TOSHIBA BiCD Digital Integrated Circuit Silicon Monolithic

TB62731FUG

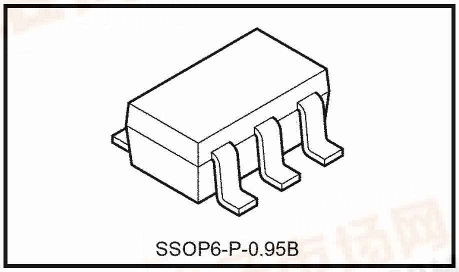
Step-up DC-DC Converter for White LED Driver

The TB62731FUG is an LED driver that uses a high power efficiency step-up DC-DC converter. The converter turns on/off 2 to 6 white LEDs in series.

The IC incorporates an N-channel MOSFET transistor used for coil-switching and a function that reduces the LED current in response to increase in temperature.

The mean LED current can be easily set using an external resistor.

The IC is ideal as a driver for LED light sources used as liquid crystal backlights for PDAs, cellular phones, and handy terminals.

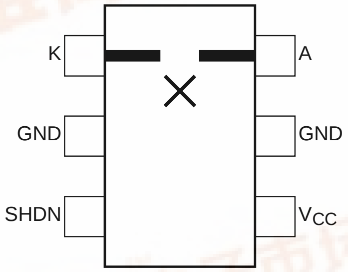


Weight: 0.016 g (typ.)

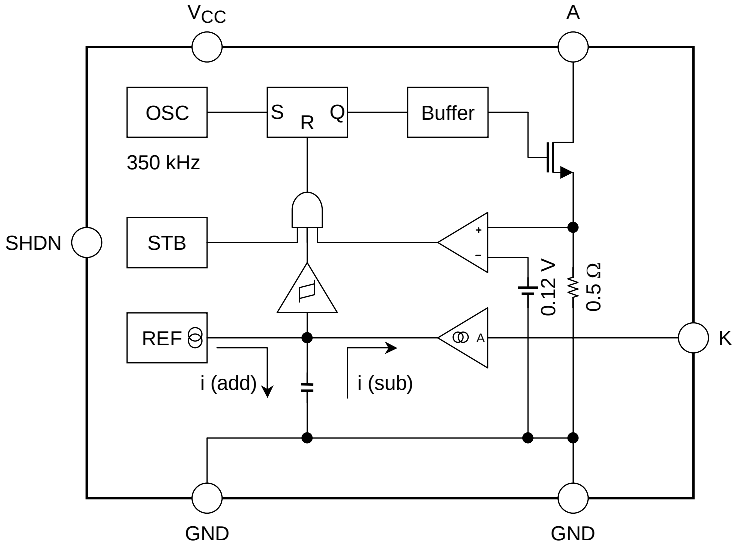
Features

- Maximum output voltage: $V_o \leq 28$ V
- Mean LED current values set according to external resistor
  - 14 mA (typ.) @R_sens = 2.7 Ω
  - 20 mA (typ.) @R_sens = 1.8 Ω
- Supply power: Up to 320 mW supported
- Compact package: SSOP6-P-0.95B, 6 pins
- Built-in temperature derating function: LED current derated automatically depending on temperature
- High power efficiency
  - Up to 80% of peak power efficiency achieved using recommended components
  - Ron = 2.0 Ω (typ.) @V_{IN} = 3.2~5.5 V
  - Built-in low Ron power MOS switch

Pin assignment (top view)



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. 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: 3.0~5.5 V
6	A	DC-DC converter switch pin. The switch is an N-channel MOSFET transistor.

Note: Connect both GND pins to ground.

Absolute Maximum Ratings (unless otherwise specified, $T_{opr} = 25°C$)

Characteristics	Symbol	Rating	Unit
Supply voltage	V_{CC}	−0.3~+6.0	V
Input voltage	V_{IN}	−0.3~+V_{CC} + 0.3	V
Pin A (anode) current	I_o (A)	+270	mA
Pin A voltage	V_o (A)	−0.3~+28	V
Power dissipation	P_D	0.41 (IC only)	W
		0.47 (IC mounted on PCB) (Note)	
Saturation thermal resistance	$R_{th\ (j\text{-}a)}$ 1	300 (IC only)	°C/W
	$R_{th\ (j\text{-}a)}$ 2	260 (IC mounted on PCB)	
Operating temperature range	T_{opr}	−40~+85	°C
Storage temperature range	T_{stg}	−40~+150	°C
Maximum junction temperature	T_j	125	°C

Note: 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, $T_{opr} = -40\text{~}85°C$)

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} − 0.5	—	V_{CC}	V
SHDN pin low-level input voltage	V_{IL}	—	—	0	—	0.5	V
SHDN pin high-level input pulse width	tpw SHDN	—	—	500	—	—	μs
Set LED current (mean)	I_o	—	V_o (A) = V_{IN} 3.0 V, V_{OUT} 16 V	5	—	20	mA

Electrical Characteristics (unless otherwise specified, Ta = −40~85°C, V_{CC} = 3.0~5.5 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)	—	V_{CC} = 3.6 V	—	0.6	0.9	mA
Current consumption at standby	I_{CC} (SHDN)	—	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
Internal MOS transistor on-resistance	Ron	—	I (A) ≦ 270 mA, Including detected resistance	—	2.0	2.5	Ω
Internal MOS transistor switching frequency	f_{OSC}	—	—	275	350	425	kHz
Pin A voltage	V_o (A)	—	—	28	—	—	V
Pin A current	I_o (A)	—	—	210	240	270	mA
Pin A leakage current	I_{oz} (A)	—	—	—	0.5	1	μA
Set LED current (mean)	I_o	—	V_{CC} = 3.2~4.2 V, R_sens = 1.8 Ω T_{opr} = 25°C (Note 1)	17.6	20	22.4	mA
Pin K derating start ambient temperature	Tdel	—	Equivalent to R_sens = 1.8 Ω, L = 4.7 μH, V_O = 16 V	—	45 (Note 2)	—	°C

Note 1: Due to operation of the temperature derating function, measure when Ta = 25°C.
Note that fluctuation in R_sens resistors is not included in the specified value.
I_O may be different from the specified value due to the relation between the inductor value and load.

Note 2: This rating is guaranteed by the design.

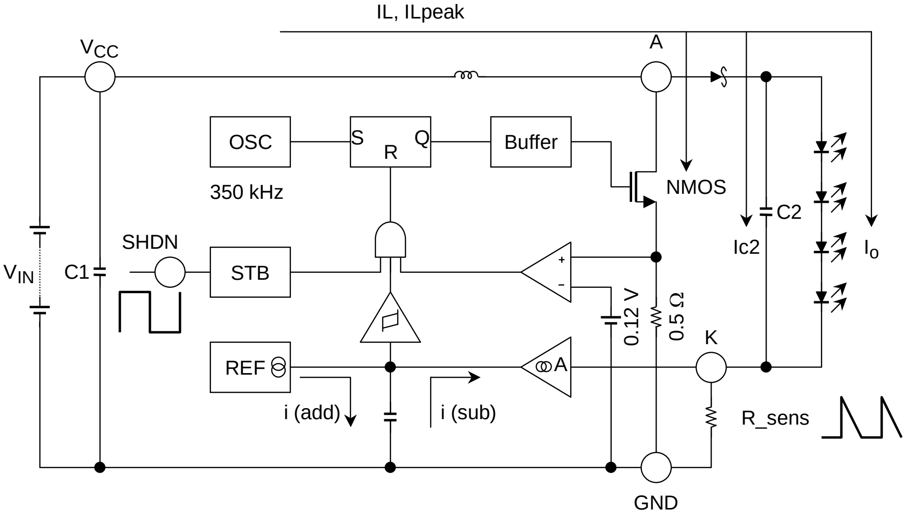


Figure 1 Application Circuit

The basic TB62731FUG circuit uses a step-up DC-DC converter and burst control of the current pulse.

Basic Operation

The internal MOS transistor (NMOS) is turned on at f_{OSC} = 350 kHz, charging energy to the inductor.

The inductance current IL increases from 0. When IL = ILpeak = 240 mA (typ.) or when 5/6 (83.3%) of f_{OSC} (= 350 kHz) is reached, the transistor is turned off.

At that time, the coil maintains IL = ILpeak, the Schottky diode is turned on, and IL = Ic2 flows. Then, Ic2 decreases, reaching IL = 0.

The above operation repeats. When Ic2 is fully charged, the surplus current becomes I_o, which flows to the LED.

The graph below shows details of the basic pulse used for burst control.

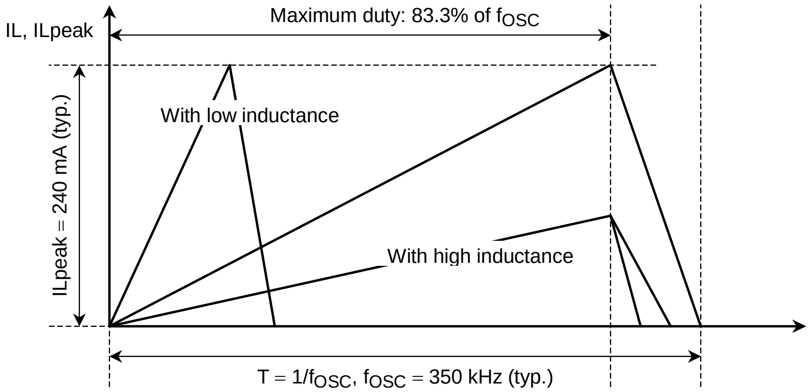


Figure 2 Switching Waveform of Inductance

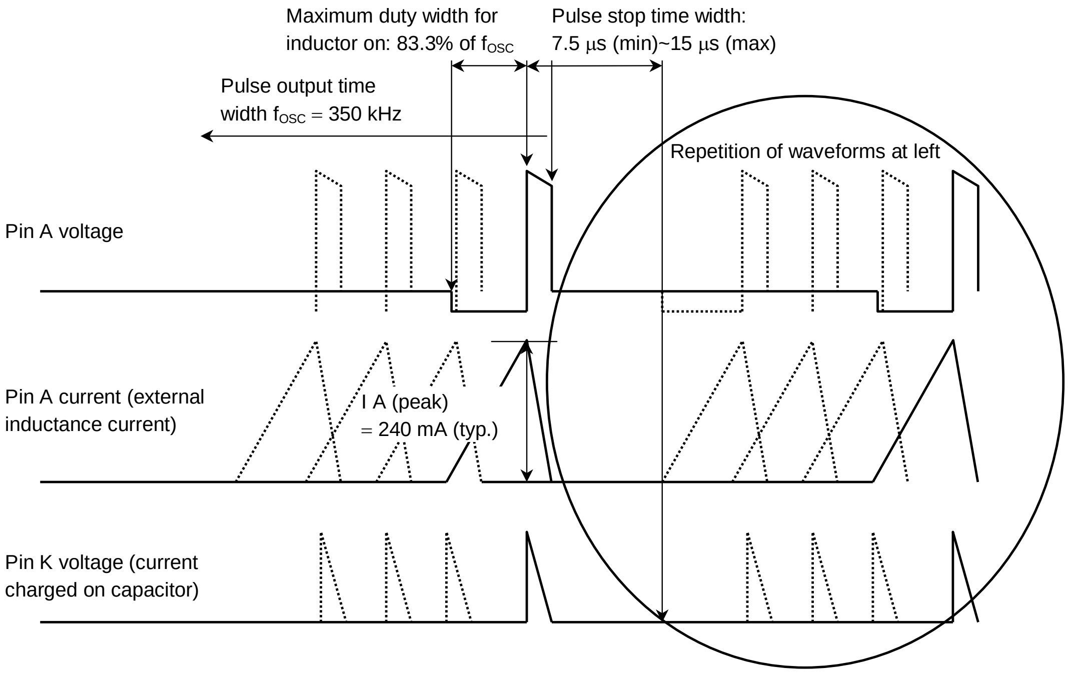


Figure 3 Burst Control Waveforms

Burst Control

Burst control is control of the number of current pulses, shown in the graph on the previous page. Control is repeated in desired cycles. The current pulse in the graph is the charged current on capacitor 2 (C2) for output.

The current pulse is supplied to the LED as current discharged from the output-side capacitor. The current pulse flows to GND via R_sens.

The waveform of the voltage charged on the output-side capacitor is fed back to the IC from pin K via C2.

The internal circuit which uses pin K for input controls the number of current pulses so that the mean voltage value of the obtained voltage waveform is 36 mV. As a result, the output current is controlled as the constant current (= mean current).

Connecting R_sens = 1.8 Ω obtains the mean current (36 mV ÷ 1.8 Ω = 20 mA).

Current is controlled by PFM (pulse frequency modulation) because the time when the output pulse is generated varies (increases/decreases).

A prerequisite is that the input power from V_{IN} is larger than the output power to the LED load. The constant current is maintained by fixing a pulse stop time of 7.5~15 μs and increasing/decreasing the number of current pulses. The number of current pulses is fewer when the input power exceeds the output power, larger when the input power is less than the output power.

The burst frequency (pulse generation frequency) at controlled constant current is calculated as follows:

fburst [Hz] = (number of current pulses x (1/275~1/350 kHz) + pulse stop time (7.5~15 μs) . . . formula 1

The IC is designed to supply a load power of 320 mW (min).

Generally, a step-up inductance of 47 μH is used for optimum design for the load power of 320 mW. When the load power is small, the inductance must be small.

Make sure the following condition for LED load between pins A and K is satisfied:

V_{IN} (V_{CC}) < LED Vf total

Note that, regardless of control by the IC, LEDs are always on.

Standby Operation

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

Output-side capacitor setting

When the output-side capacitor (C2) = 0.1 μF, the peak current to be supplied to LEDs is expected to be the set current +5~+8 mA.

When C2 = 0.01 μF, the peak current is expected to be the set current +20~30 mA; when C2 = 1 μF, it is the set current +2~3 mA. Toshiba recommend C2 = 1 μF or more considering the LED max If.

The IC is used only for lighting LEDs. The IC does not finely control output current ripples. This is because eliminating ripples is considered unnecessary as the LED emittance is recognized as the integral amount.

External inductance setting

The minimum external inductance is calculated as follows:

$$L\ (\mu H) = ((K \times P_o) - V_{IN}\ \text{min} \times I_o) \times (1/f_{OSC}\ \text{min}) \times 2 \times (1/Ip\ \text{min} \times Ip\ \text{min}) \ldots \quad \text{formula 2}$$

The above parameters are described below:

P_o: output power (power required by LED load)

P_o (W) = Vf LED × If LED + Vf schottky × If LED + R_sens × If LED × If LED

LED forward current: If LED (mA) = Set current: I_o (mA), LED forward voltage: Vf LED (V), schottky diode forward voltage: Vf schottky (V), Setting resistance: R_sens (Ω)

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

If the input voltage includes a resistance component, take the voltage drop into consideration for the minimum input voltage.

The input current I_{IN} is roughly estimated as follows:

$$I_{IN}\ (\text{mA}) = \text{VfLED} \times I_o \times (1/\eta) \times (1/V_{IN}) \ldots \text{formula 3}$$

When min V_{IN} = 3.2 (V), VfLED = 16 (V), I_o = 18 (mA), and $\eta \geqq 75$ (%), then I_{IN} = 0.12 (mA). As a result, the voltage drops by 1.2 V due to the 1-Ω DC resistance component. Because the IC's minimum V_{CC} = 3.0 V, the minimum V_{IN} is 3.12 V ($V_{IN} \geqq 3.12$ V).

I_o (A): Mean current value set according to resistance R_sens (Ω)

f_{OSC} (Hz): Switching frequency of internal MOS transistor

Specified values for f_{OSC} (kHz): 275 min, 350 typ., 475 max

Ip (A): Peak current value supplied to external inductor

Specified values for Ip (A): 230 min, 240 typ., 270 max

K: Margin of output power K = 1.1~1.3

The ideal condition is to give 1.05 to 1.3 times the output power P_o as the input power.

The loss of the IC is assumed to be included in the margin.

If K is too large, it may not be possible for the current characteristic to be the specified value. Note that K > 1.

Substitute the following conditions in formula 2.

Supply voltage V_{IN} = 3.0~4.3 (V)
Output-side capacitor C2 = 1 (μF) . . . C2 is ignored in the calculation.
Where it is assumed that,
VfLED = 16 (V), Vf schottky = 0.3 (V), R_sens = 1.8 (Ω), I_o = 20 (mA), K = 1.1

VfLED: LED Vf
Vf schottky: schottky diode Vf
R_sens: setting resistance
I_o: set current
K: margin

$$L\ (\mu H) = ((1.1 \times 16 \times 0.02) - 3 \times 0.02) \times (1/275e3) \times 2 \times (1/(0.21 \times 0.21)) = \begin{array}{l} 48.1\ (\mu H,\ V_{IN} = 3.0\ V) \\ 43.8\ (\mu H,\ V_{IN} = 4.3\ V) \end{array}$$

Thus, 48.1 (μH) is selected when the input voltage is low, 3.0 V.

Note that the calculation does not consider fluctuations in inductance. Toshiba recommend selection of an inductance of 1.2 times the calculated value.

The recommended inductance under the above conditions is L (μH) = 48.1 (μH) × 1.2 ≧ 57.7 (μH).

Selection of R_sens

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

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

I_O (mA) = 36 (mV) ÷ R_sens (Ω)

For example, when R_sens = 1.8 (Ω), I_O = 20 (mA).

Take a current error of ±10% (not including R_sens error) into consideration.

The IC has a minimum output P_O = 320 (mA, choke coil = 47 μH).

At that time, if the product of mean current I_O and output voltage V_O exceeds P_O = 320 (mW), mean current I_O may become less than the desired value.

If the IC is not connected to the output-side capacitor (for smoothing), the set current I_O can be obtained.

At that time, because the current flowing to the LED is a pulse current with a maximum peak value of 270 mA, make sure that surge current IFP (mA) does not flow to the LED.

Toshiba recommend use of components with low reactance (parasitic inductance) and minimized PCB wiring.

Toshiba also recommend allocating components in the application circuit diagram as near each other as possible.

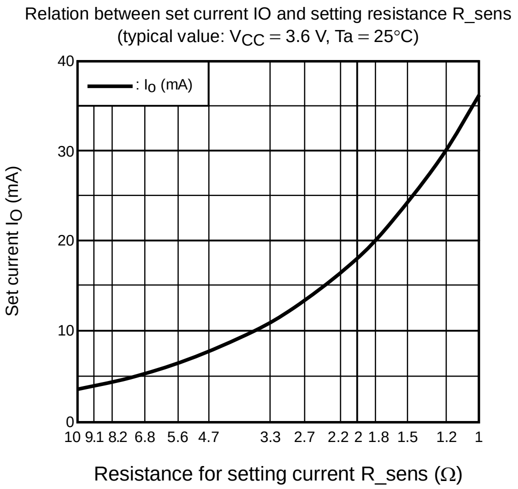


Figure 4

Output Derating Function

Toshiba recommend derating the LED current depending on the increase in ambient temperature.
The TB62731FUG is designed to ensure safe and efficient driving of white LEDs used as backlight sources for color LCDs. The IC incorporates a function that derates current according to the set temperature (the ambient temperature when the IC is mounted), Ta.

The IC features an output current that varies according to the internally-detected temperature T_{js} as follows: when T_{js} = 45 (°C), output current is 100%; when T_{js} = 100 (°C), output current is 0%.

The derating start temperature T_s (°C) is determined based on Ta (Ta = Ts when the IC is not operating) by subtracting the self-generated temperature T_{up} (°C) from T_{js} = 45 (°C).

T_s (°C) = 45 (°C) − T_{up} (°C) . . . formula 4

The derating characteristic is as shown in the graph below, Figure 5, which shows the relation between output current change ratio and internally-detected temperature (IC temperature) T_{js}.

The self-generated temperature T_{up} (°C) is calculated as follows:
T_{up} (°C) = (P loss (W) − P parts (W)) × θ_{ja} (°C/W)) . . . formula 5

P loss: power loss
P parts: power loss of parts
θ_{ja}: package saturation thermal resistance (Ω)

The parameters are described below:
DC resistance of inductor: RDC (Ω)
LED forward current: If LED (A)
LED forward voltage: Vf LED (V)
Schottky diode forward voltage: Vf schottky (V)
Setting resistance: R_sens

P loss (W) ≃ P_o (W) ÷ η (%) − P_o (W)
P_o: output power
η: power efficiency

P parts (W) ≃ RDC × I_{IN} + Vf schottky × If LED + R_sens × If LED × If LED

θ_{ja} (°C/W) ≤ 260 (°C/W)
max when IC mounted on PCB

P_o (W) = V_o (V) × I_o (A)
V_o: Vf LED output voltage
I_o: mean output current = set current

P_i (W) = V_{IN} (V) × I_{IN} (A)
P_i: input power
V_{IN}: input voltage
I_{IN}: mean input current

η (%) = 100 × P_o (W) ÷ P_i (W)

Example of calculation: Where the measurement result for any lighting circuit shows the following values:
RDC = 0.5 (Ω), P_o = 320 (mW), I_{IN} = 0.1 (mA), I_o = 20 (mA), R_sens = 1.8 (Ω), Vf schottky = 0.3 (V), and η = 70 (%)

The self-generated temperature T_{up} (°C) is calculated as follows:

T_{up} (°C) = ((0.32 – (0.32 × 0.7)) – (0.5 × 0.1 + 0.3 × 0.02 + 1.8 × 0.02 × 0.02)) × 260 = 10.2 (°C)

Thus, the derating start temperature T_s (°C) is calculated as follows:

T_s (°C) = 45 (°C) – 10.4 (°C) = 34.8 (°C)

As a result, I_O is controlled in the recommended current range as shown in Figure 5.

Since saturation thermal resistance θ_{ja} = 260 (°C/W) is the maximum value, θ_{ja} = 210~260 (°C/W) is used as a mounting condition.

Depending on the IC characteristics, peripherals, and use environment, the derating start temperature fluctuates among ICs.

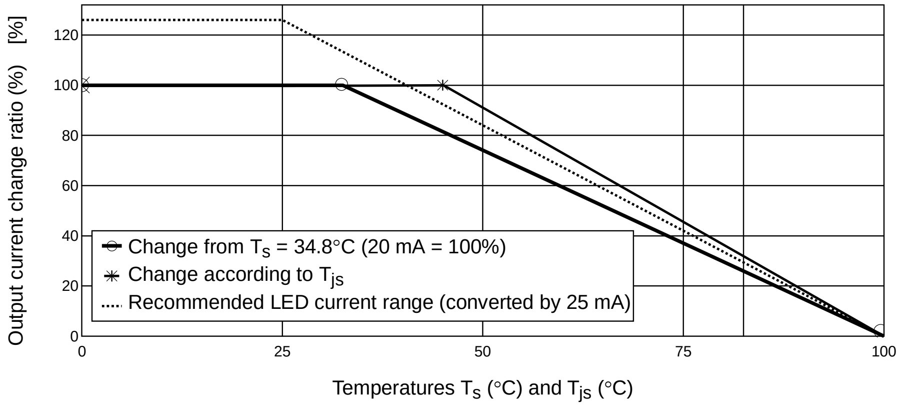
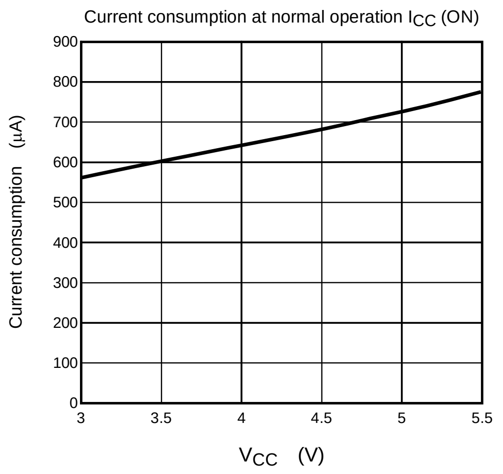
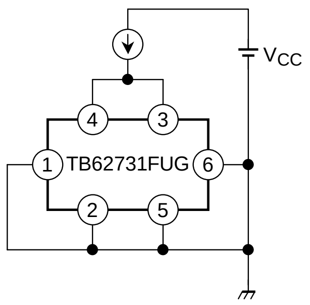
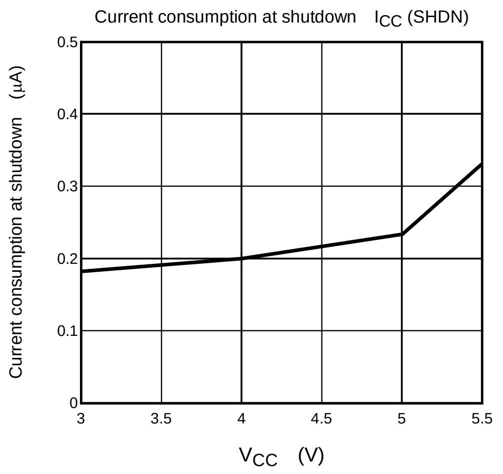
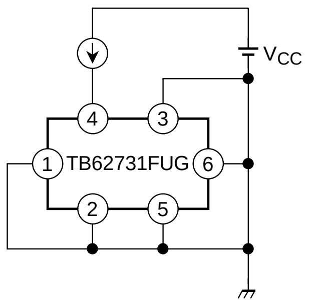


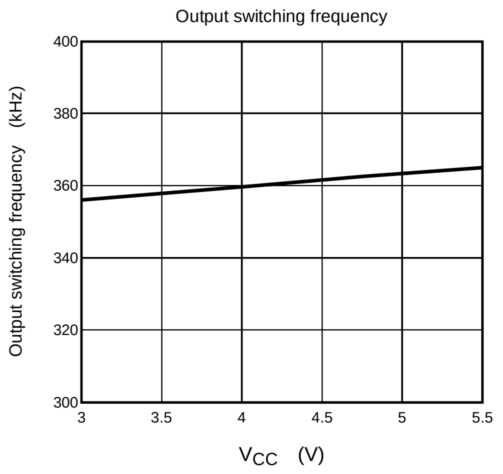
Figure 5 Derating Function of Set Current

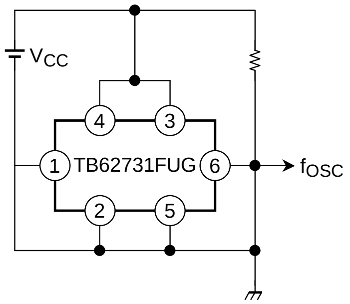

Current consumption at normal operation I_{CC} (ON)
Current consumption (μA)
900
800
700
600
500
400
300
200
100
0
3
3.5
4
4.5
5
5.5
V_{CC} (V)


V_{CC}
4
3
1
TB62731FUG
6
2
5


Current consumption at shutdown I_{CC} (SHDN)
Current consumption at shutdown (μA)
0.5
0.4
0.3
0.2
0.1
0
3
3.5
4
4.5
5
5.5
V_{CC} (V)

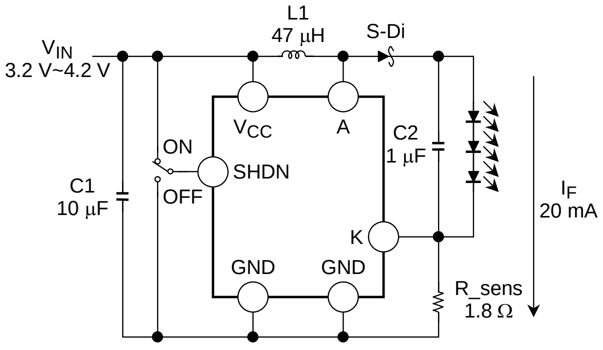

V_{CC}
4
3
1
TB62731FUG
6
2
5


Output switching frequency
Output switching frequency (kHz)
400
380
360
340
320
300
3
3.5
4
4.5
5
5.5
V_{CC} (V)

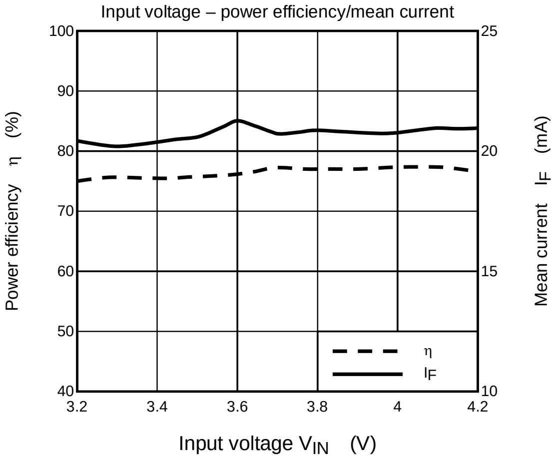

V_{CC}
4
3
1
TB62731FUG
6
f_{OSC}
2
5

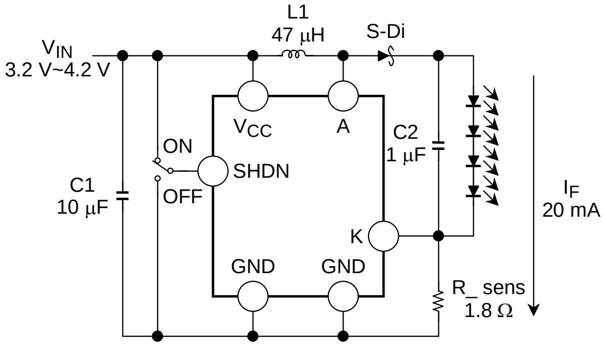
Application Circuit Example 1 (characteristic using recommended coil as reference)

Though it is necessary to consider the DC resistance of L1, an inductance of 33 to 47 (typ.) to 68 μH is suitable for turning on four LEDs.



L1: Toko A914BYW-470M
S-Di: Toshiba 1SS404 20 V/1A
LED: Nichia NSCW215T
R_sens: Rohm MCR03-1R8





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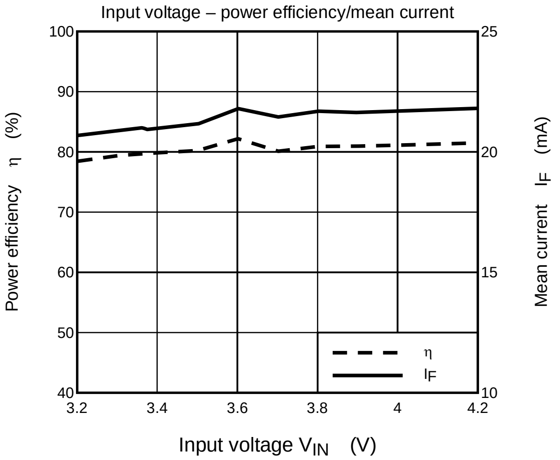

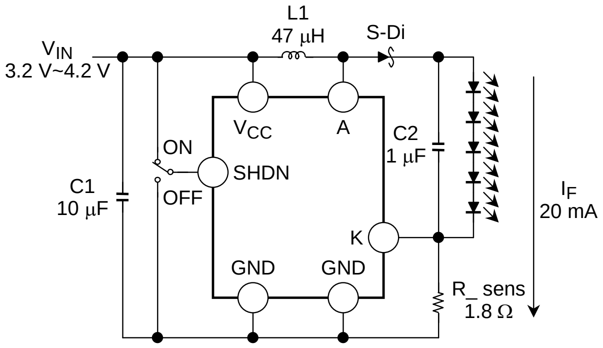

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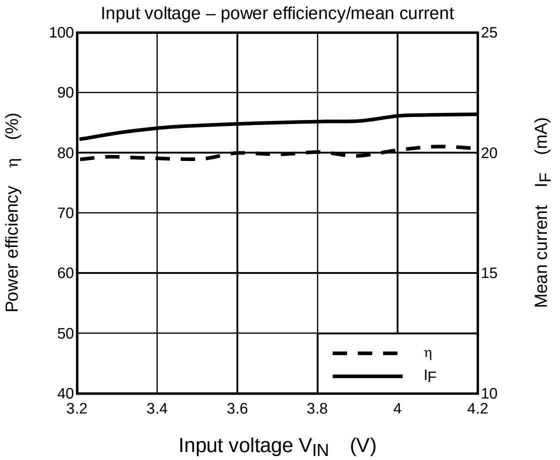
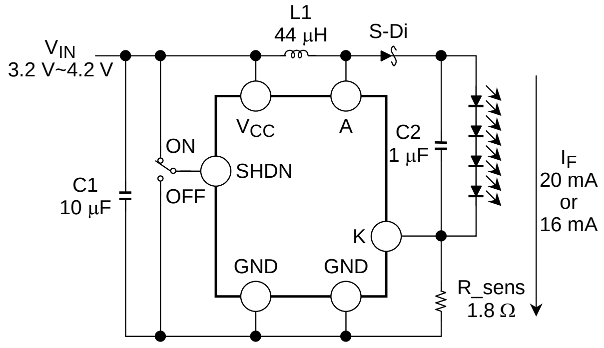
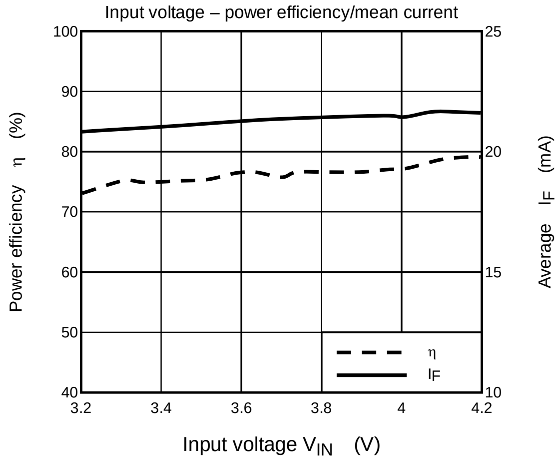


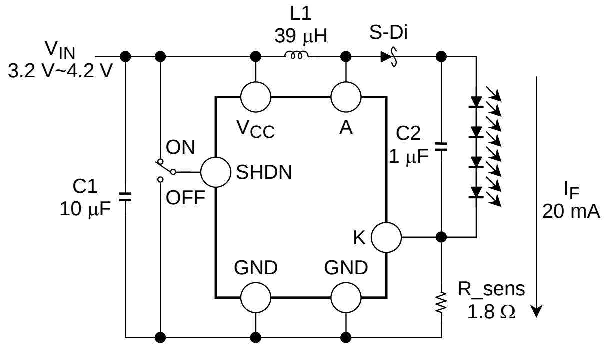
Application Circuit Example 2
(characteristic using flat coil for handy terminal as reference)

Flat coils suitable for handy terminals have a large DC resistance; thus, the power efficiency drops slightly, to about 70%.

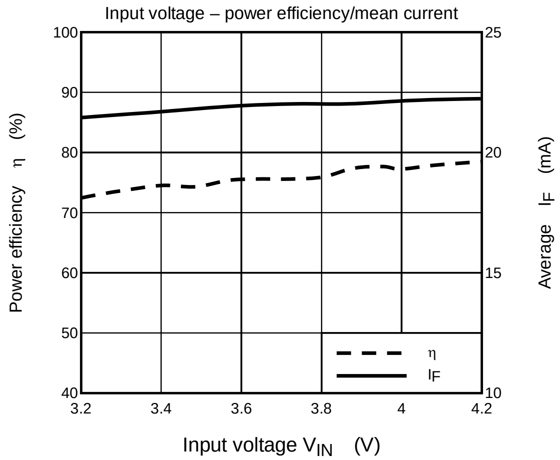


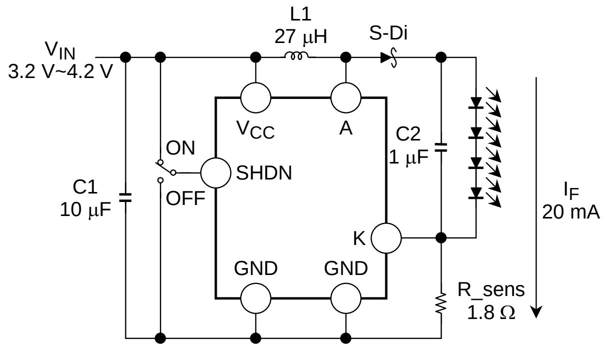
L1: TDK LDR344812T-440
S-Di: Toshiba 1SS404 20 V/1A
LED: Nichia NSCW215T
R_sens: Rohm MCR03-1R8



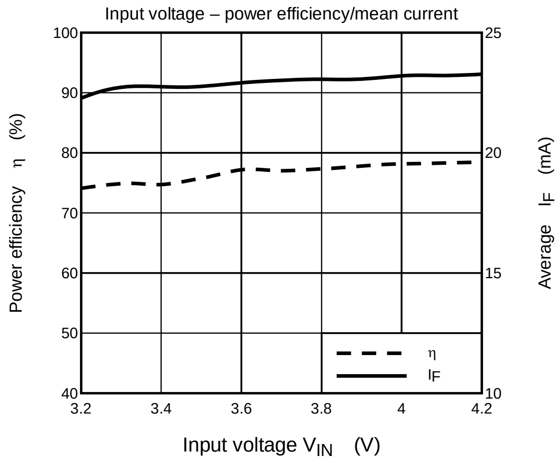


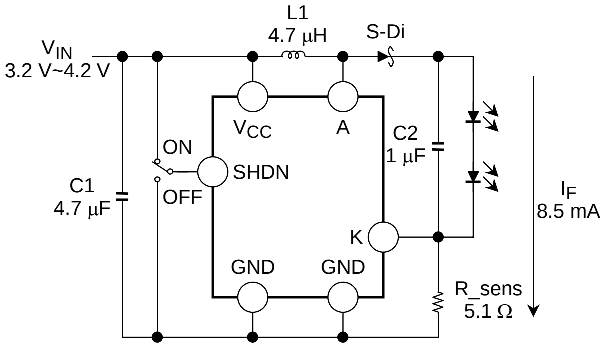
L1: TDK LDR344812T-390
S-Di: Toshiba 1SS404 20 V/1A
LED: Nichia NSCW215T
R_sens: Susumu RL0510S-1R8



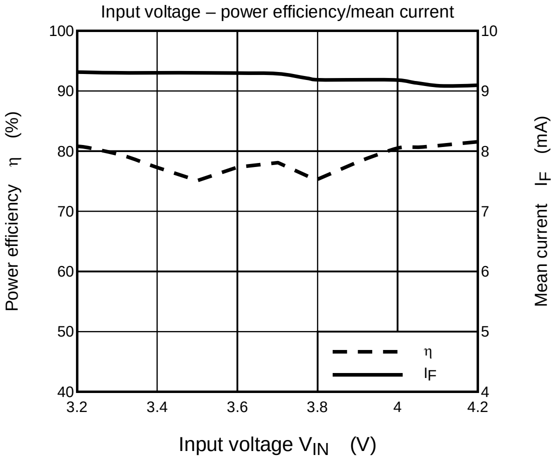


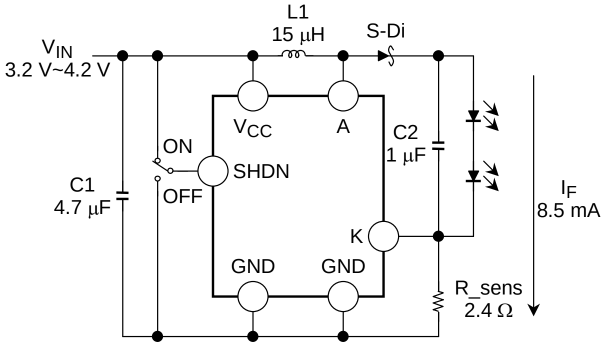
L1: Toko A914BYW-270M
S-Di: Toshiba 1SS404 20 V/1A
LED: Nichia NSCW215T
R_sens: Susumu RL0510S-1R8



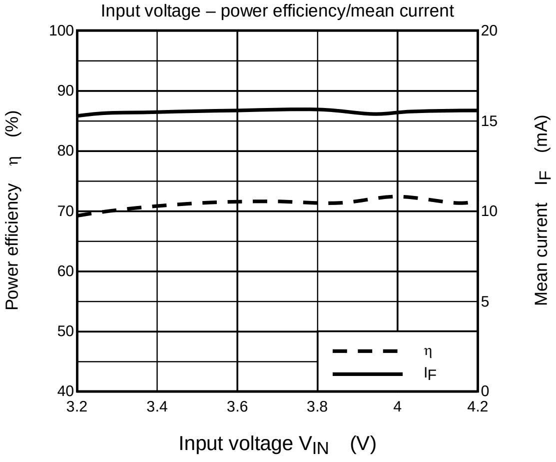


L1: Toko A914BYW-4R7
S-Di: Toshiba 1SS404 20 V/1A
LED: Nichia NSCW215T
R_sens: —





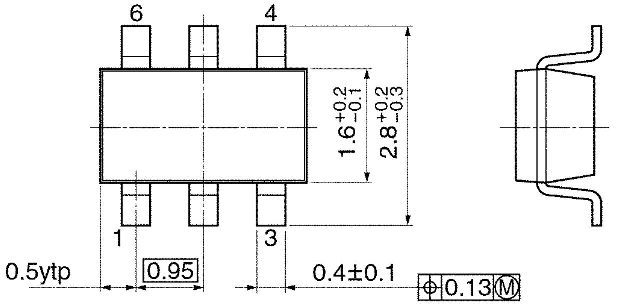
L1: Sumitomo Special Metals CXLD (CXAD) 120-150
S-Di: Toshiba 1SS404 20 V/1A
LED: Nichia NSCW215T
R_sens: —

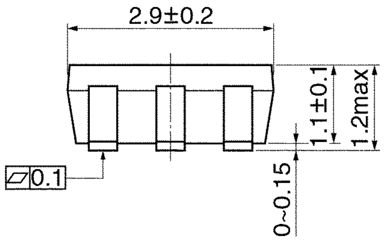


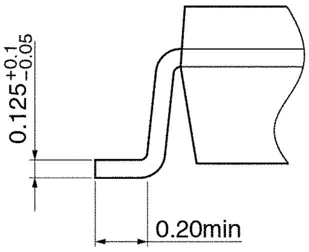
Package Dimensions

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

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030619EBA

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