Demonstration/Evaluation Board for CAT3643/3644 Quad-Mode® LED Driver

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1. INTRODUCTION

This document describes the CAT3643/3644 Demonstration/Evaluation board for the Catalyst Semiconductor CAT3643/3644, Quad-Mode fractional LED driver. The functionality and major parameters of the CAT3643/3644 can be evaluated with the CAT3643(4)DB1 or CAT3643DB2 board.

The CAT3643/3644 is a 3/4-channel charge pump that has been designed to drive with an ultra-high efficiency up to 3 or 4 LEDs connected in parallel. The CAT3643/3644 provides tightly matched regulated current through the LED outputs. The programmable current and dimming control of LEDs are achieved using a 1-wire digital interface. The maximum LED current is set by an external RSET resistor. The LED current dimming is available through 6 different levels by toggling the EN/DIM input. Detailed description and electrical characteristics are in the CAT3643 and CAT3644 data sheets..

2. BOARD HARDWARE

The demonstration/evaluation board contains the CAT3643 or CAT3644 in a typical application circuit, driving up to 3 or 4 white LEDs, respectively. The CAT3643/3644 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 CAT3643/3644 input voltage, V_{IN}, is supplied on board from a +3V voltage, V_{DD} / V_{BAT} or from an external variable voltage applied to the $V_{IN\ EXT}$ (T1) test point. The voltage supplied at the V_{IN} input of the CAT3643/3644 device can be selected using jumper options for the J1 connector (Table 1).

The EN/DIM input is controlled on board through the microcontroller when J2 connector (Table 2) is jumpered between Pin #2 and Pin #3 (jumper shunt - right position). The user interface for controlling the CAT3643/3644 through the microcontroller is provided by two momentary SPST pushbuttons: EN/DIS and DIM.

The EN/DIS (Enable/Disable) pushbutton allows the user to set the EN/DIM input high (the device enabled) or low (the device shutdown). The action of the EN/DIS pushbutton has a toggle function: first time pressing the switch it sets the EN/DIM high and the associated red LED indicator (D5) will be on. At this time, the CAT3643/3644 device will drive the white LEDs ON at the current set by the external RSET resistor (R_2 + R_3). The second action sets the EN/DIM input low and the white LEDs will be OFF.

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 < 100µs) is generated on the EN/DIM input of the CAT3643/3644 device. At every rising edge of the pulses provided at EN/DIM input, the LED current is divided by half providing 6 different levels of current. On the first transition from low to high on EN/DIM (after the device is enabled), the LED current is set to 50% from maximum current (full scale). The following pulses on EN/DIM input will set the LED current to 25%, 12.5%, 6.25% and 3.125% from initial value. The 6th pulse sets the I_{LED} current at the full scale and the dimming cycle can be repeated.

The maximum LED current (full scale) is set through the external resistors connected to the RSET pin (R_2, R_3). Using the variable resistor R_3, the maximum LED current can be set from few mA to 30mA. Most white LEDs are driven at a maximum current between 15mA and 20mA to ensure a pure “white” light.

When the DIM 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 dimming levels.

The user can also choose to drive the EN/DIM input of the CAT3643/3644 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/EXT EN/DIM (GEN) test point (Table 2).

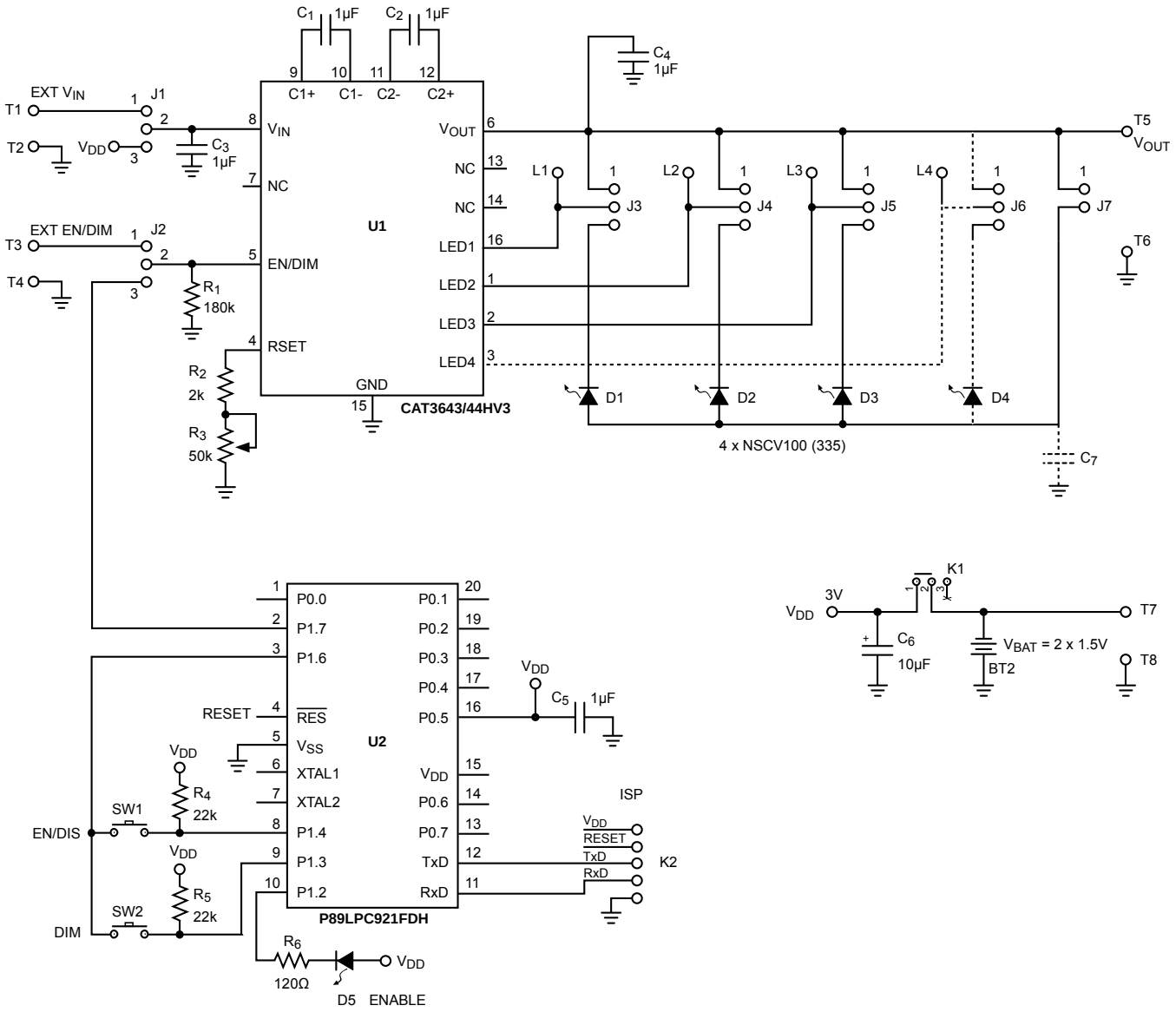


Figure 1. CAT3643/3644 Board Schematic

VIN	
EXTERNAL VIN	**INTERNAL VDD=VBAT=3V**
Jumper **J1** Pin #1-Pin #2 (**LEFT** position)	Jumper **J1** Pin #2-Pin #3 (**RIGHT** position)
Connect **Vext** at **T1** Test Point (T2 = GND)	NA

Table 1

EN/DIM	
EXTERNAL EN/DIM	**INTERNAL (microcontroller)**
Jumper **J2** Pin #1-Pin #2 (**LEFT** position)	Jumper **J2** Pin #2-Pin #3 (**RIGHT** position)
Connect Signal at **T3** Test Point (T4 = GND)	NA

Table 2

The user can connect or disconnect the CAT3643/3644 outputs to the white LEDs using the jumper options for J3, J4, J5, J6 and J7 connectors. To connect the LEDs to the CAT3643/3644 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 V_{OUT} 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 CAT3643/3644 output channel or the total output current with a current meter connected at the J3 to J7 header pin connectors.

Note:

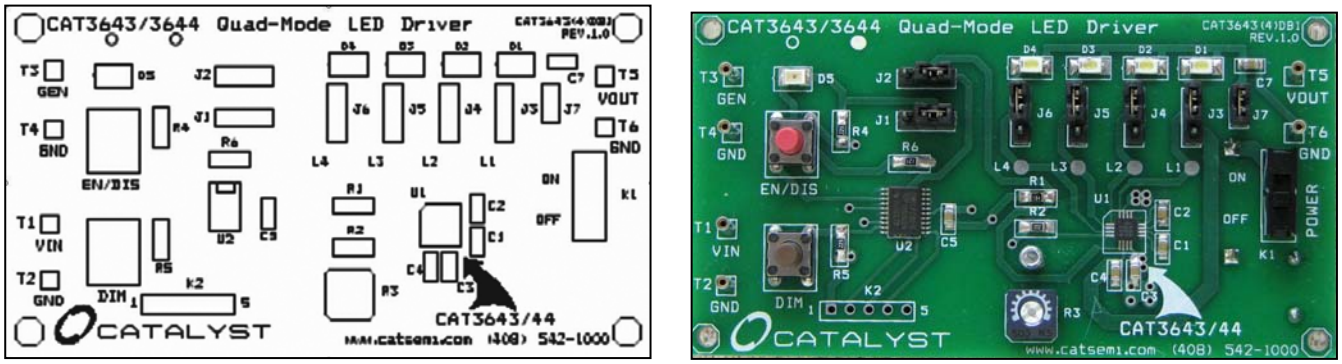
An additional C7 (1µF) capacitor is needed when a current meter is inserted to measure the LED current.

Test points T1 to T6 are available to apply the external voltages/signal generator, or to measure the output voltages/signals provided by the CAT3643/3644.

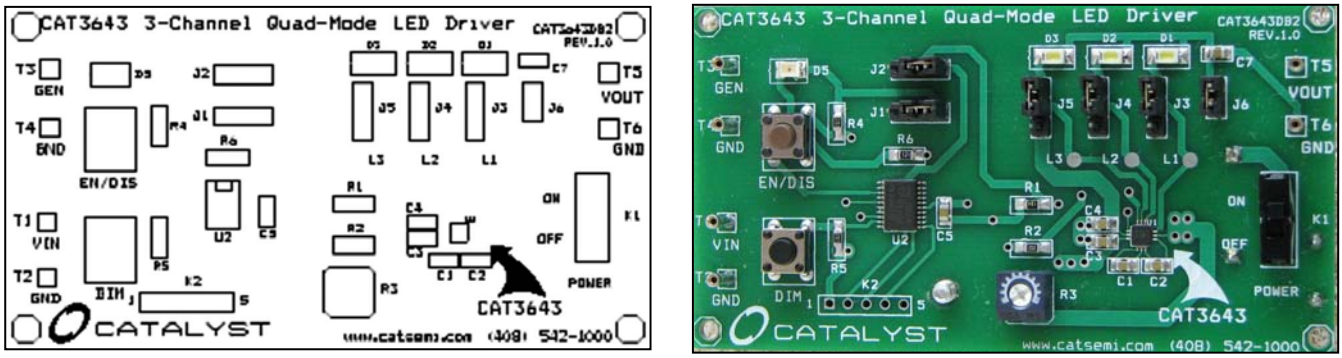
The board is available in the following options:

- **CAT3643(4)DB1** board populated either with 3-channel CAT3643 or 4-channel CAT3644 in TQFN 16-pin package;
- **CAT3643DB2** board populated with 3-channel CAT3643 in XQFN 12-pin package.

Table 1 shows the component list for this evaluation board. The component placement and the boards pictures are shown in Figure 2.



a) CAT3643(4)DB1 Board



b) CAT3643DB2 Board

Figure 2. CAT3643/3644 Demo/Evaluation Board

Table 1. CAT3643(4)DB1 and CAT3643DB2 Boards List of Components

Name	Manufacturer	Description	Part Number	Units
U1	Catalyst Semiconductor	3(4)-Channel Quad-Mode LED Driver, TQFN-16, 3 x 3mm – CAT3643(4)DB1 3-Channel Quad-Mode LED Driver, XQFN-12, 2.5 x 2.5mm – CAT3643DB2	CAT3643HV3/3644HV3 or CAT3643HL1	1
U2	Philips Semiconductor	8- bit flash microcontroller, TSSOP20	P89LPC922FDH	1
C1 to C5(C7)	AVX	Ceramic Capacitor 1µF / 10V, 10%, X5R, Size 0603	0603ZD105KAT2A	6
C6	Kemet	Tantalum Capacitor 10µF / 16V, SMD	T491B106K016AS	1
R1	Yageo	SMT Resistor 1/8W, 180kΩ, 0805	Digi-Key 311-180KCCT-ND	1
R2	Yageo	SMT Resistor 1/8W, 2kΩ, 0805	Digi-Key 311-2.0KCCT-ND	1
R3	CKT	Trimmer Pot, 1/4", 50kΩ	PKT50HK50	1
R4, R5	Yageo	SMT Resistor 1/8W, 22kΩ, 0805	Digi-Key 311-22.0KCCT-ND	2
R6	Yageo	SMT Resistor 1/8W, 120Ω, 0805	Digi-Key 311-120CCT-ND	1
D1 to D3(D4)	Nichia	White LED, SMT	NSCW100 (or NSCW335)	3(4)
D5	LiteOn	Red LED, SMT	LTST-T970KRKT	1
EN/DIS, DIM	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 J5(J6)		3-pin Header Connector, 0.1", Single Strip	Digi-Key S1012-03-ND (or equiv)	5(6)
J6 or J7		2-pin Header Connector, 0.1", Single Strip	Digi-Key S1012-02-ND (or equiv)	1
	Specialty Electronics	Shunts	2JM-G	6(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

3. CAT3643/44 EVALUATION

The CAT3643(4)DB1 and CAT3643DB2 boards give the user a way to evaluate the CAT3643 and CAT3644 in a typical application of driving multiple LEDs.

The user can connect up to 3/4 LEDs to the CAT3643/44 output, using the jumper options for J3, J4, J5, J6/J7 header-pin connectors.

The following steps are an example of how the user can evaluate the CAT3643 device, using the CAT3643(4)DB1 board.

1) Driving LEDs, Shutdown Mode, Quiescent Current, Open Circuit Configuration

a) Connect the LEDs to the CAT3643 output.

- Connect V_{OUT} to the LEDs anode terminal using a jumper at J7 header-pin connector.
- Connect each LED cathode terminal to the CAT3643 outputs, LED1 to LED3, using the jumper options (Pin #2 and Pin #3) for J3 to J5 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 V_{IN} input of the CAT3643 device. Apply the external voltage supply, V_{EXT} ($2.5V < V_{IN} < 5.0V$) between V_{IN} (T1) and GND (T2).

d) Turn "ON" the on-board POWER switch. This provides the power to the microcontroller which drives the EN/DIM input.

e) The CAT3643 is in the shutdown mode (EN/DIM 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, I_{M1}, between V_{EXT} and V_{IN} (T_1) pad to measure the shutdown current: $I_{QSHDN} << 1\mu A$

f) Set EN/DIM high by pressing the EN/DIS pushbutton (one time). The white LEDs connected to the CAT3643 outputs will be ON. The LED current is set to the full scale by the external resistors ($R_2 + R_3$) connected to RSET pin:

$$I_{LED\ max}(mA) = 132 \times 0.6V/(R_2 + R_3)k\Omega$$

The **full scale LED current value** can be adjusted on board between 2mA and 30mA using the R_3 variable resistor. The LED current through each channel can be observed using a current meter inserted between Pin #2 and Pin #3 of the associated J3 to J5 header-pin connectors (after removing the jumper shunt).

g) Observe the **open circuit configuration** functionality with the V_{OUT} pin disconnected from the LEDs:

- Set EN/DIM input high ("1") using the EN/DIS pushbutton.
- Set I_{LEDmax} = 20 mA through R3 potentiometer.
- Disconnect the LEDs from the CAT3643 V_{OUT} pin: remove the jumper shunt from the J7 connector
- Observe the CAT3643 output using a voltage meter connected on V_{OUT} (T_5) test point (GND = T_6). In this configuration with output open circuit the CAT3643 operates in 1x mode: $V_{OUT} = V_{IN}$.
- Observe the quiescent current, I_Q (1x mode), measured by the current meter connected between the V_{EXT} and V_{IN} (T1) pin:

  for V_{IN} = 3.0V to 5.0V; I_Q(1x mode) = 1mA typically.

h) The **unused LED channels** should be connected to V_{OUT} pin in order to optimize the CAT3643 functionality.

- Connect 2 LEDs at the LED1, LED2 outputs: jumper shunt between Pin #2 and Pin #3 at the associated header pin connector (up position).
- Disconnect D_3 LED from the LED3 output of the CAT3643 and connect it to the V_{OUT} pin: jumper shunt between Pin #1 and Pin #2 for J5 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 (J5):

  V_{IN} = 3.3V; I_unused_ch (LED3) = 223µA (for all ILED dimming levels)

  V_{IN} = 4.2V: I_unused_ch (LED3) = 230µA (for all ILED dimming levels)

2) Efficiency Evaluation

The efficiency is evaluated according to the following equation:

Efficiency % = $(\Sigma V_{Fi} \times I_{LED}) / (I_{IN} \times V_{IN}) \times 100$

where $V_{Fi} = V_{OUT} - V_{LEDi}$ is the voltage dropout across the LEDi , I_{LED} is the current through one LED; i = 1 to 3.

2.1) Efficiency Evaluation versus Line Voltage

a) Set the configuration for 3 LEDs connected to the CAT3643 outputs.

b) Insert a current meter, I_{M1}, between input supply voltage, V_{EXT}, and V_{IN} pad and monitor the input current.

c) Set the input voltage for the initial value V_{IN} = 2.5V. Monitor V_{IN} at V_{IN} (T1) test point with a voltage meter.

d) Set the LEDs ON at I_{LEDmax} = 20 mA (aprox): EN/DIS=ON, I_{LEDmax} set by R_3.

e) Measure the output voltage on $V_{OUT\ (T5)}$.

f) Measure V_{LED1} to V_{LED3} at L1 to L3 pad points.

g) Repeat all the above measurements for V_{IN} increase between 2.5V and 5.0V.

h) Repeat the same measurements for V_{IN} decrease from 5.0V to 2.5V.

Figure 3 and Figure 4 respectively, show the CAT3643 input current (I_{IN}) and output voltage (V_{OUT}) versus the line voltage using 3 LEDs driven at approx. 20mA. The charts show the values both for V_{IN} ascending and V_{IN} descending. The values marked with + are for V_{IN} increase and the values marked with – are taken for V_{IN} decrease. When the input voltage, V_{IN}, decreases to lower value (as it happens in the real applications due to the battery discharge), the CAT3643 device switches from 1x mode to 1.33x mode at V_{IN} = 3.5V approximately, to 1.5x mode at V_{IN} = 2.8V (approximately) and to 2x mode at V_{IN} = 2.6V (approximately).

The internal switch frequency, typical 1MHz, is shown in the waveforms from the Figure 5; CH1: signal measured on the C2+ pad; CH2: output voltage, V_{OUT} (1.33x mode, V_{IN} = 3.3V).

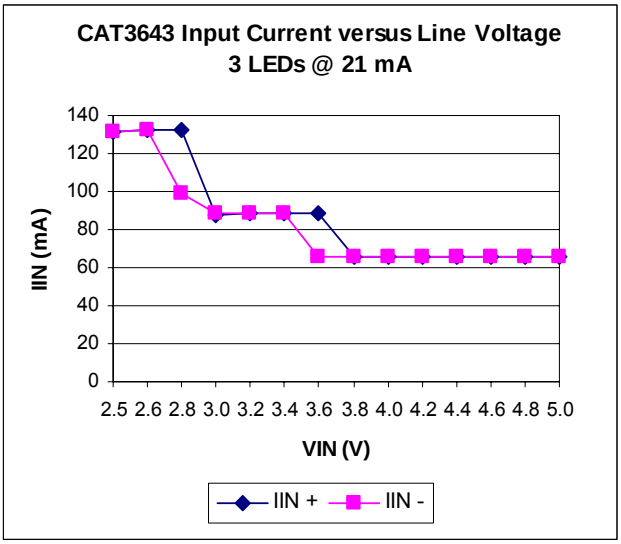


Figure 3. Input Current versus Line Voltage

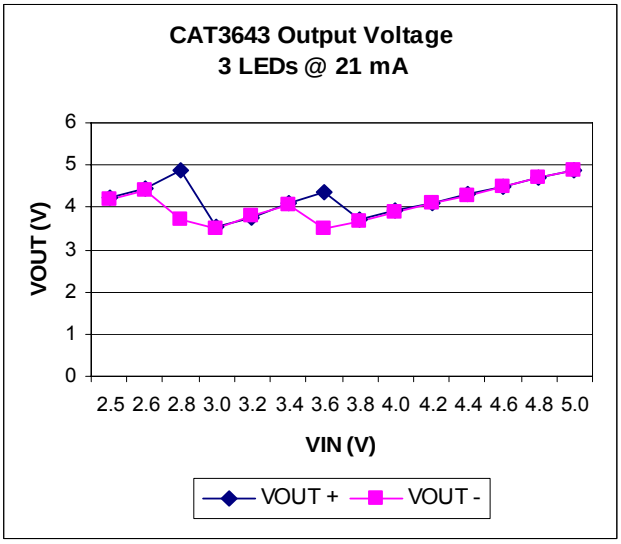


Figure 4. Output Voltage versus Line Voltage

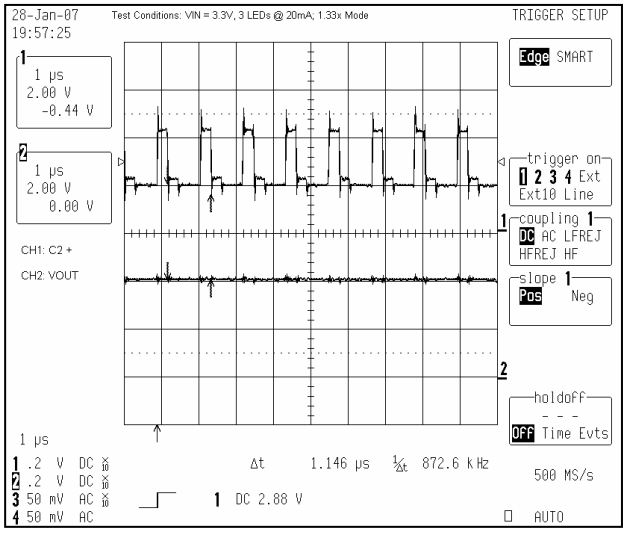


Figure 5. Internal Switch and Output Voltage (V_{IN} = 3.3V, I_{OUT} = 60mA)

The CAT3643 efficiency versus line voltage with 3 LEDs driven at 20 mA, is shown in Figure 6. The CAT3643 efficiency is optimized for Li-Ion battery applications. At the nominal battery voltage value, the CAT3643 operates in 1x mode providing a high efficiency. The 1x mode of operation is provided until V_{IN} drops below 3.5V typically. At this point the device switches to 1.33x operation mode and remains in this mode until the input voltage drops below 2.8V typically.

Note:

Eff + : Efficiency for V_{IN} increase; Eff - : Efficiency for V_{IN} decrease

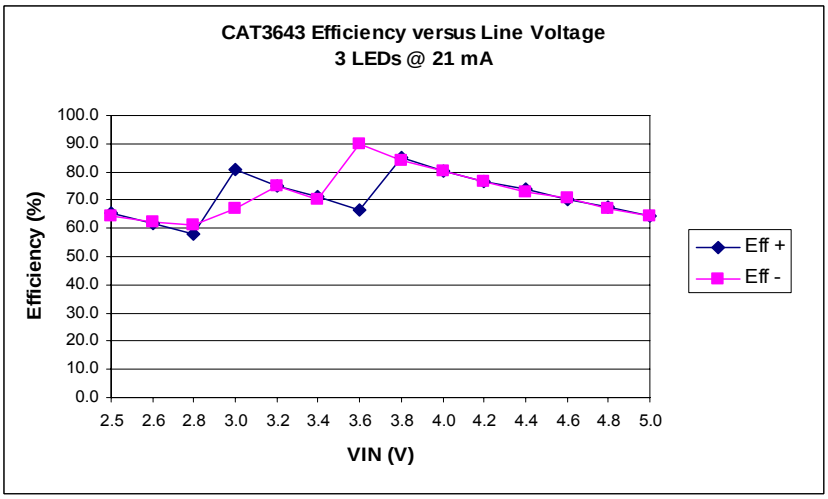


Figure 6. CAT3643 Efficiency versus Line Voltage

2.2) Efficiency Evaluation versus Load

The CAT3643 efficiency can also be evaluated versus the total output current driven through the LEDs. The following steps are an example of efficiency measure–ments for different output current values at two input voltage values.

a) Set the configuration for 3 LEDs driven by the CAT3643 device.
b) Insert a current meter, IM1, between input supply voltage, V_{EXT}, and V_{IN} pad and monitor the input current, IIN.
c) Set the input voltage for V_{IN} = 3.2V. Measure the input voltage at V_{IN} (T1) test point with a voltage meter.
d) Set the I_{LEDmax} current: set EN/DIM = "1" (EN/DIS =ON), set R_3 potentiometer for the LED current initial value, $I_{LED\ max}$ = 20mA (I_{OUT} = 3x 20mA = 60mA).
e) Observe the I_{IN} current on the IM1 meter.
f) Measure the output voltage on V_{OUT} (T5) pin.
g) Measure all the LED outputs voltages, V_{LED1} to V_{LED3}.
h) Toggle DIM switch. For every pulse the LED current is divided by half.
i) Repeat steps e) to h) for all current dimming levels, 50%, 25%, 12.5%, 6.25%, 3.12%: I_{OUT} = 30mA, 15mA, 7.5mA, 3.75mA and 1.875mA.

All the above steps can also be performed for the other input voltage, i.e. V_{IN} = 4.0V.

Figure 7 shows the CAT3643 efficiency versus the total output current driven through the LEDs for V_{IN} = 3.2V and V_{IN} = 4.0V. The efficiency has been calculated according to the following expression:
Eff = (I_{OUT} * $V_{F\_average}$) / (I_{IN} * V_{IN}),
where $V_{F\_average}$ = V_{OUT} – (V_{LED1} + V_{LED2} + V_{LED3})/3

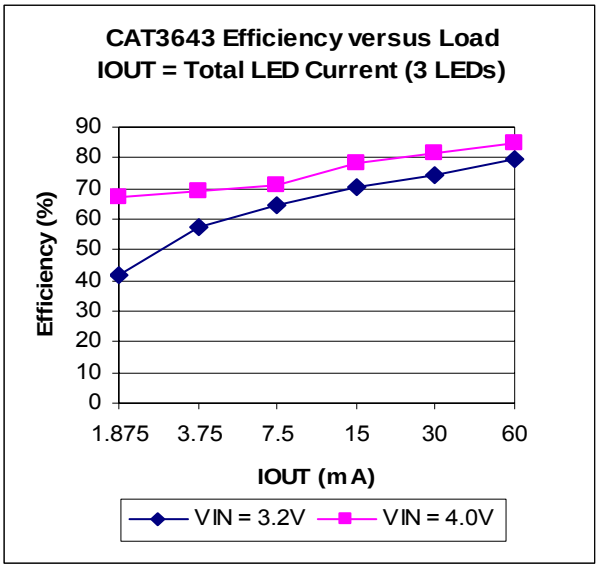


Figure 7. CAT3643 Efficiency versus Load

REVISION HISTORY

Date	Revision	Description
01/30/2007	A	Initial Issue
07-Aug-08	B	Changed “Quad-Mode™” to “Quad-Mode®”

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Document No: MD-6053
Revision: B
Issue date: 08/07/08