

# W-5614EVAL1 Evaluation Board for W-5614 1-Wire LED Driver

**HALOGEN FREE  
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## INTRODUCTION

This document describes the W-5614EVAL1 Evaluation / Demonstration Board for the COPAL ELECTRONICS W-5614, 4-channel LED driver with 1-wire interface. The functionality and major parameters of the W-5614 can be evaluated with the W-5614EVAL1 board.

The W-5614 is a 4-channel charge pump that has been designed to drive up to 4 LEDs connected in parallel. The W-5614 is operating in either 1x (LDO) mode, or 1.5x mode and provides tightly matched regulated current through the four LED outputs. The programmable current and dimming control of LEDs are achieved using a 1-wire interface. The user can set the current from 0 mA to 31mA with 1 mA step, by toggling the EN/DIM input. Detailed description and electrical characteristics are in the W-5614 data sheet.

## W-5614EVAL1 BOARD HARDWARE

The evaluation board contains the W-5614 in a typical application circuit, driving up to 4 white LEDs. The W-5614 is controlled through 1-wire interface using an 8-bit microcontroller. The board is powered from an attached 3V (2 x 1.5V AA) battery. The board schematic is shown in Figure 1.

The W-5614 input voltage, VIN, is supplied on board from a +3V voltage, VDD (VBAT = 3V) or from an external variable voltage applied to the VIN EXT (T1) pad. The voltage supplied at the VIN input of the W-5614 device can be selected using jumper options for the J1 connector.

The EN/DIM input is controlled on board through the microcontroller (EN/DIM INT) when J2 connector is

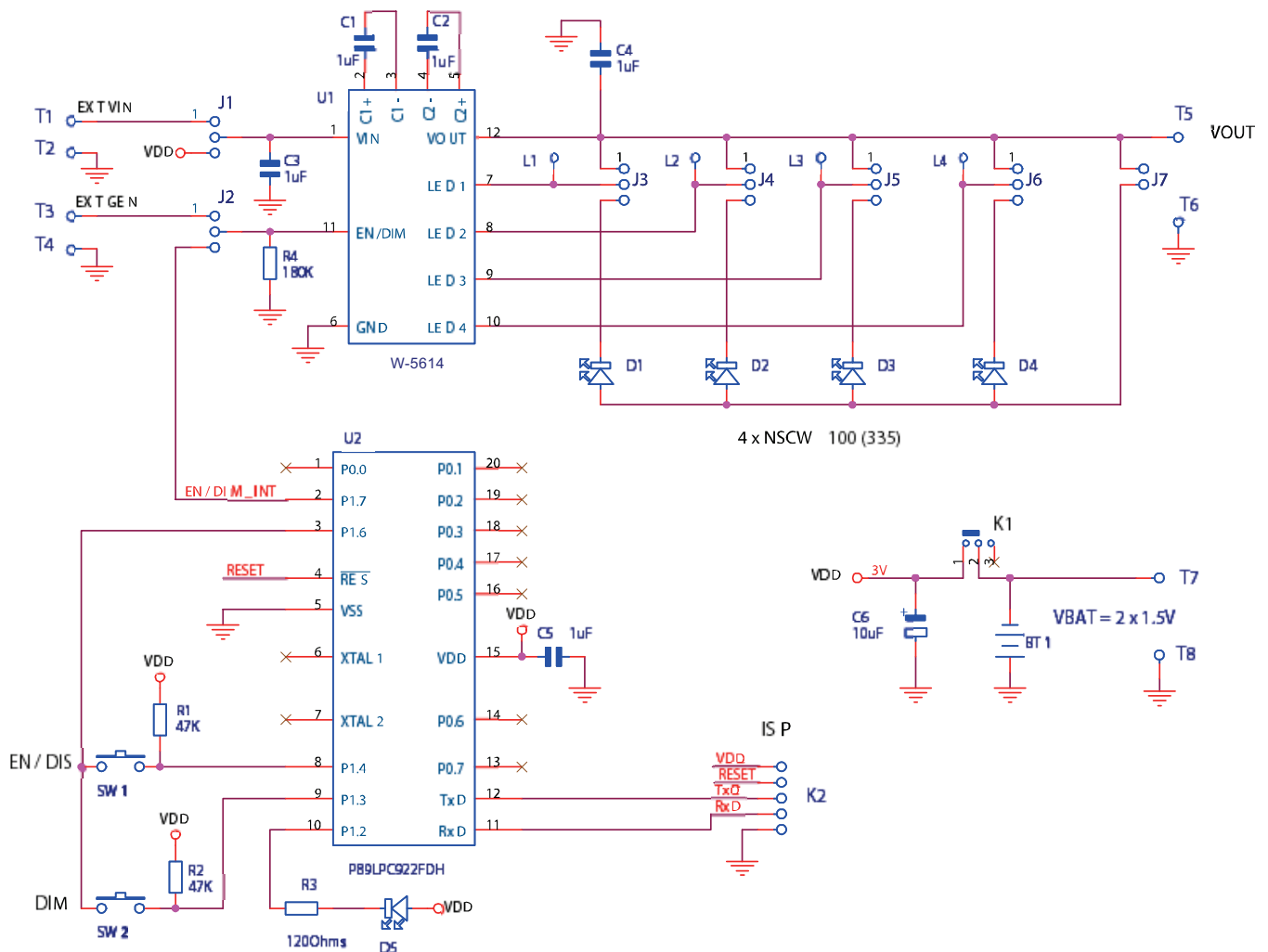
jumpered between Pin #2 and Pin #3 (jumper shunt - right position). The user interface for controlling the W-5614 through the microcontroller is provided by two momentary SPST pushbuttons: SW1 (EN/DIS) and SW2 (DIM).

The EN/DIS pushbutton allows the user to set the EN input high (the device enabled) or low (the device shutdown). The action of the SW1 pushbutton has a toggle function: first time pressing the switch it sets the EN high and the associated red LED indicator will be on. The second action sets the EN input low.

The DIM pushbutton allows the user to program the LED current. Every time the pushbutton is pressed (short action), an active low pulse ( $t_w < 200\mu s$ ) is generated on the EN/DIM input of the W-5614 device. At every falling edge of the pulses provided at EN/DIM input, the LED current is decreased by 1mA step. On the first transition from high to low on EN/DIM, the LED current is set to the maximum value of 31mA. The 32nd pulse sets the ILED = 0mA and the LEDs will be off. The next action of the DIM switch sets the current back to the maximum value of 31mA.

When the DIM (SW2) pushbutton is held down, the microcontroller sends sequentially pulses on the EN/DIM input. As a result the LED current will cycle automatically step by step through whole range of 0 to 31mA.

The user can also choose to drive the EN/DIM input of the W-5614 device with an externally provided signal, if the J2 connector has the jumper between Pin #1 and Pin #2 (jumper shunt - left position). The external signal should be connected to T3/GEN test point.



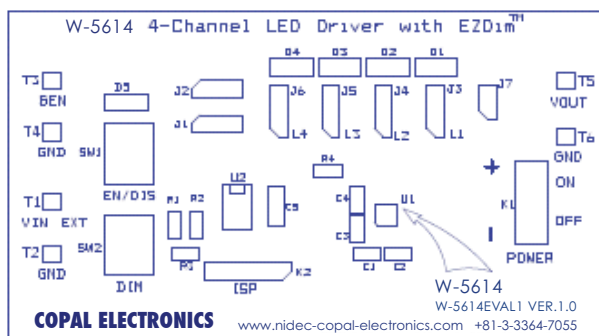
**Figure 1. W-5614EVAL1 Board Schematic**

The user can connect or disconnect the W-5614 outputs to the white LEDs using the jumper options for J3, J4, J5, J6 and J7 connectors. To connect the LEDs to the W-5614 outputs the J3 to J6 connectors should have the jumper between Pin #2 and Pin #3 (on board shunt - up position) and J7 connector jumpered. Any unused LED output pin can be connected to the VOUT pin with the jumper shunt between Pin #1 and Pin #2 (on board shunt - down position) of the corresponding J3 to J6 connectors. The user can evaluate the LED current through each W-5614 output channel or the total output current

with a current meter connected at the J3 to J7 header pin connectors.

Test points T1 to T6 are available to apply the external voltages/signal generator, or to measure the output voltages / signals provided by the W-5614.

Table 1 shows the component list for this evaluation board. The component placement for the W-5614EVAL1 is shown in Figure 2.



**Figure 2. W-5614EVAL1 Board**

**Table 1. W-5614EVAL1 Board List of Components**

Name	Manufacturer	Description	Part Number	Units
U1	COPAL ELECTRONICS	4-Channel LED Driver with 1-Wire Interface, TDFN-12	W-5614HV2	1
U2	Philips Semiconductor	8-bit flash microcontroller, TSSOP20	P89LPC922FDH	1
C1 to C5	AVX	Ceramic Capacitor 1 $\mu$ F / 10V, 10%, X5R, Size 0603	0603ZD105KAT2A	5
C6	Kemet	Tantalum Capacitor 10 $\mu$ F / 16V, SMD	T491B106K016AS	1
R1, R2	Yageo	SMT Resistor 1/8W, 47 Kohm, 0805	Digi-Key 311-47.0KCCT-ND	2
R3	Yageo	SMT Resistor 1/8W, 120 ohm, 0805	Digi-Key 311-120CCT-ND	1
R4	Yageo	SMT Resistor 1/8W, 180 Kohm, 0805	Digi-Key 311-180KCCT-ND	1
D1 to D4	Nichia	White LED, SMT	NSCW100 (or NSCW335)	4
D5	LiteOn	Red LED, SMT	LTST-T970KRKT	1
SW1, SW2	HDT	Momentary Contact Switch, SPST (On)-Off	Schukat Electronic DTS67R	2
K1	E-Switch	Slide Switch, SPDT	EG1218 (Digi-Key EG1903-ND)	1
J1 to J6		3-pin Header Connector, 0.1", Single Strip	Digi-Key S1012-03-ND (or equiv)	6
J7		2-pin Header Connector, 0.1", Single Strip	Digi-Key S1012-02-ND (or equiv)	1
	Specialty Electronics	Shunts	2JM-G	7
T1 to T6	Mil-Max	Pin Receptacle (Test Points)	#0149-0-15-01-30-14-04-0 (or equiv)	6
BTH	Keystone	Battery Holder 2 x AA 1.5V (optional)	Digi-Key 2462K-ND	1

## W-5614 EVALUATION

The W-5614EVAL1 gives the user a way to evaluate the W-5614 in a typical application of driving multiple LEDs. The user can connect up to 4 LEDs to the W-5614 output, using the jumper options for J3, J4, J5, J6 and J7 header-pin connectors.

The following steps are an example of how the user can evaluate the W-5614 white LED driver:

### 1.0) Driving LEDs, Shutdown Mode, Quiescent Current and Open Circuit Configuration

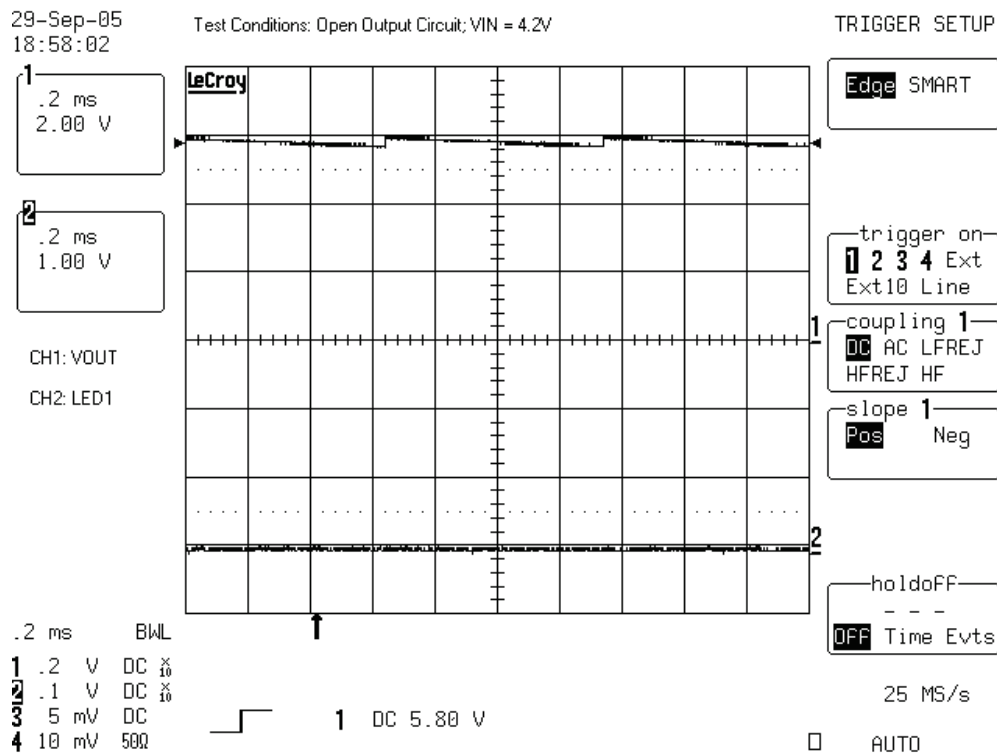
- a) Connect the LEDs to the W-5614 output.
  - Connect VOUT to the LEDs anode terminal using a jumper at J7 header-pin connector.
  - Connect each LED cathode terminal to the W-5614 outputs, LED1 to LED4, using the jumper options (Pin #2 and Pin #3) for J3 to J6 header pin connectors.
- b) Connect a jumper shunt between Pin #2 and Pin #3 (on board shunt - right position) of J2 header-pin connector. That will control the EN/DIM input from on-board microcontroller.
- c) Set the jumper shunt for the J1 connector to the left position (Pin #1 and Pin #2) to supply externally provided voltage at the VIN input of the W-5614 device. Apply the external voltage supply,  $V_{ext}$  ( $3.0V < V_{IN} < 5.0V$ ) between VIN (T1) and GND (T2).
- d) Turn "ON" the on-board POWER switch. That provides the power to the microcontroller which drives the EN/DIM input.
- e) The W-5614 is in the shutdown mode (EN pin is held low) if the SW1 switch (EN/DIS) is not pressed and the associated LED (red) is not ON.
  - Connect a current meter, IM1, between  $V_{ext}$  and VIN (T1) pad to measure the shutdown current:  $I_{QSHDN} \ll 1\mu A$ .
- f) Set EN high (EN = "1") by pressing the EN/DIS pushbutton (one time). The white

LEDs connected to the W-5614 outputs will remain OFF ( $I_{OUT} = 0mA$ ). The device operates in 1x mode.

- The current measured by IM1 meter (IIN) is the quiescent current in 1x mode of operation:  
 $I_Q$  (1x mode) = 0.4mA to 0.6mA for  $V_{IN}$  ranges between 3V and 5V
- g) Toggle EN/DIM input by pressing the DIM pushbutton (short action) 32 times. The LED current will change from the max value (31mA) to 0mA (LED OFF).
    - The input current measured by the IM1 meter represents the quiescent current in 1.5x mode:  $I_Q$  (1.5x mode) = 2.7mA to 3.4mA for  $V_{IN}$  between 3.0V and 3.6V

**Note:** The values measured at f) and g) include also  $16\mu A$  current through the R4 pull-down resistor at EN/DIM input.

- h) Observe the open circuit configuration functionality with the VOUT pin disconnected from the LEDs and the LED current preset to a certain value:
  - Toggle the EN/DIM input pressing the DIM pushbutton to set  $I_{LED} = 20mA$ .
  - Disconnect the LEDs from the W-5614 VOUT pin: remove the jumper shunt from the J7 connector.
  - Observe the quiescent current,  $I_Q$ , measured by the current meter connected between the  $V_{ext}$  and VIN (T1) pin: for  $V_{IN} = 3.3V$  to  $4.5V$ ;  $I_Q = 4.2mA$  to  $1.9mA$  typically.
  - Observe the W-5614 output using a scope probe connected on VOUT (T5) test point (GND = T6). In this configuration with output open circuit the W-5614 operates in 1.5x mode:  $V_{OUT} = 1.5 \times V_{IN}$ . For  $V_{IN}$  higher than 4.2V approximately, the output voltage is limited below  $V_{OUT} \max = 6V$ . Figure 3 shows the output voltage, VOUT for  $V_{IN} = 4.2V$ , open circuit configuration.



**Figure 3. The Output Voltage Waveform for Open Circuit Configuration, VIN = 4.2V.**

i) The unused LED channels should be connected to VOUT pin in order to optimize the W-5614 functionality.

- Connect 3 LEDs at the LED1, LED2, LED3 outputs: jumper shunt between Pin #2 and Pin #3 at the associated header pin connector (up position).
- Disconnect D4 LED from the LED4 output of the W-5614 and connect it to the VOUT pin: jumper shunt between Pin #1 and Pin #2 for J6 connector (down position).
- Observe the output sink current for the disabled channel measured by the current meter connected between the Pin #1 and Pin #2 of the corresponding header pin connector (J6), below 200 $\mu$ A:

VIN = 3.3V; I\_unused\_ch = 157 $\mu$ A (for ILED set to 31 mA to 0mA)

VIN = 4.2V: I\_unused\_ch = 165 $\mu$ A (for ILED set to 31mA to 0mA).

## 2.0) Efficiency Evaluation

The efficiency is evaluated according to the following equation:

$$\text{Efficiency \%} = (\sum VFi \times ILEDi) / (IIN \times VIN) \times 100$$

where VFi = VOUT – VLed<sub>i</sub> is the voltage dropout across the LED<sub>i</sub>, ILED<sub>i</sub> is the current through one LED; i = 1 to 4.

## 2.1) Efficiency Evaluation versus Line Voltage

- Set the configuration for 4 LEDs connected to the W-5614 outputs.
- Insert a current meter, IM1, between input supply voltage, Vext, and VIN pad and monitor the input current.
- Set the input voltage for the initial value VIN = 3V. Monitor VIN at VIN (T1) test point with a voltage meter.
- Set the LEDs On at ILED = 20mA: EN/DIS = ON. Toggle 12 times EN/DIM input through DIM Pushbutton.
- Measure the output voltage on VOUT (T5).
- Measure VLED1 to VLED4 at J3 to J6 connectors (Pin #2).
- Repeat all the above measurements for VIN increase between 3V and 5.0V.

- Repeat the same measurements for VIN decrease from 5.0V to 3.0V.

**Note:** It is recommended to turn Off/On (EN/DIS) the device and set the LED current ILED = 20mA every time when you change the VIN voltage (or at least around the switching point from 1.5x mode to 1x mode).

Figure 4 and Figure 5 respectively, show the W-5614 input current (IIN) and output voltage (VOUT) versus the line voltage using 4 LEDs driven at 20mA. The values named with + are for VIN increase and the values named with – are taken for VIN decrease. When the input voltage, VIN, decreases to lower value (as it happens in real applications due to the battery discharge), the W-5614 device switches from 1x mode to 1.5x mode at VIN = 3.6 approximately (in this study case Vsw- = 3.54V).

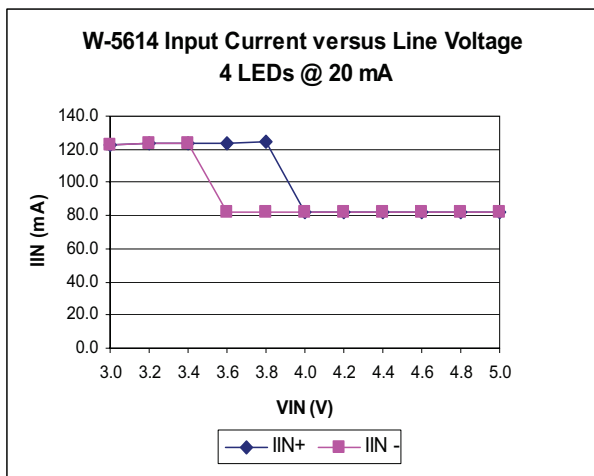


Figure 4. Input Current versus Line Voltage

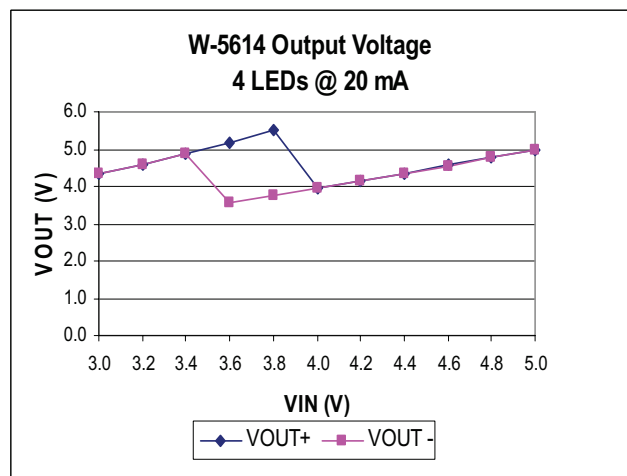
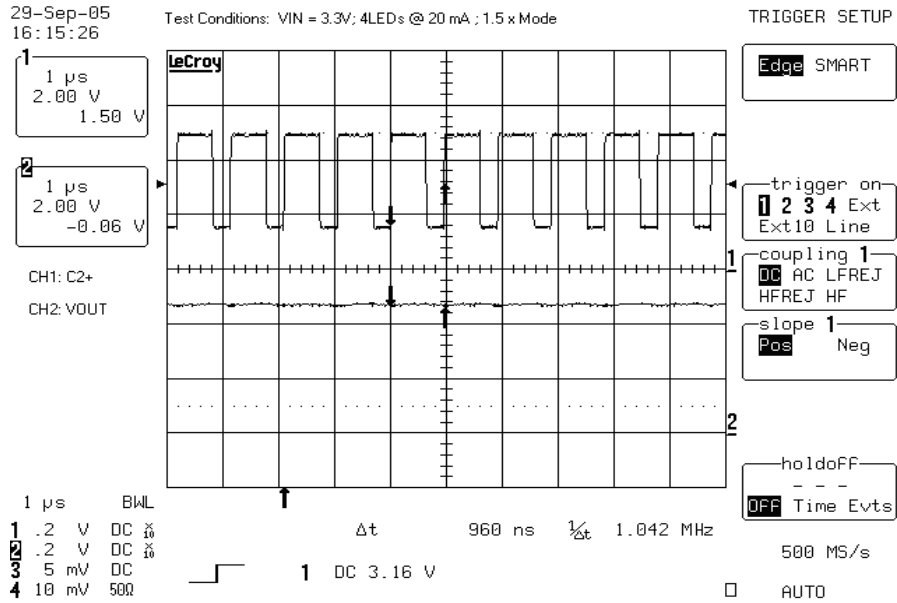


Figure 5. Output Voltage versus Line Voltage

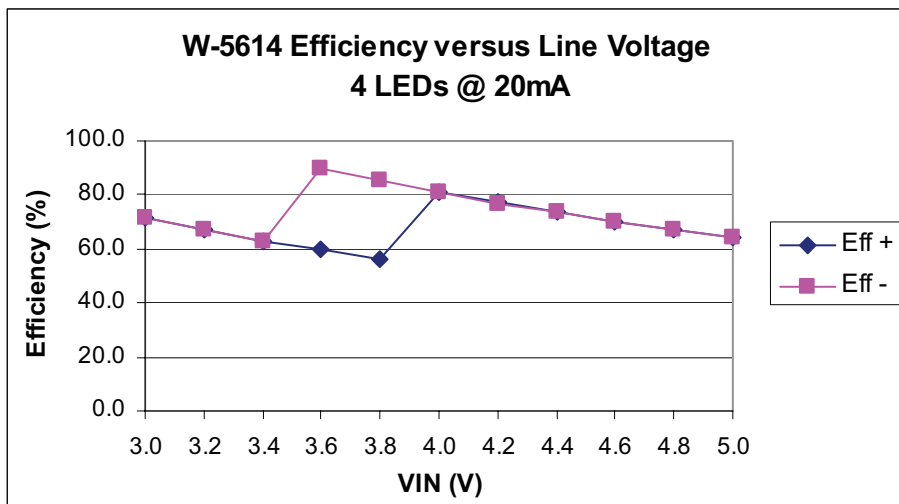


**Figure 6. Internal Switch and Output Voltage (VIN = 3.3V, IOU = 80 mA)**

The internal switch frequency, typical 1 MHz, is shown in the waveforms from the Figure 6; CH1: signal measured on the C2+ pad, CH2: output voltage, VOUT (1.5x mode, VIN = 3.3V).

The W-5614 efficiency versus line voltage with 4 LEDs driven at 20mA, is shown in Figure 7. The W-5614 efficiency is optimized for Li-Ion battery

applications. At the nominal battery voltage value, the W-5614 operates in 1x mode providing a high efficiency (>80%). The 1x mode of operation is provided until VIN drops below 3.5V typically. At this point the device switches to 1.5x operation mode. In the battery powered applications, the decrease of the line voltage (battery voltage) should be taken in consideration.



Note: Eff + : Efficiency for VIN increase; Eff - : Efficiency for VIN decrease

**Figure 7. W-5614 Efficiency versus Line Voltage**

## 2.2) Efficiency Evaluation versus Load

The W-5614 efficiency can also be evaluated versus the total output current driven through the LEDs. The following steps are an example of efficiency measurements for different output current values at two input voltage values.

- Set the configuration for 4 LEDs driven by the W-5614 device.
- Insert a current meter, IM1, between input supply voltage,  $V_{ext}$ , and VIN pad and monitor the input current, IIN.
- Set the input voltage for VIN = 3.2V. Measure the input voltage at VIN (T1) test point with a voltage meter.
- Set the ILED current using EN/DIS and DIM switches: turn Off/ON (EN/DIS) and Toggle DIM; set initial value ILED = 30mA (IOUT = 4 x 30mA = 120mA).
- Observe the IIN current on the IM1 meter.
- Measure the output voltage on VOUT (T5) pin.

- Measure all the LED outputs voltages, VLED1 to VLED4.
- Repeat steps d) to g) for the total output current IOUT = 100mA, 80mA, 60mA, 40mA and 20mA.

All the above steps can also be performed for the other input voltage, i.e. VIN = 4.0V.

**Note:** For every IOUT setting, turn the LEDs Off/On using the EN/DIS pushbutton. After enabling the device, set the desired ILED value toggling the DIM switch.

Figure 8 shows the W-5614 efficiency versus the total output current driven through the LEDs for VIN = 3.2V and VIN = 4.0V. The efficiency has been calculated according to the following expression:

$$\text{Eff} = (\text{IOUT} * \text{VF\_average}) / (\text{IIN} * \text{VIN}),$$
 where  $\text{VF\_average} = (\text{VLED1} + \text{VLED2} + \text{VLED3} + \text{VLED4})/4$ .

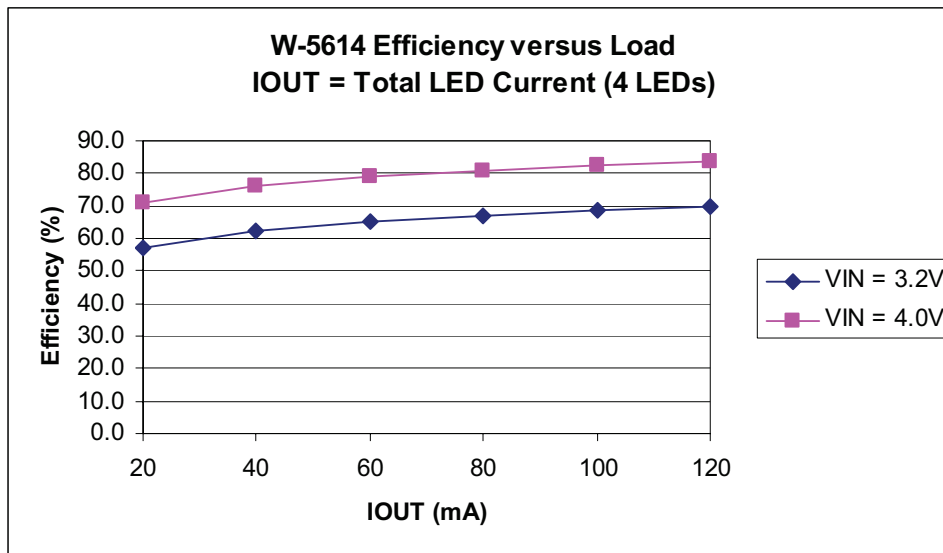


Figure 8. W-5614 Efficiency versus Load

## REVISION HISTORY

Date	Rev.	Reason
12/22/2005	A	Initial Issue

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Document No: 6046  
Revision: A  
Issue date: 12/22/05