

600mA Driver Tr. Built-In, Synchronous Step-Down DC/DC Converters

GENERAL DESCRIPTION

GreenOperation Compatible

The XC9235/XC9236/XC9237 series is a group of synchronous-rectification type DC/DC converters with a built-in 0.42 P-channel driver transistor and 0.52 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 600mA to be configured using only a coil and two capacitors connected externally. Operating voltage range is from 2.0V to 6.0V. Output voltage is internally set in a range from 0.8V to 4.0V in increments of 50mV (accuracy: $\pm 2.0\%$). With the built-in oscillator, either 1.2MHz or 3.0MHz can be selected for suiting to your particular application. As for operation mode, the XC9235 series is PWM control, the XC9236 series is automatic PWM/PFM switching control and the XC9237 series can be manually switched between the PWM control mode and the automatic PWM/PFM switching control mode, allowing fast response, low ripple and high efficiency over the full range of loads (from light load to heavy load).

The soft start and current control functions are internally optimized. During stand-by, all circuits are shutdown to reduce current consumption to as low as $1.0\mu\text{A}$ or less. With the built-in UVLO (Under Voltage Lock Out) function, the internal P-channel driver transistor is forced OFF when input voltage becomes 1.4V or lower.

The XC9235B/XC9236B/XC9237B series provide short-time turn-on by the soft start function internally set in 0.25 ms (TYP). The XC9235B(C)/XC9236B(C)/XC9237B(C) integrate C_L auto discharge function which enables the electric charge at the output capacitor C_L to be discharged via the internal auto-discharge switch located between the L_X and V_{SS} pins. When the devices enter stand-by mode, output voltage quickly returns to the V_{SS} level as a result of this function.

Two types of package SOT-25 and USP-6C are available.

APPLICATIONS

Mobile phones
Bluetooth equipment
PDAs, portable communication modem
Portable games
Digital cameras, video cameras
Cordless phones
Notebook computers

FEATURES

P-ch Driver Transistor Built-In : ON resistance 0.42
N-ch Driver Transistor Built-In : ON resistance 0.52
Input Voltage : 2.0V ~ 6.0V
Output Voltage : 0.8V ~ 4.0V
High Efficiency : 92% (TYP.)
Output Current : 600mA
Oscillation Frequency : 1.2MHz, 3.0MHz ($\pm 15\%$)
Maximum Duty Cycle : 100%
Control Methods : PWM (XC9235)
PWM/PFM Auto (XC9236)
PWM/PFM Manual (XC9237)

Soft-Start Circuit Built-In

Current Limiter Circuit Built-In (Constant Current & Latching)

Low ESR Ceramic Capacitor Compatible

Packages : SOT-25, USP-6C

C_L High Speed Discharge

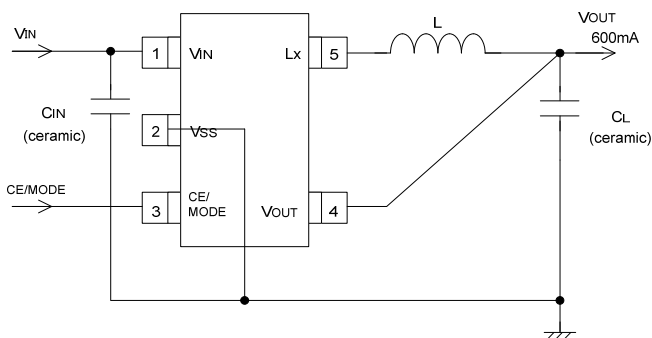
(XC9235B(C)/XC9236B(C)/XC9237B(C) Series)

High Speed Soft Start

(XC9235B/XC9236B/XC9237B Series)

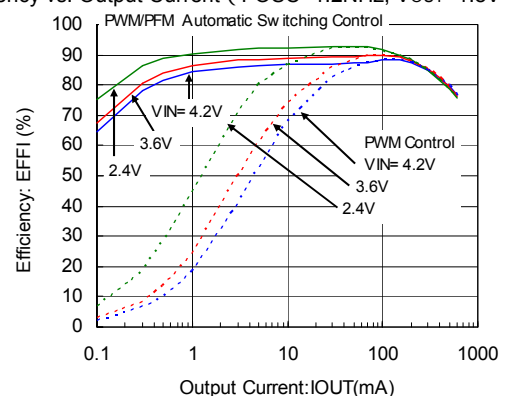
* Performance depends on external components and wiring on the PCB.

TYPICAL APPLICATION CIRCUIT

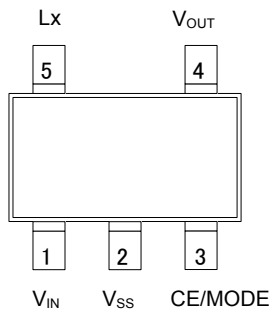


TYPICAL PERFORMANCE CHARACTERISTICS

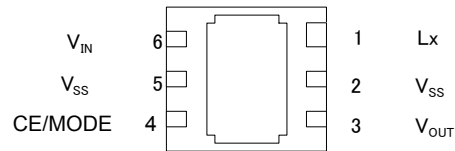
Efficiency vs. Output Current (FOSC=1.2MHz, VOUT=1.8V)



PIN CONFIGURATION



SOT-25
(Top View)



USP-6C
(BOTTOM VIEW)

* Please short the Vss pin (No. 2 and 5).
* The dissipation pad for the USP-6C 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-6C | | |
| 1 | 6 | V _{IN} | Power Input |
| 2 | 2, 5 | V _{SS} | Ground |
| 3 | 4 | CE / MODE | Chip Enable Mode Switch |
| 4 | 3 | V _{OUT} | Output Voltage Sense |
| 5 | 1 | Lx | Switching Output |

PRODUCT CLASSIFICATION

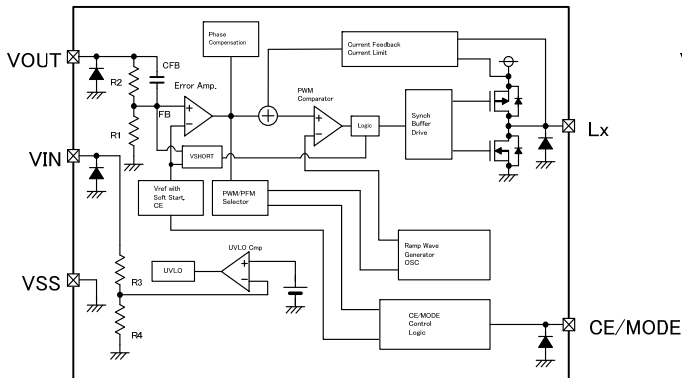
Ordering Information

| | |
|---------------|---|
| <u>XC9235</u> | PWM fixed control |
| <u>XC9236</u> | PWM / PFM automatic switching control |
| <u>XC9237</u> | PWM fixed control ↔ PWM / PFM automatic switching, manual switching |

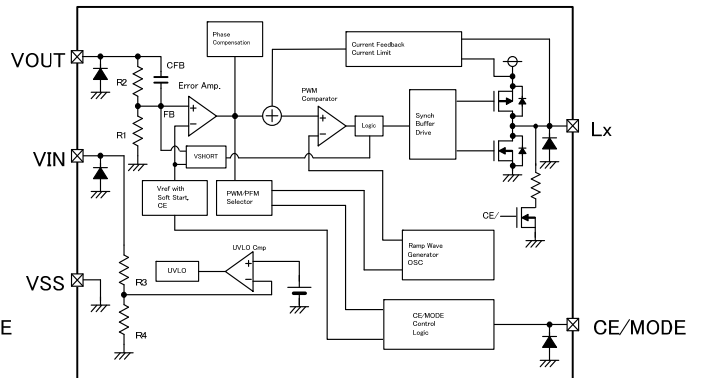
| DESIGNATOR | DESCRIPTION | SYMBOL | DESCRIPTION |
|------------|---|----------|--|
| · | Transistor built-in, Output voltage internally set (V _{OUT} product), Soft-start internally set | A | : CE input logic High Active |
| | | B | : CE input logic High Active, high speed soft start, C _L discharge |
| | | C | : CE input logic High Active, C _L discharge |
| | Output Voltage | 0~4 | : Integer number of output voltage e.g. V _{OUT} =2.8V =2, V _{OUT} =3.3V =3 |
| | Output Voltage | 0~9, A~M | : Decimal number of output voltage 50mV increments: 0.05=A, 0.15=B, 0.25=C, 0.35=D, 0.45=E, 0.55=F, 0.65=H, 0.75=K, 0.85=L, 0.95=M e.g. V _{OUT} =2.8V =2, =8 V _{OUT} =2.85V =2, =L |
| | Oscillation Frequency | C | : 1.2MHz |
| | | D | : 3.0MHz |
| | Packages | M | : SOT-25 (SOT-23-5) |
| | | E | : USP-6C |
| | Device Orientation | R | : Embossed tape, standard feed |
| | | L | : Embossed tape, reverse feed |

BLOCK DIAGRAM

XC9235A / XC9236A / XC9237A



XC9235B(C) / XC9236B(C) / XC9237B(C)



NOTE: The signal from CE/MODE Control Logic to PWM/PFM Selector is being fixed to "L" level inside, and XC9235 series chooses only PWM control.
The signal from CE/MODE Control Logic to PWM/PFM Selector is being fixed to "H" level inside, and XC9236 series chooses only PWM/PFM automatic switching control.
Diodes inside the circuit are ESD protection diodes and parasitic diodes.

ABSOLUTE MAXIMUM RATINGS

Ta=25

| PARAMETER | SYMBOL | RATINGS | UNIT |
|---------------------------------|------------------|---------------------------------------|------|
| V _{IN} Pin Voltage | V _{IN} | - 0.3 ~ 6.5 | V |
| Lx Pin Voltage | V _{Lx} | - 0.3 ~ V _{IN} + 0.3 or 6.5V | V |
| V _{OUT} Pin Voltage | V _{OUT} | - 0.3 ~ 6.5 | V |
| CE / MODE Pin Voltage | V _{CE} | - 0.3 ~ 6.5 | V |
| Lx Pin Current | I _{Lx} | ±1500 | mA |
| Power Dissipation (*Ta=25°C) | SOT-25 | 250 | mW |
| | USP-6C | 100 | |
| Operating Temperature Range | T _{opr} | - 40 ~ + 85 | °C |
| Storage Temperature Range | T _{stg} | - 55 ~ + 125 | °C |

ELECTRICAL CHARACTERISTICS

XC9237A18Cxx, $V_{OUT}=1.8V$, $F_{OSC}=1.2MHz$, $T_a=25^\circ C$

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNIT | CIRCUIT |
|--|---|--|-----------------|-----------|----------------|---------|---------|
| Output Voltage | V_{OUT} | When connected to external components, $V_{IN}=V_{CE}=5.0V$, $I_{OUT}=30mA$ | 1.764 | 1.800 | 1.836 | V | |
| Operating Voltage Range | V_{IN} | | 2.0 | - | 6.0 | V | |
| Maximum Output Current | I_{OUTMAX} | $V_{IN}=V_{OUT(E)}+2.0V$, $V_{CE}=1.0V$, When connected to external components ⁽⁹⁾ | 600 | - | - | mA | |
| U.V.L.O. Voltage | V_{UVLO} | $V_{CE}=V_{IN}$, $V_{OUT}=0V$, Voltage which Lx pin holding "L" level ^(1, *11) | 1.00 | 1.40 | 1.78 | V | |
| Supply Current | I_{DD} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=V_{OUT(E)} \times 1.1V$ | - | 15 | 33 | μA | |
| Stand-by Current | I_{STB} | $V_{IN}=5.0V$, $V_{CE}=0V$, $V_{OUT}=V_{OUT(E)} \times 1.1V$ | - | 0 | 1.0 | μA | |
| Oscillation Frequency | FOSC | When connected to external components, $V_{IN}=V_{OUT(E)}+2.0V$, $V_{CE}=1.0V$, $I_{OUT}=100mA$ | 1020 | 1200 | 1380 | kHz | |
| PFM Switching Current | I_{PFM} | When connected to external components, $V_{IN}=V_{OUT(E)}+2.0V$, $V_{CE}=V_{IN}$, $I_{OUT}=1mA$ ⁽¹²⁾ | 120 | 160 | 200 | mA | |
| Maximum I_{PFM} Limit | $MAXI_{PFM}$ | $V_{CE}=V_{IN}=(C-1)$, $I_{OUT}=1mA$ ⁽¹²⁾ | | 200 | | % | |
| Maximum Duty Cycle | MAXDTY | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=V_{OUT(E)} \times 0.9V$ | 100 | - | - | % | |
| Minimum Duty Cycle | MINDTY | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=V_{OUT(E)} \times 1.1V$ | - | - | 0 | % | |
| Efficiency ⁽²⁾ | EFFI | When connected to external components, $V_{CE}=V_{IN}=V_{OUT(E)}+1.2V$, $I_{OUT}=100mA$ | - | 92 | - | % | |
| Lx SW "H" ON Resistance 1 | R_{LxH} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=0V$, $I_{Lx}=100mA$ ⁽³⁾ | - | 0.35 | 0.55 | | |
| Lx SW "H" ON Resistance 2 | R_{LxH} | $V_{IN}=V_{CE}=3.6V$, $V_{OUT}=0V$, $I_{Lx}=100mA$ ⁽³⁾ | - | 0.42 | 0.67 | | |
| Lx SW "L" ON Resistance 1 | R_{LxL} | $V_{IN}=V_{CE}=5.0V$ ⁽⁴⁾ | - | 0.45 | 0.66 | | |
| Lx SW "L" ON Resistance 2 | R_{LxL} | $V_{IN}=V_{CE}=3.6V$ ⁽⁴⁾ | - | 0.52 | 0.77 | | - |
| Lx SW "H" Leak Current ⁽⁵⁾ | I_{LeakH} | $V_{IN}=V_{OUT}=5.0V$, $V_{CE}=0V$, $Lx=0V$ | - | 0.01 | 1.0 | μA | |
| Lx SW "L" Leak Current ⁽⁵⁾ | I_{LeakL} | $V_{IN}=V_{OUT}=5.0V$, $V_{CE}=0V$, $Lx=5.0V$ | - | 0.01 | 1.0 | μA | |
| Current Limit ⁽¹⁰⁾ | I_{LIM} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=V_{OUT(E)} \times 0.9V$ ⁽⁸⁾ | 900 | 1050 | 1350 | mA | |
| Output Voltage Temperature Characteristics | $\frac{V_{OUT}}{V_{OUT} \cdot T_{opr}}$ | $I_{OUT}=30mA$, -40 Topr 85 | - | ± 100 | - | ppm/ | |
| CE "H" Voltage | V_{CEH} | $V_{OUT}=0V$, Applied voltage to V_{CE} , Voltage changes Lx to "H" level ⁽¹¹⁾ | 0.65 | - | V_{IN} | V | |
| CE "L" Voltage | V_{CEL} | $V_{OUT}=0V$, Applied voltage to V_{CE} , Voltage changes Lx to "L" level ⁽¹¹⁾ | V_{SS} | - | 0.25 | V | |
| PWM "H" Level Voltage | V_{PWMH} | When connected to external components, $I_{OUT}=1mA$ ⁽⁶⁾ , Voltage which oscillation frequency becomes 1020 kHz FOSC 1380kHz ⁽¹³⁾ | - | - | $V_{IN} - 1.0$ | V | |
| PWM "L" Level Voltage | V_{PWML} | When connected to external components, $I_{OUT}=1mA$ ⁽⁶⁾ , Voltage which oscillation frequency becomes FOSC < 1020kHz ⁽¹³⁾ | $V_{IN} - 0.25$ | - | - | V | |
| CE "H" Current | I_{CEH} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=0V$ | - 0.1 | - | 0.1 | μA | |
| CE "L" Current | I_{CEL} | $V_{IN}=5.0V$, $V_{CE}=0V$, $V_{OUT}=0V$ | - 0.1 | - | 0.1 | μA | |
| Soft Start Time | T_{SS} | When connected to external components, $V_{CE}=0V$ V_{IN} , $I_{OUT}=1mA$ | 0.5 | 1.0 | 2.5 | ms | |
| Latch Time | T_{LAT} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=0.8 \times V_{OUT(E)}$, Short Lx at 1 resistance ⁽⁷⁾ | 1.0 | - | 20.0 | ms | |
| Short Protection Threshold Voltage | V_{SHORT} | Sweeping V_{OUT} , $V_{IN}=V_{CE}=5.0V$, Short Lx at 1 resistance, V_{OUT} voltage which Lx becomes "L" level within 1ms | 0.675 | 0.900 | 1.150 | V | |

Test conditions: Unless otherwise stated, $V_{IN}=5.0V$, $V_{OUT(E)}$ =Setting Voltage

NOTE:

*1: Including hysteresis operating voltage range.

*2: $EFFI = \{ (\text{output voltage} \times \text{output current}) / (\text{input voltage} \times \text{input current}) \} \times 100$

*3: ON resistance () = $(V_{IN} - Lx \text{ pin measurement voltage}) / 100mA$

*4: R&D value

*5: When temperature is high, a current of approximately $10 \mu A$ (maximum) may leak.

*6: The CE/MODE pin of the XC9237A series works also as an external switching pin of PWM control and PWM/PFM control. When the IC is in the operation, control is switched to the automatic PWM/PFM switching mode when the CE/MODE pin voltage is equal to or greater than V_{IN} minus 0.3V, and to the PWM mode when the CE/MODE pin voltage is equal to or lower than V_{IN} minus 1.0V and equal to or greater than V_{CEH} .

*7: Time until it short-circuits V_{OUT} with GND via 1 of resistor from an operational state and is set to $Lx=0V$ from current limit pulse generating.

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

*9: 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.

*10: Current limit denotes the level of detection at peak of coil current.

*11: "H"= $V_{IN}-V_{IN}-1.2V$, "L"= $+0.1V \sim -0.1V$

*12: XC9235 series exclude I_{PFM} and $MAXI_{PFM}$ because those are only for the PFM control's functions.

*13: XC9235/9236 series exclude V_{PWMH} and V_{PWML} because those are only for the XC9237 series' functions.

ELECTRICAL CHARACTERISTICS (Continued)

XC9237A18Dxx, $V_{OUT}=1.8V$, $F_{OSC}=3.0MHz$, $T_a=25^{\circ}C$

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNIT | CIRCUIT |
|--|---|---|-----------------|-----------|----------------|---------|---------|
| Output Voltage | V_{OUT} | When connected to external components, $V_{IN}=V_{CE}=5.0V$, $I_{OUT}=30mA$ | 1.764 | 1.800 | 1.836 | V | |
| Operating Voltage Range | V_{IN} | | 2.0 | - | 6.0 | V | |
| Maximum Output Current | I_{OUTMAX} | $V_{IN}=V_{OUT(E)}+2.0V$, $V_{CE}=1.0V$, When connected to external components ^(*9) | 600 | - | - | mA | |
| U.V.L.O. Voltage | V_{UVLO} | $V_{CE}=V_{IN}$, $V_{OUT}=0V$, Voltage which Lx pin holding "L" level ^(*1,*11) | 1.00 | 1.40 | 1.78 | V | |
| Supply Current | I_{DD} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=V_{OUT(E)} \times 1.1V$ | - | 21 | 35 | μA | |
| Stand-by Current | I_{STB} | $V_{IN}=5.0V$, $V_{CE}=0V$, $V_{OUT}=V_{OUT(E)} \times 1.1V$ | - | 0 | 1.0 | μA | |
| Oscillation Frequency | F_{OSC} | When connected to external components, $V_{IN}=V_{OUT(E)}+2.0V$, $V_{CE}=1.0V$, $I_{OUT}=100mA$ | 2550 | 3000 | 3450 | kHz | |
| PFM Switching Current | I_{PFM} | When connected to external components, $V_{IN}=V_{OUT(E)}+2.0V$, $V_{CE}=V_{IN}$, $I_{OUT}=1mA$ ^(*12) | 170 | 220 | 270 | mA | |
| Maximum IPFM Limit | $MAXI_{PFM}$ | $V_{CE}=V_{IN}=(C-1)$, $I_{OUT}=1mA$ ^(*12) | - | 200 | 300 | % | |
| Maximum Duty Cycle | $MAXDTY$ | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=V_{OUT(E)} \times 0.9V$ | 100 | - | - | % | |
| Minimum Duty Cycle | $MINDTY$ | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=V_{OUT(E)} \times 0.1V$ | - | - | 0 | % | |
| Efficiency | $EFFI$ | When connected to external components, $V_{CE}=V_{IN}=V_{OUT(E)}+1.2V$, $I_{OUT}=100mA$ | - | 86 | - | % | |
| Lx SW "H" ON Resistance 1 | R_{LXH} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=0V$, $I_{LX}=100mA$ ^(*3) | - | 0.35 | 0.55 | | |
| Lx SW "H" ON Resistance 2 | R_{LXH} | $V_{IN}=V_{CE}=3.6V$, $V_{OUT}=0V$, $I_{LX}=100mA$ ^(*3) | - | 0.42 | 0.67 | | |
| Lx SW "L" ON Resistance 1 | R_{LXL} | $V_{IN}=V_{CE}=5.0V$ ^(*4) | - | 0.45 | 0.66 | | - |
| Lx SW "L" ON Resistance 2 | R_{LXL} | $V_{IN}=V_{CE}=3.6V$ ^(*4) | - | 0.52 | 0.77 | | - |
| Lx SW "H" Leak Current ^(*5) | I_{LeakH} | $V_{IN}=V_{OUT}=5.0V$, $V_{CE}=0V$, $LX=0V$ | - | 0.01 | 1.0 | μA | |
| Lx SW "L" Leak Current ^(*5) | I_{LeakL} | $V_{IN}=V_{OUT}=5.0V$, $V_{CE}=0V$, $LX=5.0V$ | - | 0.01 | 1.0 | μA | |
| Current Limit ^(*10) | I_{LIM} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=V_{OUT(E)} \times 0.9V$ ^(*8) | 900 | 1050 | 1350 | mA | |
| Output Voltage Temperature Characteristics | $\frac{V_{OUT}}{V_{OUT} \cdot \text{topr}}$ | $I_{OUT}=30mA$, -40 Topr 85 | - | ± 100 | - | ppm/ | |
| CE "H" Voltage | V_{CEH} | $V_{OUT}=0V$, Applied voltage to V_{CE} , ^(*11) Voltage changes Lx to "H" level | 0.65 | - | V_{IN} | V | |
| CE "L" Voltage | V_{CEL} | $V_{OUT}=0V$, Applied voltage to V_{CE} , ^(*11) Voltage changes Lx to "L" level | V_{SS} | - | 0.25 | V | |
| PWM "H" Level Voltage | V_{PWMH} | When connected to external components, $I_{OUT}=1mA$ ^(*6) , Voltage which oscillation frequency becomes 2550kHz FOSC 3450kHz ^(*13) | - | - | $V_{IN} - 1.0$ | V | |
| PWM "L" Level Voltage | V_{PWML} | When connected to external components, $I_{OUT}=1mA$ ^(*6) , Voltage which oscillation frequency becomes $F_{OSC} < 2550kHz$ ^(*13) | $V_{IN} - 0.25$ | - | - | V | |
| CE "H" Current | I_{CEH} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=0V$ | - 0.1 | - | 0.1 | μA | |
| CE "L" Current | I_{CEL} | $V_{IN}=5.0V$, $V_{CE}=0V$, $V_{OUT}=0V$ | - 0.1 | - | 0.1 | μA | |
| Soft Start Time | T_{SS} | When connected to external components, $V_{CE}=0V$ V_{IN} , $I_{OUT}=1mA$ | 0.5 | 0.9 | 3.0 | ms | |
| Latch Time | T_{LAT} | $V_{IN}=V_{CE}=5.0V$, $V_{OUT}=0.8 \times V_{OUT(E)}$, Short Lx at 1 resistance ^(*7) | 1.0 | - | 20 | ms | |
| Short Protection Threshold Voltage | V_{SHORT} | Sweeping V_{OUT} , $V_{IN}=V_{CE}=5.0V$, Short Lx at 1 resistance, V_{OUT} voltage which Lx becomes "L" level within 1ms ^(*4) | 0.675 | 0.900 | 1.150 | V | |

Test conditions: Unless otherwise stated, $V_{IN}=5.0V$, $V_{OUT(E)}$ =Setting Voltage

NOTE:

*1: Including hysteresis operating voltage range.

*2: $EFFI = \{ (\text{output voltage} \times \text{output current}) / (\text{input voltage} \times \text{input current}) \} \times 100$

*3: ON resistance () = $(V_{IN} - Lx \text{ pin measurement voltage}) / 100mA$

*4: R&D value

*5: When temperature is high, a current of approximately 10 μA (maximum) may leak.

*6: The CE/MODE pin of the XC9237A series works also as an external switching pin of PWM control and PWM/PFM control. When the IC is in the operation, control is switched to the automatic PWM/PFM switching mode when the CE/MODE pin voltage is equal to or greater than V_{IN} minus 0.3V, and to the PWM mode when the CE/MODE pin voltage is equal to or lower than V_{IN} minus 1.0V and equal to or greater than V_{CEH} .

*7: Time until it short-circuits V_{OUT} with GND via 1 of resistor from an operational state and is set to $LX=0V$ from current limit pulse generating.

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

*9: 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.

*10: Current limit denotes the level of detection at peak of coil current.

*11: "H"= $V_{IN}-V_{IN}-1.2V$, "L"= $+0.1V-0.1V$

*12: XC9235 series exclude IPFM and MAXIPFM because those are only for the PFM control's functions.

*13: XC9235/9236 series exclude V_{PWMH} and V_{PWML} because those are only for the XC9237 series' functions.

ELECTRICAL CHARACTERISTICS (Continued)

XC9237B(C)18Cxx, V_{OUT}=1.8V, FOSC=1.2MHz, Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNIT | CIRCUIT |
|--|---|---|------------------------|-------|-----------------------|------|---------|
| Output Voltage | V _{OUT} | When connected to external components, V _{IN} =V _{CE} =5.0V, I _{OUT} =30mA | 1.764 | 1.800 | 1.836 | V | |
| Operating Voltage Range | V _{IN} | | 2.0 | - | 6.0 | V | |
| Maximum Output Current | I _{OUTMAX} | V _{IN} =V _{OUT(E)} +2.0V, V _{CE} =1.0V, When connected to external components ⁽⁹⁾ | 600 | - | - | mA | |
| U.V.L.O. Voltage | V _{UVLO} | V _{CE} =V _{IN} , V _{OUT} =0V, Voltage which Lx pin holding "L" level ^(1, *11) | 1.00 | 1.40 | 1.78 | V | |
| Supply Current | I _{DD} | V _{IN} =V _{CE} =5.0V, V _{OUT} =V _{OUT(E)} × 1.1V | - | 15 | 33 | μA | |
| Stand-by Current | I _{STB} | V _{IN} =5.0V, V _{CE} =0V, V _{OUT} =V _{OUT(E)} × 1.1V | - | 0 | 1.0 | μA | |
| Oscillation Frequency | FOSC | When connected to external components, V _{IN} =V _{OUT(E)} +2.0V, V _{CE} =1.0V, I _{OUT} =100mA | 1020 | 1200 | 1380 | kHz | |
| PFM Switching Current | I _{PFM} | When connected to external components, V _{IN} =V _{OUT(E)} +2.0V, V _{CE} =V _{IN} , I _{OUT} =1mA ⁽¹²⁾ | 120 | 160 | 200 | mA | |
| Maximum I _{PFM} Limit | MAXI _{PFM} | V _{CE} =V _{IN} =(C-1), I _{OUT} =1mA ⁽¹²⁾ | | 200 | | % | |
| Maximum Duty Cycle | MAXDTY | V _{IN} =V _{CE} =5.0V, V _{OUT} =V _{OUT(E)} × 0.9V | 100 | - | - | % | |
| Minimum Duty Cycle | MINDTY | V _{IN} =V _{CE} =5.0V, V _{OUT} =V _{OUT(E)} × 1.1V | - | - | 0 | % | |
| Efficiency ⁽²⁾ | EFFI | When connected to external components, V _{CE} =V _{IN} =V _{OUT(E)} +1.2V, I _{OUT} =100mA | - | 92 | - | % | |
| Lx SW "H" ON Resistance 1 | R _{LxH} | V _{IN} =V _{CE} =5.0V, V _{OUT} =0V, I _{Lx} =100mA ⁽³⁾ | - | 0.35 | 0.55 | | |
| Lx SW "H" ON Resistance 2 | R _{LxH} | V _{IN} =V _{CE} =3.6V, V _{OUT} =0V, I _{Lx} =100mA ⁽³⁾ | - | 0.42 | 0.67 | | |
| Lx SW "L" ON Resistance 1 | R _{LxL} | V _{IN} =V _{CE} =5.0V ⁽⁴⁾ | - | 0.45 | 0.66 | | |
| Lx SW "L" ON Resistance 2 | R _{LxL} | V _{IN} =V _{CE} =3.6V ⁽⁴⁾ | - | 0.52 | 0.77 | | - |
| Lx SW "H" Leak Current ⁽⁵⁾ | I _{LeakH} | V _{IN} =V _{OUT} =5.0V, V _{CE} =0V, Lx=0V | - | 0.01 | 1.0 | μA | |
| Current Limit ⁽¹⁰⁾ | I _{LIM} | V _{IN} =V _{CE} =5.0V, V _{OUT} =V _{OUT(E)} × 0.9V ⁽⁸⁾ | 900 | 1050 | 1350 | mA | |
| Output Voltage Temperature Characteristics | $\frac{V_{OUT}}{V_{OUT} \cdot \text{topr}}$ | I _{OUT} =30mA, -40 Topr 85 | - | ± 100 | - | ppm/ | |
| CE "H" Voltage | V _{CEH} | V _{OUT} =0V, Applied voltage to V _{CE} , Voltage changes Lx to "H" level ⁽¹¹⁾ | 0.65 | - | V _{IN} | V | |
| CE "L" Voltage | V _{CEL} | V _{OUT} =0V, Applied voltage to V _{CE} , Voltage changes Lx to "L" level ⁽¹¹⁾ | V _{SS} | - | 0.25 | V | |
| PWM "H" Level Voltage | V _{PWMH} | When connected to external components, I _{OUT} =1mA ⁽⁶⁾ , Voltage which oscillation frequency becomes 1020 kHz FOSC 1380kHz ⁽¹³⁾ | - | - | V _{IN} - 1.0 | V | |
| PWM "L" Level Voltage | V _{PWML} | When connected to external components, I _{OUT} =1mA ⁽⁶⁾ , Voltage which oscillation frequency becomes FOSC < 1020kHz ⁽¹³⁾ | V _{IN} - 0.25 | - | - | V | |
| CE "H" Current | I _{CEH} | V _{IN} =V _{CE} =5.0V, V _{OUT} =0V | - 0.1 | - | 0.1 | μA | |
| CE "L" Current | I _{CEL} | V _{IN} =5.0V, V _{CE} =0V, V _{OUT} =0V | - 0.1 | - | 0.1 | μA | |
| Soft Start Time (B Series) | T _{SS} | When connected to external components, V _{CE} =0V V _{IN} , I _{OUT} =1mA | - | 0.25 | 0.40 | ms | |
| Soft Start Time (C Series) | T _{SS} | When connected to external components, V _{CE} =0V V _{IN} , I _{OUT} =1mA | 0.5 | 1.0 | 2.5 | ms | |
| Latch Time | T _{LAT} | V _{IN} =V _{CE} =5.0V, V _{OUT} =0.8 × V _{OUT(E)} , Short Lx at 1 resistance ⁽⁷⁾ | 1.0 | - | 20.0 | ms | |
| Short Protection Threshold Voltage | V _{SHORT} | Sweeping V _{OUT} , V _{IN} =V _{CE} =5.0V, Short Lx at 1 resistance, V _{OUT} voltage which Lx becomes "L" level within 1ms | 0.675 | 0.900 | 1.150 | V | |
| CL Discharge | Rdischg | V _{IN} =5.0V, Lx=5.0V, V _{CE} =0V, V _{OUT} =open | 200 | 300 | 450 | | |

Test conditions: Unless otherwise stated, V_{IN}=5.0V, V_{OUT(E)}=Setting Voltage

NOTE:

*1: Including hysteresis operating voltage range.

*2: EFFI = { (output voltage × output current) / (input voltage × input current) } × 100

*3: ON resistance () = (V_{IN} - Lx pin measurement voltage) / 100mA

*4: R&D value

*5: When temperature is high, a current of approximately 10 μA (maximum) may leak.

*6: The CE/MODE pin of the XC9237A series works also as an external switching pin of PWM control and PWM/PFM control. When the IC is in the operation, control is switched to the automatic PWM/PFM switching mode when the CE/MODE pin voltage is equal to or greater than V_{IN} minus 0.3V, and to the PWM mode when the CE/MODE pin voltage is equal to or lower than V_{IN} minus 1.0V and equal to or greater than V_{CEH}.

*7: Time until it short-circuits V_{OUT} with GND via 1 of resistor from an operational state and is set to Lx=0V from current limit pulse generating.

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

*9: 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.

*10: Current limit denotes the level of detection at peak of coil current.

*11: "H"=V_{IN}-V_{IN}-1.2V, "L"=+0.1V~0.1V

*12: XC9235 series exclude I_{PFM} and MAXI_{PFM} because those are only for the PFM control's functions.

*13: XC9235/9236 series exclude V_{PWMH} and V_{PWML} because those are only for the XC9237 series' functions.

ELECTRICAL CHARACTERISTICS (Continued)

XC9237B(C)18Dxx, V_{OUT}=1.8V, FOSC=3.0MHz, T_a=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNIT | CIRCUIT |
|--|---|--|------------------------|-------|-----------------------|------|---------|
| Output Voltage | V _{OUT} | When connected to external components, V _{IN} =V _{CE} =5.0V, I _{OUT} =30mA | 1.764 | 1.800 | 1.836 | V | |
| Operating Voltage Range | V _{IN} | | 2.0 | - | 6.0 | V | |
| Maximum Output Current | I _{OUTMAX} | V _{IN} =V _{OUT(E)} +2.0V, V _{CE} =1.0V, When connected to external components (*9) | 600 | - | - | mA | |
| U.V.L.O. Voltage | V _{UVLO} | V _{CE} =V _{IN} , V _{OUT} =0V, Voltage which Lx pin holding "L" level (*1,*11) | 1.00 | 1.40 | 1.78 | V | |
| Supply Current | I _{DD} | V _{IN} =V _{CE} =5.0V, V _{OUT} =V _{OUT(E)} × 1.1V | - | 21 | 35 | μA | |
| Stand-by Current | I _{STB} | V _{IN} =5.0V, V _{CE} =0V, V _{OUT} =V _{OUT(E)} × 1.1V | - | 0 | 1.0 | μA | |
| Oscillation Frequency | FOSC | When connected to external components, V _{IN} =V _{OUT(E)} +2.0V, V _{CE} =1.0V, I _{OUT} =100mA | 2550 | 3000 | 3450 | kHz | |
| PFM Switching Current | I _{PFM} | When connected to external components, V _{IN} =V _{OUT(E)} +2.0V, V _{CE} =V _{IN} , I _{OUT} =1mA (*12) | 170 | 220 | 270 | mA | |
| Maximum IPFM Limit | MAXI _{PFM} | V _{CE} =V _{IN} =(C-1), I _{OUT} =1mA (*12) | - | 200 | 300 | % | |
| Maximum Duty Cycle | MAXDTY | V _{IN} =V _{CE} =5.0V, V _{OUT} =V _{OUT(E)} × 0.9V | 100 | - | - | % | |
| Minimum Duty Cycle | MINDTY | V _{IN} =V _{CE} =5.0V, V _{OUT} =V _{OUT(E)} × 0.1V | - | - | 0 | % | |
| Efficiency | EFFI | When connected to external components, V _{CE} =V _{IN} =V _{OUT(E)} +1.2V, I _{OUT} =100mA | - | 86 | - | % | |
| Lx SW "H" ON Resistance 1 | R _{LxH} | V _{IN} =V _{CE} =5.0V, V _{OUT} =0V, I _{Lx} =100mA (*3) | - | 0.35 | 0.55 | | |
| Lx SW "H" ON Resistance 2 | R _{LxH} | V _{IN} =V _{CE} =3.6V, V _{OUT} =0V, I _{Lx} =100mA (*3) | - | 0.42 | 0.67 | | |
| Lx SW "L" ON Resistance 1 | R _{LxL} | V _{IN} =V _{CE} =5.0V (*4) | - | 0.45 | 0.66 | | - |
| Lx SW "L" ON Resistance 2 | R _{LxL} | V _{IN} =V _{CE} =3.6V (*4) | - | 0.52 | 0.77 | | - |
| Lx SW "H" Leak Current (*5) | I _{LeakH} | V _{IN} =V _{OUT} =5.0V, V _{CE} =0V, Lx=0V | - | 0.01 | 1.0 | μA | |
| Current Limit (*10) | I _{LIM} | V _{IN} =V _{CE} =5.0V, V _{OUT} =V _{OUT(E)} × 0.9V (*8) | 900 | 1050 | 1350 | mA | |
| Output Voltage Temperature Characteristics | $\frac{V_{OUT}}{V_{OUT} \cdot \text{topr}}$ | I _{OUT} =30mA, -40 Topr 85 | - | ± 100 | - | ppm/ | |
| CE "H" Voltage | V _{CEH} | V _{OUT} =0V, Applied voltage to V _{CE} (*11) Voltage changes Lx to "H" level | 0.65 | - | V _{IN} | V | |
| CE "L" Voltage | V _{CEL} | V _{OUT} =0V, Applied voltage to V _{CE} (*11) Voltage changes Lx to "L" level | V _{SS} | - | 0.25 | V | |
| PWM "H" Level Voltage | V _{PWMH} | When connected to external components, I _{OUT} =1mA (*6), Voltage which oscillation frequency becomes 2550kHz FOSC 3450kHz (*13) | - | - | V _{IN} - 1.0 | V | |
| PWM "L" Level Voltage | V _{PWML} | When connected to external components, I _{OUT} =1mA (*6), Voltage which oscillation frequency becomes FOSC < 2550kHz (*13) | V _{IN} - 0.25 | - | - | V | |
| CE "H" Current | I _{CEH} | V _{IN} =V _{CE} =5.0V, V _{OUT} =0V | - 0.1 | - | 0.1 | μA | |
| CE "L" Current | I _{CEL} | V _{IN} =5.0V, V _{CE} =0V, V _{OUT} =0V | - 0.1 | - | 0.1 | μA | |
| Soft Start Time (B Series) | T _{SS} | When connected to external components, V _{CE} =0V V _{IN} , I _{OUT} =1mA | - | 0.32 | 0.50 | ms | |
| Soft Start Time (C Series) | T _{SS} | When connected to external components, V _{CE} =0V V _{IN} , I _{OUT} =1mA | 0.5 | 0.9 | 2.5 | ms | |
| Latch Time | T _{LAT} | V _{IN} =V _{CE} =5.0V, V _{OUT} =0.8 × V _{OUT(E)} , Short Lx at 1 resistance (*7) | 1.0 | - | 20 | ms | |
| Short Protection Threshold Voltage | V _{SHORT} | Sweeping V _{OUT} , V _{IN} =V _{CE} =5.0V, Short Lx at 1 resistance, V _{OUT} voltage which Lx becomes "L" level within 1ms | 0.675 | 0.900 | 1.150 | V | |
| CL Discharge | R _{dischg} | V _{IN} =5.0V, Lx=5.0V, V _{CE} =0V, V _{OUT} =open | 200 | 300 | 450 | | |

Test conditions: Unless otherwise stated, V_{IN}=5.0V, V_{OUT(E)}=Setting Voltage

NOTE:

*1: Including hysteresis operating voltage range.

*2: EFFI = { (output voltage × output current) / (input voltage × input current) } × 100

*3: ON resistance () = (V_{IN} - Lx pin measurement voltage) / 100mA

*4: R&D value

*5: When temperature is high, a current of approximately 10 μA (maximum) may leak.

*6: The CE/MODE pin of the XC9237A series works also as an external switching pin of PWM control and PWM/PFM control. When the IC is in the operation, control is switched to the automatic PWM/PFM switching mode when the CE/MODE pin voltage is equal to or greater than V_{IN} minus 0.3V, and to the PWM mode when the CE/MODE pin voltage is equal to or lower than V_{IN} minus 1.0V and equal to or greater than V_{CEH}.

*7: Time until it short-circuits V_{OUT} with GND via 1 of resistor from an operational state and is set to Lx=0V from current limit pulse generating.

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

*9: 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.

*10: Current limit denotes the level of detection at peak of coil current.

*11: "H"=V_{IN}-V_{IN}-1.2V, "L"=+0.1V~-0.1V

*12: XC9235 series exclude IPFM and MAXIPFM because those are only for the PFM control's functions.

*13: XC9235/9236 series exclude VPWMH and VPWML because those are only for the XC9237 series' functions.

ELECTRICAL CHARACTERISTICS (Continued)

PFM Switching Current (I_{PFM}) by Oscillation Frequency and Setting Voltage

(mA)

| SETTING VOLTAGE | 1.2MHz | | | 3.0MHz | | |
|--------------------------------|--------|------|------|--------|------|------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| $V_{OUT(E)} \leq 1.2V$ | 140 | 180 | 240 | 190 | 260 | 350 |
| $1.2V < V_{OUT(E)} \leq 1.75V$ | 130 | 170 | 220 | 180 | 240 | 300 |
| $1.8V \leq V_{OUT(E)}$ | 120 | 160 | 200 | 170 | 220 | 270 |

Input Voltage (V_{IN}) for Measuring Maximum PFM Switching Current ($MAX I_{PFM}$) Limit

| FOSC | 1.2MHz | 3.0MHz |
|------|-------------------|-------------------|
| C-1 | $V_{OUT(E)}+0.5V$ | $V_{OUT(E)}+1.0V$ |

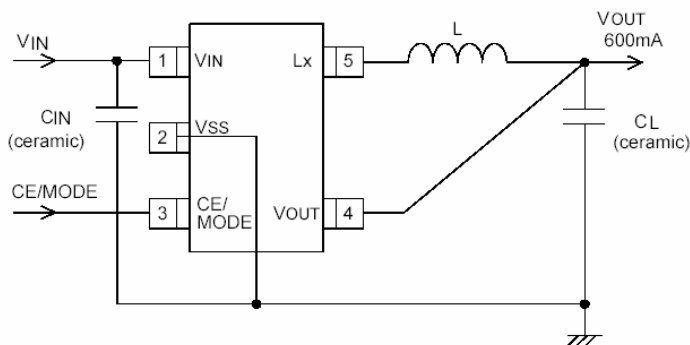
Minimum operating voltage is 2.0V.

ex.) Although when $V_{OUT(E)}$ is 1.2V and FOSC is 1.2MHz, (C-1) should be 1.7V, (C-1) becomes 2.0V for the minimum operating voltage 2.0V.

Soft-Start Time, Setting Voltage (XC9235B/36B/37B Series only)

| SERIES | FOSC | SETTING VOLTAGE | MIN. | TYP. | MAX. |
|-----------------------------|---------|-----------------------------|------|------|-------------|
| XC9235B/XC9237B | 1200kHz | $0.8 \leq V_{OUT(E)} < 1.5$ | - | 250 | $400 \mu s$ |
| | 1200kHz | $1.5 \leq V_{OUT(E)} < 1.8$ | - | 320 | $500 \mu s$ |
| | 1200kHz | $1.8 \leq V_{OUT(E)} < 2.5$ | - | 280 | $400 \mu s$ |
| | 1200kHz | $2.5 \leq V_{OUT(E)} < 4.0$ | - | 320 | $500 \mu s$ |
| XC9236B | 1200kHz | $0.8 \leq V_{OUT(E)} < 2.5$ | - | 280 | $400 \mu s$ |
| | 1200kHz | $2.5 \leq V_{OUT(E)} < 4.0$ | - | 320 | $500 \mu s$ |
| XC9235B/ XC9236B/XC9237B | 3000kHz | $0.8 \leq V_{OUT(E)} < 1.8$ | - | 280 | $400 \mu s$ |
| | 3000kHz | $1.8 \leq V_{OUT(E)} < 4.0$ | - | 320 | $500 \mu s$ |

TYPICAL APPLICATION CIRCUIT



FOSC=3.0MHz

L: 1.5 μH (NR3015, TAIYO YUDEN)

C_{IN} : 4.7 μF (Ceramic)

C_L : 10 μF (Ceramic)

FOSC=1.2MHz

L: 4.7 μH (NR4018, TAIYO YUDEN)

C_{IN} : 4.7 μF (Ceramic)

C_L : 10 μF (Ceramic)

OPERATIONAL DESCRIPTION

The XC9235/XC9236/XC9237 series consists of a reference voltage source, ramp wave circuit, error amplifier, PWM comparator, phase compensation circuit, output voltage adjustment resistors, P-channel MOSFET driver transistor, N-channel MOSFET switching transistor for the synchronous switch, current limiter circuit, U.V.L.O. circuit and others. (See the block diagram above.) The series ICs compare, using the error amplifier, the voltage of the internal voltage reference source with the feedback voltage from the V_{OUT} pin through split resistors, R1 and R2. Phase compensation is performed on the resulting error amplifier output, to input a signal to the PWM comparator to determine the turn-on time during PWM operation. The PWM comparator compares, in terms of voltage level, the signal from the error amplifier with the ramp wave from the ramp wave circuit, and delivers the resulting output to the buffer driver circuit to cause the Lx pin to output a switching duty cycle. This process is continuously performed to ensure stable output voltage. The current feedback circuit monitors the P-channel MOS driver transistor current for each switching operation, and modulates the error amplifier output signal to provide multiple feedback signals. This enables a stable feedback loop even when a low ESR capacitor such as a ceramic capacitor is used ensuring stable output voltage.

<Reference Voltage Source>

The reference voltage source provides the reference voltage to ensure stable output voltage of the DC/DC converter.

<Ramp Wave Circuit>

The ramp wave circuit determines switching frequency. The frequency is fixed internally and can be selected from 1.2MHz or 3.0MHz. 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>

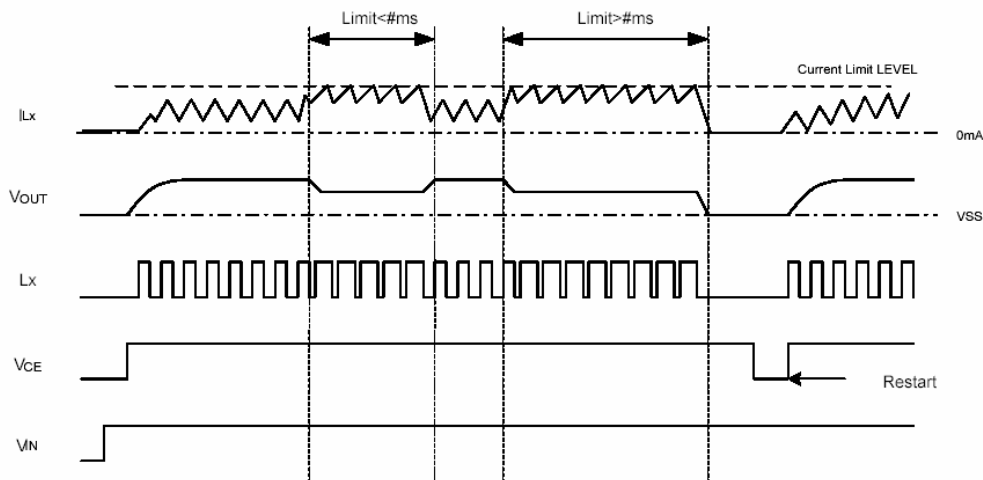
The error amplifier is designed to monitor output voltage. The amplifier compares the reference voltage with the feedback voltage divided by the internal split resistors, R1 and R2. When a voltage lower than the reference voltage is fed back, the output voltage of the error amplifier increases. The gain 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 XC9235/XC9236/XC9237 series monitors the current flowing through the P-channel MOS driver transistor connected to the Lx pin, and features a combination of the current limit mode and the operation suspension mode.

- ① When the driver current is greater than a specific level, the 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 ms and the above three steps are repeatedly performed, the IC performs the function of latching the OFF state of the driver transistor, and goes into operation suspension mode. Once the IC is in suspension mode, operations can be resumed by either turning the IC off via the CE/MODE pin, or by restoring power to the V_{IN} 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 current limit of the XC9235/XC9236/XC9237 series can be set at 1050mA 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 input capacitors are placed as close to the IC as possible.



OPERATIONAL DESCRIPTION (Continued)

<Short-Circuit Protection>

The short-circuit protection circuit monitors the internal R1 and R2 divider voltage from the V_{OUT} pin (refer to FB point in the block diagram shown in the previous page). In case where output is accidentally shorted to the Ground and when the FB point voltage decreases less than half of the reference voltage (V_{ref}) and a current more than the I_{LIM} flows to the driver transistor, the short-circuit protection quickly operates to turn off and to latch the driver transistor. In latch mode, the operation can be resumed by either turning the IC off and on via the CE/MODE pin, or by restoring power supply to the V_{IN} pin.

When sharp load transient happens, a voltage drop at the V_{OUT} is propagated to the FB point through C_{FB}, as a result, short circuit protection may operate in the voltage higher than 1/2 V_{OUT} voltage.

<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.

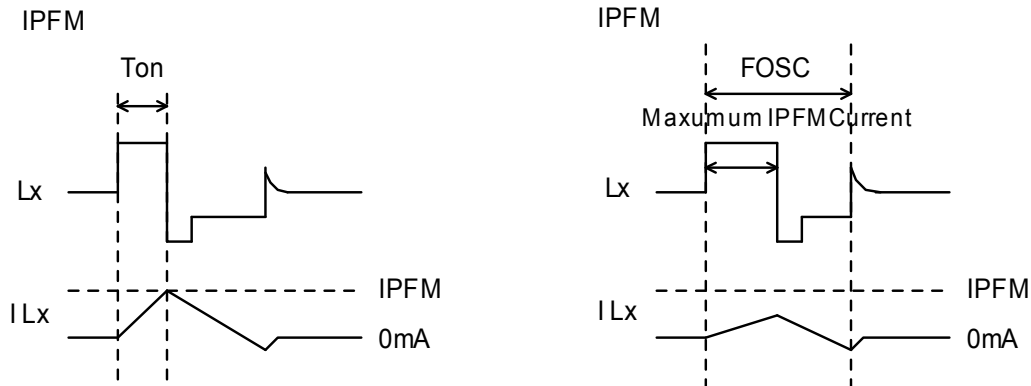
<PFM Switch Current>

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.

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

<Maximum I_{PFM} Limit>

In PFM control operation, the maximum duty ratio (MAXI_{PFM}) is set to 200% (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}.



OPERATIONAL DESCRIPTION (Continued)

< C_L High Speed Discharge >

XC9235B(C)/ XC9236B(C)/ XC9237B(C) series can quickly discharge the electric charge at the output capacitor (C_L) when a low signal to the CE pin which enables a whole IC circuit put into OFF state, is inputted via the N-channel transistor located between the L_x pin and the V_{SS} pin. When the IC is disabled, electric charge at the output capacitor (C_L) is quickly discharged so that it may avoid application malfunction. Discharge time of the output capacitor (C_L) is set by the C_L auto-discharge resistance (R) and the output capacitor (C_L). By setting time constant of a C_L auto-discharge resistance value [R] and an output capacitor value (C_L) as $\tau = C \times R$, discharge time of the output voltage after discharge via the N channel transistor is calculated by the following formulas.

$$V = V_{OUT(E)} \times e^{-t/\tau}, \text{ or } t = \tau \ln(V_{OUT(E)} / V)$$

V : Output voltage after discharge

V_{OUT(E)} : Output voltage

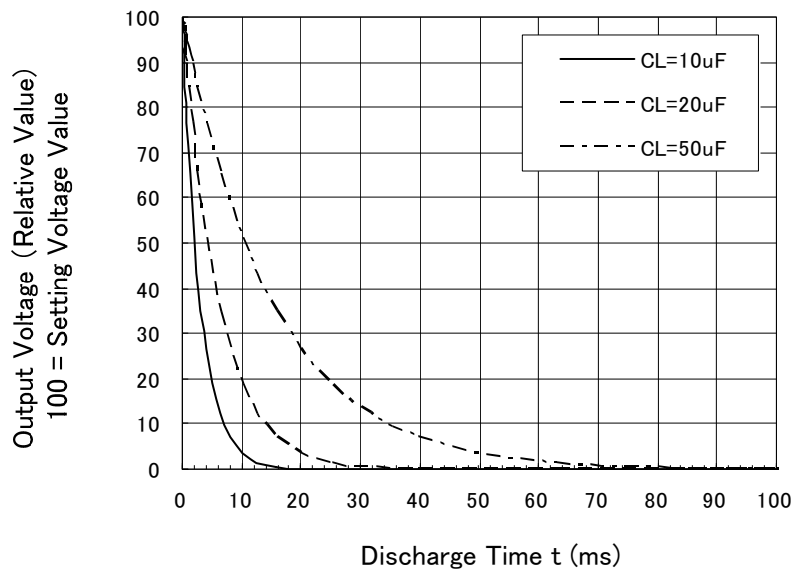
t: Discharge time,

τ : C x R

C= Capacitance of Output capacitor (C_L)

R= C_L auto-discharge resistance

Output Voltage Discharge Characteristics
R_{dischg} = 300 Ω (TYP)



OPERATIONAL DESCRIPTION (Continued)

<CE/MODE Pin Function>

The operation of the XC9235/XC9236/XC9237 series will enter into the shut down mode when a low level signal is input to the CE/MODE pin. During the shutdown mode, the current consumption of the IC becomes $0\mu A$ (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 to the CE/MODE pin is a CMOS input and the sink current is $0\mu A$ (TYP.).

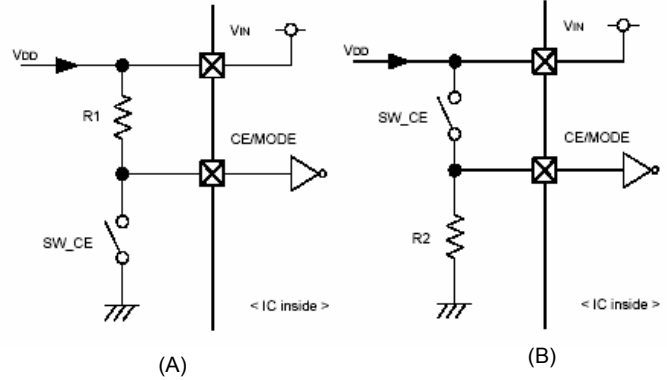
●XC9235/XC9236 series - Examples of how to use CE/MODE pin

(A)

| SW_CE | STATUS |
|-------|-----------|
| ON | Stand-by |
| OFF | Operation |

(B)

| SW_CE | STATUS |
|-------|-----------|
| ON | Operation |
| OFF | Stand-by |



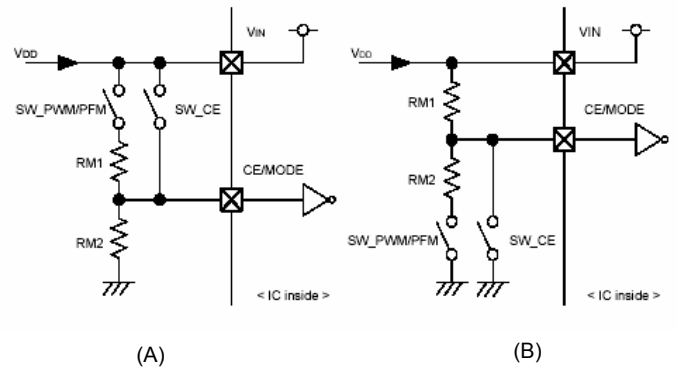
●XC9237 series - Examples of how to use CE/MODE pin

(A)

| SW_CE | SW_PWM/PFM | STATUS |
|-------|------------|-------------------------------------|
| ON | * | PWM/PFM Automatic Switching Control |
| OFF | ON | PWM Control |
| OFF | OFF | Stand-by |

(B)

| SW_CE | SW_PWM/PFM | STATUS |
|-------|------------|-------------------------------------|
| ON | * | Stand-by |
| OFF | ON | PWM Control |
| OFF | OFF | PWM/PFM Automatic Switching Control |



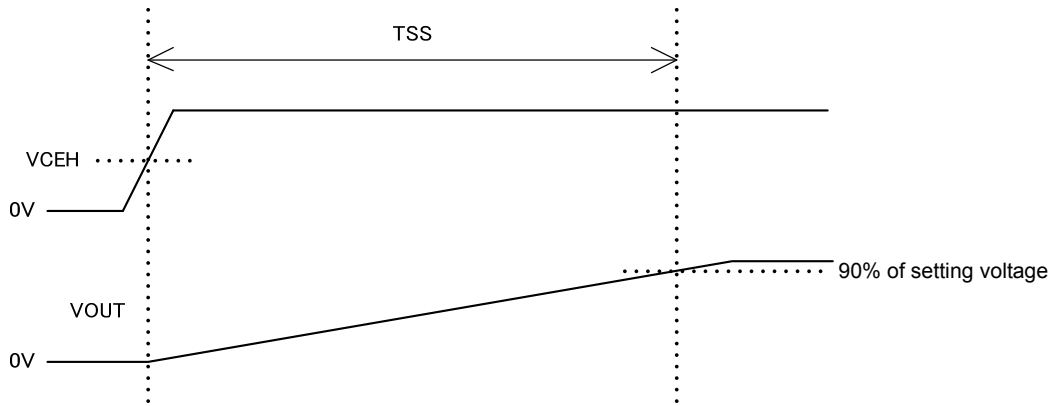
Intermediate voltage can be generated by RM1 and RM2. Please set the value of each R1, R2, RM1, RM2 from few hundreds $k\Omega$ to few hundreds $M\Omega$. For switches, CPU open-drain I/O port and transistor can be used.

OPERATIONAL DESCRIPTION (Continued)

< Soft Start >

Soft start time is available in two options via product selection.

The XC9235A/XC9236A/XC9237A/XC9235C/XC9236C/XC9237C series provide 1.0ms (TYP). The XC9225B/XC9236B/XC9237B series provide 0.25ms (TYP). Soft start time is defined as the time to reach 90% of the output setting voltage when the CE pin is turned on.



FUNCTION CHART

| CE/MODE VOLTAGE LEVEL | OPERATIONAL STATES | | |
|--------------------------|----------------------------------|---|---|
| | XC9235 | XC9236 | XC9237 |
| H Level ^(*1) | Synchronous PWM Fixed Control | Synchronous PWM/PFM Automatic Switching | Synchronous PWM/PFM Automatic Switching |
| M Level ^(*2) | | | Synchronous PWM Fixed Control |
| L Level ^(*3) | Stand-by | Stand-by | Stand-by |

Note on CE/MODE pin voltage level range

(*1) H level: $0.65V \leq H \text{ level} \leq V_{IN} V$ (for XC9235/XC9236)

H level: $V_{IN} - 0.25V \leq H \text{ level} \leq V_{IN}$ (for XC9237)

(*2) M level: $0.65V \leq M \text{ level} \leq V_{IN} - 1.0V$ (for XC9237)

(*3) L level: $0V \leq L \text{ level} \leq 0.25V$

NOTE ON USE

1. The XC9235/XC9236/XC9237 series is designed for use with ceramic output capacitors. If, however, the potential difference is too large between the input voltage and the output voltage, 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.
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 operation, 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:

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

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 turns 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 external components such as a coil.
8. When V_{IN} is less than 2.4V, limit current may not be reached because voltage falls caused by ON resistance.
9. Care must be taken when laying out the PC Board, in order to prevent misoperation of the current limit mode. Depending on the state of the PC Board, latch time may become longer and latch operation may not work. In order to avoid the effect of noise, the board should be laid out so that input capacitors are placed as close to the IC 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 1350mA (MAX.) at typical. However, the current of 1350mA 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 over current state continues for several ms, the circuit will be latched. A coil should be used within the stated absolute maximum rating in order to prevent damage to the device.

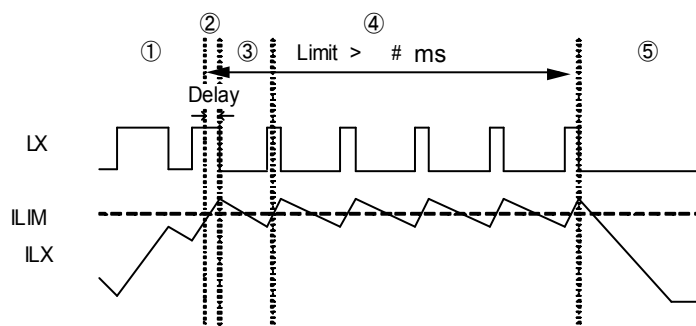
Current flows into P-ch MOSFET to reach the current limit (I_{LIM}).

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

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

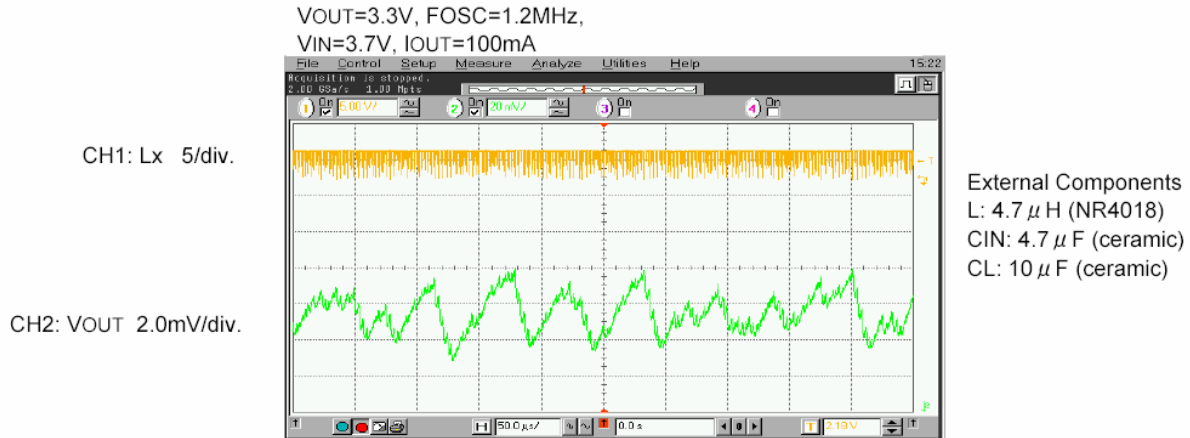
I_L oscillates very narrow pulses by the current limit for several ms.

The circuit is latched, stopping its operation.

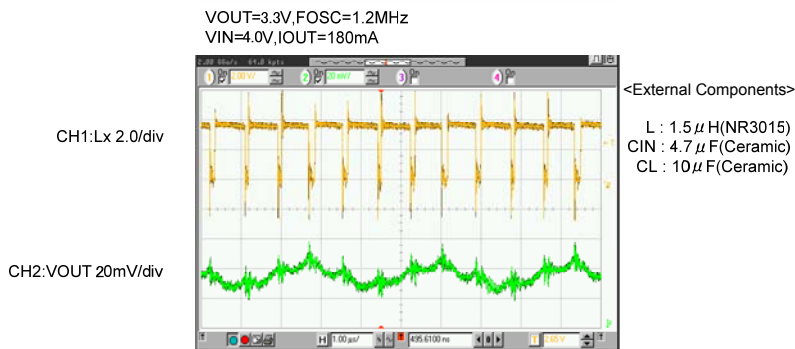


NOTE ON USE (Continued)

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. During PWM / PFM automatic switching mode, operating may become unstable at transition to continuous mode. Please verify with actual parts.



17. Please note the inductance value of the coil. The IC may enter unstable operation if the combination of ambient temperature, setting voltage, oscillation frequency, and L value are not adequate. In the operation range close to the maximum duty cycle, The IC may happen to enter unstable output voltage operation even if using the L values listed below.

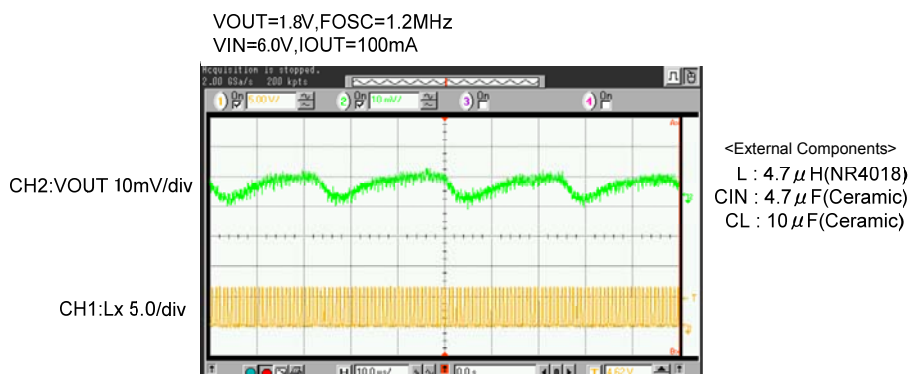


●The Range of L Value

| FOSC | V_{OUT} | L Value |
|--------|-------------------------|----------------------------|
| 3.0MHz | $0.8V < V_{OUT} < 4.0V$ | $1.0 \mu H \sim 2.2 \mu H$ |
| | $V_{OUT} \leq 2.5V$ | $3.3 \mu H \sim 6.8 \mu H$ |
| 1.2MHz | $2.5V < V_{OUT}$ | $4.7 \mu H \sim 6.8 \mu H$ |

*When a coil less value of 4.7 μ H is used at FOSC=1.2MHz or when a coil less value of 1.5 μ H is used at FOSC=3.0MHz, peak coil current more easily reach the current limit ILMI. In this case, it may happen that the IC can not provide 600mA output current.

18. It may happen to enter unstable operation when the IC operation mode goes into continuous operation mode under the condition of small input-output voltage difference. Care must be taken with the actual design unit.

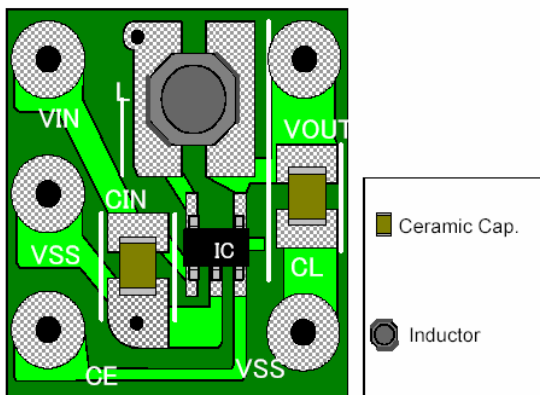


NOTE ON USE (Continued)

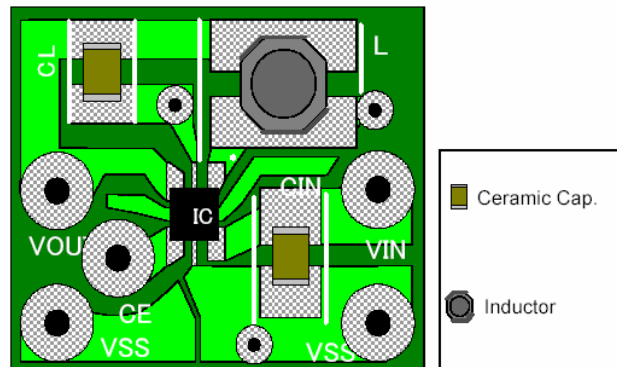
Instructions of pattern layouts

1. In order to stabilize V_{IN} 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.

●XC9235/36/37 (PKG:SOT-25)

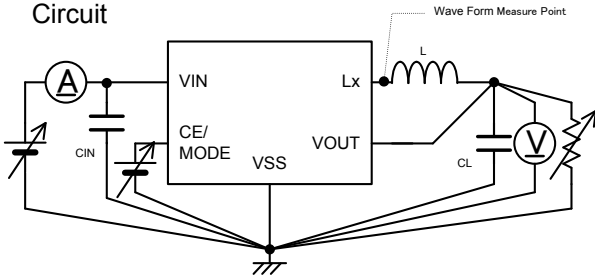


●XC9235/36/37 (PKG:USP-6C)



TEST CIRCUITS

Circuit

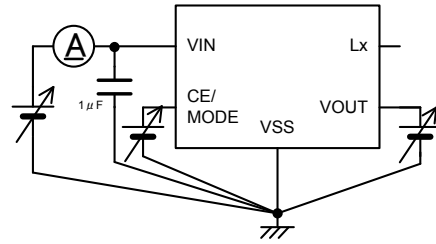


※ External Components

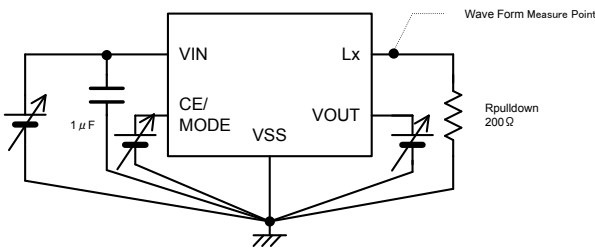
L : 1.5 μ H(NR3015) 3.0MHz
4.7 μ H(NR4018) 1.2MHz

CIN : 4.7 μ F(ceramic)
CL : 10 μ F(ceramic)

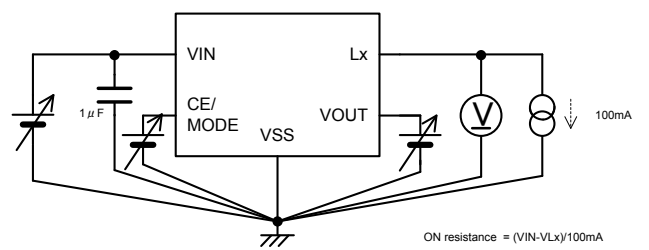
Circuit



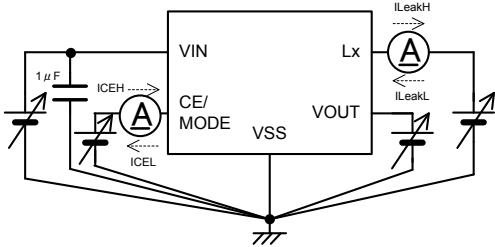
Circuit



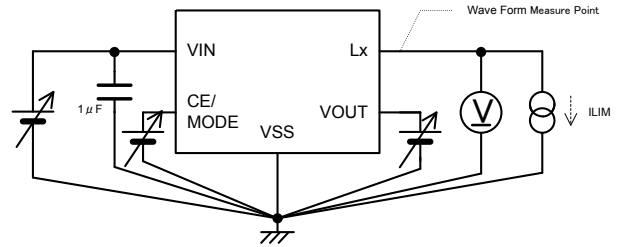
Circuit



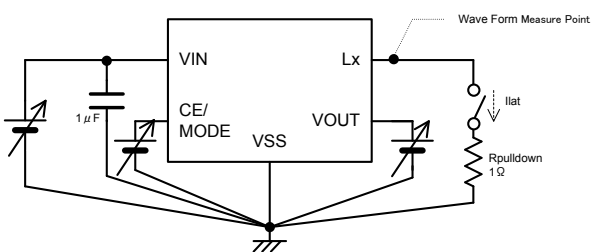
Circuit



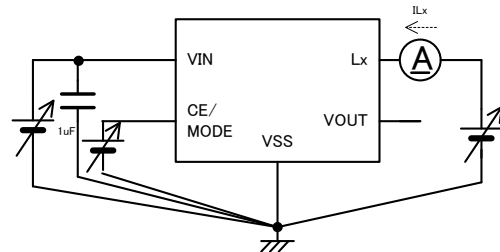
Circuit



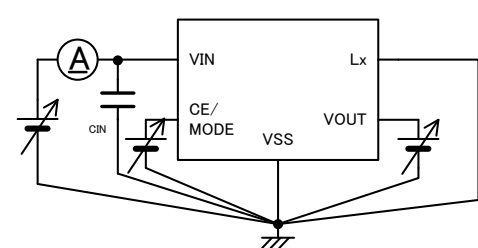
Circuit



Circuit

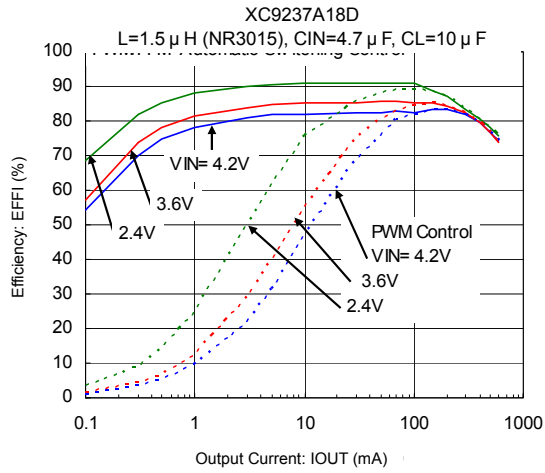
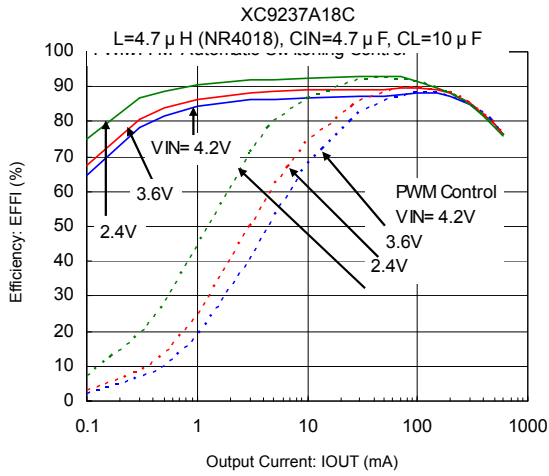


Circuit

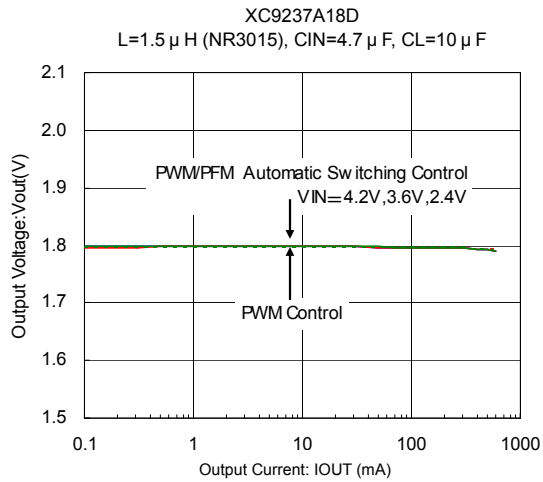
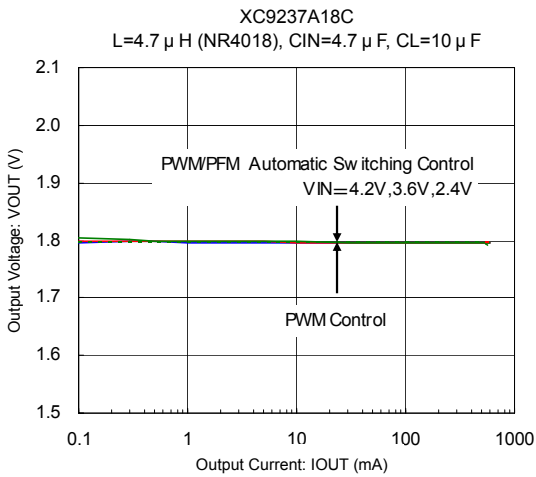


TYPICAL PERFORMANCE CHARACTERISTICS

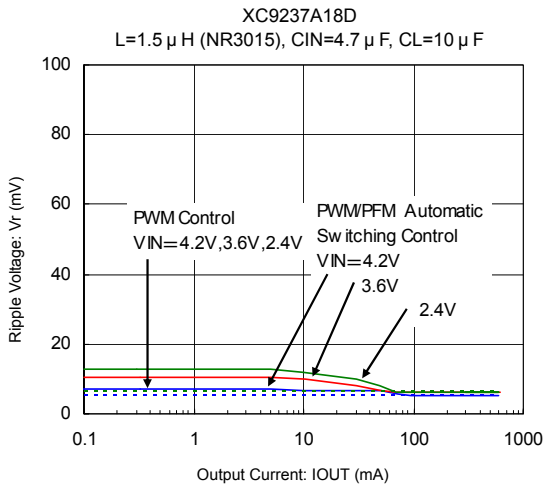
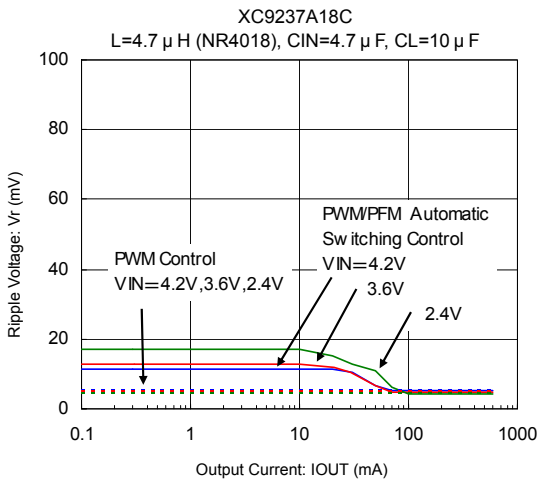
(1) Efficiency vs. Output Current



(2) Output Voltage vs. Output Current

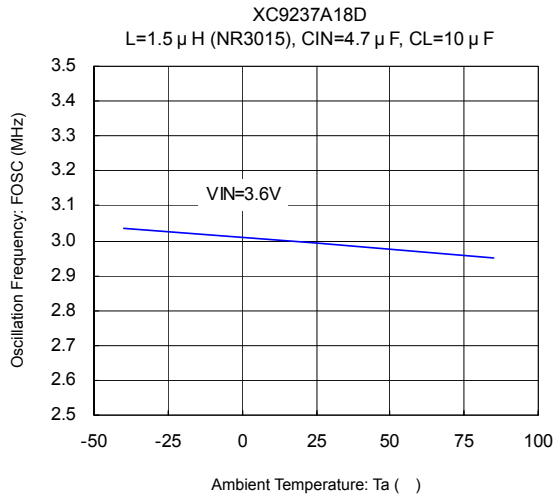
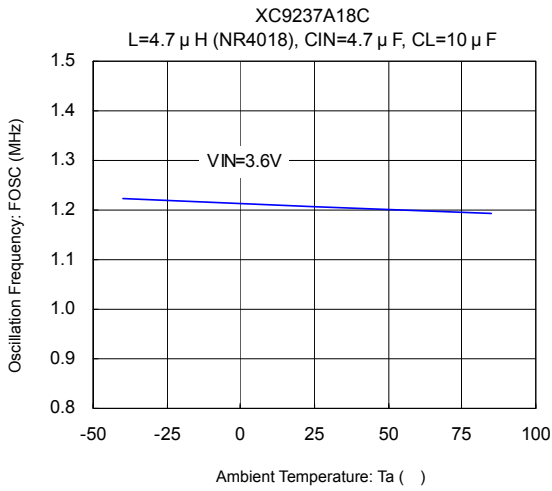


(3) Ripple Voltage vs. Output Current

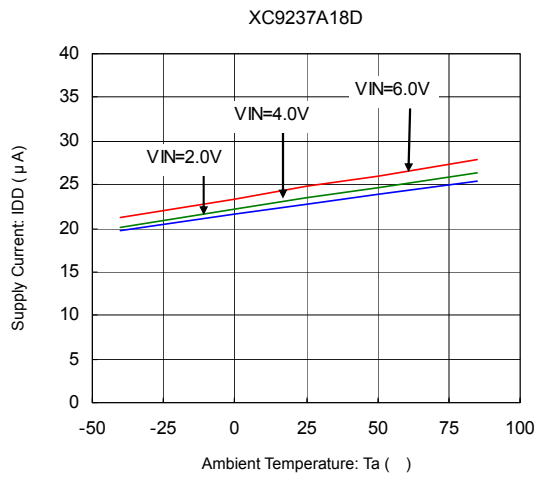
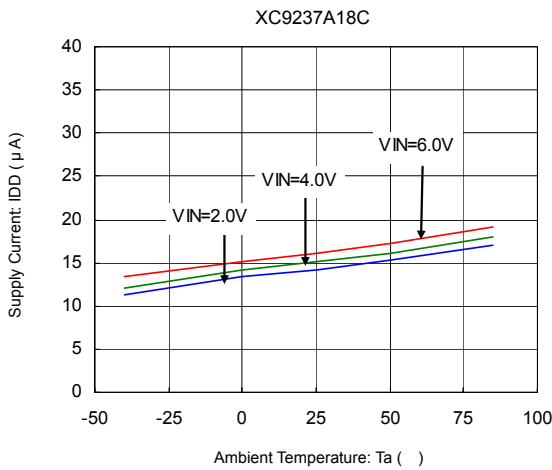


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

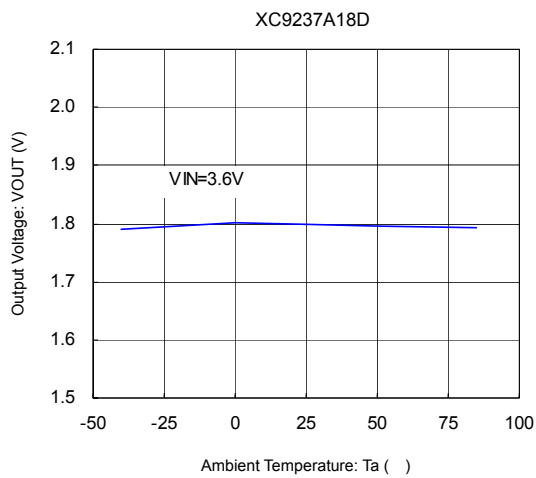
(4) Oscillation Frequency vs. Ambient Temperature



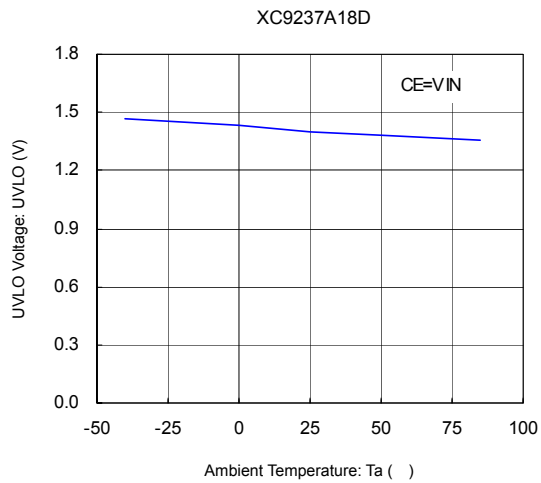
(5) Supply Current vs. Ambient Temperature



(6) Output Voltage vs. Ambient Temperature

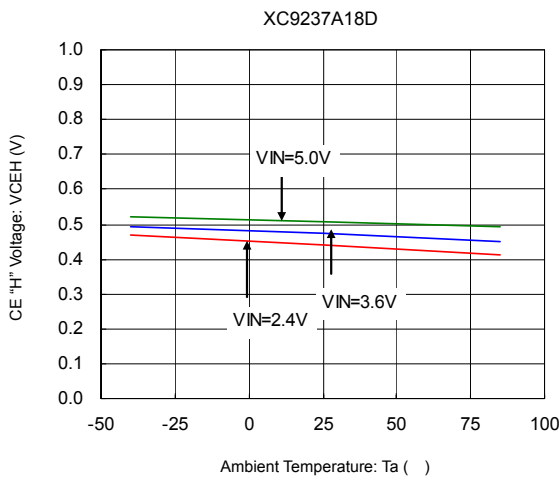


(7) UVLO Voltage vs. Ambient Temperature

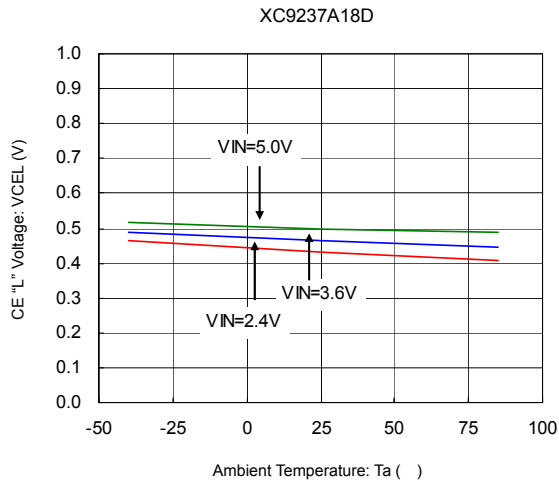


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

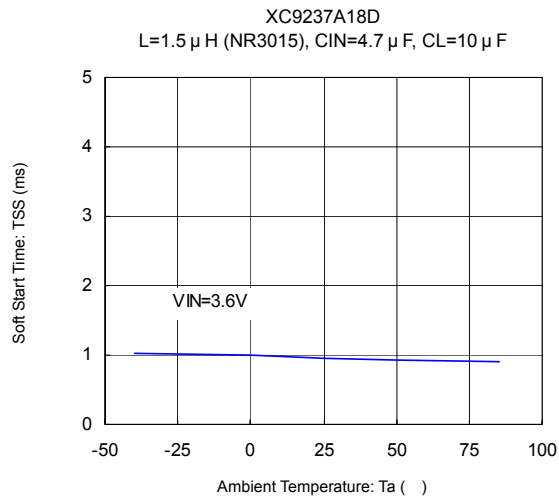
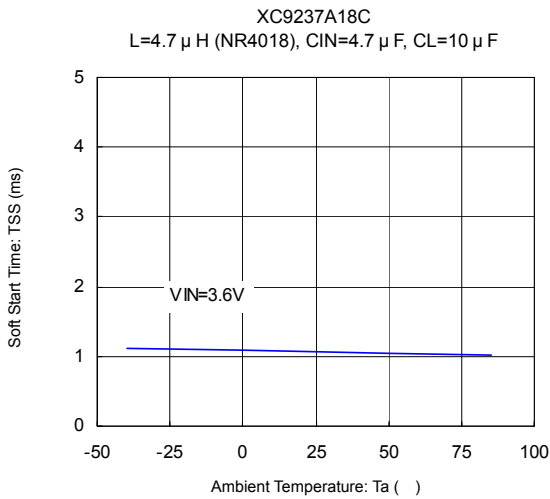
(8) CE "H" Voltage vs. Ambient Temperature



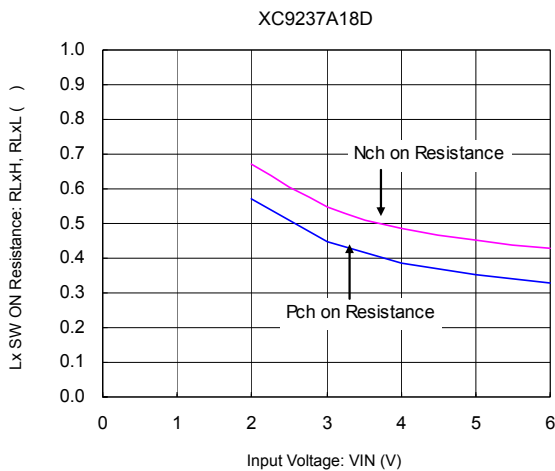
(9) CE "L" Voltage vs. Ambient Temperature



(10) Soft Start Time vs. Ambient Temperature

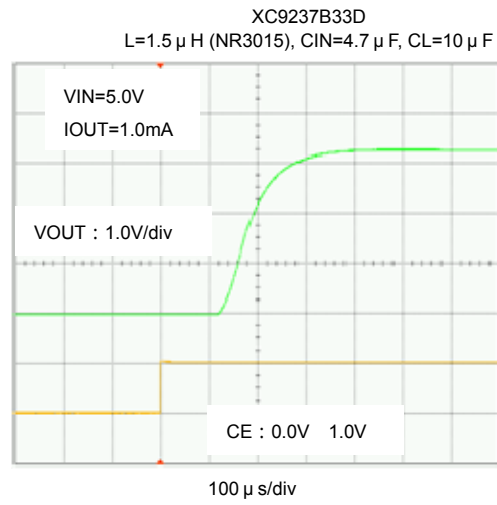
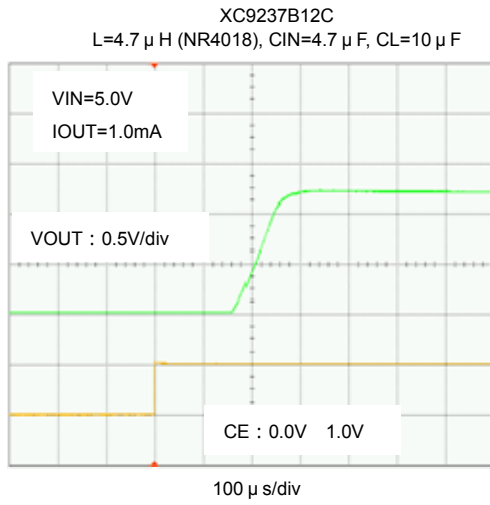


(11) "Pch / Nch" Driver on Resistance vs. Input Voltage

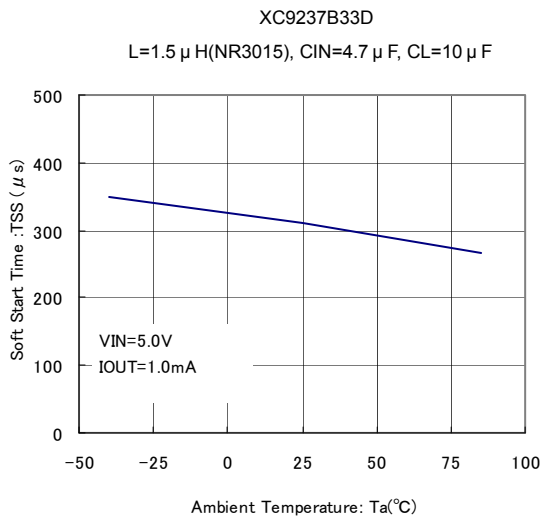
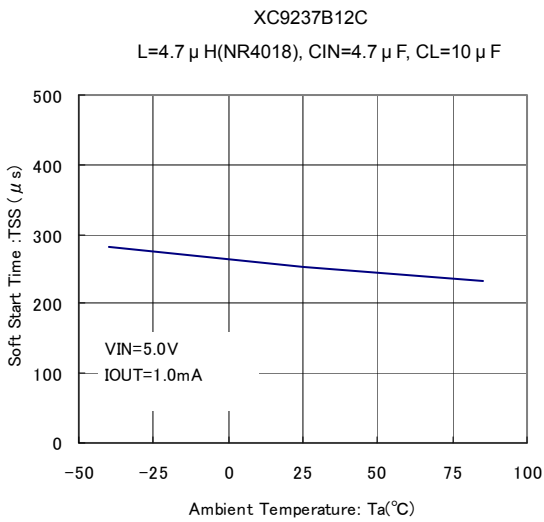


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

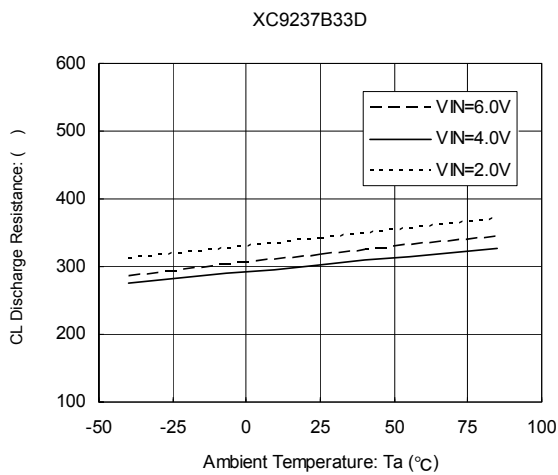
(12) XC9235B/36B/37B Rise Wave Form



(13) XC9235B/36B/37B Soft-Start Time vs. Ambient Temperature



(14) XC9235B/36B/37B CL Discharge Resistance vs. Ambient Temperature



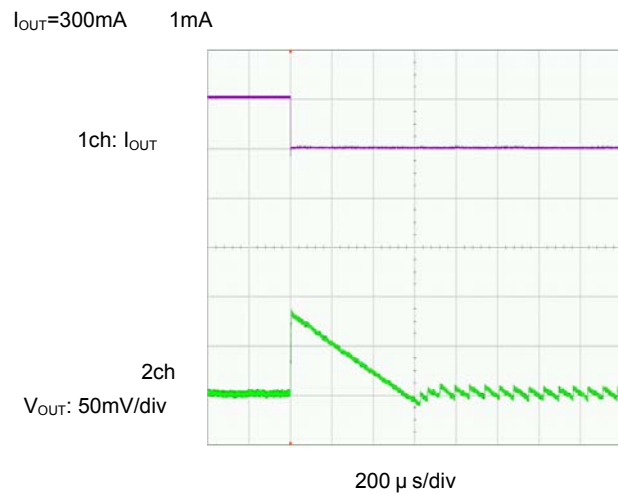
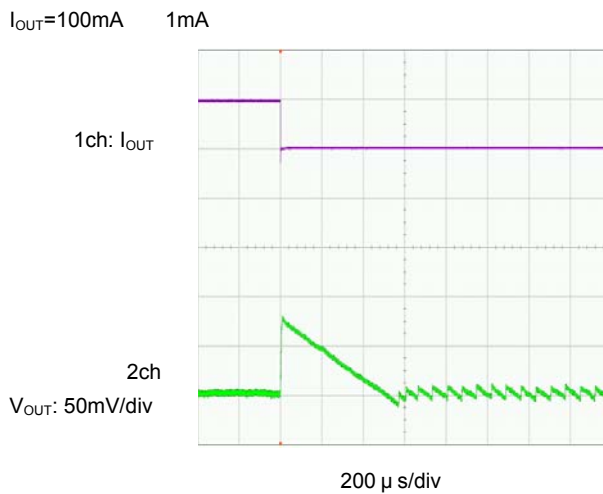
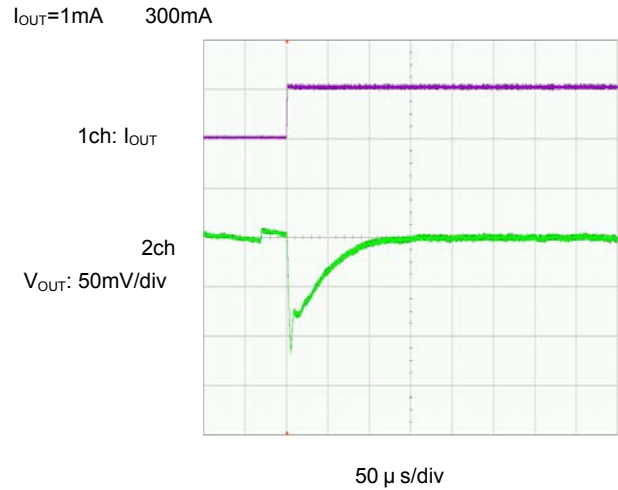
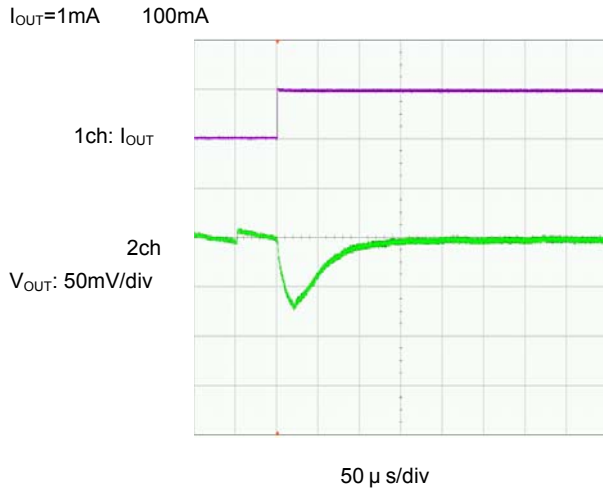
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(15) Load Transient Response

XC9237A18C

$L=4.7\ \mu\text{H}$ (NR4018), $C_{\text{IN}}=4.7\ \mu\text{F}$ (ceramic), $C_{\text{L}}=10\ \mu\text{F}$ (ceramic), $T_{\text{opr}}=25$

$V_{\text{IN}}=3.6\text{V}$, $V_{\text{CE}}=V_{\text{IN}}$ (PWM/PFM Automatic Switching Control)



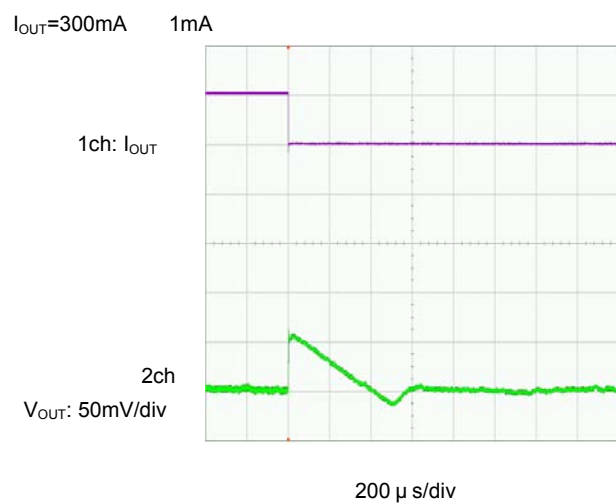
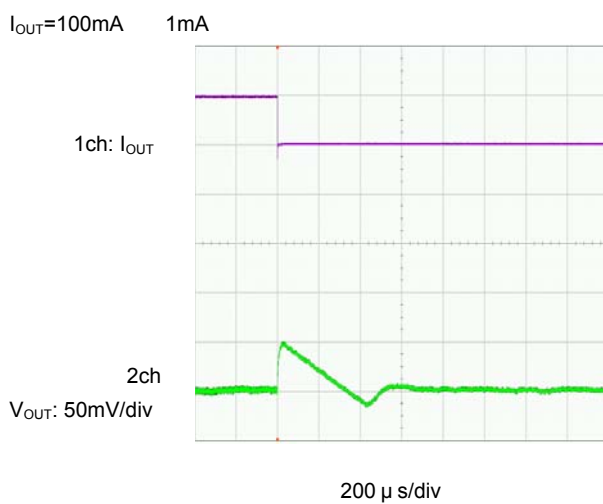
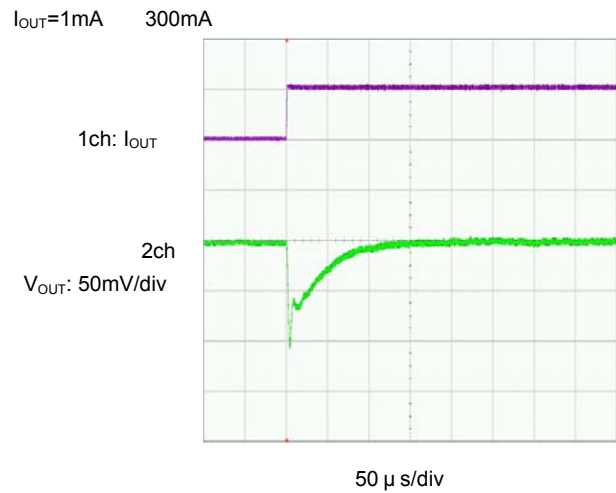
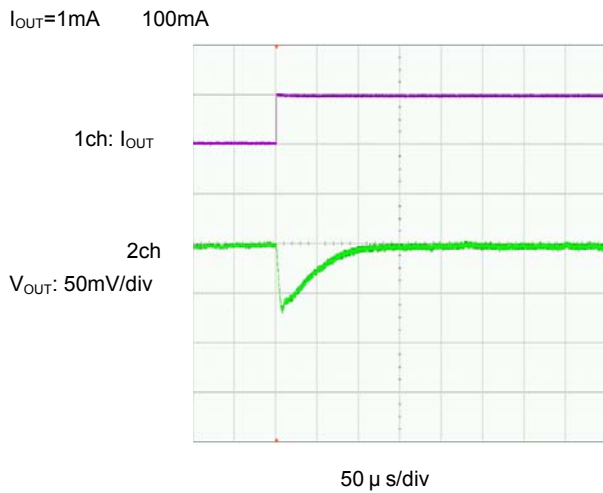
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(15) Load Transient Response (Continued)

XC9237A18C

$L=4.7\ \mu\text{H}$ (NR4018), $C_{\text{IN}}=4.7\ \mu\text{F}$ (ceramic), $C_{\text{L}}=10\ \mu\text{F}$ (ceramic), $T_{\text{opr}}=25$

$V_{\text{IN}}=3.6\text{V}$, $V_{\text{CE}}=1.8\text{V}$ (PWM Control)



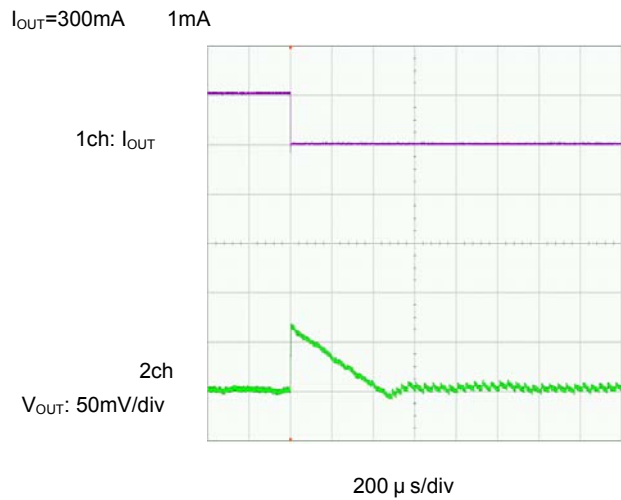
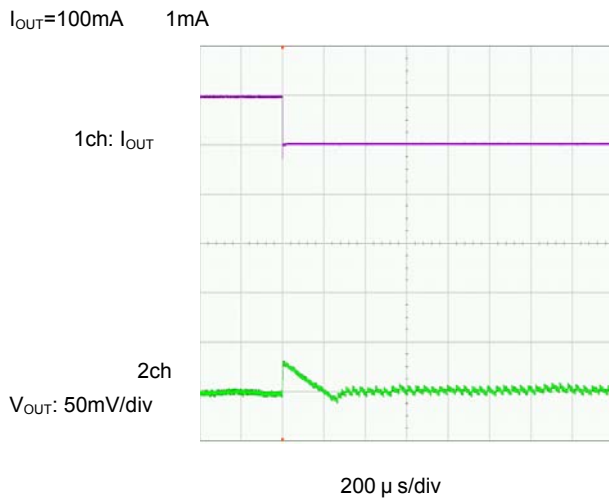
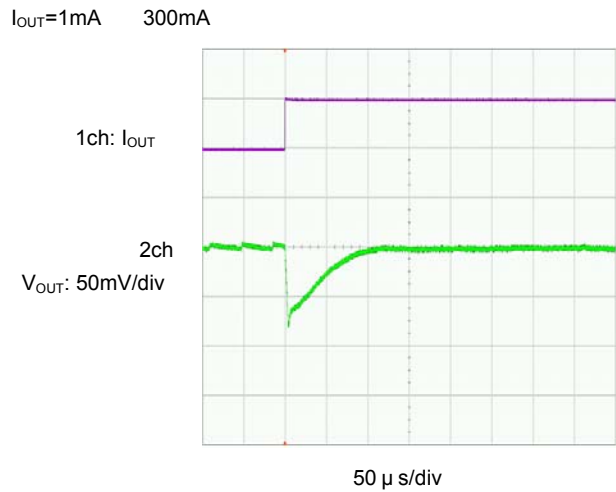
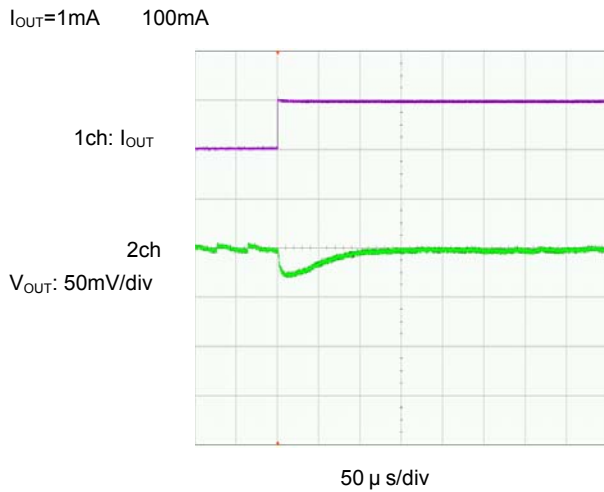
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(15) Load Transient Response (Continued)

XC9237A18D

$L=1.5\ \mu\text{H}$ (NR3015), $C_{\text{IN}}=4.7\ \mu\text{F}$ (ceramic), $C_{\text{L}}=10\ \mu\text{F}$ (ceramic), $T_{\text{opr}}=25$

$V_{\text{IN}}=3.6\text{V}$, $V_{\text{CE}}=V_{\text{IN}}$ (PWM/PFM Automatic Switching Control)



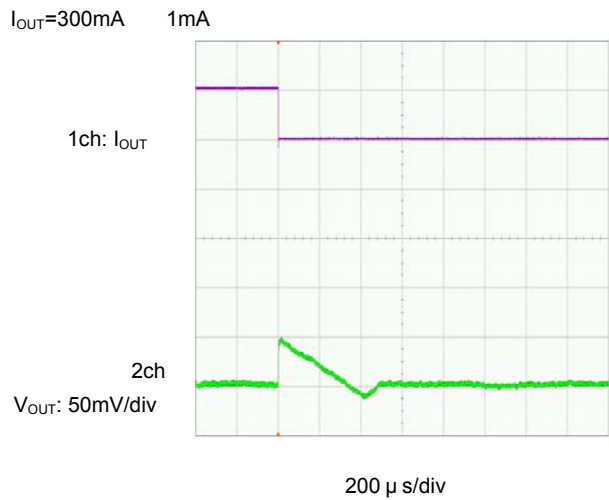
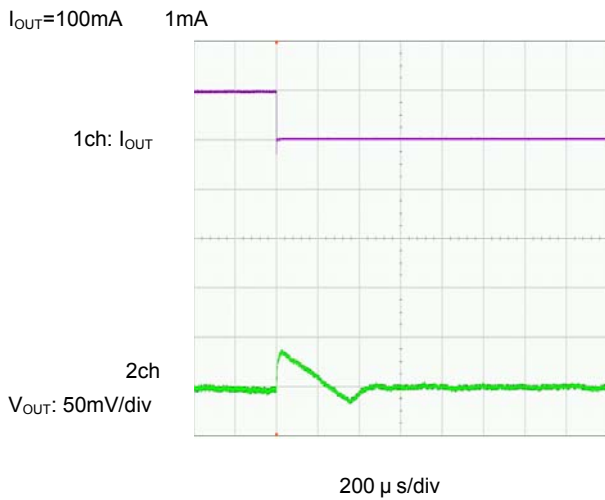
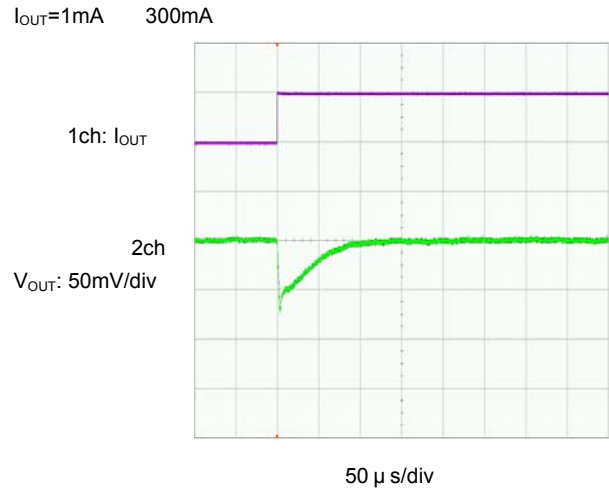
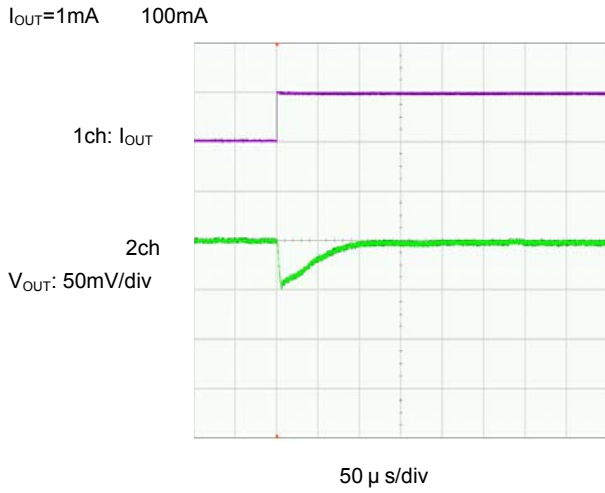
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(15) Load Transient Response (Continued)

XC9237A18D

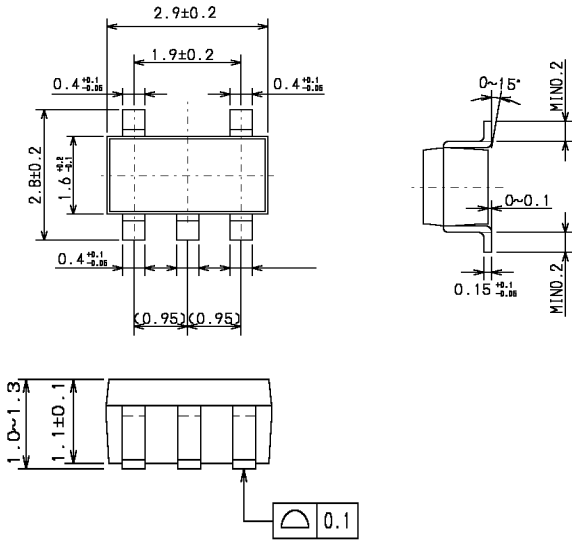
$L=1.5\ \mu\text{H}$ (NR3015), $C_{\text{IN}}=4.7\ \mu\text{F}$ (ceramic), $C_{\text{L}}=10\ \mu\text{F}$ (ceramic), $T_{\text{opr}}=25$

$V_{\text{IN}}=3.6\text{V}$, $V_{\text{CE}}=1.8\text{V}$ (PWM Control)

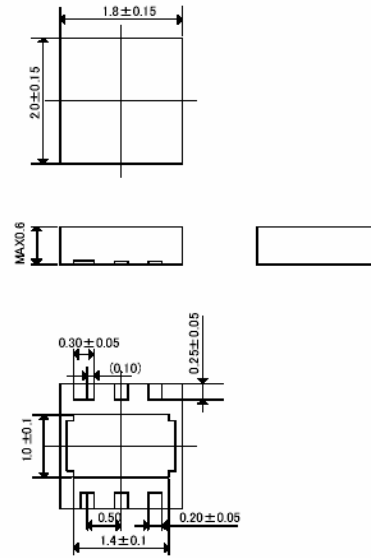


PACKAGING INFORMATION

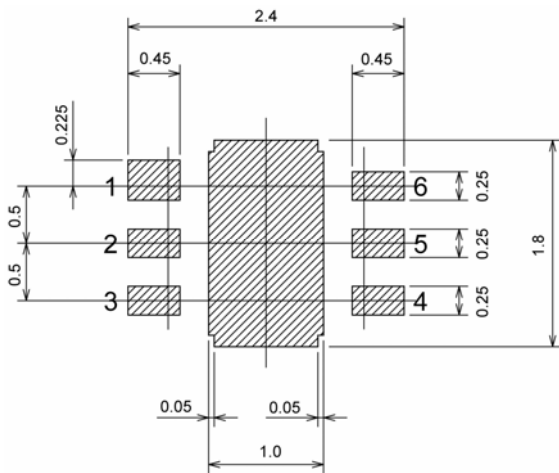
SOT-25



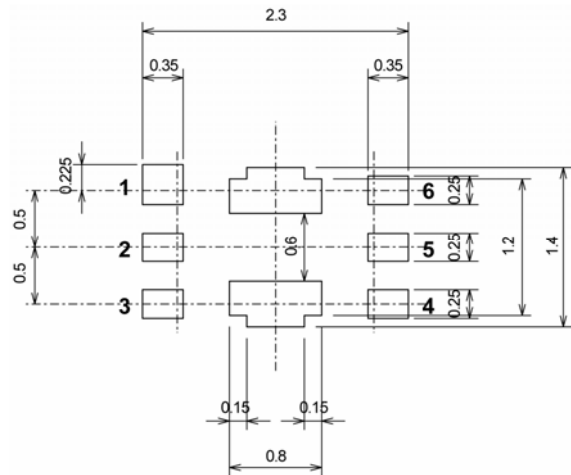
USP-6C



USP-6C Recommended Pattern Layout

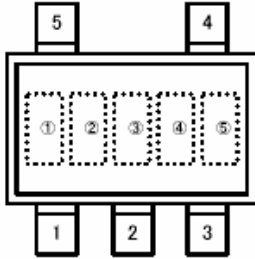


USP-6C Recommended Metal Mask Design

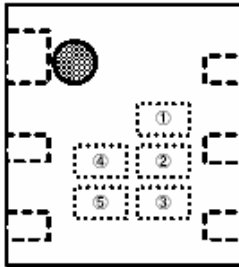


MARKING RULE

SOT-25 & USP-6C



SOT-25
(TOP VIEW)



USP-6C
(TOP VIEW)

Represent product series

| MARK | PRODUCT SERIES |
|------|----------------|
| 4 | XC9235A |
| 5 | XC9236A |
| 6 | XC9237A |
| C | XC9235B |
| D | XC9236B |
| E | XC9237B |
| K | XC9235C |
| L | XC9236C |
| M | XC9237C |

Represents integer number of output voltage and oscillation frequency

| OUTPUT VOLTAGE (V) | MARK | |
|--------------------|--------------|--------------|
| | FOSC =1.2MHz | FOSC =3.0MHz |
| 0.X | A | F |
| 1.X | B | H |
| 2.X | C | K |
| 3.X | D | L |
| 4.X | E | M |

Represents decimal point of output voltage

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

Represents production lot number

Order of 01, ...09, 10, 11, ...99, 0A, ...0Z, 1A, ...9Z, A0, ...Z9, AA, ...ZZ.
(G, I, J, O, Q, W excepted)

*No character inversion used.

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