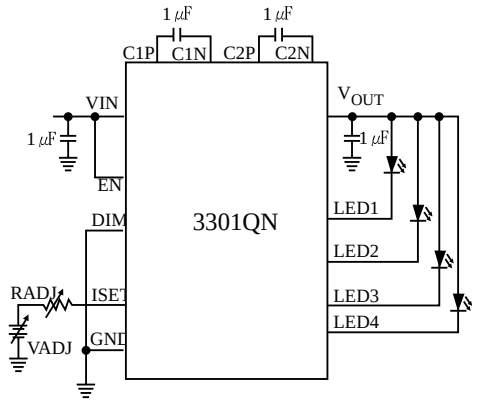
Internal high reference voltage (1.24V) helps you to choice $R_{SET}$ value of K takes low current through $R_{SET}$. Values of $R_{SET}$ for a fixed LED current are given in the table below.

| $I_{LED}$ | [mA] | 30 | 20 | 15 | 10 | 5 | 2 | 1 | 0.5 |
|---|---|---|---|---|---|---|---|---|---|
| $R_{SET}$ | [㏀] | 15.7 | 23.6 | 31.4 | 47.1 | 94 | 236 | 471 | 942 |

**• Dimming :**

| Method | External device | Range of "ILED" | Note |
|---|---|---|---|
| Analog | Voltage Source [$V_{ADJ}$] | 0.5mA~30mA | |
| | $R_{SET}$→volume resistor [$R_{ADJ}$] | 0.5mA~30mA | |
| PWM | PWM Input | 0.5mA~30mA | Recommend Freq.: 100Hz~20KHz. |
| Digital $2^N$ bit | NMOS Switched parallel resistors | 0.5mA~30mA | |

**ANALOG**

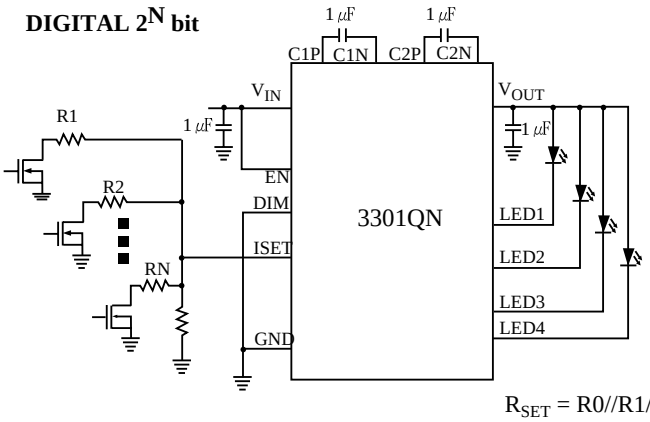



- Adjustable Voltage Source method ; $R_{ADJ}$ is fixed Value ($R_{SET}$)!
- Volume resistor method : $V_{ADJ}$ is not needed! $V_{ADJ}$=0
- In the Both case $I_{LED}$ is controlled by the equation as follows;

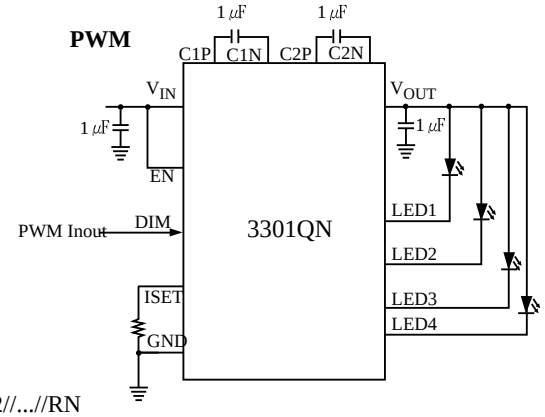
$$I_{LED}[㎃] = 380 \times \frac{(V_{REF} - V_{ADJ})}{R_{ADJ}}$$

$$I_{LED}[㎃] = 0, \text{ when}(V_{ADJ} > V_{REF})$$

**DIGITAL $2^N$ bit**




**PWM**




$R_{SET}$ = R0//R1//R2//...//RN

• **Shutdown (Enable=Low)**

When voltage of the ENABLE pin goes under 0.4V, KAC3301 enter the shutdown mode where input current go to zero and there are no current between output capacitors and transfer capacitor.

• **Soft-Start**

KAC3301 has its original soft-start function to limit inrush current at turn on. KAC3301 charges transfer capacitors and output capacitor with a constant input current until output voltage goes to the value of ($1.4 \times V_{IN}$). If output voltage reached the value of ($1.4 \times V_{IN}$) or over-voltage protection circuit is activated, LED current start to flow. But input current remains to zero until output voltage goes down to usual output operating voltage from the discharge of LED current. At the every turn on the ENABLE and output voltage less than 25% of the input voltage, soft-start sequence is introduced for the safety.

• **Short protection (various short mode)**

1) short $V_{OUT}$ pin to GND pin: If output is shorted to ground, output current is limited by the soft-start which is repeated until $V_{OUT}$ remains under 25% of $V_{IN.}$
2) short LED pin to GND pin: If this occurs at the soft-start-mode or shutdown state, KAC3301 stays at soft-start-mode. Else this is done during operating, the output current is limited by the current-limitcircuitry.
3) short $V_{OUT}$ pin to LED pin(shorted LED): There are no change but shorted LED doesn't work.

• **Open protection**

If more than one LED is opened, output voltage is limited by over-voltage-protect circuitry. But, other LEDs work continuously without change of the brightness.

• **Current limit**

There could be variable short mode in the backlight system. For example, $V_{OUT}$ pin to GND or LED pin to GND or short of LEDs, etc. In these case, large current could be flow at the output pin. KAC3301 are protected by the Thermal shutdown circuitry, but external elements might be damaged without current limit circuitry. Current limit circuitry set you to ease to design safely.

• **Over-voltage protection**

When a LED pin shorted to the ground or LED is opened itself, voltage of the LED terminal could be almost 0V without any concerning to the other conditions. In this case, output voltage might be raised over IC's maximum ratings. And, then IC may be destroyed! KAC3301 maintains over voltage protection circuitry for the prohibiting output voltage over the maximum ratings.

• **Thermal shutdown**

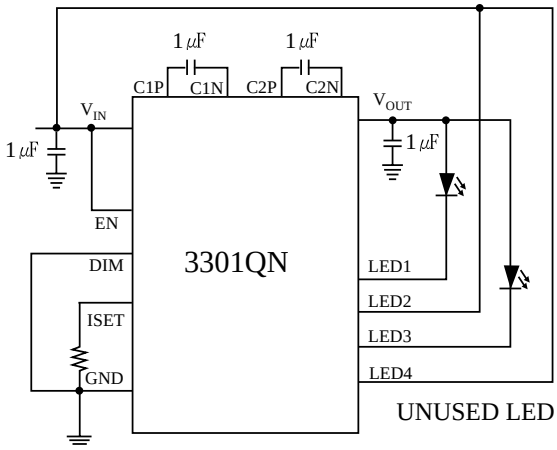
KAC3301 includes a thermal shutdown circuit which makes IC shutdown at 150℃(typ.) and recover after IC cools by approximately 40℃.

• **Input Ripple**

For LED drive ICs in mobile system, input ripple is more important than output ripple, because there are many other components which have input supply terminal from battery instead of the output terminal. KAC3301 has very excellent input ripple characteristics which is depends on the supply's impendence. You can get better input ripple characteristics, by minimizing resistance from battery to the $V_{IN}$ pin.

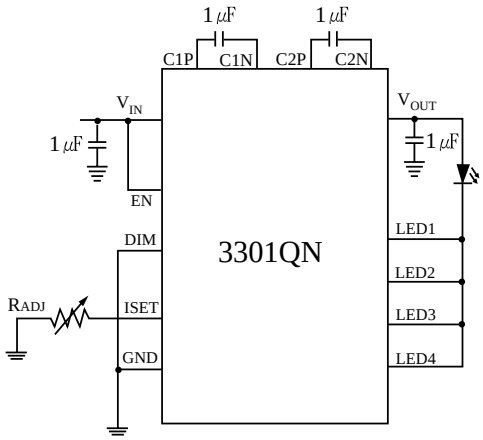
- **Unused LED**

  When driving fewer than four LEDs, connect any unused LED pin to $V_{IN}$. This makes the corresponding LED driver disable, then there is no current consumption through unused LED pin, so KAC3301 maintains its efficiency.

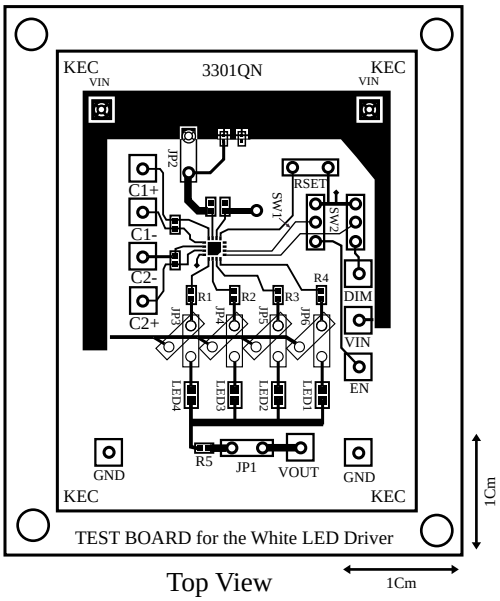


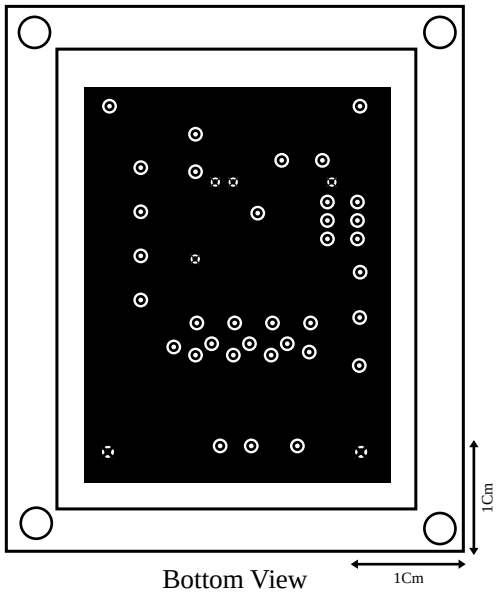

- **Flash or Large Current Drive**

  KAC3301 can be used Flash Driver when shorting pins of 4LEDs as circuits. Be careful that $R_{SET}$ should be set not for the $I_{LED}$ but for $I_{FLASH}$( $=I_{LED}$ X 4 ).



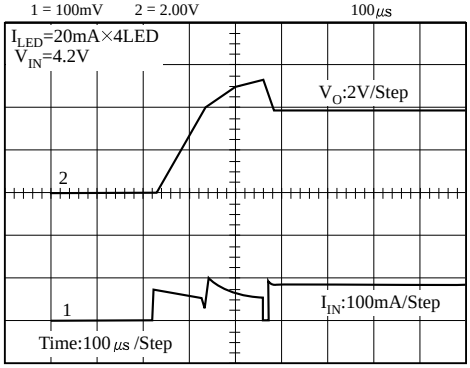

**Evaluation Board :**



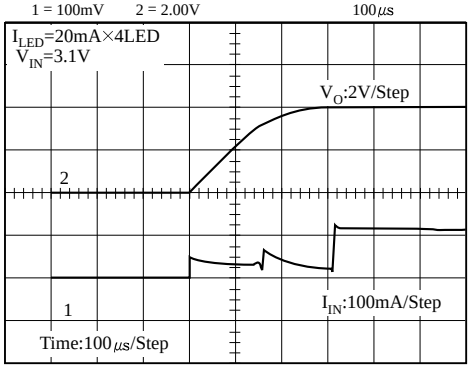



**Typical Opering Characteristics**

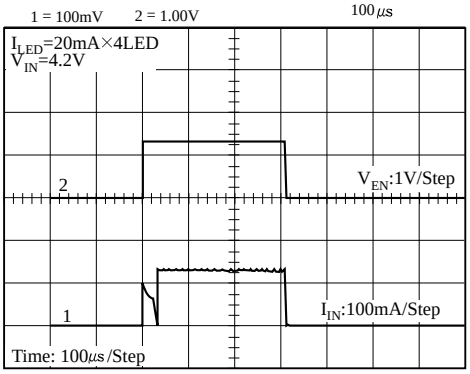
StartUP From Discharged Output (1)



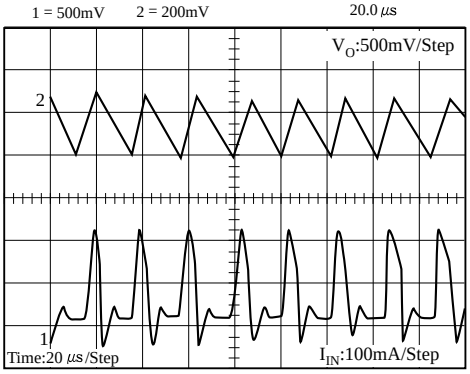

StartUP From Discharged Output (2)



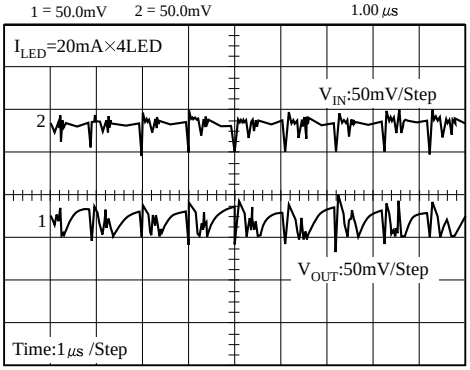

Shutdown Response



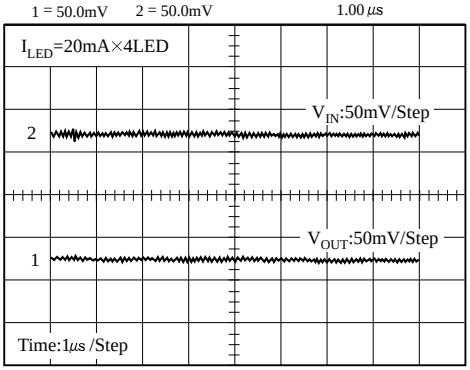

OVP When LED Open



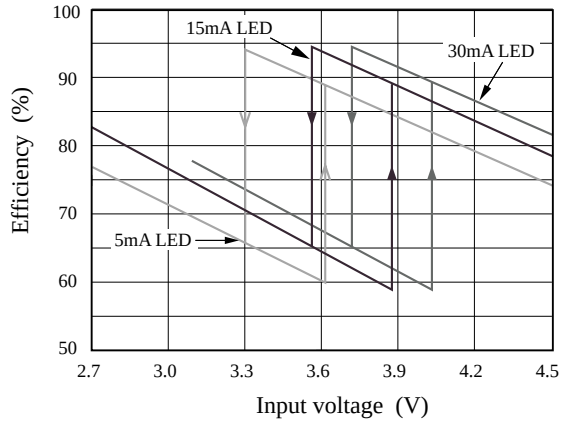

Typical Operating Wave Form in 1.5x Mode



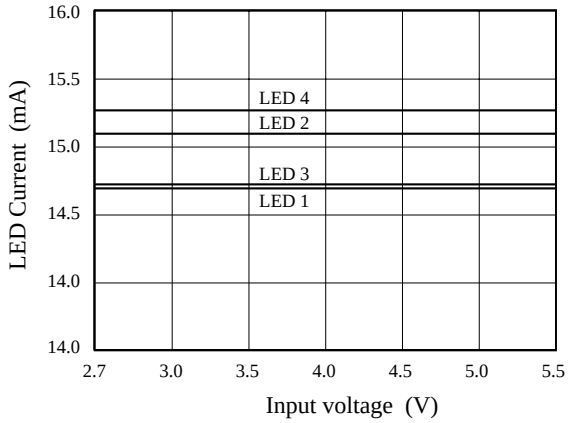

Typical Operating Wave Form in 1x Mode



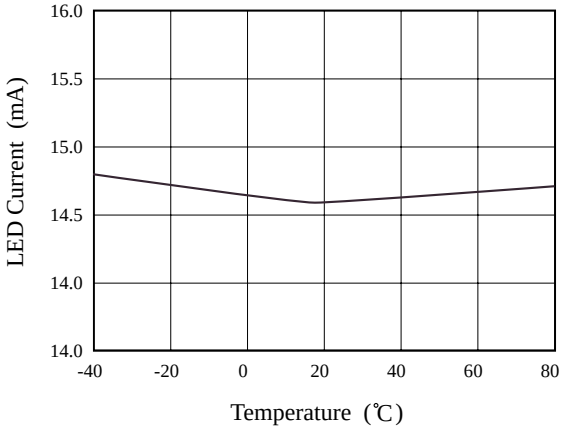
EFFICIENCY VS. SUPPLY VOLTAGE



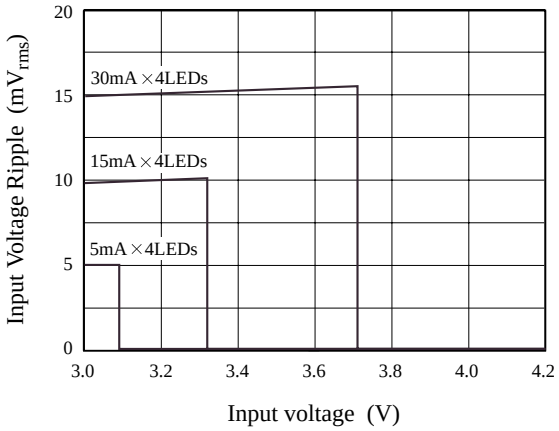

LED CURRENT VS. SUPPLY VOLTAGE



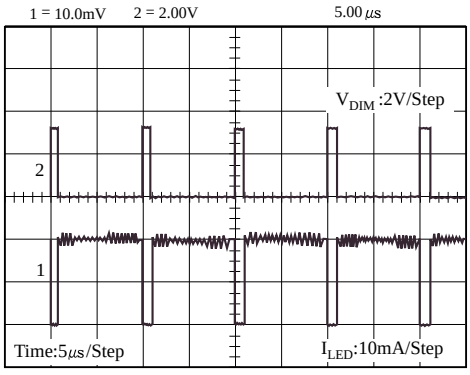

LED CURRENT VS. TEMP.




INPUT RIPPLE VS. SUPPLY VOLTAGE




PWM Dimming 90% Duty @ 100KHz




PWM Dimming 10% Duty @100KHz