TOSHIBA BiCD Digital Integrated Circuit Silicon Monolithic

TB62732FU

Step-up DC/DC Converter for White LED Driver

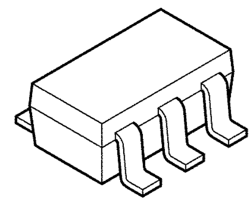
TB62732FU is the high efficiency Step-up type DC/DC converter that it is designed suitably in constant current lighting of white LED.

It is the most suitable for turning on 2 to 4 serial white LEDs with a Li-ion battery.

This IC builds in the N-ch MOS transistor which is necessary for switching of the coil.

And, LED current I_F is set up by a resistance with the outside.

This IC is the most suitable as a driver of white LED back light of the color LCD in the PDA, the cellular phone and the handy terminal machine.



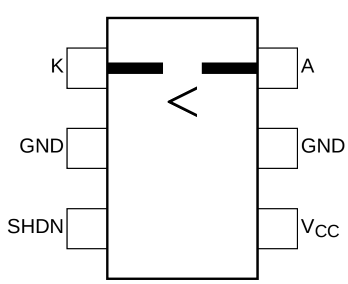
SSOP6-P-0.95B

Weight: 0.016 g (typ.)

Features

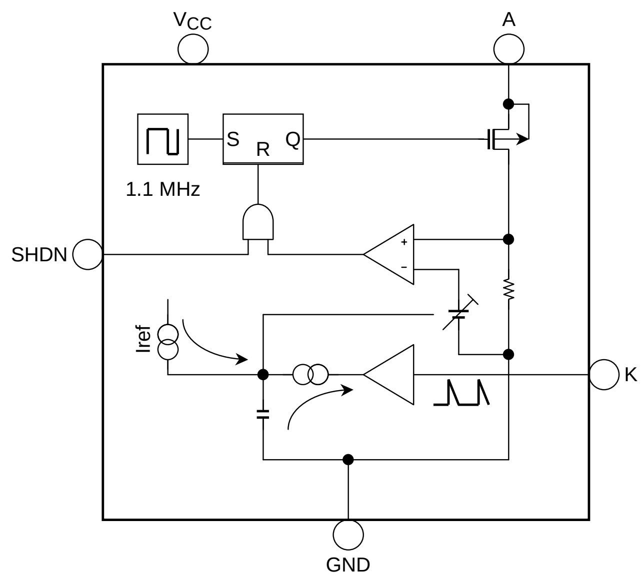
- LED current values can set according to external resistor
  - 15 mA (typ.) @R_sens = 3.3 Ω
  - 18.5 mA (typ.) @R_sens = 2.7 Ω
- 80% of the efficiency is realized. (LED serial 2 to 3, I_F = 20 mA)
- Maximum output voltage: Vo = 17 V
- Output power: Up to 320 mW supported
- Compact package: 6-pin SOT23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

Pin assignment (top view)



Note 1: Be careful of handling because there is a terminal which is poor at ESD in this product.
This IC sometimes breaks when it is mounted at 180 degree for the reversal.
Mount a circuit board in the accurate 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 LED constant current.
2, 5	GND	Ground pin for logic
3	SHDN	IC enable pin. When Low, Standby Mode and pin A 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	$R_{th\ (j\text{-}a)}$	300 (IC only) 260 (IC mounted on PCB)	°C/W
Operating temperature range	T_{opr}	−40 to +85	°C
Storage temperature range	T_{stg}	−55 to +150	°C
Maximum junction temperature	T_j	125	°C

Note 3: Derate power dissipation by 3.8 mW/°C from the Absolute maximum rating for every 1°C exceeding the ambient temperature of 25°C (when IC is mounted on 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, turn on series LEDs of 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 up 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	dI_o	—		—	±8	±12	%

Note 4: The dissipation of the R_sens resistor isn't contained in the specification. Please, be careful.
The absolute value of I_o has the possibility to change not to correspond to the specification by inductance value and the relations of the load.

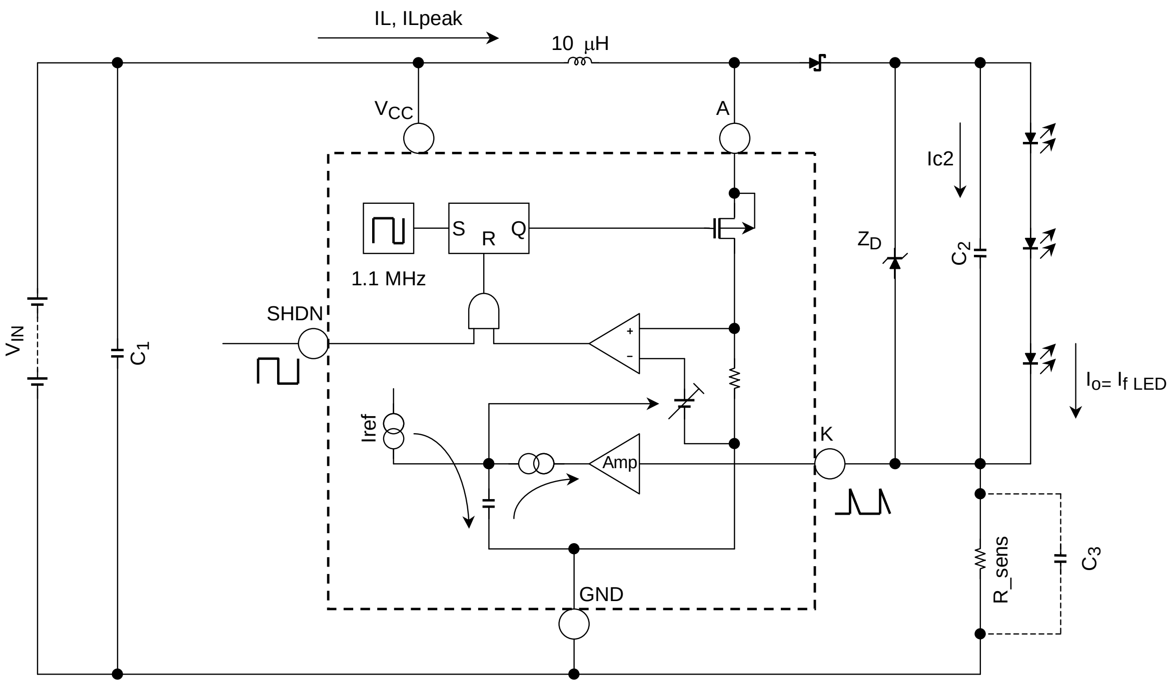


Figure 1 Application Circuit

Basic Operation

The step-up DC/DC converter is applied, and the basic circuit to the TB62732FU adopts peak control of the current pulse.

The internal MOS transistor NMOS is turned on in the fixed frequency f_{OSC} = 1 MHz, and the charge has the energy in the inductance.

Inductance electric current IL turns off NMOS when it reaches 80% of 1/1 MHz when it increased from IL = 0 and it reached IL = ILpeak = 350 (mA, typ.).

The shot key diode is turned on, and IL = Ic2 flows, because the coil may keep IL = ILpeak.

After that, Ic2 is decrease, and become IL = 0.

This operation is repeated, and Ic2 is fully done as to the charge, and it becomes I_O, and flows to LED.

The details of a basic pulse to use for the current control are shown in Figure 2.

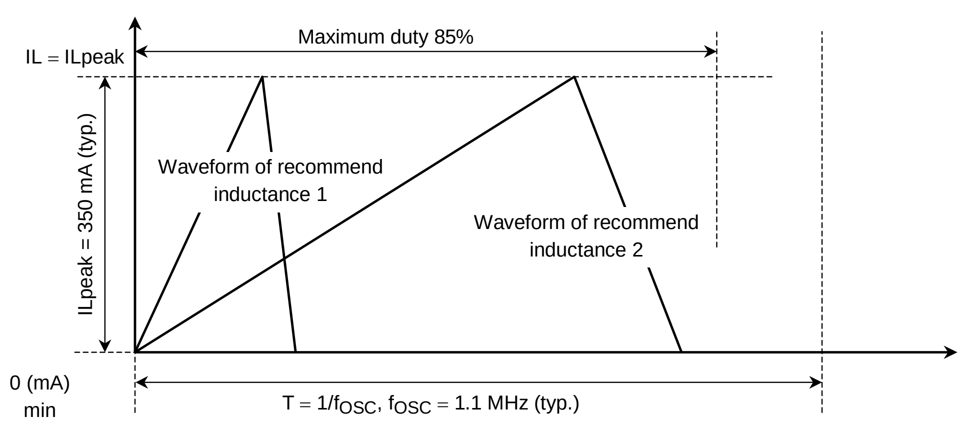


Figure 2 Switching Waveform of Inductance

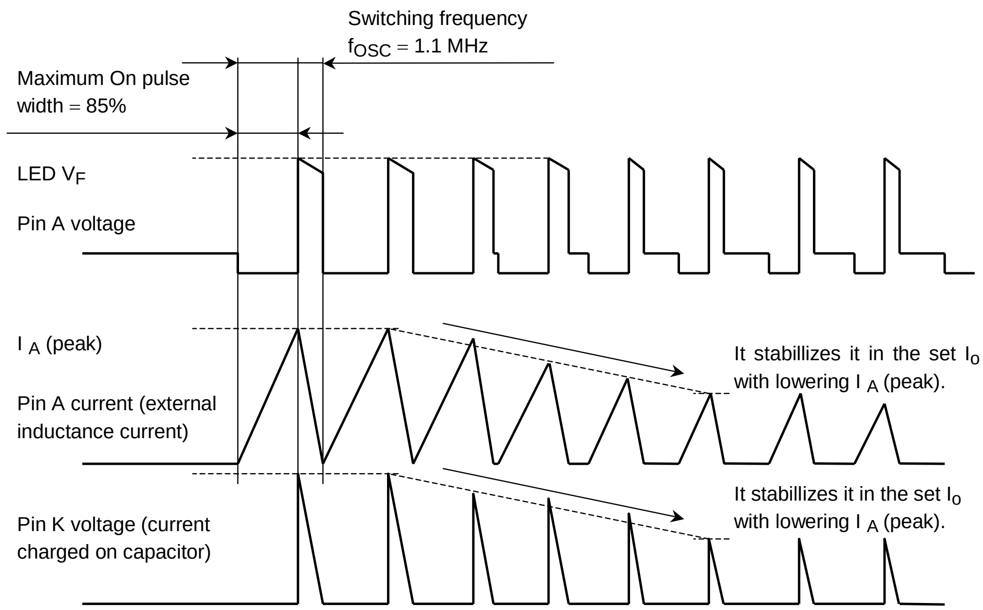


Figure 3 Burst Control Waveforms

The Stae of the Peak Current Control

Peak current control is the control that variability peak current pulse which shows in the figure 2 of the former page. The current pulse of the figure 4 is a charging current on the output side capacitor C_2.

It is supplied to LED as a discharge current on the C_2 and flows through the R_sens to GND.

And, as for the charging voltage wave form of the C_2, it feed back in the IC from the pin K.

Peak currents are decreased with the internal circuit which a pin K should be input from the AC voltage wave. It could may set at about 48 to 54 mV.

A constant current is controlled as an average current in LED as that result.

Therefore, when R_sens = 2.7 Ω is connected, it can get I_F of 19.6 mA at of 53 mV.

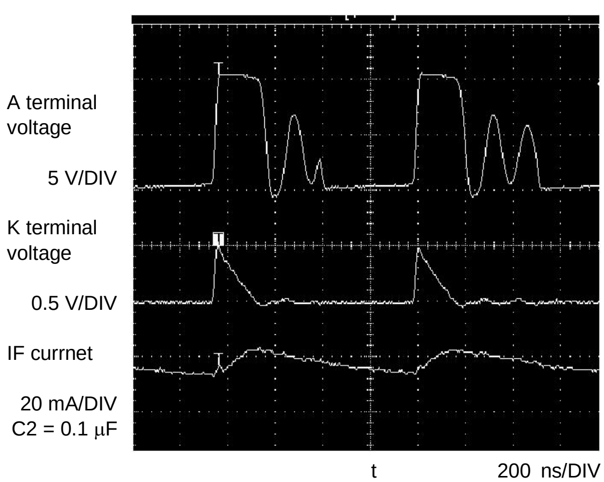
The most suitable design has a boost up inductance worn by inductance 4.7 to 10 μH to the load power 320 mW.

And, make an inductance small when load power is low.

Keep "V_{IN} (V_{CC}) < LED V_F total" strictly as a condition about the LED between the pin A and the pin K.

There are no relations with the control of the IC, and LED always comes to turn on.

Please, be careful.



Standby Operation

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

Drive Waveform

A left figure is an actual drive waveform.

From the top, the switching voltage waveform of the coil of the generator terminal, the feedback voltage wave form of the K terminal, and I_F of LED.

Output-side capacitor setting

The C_2 is upper 0.1 (μF) above is recommended from the consideration to the I_F peak.

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

External inductance setting

The minimum external inductance is calculated as follows:

L (μH) = (($K \times P_o$) − V_{IN} min × I_O) × (1/f_{OSC} min) × 2 × (1/Ip min × 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 × I_F LED + Vf schottky × I_F LED + R_sens × I_F LED × 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 to supply to the inductance.

	Min	Typ.	Max	Unit
Ip	320	350	380	MHz

For example, the following condition is substituted for the formula.
It is supposed under condition.
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} = 4.3 V) and 6.3 (μH, V_{IN} = 3 V)
Therefore, 6.3 μH in V_{CC} = 3 V whose input voltage is low is chosen.
It is sufficient by the above calculation on the standard condition.

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)

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

For example, when R_sens = 2.7 (Ω), I_O = 18.5 (mA) and current error of ±12%.

The IC has a minimum output P_O = 320 (mA).
At that time, if the product of current I_F LED and output voltage V_F LED exceeds P_O = 320 (mW), current I_F LED may become less than the desired value.

If the IC is not connected to the smoothing capacitor, set mean current I_F LED can be obtained.
At that time, because the current which flows to the LED is a sine-wave current with a maximum peak value of 380 mA, make sure that surge current I_{FP} (mA) does not flow to the LED.
Toshiba recommend use of components with low reactance (parasitic inductance) and minimized PCB wiring.

A zener diode in an application circuit example of the figure 1 is necessary for the over-voltage protection when LED becomes open.
It is recommended connecting a zener diode strongly because this driver doesn't have a voltage protection circuit.

A zener voltage is to satisfy the following condition.

i) Less than maximum output voltage of TB62732FU
ii) Upper total series LED V_F
iii) Less than maximum output capacitance C_2.

Moreover, it is possible by connecting the figure 4 like R_ZD to be able to control output current when LED becomes open, and to use small a zener diode of tolerance level.
The example of the IZD control by R_ZD connection.
(R_sens = 2.7 Ω)

R_DZ (Ω)	IZD (mA)
18	3
100	0.1

Since it may have a bad influence on the characteristic of a driver, Toshiba recommend 100 ohms or less.

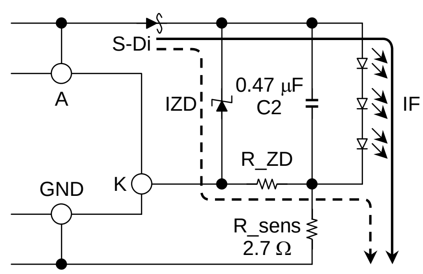
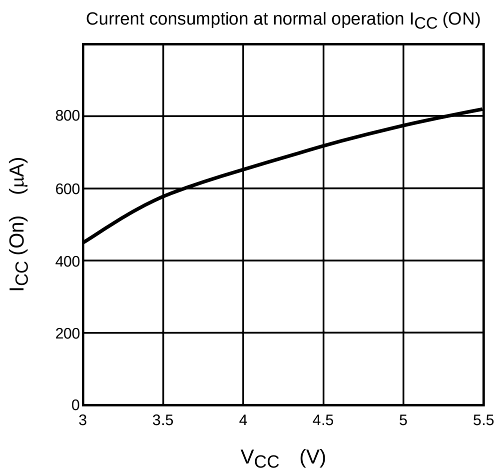
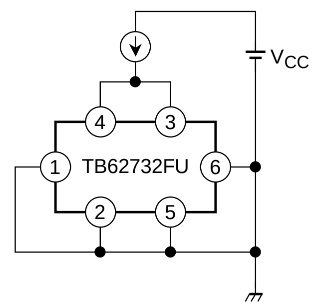
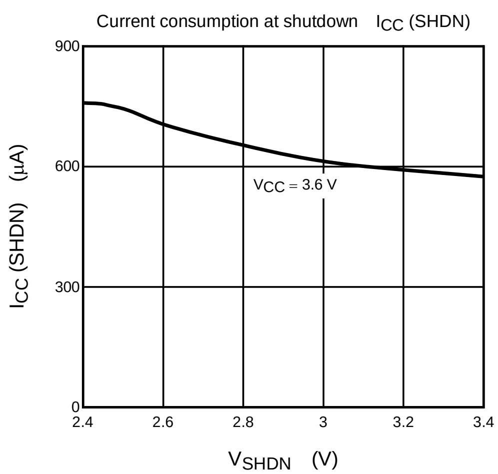
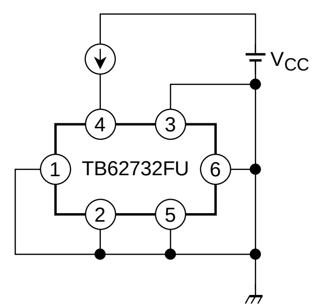


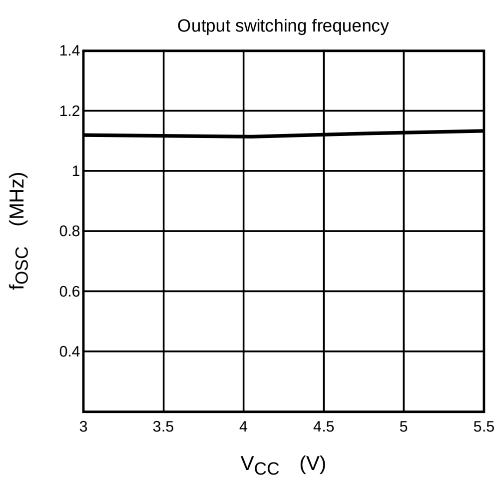
Figure 4 Application Circuit

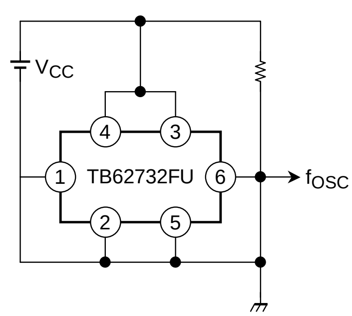

Current consumption at normal operation ICC (ON)
ICC (On) (μA)
0
200
400
600
800
3
3.5
4
4.5
5
5.5
VCC (V)


VCC
4
3
1
TB62732FU
6
2
5


Current consumption at shutdown ICC (SHDN)
ICC (SHDN) (μA)
0
300
600
900
VCC = 3.6 V
2.4
2.6
2.8
3
3.2
3.4
VSHDN (V)

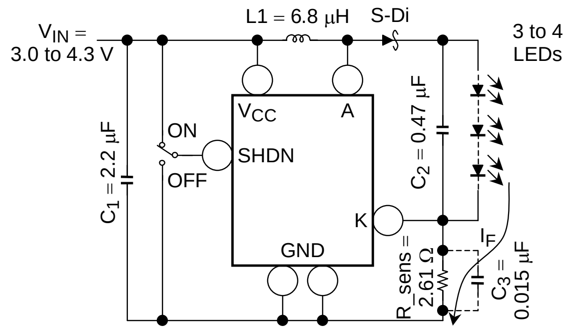

VCC
4
3
1
TB62732FU
6
2
5


Output switching frequency
fOSC (MHz)
0.4
0.6
0.8
1
1.2
1.4
3
3.5
4
4.5
5
5.5
VCC (V)


VCC
4
3
1
TB62732FU
6
fOSC
2
5

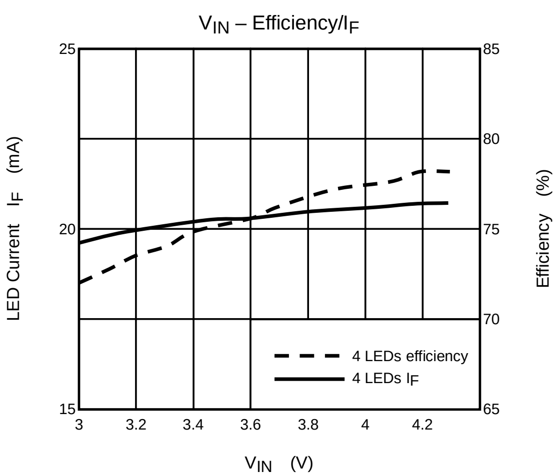
Application Evaluation Circuit Example 1
(the evaluation result example by the small coil: Coil = LDR304612T-6R8)

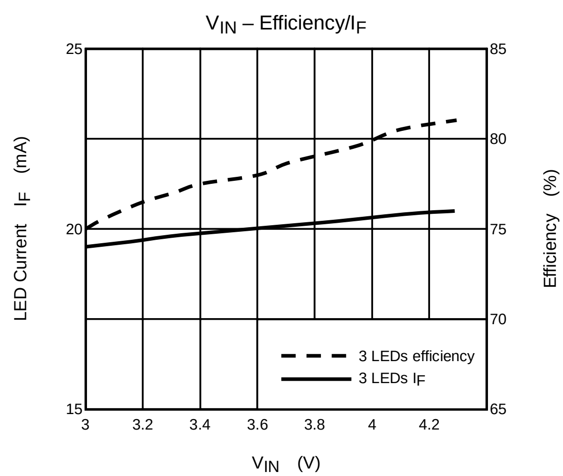
6.8 μH is the most suitable when serial 3 to 4 LEDs are turned on by I_F = 20 mA.
4.7 μH is recommended when serial 2 LEDs are turned on steadily in the range of V_{IN} > 4.5 V.

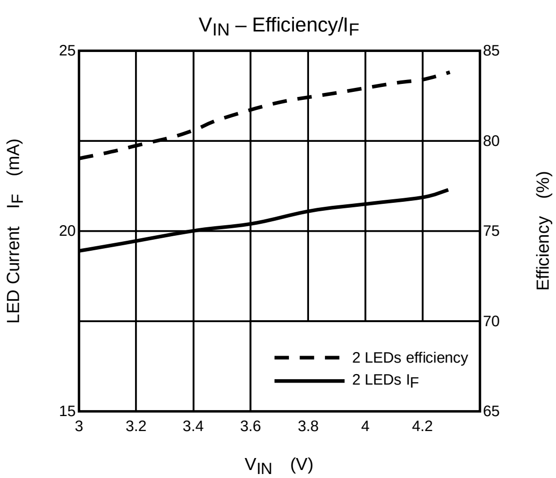


L1 : TDK LDR304612T-6R8
S-Di: TOSHIBA CUS02 30 V/1 A
LED: NICHIA NSCW215T

Note 5: It doesn't surely need to connect C_3.
The effect which becomes stable has I_F in the decrease voltage expected.







<Measurement>

The efficiency of the V_{IN} = 3.0 to 4.3 V range

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

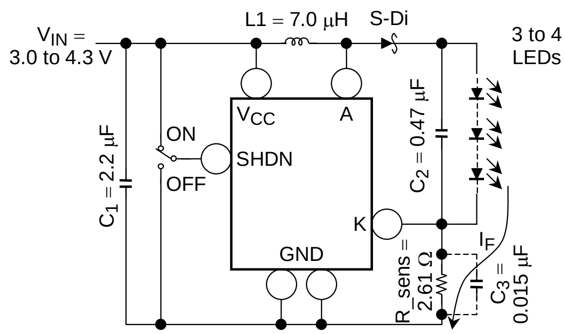
The I_F of the V_{IN} = 3.0 to 4.3 V range

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 value is our company actual measurement value. The result has the possibility to be different by the measurement environment.

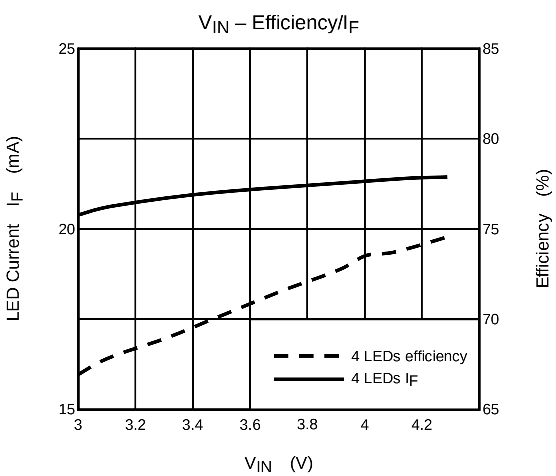
Application Evaluation Circuit Example 2
(the evaluation result example by the small coil: Coil = CXML321610-7R0)

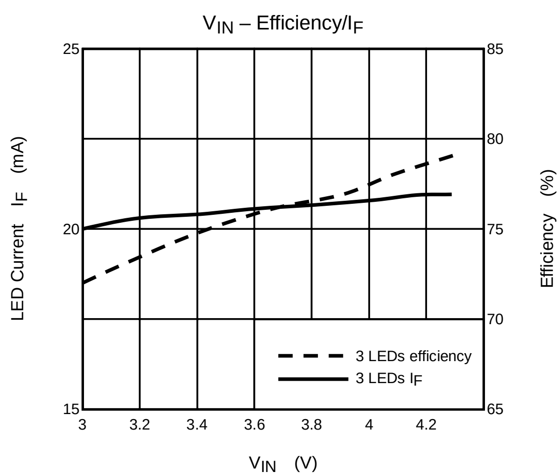
6.8 μH is the most suitable when serial 3 to 4 LEDs are turned on by I_F = 20 mA.
4.7 μH is recommended when serial 2 LEDs are turned on steadily in the range of V_{IN} > 4.5 V.

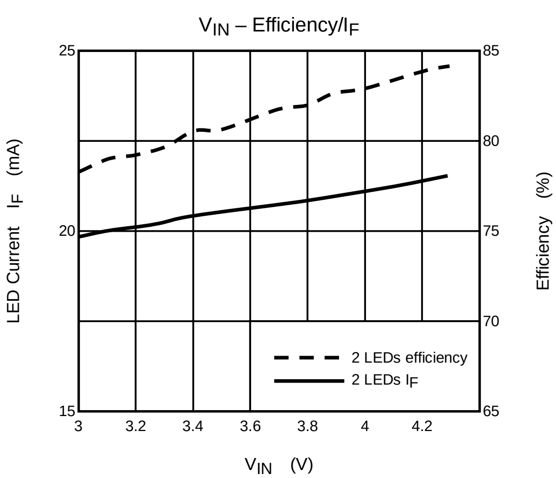


L1 : SUMITOMO CXML321610-7R0
S-Di: TOSHIBA CUS02 30 V/1 A
LED: NICHIA NSCW215T

Note 7: It doesn't surely need to connect C_3.
The effect which becomes stable has I_F in the decrease voltage expected.







<Measurement>

The efficiency of the V_{IN} = 3.0 to 4.3 V range

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

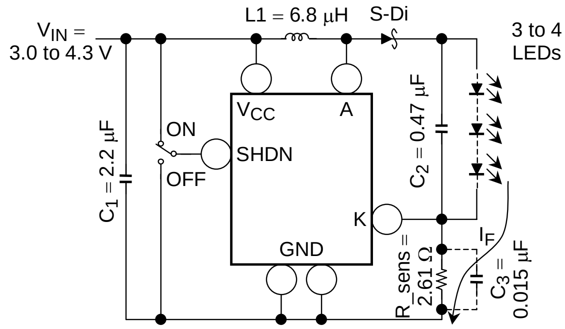
The I_F of the V_{IN} = 3.0 to 4.3 V range

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 value is our company actual measurement value. The result has the possibility to be different by the measurement environment.

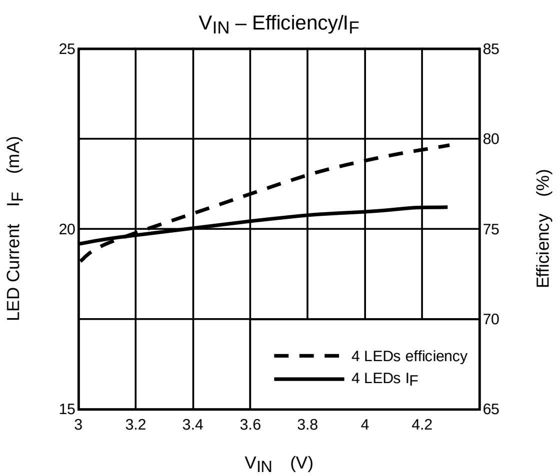
Application Evaluation Circuit Example 3
(the evaluation result example by the small coil: Coil = 976AS-6R8)

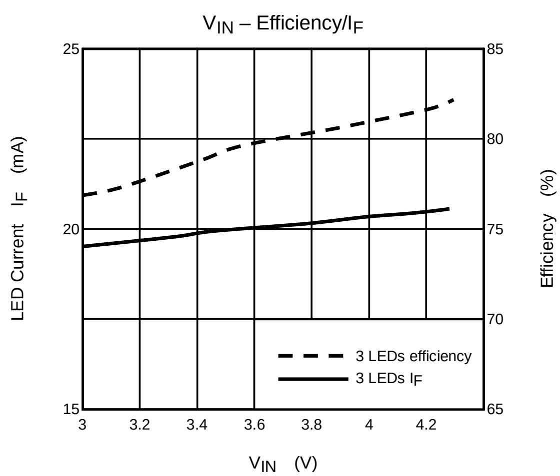
6.8 μH is the most suitable when serial 3 to 4 LEDs are turned on by I_F = 20 mA.
4.7 μH is recommended when serial 2 LEDs are turned on steadily in the range of V_{IN} > 4.5 V.

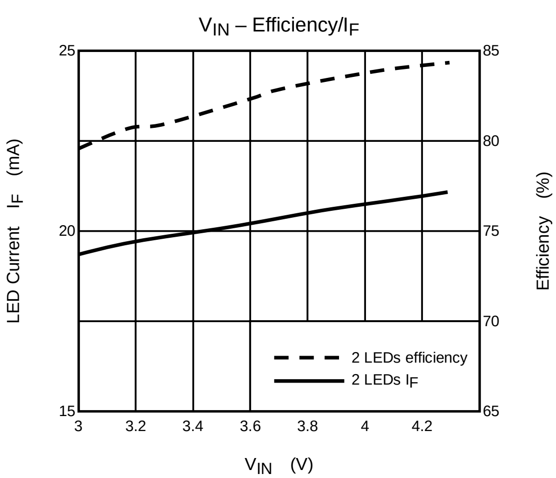


L1 : TOKO 976AS-6R8
S-Di: TOSHIBA CUS02 30 V/1 A
LED: NICHIA NSCW215T

Note 9: It doesn't surely need to connect C_3.
The effect which becomes stable has I_F in the decrease voltage expected.







<Measurement>

The efficiency of the V_{IN} = 3.0 to 4.3 V range

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

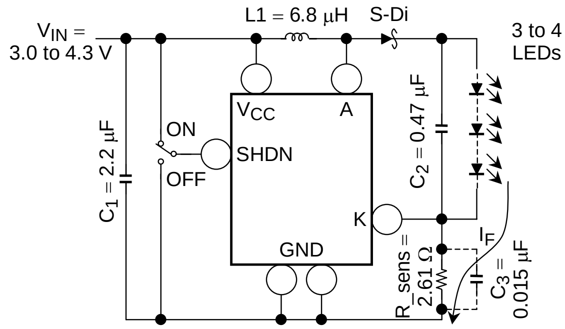
The I_F of the V_{IN} = 3.0 to 4.3 V range

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 value is our company actual measurement value. The result has the possibility to be different by the measurement environment.

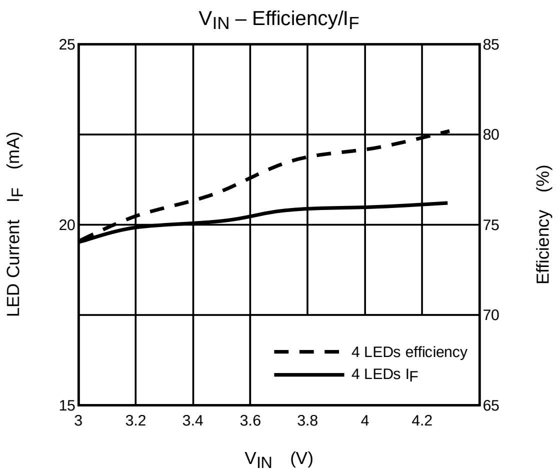
Application Evaluation Circuit Example 4
(the evaluation result example by the small coil: Coil = CXLD140-6R8)

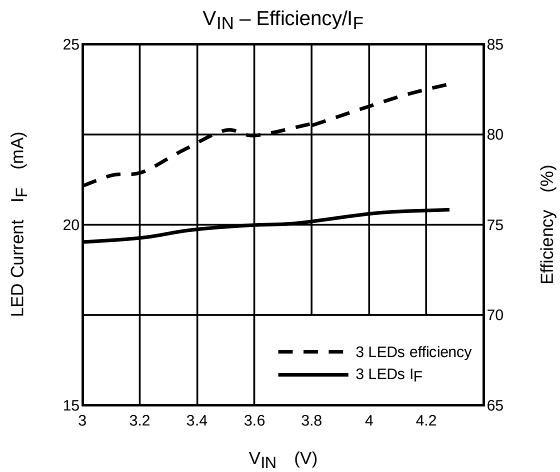
6.8 μH is the most suitable when serial 3 to 4 LEDs are turned on by I_F = 20 mA.
4.7 μH is recommended when serial 2 LEDs are turned on steadily in the range of V_{IN} > 4.5 V.

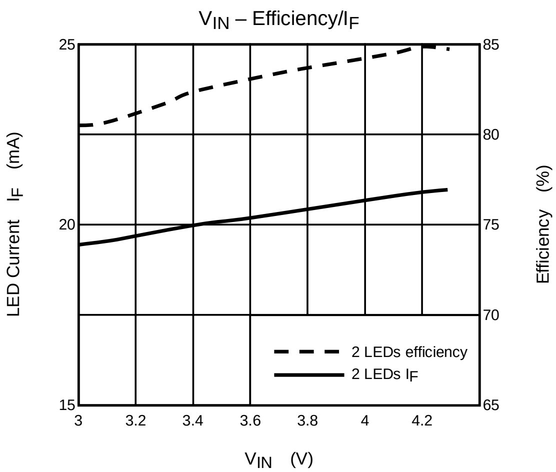


L1 : SUMITOMO CXLD140-6R8
S-Di: TOSHIBA CUS02 30 A/1 V
LED: NICHIA NSCW215T

Note11: It doesn't surely need to connect C_3.
The effect which becomes stable has I_F in the decrease voltage expected.







<Measurement>

The efficiency of the V_{IN} = 3.0 to 4.3 V range

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

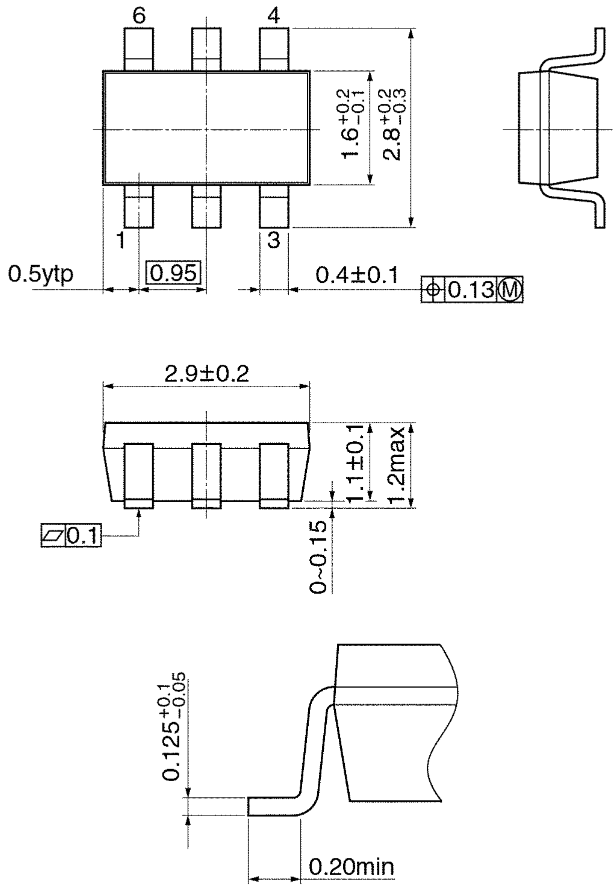
The I_F of the V_{IN} = 3.0 to 4.3 V range

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 value is our company actual measurement value. The result has the possibility to be different by the measurement environment.

Package Dimensions

SSOP6-P-0.95B Unit: mm



Weight: 0.016 g (typ.)

Notes on Contents

1. Block Diagrams

Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.

2. Equivalent Circuits

The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

3. Timing Charts

Timing charts may be simplified for explanatory purposes.

4. Application Circuits

The application circuits shown in this document are provided for reference purposes only.
Thorough evaluation is required, especially at the mass production design stage.
Toshiba does not grant any license to any industrial property rights by providing these examples of application circuits.

5. Test Circuits

Components in the test circuits are used only to obtain and confirm the device characteristics. These components and circuits are not guaranteed to prevent malfunction or failure from occurring in the application equipment.

IC Usage Considerations

Notes on Handling of ICs

(1) The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings.
Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.

(2) Use an appropriate power supply fuse to ensure that a large current does not continuously flow in case of over current and/or IC failure. The IC will fully break down when used under conditions that exceed its absolute maximum ratings, when the wiring is routed improperly or when an abnormal pulse noise occurs from the wiring or load, causing a large current to continuously flow and the breakdown can lead smoke or ignition. To minimize the effects of the flow of a large current in case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.

(3) If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. IC breakdown may cause injury, smoke or ignition.
Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.

(4) Do not insert devices in the wrong orientation or incorrectly.
Make sure that the positive and negative terminals of power supplies are connected properly.
Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.
In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.

(5) Carefully select external components (such as inputs and negative feedback capacitors) and load components (such as speakers), for example, power amp and regulator.
If there is a large amount of leakage current such as input or negative feedback condenser, the IC output DC voltage will increase. If this output voltage is connected to a speaker with low input withstand voltage, overcurrent or IC failure can cause smoke or ignition. (The over current can cause smoke or ignition from the IC itself.) In particular, please pay attention when using a Bridge Tied Load (BTL) connection type IC that inputs output DC voltage to a speaker directly.

Points to Remember on Handling of ICs

(1) Heat Radiation Design
In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (Tj) at any time and condition. These ICs generate heat even during normal use. An inadequate IC heat radiation design can lead to decrease in IC life, deterioration of IC characteristics or IC breakdown. In addition, please design the device taking into considerate the effect of IC heat radiation with peripheral components.

(2) Back-EMF
When a motor rotates in the reverse direction, stops or slows down abruptly, a current flow back to the motor's power supply due to the effect of back-EMF. If the current sink capability of the power supply is small, the device's motor power supply and output pins might be exposed to conditions beyond maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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