XC9225/XC9226/XC9227 Series

Synchronous Step-Down DC/DC Converters

GreenOperation Compatible

GENERAL DESCRIPTION

The XC9225/XC9226/XC9227 series is a group of synchronous-rectification type DC/DC converters with a built-in 0.6 P-channel driver transistor and 0.7 N-channel switching transistor, designed to allow the use of ceramic capacitors. The ICs enable a high efficiency, stable power supply with an output current of 500mA (A~D series) and 600mA (E~H series) to be configured using only a coil and two capacitors connected externally. Minimum operating voltage is 2.0V~6.0V (A~D series), 4.5V~5.5V (E~H series). Output voltage is internally programmable in a range from 0.9V to 4.0V (A~D series) and 3.0~4.0V (E~H series) in increments of 0.05V (accuracy: ± 2.0%). With the built-in oscillator, oscillation frequency is selectable from 600kHz and 1.2MHz to make available the frequency best suited to your particular application. As for operation mode, the XC9225 series is PWM control, the XC9226 series is automatic PWM/PFM switching control and the XC9227 series can be manually switched between the PWM control mode and the automatic PWM/PFM switching control mode, allowing fast response, low ripple and high efficiency over the full range of load (from light load to high output current conditions).

The soft start and current control functions are internally optimized. During standby, all circuits are shutdown to reduce current consumption to as low as 1.0μ A or less. With the built-in UVLO (Under Voltage Lock Out) function, the internal P-channel driver transistor is forced OFF when input voltage becomes 1.4V or lower. Two types of package, SOT-25 (250mW) and USP-6B (100mW), are available.
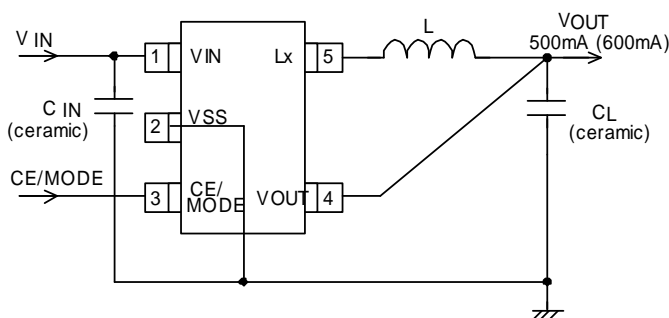
APPLICATIONS

Mobile phones (PDC, GSM, CDMA, IMT2000 etc.)
Bluetooth equipment
PDAs, Portable communication modem
Portable games
Cameras, Digital cameras
Cordless phones
Notebook computers

FEATURES

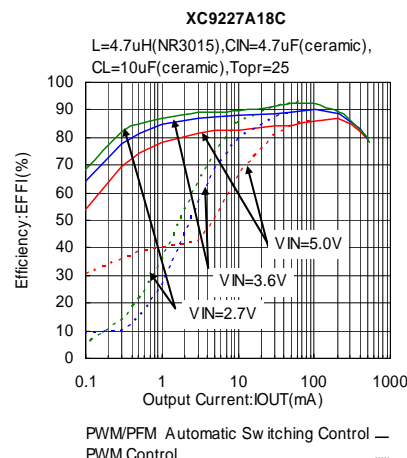|	
P-Ch Driver Tr. Built-In	: ON resistance 0.6
N-Ch DriverTr. built-in	: ON resistance 0.7
Input Voltage Range	: 2.0V~6.0V (A~D series)
	4.5V~5.5V (E~H series)
Output Voltage Range	: 0.9V~4.0V (A~D series)
	3.0~4.0V (E~H series)
	(0.05V increments)
Low Power Consumption	: 15μ A (TYP.) (VIN=3.6V, VOUT=1.8V)
Control Method	: Fixed PWM (XC9225)
	PWM/PFM Automatic (XC9226)
	PWM/PFM Manual (XC9227)
High Efficiency	: 92% (TYP.)
	(VIN=3.0V, VOUT=1.8V, IOUT=100mA)*
Output Current	: 500mA *(A~D series)
	600mA *(E~H series)
Oscillation Frequency	: 600kHz, 1.2MHz (± 15%)
Low Output Ripple	: 10mV
Maximum Duty Ratio	: 100%
Soft-Start Circuit Built-In	
Current Limiter Circuit Built-In (Constant Current & Latching)	
Low ESR Ceramic Capacitor Compatible	
Packages	: SOT-25 (SOT-23-5), USP-6B

* Performance depends on external components and wiring on the PCB
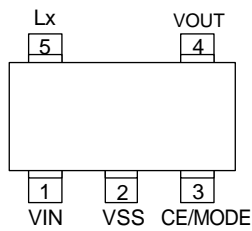
TYPICAL APPLICATION CIRCUIT
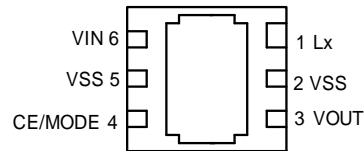

TYPICAL PERFORMANCE CHARACTERISTICS

Efficiency vs. Output Current

XC9227A18C

L=4.7uH(NR3015),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25

PWM/PFM Automatic Sw itching Control —
PWM Control ......

PIN CONFIGURATION

Lx   VOUT
5   4

1   2   3
VIN   VSS   CE/MODE

SOT-25 (TOP VIEW)

VIN 6   1 Lx
VSS 5   2 VSS
CE/MODE 4   3 VOUT

USP-6B
(BOTTOM VIEW)

* Please short the Vss (No. 2 and 5) pin.
* The dissipation pad for the USP-6B 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 VSS (No. 5) pin.

PIN ASSIGNMENT

PIN NUMBER		PIN NAME	FUNCTION
SOT-25	USP-6B		
1	6	VIN	Power Input
2	2, 5	VSS	Ground
3	4	CE / MODE	Chip Enable Mode Switch
4	3	VOUT	Output Voltage Sense
5	1	Lx	Switching Output

FUNCTIONS

CE/MODE	OPERATION		
VOLTAGE LEVEL	XC9225A SERIES	XC9226A SERIES	XC9227A SERIES
H Level *1	Synchronous PWM Fixed Control	Synchronous PWM/PFM Automatic Switching Control	Synchronous PWM/PFM Automatic Switching Control
M Level *2			Synchronous PWM Fixed Control
L Level *3	Stand-by	Stand-by	Stand-by

*CE/MODE pin voltage level range
*1. H level: VIN-0.3V   H level   VIN
*2. M level: 0.65V   M level   VIN   VIN-1.0V
*3. L level : 0V   L level   0.25V

PRODUCT CLASSIFICATION

Ordering Information

XC9225   PWM fixed control
XC9226   PWM / PFM automatic switching control
XC9227   PWM fixed control⇔PWM / PFM automatic switching, manual switching

DESIGNATOR	DESCRIPTION	SYMBOL	DESCRIPTION
	Transistor built-in, Output voltage internally set (V$_{OUT}$ product), Soft-start internally set Current limit: 700mA	A	CE input logic High Active, CE pin open (Standard)
		B	CE input logic Low Active, CE pin open (Semi-custom)
		C	CE input logic High Active, Pull-down resistor built-in (Semi-custom)
		D	CE input logic Low Active, Pull-up resistor built-in (Semi-custom)
	Transistor built-in, Output voltage internally set (VOUT product), Soft-start internally set Current limit: 900mA	E	CE input logic High Active, CE pin open (Standard)
		F	CE input logic Low Active, CE pin open (Semi-custom)
		G	CE input logic High Active, Pull-down resistor built-in (Semi-custom)
		H	CE input logic Low Active, Pull-up resistor built-in (Semi-custom)
	Output Voltage	0~4	Integer number of output voltage e.g. V$_{OUT}$=2.8V =2 *3.0V~4.0V output only for E~H series
	Output Voltage	0~9, A~M	Decimal number of output voltage 100mV increment: 00=0, 10=1, 20=2, 30=3, 40=4, 50=5, 60=6, 70=7, 80=8, 90=9 e.g. V$_{OUT}$=2.8V =2, =8 50mV increment: 05=A, 15=B, 25=C, 35=D, 45=E, 55=F, 65=H, 75=K, 85=L, 95=M e.g. V$_{OUT}$=2.85V =2, =L *3.0V~4.0V output only for E~H series
	Oscillation Frequency	6	600kHz
		C	1.2MHz
	Package	M	SOT-25 (SOT-23-5)
		D	USP-6B
	Device Orientation	R	Embossed tape, standard feed
		L	Embossed tape, reverse feed

*Output voltage range of the E, F, G, H series is 3.0~4.0V only.

BLOCK DIAGRAM
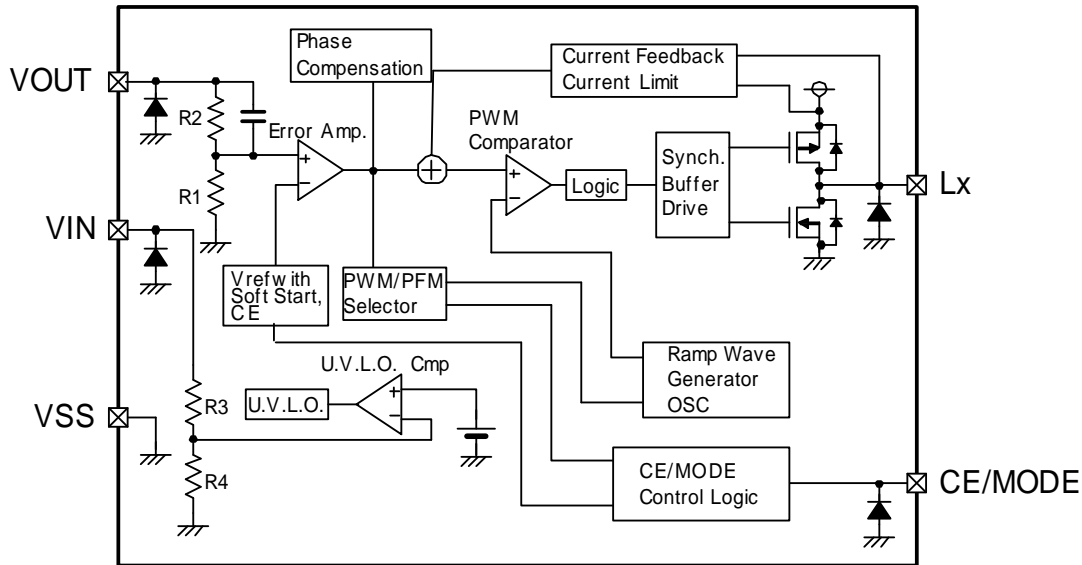
NOTE: The signal from CE/MODE Control Logic to PWM/PFM Selector is being fixed to "L" level inside,
and XC9225 series chooses only PWM control.
The signal from CE/MODE Control Logic to PWM/PFM Selector is being fixed to "H" level inside,
and XC9226 series chooses only PWM/PFM automatic switching control.

ABSOLUTE MAXIMUM RATINGS

Ta=25

PARAMETER		SYMBOL	RATINGS	UNITS
V_{IN} Pin Voltage		V_{IN}	- 0.3 ~ 6.5	V
Lx Pin Voltage		V_{Lx}	- 0.3 ~ V_{IN} + 0.3	V
V_{OUT} Pin Voltage		V_{OUT}	- 0.3 ~ 6.5	V
CE / MODE Pin Voltage		V_{CE}	- 0.3 ~ V_{IN} + 0.3	V
Lx Pin Current		I_{Lx}	± 1000	mA
Power Dissipation	SOT-25	Pd	250	mW
	USP-6B		100	
Operating Temperature Range		Topr	- 40 ~ + 85	
Storage Temperature Range		Tstg	- 55 ~ +125	

ELECTRICAL CHARACTERISTICS

XC9225A18Cxx, XC9226A18Cxx, XC9227A18Cxx V_{OUT}=1.8V, f_{OSC}=1.2MHz, Ta=25

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT	CIRCUIT
Output Voltage	V_{OUT}	When connected to external components, CE=V_{IN}, I_{OUT}=30mA	1.764	1.800	1.836	V	
Operating Voltage Range	V_{IN}	-	2.0	-	6.0	V	
Maximum Output Current	I_{OUTMAX}	V_{IN}=<T-1>V, When connected to external components (A series) (*10)	500	-	-	mA	
UVLO Voltage	V_{UVLO}	CE=V_{IN}, V_{OUT}=0V, Voltage which Lx pin voltage holding "L" level (*1), (*12)	1.00	1.40	1.78	V	
Supply Current	I_{DD}	V_{IN}=CE=3.6V, V_{OUT}=set voltage× 1.1V	-	15	35	μ A	
Stand-by Current	Istb	V_{IN}=3.6V, CE=0V, V_{OUT}=set voltage× 1.1V	-	0	1.0	μ A	
Oscillation Frequency	f_{OSC}	When connected to external components, I_{OUT}=100mA	1020	1200	1380	kHz	
PFM Switch Current	I_{PFM}	When connected to external components, CE=V_{IN}, I_{OUT}=0.1mA	120	160	200	mA	
Maximum I_{PFM} Limit	MAXIPFM	V_{IN}=V_{OUT}+1.0V, CE=V_{IN}, I_{OUT}=0.1mA	35	44	50	%	
Maximum Duty Ratio	MAXDTY	CE=V_{IN}, V_{OUT}=0V	100	-	-	%	
Minimum Duty Ratio	MINDTY	CE=V_{OUT}=V_{IN}	-	-	0	%	
Efficiency (*2)	EFFI	When connected to external components, CE=V_{IN}=3.0V, I_{OUT}=100mA	-	90	-	%	
Lx SW "H" ON Resistance	R_{LxH}	CE=0.5V_{IN}, V_{OUT}=0V, I_{Lx}=100mA (*3)	-	0.6	1.2		
Lx SW "L" ON Resistance	R_{LxL}	CE=0.5V_{IN}, I_{Lx}=100mA (*4)	-	0.7	1.4		
Lx SW "H" Leak Current	I_{LeakH}	V_{IN}=V_{OUT}=5.0V, CE=0V, Lx=0V (*5)	-	0.01	1.0	μ A	
Lx SW "L" Leak Current	I_{LeakL}	V_{IN}=V_{OUT}=5.0V, CE=0V, Lx=5.0V	-	0.01	1.0	μ A	
Current Limit (*11)	I_{LIM}	V_{IN}=CE=5.0V, V_{OUT}=0V (A series)	600	700	-	mA	
Output Voltage Temperature Characteristics	$\frac{V_{OUT}}{V_{OUT} \cdot topr}$	I_{OUT}=30mA -40 Topr 85	-	± 100	-	ppm/	
CE "H" Voltage	V_{CEH}	V_{OUT}=0V, When CE voltage is applied Lx determine "H"(*12)	0.65	-	V_{IN}	V	
CE "L" Voltage	V_{CEL}	V_{OUT}=0V, When CE voltage is applied Lx determine "L" (*12)	VSS	-	0.25	V	
PWM "H" Level Voltage	V_{PWMH}	When connected to external components, I_{OUT}=1mA (*6)	-	-	V_{IN}- 1.0	V	
PWM "L" Level Voltage	V_{PWML}	When connected to external components, I_{OUT}=1mA (*6)	V_{IN}- 0.3	-	-	V	
CE "H" Current	I_{CEH}	V_{IN}=CE=5.5V, V_{OUT}=0V	- 0.1	-	0.1	μ A	
CE "L" Current	I_{CEL}	V_{IN}=5.5V, CE=0V, V_{OUT}=0V	- 0.1	-	0.1	μ A	
Soft-Start Time	tss	When connected to external components, CE=0V V_{IN}, I_{OUT}=1mA	0.5	1.0	3.0	ms	
Latch Time	tlat	When connected to external components, V_{IN}=CE=5.0V, Short V_{OUT} by 1 resistance (*7)	1	-	20	ms	

Test conditions: Unless otherwise stated, V_{IN}=3.6V
External components L: 4.7uH (CDRH4D18C), CIN: 4.7uF (ceramic) CL: 10uF (ceramic)

<T-1> refers to the below values.
Setting voltage 1.5V>V_{OUT}≥0.9V   T-1=2.4V
Setting voltage 1.8V>V_{OUT}≥1.5V   T-1=3.0V
Setting voltage 4.0V≥V_{OUT}≥1.8V   T-1=V_{OUT}+1.2V

NOTE:
*1: Including hysteresis operating voltage range.
*2: EFFI = { (output voltage× output current) / (input voltage× input current) }× 100
*3: On resistance ( )= Lx pin measurement voltage / 100mA
*4: R&D value
*5: When temperature is high, a current of approximately 20μ A (maximum) may leak.
*6: The CE/MODE pin of the XC9227A series works also as an external PWM control and PWM/PFM control switching pin.   When the IC is in the operation, control is switched to the automatic PWM/PFM switching mode when the CE/MODE pin voltage is equal to or greater than V_{IN} minus 0.3V, and to the PWM mode when the CE/MODE pin voltage is equal to or lower than V_{IN} minus 1.0V and equal to or greater than V_{CEH}.
*7: Time until it short-circuits V_{OUT} with GND through 1   of resistance from a state of operation and is set to V_{OUT}=0V from current limit pulse generating.
*8: There is no PFM switch current for XC9225 series.   The PFM switch current is only for XC9226/9227 series.
*9: There is no PWM "H" Level Voltage or PWM "L" Level Voltage for XC9225/9226 series.   The characteristics are only for XC9227 series.
*10: When the difference between the input and the output is small, some cycles may be skipped completely before current maximizes. If current is further pulled from this state, output voltage will decrease because of P-ch driver ON resistance.
*11: Current limit denotes the level of detection at peak of coil current..
*12: "H"=V_{IN}~V_{IN}-1.2V, "L"=+0.1V~-0.1V

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ELECTRICAL CHARACTERISTICS (Continued)

XC9225A (E) 33Cxx, XC9226A (E) 33Cxx, XC9227A (E) 33Cxx $\qquad$ VOUT=3.3V, f_{OSC}=1.2MHz, Ta=25

| PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT	CIRCUIT
Output Voltage	VOUT	When connected to external components, CE=VIN, IOUT=30mA	3.234	3.300	3.366	V	
Operating Voltage Range	VIN	A series	2.0	-	6.0	V	
		E series	4.5	-	5.5	V	
Maximum Output Current	IOUTMAX	VIN=<T-1>V, when connected to external components (A series) (*10)	500	-	-	mA	
		VIN=VOUT+1.5V when connected to external components (E series) (*10)	600			mA	
U.V.L.O. Voltage	VUVLO	CE=VIN, VOUT=0V, Voltage which Lx pin voltage holding "L" level (*1), (*12)	1.00	1.40	1.78	V	
Supply Current	IDD	VIN=CE=5.0V, VOUT=set voltage× 1.1V	-	15	35	μA	
Stand-by Current	Istb	VIN=5.0V, CE=0V, VOUT=set voltage× 1.1V	-	0	1.0	μA	
Oscillation Frequency	f_{OSC}	When connected to external components, IOUT=100mA	1020	1200	1380	kHz	
PFM Switch Current	IPFM	When connected to external components, CE=VIN, IOUT=1mA	120	160	200	mA	
Maximum IPFM Current	MAXIPFM	VIN=VOUT+1.0V, CE=VIN, IOUT=0.1mA	35	44	50	%	
Maximum Duty Ratio	MAXDTY	CE=VIN, VOUT=0V	100	-	-	%	
Minimum Duty Ratio	MINDTY	CE=VOUT=VIN	-	-	0	%	
Efficiency (*2)	EFFI	When connected to external components, CE=VIN=4.5V, IOUT=100mA	-	92	-	%	
Lx SW "H" ON Resistance	RLxH	CE=0.5VIN, VOUT=0V, ILx=100mA (*3)	-	0.5	1.0		
Lx SW "L" ON Resistance	RLxL	CE=0.5VIN, ILx=100mA (*4)	-	0.6	1.2		
Lx SW "H" Leak Current	ILeakH	VIN=VOUT=5.0V, CE=0V, Lx=0V (*5)	-	0.01	1.0	μA	
Lx SW "L" Leak Current	ILeakL	VIN=VOUT=5.0V, CE=0V, Lx=5.0V	-	0.01	1.0	μA	
Current Limit (*11)	ILIM	VIN=CE=5.0V, VOUT=0V (A series)	600	700		mA	
		VIN=CE=5.0V, VOUT=0V (E series)	800	900	-	mA	
Output Voltage Temperature Characteristics	VOUT / VOUT topr	IOUT=30mA -40 Topr 85	-	± 100	-	ppm/	
CE "H" Voltage	VCEH	VOUT=0V, When CE voltage is applied Lx determine "H" (*12)	0.65	-	VIN	V	
CE "L" Voltage	VCEL	VOUT=0V, When CE voltage is applied Lx determine "L" (*12)	VSS	-	0.25	V	
PWM "H" Level Voltage	VPWMH	When connected to external components, IOUT=1mA (*6)	-	-	VIN - 1.0	V	
PWM "L" Level Voltage	VPWML	When connected to external components, IOUT=1mA (*6)	VIN - 0.3	-	-	V	
CE "H" Current	ICEH	VIN=CE=5.5V, VOUT=0V	- 0.1	-	0.1	μA	
CE "L" Current	ICEL	VIN=5.5V, CE=0V, VOUT=0V	- 0.1	-	0.1	μA	
Soft-Start Time	tss	When connected to external components, CE=0V VIN, IOUT=1mA	0.5	1.0	3.0	ms	
Latch Time	tlat	When connected to external components, VIN=CE=5.0V, Short VOUT by 1 resistance (*7)	1	-	20	ms	

Test conditions: Unless otherwise stated, VIN=5.0V
External components L: 4.7uH (CDRH4D18C), CIN: 4.7uF (ceramic) CL: 10uF (ceramic)

<T-1> refers to the below values.
Setting voltage 1.5V>VOUT≥0.9V   T-1=2.4V
Setting voltage 1.8V>VOUT≥1.5V   T-1=3.0V
Setting voltage 4.0V≥VOUT≥1.8V   T-1=VOUT+1.2V

NOTE:
*1: Including hysteresis operating voltage range.
*2: EFFI = { (output voltage× output current) / (input voltage× input current) }× 100
*3: On resistance ( )= Lx pin measurement voltage / 100mA
*4: R&D value
*5: When temperature is high, a current of approximately 20μA (maximum) may leak.
*6: The CE/MODE pin of the XC9227A series works also as an external PWM control and PWM/PFM control switching pin. When the IC is in the operation, control is switched to the automatic PWM/PFM switching mode when the CE/MODE pin voltage is equal to or greater than VIN minus 0.3V, and to the PWM mode when the CE/MODE pin voltage is equal to or lower than VIN minus 1.0V and equal to or greater than VCEH.
*7: Time until it short-circuits VOUT with GND through 1 of resistance from a state of operation and is set to VOUT=0V from current limit pulse generating.
*8: There is no PFM switch current for XC9225 series. The PFM switch current is only for XC9226/9227 series.
*9: There is no PWM "H" Level Voltage or PWM "L" Level Voltage for XC9225/9226 series. The characteristics are only for XC9227 series.
*10: When the difference between the input and the output is small, some cycles may be skipped completely before current maximizes. If current is further pulled from this state, output voltage will decrease because of P-ch driver ON resistance.
*11: Current limit denotes the level of detection at peak of coil current.
*12: "H"=VIN~VIN-1.2V, "L"=+0.1V~-0.1V

TYPICAL APPLICATION CIRCUIT
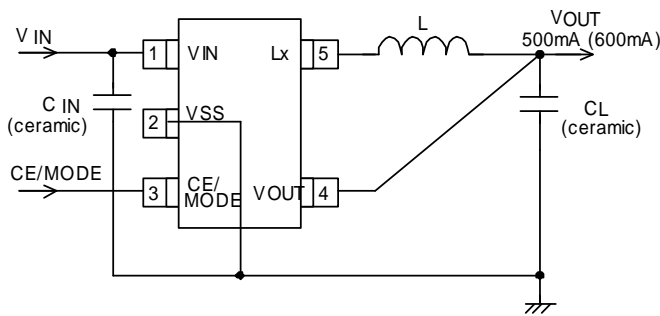
FOSC=1.2MHz
L   : 4.7μ H   (NR3015, TAIYO YUDEN)
     : 4.7μ H   (VLF4012A, TDK)
     : 4.7μ H   (CDRH4D18C, SUMIDA)
CIN : 4.7μ F   (Ceramic)
CL   : 10μ F   (Ceramic)
FOSC=600kHz
L   : 10μ H   (NR4018, TAIYO YUDEN)
     : 10μ H   (VLF4012A, TDK)
     : 10μ H   (CDRH4, SUMIDA)
CIN : 4.7μ F   (Ceramic)
CL   : 10μ F   (Ceramic)

OPERATIONAL EXPLANATION

The XC9225/9226/9227 series consists of a reference voltage source, ramp wave circuit, error amplifier, PWM comparator, phase compensation circuit, output voltage adjustment resistors, P-channel MOSFET driver transistor, N-channel MOSFET switching transistor for the synchronous switch, current limiter circuit, U.V.L.O. circuit and others. (See the block diagram above.) The series ICs compare, using the error amplifier, the voltage of the internal voltage reference source with the feedback voltage from the V_{OUT} pin through split resistors, R1 and R2. 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 PWM operation. 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 buffer driver circuit 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 monitors the P-channel MOS driver transistor current for each switching operation, and modulates the error amplifier output signal to provide multiple feedback signals. 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 DC/DC converter.
<Ramp Wave Circuit>
The ramp wave circuit determines switching frequency. The frequency is fixed internally and can be selected from 600kHz and 1.2MHz. Clock pulses generated in this circuit are used to produce ramp waveforms needed for PWM operation, and to synchronize all the internal circuits.
<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 split resistors, R1 and R2. When a voltage lower than the reference voltage is fed back, the output voltage of the error amplifier increases. The gain and frequency characteristics of the error amplifier output are fixed internally to deliver an optimized signal to the mixer.
<Current Limit>
The current limiter circuit of the XC9225 / 9226 / 9227 series monitors the current flowing through the P-channel MOS driver transistor connected to the Lx pin, and features a combination of the constant-current type current limit mode and the operation suspension mode.
   When the driver current is greater than a specific level, the constant-current type current limit function operates to turn off the pulses from the Lx pin at any given timing.
   When the driver transistor is turned off, the limiter circuit is then released from the current limit detection state.
   At the next pulse, the driver transistor is turned on. However, the transistor is immediately turned off in the case of an over current state.
   When the over current state is eliminated, the IC resumes its normal operation.
The IC waits for the over current state to end by repeating the steps   through   . If an over current state continues for a few msec and the above three steps are repeatedly performed, the IC performs the function of latching the OFF state of the driver transistor, and goes into operation suspension mode. Once the IC is in suspension mode, operations can be resumed by either turning the IC off via the CE/MODE pin, or by restoring power to the VIN 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. The constant-current type current limit of the XC9225 / 9226 / 9227 series can be set at 700mA (A~D series) and 900mA (E~H series) at typical.   Besides, care must be taken when laying out the PC Board, in order to prevent misoperation of the current limit mode.   Depending on the state of the PC Board, latch time may become longer and latch operation may not work.   In order to avoid the effect of noise, the board should be laid out so that capacitors are placed as close to the chip as possible.
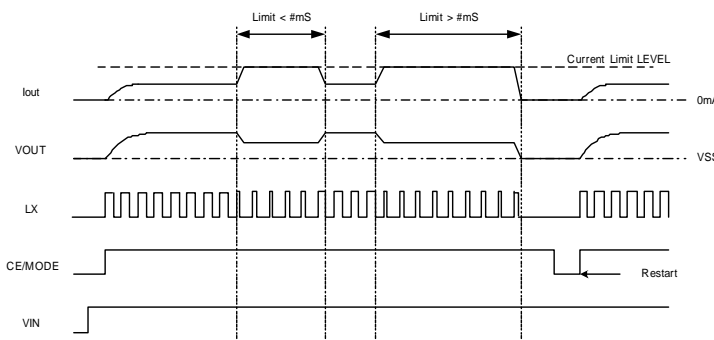
OPERATIONAL EXPLANATION (Continued)

<U.V.L.O. Circuit>
When the V_{IN} pin voltage becomes 1.4V or lower, the P-channel output driver transistor is forced OFF to prevent false pulse output caused by unstable operation of the internal circuitry. When the V_{IN} pin voltage becomes 1.8V or higher, switching operation takes place. By releasing the U.V.L.O. function, the IC performs the soft start function to initiate output startup operation. The soft start function operates even when the V_{IN} pin voltage falls momentarily below the U.V.L.O. operating voltage. The U.V.L.O. circuit does not cause a complete shutdown of the IC, but causes pulse output to be suspended; therefore, the internal circuitry remains in operation.

<PFM Switch Current>
In PFM control operation, until coil current reaches to a specified level (I_{PFM}), the IC keeps the P-ch MOSFET on. In this case, time that the P-ch MOSFET is kept on (TON) can be given by the following formula.

$TON = L \times I_{PFM} / (V_{IN} \quad V_{OUT})$ I_{PFM}

<Maximum I_{PFM} Limit>
In PFM control operation, the maximum duty ratio (MAXPFM) is set to 44% (TYP.). Therefore, under the condition that the duty increases (e.g. the condition that the step-down ratio is small), it's possible for P-ch MOSFET to be turned off even when coil current doesn't reach to I_{PFM}. I_{PFM}
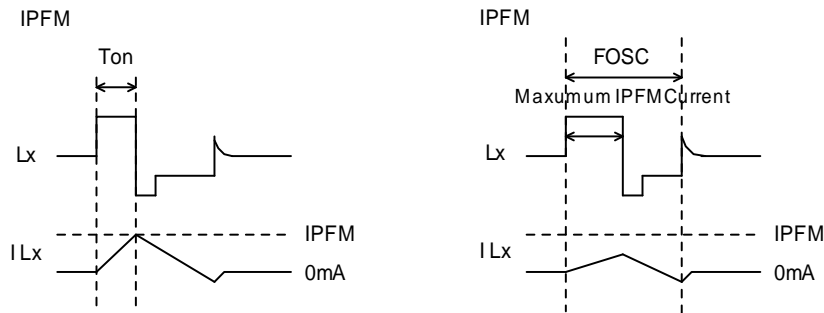
<CE/MODE Pin Function>
The operation of the XC9225A / 9226A / 9227A series will enter into the shut down mode when a low level signal is input to the CE/MODE pin. During the shut down mode, the current consumption of the IC becomes 0μ A (TYP.), with a state of high impedance at the Lx pin and V_{OUT} pin. The IC starts its operation by inputting a high level signal to the CE/MODE pin. The input to the CE/MODE pin is a CMOS input and the sink current is 0μ A (TYP.).

XC9225A / 9226A series - Examples of how to use CE/MODE pin

(A)

SW__CE	STATUS
ON	Stand-by
OFF	Operation
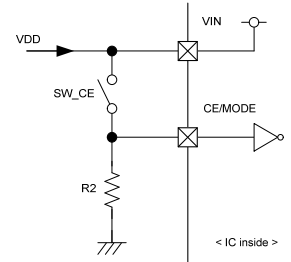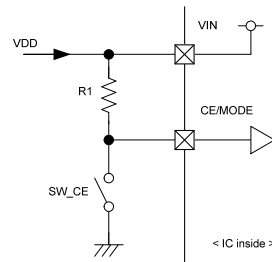
(B)

SW__CE	STATUS
ON	Operation
OFF	Stand-by

(A)

(B)

XC9227A series - Examples of how to use CE/MODE pin

(A)

SW__CE	SW__PWM/PFM	STATUS
ON	*	PWM/PFM Automatic Switching Control
OFF	ON	PWM Control
OFF	OFF	Stand-by
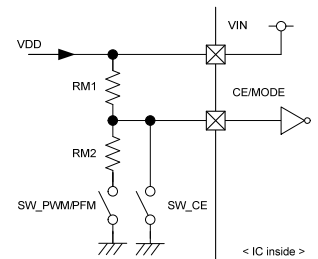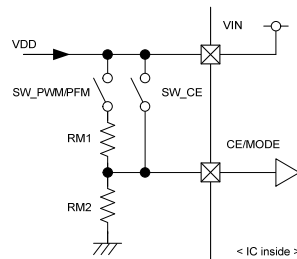
(B)

SW__CE	SW__PWM/PFM	STATUS
ON	*	Stand-by
OFF	ON	PWM Control
OFF	OFF	PWM/PFM Automatic Switching Control

(A)

(B)

Intermediate voltage can be generated by RM1 and RM2. Please set the value of each R1, R2, RM1, RM2 at around 100k . For switches, CPU open-drain I/O port and transistor can be used.
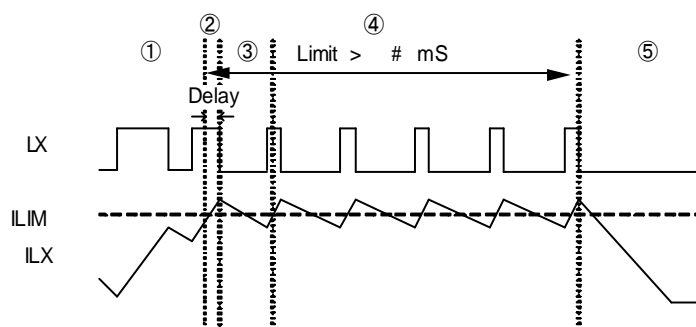
NOTES ON USE

Application Information

1 . The XC9225/9226/9227 series is designed for use with ceramic output capacitors. If, however, the potential difference between dropout voltage or output current is too large, a ceramic capacitor may fail to absorb the resulting high switching energy and oscillation could occur on the output. If the input-output potential difference is large, connect an electrolytic capacitor in parallel to compensate for insufficient capacitance.

2 . Spike noise and ripple voltage arise in a switching regulator as with a DC/DC converter. These are greatly influenced by external component selection, such as the coil inductance, capacitance values, and board layout of external components. Once the design has been completed, verification with actual components should be done.

3 . Depending on the input-output voltage differential, or load current, some pulses may be skipped, and the ripple voltage may increase.

4 . When the difference between V_{IN} and V_{OUT} is large in PWM control, very narrow pulses will be outputted, and there is the possibility that some cycles may be skipped completely.

5 . When the difference between V_{IN} and V_{OUT} is small, and the load current is heavy, very wide pulses will be outputted and there is the possibility that some cycles may be skipped completely: in this case, the Lx pin may not go low at all.

6 . With the IC, the peak current of the coil is controlled by the current limit circuit. Since the peak current increases when dropout voltage or load current is high, current limit starts operating, and this can lead to instability. When peak current becomes high, please adjust the coil inductance value and fully check the circuit operation. In addition, please calculate the peak current according to the following formula:

$Ipk = (V_{IN} - V_{OUT}) * OnDuty / (2 \times L \times FOSC) + I_{OUT}$

L: Coil Inductance Value

FOSC: Oscillation Frequency

7 . When the peak current, which exceeds limit current, flows within the specified time, the built-in P-ch driver transistor is turned off. During the time until it detects limit current and before the built-in transistor can be turned off, the current for limit current flows; therefore, care must be taken when selecting the rating for the coil or the schottky diode.

8 . When V_{IN} is less than 2.4V, limit current may not be reached because voltage falls caused by ON resistance.

9 . Care must be taken when laying out the PC Board, in order to prevent misoperation of the current limit mode. Depending on the state of the PC Board, latch time may become longer and latch operation may not work. In order to avoid the effect of noise, the board should be laid out so that capacitors are placed as close to the chip as possible.

10. Use of the IC at voltages below the recommended voltage range may lead to instability.

11. This IC should be used within the stated absolute maximum ratings in order to prevent damage to the device.

12. When the IC is used in high temperature, output voltage may increase up to input voltage level at no load because of the leak current of the driver transistor.

13. The current limit is set to 700mA (A~D series) and 900mA (E~H series) at typical. However, the current of 700/900mA or more may flow. In case that the current limit functions while the V_{OUT} pin is shorted to the GND pin, when P-ch MOSFET is ON, the potential difference for input voltage will occur at both ends of a coil. For this, the time rate of coil current becomes large. By contrast, when N-ch MOSFET is ON, there is almost no potential difference at both ends of the coil since the V_{OUT} pin is shorted to the GND pin. Consequently, the time rate of coil current becomes quite small. According to the repetition of this operation, and the delay time of the circuit, coil current will be converged on a certain current value, exceeding the amount of current, which is supposed to be limited originally. Even in this case, however, after the overcurrent state continues for several msec, the circuit will be latched. A coil should be used within the stated absolute maximum rating in order to prevent damage to the device.

Current flows into P-ch MOSFET to reach the current limit (I_{LIM}).

The current of I_{LIM} or more flows since the delay time of the circuit occurs during from the detection of the current limit to OFF of P-ch MOSFET.

Because of no potential difference at both ends of the coil, the time rate of coil current becomes quite small.

Lx oscillates very narrow pulses by the current limit for several msec.
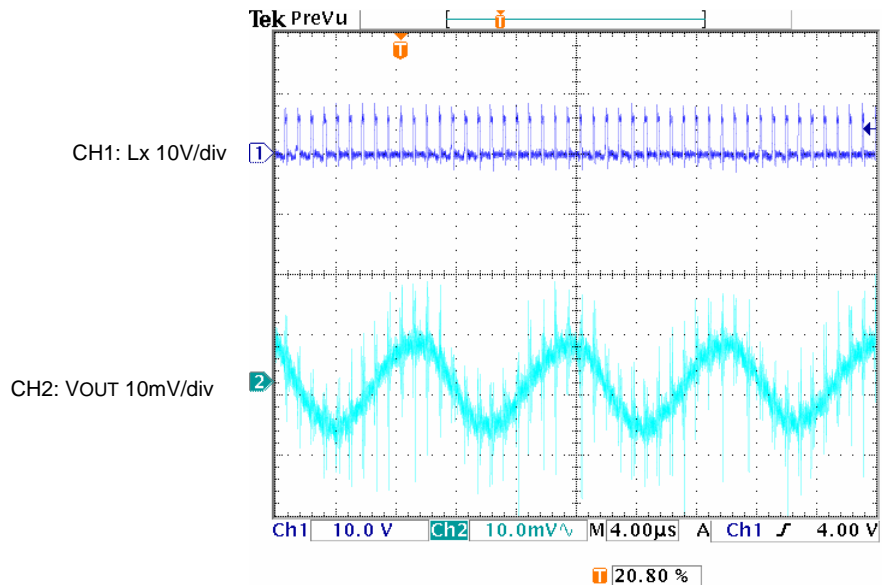
The circuit is latched, stopping its operation.

NOTES ON USE (Continued)

Application Information (Continued)

14. In order to stabilize V_{IN}'s voltage level and oscillation frequency, we recommend that a by-pass capacitor (C_{IN}) be connected as close as possible to the V_{IN} & V_{SS} pins.

15. High step-down ratio and very light load may lead an intermittent oscillation.

16. When the inductance value of the coil is large and under the condition of large dropout voltage in continuous mode, operation may become unstable.   A coil with an inductance value from 3.3μH to 6.8μH should be used. Please verify with actual parts.

ex.) V_{OUT} = 0.9V
    FOSC = 1.2MHz
    V_{IN} = 6.0V
    I_{OUT} = 70mA
    L : 10μH (CDRH4D18C)
    C_{IN} : 4.7μF (Ceramic)
    CL : 10μF (Ceramic)

CH1: Lx 10V/div

CH2: V_{OUT} 10mV/div

17. Maximum output current of the A series is 500mA and that of the E series is 600mA.   Limit current of this IC denotes a peak current, which flows to coils.   When using a coil with a small L value, output current (I_{OUT}) may not flow because the peak current increase and the limit current function operates before the output current reaches maximum output current. Accordingly, in the heavy load, the coils' value should be 4.7uH or more for 1.2MHz and 10uH or more for 600kHz.

Instructions of pattern layouts

1. In order to stabilize V_{IN}'s voltage level, we recommend that a by-pass capacitor (C_{IN}) be connected as close as possible to the V_{IN} & VSS 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. This series' internal driver transistors bring on heat because of the output current and On resistance of driver transistors. Please be careful of the heat ability of the PCB when using the XC9225/9226/9227E ~ H series.

NOTES ON USE (Continued)

Reference Pattern Layout

SOT-25
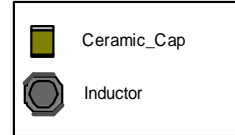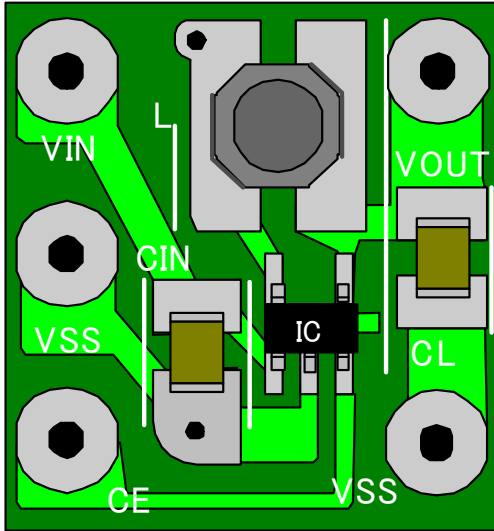
* Please use an electric wire for VIN, VOUT, VSS and CE.

USP-6B
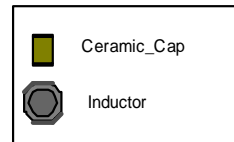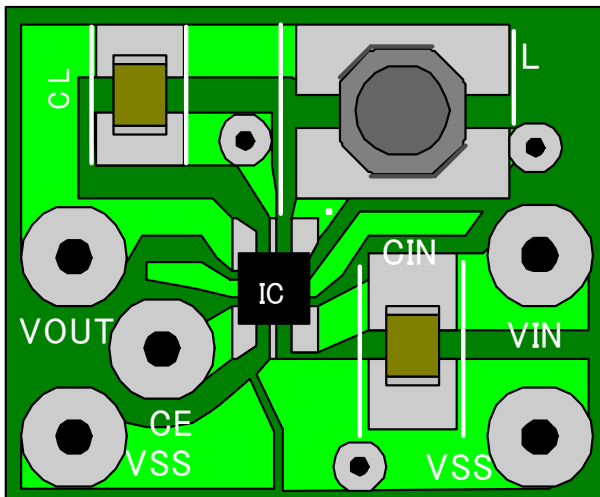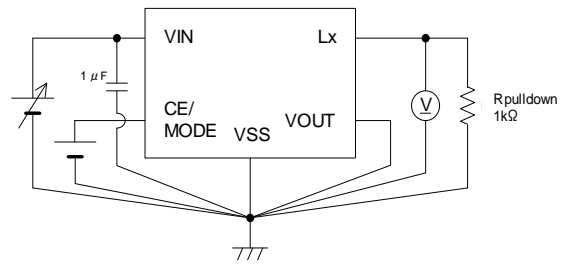

* Please use an electric wire for VIN, VOUT, VSS and CE.

TEST CIRCUITS

Circuit①
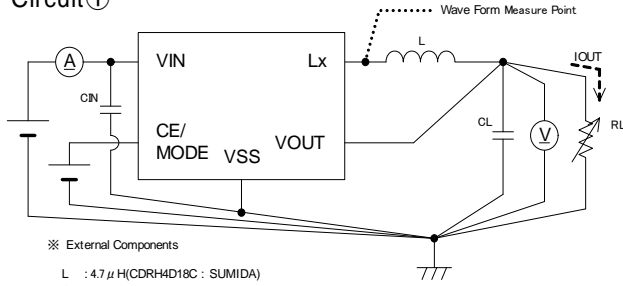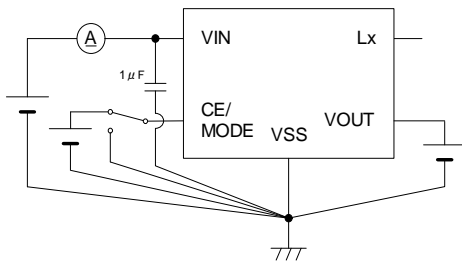
Wave Form Measure Point

| VIN | Lx |
| CE/MODE | VSS | VOUT |

A

CIN

L

CL

V

IOUT

RL

※ External Components

L   : 4.7μH(CDRH4D18C : SUMIDA)
CIN : 4.7μF(ceramic)
CL : 10μF(ceramic)

Circuit②

| VIN | Lx |
| CE/MODE | VSS | VOUT |

1μF

V

Rpulldown
1kΩ

Circuit③

A

| VIN | Lx |
| CE/MODE | VSS | VOUT |

1μF

Circuit④

Oscillation Check Point

| VIN | Lx |
| CE/MODE | VSS | VOUT |

1μF

V

Rpulldown
200Ω

Circuit⑤

| VIN | Lx |
| CE/MODE | VSS | VOUT |

1μF

V
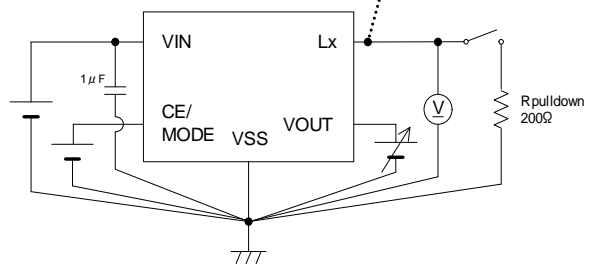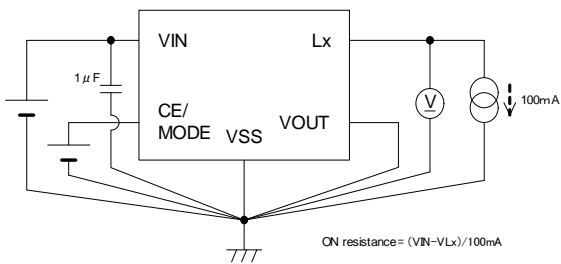
100mA

ON resistance＝ (VIN-VLx)/100mA

Circuit⑥
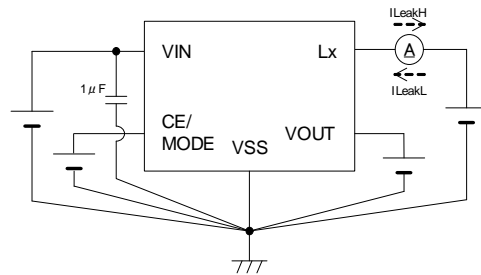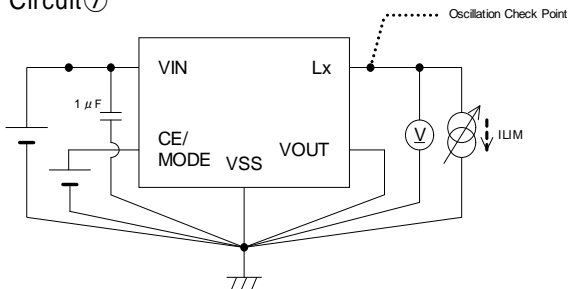
ILeakH

ILeakL

| VIN | Lx |
| CE/MODE | VSS | VOUT |

1μF

A

Circuit⑦

Oscillation Check Point

| VIN | Lx |
| CE/MODE | VSS | VOUT |

1μF

V

ILIM

Circuit⑧

ICEH

ICEL

| VIN | Lx |
| CE/MODE | VSS | VOUT |

1μF

A

V

Rpulldown
1kΩ

Circuit⑨

Wave Form Measure Point

| VIN | Lx |
| CE/MODE | VSS | VOUT |

CIN

L

CL

V

Ilat

1Ω
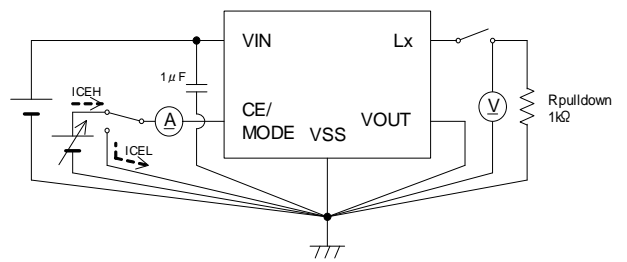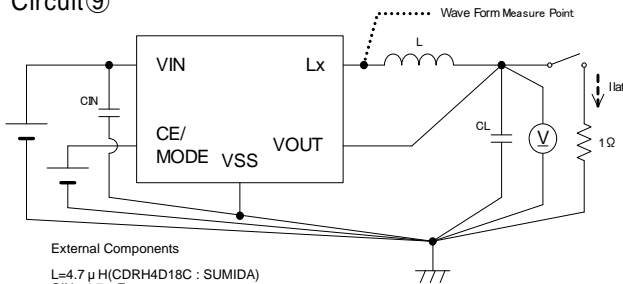
External Components

L=4.7μH(CDRH4D18C : SUMIDA)
CIN : 4.7μF
CL : 10μF

TYPICAL PERFORMANCE CHARACTERISTICS

(1) Efficiency vs. Output Current

XC9227A18C

L=4.7uH(NR3015),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25

PWM/PFM Automatic Switching Control —
PWM Control ·····

XC9227A33C

L=4.7uH(NR3015),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25

PWM/PFM Automatic Switching Control —
PWM Control ·····
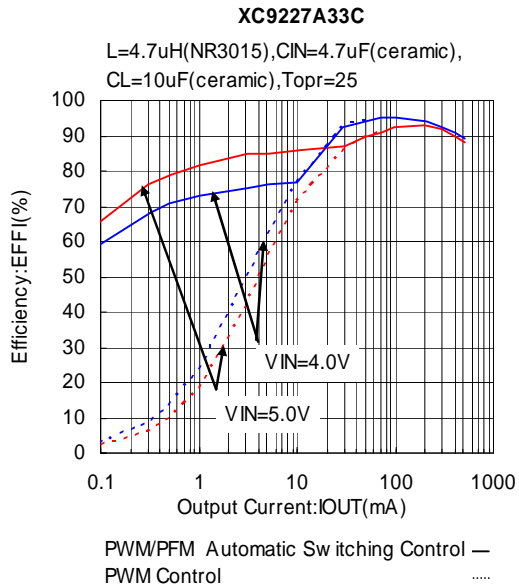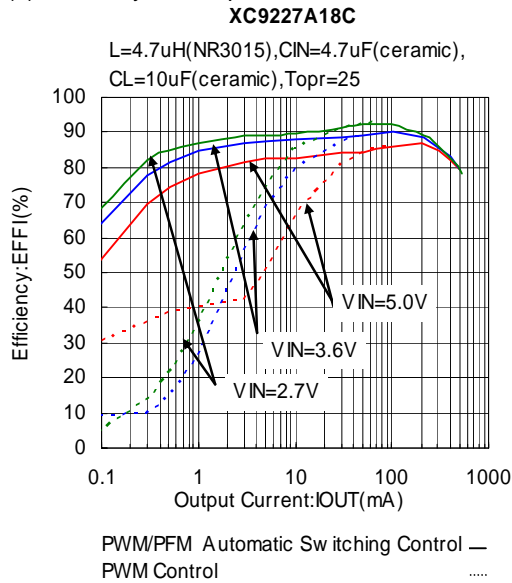
(2) Output Voltage vs. Output Current

XC9227A18C

L=4.7uH(NR3015),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25

XC9227A33C

L=4.7uH(NR3015),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25
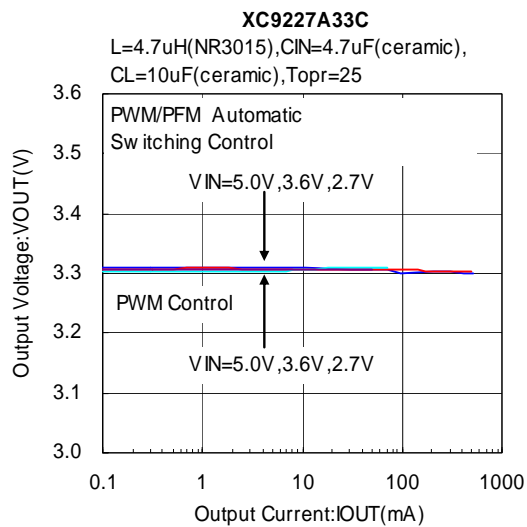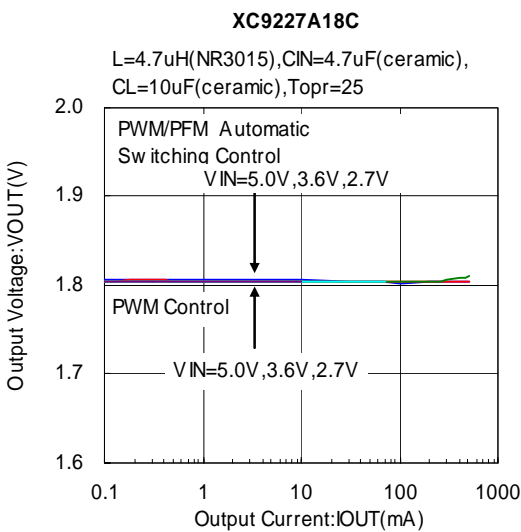
(3) Ripple Voltage vs. Output Current

XC9227A18C

L=4.7uH(NR3015),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25

XC9227A33C

L=4.7uH(NR3015),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25

TOREX

13/21
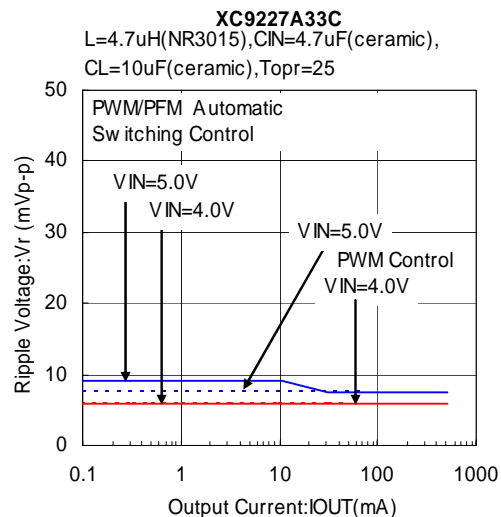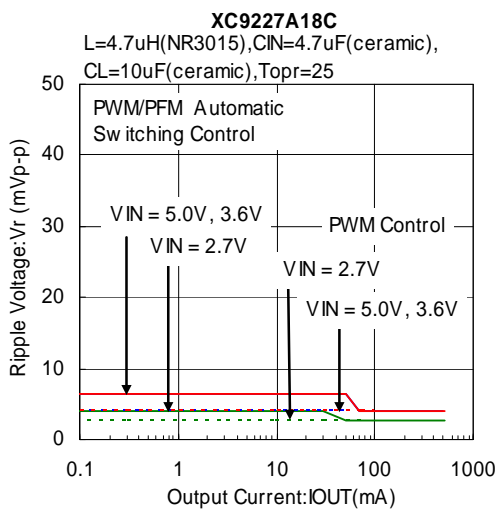
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(4) Oscillation Frequency vs. Ambient Temperature

XC9227A18C
L=4.7uH(CDRH3D16),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25

XC9227A186
L=10uH(CDRH4D18C),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25
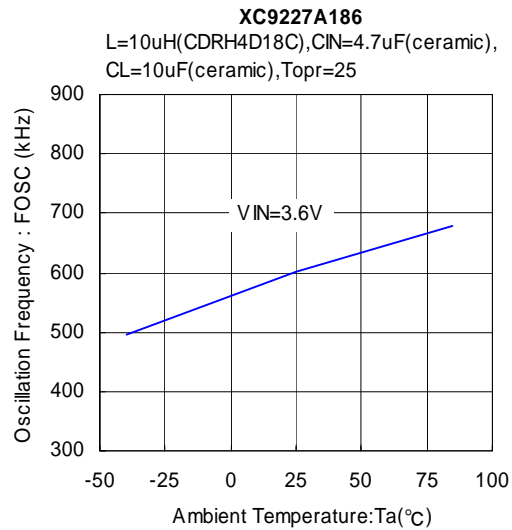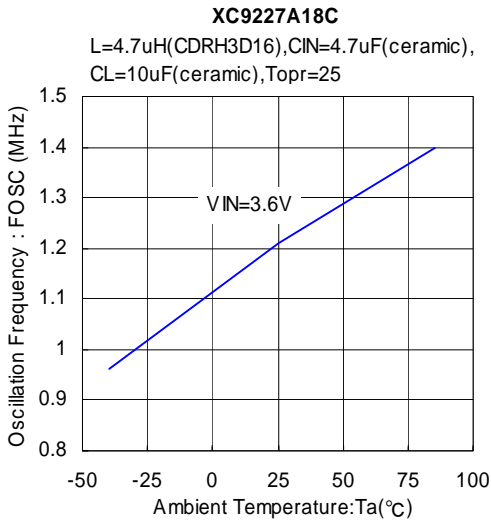
(5) Supply Current vs. Ambient Temperature

XC9227A18C

XC9227A186
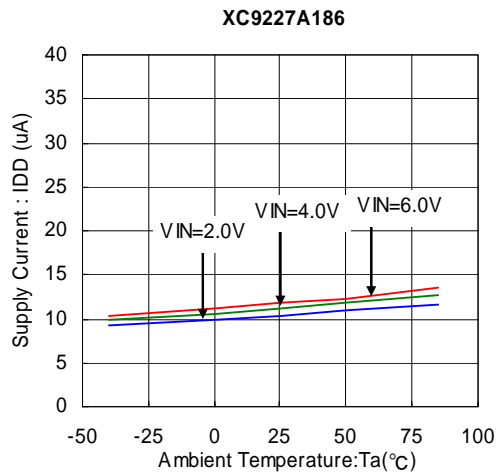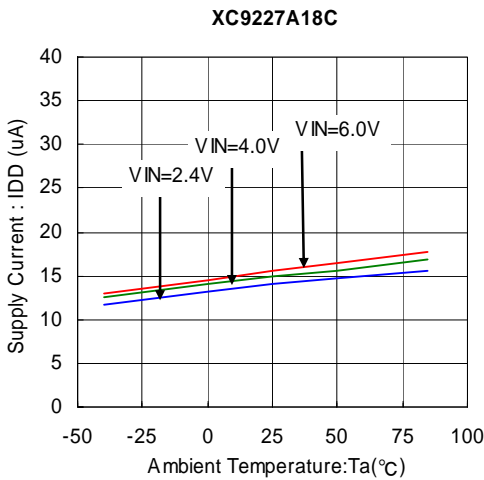
(6) Output Voltage vs. Ambient Temperature

XC9227A18C
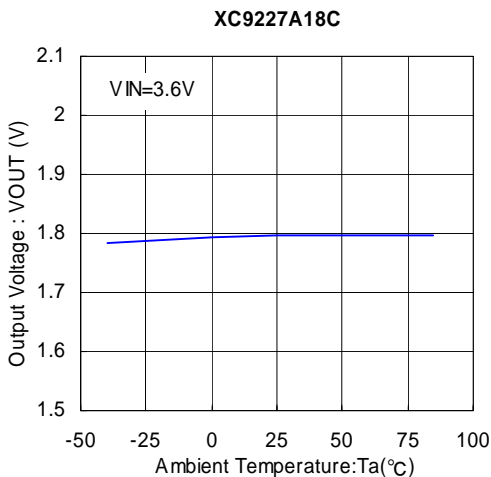
(7) U.V.L.O. Voltage vs. Ambient Temperature

XC9227A18C
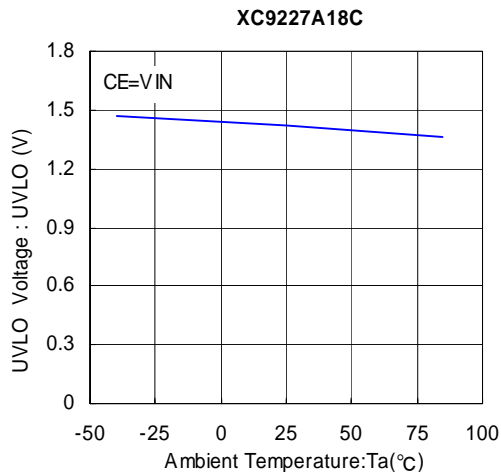
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(8) CE "H / L" Voltage vs. Ambient Temperature

XC9227A18C
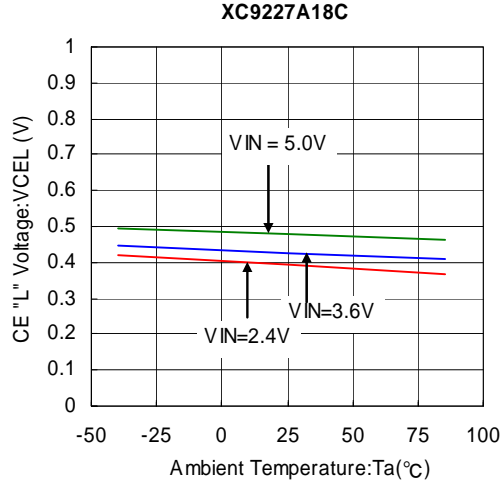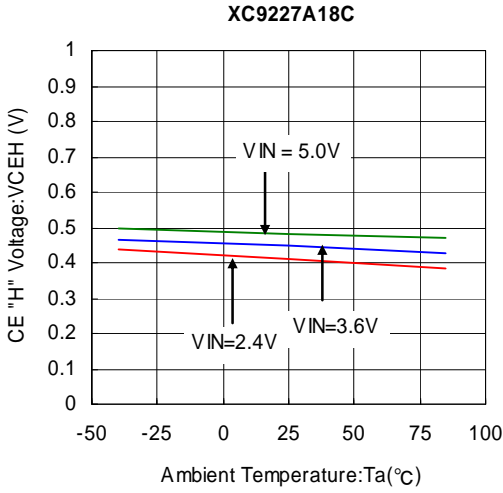
XC9227A18C

(9) Soft-Start Time vs. Ambient Temperature

XC9227A18C
L=4.7uH(CDRH4D18C),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25

XC9227A186
L=10uH(CDRH4D18C),CIN=4.7uF(ceramic),
CL=10uF(ceramic),Topr=25
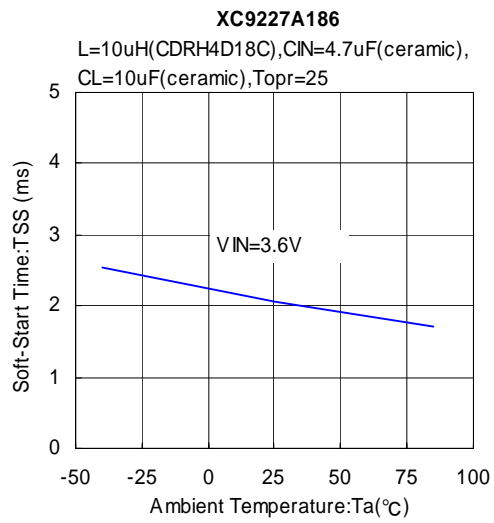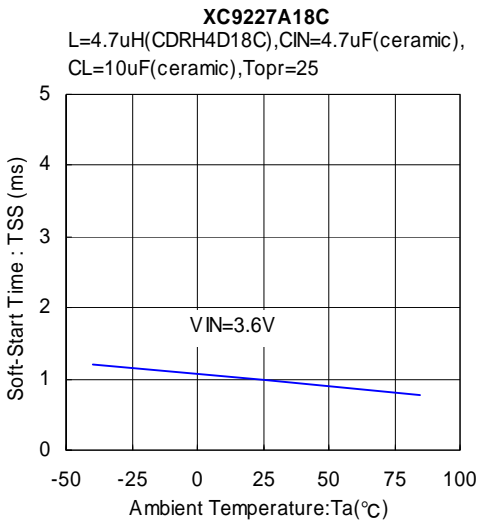
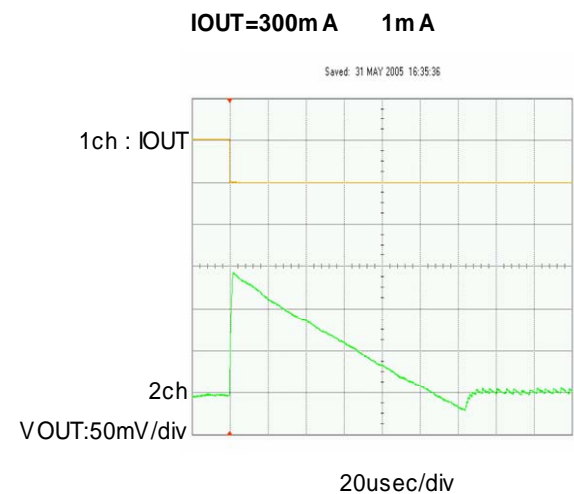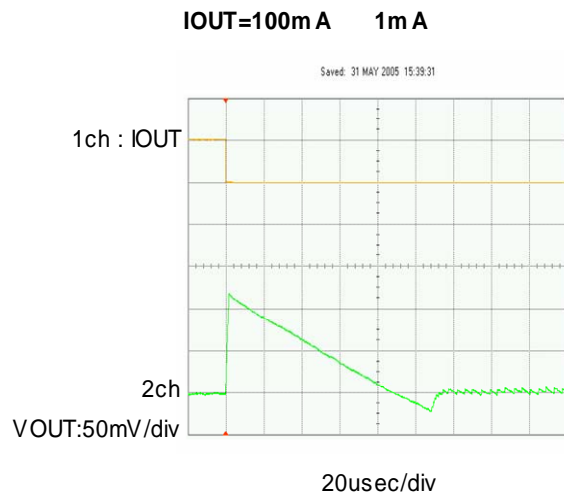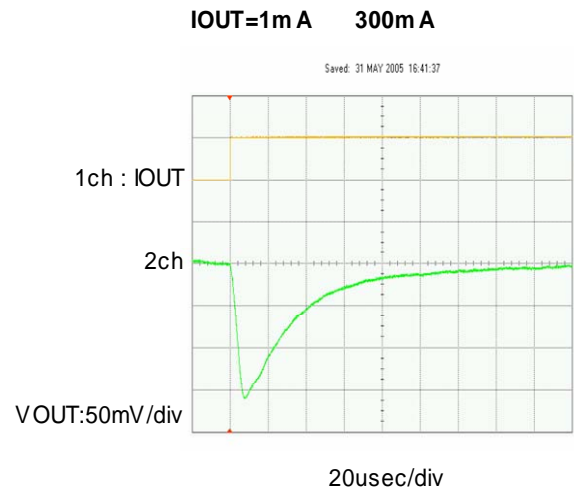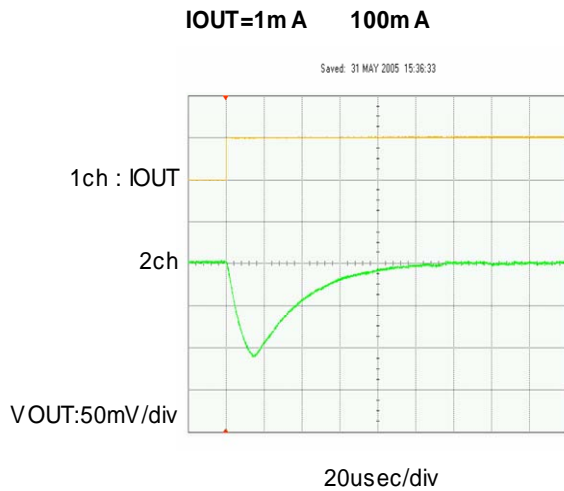(10) "P-ch / N-ch" Driver ON Resistance vs. Ambient Temperature
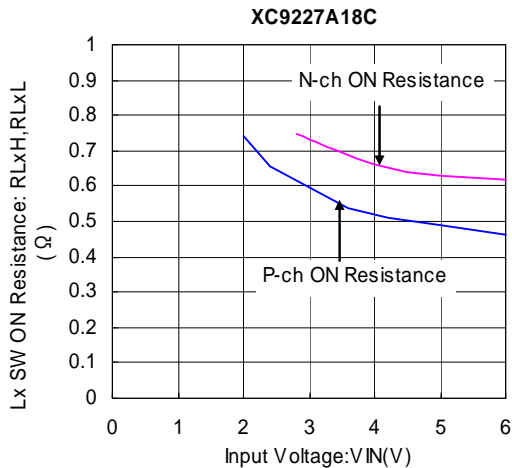
XC9227A18C

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(11) Load Transient Response Time

XC9227A18C
L=4.7μH(NR3015), CIN=4.7μF(ceramic), CL=10μF(ceramic), Topr=25
VIN=3.6V, CE=VIN (PWM/PFM Automatic Switching Control)

IOUT=1mA   100mA

Saved: 31 MAY 2005 15:36:33

1ch : IOUT

2ch

VOUT:50mV/div

20usec/div

IOUT=1mA   300mA

Saved: 31 MAY 2005 16:41:37

1ch : IOUT

2ch

VOUT:50mV/div

20usec/div

IOUT=100mA   1mA

Saved: 31 MAY 2005 15:39:31

1ch : IOUT

2ch

VOUT:50mV/div

20usec/div

IOUT=300mA   1mA

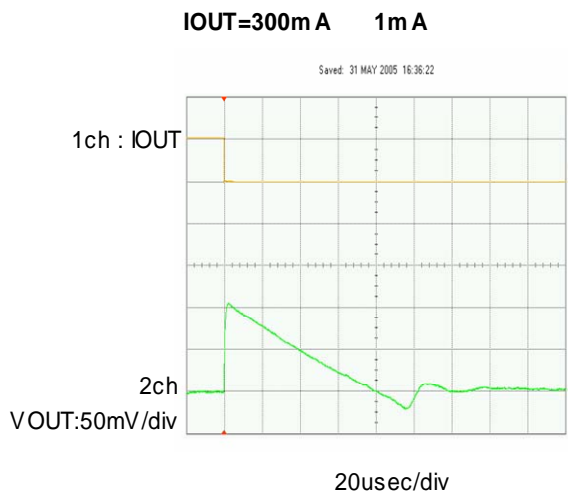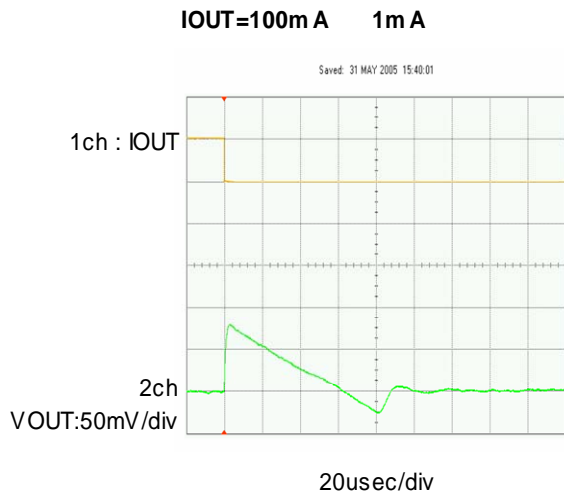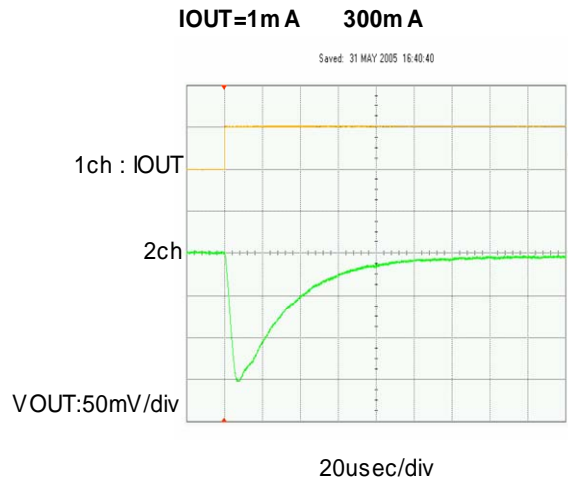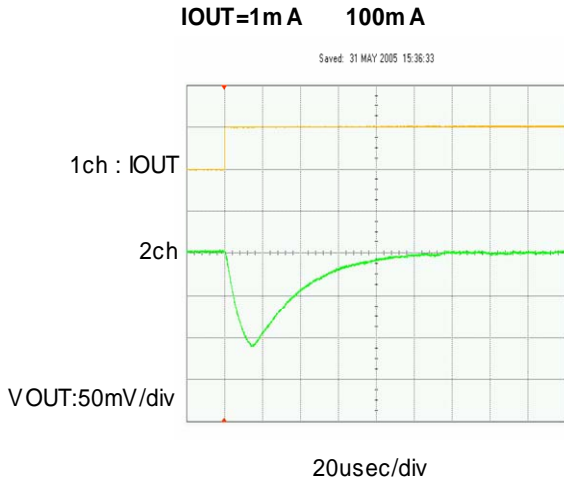Saved: 31 MAY 2005 16:35:36

1ch : IOUT

2ch

VOUT:50mV/div

20usec/div

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(12) Load Transient Response Time

XC9227A18C
L=4.7μH(NR3015), C$_{IN}$=4.7μF(ceramic), CL=10μF(ceramic), Topr=25
V$_{IN}$=3.6V, CE=V$_{IN}$ (PWM Control)

IOUT=1m A　　100m A

Saved: 31 MAY 2005 15:36:33

1ch : IOUT

2ch

VOUT:50mV/div

20usec/div

IOUT=1m A　　300m A

Saved: 31 MAY 2005 16:40:40

1ch : IOUT

2ch

VOUT:50mV/div

20usec/div

IOUT=100m A　　1m A

Saved: 31 MAY 2005 15:40:01

1ch : IOUT

2ch
VOUT:50mV/div

20usec/div

IOUT=300m A　　1m A

Saved: 31 MAY 2005 16:36:22

1ch : IOUT

2ch
VOUT:50mV/div

20usec/div

PACKAGING INFORMATION

SOT-25 (SOT-23-5)
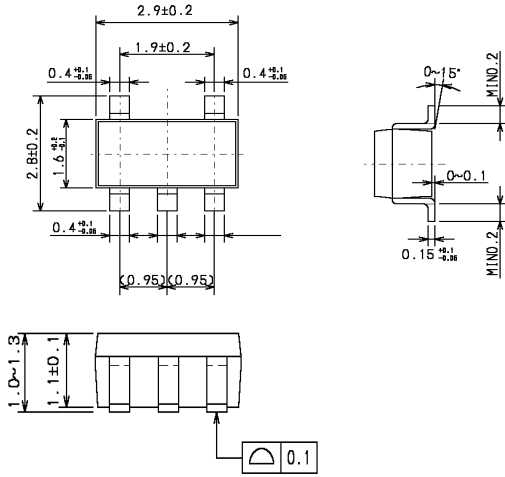
USP-6B

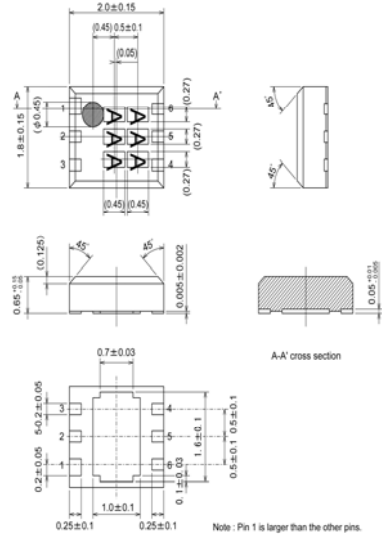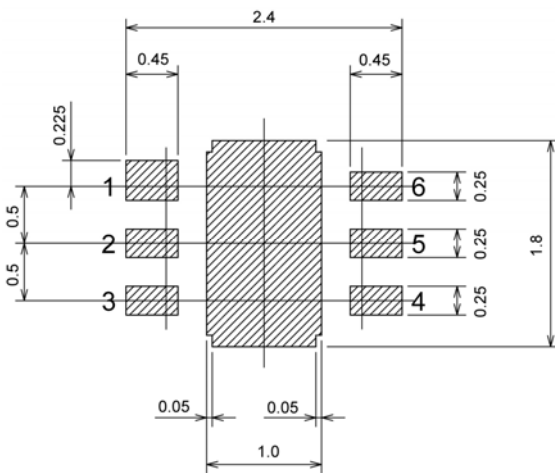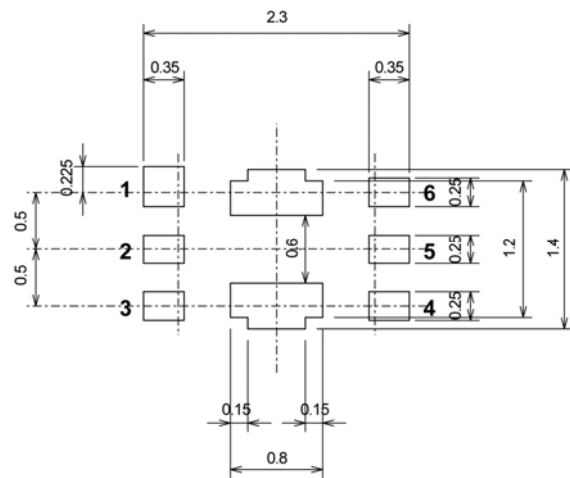USP-6B Reference Pattern Layout
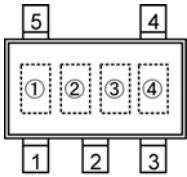
USP-6B Reference Metal Mask Design

MARKING RULE

SOT-25

SOT-25 (TOP VIEW)

Represents product series

MARK			PRODUCT SERIES
XC9225	XC9226	XC9227	
T	**U**	**V**	A
			B
T̄	Ū	V̄	C
			D
			E
T̿	Ū̄	V̿	F
			G
			H

Represents integer of output voltage

OUTPUT VOLTAGE (V)	MARK		
	A SERIES C SERIES F SERIES	B SERIES D SERIES G SERIES	E SERIES H SERIES
0.x	0̄	0̄	0̿
0.x5	A	Ā	Ā̄
1.x	1̄	1̄	1̿
1.x5	B	B̄	B̄̄
2.x	2̄	2̄	2̿
2.x5	C	C̄	C̄̄
3.x	3̄	3̄	3̿
3.x5	D	D̄	D̄̄
4.x	4̄	4̄	4̿

Represents decimal point of output voltage and oscillation frequency

OUTPUT VOLTAGE (V)	MARKING	
	OSC=600kHz	OSC=1.2MHz
x.0	0	A
x.05	0	A
x.1	1	B
x.15	1	B
x.2	2	C
x.25	2	C
x.3	3	D
x.35	3	D
x.4	4	E
x.45	4	E
x.5	5	F
x.55	5	F
x.6	6	H
x.65	6	H
x.7	7	K
x.75	7	K
x.8	8	L
x.85	8	L
x.9	9	M
x.95	9	M

Represents production lot number
0 to 9, A to Z, reversed character of 0 to 9 and A to Z repeated (G, I, J, O, Q, W excepted)

TOREX

19/21

MARKING RULE (Continued)

USP-6B
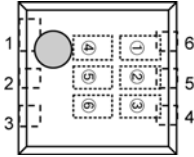
USP-6B (TOP VIEW)

Represents product series

MARK	PRODUCT SERIES
Z	XC9225xxxxxx
P	XC9226xxxxxx
R	XC9227xxxxxx

Represents the type of DC/DC converters

MARK	PRODUCT SERIES	MARK	PRODUCT SERIES
A	XC9225/26/27Axxxxx	E	XC9225/26/27Exxxxx
B	XC9225/26/27Bxxxxx	F	XC9225/26/27Fxxxxx
C	XC9225/26/27Cxxxxx	Z	XC9225/26/27Gxxxxx
D	XC9225/26/27Dxxxxx	H	XC9225/26/27Hxxxxx

Represents integer of output voltage

MARK	OUTPUT VOLTAGE (V)
0	0.xx
1	1.xx
2	2.xx
3	3.xx
4	4.xx

Represents decimal point of output voltage

MARK	OUTPUT VOLTAGE (V)	MARK	OUTPUT VOLTAGE (V)
0	x.00	A	x.05
1	x.10	B	x.15
2	x.20	C	x.25
3	x.30	D	x.35
4	x.40	E	x.45
5	x.50	F	x.55
6	x.60	H	x.65
7	x.70	K	x.75
8	x.80	L	x.85
9	x.90	M	x.95

Represents oscillation frequency

MARK	OSCILLATION FREQUENCY	PRODUCT SERIES
6	600kHz	XC9225/26/27xxx6xx
C	1.2MHz	XC9225/26/27xxxCxx

Represents production lot number
0 to 9 and A to Z repeated (G, I, J, O, Q, W excepted)

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