

WHITE LED DRIVER

FEATURES

- Very High Speed Adjustable OSC (Max 800 kHz)
- Very Wide Operating Voltage Range (2.3 V to 10 V)
- Low Loss Detector (Low Reference Voltage: $V_{REF} = 0.5 V$)
- Operates with Toko D31FU Miniature Coil (Current Limited by Input Current Sensor)
- Internal Switching Transistor
- Internal Diode
- Active High On / Off Control
- Available Intensity Control Using EN Pin with PWM Signal
- Very Small SOT23L-8 Surface Mount Package

DESCRIPTION

The TK11850L is a pulse skipping step-up DC-DC converter IC designed for White LED driver applications with the following built in: a very high current switching transistor (400 mA peak), an inductor current limit detector, low voltage reference ($V_{ref} = 0.5 V$), high speed oscillator, an error comparator, a rectifier diode (for small power output) and an ON/OFF control. The IC works with a very wide operating supply range (2.3 V to 10 V) and the adjustable output voltage can be set as high as 20 V. The device is in the ON state when the EN pin is pulled to a high level. Using the very small TK11850L and a few external components, battery powered systems with LCD displays such as digital cameras and cellular phones can be effectively backlit with white LEDs. The white LEDs are connected in series and driven at a constant current resulting in uniform brightness and high efficiency. This IC has an oscillator, which allows the designer to set the operating frequency by an external capacitor with the output controlled by pulse skipping. The reference voltage is a very low 0.5 V, achieving high efficiency operation with the constant current output. A small coil can be used because the inductor current limit detector circuit limits the peak current (caused by an input

APPLICATIONS

- LED Backlighting and Frontlighting
- LED Flashlights
- Step-up DC-DC Converters

voltage increase or the inrush current as start-up) that flows through the coil. The ON /OFF control is built-in and the circuit current can be decreased when the EN pin is low (standby mode). The white LEDs can be dimmed by applying a PWM signal to the EN (ON/OFF control) pin. With this method, the white LED brightness is still controlled by constant current resulting in constant chromaticity.

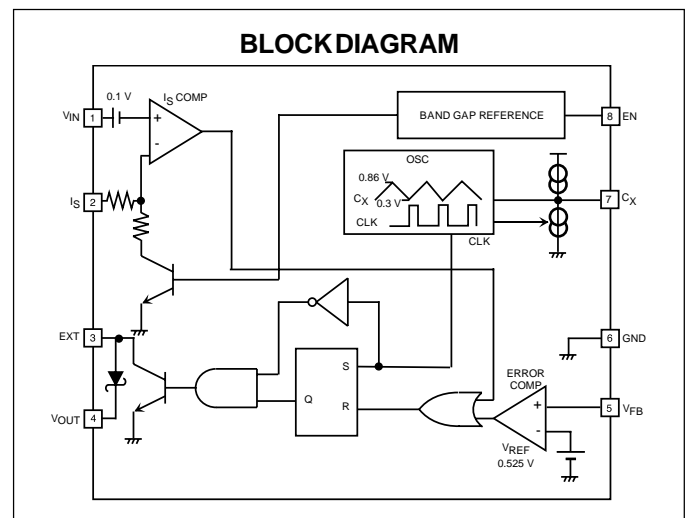
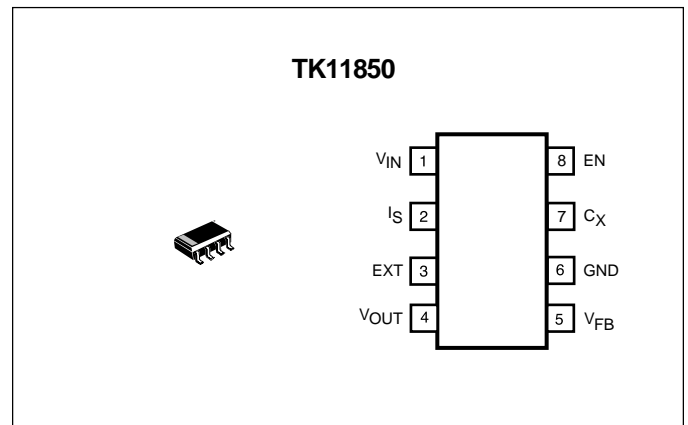
The TK11850L is available in the SOT23L-8 surface mount package.

ORDERING INFORMATION

TK11850L

Tape/Reel Code

TAPE/REEL CODE
TL: Tape Left



TK11850L

ABSOLUTE MAXIMUM RATINGS

| | | | |
|----------------------------------|----------------|-----------------------------------|---------------|
| Supply Voltage | 20 V | Operating Temperature Range | -30 to +85 °C |
| Switching Voltage | 20 V | Switching Peak Current | 400 mA |
| Operating Voltage Range | 2.3 to 10 V | Diode Current | 10 mA |
| Power Dissipation (Note 1) | 400 mW | Maximum Frequency | ~ 800 kHz |
| Storage Temperature Range | -55 to +150 °C | | |

TK11850 ELECTRICAL CHARACTERISTICS

Test Conditions: $V_{IN} = 3\text{ V}$, $V_{IS} = V_{EN} = V_{IN}$, $V_{EXT} = \text{Open}$, $V_{FB} = \text{GND}$, $C_X = 100\text{ pF}$, $T_A = 25\text{ °C}$, unless otherwise specified.

| SYMBOL | PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---------------------------------------|--|-------|-------|-------|---------------|
| OSCILLATOR SECTION (C_X PIN) | | | | | | |
| I_{CHG} | C_X Charging Current | $V_{CX} = 0.1\text{ V}$ | 16 | 22 | 30 | μA |
| I_{DIS} | C_X Discharging Current | $V_{CX} = 1.0\text{ V}$ | 35 | 49 | 65 | μA |
| I_{DIS} / I_{CHG} | Charge and Discharge Current Ratio | | | 2.2 | | |
| $V_{CX(HIGH)}$ | C_X Threshold Voltage + | V_{CX} at $I_{CHG} = 0\mu\text{A}$ | 810 | 860 | 910 | mV |
| $V_{CX(LOW)}$ | C_X Threshold Voltage - | V_{CX} at $I_{DIS} = 0\mu\text{A}$ | 260 | 300 | 340 | mV |
| V_{OSC} | C_X Oscillation Voltage | $(V_{th+}) - (V_{th-})$ | 520 | 560 | 600 | mV |
| CURRENT LIMITING COMPARATOR SECTION (I_S PIN) | | | | | | |
| V_{LIMIT} | Current Limit Sense Voltage | $V_{LIMIT} = V_{IN} - V_{IS}$ | 72 | 77 | 82 | mV |
| I_{ISIn} | I_S Pin Bias Current | $V_{IN} = V_{IS} = 3\text{ V}$ | 5 | 10 | 15 | μA |
| OUTPUT SWITCH SECTION (EXT PIN) | | | | | | |
| $V_{SW, Sat}$ | Output Transistor Saturation Voltage | $V_{CX} = 0\text{ V}$, $I_{SW} = 200\text{ mA}$ | | 0.2 | 0.4 | V |
| $I_{SW, Off}$ | Output Transistor Off Leakage Current | $V_{FB} = 1\text{ V}$, $V_{EXT} = 20\text{ V}$ | | 0.01 | 2 | μA |
| FEEDBACK COMPARATOR SECTION (V_{FB} PIN) | | | | | | |
| V_{REF} | Reference Voltage | | 0.505 | 0.525 | 0.545 | V |
| I_{FBIn} | V_{FB} Pin Output Current | $V_{FB} = 0.4\text{ V}$ | -2 | -0.3 | | μA |

Note 1: Power dissipation is 400 mW when mounted. Derate at 3.2 mW / °C for operation above 25 °C.

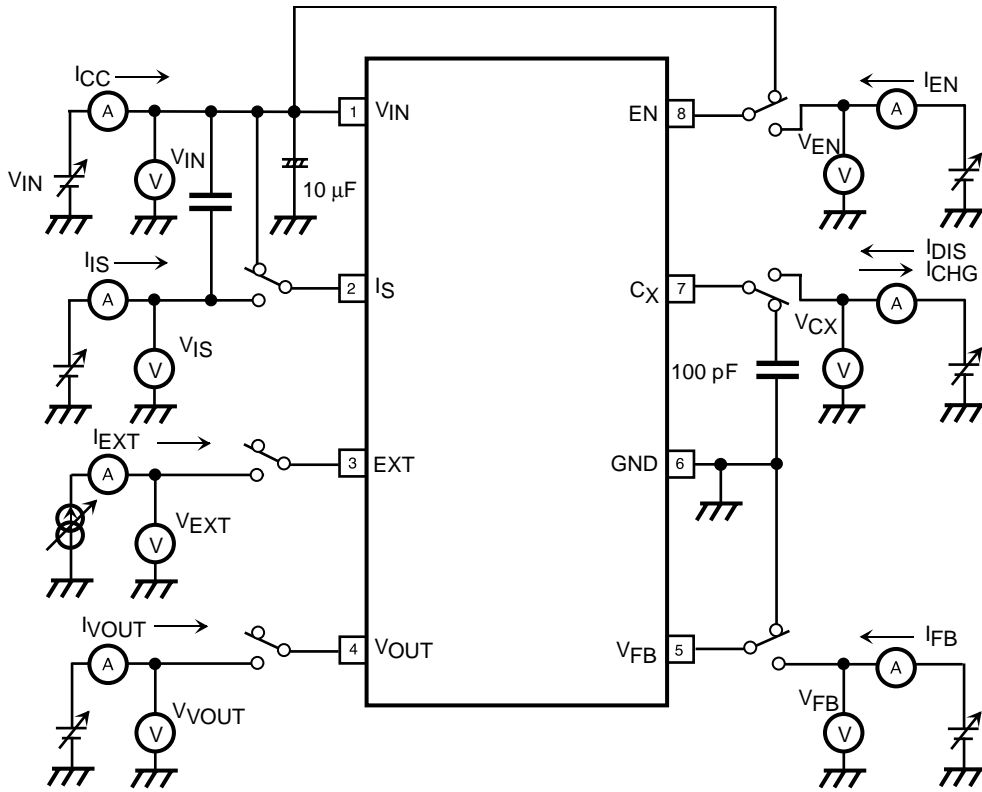
TK11850 ELECTRICAL CHARACTERISTICS (CONT)

Test Conditions: $V_{IN} = 3\text{ V}$, $V_{IS} = V_{EN} = V_{IN}$, $V_{EXT} = \text{Open}$, $V_{FB} = \text{GND}$, $C_X = 100\text{ pF}$, $T_A = 25\text{ }^\circ\text{C}$, unless otherwise specified.

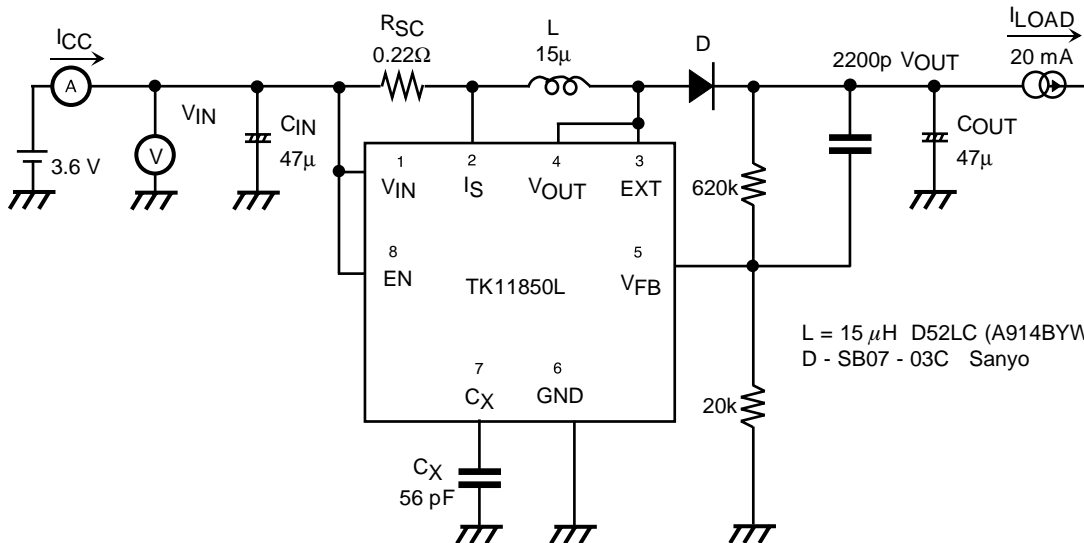
| SYMBOL | PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNITS |
|--|--------------------------|---|-----|------|-----|---------------|
| SHUTDOWN SECTION (EN PIN) | | | | | | |
| $V_{EN(HIGH)}$ | EN Threshold Voltage + | On Mode | | | 2 | V |
| $V_{EN(LOW)}$ | EN Threshold Voltage - | Shutdown Mode | 0.6 | | | V |
| I_{ENin} | EN Pin Bias Current | $V_{IN} = V_{EN} = 3\text{ V}$ | 2 | 5 | 8 | μA |
| DIODE SECTION (EXT PIN - V_{OUT} PIN) | | | | | | |
| V_F | Forward Voltage | $I_D = 10\text{ mA}$ | | 0.75 | | V |
| V_{IN} SECTION (V_{IN} PIN) | | | | | | |
| $V_{IN(LOW)}$ | Low Voltage Stop | | 1.7 | 2.0 | 2.3 | V |
| $V_{IN(HIGH)}$ | High Voltage Output Stop | | 11 | 12.5 | 14 | V |
| $I_{CC(Off)}$ | Shutdown Supply Current | $V_{EN} = 0\text{ v}$ | | 0.01 | 1 | μA |
| $I_{CC(On)}$ | Quiescent Supply Current | $V_{FB} = 1\text{ V}$ | 1 | 1.5 | 2 | mA |
| Reference Value | | | | | | |
| η | Efficiency | $I_{LOAD} = 20\text{ mA}$, $V_{OUT} = 16.5\text{ V}$, $V_{IN} = 3.6\text{ V}$ (Note 2) | | 78 | | % |

Note 2: This value is different depending on the components used, circuit conditions, etc. Thus, this is reference data only. Refer to Reference data test circuit.

TEST CIRCUIT

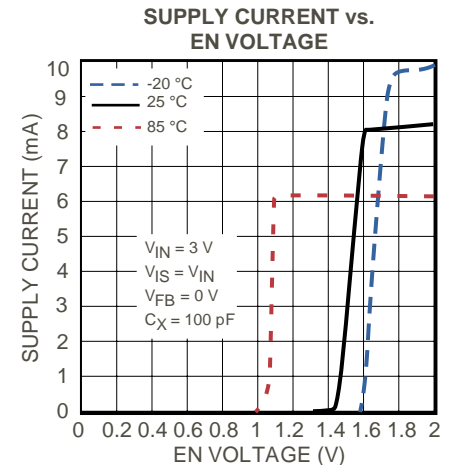
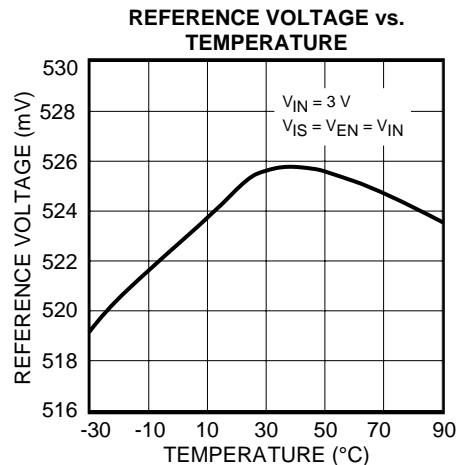
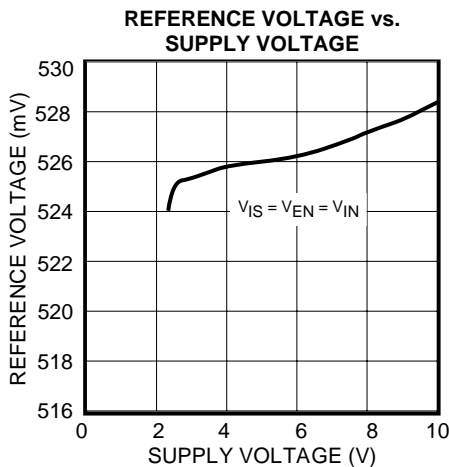
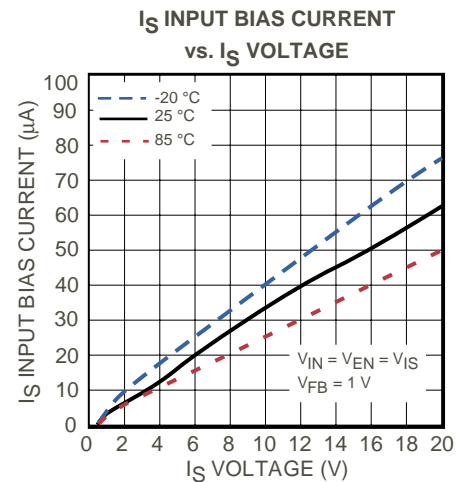
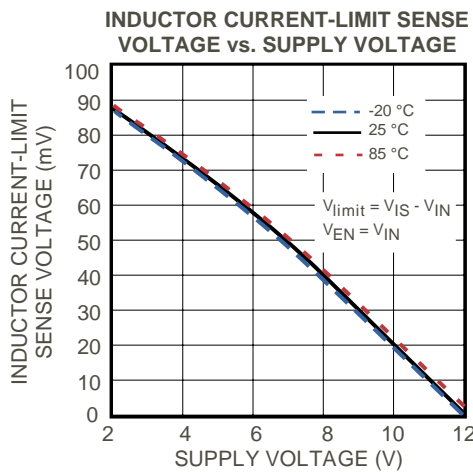
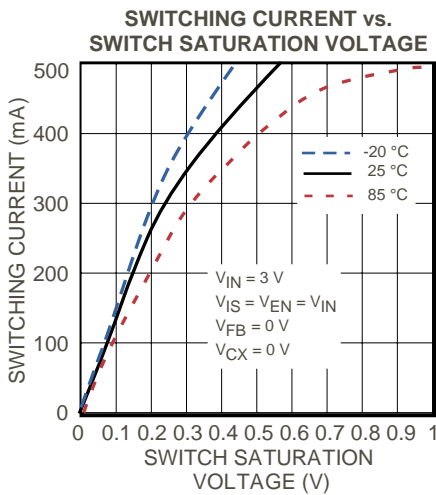
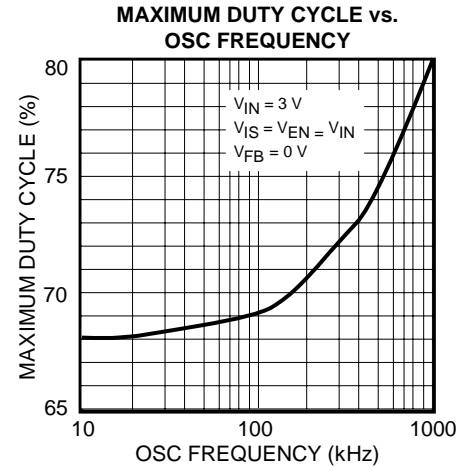
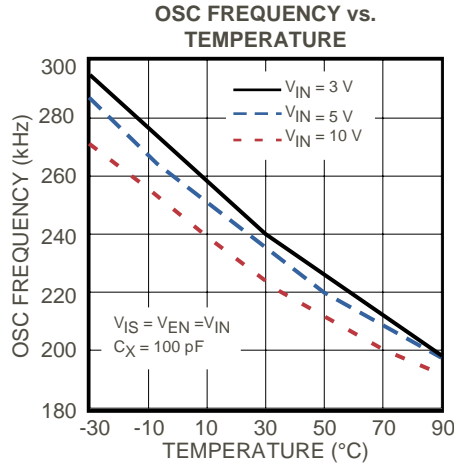
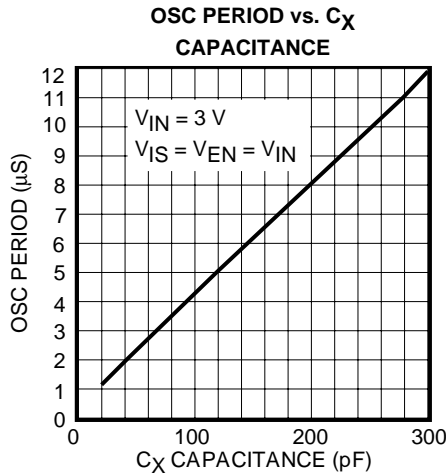


REFERENCE DATA TEST CIRCUIT



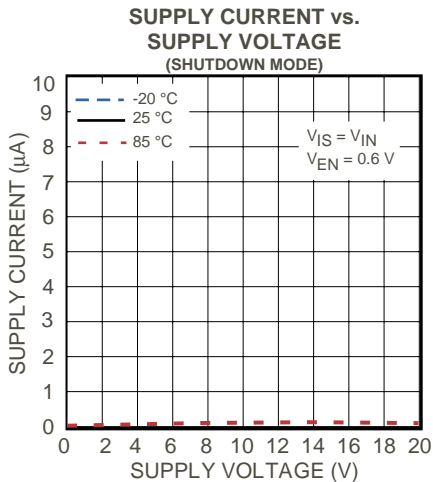
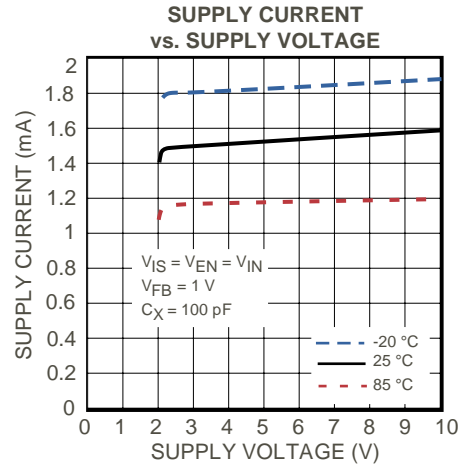
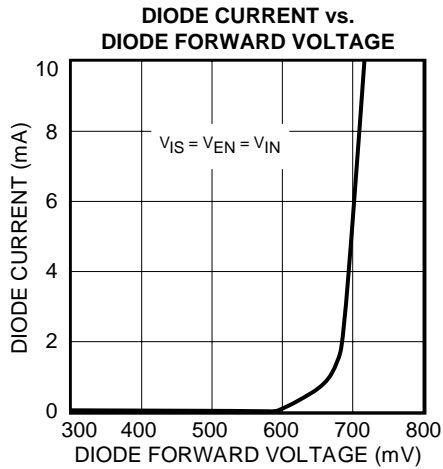
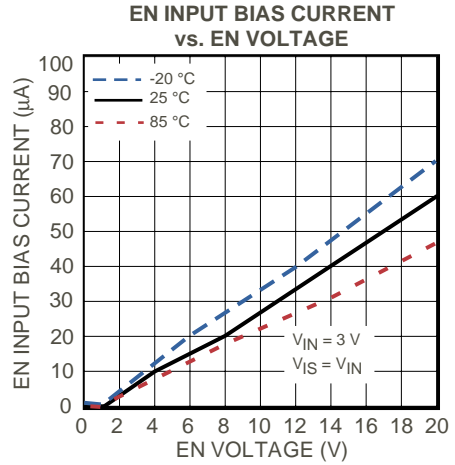
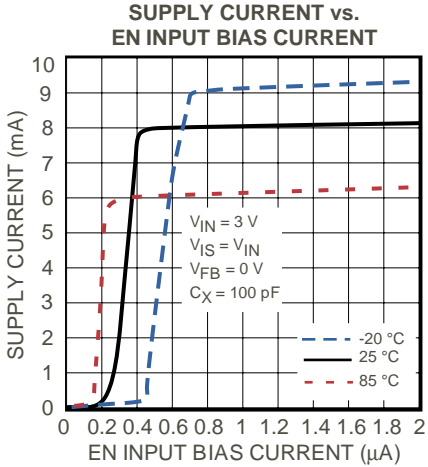
TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = 25\text{ }^\circ\text{C}$, unless otherwise specified.



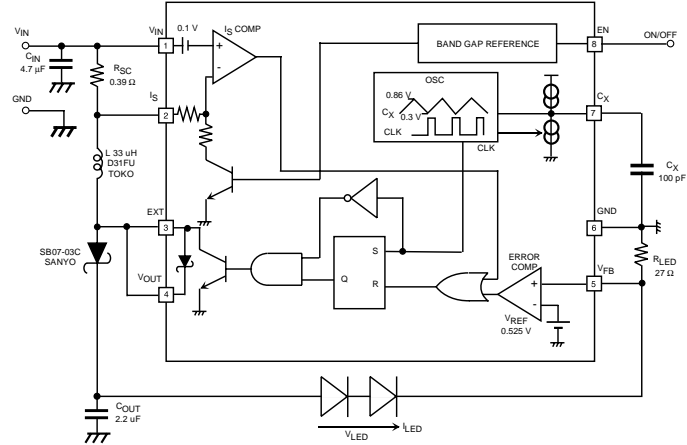
TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

$T_A = 25\text{ }^\circ\text{C}$, unless otherwise specified.



APPLICATION CIRCUIT (2 LEDs in Series)

- Input Voltage: 2.7 V
- LED Current : 20 mA
- On/Off: Pin Number 8 (EN Pin)
LED Current (I_{LED}) is set by R_{LED} .
 I_{LED} doesn't depend on V_{IN} because I_{LED} is controlled by the feedback circuit.



TYPICAL PERFORMANCE CHARACTERISTICS

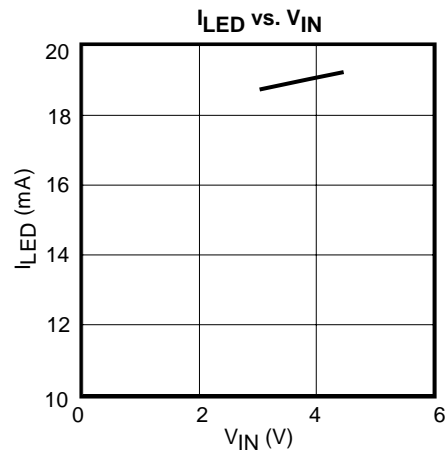
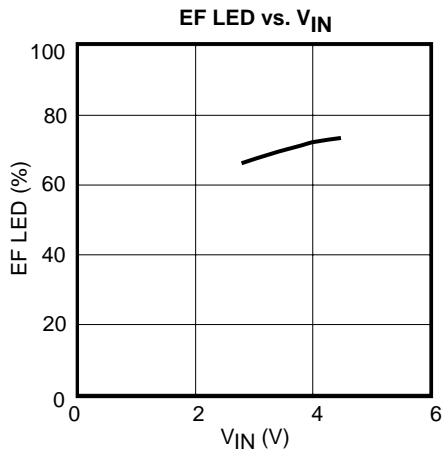
$T_A = 25\text{ }^\circ\text{C}$, unless otherwise specified.

LED Current and Efficiency Characteristics

| V_{IN} (V) | I_{IN} (mA) | V_{LED} (V) | I_{LED} (mA) | EF LED (%) |
|--------------|---------------|---------------|----------------|------------|
| 2.7 | 71.3 | 7.01 | 18.81 | 68.6 |
| 3.0 | 62.9 | 7.01 | 18.85 | 70.0 |
| 3.5 | 52.8 | 7.02 | 18.95 | 71.9 |
| 4.5 | 39.9 | 7.02 | 19.10 | 74.8 |

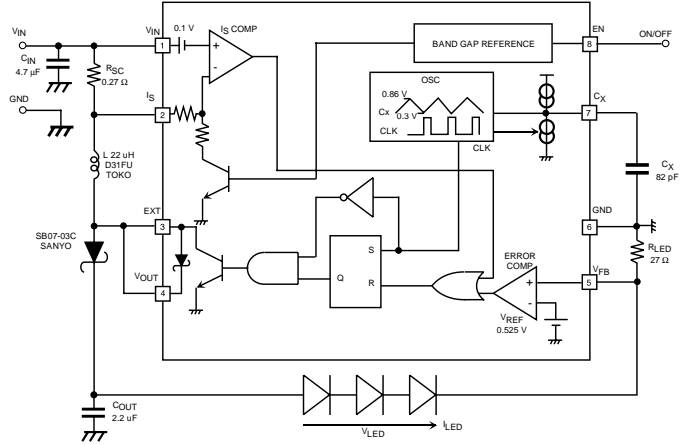
L: D31FU, 33 μ H
Toko Part Number: 888FU-330M

$$EF\ LED\ (\%) = 100 * V_{LED} * I_{LED} / V_{IN} * I_{IN}$$



APPLICATION CIRCUIT (3 LEDs in Series)

- **Input Voltage: 2.7 V**
 - **LED Current: 20 mA**
 - **On/Off: Pin Number 8 (EN Pin)**
- LED Current (I_{LED}) is set by R_{LED} .
 I_{LED} doesn't depend on V_{IN} because I_{LED} is controlled by the feedback circuit.



TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

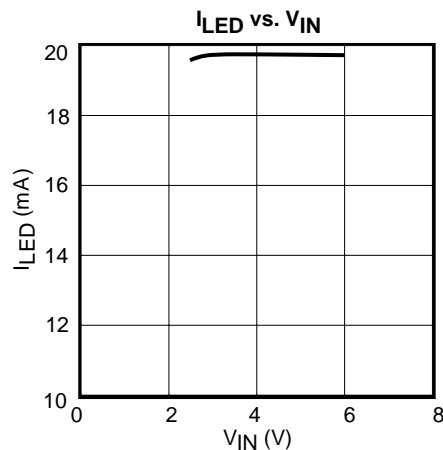
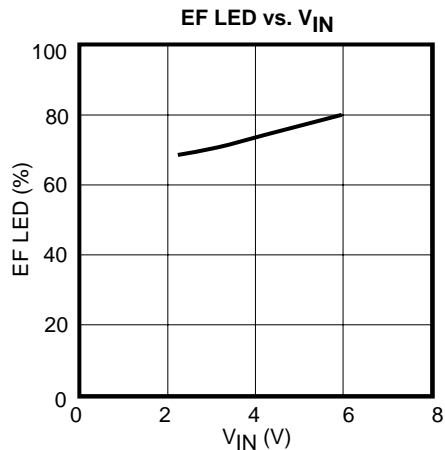
$T_A = 25\text{ }^\circ\text{C}$, unless otherwise specified.

LED Current and Efficiency Characteristics

| V_{IN} (V) | I_{IN} (mA) | V_{LED} (V) | I_{LED} (mA) | EF LED (%) |
|--------------|---------------|---------------|----------------|------------|
| 2.5 | 115.9 | 10.38 | 19.41 | 69.52 |
| 2.7 | 106.9 | 10.38 | 19.49 | 70.09 |
| 3.0 | 95.4 | 10.38 | 19.52 | 70.83 |
| 3.5 | 79.1 | 10.38 | 19.52 | 73.19 |
| 4.5 | 59.2 | 10.39 | 19.56 | 76.26 |
| 6.0 | 42.9 | 10.39 | 19.60 | 79.04 |

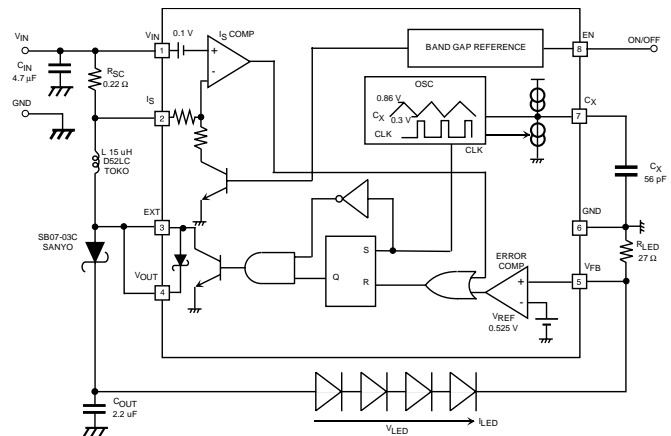
L: D31FU, 22 μ H
 Toko Part Number: 888FU-220M

$$EF\ LED\ (\%) = 100 * V_{LED} * I_{LED} / V_{IN} * I_{IN}$$



APPLICATION CIRCUIT (4 LEDs in Series)

- **Input Voltage: 2.7 V**
 - **LED Current: 20 mA**
 - **On/Off: Pin Number 8 (EN Pin)**
- LED Current (I_{LED}) is set by R_{LED} .
 I_{LED} doesn't depend on V_{IN} because I_{LED} is controlled by the feedback circuit.



TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

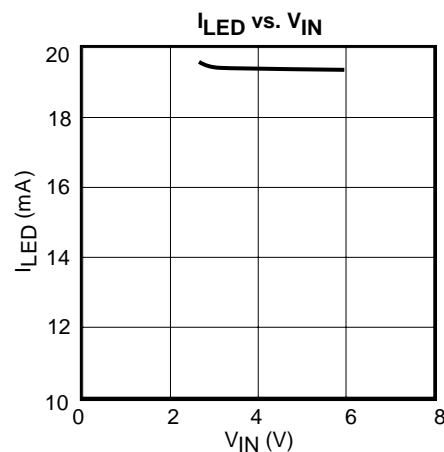
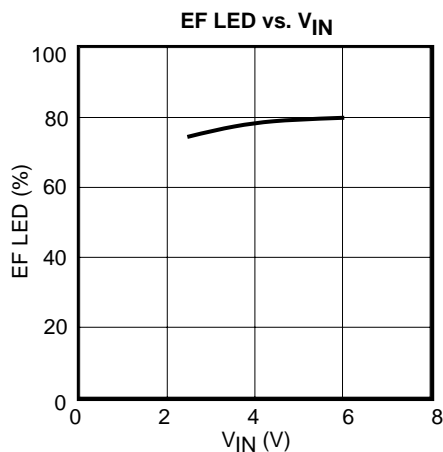
$T_A = 25\text{ }^\circ\text{C}$, unless otherwise specified.

LED Current and Efficiency Characteristics

| V_{IN} (V) | I_{IN} (mA) | V_{LED} (V) | I_{LED} (mA) | EF LED (%) |
|--------------|---------------|---------------|----------------|------------|
| 2.5 | 144.4 | 13.68 | 19.32 | 73.30 |
| 2.7 | 132.2 | 13.68 | 19.30 | 73.97 |
| 3.0 | 117.9 | 13.68 | 19.27 | 74.44 |
| 3.5 | 99.0 | 13.68 | 19.28 | 76.07 |
| 4.5 | 75.3 | 13.68 | 19.35 | 78.06 |
| 6.0 | 55.3 | 13.68 | 19.34 | 79.71 |

L: D52LC, 15µH
 Toko Part Number: A914BYNW - 150M

$$EF\ LED\ (\%) = 100 * V_{LED} * I_{LED} / V_{IN} * I_{IN}$$



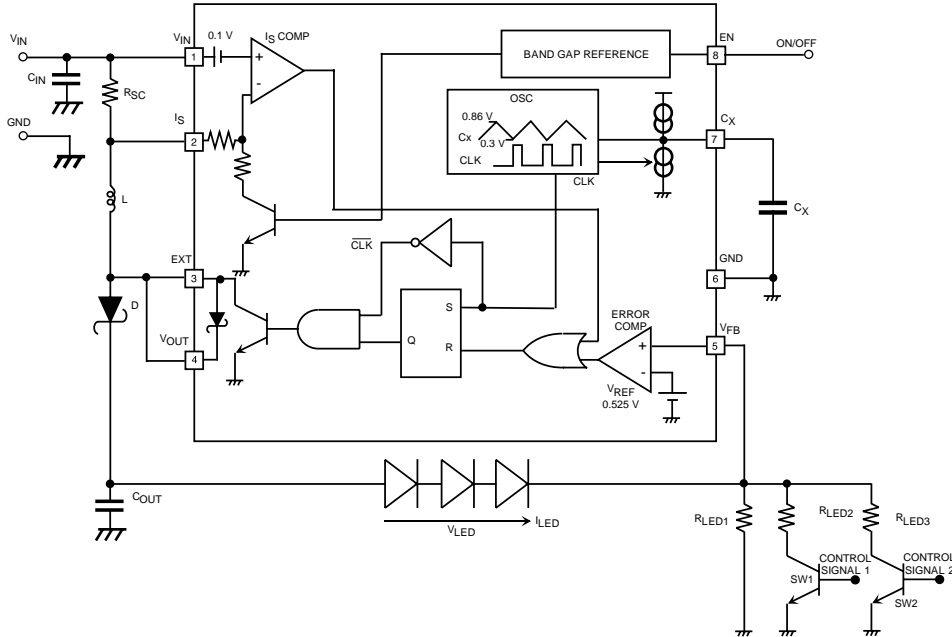
DIMMING

The following are 3 kinds of dimming methods.

1. Dimming by R_{LED}

The current of the LED (I_{LED}) is determined by R_{LED} , which can be set by switches such as transistors.

Example of 3 LEDs with a 4 brightness level circuit:



$$I_{LED} = \frac{V_{REF}}{R_{LED}}$$

R_{LED} : Total value of Resistors

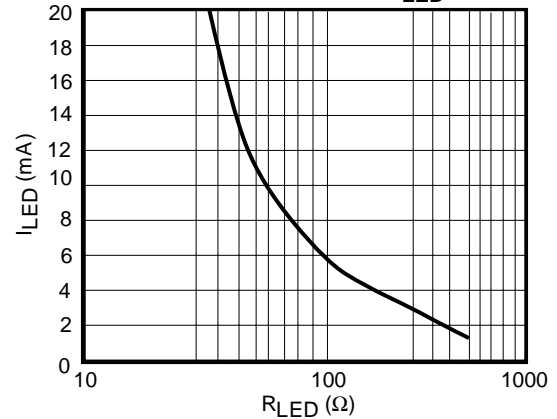
$V_{REF} = 0.525 \text{ V (typ)}$

V_{FB} Voltage = 0.525 V (typ)

I_{LED} vs. R_{LED}

| $R_{LED} (\Omega)$ | $I_{LED} (\text{mA})$ |
|--------------------|-----------------------|
| 24 | 21.9 |
| 27 | 19.5 |
| 36 | 14.6 |
| 51 | 10.4 |
| 100 | 5.4 |
| 510 | 1.1 |

LED CURRENT (I_{LED}) vs. TOTAL RESISTANCE (R_{LED})

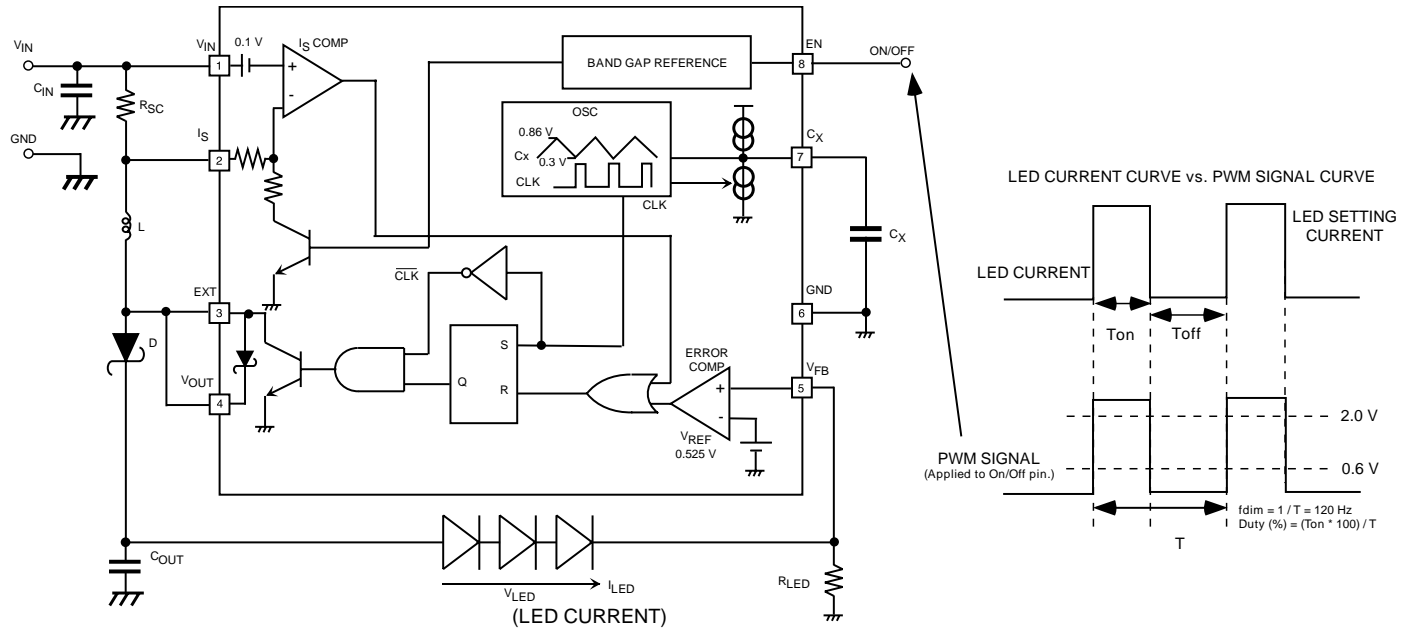


DIMMING (CONT)

2. PWM Dimming

Apply the PWM signal to the EN Terminal (Pin no. 8). In this case, a signal frequency of approximately 120 Hz is adequate. The average current of the LED changes due to the On/Off cycle of the IC, which follows the duty cycle of the PWM signal.

Set the PWM signal at a high level over 2 V and a low level under 0.6 V, with a driving current over 2 μ A.



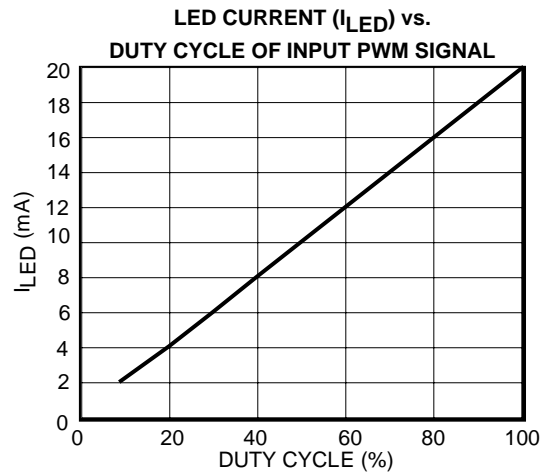
The PWM dimming LED current follows the PWM signal. (As shown above)

The average LED current is obtained from the formula below. The graph below shows an example with $I_{LED(MAX)}$ (20 mA) at a Duty Cycle up to 100%.

I_{LED} vs. DUTY

$$I_{LED(AVG)} = I_{LED(MAX)} \times \frac{Duty}{100}$$

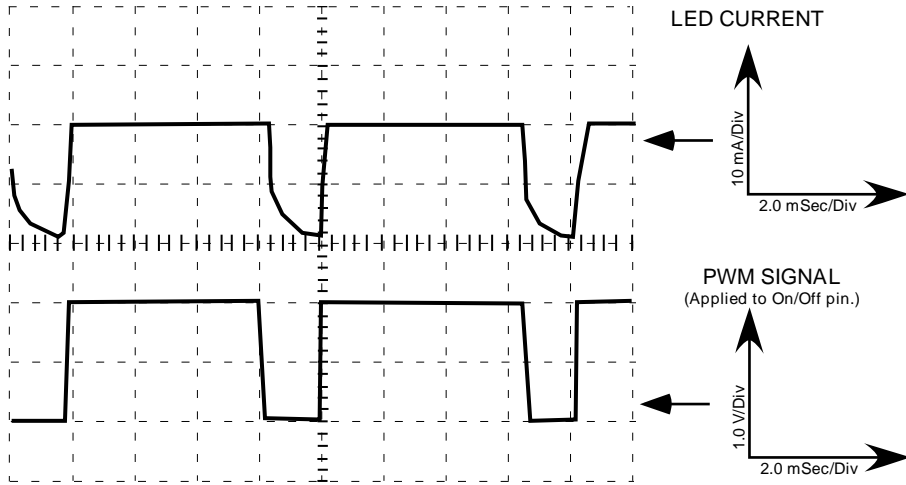
| DUTY (%) | I_{LED} (mA) |
|----------|----------------|
| 100 | 20.0 |
| 90 | 18.0 |
| 80 | 16.0 |
| 70 | 14.0 |
| 60 | 12.0 |
| 50 | 10.0 |
| 40 | 8.0 |
| 30 | 6.0 |
| 20 | 4.0 |
| 10 | 2.0 |



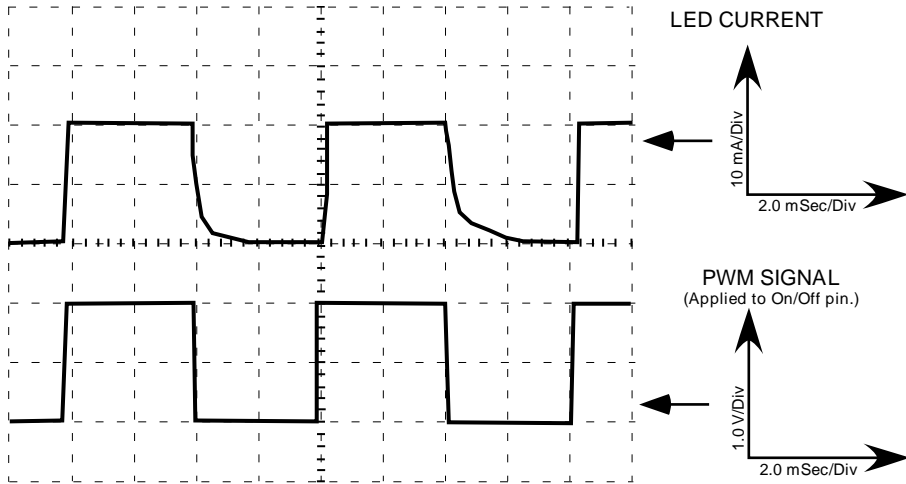
TK11850L

Input PWM signal curve vs. LED current curve (ex. Three LEDs, Output current 20 mA)

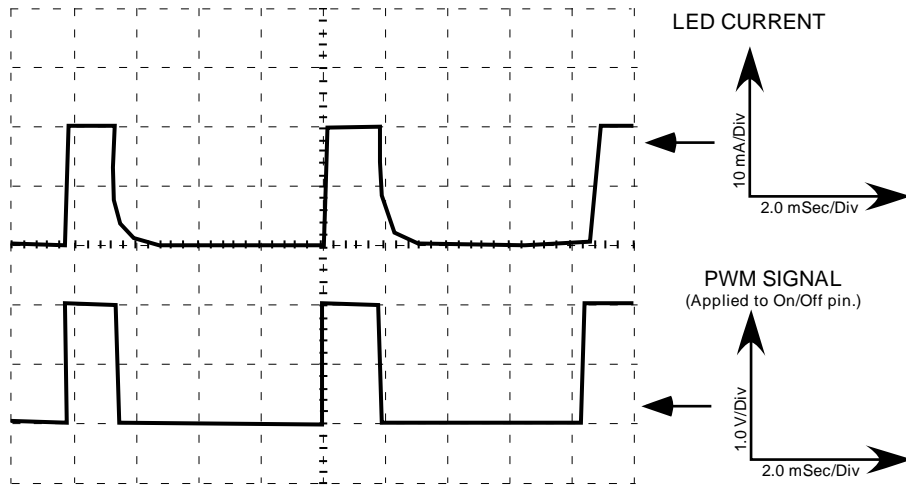
(1) Duty Cycle = 80%



(2) Duty Cycle = 50%



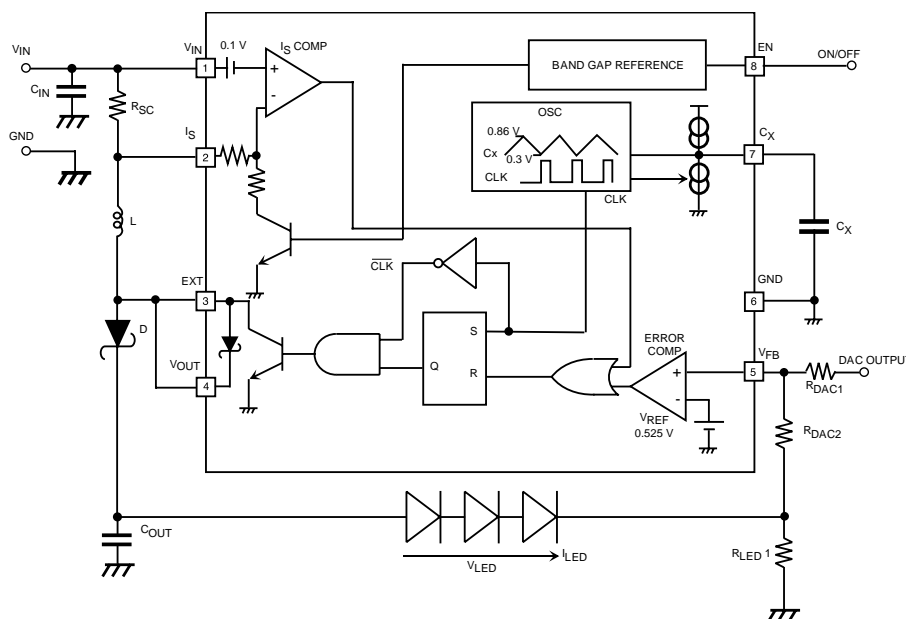
(3) Duty Cycle = 20%



DIMMING (CONT)

3. Dimming by DAC (D/A Converter) output

Dimming is achievable by applying a DAC output to the V_{FB} terminal with the addition of R_{DAC1} and R_{DAC2} .



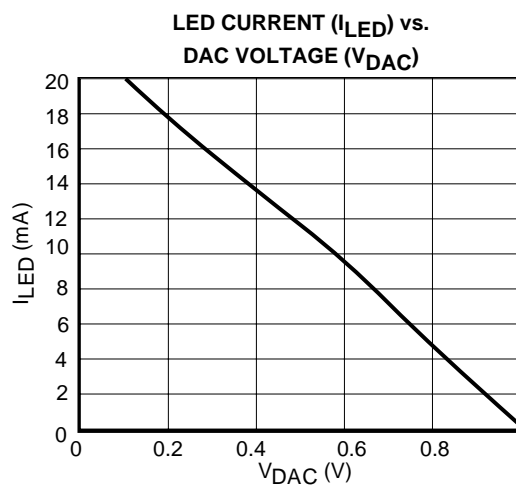
Example Conditions:

$$R_{DAC1} = R_{DAC2}$$

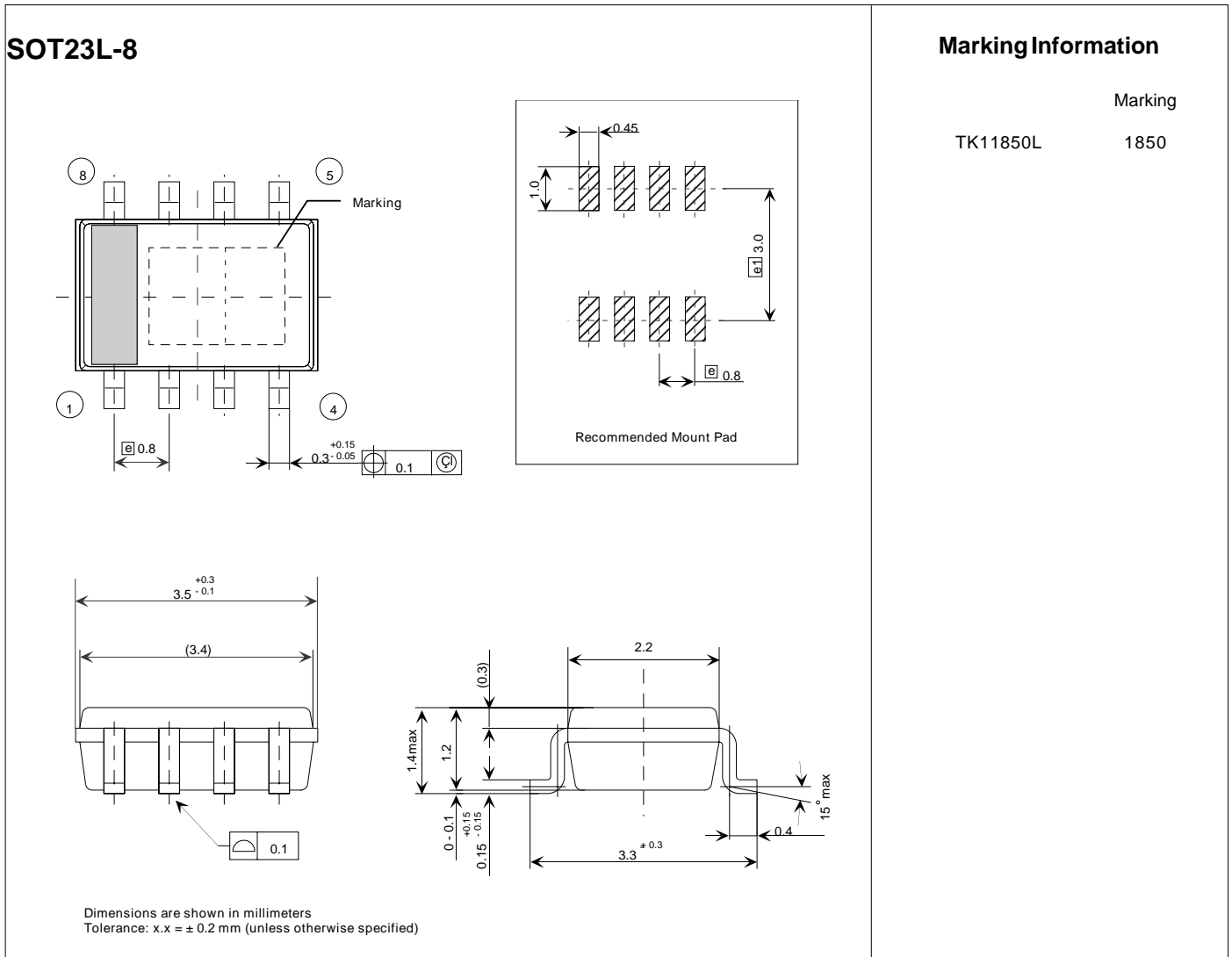
$$R_{LED} = 49 \Omega$$

I_{LED} vs. V_{DAC}

| DAC VOLTAGE (V) | LED CURRENT (mA) |
|-----------------|------------------|
| 0.1 | 19.58 |
| 0.2 | 17.45 |
| 0.3 | 15.32 |
| 0.4 | 13.21 |
| 0.5 | 11.08 |
| 0.6 | 8.95 |
| 0.7 | 6.84 |
| 0.8 | 4.71 |
| 0.9 | 2.6 |
| 1 | 0.5 |



PACKAGE OUTLINE



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