RICOH

R1213K SERIES

PWM STEP-UP DC/DC CONVERTERS

NO.EA-193-111020

OUTLINE

R1213K Series are CMOS-based, PWM control low consumption current step-up DC/DC converter ICs. A low ripple high efficiency step up DC/DC converter can be composed of R1213K with only an inductor, a diode, divider resistors and capacitors and feed back voltage is 0.8V. As protection circuits, a current limit circuit for limit peak current of Lx cycle by cycle, a timer latch protection circuit which stops built-in driver if the load current is beyond the current limit and low VOUT continues for a certain time also built in. Further, thermal shutdown function and under voltage lockout (UVLO) function are built in. Operation halting by the protection circuit is connected to the FLAG output function and control an external P-channel MOSFET and cut off the current path from the power supply to the output. To reset the latch function, restart with power-on (power supply voltage must be equal or less than UVLO detector threshold) or toggling CE pin.

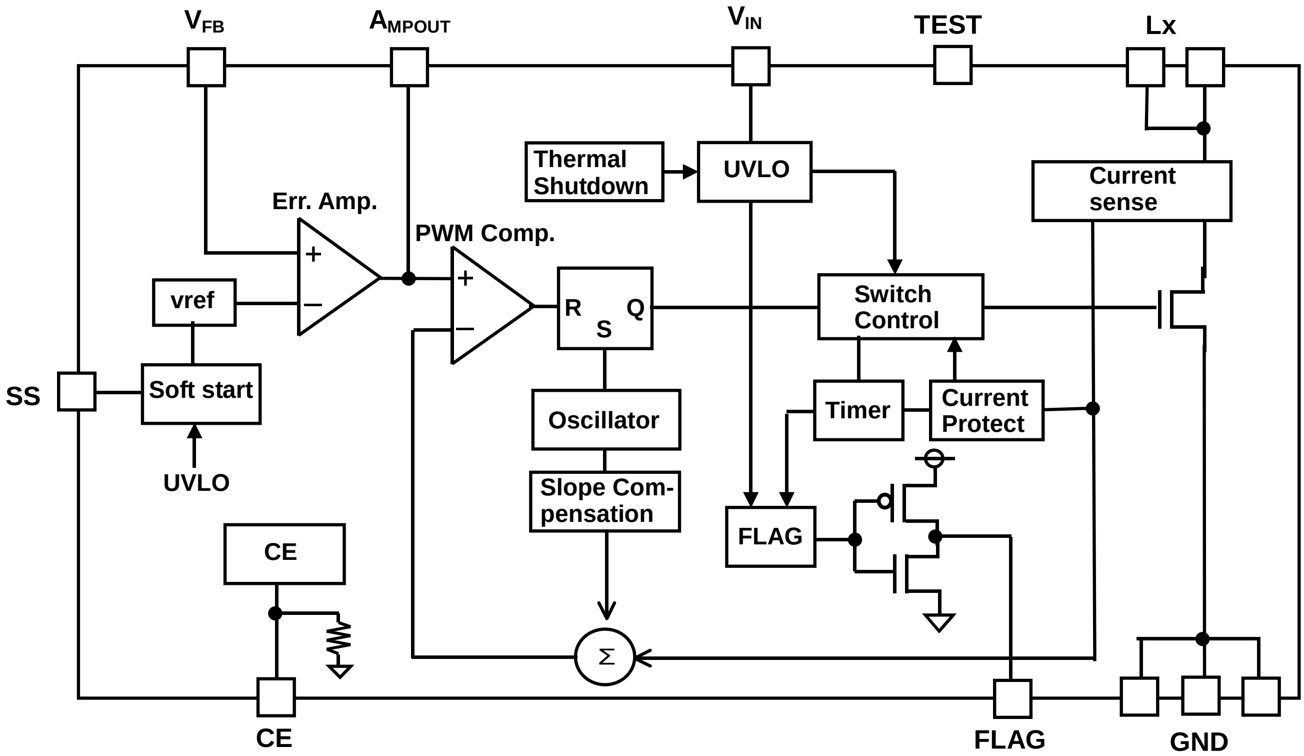
FEATURES

- Input Voltage Range ············ 2.3V ~ 5.5V
- Standby current ············ Typ. 0.1μA
- Lx peak current limit ············ Typ. 3A
- Internal driver transistor ············ NMOS = 0.07Ω
- Complete shutdown ············ with external switch (option, if necessary)
- Thermal shutdown ············ 150°C (Hysteresis 40°C)
- Timer latch protection circuit delay time ············ Typ. 32ms
- FLAG output function ············ Stop operation by protection circuit, output "H".
- UVLO ············ Typ. 2.0V
- Maximum duty cycle ············ Typ. 90%
- PWM Low Ripple Oscillator Frequency ············ 1.0MHz
- Output Voltage Range ············ Adjustable: 3.0V ~ 15.0V, V_{FB}=0.8V (Recommended range of output voltage)
- V_{FB} Voltage Tolerance ············ 0.8V ± 1.0%
- Phase compensation ············ control with AMPOUT pin
- Soft start time ············ control with SS pin
- Package ············ DFN(PLP)2730-12

APPLICATIONS

- Flash LED
- Data card
- DSC
- LCD source Bias Supplies

BLOCK DIAGRAMS



SELECTION GUIDE

According to the Set Output Voltage range for the ICs, product code should be selected.

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1213K001A-TR	DFN (PLP)2730-12	5,000 pcs	Yes	Yes
R1213K001B-TR				

function version: A version: low output voltage range (V_{OUT}:3.0V to 6.0V)
B version: high output voltage range (V_{OUT}: 6.0V to 15.0V) *** recommended range of output voltage**

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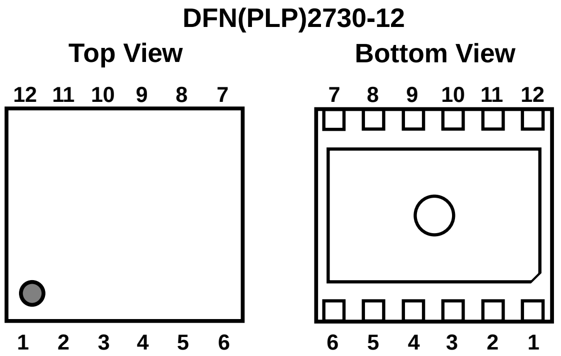
PIN CONFIGURATION



PIN DESCRIPTION

Pin No	Symbol	Pin Description
1	A_{MPOUT}	Amplifier output Pin
2	V_{FB}	Feedback Pin
3	CE	Chip enable Pin
4	GND	Ground Pin
5	GND	Ground Pin
6	GND	Ground Pin
7	TEST	TEST Pin
8	Lx	Internal NMOS Switch Drain Pin
9	Lx	Internal NMOS Switch Drain Pin
10	V_{IN}	Power Supply Pin
11	FLAG	FLAG output Pin
12	SS	Soft start setting Pin

* Tab is the substrate (GND) level. (connected to the reverse side of the IC.) Connect the tab to the GND (recommendation) or leave it open.

ABSOLUTE MAXIMAM RATINGS

(GND=0V)

Symbol	Items		Ratings	Unit
V_{IN}	V_{IN} Supply Voltage		-0.3 ~ 6.5	V
V_{AMP}	A_{MPOUT} Pin Voltage		-0.3 ~ V_{IN}+0.3	V
V_{CE}	CE Pin Voltage		-0.3 ~ 6.5	V
V_{LX}	Lx Pin Input Voltage		-0.3 ~ 18.0	V
V_{FB}	V_{FB} Pin Voltage		-0.3 ~ 6.5	V
V_{SS}	SS Pin Voltage		-0.3 ~ V_{IN}+0.3	V
V_{FLAG}	FLAG Pin Voltage		-0.3 ~ V_{IN}+0.3	V
V_{TST}	TEST Pin Voltage		-0.3 ~ V_{IN}+0.3	V
P_D	Power Dissipation *	Standard	1000	mW
		High Pd condition	1950	
Ta	Ambient Temp Range		-40 ~ + 85	°C
Tstg	Storage Temp Range		-55 ~ + 125	°C

*) For Power Dissipation, refer to PACKAGE INFORMATION to be described.

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

(Ta=25°C)

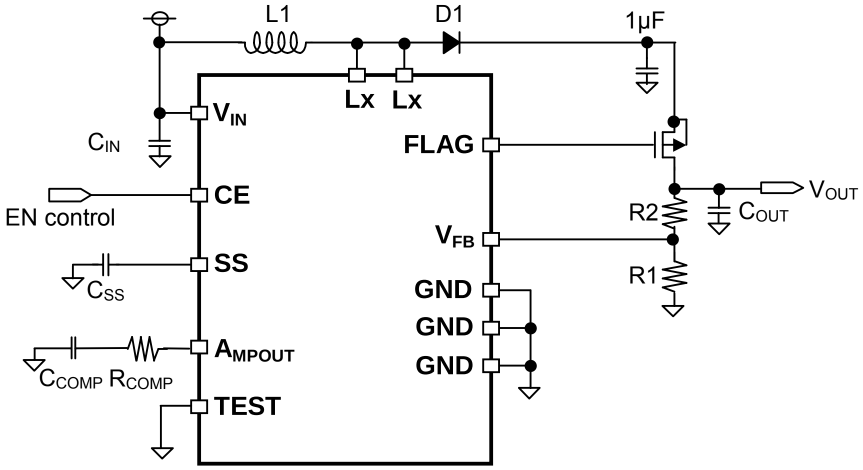
Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit
V_{IN}	Input Voltage		2.3		5.5	V
I_{DD1}	Quiescent Current 1 (No switching)	V_{IN}=5.5V V_{FB}=0.9V		550	800	μA
I_{DD2}	Quiescent Current 2	V_{IN}=5.5V V_{FB}=0V		3.0	4.5	mA
Istandby	Standby Current	V_{IN}=5.5V, V_{CE}=0V		0.1	1.5	μA
V_{UVLO1}	UVLO detector threshold	V_{IN}=3.6V to 0V, V_{FB}=0V	1.9	2.0	2.1	V
V_{UVLO2}	UVLO detector released voltage	V_{IN}=0V to 3.6V, V_{FB}=0V		V_{UVLO1} +0.12	2.25	V
V_{FB}	Feedback Voltage	V_{IN}=3.6V	0.792	0.800	0.808	V
ΔV_{FB} /ΔTa	V_{FB} Voltage Temperature Coefficient	-40°C≤Ta≤85°C		±50		ppm /°C
fosc	Switching Frequency	V_{IN}=3.6V, V_{DLY}=V_{FB}=0V	850	1000	1150	kHz
Vc_{EH}	CE "H" Input Voltage	V_{IN}=2.3V	1.5			V
Vc_{EL}	CE "L" Input Voltage	V_{IN}=5.5V			0.3	V
R_{CE}	CE Pull-down Resistance			1000		kΩ
R_{ON}	Switch On-Resistance (*1)	V_{OUT}=3.6V		0.07		Ω
I_{FBH}	V_{FB} "H" Input Current	V_{IN}=5.5V, V_{FB}=5.5V			0.15	μA
I_{FBL}	V_{FB} "L" Input Current	V_{IN}=5.5V, V_{FB}=0V	-0.15			μA
I_{CEL}	CE "L" Input Current	V_{IN}=5.5V, V_{CE}=0V	-0.2		0.2	μA
V_{OUT}	Output Voltage Range	A Version	3.0		6.0	V
		B Version	6.0		15.0	
gm	Trans Conductance (*1)	V_{IN}=3.6V		220		μS
Iss	Soft start current	V_{IN}=3.6V		12		μA
Maxduty	Maximum Duty Cycle	V_{IN}=3.6V, V_{DLY}=V_{FB}=0V	85	90	95	%
I_{LIM}	Lx Current limit (*2)	V_{IN}=3.6V	2.5	3.0	3.8	A
I_{LXOFF}	Lx Leakage Current	V_{LX}=16V		0.01	2.00	μA
T_{PRT}	Latch protection Delay time	V_{IN}=3.6V		32		ms
I_{RUSH}	Inrush Current (*2)				1.5	A

*1) Guaranteed by design, not mass production tested.

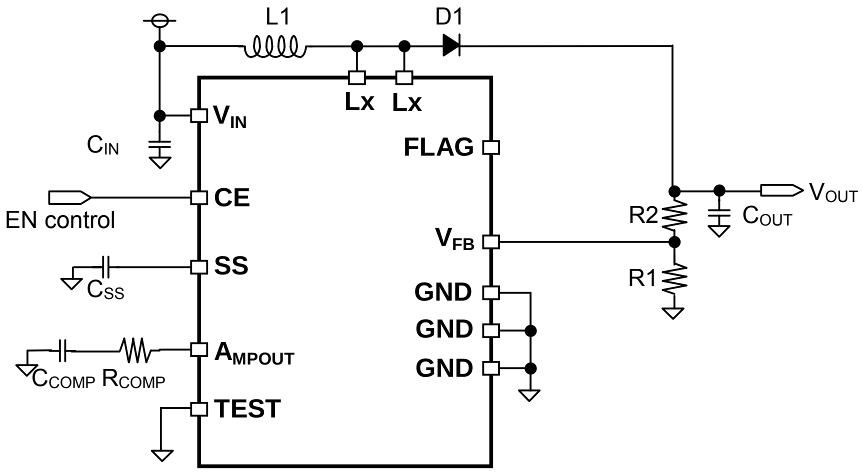
*2) In the case of connecting an external P-channel MOSFET to FLAG pin, guaranteed by design, not mass production tested.

APPLICATION NOTES

In the case of cut off power path between power supply and V_{OUT}



Standard application



External components value examples

C_{IN}	V_{IN}	Cap.	Spec.	Part Name	Manufacturer
	All	10μF	6.3V	C2012JB0J106M	TDK

C_{OUT}	V_{OUT}	Cap.	Spec.	Part Name	Manufacturer
	≤ 5V	10μF	6.3V	C2012JB0J106M	TDK
	≤ 10V	10μF	16V	C2012X5R1C106K	TDK
	all	10μF	25V	C3216X5R1E106K	TDK
	all	10μF	25V	TMK325BJ106MN	Taiyo Yuden

D1	V_{OUT}	Spec.	Part Name	Manufacturer
	all	40V 3A	CMS16	TOSHIBA
	all	40V 3A	RB056L-40	ROHM

	Ind.	Spec.	Part Name	Manufacturer
L1(*1)	2.2μH	2.2A	SPM3012T-2R2N	TDK
	2.2μH	2.7A	SPM4012T-2R2N	TDK
	2.2μH	3.5A	NR5040T2R2N	Taiyo Yuden
	4.7μH	1.7A	SPM4012T-4R7N	TDK
	4.7μH	3.1A	NR5040T4R7N	Taiyo Yuden
	6.8μH	1.4A	VLF5014ST-6R8N	TDK
	6.8μH	2.8A	RLF7030T-6R8N	TDK
	6.8μH	3.7A	NR8040T6R8N	Taiyo Yuden

Pch MOSFET	V_{OUT}	Spec.(I_{DS}, V_{DS}, V_{GS})	Part Name	Manufacturer
	all	4.5A, -30V, ±20V	UPA1914	Renesas

● Setting of Output Voltage

Output voltage can be set with divider resistors for voltage setting, R1 and R2 as shown in the typical application. Refer to the next formula.

Output Voltage = $V_{FB} \times (R1 + R2) / R1$ (V_{FB} = 0.8V)

Recommended value of resistors (R1 + R2) is equal or less than 200kΩ.

● Soft start time

Soft-start time can be set by connecting a capacitor "Css" between SS pin and GND. Soft start time can be calculated by the next formula.

Soft start time=Css x V_{FB} / Iss=8xCssx10^4

(V_{FB}=0.8V, Iss=10uA)

● Phase compensation

The R1213 requires external phase compensation to prevent from large output ripple and unstable operation and low efficiency. To make phase compensation, connect a resistance R_{COMP} and a capacitor C_{COMP} in series between A_{MPOUT} and GND. The resistance and capacitance values can be calculated with next formulas. The values are the basic values, however, to judge if they are appropriate or not, check the transient response and cut and try for adjustment.

(A version)

$R_{COMP}=90xV_{IN}xV_{OUT}xC_{OUT}/(LxI_{OUTMAX})$

$C_{COMP}=30xV_{OUT}xLxI_{OUTMAX}/(V_{IN}^2xR_{COMP})$

(B version)

$R_{COMP}=45xV_{IN}xV_{OUT}xC_{OUT}/(LxI_{OUTMAX})$

$C_{COMP}=30xV_{OUT}xLxI_{OUTMAX}/(V_{IN}^2xR_{COMP})$

V_{IN} (V)	V_{OUT} (V)	I_{OUT}max (mA)	C_{IN} (μF)	C_{OUT} (μF)	L1(μH)	R_{COMP} (kΩ)	C_{COMP} (nF)
3.3	3.8	1200	10	20	2.2	8.2	3.3
3.3	5	800	10	20	4.7	8.2	6.8
3.3	12	250	10	20	4.7	27	1.8
5.0	15	650	10	20	6.8	15	5.1

● FLAG pin

FLAG pin outputs "H" at standby, detect UVLO, detect thermal protection, and latch state and turns off the external P-channel MOSFET if it is connected to the FLG pin and cuts off the current path between the power supply and the output.

During the normal operation, the set output voltage is output, and FLG pin outputs "L" and turns on the external P-channel MOSFET if it is connected to the FLG pin.

Over voltage might be generated by the inductor current, therefore, connect 1uF capacitor between source of the external MOSFET and GND if a P-channel MOSFET is used for shutdown.

At the start up, during the soft start time, FLAG pin is synchronized with the internal driver switching and turns on and off the external P-channel MOSFET and prevents the large inrush current. If an external P-channel MOSFET is necessary, choose the MOSFET with fast switching speed (around 100ns) and small gate capacity (3nF or less). If the external P-channel MOSFET is not necessary, FLAG pin must be left open.

■ Technical Notes

External components

Make V_{IN} and GND lines sufficient. The large switching current may flow through the power supply line and GND. If their impedance is high, the internal voltage level of power supply may shift and unstable operation may result. At turning off of the internal Lx switch, spike noise may be generated by the inductor's operation. We recommend using the output capacitor and the diode with voltage rating at least 1.5 times as much as setting output voltage.

Use a Schottky type diode with high switching speed, low reverse current, and low Vf.

Use an inductor with low resistance, and large permissible current, and hardly happened magnetic saturation.

If the inductance is too low, at the maximum load current, ILX may be beyond the absolute maximum rating, choose an appropriate value. (Refer to the parts recommendation.)

The R1213K has the control switch pin for complete shutdown with an external P-channel MOSFET. When the R1213K is stand-by, detecting UVLO, thermal protection, or timer latch, by turning off the external P-channel MOSFET, the current path from power supply to output can be shutdown.

Choose the external P-channel MOSFET with fast switching speed (around 100ns) and small gate capacity (less than 3nF) if necessary.

Considering the spike noise on Lx pin is necessary so that the spike noise may not beyond the absolute maximum rating. If the spike noise is too large, put a snub circuit such as serial CR to the diode D1 and reduce the spike noise. The time constants of CR depends on the board layout and give an impact on the efficiency, therefore fully evaluation is necessary. The standard time constants are 10Ω and 300pF.

***The performance of power circuit using this IC depends upon the peripheral circuits. Pay attention in the selection of the peripheral circuits. In particular, design the peripheral circuits in a way that the values such as voltage, current, and power of each component, PCB patterns and the IC do not exceed their respected rated values.**

The R1213 function

The R1213 has the timer latch protection circuit. If the output voltage goes down by excess load current for a certain time, the internal driver is off latched and the operation of the DC/DC converter stops. If the protection circuit may work, the complete shutdown control pin outputs "H", and if an external P-channel MOSFET is connected, the MOSFET will turn off and current path between power source and output will be cut off. The protection delay time is preset at typically 32ms, therefore, if the output voltage returns to normal within the delay time, the internal protection timer counter will be reset. To release the timer latch protection, by toggling the CE pin or make the power source be set lower than UVLO detector threshold.

Connect TEST pin to GND.

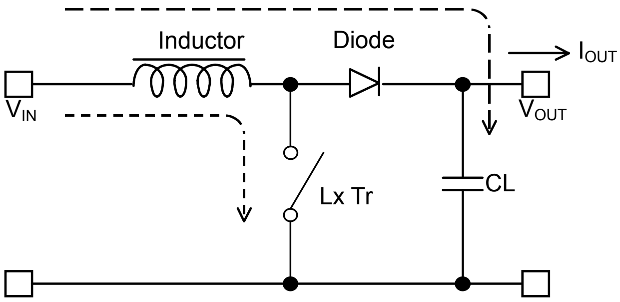
Complete shutdown SW control pin (FLAG pin) is linked the operation of soft-start, therefore, during the soft-start, pulse outputs from this FLAG pin.

To prevent the inrush current, use an appropriate capacitor for SS pin for soft-start.

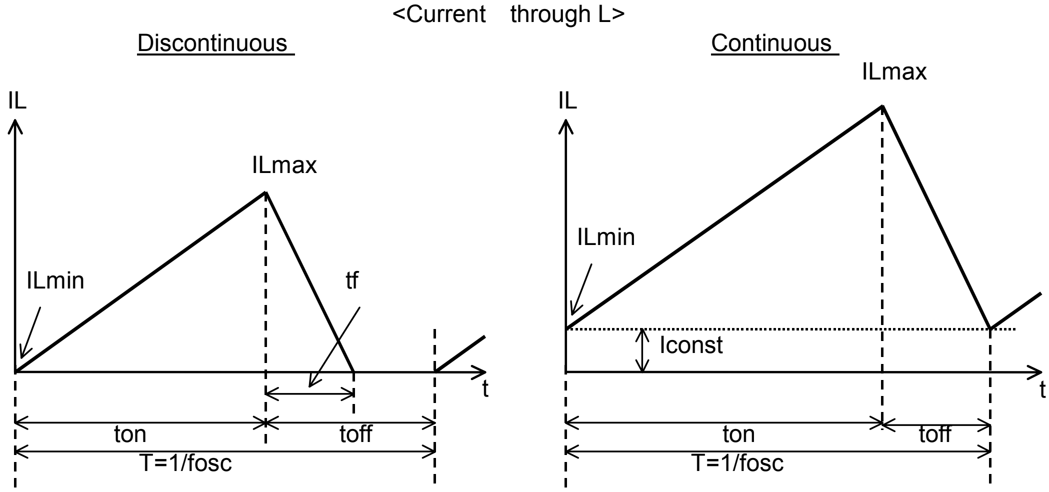
The exposed PAD of the backside should be connected to the GND plane. Especially, for the multi-layer boards, thermal via of the exposed PAD is effective for heat radiation.

OUTPUT CURRENT OF STEP-UP CIRCUIT AND EXTERNAL COMPONENTS

<Basic Circuit>



<Current through L>



There are two modes, or discontinuous mode and continuous mode for the PWM step-up switching regulator depending on the continuous characteristic of inductor current. During on time of the transistor, when the voltage added on to the inductor is described as V_{IN}, the current is $V_{IN} \times t / L$.

Therefore, the electric power, P_{ON}, which is supplied with input side, can be described as in next formula.

$$P_{ON} = \int_0^{ton} V_{IN}^2 \times t/L \, dt \quad \text{Formula 1}$$

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

$$P_{OFF} = \int_0^{tf} V_{IN} \times (V_{OUT} - V_{IN}) t/L \, dt \quad \text{Formula 2}$$

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

$$P_{AV} = 1/(ton + toff) \times \{\int_0^{ton} V_{IN}^2 \times t/L \, dt + \int_0^{tf} V_{IN} \times (V_{OUT} - V_{IN}) t/L \, dt\} \quad \text{Formula 3}$$

In PWM control, when tf = toff is true, the inductor current becomes continuous, then the operation of switching regulator becomes continuous mode. In the continuous mode, the deviation of the current is equal between on time and off time.

$$V_{IN} \times ton / L = (V_{OUT} - V_{IN}) \times toff / L \quad \text{Formula 4}$$

Further, the electric power, PAV is equal to output electric power, $V_{OUT} \times I_{OUT}$, thus,

$$I_{OUT} = fosc \times V_{IN}^2 \times ton^2 / \{2 \times L (V_{OUT} - V_{IN})\} = V_{IN}^2 \times ton / (2 \times L \times V_{OUT}) \quad \text{Formula 5}$$

When I_{OUT} becomes more than $V_{IN} \times ton \times toff / (2 \times L \times (ton + toff))$, the current flows through the inductor, then the mode becomes continuous. The continuous current through the inductor is described as Iconst, then,

$$I_{OUT} = fosc \times V_{IN}^2 \times ton^2 / (2 \times L \times (V_{OUT} - V_{IN})) + V_{IN} \times Iconst / V_{OUT} \quad \text{Formula 6}$$

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

$$ILxmax = Iconst + V_{IN} \times ton / L \quad \text{Formula 7}$$

With the formula 4, 6 and ILxmax is

$$ILxmax = V_{OUT} / V_{IN} \times I_{OUT} + V_{IN} \times ton / (2 \times L) \quad \text{Formula 8}$$

However, $ton = (1 - V_{IN} / V_{OUT}) / fosc$

Therefore, peak current is more than I_{OUT}. Considering the value of ILmax, the condition of input and output, and external components should be selected.

In the formula 7, peak current ILmax at discontinuous mode can be calculated. Put Iconst = 0 in the formula.

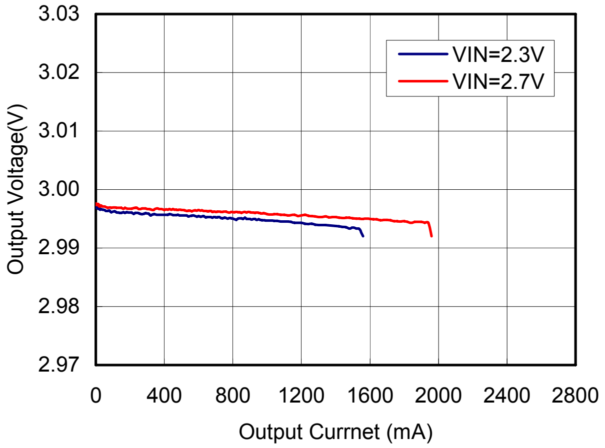
The explanation above is based on the ideal calculation, and the loss caused by Lx switch and external components is not included.

Select the inductor and the diode with referring to the peak current according to the formula 8.

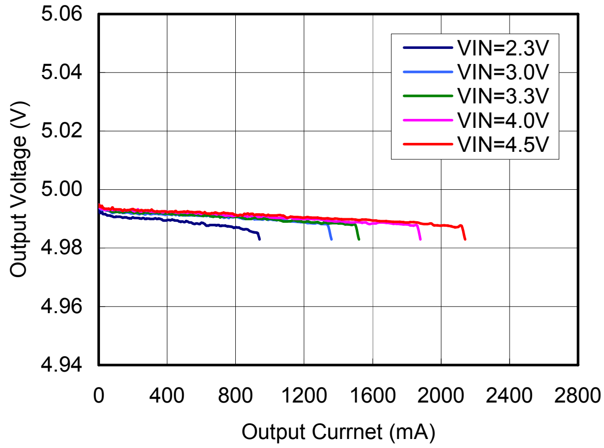
TYPICAL CHARACTERISTICS

1) Output voltage vs. Output current (Ta=25°C)

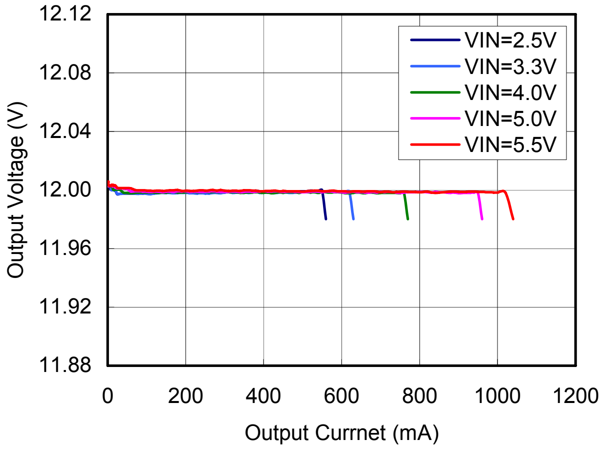
V_{OUT}=3.0V



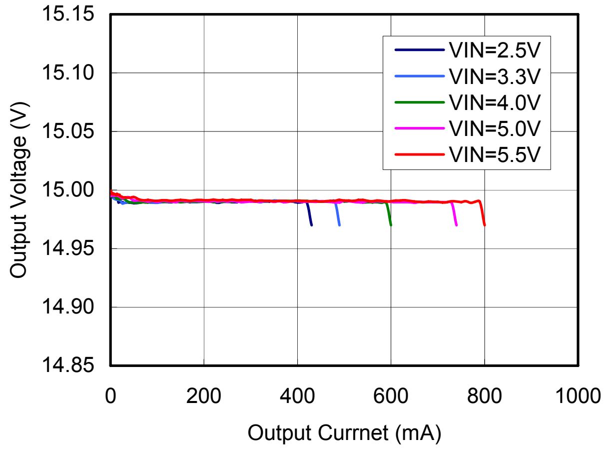
V_{OUT}=5.0V



V_{OUT}=12V

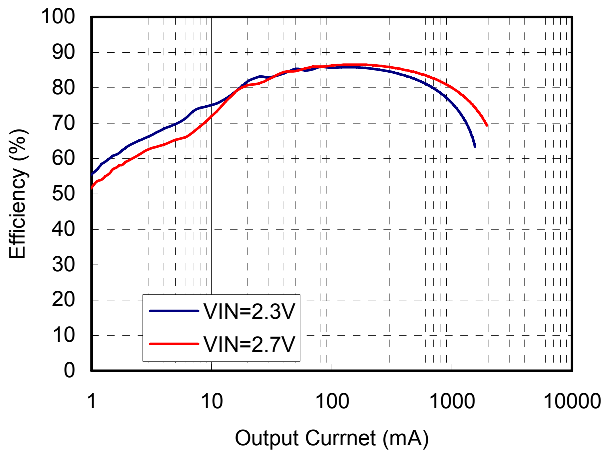


V_{OUT}=15V

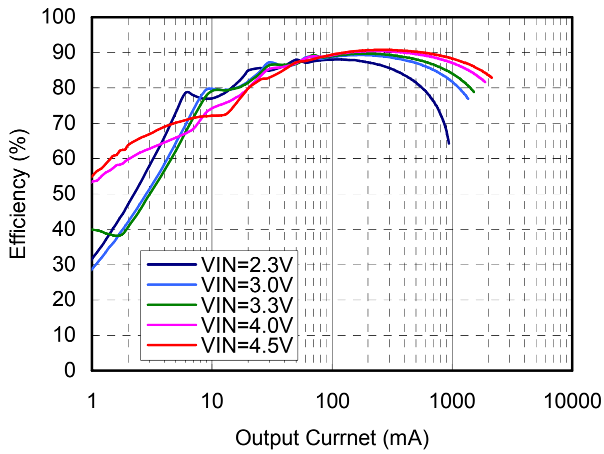


2) Efficiency vs. Output Current (Ta=25°C)

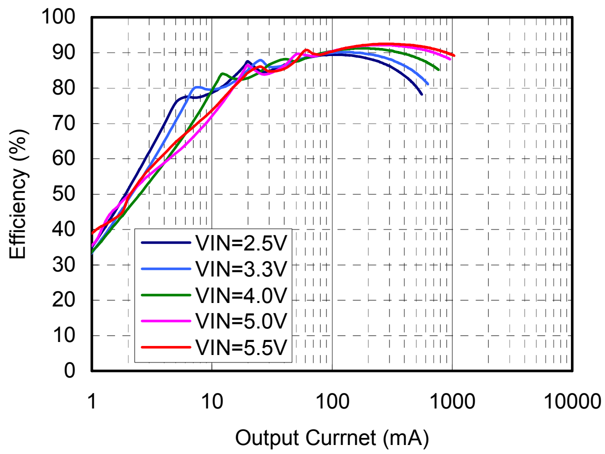
V_{OUT}=3.0V



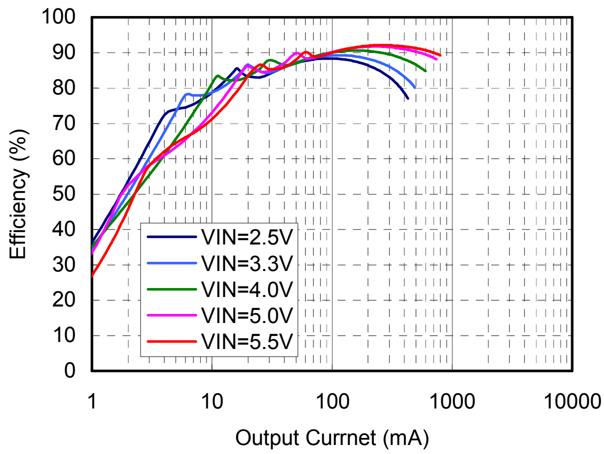
V_{OUT}=5.0V



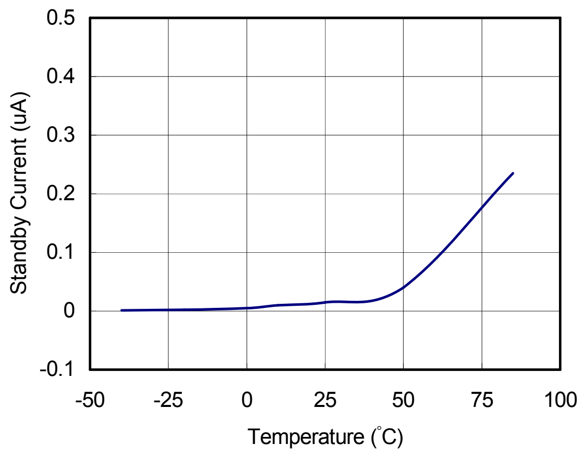
V_{OUT}=12V



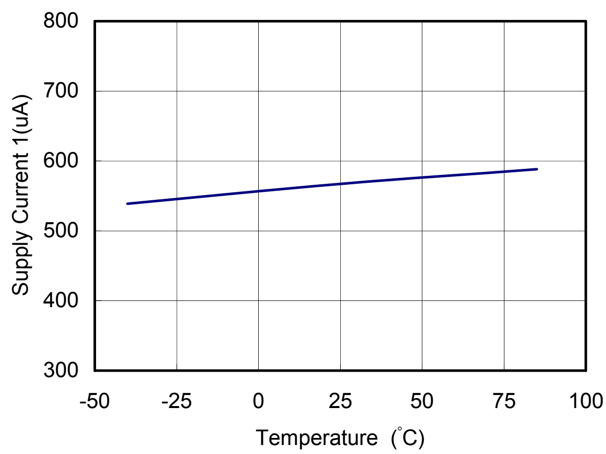
V_{OUT}=15V



3) Standby Current vs. Temperature



4) Supply Current 1 vs. Temperature



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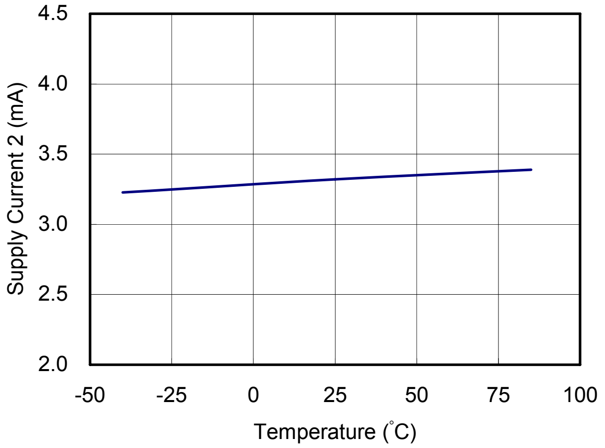
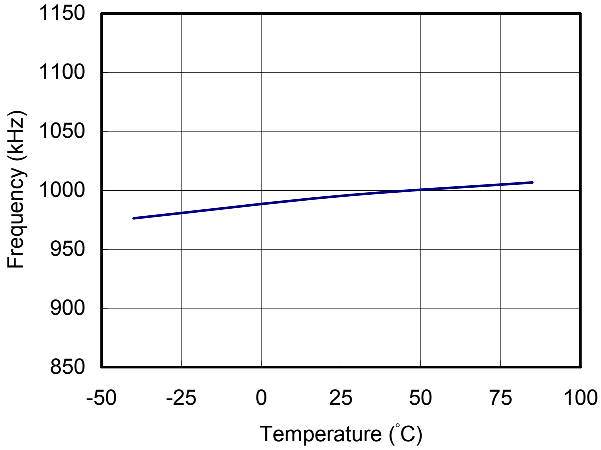
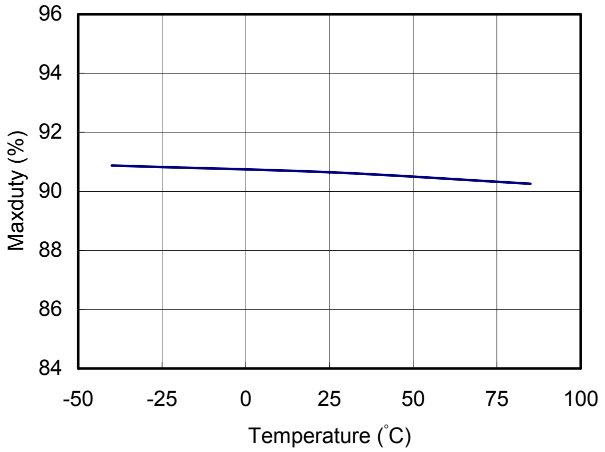
5) Supply current 2 vs. Temperature



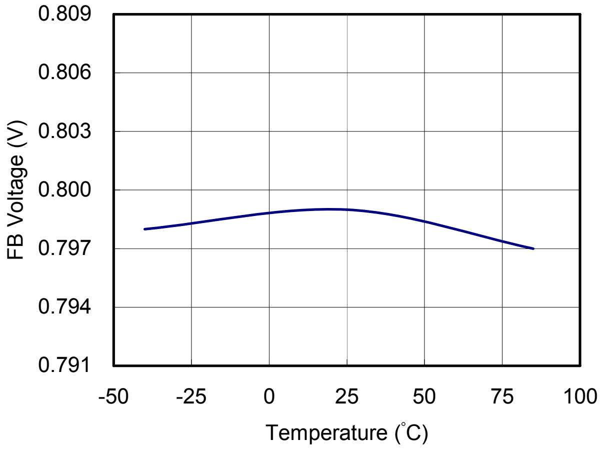
6) Oscillator frequency vs. Temperature



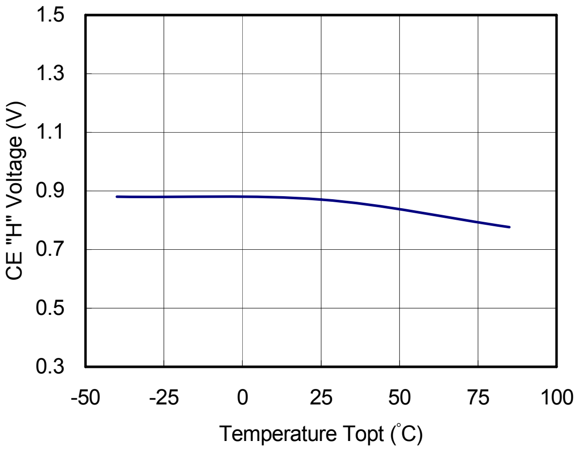
7) Maximum duty cycle vs. Temperature



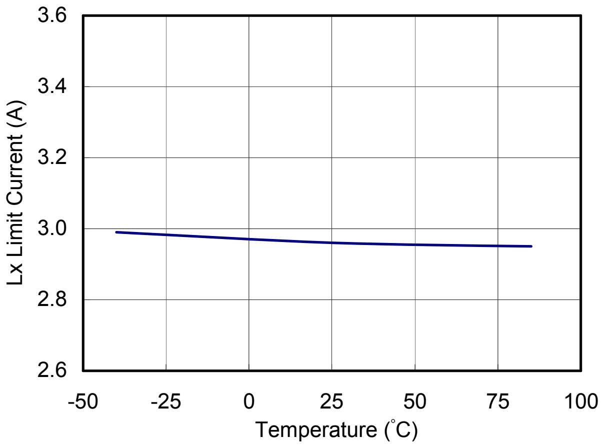
8) FB voltage vs. Temperature



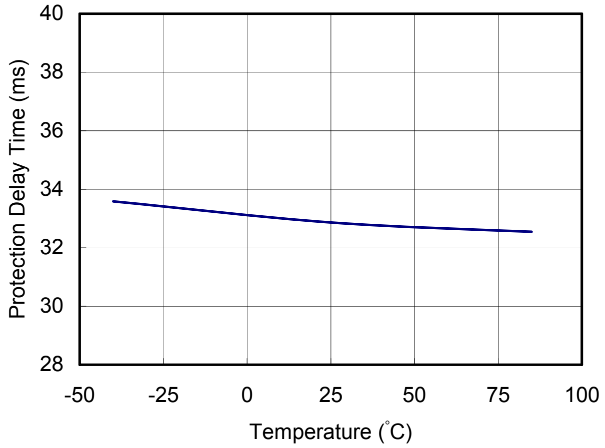
9) CE Input voltage "H" vs. Temperature



10) Lx Current limit vs. Temperature

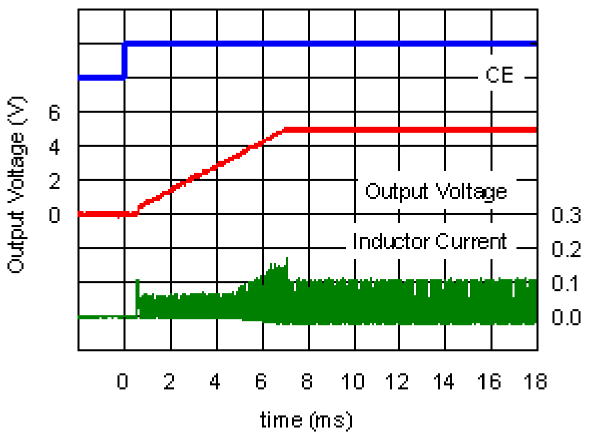


11) Protection delay time vs. Temperature

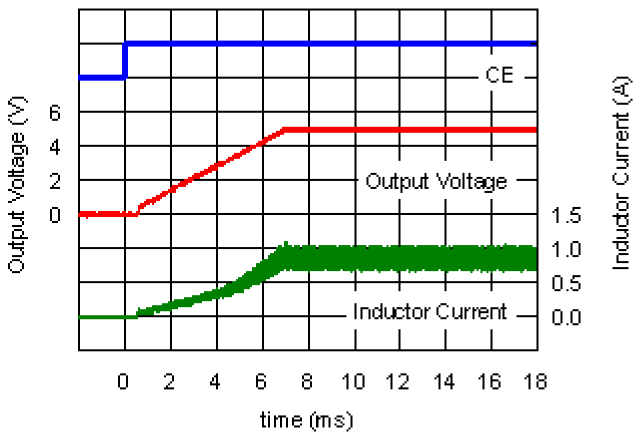


12) Start-up waveform (Ta=25°C, Css=0.1μF, with PMOSFET for cut-off current path between Vin and Vout)

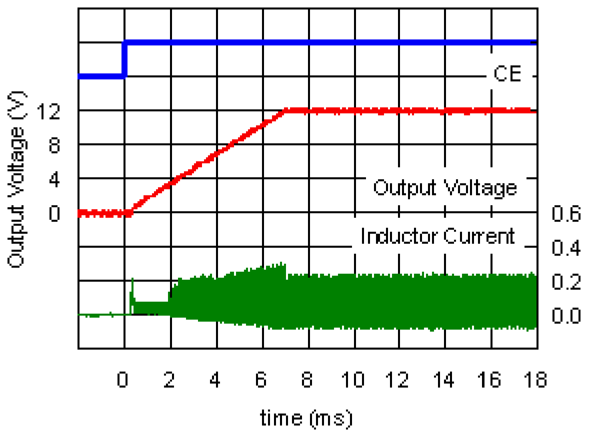
・V_{IN}=3.3V, V_{OUT}=5.0V, I_{OUT}=10mA



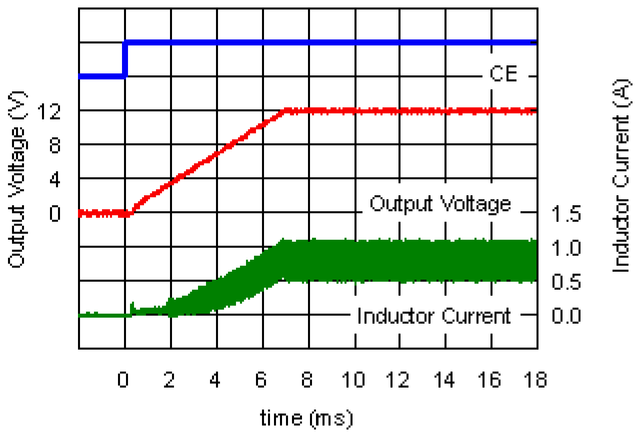
・V_{IN}=3.3V, V_{OUT}=5.0V, I_{OUT}=500mA



・V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=10mA

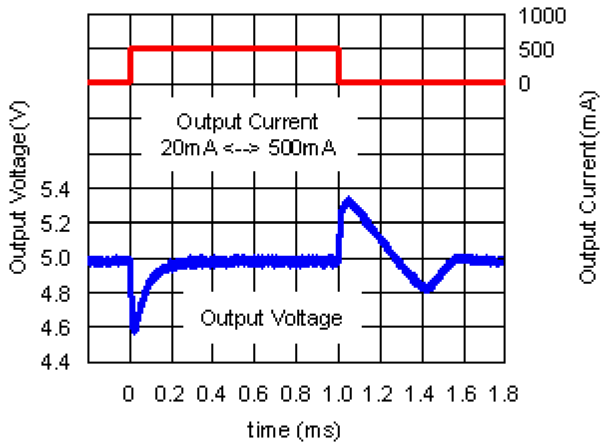


・V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=200mA

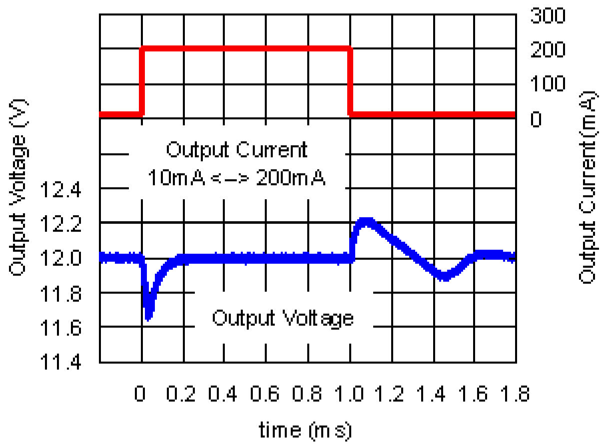


13) Load transient response (Ta=25°C)

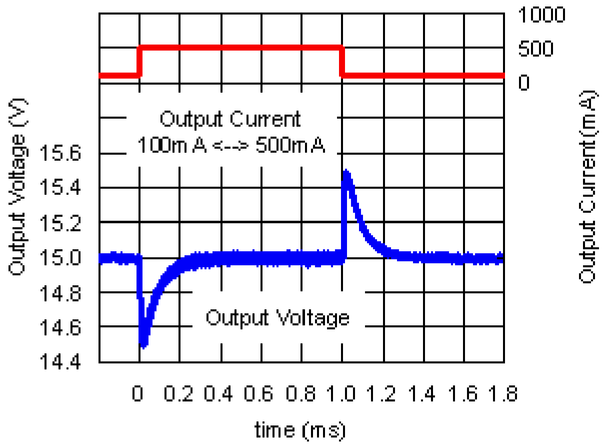
・V_{IN}=3.3V, V_{OUT}=5.0V, I_{OUT}=20⇔500mA
L=4.7µH, C_{OUT}=20µF, R_{COMP}=8.2kΩ, C_{COMP}=6.8nF



・V_{IN}=3.0V, V_{OUT}=12V, I_{OUT}=10⇔200mA
L=4.7µH, C_{OUT}=20µF, R_{COMP}=27kΩ, C_{COMP}=1.8nF

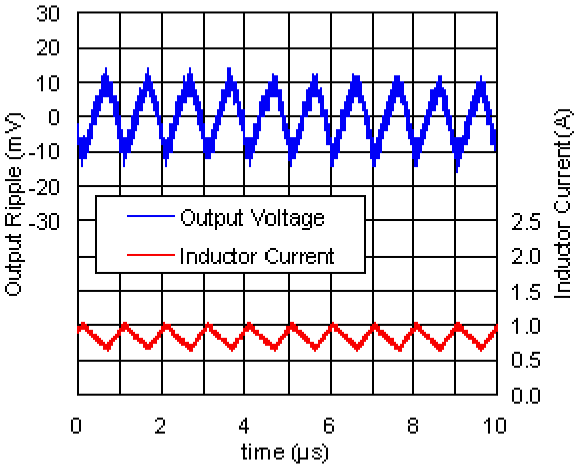


・V_{IN}=5.0V, V_{OUT}=15.0V, I_{OUT}=100⇔500mA
L=6.8µH, C_{OUT}=20µF, R_{COMP}=15kΩ, C_{COMP}=5.1nF

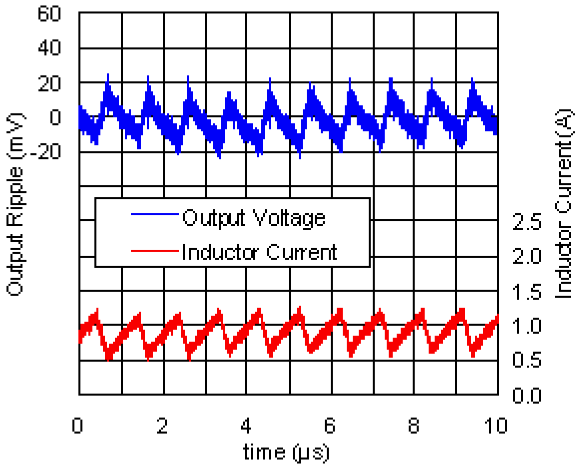


14) Output voltage waveform (Ta=25°C)

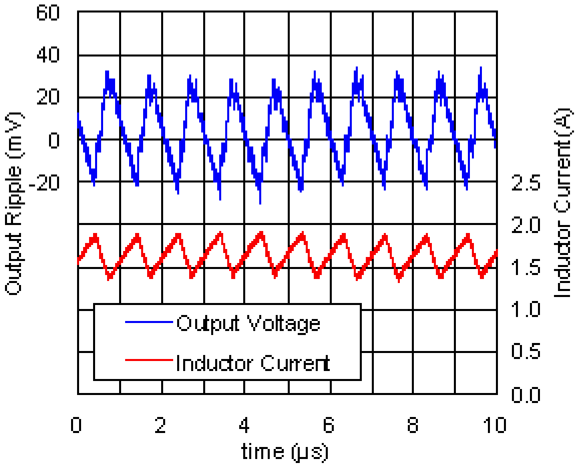
・V_{IN}=3.3V, V_{OUT}=5.0V, I_{OUT}=500mA
L=4.7μH, C_{OUT}=20μF



・V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=200mA
L=4.7μH, C_{OUT}=20μF



・V_{IN}=5.0V, V_{OUT}=15V, I_{OUT}=500mA
L=6.8μH, C_{OUT}=20μF



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