XC9206/ 9207/ 9208 Series

PWM, PWM/PFM Switchable
Driver Transistor Built-In Step-Down DC/DC Converters

Preliminary

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- **P channel Driver Transistor Built-In**
- **Input Voltage Range : 1.8V ~ 6.0V**
- **Output Voltage Range : 0.9V ~ 4.0V**
- **Oscillation Frequency : 300kHz, 600kHz, 1.2MHz**
- **Output Current : 500mA**
- **Maximum Duty Ratio : 100%**
- **PWM/PFM Switching Control (XC9207 / XC9208)**
- **Ceramic Capacitor Compatible**
- **Small Packages : SOT-25**

■ Applications

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

■ General Description

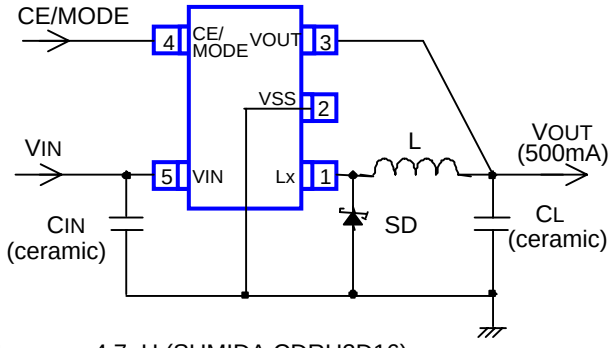
The XC9206/9207/9208 series is a group of DC/DC converters with a built-in 0.4 Ω P-channel driver transistor, offered in the SOT-25 package. The ICs are designed to allow the use of ceramic capacitors, and enable a high efficiency, and stable power supply with an output current of 500 mA, to be configured using only a coil, a diode and two capacitors connected externally.

Minimum operating voltage is 1.8 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 300 kHz, 600 kHz and 1.2 MHz to make available the frequency best suited to your particular application. Each series features different operation modes: PWM control (XC9206 series), automatic PWM/PFM switching control (XC9207 series) and manual PWM/PFM switching control (XC9208 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 0.5 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 1.6 V or lower.

■ Features

P ch driver Tr. Built-in : On resistance 0.4Ω
Output Voltage Range : 0.9V ~ 4.0V (0.1V step)
Fixed output voltage accuracy ±2%
Oscillation Frequency : 300kHz, 600kHz, 1.2MHz
Fixed oscillation frequency accuracy ±15%
Stand-by function : Istb = 0.5μA (max.)
Soft start circuit built-in
Current Limiter Circuit built-in : 600mA

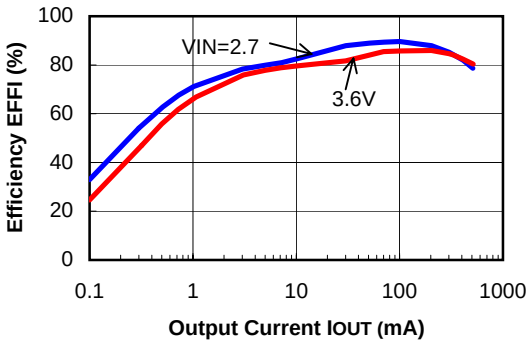
■ Typical Application Circuit



L : 4.7μH (SUMIDA CDRH3D16)
SD : CRS02 (TOSHIBA Schottky Diode)
CL : 10μH (Ceramic)
CIN : 4.7μH (Ceramic)

■ Electrical Characteristics XC9207A18C

Output Voltage 1.8V Fixed, FOSC : 1.2MHz
L=4.7μH (CDRH3D16), SD : CRS02
CIN=4.7μF (Ceramic), CL=10μF (Ceramic)



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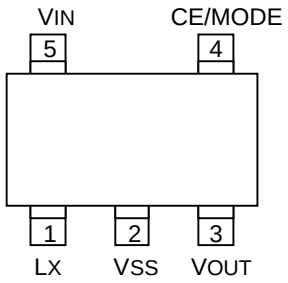
■ Pin Configuration



SOT-25
(Top View)

■ Pin Assignment

Pin Number	Pin Name	Functions
1	LX	Switching Output
2	VSS	Ground
3	VOUT	Output Voltage Sense
4	CE/MODE	Chip Enable Mode Switch
5	VIN	Power Input

■ Product Classification

● Ordering Information

XC9206 ① ② ③ ④ ⑤ ⑥ : PWM Control (Synchronous)
XC9207 ① ② ③ ④ ⑤ ⑥ : PWM / PFM Automatic Switching Control
XC9208 ① ② ③ ④ ⑤ ⑥ : PWM / PFM Manual Switching
(PWM Control : CE="H", PWM / PFM Automatic Control : CE = "M")

Symbol	Description
①	Transistor Built-in, Output voltage Internally set (VOUT product), Soft start Internally set. A : Current Limiter 600mA
②, ③	Denotes Output voltage : ex.) 1.5V Output ⇨ ② = 1, ③ = 5
④	Denotes Oscillation Frequency : 3 : 300kHz 6 : 600kHz C : 1.2MHz
⑤	Denotes Package Types : M : SOT-25
⑥	Denotes Device Orientation : R : Embossed Tape : Standard Feed L : Embossed Tape : Reverse Feed

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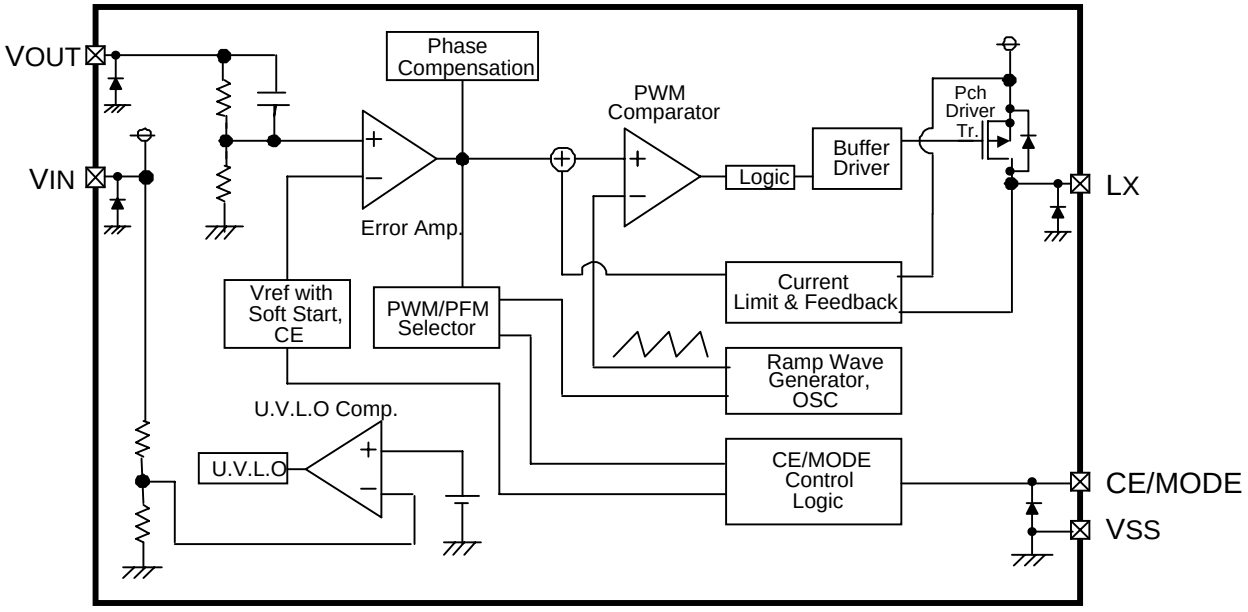
■ Block Diagram



■ Absolute Maximum Ratings

Ta = 25°C

Parameter	Symbol	Ratings	Units
VIN pin voltage	VIN	- 0.3 ~ + 6.5	V
VSS pin voltage	VSS	- 0.3 ~ + 6.5	V
Lx pin voltage	VLX	- 0.3 ~ + 6.5	V
VOUT pin voltage	VOUT	- 0.3 ~ + 6.5	V
CE / MODE pin voltage	VCE	- 0.3 ~ + 6.5	V
Lx pin current	ILX	± 800	mA
Power Dissipation	Pd	250	mW
Operational Ambient Temperature	Topr	- 40 ~ + 85	°C
Storage Temperature	Tstg	- 40 ~ + 125	°C

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■ Electrical Characteristics

XC9206A18CMR, XC9207A18CMR, XC9208A18CMR V_{OUT}=1.8V, FOSC=1.2MHz, Ta=25°C

Parameter	Symbol	Test Conditions		Min.	Typ.	Max.	Units
Output Voltage	V_{OUT1}	When connected to ext. components I_{OUT}=30mA		1.764	1.800	1.836	V
Max. Input Voltage	V_{INmax}			5.5			V
Min. Operating Voltage	V_{INmin}					1.8	V
U.V.L.O Voltage	V_{UVLO}	Voltage which LX pin voltage holding "L" level			1.4		V
Max. Output Current	I_{OUTmax}	When connected to ext. components		500			mA
Quiescent Current	I_{IN}	When connected to ext. components	PWM		170		μA
		No Load	PFM		200		
Supply Current 1	I_{DD1}	No ext. components, CE=V_{IN}, V_{OUT}=fixed voltage x 0.9			280		μA
Supply Current 2	I_{DD2}	No ext. components, CE=V_{IN}, V_{OUT}=fixed voltage x 1.1			120		μA
Stand-by Current	I_{STB}	No ext. components, CE=V_{OUT}=0V				0.5	μA
Oscillation Frequency	FOSC	When connected to ext. components I_{OUT}=30mA		1.020	1.200	1.380	MHz
Max. Duty Cycle	MAXDTY	V_{OUT}=V_{SS}		100			%
Min. Duty Cycle	MINDTY	V_{OUT}=V_{IN}				0	%
PFM pulse width rate * 2	PFMDTY	When connected to ext. components / No load			25		%
Efficiency *3	EFFI	I_{OUT}=100mA			85		%
LX SW On Resistance *4	R_{LX}	CE=V_{IN}, I_{LX}=400mA, V_{OUT}=fixed vol. x 0.9			0.4		Ω
Current Limit	I_{LIM}	V_{IN}=3.6V			600		mA
CE "H" Voltage	V_{CEH}	No Ext. components When CE/MODE voltage is applied, LX determine "H"			1.2		V
PWM "H" Voltage *5	V_{PWMH}	When connected to ext. components, I_{OUT}=1mA			V_{IN} - 0.2		V
PWM "L" Voltage *5	V_{PWML}	When Connected to ext. components, I_{OUT}=1mA			V_{IN} - 1.0		V
CE "L" Voltage	V_{CEL}	No Ext. components When CE/MODE voltage is applied, LX determine "L"		V_{SS}		0.3	V
CE "H" Current	I_{CEH}	CE=V_{IN}=5.5V, V_{OUT}=0V		- 0.1		0.1	μA
CE "L" Current	I_{CEL}	CE=0V, V_{IN}=5.5V, V_{OUT}=0V		- 0.1		0.1	μA
Soft start time	TSS	When connected to ext. components CE=0V ⇨ 2.4V			10		ms

*1 Unless otherwise stated, V_{IN} = 3.6V

*2 PFM pulse width rate applies only to XC9207 and XC9208 series.

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

*4 On resistance = V_{LX} (measurement voltage) / 0.4A

*5 The CE/MODE pin of the XC9208 series works also as an external PWM/PFM control switching pin. When the IC is in operation, control is switched to the PWM mode when the CE/MODE pin voltage is equal to or higher than V_{IN} minus 0.2 V, and to the automatic PWM/PFM switching mode when the CE/MODE pin voltage is equal to or lower than V_{IN} minus 1.0 V and equal to or higher than V_{CEH}.

■ Electrical Characteristics

XC9206A28CMR, XC9207A28CMR, XC9208A28CMR VOUT=2.8V, FOSC=1.2MHz, Ta=25°C

Parameter	Symbol	Test Conditions		Min.	Typ.	Max.	Units
Output Voltage	VOUT1	When connected to ext. components IOUT=30mA		2.744	2.800	2.856	V
Max. Input Voltage	VINmax			5.5			V
Min. Operating Voltage	VINmin					1.8	V
U.V.L.O Voltage	VUVLO	Voltage which LX pin voltage holding "L" level			1.4		V
Max. Output Current	IOUTmax	When connected to ext. components		500			mA
Quiescent Current	IIN	When connected to ext. components No Load	PWM		160		µA
			PFM		180		
Supply Current 1	IDD1	No ext. components, CE=VIN, VOUT=fixed voltage x 0.9			280		µA
Supply Current 2	IDD2	No ext. components, CE=VIN, VOUT=fixed voltage x 1.1			120		µA
Stand-by Current	ISTB	No ext. components, CE=VOUT=0V				0.5	µA
Oscillation Frequency	FOSC	When connected to ext. components IOUT=30mA		1.020	1.200	1.380	MHz
Max. Duty Cycle	MAXDTY	VOUT=VSS		100			%
Min. Duty Cycle	MINDTY	VOUT=VIN				0	%
PFM pulse width rate * 2	PFMDTY	When connected to ext. components / No load			25		%
Efficiency *3	EFFI	IOUT=100mA			90		%
LX SW On Resistance *4	RLX	CE=VIN, ILX=400mA, VOUT=fixed vol. x 0.9			0.4		Ω
Current Limit	ILIM	VIN=3.6V			600		mA
CE "H" Voltage	VCEH	No Ext. components When CE/MODE voltage is applied, LX determine "H"			1.2		V
PWM "H" Voltage *5	VPWMH	When connected to ext. components, IOUT=1mA			VIN - 0.2		V
PWM "L" Voltage *5	VPWML	When connected to ext. components, IOUT=1mA			VIN - 1.0		V
CE "L" Voltage	VCEL	No Ext. components When CE/MODE voltage is applied, LX determine "L		VSS		0.3	V
CE "H" Current	ICEH	CE=VIN=5.5V, VOUT=0V		- 0.1		0.1	µA
CE "L" Current	ICEL	CE=0V, VIN=5.5V, VOUT=0V		- 0.1		0.1	µA
Soft start time	TSS	When connected to ext. components CE=0V ⇨ 2.4V			10		ms

*1 Unless otherwise stated, VIN = 3.6V

*2 PFM pulse width rate applies only to XC9207 and XC9208 series.

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

*4 On resistance = VLX (measurement voltage) / 0.4A

*5 The CE/MODE pin of the XC9208 series works also as an external PWM/PFM control switching pin. When the IC is in operation, control is switched to the PWM mode when the CE/MODE pin voltage is equal to or higher than VIN minus 0.2 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 equal to or higher than VCEH.

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XC9206A33CMR, XC9207A33CMR, XC9208A33CMR VOUT=3.3V, FOSC=1.2MHz, Ta=25°C

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Output Voltage	VOUT1	When connected to ext. components IOUT=30mA	3.234	3.300	3.366	V
Max. Input Voltage	VINmax		5.5			V
Min. Operating Voltage	VINmin				1.8	V
U.V.L.O Voltage	VUVLO	Voltage which LX pin voltage holding "L" level		1.4		V
Max. Output Current	IOUTmax	When connected to ext. components	500			mA
Quiescent Current	IIN	When connected to ext. components PWM		170		µA
		No Load PFM		200		
Supply Current 1	IDD1	No ext. components, CE=VIN, VOUT=fixed voltage x 0.9		380		µA
Supply Current 2	IDD2	No ext. components, CE=VIN, VOUT=fixed voltage x 1.1		140		µA
Stand-by Current	ISTB	No ext. components, CE=VOUT=0V			0.5	µA
Oscillation Frequency	FOSC	When connected to ext. components IOUT=30mA	1.020	1.200	1.380	MHz
Max. Duty Cycle	MAXDTY	VOUT=VSS	100			%
Min. Duty Cycle	MINDTY	VOUT=VIN			0	%
PFM pulse width rate * 2	PFMDTY	When connected to ext. components / No load		25		%
Efficiency *3	EFFI	IOUT=100mA		90		%
LX SW On Resistance *4	RLXH	CE=VIN, ILX=400mA, VOUT=fixed vol. x 0.9		0.4		Ω
Current Limit	ILIM	VIN=3.6V		600		mA
CE "H" Voltage	VCEH	No Ext. components When CE/MODE voltage is applied, LX determine "H"		1.2		V
PWM "H" Voltage *5	VPWMH	When connected to ext. components, IOUT=1mA		VIN - 0.2		V
PWM "L" Voltage *5	VPWML	When connected to ext. components, IOUT=1mA		VIN - 1.0		V
CE "L" Voltage	VCEL	No Ext. components When CE/MODE voltage is applied, LX determine "L"	VSS		0.3	V
CE "H" Current	ICEH	CE=VIN=5.5V, VOUT=0V	- 0.1		0.1	µA
CE "L" Current	ICEL	CE=0V, VIN=5.5V, VOUT=0V	- 0.1		0.1	µA
Soft start time	TSS	When connected to ext. components CE=0V ⇨ 2.4V		10		ms

*1 Unless otherwise stated, VIN = 5.0V

*2 PFM pulse width rate applies only to XC9207 and XC9208 series.

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

*4 On resistance = VLX (measurement voltage) / 0.4A

*5 The CE/MODE pin of the XC9208 series works also as an external PWM/PFM control switching pin. When the IC is in operation, control is switched to the PWM mode when the CE/MODE pin voltage is equal to or higher than VIN minus 0.2 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 equal to or higher than VCEH.

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■ Operational Explanation

Each unit of the XC9206/07/08 series consists of a reference voltage source, ramp wave circuit, error amplifier, PWM comparator, phase compensation circuit, output voltage adjustment resistors, driver transistor, current limiter circuit, U.V.L.O. circuit and others. The XC9206/07/08 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 switching-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 rate. 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 the error amplifier output signal is modulated as a multiple feedback signal. This enables a stable feedback loop even when a low ESR capacitor, such as a ceramic capacitor, is used, ensuring stable output voltage.

< Reference Voltage Source >

The reference voltage source provides the reference voltage to ensure stable output voltage of the ICs.

< Ramp Wave Circuit >

The ramp wave circuit determines switching frequency. The frequency is fixed internally, and selectable from 300 kHz, 600 kHz and 1.2 MHz. 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 XC9206/07/08 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.

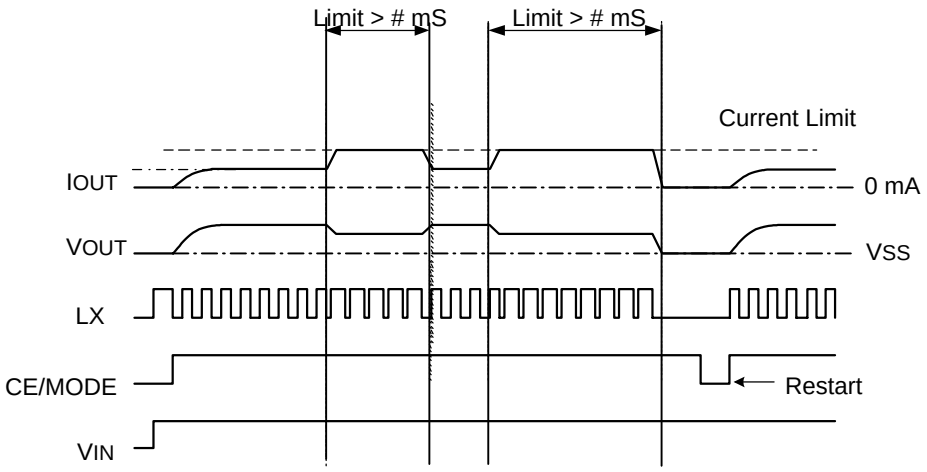
① When the driver current is greater than a specific level, the constant-current type current limit function operates to turn off the pulses from the LX pin at any given timing.

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 overcurrent state.

④ When the overcurrent state is eliminated, the IC resumes normal operation.

The IC waits for the overcurrent state to end by repeating the steps ① through ③ . If an overcurrent 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 the IC 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 600 mA.



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■ Operational Explanation

< U.V.L.O. circuit>

When the VIN pin voltage becomes 1.6 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.

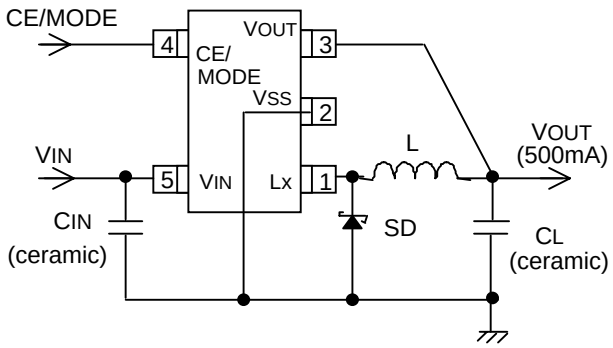
< Function of CE/MODE pin >

The XC9206/07/08 series can be triggered into a shutdown state by inputting a low level signal to the CE/MODE pin. During a shutdown state, current consumption of the IC is 0 mA (typically), and the LX and VOUT pins have high impedance. Input of a high level signal to the CE/MODE pin causes the IC to start up. The CE/MODE pin provides CMOS input. Sink current is 0 mA (typically).

< PWM / PFM >

Each series features different control modes: PWM control (XC9206 series), automatic PWM/PFM switching control (XC9207 series) and manual PWM/PFM switching control (XC9208 series).
Employing PWM control mode only, the XC9206 series is controlled with a constant frequency over a wide range of load conditions extending from light to heavy. Constant frequency operation makes it easier to configure a filter in the case of, for example, noise problems, but may decrease efficiency under light load conditions.
With the automatic PWM/PFM switching control function, the XC9207 series ICs are automatically switched from PWM control to PFM control mode under light load conditions. If during light load conditions the coil current becomes discontinuous and on-time rate falls and approaches 25%, the PFM circuit operates to output from the LX pin a pulse with an on-time rate fixed at 25%. During the PFM operation with fixed on-time rate, pulses are generated at different frequencies according to conditions of the moment. This causes a reduction in the number of switching operations per unit of time, resulting in efficiency improvement under light load conditions. However, since pulse output frequency is not constant, consideration should be given if a noise filter or the like is needed. Necessary conditions for switching to PFM operation depend on input voltage, load current, coil value and other factors.
Featuring the manual PWM/PFM switching control, the XC9208 series can be switched between the PWM control mode and the automatic PWM/PFM switching control mode at any timing. The selection of PFM control mode is not available. The ICs can be fixed to constant frequency operation mode as necessary, enabling noise control and/or the like, as well as high efficiency during PFM control under light load conditions.

■ Electrical Characteristics



① FOSC=1.2MHz product
L : 4.7μH (SUMIDA CDRH3D16)
SD : CRS02 (TOSHIBA schottky diode)
CL : 10μH (ceramic)
CIN : 4.7μH (ceramic)

② FOSC=600kHz product
L : 10μH (SUMIDA CDRH4D18C)
SD : CRS02 (TOSHIBA schottky diode)
CL : 10μH (ceramic)
CIN : 4.7μH (ceramic)

③ FOSC=300kHz product
L : 22μH (SUMIDA CDRH5D18)
SD : CRS02 (TOSHIBA schottky diode)
CL : 10μH (ceramic)
CIN : 4.7μH (ceramic)