PWM Step-Up DC/DC Controller

NO.EA-088-160113

OUTLINE

The R1211x is a CMOS-based PWM step-up DC/DC converter controller with low supply current. The R1211x consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a reference current unit, a protection circuit, and an under voltage lockout (UVLO) circuit. A low ripple and high efficiency step-up DC/DC converter can be configured by only adding few external components, such as an inductor, a diode, a power MOSFET, divider resisters, and capacitors. The R1211x002B/D has a built-in phase compensation, while the R1211x002A/C can set a phase compensation externally. The R1211x002B/D has stand-by mode. The max duty cycle is internally fixed at 90% typically. A soft-start function is built-in, and a soft-starting time is set at 9 ms typically (R1211x002A/B, 700 kHz) or 10.5 ms typically (R1211xC/D, 300 kHz). The R1211x has a latch-type protection circuit, which latches the external driver in off-state if the maximum duty cycle continues for a specified time after soft-starting time. The protection delay time can be set with an external capacitor. To release the protection, turn the power off and back on (power source voltage lower than UVLO detector threshold) or make the device into standby mode and back to active mode using the CE pin.

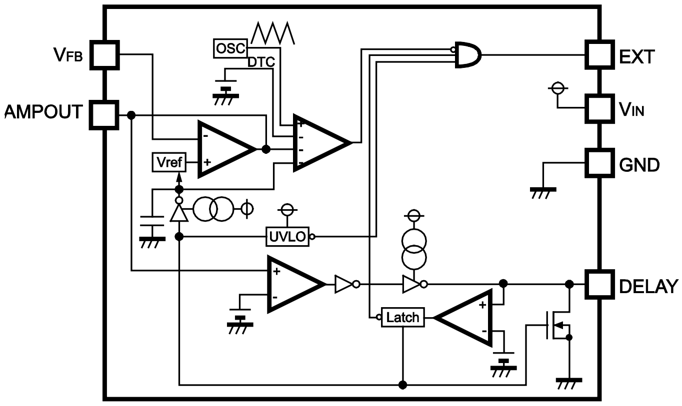
FEATURES

- Input Voltage Range ....2.5 V to 6.0 V
- Oscillator Frequency (PWM Control)...................300 kHz, 700 kHz
- Maximum Duty Cycle...Typ. 90%
- Standby Current ....Typ. 0 μA (R1211x002B/D)
- Feedback Voltage..1.0 V
- Feedback Voltage Accuracy ....±1.5%
- UVLO Threshold Level ....Typ. 2.2 V (Hysteresis Typ. 0.13 V)
- Feedback Voltage Temperature Coefficient.........±150 ppm/°C
- Built-in Latch-type Protection Circuit ....Protection delay time can be set with an external capacitor
- Packages SON-6, SOT-23-6W

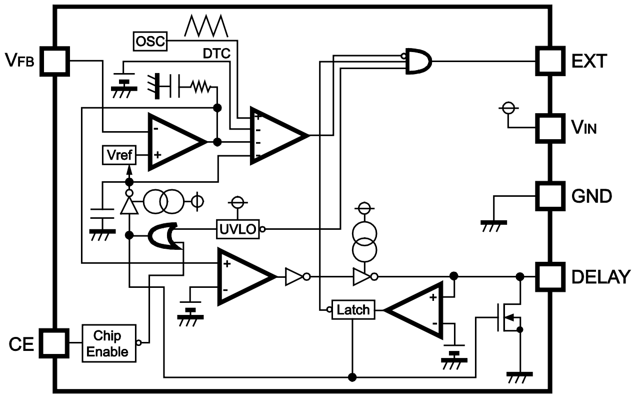
APPLICATIONS

- Constant Voltage Power Source for Portable Equipment
- Constant Voltage Power Source for LCD and CCD

BLOCK DIAGRAMS



R1211x002A/C Block Diagram



R1211x002B/D Block Diagram

SELECTION GUIDE

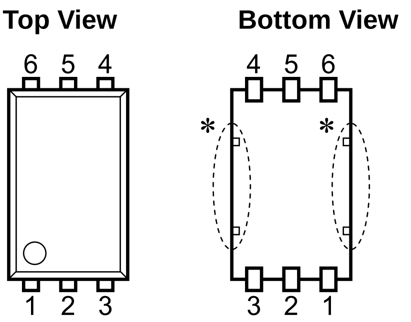
In the R1211x, the oscillator frequency, the optional function, and the package type are user-selectable options.

Selection Guide

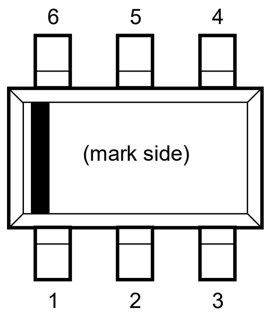
Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1211D002x-TR-FE	SON-6	3,000 pcs	Yes	Yes
R1211N002x-TR-FE	SOT-23-6W	3,000 pcs	Yes	Yes

x: Designation of Oscillator Frequency and Optional Function
(A) 700 kHz, with AMPOUT pin (External Phase Compensation Type)
(B) 700 kHz, with CE pin (Internal Phase Compensation Type, with Standby)
(C) 300 kHz, with AMPOUT pin (External Phase Compensation Type)
(D) 300 kHz, with CE pin (Internal Phase Compensation Type, with Standby)

PIN CONFIGURATIONS



SON-6 Pin Configuration



SOT-23-6W Pin Configuration

PIN DESCRIPTIONS

Pin Descriptions

Symbol	Pin No				Pin Description
	R1211x002A/C		R1211x002B/D		
	SON-6	SOT-23-6W	SON-6	SOT-23-6W	
DELAY	1	1	1	1	Pin for External Capacitor (for Setting Output Delay Time of Protection)
GND	2	5	2	5	Ground Pin
EXT	3	6	3	6	External FET Drive Pin (CMOS Output)
V_{IN}	4	4	4	4	Power Supply Pin
V_{FB}	5	3	5	3	Feedback Pin for Monitoring Output Voltage
AMPOUT	6	2	-	-	Amplifier Output Pin
CE	-	-	6	2	Chip Enable Pin ("H" Active)

∗ Tab suspension leads in the parts have GND level. (They are connected to the reverse side of this IC.)
Do not connect to other wires or land patterns.

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings (GND = 0 V)

Symbol	Item	Rating		Unit
V_{IN}	V_{IN} Pin Voltage	6.5		V
V_{EXT}	EXT Pin Output Voltage	−0.3 ~ V_{IN}+0.3		V
V_{DLY}	DELAY Pin Voltage	−0.3 ~ V_{IN}+0.3		V
V_{AMP}	AMPOUT Pin Voltage	−0.3 ~ V_{IN}+0.3		V
V_{CE}	CE Pin Input Voltage	−0.3 ~ V_{IN}+0.3		V
V_{FB}	V_{FB} Pin Voltage	−0.3 ~ V_{IN}+0.3		V
I_{AMP}	AMPOUT Pin Current	±10		mA
I_{EXT}	EXT Pin Inductor Drive Output Current	±50		mA
P_D	Power Dissipation (Standard Land Pattern)*	SOT-23-6W	430	mW
		SON-6	500	
Topt	Operating Temperature Range	−40 ~ +85		°C
Tstg	Storage Temperature Range	−55 ~ +125		°C

* For Power Dissipation, please refer to *PACKAGE INFORMATION*.

ABSOLUTE MAXIMUM RATINGS
Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages and may degrade the life time and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

ELECTRICAL CHARACTERISTICS

R1211x002A Electrical Characteristics (Topt = 25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		2.5		6.0	V
V_{FB}	Feedback Voltage	V_{IN}=3.3V	0.985	1.000	1.015	V
ΔV_{FB}/ ΔT_{opt}	V_{FB} Voltage Temperature Coefficient	−40°C ≤ Topt ≤ 85°C		±150		ppm/°C
I_{FB}	V_{FB} Input Current	V_{IN}=6V, V_{FB}=0V or 6V	−0.1		0.1	μA
f_{OSC}	Oscillator Frequency	V_{IN}=3.3V, V_{DLY}=V_{FB}=0V	595	700	805	kHz
Δf_{OSC}/ ΔT_{opt}	Oscillator Frequency Temperature Coefficient	−40°C ≤ Topt ≤ 85°C		±1.4		kHz/°C
I_{DD1}	Supply Current 1	V_{IN}=6V, V_{DLY}=V_{FB}=0V, EXT at no load		600	900	μA
maxdty	Maximum Duty Cycle	V_{IN}=3.3V, EXT "H" side	82	90	94	%
R_{EXTH}	EXT "H" ON Resistance	V_{IN}=3.3V, I_{EXT}=−20mA		5	10	Ω
R_{EXTL}	EXT "L" ON Resistance	V_{IN}=3.3V, I_{EXT}=20mA		3	6	Ω
I_{DLY1}	Delay Pin Charge Current	V_{IN}=3.3V, V_{DLY}=V_{FB}=0V	2.5	5.0	7.5	μA
I_{DLY2}	Delay Pin Discharge Current	V_{IN}=V_{FB}=2.5V, V_{DLY}=0.1V	2.5	5.5	9.0	mA
V_{DLY}	Delay Pin Detector Threshold	V_{IN}=3.3V, V_{FB}=0V,V_{DLY}=0V→2V	0.95	1.00	1.05	V
T_{START}	Soft-start Time	V_{IN}=3.3V at 90% of rising edge	4.5	9.0	13.5	ms
V_{UVLO}	UVLO Detector Threshold	V_{IN}=2.5V→2V, V_{DLY}=V_{FB}=0V	2.1	2.2	2.3	V
V_{HYS}	UVLO Detector Hysteresis	V_{IN}=2V→2.5V, V_{DLY}=V_{FB}=0V	0.08	0.13	0.18	V
I_{AMP1}	AMP "H" Output Current	V_{IN}=3.3V, V_{AMP}=1V, V_{FB}=0.9V	0.45	0.90	1.50	mA
I_{AMP2}	AMP "L" Output Current	V_{IN}=3.3V, V_{AMP}=1V, V_{FB}=1.1V	30	60	90	μA

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if when they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

R1211x002B Electrical Characteristics (Topt = 25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		2.5		6.0	V
V_{FB}	Feedback Voltage	V_{IN}=3.3V	0.985	1.000	1.015	V
$\Delta V_{FB}/\Delta Topt$	V_{FB} Voltage Temperature Coefficient	–40°C ≤ Topt ≤ 85°C		±150		ppm/°C
I_{FB}	VFB Input Current	V_{IN}=6V, V_{FB}=0V or 6V	–0.1		0.1	μA
f_{OSC}	Oscillator Frequency	V_{IN}=3.3V, V_{DLY}=V_{FB}=0V	595	700	805	kHz
$\Delta f_{OSC}/\Delta Topt$	Oscillator Frequency Temperature Coefficient	–40°C ≤ Topt ≤ 85°C		±1.4		kHz/°C
I_{DD1}	Supply Current 1	V_{IN}=6V, V_{DLY}=V_{FB}=0V, EXT at no load		600	900	μA
maxdty	Maximum Duty Cycle	V_{IN}=3.3V, EXT "H" side	82	90	94	%
R_{EXTH}	EXT "H" ON Resistance	V_{IN}=3.3V, I_{EXT}=–20mA		5	10	Ω
R_{EXTL}	EXT "L" ON Resistance	V_{IN}=3.3V, I_{EXT}=20mA		3	6	Ω
I_{DLY1}	Delay Pin Charge Current	V_{IN}=3.3V, V_{DLY}=V_{FB}=0V	2.5	5.0	7.5	μA
I_{DLY2}	Delay Pin Discharge Current	V_{IN}=V_{FB}=2.5V, V_{DLY}=0.1V	2.5	5.5	9.0	mA
V_{DLY}	Delay Pin Detector Threshold	V_{IN}=3.3V, V_{FB}=0V, V_{DLY}=0V→2V	0.95	1.00	1.05	V
T_{START}	Soft-start Time	V_{IN}=3.3V	4.5	9.0	13.5	ms
V_{UVLO}	UVLO Detector Threshold	V_{IN}=2.5V→2V, V_{DLY}=V_{FB}=0V	2.1	2.2	2.3	V
V_{HYS}	UVLO Detector Hysteresis	V_{IN}=2V→2.5V, V_{DLY}=V_{FB}=0V	0.08	0.13	0.18	V
I_{STB}	Standby Current	V_{IN}=6V, V_{CE}=0V		0	1	μA
I_{CEH}	CE "H" Input Current	V_{IN}=6V, V_{CE}=6V	–0.5		0.5	μA
I_{CEL}	CE "L" Input Current	V_{IN}=6V, V_{CE}=0V	–0.5		0.5	μA
V_{CEH}	CE "H" Input Voltage	V_{IN}=6V, V_{CE}=0V→6V	1.5			V
V_{CEL}	CE "L" Input Voltage	V_{IN}=2.5V, V_{CE}=2V→0V			0.3	V

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

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R1211x002C Electrical Characteristics (Topt = 25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		2.5		6.0	V
V_{FB}	V_{FB} Voltage Tolerance	V_{IN}=3.3V	0.985	1.000	1.015	V
ΔV_{FB}/ Δ Topt	V_{FB} Voltage Temperature Coefficient	–40°C ≤ Topt ≤ 85°C		±150		ppm/°C
I_{FB}	VFB Input Current	V_{IN}=6V, V_{FB}=0V or 6V	–0.1		0.1	μA
f_{OSC}	Oscillator Frequency	V_{IN}=3.3V, V_{DLY}=V_{FB}=0V	240	300	360	kHz
Δf_{OSC}/ Δ Topt	Oscillator Frequency Temperature Coefficient	–40°C ≤ Topt ≤ 85°C		±0.6		kHz/°C
I_{DD1}	Supply Current 1	V_{IN}=6V, V_{DLY}=V_{FB}=0V, EXT at no load		300	500	μA
maxdty	Maximum Duty Cycle	V_{IN}=3.3V, EXT "H" side	82	90	94	%
R_{EXTH}	EXT "H" ON Resistance	V_{IN}=3.3V, IEXT=–20mA		5	10	Ω
R_{EXTL}	EXT "L" ON Resistance	V_{IN}=3.3V, IEXT=20mA		3	6	Ω
I_{DLY1}	Delay Pin Charge Current	V_{IN}=3.3V, V_{DLY}=V_{FB}=0V	2.0	4.5	7.0	μA
I_{DLY2}	Delay Pin Discharge Current	V_{IN}=V_{FB}=2.5V, V_{DLY}=0.1V	2.5	5.5	9.0	mA
V_{DLY}	Delay Pin Detector Threshold	V_{IN}=3.3V, V_{FB}=0V, V_{DLY}=0V→2V	0.95	1.00	1.05	V
T_{START}	Soft-start Time	V_{IN}=3.3V	5.0	10.5	16.0	ms
V_{UVLO}	UVLO Detector Threshold	V_{IN}=2.5V→2V, V_{DLY}=V_{FB}=0V	2.1	2.2	2.3	V
V_{HYS}	UVLO Detector Hysteresis	V_{IN}=2V→2.5V, V_{DLY}=V_{FB}=0V	0.08	0.13	0.18	V
I_{AMP1}	AMP "H" Output Current	V_{IN}=3.3V, V_{AMP}=1V, V_{FB}=0.9V	0.45	0.90	1.50	mA
I_{AMP2}	AMP "L" Output Current	V_{IN}=3.3V, V_{AMP}=1V, V_{FB}=1.1V	25	50	75	μA

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

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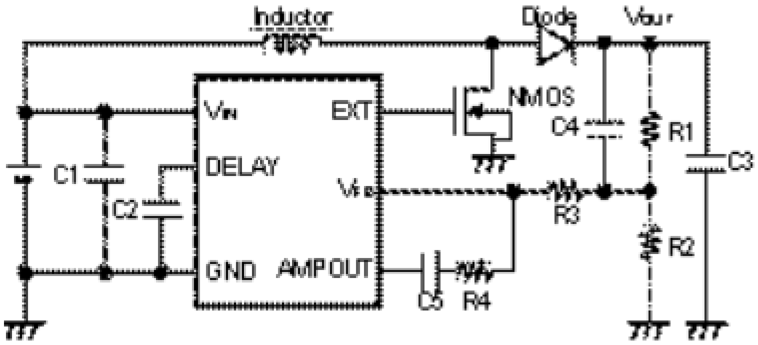
R1211x002D Electrical Characteristics (Topt = 25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		2.5		6.0	V
V_{FB}	V_{FB} Voltage Tolerance	V_{IN}=3.3V	0.985	1.000	1.015	V
ΔV_{FB}/ Δ Topt	V_{FB} Voltage Temperature Coefficient	–40°C ≤ Topt ≤ 85°C		±150		ppm/°C
I_{FB}	V_{FB} Input Current	V_{IN}=6V, V_{FB}=0V or 6V	–0.1		0.1	μA
f_{OSC}	Oscillator Frequency	V_{IN}=3.3V, V_{DLY}=V_{FB}=0V	240	300	360	kHz
Δf_{OSC}/ Δ Topt	Oscillator Frequency Temperature Coefficient	–40°C ≤ Topt ≤ 85°C		±0.6		kHz/°C
I_{DD1}	Supply Current 1	V_{IN}=6V, V_{DLY}=V_{FB}=0V, EXT at no load		300	500	μA
maxdty	Maximum Duty Cycle	V_{IN}=3.3V, EXT "H" side	82	90	94	%
R_{EXTH}	EXT "H" ON Resistance	V_{IN}=3.3V, IEXT=–20mA		5	10	Ω
R_{EXTL}	EXT "L" ON Resistance	V_{IN}=3.3V, IEXT=20mA		3	6	Ω
I_{DLY1}	Delay Pin Charge Current	V_{IN}=3.3V, V_{DLY}=V_{FB}=0V	2.0	4.5	7.0	μA
I_{DLY2}	Delay Pin Discharge Current	V_{IN}=V_{FB}=2.5V, V_{DLY}=0.1V	2.5	5.5	9.0	mA
V_{DLY}	Delay Pin Detector Threshold	V_{IN}=3.3V, V_{FB}=0V, V_{DLY}=0V→2V	0.95	1.00	1.05	V
T_{START}	Soft-start Time	V_{IN}=3.3V	5.0	10.5	16.0	ms
V_{UVLO}	UVLO Detector Threshold	V_{IN}=2.5V→2V, V_{DLY}=V_{FB}=0V	2.1	2.2	2.3	V
V_{HYS}	UVLO Detector Hysteresis	V_{IN}=2V→2.5V, V_{DLY}=V_{FB}=0V	0.08	0.13	0.18	V
I_{STB}	Standby Current	V_{IN}=6V, V_{CE}=0V		0	1	μA
I_{CEH}	CE "H" Input Current	V_{IN}=6V, V_{CE}=6V	–0.5		0.5	μA
I_{CEL}	CE "L" Input Current	V_{IN}=6V, V_{CE}=0V	–0.5		0.5	μA
V_{CEH}	CE "H" Input Voltage	V_{IN}=6V, V_{CE}=0V→6V	1.5			V
V_{CEL}	CE "L" Input Voltage	V_{IN}=2.5V, V_{CE}=2V→0V			0.3	V

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if when they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

TYPICAL APPLICATIONS AND TECHNICAL NOTES

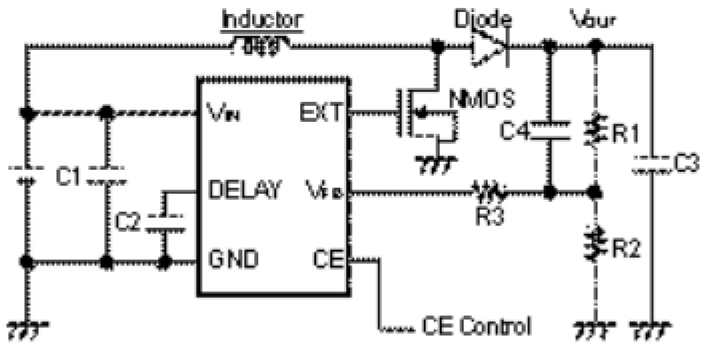


R1211x002A/R1211x002C Typical Application

NMOS: IRF7601 (International Rectifier)
Inductor: VLF504012MT-100M (TDK: 10 μH) R1211x002A
VLF504012MT-220M (TDK: 22 μH) R1211x002C
Diode: CRS10I30A (TOSHIBA)

C1: 4.7 μF (Ceramic)
C2: 0.22 μF (Ceramic)
C3: 10 μF (Ceramic)
C4: 680 pF (Ceramic)
C5: 2200 pF (Ceramic)

R1: Output Voltage Setting Resistor 1
R2: Output Voltage Setting Resistor 2
R3: 30 kΩ
R4: 30 kΩ



R1211x002B/R1211x002D Typical Application

NMOS: IRF7601 (International Rectifier)
Inductor: VLF504012MT-100M (TDK: 10 μH) R1211x002B
VLF504012MT-220M (TDK: 22 μH) R1211x002D
Diode: CRS10I30A (TOSHIBA)

C1: 4.7 μF (Ceramic)
C2: 0.22 μF (Ceramic)
C3: 10 μF (Ceramic)
C4: 680 pF (Ceramic)

R1: Output Voltage Setting Resistor 1
R2: Output Voltage Setting Resistor 2
R3: 30 kΩ

[Note] These example circuits may be applied to the output voltage requirement is 15 V or less. If the output voltage requirement is 15 V or more, ratings of NMOS and diode as shown above is over the limit, therefore, choose other external components.

- Use a 1 μF or more capacitance value of bypass capacitor between VIN pin and GND, C1 as shown in the typical applications above.

- In terms of the capacitor for setting delay time of the latch protection, C2 as shown in typical applications of the previous page, connect between Delay pin and GND pin of the IC with the minimum wiring distance.

- Connect a 1 μF or more value of capacitor between VOUT and GND, C3 as shown in typical applications of the previous page. (Recommended value is from 10 μF to 22 μF.) If the operation of the composed DC/DC converter may be unstable, use a tantalum type capacitor instead of ceramic type.

- Connect a capacitor between VOUT and the dividing point, C4 as shown in typical applications of the previous page. The capacitance value of C4 depends on divider resistors for output voltage setting. Typical value is between 100 pF and 1000 pF.

- The output voltage can be set with divider resistors for voltage setting, R1 and R2 as shown in typical applications of the previous page. Refer to the next formula.
  Output Voltage = V_{FB} x (R1 + R2) / R2
  R1 + R2 = 100 kΩ is recommended range of resistances.

- The operation of latch protection circuit is as follows: When the IC detects maximum duty cycle, charge to an external capacitor, C2 of DELAY pin starts. And maximum duty cycle continues and the voltage of DELAY pin reaches delay voltage detector threshold, V_{DLY}, outputs "L" to EXT pin and turns off the external power MOSFET. To release the latch protection operation, make the IC be standby mode with CE pin and make it active in terms of R1211x002B/D version. Otherwise, restart with power on.

- The delay time of latch protection can be calculated with C2, V_{DLY}, and Delay Pin Charge Current, I_{DLY1}, as in the next formula.
  t = C2 x V_{DLY} / I_{DLY1}
  Once after the maximum duty is detected and released before delay time, charge to the capacitor is halt and delay pin outputs "L".

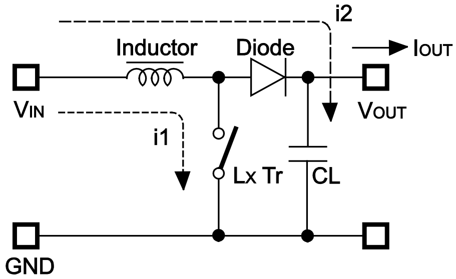
- As for R1211x002A/C version, the values and positioning of C4, C5, R3, and R4 shown in the above diagram are just an example combination. These are for making phase compensation. If the spike noise of VOUT may be large, the spike noise may be picked into VFB pin and make the operation unstable. In this case, a resistor R3, shown in typical applications of the previous page. The recommended resistance value of R3 is in the range from 10 kΩ to 50 kΩ. Then, noise level will be decreased.

- As for R1211x002B/D version, EXT pin outputs GND level at standby mode.

- Select the Power MOSFET, the diode, and the inductor within ratings (Voltage, Current, Power) of this IC. Choose the power MOSFET with low threshold voltage depending on Input Voltage to be able to turn on the FET completely. Choose the diode with low VF such as Shottky type with low reverse current IR, and with fast switching speed. When an external transistor is switching, spike voltage may be generated caused by an inductor, therefore recommended voltage tolerance of capacitor connected to VOUT is three times of setting voltage or more.

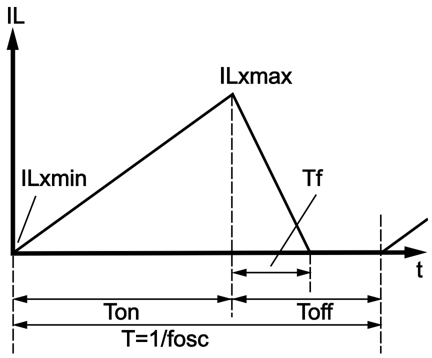
∗ The performance of power circuit with using this IC depends on external components. Choose the most suitable components for your application.

OUTPUT CURRENT AND SELECTION OF EXTERNAL COMPONENTS

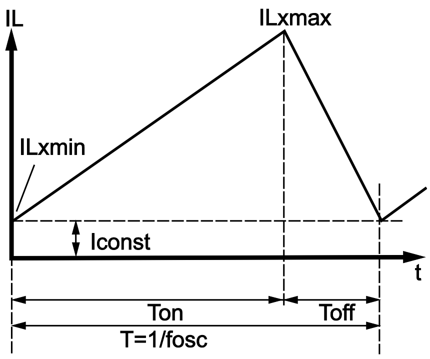


Basic Circuit

Circuit through L



Discontinuous Mode



Continuous Mode

There are two modes, or discontinuous mode and continuous mode for the PWM step-up switching regulator depending on the continuous characteristic of inductor current.

During on time of the transistor, when the voltage added on to the inductor is described as V_{IN}, the current is V_{IN} x t / L. Therefore, the electric power, P_{ON}, which is supplied with input side, can be described as in next formula.

$$P_{ON} = \int_0^{Ton} V_{IN}^2 \times t/L \ dt$$ .... Formula 1

With the step-up circuit, electric power is supplied from power source also during off time. In this case, input current is described as (V_{OUT} − V_{IN}) x t / L, therefore electric power, P_{OFF} is described as in next formula.

$$P_{OFF} = \int_0^{Tf} V_{IN} \times (V_{OUT} - V_{IN}) \times t/L \ dt$$ .... Formula 2

In this formula, Tf means the time of which the energy saved in the inductance is being emitted. Thus average electric power, P_{AV} is described as in the next formula.

$$P_{AV} = 1/(T_{ON} + T_{OFF}) \times \{\int_0^{Ton} V_{IN}^2 \times t/L \ dt + \int_0^{Tf} V_{IN} \times (V_{OUT} - V_{IN}) \times t/L \ dt\}$$ .... Formula 3

In PWM control, when Tf = Toff is true, the inductor current becomes continuos, then the operation of switching regulator becomes continuous mode.

In the continuous mode, the deviation of the current is equal between on time and off time.

$V_{IN} \times T_{ON}/L = (V_{OUT} - V_{IN}) \times Toff/L$ .... Formula 4

Further, the electric power, P_{AV} is equal to output electric power, V_{OUT} x I_{OUT}, thus,

$I_{OUT} = f_{OSC} \times V_{IN}^2 \times T_{ON}^2 / \{2 \times L \times (V_{OUT} - V_{IN})\} = V_{IN}^2 \times T_{ON}/(2 \times L \times V_{OUT})$ .... Formula 5

When I_{OUT} becomes more than formula 5, the current flows through the inductor, then the mode becomes continuous. The continuous current through the inductor is described as Iconst, then,

$I_{OUT} = f_{OSC} \times V_{IN}^2 \times T_{ON}^2 / \{2 \times L \times (V_{OUT} - V_{IN})\} + V_{IN} \times Iconst/V_{OUT}$ .... Formula 6

In this moment, the peak current, ILxmax flowing through the inductor and the driver Tr. is described as follows:

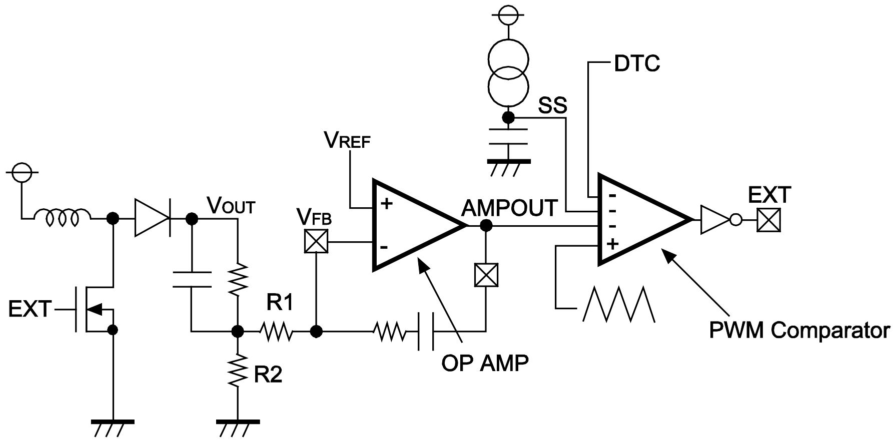
$ILxmax = Iconst + V_{IN} \times T_{ON}/L$ .... Formula 7

With the formula 4 and 6, ILxmax is,

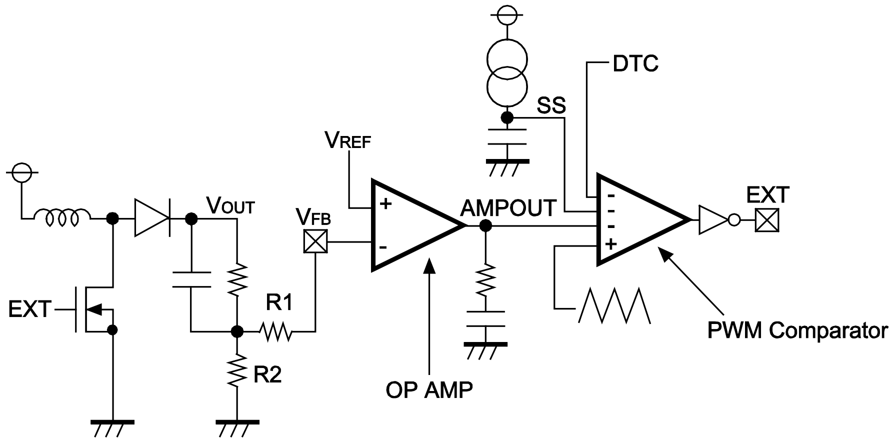
$ILxmax = V_{OUT}/V_{IN} \times I_{OUT} + V_{IN} \times T_{ON}/(2 \times L)$ .... Formula 8

Therefore, peak current is more than I_{OUT}. Considering the value of ILxmax, the condition of input and output, and external components should be selected. In the formula 7, peak current ILxmax at discontinuous mode can be calculated. Put Iconst = 0 in the formula. The explanation above is based on the ideal calculation, and the loss caused by Lx switch and external components is not included. The actual maximum output current is between 50% and 80% of the calculation. Especially, when the ILx is large, or V_{IN} is low, the loss of V_{IN} is generated with the on resistance of the switch. As for V_{OUT}, Vf (as much as 0.3 V) of the diode should be considered.

TIMING CHART



R1211x002A/ R1211x002C Timing Chart



R1211x002B/ R1211x002D Timing Chart

Soft-start Operation

Soft-start operation is starting from power-on as follows:

(Step1)

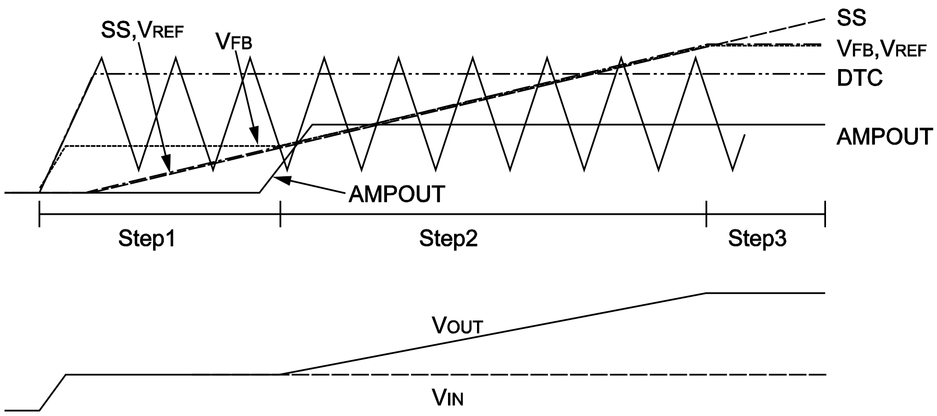
The voltage level of SS is rising gradually by constant current circuit of the IC and a capacitor. V_{REF} level which is input to OP AMP is also gradually rising. V_{OUT} is rising up to input voltage level just after the power-on, therefore, V_{FB} voltage is rising up to the setting voltage with input voltage and the ration of R1 and R2. AMPOUT is at "L", and switching does not start.

(Step2)

When the voltage level of SS becomes the setting voltage with the ration of R1 and R2 or more, switching operation starts. V_{REF} level gradually increases together with SS level. V_{OUT} is also rising with balancing V_{REF} and V_{FB}. Duty cycle depends on the lowest level among AMPOUT, SS, and DTC of the 4 input terminals in the PWM comparator.

(Step3)

When SS reaches 1 V, soft-start operation finishes. V_{REF} becomes constant voltage (= 1 V). Then the switching operation becomes normal mode.



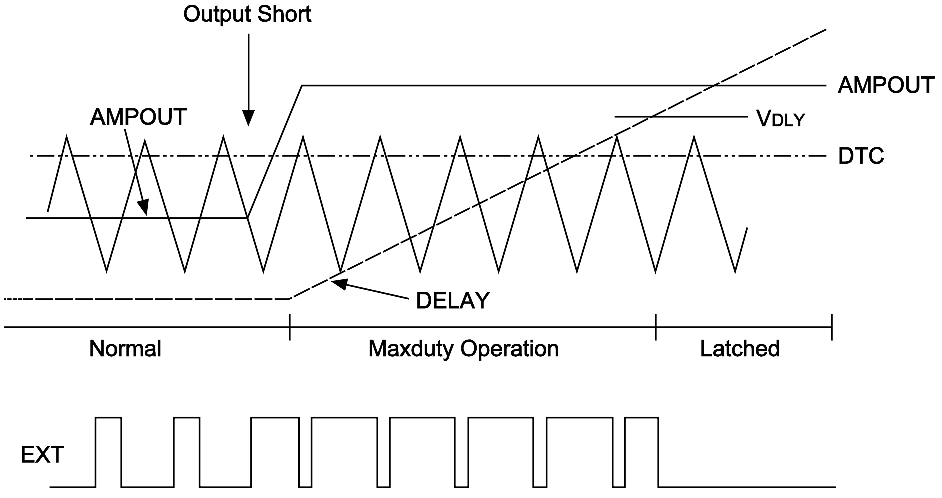
Latch Protection Operation

The operation of Latch protection circuit is as follows: When AMPOUT becomes "H" and the IC detects maximum duty cycle, charge to an external capacitor, C2 of DELAY pin starts. And maximum duty cycle continues and the voltage of DELAY pin reaches delay voltage detector threshold, V_{DLY}, outputs "L" to EXT pin and turns off the external power MOSFET. To release the latch protection operation, make the IC be standby mode with CE pin and make it active in terms of R1211x002B/D version. Otherwise, make supply voltage down to UVLO detector threshold or lower, and make it rise up to the normal input voltage. During the soft-start time, if the duty cycle may be the maximum, protection circuit does not work and DELAY pin is fixed at GND level.

The delay time of latch protection can be calculated with C2, V_{DLY}, and Delay Pin Charge Current, I_{DLY1}, as in the next formula.

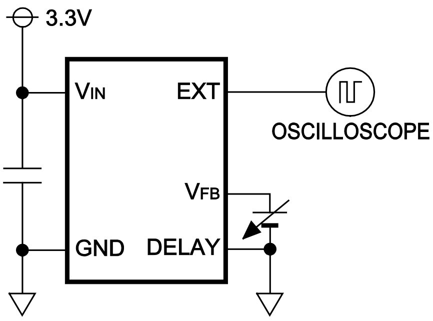
$t = C2 \times V_{DLY} / I_{DLY1}$

Once after the maximum duty is detected and released before delay time, charge to the capacitor is halt and delay pin outputs "L".

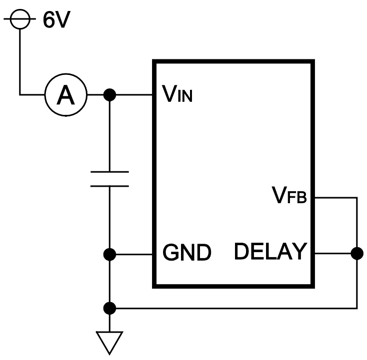


TEST CIRCUITS

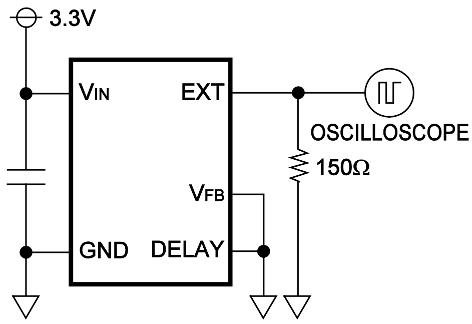
R1211x002A/ R1211x002C Test Circuits



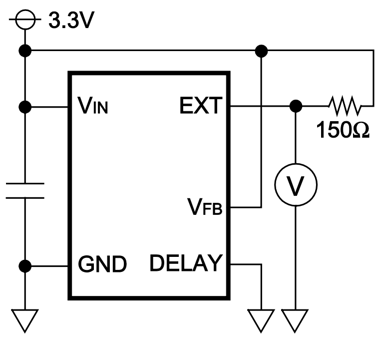
Oscillator Frequency, Maximum Duty Cycle,
V_{FB} Voltage



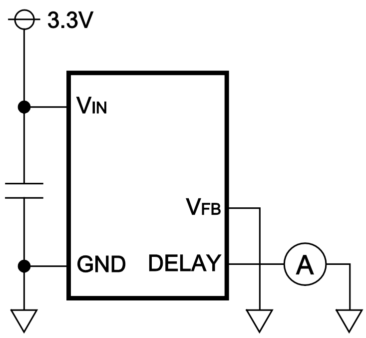
Consumption Current



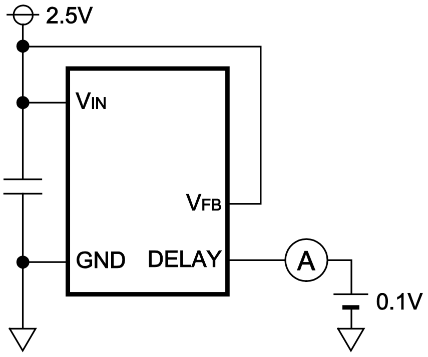
EXT "H" ON Resistance



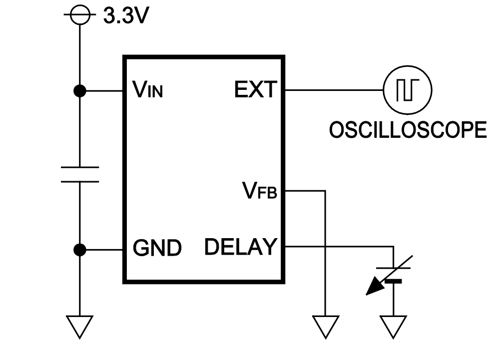
EXT "L" ON Resistance



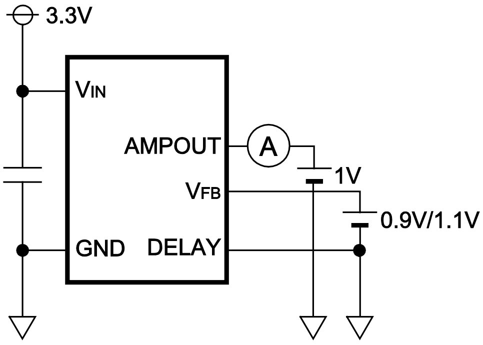
DELAY Pin Charge Current



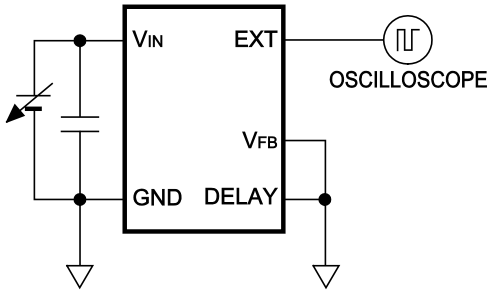
DELAY Pin Discharge Current



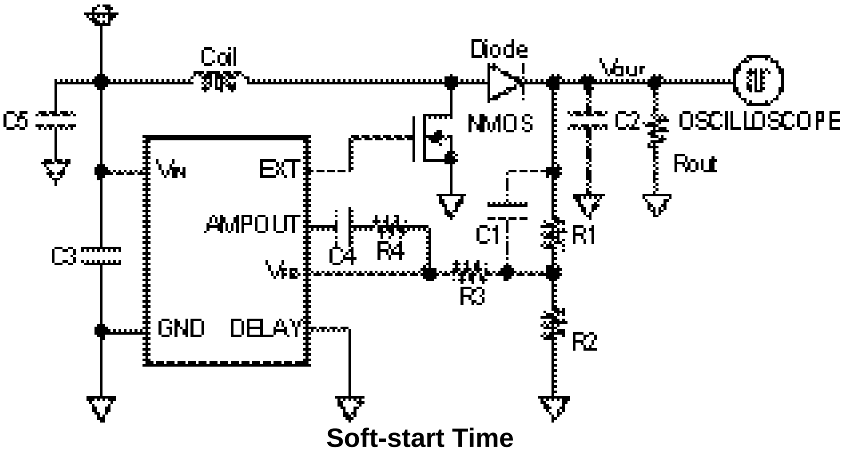
DELAY Pin Detector Threshold Voltage



AMP "H" Output Current/
"L" Output Current



UVLO Detector Threshold/
Hysteresis Range



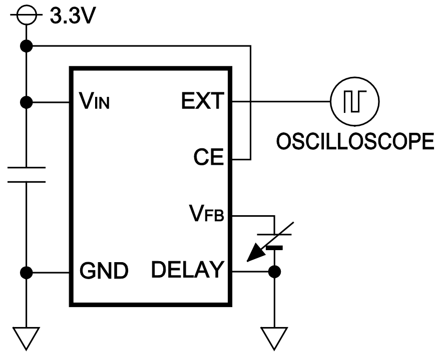
Soft-start Time

<Components>

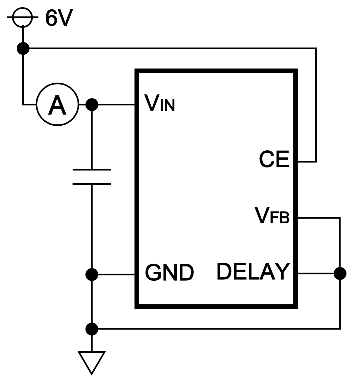
R1: 90 kΩ
R2: 10 kΩ
R3: 30 kΩ
R4: 30 kΩ
Rout: 1 kΩ/ 330 Ω
Coil: VLF504012MT-220M (TDK: 22 μH)
Diode: CRS10I30A (TOSHIBA)
NMOS: IRF7601 (International Rectifier)

C1: 680 pF (Ceramic)
C2: 22 μF (Tantalum) + 2.2 μF (Ceramic)
C3: 2.2 μF (Ceramic) + 68 μF (Tantalum)
C4: 2200 pF (Ceramic)
C5: 22 μF (Tantalum)

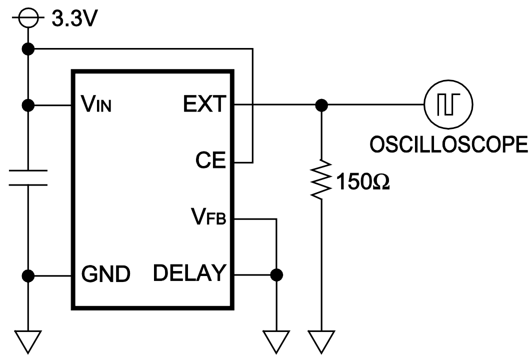
R1211x002B/ R1211x002D Test Circuits



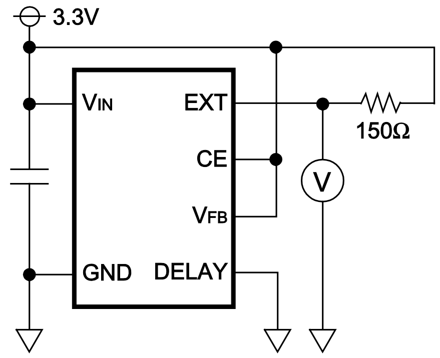
Oscillator Frequency, Maximum Duty Cycle, VFB Voltage



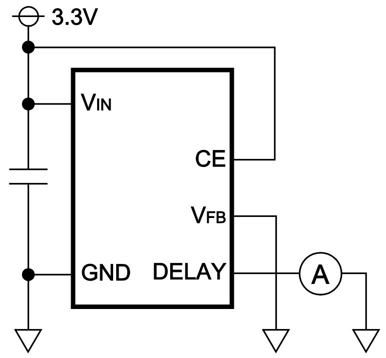
Consumption Current



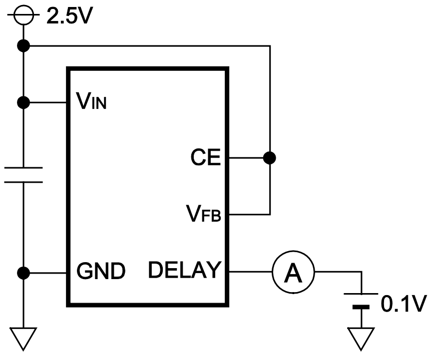
EXT "H" ON Resistance



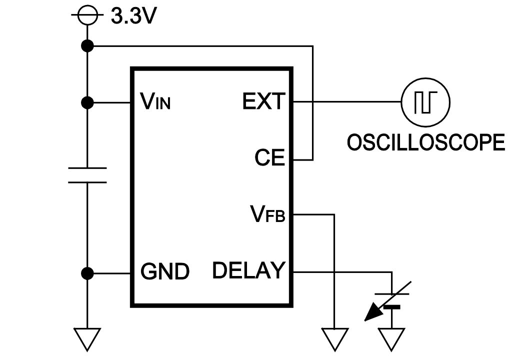
EXT "L" ON Resistance



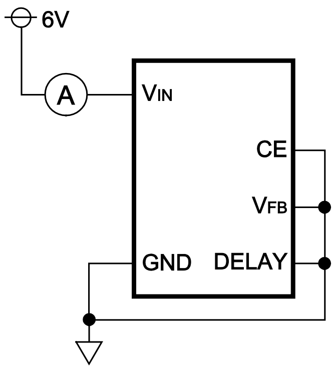
DELAY Pin Charge Current



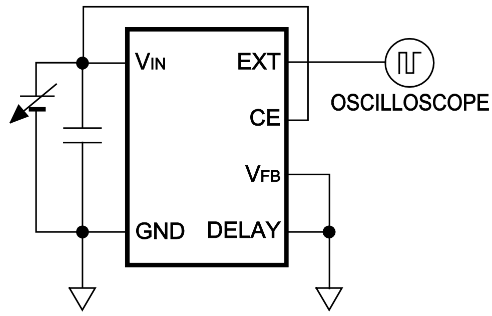
DELAY Pin Discharge Current



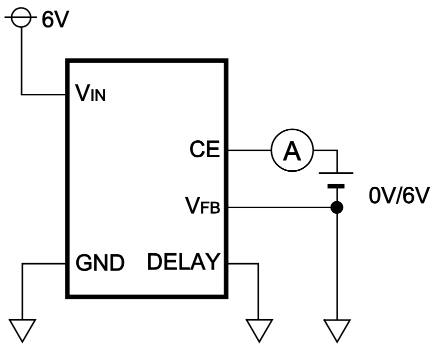
DELAY Pin Detector Threshold Voltage



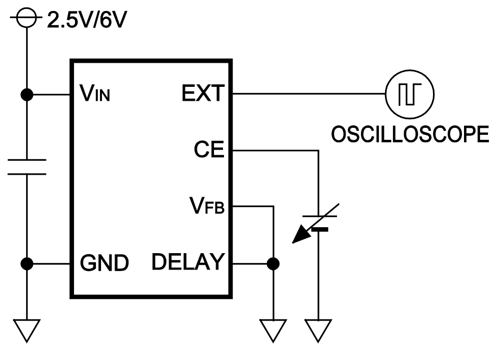
Standby Current



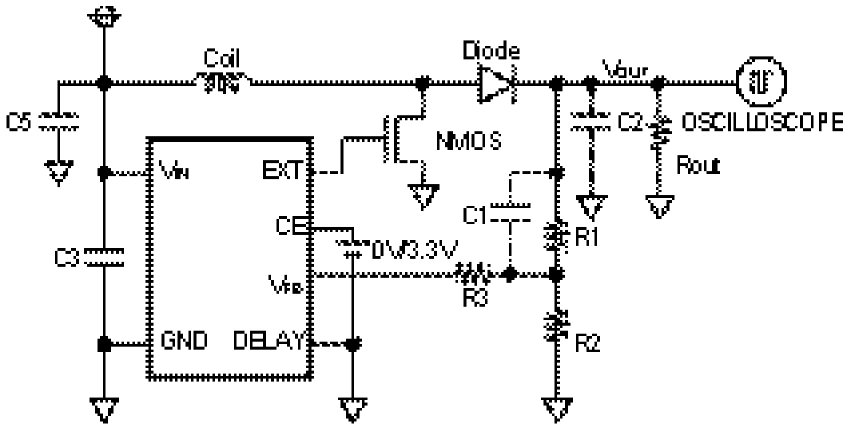
UVLO Detector Threshold/
UVLO Hysteresis Range



CE "L" Input Current/ "H" Input Current



CE "L" Input Voltage/ "H" Input Voltage



Soft-start Time

<Components>
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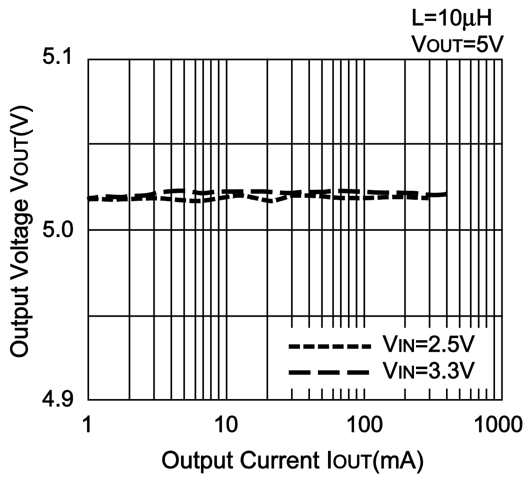
R2: 10 kΩ
R3: 30 kΩ
Rout: 1 kΩ/ 330 Ω
Coil: VLF504012MT-220M (TDK: 22 μH)
Diode: CRS10I30A (TOSHIBA)
NMOS: IRF7601 (International Rectifier)

C1: 680 pF (Ceramic)
C2: 22 μF (Tantalum) + 2.2 μF (Ceramic)
C3: 2.2 μF (Ceramic) + 68 μF (Tantalum)
C5: 22 μF (Tantalum)

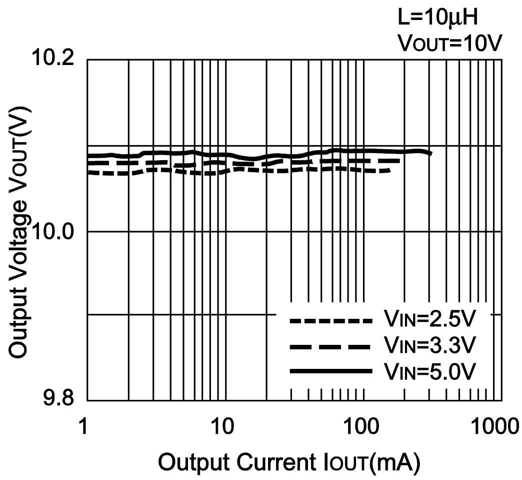
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current

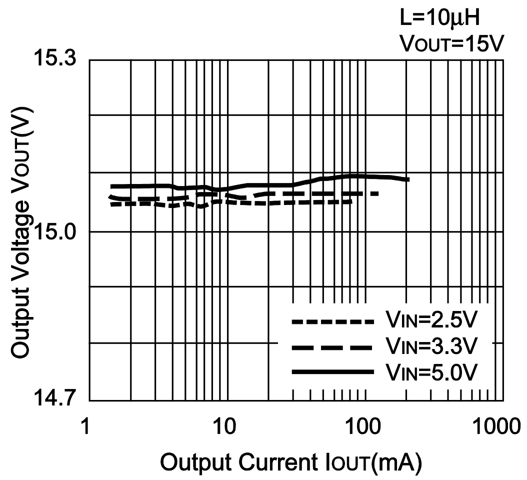
R1211x002A



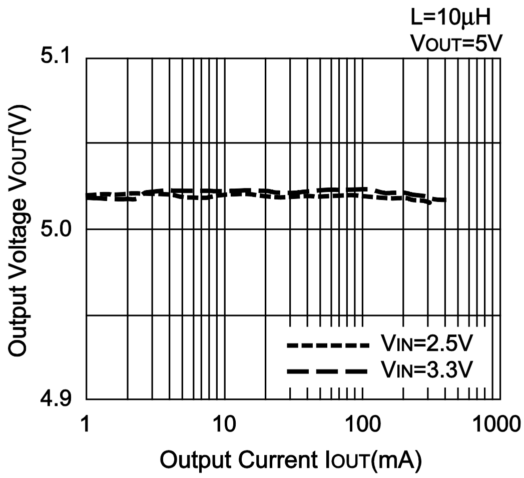
R1211x002A



R1211x002A



R1211x002B



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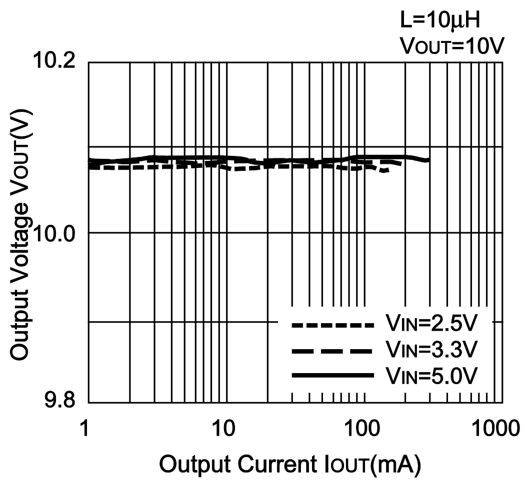
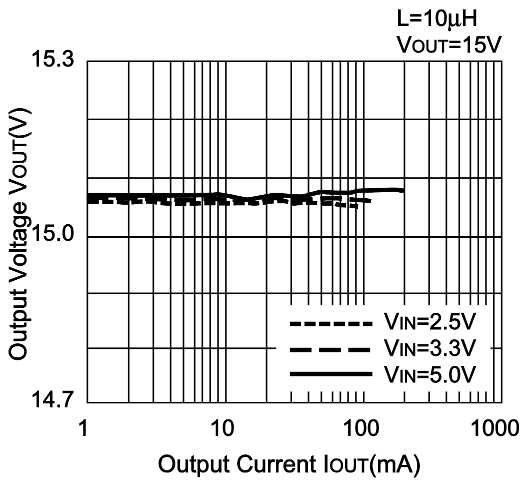
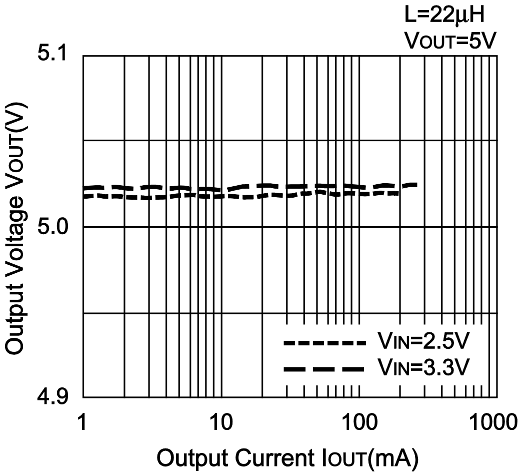


R1211x002B



R1211x002C



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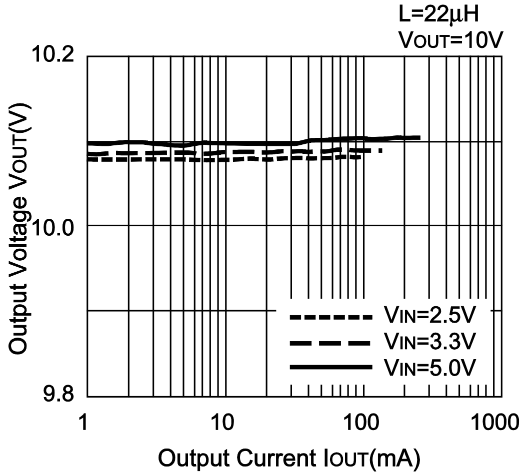

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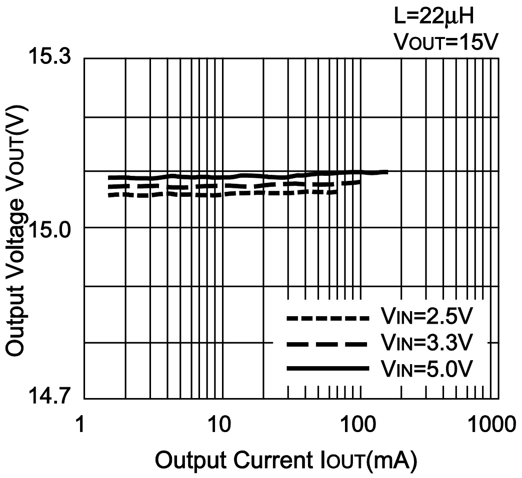
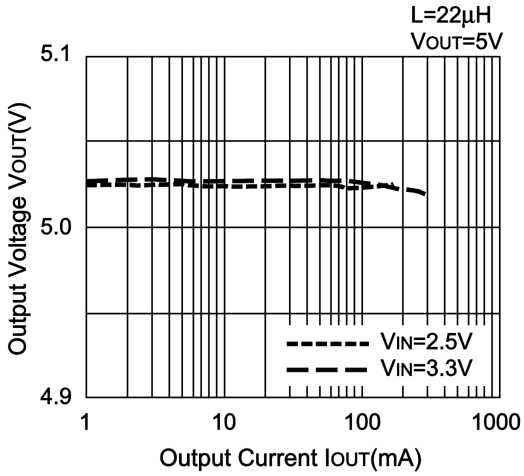


R1211x002D



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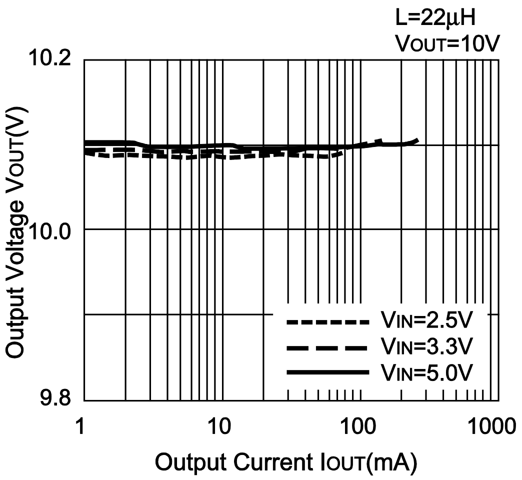

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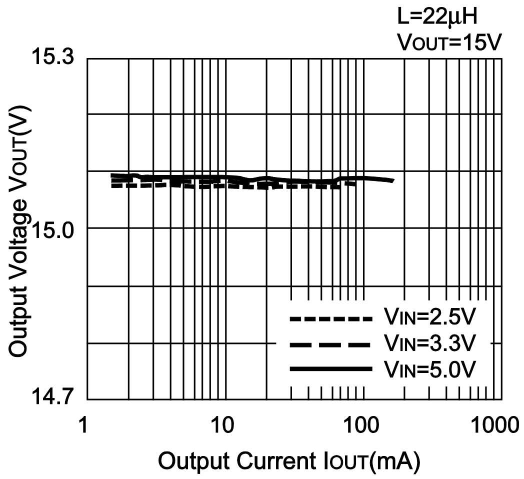
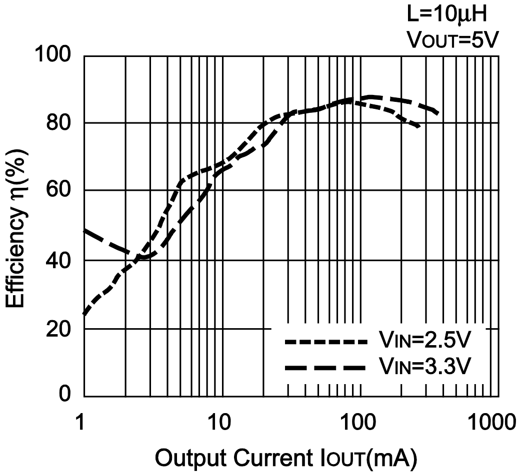


2) Efficiency vs. Output Current

R1211x002A



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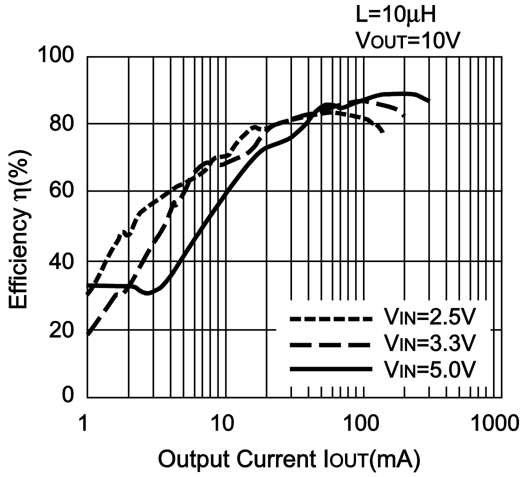

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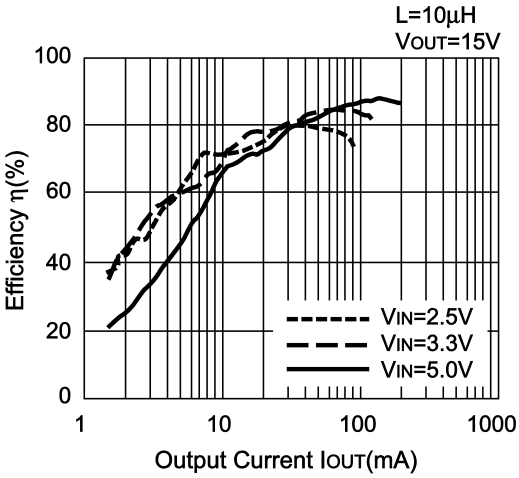

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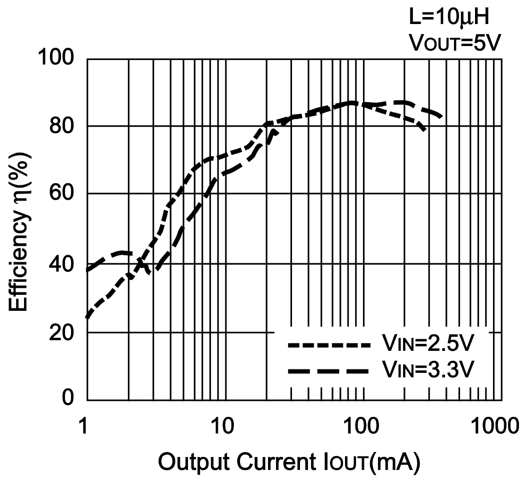

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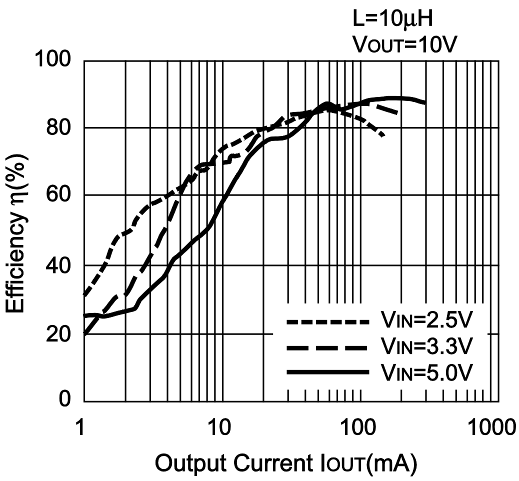

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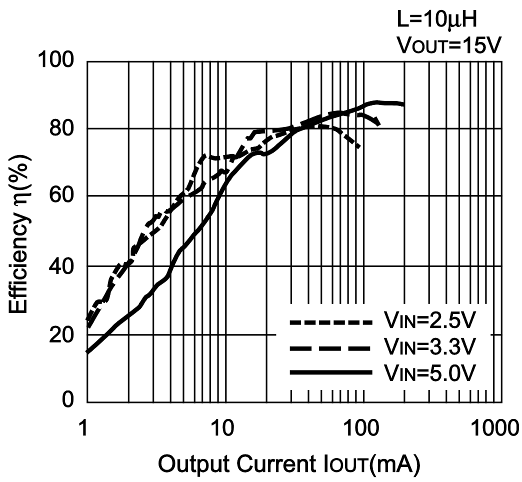

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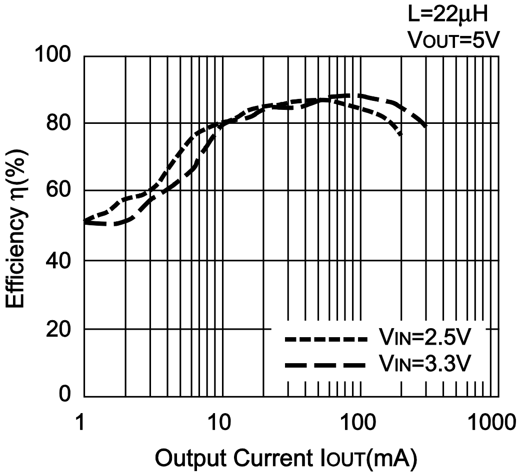

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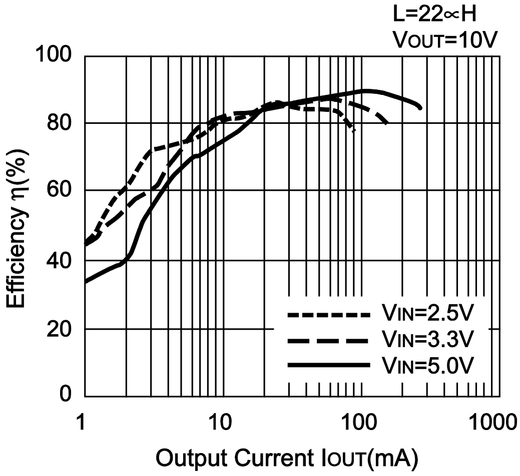

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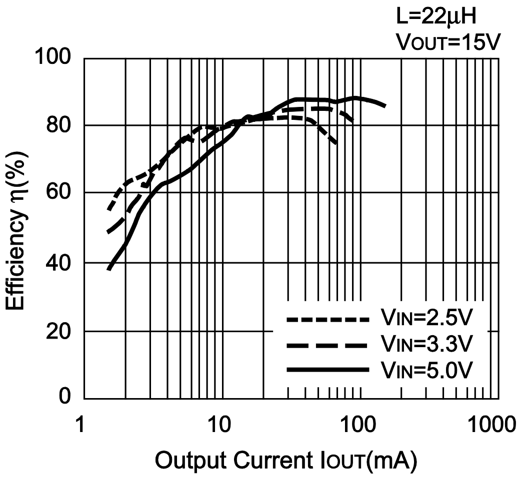
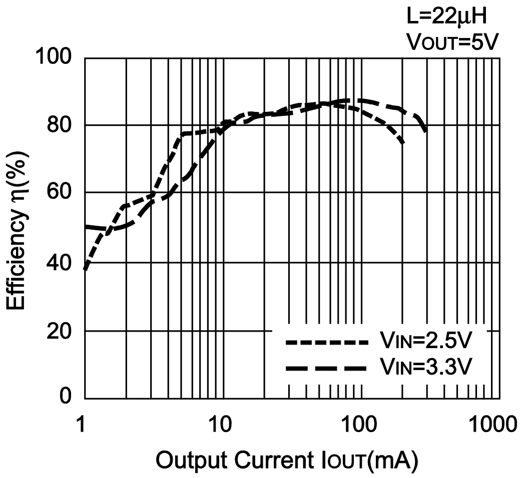


R1211x002D



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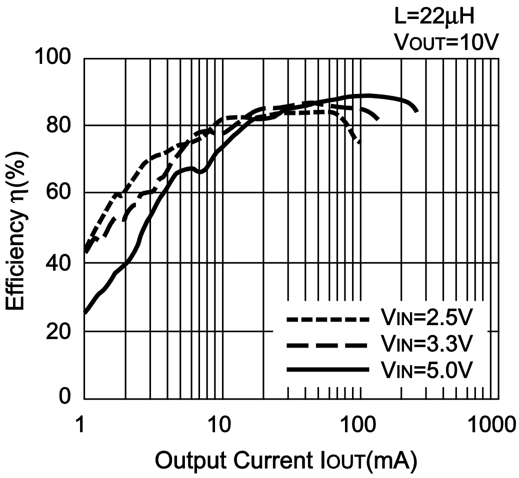

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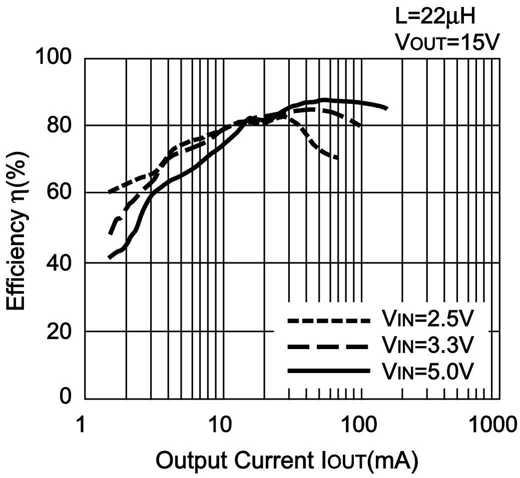
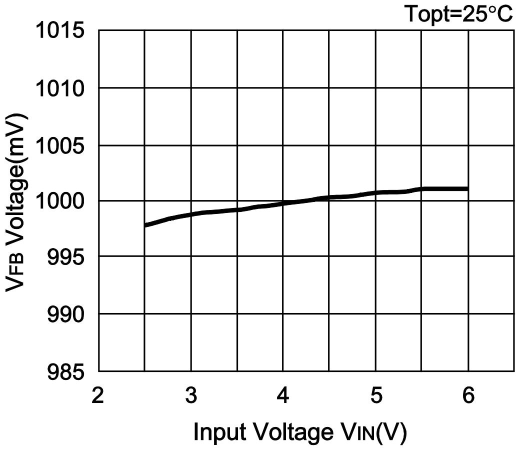


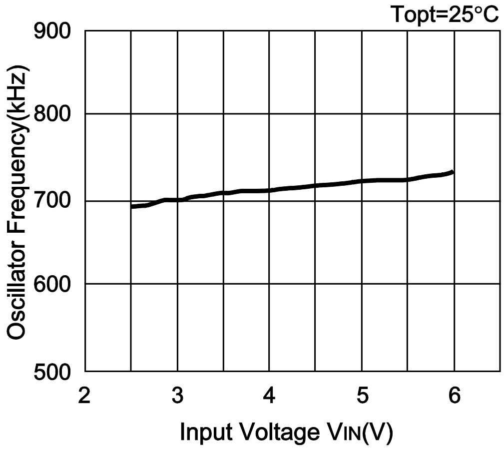
3) VFB Voltage vs. Input Voltage

R1211x002x

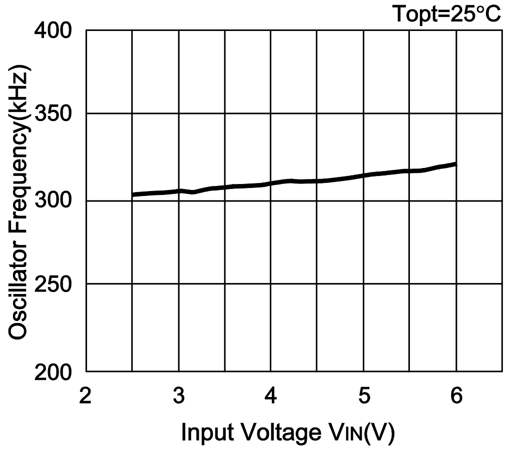


4) Oscillator Frequency vs. Input Voltage

R1211x002A/B

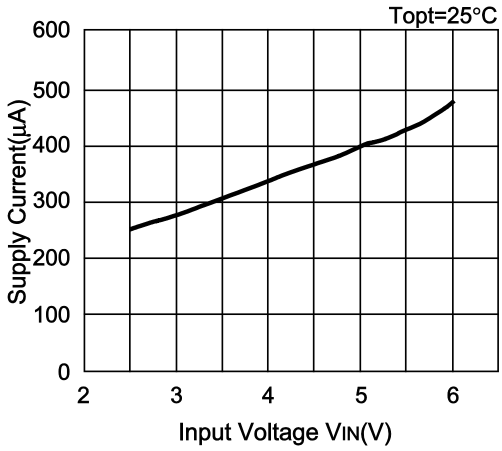


R1211x002C/D

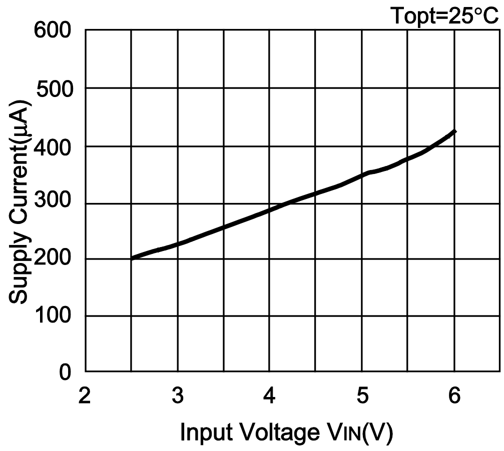


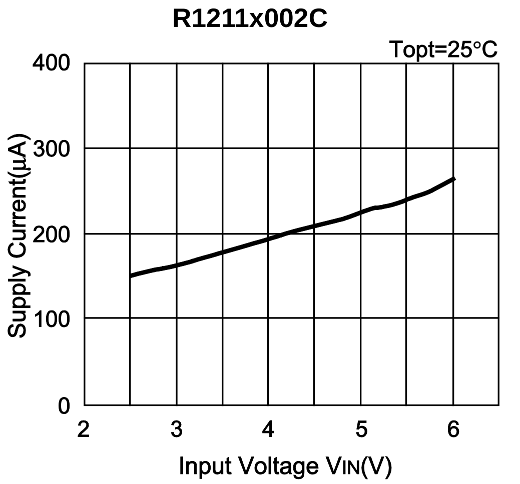
5) Supply Current vs. Input Voltage

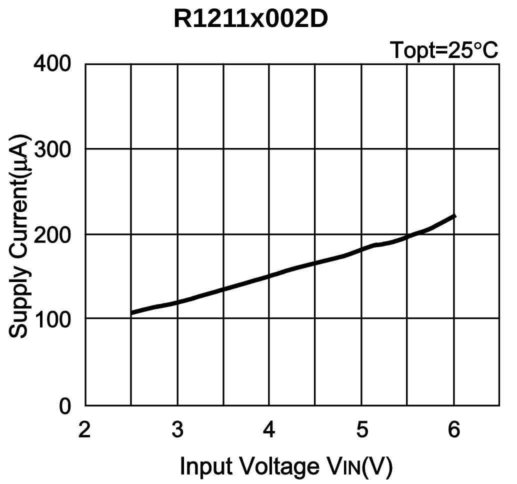
R1211x002A



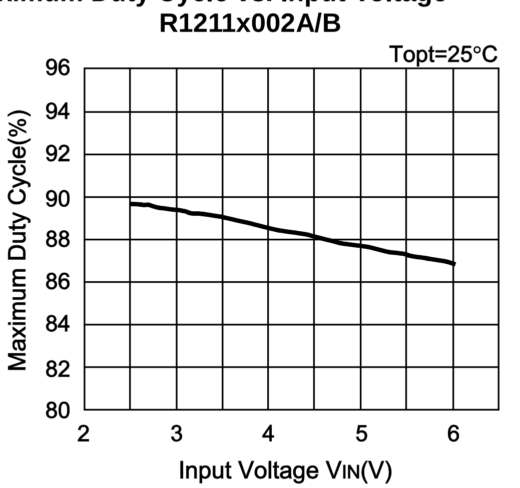
R1211x002B

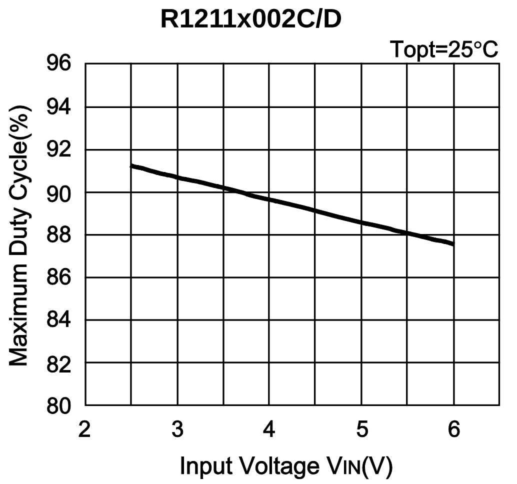




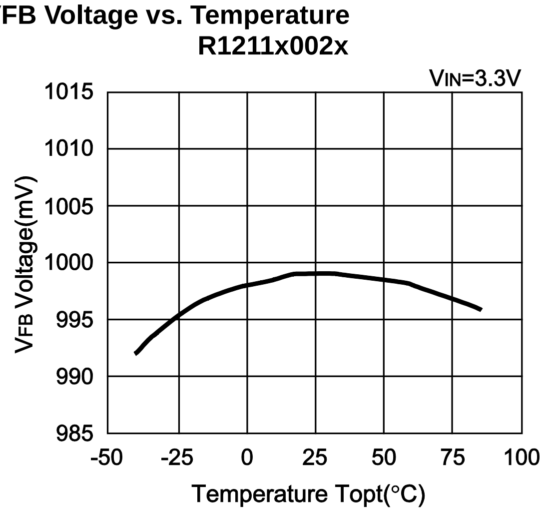


6) Maximum Duty Cycle vs. Input Voltage



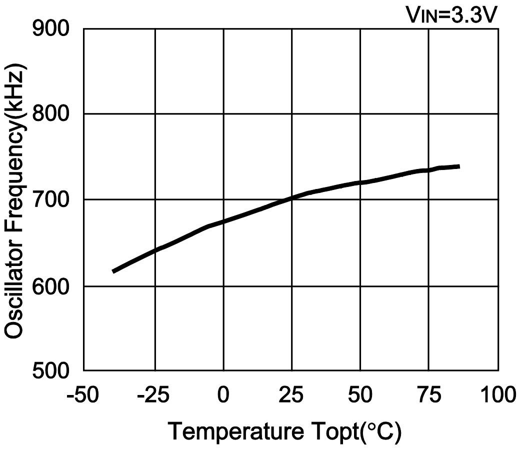


7) VFB Voltage vs. Temperature

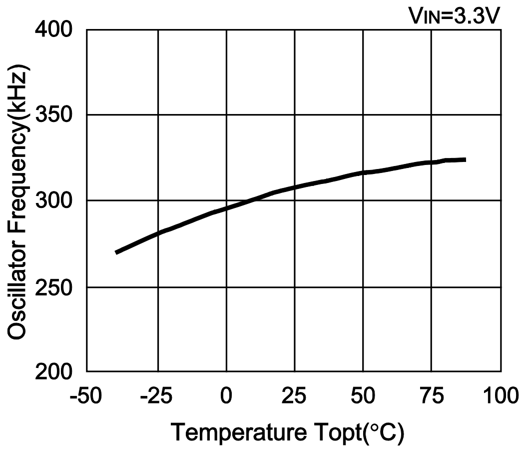


8) Oscillator Frequency vs. Temperature

R1211x002A/B

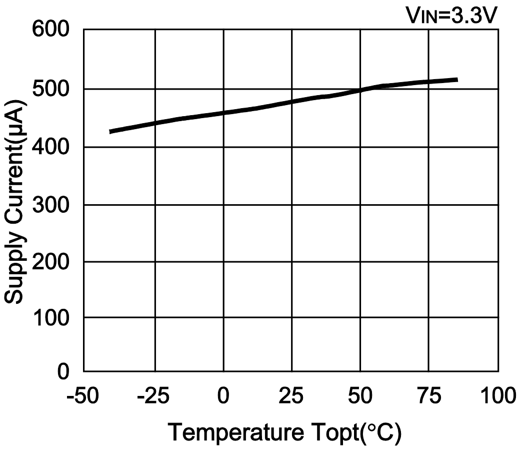


R1211x002C/D

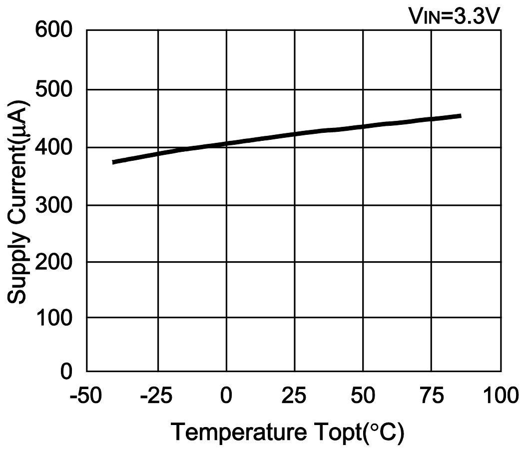


9) Supply Current vs. Temperature

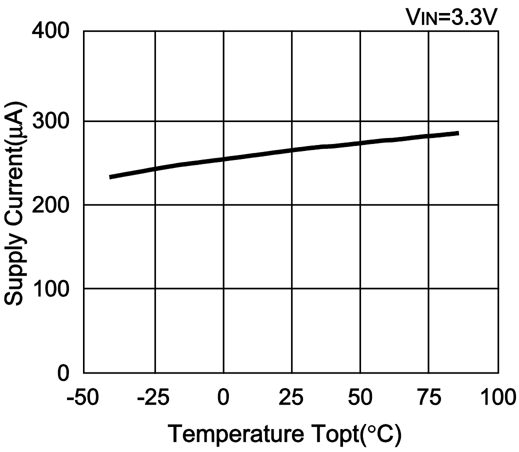
R1211x002A



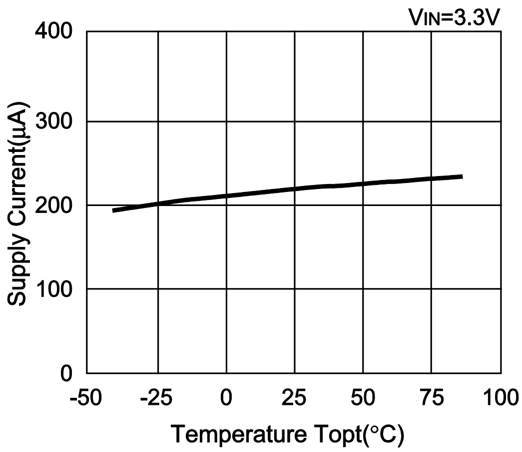
R1211x002B



R1211x002C

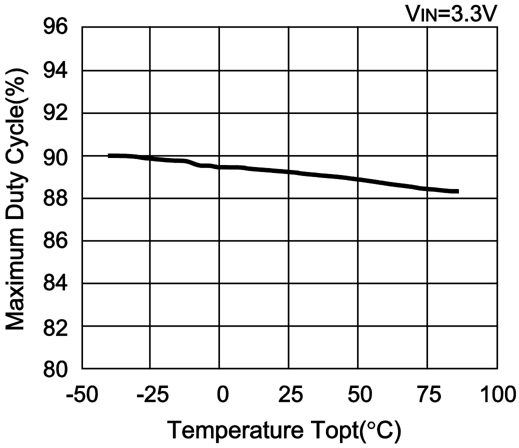


R1211x002D

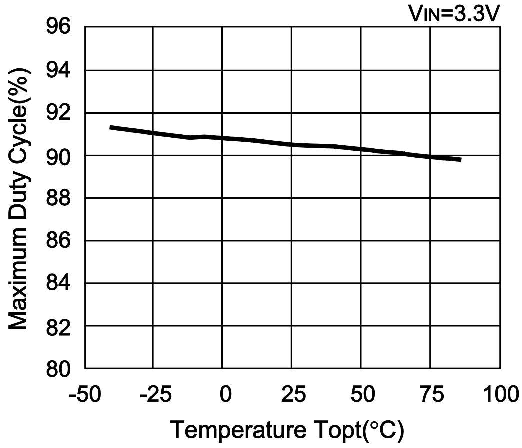


10) Maximum Duty Cycle vs. Temperature

R1211x002A/B

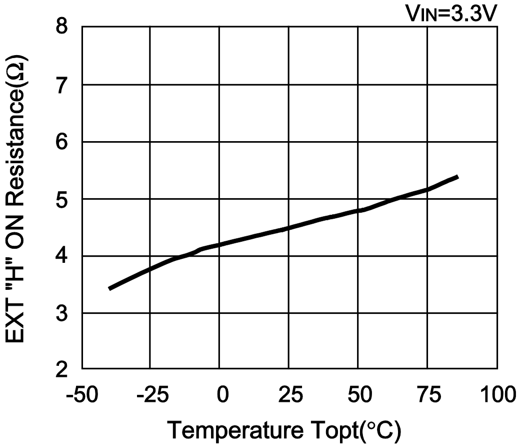


R1211x002C/D



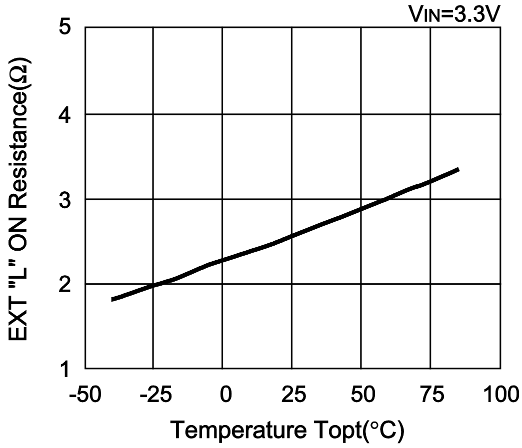
11) EXT "H" On Resistance vs. Temperature

R1211x002x



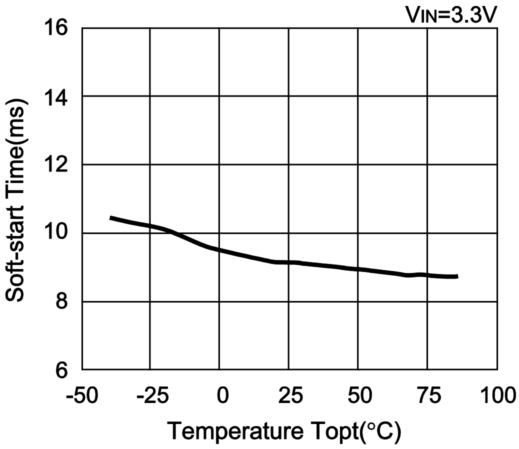
12) EXT "L" On Resistance vs. Temperature

R1211x002x

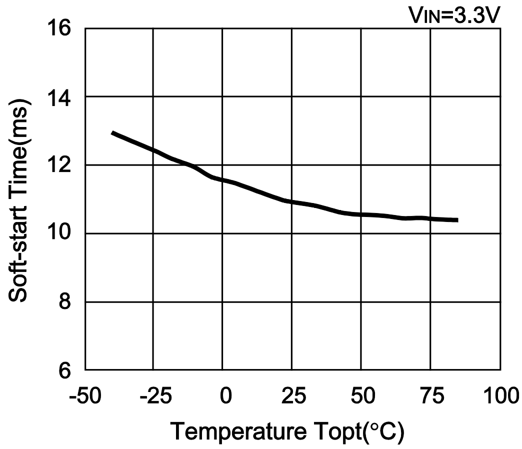


13) Soft-start Time vs. Temperature

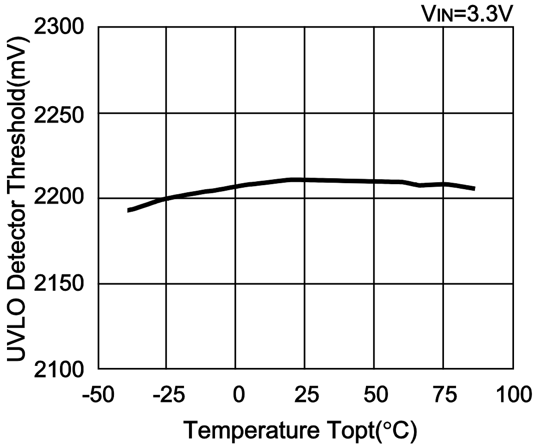
R1211x002A/B



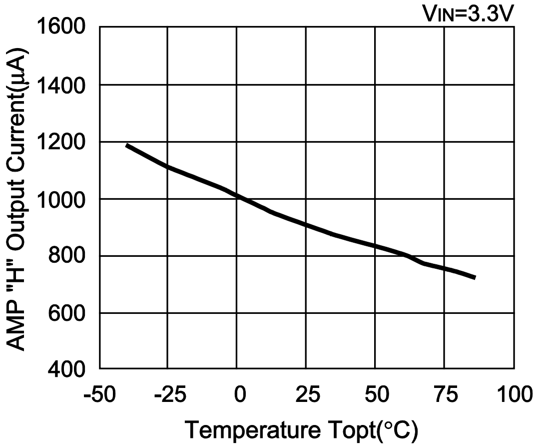
R1211x002C/D



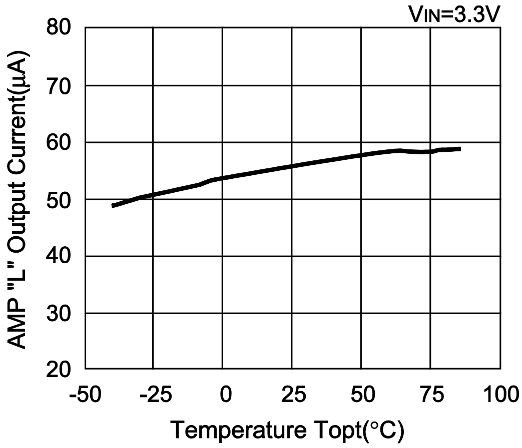
14) UVLO Detector Threshold vs. Temperature
R1211x002x



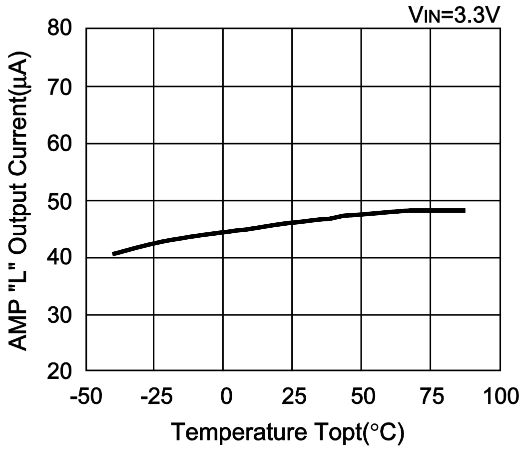
15) AMP "H" Output Current vs. Temperature
R1211x002A/C



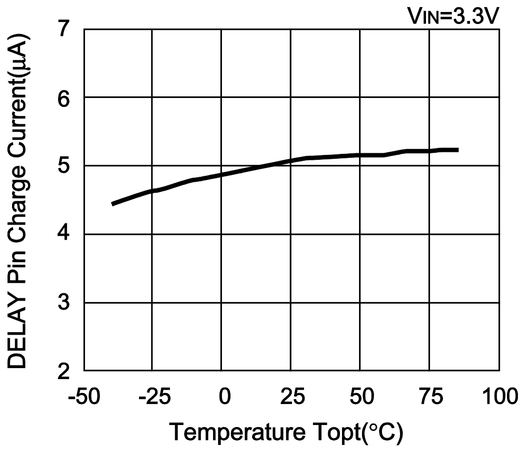
16) AMP "L" Output Current vs. Temperature
R1211x002A



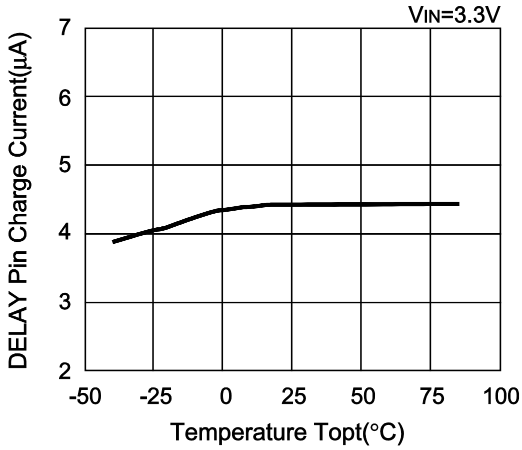
R1211x002C



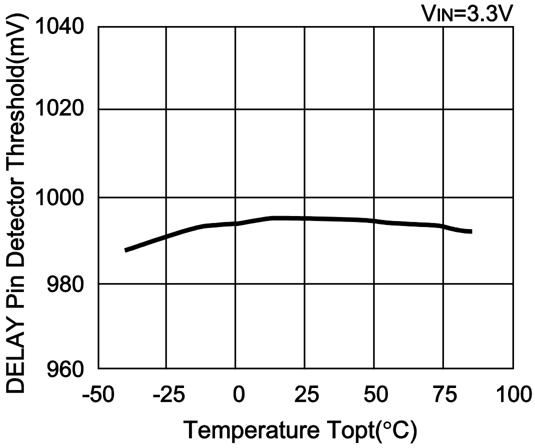
17) DELAY Pin Charge Current vs. Temperature
R1211x002A/B



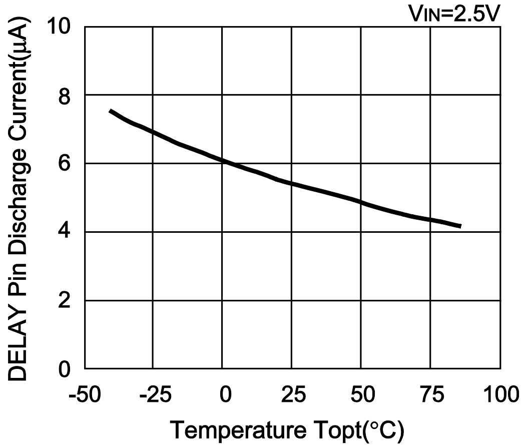
R1211x002C/D



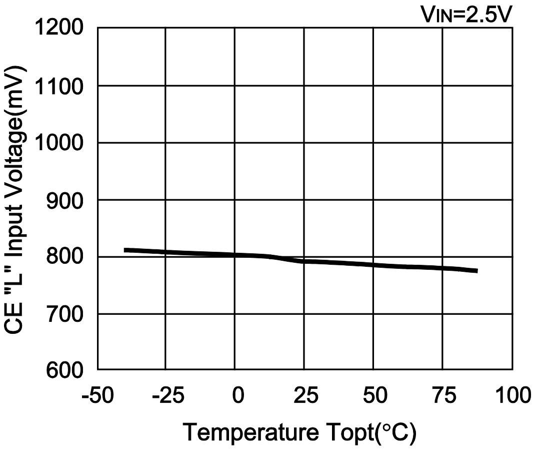
18) DELAY Pin Detector Threshold vs. Temperature
R1211x002x



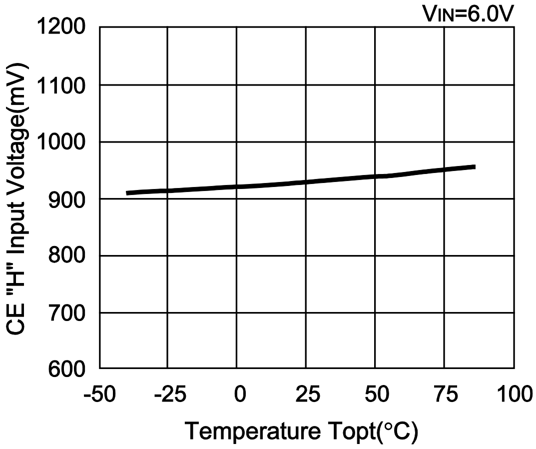
19) DELAY Pin Discharge Current vs. Temperature
R1211x002x



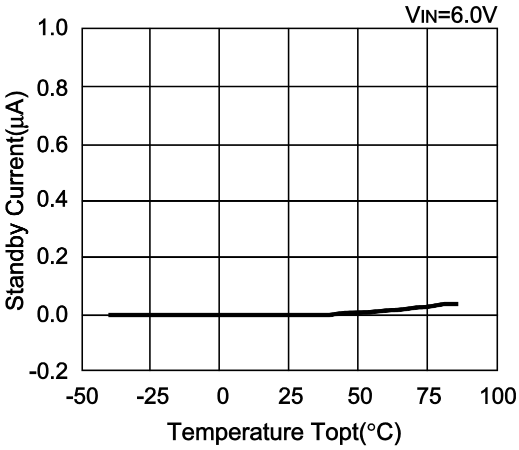
20) CE "L" Input Voltage vs. Temperature
R1211x002B/D



21) CE "H" Input Voltage vs. Temperature
R1211x002B/D



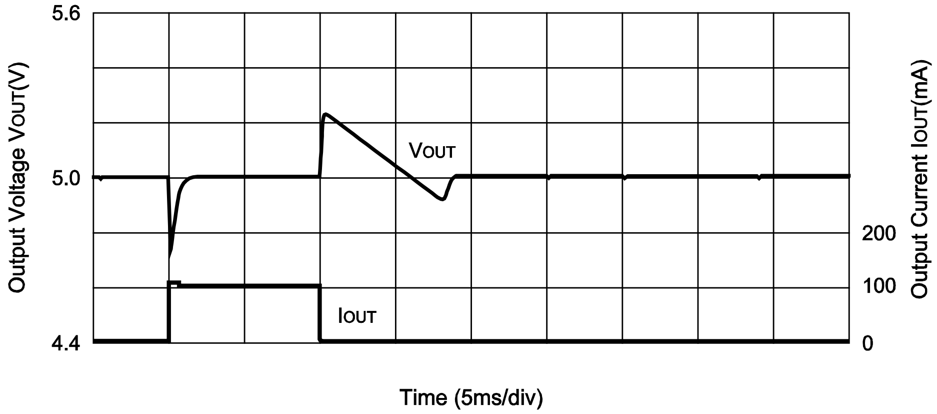
22) Standby Current vs. Temperature
R1211x002B/D



23) Load Transient Response

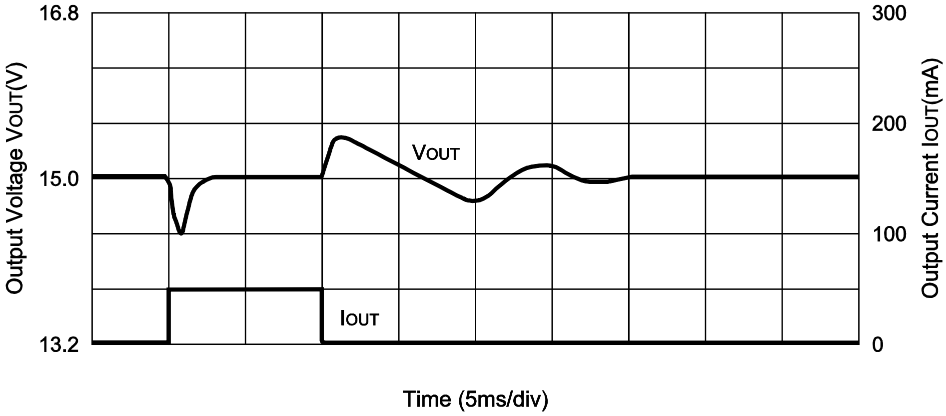
R1211x002A

L=10µH
V_{IN}=3.3V, C3=22µF
V_{OUT}=5V, I_{OUT}=1-100mA



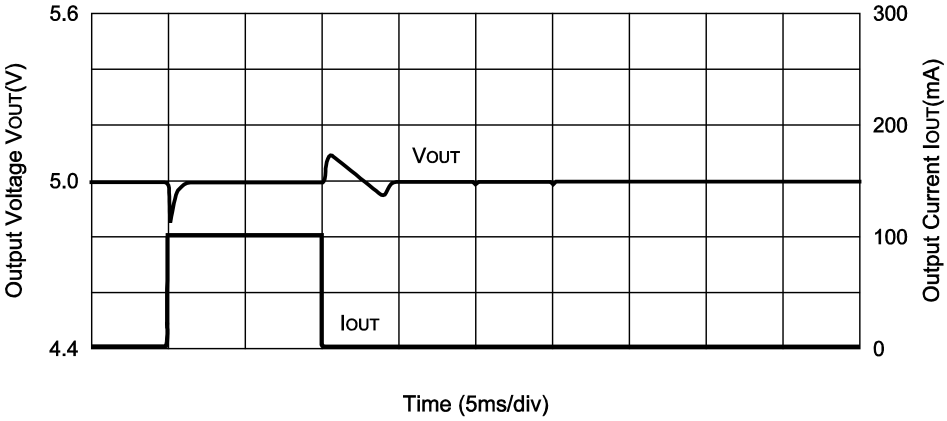
R1211x002A

L=10µH
V_{IN}=3.3V, C3=22µF
V_{OUT}=15V, I_{OUT}=1-50mA

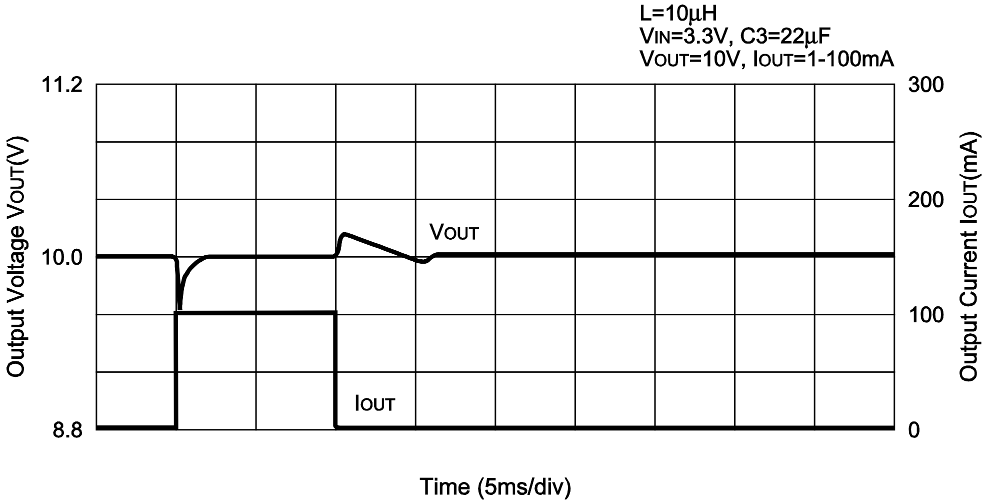


R1211x002B

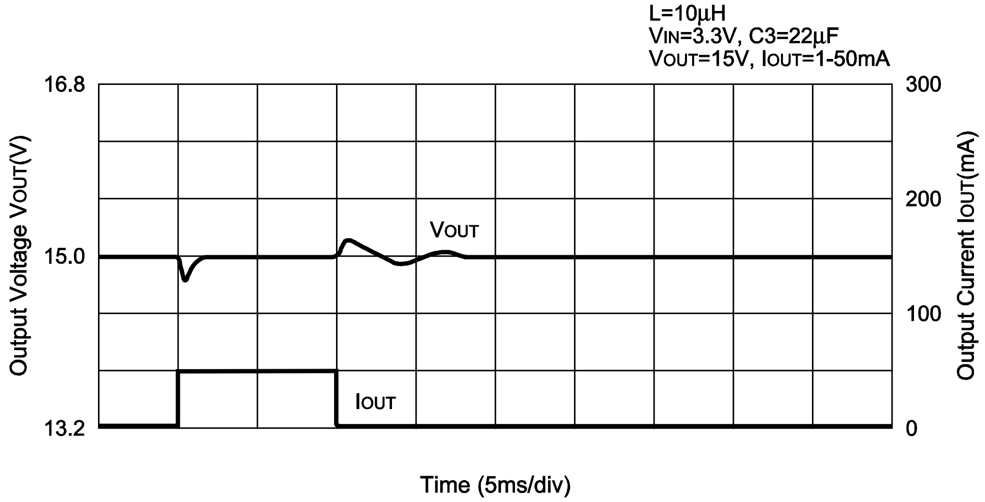
L=10µH
V_{IN}=3.3V, C3=22µF
V_{OUT}=5V, I_{OUT}=1-100mA



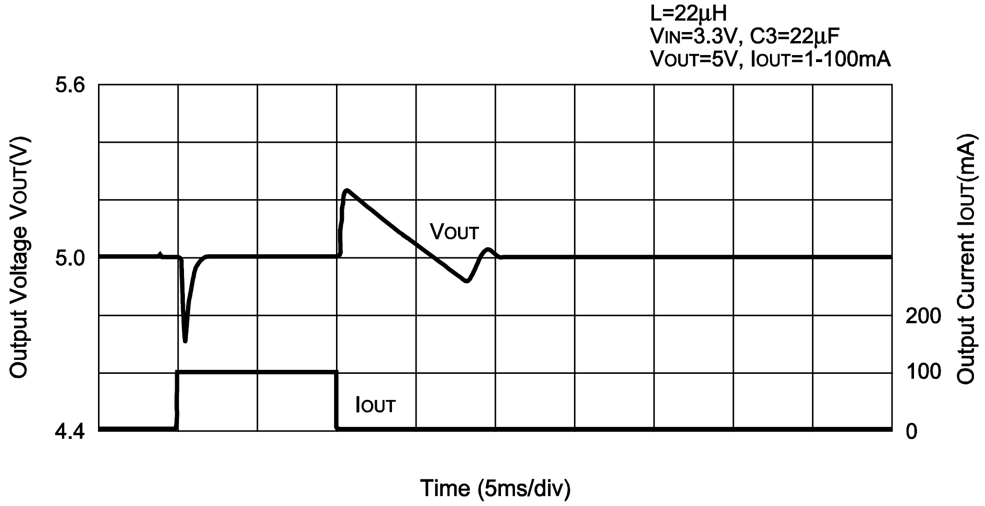
R1211x002B



R1211x002B

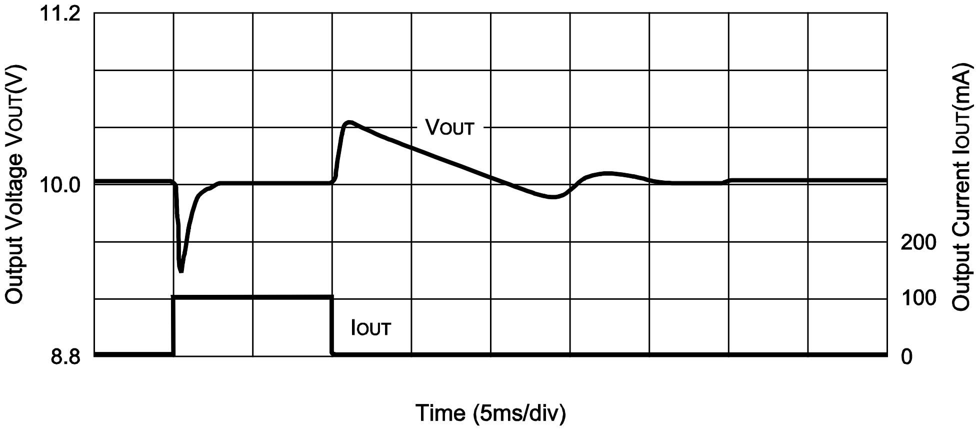


R1211x002C



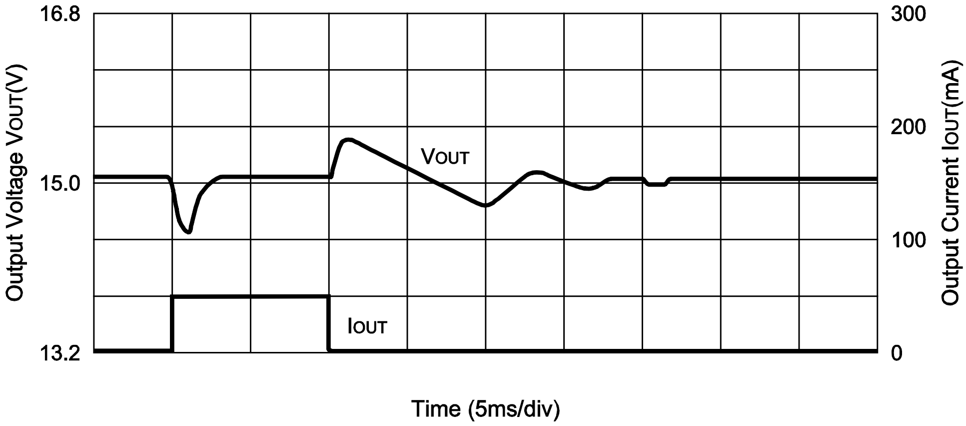
R1211x002C

L=22µH
V_{IN}=3.3V, C3=22µF
V_{OUT}=10V, I_{OUT}=1-100mA



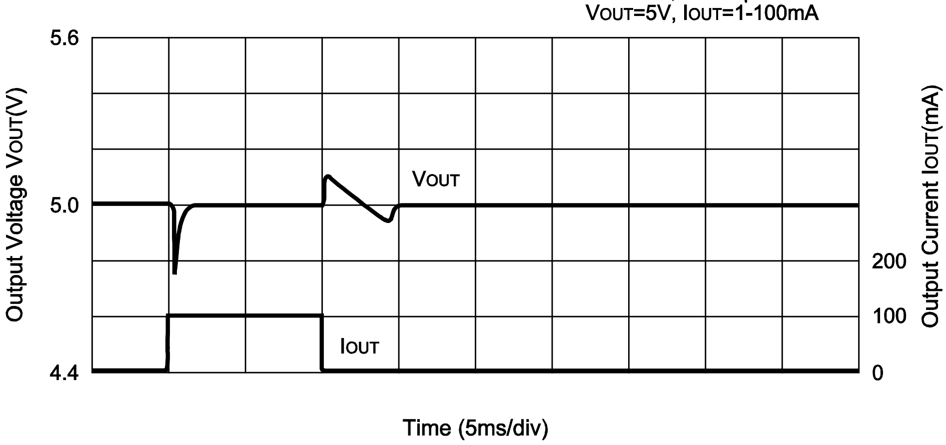
R1211x002C

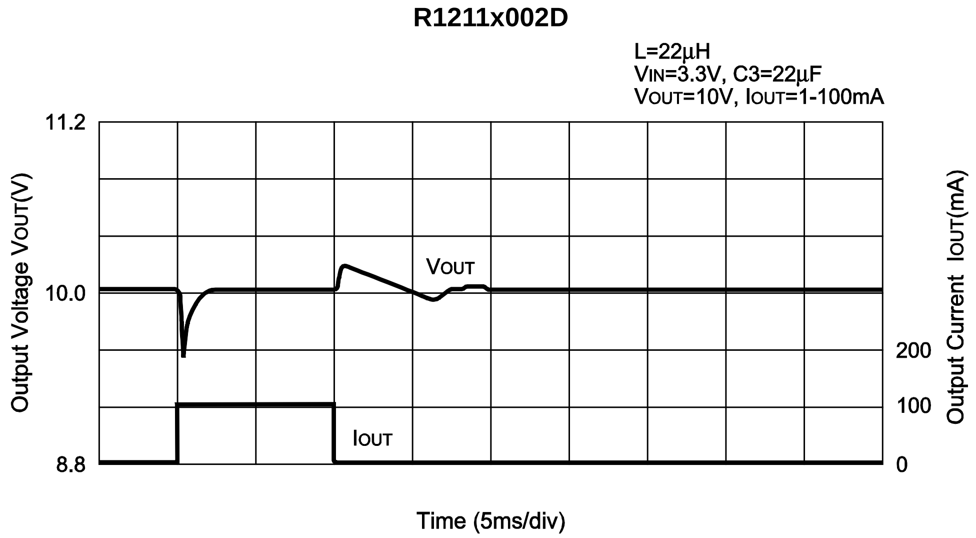
L=22µH
V_{IN}=3.3V, C3=22µF
V_{OUT}=15V, I_{OUT}=1-50mA

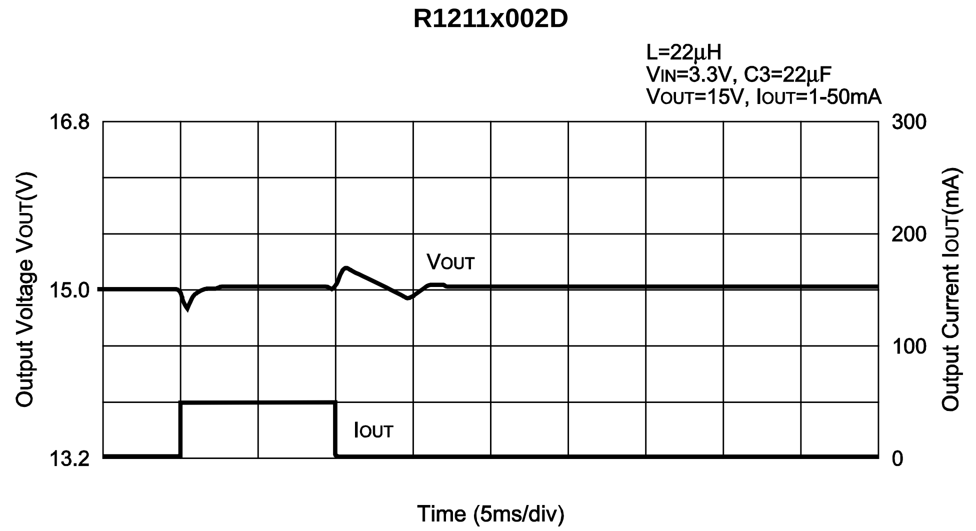


R1211x002D

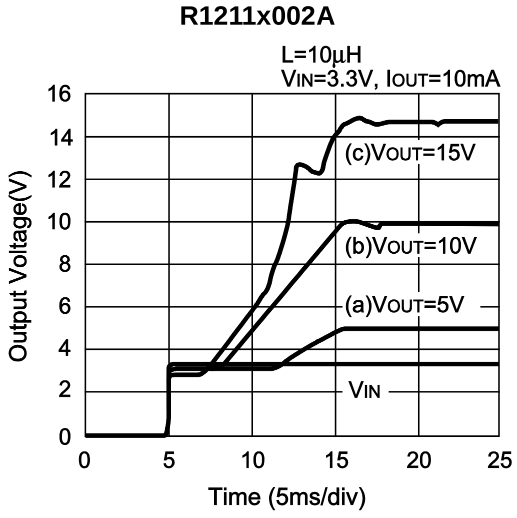
L=22µH
V_{IN}=3.3V, C3=22µF
V_{OUT}=5V, I_{OUT}=1-100mA

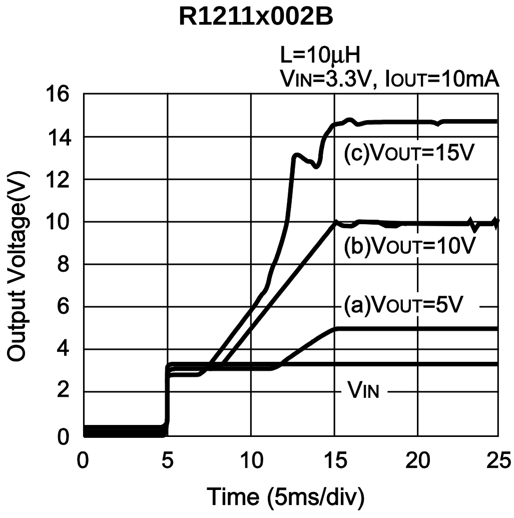


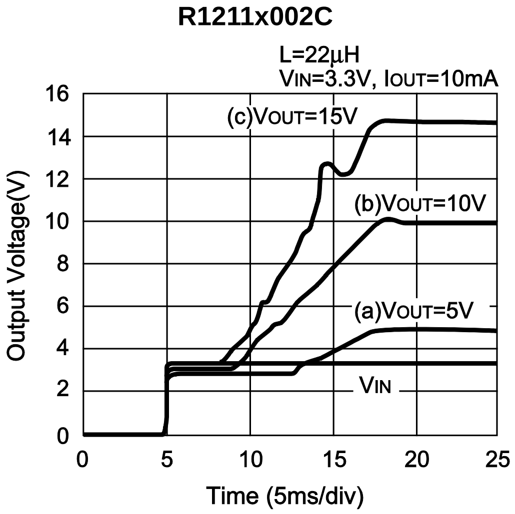


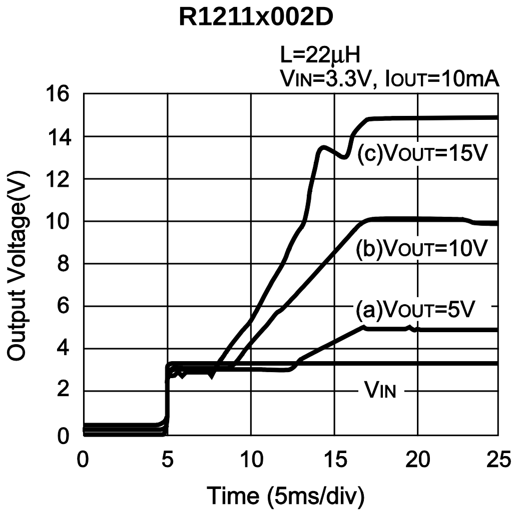


24) Power-on Response

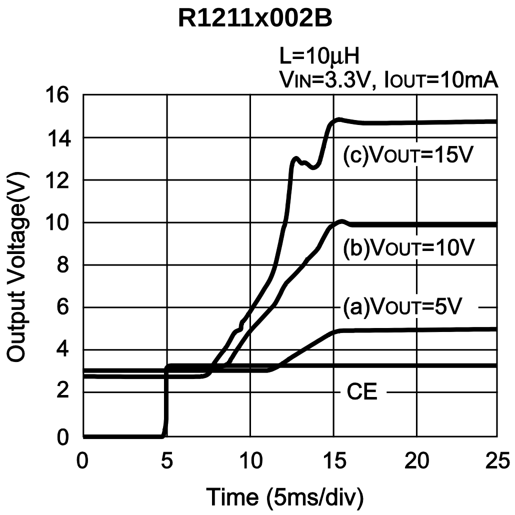


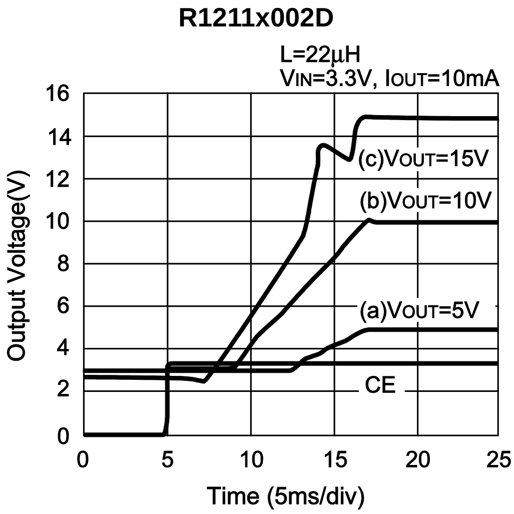






25) Turn-on speed with CE pin





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