RICOH

RP504x SERIES

600mA* Step-down DC/DC Converter with Synchronous Rectifier

NO.EA-259-110530

OUTLINE

The RP504x Series are low supply current CMOS-based 600mA* step-down DC/DC Converters with synchronous rectifier. Each of these ICs consists of an oscillator, a reference voltage unit, an error amplifier, a switching control circuit, a mode control circuit(Ver.A, D), a soft-start circuit, a "latch type" protection circuit, an under voltage lockout (UVLO) circuit, and switching transistors. A low ripple, high efficiency synchronous rectifier step-down DC/DC converter can be easily composed of this IC with only an inductor and capacitors. Since packages are SOT-23-5, DFN1616-6B, DFN(PLP)1216-6F, high density mounting on boards is possible.

As protection circuits, the RP504x Series contain a current limit circuit which limits the Lx peak current in each clock cycle, and a latch type protection circuit which latches the built-in driver to the OFF state if the load current exceeds the limit value or the output short continues for a specified time (the protection delay time). The latch protective circuit can be released by once putting the IC into the standby mode with the CE pin and then into the active mode, or, by turning the power off and back on. Setting the supply voltage lower than the UVLO detector threshold can also release the latch protective circuit.

In terms of the output voltage, since the feedback resistances are built-in, the voltage is fixed internally. 0.1V step output can be set by laser-trim and ±1.5% or ±18mV tolerance depending on the output voltage is guaranteed. By inputting a signal to a MODE pin, the RP504x Series can be switched between PWM/VFM auto switching control and Forced PWM control. PWM/VFM auto switching control switches to high-efficiency VFM mode in low output current. Forced PWM control switches to fixed-frequency Forced PWM mode for reducing noise in low output current.

*)This is an approximate value, because output current depends on conditions and external parts.

FEATURES

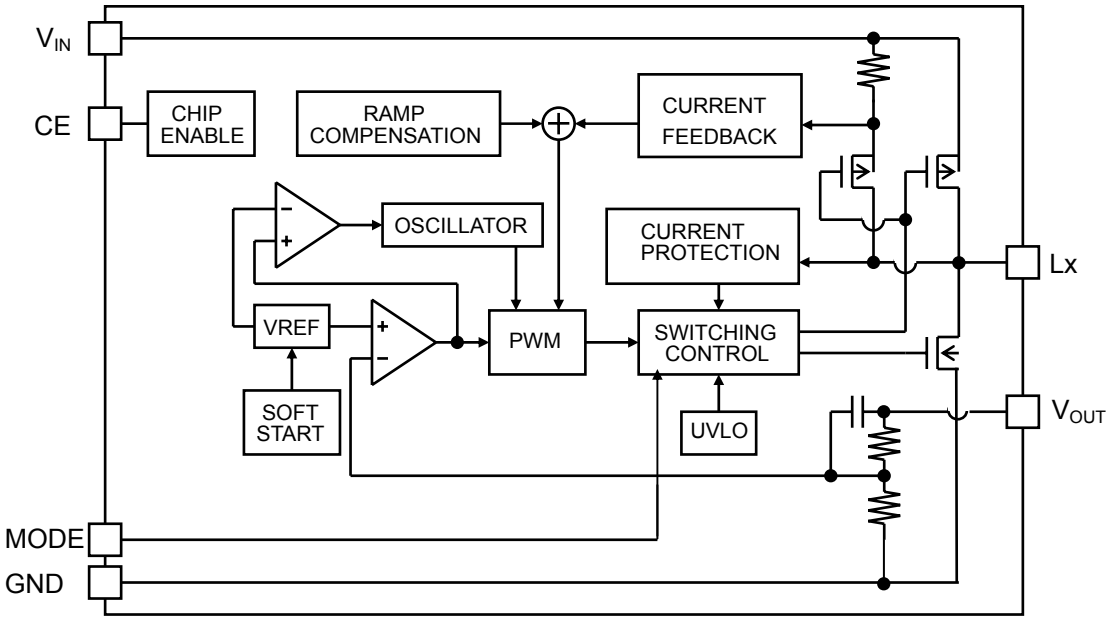
- Supply Current ..... Typ. 25μA(at VFM mode, at no load)
- Standby Current ..... Max. 5μA
- Input Voltage Range ..... 2.3V to 5.5V (V_{OUT}≧1.0V)
- Output Voltage Range..... 0.8V to 3.3V (With a 0.1V step)
- Output Voltage Accuracy..... ±1.5% (V_{OUT}≥1.2V), ±18mV (V_{OUT}<1.2V)
- Temperature-Drift Coefficient of Output Voltage ... Typ. ±40ppm/°C
- Oscillator Frequency ..... Typ. 2.25MHz
- Oscillator Maximum Duty Cycle..... Min. 100%
- Built-in Driver ON Resistance ..... Typ. Pch. 0.34Ω、Nch. 0.43Ω(V_{IN}=3.6V)
- UVLO Detector Threshold..... Typ. 2.0V
- Soft Start Time..... Typ. 0.15ms
- L_X Current Limit ..... Typ. 900mA
- Latch type Protection Circuit ..... Typ. 1.5ms
- Auto discharge function ..... Only for D Version
- Two choices of Switching Mode..... DFN1616-6B and DFN(PLP)1216-6F are available in adjustable switching control options from PWM/VFM auto switching type or Forced PWM type by using MODE pin. SOT-23-5 is available in fixed switching control options: PWM/VFM auto switching type for B version or Forced PWM type for C version.
- Packages ..... SOT-23-5, DFN1616-6B, DFN(PLP)1216-6F

APPLICATIONS

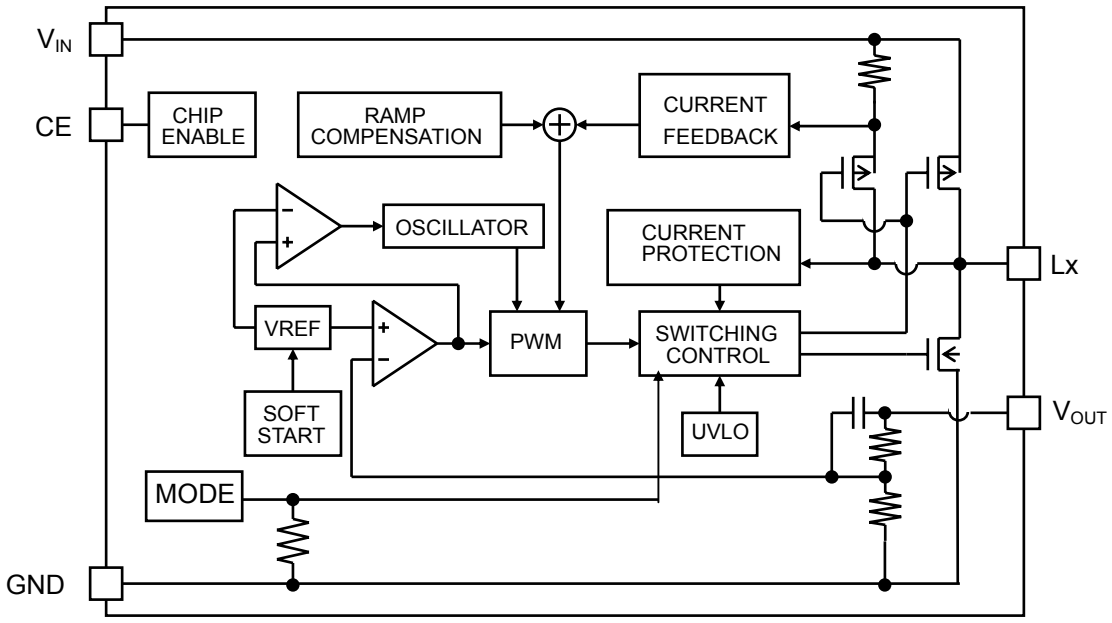
- Power source for battery-powered equipment.
- Power source for hand-held communication equipment, cameras, VCRs, camcorders.
- Power source for HDD, portable equipment.

BLOCK DIAGRAMS

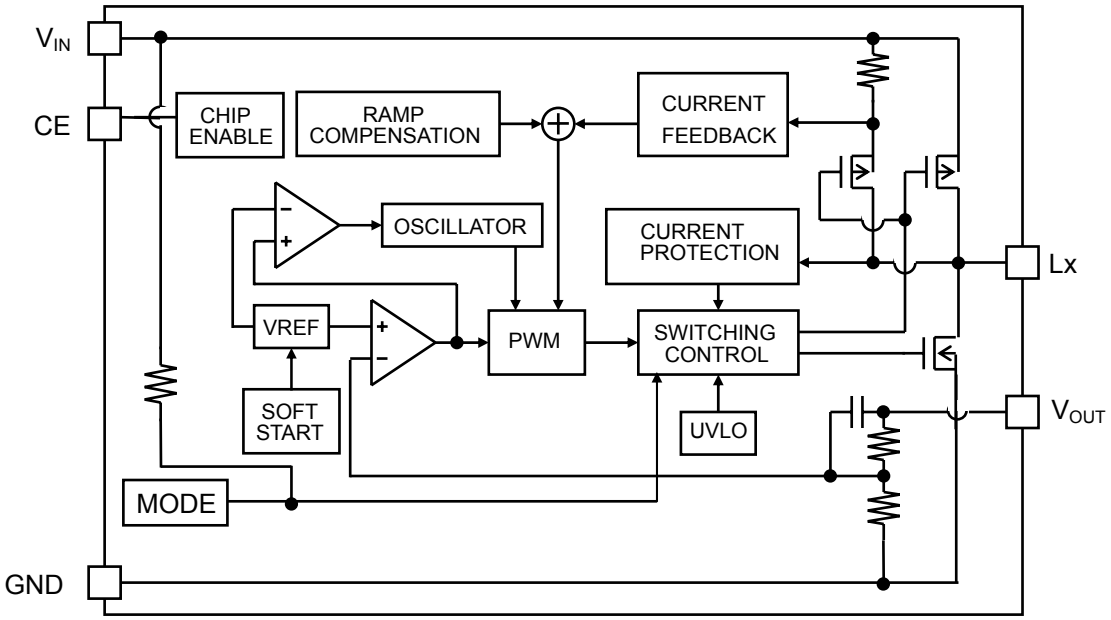
RP504xxxxA



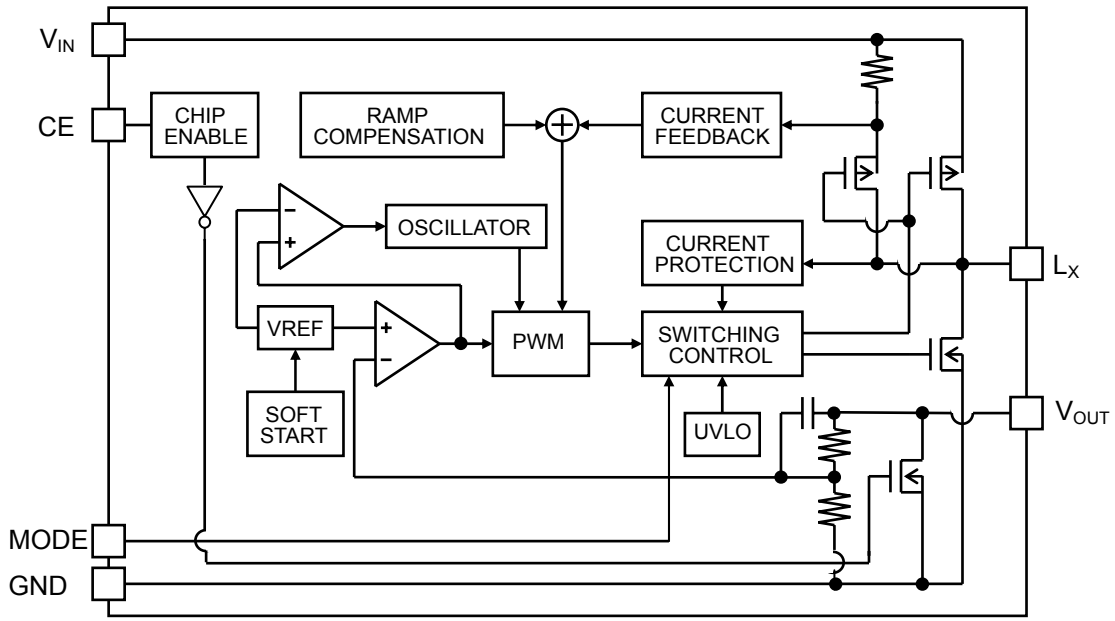
RP504xxxxB



RP504xxxxC



RP504xxxxD



SELECTION GUIDE

In the RP504x Series, output voltage, MODE control, auto discharge function, and package for the ICs are selectable at the user's request.

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
RP504Nxx1$-TR-FE	SOT-23-5	3,000 pcs	Yes	Yes
RP504Lxx1$-TR	DFN1616-6B	5,000 pcs	Yes	Yes
RP504Kxx1$-E2	DFN(PLP)1216-6F	5,000 pcs	Yes	Yes

xx : The output voltage can be designated in the range from 0.8V(08) to 3.3V(33) in 0.1V steps[*1].
Designation is possible in the range from 0.8V to 3.3V with a step of 0.1V
(Refer to the marking information)

$: Designation of mask option

Symbol	Package	Mode Control	Auto discharge function
A	DFN1616-6B DFN(PLP)1216-6F	Yes ("H" forced PWM, "L" PWM/VFM automatic shift)	No
B	SOT-23-5	No (PWM/VFM automatic shift)	No
C	SOT-23-5	No (forced PWM)	No
D	DFN1616-6B DFN(PLP)1216-6F	Yes ("H" forced PWM, "L" PWM/VFM automatic shift)	Yes

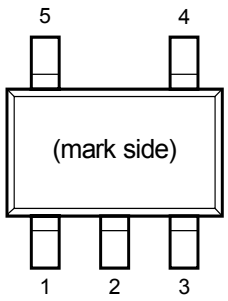
Auto-discharge function quickly lowers the output voltage to 0V, when the chip enable signal is switched from the active mode to the standby mode, by releasing the electrical charge accumulated in the external capacitor.

∗1) 0.05V step is also available as a custom code.

PIN CONFIGURATIONS

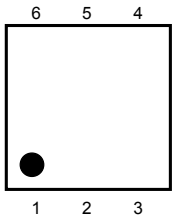
● **SOT-23-5**

Top View

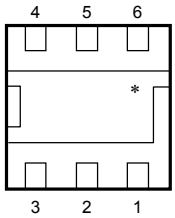


● **DFN1616-6B***

Top View

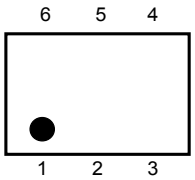


Bottom View

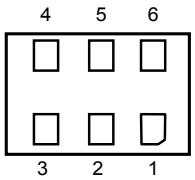


● **DFN(PLP)1216-6F**

Top View



Bottom View



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PIN DESCRIPTIONS

- **RP504Nxx1B, RP504Nxx1C : SOT-23-5**

Pin No.	Symbol	Description
1	V_{OUT}	Output Pin
2	GND	Ground Pin
3	L_X	L_X Switching Pin
4	V_{IN}	Input Pin
5	CE	Chip Enable Pin ("H" Active)

- **RP504Lxx1A, RP504Lxx1D : DFN1616-6B**

Pin No.	Symbol	Description
1	CE	Chip Enable Pin ("H" Active)
2	MODE	Mode Control Pin (“H” forced PWM, “L” PWM/VFM automatic shift)
3	V_{IN}	Input Pin
4	L_X	L_X Switching Pin
5	GND	Ground Pin
6	V_{OUT}	Output Pin

∗) Tab is GND level. (They are connected to the reverse side of this IC.)
The tab is better to be connected to the GND, but leaving it open is also acceptable.

- **RP504Kxx1A, RP504Kxx1D : DFN(PLP)1216-6F**

Pin No.	Symbol	Description
1	V_{IN}	Input Pin
2	MODE	Mode Control Pin (“H” forced PWM, “L” PWM/VFM automatic shift)
3	CE	Chip Enable Pin ("H" Active)
4	V_{OUT}	Output Pin
5	GND	Ground Pin
6	L_X	L_X Switching Pin

ABSOLUTE MAXIMUM RATINGS

(GND=0V)

Symbol	Item	Rating	Unit
V_{IN}	V_{IN} Input Voltage	-0.3 to 6.5	V
V_{LX}	L_X Pin Voltage	-0.3 to V_{IN} + 0.3	V
V_{CE}	CE Pin Input Voltage	-0.3 to 6.5	V
V_{MODE}	Mode Control Pin Voltage	-0.3 to 6.5	V
V_{OUT}	V_{OUT} Pin Voltage	-0.3 to 6.5	V
I_{LX}	L_X Pin Output Current	900	mA
P_D	Power Dissipation (SOT-23-5) *	420	mW
	Power Dissipation (DFN1616-6B) *	640	
	Power Dissipation (DFN(PLP)1216-6F) *	385	
Ta	Operating Temperature Range	-40 to 85	°C
Tstg	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.

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.

ELECTRICAL CHARACTERISTICS

- **RP504xxxxA, RP504xxxxD**

(Ta=25°C)

Symbol	Item	Conditions		Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage	V_{OUT} ≥1.0		2.3		5.5	V
		V_{OUT} <1.0		2.3		4.5	
V_{OUT}	Output Voltage	V_{IN}=V_{CE}=3.6V or V_{SET}+1V	V_{OUT}≥1.2V	×0.985		×1.015	V
			V_{OUT}<1.2V	-0.018		+0.018	
$\Delta V_{OUT}/\Delta T$	Output Voltage Temperature Coefficient	-40°C ≦ Ta ≦85°C			±40		ppm/°C
fosc	Oscillator Frequency	V_{IN}=V_{CE}=3.6V or V_{SET}+1V		1.95	2.25	2.55	MHz
I_{DD1}	Supply Current 1	V_{IN}=V_{CE}=5.5V, V_{OUT}=V_{SET}×0.8			400	800	μA
I_{DD2}	Supply Current 2	V_{IN}=V_{CE}=V_{OUT}=5.5V	V_{MODE}=0V		25	40	μA
			V_{MODE}=5.5V		400	800	
Istandby	Standby Current	V_{IN}=5.5V,V_{CE}=0V			0	5	μA
I_{CEH}	CE "H" Input Voltage	V_{IN}=V_{CE}=5.5V		-1	0	1	μA
I_{CEL}	CE "L" Input Voltage	V_{IN}=5.5V,V_{CE}=0V		-1	0	1	μA
I_{MODEH}	Mode "H" Input Current	V_{IN}=V_{MODE}=5.5V		-1	0	1	μA
I_{MODEL}	Mode "L" Input Current	V_{IN}=5.5V, V_{MODE}=0V		-1	0	1	μA
I_{VOUTH}	V_{OUT} "H" Input Current*1	V_{IN}=V_{OUT}=5.5V,V_{CE}=0V		-1	0	1	μA
I_{VOUTL}	V_{OUT} "L" Input Current	V_{IN}=5.5V,V_{CE}=V_{OUT}=0V		-1	0	1	μA
$I_{LXLEAKH}$	Lx Leakage Current "H"	V_{IN}=V_{LX}=5.5V,V_{CE}=0V		-1	0	5	μA
$I_{LXLEAKL}$	Lx Leakage Current "L"	V_{IN}=5.5V,V_{CE}=V_{LX}=0V		-5	0	1	μA
V_{CEH}	CE "H" Input Voltage	V_{IN}=5.5V		1.0			V
V_{CEL}	CE "L" Input Voltage	V_{IN}=2.3V				0.4	V
V_{MODEH}	Mode ”H” Input Voltage	V_{IN}=V_{CE}=5.5V		1.0			V
V_{MODEL}	Mode ”L” Input Voltage	V_{IN}=V_{CE}=2.3V				0.4	V
R_{LOW}	Nch On Resistance*2	V_{IN}=3.6V,V_{CE}=0V			30		Ω
R_{ONP}	On Resistance of Pch Tr.	V_{IN}=3.6V, I_{LX}=−100mA			0.34		Ω
R_{ONN}	On Resistance of Nch Tr.	V_{IN}=3.6V, I_{LX}=−100mA			0.43		Ω
Maxduty	Oscillator Maximum Duty Cycle			100			%
tstart	Soft-start Time	V_{IN}=V_{CE}=3.6V or V_{SET}+1V			150	310	μs
I_{LXlim}	Lx Current Limit	V_{IN}=V_{CE}=3.6V or V_{SET}+1V		700	900		mA
tprot	Protection Delay Time	V_{IN}=V_{CE}=3.6V or V_{SET}+1V		0.5	1.5	5	ms
V_{UVLO1}	UVLO Detector Threshold	V_{IN}=V_{CE}		1.9	2.0	2.1	V
V_{UVLO2}	UVLO Released Voltage	V_{IN}=V_{CE}		2.0	2.1	2.2	V

Test circuit is "OPEN LOOP" and AGND=PGND=0V unless otherwise specified.
∗1) without auto discharge version only
∗2) with auto discharge version only

- **RP504xxxxB, RP504xxxxC**

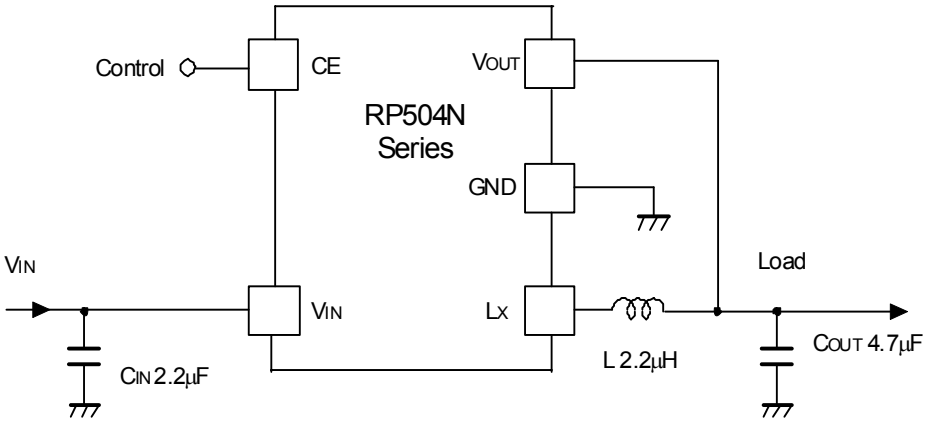
(Ta=25°C)

Symbol	Item	Conditions		Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage	V_{OUT} ≥1.0		2.3		5.5	V
		V_{OUT} <1.0		2.3		4.5	
V_{OUT}	Output Voltage	V_{IN}=V_{CE}=3.6V or V_{SET}+1V	V_{OUT} ≥1.2V	×0.985		×1.015	V
			V_{OUT} < 1.2V	-0.018		+0.018	
$\Delta V_{OUT}/\Delta T$	Output Voltage Temperature Coefficient	-40°C ≦Ta ≦85°C			±40		ppm/°C
fosc	Oscillator Frequency	V_{IN}=V_{CE}=3.6V or V_{SET}+1V		1.95	2.25	2.55	MHz
I_{DD1}	Supply Current 1	V_{IN}=V_{CE}=5.5V, V_{OUT}=V_{SET}×0.8			400	800	μA
I_{DD2}	Supply Current 2	V_{IN}=V_{CE}=V_{OUT}=5.5V	RP504xxxxB		40	60	μA
			RP504xxxxC		500	840	
Istandby	Standby Current	V_{IN}=5.5V,V_{CE}=0V			0	5	μA
I_{CEH}	CE "H" Input Voltage	V_{IN}=V_{CE}=5.5V		-1	0	1	μA
I_{CEL}	CE "L" Input Voltage	V_{IN}=5.5V,V_{CE}=0V		-1	0	1	μA
I_{VOUTH}	V_{OUT} "H" Input Current	V_{IN}=V_{OUT}=5.5V,V_{CE}=0V		-1	0	1	μA
I_{VOUTL}	V_{OUT} "L" Input Current	V_{IN}=5.5V,V_{CE}=V_{OUT}=0V		-1	0	1	μA
$I_{LXLEAKH}$	Lx Leakage Current "H"	V_{IN}=V_{LX}=5.5V,V_{CE}=0V		-1	0	5	μA
$I_{LXLEAKL}$	Lx Leakage Current "L"	V_{IN}=5.5V,V_{CE}=V_{LX}=0V		-5	0	1	μA
V_{CEH}	CE "H" Input Voltage	V_{IN}=5.5V		1.0			V
V_{CEL}	CE "L" Input Voltage	V_{IN}=2.3V				0.4	V
R_{ONP}	On Resistance of Pch Tr.	V_{IN}=3.6V, I_{LX}=−100mA			0.34		Ω
R_{ONN}	On Resistance of Nch Tr.	V_{IN}=3.6V, I_{LX}=−100mA			0.43		Ω
Maxduty	Oscillator Maximum Duty Cycle			100			%
tstart	Soft-start Time	V_{IN}=V_{CE}=3.6V or V_{SET}+1V			150	310	μs
I_{LXlim}	Lx Current Limit	V_{IN}=V_{CE}=3.6V or V_{SET}+1V		700	900		mA
tprot	Protection Delay Time	V_{IN}=V_{CE}=3.6V or V_{SET}+1V		0.5	1.5	5	ms
V_{UVLO1}	UVLO Detector Threshold	V_{IN}=V_{CE}		1.9	2.0	2.1	V
V_{UVLO2}	UVLO Released Voltage	V_{IN}=V_{CE}		2.0	2.1	2.2	V

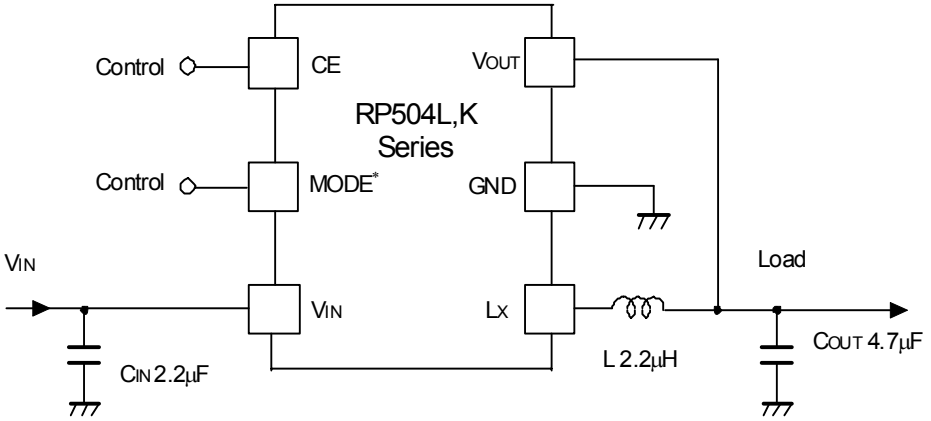
Test circuit is "OPEN LOOP" and AGND=PGND=0V unless otherwise specified.

TYPICAL APPLICATION

● **RP504N:SOT-23-5 (MODE Pin is not included.)**



● **RP504L:DFN1616-6B / RP504K:DFN(PLP)1216-6F (MODE Pin is included.)**



∗) MODE="H" forced PWM
MODE="L" PWM/VFM automatic shift

Symbol	Recommendation components		
C_{IN}	2.2μF	Ceramic	C1608JB0J225K (TDK)
	2.2μF×2		C1005JB0J225K (TDK) JMK105BJ225MV (Taiyo Yuden)
	4.7μF		C1005X5R0J475M (TDK) JMK105BJ475MV (Taiyo Yuden)
C_{OUT}	4.7μF	Ceramic	C1608JB0J475K (TDK) GRM188B30J475KE18 (Murata)
L	2.2μH	Inductor	MIPSZ2520D2R2 (FDK) MIPS2520D2R2 (FDK) MLP2520S2R2M (TDK) VLS252010T-2R2M (TDK) CKP2520－2R2M (Taiyo Yuden)

TECHNICAL NOTES

When you use these ICs, consider the following issues:

・Set external components such as an inductor, C_{IN}, C_{OUT} as close as possible to the IC, in particular, minimize the wiring to V_{IN} pin and PGND pin. Reinforce the V_{IN}, PGND, and V_{OUT} lines sufficiently. Large switching current may flow in these lines. If the impedance of V_{IN} and PGND lines is too large, the internal voltage level in this IC may shift caused by the switching current, and the operation might be unstable. The wiring between V_{OUT} and load and between L and V_{OUT} should be separated.

・The recommended capacitance value for the CIN capacitor connected between the V_{IN} and PGND pins is 2.2μF or more. Also, the recommended capacitance value for the C_{OUT} capacitor is 4.7μF ~ 10μF.Please be aware of the characteristics of bias dependence and temperature fluctuation of ceramic capacitor.

・Choose an inductor with inductance range from 2.2μH to 4.7μH. The phase compensation has been made by these values with output capacitors. The recommendation characteristics of the inductor are low DC resistance, large enough permissible current, and strong against the magnetic saturation. Inductance value may shift depending on an inductor. If the inductance value at an actual load current is low, L_X peak current may increase and may overlap the L_X current limit. As a result, over current protection may work.

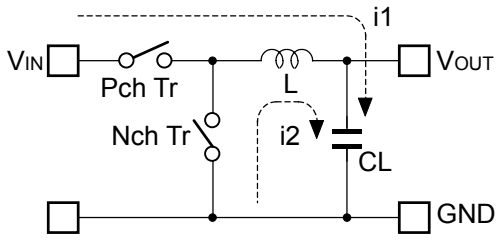
・Over current protection circuit, Latch-type protection circuit may be affected by self-heating and heat radiation environment.

∗ The performance of power supply circuits using this IC largely depends on the peripheral circuits. Please be very careful when setting the peripheral parts. When designing the peripheral circuits of each part, PCB patterns, and this IC, please do not exceed the rated values (Voltage, Current, Power).

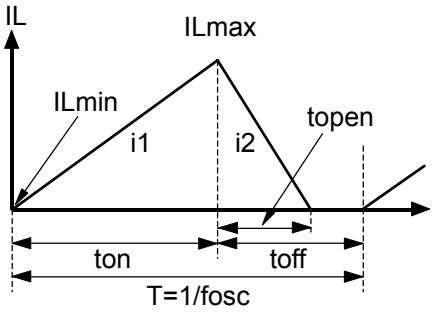
Operation of step-down DC/DC converter and Output Current

The DC/DC converter charges energy in the inductor when L_X transistor is ON, and discharges the energy from the inductor when L_X 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:

<Basic Circuit>



<Current through L>



- Step 1: Pch Tr. turns on and current IL (=i1) flows, and energy is charged into CL. At this moment, IL increases from I_{Lmin} (=0) to reach I_{Lmax} in proportion to the on-time period (t_{on}) of Pch Tr.
- Step 2: When Pch Tr. turns off, Synchronous rectifier Nch Tr. turns on in order that L maintains IL at I_{Lmax}, and current IL (=i2) flows.
- Step 3: IL (=i2) decreases gradually and reaches IL=I_{Lmin}=0 after a time period of t_{open}, and Nch Tr. turns off. Provided that in the continuous mode, next cycle starts before IL becomes to 0 because t_{off} time is not enough. In this case, IL 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 Pch Tr. turns on and off.
The difference between I_{Lmax} and I_{Lmin}, which is represented by ΔI:

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

wherein,

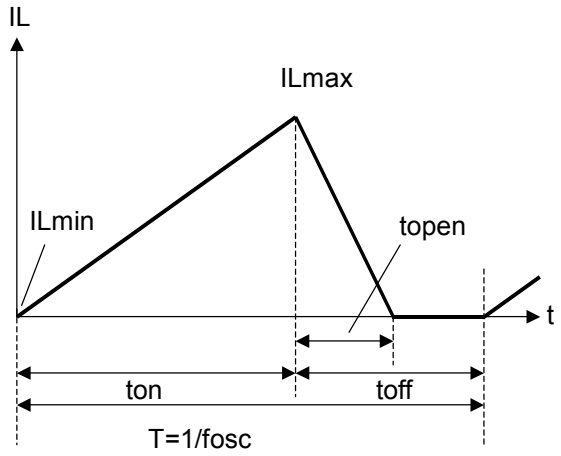
$T = 1 / f_{osc} = t_{on} + t_{off}$
duty (%)$= t_{on} / T \times 100 = t_{on} \times f_{osc} \times 100$
$t_{open} \leq t_{off}$

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

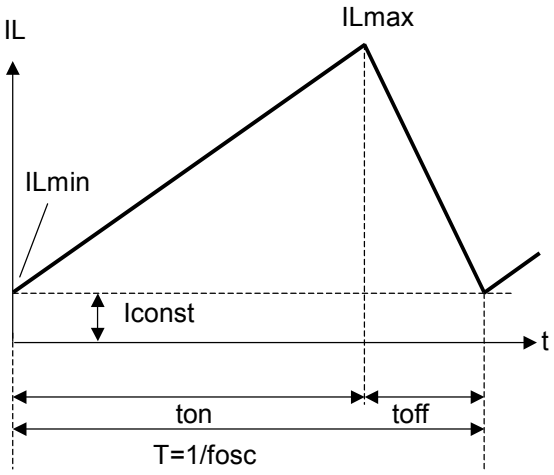
Discontinuous mode and Continuous mode

When the output current (I_{OUT}) is relatively small, $t_{open} < t_{off}$ as illustrated in the above diagram. In this case, the energy is charged in the inductor during the time period of t_{on} and is discharged in its entirely 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.

Discontinuous mode



Continuous mode



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

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

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

The relation between the output current and external components is as follows:

(Wherein, Ripple Current p-p value is described as I_{RP}, ON resistance of Pch Tr. and Nch Tr. of L_X are respectively described as R_{ONP} and R_{ONN}, and the DC resistor of the inductor is described as R_L.)

When Pch Tr. of L_X is ON:

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

When Pch Tr. of L_X is "OFF" (Nch Tr. is "ON"):

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

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

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

Ripple Current is as follows:

$$I_{RP} = (V_{IN} - V_{OUT} - R_{ONP} \times I_{OUT} - R_L \times I_{OUT}) \times D_{ON} / f_{osc} / L \quad \text{Equation 6}$$

wherein, peak current that flows through L, and L_X Tr. is as follows:

$$I_{Lxmax} = I_{OUT} + I_{RP} / 2 \quad \text{Equation 7}$$

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

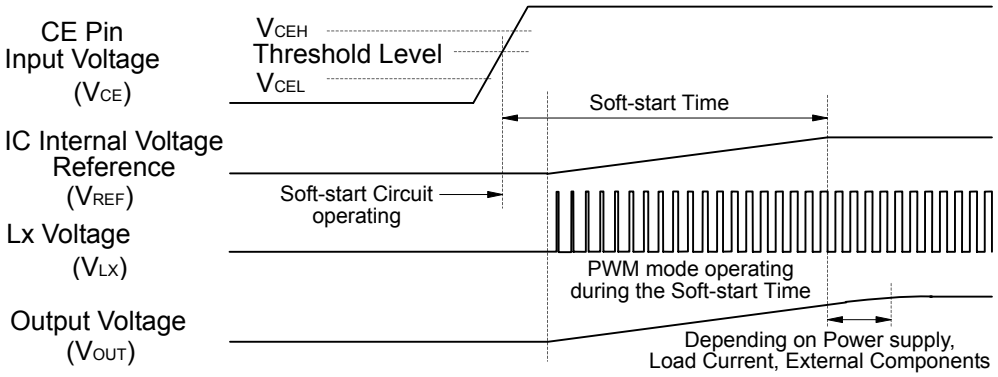
∗The above explanation is directed to the calculation in an ideal case in continuous mode.

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.

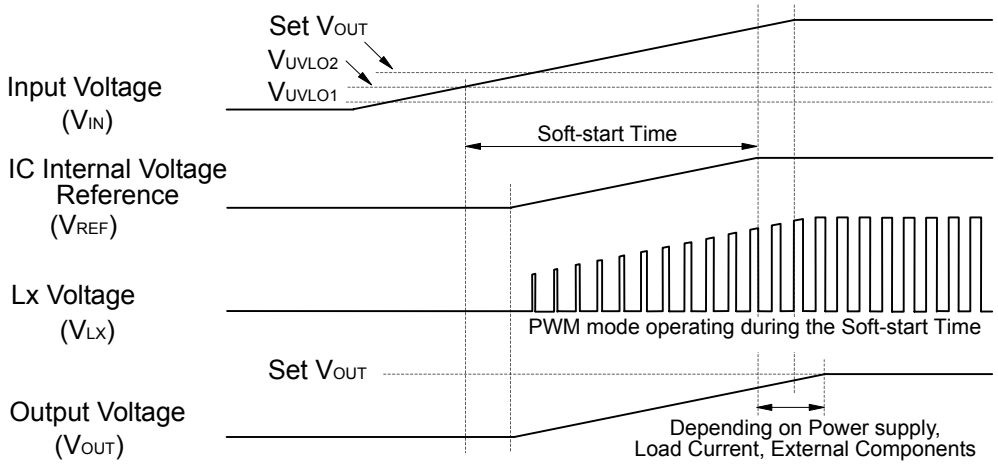


Soft-start time is the time interval from soft start circuit starting point to the reference voltage level reaching point up to this constant level.

∗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.



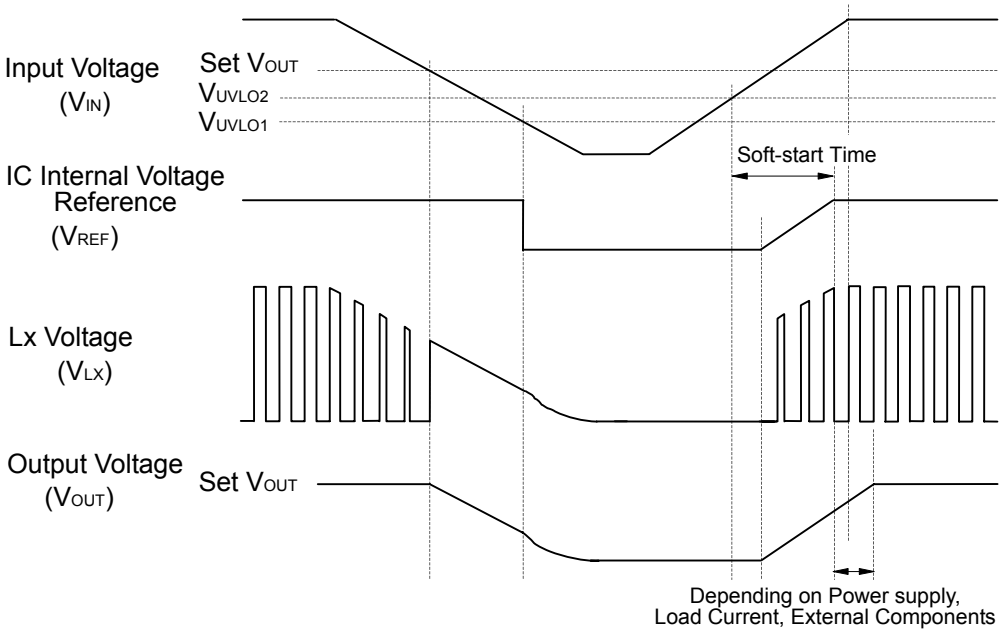
∗Turn-on speed is affected by next conditions;
(a) Input Voltage (V_{IN}) rising speed depending on the power supplier to the IC and input capacitor C_{IN}.
(b) Output Capacitor C_{OUT} value and load current value.

(2) Under Voltage Lockout (UVLO) Circuit

The step-down DC/DC converter stops and ON duty becomes 100%, 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, switching transistors turn off and the output voltage drops according to the load and output capacitor C_{OUT} value.

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}).



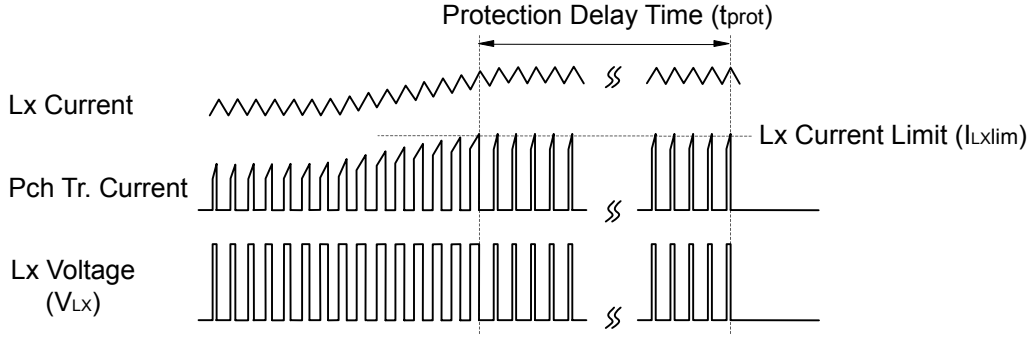
∗Actually, the waveform of V_{OUT} at UVLO working and releasing varies depending on the initial voltage of C_{OUT} and load current situation.

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

Over current protection circuit supervises the inductor peak current (the current flowing through Pch transistor) in each switching cycle, and if the current exceeds the L_X current limit (I_{LXlim}), turns off Pch transistor. The L_X current limit of RP504x is Typ.900mA.

Latch type protection circuit latches the built-in driver to the OFF state and stops the operation of DC/DC converter if the over current status continues or the output voltage continues being the half of the setting voltage for equal or longer than protection delay time (t_{prot}).

∗L_X current limit (I_{LXlim}) and protection delay time (t_{prot}) could be easily affected by self-heating or ambient environment. If the input voltage (V_{IN}) drops drastically or becomes unstable due to short-circuit, the protection operation and protection delay time may be affected.

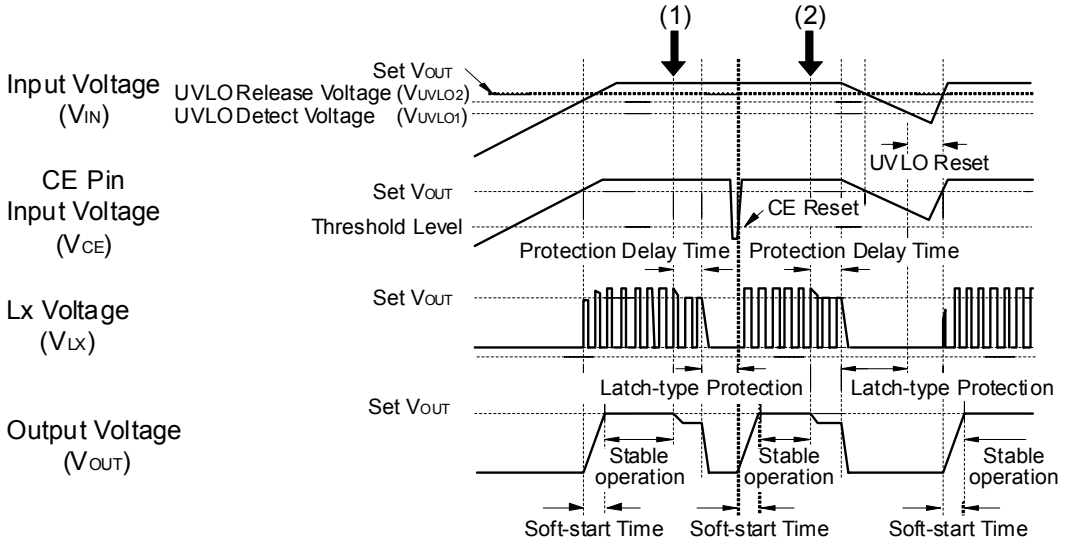


To release the condition of latch type protection, restart this IC by inputting "L" signal to CE pin, or restart this IC with power-on or make the supply voltage lower than UVLO detector threshold (V_{UVLO1}) level.

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.

Point(1) : If the large current flows through the circuit or the IC goes into low output voltage condition due to short-circuit or other reasons, the latch type protection circuit latches the built-in driver to OFF state after the protection delay time (t_{prot}). Then, V_{LX} becomes "L" and the output voltage turns OFF. In this timing chart below, the latch protective circuit can be released by once putting the IC into "L" with the CE pin and then into "H" again.

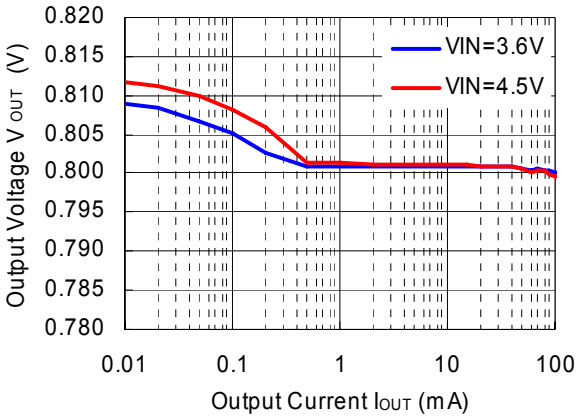
Point(2) : The latch type protection can be released by UVLO reset by making the input voltage lower than the UVLO detector threshold(V_{UVLO1}).



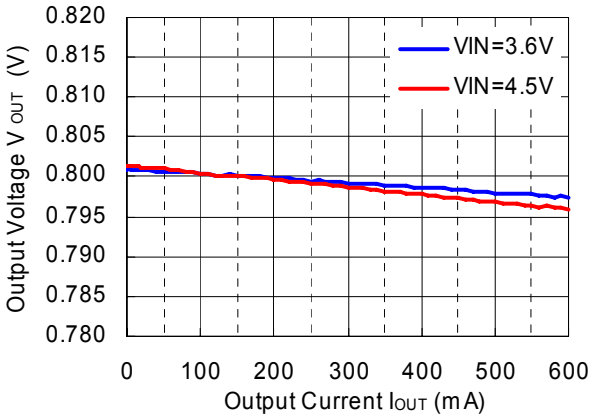
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current

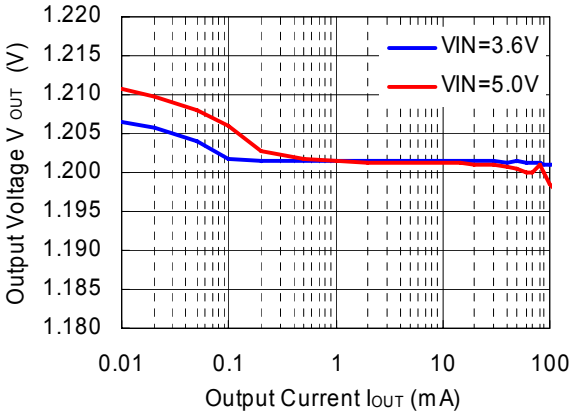
RP504x V_{OUT}=0.8V
MODE="L"PWM/VFM automatic shift



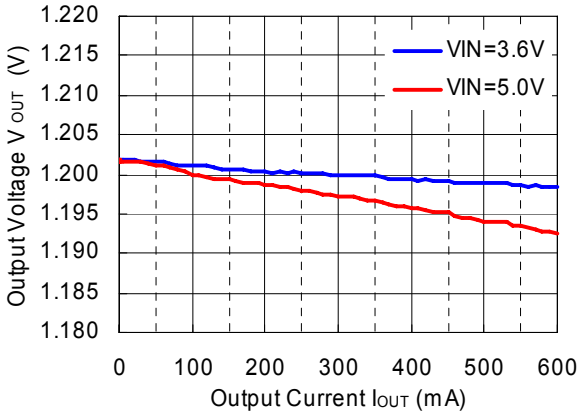
RP504x V_{OUT}=0.8V
MODE="H" forced PWM



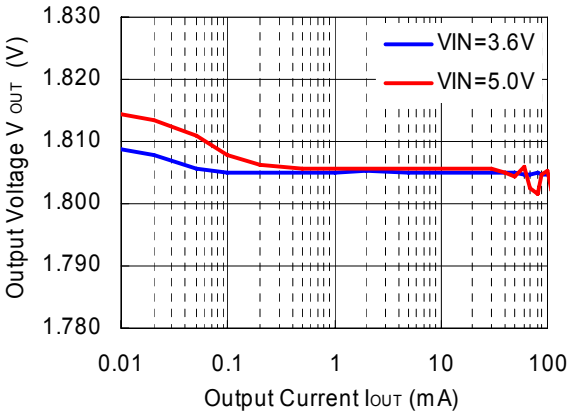
RP504x V_{OUT}=1.2V
MODE="L"PWM/VFM automatic shift



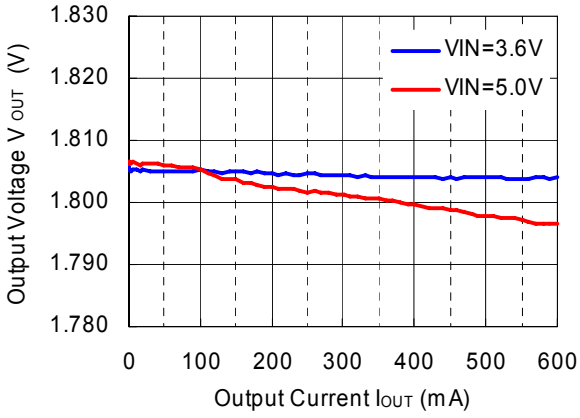
RP504x V_{OUT}=1.2V
MODE="H" forced PWM



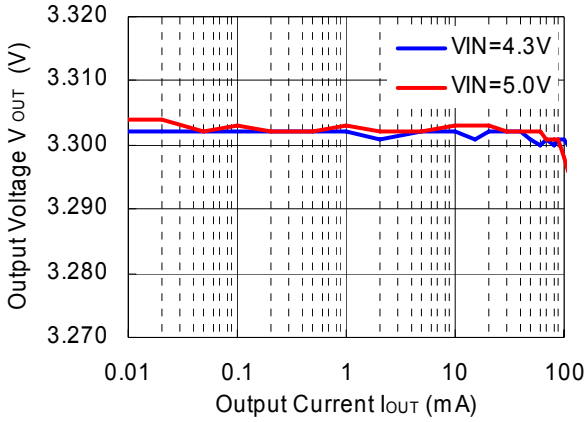
RP504x V_{OUT}=1.8V
MODE="L"PWM/VFM automatic shift



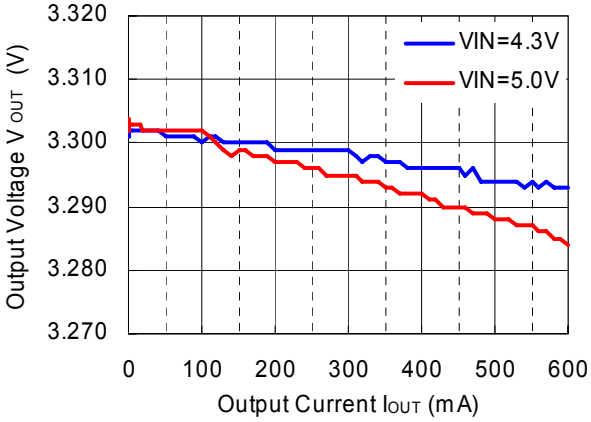
RP504x V_{OUT}=1.8V
MODE="H" forced PWM



RP504x V_{OUT}=3.3V
MODE="L"PWM/VFM automatic shift

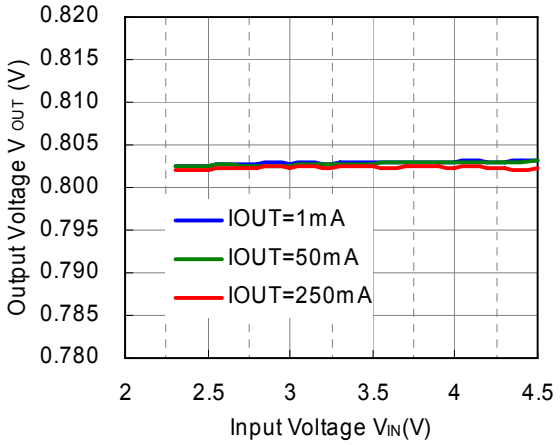


RP504x V_{OUT}=3.3V
MODE="H" forced PWM

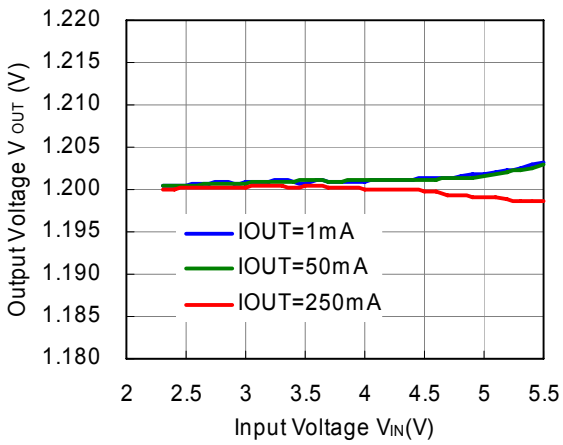


2) Output Voltage vs. Input Voltage

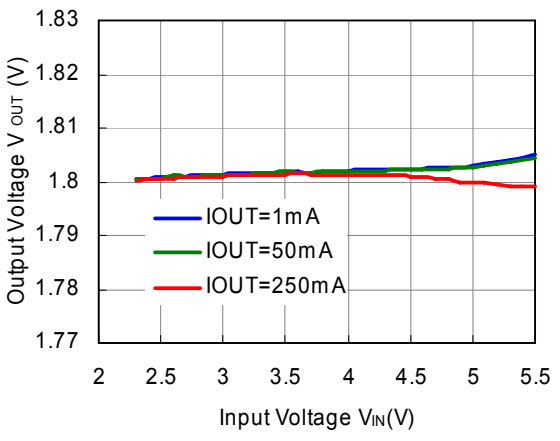
RP504x V_{OUT}=0.8V
MODE="H" forced PWM



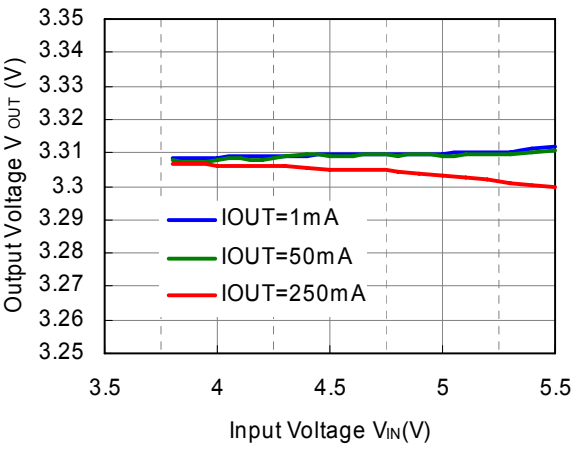
RP504x V_{OUT}=1.2V
MODE="H" forced PWM



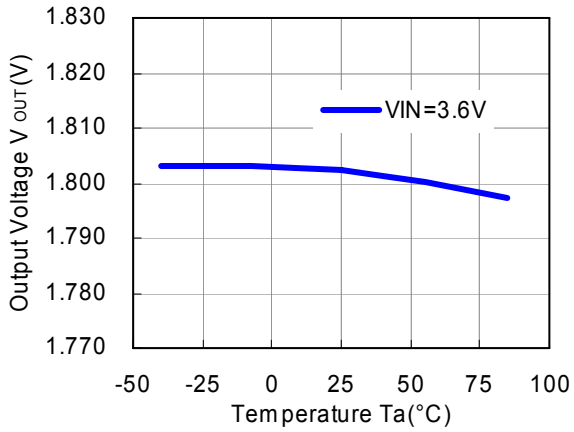
RP504x V_{OUT}=1.8V
MODE="H" forced PWM



RP504x V_{OUT}=3.3V
MODE="H" forced PWM

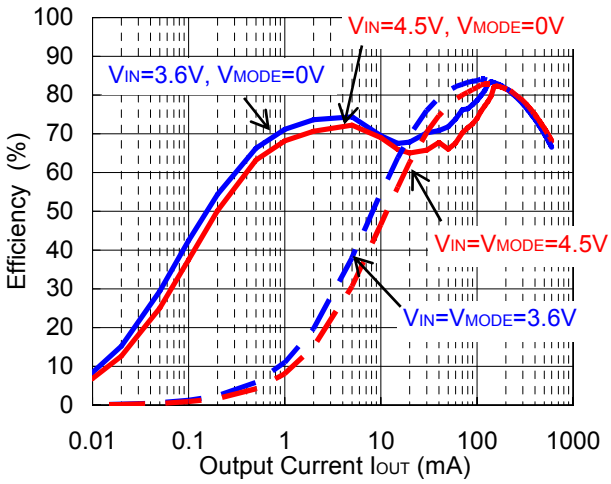


3) Output Voltage vs. Temperature

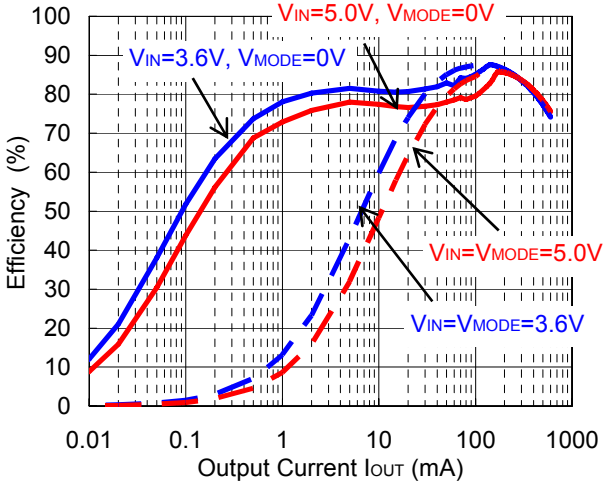


4) Efficiency vs. Output Current

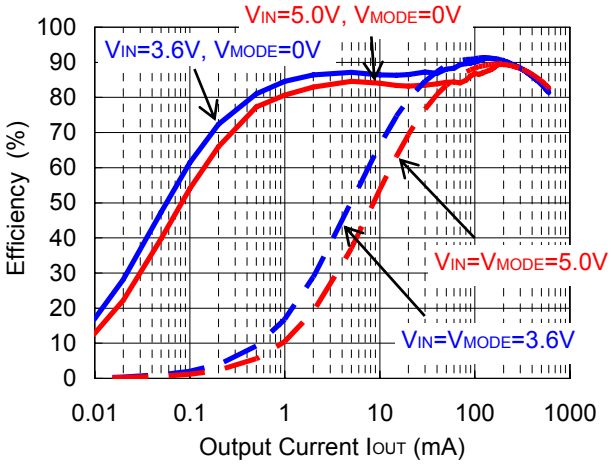
RP504x VOUT=0.8V



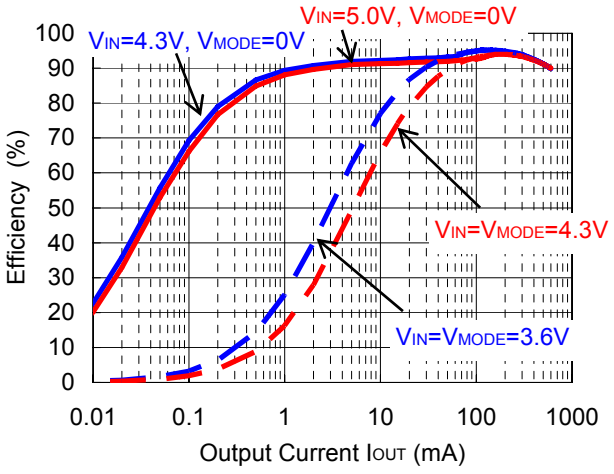
RP504x VOUT=1.2V



RP504x VOUT=1.8V

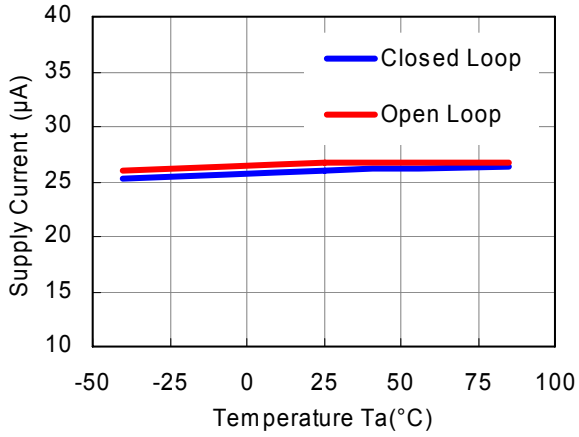


RP504x VOUT=3.3V



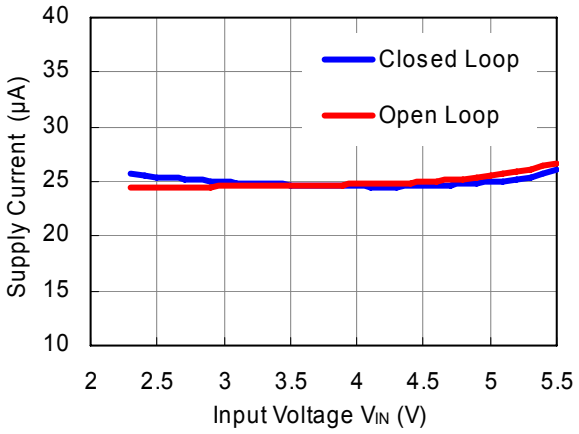
5) Supply Current vs. Temperature

RP504x V_{OUT}=1.8V(V_{IN}=5.5V)
MODE="L"PWM/VFM automatic shift



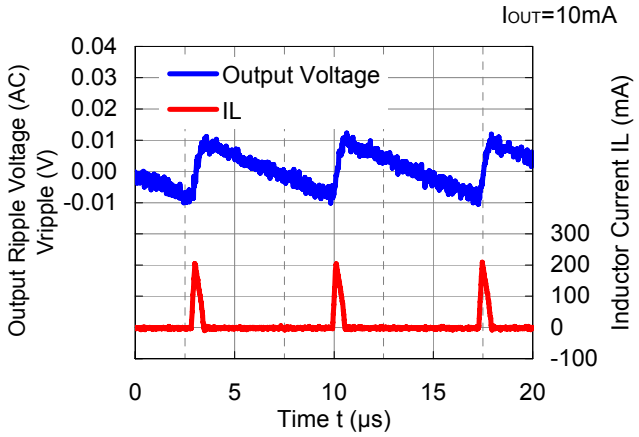
6) Supply Current vs. Input Voltage

RP504x V_{OUT}=1.8V
MODE="L"PWM/VFM automatic shift

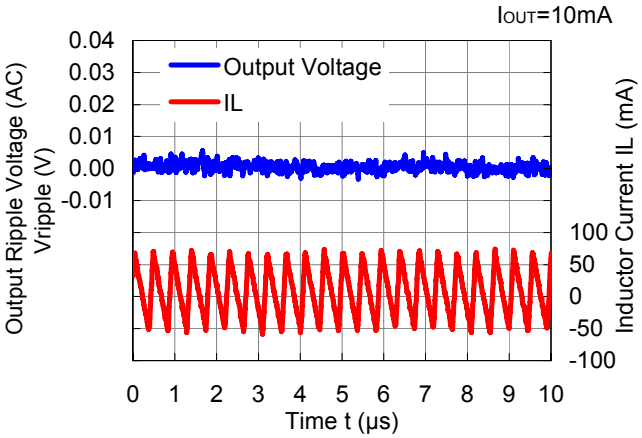


7) Output Ripple Voltage Vripple

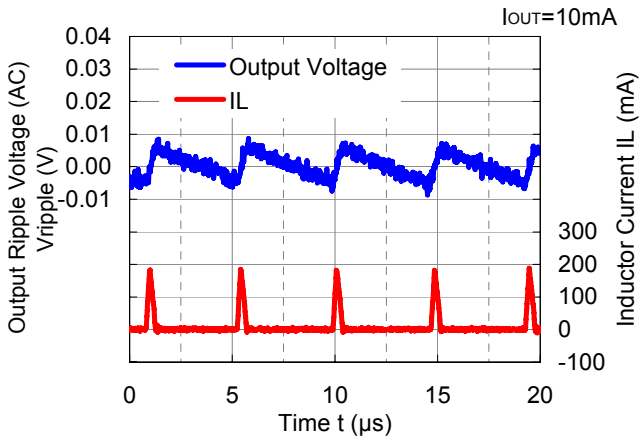
RP504x V_{OUT}=0.8V(V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



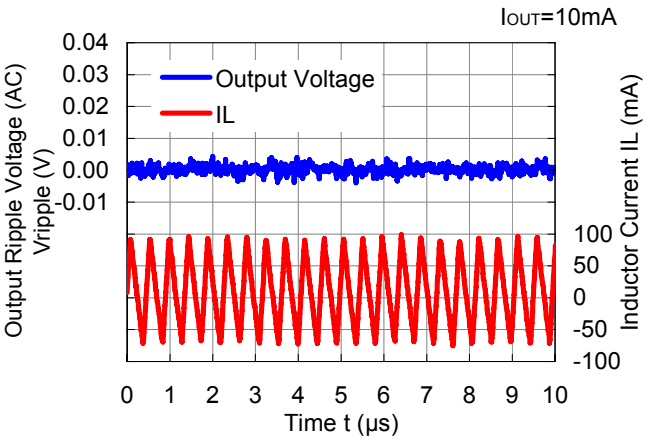
RP504x V_{OUT}=0.8V(V_{IN}=3.6V)
MODE="H" forced PWM



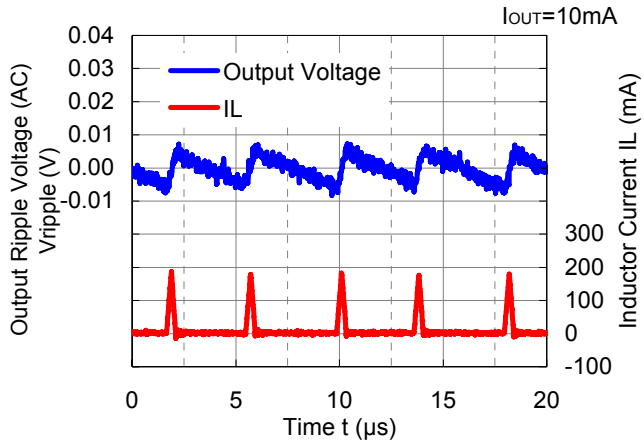
RP504x V_{OUT}=1.2V(V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



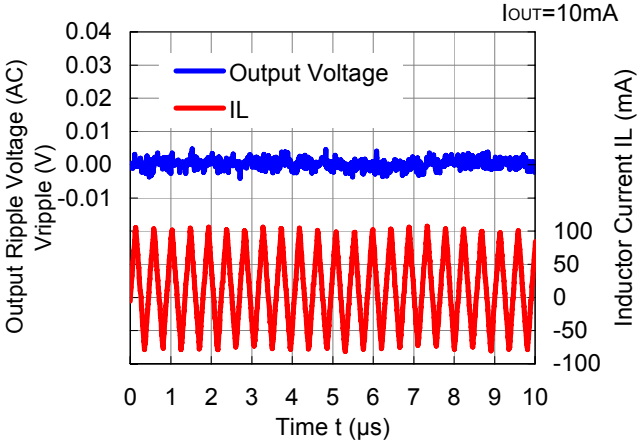
RP504x V_{OUT}=1.2V(V_{IN}=3.6V)
MODE="H" forced PWM



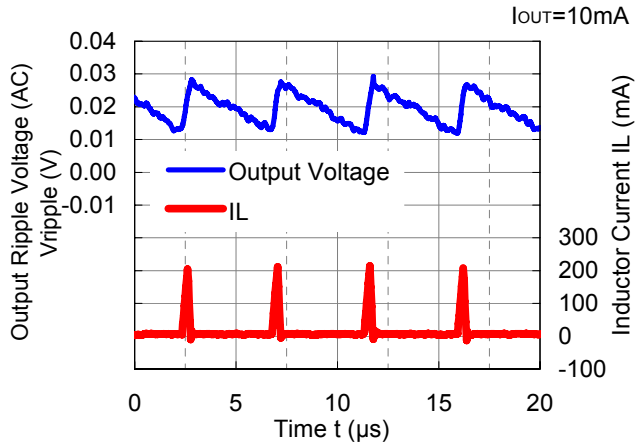
RP504x V_{OUT}=1.8V(V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



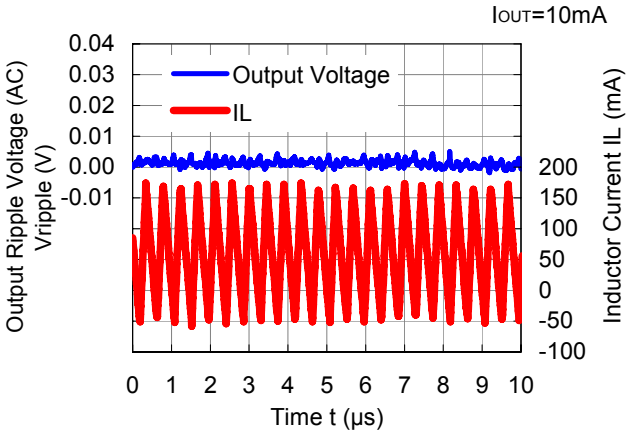
RP504x V_{OUT}=1.8V(V_{IN}=3.6V)
MODE="H" forced PWM



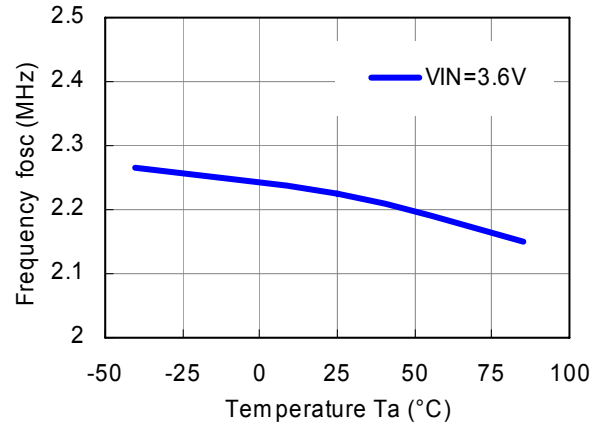
RP504x V_{OUT}=3.3V(V_{IN}=5.0V)
MODE="L"PWM/VFM automatic shift



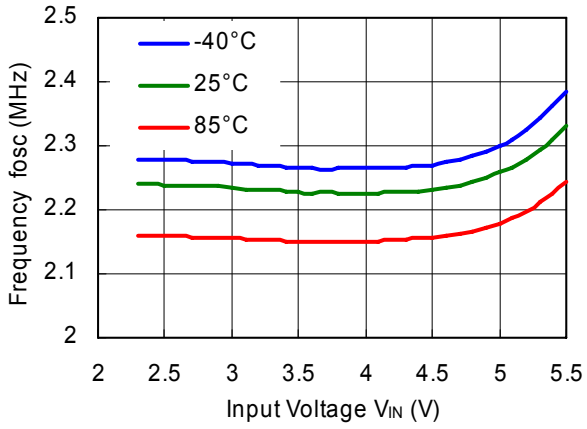
RP504x V_{OUT}=3.3V(V_{IN}=5.0V)
MODE="H" forced PWM



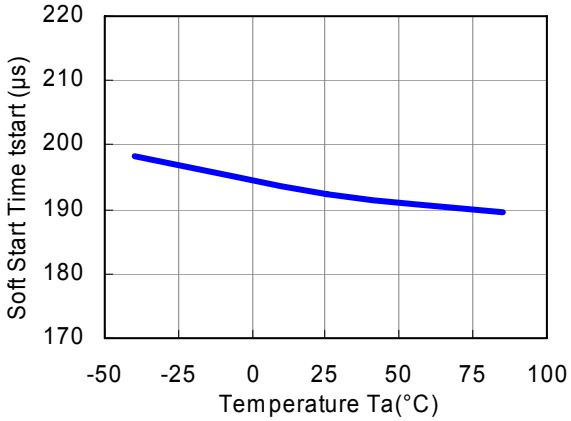
8) Frequency vs. Temperature



9) Frequency vs. Input Voltage

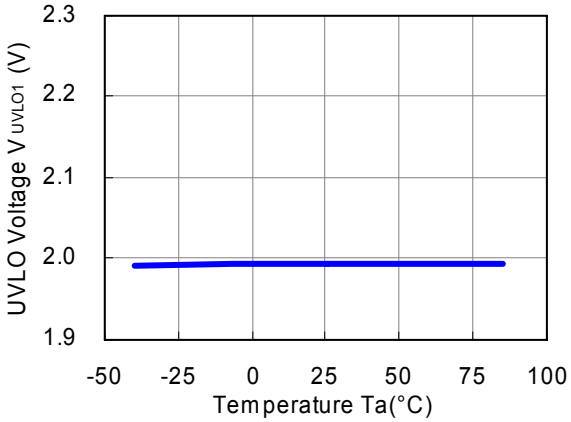


10) Soft Start Time vs. Temperature

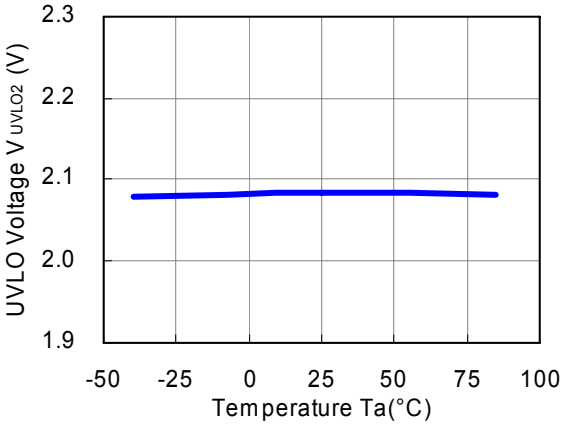


11) UVLO Detector Threshold / Released Voltage vs. Temperature

UVLO Detector Threshold Voltage

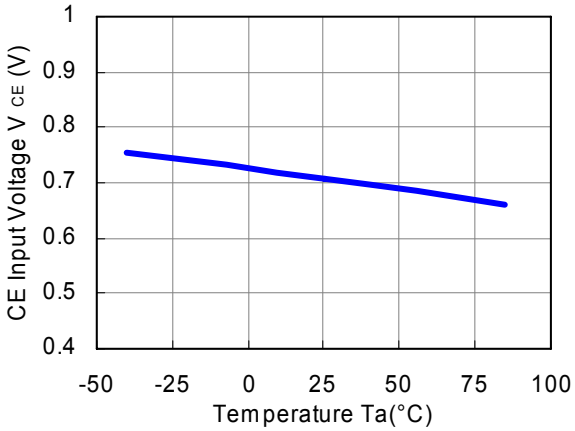


UVLO Released Voltage

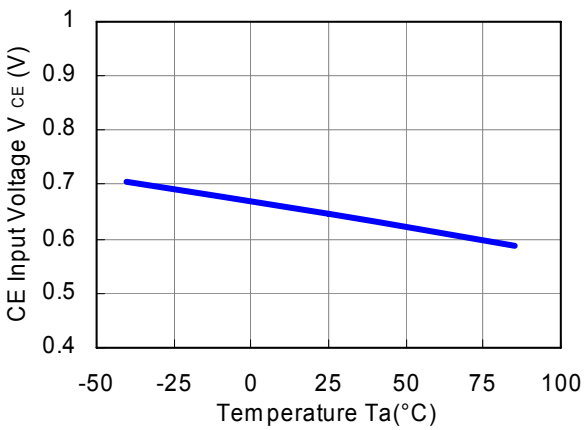


12) CE Input Voltage vs. Temperature

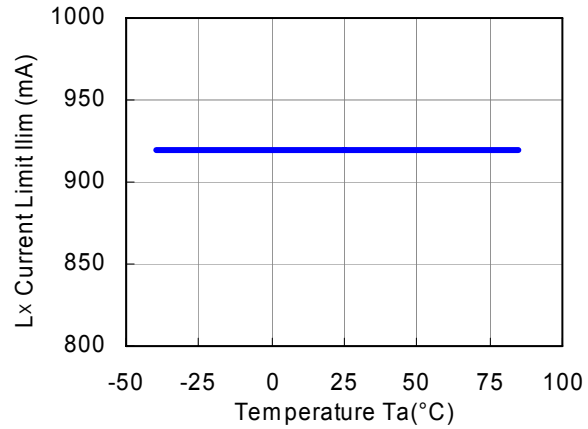
CE“H” Input Voltage(V_{IN}=5.5V)



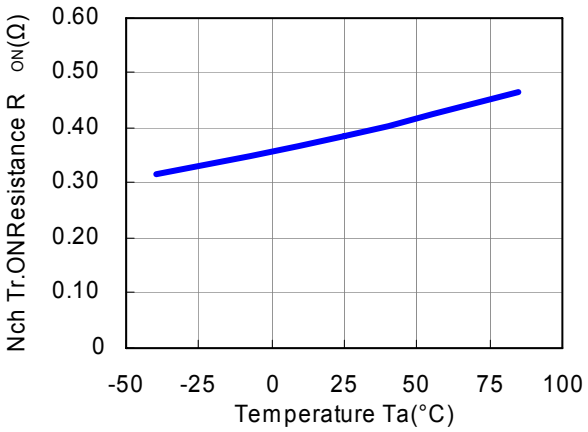
CE“H” Input Voltage (V_{IN}=2.3V)



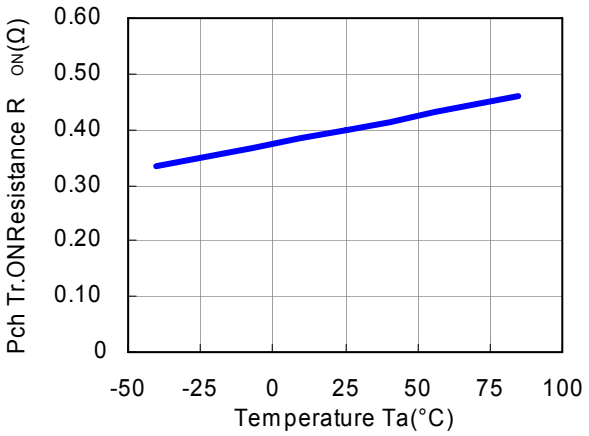
13) L_X Current Limit vs. Temperature



14) Nch Tr. ON Resistance vs. Temperature

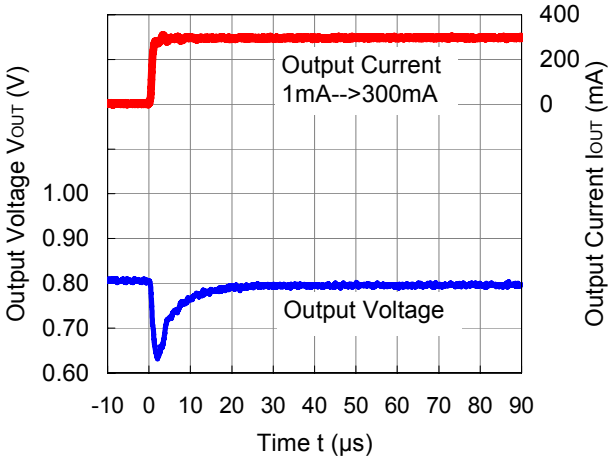


15) Pch Tr. ON Resistance vs. Temperature

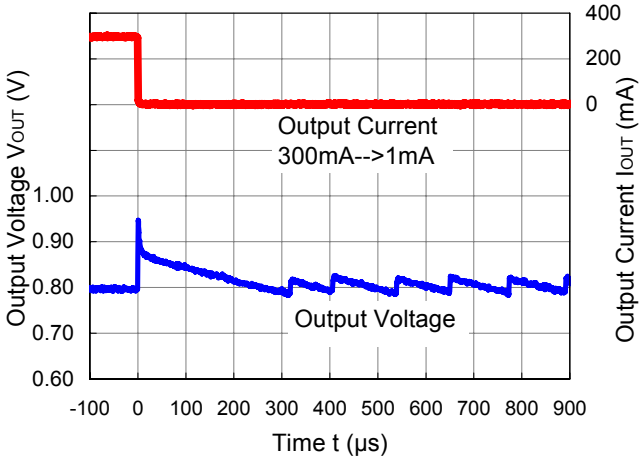


16) Load Transient Response

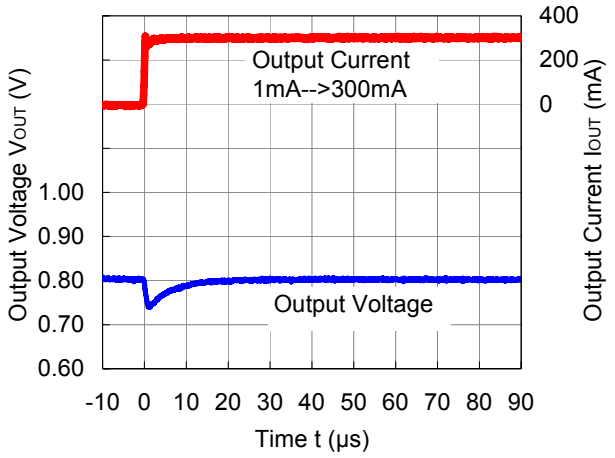
RP504x081x (V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



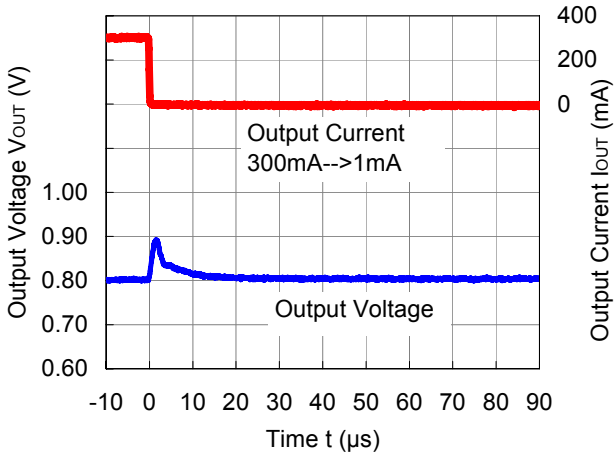
RP504x081x (V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



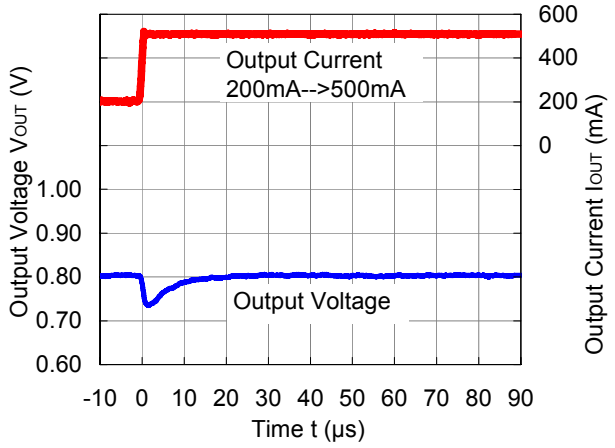
RP504x081x (V_{IN}=3.6V)
MODE="H" forced PWM



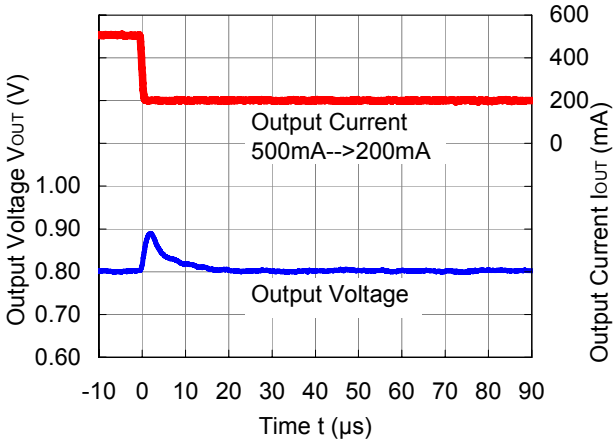
RP504x081x (V_{IN}=3.6V)
MODE="H" forced PWM



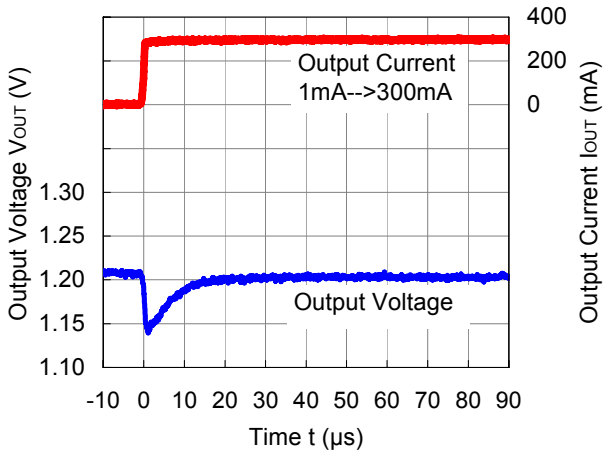
RP504x081x (V_{IN}=3.6V)



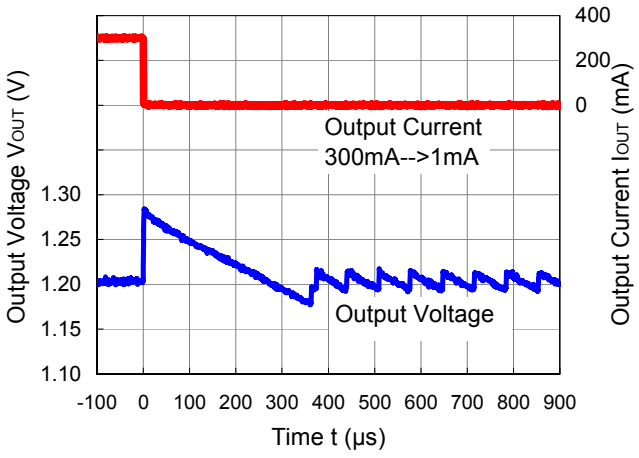
RP504x081x (V_{IN}=3.6V)



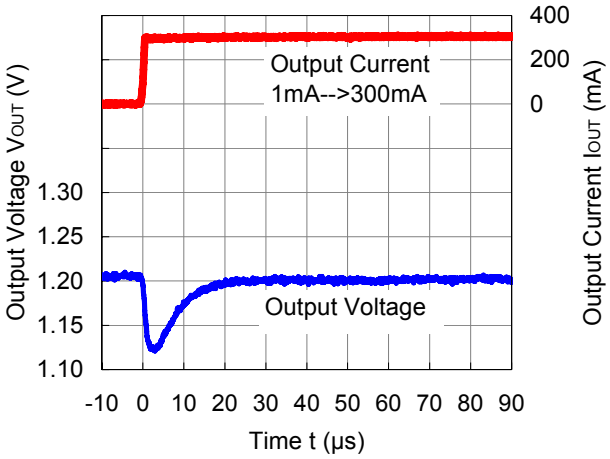
RP504x121x (V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



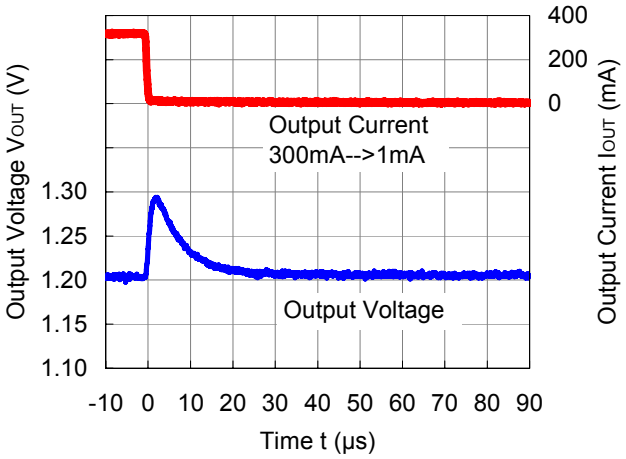
RP504x121x (V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



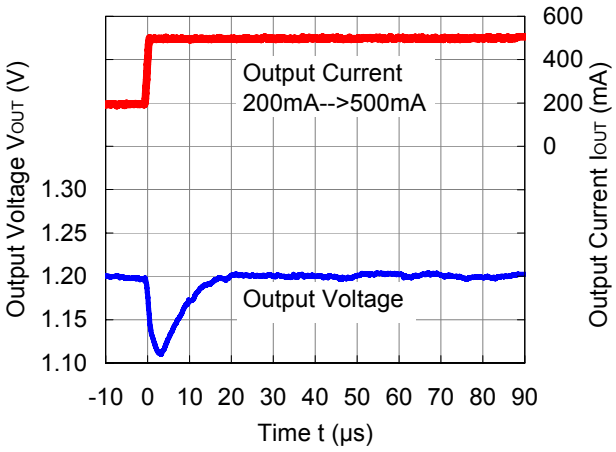
RP504x121x (V_{IN}=3.6V)
MODE="H" forced PWM



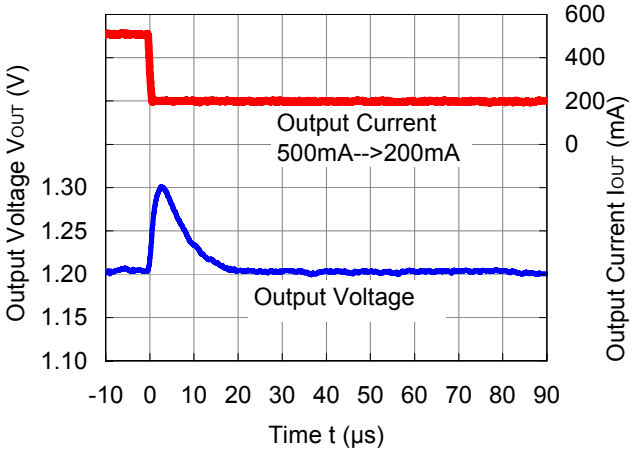
RP504x121x (V_{IN}=3.6V)
MODE="H" forced PWM



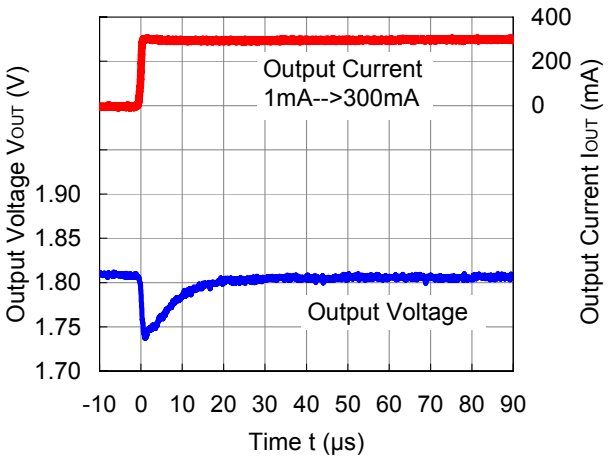
RP504x121x (V_{IN}=3.6V)



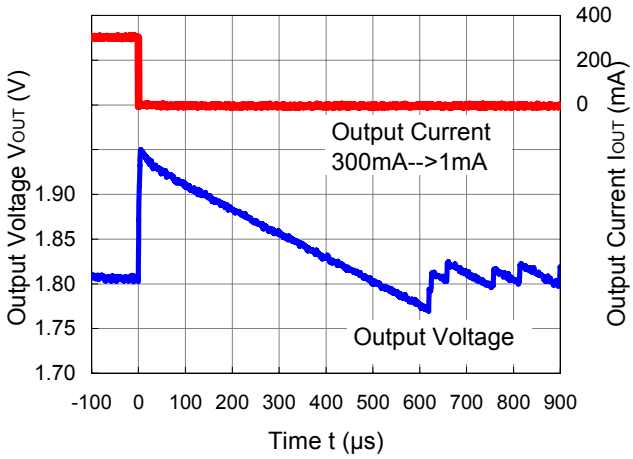
RP504x121x (V_{IN}=3.6V)



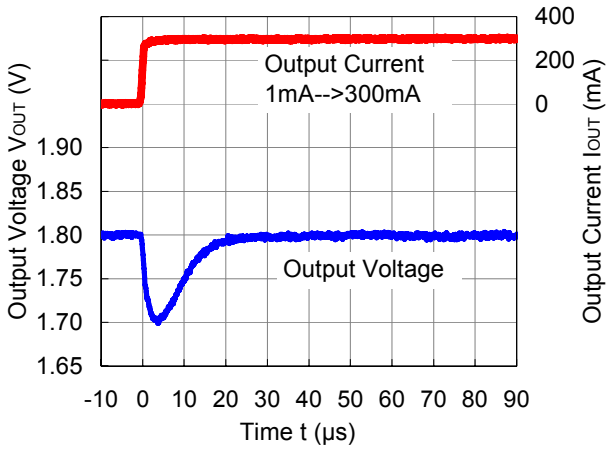
RP504x181x (V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



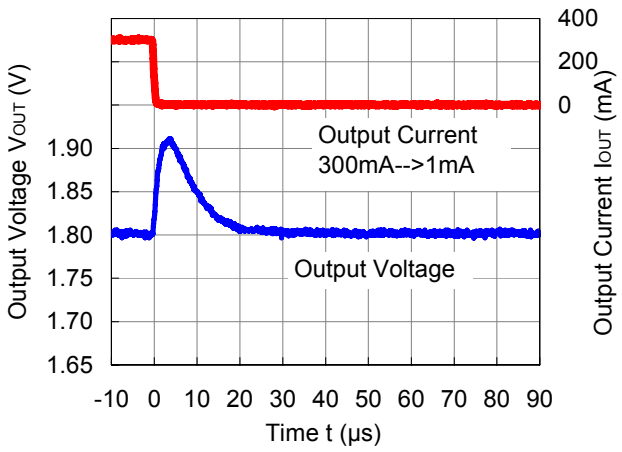
RP504x181x (V_{IN}=3.6V)
MODE="L"PWM/VFM automatic shift



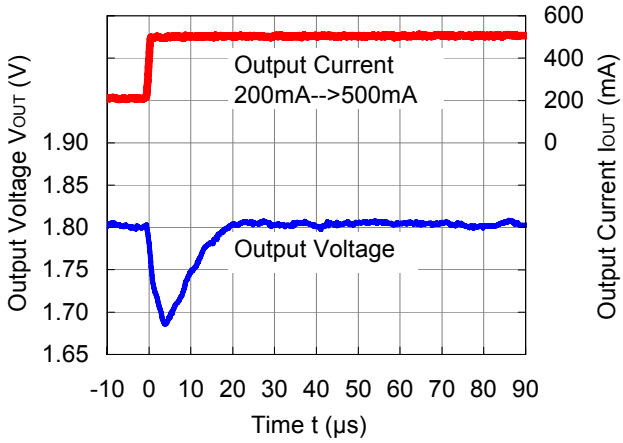
RP504x181x (V_{IN}=3.6V)
MODE="H" forced PWM



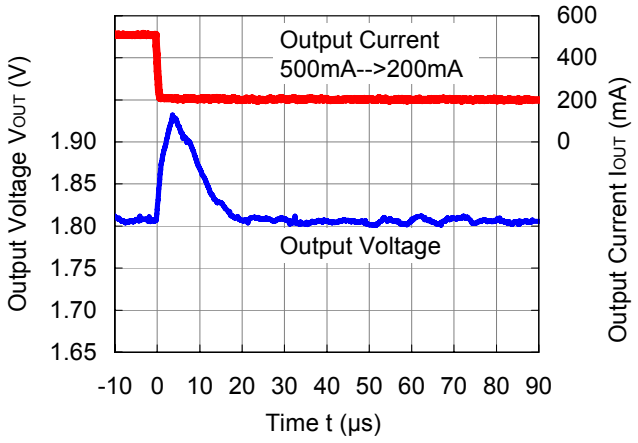
RP504x181x (V_{IN}=3.6V)
MODE="H" forced PWM



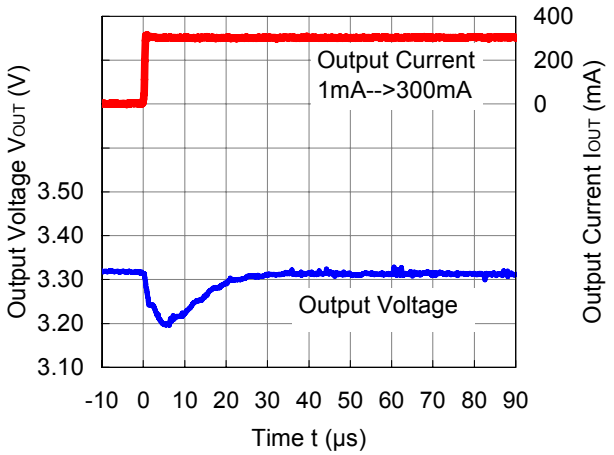
RP504x181x (V_{IN}=3.6V)



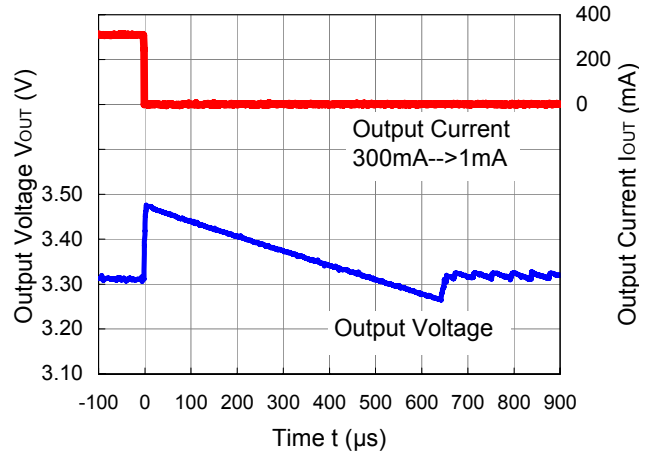
RP504x181x (V_{IN}=3.6V)



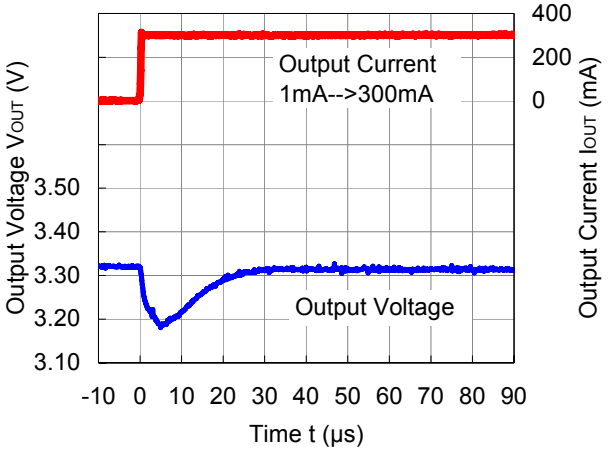
RP504x331x (V_{IN}=5.0V)
MODE="L"PWM/VFM automatic shift



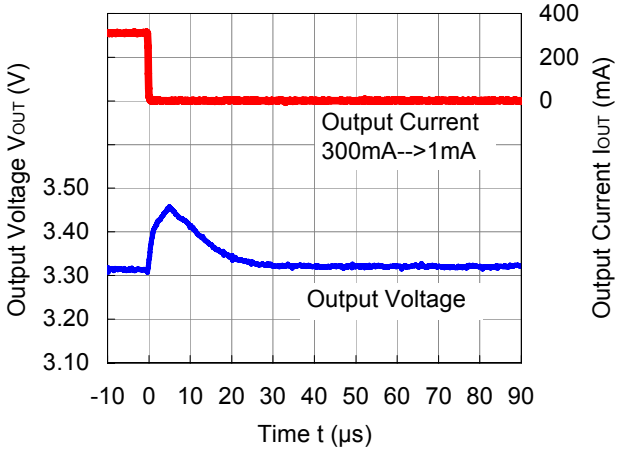
RP504x331x (V_{IN}=5.0V)
MODE="L"PWM/VFM automatic shift



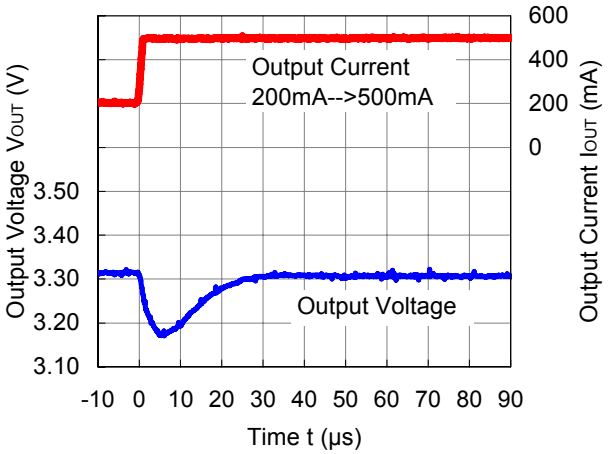
RP504x331x (V_{IN}=5.0V)
MODE="H" forced PWM



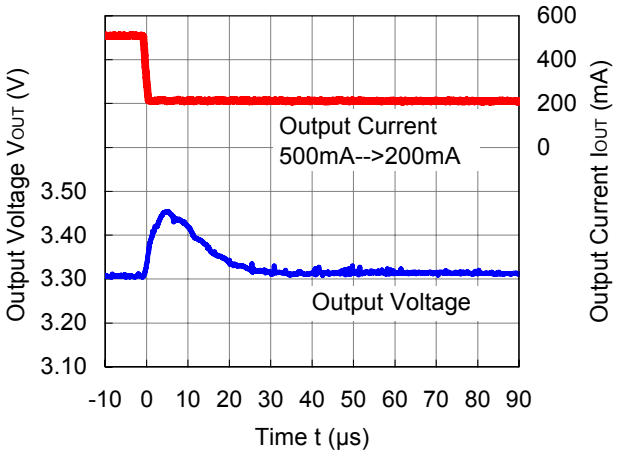
RP504x331x (V_{IN}=5.0V)
MODE="H" forced PWM



RP504x331x (V_{IN}=5.0V)

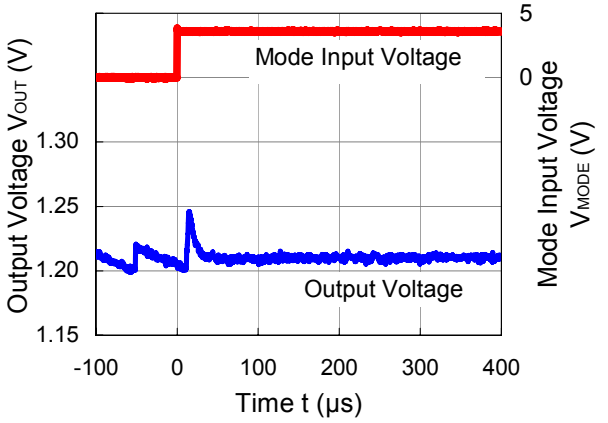


RP504x331x (V_{IN}=5.0V)

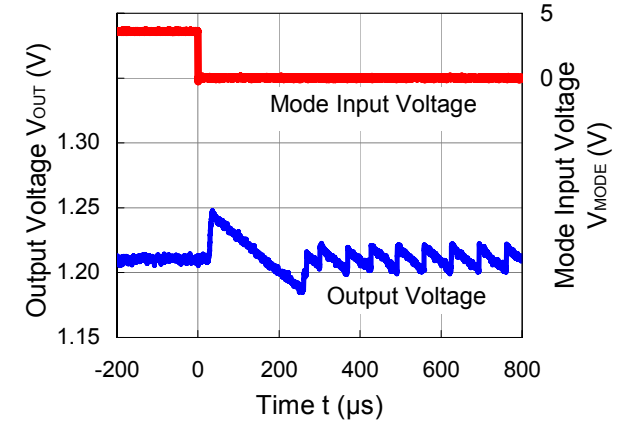


17) Mode Switching Waveform

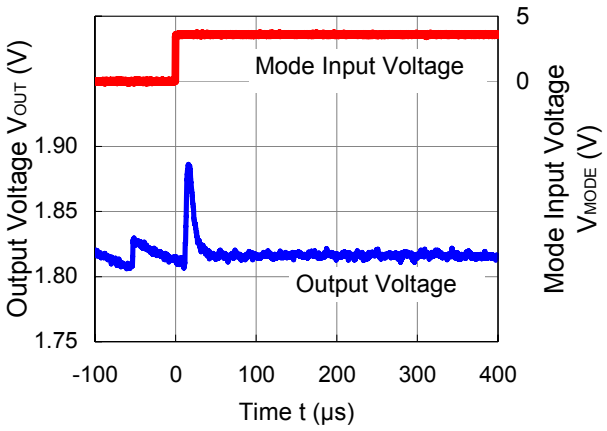
RP504x (V_{IN}=1.2V, I_{OUT}=1mA)
MODE="L" --> MODE="H"



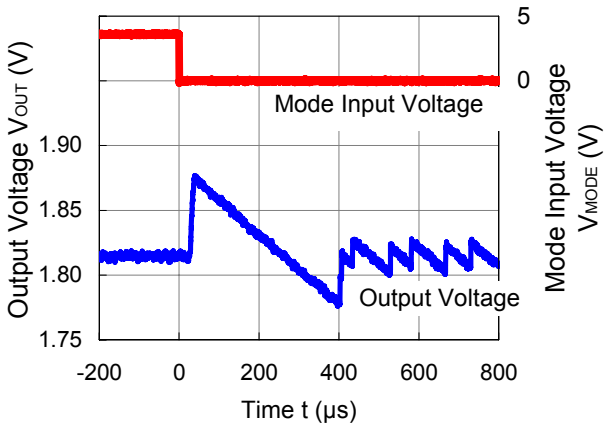
RP504x (V_{IN}=1.2V, I_{OUT}=1mA)
MODE="H" --> MODE="L"



RP504x (V_{IN}=1.8V, I_{OUT}=1mA)
MODE="L" --> MODE="H"



RP504x (V_{IN}=1.8V, I_{OUT}=1mA)
MODE="H" --> MODE="L"



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RICOH COMPANY, LTD.
Electronic Devices Company
● **Shin-Yokohama office (International Sales)**
3-2-3, Shin-Yokohama, Kohoku-ku, Yokohama City, Kanagawa 222-8530, Japan
Phone: +81-45-477-1697 Fax: +81-45-477-1698

RICOH EUROPE (NETHERLANDS) B.V.
● **Semiconductor Support Centre**
Prof. W.H.Keesomlaan 1, 1183 DL Amstelveen, The Netherlands
P.O.Box 114, 1180 AC Amstelveen
Phone: +31-20-5474-309 Fax: +31-20-5474-791

RICOH ELECTRONIC DEVICES KOREA Co., Ltd.
11 floor, Haesung 1 building, 942, Daechidong, Gangnamgu, Seoul, Korea
Phone: +82-2-2135-5700 Fax: +82-2-2135-5705

RICOH ELECTRONIC DEVICES SHANGHAI Co., Ltd.
Room403, No.2 Building, 690#Bi Bo Road, Pu Dong New district, Shanghai 201203, People's Republic of China
Phone: +86-21-5027-3200 Fax: +86-21-5027-3299

RICOH COMPANY, LTD.
Electronic Devices Company
● **Taipei office**
Room109, 10F-1, No.51, Hengyang Rd., Taipei City, Taiwan (R.O.C.)
Phone: +886-2-2313-1621/1622 Fax: +886-2-2313-1623