XCL233 Series

ETR28023-001a

Ultra-Low Quiescent Current, Inductor Built-in Step-Down DC/DC Converter with Output voltage selectable function

☆Green Operation compatible

■GENERAL DESCRIPTION

The XCL233 series is a synchronous step-down micro DC/DC converter which integrates an inductor and a control IC in one tiny package. It uses an ultra-low current consumption circuit and PFM control. The control IC and coil are integrated to achieve miniaturization, and a space-saving power supply can be configured simply by adding two external capacitors. the ultra-low current consumption circuit and PFM control method realize high efficiency with a light load.

Additionally two-preset output voltage switchover function is available with using VSET pin.

This function can select an appropriate output voltage based on the MCU behavior mode and contribute a power consumption reduction for a total system. An operating voltage range of 1.8V to 6.0V enables support for applications that require an internally fixed output voltage from 0.5V to 3.6V.

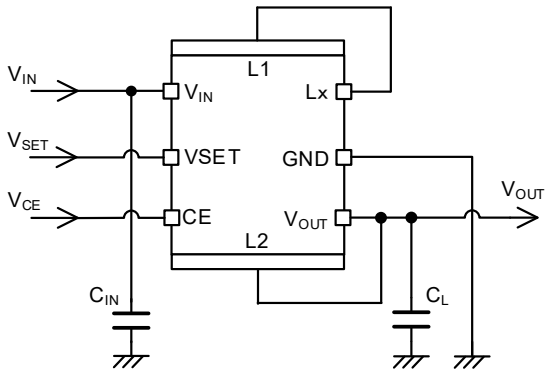
■APPLICATIONS

- Smart meter
- Low Power RF
- Sensor Module
- Wearable Devices
- Energy Harvest devices
- Back-up power supply circuit
- Smart card
- Devices with 1 Lithium cell

■FEATURES

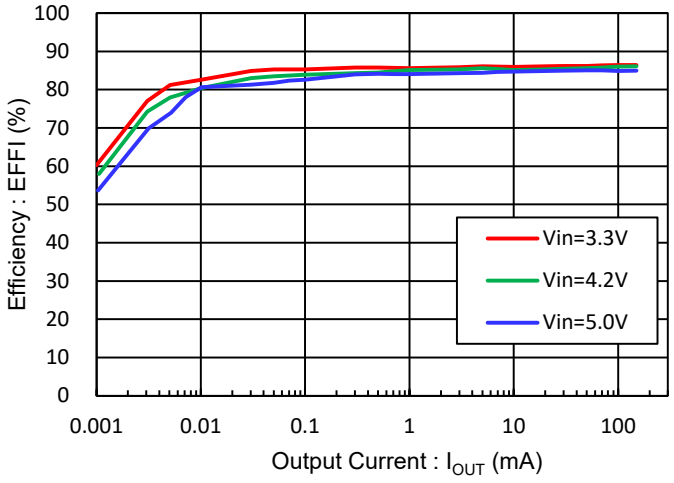
Input Voltage Range	:	1.8V ~ 6.0V
Output Voltage Setting	:	0.5V ~ 1.9V (0.05V increments)
		2.0V ~ 3.6V (0.1V increments)
Output Voltage Accuracy		±20mV ($V_{OUT1,2} \leqq 1.0V$)
		±2.0% ($V_{OUT1,2} > 1.0V$)
Output Current	:	150mA
Supply Current	:	200nA @ V_{OUT}=1.8V
Control Method	:	PFM control
Efficiency		86% (V_{IN}=3.6V, V_{OUT}=1.8V, Iout=10mA)
Function	:	Output Voltage selectable function
		C_L Discharge (D Type)
		UVLO
Protection Functions	:	Short Protection
Input / Output Capacitor	:	Ceramic Capacitor Compatible
Operation Ambient Temperature	:	-40 ~ 85℃
Package	:	CL-2025-03 (2.5 x 2.0 x 1.04 mm)
Environmentally Friendly		EU RoHS compliant, Pb Free

■TYPICAL APPLICATION CIRCUIT

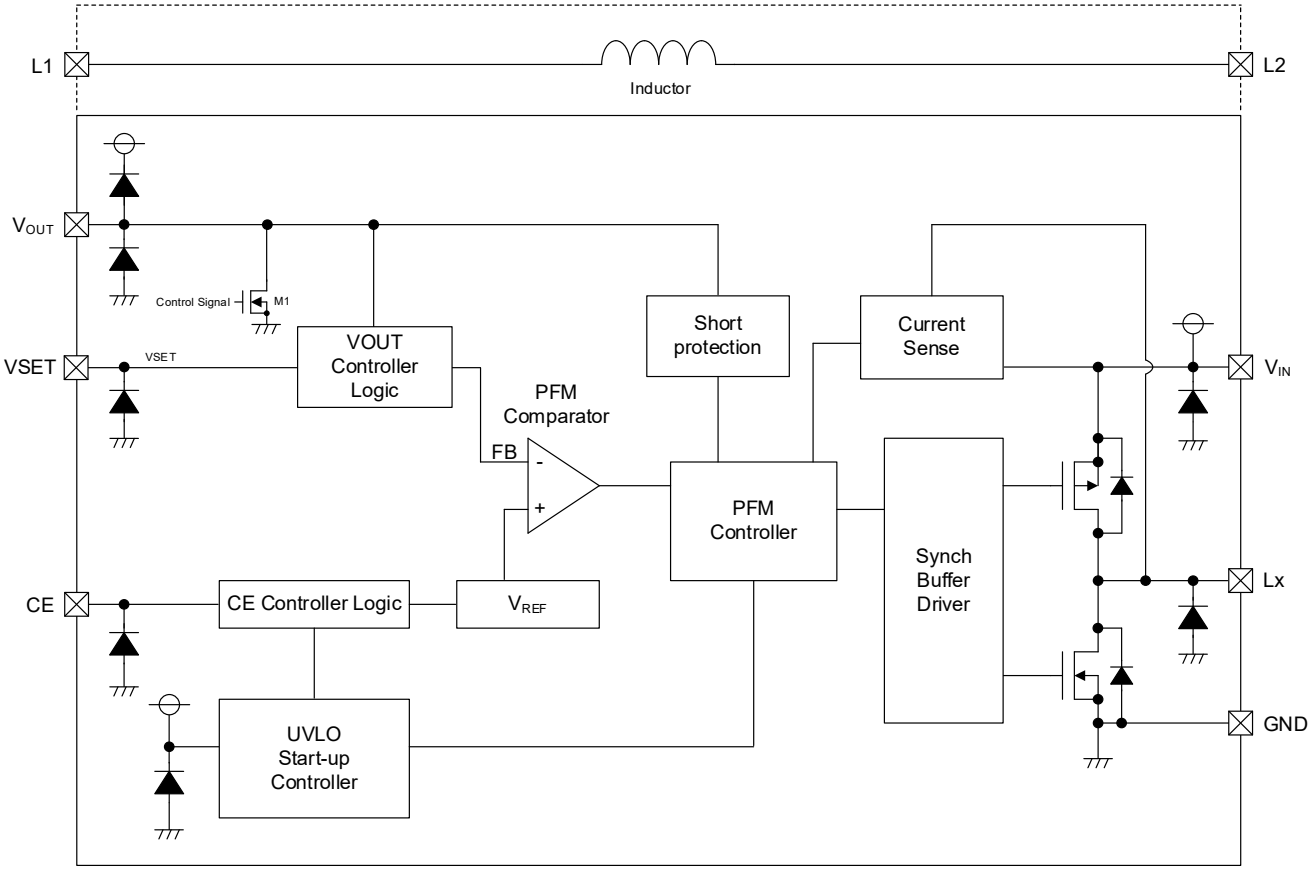


■TYPICAL PERFORMANCE CHARACTERISTICS

V_{OUT} =1.8V, C_{IN}=10μF, C_L=20μF, Ta=25℃



■ BLOCK DIAGRAM



* Diodes inside the circuits are ESD protection diodes and parasitic diodes.
XCL233B does not have C_L Discharge function.

■PRODUCT CLASSIFICATION

1) Ordering information

XCL233①②③④⑤⑥-⑦

DESIGNATOR	ITEM	SYMBOL	DESCRIPTION
①	Product Type	B	Without C_L Discharge
		D	With C_L Discharge
②③④ (*2)	Output Voltage	Refer to the table	Output Voltage combination V_{OUT1} : 0.50V ~ 3.60V V_{OUT2} : 0.50V ~ 3.60V ($V_{OUT1,2}$ ≦1.9V : 0.05V increments, $V_{OUT1,2}$ ＞ 1.9V : 0.1V increments)
⑤⑥-⑦ (*1)	Packages (Order Unit)	KR-G	CL-2025-03(*3) (3,000pcs/Reel)

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

(*2) The standard specification is V_{OUT1} ＜ V_{OUT2}.
With regard to other voltage, please contact our sales representative.

(*3) CL-2025-03 Reels are shipped in moisture-proof packaging.

2) Selection Guide

FUNCTION	B TYPE		D TYPE	
	V_{OUT1} or V_{OUT2} ＜1.2V	$V_{OUT1,2}$ ≧1.2V	V_{OUT1} or V_{OUT2} ＜1.2V	$V_{OUT1,2}$ ≧1.2V
Output Voltage	Output voltage selectable by VSET pin			
Short Protection	-	Yes	-	Yes
C_L Discharge	-		Yes	
Chip Enable	Yes			
UVLO	Yes			

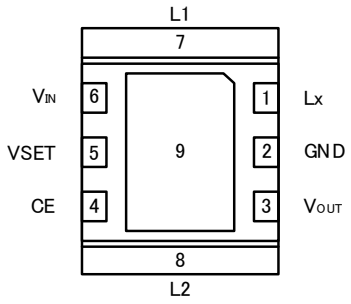
●Symbols ②③④ : Output voltage and part number combination

When using output voltage switching function Standard part number

②③④		V_{OUT1} (V)																
		0.50	0.60	0.65	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.50	1.80	1.85	2.00	2.20	2.50	3.00
V_{OUT2} (V)	0.50	-	-	R04	-	R16	-	-	-	-	-	-	-	-	-	-	-	-
	0.60	N02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	0.65	N03	001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	0.70	N04	002	061	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	0.80	N06	004	063	121	-	-	-	-	-	-	-	-	-	-	-	-	-
	0.90	N08	006	065	123	236	-	-	-	-	-	-	-	-	-	-	-	-
	1.00	N10	008	067	125	238	347	-	-	-	-	-	-	-	-	-	-	-
	1.10	N12	010	069	127	240	349	454	-	-	-	-	-	-	-	-	-	-
	1.20	N14	012	071	129	242	351	456	557	-	-	-	-	-	-	-	-	-
	1.30	N16	014	073	131	244	353	458	559	656	-	-	-	-	-	-	-	-
	1.50	N20	018	077	135	248	357	462	563	660	753	-	-	-	-	-	-	-
	1.80	N26	024	083	141	254	363	468	569	666	759	933	-	-	-	-	-	-
	1.85	N27	025	084	142	255	364	469	570	667	760	934	B67	-	-	-	-	-
	2.00	N30	028	087	145	258	367	472	573	670	763	937	B70	C06	-	-	-	-
	2.20	N34	032	091	149	262	371	476	577	674	767	941	B74	C10	D10	-	-	-
	2.50	N40	038	097	155	268	377	482	583	680	773	947	B80	C16	D16	E35	-	-
	3.00	N50	048	107	165	278	387	492	593	690	783	957	B90	C26	D26	E45	F93	-
	3.30	N56	054	113	171	284	393	498	599	696	789	963	B96	C32	D32	E51	F99	K66

With regard to other voltage, please contact our sales representative.

■PIN CONFIGURATION



CL-2025-03
< BOTTOM VIEW >

■PIN ASSIGNMENT

PIN NUMBER	PIN NAME	FUNCTION
1	Lx	Switching
2	GND	Ground
3	V_{OUT}	Output Voltage
4	CE	Chip Enable
5	VSET	Output Voltage Control
6	V_{IN}	Input Voltage
7	L1	Inductor Electrodes
8	L2	Inductor Electrodes
9	EP	Exposed thermal pad. The Exposed pad must be connected to GND(Pin2).

■ FUNCTION

PIN NAME	SIGNAL	STATUS
CE	H	Active
	L	Stand-by
	OPEN	Undefined State (*1)

(*1) Please do not leave the CE pin open.

PIN NAME	SIGNAL	STATUS
VSET	H	V_{OUT2}
	L	V_{OUT1}
	OPEN	Undefined State (*2)

(*2) Please do not leave the VSET pin open.

■ABSOLUTE MAXIMUM RATINGS

Ta=25℃

PARAMETER	SYMBOL	RATINGS	UNITS
V_{IN} Pin Voltage	V_{IN}	-0.3 ~ 7.0	V
Lx Pin Voltage	V_{LX}	-0.3 ~ V_{IN} + 0.3 or 7.0 (*1)	V
V_{OUT} Pin Voltage	V_{OUT}	-0.3 ~ V_{IN} + 0.3 or 7.0 (*1)	V
CE Pin Voltage	V_{CE}	-0.3 ~ 7.0	V
VSET Pin Voltage	VSET	-0.3 ~ 7.0	V
Power Dissipation	Pd	800 (40mm × 40mm standard board) (*2)	mW
Junction Temperature	Tj	-40 ~ 125	℃
Storage Temperature	Tstg	-55 ~ 125	℃

* All voltages are described based on the GND pin.

(*1) The maximum value should be either V_{IN}+0.3V or 7.0V in the lowest.

(*2) The power dissipation figure shown is PCB mounted and is for reference only.
Please refer to PACKAGING INFORMATION for the mounting condition.

■RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNITS
V_{IN} Pin Voltage	V_{IN}	1.8	~	6.0	V
I_{OUT} Current	I_{OUT}	0	~	150	mA
CE Pin Voltage	V_{CE}	0.0	~	6.0	V
VSET Pin Voltage	VSET	0.0	~	6.0	V
Operating Ambient Temperature	Topr	-40	~	85	℃
Junction Temperature	Tj	-40	~	105	℃

* All voltages are described based on the GND pin.

■ELECTRICAL CHARACTERISTICS

Ta=25℃

PARAMETER	SYMBOL	CONDITIONS		MIN.	TYP.	MAX.	UNITS	CIRCUIT
Output Voltage1(*1)	V_{OUT1}	When connected to external components, VSET = 0.0V , I_{OUT} = 30mA		-	<T-1>	-	V	①
Output Voltage1-2	V_{OUT1-2}	VSET = 0.0V, Voltage which L_X pin changes “H” to “L” level while V_{OUT} is increase. (*5)		<E-1>	<E-2>	<E-3>	V	②
Output Voltage2(*1)	V_{OUT2}	When connected to external components, VSET = V_{IN} , I_{OUT} = 30mA		-	<T-1>	-	V	①
Output Voltage2-2	V_{OUT2-2}	VSET = V_{IN}, Voltage which L_X pin changes “H” to “L” level while V_{OUT} is increase. (*5)		<E-1>	<E-2>	<E-3>	V	②
Operating Voltage Range	V_{IN}	-		1.8	-	6.0	V	①
Maximum Output Current	I_{OUTMAX}	When connected to external components (*2)		150	-	-	mA	①
UVLO Release Voltage	V_{UVLOR}	V_{OUT} = 0.0V , V_{CE} = VSET = 1.8V Voltage which Lx pin holding "H" level(*5)	Ta=25℃	-	1.50	1.78	V	②
			Ta=-40~85℃(*3)					
UVLO Detect Voltage	V_{UVLOD}	V_{OUT} = 0.0V , V_{CE} = VSET = 1.8V Voltage which Lx pin holding "L" level(*5)	Ta=25℃	1.00	1.40	-	V	②
			Ta=-40~85℃(*3)					
Quiescent Current	Iq	V_{IN}= V_{CE} =<C-1>, VSET = 0.0V , V_{OUT} = V_{OUT1}×1.05		-	<E-4>	<E-5>	nA	③
Stand-by Current	I_{STB}	V_{IN} = 6.0V , V_{CE} = V_{OUT} =0.0V		-	0.0	0.1	μA	③
PFM Switching Current	I_{PFM}	When connected to external components, V_{IN} = $V_{OUT(T)}$ + 2.0V, I_{OUT} = 10mA		-	400	600	mA	①
Lx SW ”H” ON Resistance	R_{LXH}	V_{OUT} = 0.0V, V_{IN} = V_{CE} = VSET = 5.0V, ILx = 50mA		-	0.40	0.50	Ω	④
Lx SW ”L” ON Resistance(*3)	R_{LXL}	V_{IN} = 5.0V		-	0.35	0.45	Ω	-
Lx SW ”H” Leakage Current	I_{LeakH}	V_{IN} = 6.0V , V_{OUT} = V_{CE} = VSET = 0.0V , VLx = 6.0V		-	0.0	0.1	μA	④
Lx SW ”L” Leakage Current	I_{LeakL}	V_{IN} = 6.0V , V_{OUT} = V_{CE} = VSET = 0.0V , VLx = 0.0V		-	0.0	0.1	μA	④
Output Voltage Temperature Characteristics	ΔV_{OUT}/ (V_{OUT}・ΔT_{opr})	I_{OUT} = 30mA -40℃ ≦ Topr ≦ 85℃		-	±100	-	ppm/ ℃	①

Unless otherwise stated, V_{IN}=5V, V_{CE}=5V, $V_{OUT(T)}$=Nominal Value

(*1) V_{OUT1} and V_{OUT2} are the average values of the output voltage considering the ripple voltage and they are set so that they can be a setting output voltage with this evaluation condition.

(*2) The maximum output current performance varies based on a voltage difference between an input voltage and an output voltage, and external components and so on. Regarding detail of this variation, please refer to OPERATIONAL EXPLANATION and NOTE ON USE section.

(*3) Design value

(*4) SHORT PROTECTION with LATCH is not available if V_{OUT1} or V_{OUT2} is 1.2V or less.

(*5) "H" = V_{IN} ~ V_{IN} -1.2V, "L" = 0.1V ~ -0.1V

■ELECTRICAL CHARACTERISTICS

Ta=25℃

PARAMETER	SYMBOL	CONDITIONS		MIN.	TYP.	MAX.	UNITS	CIRCUIT
CE "H" Voltage	V_{CEH}	VSET = V_{IN} , V_{OUT} = 0.0V, Voltage which Lx pin holding “H” level(*5)	Ta=25℃	1.2	-	6.0	V	②
			Ta=-40~85℃(*3)					
CE "L" Voltage	V_{CEL}	VSET = V_{IN} , V_{OUT} = 0.0V, Voltage which Lx pin holding “L” level(*5)	Ta=25℃	GND	-	0.3	V	②
			Ta=-40~85℃(*3)					
CE “H” Current	I_{CEH}	V_{IN} = 6.0V, V_{OUT} = 0.0V , V_{CE} = 6.0V, VSET = 6.0V		-0.1	0.0	0.1	μA	④
CE “L” Current	I_{CEL}	V_{IN} = 6.0V, V_{OUT} = 0.0V , V_{CE} = 0.0V, VSET = 6.0V		-0.1	0.0	0.1	μA	④
VSET "H" Voltage	$VSET_H$	V_{OUT} = (V_{OUT1} + V_{OUT2}) / 2 , V_{OUT1}＜V_{OUT2} →Voltage which Lx pin holding “H” level(*5) V_{OUT1}＞V_{OUT2} →Voltage which Lx pin holding “L” level(*5)	Ta=25℃	1.2	-	6.0	②	②
			Ta=-40~85℃(*3)					
VSET "L" Voltage	$VSET_L$	V_{OUT} = (V_{OUT1} + V_{OUT2}) / 2 , V_{OUT1}＜V_{OUT2} →Voltage which Lx pin holding “L” level(*5) V_{OUT1}＞V_{OUT2} →Voltage which Lx pin holding “H” level(*5)	Ta=25℃	GND	-	0.3	②	②
			Ta=-40~85℃(*3)					
VSET “H” Current	$IVSET_H$	V_{IN} = 6.0V, V_{OUT} = 0.0V , V_{CE} = 6.0V, VSET = 6.0V		-0.1	0.0	0.1	μA	④
VSET “L” Current	$IVSET_L$	V_{IN} = 6.0V, V_{OUT} = 0.0V , V_{CE} = 6.0V, VSET = 0.0V		-0.1	0.0	0.1	μA	④
Short Protection Threshold Voltage (*4)	V_{SHORT}	VSET = 5.0V, Voltage which Lx pin holding “L” level(*5)	Ta=25℃	0.10	0.54	0.80	②	②
			Ta=-40~85℃(*3)					
C_L Discharge (Type D)	R_{DCHG}	V_{IN} = 5.0V, V_{CE} = 0.0V, V_{OUT} =0.1V, VSET =5.0V		29	45	60	Ω	②
Inductance Value	L	Test Frequency=1MHz		-	2.2	-	μH	
Inductor Rated Current	I_{DC_L}	ΔT=+40℃ Current value that raises the temperature by 40℃ with DC current		-	850	-	mA	

Unless otherwise stated, V_{IN}=5V, V_{CE}=5V, $V_{OUT(T)}$=Nominal Value

(*1) V_{OUT} are the average values of the output voltage considering the ripple voltage and they are set so that they can be a setting output voltage with this evaluation condition.

(*2) The maximum output current performance varies based on a voltage difference between an input voltage and an output voltage, and external components and so on. Regarding detail of this variation, please refer to OPERATIONAL EXPLANATION and NOTE ON USE section.

(*3) Design value

(*4) SHORT PROTECTION with LATCH is not available if V_{OUT1} or V_{OUT2} is 1.2V or less.

(*5) "H" = V_{IN} ~ V_{IN} -1.2V, "L" = 0.1V ~ -0.1V

■ELECTRICAL CHARACTERISTICS

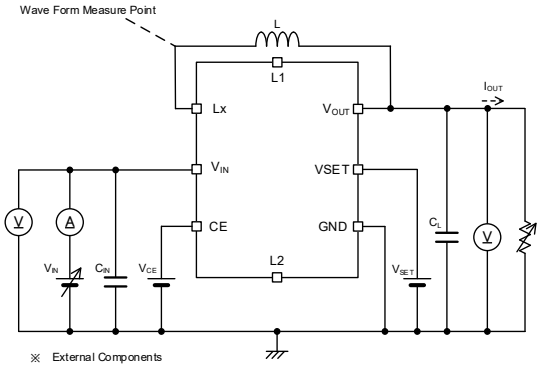
SPEC Table

Nominal Output Voltage $V_{OUT(T)}$	V_{OUT} (V)	V_{OUT1-2} (V)			V_{IN} (V)	Iq (nA)	
	<T-1>	<E-1>	<E-2>	<E-3>	<C-1>	<E-4>	<E-5>
	TYP.	MIN.	TYP.	MAX.	V_{IN}	TYP.	MAX.
0.50	0.500	0.460	0.480	0.500	1.80	200	600
0.60	0.600	0.560	0.580	0.600	1.80	200	600
0.70	0.700	0.660	0.680	0.700	1.80	200	600
0.80	0.800	0.760	0.780	0.800	1.80	200	600
0.90	0.900	0.860	0.880	0.900	1.80	200	600
1.00	1.000	0.960	0.980	1.000	1.80	200	600
1.10	1.100	1.058	1.080	1.102	1.80	200	600
1.20	1.200	1.156	1.180	1.204	1.80	200	600
1.30	1.300	1.254	1.280	1.306	1.80	200	600
1.40	1.400	1.352	1.380	1.408	1.90	200	600
1.50	1.500	1.450	1.480	1.510	2.00	200	600
1.60	1.600	1.548	1.580	1.612	2.10	200	600
1.70	1.700	1.646	1.680	1.714	2.20	200	600
1.80	1.800	1.744	1.780	1.816	2.30	200	600
1.90	1.900	1.842	1.880	1.918	2.40	200	600
2.00	2.000	1.940	1.980	2.020	2.50	210	630
2.10	2.100	2.038	2.080	2.122	2.60	210	630
2.20	2.200	2.136	2.180	2.224	2.70	210	630
2.30	2.300	2.234	2.280	2.326	2.80	210	630
2.40	2.400	2.332	2.380	2.428	2.90	210	630
2.50	2.500	2.430	2.480	2.530	3.00	220	660
2.60	2.600	2.528	2.580	2.632	3.10	220	660
2.70	2.700	2.626	2.680	2.734	3.20	220	660
2.80	2.800	2.724	2.780	2.836	3.30	220	660
2.90	2.900	2.822	2.880	2.938	3.40	230	690
3.00	3.000	2.920	2.980	3.040	3.50	230	690
3.10	3.100	3.018	3.080	3.142	3.60	230	690
3.20	3.200	3.116	3.180	3.244	3.70	240	720
3.30	3.300	3.214	3.280	3.346	3.80	240	720
3.40	3.400	3.312	3.380	3.448	3.90	240	720
3.50	3.500	3.410	3.480	3.550	4.00	250	750
3.60	3.600	3.508	3.580	3.652	4.10	250	750

With regard to other voltage, please contact our sales representative.

■TEST CIRCUITS

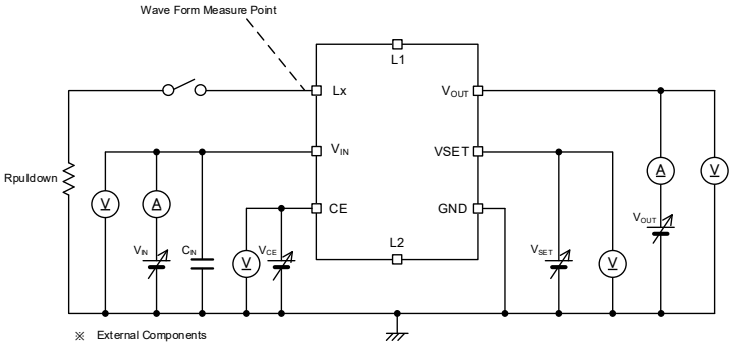
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※ External Components

L : 2.2μH(For test process)
C_{IN} : 10μF
C_L : 10μF

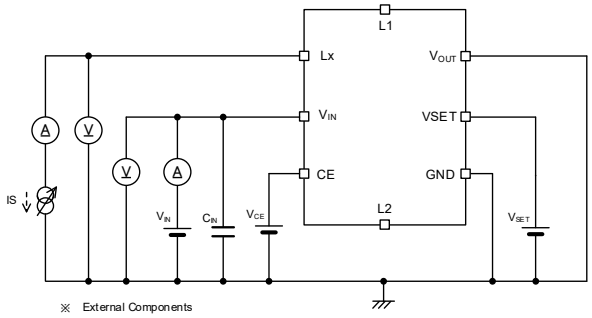
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※ External Components

C_{IN} : 10μF
Rpulldown : 100Ω

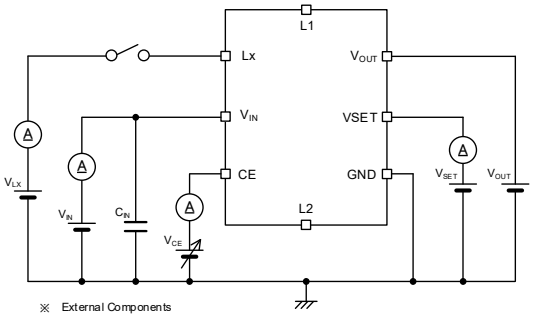
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※ External Components

C_{IN} : 10μF

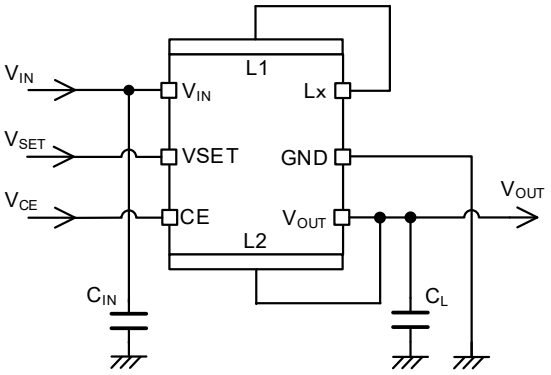
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※ External Components

C_{IN} : 0.1μF

■TYPICAL APPLICATION CIRCUIT



(NOTES):
The coil is exclusively for this product.
Please do not use it for any purpose other than this product.

【Typical Examples】

	Manufacturer	Product Number	Value	Size
C_{IN}	Murata	GRM188R61A106ME69	10μF/10V	1.6 x 0.8 x 1.0mm
	Taiyo Yuden	MSASL168BB5106MTNB33		
	TDK	C1608X5R1A106M		
C_L	Murata	GRM188R61A106ME69	10μF/10V	1.6 x 0.8 x 1.0mm
		GRM188R61A226ME15	22μF/10V	
	Taiyo Yuden	MSASL168BB5106MTNB33	10μF/10V	
		MSASL168BB5226MTNA01	22μF/10V	
		MSASJ168BB5226MTNA01	22μF/6.3V	
	TDK	C1608X5R1A106M	10μF/10V	
		C1608X5R1A226M	22μF/10V	

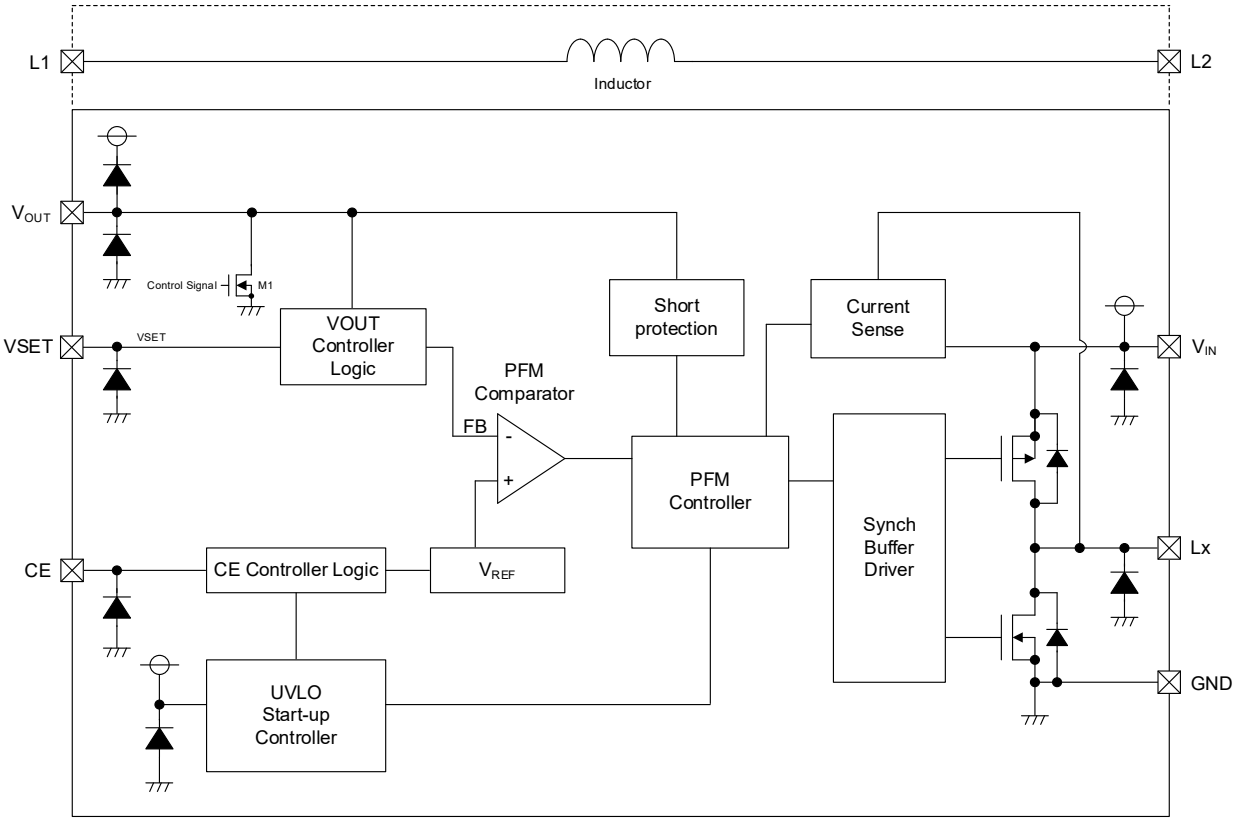
* Please select the components taking into consideration the rated voltage, rated current, and ceramic capacitor DC bias characteristics, etc.

* Use a ceramic capacitor with an execution capacitance value equal to or higher than the recommended component.
If a capacitor with a low effective capacitance value is used, the output voltage may become unstable.

* Please increase a capacitance value for C_L in order to reduce output ripple voltages.
C_L such as tantalum capacitors which have a larger ESR value can increase output ripple voltages.
If large-capacity capacitors such as electrolytic capacitors are connected in parallel, the inrush current may increase at startup and the output voltage may become unstable.

■OPERATIONAL EXPLANATION

The XCL233 series consists of a reference voltage supply, PFM comparator, Pch driver FET, Nch driver FET, current sensing circuit, PFM control circuit, CE control circuit, and others.



< BLOCK DIAGRAM >

The efficiency performance at a light load current is significantly improved compared to existing Torex products by implementing a current limit PFM as a control method and reducing a consumption current by IC itself.

■OPERATIONAL EXPLANATION (Continued)

<Normal operation>

This IC controls the output voltage by adjusting the following ①~③ operation intervals in response to the output current.

The V_{OUT1} and V_{OUT2} output voltage average values during actual operation depend on V_{OUT1-2}, V_{OUT2-2} and the ripple voltage during actual operation and are calculated as follows. For this reason, if the ripple voltage changes due to the influence of the input voltage, output voltage, or peripheral components, etc., the output voltage average value will change.

$$V_{OUT1} = V_{OUT1-2} + \text{Ripple Voltage} \times 1/2(\text{VSET= "L"})$$
$$V_{OUT2} = V_{OUT2-2} + \text{Ripple Voltage} \times 1/2(\text{VSET= "H"})$$

①The feedback voltage (FB voltage) is the voltage that results from dividing the output voltage with the V_{OUT} Controller logic circuit. The PFM comparator compares this FB voltage to V_{REF}. When the FB voltage is lower than V_{REF}, the PFM comparator sends a signal to the PFM control circuit to turn on the Pch driver FET.

The On Time to Pch driver FET can be obtained by the following equation.

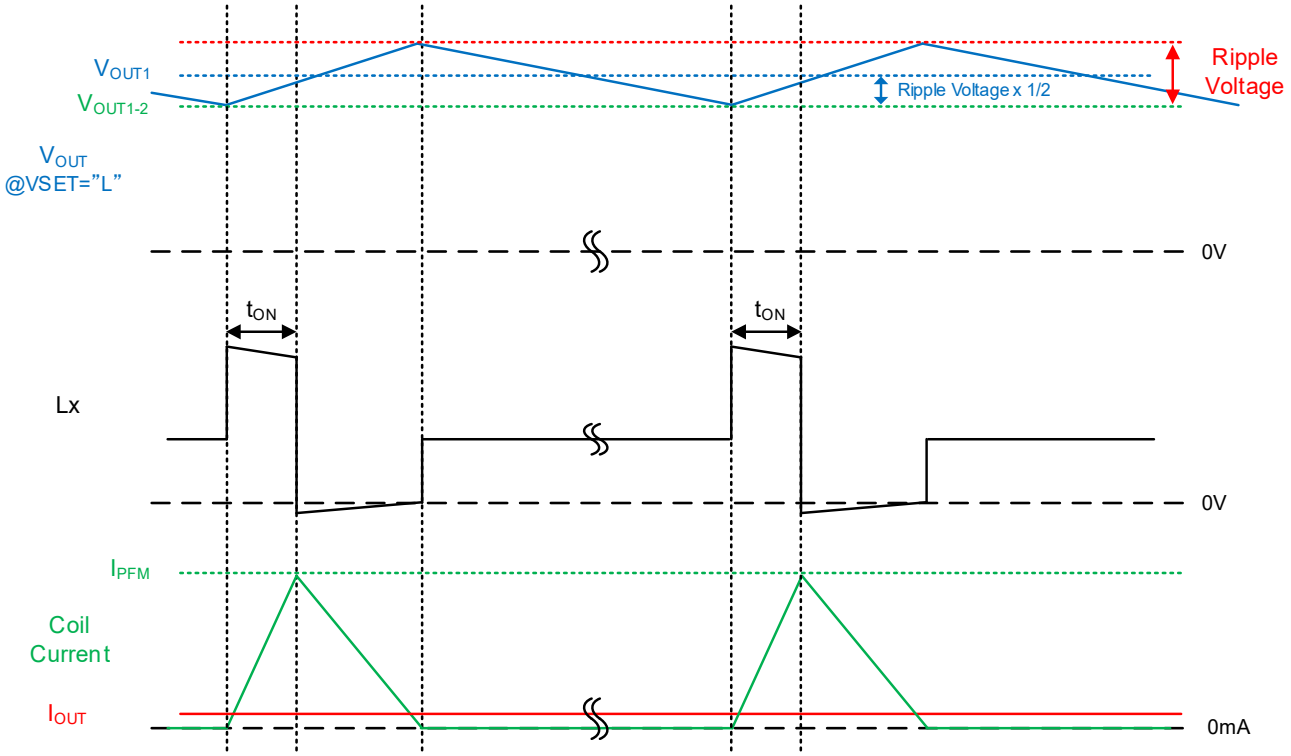
$$t_{ON} = L \times I_{PFM} / (V_{IN} - V_{OUT})$$

②When the Pch driver FET turns on, the coil current increases until the coil current reaches PFM Switching Current (I_{PFM}). When the coil current reaches I_{PFM}, the Pch driver FET turns off and then the Nch driver FET turns on.

③ After the Nch driver FET turns on, the coil current will decrease and when the coil current goes down to approx. 0mA, the Nch driver FET will turn off.

The Pch driver FET and Nch driver FET remain off until the FB voltage becomes lower than the reference voltage V_{REF}.

The above ①~③ switching operations increase the FB voltage accompanying the output voltage increase, but if the PFM comparator determines the FB voltage is lower than the reference voltage V_{REF} before the coil current reaches 0mA, the Nch driver FET turns off and the status moves to ①.



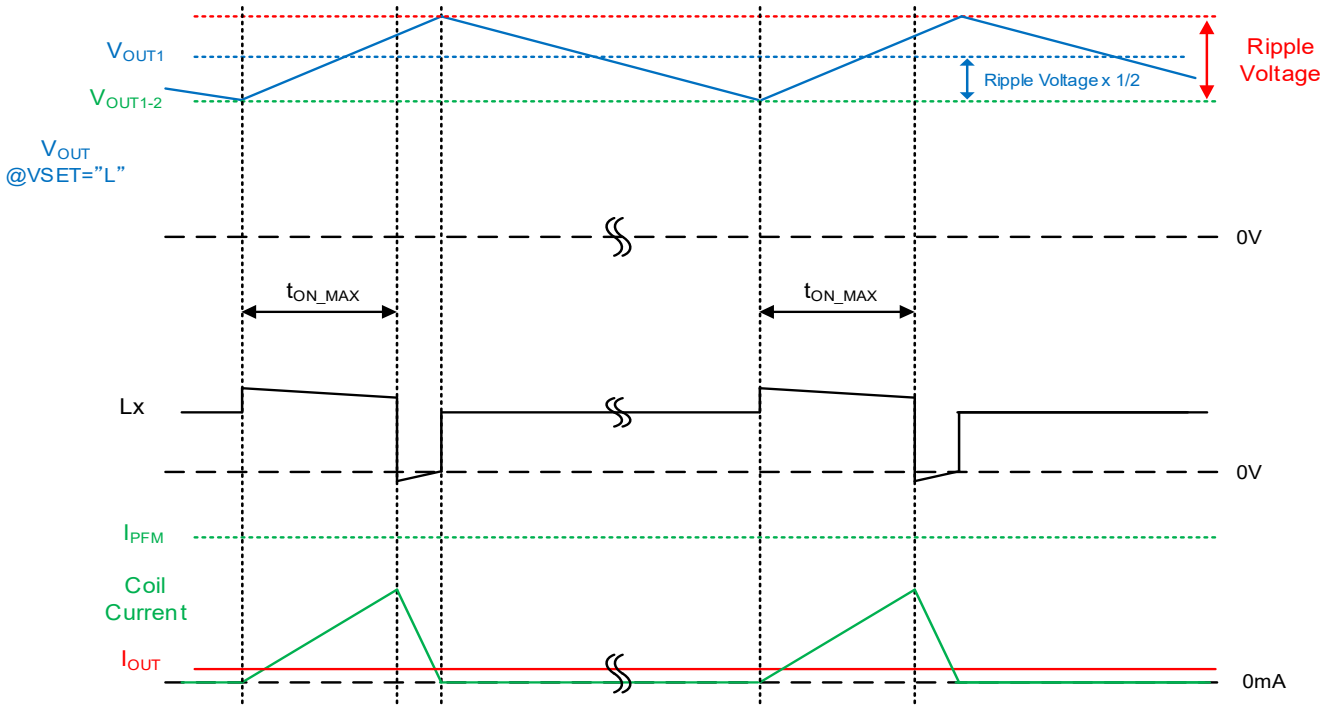
■OPERATIONAL EXPLANATION (Continued)

<Maximum on-time function, 100% Duty operation>

When the input / output potential difference decreases, the on-time required for the coil current to reach I_{PFM} increases, and the output ripple voltage tends to increase. Therefore, under conditions where the input / output potential difference is small, excessive ripple voltage is suppressed by limiting the maximum on-time that the Pch driver FET can turn on after the FB voltage becomes higher than the reference voltage V_{REF} to 3.0μs (TYP.).

If the input / output potential difference is further reduced, the FB voltage is always lower than the reference voltage V_{REF}, so the 100% duty operation is performed and the Pch driver FET is always on.

At 100% duty, the current consumption of the IC increases compared to normal operation.



■OPERATIONAL EXPLANATION (Continued)

<CE function>

When "H" voltage (V_{CEH}) is fed to the CE pin, normal operation starts after raising the output voltage with Start-up Mode.

When the "L" voltage (V_{CEL}) is fed to the CE pin, it enters the stand-by state and the current consumption is suppressed to 0.0μA (TYP.). Additionally, Pch MOS driver FET and Nch MOS driver FET are turned off.

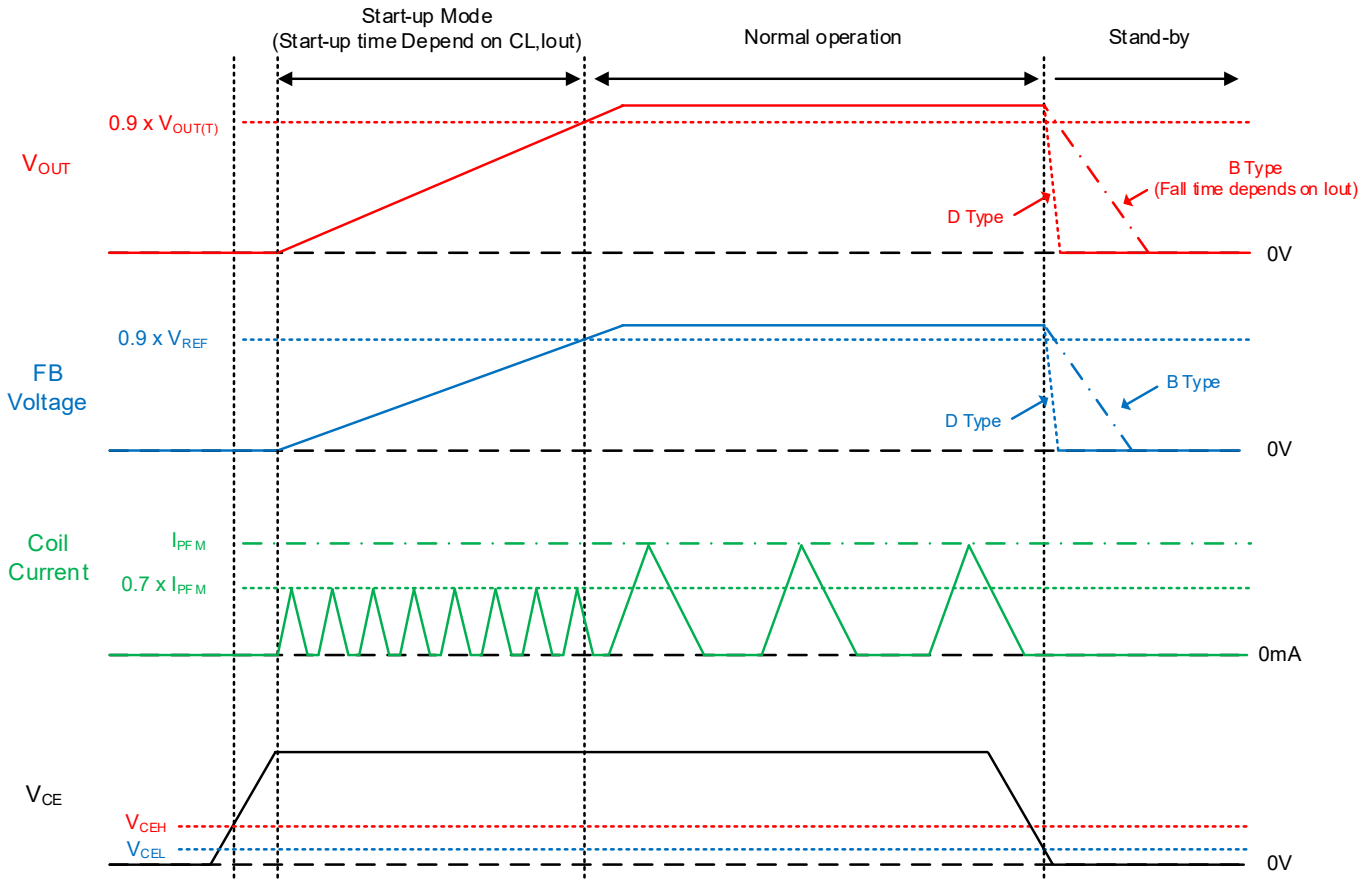
<Start-up Mode>

After “H” voltage (V_{CEH}) is fed to CE pin and UVLO function is released, by the time when FB voltage goes up to 0.9 x V_{REF}, the startup mode operates.

Unlike the normal operation, the start-up mode stops the operation of the short-circuit protection function and prevents the IC from being inadvertently stopped.

In order to suppress the inrush current, the peak current of the coil is limited to 0.7 x I_{PFM}, and the Nch driver FET does not turn on and the coil current flows through the parasitic diode of the Nch driver FET.

The rise time of the output voltage depends on the output capacitance and output current.



<UVLO function>

When the V_{IN} voltage becomes UVLO Detect Voltage (V_{UVLOD}) or less, the UVLO function operates to forcibly turn off the Pch MOS driver FET to prevent erroneous pulse output due to operation instability of the internal circuit.

During the UVLO function, the Pch driver FET and Nch driver FET turn off, and the Nch FET M1 between the V_{OUT} pin and GND pin turns on to discharge the output capacitance and make the output voltage be lower.

When the V_{IN} voltage becomes UVLO Release Voltage (V_{UVLOR}) or more, the UVLO function is canceled. After the UVLO function is canceled, the output voltage rises with the startup mode, and then the normal operation is performed.

Moreover, during the UVLO operation, the current consumption increases because the internal circuit is operating and the switching operation is stopped, not the stand-by state.

■OPERATIONAL EXPLANATION (Continued)

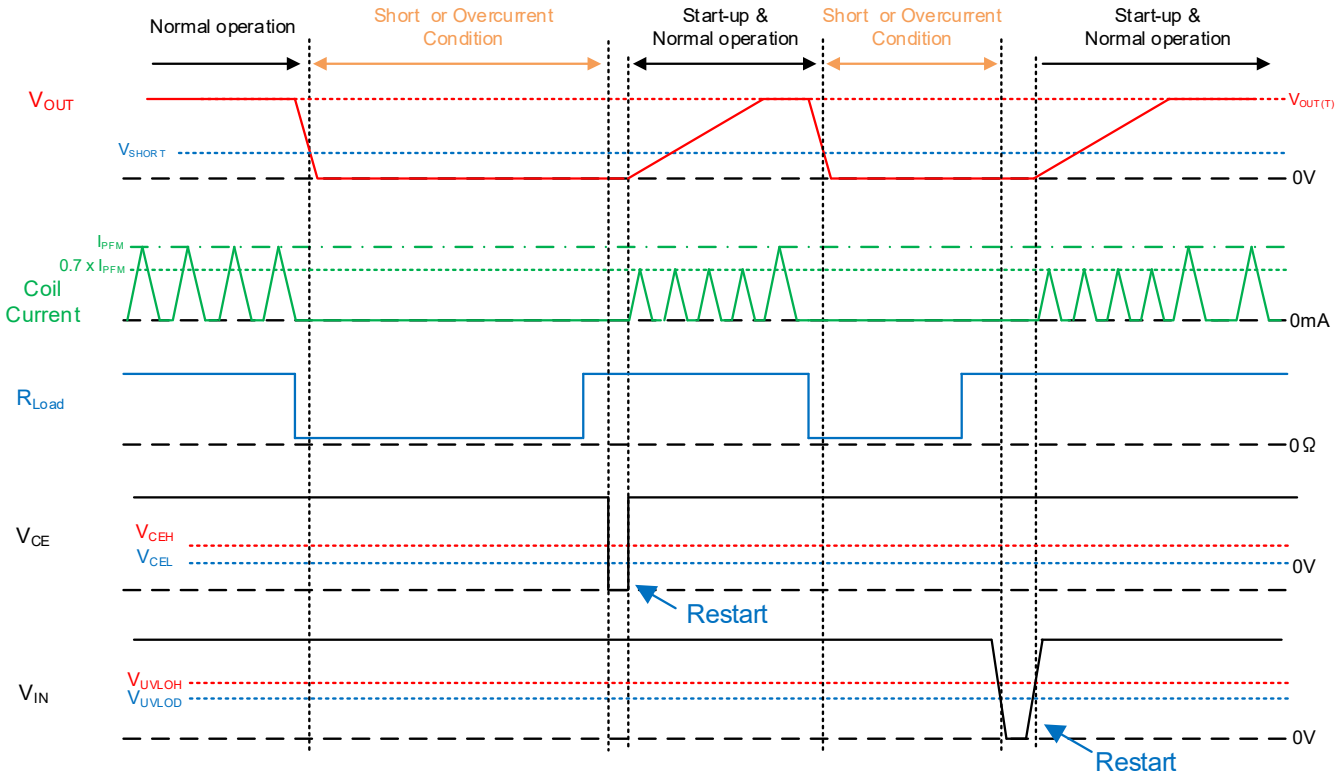
<Short protection function>

・Case (a) : $V_{OUT1,2}$ ≧1.2V

The short-circuit protection function monitors the V_{OUT} pin voltage, and if the V_{OUT} pin voltage drops below the Short Protection Threshold Voltage (V_{SHORT}) due to a short circuit or overcurrent, the short circuit protection function operates.

When the short-circuit protection function is activated, the Pch driver FET and Nch driver FET are held off. If the V_{OUT} pin voltage exceeds the Short Protection Threshold Voltage (V_{SHORT}) after the short-circuit protection function is activated, normal operation resumes.

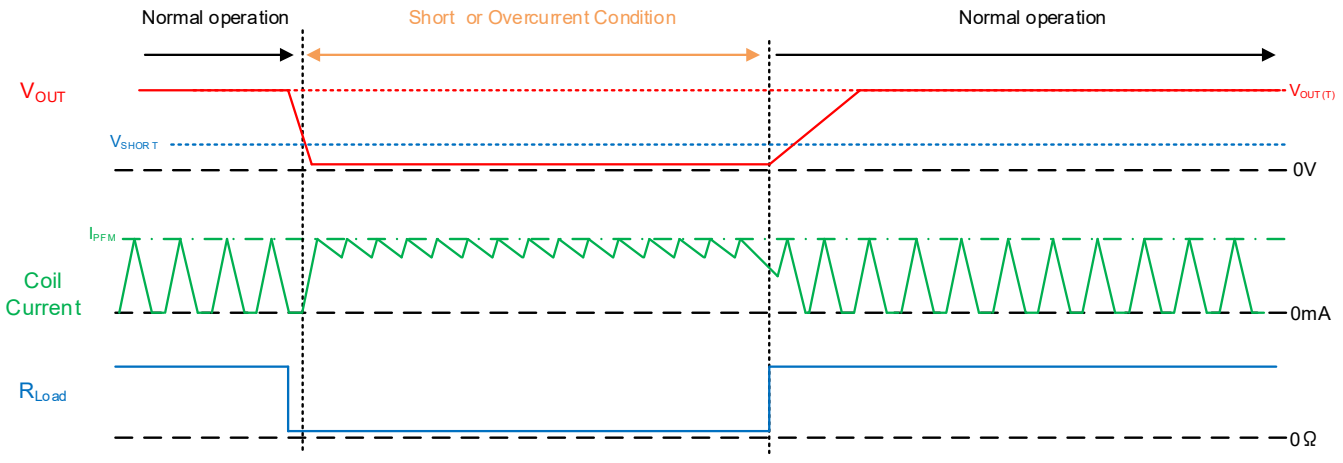
To cancel the short-circuit protection function, it is necessary to start the IC after putting the IC in the standby state with the CE function, or to raise the input voltage after setting the input voltage below the UVLO detection voltage (V_{UVLOD}).



・Case (b) : V_{OUT1} or V_{OUT2} ＜1.2V

The short-circuit protection function is not implemented in the part numbers where V_{OUT1} or V_{OUT2} is less than 1.2V. If a short circuit or overcurrent occurs, the output voltage will drop and switching operation will continue.

When the short-circuit state or excessive output current is released, the output voltage rises quickly to the set output voltage.



■OPERATIONAL EXPLANATION (Continued)

<C_L Discharge function (D type)>

On the XCL233 series, a C_L discharge function is available as an option.

C_L discharge function turns on the Nch FET M1 between the V_{OUT} pin and GND pin when the stand-by condition in order to discharge the output capacitance quickly and make the output voltage be lower.

This prevents malfunctioning of the application in the event that a charge remains on C_L when the IC is stand-by state.

The discharge time is determined by C_L and the C_L discharge resistance R_{DCHG}, including the Nch FET M1.

the discharge time of the output voltage is calculated by means of the equation below.

$$V = V_{OUT(T)} \times e^{-t/\tau}$$

$$t = \tau \ln(V_{OUT(T)} / V)$$

V	: Output voltage during discharge
$V_{OUT(T)}$	: Output voltage
t	: Discharge time
C_L	: Effective capacitance of Output capacitor
R_{DCHG}	: C_L auto-discharge resistance
τ	: $C_L \times R_{DCHG}$

<Output Voltage selectable function>

When "H" voltage ($VSET_H$) is fed to the VSET pin, the set output voltage operates as V_{OUT2}, and when "L" voltage ($VSET_L$) is fed, the set output voltage operates as V_{OUT1}.

When the VSET pin voltage is switched during normal operation, the set output voltage is changed to the changed output voltage after a certain period.

VSET SIGNAL	Output Voltage	Comment
H	V_{OUT2} (Higher Set Voltage)	-
L	V_{OUT1} (Lower Set Voltage)	-
H → L	V_{OUT2} → V_{OUT1} (V_{OUT1} < V_{OUT2})	Output voltage starts to drop to V_{OUT1} 30μs after “L” input. Falling speed depends on output current.
	V_{OUT2} → V_{OUT1} (V_{OUT1} > V_{OUT2})	Output voltage starts to rise to V_{OUT2} 30μs after “L” input. Rise speed depends on I_{PFM}.
L → H	V_{OUT1} → V_{OUT2} (V_{OUT1} < V_{OUT2})	Output voltage starts to rise to V_{OUT2} 30μs after “H” input. Rise speed depends on I_{PFM}.
	V_{OUT1} → V_{OUT2} (V_{OUT1} > V_{OUT2})	Output voltage starts to drop to V_{OUT1} 30μs after “H” input. Falling speed depends on output current.

■NOTE ON USE

1. Be careful not to exceed the absolute maximum ratings for externally connected components and this IC.
If it exceeds the absolute maximum rating, it may deteriorate or be destroyed.
Also, if used under conditions outside the recommended operating range, the IC may not operate normally or may cause deterioration.

2. The DC/DC converter characteristics greatly depend not only on the characteristics of this IC but also on those of externally connected components, so refer to EXTERNAL COMPONENTS SELECTION and the specifications of each component and be careful when selecting the components. Be especially careful of the characteristics of the capacitor used for the load capacity C_L and use a capacitor with B characteristics (JIS Standard) or an X7R/X5R (EIA Standard) ceramic capacitor.

3. The CE pin and VSET pin does not have an internal pull-up or pull-down, etc. Apply the prescribed voltage to the CE pin and VSET pin.
If an intermediate voltage is fed to the CE and VSET pins, a through current will flow through the input stage of the CE and VSET pins, increasing current consumption.

4. At light loads or when IC operation is stopped, leakage current from the Pch driver FET may cause the output voltage to rise.

5. Switching operation may be performed continuously due to internal delay or input offset of the PFM comparator circuit.
If the switching operation continues, the output ripple voltage increases and the output voltage rises as the ripple voltage increases.

6. When the input / output potential difference is small, the ripple voltage increases and the output voltage may increase.

7. Since the short-circuit protection function is not implemented in the part number where both of or either V_{OUT1} or V_{OUT2} is less than 1.2V, the coil current may be superposed under the condition of high input voltage and excessive output current.

8. During start-up mode, the peak current of the coil is set lower than in normal operation, so the output voltage may not rise under conditions where the output current is large during start-up.

9. To suppress current consumption, UVLO detection is performed only for a certain period after the Pch driver FET is turned on. For this reason, the UVLO function may not operate if the VIN pin voltage instantaneously drops below the UVLO detection voltage (V_{UVLOD}).

10. Under the conditions of Vin≦2.7V, set output voltage ≦1.0V and Ta≧65℃, the efficiency can drastically drop.
Normally after the Nch driver FET turns on, the coil current falls to 0mA, and then Nch driver FET turns off.
Under the above conditions, however, before the coil current falls to 0mA, Nch driver FET turns off and its loss increases, which leads to the drop of efficiency.

11. This IC is an Inductor Built-in product, do not place it in an environment with a strong magnetic field such as near a magnet. The influence of a strong magnetic field may cause a decrease in inductance value, deterioration of efficiency, and abnormal operation of the IC.

12. For temporary, transitional voltage drop or voltage rising phenomenon, the IC is liable to malfunction should the ratings be exceeded.

13. 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.

■NOTE ON USE (Continued)

14. Instructions of pattern layouts

(1) 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} & GND pins.

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

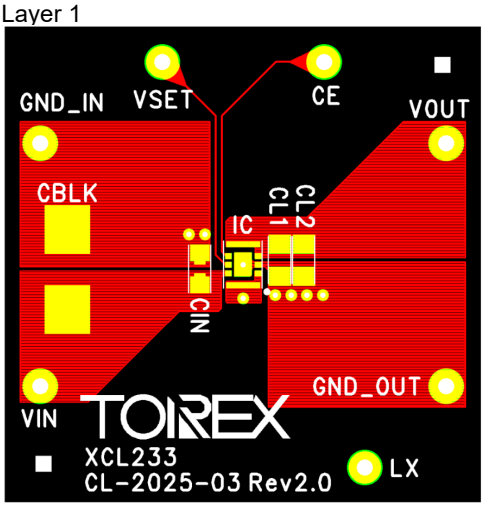
(3) Wire external components as close to the IC as possible and use thick, short connecting traces to reduce the circuit impedance.

(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.

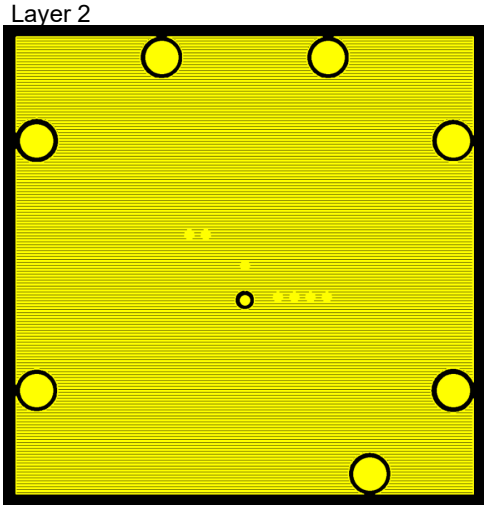
(5) The IC is a heat-generating component, and heat dissipation measures may be required depending on the conditions of use. If necessary, perform thermal design with PCB layout, etc.

< Reference pattern layout >

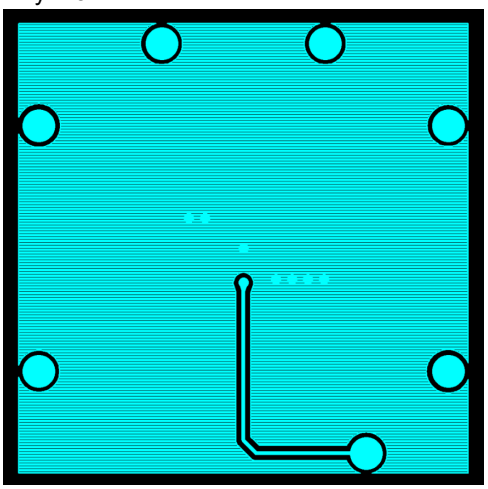
Layer 1



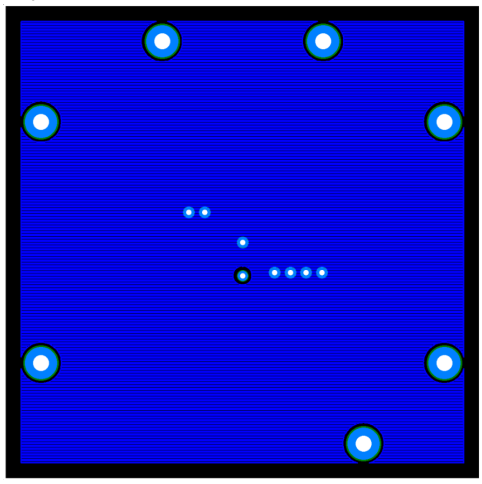
Layer 2



Layer 3



Layer 4



■Notes on handling of product

(1) The coil mounted on this product complies with the general surface mount type chip inductor specifications, and may have scratches, flux stains, etc.

(2) Do not use this product in the following environments. Places exposed to water or salt water, places where condensation occurs, places where toxic gases (hydrogen sulfide, zinc acid, chlorine, ammonia, etc.) are present.

(3)Please do not wash this product with solvent.

■Notes on mounting

(1) Please set the mounting position accuracy within 0.05 mm.

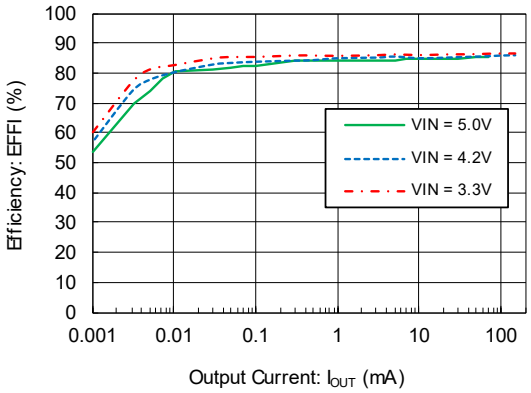
(2) The proper position of mounting is based on the coil terminal

■ TYPICAL PERFORMANCE CHARACTERISTICS

(1) Efficiency vs. Output Current

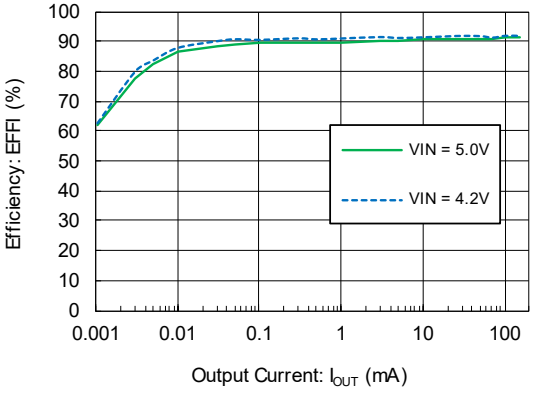
V_{OUT}=1.8V

C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASJ168BB5226MTNA01(22μF/6.3V)



V_{OUT}=3.3V

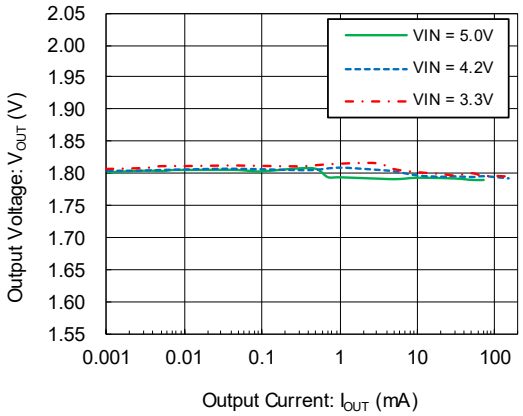
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASJ168BB5226MTNA01(22μF/6.3V)



(2) Output Voltage vs. Output Current

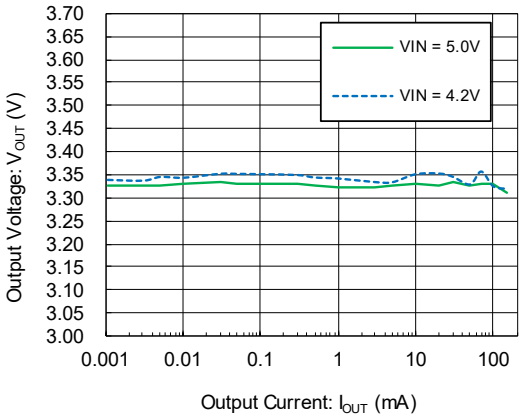
V_{OUT}=1.8V

C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASJ168BB5226MTNA01(22μF/6.3V)



V_{OUT}=3.3V

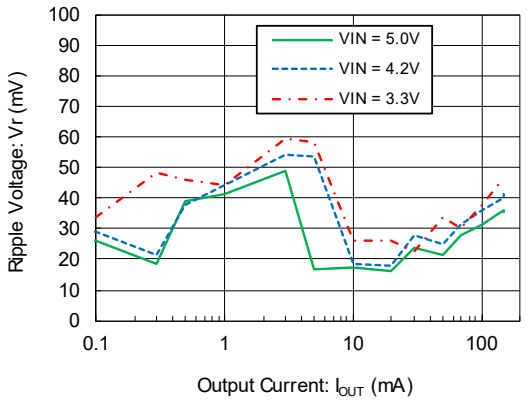
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASJ168BB5226MTNA01(22μF/6.3V)



(3) Ripple Voltage vs. Output Current

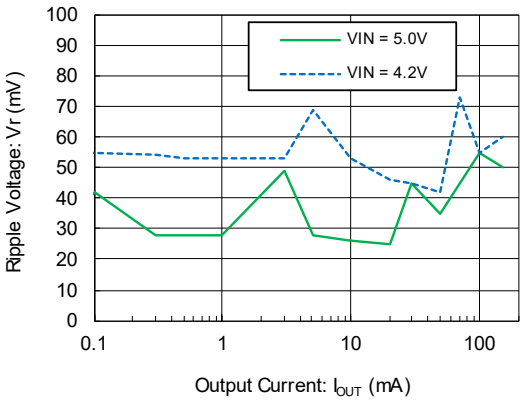
V_{OUT}=1.8V

C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASJ168BB5226MTNA01(22μF/6.3V)



V_{OUT}=3.3V

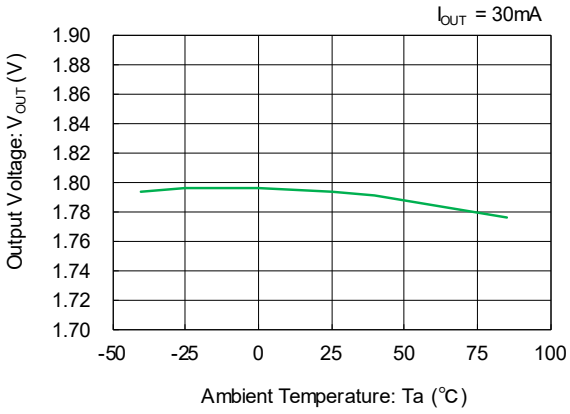
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASJ168BB5226MTNA01(22μF/6.3V)



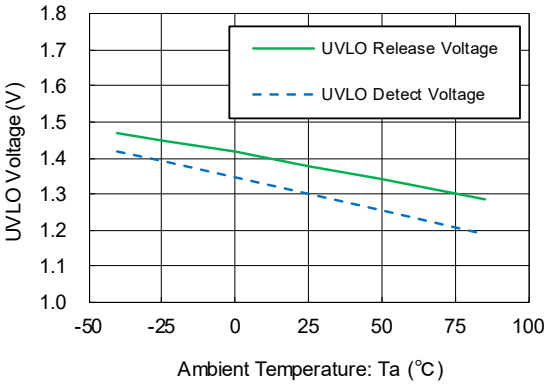
■TYPICAL PERFORMANCE CHARACTERISTICS

(4) Output Voltage vs. Ambient

V_{OUT}=1.8V

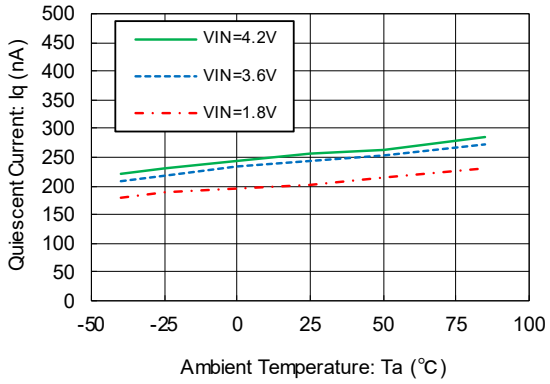


(5) UVLO Voltage vs. Ambient

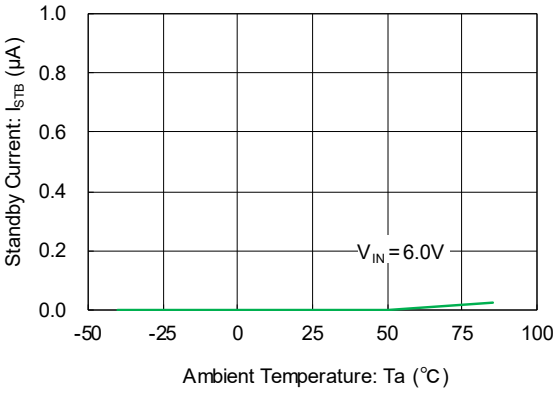


(6) Quiescent Current vs. Ambient Temperature

V_{OUT}=0.6V



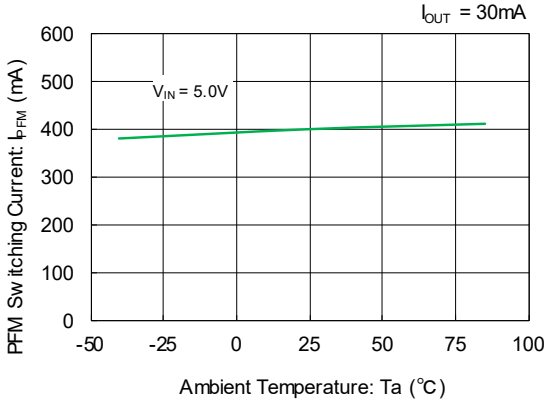
(7) Stand-by Current vs. Ambient Temperature



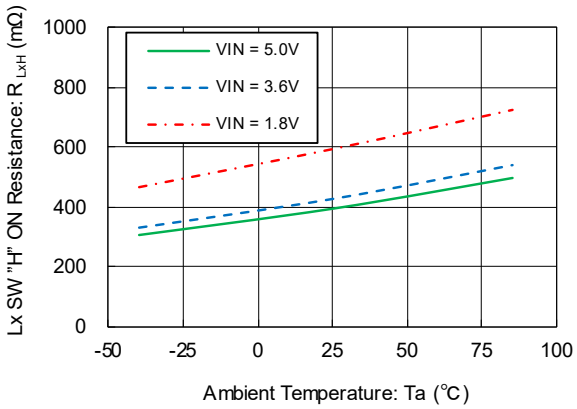
(8) PFM Switching Current vs. Ambient Temperature

V_{OUT}=0.6V

C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2

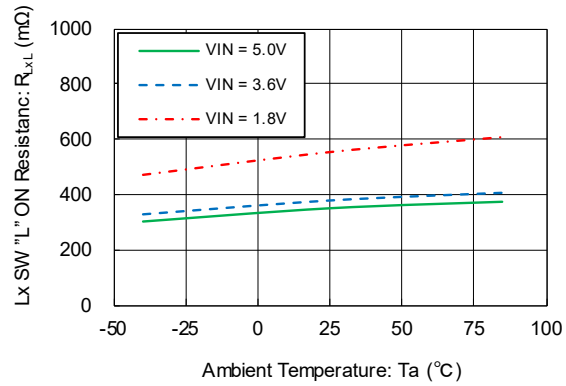


(9) Lx SW "H" ON Resistance vs. Ambient Temperature

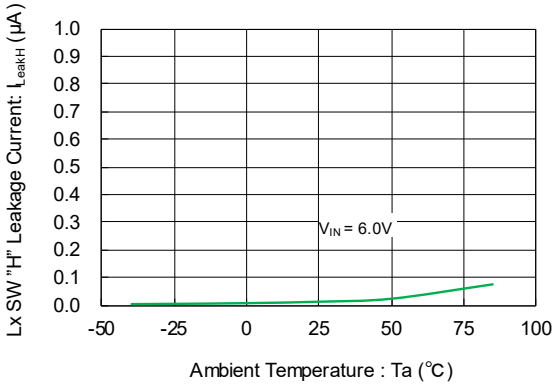


■TYPICAL PERFORMANCE CHARACTERISTICS

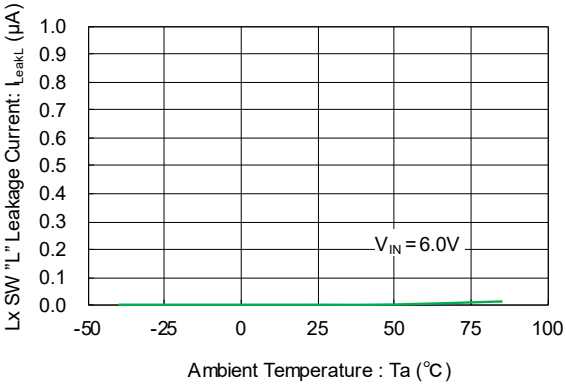
(10) Lx SW "L" ON Resistanc vs. Ambient Temperature



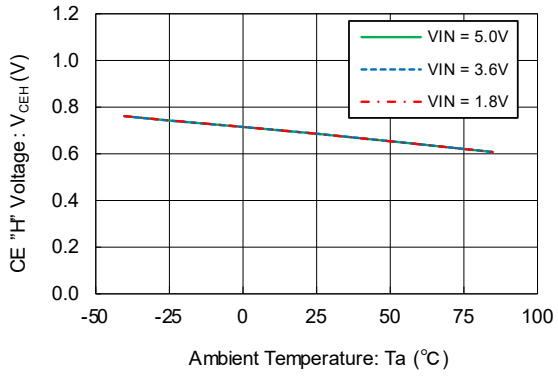
(11) Lx SW "H" Leakage Current vs. Ambient Temperature



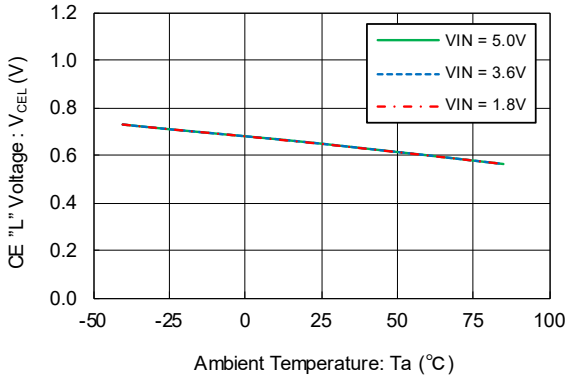
(12) Lx SW "L" Leakage Current vs. Ambient Temperature



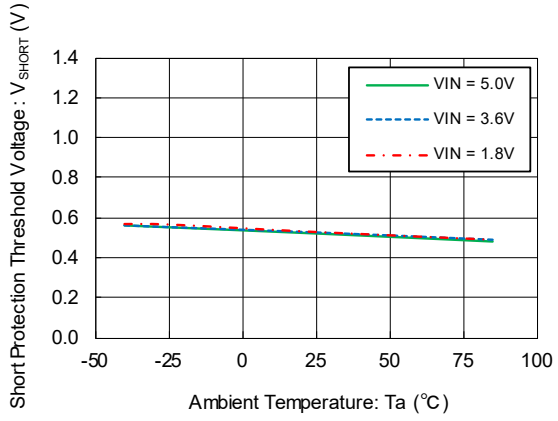
(13) CE "H" Voltage vs. Ambient Temperature



(14) CE "L" Voltage vs. Ambient Temperature

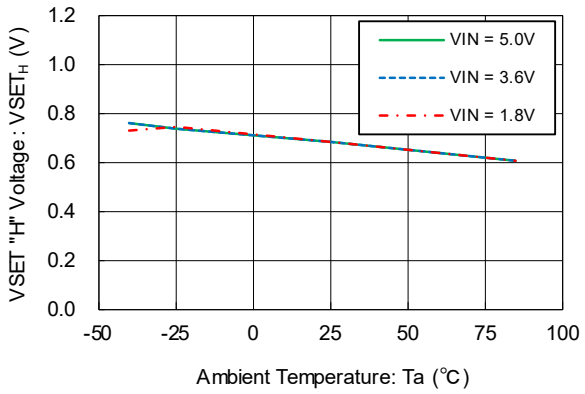


(15) Short Protection Threshold vs. Ambient Temperature

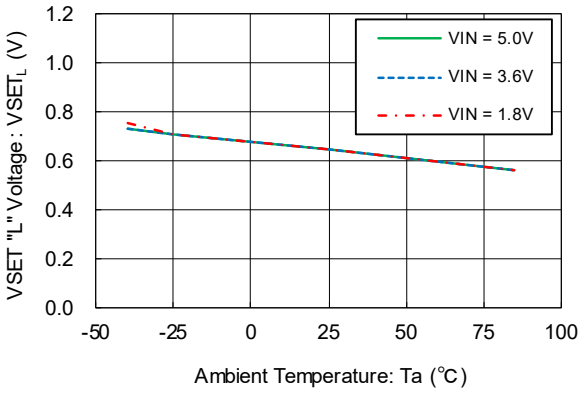


■TYPICAL PERFORMANCE CHARACTERISTICS

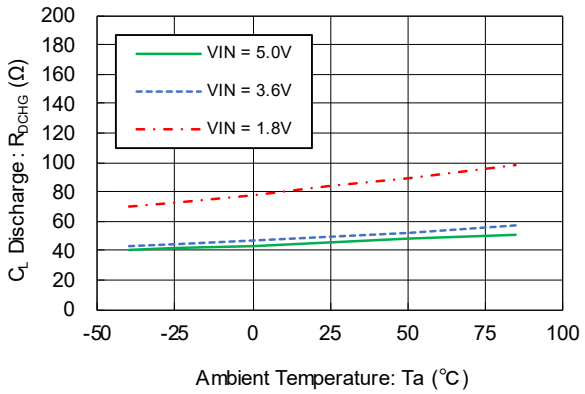
(16) VSET "H" Voltage vs. Ambient Temperature



(17) VSET "L" Voltage vs. Ambient Temperature



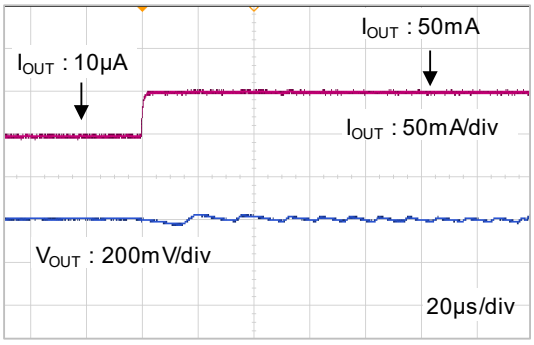
(18) C_L Discharge Resistance vs. Ambient Temperature



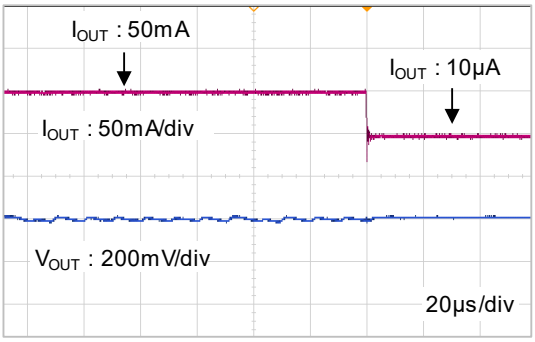
■TYPICAL PERFORMANCE CHARACTERISTICS

(19) Load Transient Respones

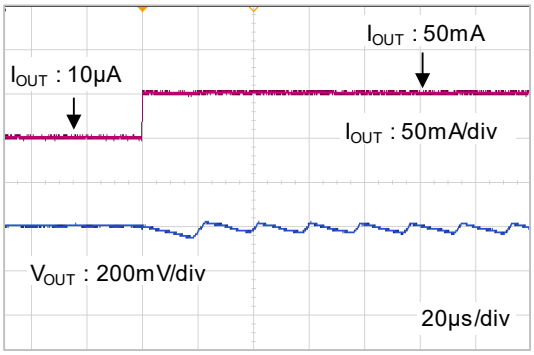
V_{OUT}=1.8V
V_{IN} = 3.6V ,I_{OUT} = 10μA ⇒ 50mA ,tr = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



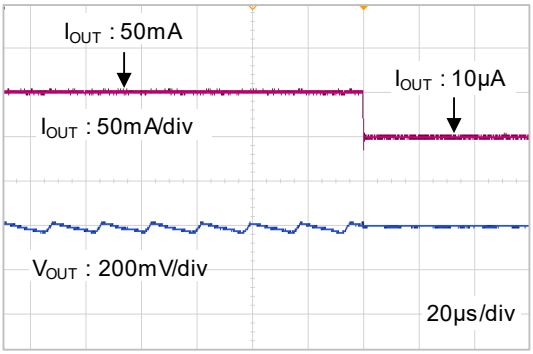
V_{OUT}=1.8V
V_{IN} = 3.6V ,I_{OUT} = 50mA ⇒ 10μA ,tf = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



V_{OUT}=3.0V
V_{IN} = 3.6V ,I_{OUT} = 10μA ⇒ 50mA ,tr = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



V_{OUT}=3.0V
V_{IN} = 3.6V ,I_{OUT} = 50mA ⇒ 10μA ,tf = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2

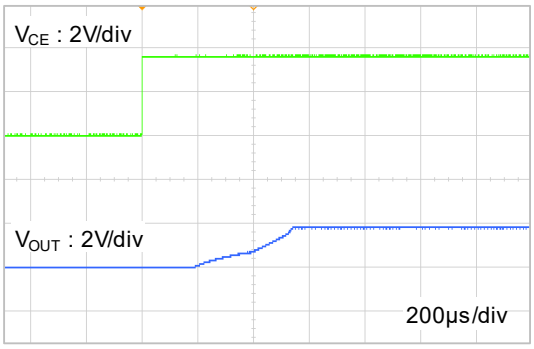


■TYPICAL PERFORMANCE CHARACTERISTICS

(20) Startup Mode

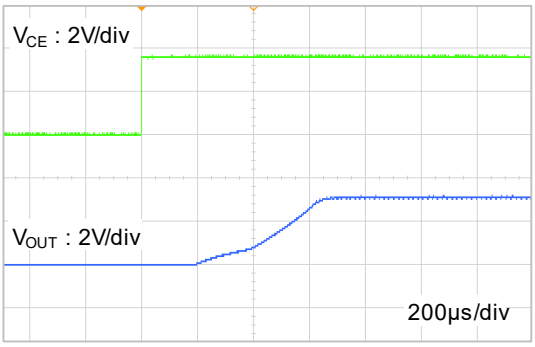
V_{OUT}=1.8V

V_{IN} = 3.6V, V_{CE} = 0.0V ⇒ 3.6V, tr = 5μs, RL = 36Ω
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



V_{OUT}=3.0V

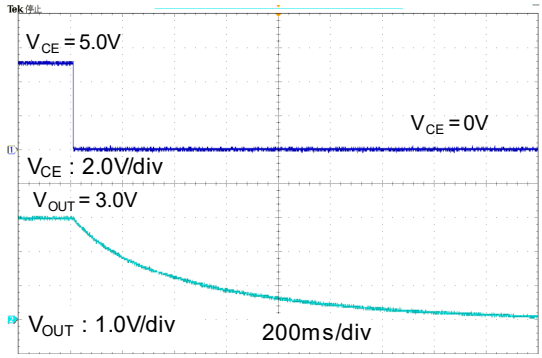
V_{IN} = 3.6V, V_{CE} = 0.0V ⇒ 3.6V, tr = 5μs, RL = 60Ω
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



(21) Falling waveform

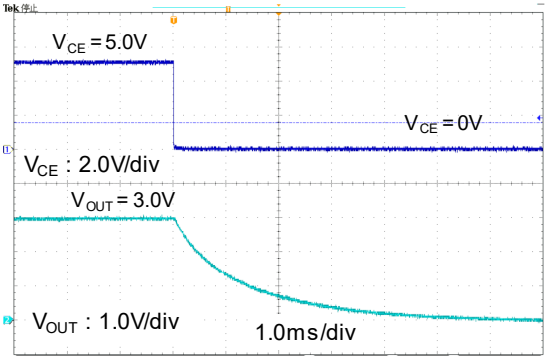
XCL233BB90KR-G(Without C_L Discharge)

V_{IN} = 5.0V, VSET=5.0V, V_{OUT} = 3.0V, RL = 30kΩ
V_{CE} = 5.0V ⇒ 0V, tf = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



XCL233DB90KR-G(With C_L Discharge)

V_{IN} = 5.0V, VSET=5.0V, V_{OUT} = 3.0V, RL = 30kΩ
V_{CE} = 5.0V ⇒ 0V, tf = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2

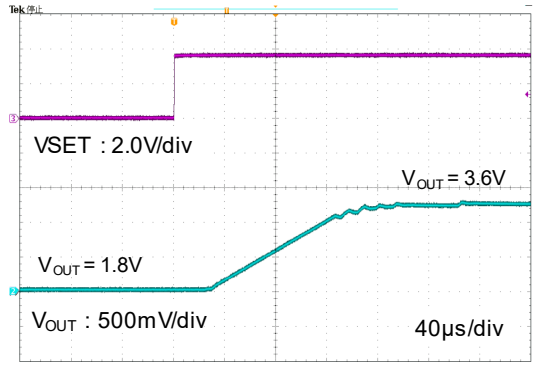


■TYPICAL PERFORMANCE CHARACTERISTICS

(22) Output voltage selectable function

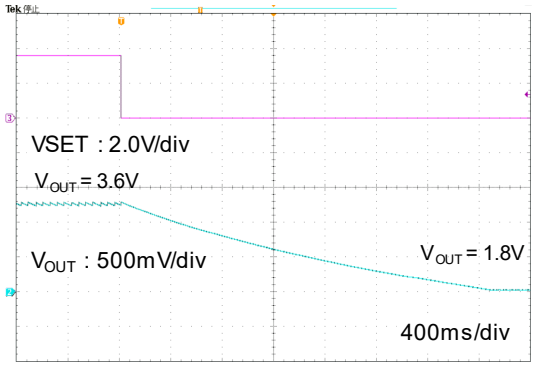
XCL233BB90KR-G

V_{IN} = 3.6V, V_{OUT} = 1.8V ⇒ 3.0V, RL = 180kΩ
VSET = 0V ⇒ 3.6V, tr = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



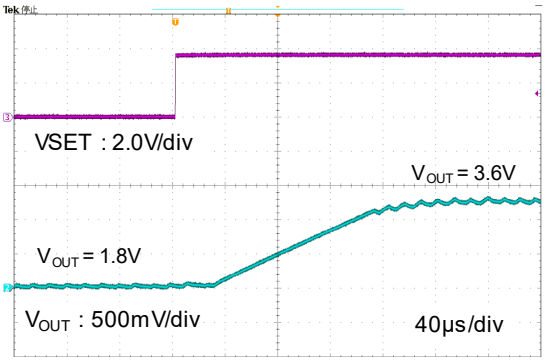
XCL233BB90KR-G

V_{IN} = 3.6V, V_{OUT} = 3.0V ⇒ 1.8V, RL = 180kΩ
VSET = 3.6V ⇒ 0V, tf = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



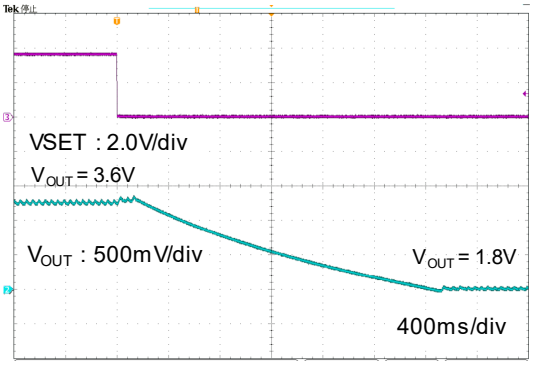
XCL233BB90KR-G

V_{IN} = 3.6V, V_{OUT} = 1.8V ⇒ 3.0V, RL = 36Ω
VSET = 0V ⇒ 3.6V, tr = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



XCL233BB90KR-G

V_{IN} = 3.6V, V_{OUT} = 3.0V ⇒ 1.8V, RL = 36Ω
VSET = 3.6V ⇒ 0V, tf = 5μs
C_{IN} = MSASL168BB5106MTNB33(10μF/10V)
C_L = MSASL168BB5226MTNA01(22μF/10V) ×2



■PACKAGING INFORMATION

For the latest package information go to, www.torexsemi.com/technical-support/packages

PACKAGE	OUTLINE / LAND PATTERN	THERMAL CHARACTERISTICS
CL-2025-03	CL-2025-03 PKG	CL-2025-03 Power Dissipation

■MARKING RULE

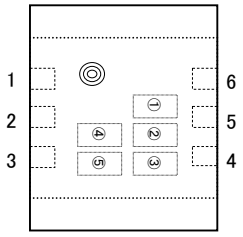
① represents products series

MARK	PRODUCT SERIES
B	XCL233******-G

②,③ represents internal sequential number
01～09、10～99、A0～A9、B0～B9・・・Z0～Z9、AA～AZ、BA～BZ・・・ZA～ZZ repeated.
(G, I, J, O, Q, W excluded)

④⑤ represents production lot number
01～09, 0A～0Z, 11～9Z, A1～A9, AA～AZ, B1～ZZ in order. (G, I, J, O, Q, W excluded)
* No character inversion used.

CL-2025-03



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