2CH PWM DC/DC CONTROLLER

NO.EA-086-160125

OUTLINE

The R1280D002x Series are CMOS-based 2-channel PWM Step-up (as Channel 1)/Inverting (as Channel 2) DC/DC converter controllers.

Each of the R1280D002x Series consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a reference current unit, a protection circuit, and an under voltage lockout (UVLO) circuit. A high efficiency Step-up/Inverting DC/DC converter can be composed of this IC with inductors, diodes, power MOSFETs, resisters, and capacitors. Each Output Voltage can be adjustable with external resistors, while soft-start time can be adjustable with external capacitors.

Maximum Duty Cycle of R1280D002A and C series can be also adjustable with external resistors.

Maximum Duty Cycle of R1280D002B is built-in as 90%(Typ.).

When CE pin of R1280D002B is set at GND level, this IC turns off external power MOSFETs of Step-up/Inverting as Standby-mode.

Standby current is typically 0μA.

As for a protection circuit, if Maximum duty cycle of either Step-up DC/DC converter side or Inverting DC/DC converter side is continued for a certain time, the R1280D Series latch both external drivers with their off state by its Latch-type protection circuit. Delay time for protection is internally fixed typically at 100ms. To release the protection circuit, restart with power-on (Voltage supplier is equal or less than UVLO detector threshold level), or as for R1280D002B, once after making the circuit be stand-by with chip enable pin and enable the circuit again.

FEATURES

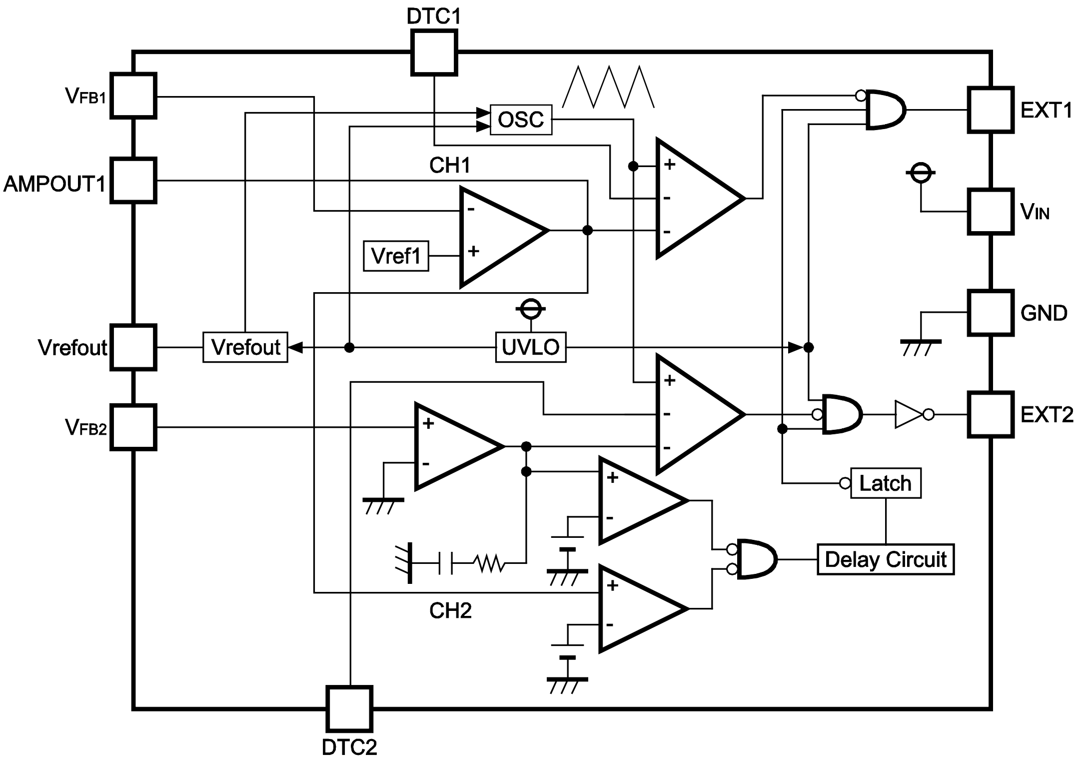
- Input Voltage Range .... 2.5V to 5.5V
- Built-in Latch-type Protection Function by monitoring duty cycle (Fixed Delay Time Typ. 100ms)
- Oscillator Frequency .... 700kHz (R1280D002A,B)/200kHz (R1280D002C)
- Maximum Duty Cycle .... Typ. 90% (Only applied to R1280D002B Series)
- High Reference Voltage Accuracy .... ±1.5%
- U.V.L.O. Threshold... Typ. 2.2V (Hysteresis: Typ. 0.1V)
- Small Package .... thin SON-10 (package thickness Max. 0.9mm)

APPLICATIONS

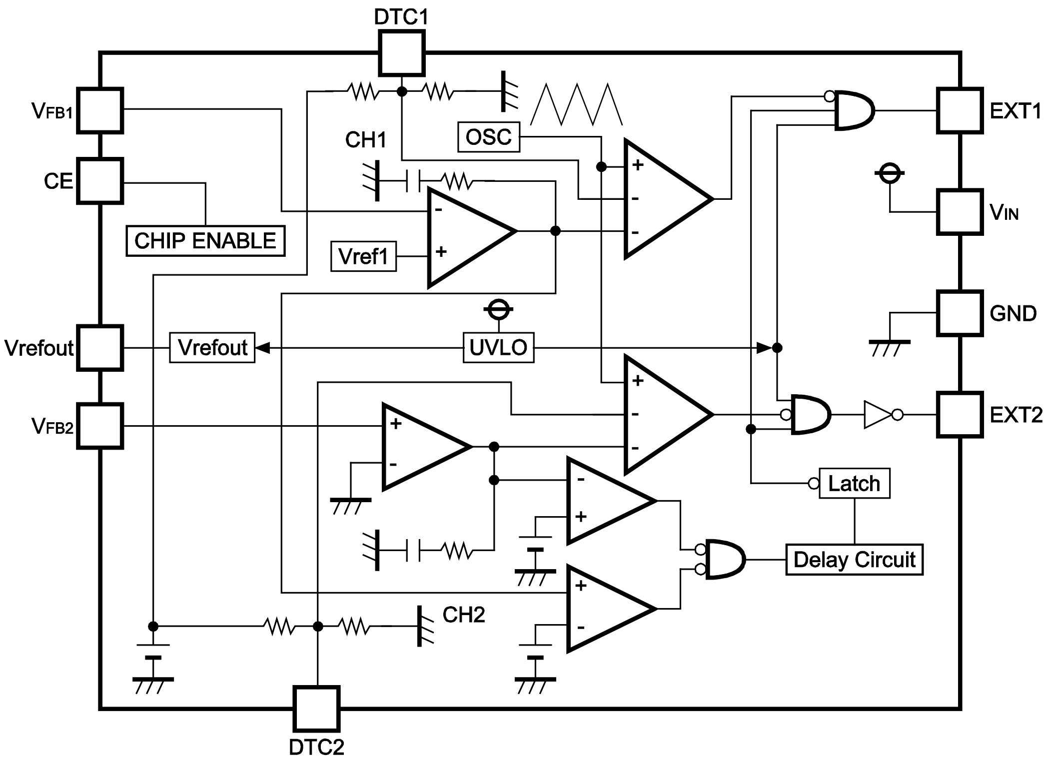
- Constant Voltage Power Source for Portable Equipment.
- Constant Voltage Power Source for LCD and CCD.

BLOCK DIAGRAM

- **R1280D002A/C**



- **R1280D002B**



SELECTION GUIDE

The mask option for the ICs can be selected at the user's request. The selection can be made with designating the part number as shown below;

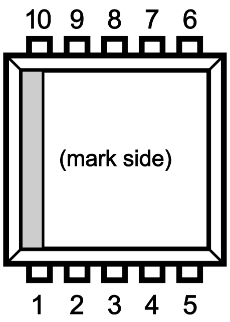
Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1280D002x-TR-FE	SON-10	3,000 pcs	Yes	Yes

x: Designation of Mask Option
A version: fosc=700kHz, with External Phase Compensation for Channel 1
B version: fosc=700kHz, with Internal Phase Compensation and standby mode
C version: fosc=200kHz, with External Phase Compensation for Channel 1

PIN CONFIGURATION

● SON10



PIN DESCRIPTION

- **R1280D002A/C**

Pin No	Symbol	Description
1	EXT1	External Transistor of Channel 1 Drive Pin (CMOS Output)
2	GND	Ground Pin
3	AMPOUT1	Amplifier Output Pin of Channel 1
4	DTC1	Maximum Duty Cycle of Channel 1 Setting Pin
5	V_{FB1}	Feedback pin of Channel 1
6	V_{FB2}	Feedback pin of Channel 2
7	DTC2	Maximum Duty Cycle of Channel 2 Setting Pin
8	Vrefout	Reference Output Pin
9	V_{IN}	Voltage Supply Pin of the IC
10	EXT2	External Transistor of Channel 2 Drive Pin (CMOS Output)

- **R1280D002B**

Pin No	Symbol	Description
1	EXT1	External Transistor of Channel 1 Drive Pin (CMOS Output)
2	GND	Ground Pin
3	CE	Chip Enable Pin
4	DTC1	Soft-start Time of Channel 1 Setting Pin
5	V_{FB1}	Feedback pin of Channel 1
6	V_{FB2}	Feedback pin of Channel 2
7	DTC2	Soft-start Time of Channel 2 Setting Pin
8	Vrefout	Reference Output Pin
9	V_{IN}	Voltage Supply Pin of the IC
10	EXT2	External Transistor of Channel 2 Drive Pin (CMOS Output)

ABSOLUTE MAXIMUM RATINGS

- **R1280D002A/C**

Symbol	Item	Rating	Unit
V_{IN}	V_{IN} Pin Voltage	6.5	V
$V_{EXT1,2}$	$V_{EXT1,2}$ Pin Output Voltage	-0.3~$V_{IN}+0.3$	V
$V_{AMPOUT1}$	AMPOUT1 Pin Voltage	-0.3~$V_{IN}+0.3$	V
$V_{DTC1,2}$	DTC1,2 Pin Voltage	-0.3~$V_{IN}+0.3$	V
Vrefout	V_{REFOUT} Pin Voltage	-0.3~$V_{IN}+0.3$	V
$V_{FB1,2}$	$V_{FB1,VFB2}$ Pin Voltage	-0.3~$V_{IN}+0.3$	V
$I_{EXT1,2}$	EXT1,2 Pin Output Current	±50	mA
P_D	Power Dissipation	250	mW
Topt	Operating Temperature Range	−40 to +85	°C
Tstg	Storage Temperature Range	−55 to +125	°C

- **R1280D002B**

Symbol	Item	Rating	Unit
V_{IN}	V_{IN} Pin Voltage	6.5	V
$V_{EXT1,2}$	$V_{EXT1,2}$ Pin Output Voltage	-0.3~$V_{IN}+0.3$	V
V_{CE}	CE Pin Voltage	-0.3~$V_{IN}+0.3$	V
$V_{DTC1,2}$	DTC1,2 Pin Voltage	-0.3~$V_{IN}+0.3$	V
Vrefout	V_{REFOUT} Pin Voltage	-0.3~$V_{IN}+0.3$	V
$V_{FB1,2}$	V_{FB1},V_{FB2} Pin Voltage	-0.3~$V_{IN}+0.3$	V
$I_{EXT1,2}$	EXT1,2 Pin Output Current	±50	mA
P_D	Power Dissipation	250	mW
Topt	Operating Temperature Range	−40 to +85	°C
Tstg	Storage Temperature Range	−55 to +125	°C

ELECTRICAL CHARACTERISTICS

• R1280D002A

Topt=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		2.5		5.5	V
V_{REFOUT}	V_{REFOUT} Voltage Tolerance	V_{IN}=3.3V, I_{OUT}=1mA	1.478	1.500	1.522	V
I_{ROUT}	V_{REFOUT} Output Current	V_{IN}=3.3V	20			mA
$\Delta V_{REFOUT}/\Delta V_{IN}$	V_{REFOUT} Line Regulation	2.5V ≦ V_{IN} ≦ 5.5V		2	6	mV
$\Delta V_{REFOUT}/\Delta I_{OUT}$	V_{REFOUT} Load Regulation	1mA ≦ I_{ROUT} ≦ 10mA V_{IN}=3.3V		6	12	mV
I_{LIM}	V_{REFOUT} Short Current Limit	V_{IN}=3.3V, V_{REFOUT}=0V		25		mA
$\Delta V_{REFOUT}/\Delta T$	V_{REFOUT} Voltage Temperature Coefficient	−40°C ≦ Topt ≦ 85°C		±150		ppm/°C
V_{FB1}	V_{FB1} Voltage	V_{IN}=3.3V	0.985	1.000	1.015	V
$\Delta V_{FB1}/\Delta T$	V_{FB1} Voltage Temperature Coefficient	−40°C ≦ Topt ≦ 85°C		±150		ppm/°C
$I_{FB1,2}$	$I_{FB1,2}$ Input Current	V_{IN}=5.5V,V_{FB1} or V_{FB2}=0V or 5.5V	−0.1		0.1	µA
f_{OSC}	Oscillator Frequency	EXT1,2 Pins at no load, V_{IN}=3.3V	595	700	805	kHz
I_{DD1}	Supply Current	V_{IN}=5.5V, EXT1,2 pins at no load		1.4	3.0	mA
R_{EXTH1}	EXT1 "H" ON Resistance	V_{IN}=3.3V, I_{EXT}=−20mA		4.0	8.0	Ω
R_{EXTL1}	EXT1 "L" ON Resistance	V_{IN}=3.3V, I_{EXT}=20mA		2.7	5.0	Ω
R_{EXTH2}	EXT2 "H" ON Resistance	V_{IN}=3.3V, I_{EXT}=−20mA		4.0	8.0	Ω
R_{EXTL2}	EXT2 "L" ON Resistance	V_{IN}=3.3V, I_{EXT}=20mA		3.7	8.0	Ω
T_{DLY}	Delay Time for Protection	V_{IN}=3.3V, V_{FB1}=1.1V→0V	60	100	140	ms
V_{UVLOD}	UVLO Detector Threshold		2.10	2.20	2.35	V
V_{UVLO}	UVLO Released Voltage			V_{UVLOD} +0.10	2.45	V
V_{DTC10}	CH1 Duty=0%	V_{IN}=3.3V	0.1	0.2	0.3	V
$V_{DTC1100}$	CH1 Duty=100%	V_{IN}=3.3V	1.1	1.2	1.3	V
V_{DTC20}	CH2 Duty=0%	V_{IN}=3.3V	0.1	0.2	0.3	V
$V_{DTC2100}$	CH2 Duty=100%	V_{IN}=3.3V	1.1	1.2	1.3	V
A_{V1}	CH1 Open Loop Gain	V_{IN}=3.3V		110		dB
F_{T1}	CH1 Single Gain Frequency Band	V_{IN}=3.3V, A_{V1}=0dB		1.9		MHz
V_{ICR1}	CH1 Input Voltage Rang	V_{IN}=3.3V		0.7 to V_{IN}		V
I_{AMPL}	CH1 Sink Current	V_{IN}=3.3V, $V_{AMPOUT1}$=1.0V, V_{FB1}=V_{FB1}+ 0.1V	70	115		µA
I_{AMPH}	CH1 Source Current	V_{IN}=3.3V, $V_{AMPOUT1}$=1.0V, V_{FB1}=V_{FB1}− 0.1V		−1.4	−0.7	mA
A_{V2}	CH2 Open Loop Gain	V_{IN}=3.3V		60		dB
F_{T2}	CH2 Single Gain Frequency Band	V_{IN}=3.3V, AV2=0dB		3		MHz
V_{ICR2}	CH2 Input Voltage Range	V_{IN}=3.3V		−0.2 to V_{IN}−1.3		V
V_{FB2}	CH2 Input Offset Voltage	V_{IN}=3.3V	−12		12	mV

- **R1280D002B**

Topt=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		2.5		5.5	V
V_{REFOUT}	V_{REFOUT} Voltage Tolerance	V_{IN}=3.3V, I_{OUT}=1mA	1.478	1.500	1.522	V
I_{ROUT}	V_{REFOUT} Output Current	V_{IN}=3.3V	20			mA
$\Delta V_{REFOUT}/\Delta V_{IN}$	V_{REFOUT} Line Regulation	2.5V ≦ V_{IN} ≦ 5.5V		2	6	mV
$\Delta V_{REFOUT}/\Delta I_{OUT}$	V_{REFOUT} Load Regulation	1mA ≦ I_{ROUT} ≦ 10mA V_{IN}=3.3V		6	12	mV
I_{LIM}	V_{REFOUT} Short Current Limit	V_{IN}=3.3V, V_{REFOUT}=0V		25		mA
$\Delta V_{REFOUT}/\Delta T$	V_{REFOUT} Voltage Temperature Coefficient	−40°C ≦ Topt ≦ 85°C		±150		ppm/°C
V_{FB1}	V_{FB1} Voltage	V_{IN}=3.3V	0.985	1.000	1.015	V
$\Delta V_{FB1}/\Delta T$	V_{FB1} Voltage Temperature Coefficient	−40°C ≦ Topt ≦ 85°C		±150		ppm/°C
$I_{FB1,2}$	$I_{FB1,2}$ Input Current	V_{IN}=5.5V,V_{FB1} or V_{FB2}=0V or 5.5V	−0.1		0.1	μA
f_{OSC}	Oscillator Frequency	EXT1,2 Pins at no load, V_{IN}=3.3V	595	700	805	kHz
I_{DD1}	Supply Current	V_{IN}=5.5V, EXT1,2 pins at no load		1.4	3.0	mA
Maxdty	Maximum Duty Cycle	V_{IN}=3.3V, $C_{DTC1,2}$=1000pF	84	90	95	%
R_{EXTH1}	EXT1 "H" ON Resistance	V_{IN}=3.3V, I_{EXT}=−20mA		4.0	8.0	Ω
R_{EXTL1}	EXT1 "L" ON Resistance	V_{IN}=3.3V, I_{EXT}=20mA		2.7	5.0	Ω
R_{EXTH2}	EXT2 "H" ON Resistance	V_{IN}=3.3V, I_{EXT}=−20mA		4.0	8.0	Ω
R_{EXTL2}	EXT2 "L" ON Resistance	V_{IN}=3.3V, I_{EXT}=20mA		3.7	8.0	Ω
T_{DLY}	Delay Time for Protection	V_{IN}=3.3V, V_{FB1}=1.1V→0V	60	100	140	ms
T_{SS1}	Soft Start Time1 for Ch1	V_{IN}=3.3V, C_{DTC1}=0.33μF		10		ms
T_{SS2}	Soft Start Time2 for Ch2	V_{IN}=3.3V, C_{DTC2}=0.33μF		15		ms
V_{CEH}	CE "H" Input Voltage	V_{IN}=5.5V	1.5			V
V_{CEL}	CE "L" Input Voltage	V_{IN}=2.5V			0.3	V
V_{UVLOD}	UVLO Detector Threshold		2.10	2.20	2.35	V
V_{UVLO}	UVLO Released Voltage			V_{UVLOD} +0.10	2.45	V
I_{CEH}	CE "H" Input Current	V_{IN}= V_{CE}=5.5V	−0.1		0.1	μA
I_{CEL}	CE "L" Input Current	V_{IN}=5.5V, V_{CE}=0.0V	−0.1		0.1	μA
I_{STB}	Standby Current	V_{IN}=5.5V, V_{CE}=0.0V		0	2	μA
V_{OFF2}	Input Offset Voltage of Ch2.	V_{IN}=3.3V	−12		12	mV

- **R1280D002C**

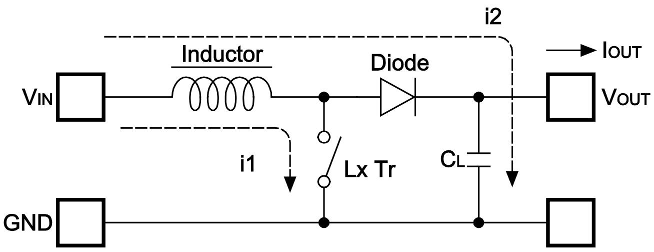
Topt=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		2.5		5.5	V
V_{REFOUT}	V_{REFOUT} Voltage Tolerance	V_{IN}=3.3V, I_{OUT}=1mA	1.478	1.500	1.522	V
I_{ROUT}	V_{REFOUT} Output Current	V_{IN}=3.3V	20			mA
$\Delta V_{REFOUT}/\Delta V_{IN}$	V_{REFOUT} Line Regulation	2.5V ≦ V_{IN} ≦ 5.5V		2	6	mV
ΔV_{REFOUT} $/\Delta I_{OUT}$	V_{REFOUT} Load Regulation	1mA ≦ I_{ROUT} ≦ 10mA V_{IN}=3.3V		6	12	mV
I_{LIM}	V_{REFOUT} Short Current Limit	V_{IN}=3.3V, V_{REFOUT}=0V		25		mA
$\Delta V_{REFOUT}/\Delta T$	V_{REFOUT} Voltage Temperature Coefficient	−40°C ≦ Topt ≦ 85°C		±150		ppm/°C
V_{FB1}	V_{FB1} Voltage	V_{IN}=3.3V	0.985	1.000	1.015	V
$\Delta V_{FB1}/\Delta T$	V_{FB1} Voltage Temperature Coefficient	−40°C ≦ Topt ≦ 85°C		±150		ppm/°C
$I_{FB1,2}$	$I_{FB1,2}$ Input Current	V_{IN}=5.5V,V_{FB1} or V_{FB2}=0V or 5.5V	−0.1		0.1	μA
f_{OSC}	Oscillator Frequency	EXT1,2 Pins at no load, V_{IN}=3.3V	160	200	240	kHz
I_{DD1}	Supply Current	V_{IN}=5.5V, EXT1,2 pins at no load		0.7	1.2	mA
R_{EXTH1}	EXT1 "H" ON Resistance	V_{IN}=3.3V, I_{EXT}=−20mA		4.0	8.0	Ω
R_{EXTL1}	EXT1 "L" ON Resistance	V_{IN}=3.3V, I_{EXT}=20mA		2.7	5.0	Ω
R_{EXTH2}	EXT2 "H" ON Resistance	V_{IN}=3.3V, I_{EXT}=−20mA		4.0	8.0	Ω
R_{EXTL2}	EXT2 "L" ON Resistance	V_{IN}=3.3V, I_{EXT}=20mA		3.7	8.0	Ω
T_{DLY}	Delay Time for Protection	V_{IN}=3.3V, V_{FB1}=1.1V→0V	50	100	150	ms
V_{UVLOD}	UVLO Detector Threshold		2.10	2.20	2.35	V
V_{UVLO}	UVLO Released Voltage			V_{UVLOD} +0.10	2.45	V
V_{DTC10}	CH1 Duty=0%	V_{IN}=3.3V	0.15	0.25	0.35	V
$V_{DTC1100}$	CH1 Duty=100%	V_{IN}=3.3V	1.1	1.2	1.3	V
V_{DTC20}	CH2 Duty=0%	V_{IN}=3.3V	0.15	0.25	0.35	V
$V_{DTC2100}$	CH2 Duty=100%	V_{IN}=3.3V	1.1	1.2	1.3	V
A_{V1}	CH1 Open Loop Gain	V_{IN}=3.3V		110		dB
F_{T1}	CH1 Single Gain Frequency Band	V_{IN}=3.3V, A_{V1}=0dB		1.9		MHz
V_{ICR1}	CH1 Input Voltage Range	V_{IN}=3.3V		0.7 to V_{IN}		V
I_{AMPL}	CH1 Sink Current	V_{IN}=3.3V, $V_{AMPOUT1}$=1.0V, V_{FB1}=V_{FB1}+ 0.1V	70	115		μA
I_{AMPH}	CH1 Source Current	V_{IN}=3.3V, $V_{AMPOUT1}$=1.0V, V_{FB1}=V_{FB1}− 0.1V		−1.4	−0.7	mA
A_{V2}	CH2 Open Loop Gain	V_{IN}=3.3V		60		dB
F_{T1}	CH2 Single Gain Frequency Band	V_{IN}=3.3V, A_{V2}=0dB		3		MHz
V_{ICR1}	CH2 Input Voltage Range	V_{IN}=3.3V		−0.2 to V_{IN}−1.3		V
V_{FB2}	CH2 Input Offset Voltage	V_{IN}=3.3V	−12		12	mV

Operation of Step-up DC/DC Converter and Output Current

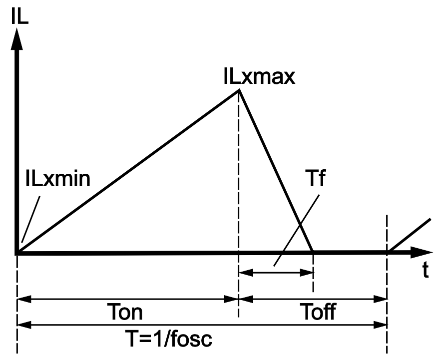
Step-up DC/DC Converter makes higher output voltage than input voltage by releasing the energy accumulated during on time of L_X Transistor on input voltage.

<Basic Circuit>

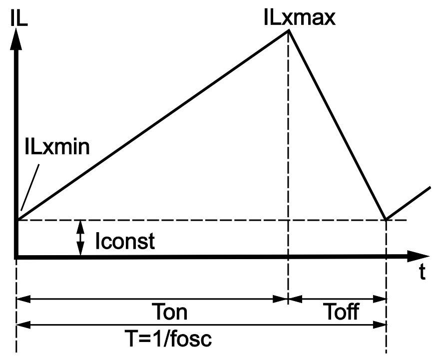


<Current through L>

Discontinuous Mode



Continuous Mode



Step 1. L_X Tr. is on, then the current IL=i1 flows, and the energy is charged in L. In proportion to the on time of L_X Tr. (Ton), IL=i1 increases from IL=IL_Xmin=0 and reaches IL_Xmax.

Step 2. When the L_X Tr. is off, L turns on Schottky Diode (SD), and IL=i2 flows to maintain IL=IL_Xmax.

Step 3. IL=i2 gradually decreases, and after Tf passes, IL=IL_Xmin=0 is true, then SD turns off. Note that in the case of the continuous mode, before IL=IL_Xmin=0 is true, Toff passes, and the next cycle starts, then L_X Tr. turns on again.
In this case, IL_Xmin>0, therefore IL=IL_Xmin>0 is another starting point and IL_X max increases.

With the PWM controller, switching times during the time unit are fixed. By controlling T_{on}, output voltage is maintained.

Output Current and Selection of External Components

Output Current of Step-up Circuit and External Components

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.

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

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

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

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

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

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

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

$$I_{OUT} = f_{OSC} \times V_{IN}^2 \times Ton^2/\{2 \times L \times (V_{OUT} - V_{IN})\} = V_{IN}^2 \times Ton/(2 \times L \times V_{OUT})$$ .... 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,

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

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

$IL_Xmax = Iconst + V_{IN} \times Ton/L$ ....Formula 7

With the formula 4,6, and IL_Xmax is,

$IL_Xmax = V_{OUT}/V_{IN} \times I_{OUT} + V_{IN} \times Ton/(2 \times L)$..........Formula 8

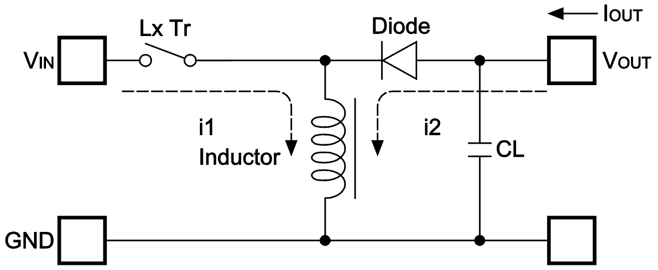
Therefore, peak current is more than I_{OUT}. Considering the value of IL_Xmax, the condition of input and output, and external components should be selected.

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

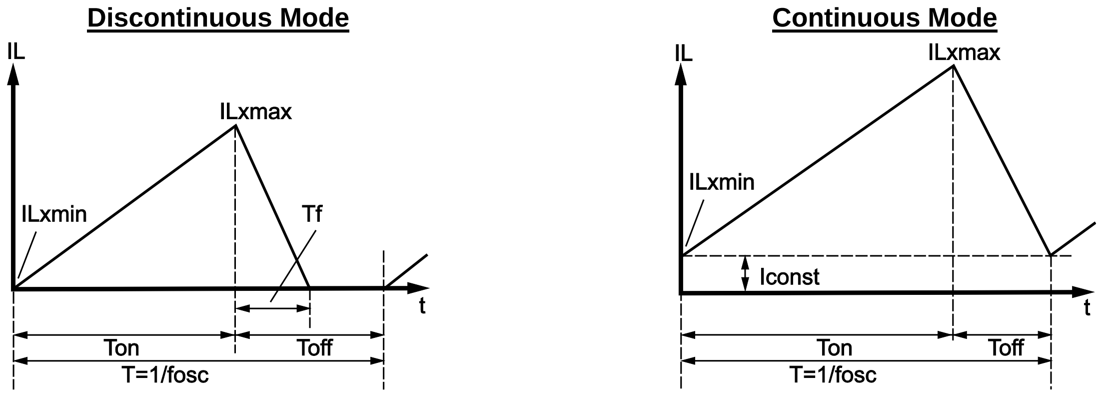
The explanation above is based on the ideal calculation, and the loss caused by L_X switch and external components is not included. The actual maximum output current is between 50% and 80% of the calculation. Especially, when the IL_X is large, or V_{IN} is low, the loss of V_{IN} is generated with the on resistance of the switch. As for V_{OUT}, Vf (as much as 0.3V) of the diode should be considered.

Operation of Inverting DC/DC converter and Output Current

Inverting DC/DC converter saves energy during on time of Lx transistor, and supplies the energy to output during off time, output voltage opposed to input voltage is obtained.



<Current through L>



Step 1. Lx Tr. turns on, current, IL=i1 flows, energy is charged in L. In proportion to the on time, Ton, of Lx Tr. IL=i1 increases from IL=ILxmin=0 and reaches ILxmax.

Step 2. When the Lx Tr. turns off, L turns on Shottky diode (SD) and flow IL=i2 to maintain IL = ILxmax.

Step 3. IL=i2 decreases gradually, after Tf passes, IL=ILxmin=0 is true, then SD turns off. Note that in the case of continuous mode, before IL=ILxmin=0 is true, Toff passes and next cycle starts, then Lx Tr. turns on. In this case, ILxmin>0, therefore IL increases from IL=ILxmin>0.

With the PWM controller, switching time (fosc) in the time unit is fixed, and by controlling Ton, output voltage is maintained.

Output Current and Selection of External Components

There are also two modes, or discontinuous mode and continuous mode for the PWM inverting 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, which is supplied with input side, can be described as in next formula.

$$P = \int_0^{Ton} V_{IN}^2 \times t/L \; dt \quad \text{.......... Formula 9}$$

Thus average electric power in one cycle, P_{AV} is described as in the next formula.

$$P_{AV} = 1/(Ton + Toff) \times \int_0^{Ton} V_{IN}^2 \times t/L \; dt = V_{IN}^2 \times Ton^2/(2 \times L \times (Ton + Toff)) \quad \text{.......... Formula 10}$$

This electric power P_{AV} equals to output electric power $V_{OUT} \times I_{OUT}$, thus,

$$I_{OUT} = f_{OSC} \times V_{IN}^2 \times Ton^2/(2 \times L \times V_{OUT}) \quad \text{.......... Formula 11}$$

When I_{OUT} becomes more than $V_{IN} \times Ton \times Toff/(2 \times L \times (Ton+Toff))$, the current flows through the inductor continuously, then the mode becomes continuous. In the continuous mode, the deviation of the current equals between Ton and Toff, therefore,

$$V_{IN} \times Ton/L = V_{OUT} \times Toff/L \quad \text{.......... Formula 12}$$

In this moment, the current flowing continuously through L, is assumed as Iconst, I_{OUT} is described as in the next formula:

$$I_{OUT} = f_{OSC} \times V_{IN}^2 \times T_{ON}^2/(2 \times L \times V_{OUT}) + Ton/(Ton+Toff) \times V_{IN} \times Iconst/V_{OUT} \quad \text{.......... Formula 13}$$

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

$$IL_X max = Iconst + V_{IN} \times Ton/L \quad \text{.......... Formula 14}$$

With the formula 12,13, ILxmax is,

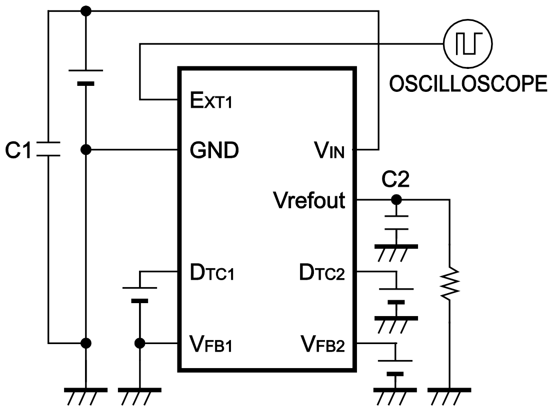
$$IL_X max = (Ton+Toff)/Toff \times I_{OUT} + V_{IN} \times Ton/(2 \times L) \quad \text{.......... Formula 15}$$

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

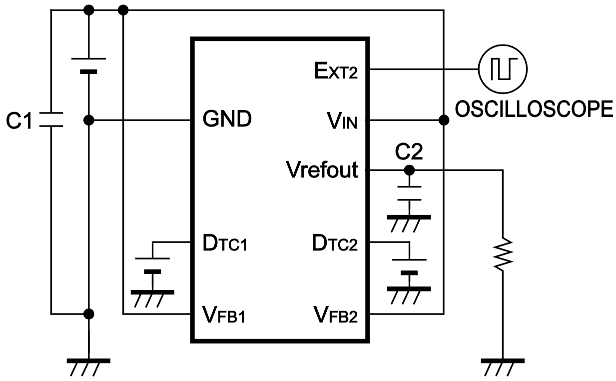
In the formula 14, peak current $IL_X max$ at discontinuous mode can be calculated. Put Iconst=0 in the formula.

The explanation above is based on the ideal calculation, and the loss caused by L_X switch and external components is not included. The actual maximum output current is between 50% and 80% of the calculation. Especially, when the IL_X is large, or V_{IN} is low, the loss of V_{IN} is generated with the on resistance of the switch. As for V_{OUT}, Vf (as much as 0.3V) of the diode should be considered.

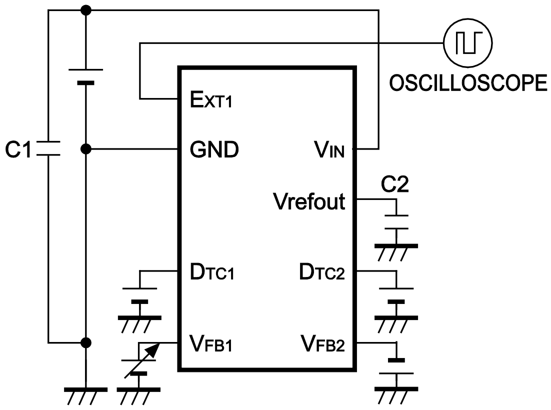
TEST CIRCUITS



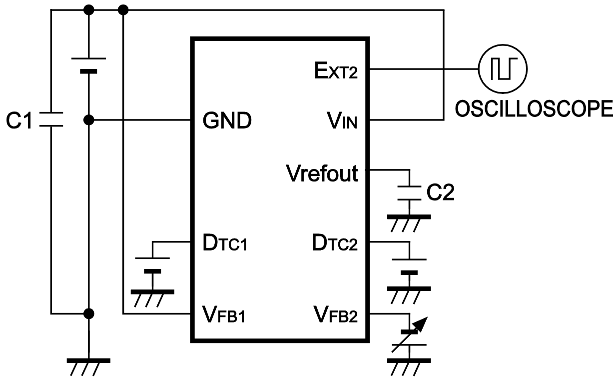
Test Circuit 1



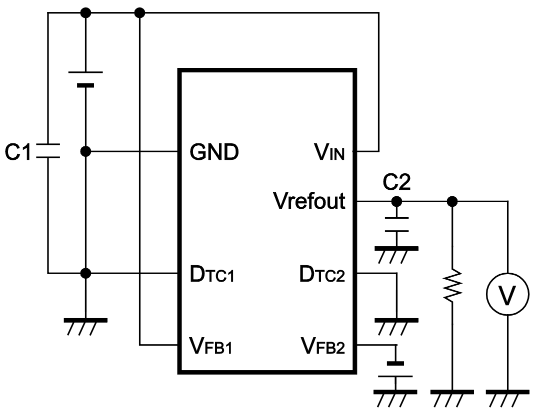
Test Circuit 2



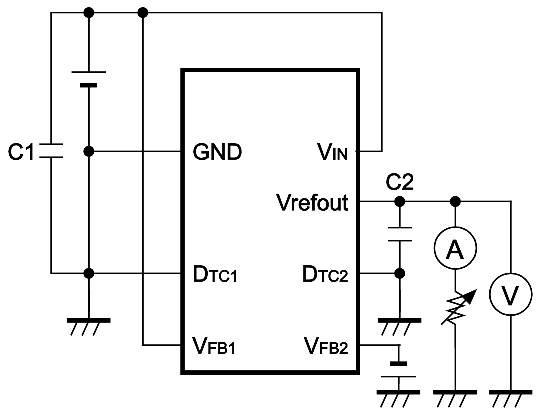
Test Circuit 3



Test Circuit 4

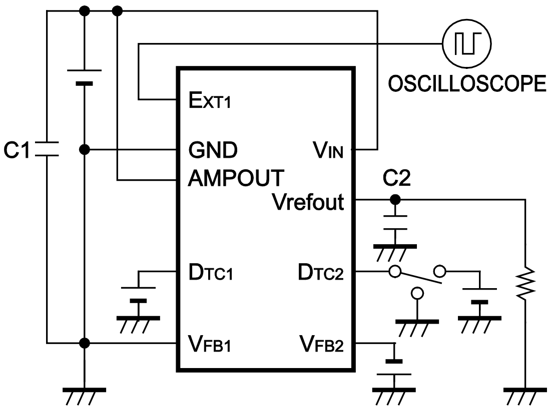


Test Circuit 5

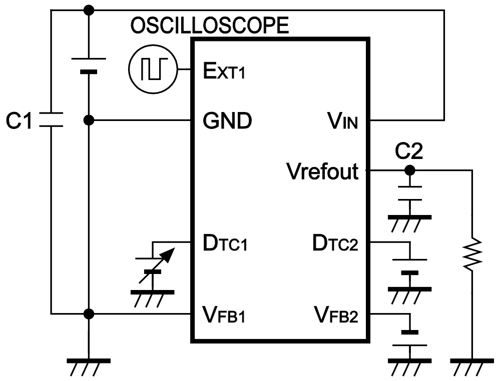


Test Circuit 6

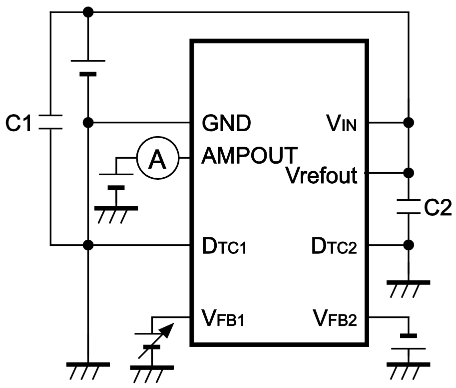
RICOH



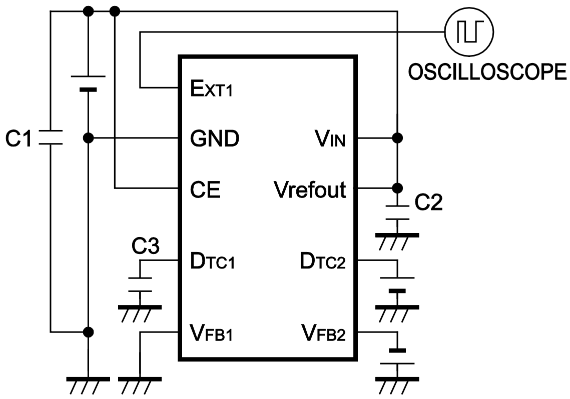
Test Circuit 7



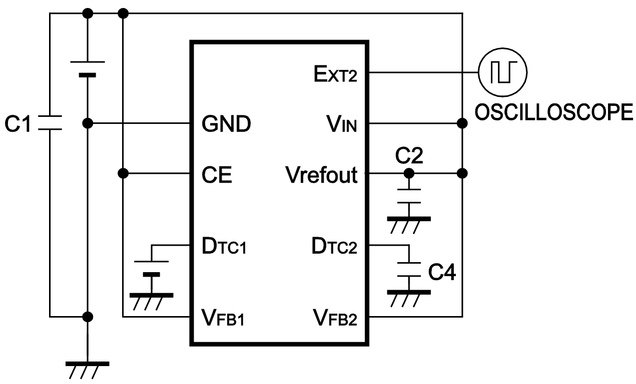
Test Circuit 8



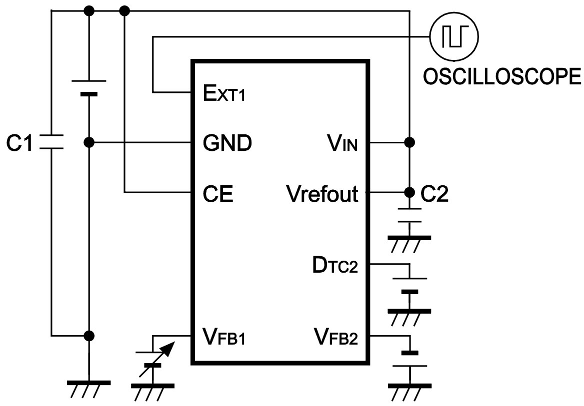
Test Circuit 9



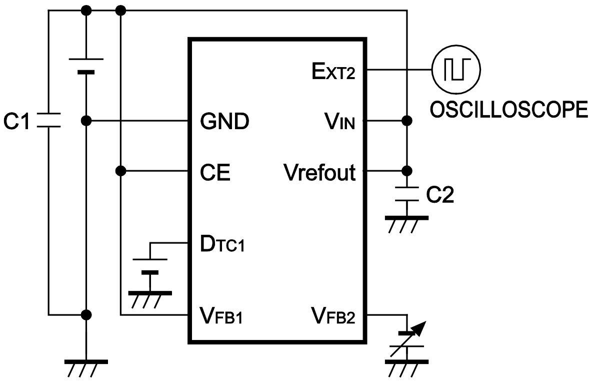
Test Circuit 10



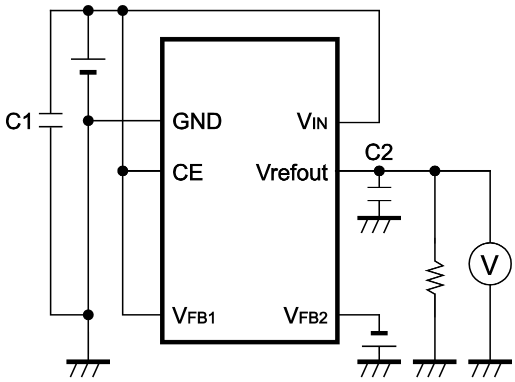
Test Circuit 11



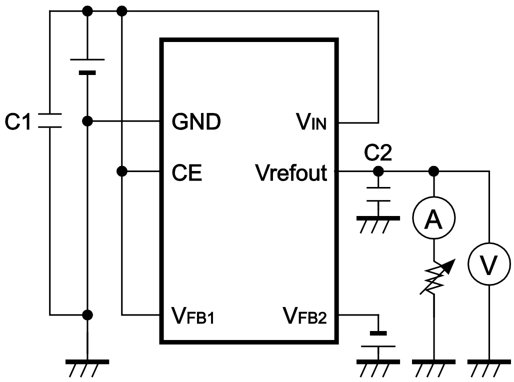
Test Circuit 12



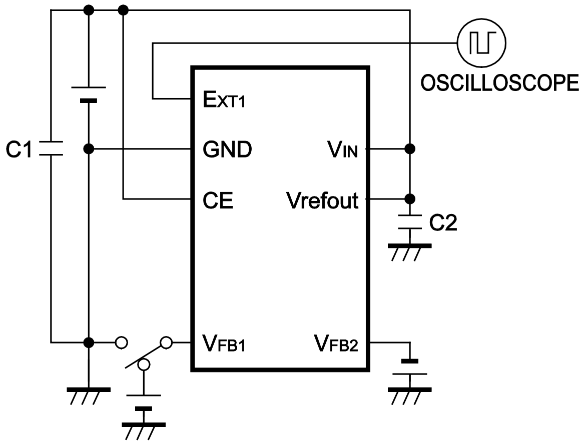
Test Circuit 13



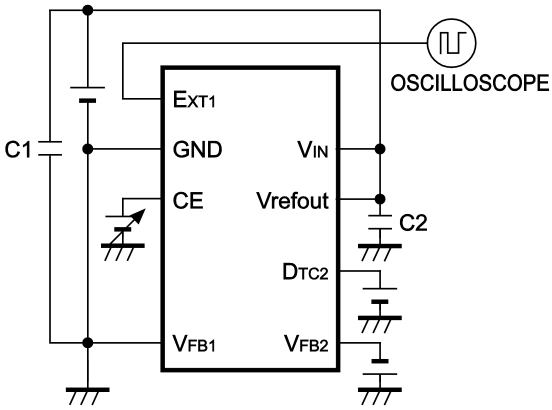
Test Circuit 14



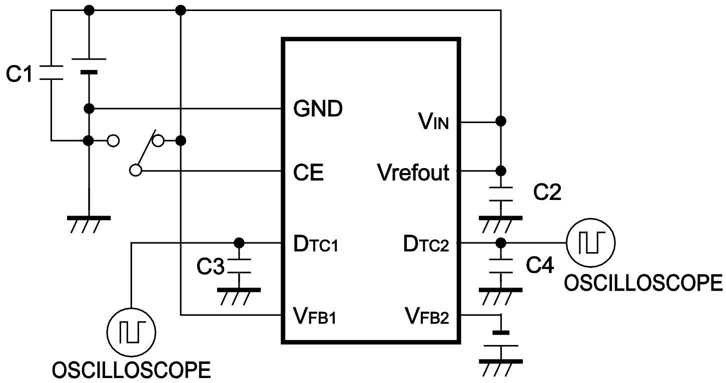
Test Circuit 15



Test Circuit 16



Test Circuit 17



Test Circuit 18

RICOH

Typical Characteristics shown in the following pages are obtained with test circuits shown above.

- **R1280D002A/C**

Test Circuit 1,2 : ypical Characteristic 4)
Test Circuit 3 : Typical Characteristic 6)
Test Circuit 4 : Typical Characteristic 7)
Test Circuit 5 : Typical Characteristic 8)
Test Circuit 6 : Typical Characteristics 9) 10)
Test Circuit 7 : Typical Characteristic 11)
Test Circuit 8 : Typical Characteristic 12)
Test Circuit 9 : Typical Characteristics 13) 14)

- **R1280D002B**

Test Circuit 10,11 : Typical Characteristics 4) 5)
Test Circuit 12 : Typical Characteristic 6)
Test Circuit 13 : Typical Characteristic 7)
Test Circuit 14 : Typical Characteristic 8)
Test Circuit 15 : Typical Characteristics 9) 10)
Test Circuit 16 : Typical Characteristic 11)
Test Circuit 17 : Typical Characteristics 15) 16)
Test Circuit 18 : Typical Characteristics 17) 18)
Standard Circuit Example: Typical Characteristics 1) 2) 3) 19) 20)

Note) Capacitors' values of test circuits
Capacitors: Ceramic Type:
C1=4.7μF, C2=1.0μF, C3=C4=1000pF

Efficiency η(%) can be calculated with the next formula:

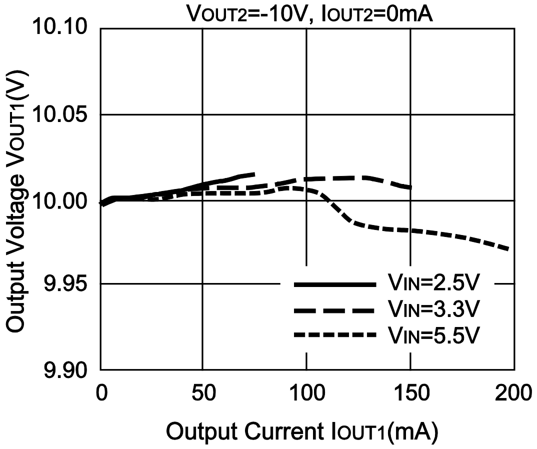
$\eta=(V_{OUT1}\times I_{OUT1}+V_{OUT2}\times I_{OUT2})/(V_{IN}\times I_{IN})\times 100$

TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current

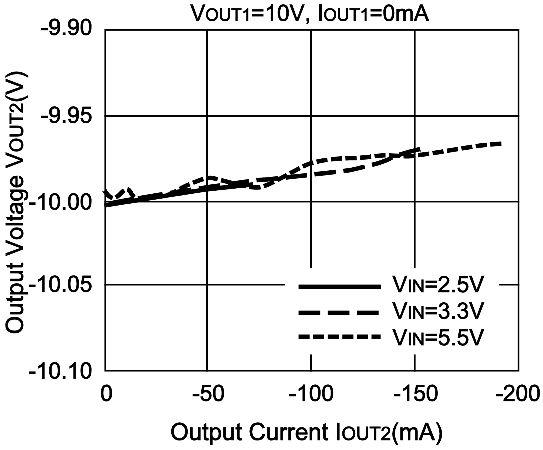
R1280D002A

Topt=25 C, L1=6.8µH, C1=10µF
VOUT2=-10V, IOUT2=0mA



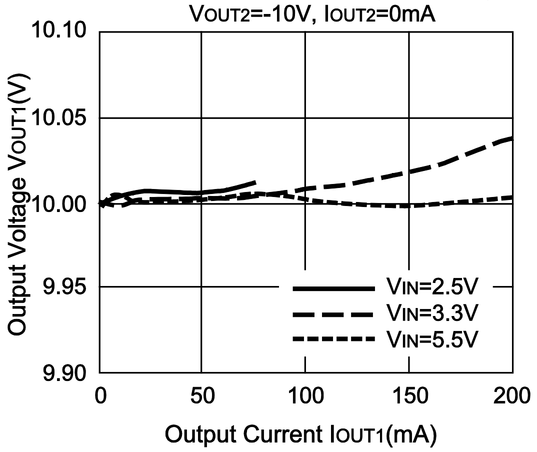
R1280D002A

Topt=25 C, L2=6.8µH, C2=10µF
VOUT1=10V, IOUT1=0mA



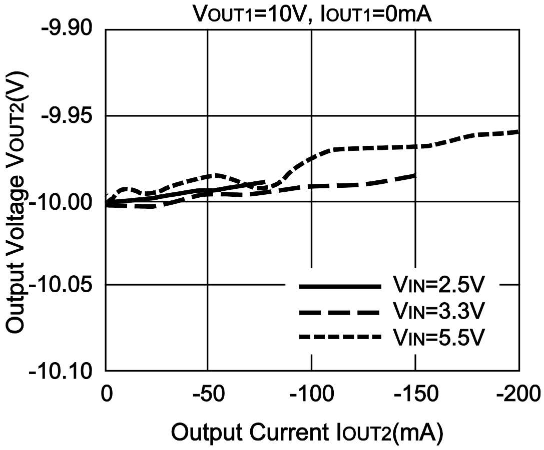
R1280D002B

Topt=25 C, L1=6.8µH, C1=10µF
VOUT2=-10V, IOUT2=0mA



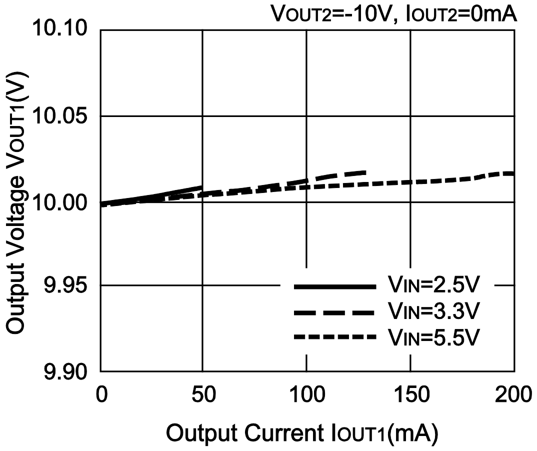
R1280D002B

Topt=25 C, L2=6.8µH, C2=10µF
VOUT1=10V, IOUT1=0mA



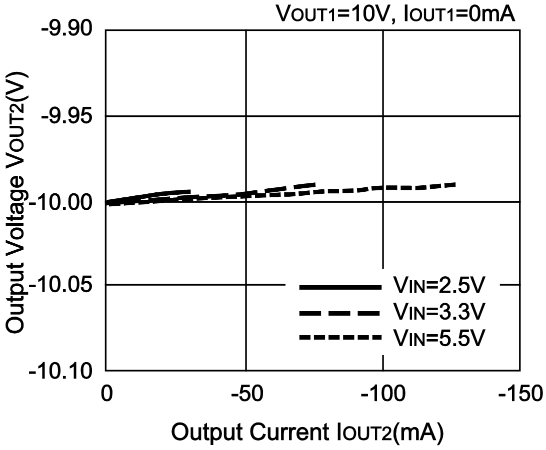
R1280D002C

L1=22µH, C1=10µF
VOUT2=-10V, IOUT2=0mA



R1280D002C

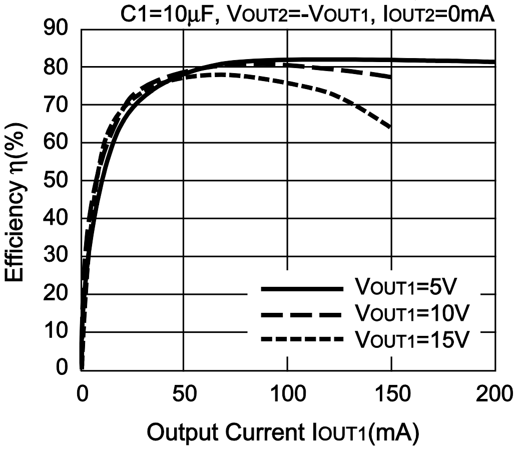
L2=22µH, C2=10µF
VOUT1=10V, IOUT1=0mA



2) Efficiency vs. Output Current

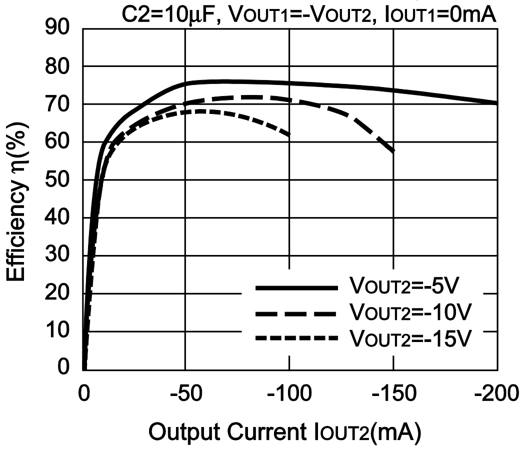
R1280D002A

V_{IN}=3.3V, Topt=25 C, L1=6.8µH
C1=10µF, V_{OUT2}=-V_{OUT1}, I_{OUT2}=0mA



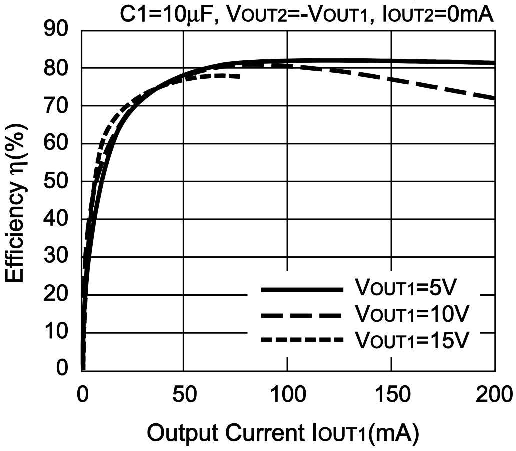
R1280D002A

V_{IN}=3.3V, Topt=25 C, L2=6.8µH
C2=10µF, V_{OUT1}=-V_{OUT2}, I_{OUT1}=0mA



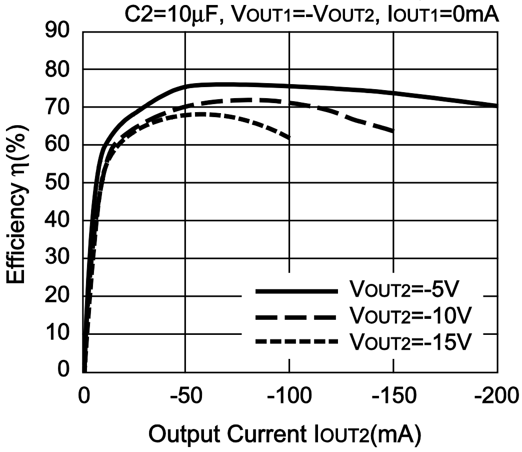
R1280D002B

V_{IN}=3.3V, Topt=25 C, L1=6.8µH
C1=10µF, V_{OUT2}=-V_{OUT1}, I_{OUT2}=0mA



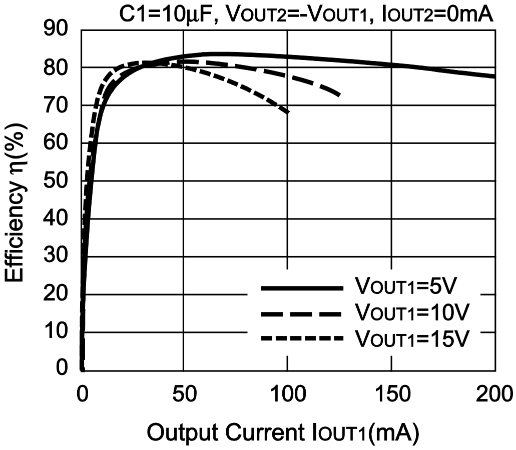
R1280D002B

V_{IN}=3.3V, Topt=25 C, L2=6.8µH
C2=10µF, V_{OUT1}=-V_{OUT2}, I_{OUT1}=0mA



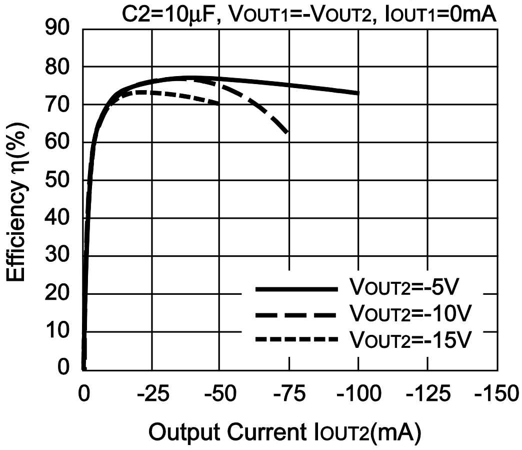
R1280D002C

V_{IN}=3.3V, Topt=25 C, L1=22µH
C1=10µF, V_{OUT2}=-V_{OUT1}, I_{OUT2}=0mA



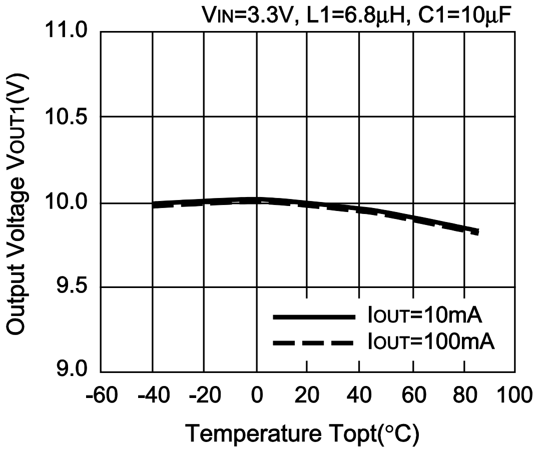
R1280D002C

V_{IN}=3.3V, Topt=25 C, L2=22µH
C2=10µF, V_{OUT1}=-V_{OUT2}, I_{OUT1}=0mA

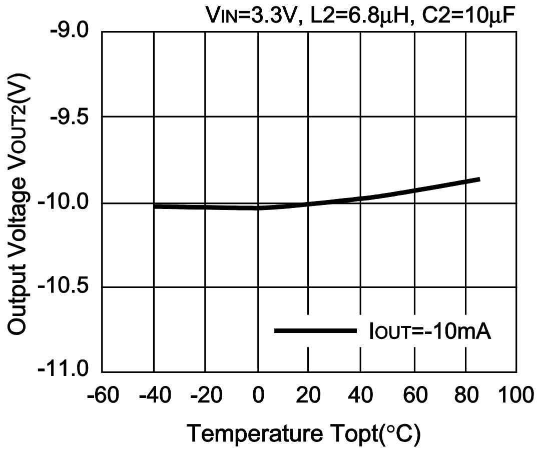


3) Output Voltage vs. Temperature

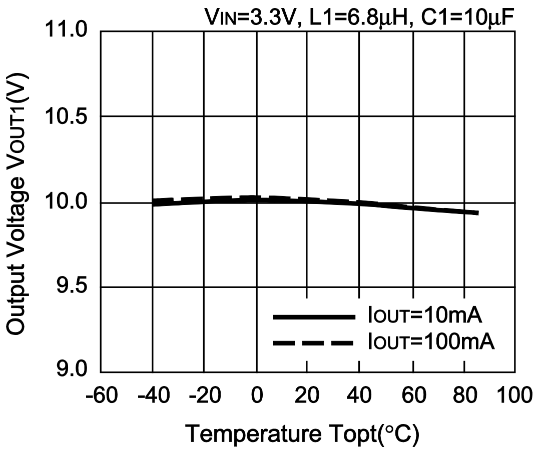
R1280D002A



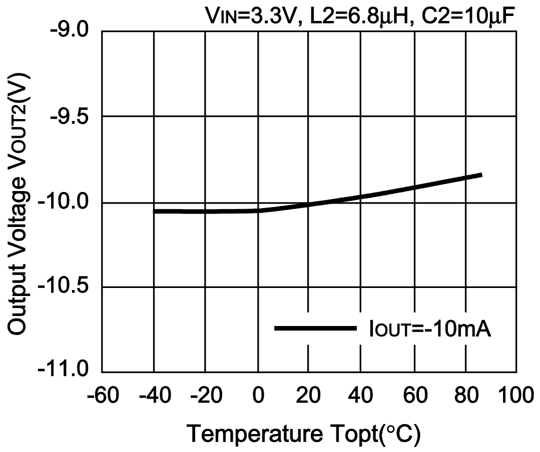
R1280D002A



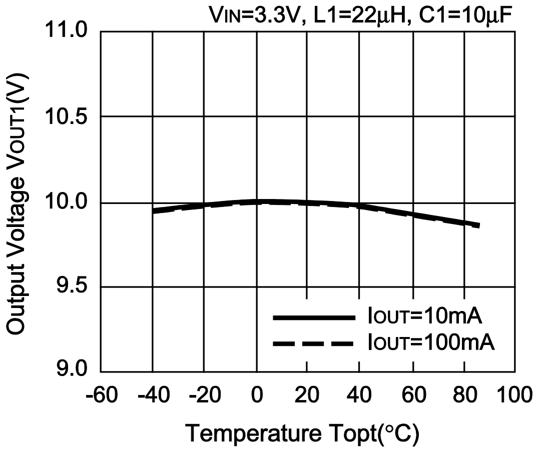
R1280D002B



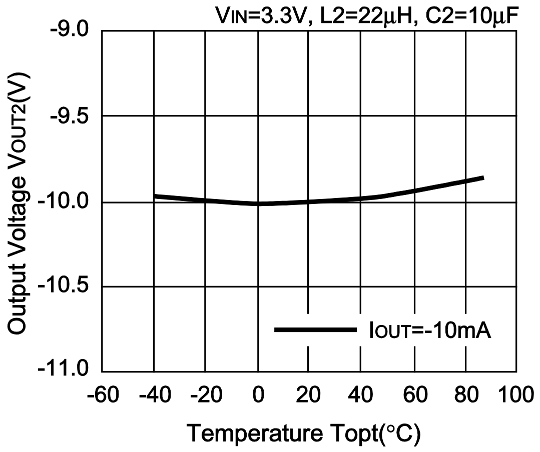
R1280D002B



R1280D002C

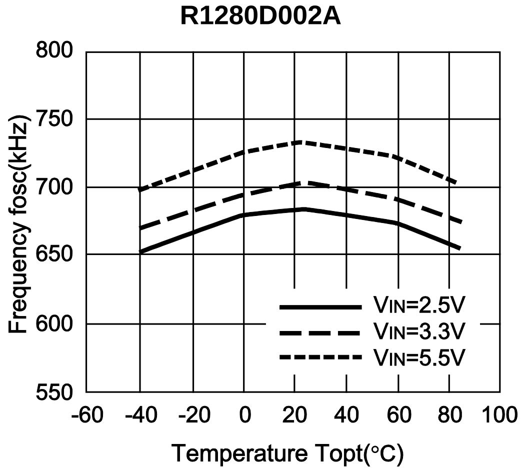


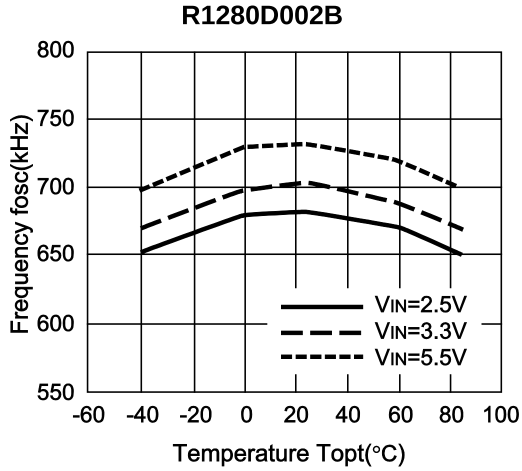
R1280D002C

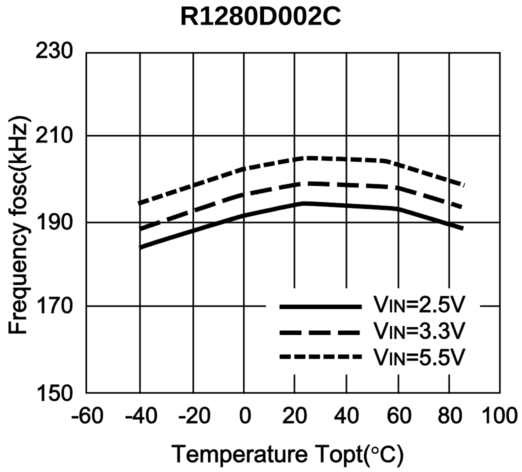


RICOH

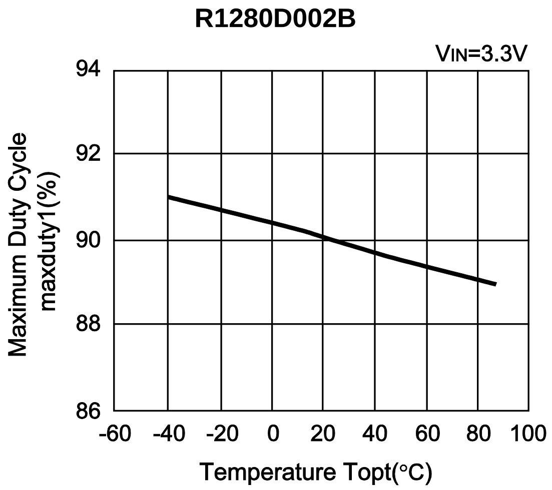
4) Frequency vs. Temperature

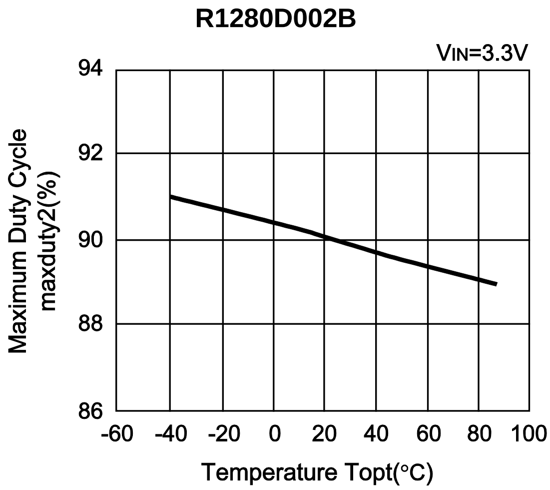




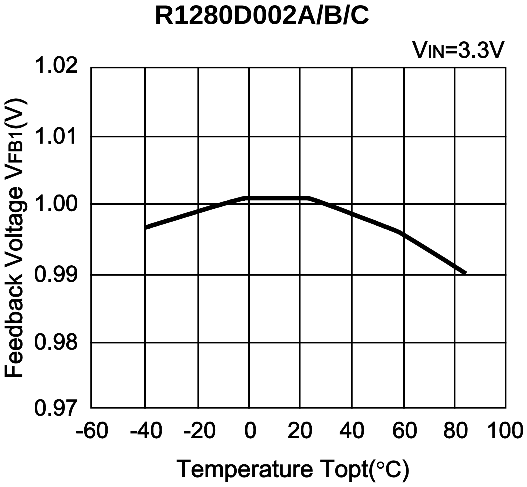


5) Maximum Duty Cycle vs. Temperature

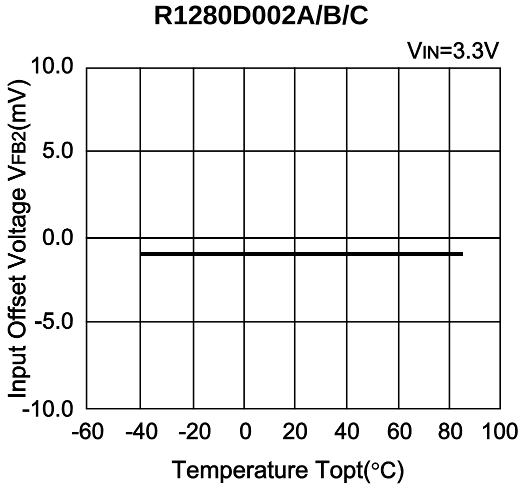




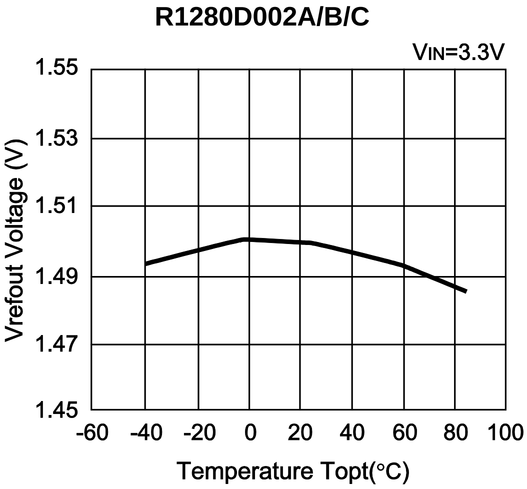
6) Feedback Voltage vs. Temperature



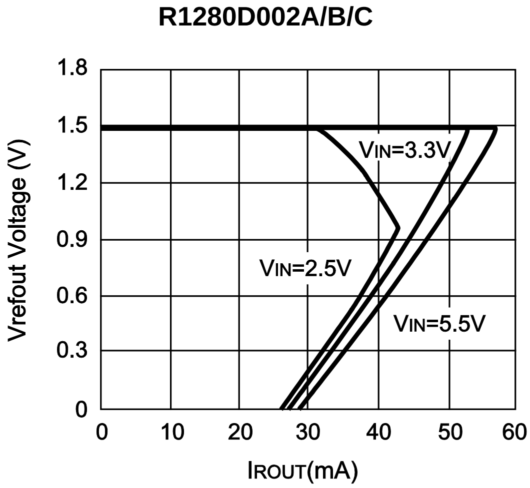
7) Input Offset Voltage vs. Temperature



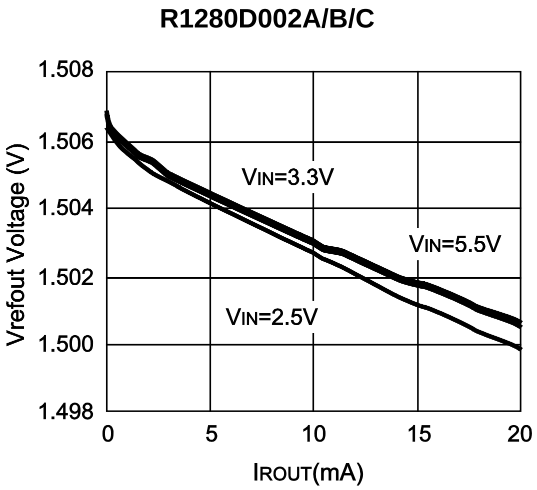
8) Vrefout Output Voltage vs. Temperature



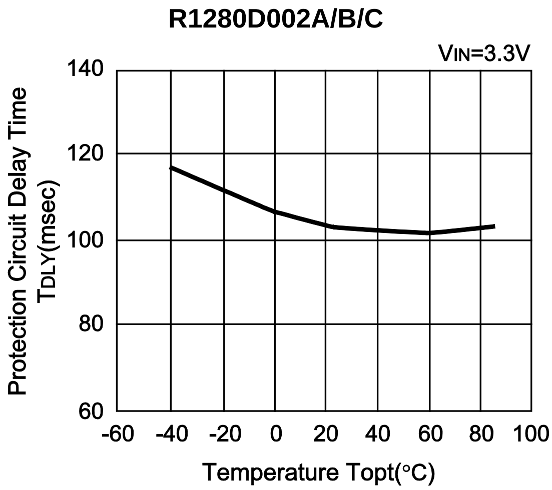
9) Vrefout Output Voltage vs. Output Current



10) Vrefout Output Voltage vs. Output Current

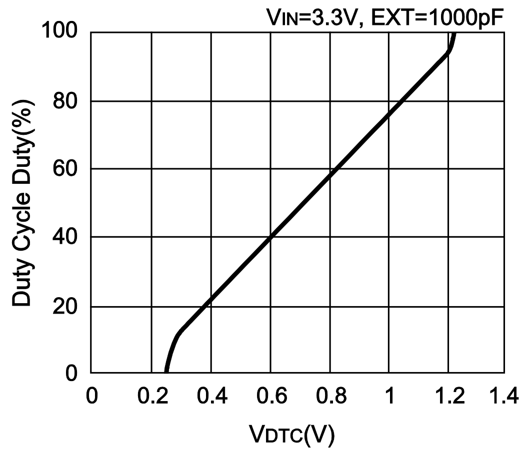


11) Protection Circuit Delay Time vs. Temperature

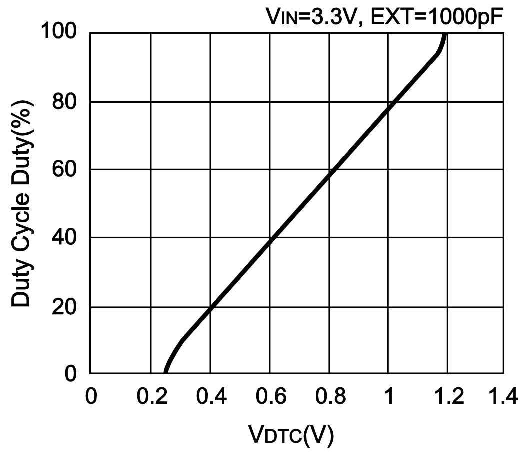


12) Duty Cycle vs. DTC Voltage

R1280D002A

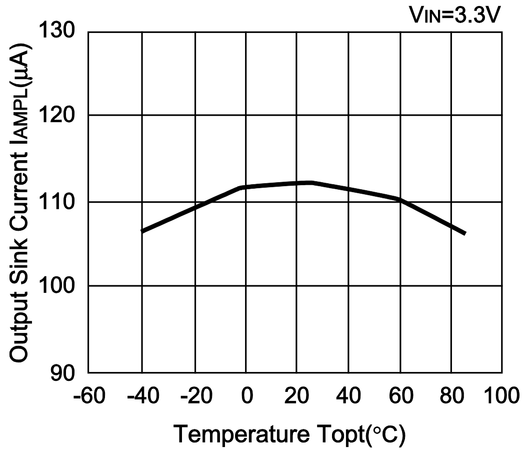


R1280D002C



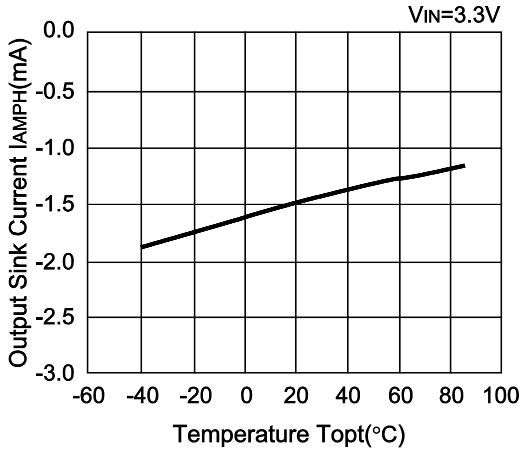
13) Output Sink Current vs. Temperature

R1280D002A/C



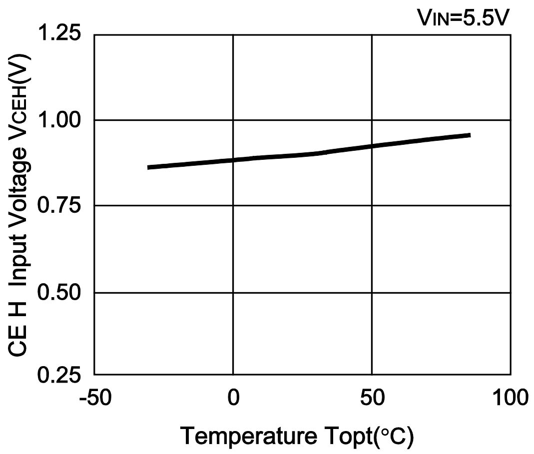
14) Output Source Current vs. Temperature

R1280D002A/C



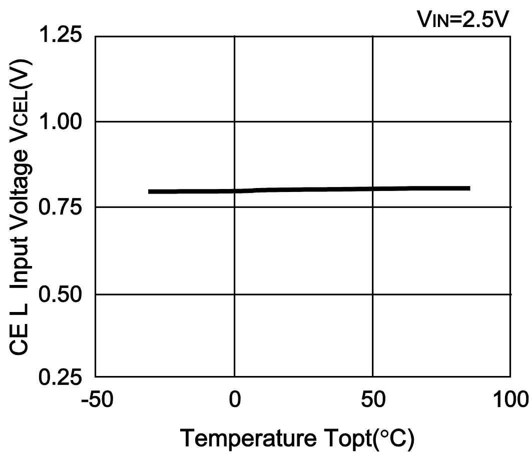
15) CE "H" Input Voltage vs. Temperature

R1280D002B

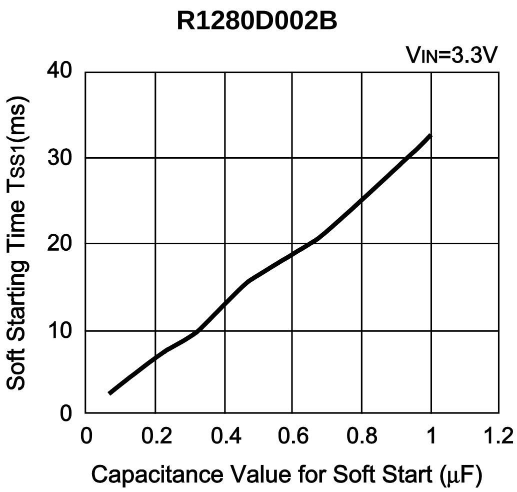


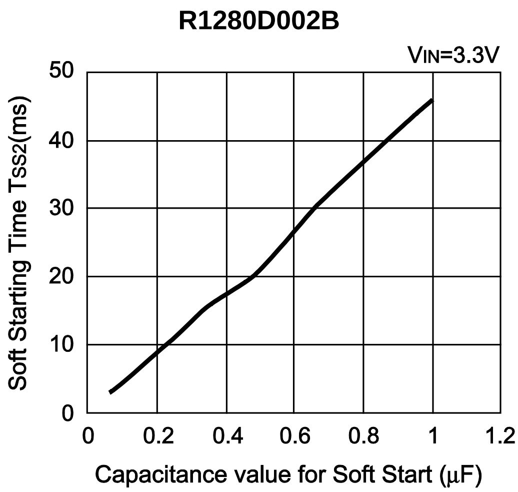
16) CE "L" Input Voltage vs. Temperature

R1280D002B

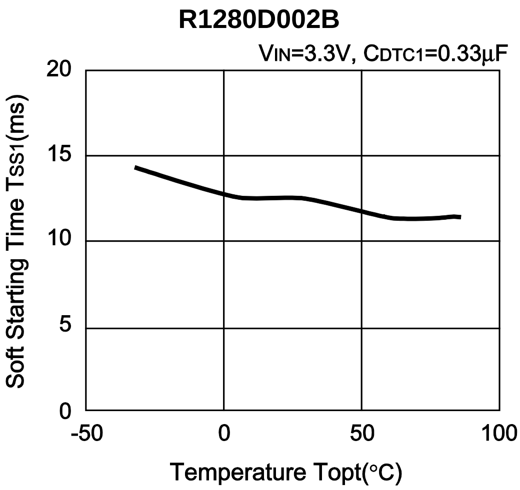


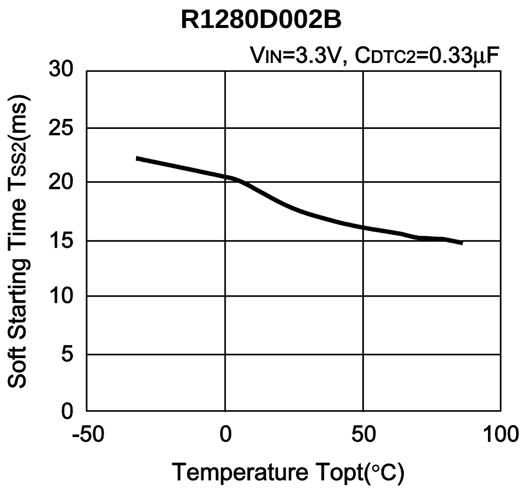
17) Soft Starting Time vs. Capacitance value



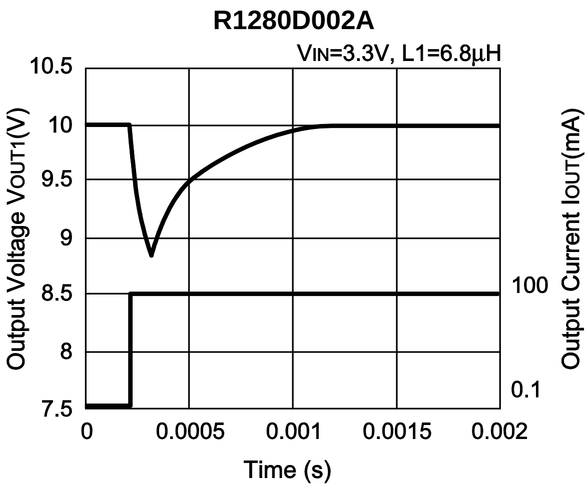


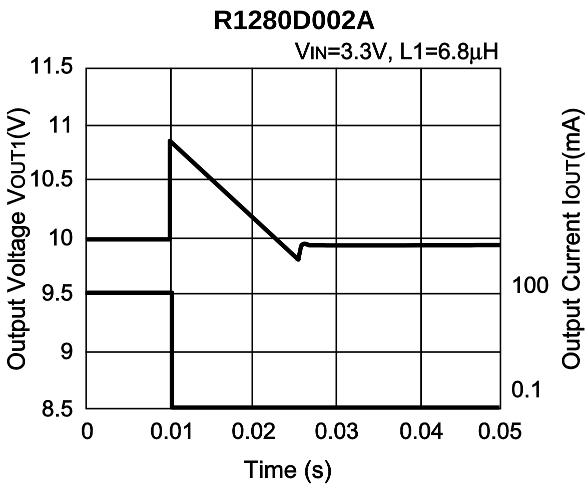
18) Soft Starting Time vs. Temperature





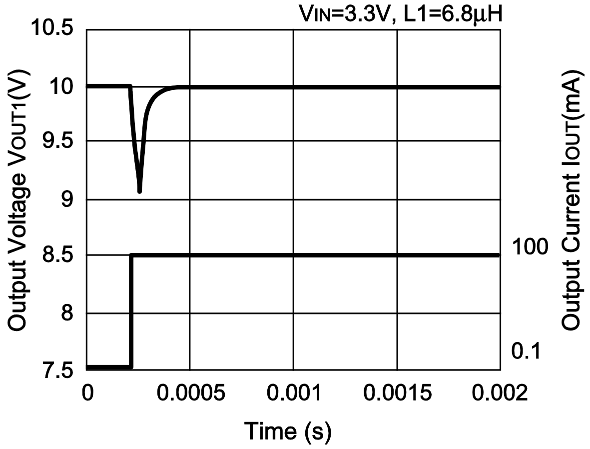
19) Load Transient Response(Step-up Side)



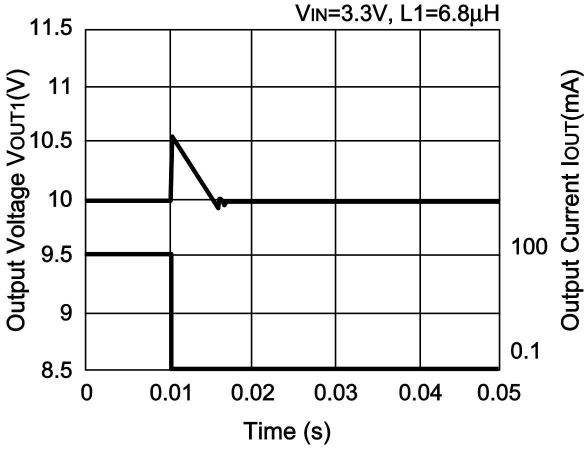


RICOH

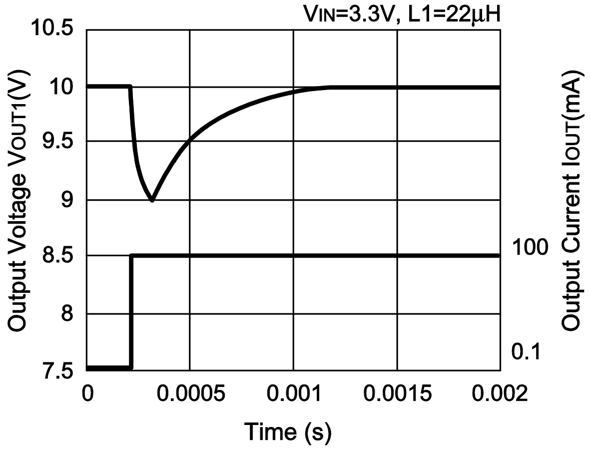
R1280D002B



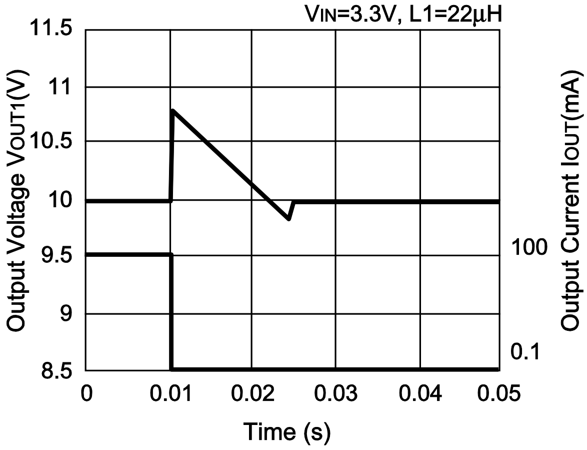
R1280D002B



R1280D002C

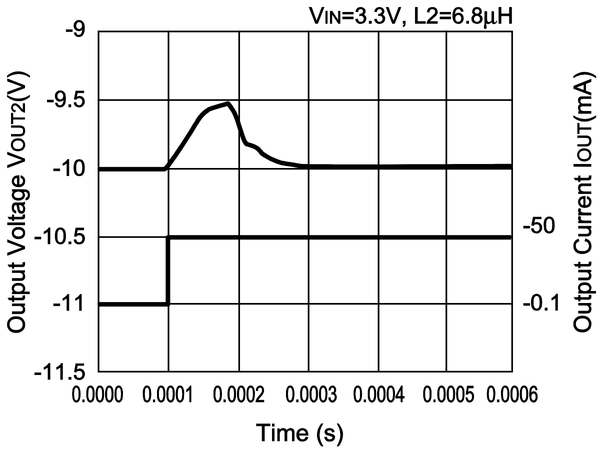


R1280D002C

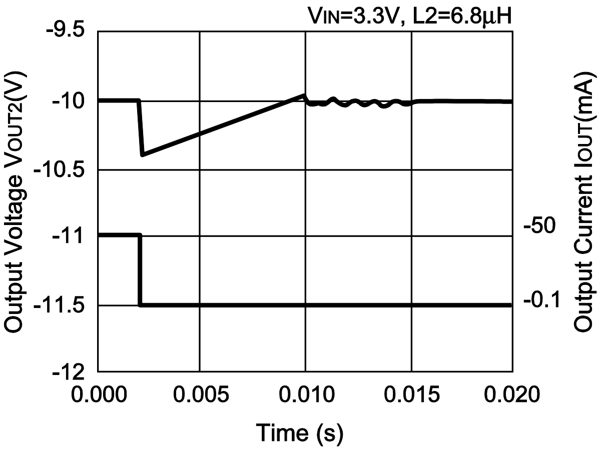


20) Load Transient Response (Inverting Side)

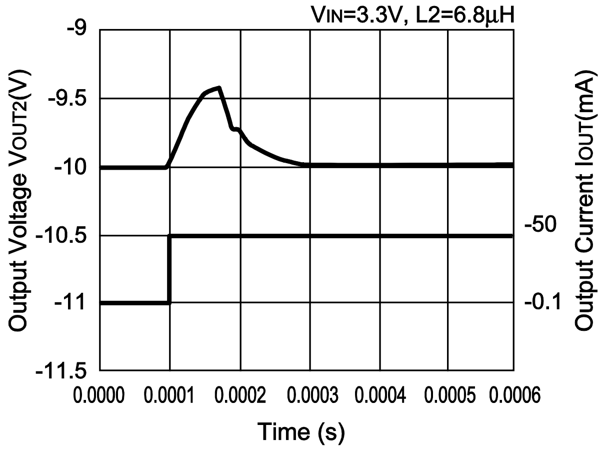
R1280D002A



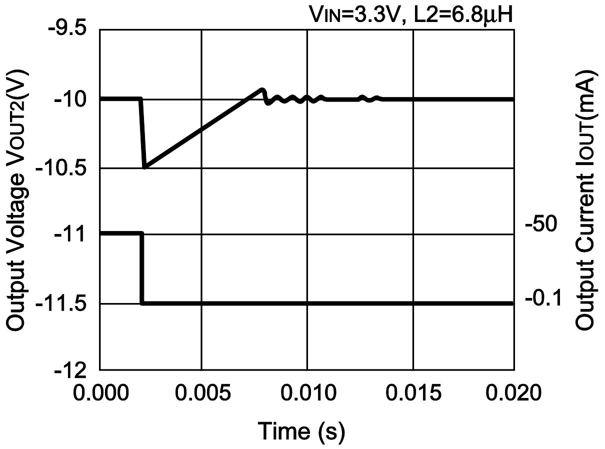
R1280D002A



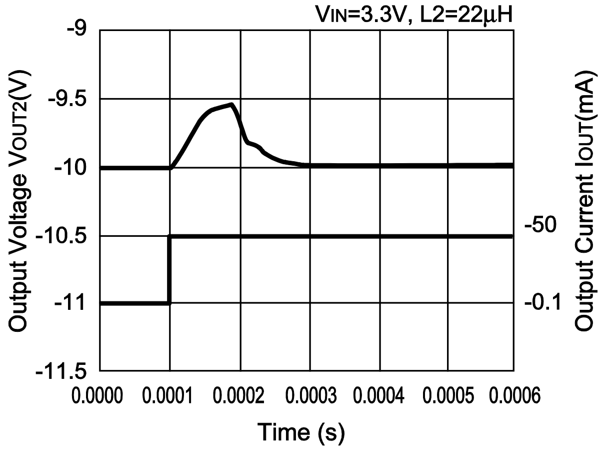
R1280D002B



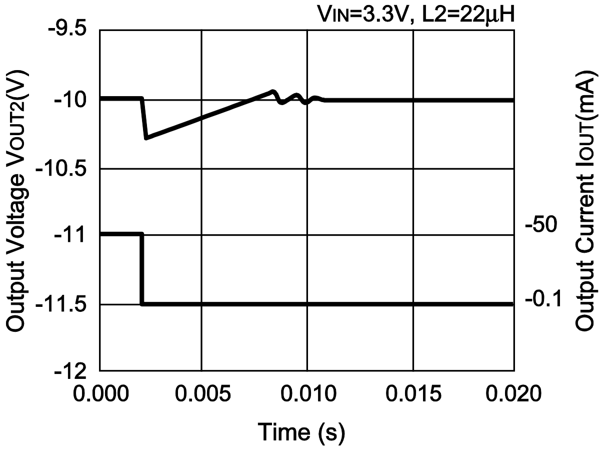
R1280D002B



R1280D002C



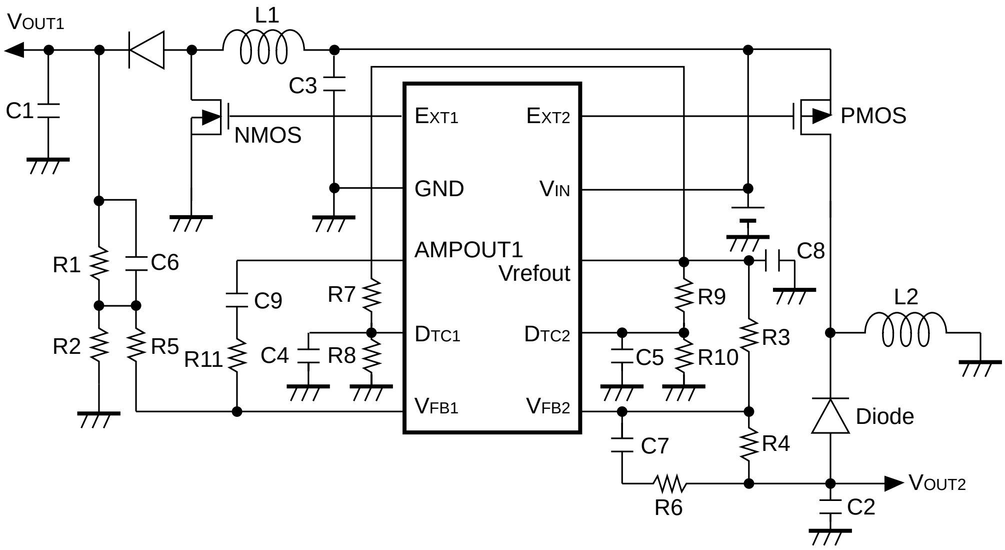
R1280D002C



RICOH

TYPICAL APPLICATION AND TECHNICAL NOTES

- **R1280D002A/C**

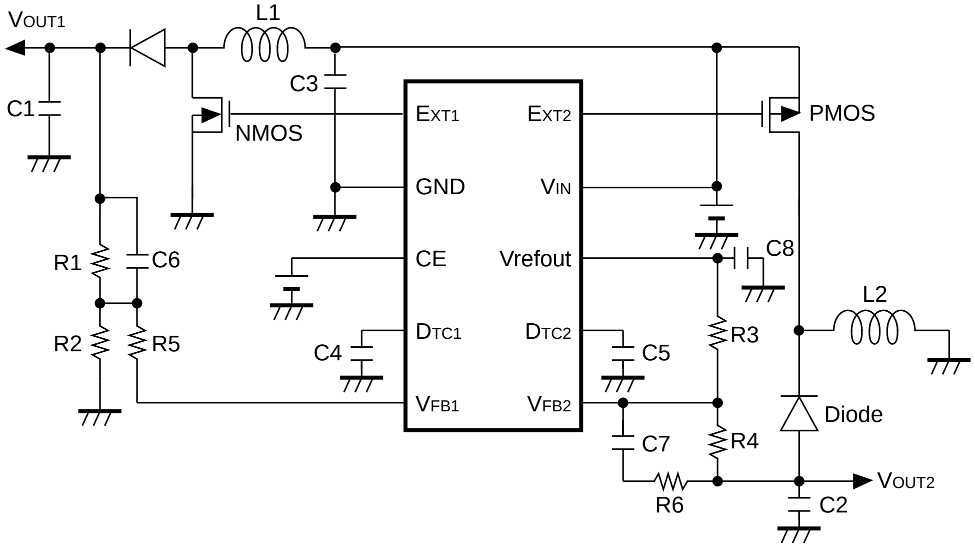


External Components

Inductor L1,2:	6.8µH, VLF504012MT (TDK) for A type, 22µH for C type
Diode:	CRS10I30A (Toshiba)
NMOS:	IRF7601 (International Rectifier)
PMOS:	Si3443DV (Siliconix)
Resistors:	R1, R2, R3, and R4 are for Setting Output Voltage. Recommendation values are R1+R2≤100kΩ or R3+R4≤100kΩ R5=43kΩ, R6=10kΩ, R7=R9=22kΩ, R8=R10=43kΩ, R11=220kΩ
Capacitors: (Example)	Ceramic Capacitor
R1280D002A:	C1=C2=10µF, C3=4.7 F, C4=0.22µF, C5=0.47µF, C6=120pF, C7=50pF, C8=1µF, C9=1000pF
R1280D002C:	C1=C2=10 F, C3=4.7µF, C4=0.22µF, C5=0.47µF, C6=220pF, C7=330pF, C8=1µF, C9=1000pF

Note: Maximum voltage tolerance of each component should be considered. With the transistor shown above is appropriate to set up to ±15V as output voltage.

- **R1280D002B**

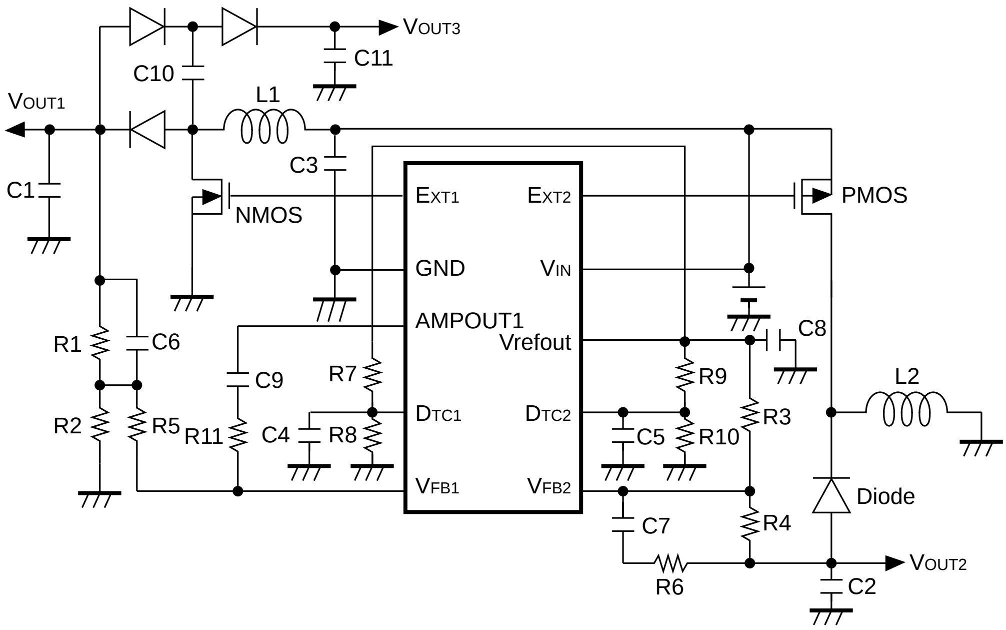


External Components
Inductor L1,2: 6.8µH, VLF504012MT (TDK)
Diode: CRS10I30A (Toshiba)
NMOS: IRF7601 (International Rectifier)
PMOS: Si3443DV (Siliconix)
Resistors: R1, R2, R3, and R4 are for Setting Output Voltage. Recommendation values are
R1+R2≤100kΩ or R3+R4≤100kΩ
R5=43kΩ, R6=10kΩ
Capacitors: Ceramic Capacitor
(Example)
C1=C2=10µF, C3=4.7µF, C4=0.33µF, C5=0.33µF, C6=120pF, C7=50pF, C8=1µF

Note: Maximum voltage tolerance of each component should be considered. With the transistor shown above is appropriate to set up to ±15V as output voltage.

APPLICATION EXAMPLE

- **R1280D002A/C**



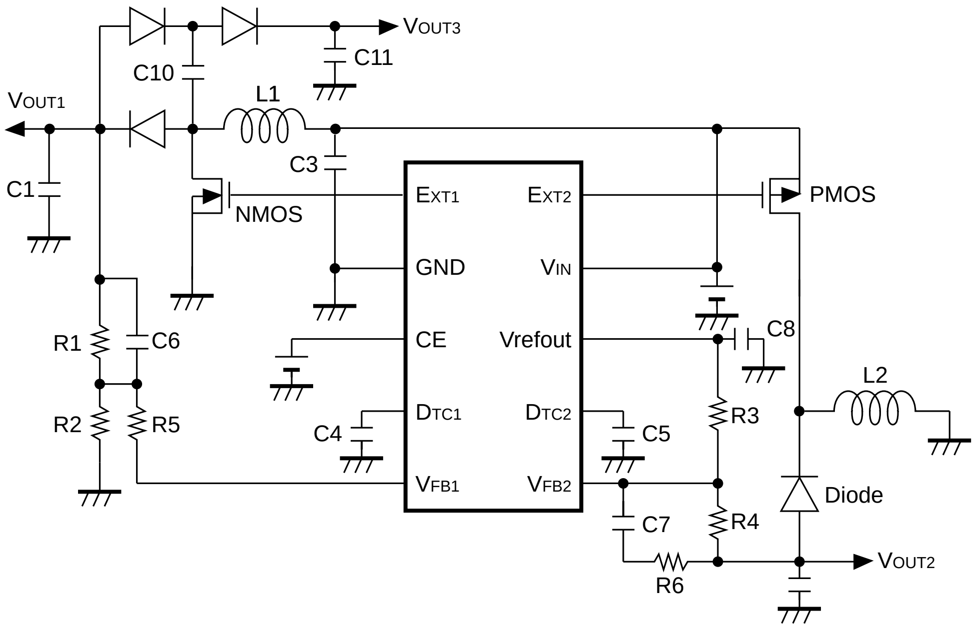
External Components

Inductor L1,2:	6.8µH, VLF504012MT (TDK) for A version, 22µH for R1280D002C
Diode:	CRS10I30A (Toshiba)
NMOS:	IRF7601 (International Rectifier)
PMOS:	Si3443DV (Siliconix)
Resistors:	R1, R2, R3, and R4 are for Setting Output Voltage. Recommendation values are R1+R2≤100kΩ or R3+R4≤100kΩ R5=43kΩ, R6=10kΩ, R7=R9=22kΩ, R8=R10=43kΩ, R11=220kΩ
Capacitors: (Example)	Ceramic Capacitor
R1280D002A:	C1=C2=10µF, C3=4.7µF, C4=0.22 F, C5=0.47µF, C6=120pF, C7=50pF, C8=C10=C11=1µF, C9=1000pF
R1280D002C:	C1=C2=10µF, C3=4.7µF, C4=0.22µF, C5=0.47µF, C6=220pF, C7=330pF, C8=C10=C11=1µF, C9=1000pF

This IC can be used 3 Output TFT Bias Circuit as shown above. V_{OUT3}=2xV_{OUT1}-Vf

Note: Maximum voltage tolerance of each component should be considered. With the transistor shown above is appropriate to set up to +15V as V_{OUT1}, -15V as V_{OUT2}, 30V as V_{OUT3}.

- **R1280D002B**



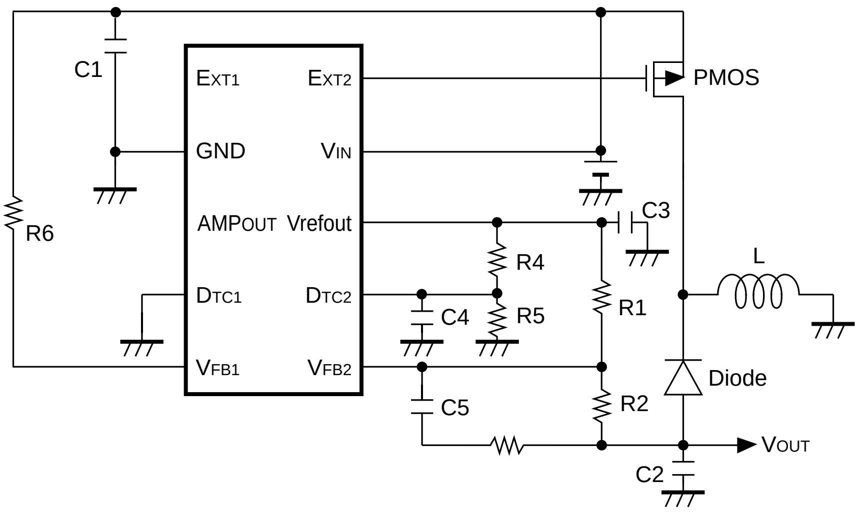
External Components

Inductor L1,2:	6.8µH, VLF504012MT (TDK)
Diode:	CRS10I30A (Toshiba)
NMOS:	IRF7601 (International Rectifier)
PMOS:	Si3443DV (Siliconix)
Resistors:	R1, R2, R3, and R4 are for Setting Output Voltage. Recommendation values are R1+R2 100kΩ or R3+R4 100kΩ, R5=43kΩ, R6=10kΩ,
Capacitors: (Example)	Ceramic Capacitor
R1280D002B:	C1=C2=10µF, C3=4.7µF, C4=0.22µF, C5=0.33µF, C6=120pF, C7=50pF, C8=C10=C11=1µF

This IC can be used 3 Output TFT Bias Circuit as shown above. V_{OUT3}=2xV_{OUT1}-Vf

Note: Maximum voltage tolerance of each component should be considered. The transistor shown above is appropriate to set up to +15V as V_{OUT1}, -15V as V_{OUT2}, 30V as V_{OUT3}

- **R1280D002A/C**



Components examples
Inductor L: 6.8µH VLF504012MT (TDK) (R1280D002C: 22µH)
Diode: CRS10I30A (Toshiba)
PMOS: Si3443DV (Siliconix)
Resistance: As setting resistors total value for the output voltage, R1+R2 should be 100kΩ or less.
R1=10kΩ R2=68kΩ R3=10kΩ R4=22kΩ
R5=43kΩ R6=1kΩ
∗In the circuit above, output, V_{OUT}=-10V
Capacitors Ceramic Type
R1280D002A Ex.)
C1=4.7µF C2=10µF C3=1µF C4=0.47µF C5= 50pF
R1280D002C Ex.)
C1=4.7µF C2=10µF C3=1µF C4=0.47µF C5=330pF

As for R1280D002B, when DTC1 is OPEN and V_{FB1}=V_{DD}, then the R1280D002B can be used as an inverting controller without step-up channel.

Note: Consider the ratings of external components including voltage tolerance. With the transistor in the circuit above, V_{OUT}=-15V is the voltage setting limit.

If this IC is used as an inverting controller without step-up channel, Vrefout pin and V_{FB1}, DTC1 pin should not connect one another. Both the direct connection and via resistor are not permitted.

EXTERNAL COMPONENTS

1. How to set the output voltages
   As for step-up side, feedback (V_{FB1}) pin voltage is controlled to maintain 1V, therefore,

$$V_{OUT1}: R1+R2=V_{FB1}: R2$$

   Thus, $V_{OUT1}=V_{FB1}\times(R1+R2)/R2$
   Output Voltage is adjustable with R1 and R2.
   As for inverting side, Feedback (V_{FB2}) pin voltage is controlled to maintain 0V, therefore,

$$\mathrm{Vrefout} : R3=|-V_{OUT2}|:R4$$

   Thus, $|-V_{OUT2}|=\mathrm{Vrefout}\times R4/R3$
   Output Voltage is adjustable with R3 and R4.

2. How to set Soft-Start Time
   As for R1280D002B, soft-start time is adjustable with connecting a capacitor to DTC pin.
   Soft starting time, T_{SS1} and T_{SS2} are adjustable. Soft-start time can be set with the time constant of RC.
   Soft-start time can be described as in next formula. (Topt=25°C)

$$T_{SS1}\cong RS1\times C4,\ T_{SS2}\cong RS2\times C5$$

In the above formulas, RS1 value is Typ. 32kΩ, while RS2 value is Typ. 45kΩ. Tolerance of these values is ±25% caused by dispersion of wafer process parameters.

On the other hand, as for R1280D002A/C, each soft-start time is set with the time constant of each external resistors and capacitor shown as in the next formula.

$$T_{SS1}\cong R_{O1}\times C4,\ T_{SS2}\cong R_{O2}\times C5$$

In the above formula, $R_{O1}=(R7\times R8)/(R7+R8)$, $R_{O2}=(R9\times R10)/(R9+R10)$

TECHNICAL NOTES on EXTERNAL COMPONENTS

- External components should be set as close to this IC as possible. Especially, wiring of the capacitor connected to V_{IN} pin should be as short as possible.
- Enforce the ground wire. Large current caused by switching operation flows through GND pin. If the impedance of ground wire is high, internal voltage level of this IC might fluctuate and operation could be unstable.
- Recommended capacitance value of C3 is equal or more than 4.7μF. Recommended maximum voltage tolerance of C3 is three times as large as set output voltage or more, because the external transistor might generate a high voltage with a shape of spike because of an effect from inductor.
- If the spike noise of V_{OUT} is too large, the noise is feedback from V_{FB1} pin and operation might be unstable. In that case, use the resistor ranging from 10kΩ to 50kΩ as R5 and try to reduce the noise level. In the case of V_{OUT2}, use the resistor as much as 10kΩ as R6.
- Select an inductor with low D.C. current, large permissible current, and uneasy to cause magnetic saturation. If the inductance value is too small, IL_X might be beyond the absolute maximum rating at the maximum load.
- Select a Schottky diode with fast switching speed and large enough permissible current.
- Recommended capacitance value of C1 and C2 is as much as Ceramic 10μF. In case that the operation with the system of DC/DC converter would be unstable, add a series resister less than 0.5Ω to each output capacitor or use tantalum capacitors with appropriate ESR. If you choose too large ESR, ripple noise may be forced to V_{FB1} and V_{FB2} , and unstable operation may result. Use a capacitor with three times as large as voltage tolerance of the capacitor.
- In this IC, for the test efficiency, Latch release function is included. By forcing (V_{IN}-0.3)V or more voltage to DTC1 pin or DTC2 pin, Latch release function works.
- Consider the threshold voltage of Power MOSFET transistor. Select an appropriate MOSFET transistor, depending on the input voltage in order to make the MOSFET turn on completely.
- Performance of the power controller with using this IC depends on external components. Each component, layout should not be beyond each absolute maximum rating such as voltage, current, and power dissipation.

1. The products and the product specifications described in this document are subject to change or discontinuation of production without notice for reasons such as improvement. Therefore, before deciding to use the products, please refer to Ricoh sales representatives for the latest information thereon.
2. The materials in this document may not be copied or otherwise reproduced in whole or in part without prior written consent of Ricoh.
3. Please be sure to take any necessary formalities under relevant laws or regulations before exporting or otherwise taking out of your country the products or the technical information described herein.
4. The technical information described in this document shows typical characteristics of and example application circuits for the products. The release of such information is not to be construed as a warranty of or a grant of license under Ricoh's or any third party's intellectual property rights or any other rights.
5. The products listed in this document are intended and designed for use as general electronic components in standard applications (office equipment, telecommunication equipment, measuring instruments, consumer electronic products, amusement equipment etc.). Those customers intending to use a product in an application requiring extreme quality and reliability, for example, in a highly specific application where the failure or misoperation of the product could result in human injury or death (aircraft, spacevehicle, nuclear reactor control system, traffic control system, automotive and transportation equipment, combustion equipment, safety devices, life support system etc.) should first contact us.
6. We are making our continuous effort to improve the quality and reliability of our products, but semiconductor products are likely to fail with certain probability. In order to prevent any injury to persons or damages to property resulting from such failure, customers should be careful enough to incorporate safety measures in their design, such as redundancy feature, fire containment feature and fail-safe feature. We do not assume any liability or responsibility for any loss or damage arising from misuse or inappropriate use of the products.
7. Anti-radiation design is not implemented in the products described in this document.
8. The X-ray exposure can influence functions and characteristics of the products. Confirm the product functions and characteristics in the evaluation stage.
9. WLCSP products should be used in light shielded environments. The light exposure can influence functions and characteristics of the products under operation or storage.
10. There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact Ricoh sales or our distributor before attempting to use AOI.
11. Please contact Ricoh sales representatives should you have any questions or comments concerning the products or the technical information.

RoHS Compliant
Halogen Free

Ricoh is committed to reducing the environmental loading materials in electrical devices with a view to contributing to the protection of human health and the environment.
Ricoh has been providing RoHS compliant products since April 1, 2006 and Halogen-free products since April 1, 2012.

RICOH ELECTRONIC DEVICES CO., LTD.

https://www.e-devices.ricoh.co.jp/en/

Sales & Support Offices

Ricoh Electronic Devices Co., Ltd.
Shin-Yokohama Office (International Sales)
2-3, Shin-Yokohama 3-chome, Kohoku-ku, Yokohama-shi, Kanagawa, 222-8530, Japan
Phone: +81-50-3814-7687 Fax: +81-45-474-0074

Ricoh Americas Holdings, Inc.
675 Campbell Technology Parkway, Suite 200 Campbell, CA 95008, U.S.A.
Phone: +1-408-610-3105

Ricoh Europe (Netherlands) B.V.
Semiconductor Support Centre
Prof. W.H. Keesomlaan 1, 1183 DJ Amstelveen, The Netherlands
Phone: +31-20-5474-309

Ricoh International B.V. - German Branch
Semiconductor Sales and Support Centre
Oberrather Strasse 6, 40472 Düsseldorf, Germany
Phone: +49-211-6546-0

Ricoh Electronic Devices Korea Co., Ltd.
3F, Haesung Bldg, 504, Teheran-ro, Gangnam-gu, Seoul, 135-725, Korea
Phone: +82-2-2135-5700 Fax: +82-2-2051-5713

Ricoh Electronic Devices Shanghai Co., Ltd.
Room 403, No.2 Building, No.690 Bibo Road, Pu Dong New District, Shanghai 201203, People's Republic of China
Phone: +86-21-5027-3200 Fax: +86-21-5027-3299

Ricoh Electronic Devices Shanghai Co., Ltd.
Shenzhen Branch
1205, Block D(Jinlong Building), Kingkey 100, Hongbao Road, Luohu District, Shenzhen, China
Phone: +86-755-8348-7600 Ext 225

Ricoh Electronic Devices Co., Ltd.
Taipei office
Room 109, 10F-1, No.51, Hengyang Rd., Taipei City, Taiwan (R.O.C.)
Phone: +886-2-2313-1621/1622 Fax: +886-2-2313-1623