XC9215/ 9216/ 9217 Series

Synchronous Step-Down DC/DC Converters with 400mA Driver Transistor Built-In

Preliminary

July 31, 2003 Ver. 2

- Synchronous Step-Down DC/DC Converters
- High Efficiency : 90%
- Low Ripple Rejection : 10mV
- Output Current : 400mA
- Oscillation Frequency : 600kHz, 1.2MHz
- PWM/PFM Switching Control (XC9216)
- Manual Switching Control (XC9217)
- Maximum Duty Ratio : 100%
- Ceramic Capacitor Compatible
- Small Packages : SOT-25, USP-6B

APPLICATIONS

- Mobile phones (PDC, GSM, CDMA, IMT2000 etc.)
- Bluetooth equipment
- PDA, Portable communication modem
- Portable game
- Camera, Digital camera, Camcorder
- Cordless phone
- Note book computer

GENERAL DESCRIPTION

The XC9215/9216/9217 series is a group of synchronous-rectification type DC/DC converters with a built-in 0.6 Ω P-channel driver transistor and 0.7 Ω 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 400 mA to be configured using only a coil and two capacitors connected externally.

Minimum operating voltage of the series is 2.0 V. Output voltage is internally programmable in a range from 0.9 V to 4.0 V in increments of 0.1 V (accuracy: ± 2.0%). With the built-in oscillator, oscillation frequency is selectable from 600 kHz and 1.2MHz to make available the frequency best suited to your particular application.

Each series features different operation modes : PWM control (XC9215 series), automatic PWM/PFM switching control (XC9216 series), and manual PWM/PFM switching control (XC9217 series), 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 1.0 μA or less.

With the built-in U.V.L.O. (Under Voltage Lock Out) function, the internal P channel driver transistor is forced OFF when input voltage becomes 1.4 V or lower.

Two types of packages, 250 mW (SOT-25) and 100 mW (USP-6B), are available depending on applications.

FEATURES

Pch driver Tr. Built-in	: ON resistance 0.6Ω
Nch driver Tr. Built-in	: On resistance 0.7Ω (Synchronous)
Input Voltage Range	: 2.0V ~ 6.0V
Output Voltage Range	: 0.9V ~ 4.0V (0.1V step)
High Efficiency	: 90% (TYP.) <VIN=3.0V, VOUT=1.8V, IOUT=100mA>*
Output Current	: 400mA <VIN=3.0V, VOUT=1.8V>*
Oscillation Frequency	: 600kHz, 1.2MHz (Fixed oscillation frequency accuracy ±15%)

PWM/PFM control is selectable

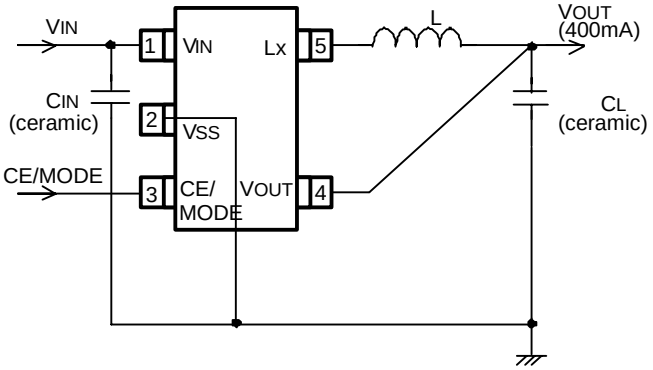
Soft start circuit built-in

Current Limiter Circuit built-in (Constant current + Latch)

Ceramic Capacitor Compatible

*The characteristic changes with external parts, substrate wiring, etc.

TYPICAL APPLICATION CIRCUIT



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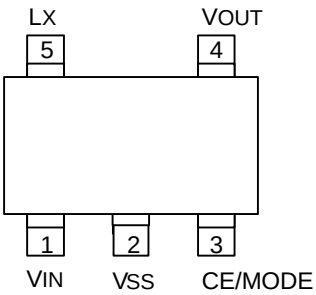
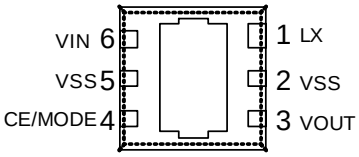
■ PIN CONFIGURATION



SOT-25 (TOP VIEW)



USP-6B (BOTTOM VIEW)

■ PIN ASSIGNMENT

PIN NUMBER		PIN NAME	FUNCTIONS
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

* Please short VSS pin (pin # 2, 5) when use.
* Recommended not to connect the heat dissipation board to any pin on the circuit. When connected to the circuit due to a problem of heat dissipation or mounting intensity, connect with the ground pin (PIN NUMBER 5).

■ PRODUCT CLASSIFICATION

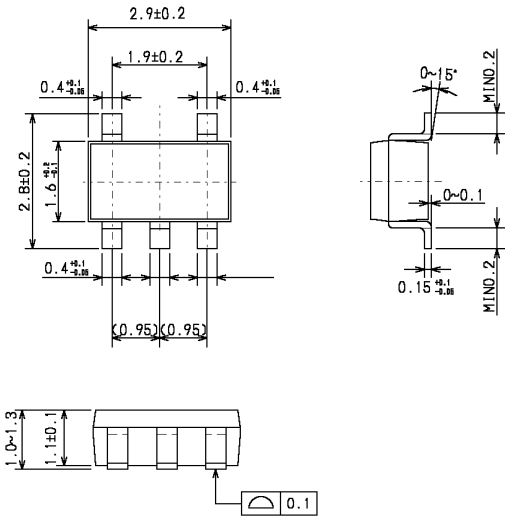
● Ordering Information

XC9215 ① ② ③ ④ ⑤ ⑥ : PWM Control (Synchronous)
XC9216 ① ② ③ ④ ⑤ ⑥ : PWM / PFM Automatic Switching Control
XC9217 ① ② ③ ④ ⑤ ⑥ : PWM control or PWM / PFM Manual Switching

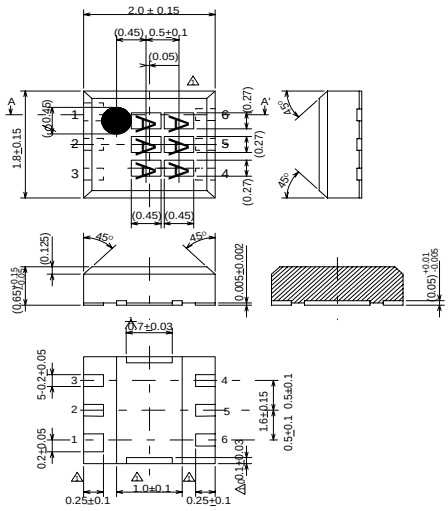
SYMBOL	DESCRIPTION
①	Transistor Built-in, Output voltage internally set (VOUT product), Soft start internally set. A : Current Limiter 700mA
②, ③	Denotes Output voltage : ex.) 1.5V Output ⇨ ② = 1, ③ = 5
④	Denotes Oscillation Frequency : 6 : 600kHz C : 1.2MHz
⑤	Denotes Package Types : M : SOT-25 D : USP-6B
⑥	Denotes Device Orientation : R : Embossed Tape : Standard Feed L : Embossed Tape : Reverse Feed

■ PACKAGING INFORMATION

❍ SOT-25



❍ USP-6B



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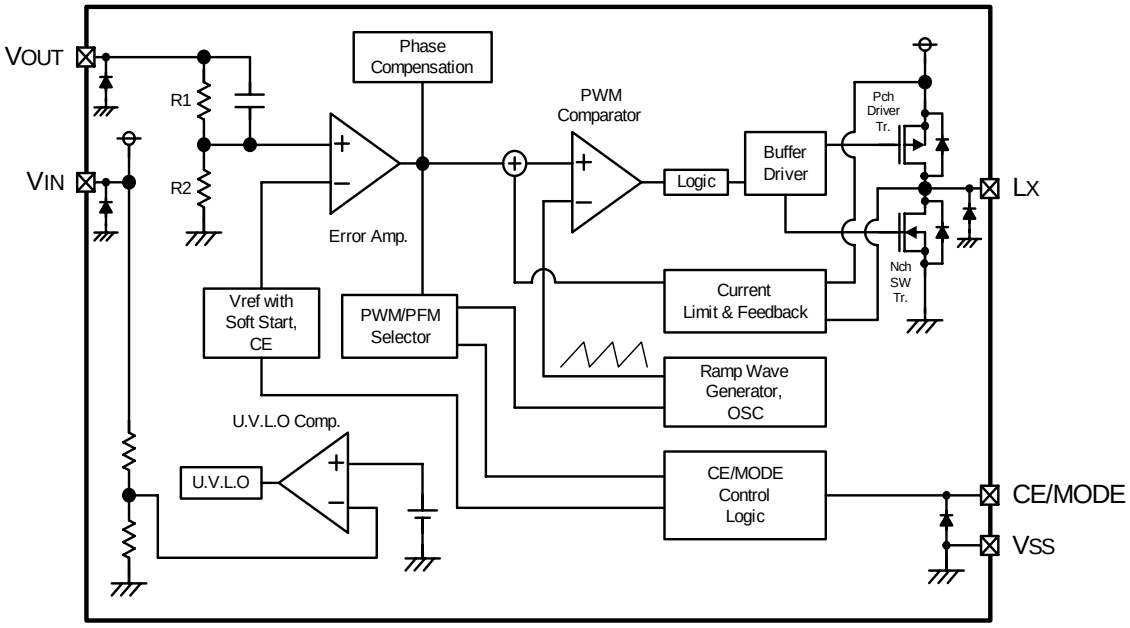
■ BLOCK DIAGRAM



Note) The signal from CE/MODE Control Logic to PWM/PFM Selector is being fixed to "L" level inside, and XC9215 series chooses PWM control.
The signal from CE/MODE Control Logic to PWM/PFM Selector is being fixed to "H" level inside, and XC9216 series chooses only PWM/PFM automatic switching control.

■ ABSOLUTE MAXIMUM RATINGS

Ta = 25°C

PARAMETER	SYMBOL	RATINGS		UNITS
VIN Pin Voltage	VIN	- 0.3 ~ + 6.5		V
Lx Pin Voltage	VLx	- 0.3 ~ VIN + 0.3		V
VOUT Pin Voltage	VOUT	- 0.3 ~ + 6.5		V
CE / MODE Pin Voltage	VCE	- 0.3 ~ VIN + 0.3		V
Lx Pin Current	ILx	± 1000		mA
Power Dissipation	Pd	SOT-25	250	mW
		UPS-6B	100	
Operational Ambient Temperature	Topr	- 40 ~ + 85		°C
Storage Temperature	Tstg	- 55 ~ + 125		°C

■ ELECTRICAL CHARACTERISTICS

XC9215A18CMx, XC9216A18CMx, XC9217A18CMx VOUT=1.8V, FOSC=1.2MHz, Ta=25°C

PARAMETER	SYMBOL	CONDITIONS	STANDARD VALUE			UNIT	CIRCUIT
			MIN	TYP	MAX		
Output Voltage	VOUT	When connected to ext. components CE=VIN, IOUT=30mA	1.764	1.800	1.836	V	①
Operating Voltage Range	VIN		2.0	-	6.0	V	①
Maximum Output Current	IOUTmax	When connected to ext. components	400	-	-	mA	①
U.V.L.O Voltage	VUVLO	CE=VIN, VOUT=0V, Voltage which Lx pin voltage holding "L" level (*1)	1.00	1.40	1.78	V	②
Supply Current 1	IDD	CE=VIN, VOUT=fixed voltage x 1.1V	-	70	-	μA	③
Stand-by Current	ISTB	CE=VSS, VOUT=fixed voltage x 1.1V	-	0	1.0	μA	③
Oscillation Frequency	FOSC	When connected to ext. components, PWM fixed control IOUT=100mA	1020	1200	1380	kHz	①
PFM switching current	IPFM	When connected to ext. components (XC9216, XC9217 only), CE=VIN, IOUT=1mA	-	140	-	mA	①
Maximum Duty Cycle	MAXDTY	CE=VIN, VOUT=0V	100	-	-	%	④
Minimum Duty Cycle	MINDTY	CE=VOUT=VIN	-	-	0	%	④
Efficiency (*2)	EFFI	When connected to ext. components VIN=CE=3.0V, IOUT=100mA	-	90	-	%	①
LX SW 'H' ON Resistance	RLxH	CE=0.5VIN, VOUT=0V, ILx=100mA (*3)	-	0.6	1.2	Ω	⑤
LX SW 'L' ON Resistance	RLxL		-	0.7	-	Ω	-
Current Limit	ILIM	VIN=CE=5.0V, VOUT=0V (*4)	-	700	-	mA	⑥
Output Voltage Temperature Characteristics	△VOUT / VOUT・△topr	IOUT=1mA -40°C≤Topr≤85°C	-	±100	-	ppm/°C	①
CE "H" Voltage	VCEH	VOUT=0V, When CE voltage is applied. LX determine "H"	0.9	-	VIN	V	⑦
CE "L" Voltage	VCEL	VOUT=0V, When CE voltage is applied. LX determine "Z"	VSS	-	0.3	V	⑦
PWM "H" Level Voltage	VPWMH	When connected to ext. components (XC9217 only) IOUT=1mA (*5)	-	-	VIN-1.0	V	①
PWM "L" Level Voltage	VPWML	When connected to ext. components (XC9217 only) IOUT=1mA (*5)	VIN-0.3	-	-	V	①
CE "H" Current	ICEH	VIN=CE=5.5V, VOUT=0V	-0.1	-	0.1	μA	⑦
CE "L" Current	ICEL	VIN=5.5V, CE=0V, VOUT=0V	-0.1	-	0.1	μA	⑦
Soft start time	TSS	When connected to ext. components CE=0V ⇨ VIN, IOUT=1mA	0.5	1.0	3.0	ms	①
Latch Time	Tlat	When connected to ext. components VIN=CE=5.0V, short VOUT by 1Ω resistance (*6)	1.0	-	20.0	ms	⑧

Test condition : Unless otherwise stated, VIN = 3.6V

*1 Including Hysteresis oprating voltage range.

*2 EFFI = [(Output Voltage x Output Current) / (Input Voltage x Input Current)] x 100

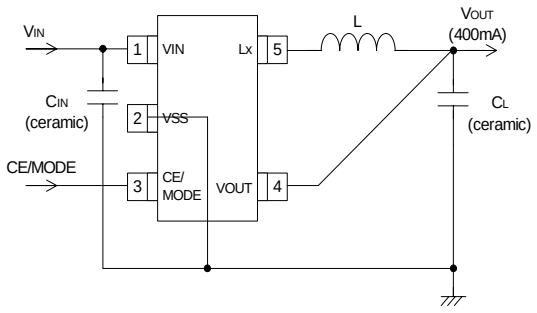
*3 On resistance = (VIN-VLX) / 100mA *VLX : measurement voltage

*4 When VIN is less than 2.4V, limit current may not be reached because voltage falls caused by ON resistance.

*5 The CE/MODE pin of the XC9217A series works as an external PWM control and PWM/PFM control switching pin. When the IC is in the operation, control is switched to the PWM mode when the CE/MODE pin voltage is equal to or greater than VIN minus 0.3 V, and to the automatic PWM/PFM switching mode when the CE/MODE pin voltage is equal to or lower than VIN minus 1.0 V, and is equal to or higher than VCEH.

*6 Time until it short-circuits VOUT with GND through 1 Ω of resistance from a state of operation and is set to VOUT=0V from current limit pulse generating.

■ TYPICAL APPLICATION CIRCUIT



* XC9216/17 series Wire Connection

❍ FOSC = 1.2MHz

L :	3.3μH	(CDRH3D16 SUMIDA)
CIN :	4.7μF	(Ceramic)
CL :	10μF	(Ceramic)

❍ FOSC = 600kHz

L :	6.8μH	(CDRH4D18C SUMIDA)
CIN :	4.7μF	(Ceramic)
CL :	10μF	(Ceramic)

■ NOTES ON USE

● Application Infromation

1. The XC9215/9216/9217 series are designed for use with an output ceramic capacitor. If, however, the potential difference between input and output 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. PWM fixed control or PWM/PFM automatic switching control are selectable for XC9217 series by using the CE/MODE pin.
3. Spike noise and ripple voltage arise in a switching regulator as with a DC/DC converter. These are greatly influenced by the 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.
4. Depending on the input-output voltage differential, or load current, some pulses may be skipped, and the ripple voltage may increase.
5. When the difference between VIN and VOUT is large is large and the load is light, very narrow pulses will be outputted, and there is the possibility that some cycles may be skipped completely.
6. When the difference between VIN and VOUT is low, and the load current is high, 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.
7. With the IC, the peak current of the coil is controlled by the current limit circuit. Since the peak current increases when the dropout voltage or load current is high, current limit starts operating, and this can lead to instability. When the 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 = (VIN - VOUT) x On Duty / (2 x L x FOSC) + IOUT

   L : Coil Inductance Value

   FOSC : Oscillation Frequency

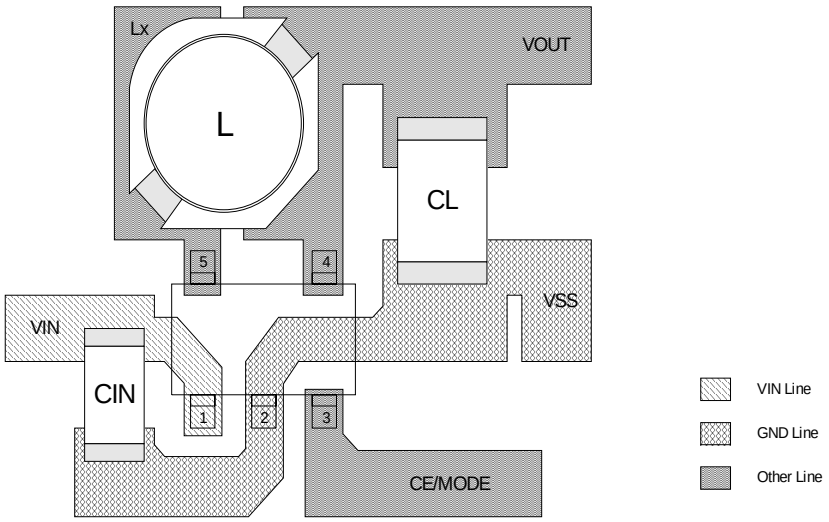
8. When the peak current which exceeds limit current flows within the specified time, the built-in Pch driver transistor is turned off. During the time until it detects limit current and before the built-in transistor can be turned off, the current for limit current flows; therefore, care must be taken when selecting the rating for the coil the schottky diode.
9. When VIN is less than 2.4V, limit current may not be reached because voltage falls caused by ON resistance.
10. 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.
11. Use of the IC at voltages below the recommended voltage range may lead to instability.
12. This IC should be used within the stated absolute maximum ratings in order to prevent damage to the device.

Preliminary

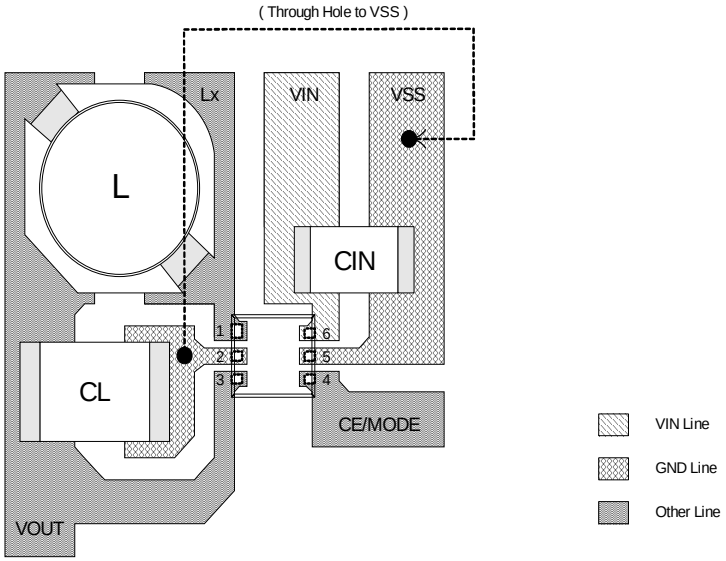
- Instructions on Pattern Layout
  1. In order to stabilize VDD's voltage level, we recommend that a by-pass capacitor (CIN) be connected as close as possible to the VIN & VSS pins.
  2. Please mount each external component as close to the IC as possible, and connect it to GND with the shortest possilble PCB traces.
  3. Wire external components as close to the IC as possible and use thick, short connecting PCB traces to reduce the circuit impedance.
  4. Make sure that the PCB GND traces are as think as possible, as variations in ground potential caused by high ground currents at the time of switching may result in instability.

- Pattern Layouts

  ❍ SOT-25



  ❍ USP-6B



■ OPERATIONAL EXPLANATION

Each unit of the XC9215/9216/9217 series consists of a reference voltage source, ramp wave circuit, error amplifier, PWM comparator, phase compensation circuit, output voltage adjustment resistors, P-channel MOS driver transistor, N-channel MOS synchronous rectification switch, current limiter circuit, U.V.L.O. circuit and others. The series ICs compare, using the error amplifier, the voltage of the internal voltage reference source with the feedback voltage from the VOUT pin through 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 ICs.

<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 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 XC9215/9216/9217 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.

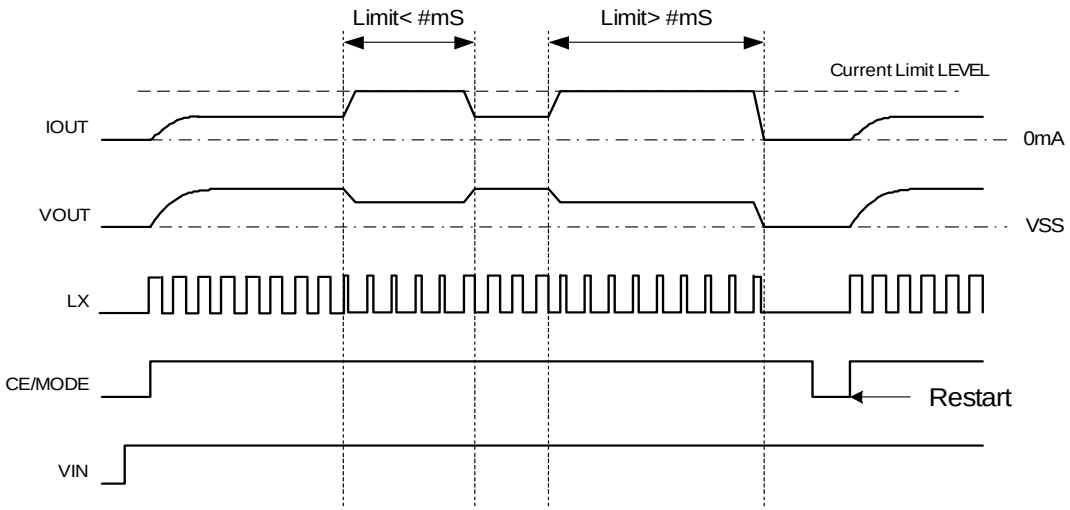
① When the driver current is greater than a specific level, the constant-current type current limit function operates to turn off the pulses from the LX pin at any given time.

② When the driver transistor is turned off, the limiter circuit is then released from the current limit detection state.

③ 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.

④ 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 ① through ③. If an over current state continues for several 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.
After being put into suspension mode, the IC can resume operation by turning itself off once and then starting it up using 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 can be set at 700 mA.

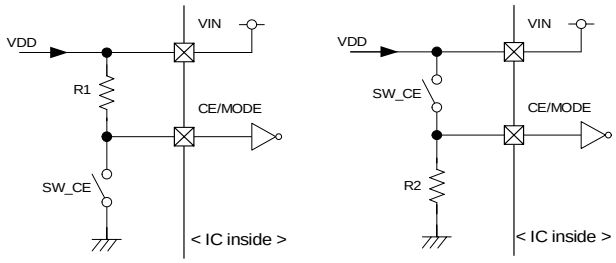


■ OPERATIONAL EXPLANATION (Continued)

<U.V.L.O. circuit>
When the VIN pin voltage becomes 1.4 V 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 VIN pin voltage becomes 1.8 V 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 VIN 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.

<CE/MODE Pin>
The XC9215/9216/9217 series will enter into shut down mode by inputting a low level signal to the CE/MODE pin. During shut down mode, the current consumption of the IC becomes 0 μA (TYP.), with a state of high impedance at the LX pin and VOUT pin. The IC starts its operation by inputting a high level signal to the CE/MODE pin. The input of the CE/MODE pin is a CMOS input and the sink current is 0 μA (TYP.).

● XC9215 / 16



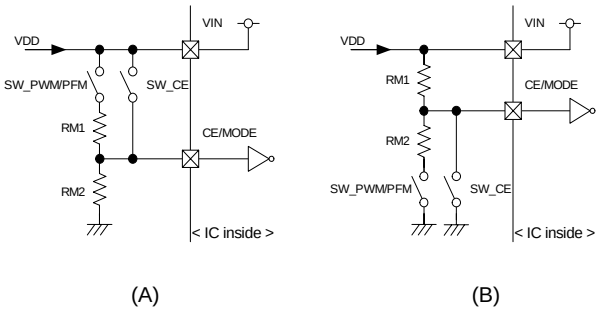
(A)

SW_CE	STATUS
ON	Chip Disable
OFF	Operation

(B)

SW_CE	STATUS
ON	Operation
OFF	Chip Disable

● XC9217



(A)

SW_CE	SW_PMW/PFM	STATUS
ON	*	PWM/PFM automatic switching control
OFF	ON	PWM control
OFF	OFF	Chip Disable

(B)

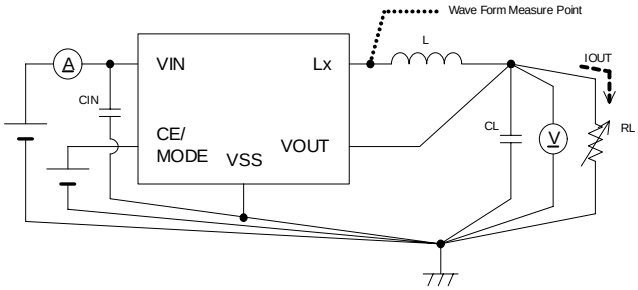
SW_CE	SW_PMW/PFM	STATUS
ON	*	Chip Disable
OFF	ON	PWM control
OFF	OFF	PWM/PFM automatic switching control

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

Preliminary

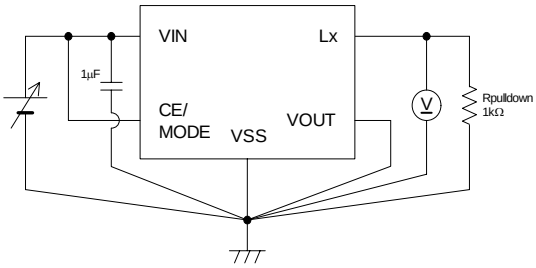
■ TEST CIRCUITS

Circuit ①

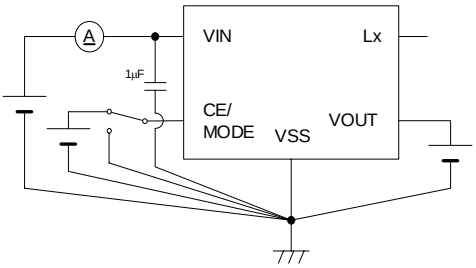


	1.2MHz	600kHz
CIN	4.7μF (Ceramic)	4.7μF (Ceramic)
CL	10μF (Ceramic)	10μF (Ceramic)
L	3.3μH	6.8μH

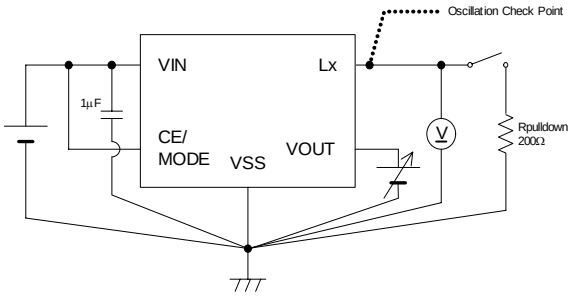
Circuit ②



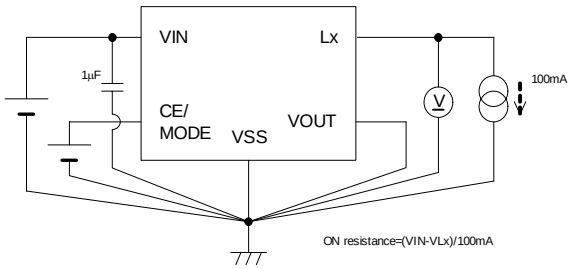
Circuit ③



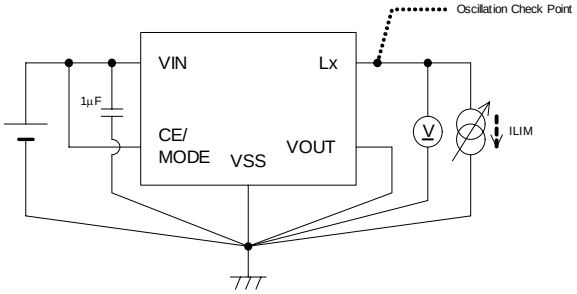
Circuit ④



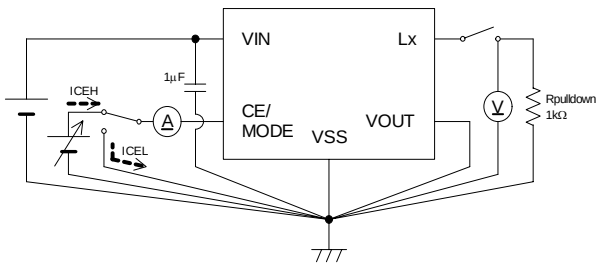
Circuit ⑤



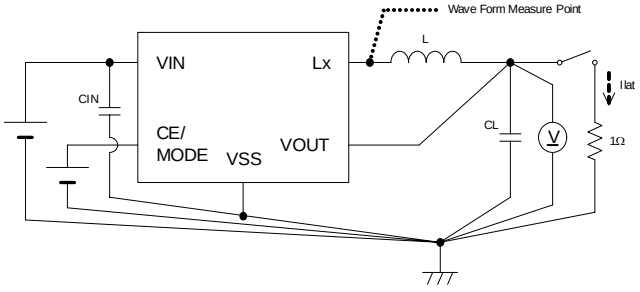
Circuit ⑥



Circuit ⑦



Circuit ⑧



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