XC9133 Series

Step-Up DC/DC Converter-LED Backlight Driver

■GENERAL DESCRIPTION

The XC9133 series is a fixed frequency, constant current step-up DC/DC converter which is optimized for LED backlight applications in mobile phones, PDAs and digital cameras. Output voltage of up to 17.5V is possible so that four white LEDs can be driven in series. Since the LED current is set by only one external resistor, all white LEDs placed in series can be turned on at the same time. The new DC/DC Converter is also able to drive a network of two parallel banks of three LEDs. LED dimming is controlled by adjusting the duty cycle of a PWM signal (10kHz Max.) applied to the CE pin.

Efficiency is high with a 0.2V low feedback reference voltage ensuring the R_{LED} losses are minimal. In addition, an internal MOSFET with a low R_{DSON} of 2.4Ω is used. A low profile and small board area solution can be achieved using a chip inductor and a small ceramic output capacitor C_L=0.22μF as a result of the high 1MHz switching frequency.

If white LEDs are opened or damaged, the detector built in the Lx pin causes the IC to stop oscillating, preventing excessive increase of the output voltage.

■APPLICATIONS

- ●For White LED drivers
- ●Smart phones / Mobile phones
- ●Mobile devices / terminals
- ●Digital still cameras

■FEATURES

Input Voltage Range	: 2.5V ~ 6.0V
Output Voltage Range	: Up to 17.5V externally set-up
	Reference voltage 0.2V $\pm$5%
Oscillation Frequency	: 1.0MHz±20%
ON Resistance	: 2.4Ω
High Efficiency	: 85%
	3 white LEDs in series
	V_{IN}=3.6V, I_{LED}=20mA
Control	: PWM control
Stand-by Current	: I_{STB}=1.0μA (MAX.)
Output Capacitor	: 0.22μF, ceramic
Lx Limit Current	: 360mA（TYP.）
Lx Overvoltage Limit	: 19V (TYP.)
Operating Ambient Temperature	: -40℃～+85℃
Packages	: SOT-25
Environmentally Friendly	: EU RoHS Compliant, Pb Free

■TYPICAL APPLICATION CIRCUIT
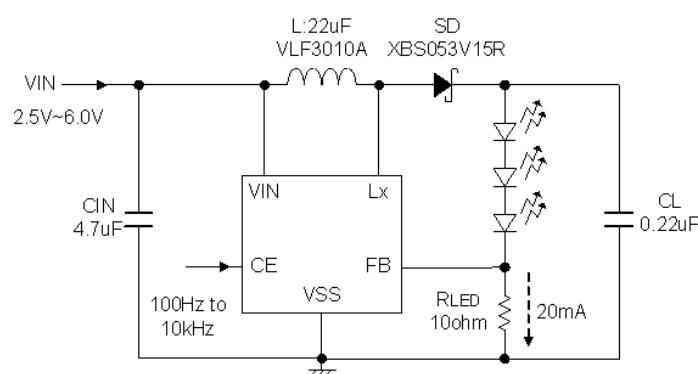
■TYPICAL PERFORMANCE CHARACTERISTICS

●XC9133B02A Series
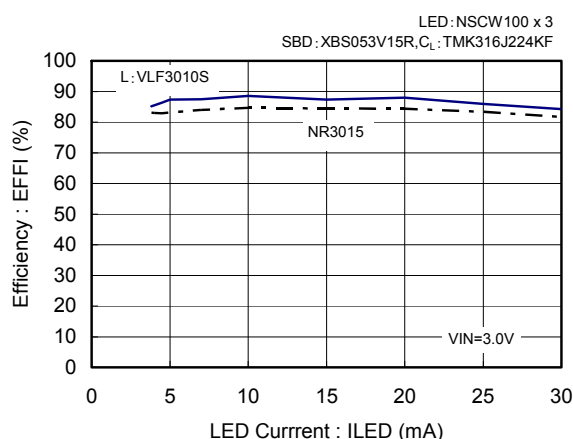
■PIN CONFIGURATION

SOT-25 (TOP VIEW)
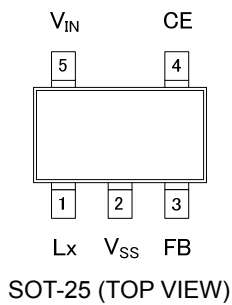
■PIN ASSIGNMENT

PIN NUMBER SOT-25	PIN NAME	FUNCTIONS
1	Lx	Switch
2	V_{SS}	Ground
3	FB	Voltage Feedback
4	CE	Chip Enable
5	V_{IN}	Power Input

■CE PIN FUNCTION

CE PIN	OPERATIONAL STATE
H	Operation
L	Shut-down

■PRODUCT CLASSIFICATION

●Ordering Information

XC9133①②③④⑤⑥-⑦

DESIGNATOR	ITEM	SYMBOL	DESCRIPTION
①	Lx Overvoltage Limit	B	Available
②③	FB Voltage	02	0.2V
④	Oscillation Frequency	A	1MHz
⑤⑥-⑦[*1]	Package (Order Unit)	MR	SOT-25 (3,000pcs/Reel)
		MR-G	SOT-25 (3,000pcs/Reel)

[*1] The "-G" suffix denotes Halogen and Antimony free as well as being fully EU RoHS compliant.

■BLOCK DIAGRAMS

●XC9133B02A
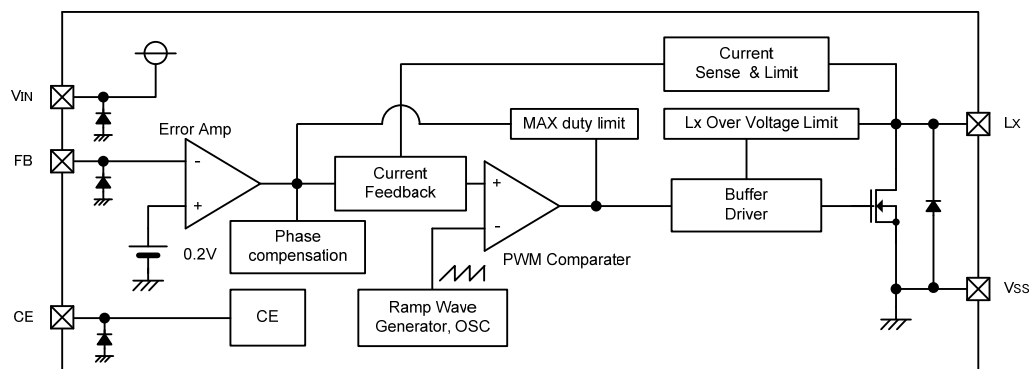
■ ABSOLUTE MAXIMUM RATINGS

Ta = 25℃

PARAMETER	SYMBOL	RATINGS	UNITS
V_{IN} Pin Voltage	V_{IN}	$V_{SS} - 0.3 \sim 7.0$	V
Lx Pin Voltage	V_{Lx}	$V_{SS} - 0.3 \sim 22.0$	V
FB Pin Voltage	V_{FB}	$V_{SS} - 0.3 \sim 7.0$	V
CE Pin Voltage	V_{CE}	$V_{SS} - 0.3 \sim 7.0$	V
Lx Pin Current	I_{Lx}	1000	mA
Power Dissipation	Pd	250	mW
Operating Ambient Temperature	Topr	- 40 ~ + 85	℃
Storage Temperature	Tstg	- 55 ~ +125	℃

■ELECTRICAL CHARACTERISTICS

●XC9133B02AMR

Ta = 25°C

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT.	CIRCUIT
FB Voltage	V_{FB}		0.19	0.20	0.21	V	①
Output Voltage Range	V_{OUTSET}		V_{IN}	-	17.5	V	①
Input Voltage Range	V_{IN}		2.5	-	6.0	V	①
Supply Current 1	I_{DD1}		-	420	720	μA	②
Supply Current 2	I_{DD2}	$V_{IN}=V_{Lx}$, FB=0.4V	-	60	140	μA	③
Stand-by Current	I_{STB}	CE=0V, V_{Lx}=5.0V	-	0	1.0	μA	③
Oscillation Frequency[*1]	f_{OSC}		0.8	1.0	1.2	MHz	②
Maximum Duty Cycle	MAXDTY		86	92	98	%	②
Efficiency[*2]	EFFI	When connected to ext. components, V_{IN}=3.6V, R_{LED}=20Ω	-	85	-	%	①
Current Limit	I_{LIM}	When connected to ext. components, V_{IN}=3.6V	260	360	460	mA	④
Lx Overvoltage Limit	V_{LxOVL}	Voltage which Lx pin voltage holding "High" level $V_{IN} \geqq 2.5V$	18.0	19.0	22.0	V	②
Lx ON Resistance	R_{SWON}	V_{IN}=3.6V, V_{Lx}=0.4V [*3]	-	2.4		Ω	④
Lx Leakage Current	I_{LxL}	Same as I_{STB}	-	0.0	1.0	μA	③
CE High Voltage	V_{CEH}	CE applied voltage when Lx starts oscillation	0.65	-	6.0	V	②
CE Low Voltage	V_{CEL}	CE applied voltage which Lx pin voltage holding "High" level	V_{SS}	-	0.2	V	②
CE High Current	I_{CEH}	Same as I_{DD2}	-0.1	-	0.1	μA	③
CE Low Current	I_{CEL}	Same as I_{STB}	-0.1	-	0.1	μA	③
FB High Current	I_{FBH}	Same as I_{DD2}	-0.1	-	0.1	μA	③
FB Low Current	I_{FBL}	Same as I_{STB}	-0.1	-	0.1	μA	③

NOTE: *Test circuit ①: Unless otherwise stated, V_{IN}=3.0V, V_{CE}=3.0V, R_{LED}=10Ω
       *Test circuit ②: Unless otherwise stated, V_{IN}=3.0V, V_{CE}=3.0V, V_{FB}=0.0V, V_{PULL}=5.0V, R_{PULL}=100Ω
       *Test circuit ③: Unless otherwise stated, V_{IN}=3.0V, V_{CE}=3.0V, V_{FB}=0.0V
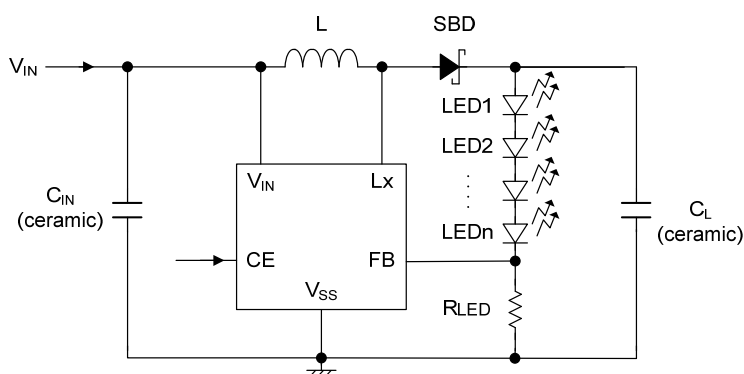   *Test circuit ④: Unless otherwise stated, V_{CE}=3.0V, V_{PULL}=5.0V

[*1]: The duty cycle is forcibly reduced when maximum duty cycle periods are repeated.

[*2]: LED NSPW310BS x 3, EFFI = {[(output voltage) x (output current)] / [(input voltage) x (input current)]} x 100

[*3]: V_{PULL} is adjusted to make V_{Lx} 0.4V when the driver transistor is turned on.

■TYPICAL APPLICATION CIRCUITS

●XC9133B02A

■EXTERNAL COMPONENTS

SYMBOL	VALUE	PART NUMBER	MANUFACTURER
L	22 μH	VLF3010A-220MR	TDK
SBD [*1]	-	XBS053V15R [*2]	TOREX
		MA2Z720	PANASONIC
C_{IN}	4.7 μF	JMK107BJ475MA-B	TAIYO YUDEN
C_L [*3]	0.22 μF	TMK107BJ224KA-B	TAIYO YUDEN

NOTE:

*1: Please use a Schottky barrier diode (SBD) with a low junction capacitance.

*2: For using the XBS053V15R with four white LEDs in series, please be noted with a direct reverse voltage (V_R=20V) and a repetitive peak reverse voltage (V_{RM}=30V).

*3: Use ceramic capacitors processing a low temperature coefficient.

■OPERATIONAL EXPLANATION

The series consists of a reference voltage source, ramp wave circuit, error amplifier, PWM comparator, phase compensation circuit, Lx overvoltage limit circuit, N-channel MOS driver transistor, current limiter circuit and others. Phase compensation is performed on the resulting error amplifier output, to input a signal to the PWM comparator to determine the turn-on time during switching.   The PWM comparator compares, in terms of voltage level, the signal from the error amplifier with the ramp wave from the ramp wave circuit, and delivers the resulting output to the N-channel MOS driver transistor to cause the Lx pin to output a switching duty cycle.   This process is continuously performed to ensure stable output voltage. The current feedback circuit detects the N-channel MOS driver transistor's current for each switching operation, and modulates the error amplifier output signal.   This enables a stable feedback loop even when a low ESR capacitor, such as a ceramic capacitor, is used, ensuring stable output voltage.

<Reference Voltage Source>
The reference voltage source provides the reference voltage to ensure stable output voltage of the IC.

<Ramp Wave Circuit>
The ramp wave circuit determines switching frequency.   The 1MHz (TYP.) of frequency is fixed internally.
Clock pulses generated in this circuit are used to produce ramp waveforms needed for PWM operation.
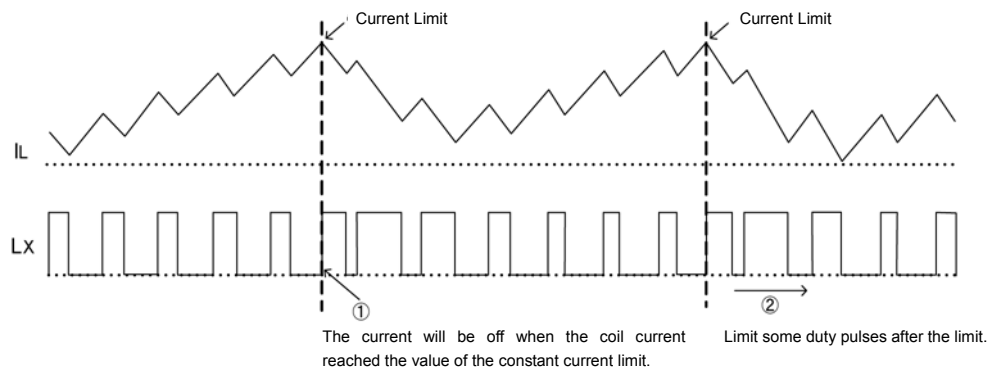
<Error Amplifier>
The error amplifier is designed to monitor output voltage.   The amplifier compares the reference voltage with the FB pin voltage.   When a feed-back voltage becomes lower than the reference voltage, an output voltage of the error amplifier is increased.   Gain and frequency characteristics of the error amplifier output are fixed internally as an optimize signal.

■OPERATIONAL EXPLANATIONS (Continued)

<Current Limit>

The current limit circuit of the XC9133 series monitors the current flowing through the N-channel MOS driver transistor connected to the Lx pin, and features a combination of the constant-current type current limit mode and the duty cycle limit of the next pulse.

①When the driver current is greater than a specific levels, the constant-current type current limit function operates to turn off the pulses from the Lx pin at any given timing.

②The IC controls the next pulse to be smaller than the first pulse.

The current will be off when the coil current reached the value of the constant current limit.

Limit some duty pulses after the limit.

<Lx Overvoltage Limit Circuit>

XC9133 series' Lx overvoltage limit circuit monitors the Lx pin voltage.   When the Lx pin voltage exceeds than 19V (TYP.), the IC performs the function of latching the OFF state of the driver transistor, and goes into operation suspension mode. In suspension mode, operations can be resumed by restoring power to the V_{IN} pin.   The suspension mode does not mean a complete shutdown, but a state in which pulse output is suspended; therefore, the internal circuitry remains in operation.

<Maximum Duty Cycle Limit>

The XC9133 series' maximum duty cycle limit circuit monitors the duty cycle.   When the maximum duty cycle is repeated for a certain time, the IC controls the error amplifier output so that the duty cycle of the next pulse becomes smaller than that of the first pulse.

<CE Pin Function>

The operation of the XC9133 series will enter into the shut down mode when a low level signal is input to the CE pin. During the shut down mode, the supply current is 0μA (TYP.), with high impedance at the Lx pin.   The IC starts its operation with a high level signal to the CE pin.   The input to the CE pin is a CMOS input and the sink current is 0μA (TYP.). 100μs after disable, the IC goes into suspension mode and supply current is minimal.   After this, the IC will be in stand-by mode and the supply current will be 0μA (TYP.).

■NOTES ON USE

<Lx (Pin 1): Switch Pin>
Please connect the anode of a Schottky barrier diode and an inductor to the Lx pin.

<FB (Pin 3): Voltage Feedback Pin>
The reference voltage is 200mV (TYP.).   A resistor (R_{LED}) should be connected to the FB pin for setting the cathode of LEDs and a constant current value.   The resistance value can be calculated by the following equation.

$R_{LED}=0.2 / I_{LED}$
I_{LED}=Setting constant current value

Typical example:

I_{LED}	R_{LED}	I_{LED}	R_{LED}
5mA	40Ω	13.3mA	15Ω
10mA	20Ω	20mA	10Ω

<CE (Pin 4): Chip Enable Pin>
An ENABLED state is reached when the CE voltage exceeds 0.65V and a DISABLED state when the CE Voltage falls below 0.2V.

<V_{IN} (Pin 5): Power Supply Pin>
Please connect an inductor and an input by-pass capacitor (C_{IN}) to the V_{IN} pin.

1. For temporary, transitional voltage drop or voltage rising phenomenon, the IC is liable to malfunction should the ratings be exceeded.
2. Torex places an importance on improving our products and their reliability.
   We request that users incorporate fail-safe designs and post-aging protection treatment when using Torex products in their systems.
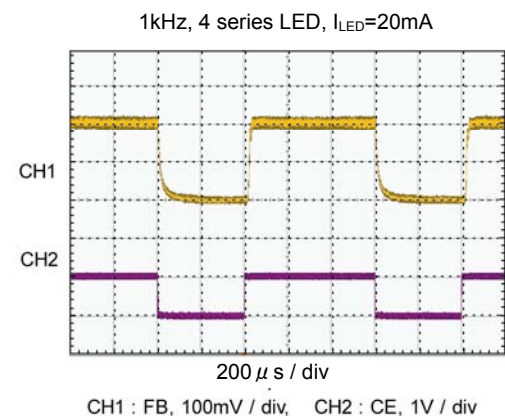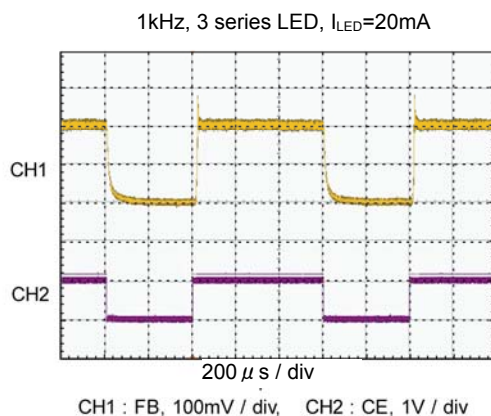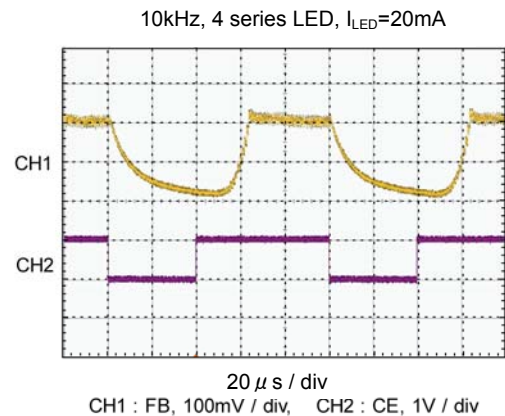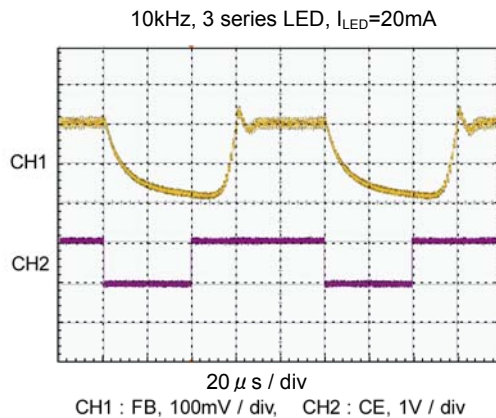
■APPLICATION INFORMATION

<Dimming Control>

1. Applying PWM signal to the CE pin

The XC9133 repeats on/off operations by a PWM signal applied to the CE pin.   The magnitude of LED current, I_{LED}, when the diode is on, is determined by R_{LED}.   The magnitude is zero when the diode is off.   The average of LED current is proportional to the positive duty ratio of the PWM signal.

The frequency of the PWM signal can be controlled to the optimum value between 100Hz and 10kHz.   With regard to the amplitude of the PWM signal, the high level should be higher than the "H" voltage of CE, V_{CEH}, and the low level, lower than the "L" voltage of CE, V_{CEL}.

10kHz, 3 series LED, I_{LED}=20mA

20 μ s / div

CH1 : FB, 100mV / div,   CH2 : CE, 1V / div

10kHz, 4 series LED, I_{LED}=20mA

20 μ s / div

CH1 : FB, 100mV / div,   CH2 : CE, 1V / div

1kHz, 3 series LED, I_{LED}=20mA

200 μ s / div

CH1 : FB, 100mV / div,   CH2 : CE, 1V / div

1kHz, 4 series LED, I_{LED}=20mA

200 μ s / div

CH1 : FB, 100mV / div,   CH2 : CE, 1V / div

2. Step-Wise Regulation of LED Current

In some applications, it may be necessary to incorporate step-wise regulation of LED current, I_{LED}.   Step-wise regulation of LED illumination is achieved by connecting a switch element SW1 in parallel with R_{LED} and in series with R_{LED1} and turning SW1 on and off, as shown below.   Choose a resistance of R_{LED} so that the minimum necessary current is gained when switch element SW1 is off.   The resistance of R_{LED1} should be such that a desired increase of current passed through the LED is gained when the switch element is on.

Ex.)   Current I_{LED} = 5mA and 15mA
R_{LED} = 200mV / 5mA = 40 Ω
R_{LED1} = 200mV / (15mA – 5mA) = 20 Ω
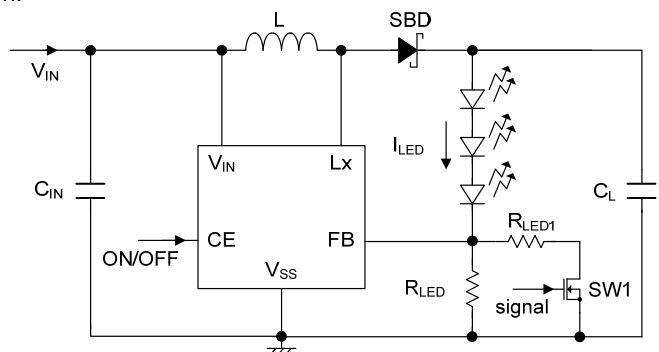

Figure   Circuit using Step-wise Regulation of LED Current

■APPLICATION INFORMATION (Continued)

<Dimming Control (Continued)>

3. Using DC Voltage

If in an application it is necessary to control the LED current by a variable DC voltage, illumination control of LED is achieved by connecting R1 and R2 and applying a direct-current voltage to R2, as shown below.

When R1>>R_{LED}, I_{LED} which flows into LEDs can be calculated by the following equation;

$$I_{LED} = (V_{REF} - R1 / R2 (V_{DC} - V_{REF})) / R_{LED}$$
V_{REF} = 0.2V (TYP.)

Ex.1) When R1 = 10k Ω, R2 = 100k Ω, R_{LED} = 10 Ω,
In the range of 0.2V to 2.2V DC, I_{LED}
(LED current) varies between 20mA to 0mA.
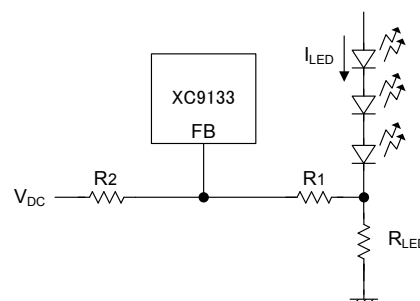
Figure   Circuit using DC voltage

Ex.2) When R1 = 10k Ω, R2 = 100k Ω, R3 = 10k Ω,
C1 = 0.1μF, RLED = 10Ω, the average LED current will be 10mA by inputting a PWM signal of CE 'H' level: 2.2V, CE 'L' level: 0V, duty cycle: 50%, oscillation frequency: 100Hz. As well as the way of dimming control by applying the PWM signal to the CE pin, the average LED current increases proportionally with the positive duty cycle of the PWM signal.
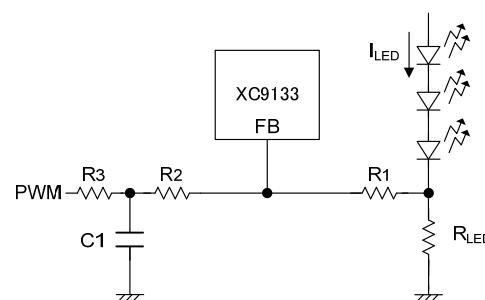
Figure   Circuit inputting a PWM signal to the FB pin

<Prevent Emission Caused by White LEDs Leakage>

When the input voltage (V_{IN}) is high, minimum illumination may occur even if the CE pin is in the disable state.   If this happens, please connect a transistor to between the LED and the FB pin.   By driving the CE signal in-phase and cutting the pass to current, the minimum illumination can be prevented.
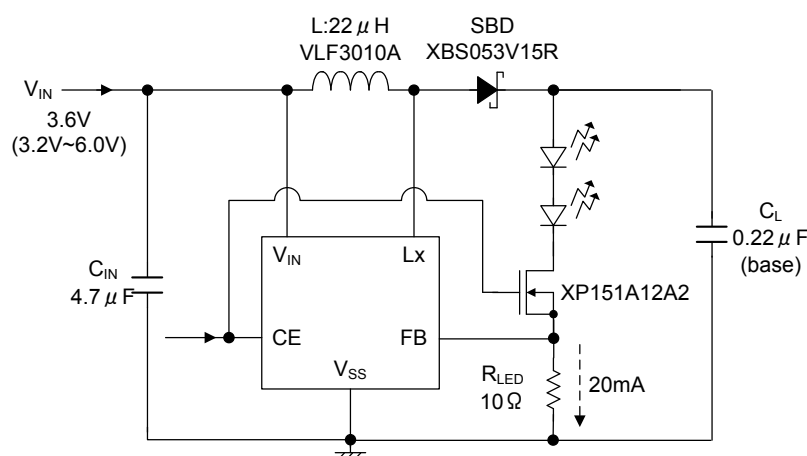
Figure   Circuit Prevent Emission Caused by White LEDs Leakage

■APPLICATION INFORMATION (Continued)

<Illumination of Six in Total White LEDs>
It is possible to illuminate three-series two parallel white LEDs, six in total, using an input voltage $V_{IN} \geqq 3.2V$.
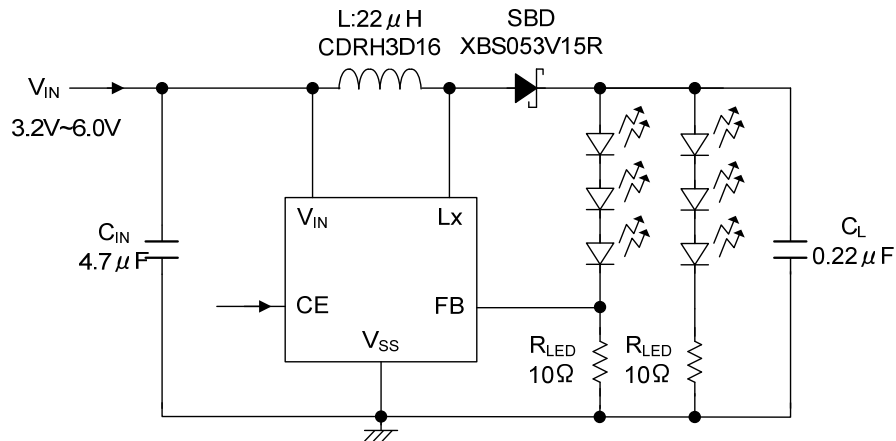

Figure   Circuit Illumination of Six in Total White LEDs

<Use as Flash>
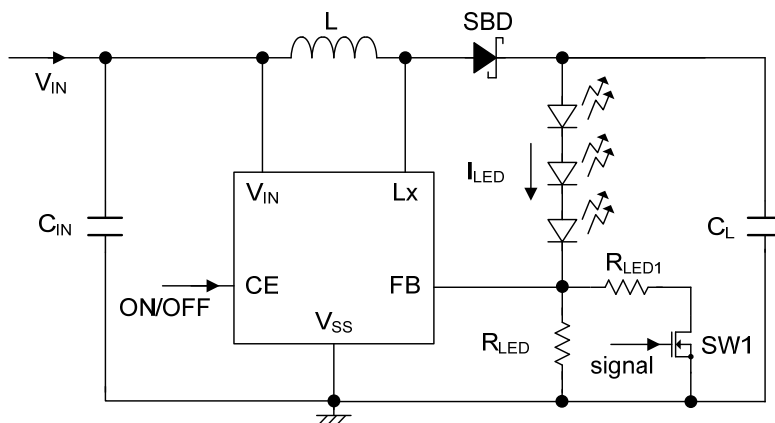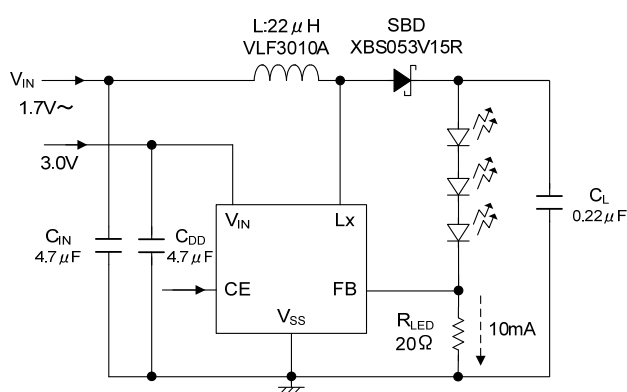An LED current 65mA (MAX.) can be supplied to two white LEDs.
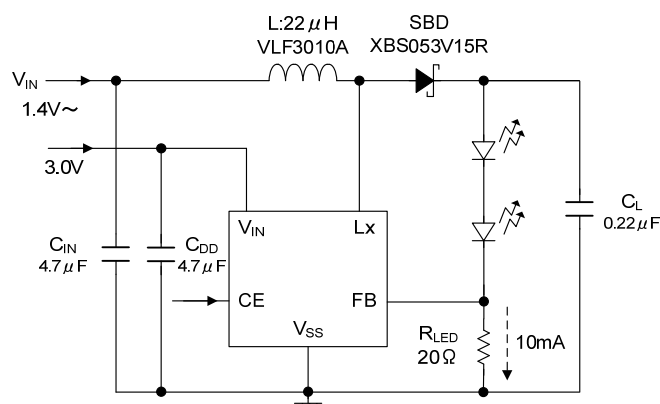

Figure   Circuit using a Flash

■APPLICATION INFORMATION (Continued)

<Separate Supply Source of the Step-up Circuit (V$_{IN}$) from V$_{IN}$ Pin>
Supply source of the step-up circuit can be used separately from V$_{IN}$ pin.

Circuit example of separating supply source of
the step-up circuit from V$_{IN}$ pin (3 LEDs)

Circuit example of separating supply source of
the step-up circuit from V$_{IN}$ pin (2 LEDs)

Note: Please input 2.5V~6V to the V$_{IN}$ pin when you use.

<LED Open-circuit Protection>
If white LEDs are opened or damaged, the FB pin is pulled down, so that the operating duty ratio reaches the maximum. Accordingly, the output voltage continues to increase, possibly causing the Lx pin voltage to exceed the absolute maximum rating of 22V.
If white LEDs are opened or damaged, the detector built in the Lx pin causes the IC to stop oscillating, preventing excessive increase of the output voltage.   However, the detector may detect an overvoltage if the Lx pin voltage exceeds 18V, which is the overvoltage limit, even when no LEDs are open.   Therefore, care must be taken if four LEDs each having a forward voltage of 4.45V or more are connected in series.

<Startup Inrush Current>
   The XC9133 series has no soft-start circuit built-in in order to minimize delay at startup.   The inrush current can reach up to the current limit I$_{LIM}$.
   In some cases, overshoot can occur.

## ■APPLICATION INFORMATION (Continued)

\<Instruction on Pattern Layout\>

1. In order to stabilize V_{IN}'s voltage level, we recommend that an input by-pass capacitor (C_{IN}) be connected as close as possible to the V_{IN} & V_{SS} pins.
2. Please mount each external component as close to the IC as possible.
3. Wire external components as close to the IC as possible and use thick, short connecting traces to reduce the circuit impedance.
4. Make sure that the PCB GND traces are as thick as possible, as variations in ground potential caused by high ground currents at the time of switching may result in instability of the IC.
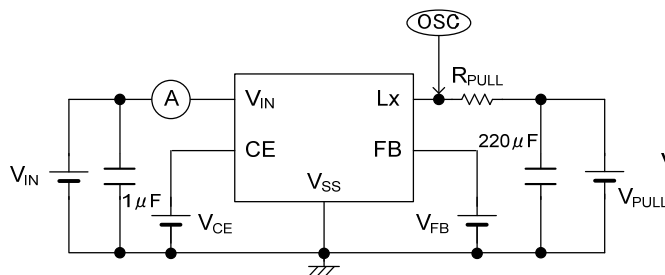
●XC9133B Series Pattern Layout
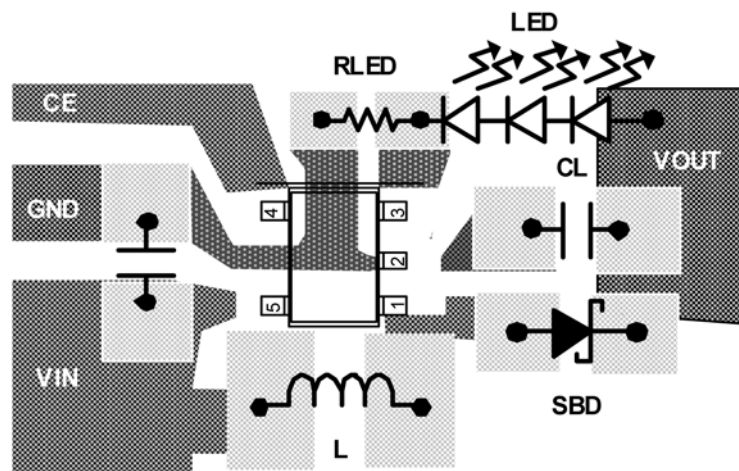
■TEST CIRCUITS

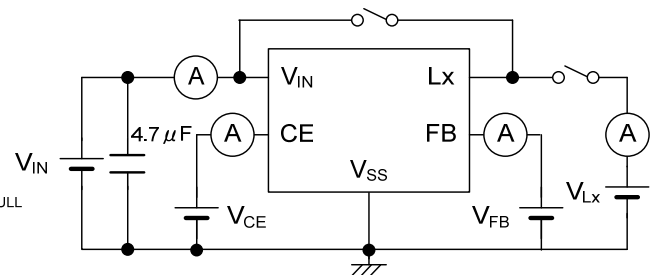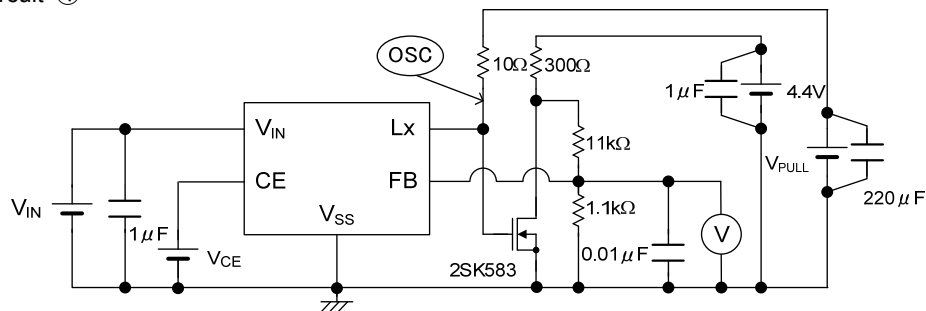● Circuit ① (XC9133B02A Series)
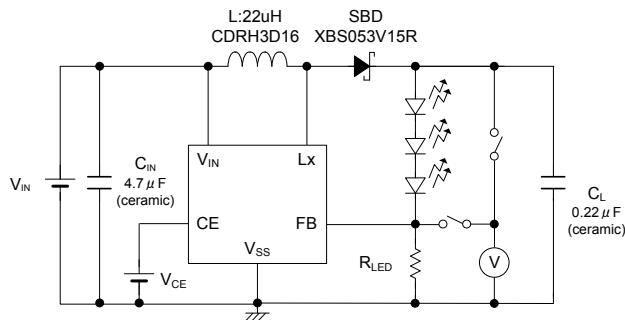
● Circuit ②

● Circuit ③

● Circuit ④

1. The measurement method of Lx ON Resistance R_{SWON}
Using the circuit ④, Lx ON resistance can be measured by adjusting V_{PULL} voltage to set Lx voltage V_{LX} 0.4V when the driver transistor is ON.
The oscilloscope is used for measuring the Lx voltage when the driver transistor is ON.

$$R_{SWON} = 0.4 / ((V_{PULL} - 0.4) /10)$$

2. The measurement method of current limit I_{LIM}
Using the circuit ④, current limit I_{LIM} can be calculated by the equation including V_{PULL} voltage when FB voltage is decreased while V_{PULL} voltage is adjusted and Lx voltage V_{LX} when the driver transistor is ON.
The oscilloscope is used for measuring the Lx voltage when the driver transistor is ON.
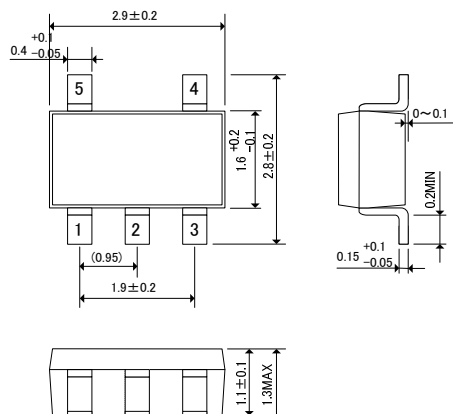
$$I_{LIM} = (V_{PULL} - V_{LX}) / R_{PULL}$$
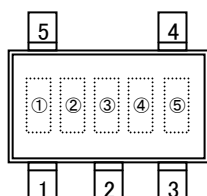$$R_{PULL} = 10Ω$$

■PACKAGING INFORMATION

●SOT-25

(unit : mm)

■ MARKING RULE

●SOT-25

① represents product series

MARK	PRODUCT SERIES
N	XC9133****M*

② represents Lx overvoltage limit

MARK	Lx OVERVOLTAGE LIMIT	PRODUCT SERIES
B	Available	XC9133****M*

③ represents oscillation frequency

MARK	OSCILLATION FREQUENCY	PRODUCT SERIES
A	1MHz	XC9133****M*

④⑤ represents production lot number
   01 to 09, 0A to 0Z, 11 to 9Z, A1 to A9, AA to Z9, ZA to ZZ repeated.
   (G, I, J, O, Q, W excepted)
    * No character inversion used.

1. The product and product specifications contained herein are subject to change without notice to improve performance characteristics. Consult us, or our representatives before use, to confirm that the information in this datasheet is up to date.

2. The information in this datasheet is intended to illustrate the operation and characteristics of our products. We neither make warranties or representations with respect to the accuracy or completeness of the information contained in this datasheet nor grant any license to any intellectual property rights of ours or any third party concerning with the information in this datasheet.

3. Applicable export control laws and regulations should be complied and the procedures required by such laws and regulations should also be followed, when the product or any information contained in this datasheet is exported.

4. The product is neither intended nor warranted for use in equipment of systems which require extremely high levels of quality and/or reliability and/or a malfunction or failure which may cause loss of human life, bodily injury, serious property damage including but not limited to devices or equipment used in 1) nuclear facilities, 2) aerospace industry, 3) medical facilities, 4) automobile industry and other transportation industry and 5) safety devices and safety equipment to control combustions and explosions. Do not use the product for the above use unless agreed by us in writing in advance.

5. Although we make continuous efforts to improve the quality and reliability of our products; nevertheless Semiconductors are likely to fail with a certain probability. So in order to prevent personal injury and/or property damage resulting from such failure, customers are required to incorporate adequate safety measures in their designs, such as system fail safes, redundancy and fire prevention features.

6. Our products are not designed to be Radiation-resistant.

7. Please use the product listed in this datasheet within the specified ranges.

8. We assume no responsibility for damage or loss due to abnormal use.

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TOREX SEMICONDUCTOR LTD.

Данный компонент на территории Российской Федерации

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Нашей специализацией является поставка электронной компонентной базы двойного назначения, продукции таких производителей как XILINX, Intel (ex.ALTERA), Vicor, Microchip, Texas Instruments, Analog Devices, Mini-Circuits, Amphenol, Glenair.

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