# SC604A
# Low Noise, High Efficiency Regulated White LED Driver

POWER MANAGEMENT

## Description

The SC604A is a very high efficiency charge pump white LED driver driver from the mAhXLife™ family of products, optimized for Li-Ion battery applications.

The four (4) LED outputs are current matched for consistent LED brightness. Extremely low battery current is achieved by automatically reconfiguring the charge pump to match circuit conditions. Using four LEDs, each at 20mA for a total $I_{OUT}$= 80mA, the SC604A can use less than 83mA from the supply for most of the battery life.

Patented low noise mode switching circuitry and constant output current allow the use of extremely small input and output capacitors.

## Features

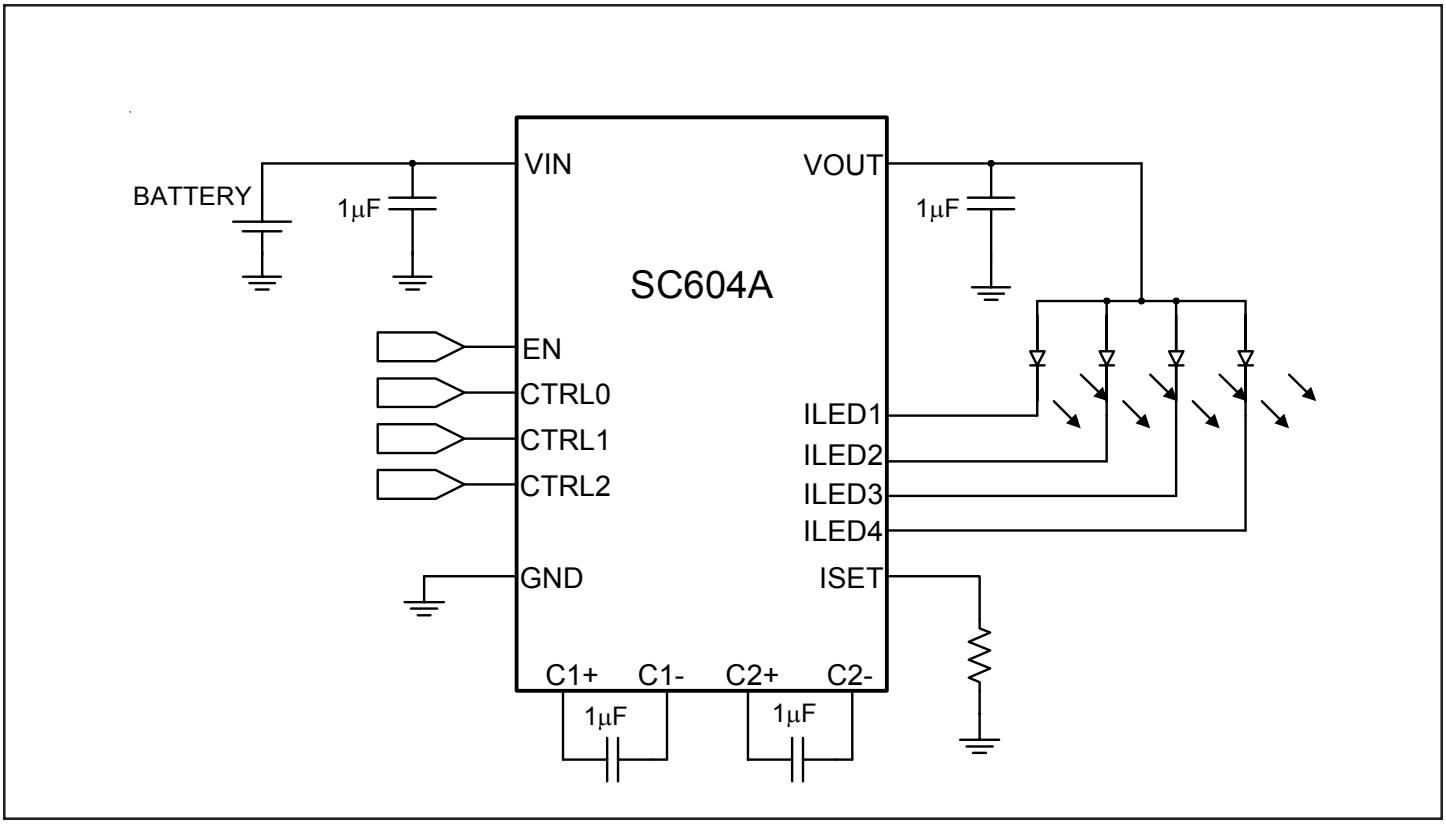
- Very high efficiency over 90% of battery life
- Peak efficiency over 92%
- Current regulation for up to 4 LEDs
- Digital 3 bit output control logic
- Current matching tolerance of ±3% typical
- Wide current range per LED [0.5mA - 30mA]
- High available total LED current = 4 • $I_{LED}$ = 120mA
- Low Shutdown Current: 1µA typical
- Soft start / In-rush current limiting
- Short circuit protection
- MLP-16 [4x4] Package
- Fixed frequency 250kHz
- 1x, 1.5x and 2x charge pump modes of operation

## Applications

- Cellular phones
- LED backlighting
- PDA power supplies
- Portable devices
- Electronic books
- Wireless web appliances
- LCD Modules

## Typical Application Circuit

**Patent Pending**



## Absolute Maximum Ratings

Exceeding the specifications below may result in permanent damage to the device, or device malfunction. Operation outside of the parameters specified in the Electrical Characteristics section is not implied.

| Parameter | Symbol | Maximum | Units |
|---|---|---|---|
| Supply Voltage | VIN | -0.3 to +7.0 | V |
| Output Voltage | $V_{OUT}$ | -0.3 to +7.0 | V |
| $V_{OUT}$ Short Circuit Duration | SC | Indefinite | s |
| Thermal Resistance, Junction to Ambient (1) | $\theta_{JA}$ | 40 | °C/W |
| Operating Ambient | $T_A$ | -40 to +85 | °C |
| Junction Temperature Range | $T_J$ | -40 to +150 | °C |
| Storage Temperature Range | $T_{STG}$ | -65 to +150 | °C |
| IR Reflow Temperature SC604AIMLTR | $T_{LEAD}$ | 240 | °C |
| IR Reflow Temperature SC604AIMLTRT | $T_{LEAD}$ | 260 | °C |

Note: (1) By JESD51 standards

## Electrical Characteristics

Unless specified: $T_A$ = -40°C to 85°C, $V_{IN}$= 2.85V to 5.5V, C1 = C2 = 1.0µF (ESR = 0.03Ω). Typical values @ $T_A$=25°C, LED $V_F$ = 3.4V.
This device is ESD sensitive. Use of standard ESD handling precautions is required.

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Input Supply Voltage | VIN | | 2.5 | | 6.5 | V |
| Current into LEDs 1, 2, 3 and 4 | $I_{LED}$ | $R_{SET}$ = 24.0kΩ | | 20 | | mA |
| | | $R_{SET}$ = 94.0kΩ | | 5.0 | | mA |
| | | 2.7V < VIN < 5.5V | 0.5 | | 20 | mA |
| | | 3.1V < VIN < 5.5V | 0.5 | | 30 | mA |
| Quiescent Current | $I_Q$ | $I_{OUT}$ = 5mA | | 1500 | 2000 | µA |
| | | Enable = 0V | | 1 | 7 | µA |
| $I_{LED}$ Accuracy | $I_{LED-ERR}$ | 0.5mA ≤ $I_{LED}$ ≤ 30mA | | ± 5 | | % |
| Current Matching | $I_{LED-LED-ERR}$ | 0.5mA ≤ $I_{LED}$ ≤ 30mA | | ± 3 | | % |
| 1x mode to 1.5x mode transition voltage ($V_{IN}$ falling) | $V_{TRANS1X}$ | $V_{LED}$ = 3.6V, $I_{OUT}$ = 80mA, $I_{LED}$ = 20mA | | 3.796 | | V |
| 1.5x mode to 2x mode transition voltage ($V_{IN}$ falling) | $V_{TRANS1.5X}$ | $V_{LED}$ = 3.6V, $I_{OUT}$ = 80mA, $I_{LED}$ = 20mA | | 3.320 | | V |
| Oscillator Frequency | $f_{OSC}$ | | 212.5 | 250 | 287.5 | kHz |
| Output Over Voltage Protection (1) | $V_{OVP}$ | Open circuit at any LED that is programmed to be in the On state | 5.0 | | | V |

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## Electrical Characteristics (Cont.)

Unless specified: $T_A$ = -40°C to 85°C, $V_{IN}$= 2.85V to 5.5V, C1 = C2 = 1.0µF (ESR = 0.03Ω). Typical values @ $T_A$=25°C, LED $V_F$ = 3.4V.

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Input Current Limit | ILIMIT | Short circuit applied from VOUT to GND | | 220 | 850 | mA |
| Input High Threshold | $V_{IH}$ | Input high logic threshold | 1.3 | | | V |
| Input Low Threshold | $V_{IL}$ | Input low logic threshold | | | 0.4 | V |
| Input High Current | $I_{IH}$ | $V_{IH}$= $V_{IN}$ | | | 10 | µA |
| Input Low current | $I_{IL}$ | $V_{IL}$= GND | | | 10 | µA |

Notes:
(1) Guaranteed by design

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## Definitions

### $I_{LED}$ Accuracy

The LED current is determined by the $R_{SET}$ resistor ($I_{LED}$ vs. $R_{SET}$ data is found on pages 9 and 10). This term does not include the tolerance of the resistor $R_{SET}$. If maximum accuracy is required, a precision resistor is needed. To calculate the error $I_{LED-ERR}$[%], use the formula

$$I_{LED-ERR}\ [\%] = \pm \frac{(I_{LED})_{MEASURED} - I_{LED}}{I_{LED}} \cdot 100\%$$

### Current Matching

Current Matching refers to the difference in current from one LED to the next. The ΔI between any two LEDs will meet this requirement. To calculate the error $I_{LED-LED-ERR}$, first identify the highest and lowest value of the 4 LED currents, and use the formula:

$$I_{LED-LED-ERR}\ [\%] = \left( \frac{I_{MAX}}{\frac{I_{MAX} + I_{MIN}}{2}} - 1 \right) \cdot 100\%$$

or

$$\left( \frac{I_{MIN}}{\frac{I_{MAX} + I_{MIN}}{2}} - 1 \right) \cdot 100\%$$

which reduces to ±

$$\left( \frac{I_{MAX} - I_{MIN}}{I_{MAX} + I_{MIN}} \right) \cdot 100\%$$

### 1x Mode, 1.5x Mode and 2x Mode

1x Mode, 1.5x Mode and 2x Mode all refer to the charge pump configuration. These modes boost the battery input voltage and ensure there is enough voltage at $V_{OUT}$ so that the regulated current will flow through the LEDs and return via the $I_{LED}$ pins.

### Input Current

The total input current of the SC604A is a function of the sum of the LED currents, the charge pump mode and the quiescent current. The quiescent current trend is charted on page 12 and used to calculate $I_{IN}$ in the following examples.

$$I_{IN} = I_{OUT} \cdot \text{Mode} + I_Q =$$

$$(I_{LED1}+I_{LED2}+I_{LED3}+I_{LED4}) \cdot \text{Mode} + I_Q$$

Example 1:

Mode = 1x, $I_Q$ = 2.4mA,
$I_{LED1}+I_{LED2}+I_{LED3}+I_{LED4}$ = 4 • 15mA = 60mA

Answer 1:

$I_{IN} = I_{OUT}$ • Mode + $I_Q$ = 60mA • 1 + 2.4mA = 62.4mA

Example 2:

Mode = 1.5x, $I_Q$ = 2.4mA,
$I_{LED1}+I_{LED2}+I_{LED3}+I_{LED4}$ = 4 • 15mA = 60mA

Answer 2:

$I_{IN} = I_{OUT}$ • Mode + $I_Q$ = 60mA • 1.5 + 2.4mA = 92.4mA

### Mode Transition Voltage

Mode transition voltage refers to the input voltage at the point just before the charge pump changes from a weaker mode to a stronger mode. $V_{TRANS1X}$ is the transition from 1x to 1.5x mode, and $V_{TRANS1.5X}$ is the transition from 1.5x to 2x mode. Equations for $V_{TRANS1X}$ and $V_{TRANS1.5X}$ are given on page 7.

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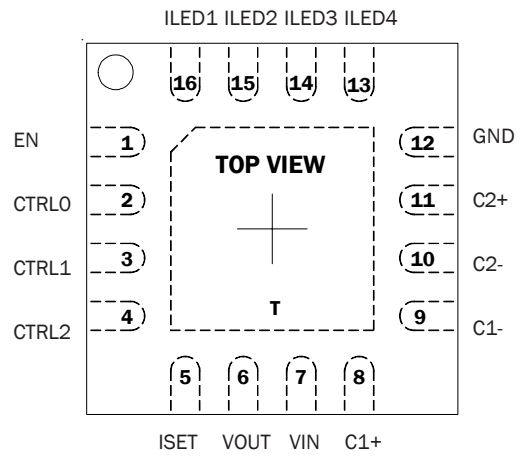
## Pin Configuration




**MLPQ16: 4X4 16 LEAD**

## Ordering Information

| DEVICE | PACKAGE(1) |
|---|---|
| SC604AIMLTR | MLP-16 |
| SC604AIMLTRT(2) | MLP-16 |
| SC604EVB | Evaluation Board |

Notes:
(1) Available in tape and reel only. A reel contains 3000 devices.
(2) Available in lead-free package only. This product is fully WEEE and RoHS compliant.

## Pin Descriptions

| Pin | Pin Name | Pin Function |
|---|---|---|
| 1 | EN | Active high enable |
| 2 | CTRL0 | Output control bit 0 (see Table 1 on page 6) |
| 3 | CTRL1 | Output control bit 1 (see Table 1 on page 6) |
| 4 | CTRL2 | Output control bit 2 (see Table 1 on page 6) |
| 5 | ISET | LED current is set by the value of the resistor $R_{SET}$ connected from the ISET pin to ground. Do not short the ISET pin. $V_{ISET}$ is typically 1.22V |
| 6 | VOUT | Voltage output source for connection to the LED anodes |
| 7 | VIN | Voltage input |
| 8 | C1+ | Positive terminal of bucket capacitor 1 |
| 9 | C1- | Negative terminal of bucket capacitor 1 |
| 10 | C2- | Negative terminal of bucket capacitor 2 |
| 11 | C2+ | Positive terminal of bucket capacitor 2 |
| 12 | GND | Ground |
| 13 | ILED4 | Current sink for LED 4 [If not in use, pin must be left open](1) |
| 14 | ILED3 | Current sink for LED 3 [If not in use, pin may be left open, grounded, or connected to $V_{IN}$](1) |
| 15 | ILED2 | Current sink for LED 2 [If not in use, pin may be left open, grounded, or connected to $V_{IN}$](1) |
| 16 | ILED1 | Current sink for LED 1 [If not in use, pin may be left open, grounded, or connected to $V_{IN}$](1) |
| T | Thermal Pad | Pad for heatsinking purposes. Connect to ground plane using multiple vias. Not connected Internally |

Note: (1) The CTRL word must match the outputs in use.

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## Block Diagram

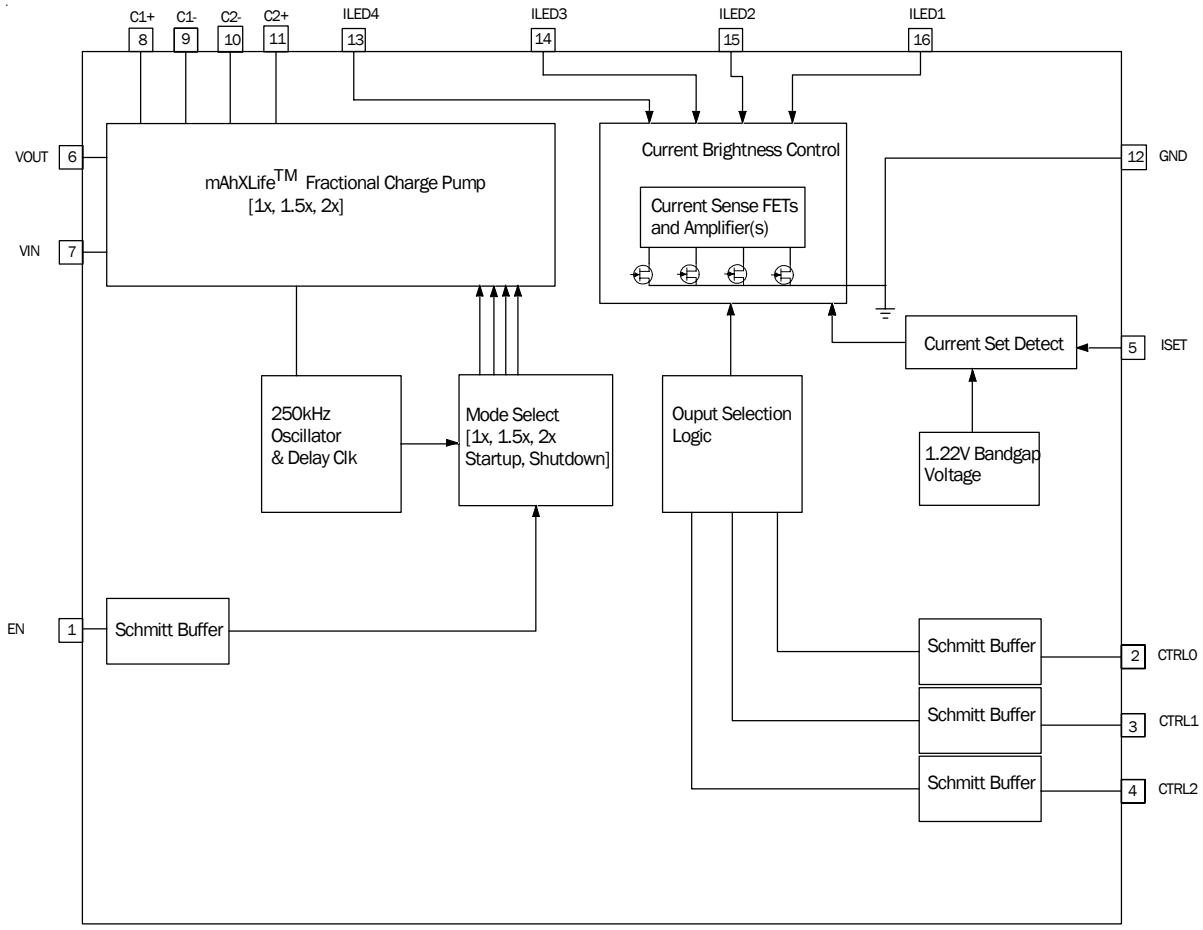


**Table 1 - LED Enable Logic**

| Control Inputs (1) | | | Output Status | | | |
|---|---|---|---|---|---|---|
| **CTRL2** | **CTRL1** | **CTRL0** | **LED4** | **LED3** | **LED2** | **LED1** |
| 0 | 0 | 0 | OFF | OFF | OFF | ON |
| 0 | 0 | 1 | OFF | OFF | ON | OFF |
| 0 | 1 | 0 | OFF | ON | OFF | OFF |
| 0 | 1 | 1 | ON | OFF | OFF | OFF |
| 1 | 0 | 0 | OFF | OFF | ON | ON |
| 1 | 0 | 1 | OFF | ON | ON | ON |
| 1 | 1 | 0 | ON | ON | ON | ON |
| 1 | 1 | 1 | OFF | OFF | OFF | OFF |

Notes:
(1) The sequencing of Enable and logic state CTRL{2,1,0} = [1, 1, 1] will affect quiescent state current. $I_Q$ = 100µA if Enable transitions high before CTRL{2,1,0} transitions to [1, 1, 1]. $I_Q$ = 400µA if Enable transitions high after CTRL{2,1,0} transitions to [1, 1, 1]. If Enable = high and CTRL{2,1,0}= [1, 1, 1] is to be used for an extended period of time, it is recommended that Enable = High when change to the [1, 1, 1] state to achieve the lower $I_Q$ level.

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## Applications Information

### Detailed Description

The SC604A contains a fractional charge pump, mode selection circuit, output selection logic, current setting detection circuit, and four current sense circuits. All are depicted in the block diagram on page 6.

The fractional charge pump multiplies the input voltage a multiple of 1, 1.5 or 2 times the input voltage. The charge pump switches at a fixed 250kHz whenever the mode is 1.5x or 2x. The charge pump does not switch during 1x mode, saving power and improving efficiency.

The mode selection circuit automatically selects the mode as 1x, 1.5x or 2x based on circuit conditions such as LED voltage, input voltage and load current. 1x is the most efficient mode, followed by 1.5x and 2x modes. At lower voltages a stronger mode may be needed to maintain regulation, if so, the mode will change first to 1.5x and then to 2x. 2x mode usually operates for a much shorter run time compared to 1x mode, and 2x mode maintains the output until the battery is discharged to 2.85V or less. The LED requiring the highest voltage drop will determine the output voltage needed to drive all outputs with adequate bias. Comparing all cathodes and regulating VOUT for the LED with the lowest cathode voltage ensures sufficient bias for all LEDs.

Output selection logic enables control over the LED outputs for on and off functions with eight (8) different output states. The states are defined in Table 1 on page 6.

The current set and detection circuit uses an external resistor and a 1.22V reference to program the LED current.

Four (4) current regulating circuits sink matched currents from the LEDs. LEDs with matched forward voltage will produce the best possible matched currents. For best matching performance it is recommended that the $\Delta Vf$ between LEDs be under 250mV. (For more information on $\Delta Vf$ considerations refer to Semtech application notes).

### Designing for Lowest Possible Battery Current

The SC604A efficiency and battery current are shown in the plots that follow on page 8. For this example, 4 LEDs are matched at 15mA each. The battery current remains low at 63mA well into the Li-Ion battery range as indicated in the plot by a boundary box. The SC604A uses 1x mode ($I_{IN}=I_{OUT}+I_Q$) for part of the input voltage range, conserving significant energy from the battery. A similar four (4) output device uses only 1.5x mode ($I_{IN}= I_{OUT} \cdot 1.5+I_Q$) over the input voltage range. This means that the SC604A will have about 25% higher efficiency than a 1.5x only charge pump. Where the competition drops off at 3V, the SC604A uses 2x mode to extend the operating range down to a battery voltage of only 2.85V.

The input voltages at which the mode transitions occur are dependent on the forward voltage $V_F$ of the LED used and the LED current $I_{LED}$. To keep the battery current low and in the 1x mode for as long as possible, it is best to choose an LED with a lower $V_F$.

The mode transition voltages $V_{TRANS1X}$ and $V_{TRANS1.5X}$ can be estimated by the following equations:

$$V_{TRANS1X} = V_F + V_{ILED} + [(\#\text{ of LEDs used}) \cdot I_{LED} \cdot 1.2]$$

$$V_{TRANS1.5X} = \frac{V_F + V_{ILED} + [(\#\text{ of LEDs used}) \cdot I_{LED} \cdot 16]}{1.5}$$

where, $V_F$ is the forward LED voltage measured from anode to cathode, $V_{ILED}$ is the voltage at the ILED pin, typically $V_{ILED}$ = 100mV, $I_{LED}$ is the LED current.

Power efficiency can now be estimated for comparison with the intended battery voltage range.

$$\text{Efficiency [\%]} = \frac{V_{OUT} \cdot I_{OUT}}{V_{IN} \cdot (I_{OUT} \cdot \text{Mode} + I_Q)} \cdot 100\%$$

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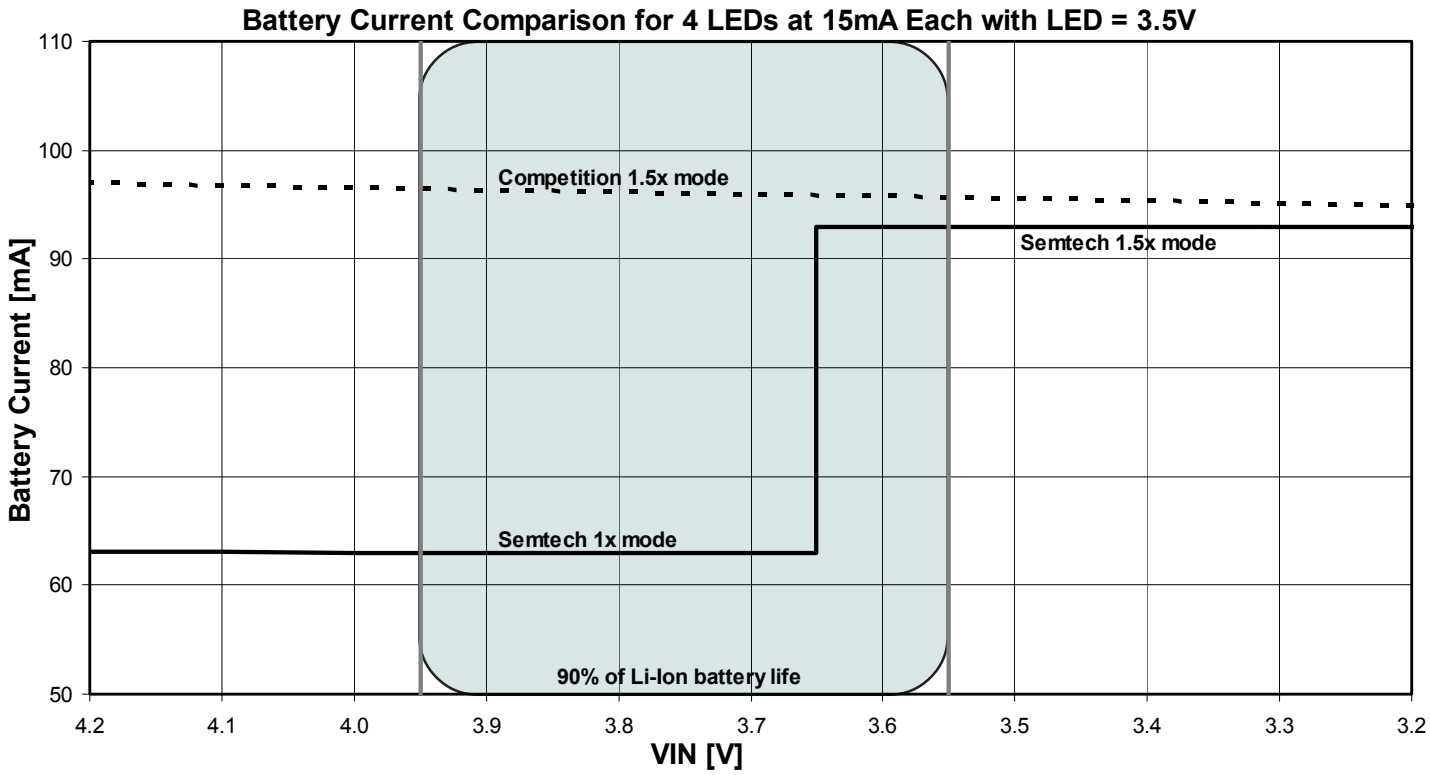


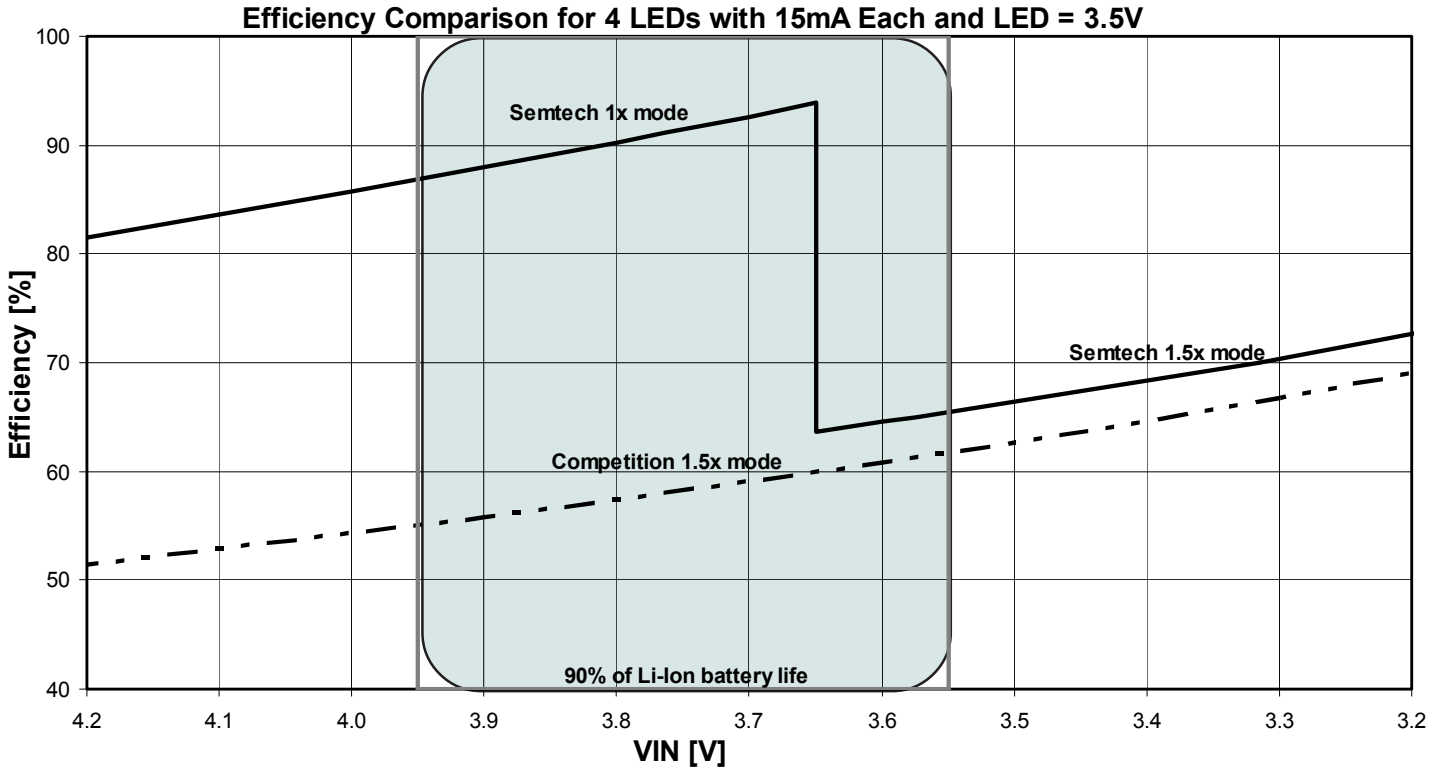


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## Methods for Setting LED Current

There are four methods for setting and adjusting the LED current outlined here. The methods are:

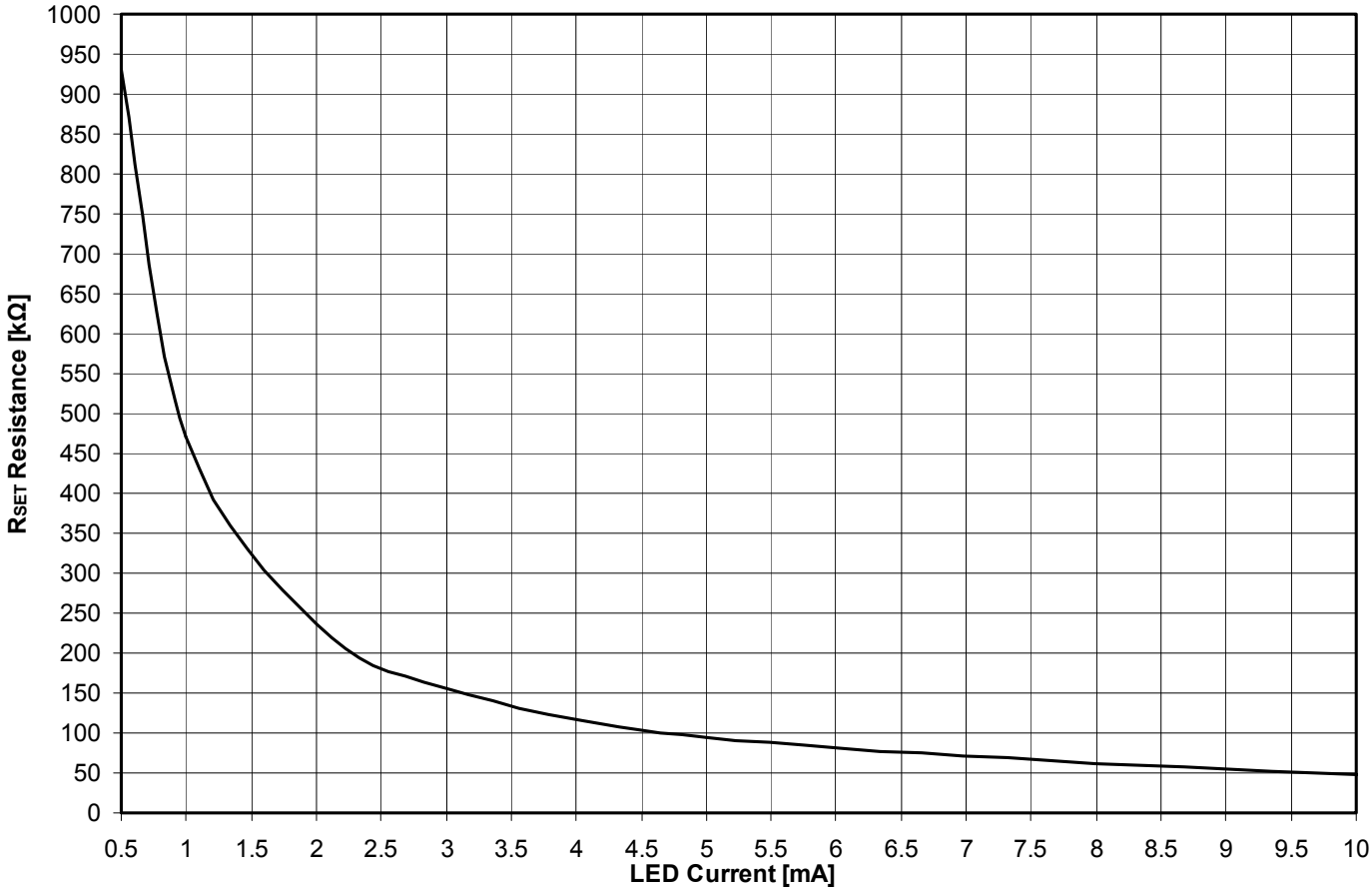
**1) $R_{SET}$ only**
**2) Analog Reference $V_{ADJ}$**
**3) NMOS switched parallel resistors**
**4) PWM Input**

**Method 1.** The most basic means of setting the LED current is with a resistor connected from ISET to GND, as shown in the application circuit on Page 1. The resistor $R_{SET}$ establishes the reference current needed for a constant LED current. Values of $R_{SET}$ for a fixed LED current are given in Table 2 and also in the below graph, "Typical $R_{SET}$ Resistance vs. LED Current". Methods 2 and 3 on page 10 are for setting the LED current allow for brightness control.

**Table 2 - Resistor Value Selection**

| $R_{SET}$ Value | | | |
|---|---|---|---|
| ILED[mA] | $R_{SET}$[kΩ] | Nearest kΩ Standard Value | Standard Value % Difference |
| 0.5 | 931 | 931 | 0.0% |
| 1 | 471 | 470 | -0.2% |
| 2 | 237 | 237 | 0.0% |
| 3 | 155 | 154 | -0.6% |
| 5 | 94.0 | 93.1 | -1.0% |
| 10 | 47.5 | 47.5 | 0.0% |
| 15 | 31.83 | 31.6 | -0.7% |
| 20 | 24.0 | 24.0 | 0.0% |
| 30 | 16.5 | 16.5 | 0.0% |

**Typical $R_{SET}$ Resistance vs. LED Current**

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## Methods for Setting LED Current (Cont.)

**Method 2.** The example circuit in Figure 1 uses a 16.5kΩ resistor and an analog input DC voltage, $V_{ADJ}$, which varies from 1.2V to 0V to control LED current from 1mA to 30mA. Table 3 shows the resulting output. If necessary, the analog $V_{ADJ}$ voltage can be sourced from a voltage higher than 1.2V, but the source must be divided down so that the $V_{ADJ}$ mode will not exceed 1.2V. For lower current applications and for higher resolution, a larger resistor may be substituted in this circuit. PWM applications are also possible with this circuit by application of RC filtering. (Consult with Semtech for detailed application support).

**Method 3.** The circuit in Figure 2 uses open drain NMOS transistors to set an equivalent resistance for $R_{SET}$. Parallel combinations are switched on and off for R1, R2 and R3. R4 is always connected, so that a minimum value of LED current can be maintained at 1.5mA.

**Figure 1 - Analog Voltage for LED Current Control**

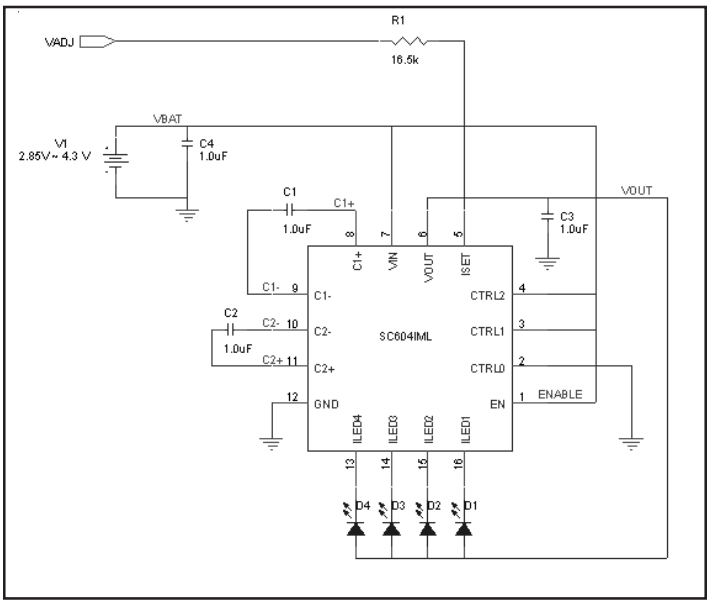


**Figure 2 - 3 Bit LED Current Control with Open Drain**

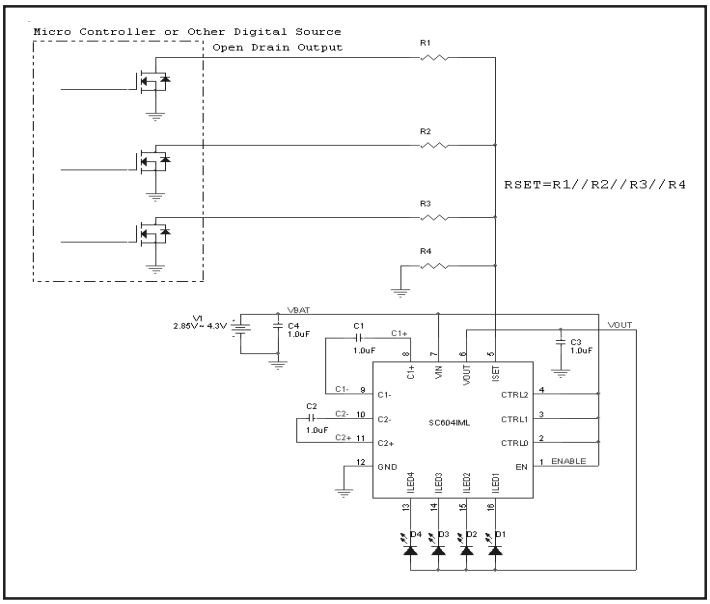


**Table 3 - Analog Voltage for LED Current Control**

| $V_{ADJ}$ [V] | $I_{LED}$ [mA] | $V_{ADJ}$ [V] | $I_{LED}$ [mA] |
|---|---|---|---|
| 0.000 | 30.2 | 0.600 | 14.8 |
| 0.100 | 27.7 | 0.700 | 12.3 |
| 0.200 | 25.1 | 0.800 | 9.7 |
| 0.300 | 22.5 | 0.900 | 7.1 |
| 0.400 | 20.0 | 1.000 | 2.1 |
| 0.500 | 17.3 | 1.150 | 1.0 |

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## Methods for Setting LED Current (Cont.)

**Method 4.** LED current may also be controlled by applying a PWM signal to any of the CTRL2, CTRL1 and CTRL0 inputs. The circuit in Figure 3 turns 4 LEDs on and off by applying a PWM signal to the CTRL0 input. This circuit uses resistor $R_{SET}$ to set the on state current and the average LED current is then proportional to the percentage of on-time when the CTRL0 pin is a logic low. Average LED current is approximately equal to:

$$I_{AVG} = (t_{ON} \bullet I_{LED_ON})/(t_{ON} + t_{OFF})$$

The recommended PWM frequency is between 100Hz and 500Hz. Due to start up delay and ramp up time, frequency >500Hz will result in error in the average value of $I_{LED}$. Frequency <100Hz can naturally cause the LEDs to blink visibly.

In PWM applications where ILED4 is not used, keep ILED4 pin 13 open. Connecting ILED4 to ground can result in the charge pump operating in open loop mode. Connecting ILED4 to $V_{IN}$ will work but will cause shutdown current $I_Q$ to increase to approximately $V_{IN}$ / 100k.

**Figure 3 - PWM Example Circuit**

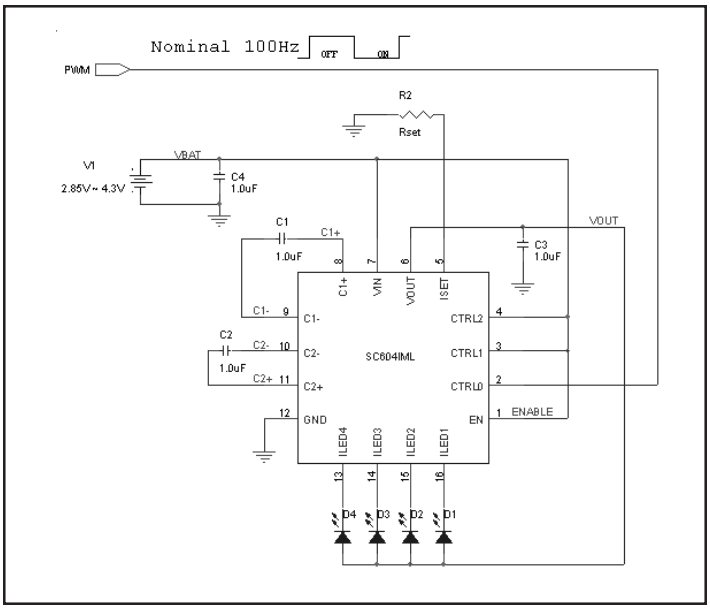


**Table 4 - Summary of LED Current Control**

| LED Current Control Method | | Figure of Reference | LED Current Range | Brightness Control |
|---|---|---|---|---|
| Method 1 | $R_{SET}$ Only | Circuit on Page 1 | 0.5mA < $I_{LED}$ < 30mA | Fixed Brightness |
| Method 2 | Analog Reference $V_{ADJ}$ | Figure 1 on Page 10 | 0.5mA < $I_{LED}$ < 30mA | Infinite |
| Method 3 | NMOS Switched Parallel Resistors | Figure 2 on Page 10 | 0.5mA < $I_{LED}$ < 30mA | $2^N$ Stepped Current Levels(1) |
| Method 4 | PWM CTRLx Input(s) | Figure 3 on page 11 | 0.5mA < $I_{LED}$ < 30mA | Infinite |

Note: 1) "N" is the number of NMOS transistors used for brightness control.

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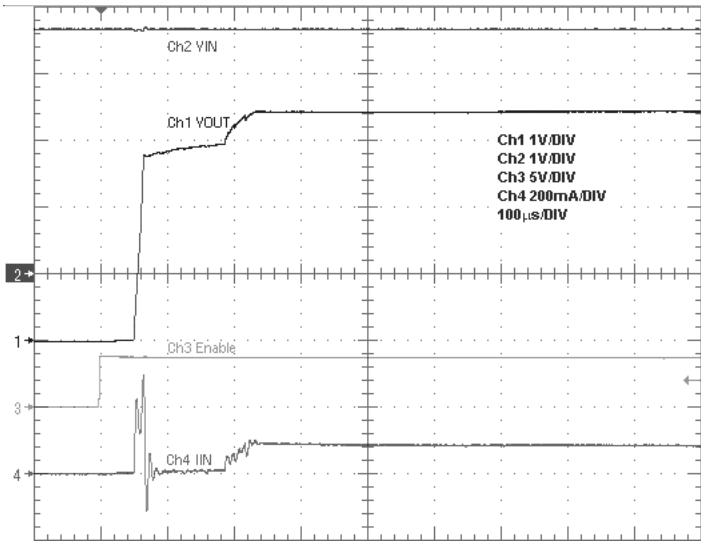
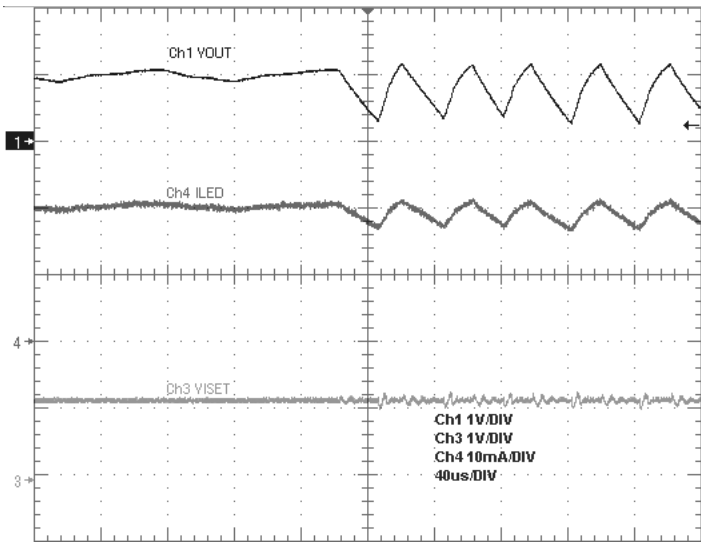
## Typical Characteristics

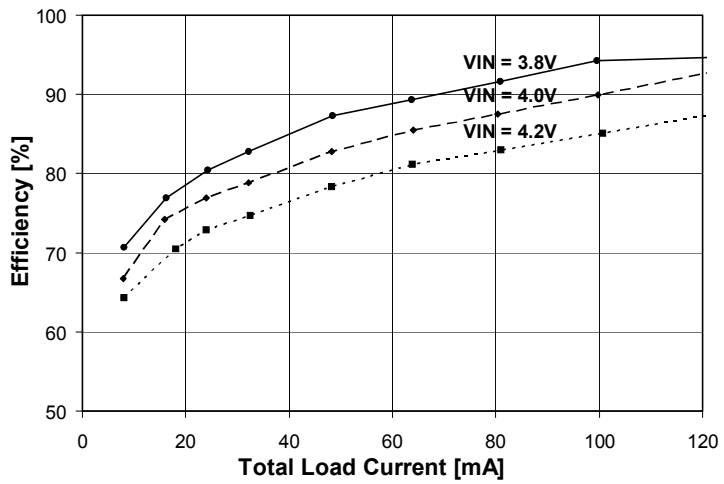
### Startup with 4 LEDs at 20 mA



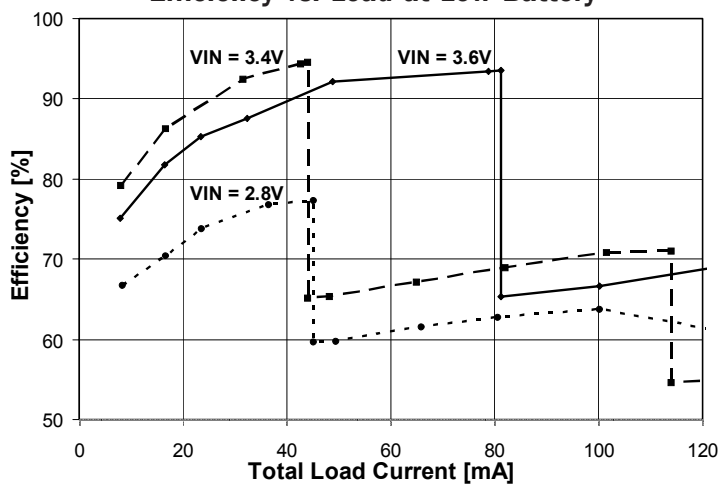

### OVP Event with LED Open Circuit



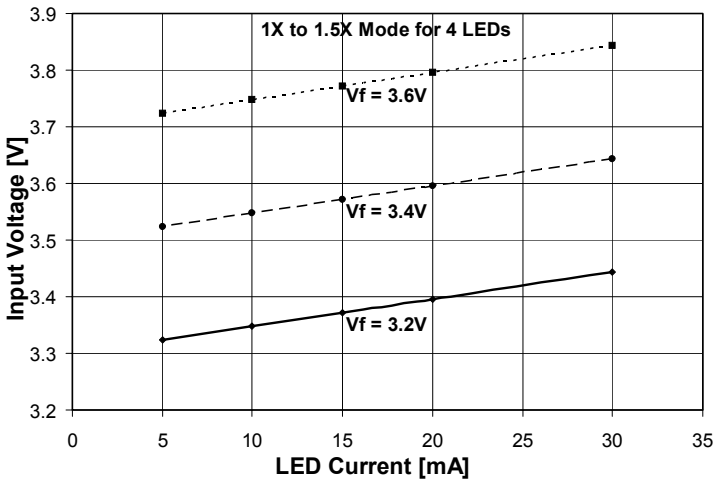

### Efficiency vs. Load at High Battery



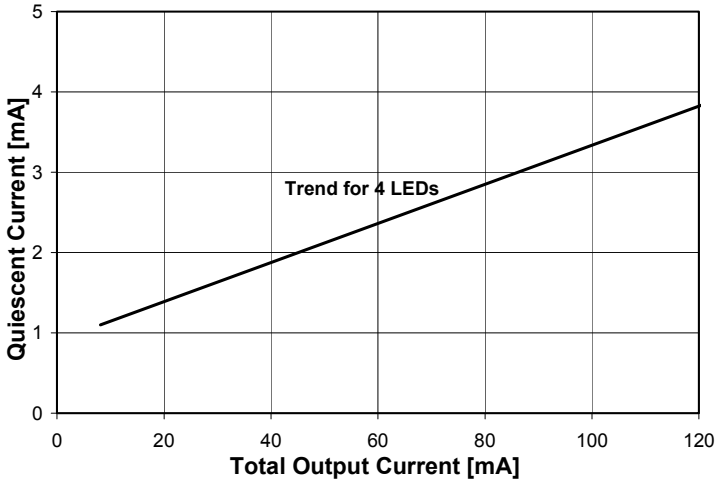

### Efficiency vs. Load at Low Battery




### Mode Transition Voltage vs. LED Voltage




### Quiescent Current Trend

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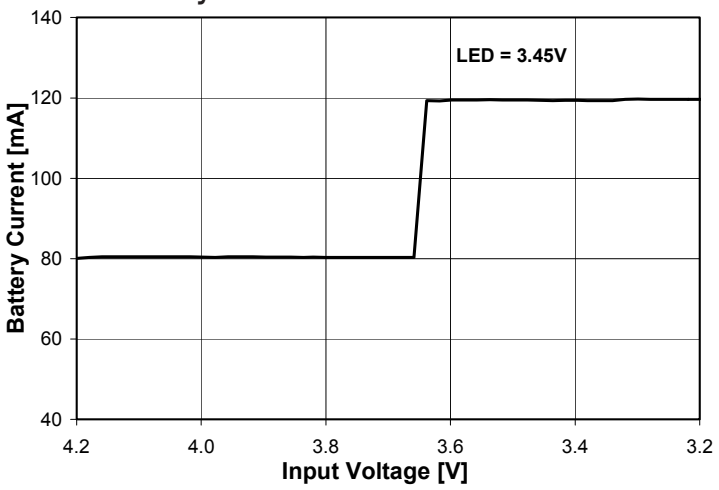
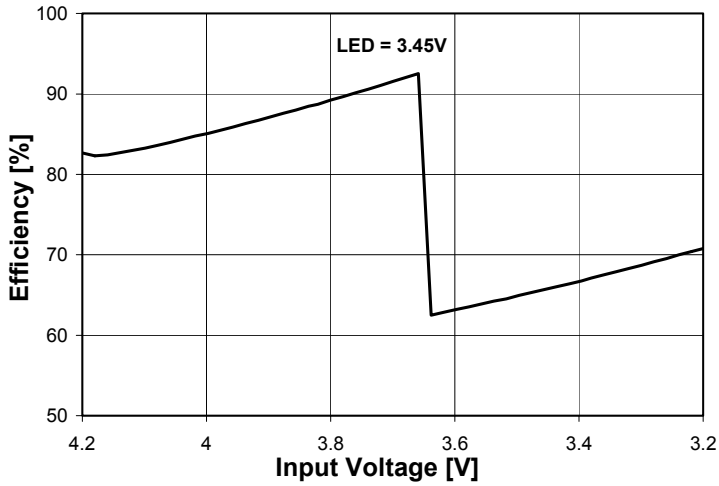
## Typical Characteristics with 4 LEDs

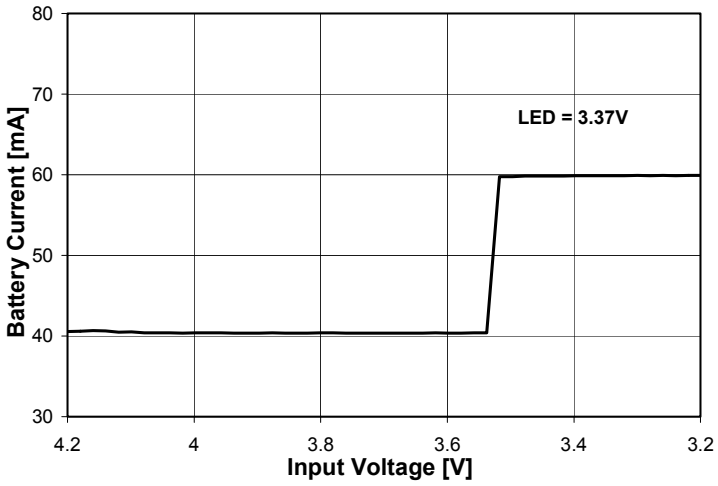
**Battery Current for 4 LEDs at 20mA**



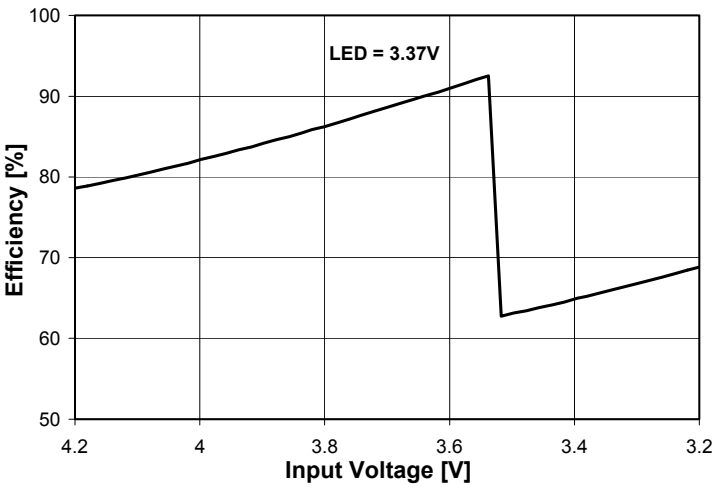

**Efficiency for 4 LEDs at 20mA**



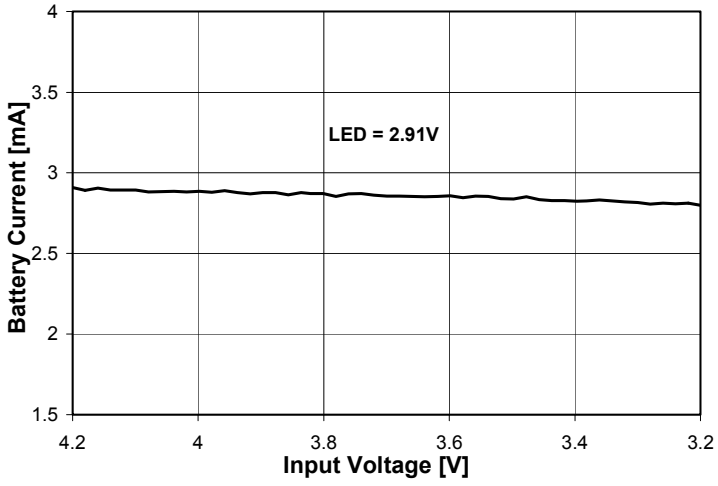

**Battery Current for 4 LEDs at 10mA**



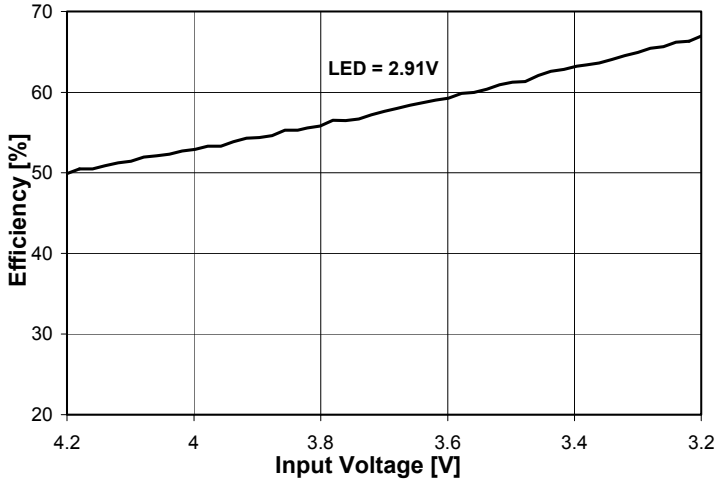

**Efficiency for 4 LEDs at 10mA**




**Battery Current for 4 LEDs at 0.5mA**




**Efficiency for 4 LEDs at 0.5mA**

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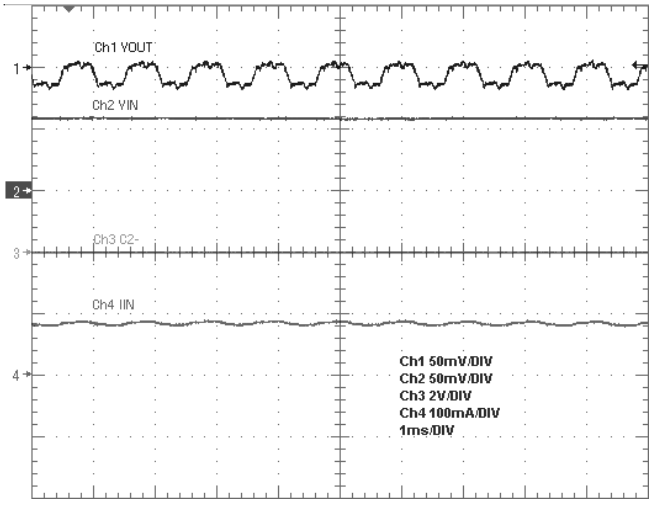
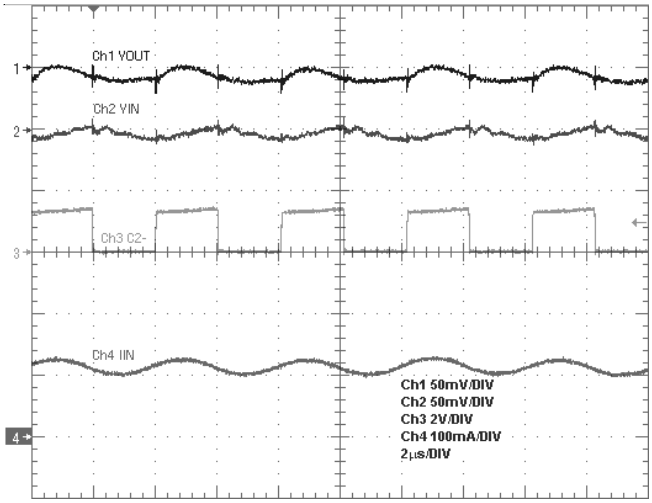
## Typical Characteristics with 4 LEDs

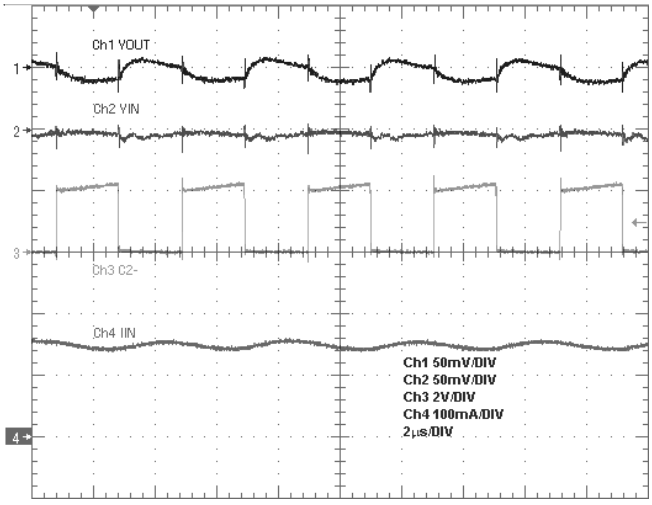
### Ripple in 1x Mode for 4 LEDs at 20mA Each




### Ripple in 1.5x Mode for 4 LEDs at 20mA Each




### Ripple in 2x Mode for 4 LEDs at 20mA Each

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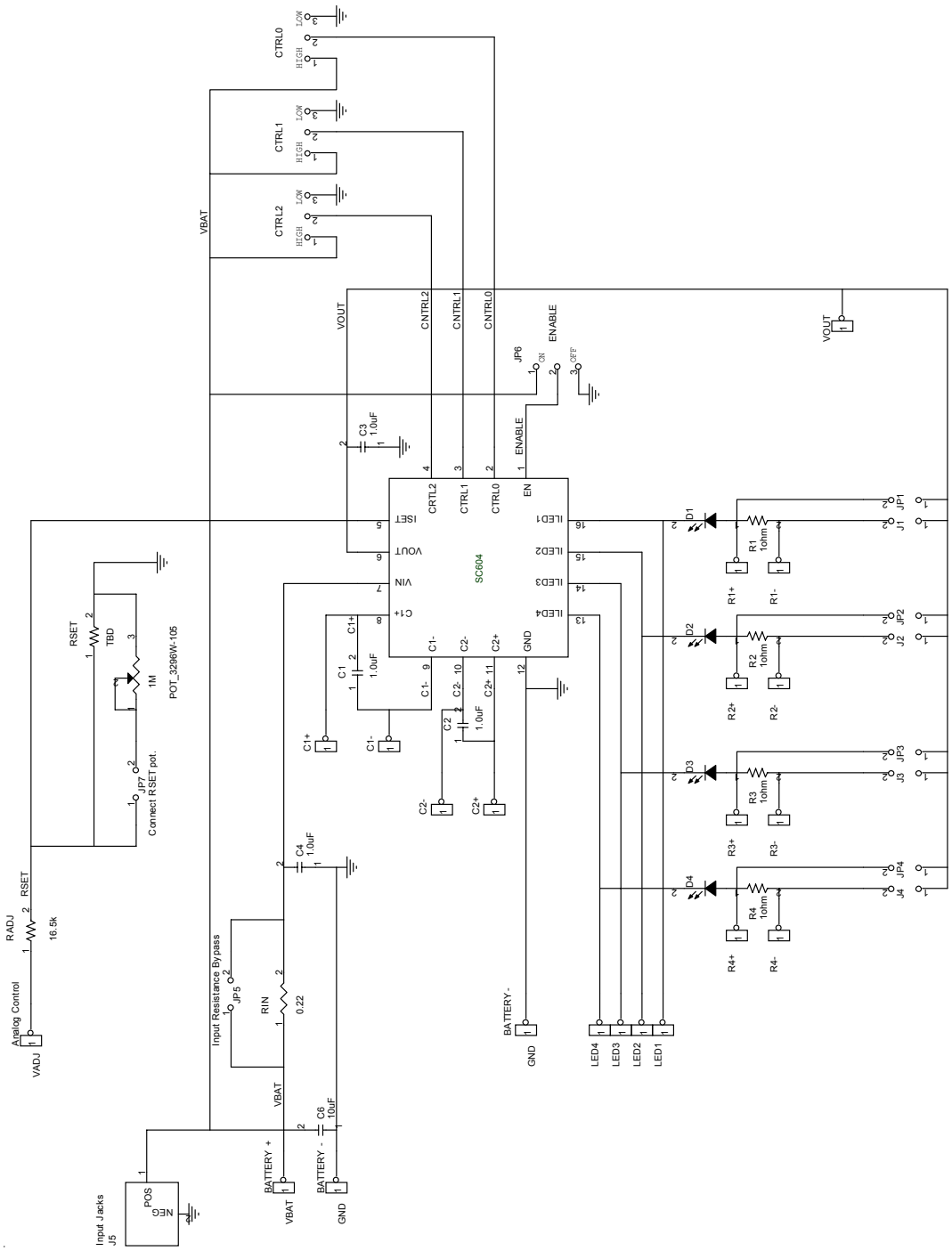
## Evaluation Board Schematic

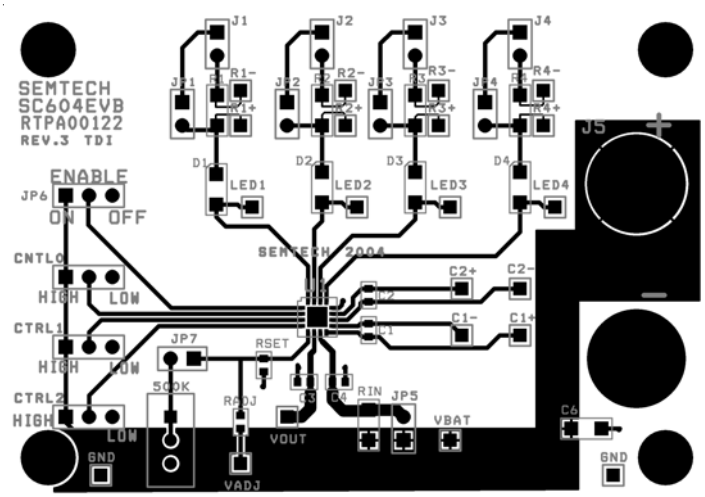


## Evaluation Board Bill of Materials

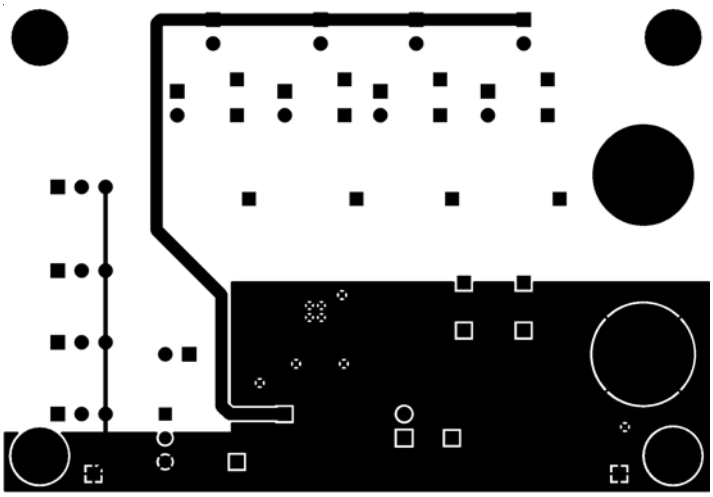
| Reference | Value | Comment |
|---|---|---|
| U1 | SC604A | Component references in bold are the only essential design components. |
| C1,C2,C3,C4 | 1.0µF | Bucket, input and output capacitors. Ceramic, low ESR type, 6.3V rating or higher. |
| C6 | 10µF | This extra capacitor supports usage of long power leads from benchtop supply. |
| D1,D2,D3,D4 | - | Add LEDs to meet the requirements of the application. |
| J1, J2, J3, J4 | - | Jumpers in series with each LED. |
| JP1,JP2,JP3,JP4 | - | Jumpers to bypass each 1Ω sense resistor and bypass J1, J2, J3 and J4. |
| JP5 | - | Jumper for bypassing the R4 input resistor. |
| JP6 | - | Enable jumper. |
| JP7 | - | Connects RSET potentiometer. Remove this jumper when using a fixed value R1. |
| CTRL0,CTRL1,CTRL2 | - | Jumpers provide High/Low settings for the control bits. |
| RSET | - | RSET resistor |
| | 3296W-105 | Evaluation board has 1MΩ potentiometer in place of R1. |
| R4 | 0.22Ω | Series input resistor for studying effects of input resistance. |
| RADJ | 16.5kΩ | Resistor for analog brightness control. Apply test signal of 0 to 1.2V at VADJ test point. |
| J5 | - | Banana jacks for power supply. |

## Evaluation Board Gerber Plots

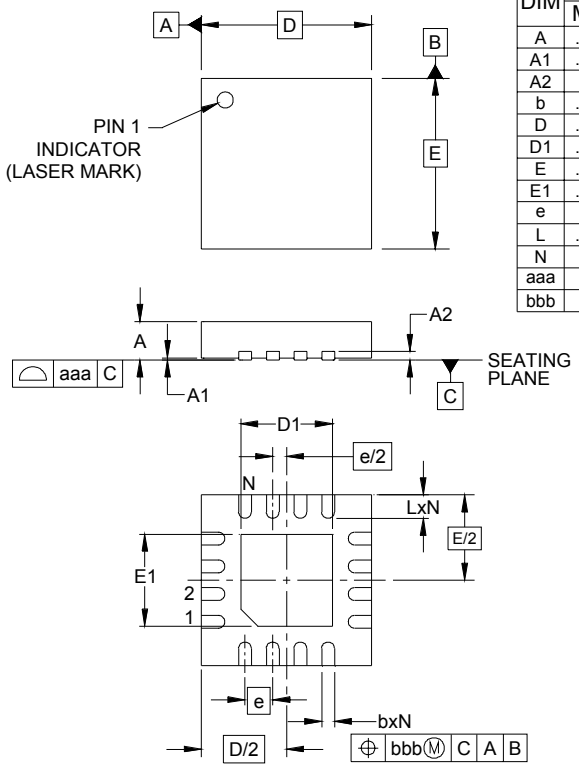
Top View




Bottom View



## Outline Drawing- MLP-16 [4x4]




| DIM | DIMENSIONS | | | | | |
|---|---|---|---|---|---|---|
| | INCHES | | | MILLIMETERS | | |
| | MIN | NOM | MAX | MIN | NOM | MAX |
| A | .031 | - | .040 | 0.80 | - | 1.00 |
| A1 | .000 | - | .002 | 0.00 | - | 0.05 |
| A2 | - | (.008) | - | - | (0.20) | - |
| b | .010 | .012 | .014 | 0.25 | 0.30 | 0.35 |
| D | .153 | .157 | .161 | 3.90 | 4.00 | 4.10 |
| D1 | .074 | .085 | .089 | 1.90 | 2.15 | 2.25 |
| E | .153 | .157 | .161 | 3.90 | 4.00 | 4.10 |
| E1 | .074 | .085 | .089 | 1.90 | 2.15 | 2.25 |
| e | .026 BSC | | | 0.65 BSC | | |
| L | .018 | .022 | .026 | 0.45 | 0.55 | 0.65 |
| N | 16 | | | 16 | | |
| aaa | .003 | | | 0.08 | | |
| bbb | .004 | | | 0.10 | | |

NOTES:

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).
2. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

## Marking Information

yyww = Datecode (Example: 0452)

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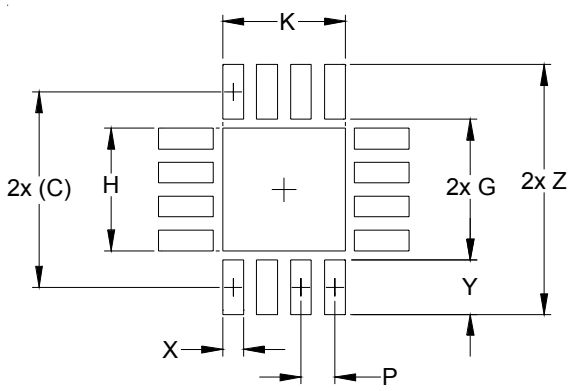
## Land Pattern MLP-16pin [4x4]




| DIMENSIONS | | |
|---|---|---|
| DIM | INCHES | MILLIMETERS |
| C | (.148) | (3.75) |
| G | .106 | 2.70 |
| H | .091 | 2.30 |
| K | .091 | 2.30 |
| P | .026 | 0.65 |
| X | .016 | 0.40 |
| Y | .041 | 1.05 |
| Z | .189 | 4.80 |

NOTES:

1. THIS LAND PATTERN IS FOR REFERENCE PURPOSES ONLY. CONSULT YOUR MANUFACTURING GROUP TO ENSURE YOUR COMPANY'S MANUFACTURING GUIDELINES ARE MET.

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