TOSHIBA BiCD Digital Integrated Circuit   Silicon Monolithic

TB62732FUG

Step-up DC/DC Converter for White LED Driver

The TB62732FUG is a high-efficiency step-up DC/DC converter designed and optimized for the constant-current lighting of white LEDs.

This IC is particularly suitable for illuminating two to four serial white LEDs with a Li-ion battery.

The IC incorporates an N-ch MOS transistor, which is necessary for switching of the coil.

Also, the LED current I_F can be easily set through the use of an external resistor.

The TB62732FUG is best suited for use as a driver for white LED source backlighting in color LCDs used on PDAs, cellular phones and handy terminal devices.

SSOP6-P-0.95B
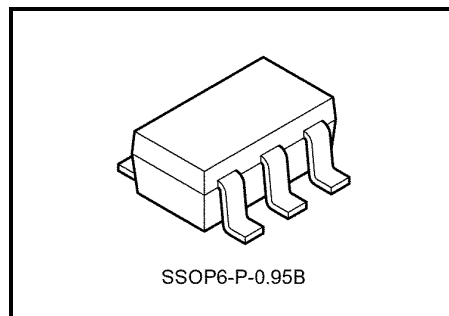
Weight: 0.016 g (typ.)

Features

- LED current values can set through the use of an external resistor
     15 mA (typ.) @R_sens = 3.3 Ω
     18.5 mA (typ.) @R_sens = 2.7 Ω
- Efficiency of 80% realized (serial LEDs 2 to 3, I_F = 20 mA)
- Maximum output voltage: Vo = 17 V
- Output power: Up to 320 mW supported
- Compact package: 6-pin SOT23 (SSOP6-P-0.95B)
- Built-in N-channel MOS with low ON-resistance (Ron)
     Ron = 2.0 Ω (typ.) @V_{CC} = V_{IN} = 3.6 V
- Switching frequency: 1.1 MHz (typ.)
- Output capacitor
     Small capacity of 0.47 µF
- Inductance: 2.2 µH to 10 µH

Pin assignment (top view)
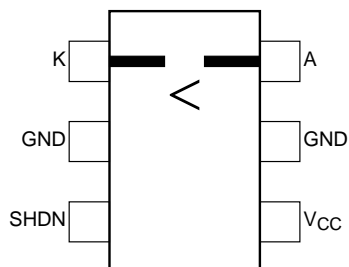
Note 1: This product contains pins that are vulnerable to electrostatic discharge. Handle with care.
         This IC may break if mounted 180 degrees in the reverse direction. Be sure to orientate the IC in the correct direction.

Block Diagram
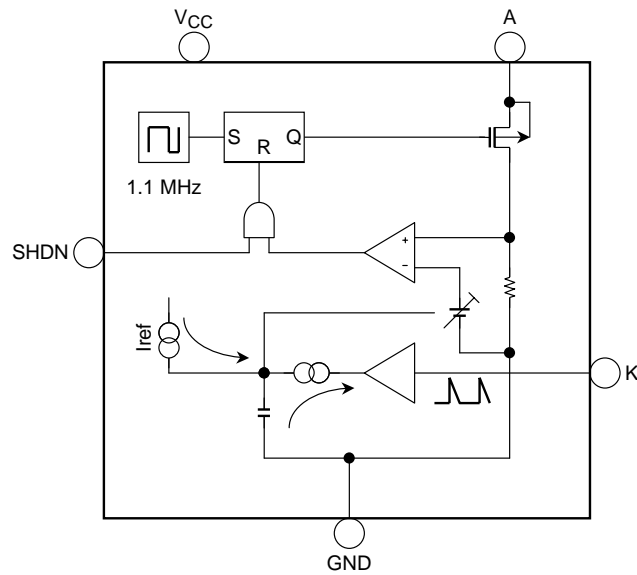
Pin Functions

No	Symbol	Function
1	K	Pin connecting LED cathode to resistor used to set current. Feedback pin for voltage waveforms for controlling the LED constant current.
2, 5	GND	Ground pin for the logic
3	SHDN	IC enable pin.If Low, Standby Mode takes effect and pin A is turned off.
4	V_{CC}	Input pin for power supply for operating the IC. Operating voltage range: 3.0 to 5.5 V
6	A	DC-DC converter switch pin. The switch is an N-channel MOSFET transistor.

Note 2:   Connect both GND pins to ground.

Absolute Maximum Ratings

Characteristics	Symbol	Rating	Unit
Supply voltage	V_{CC}	−0.3 to +6.0	V
Input voltage	V_{IN}	−0.3 to +V_{CC} + 0.3	V
Switching pin current	I_O (A)	380	mA
Switching pin voltage	V_O (A)	−0.3 to 17	V
Power dissipation	P_D	0.41 (IC only)	W
		0.47 (IC mounted on PCB) (Note 3)	
Saturation thermal resistance	$R_{th\ (j-a)}$	300 (IC only) 260 (IC mounted on PCB)	°C/W
Operating temperature range	T_{opr}	−40 to +85	°C
Storage temperature range	T_{stg}	−40 to +150	°C
Maximum junction temperature	T_j	125	°C

Note 3: The power dissipation is derated by 3.8 mW/°C from the maximum rating for every 1°C exceeding the
ambient temperature of 25°C (when the IC is mounted on a PCB).

Recommended Operating Conditions
(unless otherwise specified, Ta = 25°C and V_{CC} = 3.6 V)

Characteristics	Symbol	Test circuit	Test condition	Min	Typ.	Max	Unit
Supply voltage	V_{CC}	—	—	3.0	—	4.3	V
SHDN pin high-level input voltage	V_{IH}	—	V_{CC} = 3 to 4.3 V	2.6	—	V_{CC}	V
SHDN pin low-level input voltage	V_{IL}	—	V_{CC} = 3 to 4.3 V	0	—	0.5	V
SHDN pin input pulse width	tpw SHDN	—	SHDN = High and Low level	50	—	—	μs
Set LED current	I_o	—	V_{CC} = 3 V, illuminating series LEDs 2 to 4	5	—	20	mA

Electrical Characteristics
(unless otherwise specified, Ta = 25°C, V$_{CC}$ = 3.6 V, V$_{SHDN}$ = 3.6 V)

Characteristics	Symbol	Test circuit	Test condition	Min	Typ.	Max	Unit
Supply voltage	V$_{CC}$	—	—	3.0	—	5.5	V
Current consumption at operation	I$_{CC}$ (on)	—	SHDN = V$_{CC}$	—	0.52	0.8	mA
Current consumption at standby	I$_{CC}$ (off)	—	SHDN = 0 V	—	0.5	1.0	μA
SHDN pin current	I_SHDN	—	SHDN = V$_{CC}$, Built-in pull-down resistor	—	4.2	7	μA
MOS transistor on-resistance	Ron	—	I$_o$ = 300 mA, detection resistance value is contained	—	2.0	2.5	Ω
MOS transistor switching frequency	f$_{OSC}$	—	—	0.77	1.1	1.43	MHz
Pin A voltage	V$_o$ (A)	—	—	17	—	—	V
Pin A current	I$_o$ (A)	—	—	—	350	380	mA
Pin A leakage current	I$_{oz}$ (A)	—	—	—	0.5	1	μA
Set LED current I$_F$	I$_o$	—	R_sens = 2.7 Ω, L = 6.8 μH (Note 4)	—	18.5	—	mA
LED current V$_{CC}$ dependence	dl$_o$	—		—	±8	±12	%

Note 4: Fluctuation in R_sens resistors is not included in the specified value.
The absolute value of Io may vary and therefore differ from the value specified due to the relation between the inductor value and the load.
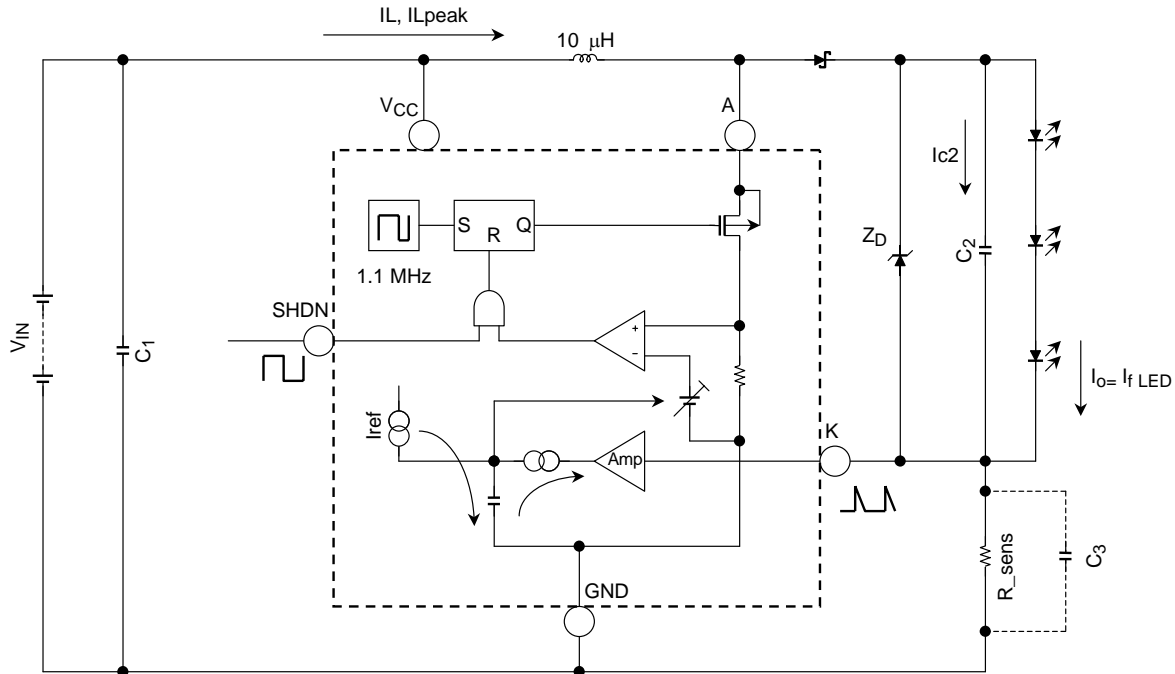
Figure 1　Application Circuit

Basic Operation

The basic TB62732FUG circuit uses a step-up DC/DC converter, and features peak control of the current pulse.

The inductance is turned on and off with the fixed frequency f_{OSC} (1.1 MHz (typ.)), and the inductor is charged with energy.

When the inductance is turned on, the inductor current IL increases from IL = 0; and when IL = ILpeak is reached, the inductance is turned off.

At this point, the Schottky diode is turned on and IL = Ic2 flows so that the coil may retain IL = ILpeak.

After that, Ic2 is decreased, and IL = 0 is reached.

This operation is repeated; and as soon as Ic2 has fully charged C2, I_0 flows to the LED.

The details of the basic pulse used for the current control are shown in Figure 2.
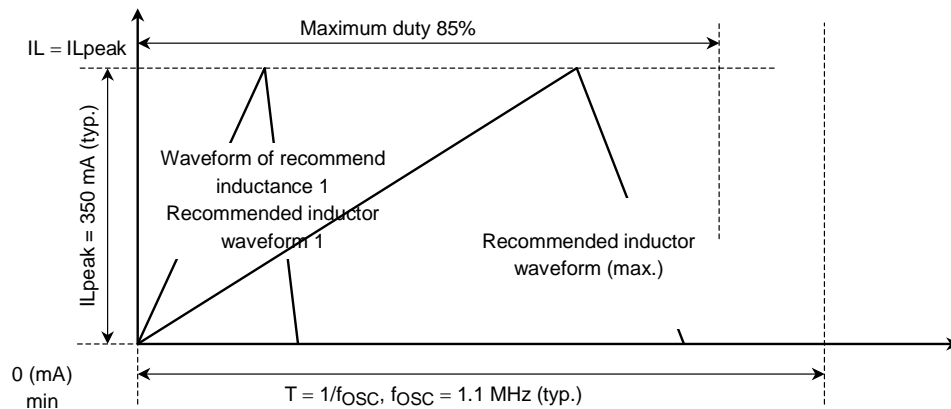
Figure 2　Switching Waveform of Inductance

Switching frequency
f_{OSC} = 1.1 MHz

Maximum On pulse
width = 85%

LED V_F

Pin A voltage

I_A (peak)

Pin A current (external
inductance current)

As I_A (peak) is lowered, it is stabilized at the set value I_O..

Pin K voltage (current
charged on capacitor)

As I_A (peak) is lowered, it is stabilized at the set value I_O.
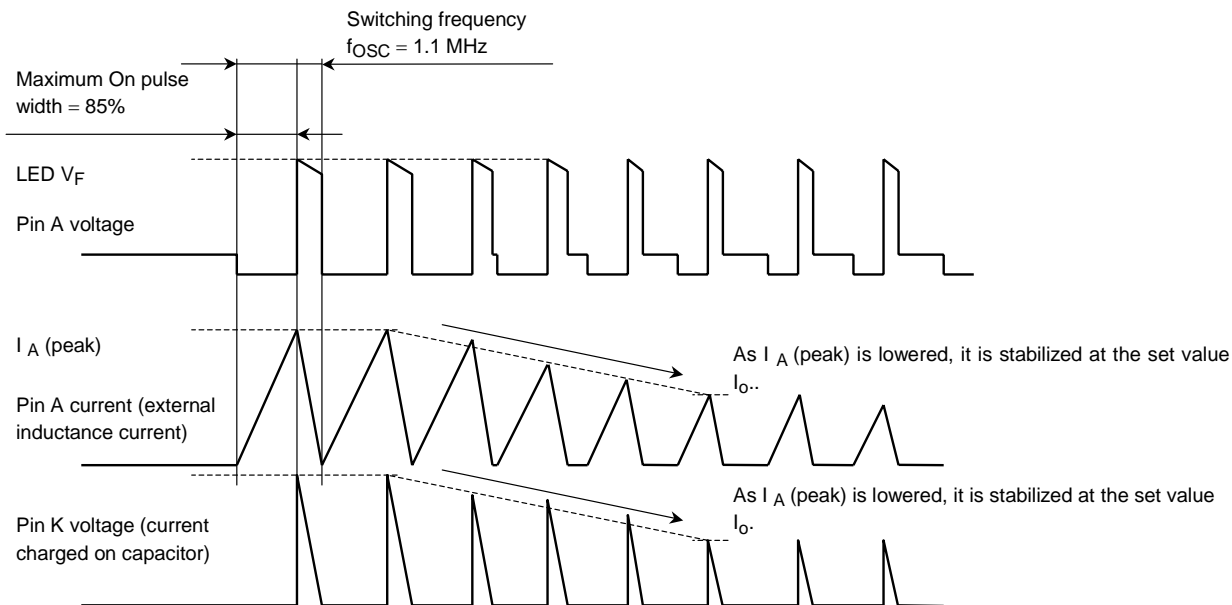
Figure 3   Burst Control Waveforms

State of Peak Current Control

   "Peak current control" is control that can vary the peak current pulse shown in Figure 2 on the previous page. The current pulse in Figure 2 is a charging current on the output side capacitor C_2. This is supplied to the LED as a C2 discharge current and flows through the R_sens resistor to GND.

   The charging voltage wave form of C_2 is fed back to the IC from pin K.

   In the internal circuit to which it is assumed pin K is input, the mean value of the AC voltage waveform obtained decreases the peak current to an assumed value of approximately 48 to 54 mV.

   As a result, a constant current is controlled as an average current in the LED.

   Therefore, if R_sens = 2.7 Ω is connected, an I_F current of 19.6 mA can be obtained.

   The TB62732FUG is designed to be able to supply a load power of 320 mW (min.).   With an inductance of 4.7 to 10 μH, the boost inductor has been optimally designed for this load power of 320 mW.

   Also, make the inductance small when the load power is low.

   A condition applying to the LED load between pins A and K is that

$$V_{IN} (V_{CC}) < LED V_F \text{ total}$$

should be strictly maintained.

   The LED will be illuminated always regardless of the IC control. Care should be taken in this regard.

Pin A
voltage

5 V/DIV

Pin K
tvoltage

0.5 V/DIV

IF current

20 mA/DIV
C2 = 0.1 μF

t   200 ns/DIV
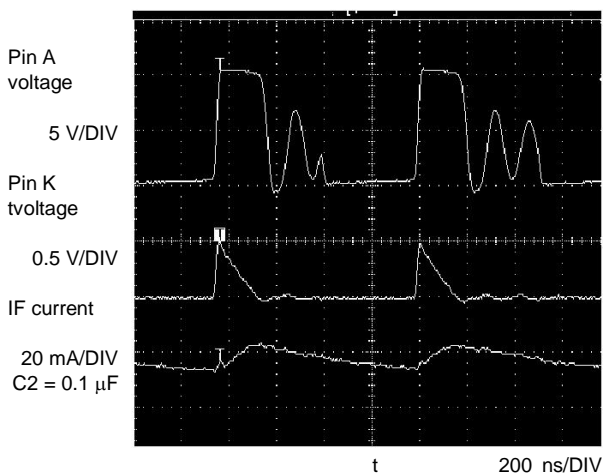
Standby Operation

   The SHDN pin is used to set normal or standby operation. When SHDN is set to Low, operation is in standby; when the pin is High, the LED is turned on. Current consumption in Standby Mode is 1 μA (max).

Drive Waveform

   The figure on the left is an actual drive waveform.
   From the top, the switching voltage waveform of the coil of the generator terminal (pin A), the feedback voltage wave form of pin K, and the LED I_F.

Output-side capacitor setting

To reduce the effect of ripple current, we recommend $C_2 = 0.47$ (μF) or above.

Capacitor C_2 (μF)	Ripple Current (mA)	Note
0.01	15 to 25	
0.1	5 to 8	
0.47	2 to 4	Recommend
1	1 to 3	

External inductance setting

The minimum external inductance is calculated as follows:

L (μH) = $((K \times P_o) - V_{IN}$ min $\times I_O) \times (1/f_{OSC}$ min$) \times 2 \times (1/Ip$ min $\times Ip$ min$)$ . . .   formula 2

The above parameters are described below:

P_o: output power (power required by LED load)
  P_o (W) = V_F LED $\times I_F$ LED + Vf schottky $\times I_F$ LED + R_sens $\times I_F$ LED $\times I_F$ LED
  LED forward current: I_F LED (mA) = Set current: I_O (mA), LED forward voltage: V_F LED (V),
  Schottky diode forward voltage: Vf schottky (V),
  Setting resistance: R_sens (Ω)

V_{IN} min (V): Minimum input voltage (battery voltage)

I_O (A): The average current value established with R_sens.

f_{OSC} (Hz): The switching frequency of the internal MOS transistor

	Min	Typ.	Max	Unit
f_{OSC}	0.77	1.1	1.43	MHz

Ip (A): Peak current value for supply to the inductance

	Min	Typ.	Max	Unit
Ip	320	350	380	MHz

For example, the following condition is substituted for the formula:

  Input voltage V_{IN}: V_{IN} = 3 to 4.3 V,
  V_F LED = 16 V, Schottky diode Vf: Schottky = 0.3 (V),
  Setup resistance R_sens: R_sens = 2.7 (Ω),
  Setup current I_O: I_O = 18.5 mA,
  L (μH) = 5.6 (μH, V_{IN} = 3.0 V) and 6.3 (μH, V_{IN} = 4.3 V).

 In this case, Toshiba recommend selection of L = 5.6 (μH) when V_{CC} = 3 V.   .
This value does not allow for inductor variation and temperature characteristics; therefore we strongly
recommend that these factors be taken into account when selecting products.

Selection of R_sens

The resistance R_sens (Ω) between pin K and GND is used for setting the output current I_O. The mean output current I_O can be set using this resistance.

The mean current I_O (mA) to be set is roughly calculated as follows:

I_O (mA) = V (K): pin K feedback voltage (mV) $\div$ R_sens Ω)

Number of LEDs	Pin K voltage V (K)	Note
2	48	
3	50	
4	52	

For example, if R_sens = 2.7 (Ω), then I_O = 18.5 (mA) with a current error of ±12%.

The IC has a minimum output P_O = 320 (mW).
In this case, if the product Po of the set current I_F LED and the output voltage V_F LED exceeds P_O = 320 (mW), it is possible that the current IF LED will not exceed a given value.

If the IC is not connected to the smoothing capacitor, then I_F LED is obtained as the mean current.
In this instance, because the current which flows to the LED is a triangular waveform current with a maximum peak value of 380 mA, make sure that the inrush current I_{FP} (mA) does not flow to the LED.
Toshiba recommend use of components with low reactance (parasitic inductance) and minimized PCB wiring.

Protection for when the LED is open

The zener diode in the example application circuit in Figure 1 is necessary for over-voltage protection when the LED is open.
It is strongly recommended that a zener diode be connected since this driver lacks a voltage protection circuit.

The zener voltage should satisfy the following conditions:
    i) $\leq$ maximum output voltage of the TB62732FUG
    ii) $\geq$ LED aggregate V_f
    iii) $\leq$ maximum output capacitance C_2.

Moreover, it is possible to control the output current IZD for when the LED is open by connecting the R_ZD as in Figure 4, and to use a zener diode with lower power dissipation.
Standard for Control of Output Current IZD through R_ZD Connection
(R_sens = 2.7 Ω)

R_DZ (Ω)	IZD (mA)
18	3
100	0.1

Since driver characteristics may be adversely affected, Toshiba recommend 100 Ω or less.
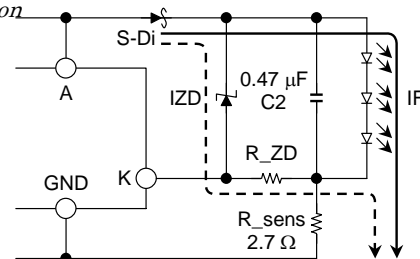
Figure 4   Application Circuit

Current consumption at normal operation I_{CC} (ON)
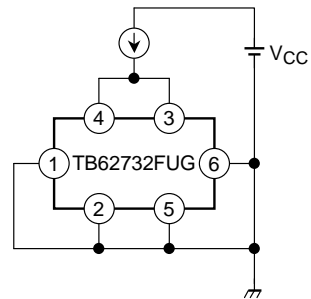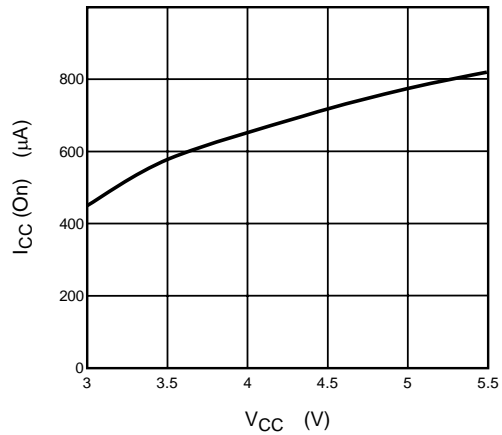
Current consumption at shutdown I_{CC} (SHDN)

$V_{CC} = 3.6$ V
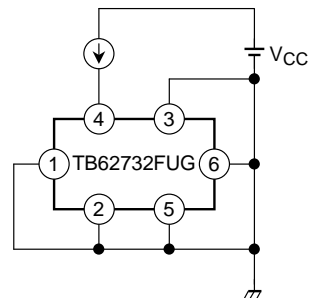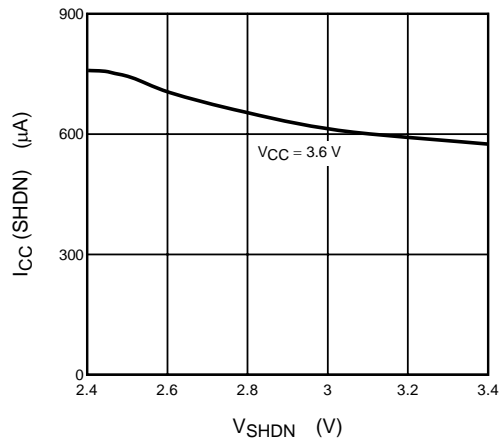
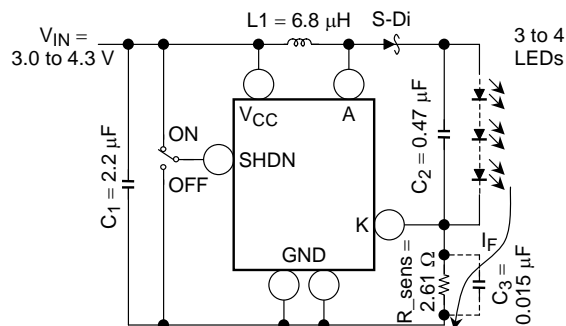
Output switching frequency
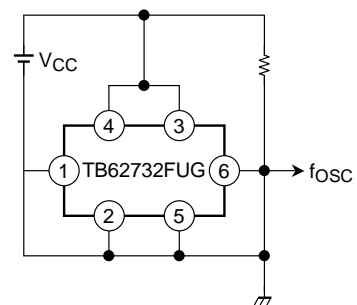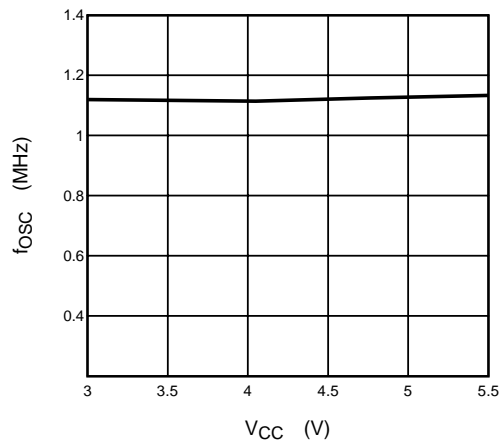
Application Evaluation Circuit Example 1
(Example of evaluation result using a small coil: Coil LDR304612T-6R8)

6.8 µH is optimum for illuminating serial LEDs 3 to 4 LEDs using I_F = 20 mA.

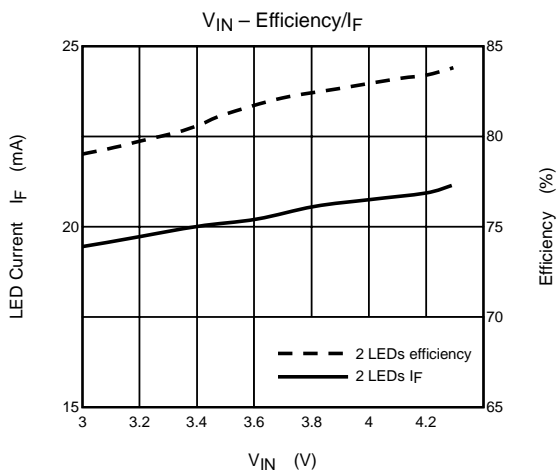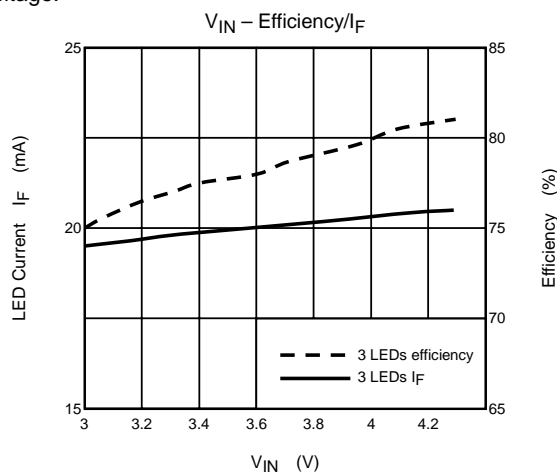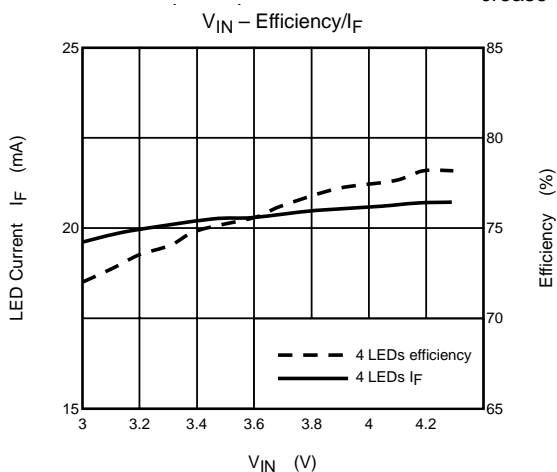4.7 µH is recommended for steady illumination of serial LED 2 in the range V_{IN} > 4.5 V.

L1 : TDK LDR304612T-6R8
S-Di: TOSHIBA CUS02 30 V/1 A
LED: NICHIA NSCW215T

Note 5: Connection of C$_3$ is not necessary in every case.
The I_F is regarded to stabilize on decrease of voltage.

V_{IN} – Efficiency/I_F

V_{IN} – Efficiency/I_F

V_{IN} – Efficiency/I_F

<Measurement>
Efficiency in the range V_{IN} = 3.0 to 4.3 V

Number of LED	Efficiency (%)	Average Efficiency (%)
2	79.0 to 83.8	81.6
3	75.1 to 80.9	78.3
4	72.0 to 78.3	75.7

I_F in the range V_{IN} = 3.0 to 4.3 V

Number of LED	I_F (mA)	V_{CC} Dependence (%)
2	19.5 to 21.1	7.8
3	19.5 to 20.5	4.9
4	19.6 to 20.7	5.3

Note 6: The above values have been obtained through Toshiba's own measurements. However, results may vary according to the measurement environment.

2004-09-28

Application Evaluation Circuit Example 2
(Example of evaluation result using a small coil: Coil CXML321610-7R0)

6.8 μH is optimum for illumination of serial LEDs 4 to 3 using I_F = 20 mA.

4.7 μH is recommended for steady illumination of serial LED 2 in the range V_{IN} > 4.5 V.
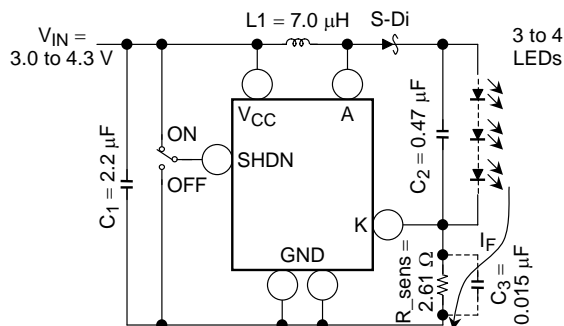
L1 : SUMITOMO CXML321610-7R0
S-Di: TOSHIBA CUS02 30 V/1 A
LED: NICHIA NSCW215T

Note 7: Connection of C_3 is not necessary in every case. .
The IF is expected to stabilize on decrease of voltage. .

<Measurement>
Efficiency in the range V_{IN} = 3.0 to 4.3 V
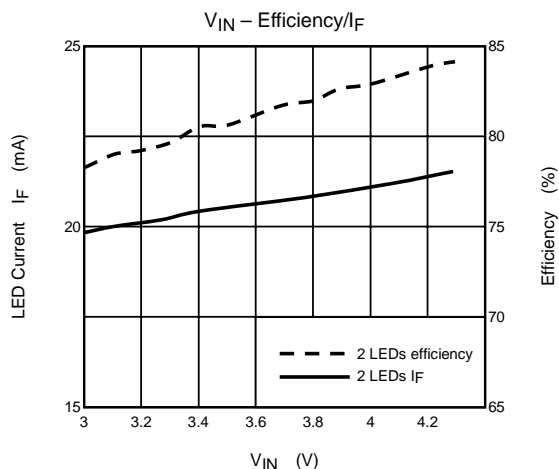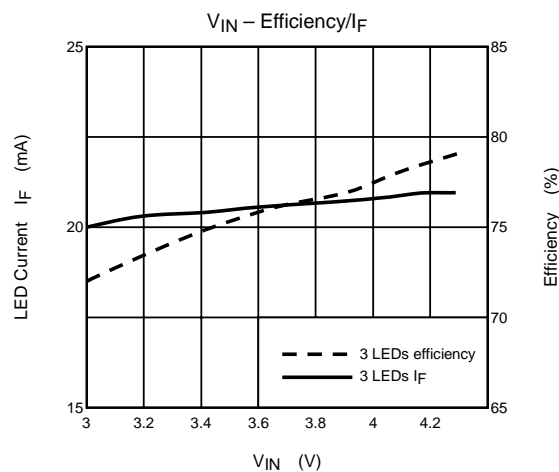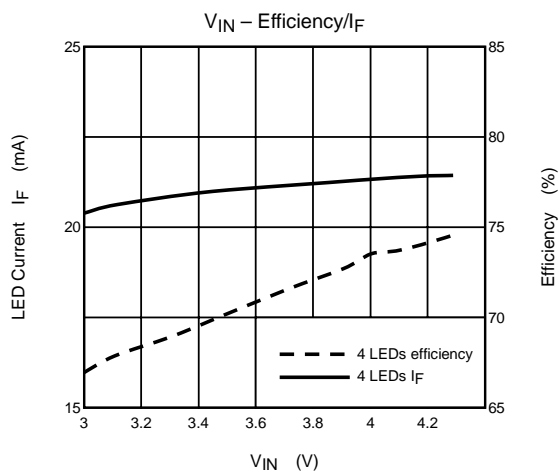
Number of LED	Efficiency (%)	Average Efficiency (%)
2	78.2 to 84.1	81.3
3	72.0 to 79.1	75.8
4	66.9 to 71.1	74.6

I_F in the range V_{IN} = 3.0 to 4.3 V

Number of LED	I_F (mA)	V_{CC} Dependence (%)
2	19.8 to 21.6	8.1
3	20.0 to 21.0	4.8
4	20.4 to 21.5	4.9

Note 8: The above values have been obtained through Toshiba's own measurements. However, results may vary according to the measurement environment.

Application Evaluation Circuit Example 3
(Example of evaluation result using a small coil: Coil 976AS-6R8)

6.8 µH is optimum for illumination of serial LEDs 4 to 3 using I_F = 20 mA.

4.7 µH is recommended for steady illumination of serial LED 2 in the range V_{IN} > 4.5 V.
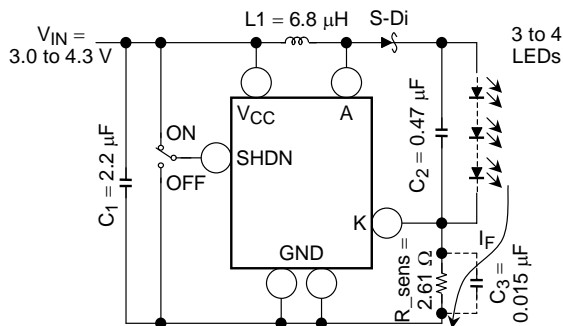
L1 : TOKO 976AS-6R8
S-Di: TOSHIBA CUS02 30 V/1 A
LED: NICHIA NSCW215T

Note 9: Connection of C_3 is not necessary in every case. .
The IF is expected to stabilize on decrease of voltage. .

<Measurement>
Efficiency in the range V_{IN} = 3.0 to 4.3 V
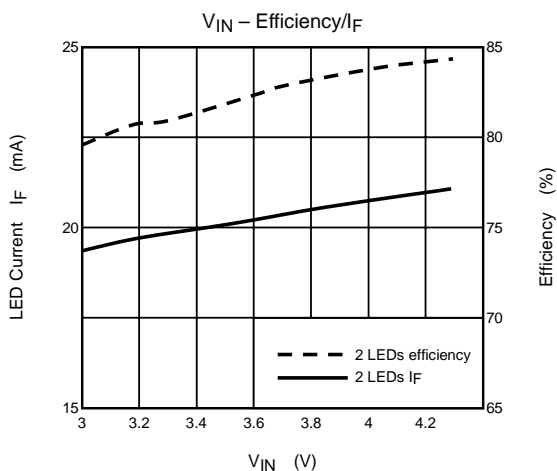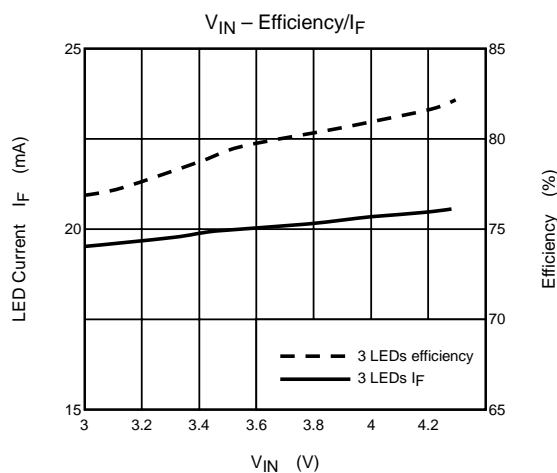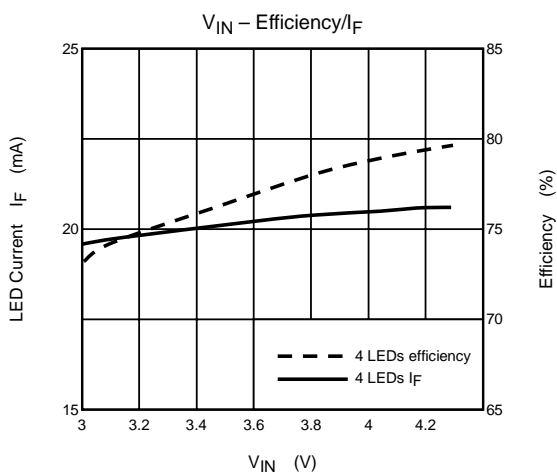
Number of LED	Efficiency (%)	Average Efficiency (%)
2	79.7 to 84.4	82.3
3	76.7 to 82.1	79.5
4	73.1 to 79.7	74.0

I_F in the range V_{IN} = 3.0 to 4.3 V

Number of LED	I_F (mA)	V_{CC} Dependence (%)
2	19.4 to 21.1	8.1
3	19.5 to 20.5	5.1
4	19.6 to 20.7	5.3

Note 10: The above values have been obtained
through Toshiba's own measurements.
However, results may vary according to the
measurement environment.

Application Evaluation Circuit Example 4
(Example of evaluation result using a small coil: Coil CXLD140-6R8)

6.8 μH is optimum for illumination of serial LEDs 4 to 3 using I_F = 20 mA.

4.7 μH is recommended for steady illumination of serial LED 2 in the range V_{IN} > 4.5 V.
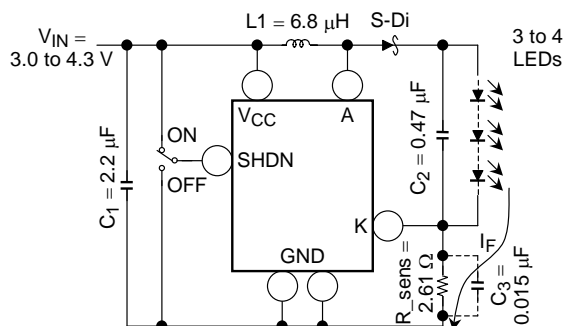
L1 : SUMITOMO CXLD140-6R8
S-Di: TOSHIBA CUS02 30 A/1 V
LED: NICHIA NSCW215T

Note11: Connection of C_3 is not necessary in every case. .
The IF is expected to stabilize on decrease of voltage. .

<Measurement>
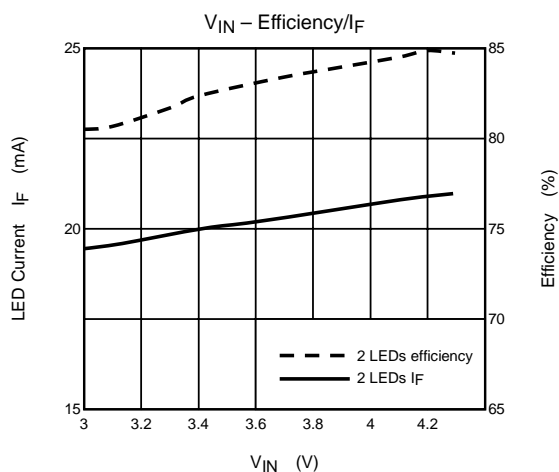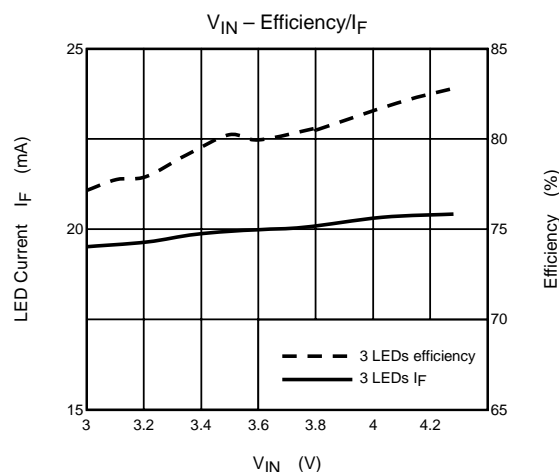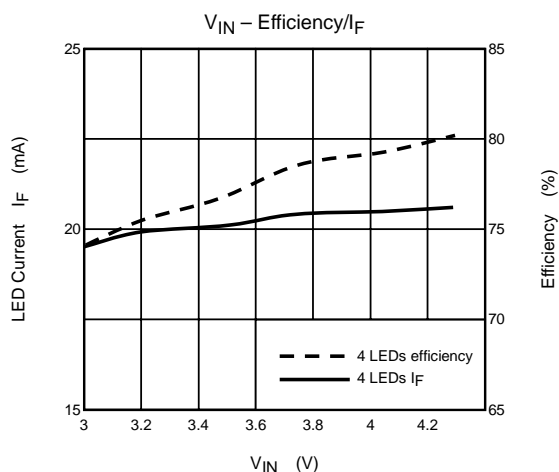
Efficiency in the range V_{IN} = 3.0 to 4.3 V

Number of LED	Efficiency (%)	Average Efficiency (%)
2	80.3 to 84.9	82.9
3	77.2 to 82.8	80.2
4	74.1 to 80.4	77.6

I_F in the range V_{IN} = 3.0 to 4.3 V

Number of LED	I_F (mA)	V_{CC} Dependence (%)
2	19.4 to 21.0	7.6
3	19.5 to 20.5	5.1
4	19.6 to 20.7	5.3

Note 12: The above values have been obtained through Toshiba's own measurements. However, results may vary according to the measurement environment.

Package Dimensions

SSOP6-P-0.95B   Unit: mm
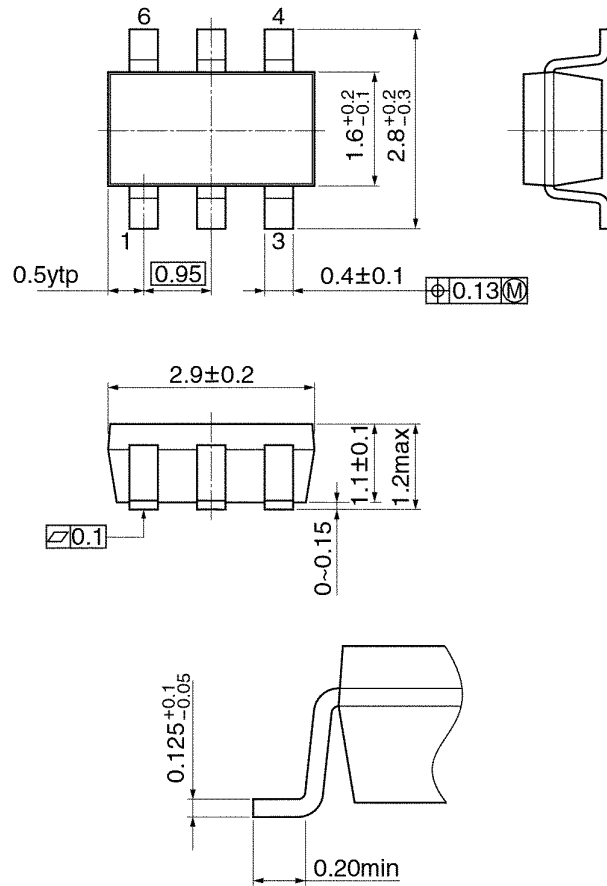
Weight: 0.016 g (typ.)

About solderability, following conditions were confirmed

- Solderability

  (1) Use of Sn-63Pb   solder Bath
  - · solder bath temperature = 230°C
  - · dipping time = 5 seconds
  - · the number of times = once
  - · use of R-type flux

  (2) Use of Sn-3.0Ag-0.5Cu   solder Bath
  - · solder bath temperature = 245°C
  - · dipping time = 5 seconds
  - · the number of times = once
  - · use of R-type flux

RESTRICTIONS ON PRODUCT USE

030619EBA