XC9509 Series

Synchronous Step-Down DC/DC Converter with Built-In LDO Regulator in Parallel plus Voltage Detector

- ◆ Input Voltage Range 2.4V ~ 6.0V
- ◆ Output Voltage Range DC/DC 0.9 ~ 4.0V (±2%)
  VR 0.9 ~ 4.0V (±2%)
  VD 0.9 ~ 5.0V (±2%)
- ◆ Switching Frequency 300kHz, 600kHz, 1.2MHz
- ◆ Output Current DC/DC 600mA
  VR 200mA
- ◆ Ultra Small Packages MSOP-10, USP-10
- ◆ Ceramic Capacitor Compatible

■ APPLICATIONS

- HDD
- CD-R / RW, DVD
- PDAs, portable communication modem
- Cellular phones
- Palmtop computers
- Cameras, video recorders

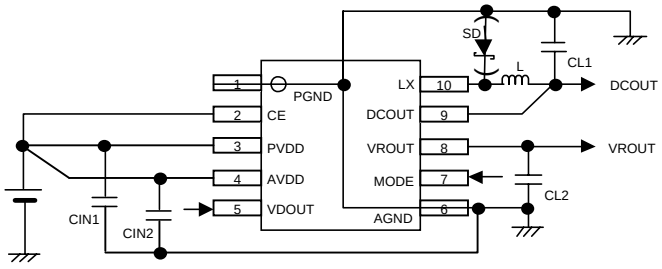
■ GENERAL DESCRIPTION

The XC9509 series consists of a step-down DC/DC converter and a high-speed LDO regulator connected in parallel with the DC/DC converter's output. A voltage detector is also built-in. Since the input for the LDO voltage regulator block comes from the input power supply, it is suited for use with various applications.
The DC/DC converter block incorporates a P-Channel driver transistor and a synchronous N-Channel switching transistor. With an external coil, diode and two capacitors, the XC9509 can deliver output currents up to 600mA at efficiencies over 90%. The XC9509 is designed for use with small ceramic capacitors.
A choice of three switching frequencies are available, 300 kHz, 600 kHz, and 1.2 MHz.
Output voltage settings for the DC/DC and VR are set-up internally in 0.1V steps within the range of 0.9V to 4.0V (± 2.0%). For the VD, the range is of 0.9V to 5.0V (± 2.0%).
The soft start time of the series is internally set to 5ms. 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.
The functions of the MODE pin can be selected via the external control pin to switch the DC/DC control mode and the disable pin to shut down either the DC/DC block or the regulator block.

■ FEATURES

Input Voltage Range :	2.4V ~ 6.0V
Load Capacitors :	Ceramic Capacitors Compatible
	(Low ESR Capacitors)
VD Function :	Sense internally either
	VDD, DCOUT, or VROUT.
	Nch Open Drain Output
<DC/DC Converter>	
Output Voltage Range :	0.9 ~ 4.0V (±2%)
Output Current :	600mA
Controls :	PWM Control PWM, PWM / PFM Automatic Switching External
Oscillation Frequency :	300kHz, 600kHz, 1.2MHz
<Regulator>	
Output Voltage Range :	0.9 ~ 4.0V (±2%)
Current Limit	300mA
Dropout Voltage :	80mV @ IOUT=100mA (VOUT=2.8V)
High Ripple Rejection	60dB @1kHz (VOUT=2.8V)

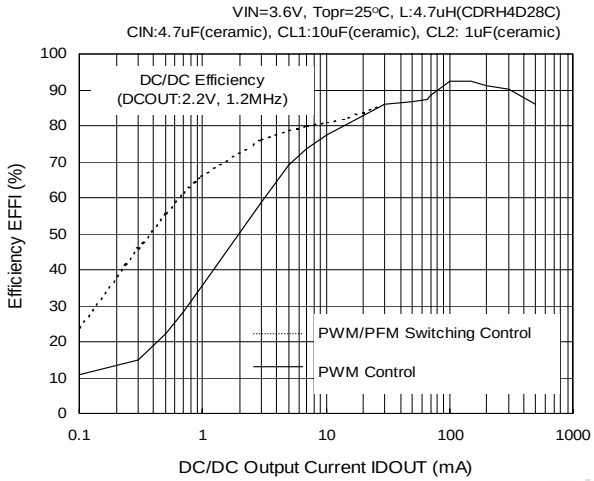
■ TYPICAL APPLICATION CIRCUIT



MSOP-10
(TOP VIEW)

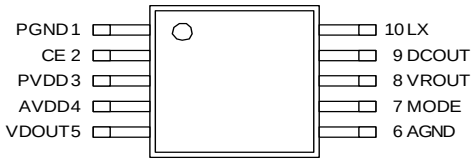
■ TYPICAL PERFORMANCE CHARACTERISTICS

XC9509Hxxxx

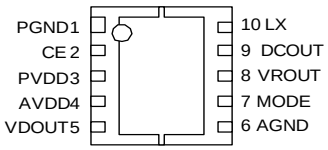


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■ PIN CONFIGURATION



MSOP-10(TOP VIEW)



USP-10(TOP VIEW)

■ PIN ASSIGNMENT

PIN NUMBER	PIN NAME	FUNCTION
1	PGND	Power Ground
2	CE	Chip Enable
3	PVDD	Power Supply 1
4	AVDD	Power Supply 2
5	VDOUT	VD Input
6	AGND	Analog Ground
7	MODE	Mode Switch
8	VROUT	VR Output
9	DCOUT	DC/DC Output
10	LX	Switch

■ SELECTION GUIDE

● Ordering Information

XC9509 ①②③④⑤⑥ The input for the voltage regulator block comes from VDD.

DESIGNATOR	SYMBOL	DESCRIPTION
①		Control Methods, the MODE pin, the VD Sense pin (See the chart below)
②③		Setting voltage and specifications of each DC/DC, VR, and VD (Based on the internal standard)
④		Oscillation Frequency of DC/DC :
	3	300kHz
	6	600kHz
	C	1.2MHz
⑤		Package Type :
	A	MSOP-10
	D	USP-10
⑥		Device Orientation :
	R	Embossed Tape : Standard Feed
	L	Embossed Tape : Reverse Feed

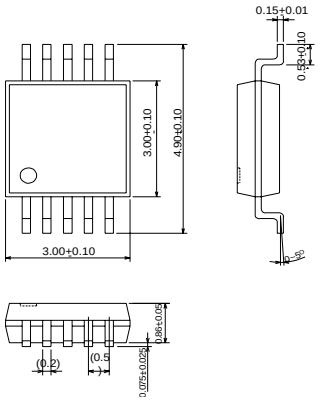
❍ Control Methods, MODE Pins, and VD SENSE Pins

SERIES	①	DC/DC CONTROL METHODS	MODE PINS (H LEVEL)	MODE PINS (L LEVEL)	VD SENSE
XC9509	A	PWM Control	VR : OFF	VR : ON	VDD
	B				DCOUT
	C				VROUT
	D		DC/DC : OFF	DC/DC : ON	VDD
	E				DCOUT
	F				VROUT
	H	PWM, PFM/PWM Manual Switch	PFM/PWM Auto Switch	PWM Control	VDD
	K				DCOUT
	L				VROUT

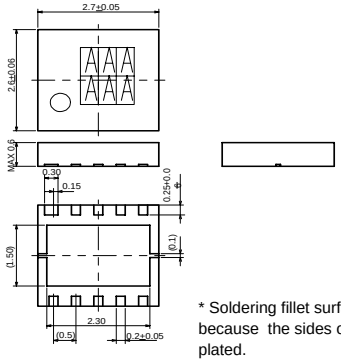
* The XC9509A to F series' MODE pin switches either the regulator block or DC/DC block to stand-by mode.
When the CE mode is off, every function except for the VD function enters into stand-by mode.
(The MODE pin does not operate independently.)

■ PACKAGING INFORMATION

❍ MSOP-10

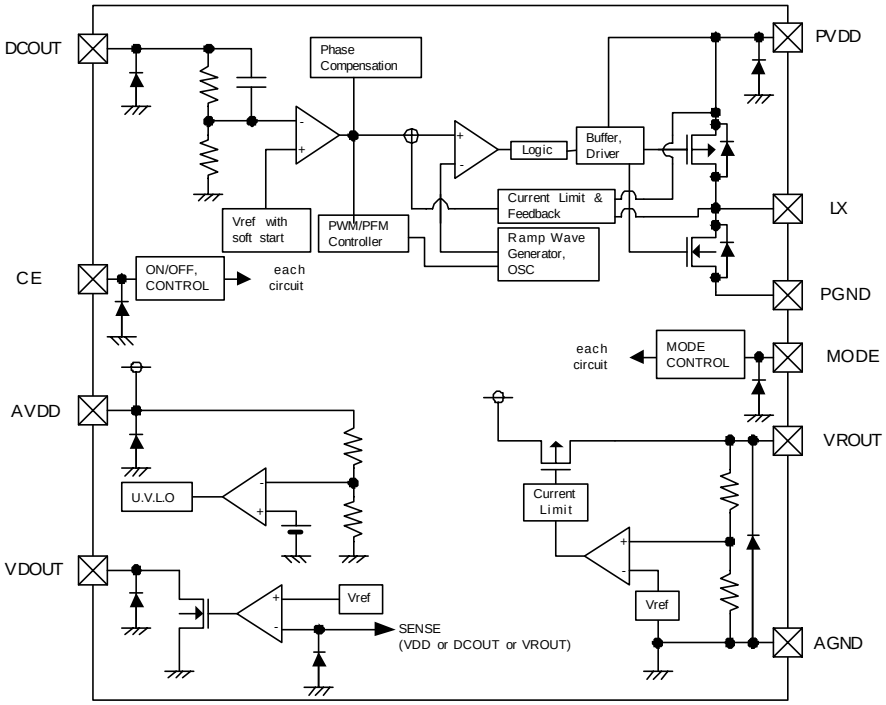


❍ USP-10



* Soldering fillet surface is not formed because the sides of the pins are not plated.

■ BLOCK DIAGRAM



* Diodes shown in the above circuits are protective diodes.

■ ABSOLUTE MAXIMUM RATINGS

Ta=25°C

PARAMETER	SYMBOL	RATINGS	UNITS
AVDD Pin Voltage	AVDD	- 0.3 ~ 6.5	V
PVDD Pin Voltage	PVDD	- 0.3 ~ VDD + 0.3	V
DCOUT Pin Voltage	DCOUT	- 0.3 ~ VDD + 0.3	V
VROUT Pin Voltage	VROUT	- 0.3 ~ VDD + 0.3	V
VDOUT Pin Voltage	VDOUT	- 0.3 ~ VDD + 0.3	V
LX Pin Voltage	LX	- 0.3 ~ VDD + 0.3	V
CE Pin Voltage	CE	- 0.3 ~ VDD + 0.3	V
MODE Pin Voltage	MODE	- 0.3 ~ VDD + 0.3	V
Continuous Power Dissipation (*1) MSOP-10	Pd	350	mW
Continuous Power Dissipation (*1) USP-10	Pd	120 (*2)	mW
Operating Temperature Range	Topr	- 40 ~ + 85	°C
Storage Temperature Range	Tstg	- 55 ~ + 125	°C

(*1) IOUT = Pd / (VIN - VOUT) when PC board mounting.

(*2) Package power dissipation

■ ELECTRICAL CHARACTERISTICS

XC9509HxxCAx

❍ Common Characteristics

Ta=25°C

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	TEST CIRCUIT
Supply Current 1	IDD1	VIN=CE=DCOUT=5.0V	-	300	-	μA	①
Supply Current 2	IDD2	VIN=CE=5.0V, DCOUT=0V	-	240	-	μA	①
Stand-by Current (note 1)	ISTB	VIN=6.5V, CE=0V	-	0.6	2.5	μA	①
Input Voltage Range	VIN		2.4	-	6.0	V	-
U.V.L.O. Voltage (note 2)	VUVLO		1.00	1.40	1.78	V	③
CE 'H' Level Voltage	VCEH		0.6	-	VDD	V	③
CE 'L' Level Voltage	VCEL		VSS	-	0.25	V	③
CE 'H' Level Current	ICEH		- 0.1	-	0.1	μA	①
CE 'L' Level Current	ICEL		- 0.1	-	0.1	μA	①
MODE 'H' Level Voltage	VMH		0.6	-	VDD	V	③
MODE 'L' Level Voltage	VML		VSS	-	0.25	V	③
MODE 'H' Level Current	IMH		- 0.1	-	0.1	μA	①
MODE 'L' Level Current	IML		- 0.1	-	0.1	μA	①

❍ DC/DC Converter (2.2V product)

Ta=25°C

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	TEST CIRCUIT
Output Voltage	DCOUT	Connected to the external components, IDOUT=30mA	2.156	2.200	2.244	V	③
Oscillation Frequency	FOSC	Connected to the external components, IDOUT=10mA	1.02	1.20	1.38	MHz	③
Maximum Duty Ratio	MAXDUTY	DCOUT=0V	100	-	-	%	④
Manimum Duty Ratio	MINDUTY	DCOUT=VIN	-	-	0	%	④
PFM Duty Ratio	PFMDUTY	Connected to the external components, No Load	21	30	38	%	③
LX SW 'High' On Resistance (note 3)	RLXH	DCOUT=0V, LX=VIN-0.05V	-	0.5	-	Ω	⑤
LX SW 'Low' On Resistance	RLXL		-	0.5	-	Ω	
Maximum Output Current	IMAX1		600	-	-	mA	③
Current Limit	ILIM1		-	1.2	-	A	⑥
Efficiency (note 4)	EFFI	Connected to the external components, IDOUT=100mA	-	90	-	%	③
Output Voltage Temperature Characteristics	△VOUT / △Topr • VOUT	IDOUT=30mA -40°C≦Topr≦85°C	-	±100	-	ppm /°C	③
Soft Start Time	TSS	Connected to the external components, CE=0V⇨VIN, IDOUT=1mA	-	5	-	mS	③
Latch Time (note 5)	Tlat	Connected to the external components, VIN=CE=5.0V, Short DCOUT by 1Ω resistor	-	8	-	mS	③

❍ Regulator (1.8V product)

Ta=25°C

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	TEST CIRCUIT
Output Voltage	VROUT(E)	IROUT=30mA	1.764	1.800	1.836	V	②
Maximum Output Current	IMAX2		200	-	-	mA	②
Load Regulation	△VROUT	1mA≦IROUT≦100mA	-	15	50	mV	②
Dropout Voltage 1 (note 6)	Vdif 1	IROUT=30mA	-	30	-	mV	②
Dropout Voltage 2	Vdif 2	IROUT=100mA	-	85	-	mV	②
Line Regulation	△VOUT / △VIN • VOUT	IROUT=30mA VROUT(T)+1V≦VIN≦6V	-	0.2	-	%/V	②
Current Limit	ILIM2	VROUT=VROUT(E)x0.9	-	300	-	mA	⑦
Short-Circuit Current	ISHORT	VROUT=VSS	-	30	-	mA	⑦
Ripple Rejection Rate	PSRR	VIN={VOUT(T) + 1.0} VDC + 0.5Vp-pAC IROUT=30mA, f=1kHz	-	60	-	dB	②
Output Voltage Temperature Characteristics	△VOUT / △Topr • VOUT	IDOUT=30mA -40°C≦Topr≦85°C	-	±100	-	ppm /°C	②

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■ ELECTRICAL CHARACTERISTICS (Continued)

❍ Detector (2.7V product) Ta=25°C

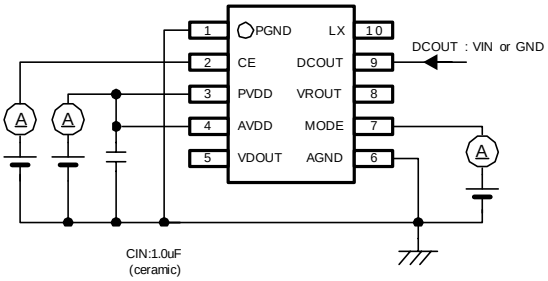
PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	TEST CIRCUIT
Detect Voltage	VDF		2.646	2.700	2.754	V	⑧
Hysteresis Range	VHYS		3	5	8	%	-
VD Output Current	IVD	VDOUT=0.5V	1	-	-	mA	⑨
Output Voltage Temperature Characteristics	△VDF / △Topr • VDF	-40°C≤Topr≤85°C	-	±100	-	ppm /°C	⑧

Test Conditions : Unless otherwise stated; * VROUT(T) : Setting Output Voltage
DC/DC : VIN=3.6V [@ DCOUT:2.2V]
VD : VIN=6.0V
VR : VIN = VROUT(T) + 1.0 (V) [When VROUT(T) ≤1.4V, VIN =2.4V]

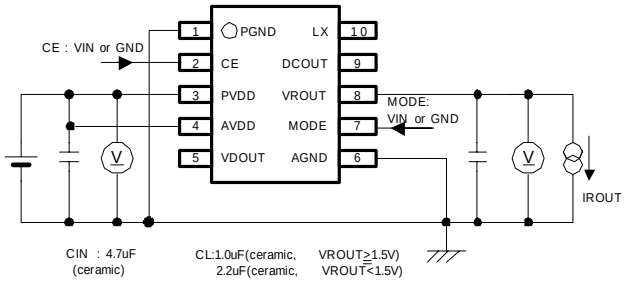
note 1 : VD operates when in stand-by mode.
note 2 : Including hysteresis operating voltage range.
note 3 : On resistance = 0.05V / ILX
note 4 : EFFI = { (Output Voltage x Output Current) / (Input Voltage x Input Current) } x 100
note 5 : Time until it short-circuits DCOUT with GND through 1Ω of resistance from a state of operation and is set to DCOUT=0V from current limit pulse generating.
note 6 : Vdif = (VIN1 (note 7) - VROUT1 (note 8))
note 7 : VIN 1 = The input voltage when VROUT1 appears as input voltage is gradually decreased.
note 8 : VROUT1 = A voltage equal to 98% of the output voltage whenever an amply stabilized IOUT {VROUT(T) + 1.0V} is input.

■ TEST CIRCUITS

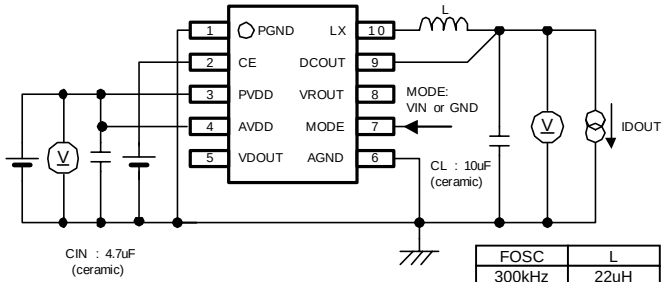
Circuit ① Supply Current, Stand-by Current, CE Current, MODE Current



Circuit ② Output Voltage (VR), Load Stability, Dropout Voltage, CE Current (MODE Current)

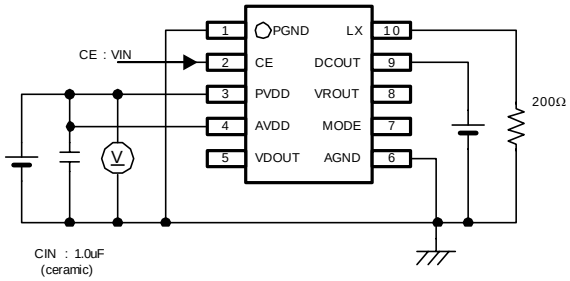


Circuit ③ Output Voltage (DC/DC) Oscillation Frequency, U.V.L.O. Voltage, Soft start Time, Latch Time, CE Voltage, (PFM Duty Cycle), (MODE Voltage)

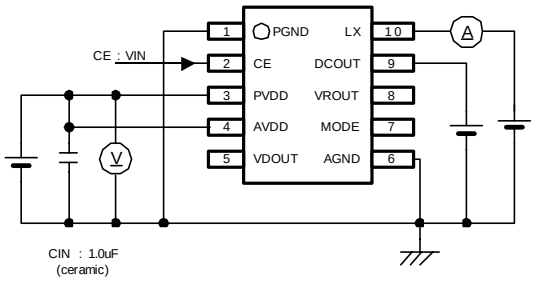


FOSC	L
300kHz	22uH
600kHz	10uH
1.2MHz	4.7uH

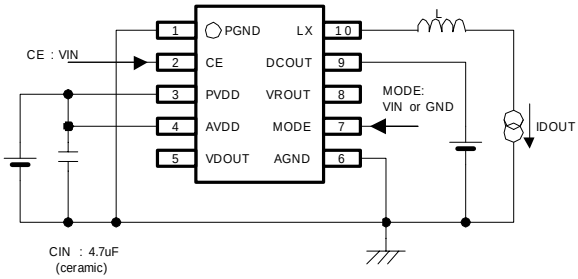
Circuit ④ Minimum Duty Cycle, Maximum Duty Cycle



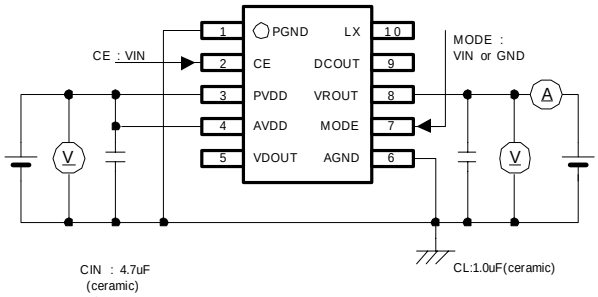
Circuit ⑤ Lx ON Resistance



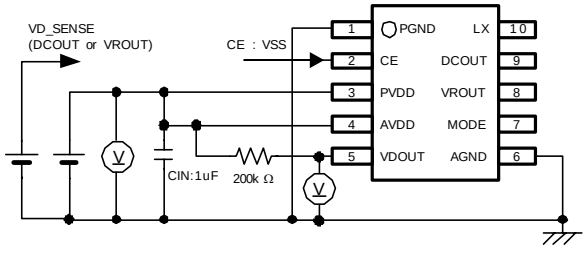
Circuit ⑥ Current Limit 1 (DC/DC)



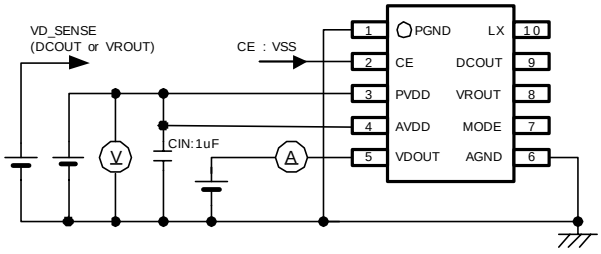
Circuit ⑦ Current Limit 2 (VR), Short Protection (VR)



Circuit ⑧ Detect Voltage, Release Voltage

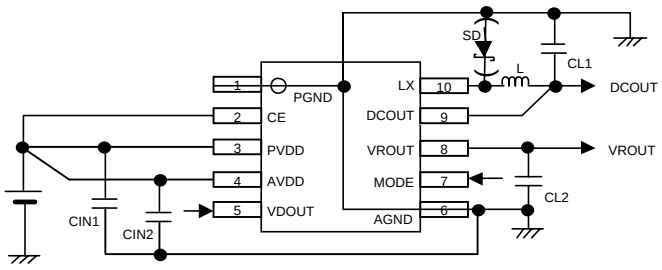


Circuit ⑨ Detect Voltage, Release Voltage



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■ TYPICAL APPLICATION CIRCUIT



MSOP-10
(TOP VIEW)

FOSC	L
1.2MHz	4.7μH (CDRH4D28C, SUMIDA)
600kHz	10μH (CDRH4D28C, SUMIDA)
300kHz	22μH (CDRH4D28C, SUMIDA)

CIN : 4.7μF (ceramic, TAIYO-YUDEN)
CL1 : 10μF (ceramic, TAIYO-YUDEN)
CL2 : 1μF (ceramic, TAIYO-YUDEN), VROUT≧1.5V
: 2.2μF (ceramic, TAIYO-YUDEN), VROUT<1.5V

■ OPERATIONAL EXPLANATION

The XC9509 series consists of a synchronous step-down DC/DC converter, a high speed LDO voltage regulator, and a voltage detector.

❍ DC/DC Converter

The series consists of a reference voltage source, ramp wave circuit, error amplifier, PWM comparator, phase compensation circuit, output voltage adjustment resistors, driver transistor, synchronous 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 split resistors. 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 300kHz, 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 split resistors. 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.

< PWM/PFM >

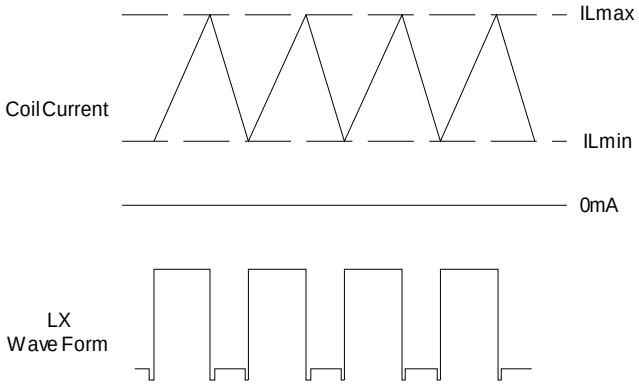
The PWM mode of the XC9509A to F series are controlled on a specified frequency from light loads through the heavy loads. Since the frequency is specified, the composition of a noise filter etc. becomes easy. However, the efficiency at the time of the light load may become low. The XC9509H to L series can switch in any timing between PWM control and PWM/PFM automatic switching control. The series can not control only PFM mode. If needed, the operation can be set on a specified frequency; therefore, the control of the noise etc. is possible and the high efficiency at the time of the light load during PFM control mode is possible. With the automatic PWM/PFM switching control function, the 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 lower than 30%, the PFM circuit operates to output a pulse with 30% of a fixed on-time rate from the Lx pin. During PFM operation with this 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.

■ OPERATIONAL EXPLANATION (Continued)

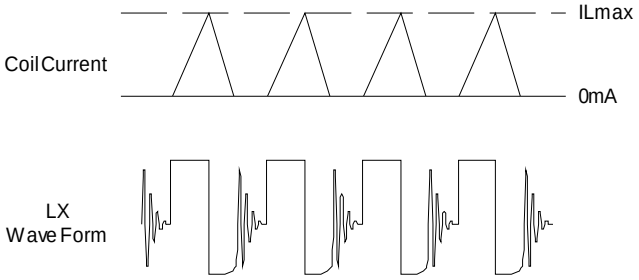
< Synchronous / Non-synchronous >

The XC9509 series automatically switches synchronous / non synchronous according to the state of the DC/DC converter.
In the series, highly efficient operation using the synchronous mode while the coil current is in a continuation state.
The series enters non-synchronous operation when the built-in Nch switching transistor for synchronous operation is shutdown which happens when the load current becomes low and the operation changes to a discontinuous state.
The IC can operate without an external schottky diode because the parasitic diode in the Nch switching transistor provides the circuit's step-down operation. However, since Vf of the parasitic diode is high 0.6V, the efficiency level during non-synchronous operation shows a slight decrease. Please use an external schottky diode if high efficiency is required during light load current.

❍ Continuous Mode : Synchronous



❍ Discontinuous Mode : Non-Synchronous

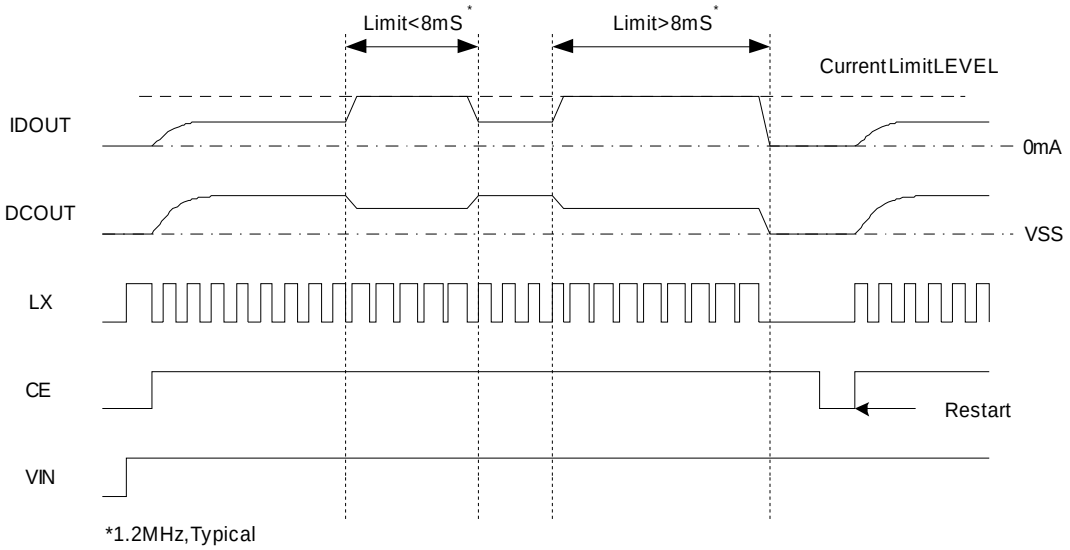


< Current Limit >

The current limiter circuit of the XC9509 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 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 8msec 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 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 XC9509 series can be set at 1.2A.



*1.2MHz, Typical

■ 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.

❍ High Speed LDO Voltage Regulator

The voltage regulator block of the XC9509 series consists of a reference voltage source, error amplifier, and current limiter circuit.
The voltage divided by split resistors is compared with the internal reference voltage by the error amplifier. The P-Channel MOSFET, which is connected to the VROUT pin, is then driven by the subsequent output signal. The output voltage at the VROUT pin is controlled and stabilized by a system of negative feedback. A stable output voltage is achievable even if used with low ESR capacitors as a phase compensation circuit is built-in.

< Reference Voltage Source >

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

< Error Amplifier >

The error amplifier compares the reference voltage with the signal from VROUT, and the amplifier controls the output of the Pch driver transistor.

<Current Limit Circuit>
The voltage regulator block includes a combination of a constant current limiter circuit and a foldback circuit. The voltage regulator senses output current of the built-in P channel output driver transistor inside. When the load current reaches the current limit level, the current limiter circuit operates and the output voltage of the voltage regulator block drops. As a result of this drop in output voltage, the foldback circuit operates, output voltage drops further and the load current decreases. When the VROUT and GND pin are shorted, the load current of about 30mA flows.

❍ Voltage Detector

The detector block of the XC9509 series detects output voltage from the VDOUT pin while sensing either VDD, DCOUT, or VROUT internally.

(N channel Open Drain Type)

<CE Pin Function>
The operation of the XC9509 series' DC/DC converter block and voltage regulator block will enter into the shut down mode when a low level signal is input to the CE pin. During the shut down mode, the current consumption occurs only in the detector and is 0.6 μA (TYP.), with a state of high impedance at the Lx pin and the DCOUT pin. The IC starts its operation by inputting a high level signal to the CE pin. The input to the CE pin is a CMOS input and the sink current is 0 μA (TYP.).

<MODE Pin Function>
The operation of the XC9509A series' voltage detector block will enter into stand-by mode when a high level signal is input to the MODE pin. When a low level signal is input, the voltage regulator block will enter into stand-by mode. However, if the IC enters into stand-by mode via the CE pin, the voltage regulator block also shuts down. Likewise, if the XC9509B series enters into stand-by mode via the CE pin, the DC/DC converter block can also shut down. With the XC9509C series control can be PWM control when the MODE pin is 'H' level and PWM/PFM automatic switching control when the MODE pin is 'L' level.