XCL230/XCL231 Series

ETR28019-000b

0.6A,36V Inductor Built-in Step-down “micro DC/DC” Converter

Advance Information (Design Target)

■GENERAL DESCRIPTION

The XCL230/XCL231 series are small size(3.0mm×3.0mm, h=1.6mm) synchronous step-down DC/DC converter ICs with a built-in high-side / low-side driver transistor. An internal coil simplifies the circuit and enables minimization of noise and other operational trouble due to the circuit wiring.Compatible with Low ESR capacitors such as ceramic capacitors for the load capacitor (C_L).
The XCL230/231 series has operating voltage range of 3.0V～36.0V and high-efficiency power supply up to an output current of 0.6A. 1.2MHz can be selected for the switching frequency.

The XCL230 series has a fixed frequency, enabling the suppression of output ripple. The XCL231 series achieves high efficiency while holding down output ripple across the full range of loads, from light to heavy by PWM/PFM automatic switchover control, IC can change the control method between PWM and PFM based on the output current requirement. A 0.75V reference voltage source is incorporated in the IC, and the output voltage can be set to a value from 1.0V to 5.0V using external resistors (R_{FB1}, R_{FB2}).
The soft-start time is internally set to 2.0ms (TYP.), but can be adjusted to set a longer time using an external resistor and capacitor.
With the built-in UVLO function, the driver transistor is forced OFF when input voltage becomes 2.7V or lower.
The output state can be monitored using the power good function. Internal protection circuits include over current protection, short-circuit protection, and thermal shutdown circuits to enable safe use.

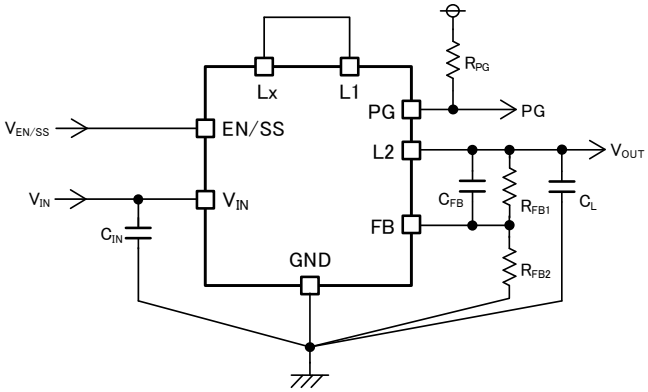
■APPLICATIONS

- Energy Mater
- Gas Detector
- Various Sensor
- Industrial Equipment
- Home appliance

■FEATURES

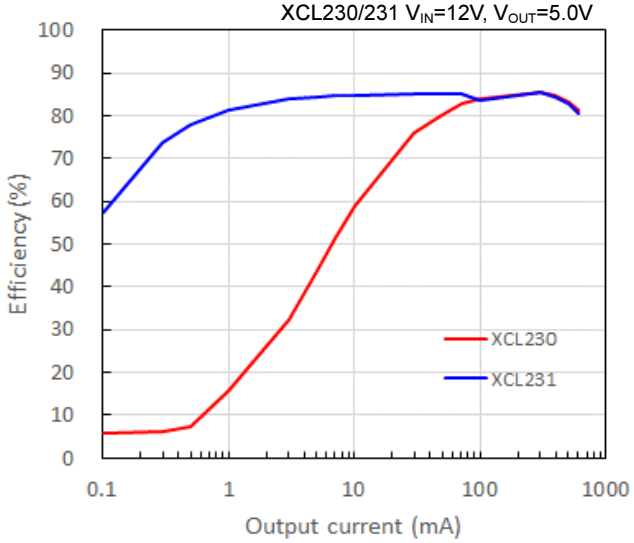
Input Voltage Range	:	3～36V(Absolute Max 40V)
Output Voltage Range		1.0～5.0V
FB Voltage	:	0.75V±1.5%
Oscillation Frequency	:	1.2MHz
Max Output Current	:	0.6A
Control Methods	:	PWM control(XCL230) PWM/PFM Auto Switch(XCL231) Efficiency85%@12V→5V、300mA
Soft-start Time	:	Adjustable by RC
Protection Circuits	:	Over Current Protection
	:	Thermal Shutdown
		Short-circuit Protection
Low ESR Ceramic Capacitor	:	Ceramic Capacitor
Packages	:	DFN3030-10B
Environmentally Friendly		EU RoHS Compliant, Pb Free

■TYPICAL APPLICATION CIRCUIT

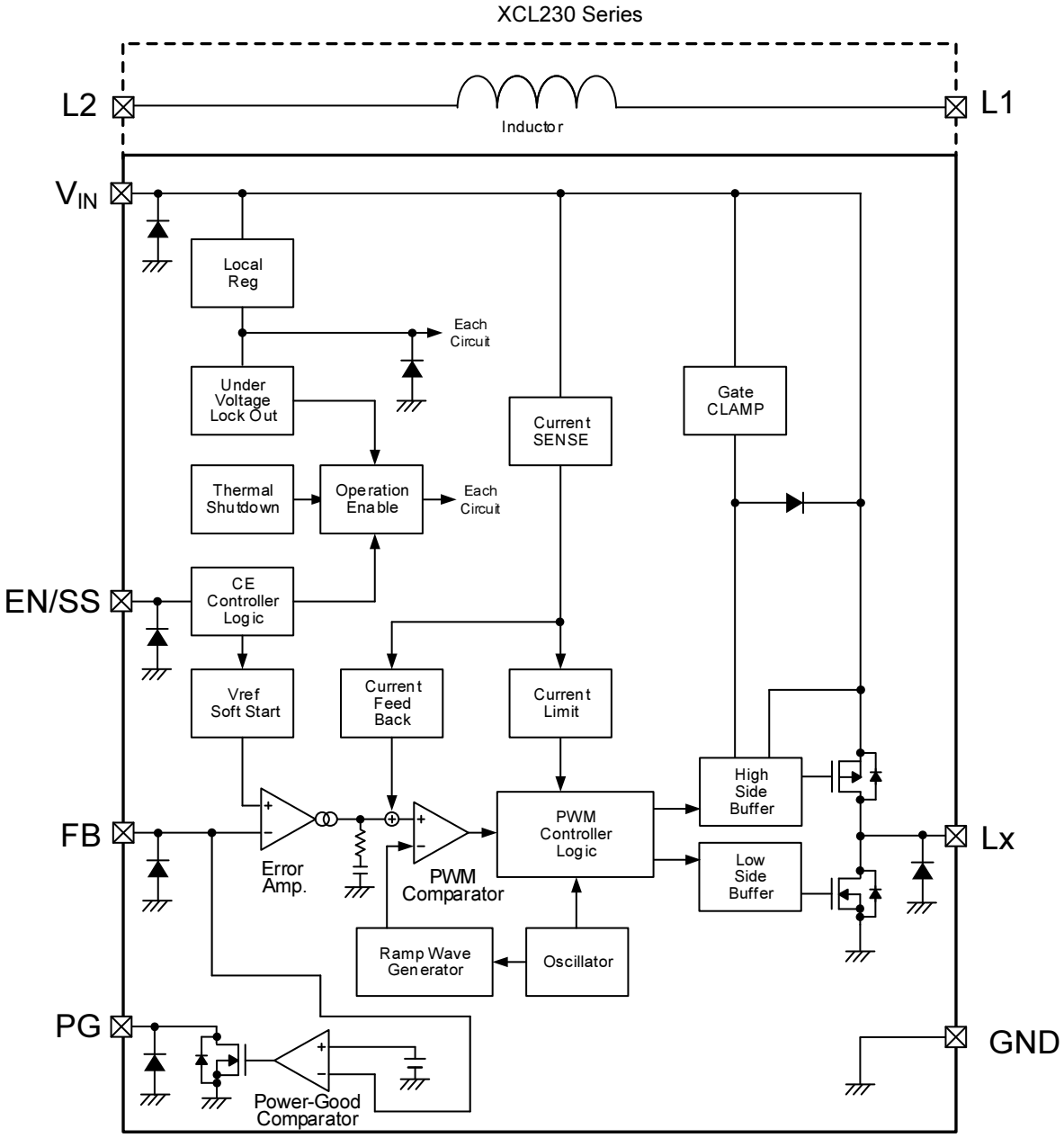


■ TYPICAL PERFORMANCE CHARACTERISTICS

XCL230/231 V_{IN}=12V, V_{OUT}=5.0V

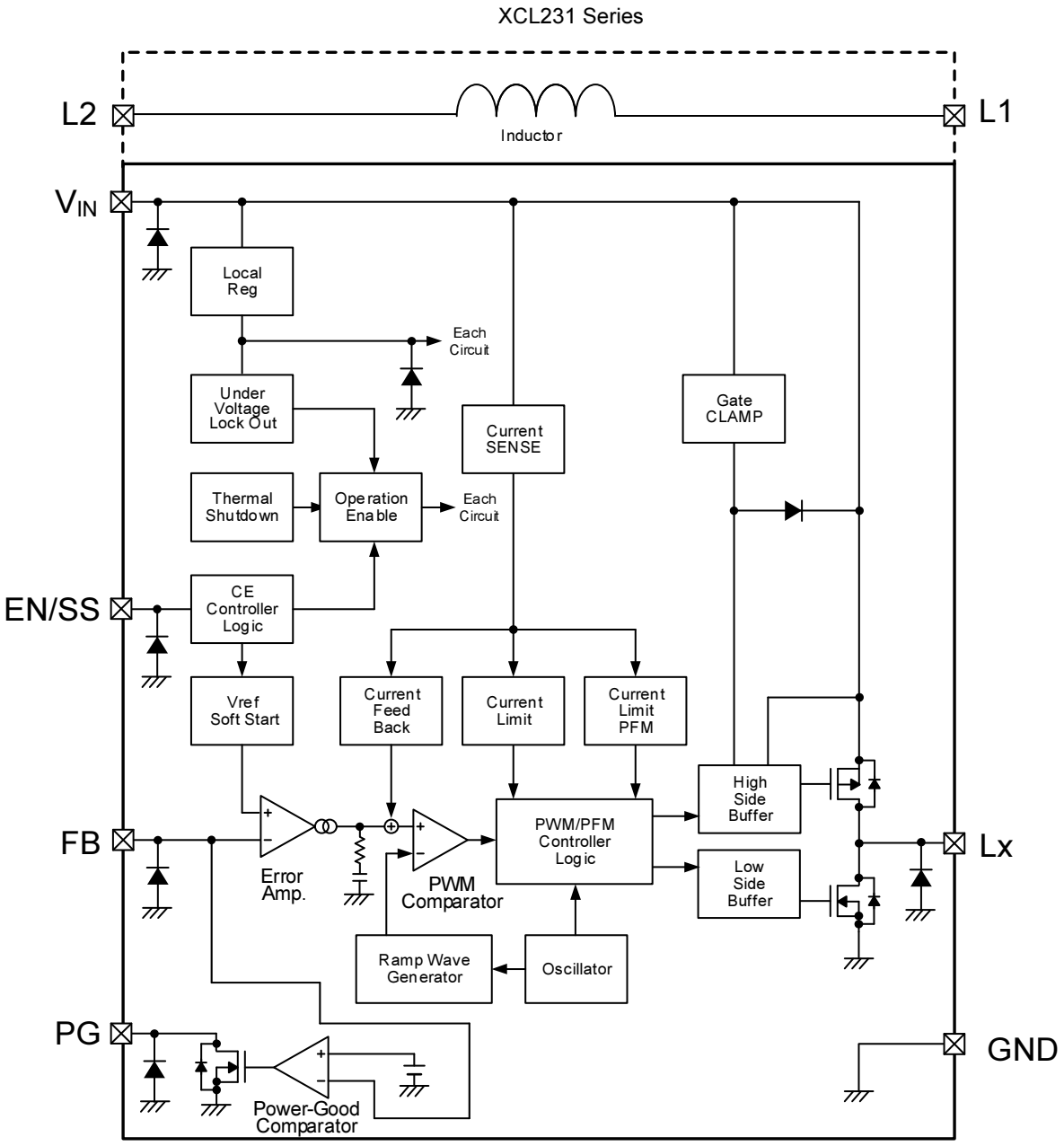


■BLOCK DIAGRAM



The XCL230 series is fixed to PWM control.
Diodes inside the circuit are an ESD protection diodes and a parasitic diodes

■BLOCK DIAGRAM



The XCL231 series is PWM / PFM automatic switching control.
Diodes inside the circuit are an ESD protection diodes and a parasitic diodes

■PRODUCT CLASSIFICATION

●Ordering Information

XCL230①②③④⑤⑥ PWM control

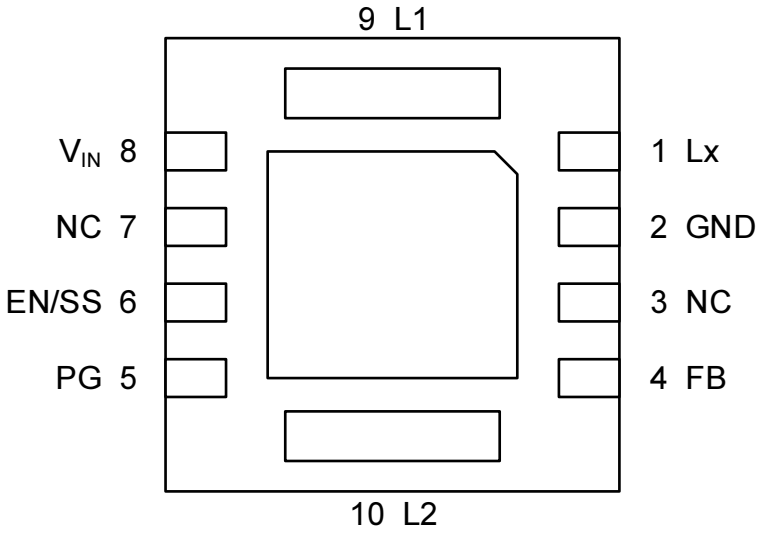
XCL231①②③④⑤⑥ PWM/PFM automatic

DESIGNATOR	ITEM	SYMBOL	DESCRIPTION
①	Type	B	Refer to Selection Guide
②③	FB Voltage	0K	0.75V
④	Oscillation Frequency	1	1.2MHz
⑤⑥	Packages (Order Unit)	H2	DFN3030-10B(3000pcs/Reel)

●Selection Guide

TYPE	Chip Enable	UVLO	Thermal Shutdown	Power Good	Soft Start	Current Limiter	Automatic Recovery (Current Limiter)
B	YES	YES	YES	YES	YES	YES	YES

■PIN CONFIGURATION



(BOTTOM VIEW)

* The dissipation pad for the DFN3030-10B package should be solder-plated in recommended mount pattern and metal masking so as to enhance mounting strength and heat release. If the pad needs to be connected to other pins, it should be connected to the GND (No. 2) pin.

■PIN ASSIGNMENT

PIN NUMBER	PIN NAME	FUNCTION
1	LX	Switching Output
2	GND	Ground
3	NC	No Connection
4	FB	Output Voltage Sense
5	PG	Power good Output
6	EN/SS	Enable Soft-start
7	NC	No Connection
8	V_{IN}	Power Input
9	L1	Inductor Electrodes
10	L2	Inductor Electrodes

* These 3 and 7-pin NC terminal is not connected to an IC chip.

■FUNCTION CHART

PIN NAME	SIGNAL	STATUS
EN/SS	H	Active
	L	Stand-by
	OPEN	Undefined State(*1)
PG	H(Low impedance)	FB pin Voltage > V_{FB} x 0.9
	L(High impedance)	FB pin Voltage ≦ V_{FB} x 0.9

(*1) Please do not leave the EN/SS pin open. Each should have a certain voltage

■ABSOLUTE MAXIMUM RATINGS

Ta=25℃

PARAMETER	SYMBOL	RATINGS	UNITS
V_{IN} Pin Voltage	V_{IN}	-0.3 ～ +40	V
EN/SS Pin Voltage	$V_{EN/SS}$	-0.3 ～ +40	V
FB Pin Voltage	V_{FB}	-0.3 ～ +6.2	V
PG Pin Voltage	V_{PG}	-0.3 ～ +6.2	V
PG Pin Current	I_{PG}	8	mA
Lx Pin Voltage	V_{Lx}	-0.3 ～ V_{IN}+0.3 or +40 (*1)	V
Lx Pin Current	I_{Lx}	1800	mA
Power Dissipation	Pd	1950 (JESD51-7 Board) (*2)	mW
Surge Voltage	V_{SURGE}	+46(*3)	V
Operating Ambient Temperature	Topr	-40 ～ +105	℃
Storage Temperature	Tstg	-55 ～ +125	℃

* All voltages are described based on the GND pin.

(*1) The maximum value should be either V_{IN}+0.3 or 40 in the lowest.

(*2) The power dissipation figure shown is PCB mounted and is for reference only.
Please see the power dissipation page for the mounting condition.

(*3) Impressed Time≦400ms

■ELECTRICAL CHARACTERISTICS

XCL230/XCL231Series Ta=25℃

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT	CIRCUIT
FB Voltage	V_{FBE}	V_{FB}=0.739V→0.761V, FB Voltage when Lx pin voltage changes from "H" level to "L" level	0.739	0.750	0.761	V	②
Output Voltage Setting Range (*1)	V_{OUTSET}	-	1.0	-	5.0	V	-
Input Voltage Operating Range (*1)	V_{IN}	-	3.0	-	36.0	V	-
UVLO Detect Voltage	V_{UVLOD}	$V_{EN/SS}$=12V,V_{IN}=2.8V→2.6V,V_{FB}=0V V_{IN} Voltage which Lx pin voltage holding "H" level	2.6	2.7	2.8	V	②
UVLO Release Voltage	V_{UVLOR}	$V_{EN/SS}$=12V,V_{IN}=2.7V→2.9V,V_{FB}=0V V_{IN} Voltage which Lx pin voltage holding "L" level	2.7	2.8	2.9	V	②
Quiescent Current(XCL230)	I_q	V_{FB}=0.825V	-	180	350	μA	④
Stand-by Current	I_{STBY}	V_{IN}=12V, $V_{EN/SS}$=V_{FB}=0V	-	1.65	2.50	μA	④
Oscillation Frequency	f_{OSC}	Connected to external components, I_{OUT}=200mA	1.098	1.200	1.302	MHz	①
Minimum On Time	t_{ONMIN}	Connected to external components	-	85 (*2)	-	ns	①
Minimum Duty Cycle	D_{MIN}	V_{FB}=0.825V	-	-	0	%	②
Maximum Duty Cycle	D_{MAX}	V_{FB}=0.675V	100	-	-	%	②
Lx SW "H" On Resistance	R_{LxH}	V_{FB}=0.675V, I_{Lx}=200mA	-	1.20	1.38	Ω	⑤
Lx SW "L" On Resistance	R_{LxL}	V_{FB}=0.825V, I_{Lx}=200mA	-	0.60(*2)	-	Ω	⑤
PFM Switch Current(XCL231)	I_{PFM}	Connected to external components, V_{IN}=$V_{EN/SS}$=12V、I_{OUT}=1mA	-	400	-	mA	①
High side Current Limit (*3)	I_{LIMH}	V_{FB}=V_{FBE}×0.98	-	1.30	-	A	⑤
Internal Soft-Start Time	t_{SS1}	V_{FB}=0.675V	1.6	2.0	2.4	ms	②
External Soft-Start Time	t_{SS2}	V_{FB}=0.675V R_{SS}=430kΩ, C_{SS}=0.47μF	21	26	33	ms	③
PG detect Voltage	V_{PGDET}	V_{FB}=0.712V→0.638V, R_{PG}:100kΩ pull-up to 5V FB Voltage when PG pin voltage changes from "H" level to "L" level	0.638	0.675	0.712	V	⑤
PG Output voltage	V_{PG}	V_{FB}=0.6V, I_{PG}=1mA	-	-	0.3	V	②
Efficiency	EFFI	Connected to external components, V_{IN}=12V, V_{OUT}=5V, I_{OUT}=300mA	-	85	-	%	①
FB Voltage Temperature Characteristics	ΔV_{FB}/ (ΔT_{opr}・V_{FBE})	-40℃≦T_{opr}≦105℃	-	±100	-	ppm/℃	②

Test Condition: Unless otherwise stated, V_{IN}=12V, $V_{EN/SS}$=12V, V_{PG}=OPEN (*4)
Peripheral parts connection conditions :
L=4.7μH, R_{FB1}=680kΩ, R_{FB2}=120kΩ, C_{FB}=18pF, C_L=10μF×2parallel, C_{IN}=2.2μF
(*1) Please use within the range of V_{OUT}/V_{IN}≧t_{ONMIN}×f_{OSC}
(*2) Design reference value. This parameter is provided only for reference.
(*3) Current limit denotes the level of detection at peak of coil current.

■ELECTRICAL CHARACTERISTICS

XCL230/XCL231 Series

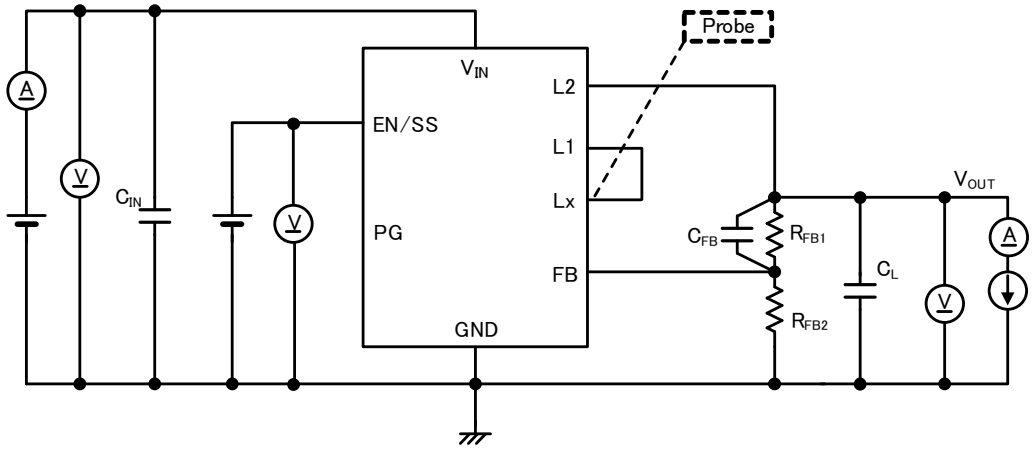
Ta=25℃

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT	CIRCUIT
FB "H" Current	I_{FBH}	V_{IN}=$V_{EN/SS}$=36V, V_{FB}=3.0V	-0.1	-	0.1	μA	④
FB "L" Current	I_{FBL}	V_{IN}=$V_{EN/SS}$=36V, V_{FB}=0V	-0.1	-	0.1	μA	④
EN/SS "H" Voltage	$V_{EN/SSH}$	$V_{EN/SS}$=0.3V→2.5V, V_{FB}=0.71V EN/SS Voltage when Lx pin voltage changes from "L" level to "H" level	2.5	-	36.0	V	②
EN/SS "L" Voltage	$V_{EN/SSL}$	$V_{EN/SS}$=2.5V→0.3V, V_{FB}=0.71V EN/SS Voltage when Lx pin voltage changes from "H" level to "L" level	-	-	0.3	V	②
EN/SS "H" Current	$I_{EN/SSH}$	V_{IN}=$V_{EN/SS}$=36V, V_{FB}=0.825V	-	0.1	0.3	μA	④
EN/SS "L" Current	$I_{EN/SSL}$	V_{IN}=36V, $V_{EN/SS}$=0V, V_{FB}=0.825V	-0.1	-	0.1	μA	④
Thermal Shutdown Temperature	T_{TSD}	Junction Temperature	-	150	-	℃	-
Hysteresis Width	T_{HYS}	Junction Temperature	-	25	-	℃	-
Inductance	L	Test Freq.=1MHz	-	4.3	-	μH	-
Inductor Rated Current	I_{DC}	⊿T=+40℃	-	1000	-	mA	-

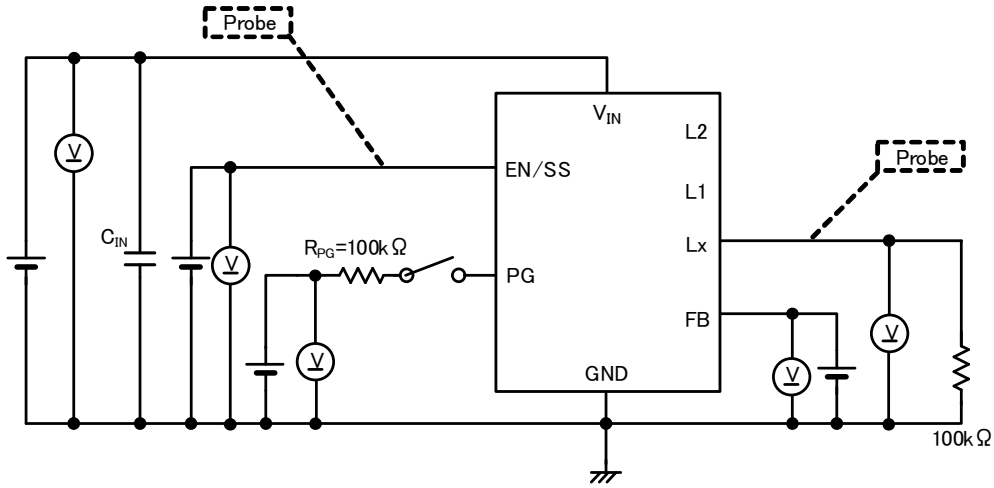
Test Condition: Unless otherwise stated, V_{IN}=12V, $V_{EN/SS}$=12V, V_{PG}=OPEN

■TEST CIRCUITS

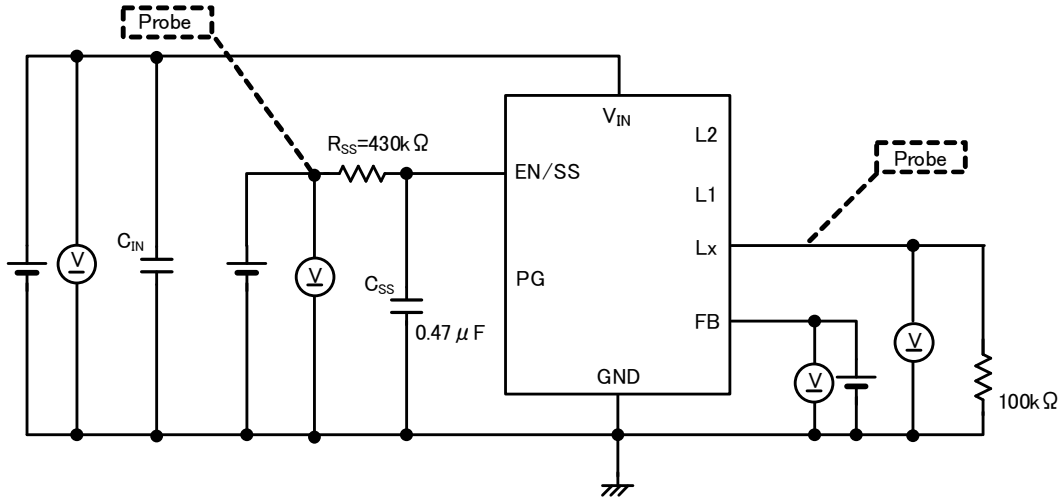
Circuit No.①



Circuit No.②

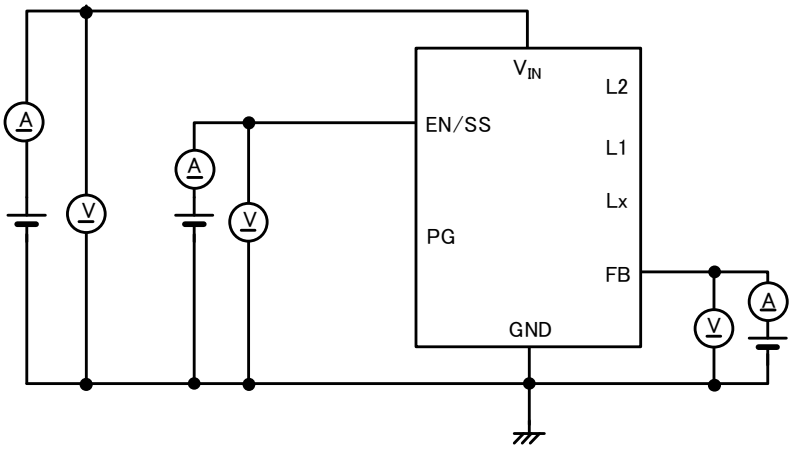


Circuit No.③

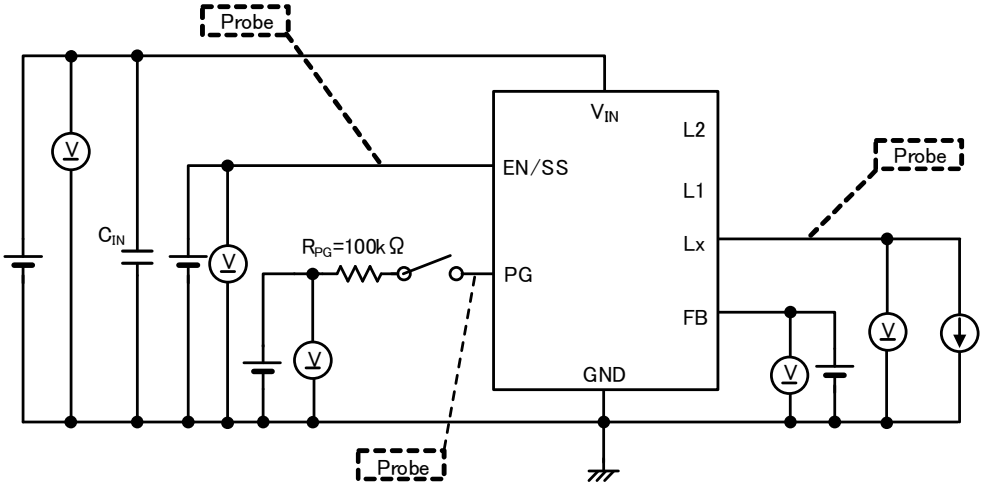


■TEST CIRCUITS

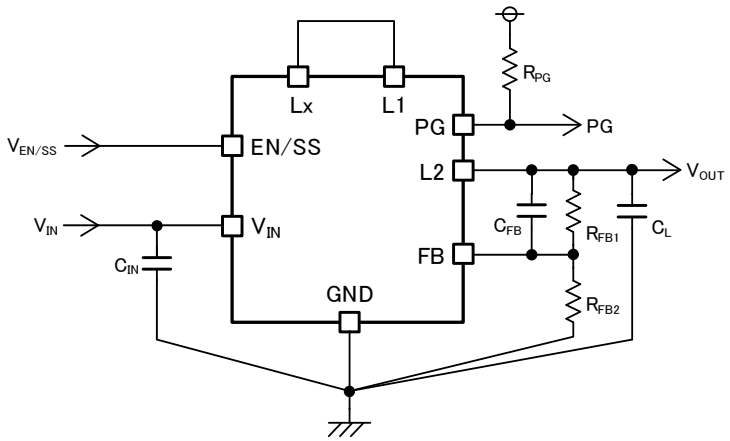
Circuit No.④



Circuit No.⑤



■TYPICAL APPLICATION CIRCUIT



*Coil is dedicated to this product. Please do not use it for purposes other than this product.

【Typical example】

	VALUE	PRODUCT NUMBER	Notes
C_{IN}	50V/4.7μF	C2012X6S1H475K125AC (TDK)	V_{IN}<20V
			V_{IN}≧20V, 2parallel
C_L	10V/10μF	C2012X7R1A106K125AC (TDK)	2parallel
	35V/10μF	C3216X7R1E106K160AB (TDK)	

*When under the condition of the voltage difference between input voltage and output voltage is low,
Please use 125℃ product, which has small capacity drop.

<Output voltage setting>
The output voltage can be set by adding an external dividing resistor.
The output voltage is determined by the equation below based on the values of R_{FB1} and R_{FB2}.

$V_{OUT}=0.75V\times(R_{FB1}+R_{FB2})/R_{FB2}$
但し、R_{FB2}≦400kΩ

<C_{FB} setting>
Adjust the value of the phase compensation speed-up capacitor C_{FB} using the equation below.

$$C_{FB}=\frac{1}{2\pi\times fzfb\times R_{FB1}}$$

$$fzfb=\frac{1}{2\pi\sqrt{C_L\times L}}$$

【Setting Example】
To set output voltage to 5V with fosc=1.2MHz, C_L=20μF, L=4.3μH
When R_{FB1}=680kΩ, R_{FB2}=120kΩ, V_{OUT}=0.75V× (680kΩ+120kΩ) / 120kΩ=5.0V
And fzfb is set to a target of 16.42kHz using the above equation,
C_{FB}=1/(2×π×16.42kHz×680kΩ)=14.26pF≒15pF

XCL230B0K1 / f_{OSC}=1.2MHz					
V_{OUTSET}	R_{FB1}	R_{FB2}	L	C_{FB}	fzfb
1.2V	120kΩ	200kΩ	4.3μH	82pF	16.4kHz
3.3V	510kΩ	150kΩ	4.3μH	18pF	16.4kHz
5.0V	680kΩ	120kΩ	4.3μH	15pF	16.4kHz

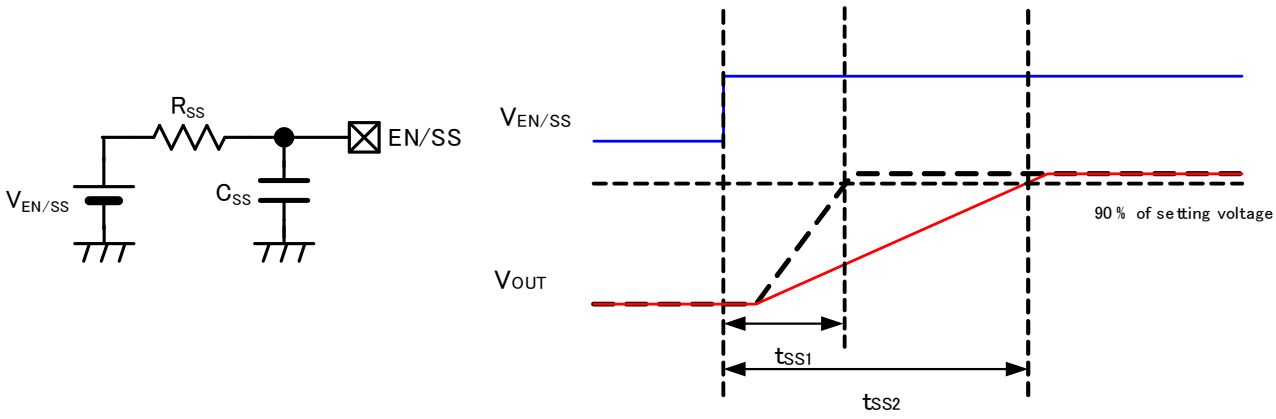
<Soft-start Time Setting>

The soft-start time can be adjusted by adding a capacitor and a resistor to the EN/SS pin.
Soft-start time (t_{ss2}) is approximated by the equation below according to values of $V_{EN/SS}$, R_{SS}, and C_{SS}.

$$t_{ss2}=C_{ss}\times R_{ss}\times \ln (V_{EN/SS} / (V_{EN/SS}-1.45V))$$

【Setting Example】
When C_{SS}=0.47μF, R_{SS}=430kΩ and $V_{EN/SS}$=12V,、
t_{SS2} = 0.47μF x 430kΩ x (ln (12V/(12V-1.45V)) = 26ms(Approx)

*The soft-start time is the time from the start of $V_{EN/SS}$ until the output voltage reaches 90% of the set voltage.
If the EN/SS pin voltage rises steeply without connecting C_{SS} and R_{SS} (R_{SS}=0Ω), Output rises with taking the soft-start time of t_{ss1}=2.0ms (TYP.) which is fixed internally.

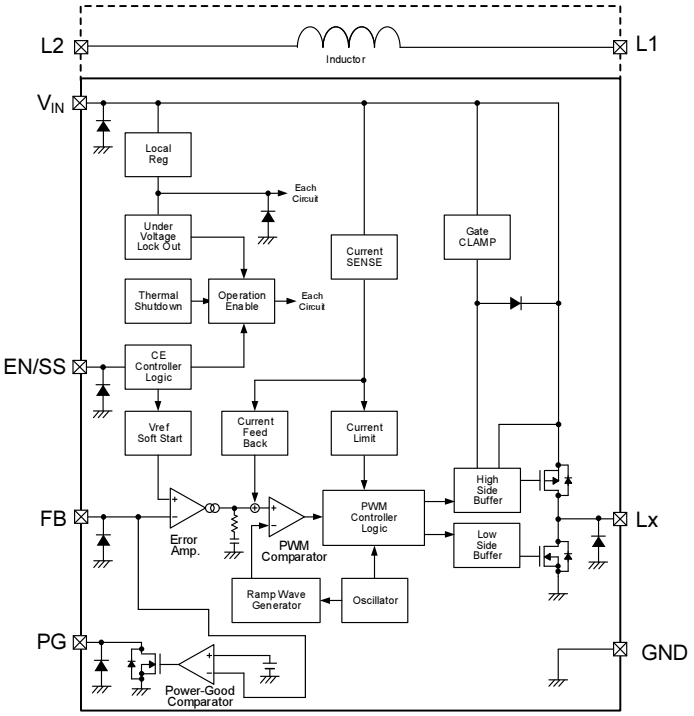


・R_{PG} Terminal
Connect PG terminal to Nch open drain output, please connect pull up resistor (about 100 kΩ) to PG terminal.
When not using the power good function, connect the PG terminal to GND or use it open.

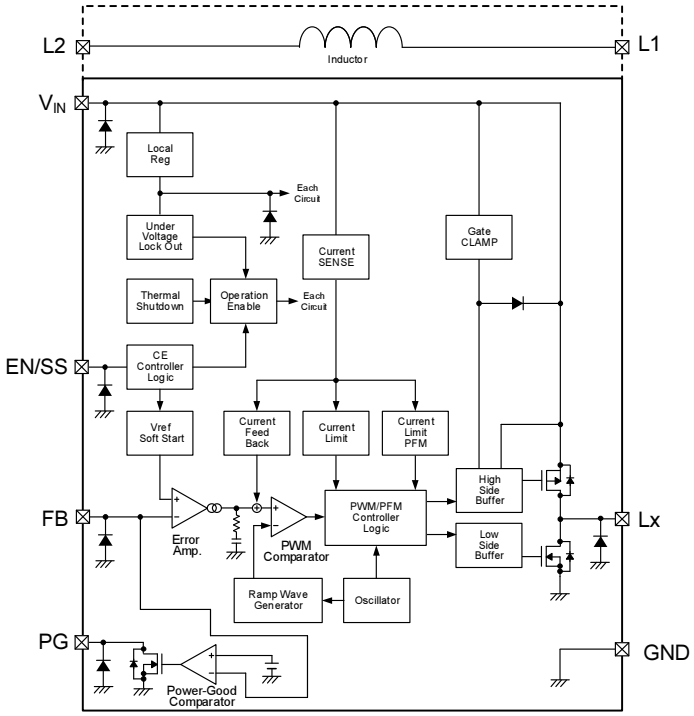
■OPERATIONAL EXPLANATION

The XCL230/XCL231 series consists internally of a reference voltage supply with soft-start function, error amp, PWM comparator, ramp wave circuit, oscillator circuit, Current limiting PFM circuit, phase compensation (Current feedback) circuit, current limiting circuit, High-side driver Tr., Low-side driver Tr., buffer drive circuit, internal power supply (Local Reg) circuit, under-voltage lockout (UVLO) circuit, gate clamp (CLAMP) circuit, thermal shutdown (TSD) circuit, power good comparator, PWM/PFM control block and other elements.
The voltage feedback from the FB pin is compared to the internal reference voltage by the error amp, the output from the error amp is phase compensated, and the signal is input to the PWM comparator to determine the ON time of switching during PWM operation. The output signal from the error amp is compared to the ramp wave by the PWM comparator, and the output is sent to the buffer drive circuit and output from the L_X pin as the duty width of switching. This operation is performed continuously to stabilize the output voltage.
The driver transistor current is monitored at each switching by the phase compensation (Current feedback) circuit, and the output signal from the error amp is modulated as a multi-feedback signal. This allows a stable feedback system to be obtained even when a low ESR capacitor such as a ceramic capacitor is used, and this stabilizes the output voltage.

XCL230 Series



XCL231 Series



* Diodes inside the circuits are ESD protection diodes and parasitic diodes

<Reference voltage source>
The reference voltage source provides the reference voltage to ensure stable output voltage of the DC/DC converter.

<Oscillator circuit>
The oscillator circuit determines switching frequency.1.2MHz is available for the switching frequency.
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 feedback voltage divided by the internal voltage divider, R_{FB1} and R_{FB2}. When a voltage is lower than the reference voltage, then the voltage is fed back, the output voltage of the error amplifier increases. The error amplifier output is fixed internally to deliver an optimized signal to the mixer.

■OPERATIONAL EXPLANATION

<Current limiting>
The current limiting circuit of the XCL230/XCL231 series monitors the current that flows through the High-side driver transistor and
Low-side driver transistor, and when over-current is detected, the current limiting function activates.

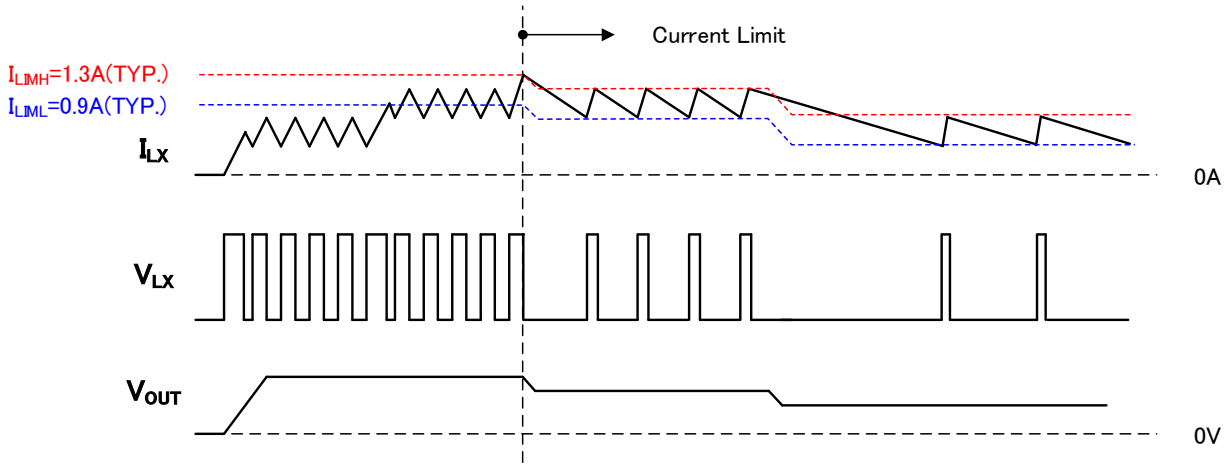
(1) High-side driver Tr. current limiting
The current in the High-side driver Tr. is detected to equivalently monitor the peak value of the coil current. The High-side driver Tr. current limiting function forcibly turns off the High-side driver Tr. when the peak value of the coil current reaches the High-side driver current limit value I_{LIMH}.

High-side driver Tr. current limit value I_{LIMH}=1.3A (TYP.)

(2) Low-side driver Tr. current limiting
The current in the Low-side driver Tr. is detected to equivalently monitor the bottom value of the coil current. The Low-side driver Tr. current limiting function operates when the High-side driver Tr. current limiting value reaches I_{LIMH}. The Low-side driver Tr. current limiting function prohibits the High-side driver Tr. from turning on in an over-current state where the bottom value of the coil current is higher than the Low-side driver Tr. current limit value I_{LIML}.

Low side driver Tr. current limit value I_{LIML}=0.9A (TYP.)

The current foldback circuit operates control to lower the switching frequency f_{OSC}. When the over-current state is released, normal operation resumes.



<Soft-start function>
The output voltage of XCL230/XCL231 rises with soft start by slowly raising the reference voltage. The rise time of this reference voltage is the soft start time. The soft-start time is set to 2.0ms (TYP.) which is fixed internally or to the time set by adding a capacitor and a resistor to the EN / SS pin whichever is later.

<Thermal shutdown>
The thermal shutdown (TSD) as an over temperature limit is built in the XCL230/XCL231 series.
When the junction temperature reaches the detection temperature, the driver transistor is forcibly turned off. When the junction temperature falls to the release temperature while in the output stop state, restart takes place by soft-start.

<UVLO>
When the V_{IN} pin voltage falls below 2.7V (TYP.), the driver transistor is forcibly turned off to prevent false pulse output due to instable operation of the internal circuits. When the V_{IN} pin voltage rises above 2.8V (TYP.), the UVLO function is released, the soft-start function activates, and output start operation begins. Stopping by UVLO is not shutdown; only pulse output is stopped and the internal circuits continue to operate.

<Power good>
When the FB voltage drops below 90% (TYP.), the PG pin outputs an "L" signal. The PG pin is an Nch open drain output, therefore a pull-up resistance (approx. 100kΩ) must be connected to the PG pin.

■NOTE ON USE

1) For the phenomenon of temporal and transitional voltage decrease or voltage increase, the IC may be damaged or deteriorated if IC is used beyond the absolute MAXIMUM specifications.

2) Make sure that the absolute maximum ratings of the external components and of this IC are not exceeded.

3) The DC/DC converter characteristics depend greatly on the externally connected components as well as on the characteristics of this IC, so refer to the specifications and standard circuit examples of each component when carefully considering which components to select.
Be especially careful of the capacitor characteristics and use X7R or X5R (EIA standard) ceramic capacitors.
The capacitance decrease caused by the bias voltage may become remarkable depending on the external size of the capacitor.

4) The DC/DC converter of this IC uses a current-limiting circuit to monitor the coil peak current. If the potential dropout voltage is large or the load current is large, the peak current will increase, which makes it easier for current limitation to be applied which in turn could cause the operation to become unstable.

5) If there is a large dropout voltage, a circuit delay could create the ramp-up of coil current with staircase waveform exceeding the current limit.

6) Even in the PWM control, the intermittent operation occurs and the ripple voltage becomes higher, when the minimum On Time is faster than 85ns (typ.) as well as the dropout voltage is large and output current is small.

7) The ripple voltage could be increased when switching from discontinuous conduction mode to continuous conduction mode and at switching to 100% Duty cycle. Please evaluate IC well on customer's PCB.

8) If the voltage at the EN/SS Pin does not start from 0V but it is at the midpoint potential when the power is switched on, the soft start function may not work properly and it may cause the larger inrush current and bigger ripple voltages.

■NOTE ON USE

9) Instructions of pattern layouts

(1) The operation may become unstable due to noise and/or phase lag from the output current when the wire impedance is high, please place the input capacitor(C_{IN}) and the output capacitor (C_L) as close to the IC as possible.

(2) In order to stabilize V_{IN} voltage level, we recommend that a by-pass capacitor (C_{IN}) be connected as close as possible to the V_{IN} and PGND pins.

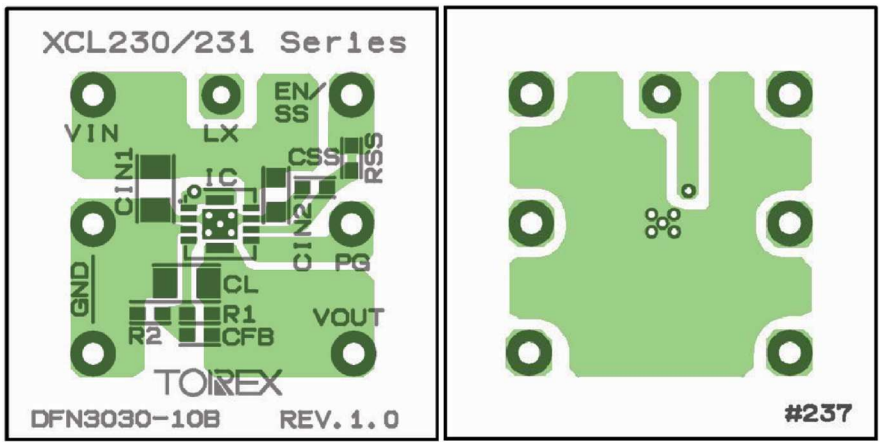
(3) Please mount each external component as close to the IC as possible.

(4) Wire external components as close to the IC as possible and use thick, short connecting traces to reduce the circuit impedance.

(5) Make sure that the 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.

(6) Please note that internal driver transistors bring on heat because of the load current and ON resistance of High-side driver transistor,
Low-side driver transistor.

< Reference Pattern Layout >



< Top View > < Bottom View >

10) 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.

■About the appearance (coil part)

(1) Coils are compliant with general surface mount type chip coil (inductor) specifications and may have scratches, flux contamination and the like.

(2) This product has a coil which is soldered on top of the package. There is no problem with normal board mounting reflow. If the excessive shock is provided during reflow, there is a possibility to cause the coil misaligned or have the coil fell off. Please be careful not to provide excessive shock to the PCB during the board mounting reflow.

■PACKAGING INFORMATION

Please see below for the latest package information.

PACKAGE	URL
DFN3030-10B	https://www.torex.co.jp/technical-support/packages/dfn3030-10b/

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.

9.

TOREX SEMICONDUCTOR LTD.