XC9253R Series

ETR0528_002

Synchronous Step-Down DC/DC Converter

☆GreenOperation Compatible

■GENERAL DESCRIPTION

The XC9253R series is a group of synchronous-rectification type DC/DC converters with a built-in 0.6Ω P-channel driver transistor and 0.7Ω 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 to be configured using only a coil and two capacitors connected externally. Minimum operating voltage is 2.0V~6.0V. Output voltage is 3.3V(accuracy: ±2.0%). With the built-in oscillator, oscillation frequency is set to 600kHz. As for operation mode, the XC9253R series is automatic PWM/PFM switching control 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 1.0μA 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 and USP-6B, are available.

■APPLICATIONS

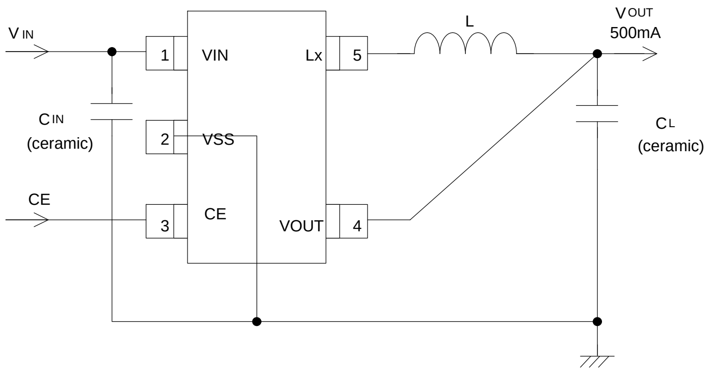
- ●Mobile phones
- ●Bluetooth equipment
- ●PDAs, Portable communication modem
- ●Portable games
- ●Cameras, Digital cameras
- ●Cordless phones
- ●Notebook computers

■FEATURES

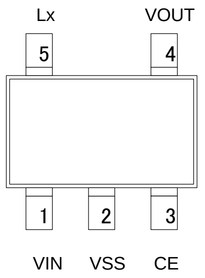
P-Ch Driver Tr. Built-In	: ON resistance 0.6Ω
N-Ch DriverTr. built-in	: ON resistance 0.7Ω
Input Voltage Range	: 2.0V~6.0V
Output Voltage Range	: 3.3V
Low Power Consumption	: 15μA (TYP.) (V_{IN}=3.6V)
Control Method	: PWM/PFM Automatic
High Efficiency	: 92% (TYP.) (V_{IN}=4.5V, V_{OUT}=3.3V, I_{OUT}=100mA)
Output Current	: 500mA
Oscillation Frequency	: 600kHz (±15%)
Low Output Ripple	: 10mV
Maximum Duty Ratio	: 100%
Operating Ambient Temperature	: -40℃ ～ +85℃
Packages	: SOT-25, USP-6B

Soft-Start Circuit Built-In
Current Limiter Circuit Built-In (Constant Current & Latching)
Low ESR Ceramic Capacitor Compatible
* Performance depends on external components and wiring on the PCB

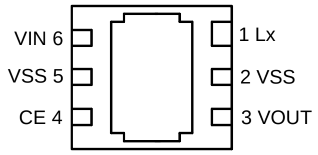
■TYPICAL APPLICATION CIRCUIT



■PIN CONFIGURATION



SOT-25
(TOP VIEW)



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	Chip Enable
4	3	VOUT	Output Voltage Sense
5	1	Lx	Switching Output

■FUNCTIONS

CE VOLTAGE LEVEL	OPERATION XC9253R SERIES
H Level	Synchronous PWM/PFM Automatic Switching Control
L Level	Stand-by

■PRODUCT CLASSIFICATION

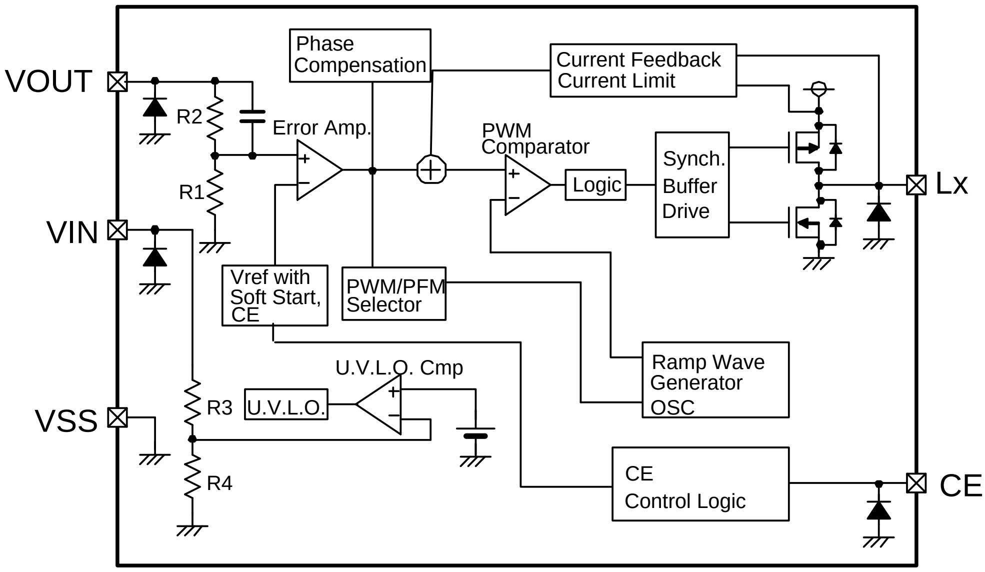
●Ordering Information

PWM / PFM automatic switching control

PRODUCT NAME	PACKAGE (ORDER UNIT)
XC9253R001MR-G(*1)	SOT-25 (3,000/Reel)
XC9253R001DR-G(*1)	USP-6B (3,000/Reel)

(*1) The “-G” suffix indicates that the products are Halogen and Antimony free as well as being fully RoHS compliant.

■BLOCK DIAGRAM



NOTE: The signal from CE Control Logic to PWM/PFM Selector is being fixed to "H" level inside, and XC9253R 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 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 Ambient Temperature		Topr	- 40 ~ + 85	℃
Storage Temperature		Tstg	- 55 ~ +125	℃

■ELECTRICAL CHARACTERISTICS (Continued)

XC9253R001xx

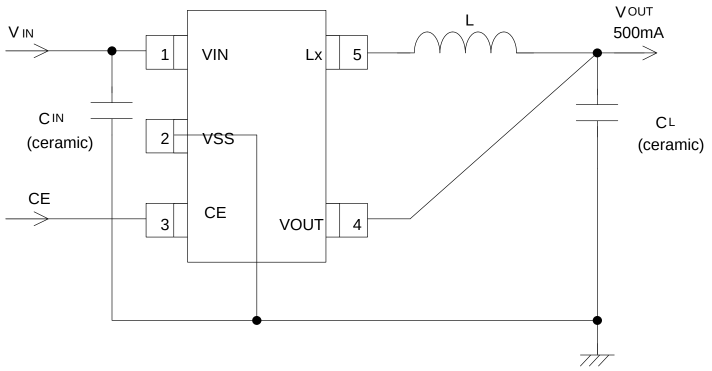
V_{OUT}=3.3V, f_{OSC}=600kHz, Ta=25℃

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT	CIRCUIT
Output Voltage	V_{OUT}	When connected to external components, V_{CE}=V_{IN}, I_{OUT}=30mA	3.234	3.300	3.366	V	①
Operating Voltage Range	V_{IN}		2.0	-	6.0	V	①
Maximum Output Current	I_{OUTMAX}	V_{IN}=V_{OUT}+1.2V, when connected to external components (A series) (*7)	500	-	-	mA	①
U.V.L.O. Voltage	V_{UVLO}	V_{CE}=V_{IN}, V_{OUT}=0V, Voltage which Lx pin voltage holding "L" level (*1), (*9)	1.00	1.40	1.78	V	②
Supply Current	I_{DD}	V_{IN}=V_{CE}=5.0V, V_{OUT}=set voltage×1.1V	-	12	30	μA	③
Stand-by Current	I_{STB}	V_{IN}=5.0V, V_{CE}=0V, V_{OUT}=set voltage×1.1V	-	0	1.0	μA	③
Oscillation Frequency	fosc	When connected to external components, I_{OUT}=100mA	510	600	690	kHz	①
PFM Switch Current	I_{PFM}	When connected to external components, V_{CE} =V_{IN}, I_{OUT}=1mA	120	160	200	mA	①
Maximum IPFM Current	MAXIPFM	V_{IN}=V_{OUT}+1.0V, V_{CE}=V_{IN}, I_{OUT}=0.1mA	35	44	50	%	①
Maximum Duty Ratio	MAXDTY	V_{CE}=V_{IN}, V_{OUT}=0V	100	-	-	%	④
Minimum Duty Ratio	MINDTY	V_{CE}=V_{OUT}=V_{IN}	-	-	0	%	④
Efficiency (*2)	EFFI	When connected to external components, V_{CE}=V_{IN}=4.5V, I_{OUT}=100mA	-	92	-	%	①
Lx SW "H" ON Resistance	R_{LxH}	V_{CE}=0.5V_{IN}, V_{OUT}=0V, ILx=100mA (*3)	-	0.5	1.0	Ω	⑤
Lx SW "L" ON Resistance	R_{LxL}	V_{CE}=0.5V_{IN}, ILx=100mA (*4)	-	0.6	1.2	Ω	⑤
Lx SW "H" Leak Current	I_{LeakH}	V_{IN}=V_{OUT}=5.0V, V_{CE}=0V, Lx=0V (*5)	-	0.01	1.0	μA	⑥
Lx SW "L" Leak Current	I_{LeakL}	V_{IN}=V_{OUT}=5.0V, V_{CE} =0V, Lx=5.0V	-	0.01	1.0	μA	⑥
Current Limit (*8)	I_{LIM}	V_{IN}=V_{CE}=5.0V, V_{OUT}=0V	600	700		mA	⑦
Output Voltage Temperature Characteristics	$\frac{\Delta V_{OUT}}{V_{OUT} \cdot \Delta Topr}$	I_{OUT}=30mA -40℃≦Topr≦85℃	-	±100	-	ppm/ ℃	①
CE "H" Voltage	V_{CEH}	V_{OUT}=0V, When CE voltage is applied Lx determine "H" (*9)	0.65	-	V_{IN}	V	⑧
CE "L" Voltage	V_{CEL}	V_{OUT}=0V, When CE voltage is applied Lx determine "L" (*9)	VSS	-	0.25	V	⑧
CE "H" Current	I_{CEH}	V_{IN}=V_{CE}=5.5V, V_{OUT}=0V	- 0.1	-	0.1	μA	⑧
CE "L" Current	I_{CEL}	V_{IN}=5.5V, V_{CE}=0V, V_{OUT}=0V	- 0.1	-	0.1	μA	⑧
Soft-Start Time	t_{SS}	When connected to external components, V_{CE}=0V→V_{IN}, I_{OUT}=1mA	0.5	1.0	3.0	ms	①
Latch Time	tlat	When connected to external components, V_{IN}=V_{CE}=5.0V, Short V_{OUT} by 1Ω resistance (*6)	1	-	20	ms	⑨

Test conditions: Unless otherwise stated, V_{IN}=5.0V
External components L: 10μH, CIN: 4.7μF (ceramic) CL: 10μF (ceramic)

NOTE:
*1:Including hysteresis operating voltage range.
*2:EFFI = { (output voltage×output current) / (input voltage×input current) }×100
*3:On resistance (Ω)= Lx pin measurement voltage / 100mA
*4:Design value
*5:When temperature is high, a current of approximately 20μA (maximum) may leak.
*6: Time until it short-circuits VOUT with GND through 1Ω of resistance from a state of operation and is set to VOUT=0V from current limit pulse generating.
*7: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.
*8: Current limit denotes the level of detection at peak of coil current..
*9: "H"=V_{IN}~V_{IN}-1.2V, "L"=+0.1V~-0.1V

■TYPICAL APPLICATION CIRCUIT



●fosc=600kHz

L	: 10 μ H	(NR4018, TAIYO YUDEN)
	: 10 μ H	(VLF4012A, TDK)
	: 10 μ H	(CDRH4, SUMIDA)
CIN	: 4.7 μ F	(Ceramic)
CL	: 10 μ F	(Ceramic)

■OPERATIONAL EXPLANATION

The XC9253R 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 VOUT 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.

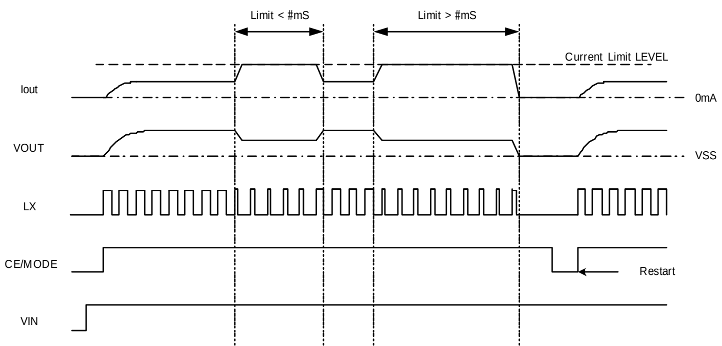
<Ramp Wave Circuit>
The ramp wave circuit determines switching frequency. The frequency is fixed internally as 600kHz. Clock pulses generated in this circuit are used to produce ramp waveforms needed for PWM operation, and to synchronize all the internal circuits.

<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 XC9253R 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 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 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 XC9253R series can be set at 700mA 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.



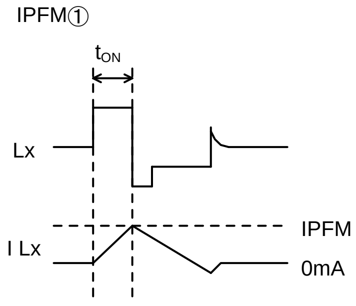
■OPERATIONAL EXPLANATION (Continued)

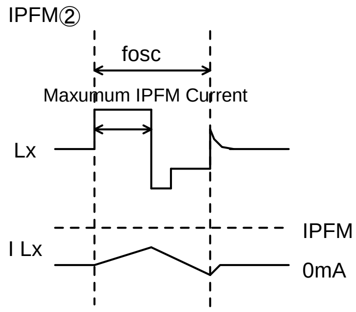
<U.V.L.O. Circuit>
When the V_{IN} pin voltage becomes 1.4V or lower, the P-channel output driver transistor is forced OFF to prevent false pulse output caused by unstable operation of the internal circuitry. When the V_{IN} pin voltage becomes 1.8V or higher, switching operation takes place. By releasing 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 (t_{ON}) can be given by the following formula.

$t_{ON} = L \times I_{PFM} / (V_{IN} - V_{OUT})$ →I_{PFM}①

<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}②





<CE Pin Function>
The operation of the XC9253R series 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 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 pin. The input to the CE pin is a CMOS input and the sink current is 0 μA (TYP.).

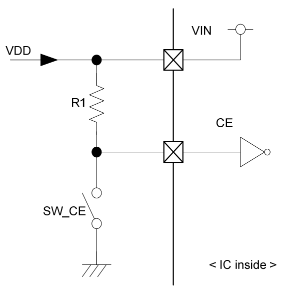
●XC9253R series - Examples of how to use CE pin

(A)

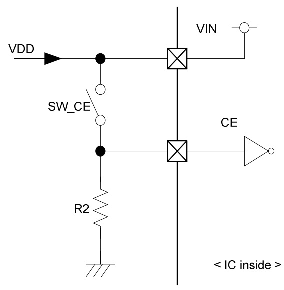
SW_CE	STATUS
ON	Stand-by
OFF	Operation

(B)

SW_CE	STATUS
ON	Operation
OFF	Stand-by



(A)

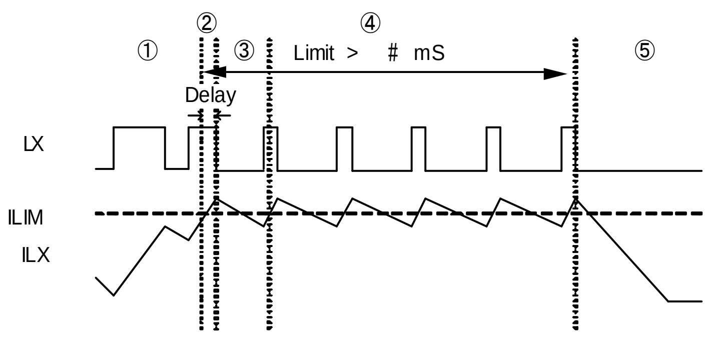


(B)

■NOTES ON USE

●Application Information

1 . The XC9253R 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 VIN 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 at typical. However, the current of 700mA 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.
   ①Current flows into P-ch MOSFET to reach the current limit (I_{LIM}).
   ②The 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.
   ③Because of no potential difference at both ends of the coil, the time rate of coil current becomes quite small.
   ④Lx oscillates very narrow pulses by the current limit for several msec.
   ⑤The 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.
17. Maximum output current is 500mA. 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 10μH or more for 600kHz.

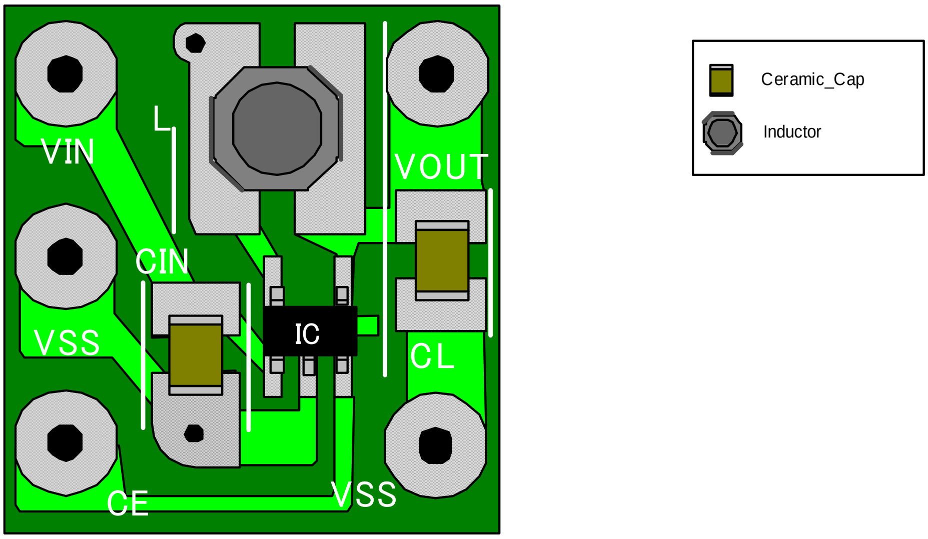
●Instructions of pattern layouts

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} & V_{SS} 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 XC9253R series.

■NOTES ON USE (Continued)

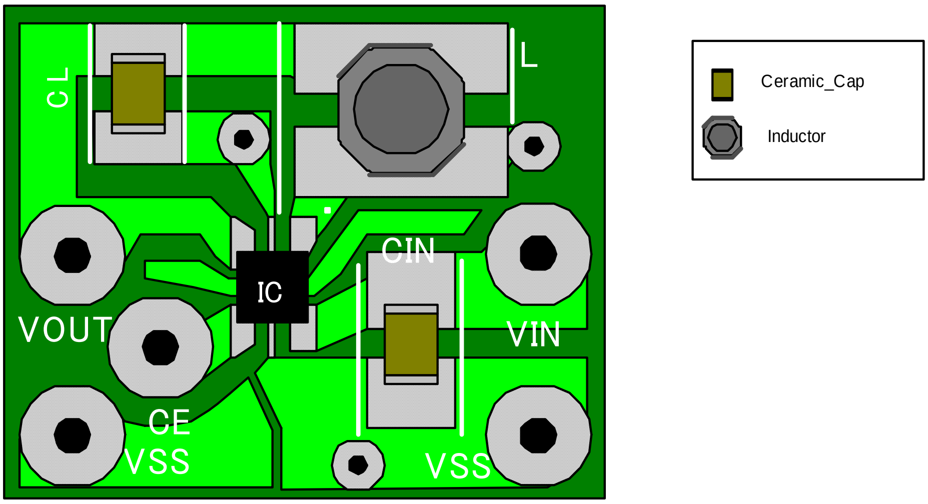
●Reference Pattern Layout

SOT-25



* Please use an electric wire for V_{IN}, V_{OUT}, V_{SS} and CE.

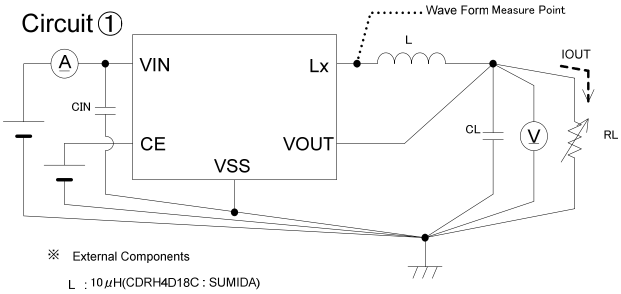
USP-6B



* Please use an electric wire for V_{IN}, V_{OUT}, V_{SS} and CE.

■TEST CIRCUITS

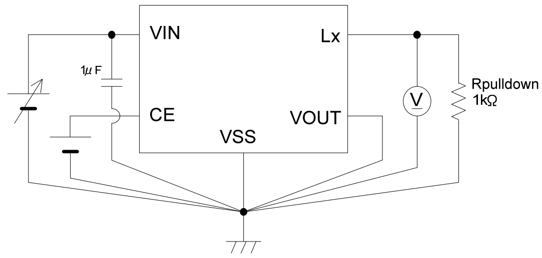
Circuit ①



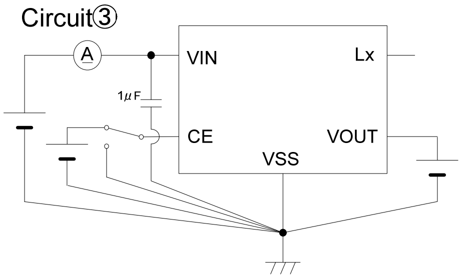
※ External Components

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

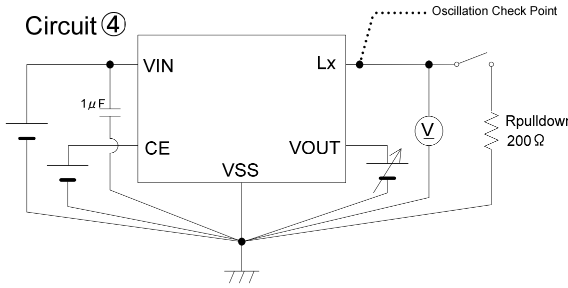
Circuit ②



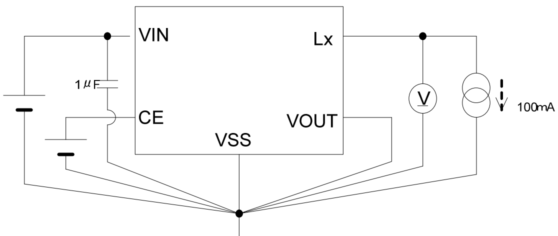
Circuit③



Circuit ④

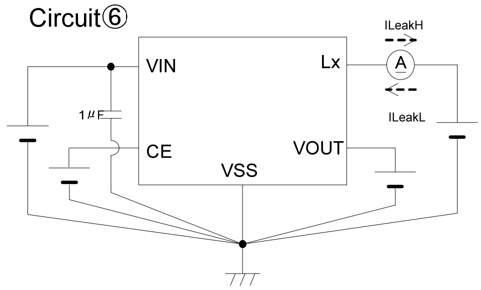


Circuit⑤

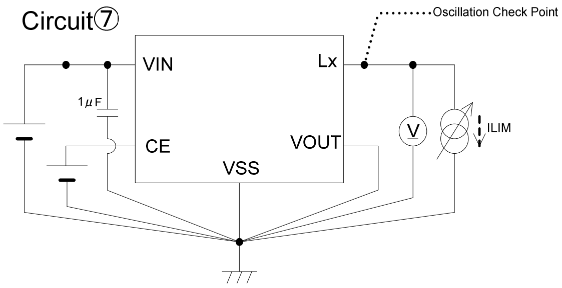


ON resistance= (VIN−VLx)/100mA

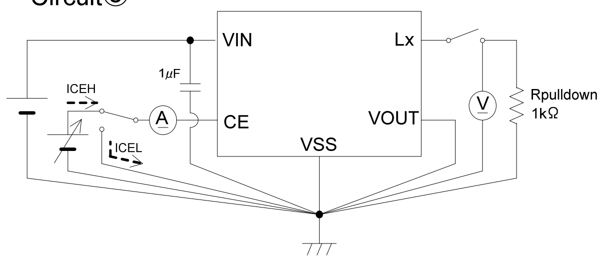
Circuit⑥



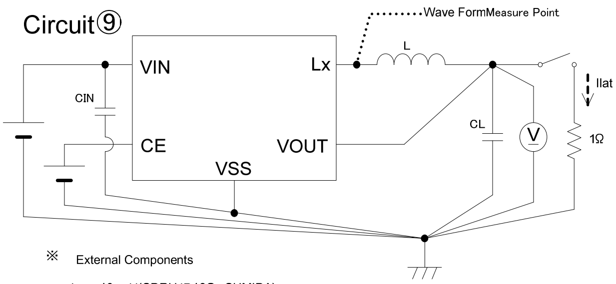
Circuit⑦



Circuit⑧



Circuit⑨

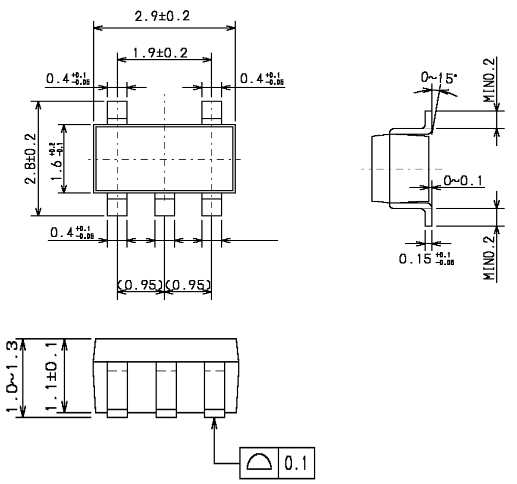


※ External Components

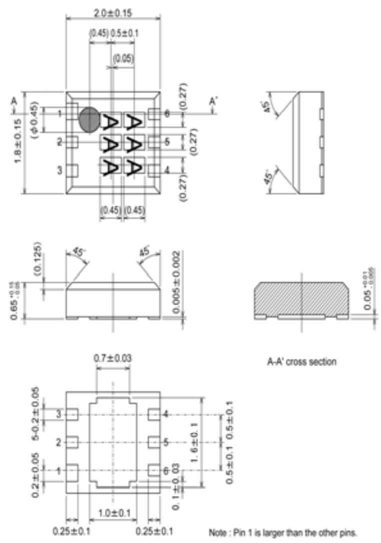
L : 10μ H(CDRH4D18C : SUMIDA)
CIN : 4.7μF
CL : 10μF

■PACKAGING INFORMATION

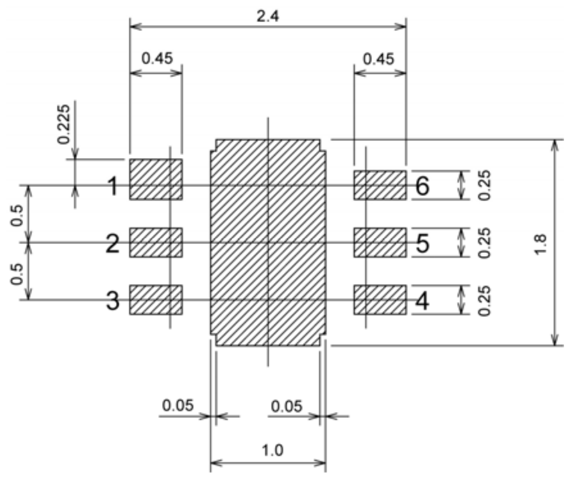
●SOT-25



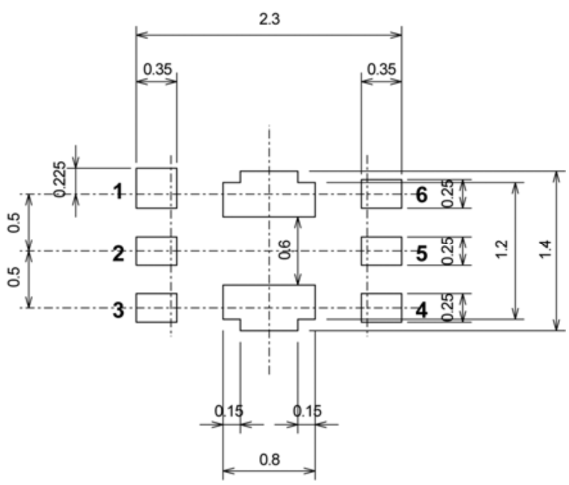
●USP-6B



●USP-6B Reference Pattern Layout

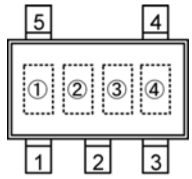


●USP-6B Reference Metal Mask Design



■MARKING RULE

●SOT-25



SOT-25 (TOP VIEW)

① represents product series

MARK	PRODUCT SERIES
U	XC9253R

② represents integer of output voltage

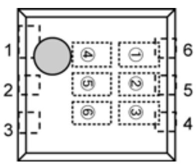
OUTPUT VOLTAGE (V)	MARK	PRODUCT SERIES
3.x	3	XC9253R001xx

③ represents decimal point of output voltage and oscillation frequency

OUTPUT VOLTAGE (V)	MARK
x.3	3

④ 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)

●USP-6B



USP-6B (TOP VIEW)

① represents product series

MARK	PRODUCT SERIES
P	XC9253R

② represents the type of DC/DC converters

MARK	PRODUCT SERIES
A	XC9253R001xx

③ represents integer of output voltage

MARK	OUTPUT VOLTAGE (V)
3	3.xx

④ represents decimal point of output voltage

MARK	OUTPUT VOLTAGE (V)
3	x.30

⑤ represents oscillation frequency

MARK	OSCILLATION FREQUENCY	PRODUCT SERIES
6	600kHz	XC9253R001xx

⑥ represents production lot number
0 to 9 and A to Z repeated (G, I, J, O, Q, W excepted)

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4. The products in this datasheet are not developed, designed, or approved for use with such equipment whose failure of malfunction can be reasonably expected to directly endanger the life of, or cause significant injury to, the user.
   (e.g. Atomic energy; aerospace; transport; combustion and associated safety equipment thereof.)
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