CAT3606EVAL1 EVALUATION BOARD FOR CAT3606 WHITE LED DRIVER

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INTRODUCTION

This document describes the CAT3606EVAL1 Evaluation Board for the Catalyst Semiconductor CAT3606 white LED driver. The functionality and major parameters of the CAT3606 can be evaluated with the CAT3606EVAL1 board.

The CAT3606 is a 6-channel charge pump that has been designed to drive up to 6 LEDs connected in parallel. The device features a digital control On/Off for 2 groups of LEDs, allowing to control the main and sub displays. The CAT3606 is operating in either 1x mode (LDO), or 1.5x mode and provides tightly matched regulated current through the six LED outputs. A single external resistor sets the LED current between 2mA and 30 mA. LED current can be adjusted using either a pulse width modulated (PWM) signal or a DC voltage. Detailed descriptions and electrical characteristics are in the CAT3606 data sheet.

CAT3606EVAL1 BOARD HARDWARE

The evaluation board contains the CAT3606 in a typical application circuit, driving up to 6 white LEDs. The user can connect, or disconnect, the CAT3606 outputs to the white LEDs using the jumper options for J2, J3, J4, J5, J6, J7 and J8 connectors. The board schematic is shown in Figure 1.

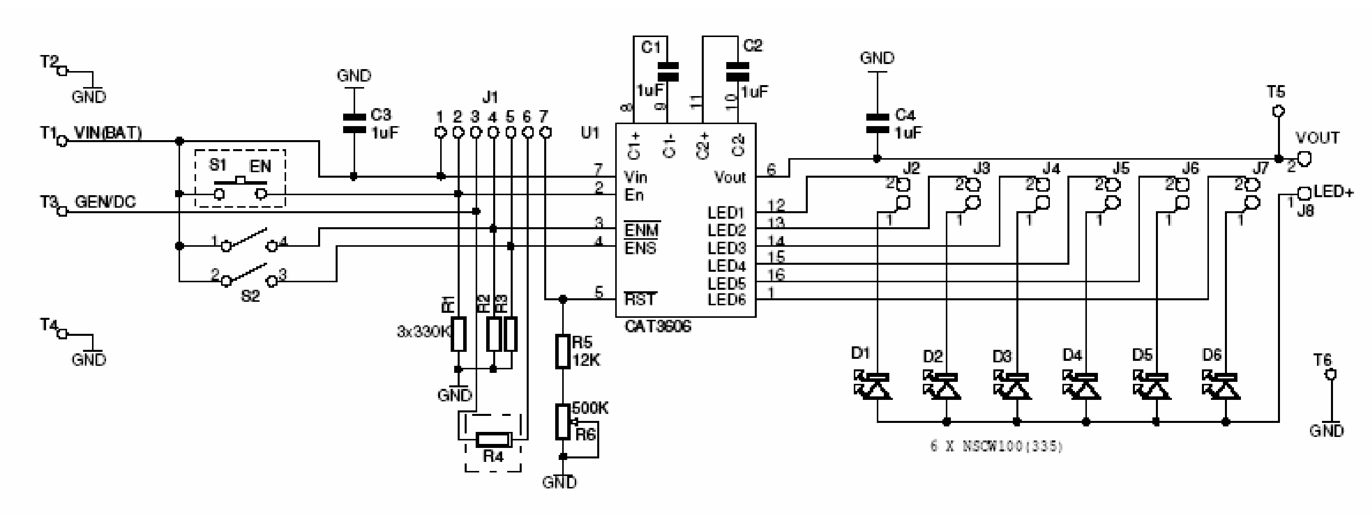

Figure 1. **CAT3606EVAL1 Board Schematic**

The board is powered from an external voltage applied to the VIN (T1) pad. The CAT3606 features two control inputs, ENM and ENS, which allow turning ON / OFF independently one of the 2 groups of LEDs: ENM controls LED1 to LED4 (Main) and ENS controls the LED5 and LED6 (Sub). The user can control the ENM and ENS inputs using the S2 DIP switch.

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The LED current is set through the external resistors connected to the RSET pin (R5, R6). Using the variable resistor R6, the LED current can be set from 2mA to 30mA. Most white LEDs are driven at a maximum current between 15mA and 20mA to ensure a pure “white” light.

The board also demonstrates the CAT3606 shutdown mode and LED brightness control by using an external PWM signal, or DC voltage. Resistor R4 (soldered on board by the user) is used to adjust the LED current using the dimming control with an external applied DC voltage on the RSET pin. The ON/OFF operation using the enable (EN) input and dimming control, can be selected using the jumper options for the J1 connector.

Test points T1 to T6 are available to apply the external voltages/signal generator, or to measure the output voltages / signals provided by the CAT3606. The L1 to L6 pads are also available as test points for the CAT3606 LED1 to LED6 outputs.

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

Table 1. CAT3606EVAL1 Board List of Components

Name	Manufacturer	Description	Part Number	Units
U1	Catalyst	Charge Pump White LED Driver, QFN-16	CAT3606HS4	1
C1 to C4	Murata Electronics	Ceramic Capacitor 1uF / 10V, 10%, X5R, Size 0805	GRM219R61A105KC01D (Digi-Key 490-1702-1-ND)	4
R1 to R3	Yageo	SMT Resistor 1/16W, 330Kohm, 0603	Digi-Key 311-330KHCT-ND	3
R4	Yageo	Metal Film Resistor 1/16W (Not soldered on board)	Digi-Key 40.0KXBK-ND	1
R5	Yageo	SMT Resistor 1/16W, 12 Kohm, 0603	Digi-Key 311-12KHCT-ND	1
R6	Bourns	Trimmer Pot, 1/4", 500 Kohm	3329W-504-ND (or equiv)	1
D1 to D6	Nichia	White LED, SMT	NSCW100 (or NSCW335)	6
J1		7-pin Header Connector, 0.1", Single Strip	Digi-Key S1012-07-ND (or equiv)	1
J2 to J8		2-pin Header Connector, 0.1", Single Strip	Digi-Key S1012-02-ND (or equiv)	7
S1	E-Switch	Momentary Contact Switch, SPST (on)-off, (Not soldered on board)	TL1100F160Q (Digi-Key EG1821-ND)	1
S2	C&K	Dip Switch, Low Profile, 2Pos, SPST	SDA02H1KD (Digi-Key CKN1276-ND)	1
T1 to T6	Mil-Max	Pin Receptacle (Test Points)	#0149-0-15-01-30-14-04-0 (or equiv)	6

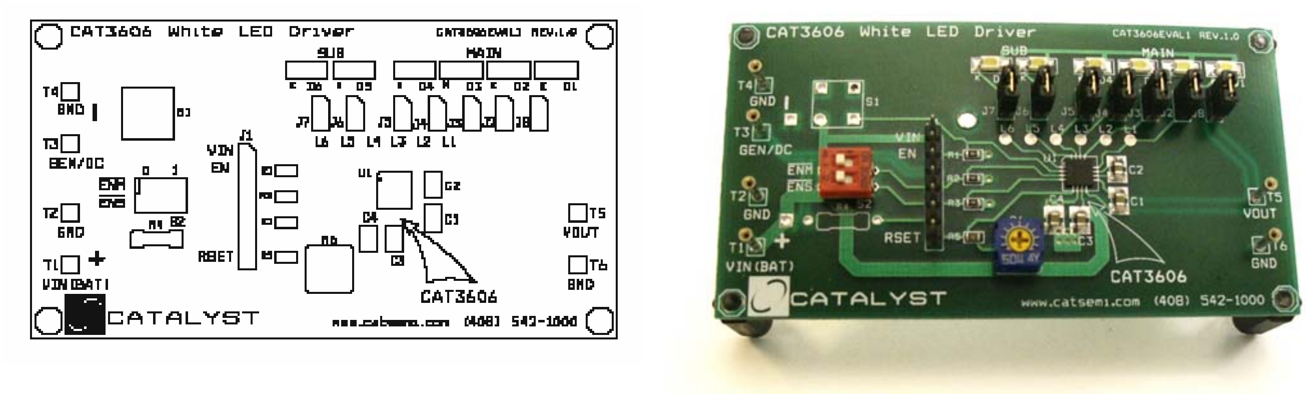


Figure 2. CAT3606EVAL1 Board

CAT3606 EVALUATION

The CAT3606EVAL1 gives the user a way to evaluate the CAT3606 in a typical application of driving multiple LEDs.

The following steps are an example of how the user can evaluate the CAT3606 white LED driver:

1) Driving LEDs, Shutdown Mode and Open Circuit Configuration

a) Connect the LEDs to the CAT3606 output.

- Connect VOUT to the LEDs anode terminal (LED+) using a jumper shunt between Pin #1 and Pin #2 of J8 header-pin connector.
- Connect each LED cathode terminal to the CAT3606 outputs, LED1 to LED6, using a jumper for the J2 to J7 header pin connectors.

b) Set the R6 potentiometer to the middle position.

c) Apply the external voltage supply, Vext (3.0 < VIN < 5.0V) between VIN (T1) and GND (T2).

d) The CAT3606 is in the **shutdown mode** (EN pin is connected to GND) if the J1 connector is not jumpered (Pin #1, Pin #2).

- Connect a current meter, IM1, between Vext and VIN pad to measure the shutdown current: IQSHDN < 1µA.
- Using the S2 switch set the combination for the CAT3606 control inputs: ENM = “0”, ENS =” 0” (do not include the currents through the pull-down resistors, R2 and R3).
- Observe the current measured by IM1 for the CAT3606 shutdown current: the value is near zero (<< 1uA).

e) Connect EN pin of the CAT3606 to VIN using a jumper shunt between Pin #1 and Pin #2 of J1 connector

- Observe that LEDs are ON. All 6 LEDs are ON for ENM = “0”, ENS = “0”.
- Change the S1 switch positions to control the ENM and ENS inputs in order to turn ON/OFF a group of LEDs, according to the following table.

EN	ENM	ENS	**LED1 – LED4 Main**	**LED5 – LED6 Sub**
0	x	x	-	-
1	1	1	-	-
1	0	1	ON	-
1	1	0	-	ON
1	0	0	ON	ON

f) Disconnect the LEDs from the CAT3606 output: remove the jumper shunt from the J8 connector. Observe the **open circuit configuration** functionality for EN = “1”and two configurations for the ENM, ENS inputs:

- Set **EN = 1, ENM = 0, ENS = 0**
- Observe the quiescent current, IQ, measured by the current meter connected between the Vext and VIN (T1) pin: IQ = 2.5mA – 3.5 mA typically.
- Observe the CAT3606 output using a scope probe connected on VOUT (T5) test point (GND = T6). In this configuration with output open circuit the CAT3606 operates in 1.5x mode: VOUT = 1.5 x VIN.
  For higher VIN than 4.2V approximately, the device switches to 1x mode operation to protect the output: VOUT max = 6V.

- Set **EN = 1, ENM = 1, ENS = 1**
- Observe the quiescent current, IQ, measured by the current meter connected between the Vext and VIN (T1) pin: IQ = 0.4mA – 0.48 mA typically for VIN =3V to 5.5V. In this configuration the device operates in x1 mode.

Figure 3 shows the output voltage, VOUT for VIN = 4.2V, open circuit configuration, EN=1, ENM = 0, ENS = 0.

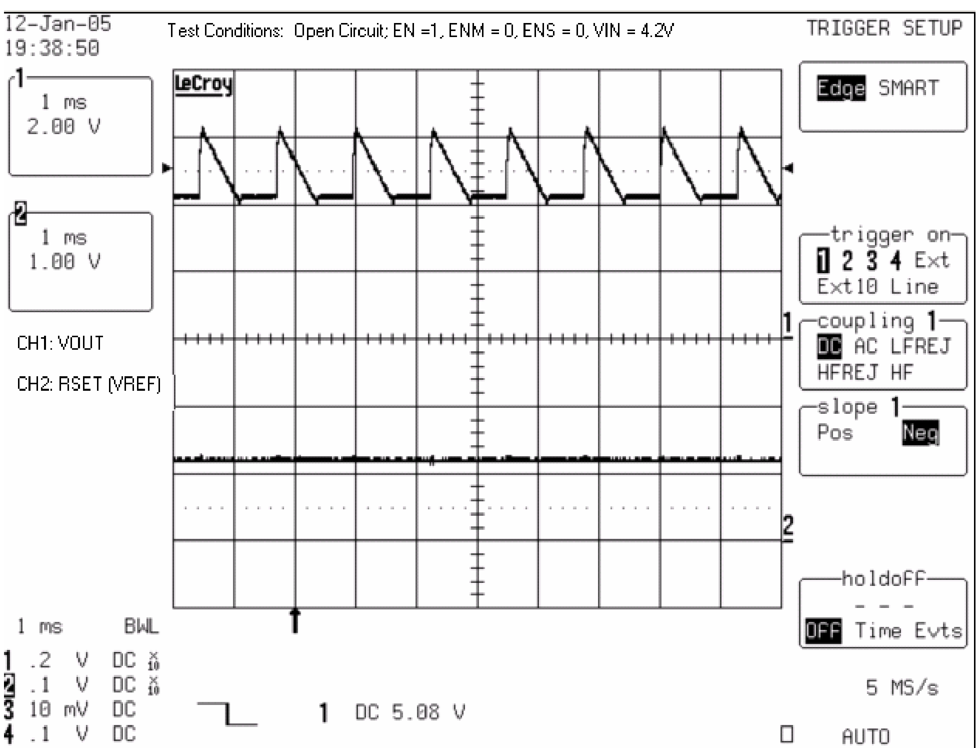


Figure 3. The Output Voltage Waveform for Open Circuit Configuration, VIN = 4.2V (EN = 1, ENM=0, ENS =0)

2) LED Current Evaluation

2.1) Programming LED current

LED current is programmed using the external resistors, RSET = R5 + R6, connected to the RSET pin. The voltage at the RSET pin is internally regulated to the typical value of 1.2V.

The user can set the LED current using the variable resistor, R6. The following steps are an example for the ILED programming.

- Set the input voltage: ex. VIN = 3.6V.
- Disconnect the jumper from the J2 connector and insert a current meter between these pins to monitor the LED current, ILED1.
- Rotate the potentiometer R6 and observe the ILED1 value on the current meter. Various LED current values and the associated RSET value measured on one evaluation board are listed below:

ILED (mA)	RSET (Kohm)
2	265
5	100
10	50
15	30
20	20
25	17
30	15

The CAT3606EVAL1 board uses the R6 = 500 Kohm potentiometer in order to demonstrate the wide range for the ILED setting. The user can use a smaller value variable resistor for a reduced variation range and more précised setting of the LED current.

2.2) LED Current Matching

The LED current is regulated to a value programmed by the user. The six LED output currents, ILED1 to ILED6, are tightly matched to provide uniformity of LEDs brightness.

The CAT3606EVAL1 board provides the user a way to evaluate the current through each LED connected to the CAT604 outputs.
The current matching between the 6 LED outputs can be calculated by the following expression:

$$\Delta I (\%) = (ILEDmax – ILEDmin) / (ILEDmax + ILEDmin) \times 100$$

where the ILEDmax and ILEDmin are the highest and respectively the lowest value of the six LED currents.

The following procedure may be used to evaluate the LED currents regulation versus input voltage and the current matching between the LEDs.

- Set the ILED to a programmed value using the R6 potentiometer (i.e. 15mA for VIN = 3.6V)
- Vary the VIN voltage between 3.2V and 5.2V
- For every VIN, observe the value of each ILED measured by the current meter inserted between the LED cathode terminal and associated CAT3606 LED output (use the J2 to J7 header pin connectors).

Figure 4 shows the LED current regulation versus input voltage for all 6 LEDs and the LED to LED current matching (ΔI) based on measurements performed on one board.

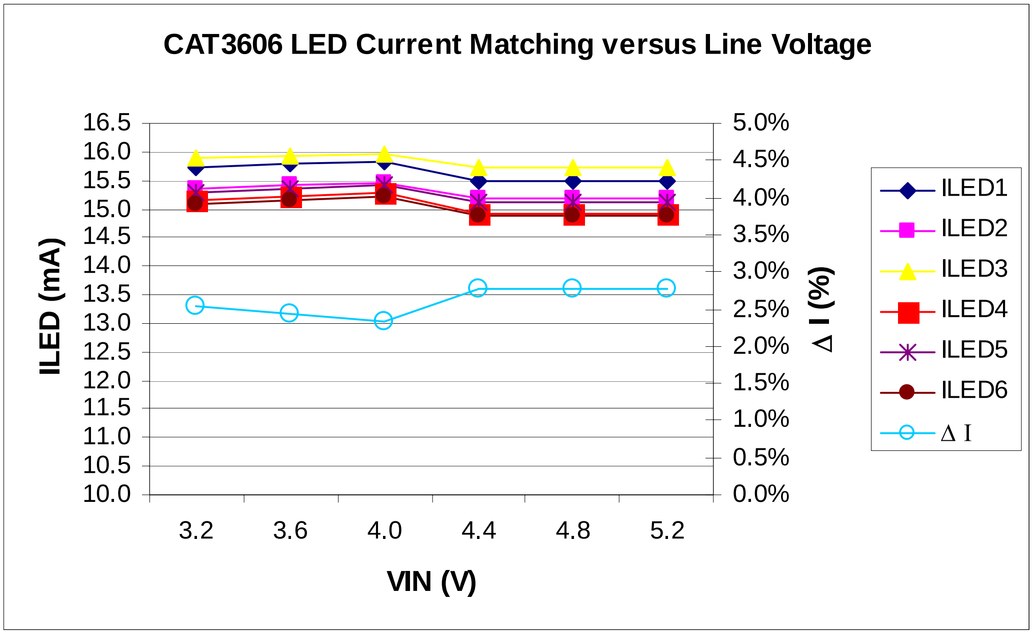


Figure 4. LED to LED Current Matching versus Line Voltage, 6 LEDs @ 15 mA

3) Efficiency Evaluation

The efficiency is evaluated according to the following equation:

Efficiency % = Σ (VFi x ILEDi) / (IIN x VIN) x 100

where VFi = VOUT – VLEDi is the voltage dropout across the LEDi , ILEDi is the current through one LED; i = 1 to 6.

3.1) Efficiency Evaluation versus Line Voltage

a) Set the configuration for 6 LEDs ON at ILED = 15 mA.
b) Insert a current meter, IM1, between input supply voltage, Vext, and VIN pad and monitor the input current, IIN.
c) Set the input voltage for the initial value VIN = 3V. Monitor VIN at VIN (T1) test point with a voltage meter.
d) Measure the output voltage on VOUT (T5)
e) Measure each VLED output voltage on L1, L2, L3, L4, L5, L6 pads available on board.
f) Repeat all the above measurements for VIN increase between 3V and 5.0V.
g) Repeat the same measurements for VIN decrease from 5.0V to 3.0V.

Figure 5 and Figure 6 respectively, show the CAT3606 input current (IIN) and output voltage (VOUT) versus the line voltage using 6 LEDs driven at 15mA. The values named with + are for VIN increase and the values named with – are taken for VIN decrease.

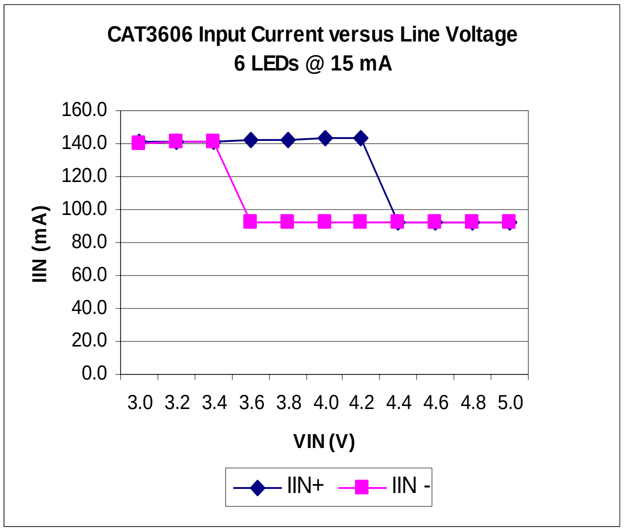


Figure 5. Input Current versus Line Voltage

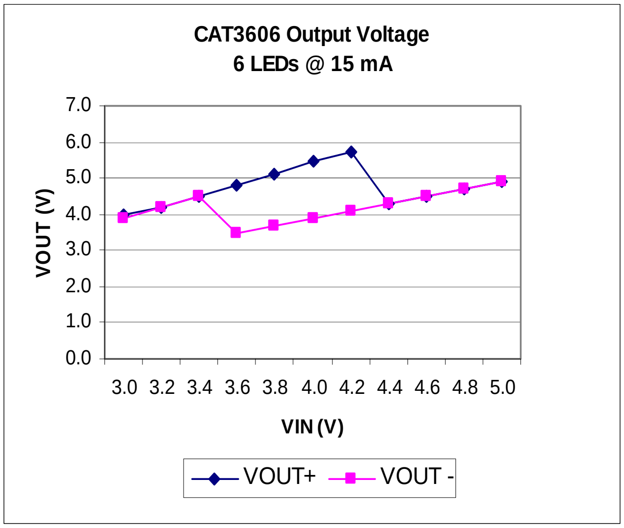


Figure 6. Output Voltage versus Line Voltage

The internal switch frequency, typical 1 MHz, is shown in the waveforms from the Figure 7; CH2: signal measured on the C2+ pad, CH1: output voltage, VOUT (1.5x mode, VIN = 3.2V).

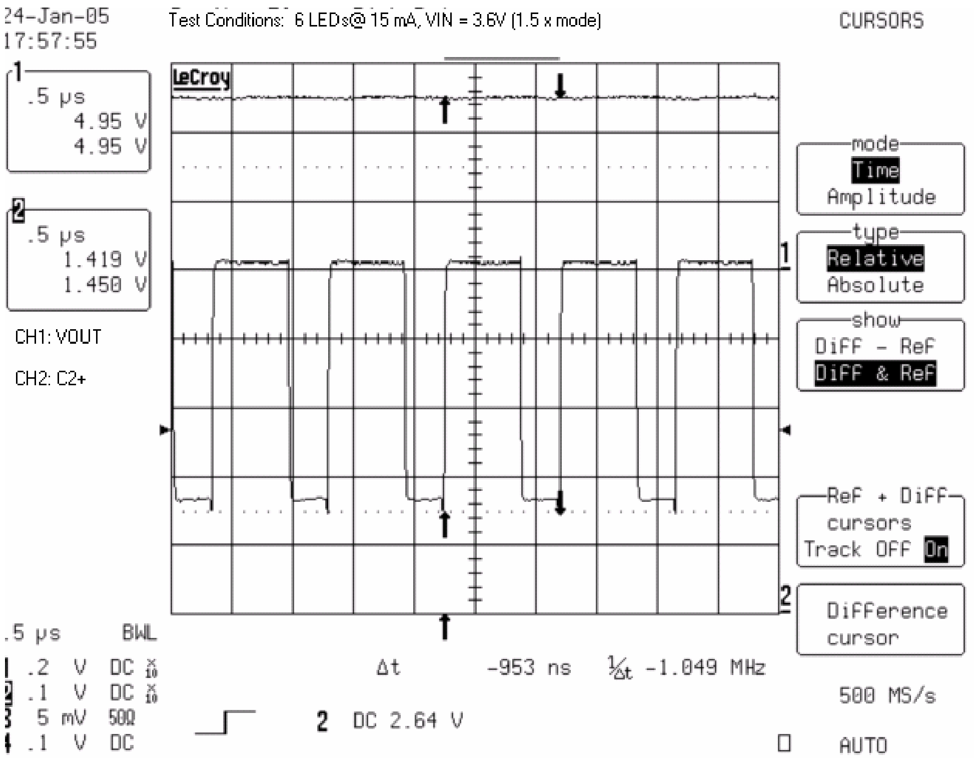
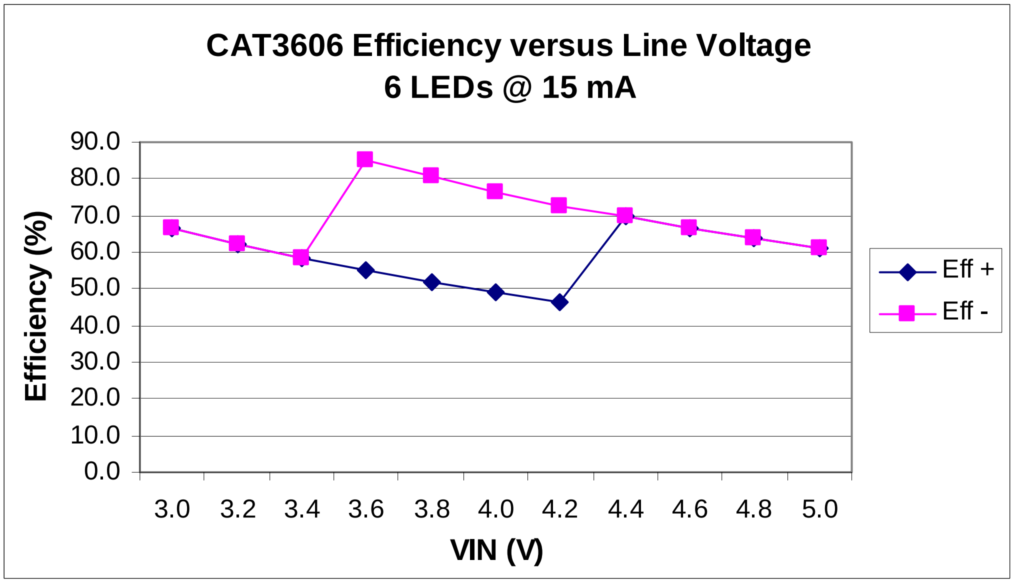


Figure 7. Output Voltage and Internal Switch (VIN = 3.2V, IOUT = 60 mA)

The CAT3606 efficiency versus line voltage with 6 LEDs driven at 15 mA, is shown in Figure 8. The CAT3606 efficiency is optimized for Li-Ion battery applications. At the nominal battery voltage value, the CAT3606 operates in 1x mode providing a high efficiency. The 1x mode of operation is provided until VIN drops below 3.6V 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 8. CAT3606 Efficiency versus Line Voltage

3.2) Efficiency Evaluation versus Load

The CAT3606 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.

a) Set the configuration for 6 LEDs driven by the CAT3606 device.
b) Insert a current meter, IM1, between input supply voltage, Vext, and VIN pad and monitor the input current, IIN. It is preferable to use a power supply with a current meter embedded for an accurate start-up of the CAT3606 device.
c) Set the input voltage for VIN = 3.2V. Measure the input voltage at VIN (T1) test point with a voltage meter.
d) Insert a current meter IM2 using the J8 connector to monitor the total output current, IOUT.
e) Adjust the R7 potentiometer for the IOUT = 30 mA (ILED = 5 mA).
f) Power Off the device (Vext = Off)
g) Set EN = 0 (disconnect the jumper from J1 connector, Pin #1 and Pin #2)
h) Disconnect the current meter, IM2 from the output and connect the jumper on J6 connector
i) Power On the device (apply Vext with EN = “0)
j) Set EN = 1 (insert the jumper on J1 connector)
k) Observe the IIN current..
l) Measure the output voltage on VOUT (T5) pin.
m) Measure all the LED outputs voltages on L1 to L6 pads.
n) Repeat steps d) to m) for the total output current IOUT = 60 mA, 90 mA, 120 mA, 150 mA and 180 mA

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

Note that the device must be powered in the shutdown mode in order to start the operation in 1x mode.

Figure 9 shows the CAT3606 efficiency versus the total output current driven through the LEDs for VIN = 3.2V and VIN = 4.0V.

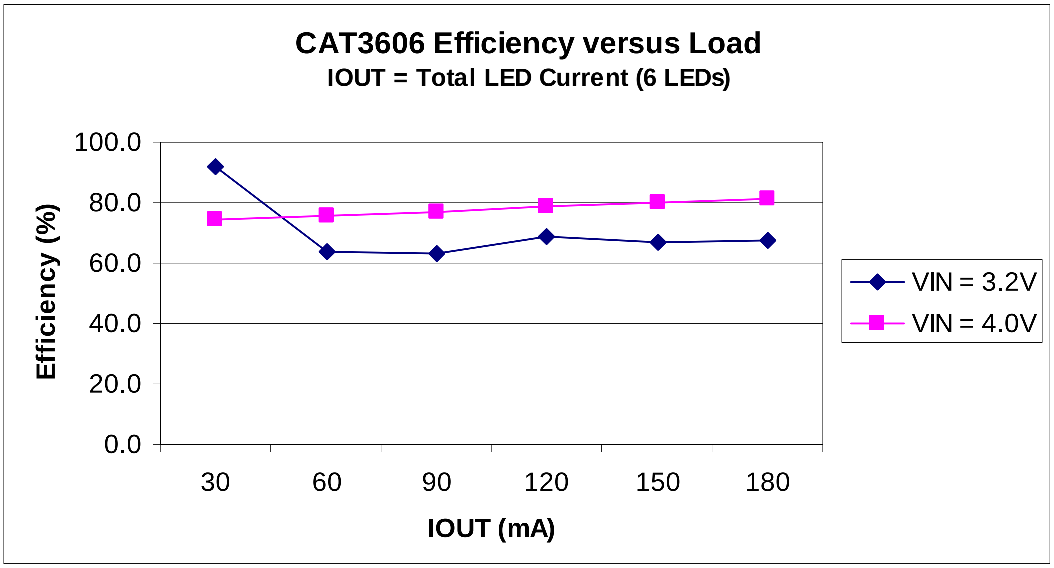


Figure 9. CAT3606 Efficiency versus Load

4) Dimming Control

The LED brightness control can be accomplished by using a PWM signal applied to the EN pin, or to the ENM, ENS inputs. The other method is to use a variable DC voltage applied through a resistor to RSET pin.

4.1) Dimming using a PWM signal on the Enable inputs

The LEDs are turned-off and on at the PWM frequency. The average current changes with the duty cycle and the LED brightness changes accordingly. The peak current value sets the light spectrum.

a) PWM signal applied to the EN pin

- Connect the jumper shunt between Pin #2 and Pin #3 of the J1 connector.
- Apply a pulse signal generator to the GEN/DC (T3) pad; Frequency = 50 Hz - 100 Hz; Amplitude 0V to 2V, VIN = 3.6V.
- Modify the duty cycle between 0% and 100%.
- Observe the average current through LEDs. For 0% duty cycle, the ILED will be off (ILED = 0mA); At the maximum duty cycle, the LED will be driven at the maximum current set by the R6 potentiometer.

Figure 10 shows the total LED current, IOUT, measured with a current probe (CH3) using a PWM signal (50% duty cycle) applied to the EN pin (CH1).

Figure 11 shows the CAT3606 wake-up from shutdown mode (EN going from “0” to “1). The device starts in 1x mode and after a delay of 750 us approximately, the CAT3606 enters in that operation mode required by load. In this case, with VIN = 3.2V and 6 LEDs driven at 15 mA, the device enters after the start-up period in 1.5x mode. The CH3 waveform shows the input current, IIN, during the wake-up from the shutdown mode.
Due to the start-up period of hundreds of us when the EN signal goes active, the dimming control using the PWM on EN pin requires a slower frequency (i.e. 50Hz – 100 Hz).

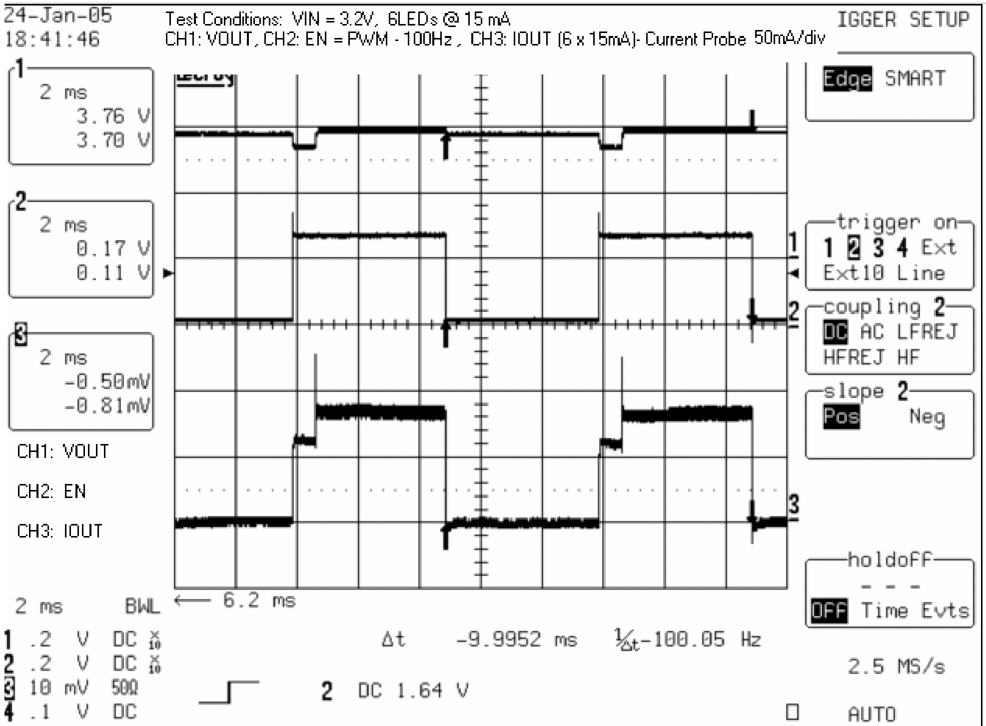


Figure 10. Total LED Current Waveform with PWM on EN pin

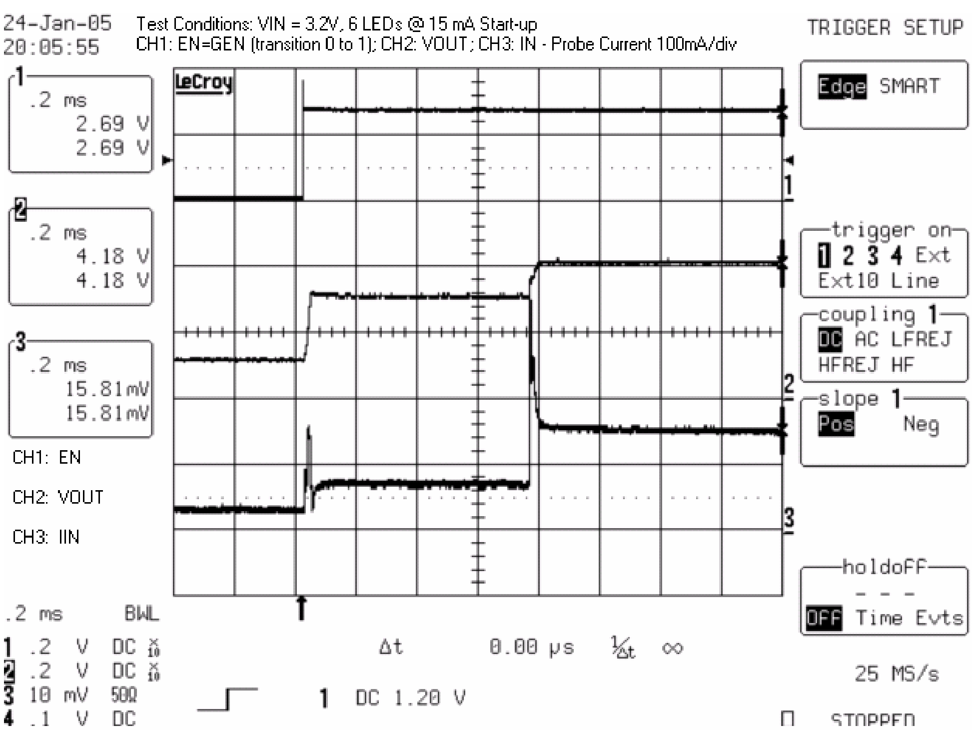


Figure 11. CAT3606 Wake-Up from Shutdown Mode (VIN = 3.2V)

b) PWM signal applied to the ENM pin

- Connect the jumper shunt between Pin #1 and Pin #2 of the the J1 connector (EN = "1").
- Set the S1 switch: ENM= 0, ENS = 1 (4 LEDs - ON).
- Connect the jumper shunt between Pin #3 and Pin #4 of the J1 connector (ENM = GEN = PWM signal).
- Apply a pulse signal generator to the GEN/DC (T3) pad; Frequency = 100 Hz – 1 KHz; Amplitude 0V to 2; VIN = 3.6V.
- Modify the duty cycle between 0% and 100%.
- Observe the average current through LEDs. For 0% duty cycle, the 4 LEDs will be ON, driven at the maximum current set by the R6 potentiometer (ILED = 15mA); At the maximum duty cycle, the LEDs will be OFF (ILED = 0 mA).

Figure 12 shows the total LED current through 4 LEDs, IOUT, measured with a current probe (CH3: 50 mA/div) using a PWM signal (60% duty cycle) applied to the ENM pin (CH1).

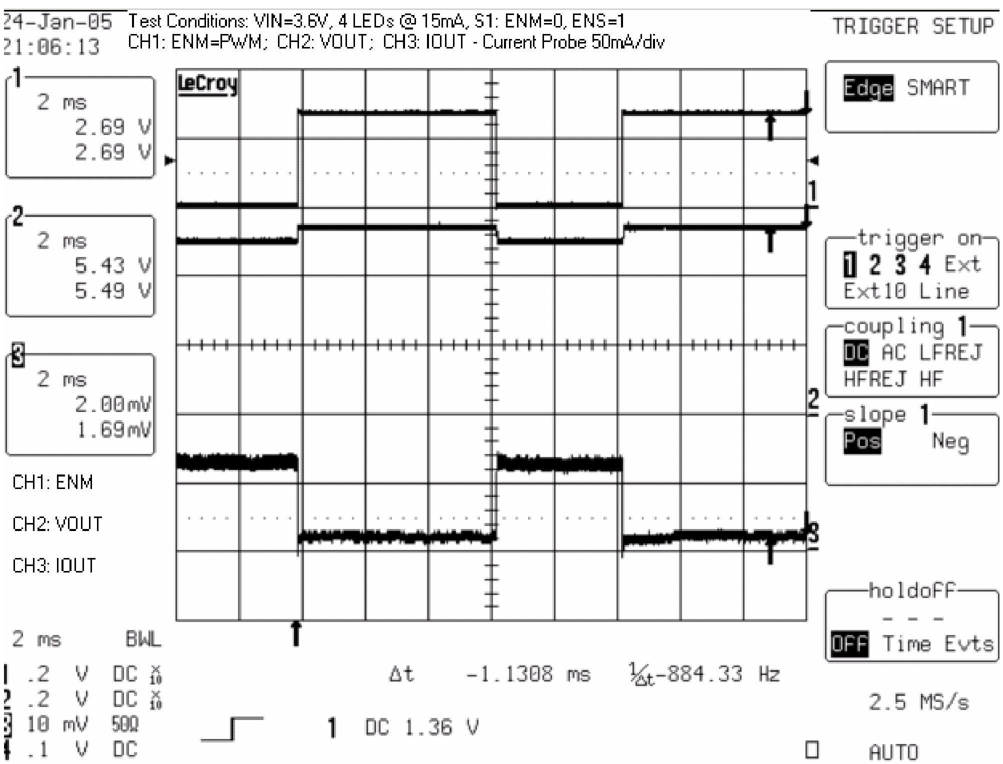


Figure 12. Total LED Current (4 LEDs) Waveform with PWM on ENM pin.

4.2) Dimming using a DC voltage applied to the RSET pin

A variable external DC voltage can be applied through a serial resistor (R4) to the RSET pin to adjust the LED current. As the DC voltage is increased, the voltage drop on resistor R4 is increased and the voltage drop on RSET (R5 + R6) is decreased, thus the LED current decreases. When the adjustable DC voltage value, V_{DC}-var, is zero, the LED current will be at the maximum value. The R4 in parallel with RSET (R5 + R6) should be equal or higher than 15 Kohm to limit the maximum ILED value (i.e. ILED max = 30 mA).

The following procedure is an example of LED current dimming with an adjustable DC voltage applied on RSET pin:

- Connect the EN pin to VIN: jumper shunt between Pin #1 and Pin #2 of J1 connector.
- Set ENM=0, ENS=0 (6 LEDs ON); VIN = 3.6V
- Mount the R4 = 40 Kohm on board
- Connect R4 resistor to the RSET pin using a jumper between Pin #6 and Pin #7 of J1 connector.
- Apply the external variable DC voltage between GEN/DC (T3) and GND (T4). Set V_{DC}-var = 0V
- Adjust R6 to set the ILEDmax value current: (i.e. ILED_MAX = 25 mA). Monitor ILED with a current meter inserted on J2 connector.
- Increase the DC voltage value using small steps.
- Observe the ILED current decreases from the ILED MAX (25 mA – previous set) to ILED MIN (0 mA for V_{DC-MAX} = 2.8V).