

PWM/PFM step-down DC/DC Converters with synchronous rectifier and Through mode

NO.EA-197-111124

OUTLINE

The RP904 series are CMOS-based PWM/PFM step-down DC/DC Converters with synchronous rectifier, low supply current and through mode.

DC/DC converter of the RP904X consists of an oscillator, a PWM/PFM control circuit, a reference voltage unit, an error amplifier, a soft-start circuit, protection circuits, a protection against miss operation under low voltage (UVLO), PWM-DC to DC converter or bypass switch alternative circuit, a chip enable circuit, and a driver transistor. A high efficiency step-down DC/DC converter can be easily composed of this IC with only a few kinds of external components, or an inductor and capacitors.

The output voltage of the DC/DC converter has two kinds of output voltage, and alternative with the VSEL pin.

The RP904 series are PWM/PFM step-down DC/DC converter, thus, when the load current is small, the operation can be switching into the PFM operation from PWM control if the user chooses the VFM mode. As protection circuits, the current limit circuit which limits peak current of Lx at each clock cycle, and the latch type protection circuit which works if the term of the over-current condition keeps on a certain time in PWM mode. Latch-type protection circuit works to latch an internal driver with keeping it disable. To release the protection, after disable this IC with a chip enable circuit, enable it again, or restart this IC with power-on or make the supply voltage at UVLO detector threshold level or lower than UVLO.

The RP904 has also a bypass switch between V_{DD} and V_{OUT} .

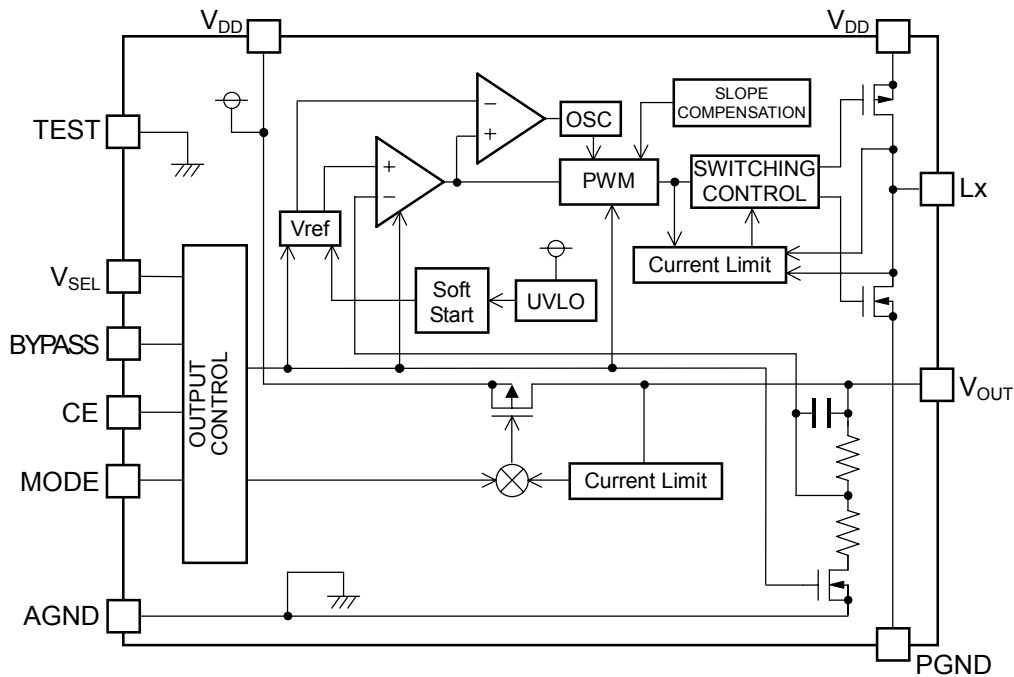
FEATURES

Built-in Driver ON Resistance.....	Typ. Pch 0.25Ω, Nch 0.23Ω ($V_{IN}=3.6V$)
Input Voltage.....	2.5V to 5.5V (2.5V to 5.0V in case of $V_{SET2}<1.2V$)
Built-in Soft-start Function	Typ. 0.135ms
Latch-type Protection Function.....	Typ. 0.8ms
Standby Current.....	Typ. 0.02μA
Output Current.....	Min. 1A(DC/DC in PWM mode), (switch)
Oscillator Frequency.....	Typ. 2MHz
Bypass switch on resistance	Typ. 68mΩ
Operation select is possible among DC/DC mode, and through switch mode with BYPASS pin	
Absolute Input Maximum Rating.....	6.5V
Output Voltage	Built-in Driver Stepwise Setting with a step of 0.1V in the range of 1.2V to 3.3V(V_{SET1}), 1.0V to 1.5V(V_{SET2}) $V_{SET2}+0.2V \leq V_{SET1}$
Package.....	WLCSP-11-P2

APPLICATIONS

Power source for portable equipment such as DSC, DVC, and communication equipment

BLOCK DIAGRAM



RP904xxxxA: MODE pin= "H": PWM mode, MODE pin= "L" VFM mode

V_{SET} pin = "H": V_{OUT}=V_{SET1} V_{SEL} pin="L": V_{OUT}=V_{SET2}

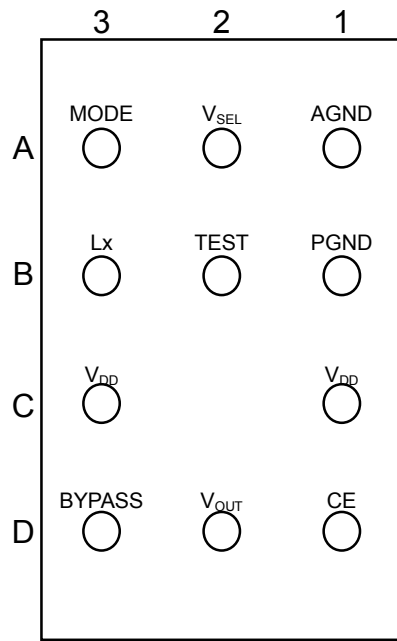
Bypass pin="H": DC/DC Mode, Bypass pin="L" Bypass Mode

Pin name	Pin state at off
CE	Pull Down
MODE	Pull Down
V _{SEL}	Pull Down
BYPASS	Pull Down

PIN DESCRIPTION

Pin No.	Symbol	Description
1A	AGND	Ground Pin
2A	V _{SEL}	Output Voltage Alternative Pin
3A	MODE	PWM/VFM alternative Pin
1B	PGND	Ground Pin
2B	TEST	TEST Pin (Connect this pin to the GND)
3B	Lx	Lx Pin
1C, 3C	V _{DD}	Voltage Supply Pin
1D	CE	Chip Enable Pin (active with "H")
2D	V _{OUT}	Output Pin
3D	BYPASS	Bypass enable Pin (DC/DC or Bypass control)

*) All V_{DD} terminals must be connected.



BOTTOM VIEW

SELECTION GUIDE

In the RP904x Series, the output voltage, and the taping type for the ICs can be selected at the user's request.

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
RP904Zxx1*-E2-F	WLCSP-11-P2	4,000pcs	Yes	Yes
xx : Setting Output Voltage (V_{OUT}) combination, alphanumeric custom code.				
* : Designation of chip enable and BYPASS pin polarities (A) CE; "H" active, BYPASS pin; "H"=DC/DC converter mode, "L" = Bypass Mode				

ABSOLUTE MAXIMUM RATINGS

AGND=PGND=0V

Symbol	Item	Rating	Unit
V_{DD}	V_{DD} Supply Voltage	-0.3 to 6.5	V
V_{LX}	Lx Pin Voltage	-0.3 to $V_{DD}+0.3$	V
V_{CE}	CE Pin Input Voltage	-0.3 to 6.5	V
V_{MODE}	MODE Pin Input Voltage	-0.3 to 6.5	V
V_{BYPASS}	BYPASS Pin Input Voltage	-0.3 to 6.5	V
V_{SEL}	V_{SEL} Pin Input Voltage	-0.3 to 6.5	V
V_{OUT}	V_{OUT} Pin Voltage	-0.3 to $V_{DD}+0.3$	V
I_{LX}	Lx Pin Output Current	2000	mA
I_{OUT}	V_{OUT} Pin Output Current	1400	mA
P_D	Power Dissipation	1000	mW
T_a	Operating Temperature Range	-40 to+85	°C
T_{stg}	Storage Temperature Range	-55 to+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

RP904Zxx1A

(Ta=25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V _{DD}	Operating Input Voltage	V _{DD}	2.5		5.5	V
I _{DD1}	Supply Current 1 (Standby mode)	V _{DD} =5.5V, V _{CE} =V _{BYPASS} =0V			5.0	μA
I _{DD2}	Supply Current 2 (Through mode)	V _{DD} =V _{CE} =V _{SEL} =3.6V, V _{BYPASS} =0V	350		850	μA
I _{DD3}	Supply Current 3	V _{DD} =V _{CE} =V _{BYPASS} =V _{MODE} =3.6V, V _{OUT} =GND (No switching)	300		650	μA
I _{DD4}	Supply Current 4	V _{DD} =V _{CE} =V _{SEL} =V _{MODE} =0V, V _{OUT} =V _{DD} (No switching) *1	140		240	μA

*1) If V_{OUT}>V_{SET}, internal oscillation stops.

DC/DC Part

(Ta=25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit.
V _{OUT}	Output Voltage	V _{DD} =3.6V, V _{SET} ≥ 1.6V	x0.98		x1.02	V
		Open Loop, V _{SET} <1.6V	-0.03		+0.03	
fosc	Oscillator Frequency	V _{DD} =3.6V	1.60	2.00	2.40	MHz
t _{START}	Soft-start Time	V _{DD} =3.6V, Open Loop		0.135	0.170	ms
R _{ONP} **	ON Resistance of Pch Transistor *Note 1	V _{DD} =3.6V, I _{LX} = -100mA		0.250	0.450	Ω
R _{ONN} **	ON Resistance of Nch Transistor *Note 1	V _{DD} =3.6V, I _{LX} = -100mA		0.230	0.450	Ω
I _{LXLEAK}	Lx Leakage Current	V _{DD} =5.5V, V _{CE} =0V, Lx=5.5V/0V	-10.0	0.3	10.0	μA
I _{VOUT}	V _{OUT} Leakage Current	V _{DD} =5.5V, V _{CE} =0V, V _{OUT} =5.5V	-1.0	0.002	1.0	μA
ΔV _{OUT} /ΔTa	Output Voltage Temperature Coefficient	-40°C≤Ta≤85°C		±100		ppm/°C
Maxduty	Oscillator Maximum Duty Cycle		100			%
I _{LXLIM} **	Lx Current Limit *Note 1	V _{DD} =3.6V, Open Loop	1200	1600	2000	mA
t _{PROT}	Protection Delay Circuit	V _{DD} =3.6V	0.3	0.8	2.0	ms
t _{SETDC} **	DC/DC output settling time *Note 1	setting signal receive->90% of V _{OUT} , I _{OUT} ≥ 100mA *Note 2		25		μs
V _{UVLO1}	UVLO Threshold Voltage	V _{DD} =V _{CE} , V _{BYPASS} =V _{OUT} =0V	2.15	2.25	2.35	V
V _{UVLO2}	UVLO Released Voltage	V _{DD} =V _{CE} , V _{BYPASS} =V _{OUT} =0V	2.25	2.35	2.45	V
I _{PDM}	MODE pull-down current	V _{DD} =V _{MODE} =3.6V	1.0	2.0	6.0	μA
V _{MODEH}	MODE "H" Input Voltage		1.1			V
V _{MODEL}	MODE "L" Input Voltage		0.0		0.45	V
I _{PDV}	V _{SEL} pull-down current	V _{DD} =V _{SEL} =3.6V	1.0	2.0	6.0	μA
V _{VSELH}	V _{SEL} "H" Input Voltage		1.1			V
V _{VSELL}	V _{SEL} "L" Input Voltage		0.0		0.45	V

Bypass Switch

(Ta=25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
R _{ON} **	Bypass Switch On Resistance *Note 1	V _{DD} =3.0V		68	120	mΩ
I _{leak}	Switch Off leakage current		0.1	2.0	20.0	μA
I _{BYPLIM} **	Bypass Current Limit *Note 1	V _{DD} =2.8V to 3.3V	1.02	1.40	1.80	A
I _{BYPPROT}	Bypass Protection Delay Circuit		0.3	0.8	2.0	ms
I _{PDB}	BYPASS pull-down current	V _{DD} =V _{BYPASS} =3.6V	1.0	2.0	6.0	μA
V _{BYPASSH}	BYPASS"H" Input Voltage		1.1			V
V _{BYPASSL}	BYPASS"L" Input Voltage		0.0		0.45	V

Others

(Ta=25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
t _{SETBYP} **	BYPASS output settling time *Note 1	setting signal receive->90% of V _{DD} *Note 3		25		μs
I _{PDC}	CE pull-down current	V _{DD} =V _{CE} =3.6V	1.0	2.0	6.0	μA
V _{CEH}	CE "H" Input Voltage		1.1			V
V _{CEL}	CE "L" Input Voltage		0.00		0.45	V

*Note1) This item is guaranteed by design.

*Note2) This item describes the transition time from V_{SEL}="L" to "H" or "H" to "L" at V_{MODE}="H" and V_{BYPASS}="H" or at V_{MODE}="H" and V_{BYPASS}="L" or V_{BYPASS}="L" to "H" at V_{MODE}="H", V_{SEL}="H".

*Note3) This item describes the transition time from V_{BYPASS}="H" to "L" at V_{MODE}="H" and V_{SEL}="H".

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. The semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

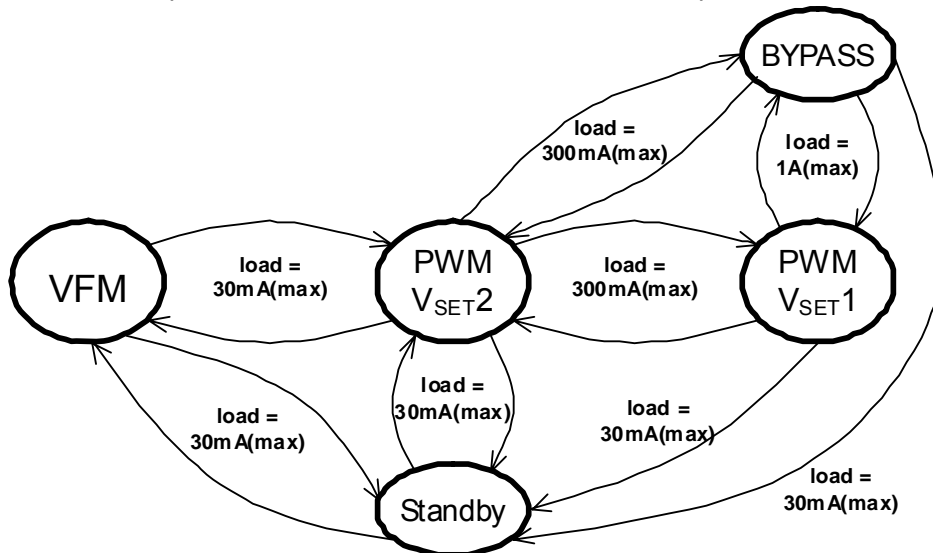
LOGIC TABLE

CE	0	1	1	1	1
V _{SEL}	0/1	0	0	1	1
BYPASS	0/1	0/1	0/1	0	1
MODE	0/1	0	1	0/1	0/1
STATE	Standby	VFM	PWM(V _{SET2})	BYPASS	PWM(V _{SET1})

- * Note 1) If V_{SET1} is not necessary, by fixing the logic of BYPASS at "L" and MODE at "H", DC/DC mode (V_{SET2}) and the bypass mode can be switched over with VSEL pin. (V_{SEL}="H": Bypass mode)
- * Note 2) If V_{SET2} is not necessary, by fixing the logic of VSEL at "H", DC/DC mode (V_{SET1}) and the bypass mode can be switched over with BYPASS pin. (BYPASS="L": Bypass mode)

OUTPUT CURRENT LIMIT CONDITION at MODE TRANSIENT

In terms of the operation of mode transient, the maximum output current at mode transient is as follows:



Note 1) At the start-up, if the first mode is VFM or PWM of V_{SET2}, at first, power on, and the secondly, forced the enable signal to CE pin.

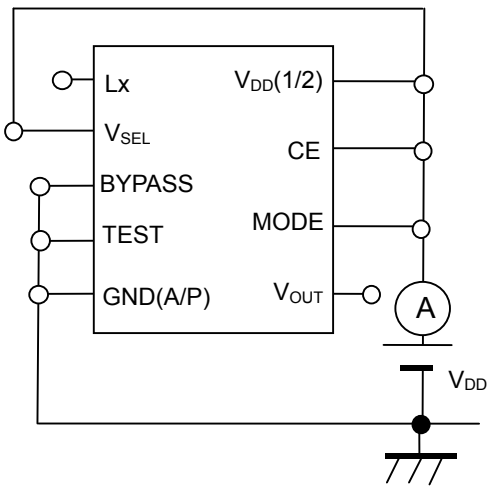
Note 2) In the actual application, if a magnet or similar to magnet is put very close to the IC, the IC itself is not affected, however, the inductor may be affected and the inductance value may shift, as a result, the inductance value could be not enough for the operation of the RP904Z.

In our simulation, if the inductance value decreases to 0.5μH or less, the peak of the ripple current increases and detected at start-up and the operation may stop. In this case, gain shifts lower and the operation could be unstable against the input and load variation.

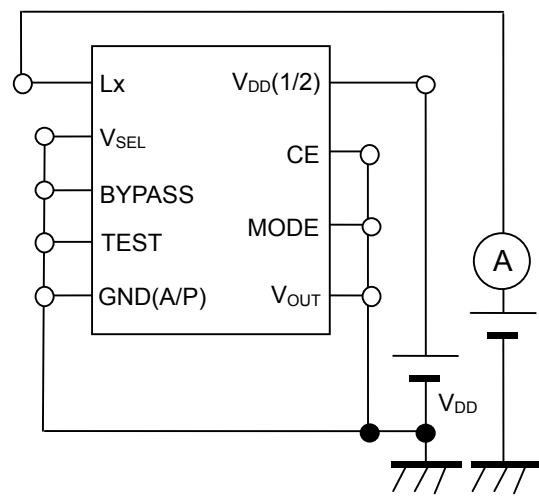
At the operation, at least 1μH inductance value is necessary.
As an initial value, the nominal inductance value should be 2.2μF or more.

TEST CIRCUITS

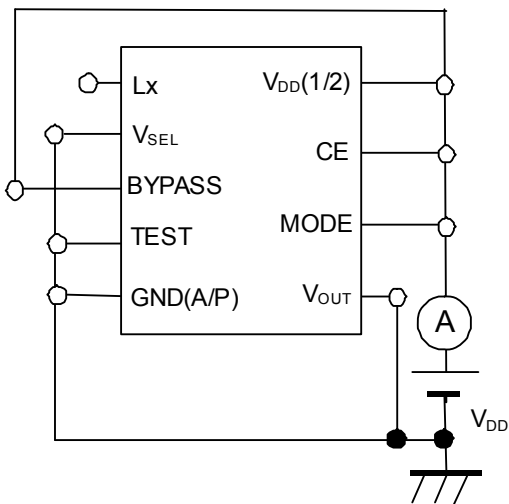
Supply Current 2



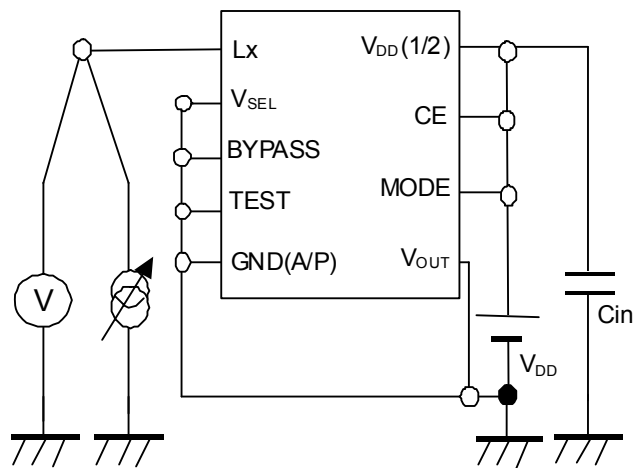
Lx Leakage Current



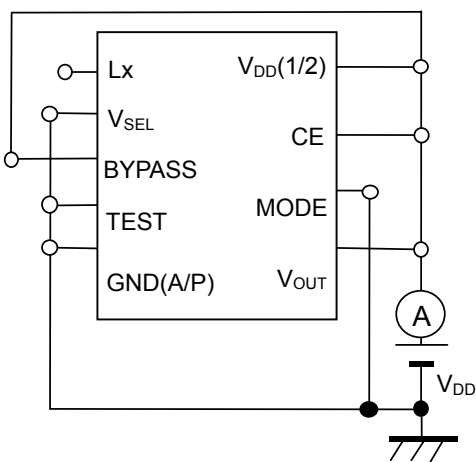
Supply Current 3



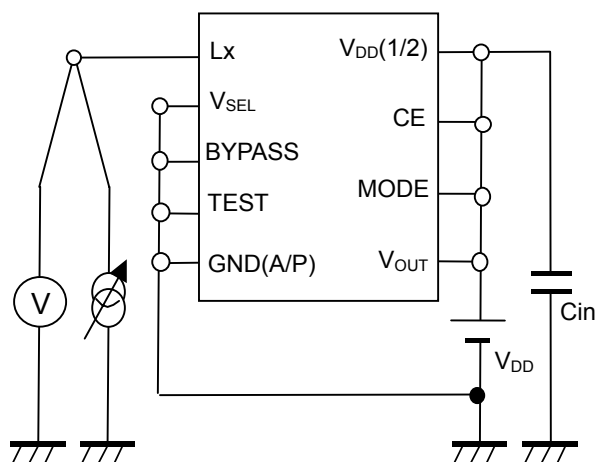
Lx On resistance (Pch)



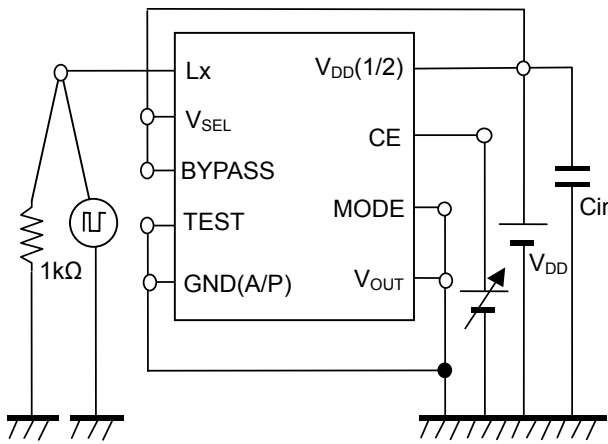
Supply Current 4



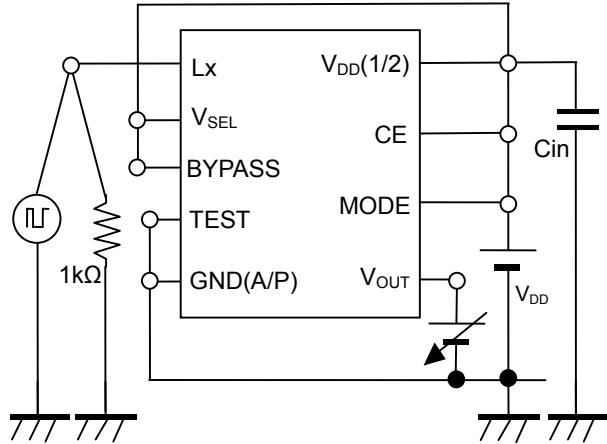
Lx On resistance (Nch)



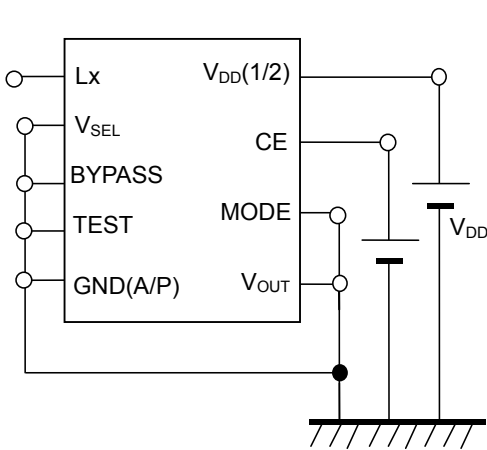
CE Input Voltage



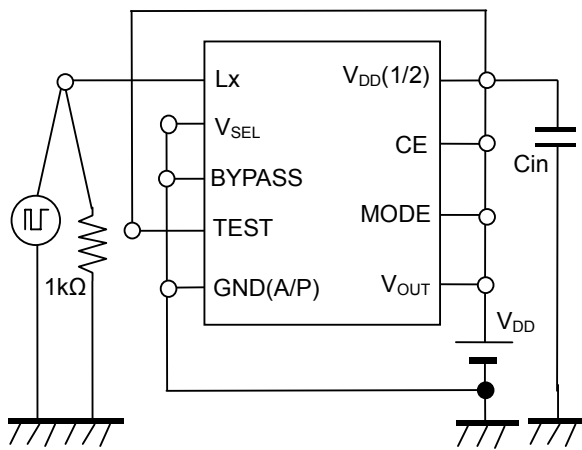
Output Voltage



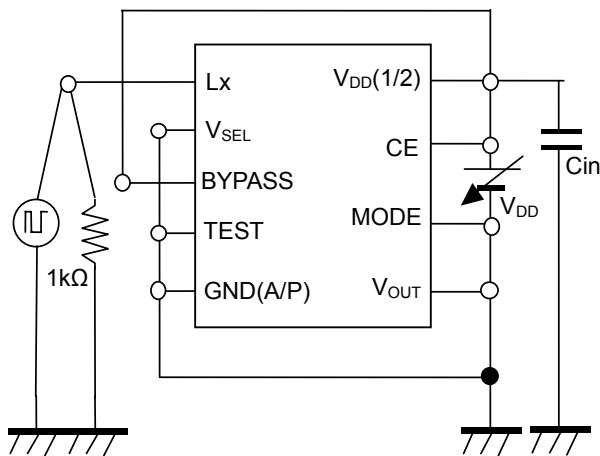
CE Input Current



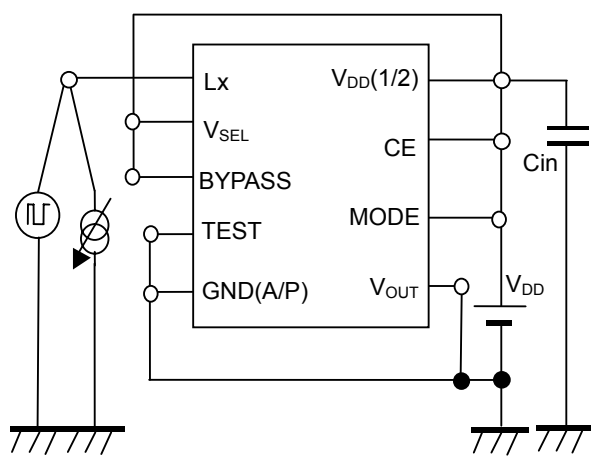
Oscillator Frequency



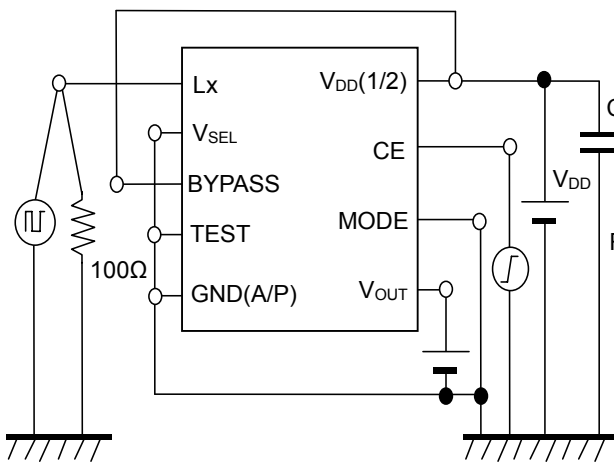
UVLO Detector Threshold/Released Voltage Hysteresis



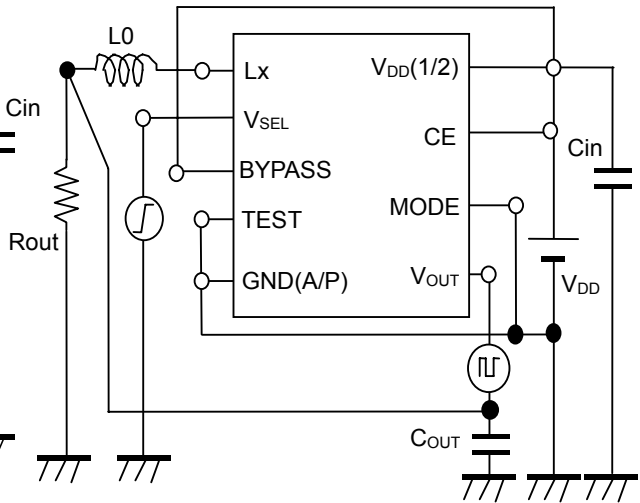
Lx Current Limit "H"



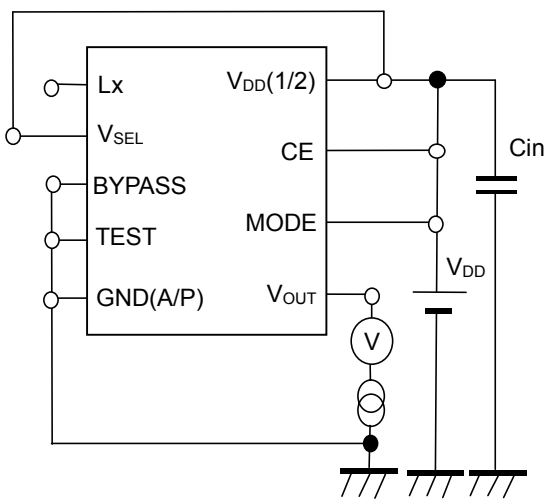
Soft Start Time



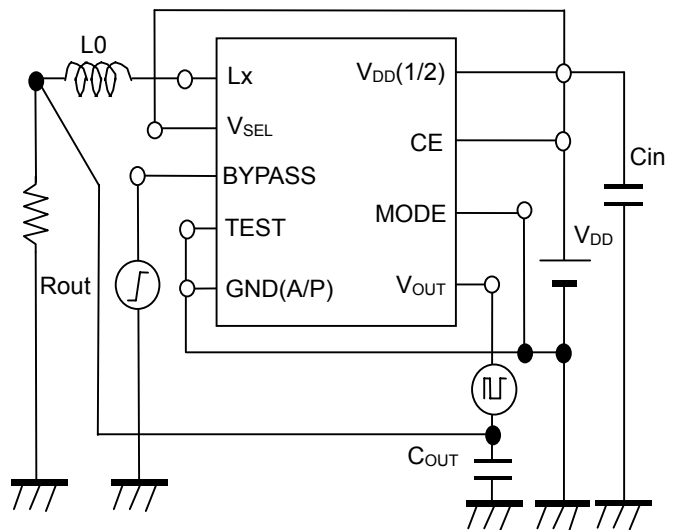
Output Settling Time 1



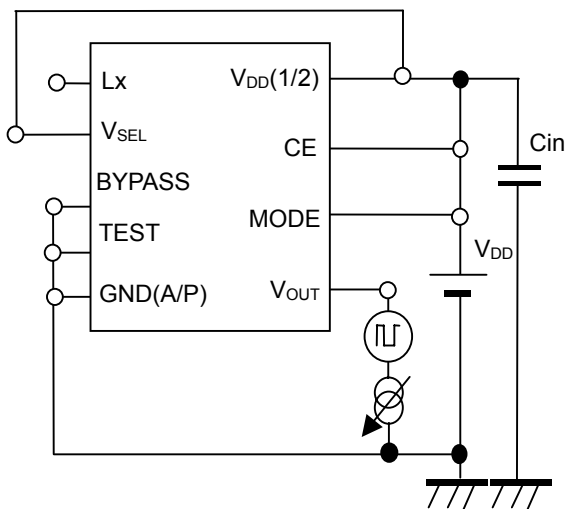
BYPASS ON resistance



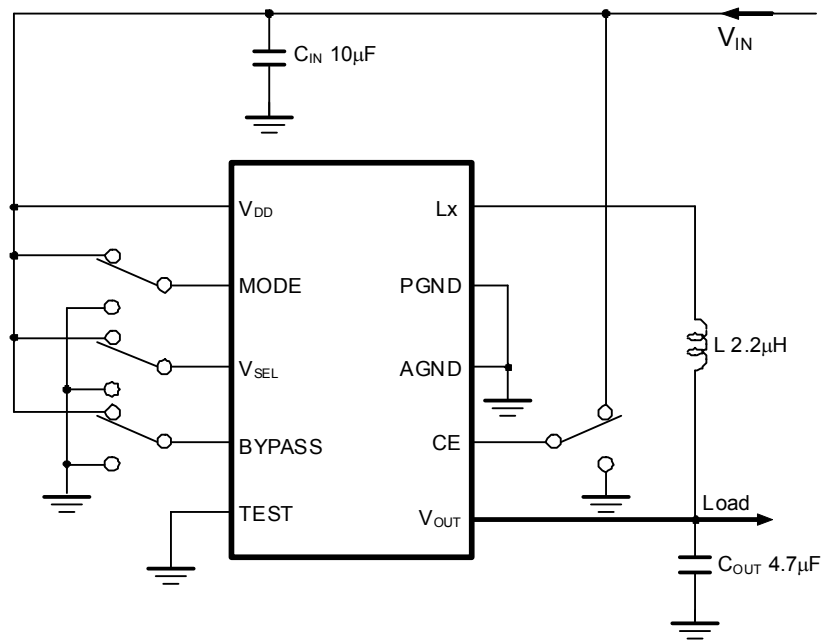
Output Settling Time 2



BYPASS Current Limit



TYPICAL APPLICATION



Parts Recommendation

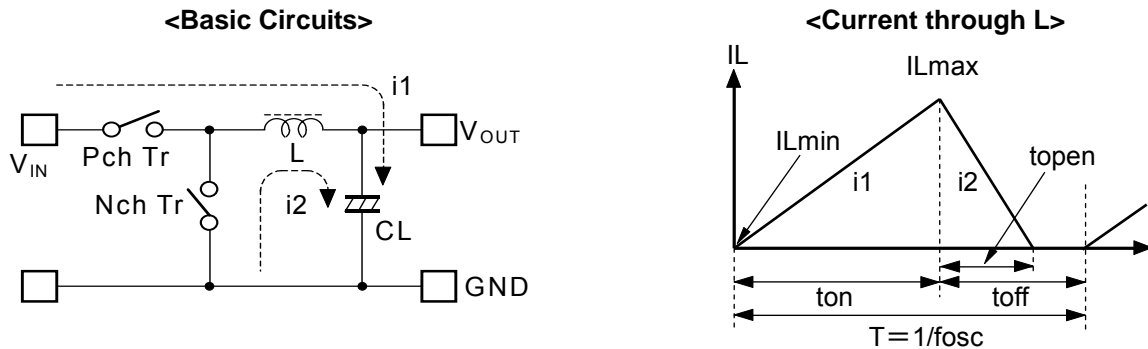
C_{IN}	10µF Ceramic type (C2012JB0J106K: TDK)
C_{OUT}	4.7µF Ceramic type (C2012JB1A475K: TDK) (JMK107BJ475MA: TaiyoYuden)
L	2.2µH(CKP2520: Taiyo Yuden) (NR3010: Taiyo Yuden) (MIPS2520: FDK)

External Components

- If PGND pin and AGND pin are connected in common, put the input capacitor C_{IN} as 10µF or more at the nearest connect point.
- If an input capacitor C_{IN} is set to the PGND pin and AGND pin respectively, set 10µF or more capacitor to PGND pin.
- Connect the TEST pin to the GND. Connect TEST pin can be in common with PGND pin and AGND pin.

OPERATION of step-down DC/DC converter and Output Current

The step-down DC/DC converter charges energy in the inductor when Lx transistor is ON, and discharges the energy from the inductor when Lx transistor is OFF and controls with less energy loss, so that a lower output voltage than the input voltage is obtained. The operation will be explained with reference to the following diagrams:



- Step 1: P-channel Tr. turns on and current $I_L (=i_1)$ flows, and energy is charged into CL. At this moment, I_L increases from $I_{Lmin} (=0)$ to reach I_{Lmax} in proportion to the on-time period (t_{on}) of P-channel Tr.
- Step 2: When P-channel Tr. turns off, Synchronous rectifier N-channel Tr. turns on in order that L maintains I_L at I_{Lmax} , and current $I_L (=i_2)$ flows.
- Step 3: $I_L (=i_2)$ decreases gradually and reaches $I_L = I_{Lmin} = 0$ after a time period of t_{open} , and N-channel Tr. Turns off. Provided that in the continuous mode, next cycle starts before I_L becomes to 0 because t_{off} time is not enough. In this case, I_L value increases from this $I_{Lmin} (>0)$.

In the case of PWM control system, the output voltage is maintained by controlling the on-time period (t_{on}), with the oscillator frequency (f_{osc}) being maintained constant.

The maximum value (I_{Lmax}) and the minimum value (I_{Lmin}) of the current flowing through the inductor are the same as those when P-channel Tr. turns on and off.

The difference between I_{Lmax} and I_{Lmin} , which is represented by ΔI ;

$$\Delta I = I_{Lmax} - I_{Lmin} = V_{OUT} \times t_{open} / L = (V_{DD} - V_{OUT}) \times t_{on} / L \dots \dots \dots \text{Equation 1}$$

Wherein, $T = 1/f_{osc} = t_{on} + t_{off}$

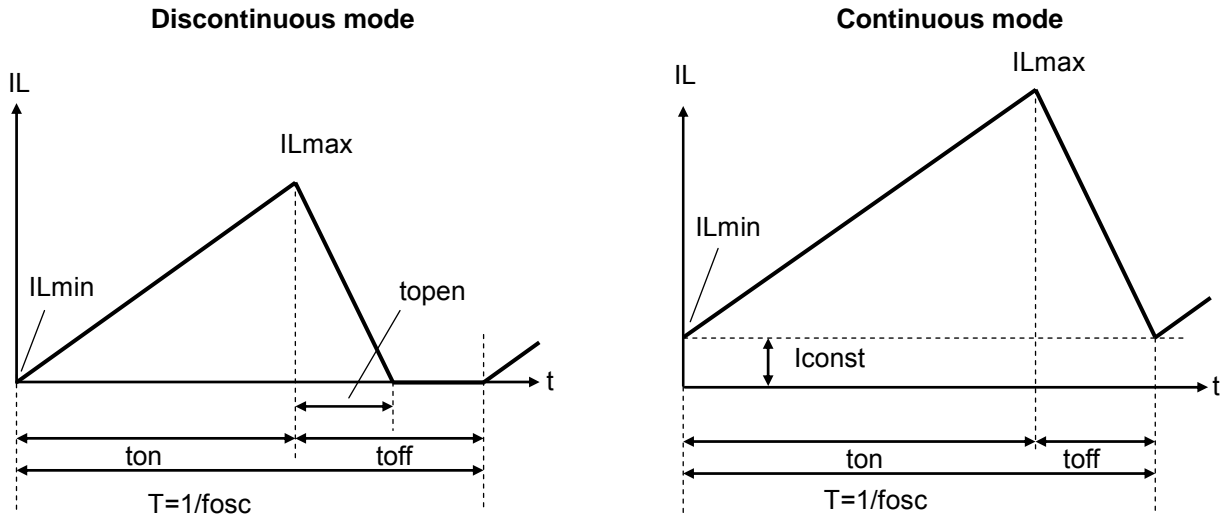
$$\text{duty (\%)} = t_{on} / T \times 100 = t_{on} \times f_{osc} \times 100$$

$$t_{open} \leq t_{off}$$

In Equation 1, $V_{OUT} \times t_{open} / L$ and $(V_{DD} - V_{OUT}) \times t_{on} / L$ respectively show the change of the current at "ON", and the change of the current at "OFF".

Discontinuous mode and Continuous mode

When the output current (I_{OUT}) is relatively small, $t_{open} < t_{off}$ as illustrated in the following diagram. In this case, the energy is charged in the inductor during the time period of t_{on} and is discharged in its entirety during the time period of t_{off} , therefore I_{Lmin} becomes to zero ($I_{Lmin}=0$). When I_{OUT} is gradually increased, eventually, t_{open} becomes to t_{off} ($t_{open}=t_{off}$), and when I_{OUT} is further increased, I_{Lmin} becomes larger than zero ($I_{Lmin}>0$). The former mode is referred to as the discontinuous mode and the latter mode is referred to as continuous mode.



In the continuous mode, when Equation 1 is solved for t_{on} and assumed that the solution is t_{onc} ,

$$t_{onc} = T \times V_{OUT} / V_{IN} \dots\dots\dots \text{Equation 2}$$

When $t_{on} < t_{onc}$, the mode is the discontinuous mode, and when $t_{on} = t_{onc}$, the mode is the continuous mode.

OUTPUT CURRENT AND SELECTION OF EXTERNAL COMPONENTS

When P-channel Tr. of Lx is ON:

(Wherein, Ripple Current P-P value is described as I_{RP} , ON resistance of P-channel Tr. and N-channel Tr. of Lx are respectively described as R_{ONP} and R_{ONN} , and the DC resistor of the inductor is described as R_L .)

$$V_{DD} = V_{OUT} + (R_{ONP} + R_L) \times I_{OUT} + L \times I_{RP} / t_{on} \dots\dots\dots \text{Equation 3}$$

When P-channel Tr. of Lx is "OFF"(N-channel Tr. is "ON"):

$$L \times I_{RP} / t_{off} = R_L \times I_{OUT} + V_{OUT} + R_{ONN} \times I_{OUT} \dots\dots\dots \text{Equation 4}$$

Put Equation 4 to Equation 3 and solve for ON duty of P-channel transistor, $t_{on} / (t_{off} + t_{on}) = D_{ON}$,

$$D_{ON} = (V_{OUT} - R_{ONN} \times I_{OUT} + R_L \times I_{OUT}) / (V_{DD} + R_{ONN} \times I_{OUT} - R_{ONP} \times I_{OUT}) \dots\dots\dots \text{Equation 5}$$

Ripple Current is as follows;

$$I_{RP} = (V_{DD} - V_{OUT} - R_{ONP} \times I_{OUT} - R_L \times I_{OUT}) \times D_{ON} / f / L \dots\dots\dots \text{Equation 6}$$

Wherein, peak current that flows through L, and Lx Tr. is as follows;

$$I_{Lmax} = I_{OUT} + I_{RP} / 2 \dots\dots\dots \text{Equation 7}$$

Consider I_{Lmax} , condition of input and output and select external components.

* The above explanation is directed to the calculation in an ideal case in continuous mode.

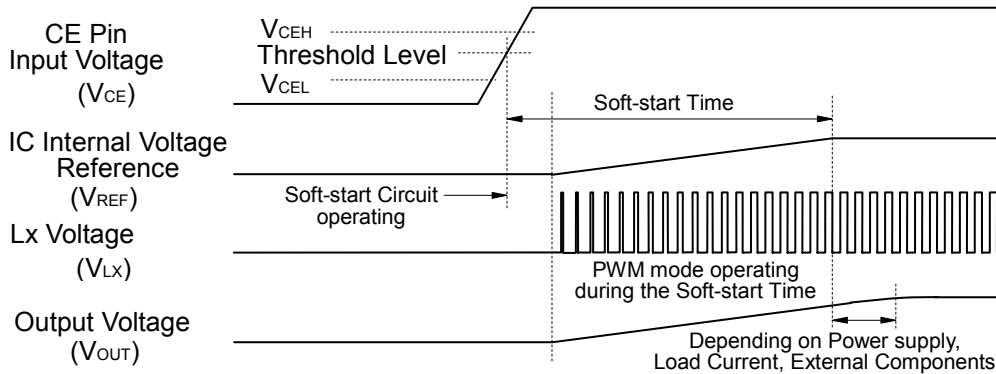
If CE pin input signal is forced earlier than the supply voltage, V_{OUT} rises up with keeping its voltage difference between the input and the output fixed by the input voltage against V_{DD} .

TIMING CHART

(1) Soft Start Time

In the case of starting this IC with CE

In the case of starting this IC with CE, the operation can be as in the timing chart below. When the voltage of CE pin (V_{CE}) is beyond the threshold level, the operation of the IC starts. The threshold voltage of CE pin is in between CE "H" input voltage (V_{CEH}) and CE "L" input voltage (V_{CEL}) described in the electrical characteristics table. Soft-start circuit operates, and after the certain time, the reference voltage inside the IC (V_{REF}) is rising gradually up to the constant value.



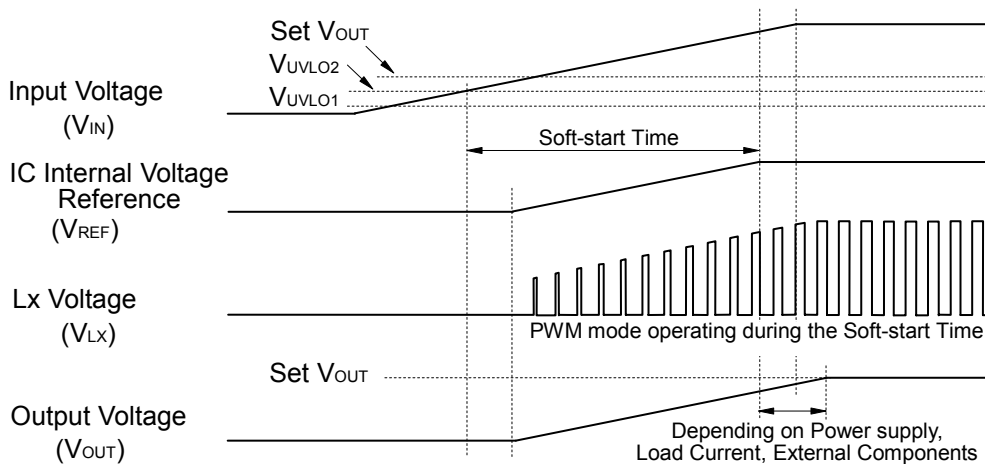
Soft-start time is the time interval from soft start circuit starting point to the reference voltage level reaching point up to this constant level.

*Soft start time is not always equal to the turn-on speed of DC/DC converter.

The power supply capacity for this IC, load current, inductance and capacitance values affect the turn-on speed.

In the case of starting with power supply

In the case of starting with power supply, when the input voltage (V_{IN}) is larger than UVLO released voltage (V_{UVLO2}), soft start circuit operates, and after that, the same explanation above is applied to the operation. Soft-start time is the time interval from soft start circuit starting point to the reference voltage level reaching point up to this constant level.



*Turn-on speed is affected by next conditions;

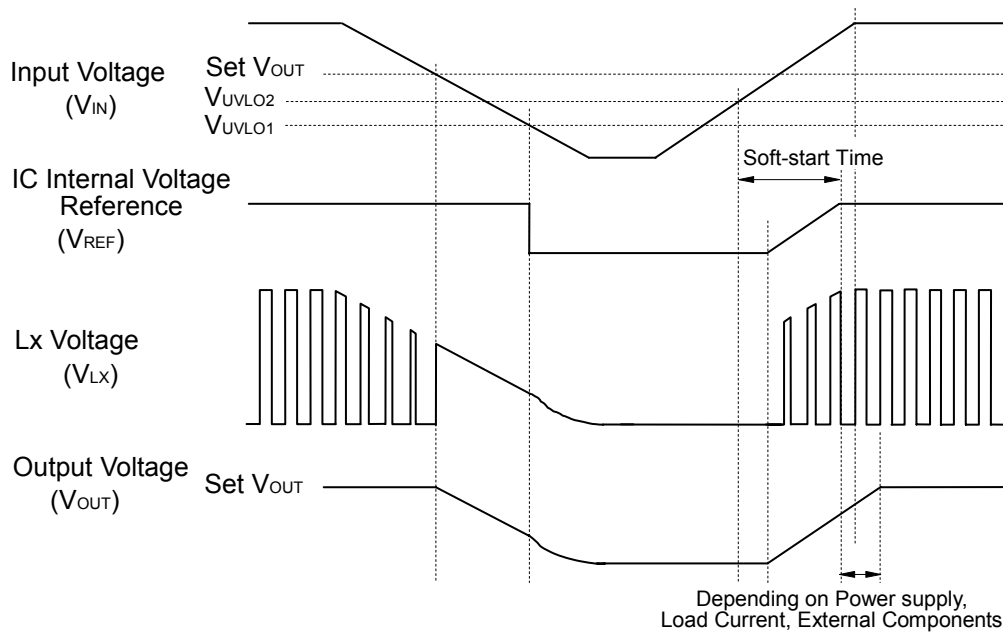
- (a) Input Voltage (V_{IN}) rising speed depending on the power supplier to the IC and input capacitor C_{IN} .
- (b) Output Capacitor C_{OUT} value and load current value.

• (2) Under Voltage Lockout (UVLO) Circuit

The step-down DC/DC converter stops switching if input voltage (V_{IN}) becomes less than the set output voltage (Set V_{OUT}), the output voltage (V_{OUT}) gradually drops according to the input voltage (V_{IN}). If the input voltage drops more and becomes less than UVLO detector threshold (V_{UVLO1}), the under voltage lockout circuit (UVLO) operates, the IC internal reference voltage (V_{REF}) stops and the output voltage drops according to the load.

To restart the normal operation, the input voltage (V_{IN}) must be more than the UVLO released voltage (V_{UVLO2}).

The timing chart below describes the operation with varying the input voltage (V_{IN}).



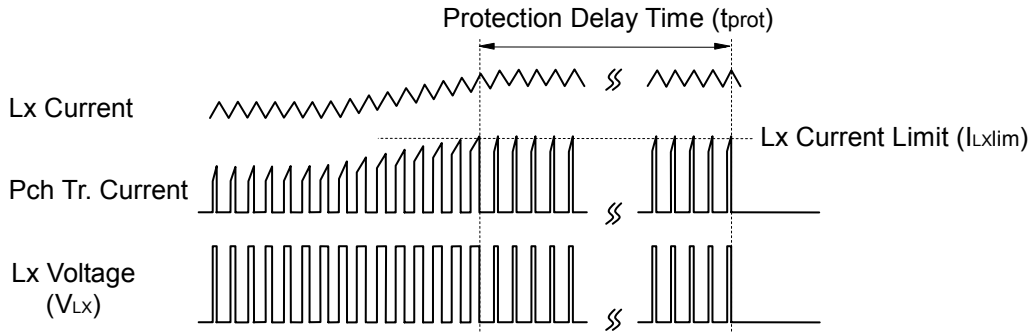
*Actually, the waveform of V_{OUT} at UVLO working and releasing varies depending on the initial voltage of C_{OUT} and load current situation.

(3) Over Current Protection Circuit, Latch Type Protection Circuit

Over current protection circuit supervises the coil peak current (the current flowing Pch transistor) at each switching cycle, and if the current beyond the Lx current limit (I_{Lxlim}), Pch transistor is turned off. the Lx current limit of RP904K is Typ.1.6A.

Further, if the over current status continues equal or longer than protection delay time, or, when the Lx limit current is exceeded even once when the driver operates by duty 100%, a built-in driver is latched in the OFF state and the operation of DC/DC converter stops.

*Lx current limit and protection delay time is affected by self-heating and ambient environment. If the output is short and the input voltage (V_{IN}) is drastically dropped or becomes unstable, the protection operation and delay time may vary.

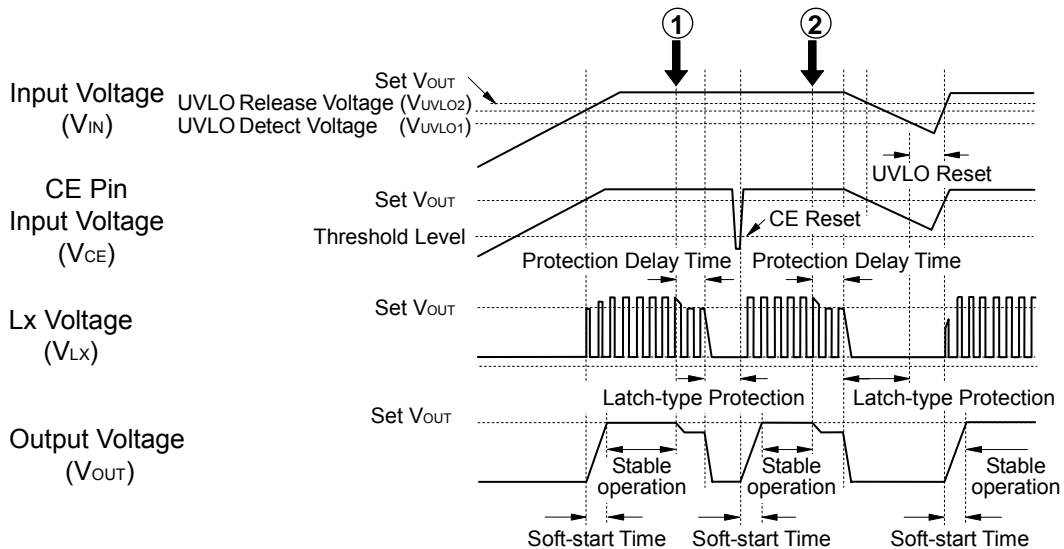


To release the condition of latch type protection, restart this IC by inputting "L" signal to CE pin, or restart this IC with power-on or make the supply voltage lower than UVLO detector threshold (V_{UVLO1}) level.

The timing chart shown below describes the changing process of input voltage rising, stable operating, operating with large current, reset with CE pin, stable operating, input voltage falling, input voltage recovering, and stable operating.

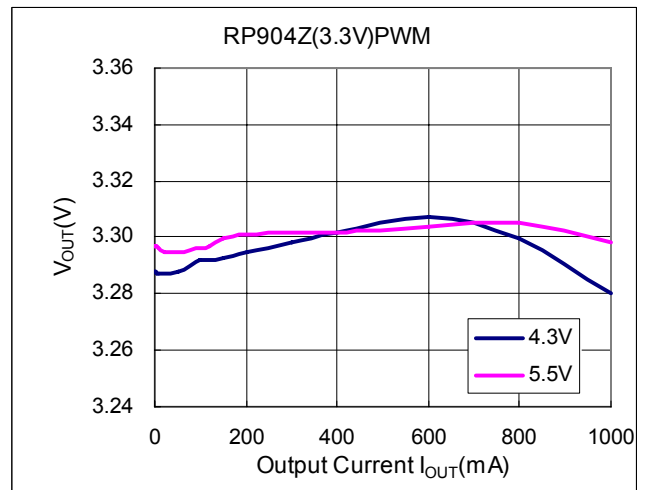
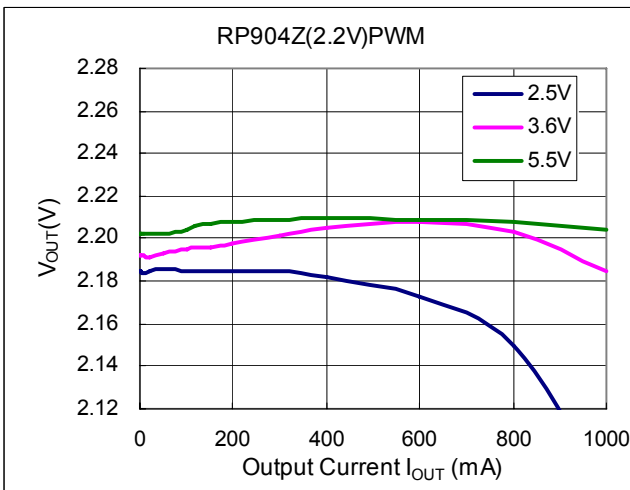
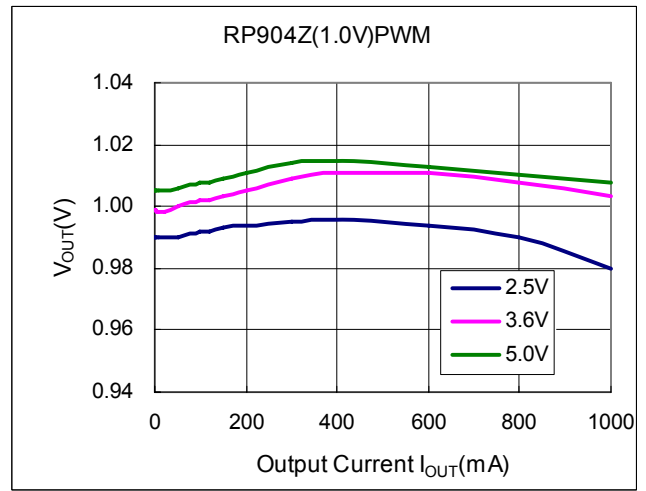
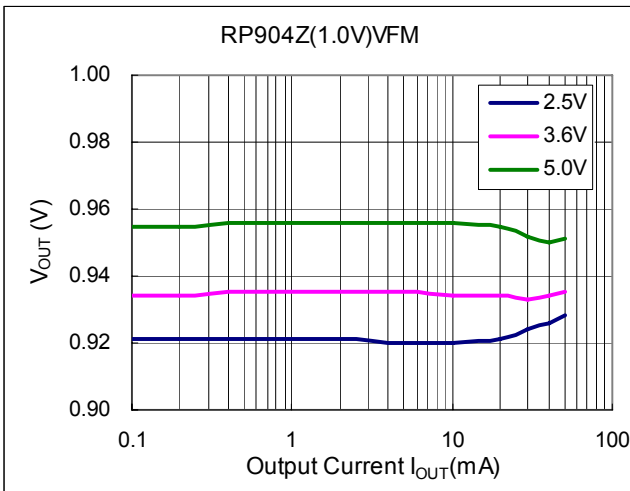
If too large current flows through the circuit because of short or other reasons, after the delay time of latch type protection a built-in driver is latched in the OFF state and V_{Lx} signal will be "L", then output will turn off. At the point ①, release the latch type protection is realized with CE reset as changed CE signal from "L" to "H".

At the point ②, release the latch type protection is realized with UVLO reset as make the supply voltage lower than UVLO detector threshold (V_{UVLO1}) level.

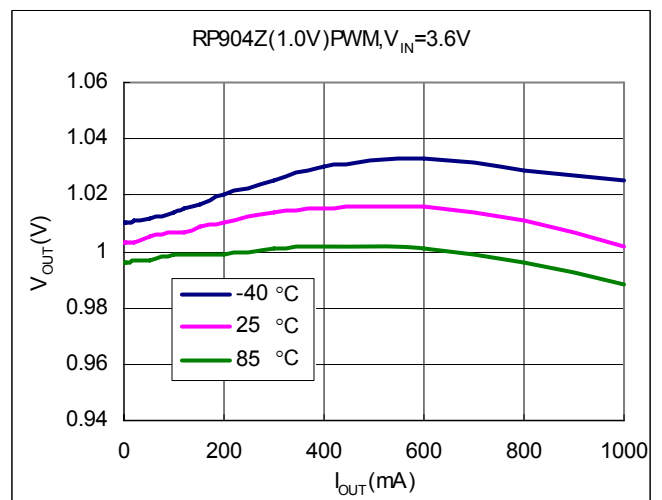
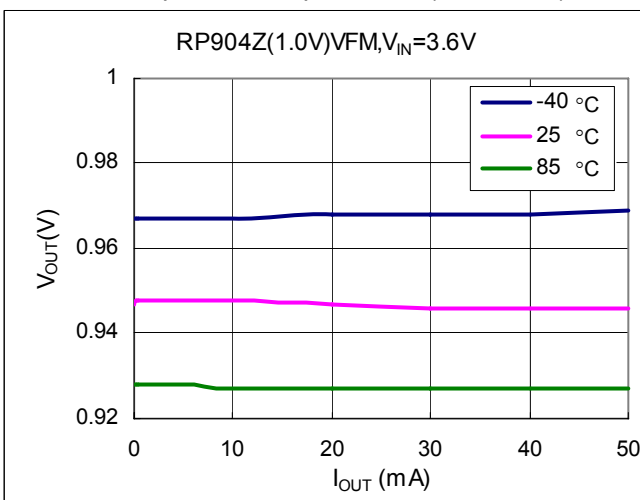


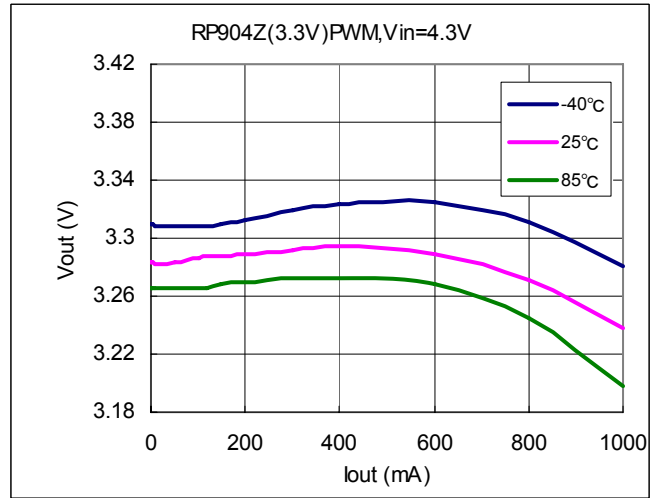
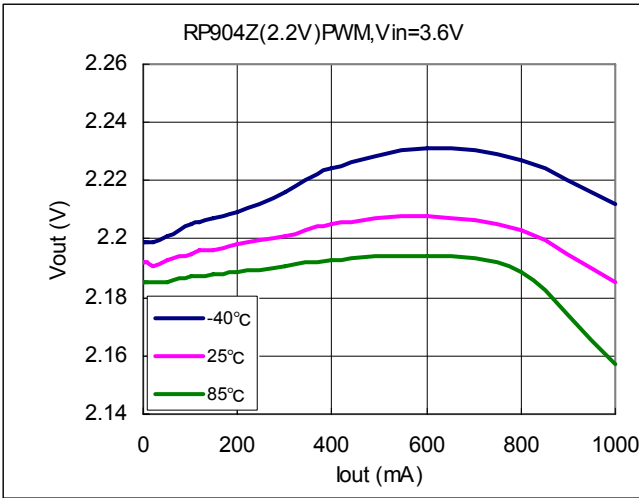
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current
1-1 Input Voltage Dependence

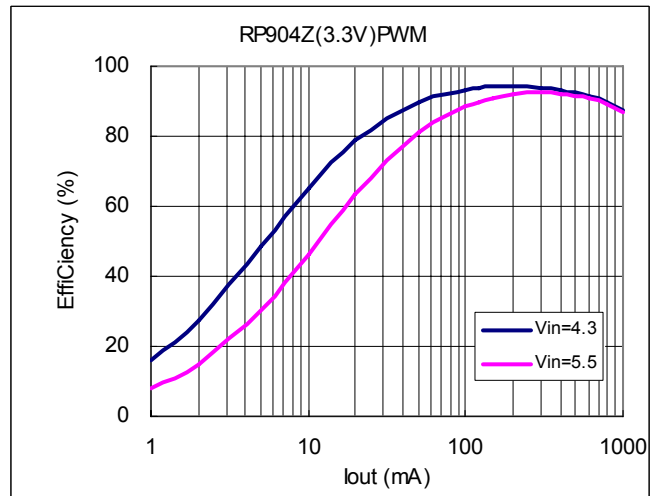
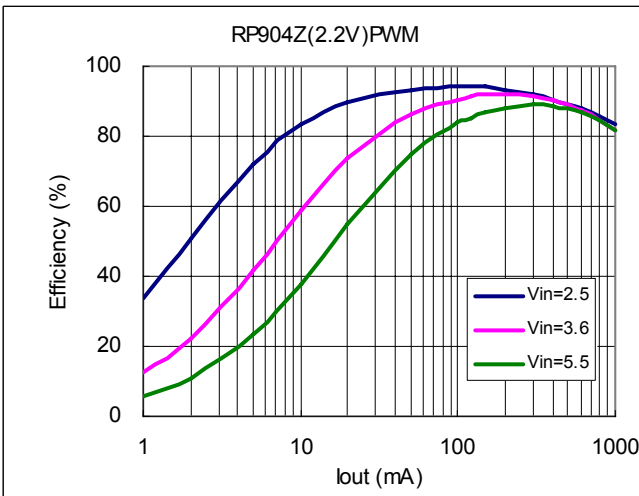
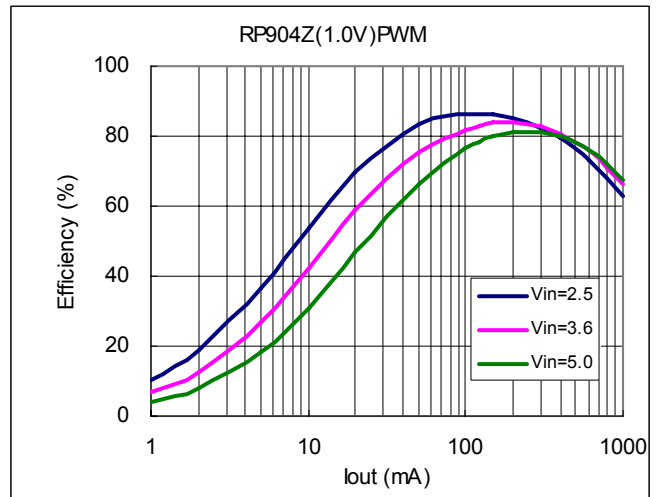
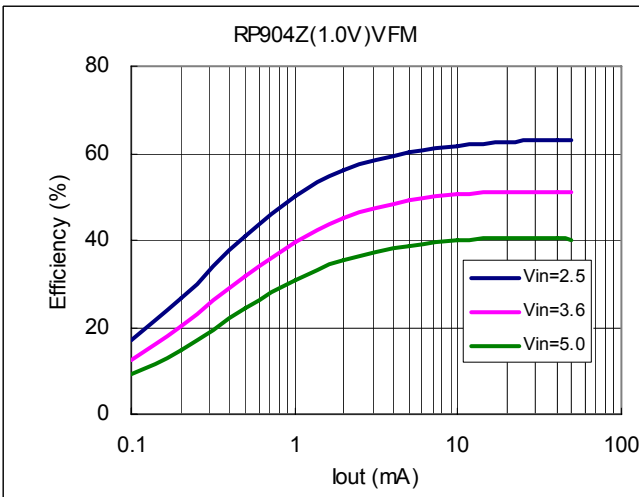


1-2 Temperature Dependence ($V_{SET}=2.9V$)

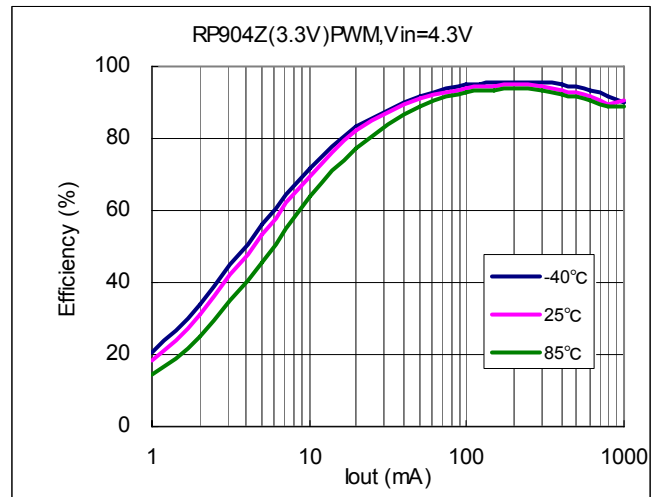
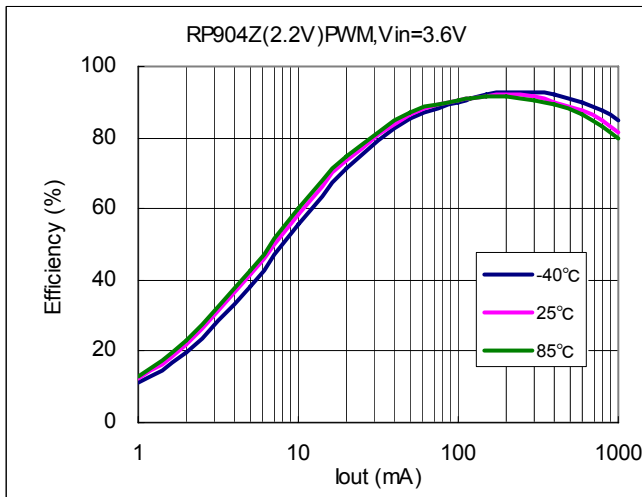
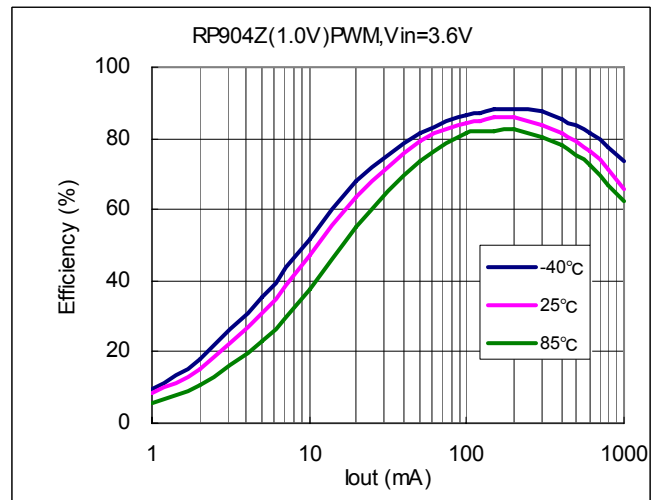
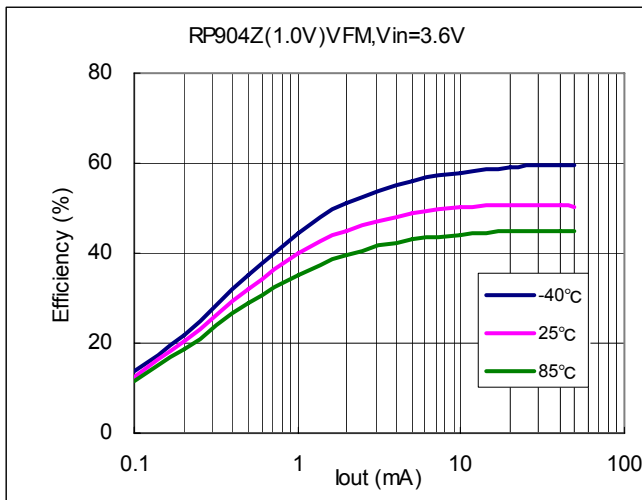




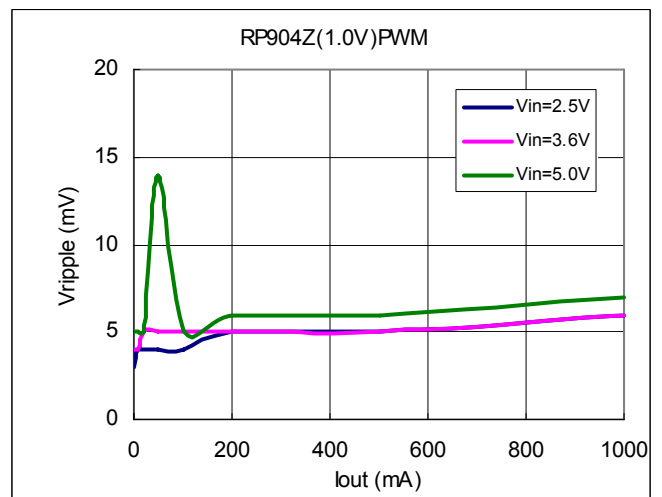
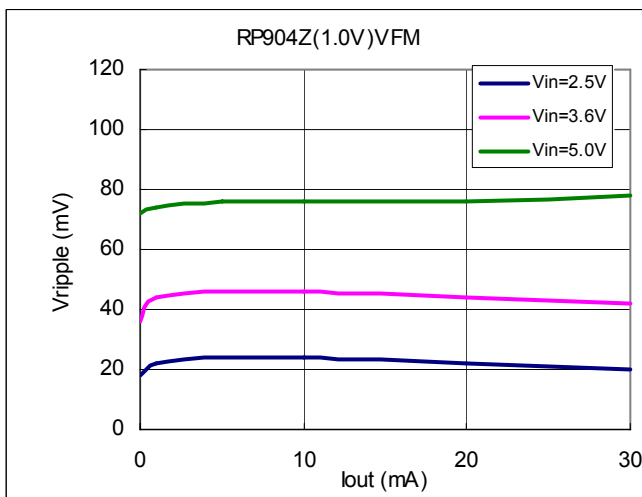
2) Efficiency vs. Output Current
2-1 Input Voltage Dependence

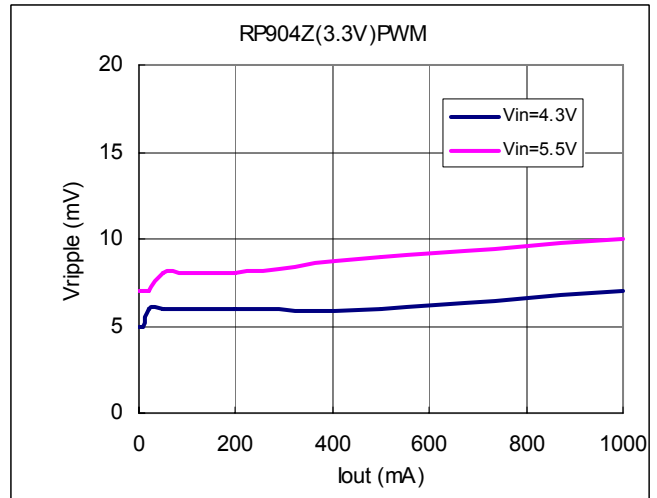
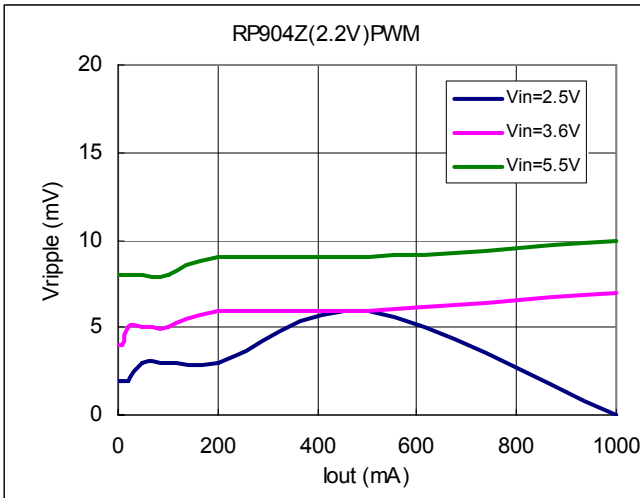


2-2. Temperature Dependence

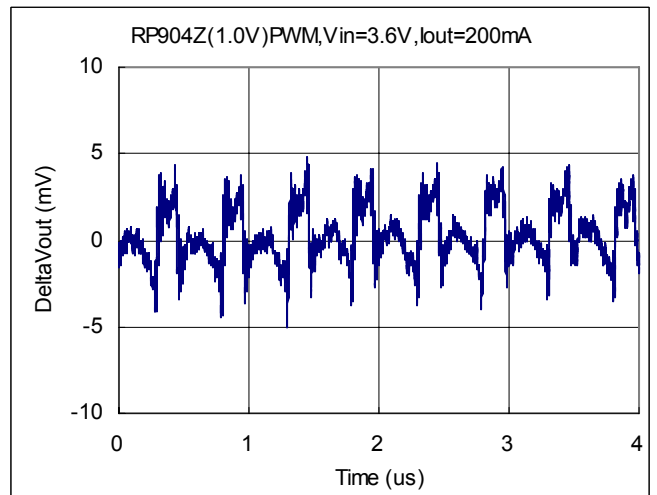
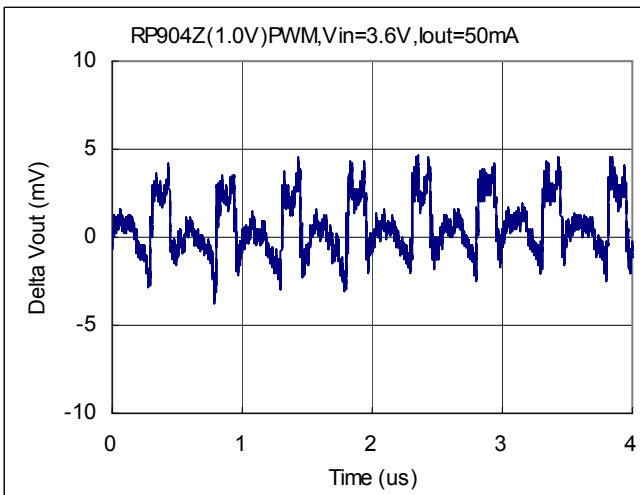
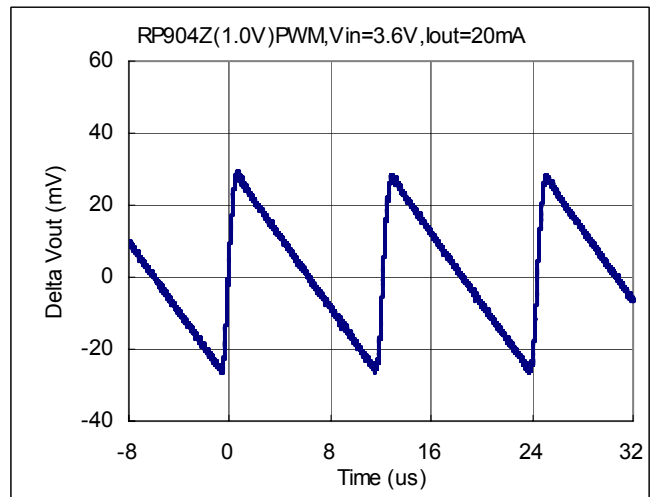
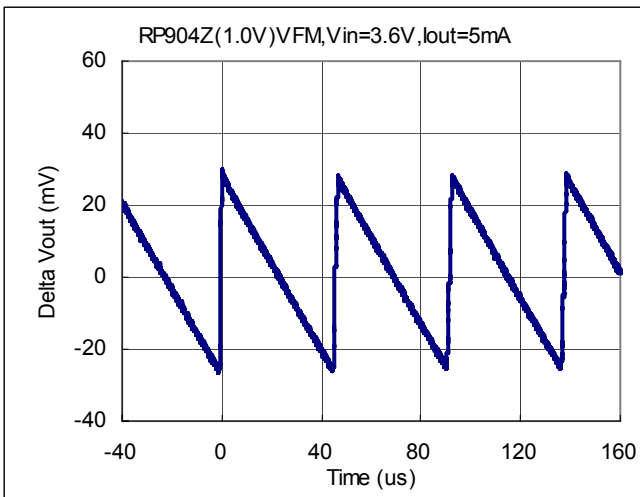


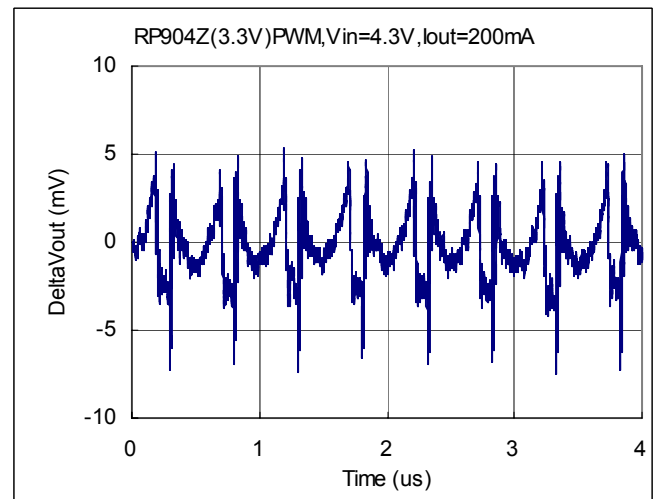
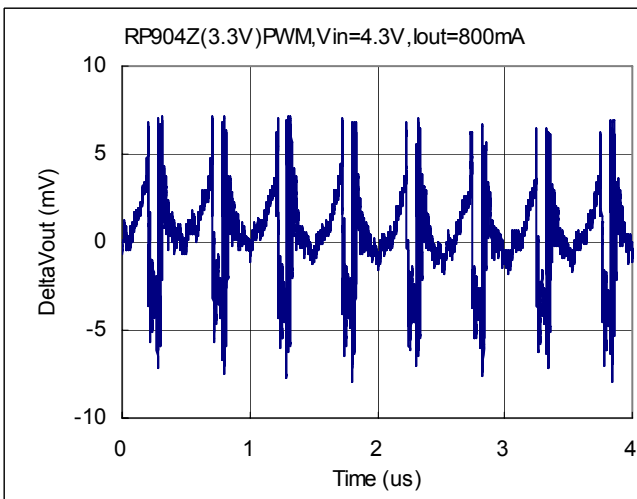
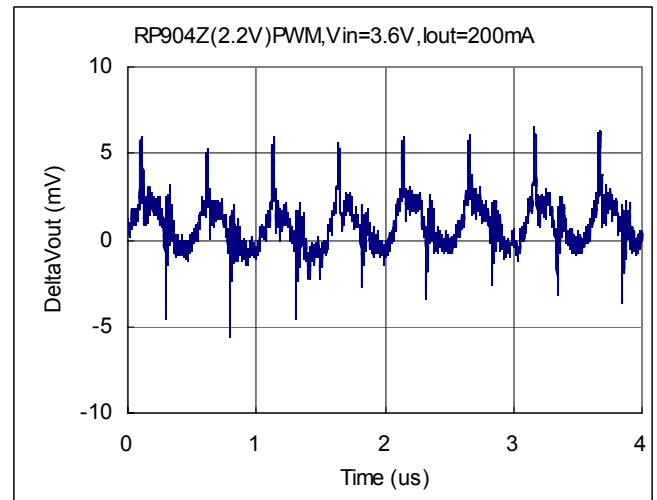
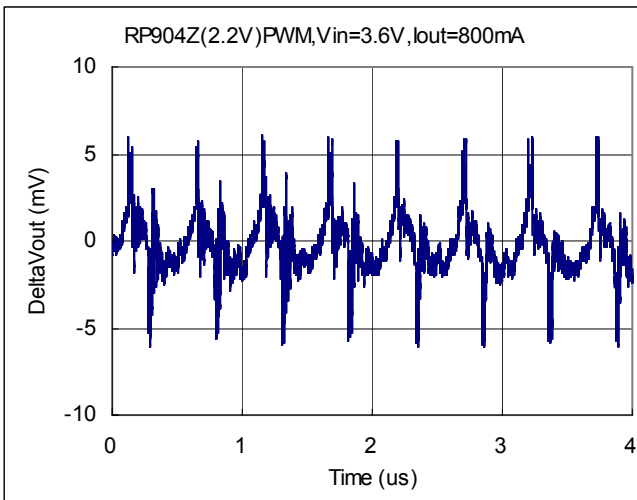
3) Output Ripple Voltage vs. Output Current



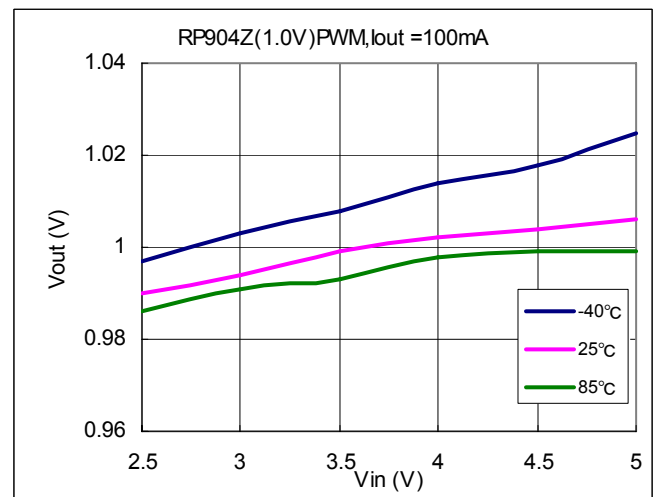
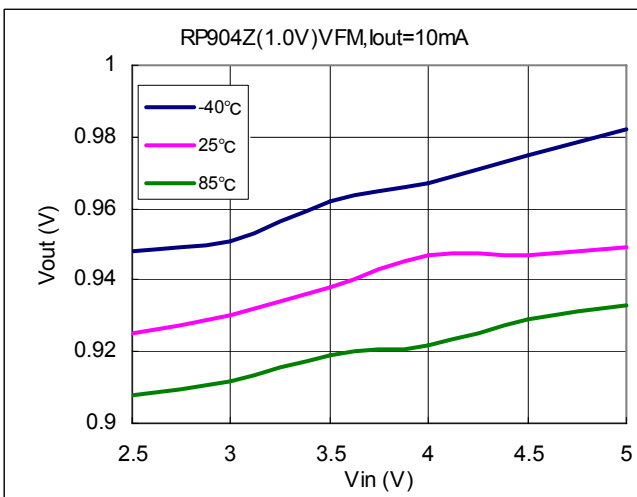


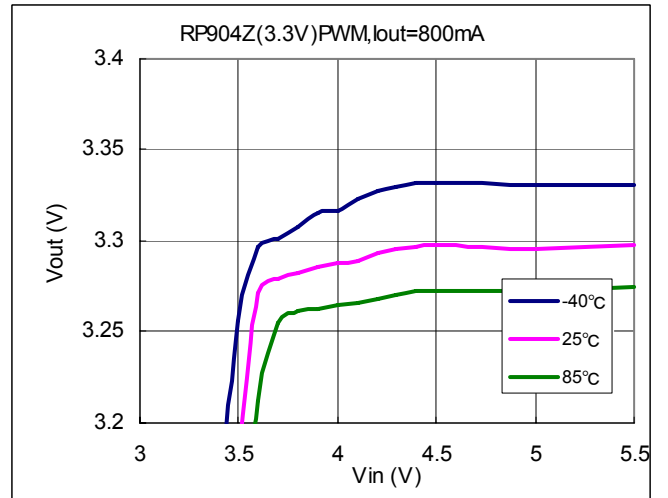
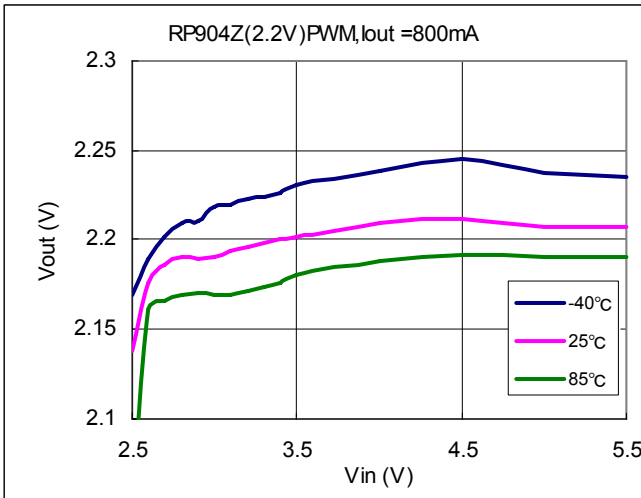
4) Output Waveform



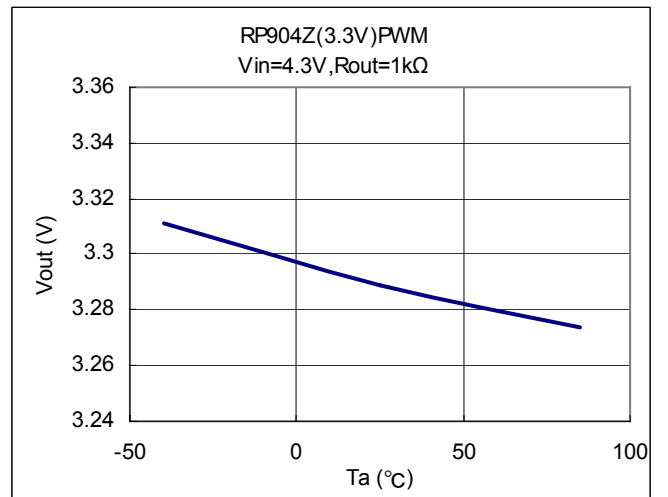
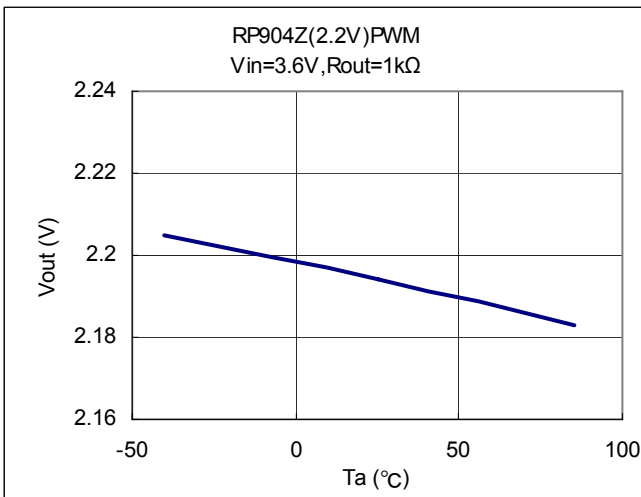
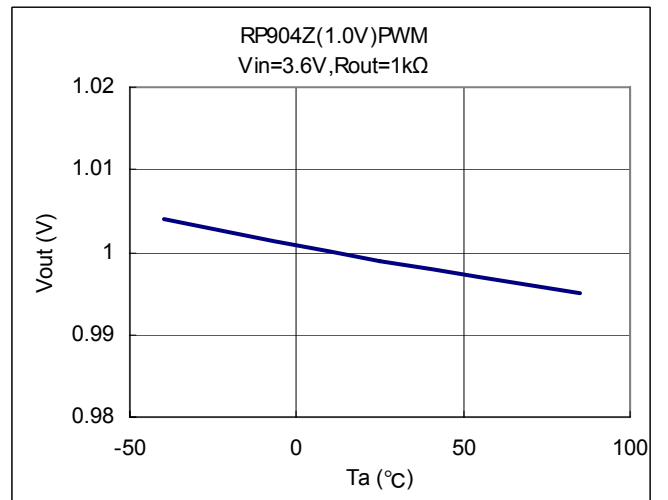
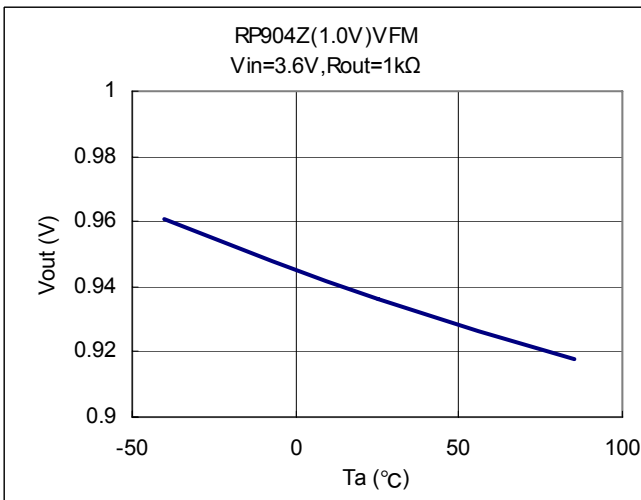


5) Output Voltage vs. Input Voltage

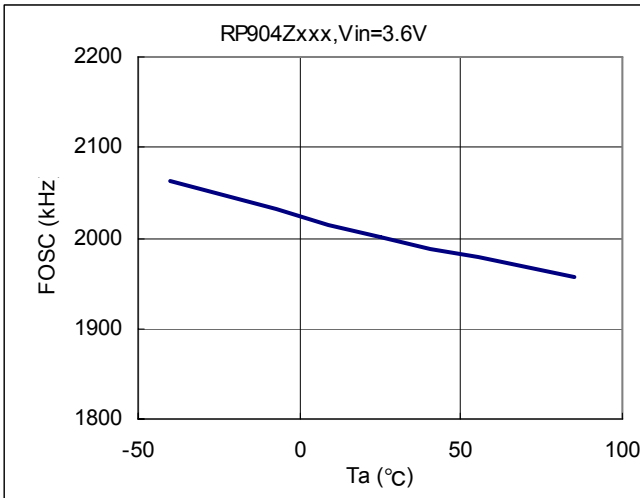




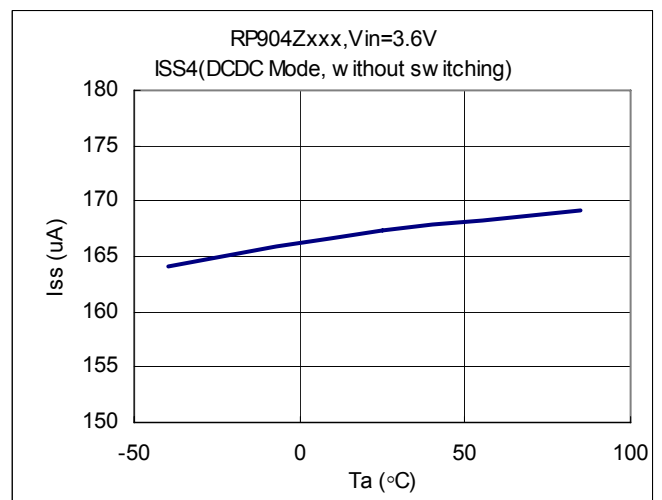
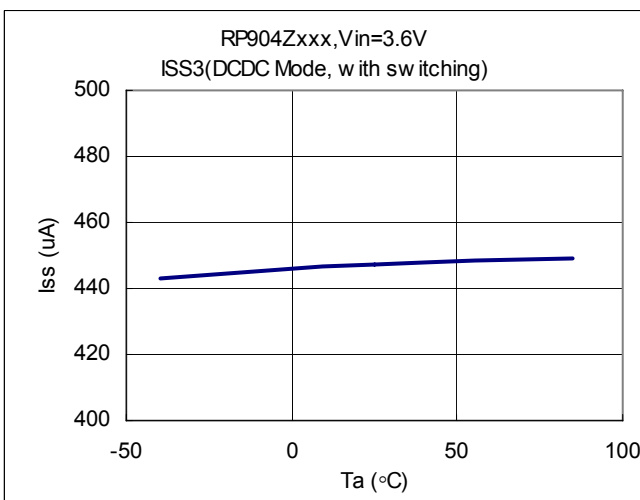
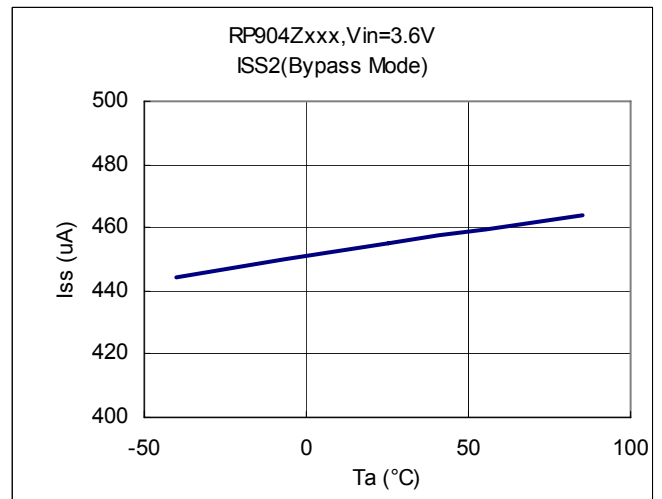
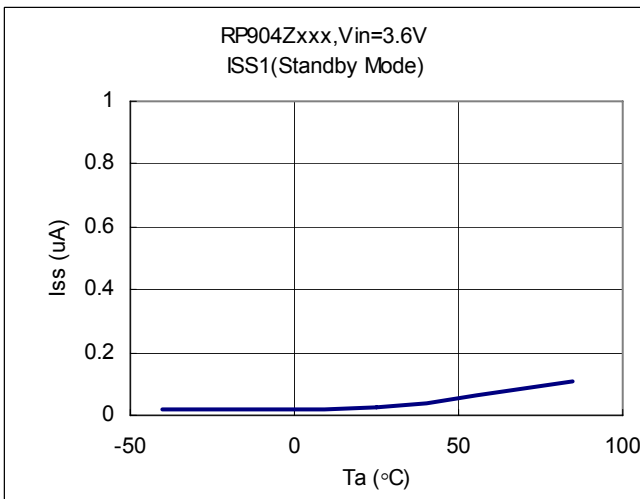
6) Output Voltage vs. Temperature



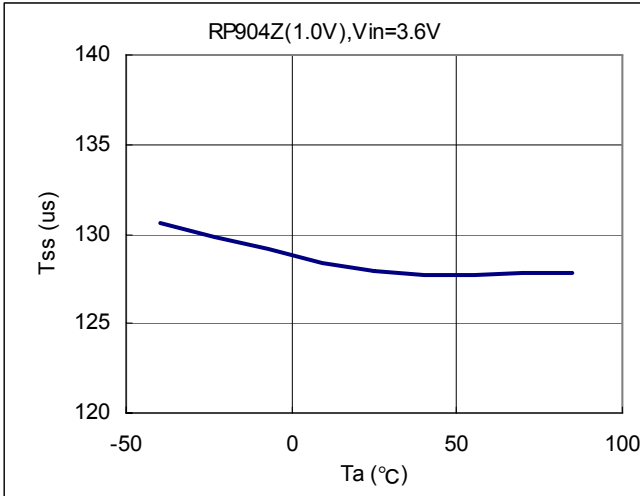
7) Oscillator Frequency vs. Temperature



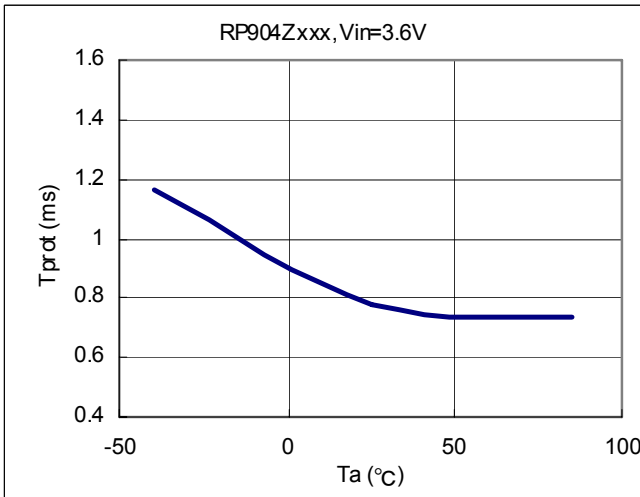
8) Supply Current vs. Temperature



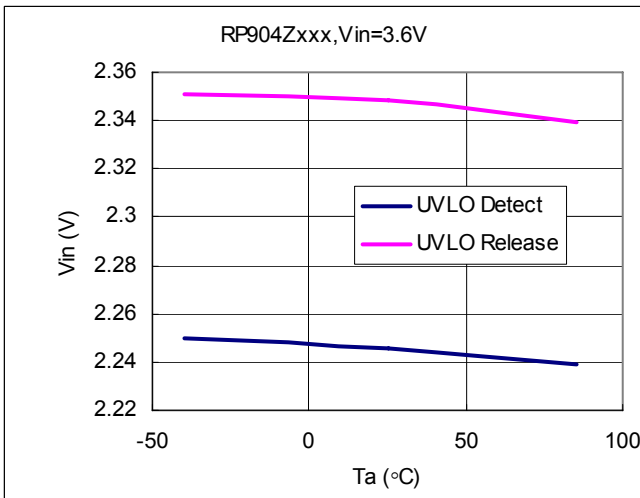
9) Soft-start Time vs. Temperature



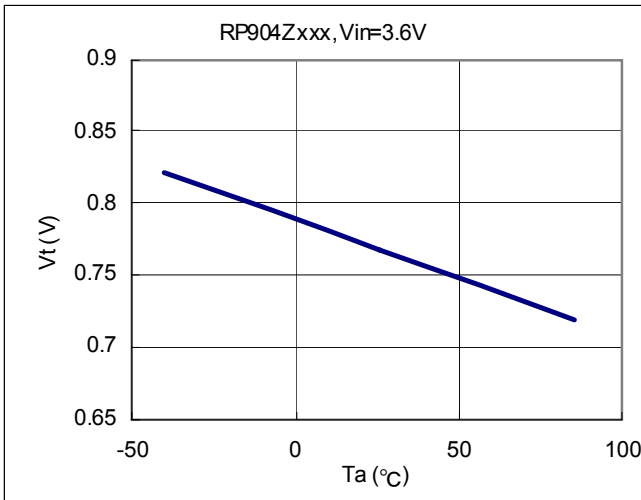
10) Protection Delay Time vs. Temperature



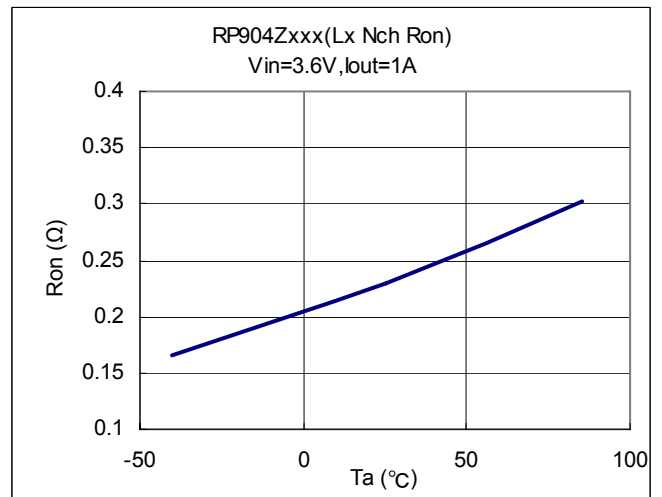
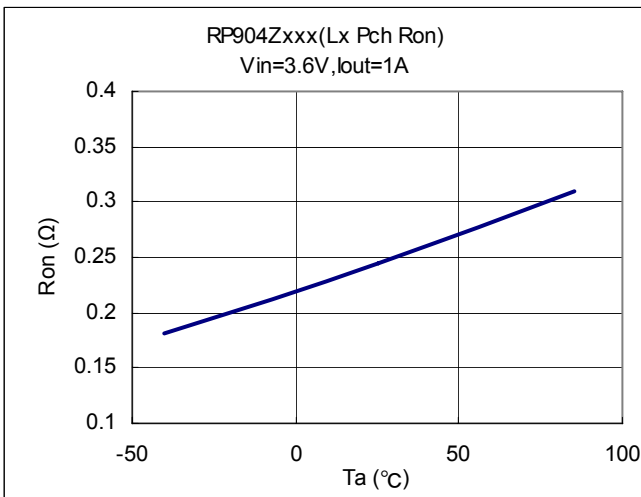
11) UVLO Detector Threshold / Released Voltage vs. Temperature



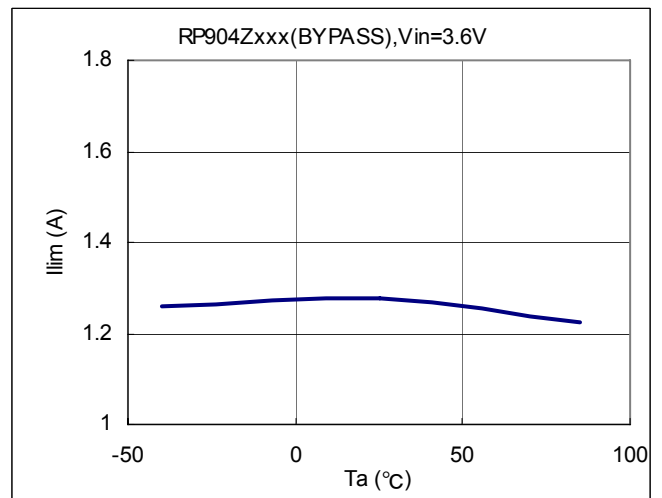
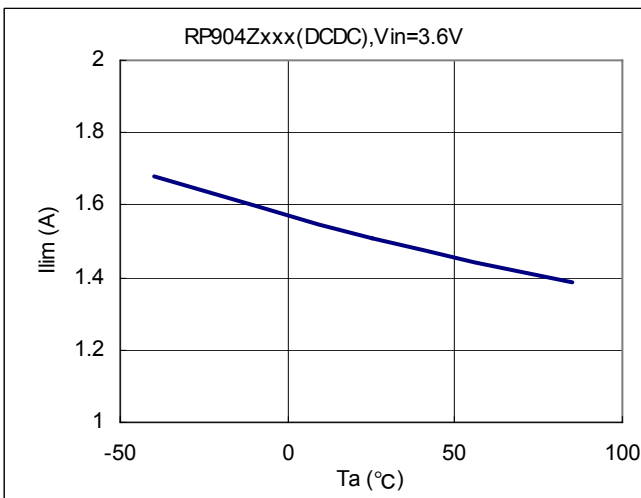
12) CE Input Threshold Voltage vs. Temperature



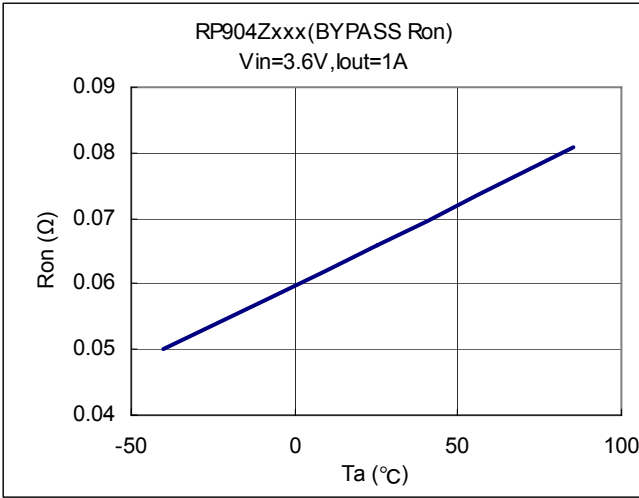
13) L_x Transistor ON Resistance vs. Temperature



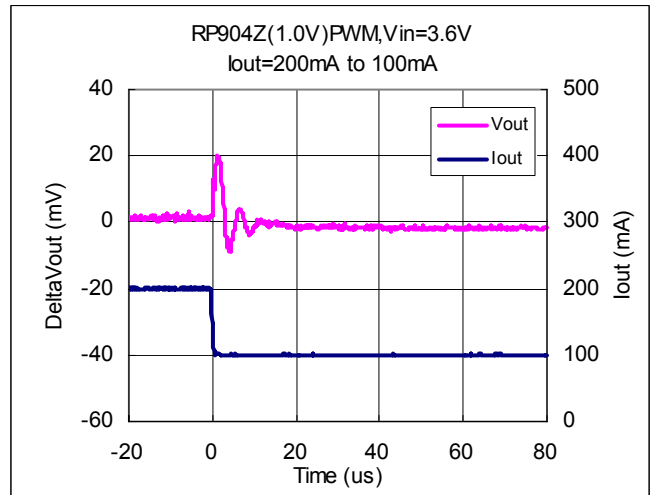
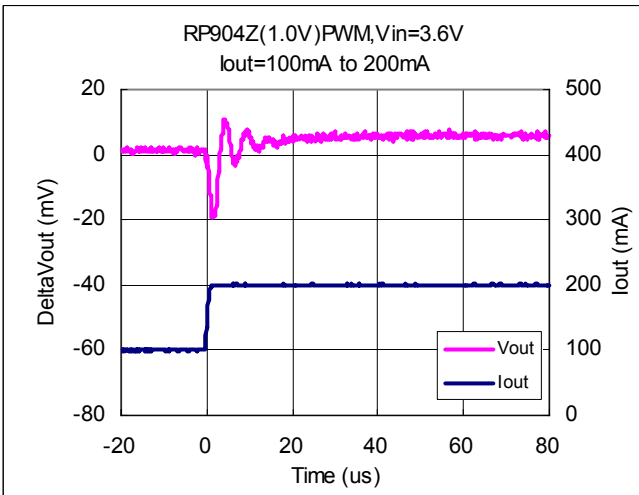
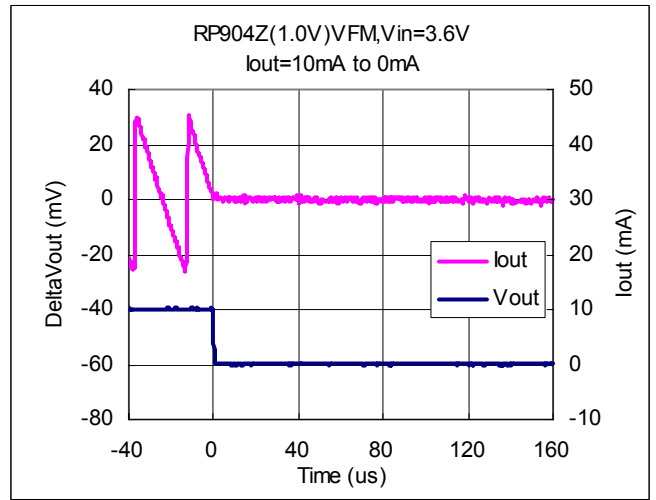
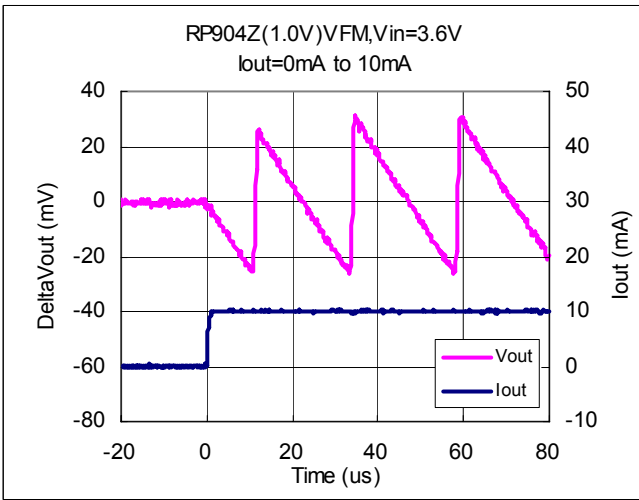
14) Current Limit vs. Temperature

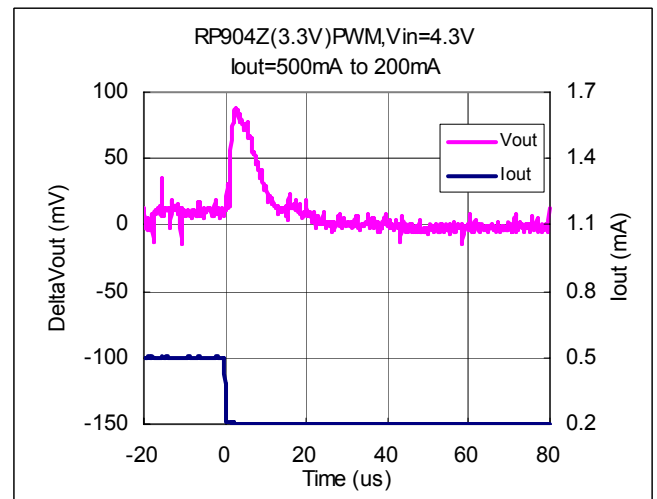
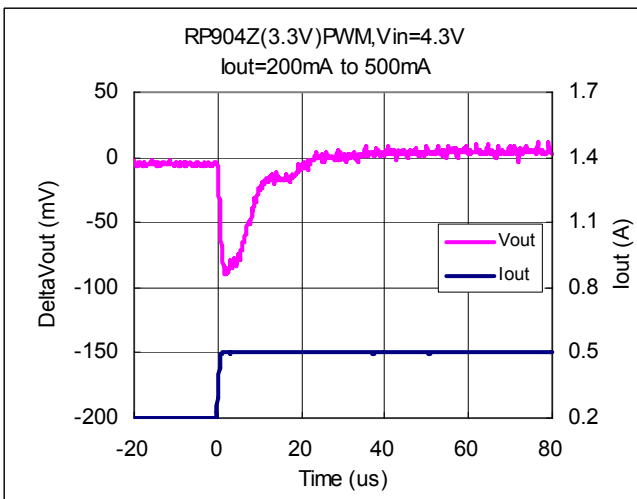
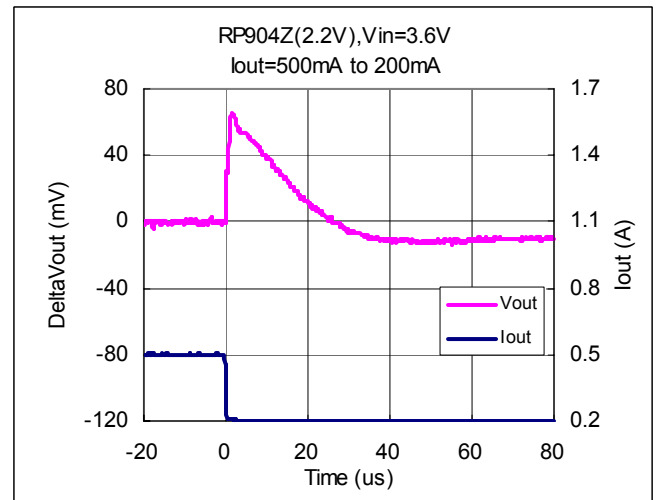
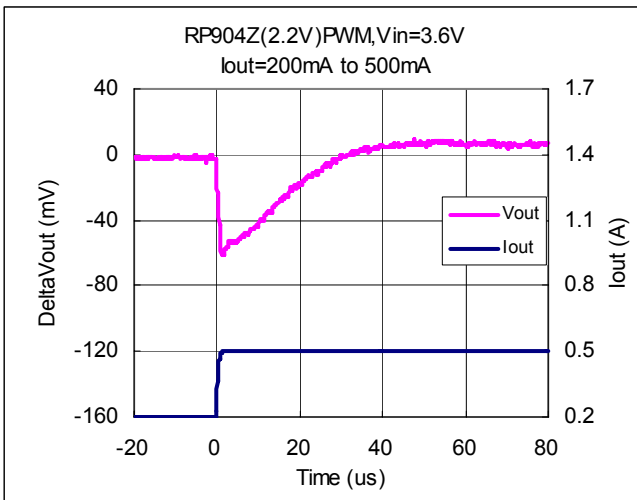


15) BYPASS Switch ON Resistance VS. Temperature

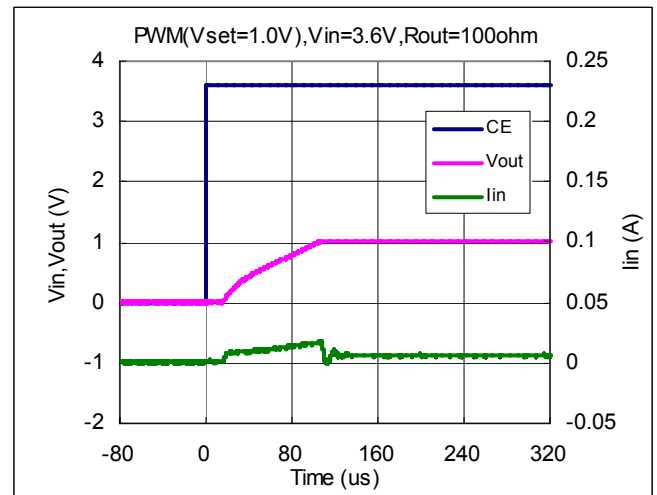
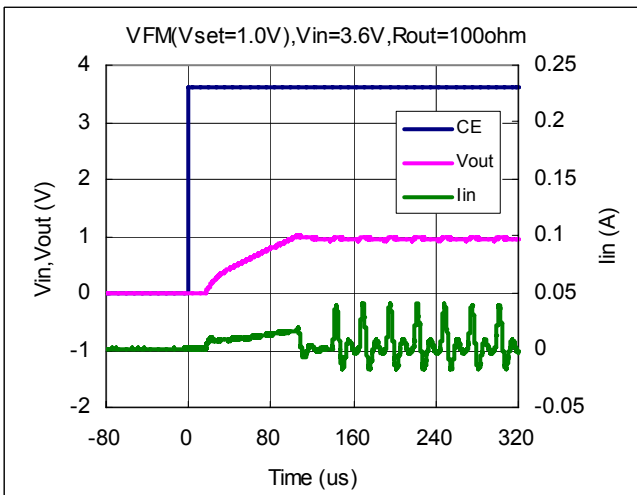


16) Load Transient Response



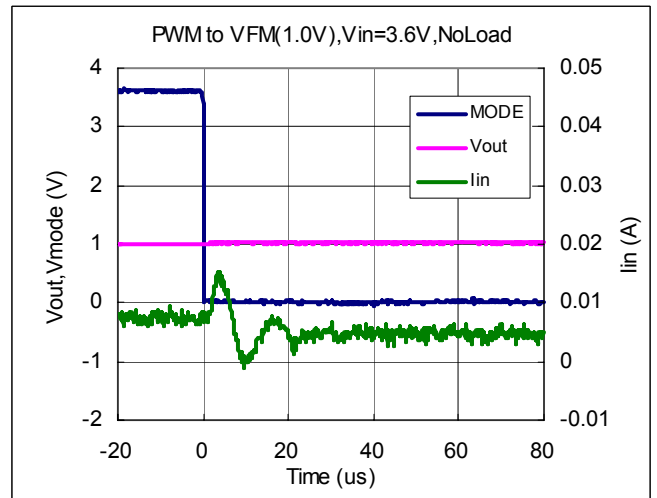
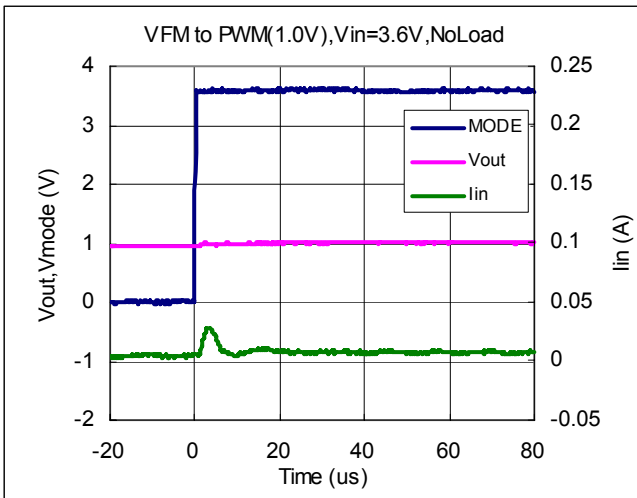


17) Start-Up Waveform

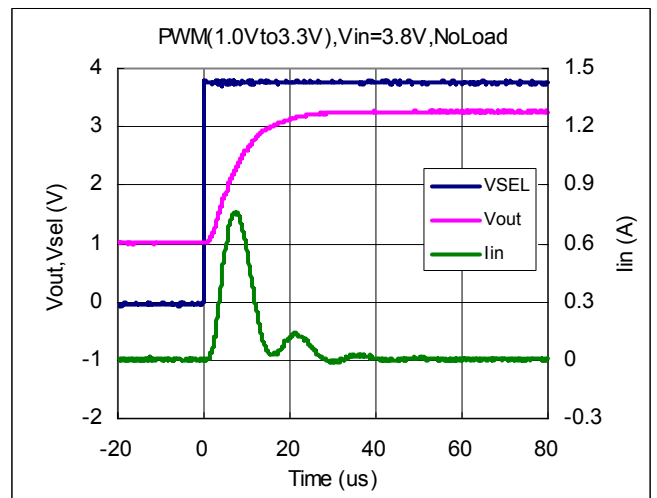
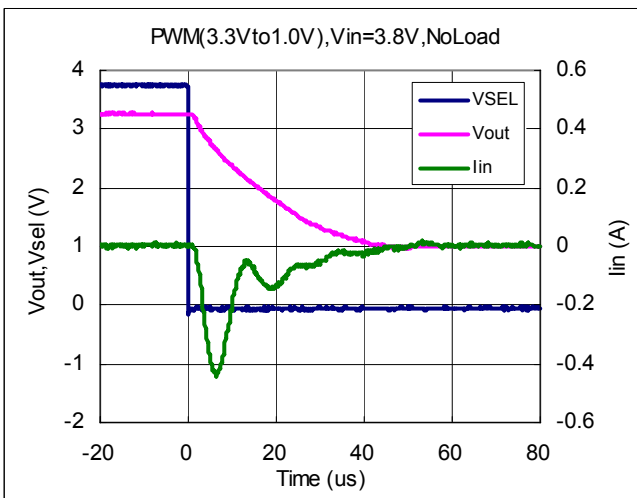


18) Transition Waveform

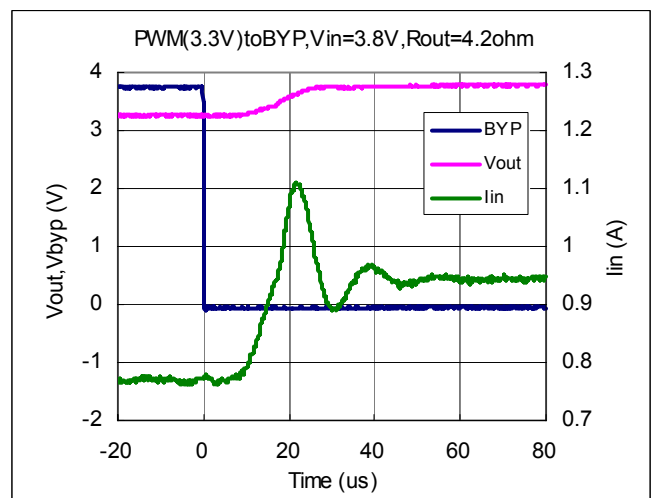
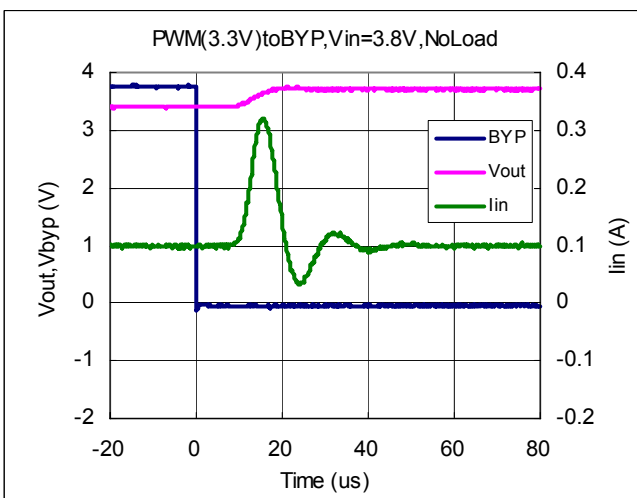
18-1 Transition between VFM-PWM2

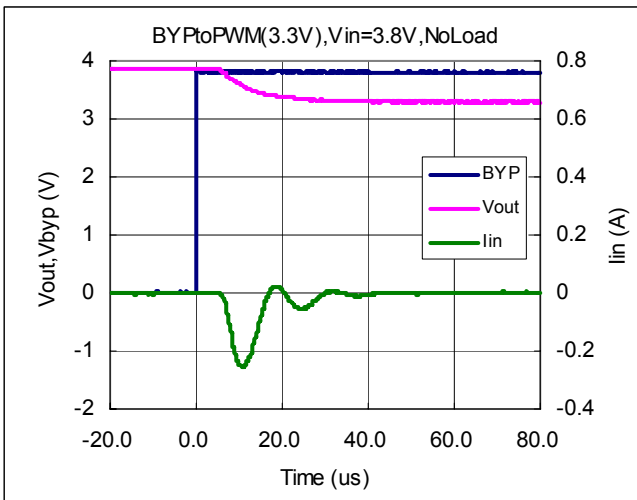


18-2 Transition between PWM1-PWM2

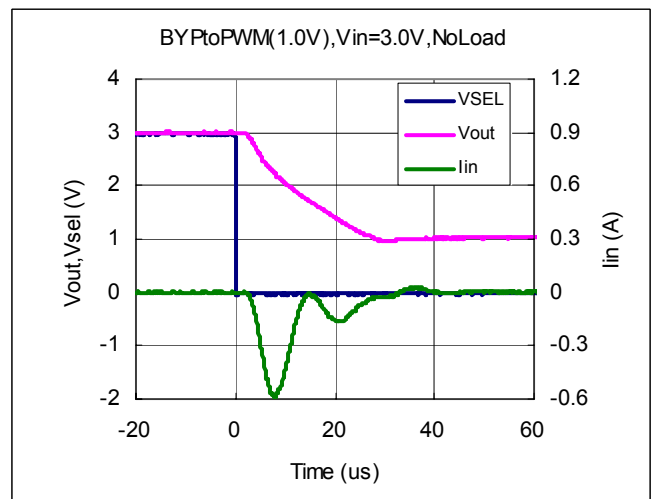
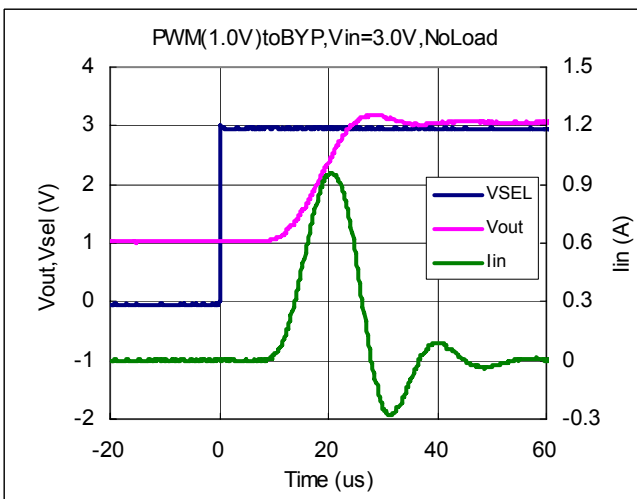


18-3 Transition between PWM1-BYPASS





18-4 Transition between PWM2-BYPASS



*External Components for the measurement of typical characteristics

C_{IN} : 10 μ F (C2012JB0J106K: TDK)

C_{OUT} : 4.7 μ F (JMK107BJ475MA: Taiyo Yuden)

L: 2.2 μ H(CKP2520: Taiyo Yuden)



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Ricoh completed the organization of the Lead-free production for all of our products. After Apr. 1, 2006, we will ship out the lead free products only. Thus, all products that will be shipped from now on comply with RoHS Directive.