

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, resistors, 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 0 μ A.

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

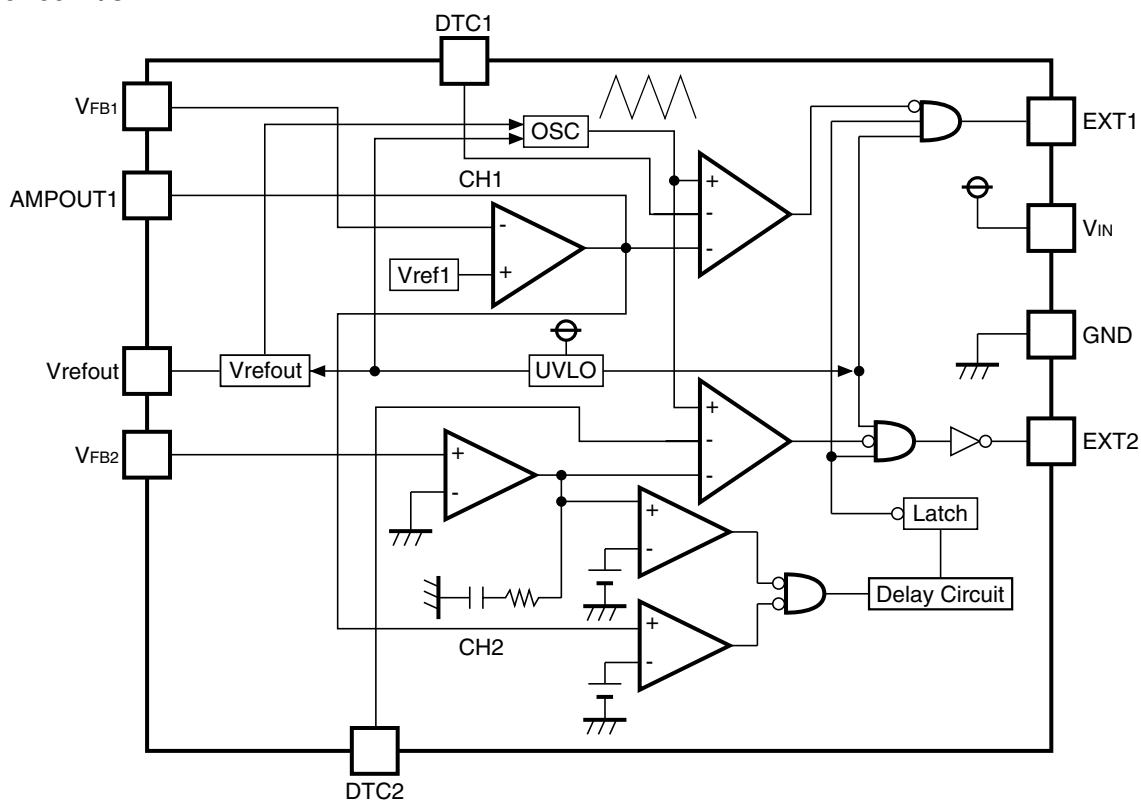
- Input Voltage Range2.5V to 5.5V
- Built-in Latch-type Protection Function by monitoring duty cycle (Fixed Delay Time Typ. 100ms)
- Oscillator Frequency700kHz (R1280D002A,B)/200kHz (R1280D002C)
- Maximum Duty CycleTyp. 90% (Only applied to R1280D002B Series)
- High Reference Voltage Accuracy $\pm 1.5\%$
- U.V.L.O. ThresholdTyp. 2.2V (Hysteresis: Typ. 0.1V)
- Small Packagethin SON-10 (package thickness Max. 0.9mm)

APPLICATIONS

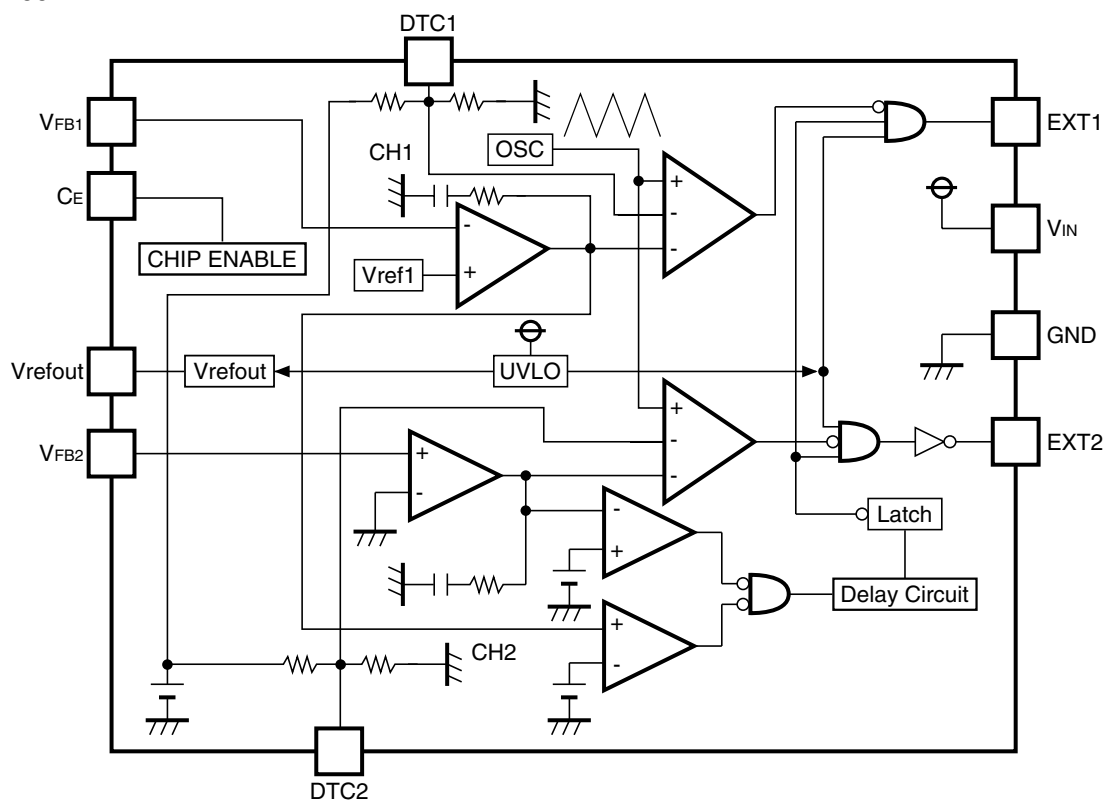
- Constant Voltage Power Source for Portable Equipment.
- Constant Voltage Power Source for LCD and CCD.

BLOCK DIAGRAM

- **R1280D002A/C**



- **R1280D002B**



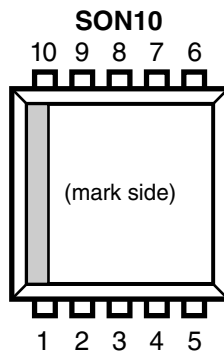
SELECTION GUIDE

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;

R1280D002x-TR ←Part Number
 ↑ ↑
 a b

Code	Contents
a	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
b	Designation of Taping Type : (Refer to Taping Specifications.)

PIN CONFIGURATION



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	V _{refout}	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	V _{refout}	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	$-0.3 \sim V_{IN} + 0.3$	V
$V_{AMPOUT1}$	AMPOUT1 Pin Voltage	$-0.3 \sim V_{IN} + 0.3$	V
$V_{DTC1,2}$	DTC1,2 Pin Voltage	$-0.3 \sim V_{IN} + 0.3$	V
V_{refout}	V_{REFOUT} Pin Voltage	$-0.3 \sim V_{IN} + 0.3$	V
$V_{FB1,2}$	V_{FB1}, V_{FB2} Pin Voltage	$-0.3 \sim V_{IN} + 0.3$	V
$I_{EXT1,2}$	EXT1,2 Pin Output Current	± 50	mA
P_D	Power Dissipation	250	mW
T_{opt}	Operating Temperature Range	-40 to +85	°C
T_{stg}	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	$-0.3 \sim V_{IN} + 0.3$	V
V_{CE}	CE Pin Voltage	$-0.3 \sim V_{IN} + 0.3$	V
$V_{DTC1,2}$	DTC1,2 Pin Voltage	$-0.3 \sim V_{IN} + 0.3$	V
V_{refout}	V_{REFOUT} Pin Voltage	$-0.3 \sim V_{IN} + 0.3$	V
$V_{FB1,2}$	V_{FB1}, V_{FB2} Pin Voltage	$-0.3 \sim V_{IN} + 0.3$	V
$I_{EXT1,2}$	EXT1,2 Pin Output Current	± 50	mA
P_D	Power Dissipation	250	mW
T_{opt}	Operating Temperature Range	-40 to +85	°C
T_{stg}	Storage Temperature Range	-55 to +125	°C

ELECTRICAL CHARACTERISTICS

• R1280D002A

T_{opt}=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 ≤ T _{opt} ≤ 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 ≤ T _{opt} ≤ 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 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

• R1280D002B

T_{opt} = 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 _{LM}	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 ≤ T _{opt} ≤ 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 ≤ T _{opt} ≤ 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	%
REXTH1	EXT1 "H" ON Resistance	V _{IN} = 3.3V, I _{EXT} = -20mA		4.0	8.0	Ω
REXTL1	EXT1 "L" ON Resistance	V _{IN} = 3.3V, I _{EXT} = 20mA		2.7	5.0	Ω
REXTH2	EXT2 "H" ON Resistance	V _{IN} = 3.3V, I _{EXT} = -20mA		4.0	8.0	Ω
REXTL2	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

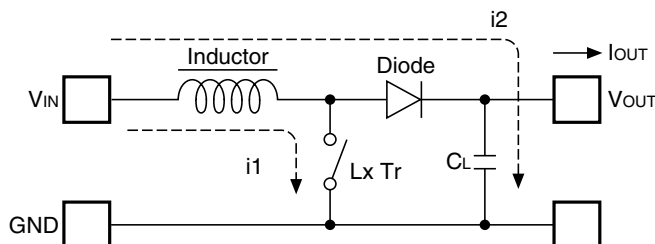
• R1280D002C
 $T_{opt}=25^{\circ}\text{C}$

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 ≤ T _{opt} ≤ 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 ≤ T _{opt} ≤ 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

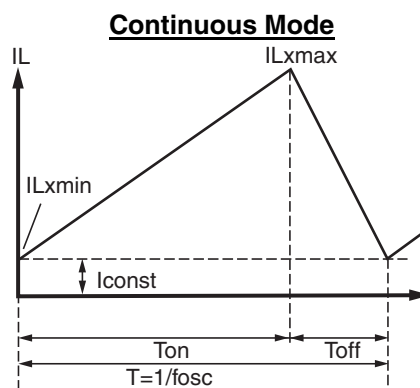
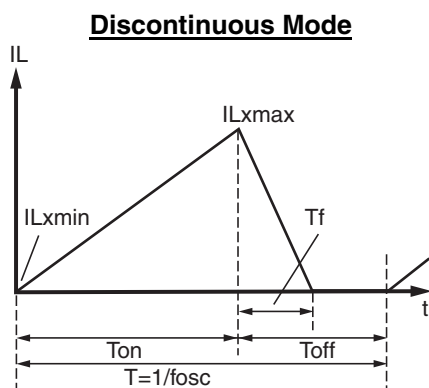
Operation of Step-up DC/DC Converter and Output Current

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_x >



- Step 1. L_x Tr. is on, then the current $I_L = i1$ flows, and the energy is charged in L . In proportion to the on time of L_x Tr. (T_{on}), $I_L = i1$ increases from $I_L = I_{Lxmin} = 0$ and reaches I_{Lxmax} .
- Step 2. When the L_x Tr. is off, L turns on Schottky Diode (SD), and $I_L = i2$ flows to maintain $I_L = I_{Lxmax}$.
- Step 3. $I_L = i2$ gradually decreases, and after T_f passes, $I_L = I_{Lxmin} = 0$ is true, then SD turns off. Note that in the case of the continuous mode, before $I_L = I_{Lxmin} = 0$ is true, T_{off} passes, and the next cycle starts, then L_x Tr. turns on again.

In this case, $I_{Lxmin} > 0$, therefore $I_L = I_{Lxmin} > 0$ is another starting point and I_{Lx} 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.

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

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.

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

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

$$P_{AV} = 1/(T_{on} + T_{off}) \times \left\{ \int_0^{T_{on}} V_{IN}^2 \times t/L \, dt + \int_0^{T_f} V_{IN} \times (V_{OUT} - V_{IN}) t/L \, dt \right\} \quad \dots\dots\dots \text{Formula 3}$$

In PWM control, when $T_f = T_{off}$ 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.

$$V_{IN} \times T_{on}/L = (V_{OUT} - V_{IN}) \times T_{off}/L \quad \dots\dots\dots \text{Formula 4}$$

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

$$I_{OUT} = f_{osc} \times V_{IN}^2 \times T_{on}^2 / \{2 \times L \times (V_{OUT} - V_{IN})\} = V_{IN}^2 \times T_{on} / (2 \times L \times V_{OUT}) \quad \dots\dots\dots \text{Formula 5}$$

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

$$I_{OUT} = f_{osc} \times V_{IN}^2 \times T_{on}^2 / (2 \times L \times (V_{OUT} - V_{IN})) + V_{IN} \times I_{const} / V_{OUT} \quad \dots\dots\dots \text{Formula 6}$$

In this moment, the peak current, $IL_{x\max}$ flowing through the inductor and the driver Tr is described as follows:

$$IL_{x\max} = I_{\text{const}} + V_{\text{IN}} \times T_{\text{on}} / L \dots \dots \dots \text{Formula 7}$$

With the formula 4,6, and $IL_{x\max}$ is,

$$IL_{x\max} = V_{\text{OUT}} / V_{\text{IN}} \times I_{\text{OUT}} + V_{\text{IN}} \times T_{\text{on}} / (2 \times L) \dots \dots \dots \text{Formula 8}$$

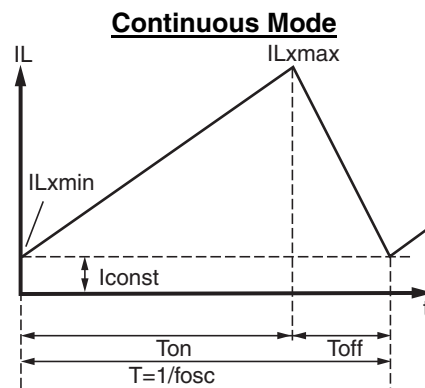
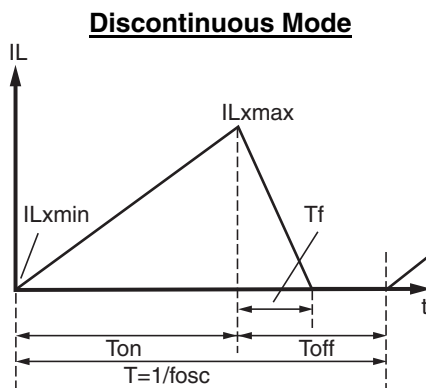
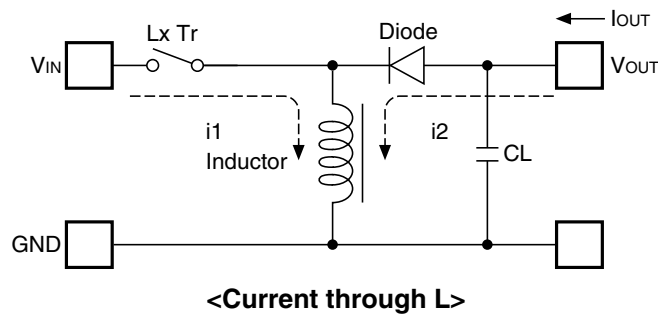
Therefore, peak current is more than I_{OUT} . Considering the value of $IL_{x\max}$, the condition of input and output, and external components should be selected.

In the formula 7, peak current $IL_{x\max}$ at discontinuous mode can be calculated. Put $I_{\text{const}}=0$ 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} , V_f (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 L_x transistor, and supplies the energy to output during off time, output voltage opposed to input voltage is obtained.



- Step 1. L_x Tr. turns on, current, $IL=i1$ flows, energy is charged in L. In proportion to the on time, T_{on} , of L_x Tr. $IL=i1$ increases from $IL=IL_{xmin}=0$ and reaches IL_{xmax} .
- Step 2. When the L_x Tr. turns off, L turns on Shottky diode (SD) and flow $IL=i2$ to maintain $IL = IL_{xmax}$.
- Step 3. $IL=i2$ decreases gradually, after T_f passes, $IL=IL_{xmin}=0$ is true, then SD turns off. Note that in the case of continuous mode, before $IL=IL_{xmin}=0$ is true, T_{off} passes and next cycle starts, then L_x Tr. turns on. In this case, $IL_{xmin}>0$, therefore IL increases from $IL=IL_{xmin}>0$.

With the PWM controller, switching time (f_{osc}) in the time unit is fixed, and by controlling T_{on} , 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.

$$P = \int_0^{T_{on}} V_{IN}^2 \times t/L dt \quad \dots\dots\dots \text{Formula 9}$$

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

$$P_{AV} = 1/(T_{on} + T_{off}) \times \int_0^{T_{on}} V_{IN}^2 \times t/L dt = V_{IN}^2 \times T_{on}^2 / (2 \times L \times (T_{on} + T_{off})) \quad \dots\dots\dots \text{Formula 10}$$

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

$$I_{OUT} = f_{osc} \times V_{IN}^2 \times T_{on}^2 / (2 \times L \times V_{OUT}) \dots\dots\dots \text{Formula 11}$$

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

$$V_{IN} \times T_{on} / L = V_{OUT} \times T_{off} / L \quad \dots\dots\dots \text{Formula 12}$$

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

$$I_{OUT} = f_{osc} \times V_{IN}^2 \times T_{on}^2 / (2 \times L \times V_{OUT}) + T_{on} / (T_{on} + T_{off}) \times V_{IN} \times I_{const} / V_{OUT} \quad \dots\dots\dots \text{Formula 13}$$

In this moment, the peak current, I_{Lxmax} flowing through the inductor and the driver Tr is described as follows:

$$I_{Lxmax} = I_{const} + V_{IN} \times T_{on} / L \quad \dots\dots\dots \text{Formula 14}$$

With the formula 12,13, I_{Lxmax} is,

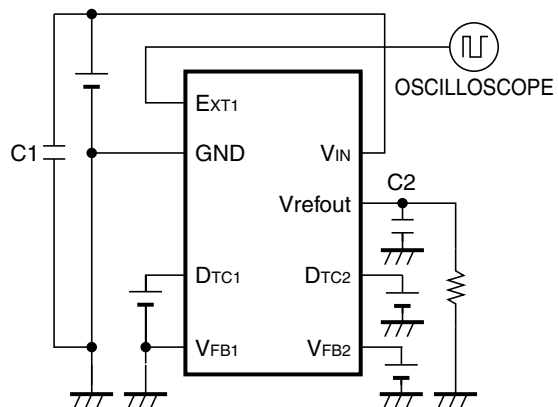
$$I_{Lxmax} = (T_{on} + T_{off}) / T_{off} \times I_{OUT} + V_{IN} \times T_{on} / (2 \times L) \quad \dots\dots\dots \text{Formula 15}$$

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

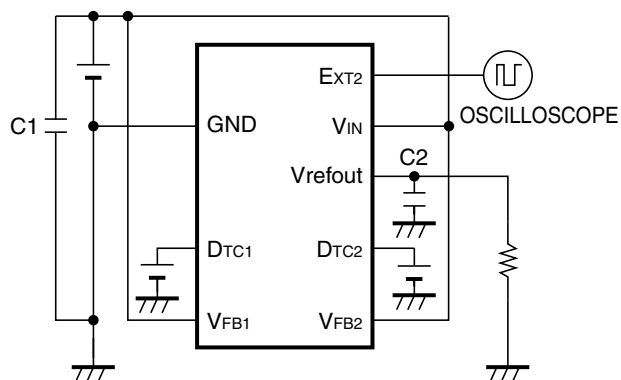
In the formula 14, peak current I_{Lxmax} at discontinuous mode can be calculated. Put $I_{const}=0$ in the formula.

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 I_{Lx} 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} , V_f (as much as 0.3V) of the diode should be considered.

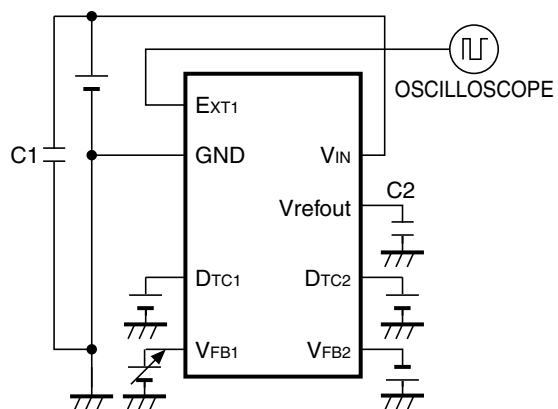
TEST CIRCUITS



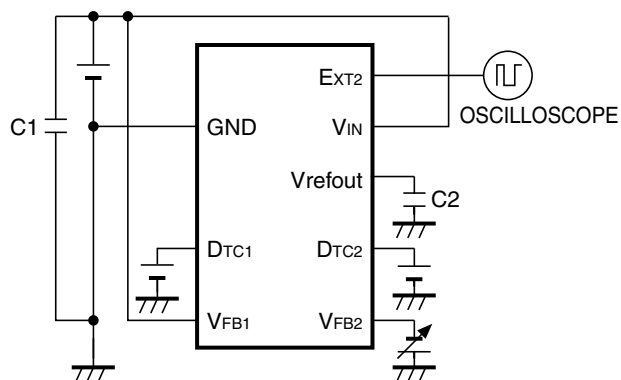
Test Circuit 1



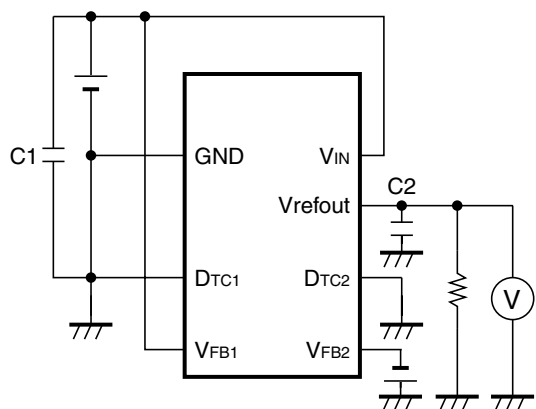
Test Circuit 2



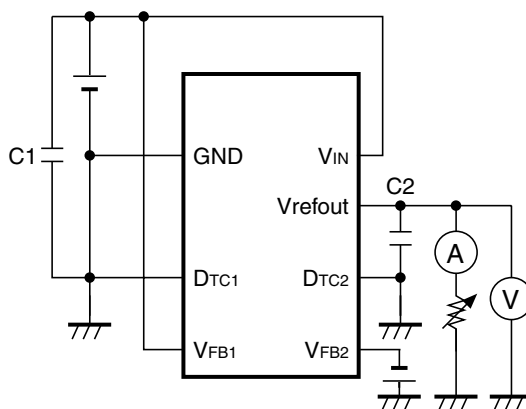
Test Circuit 3



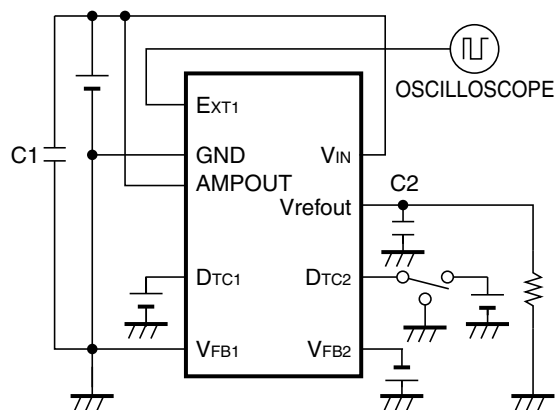
Test Circuit 4



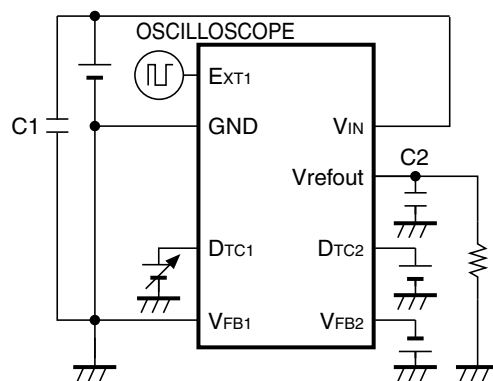
Test Circuit 5



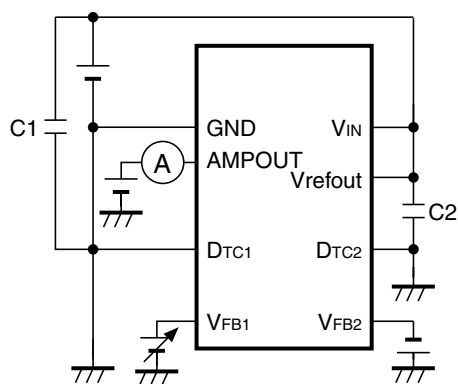
Test Circuit 6



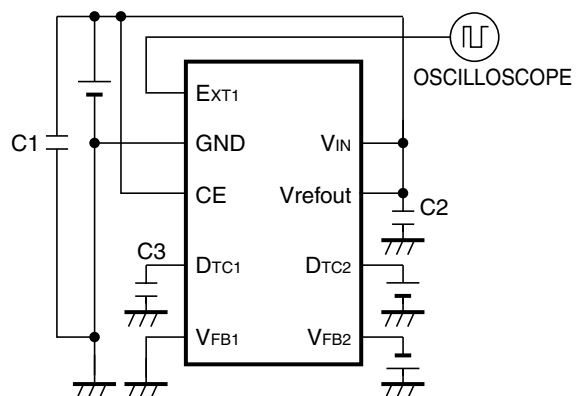
Test Circuit 7



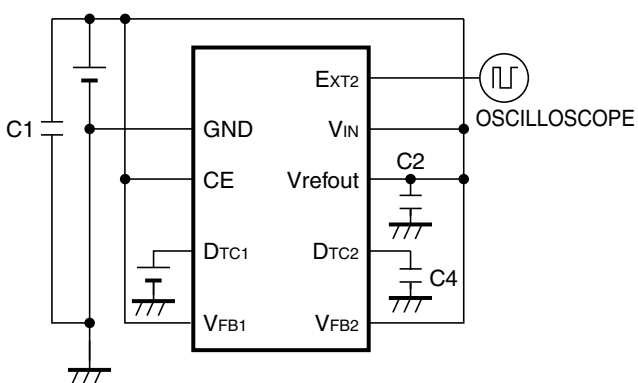
Test Circuit 8



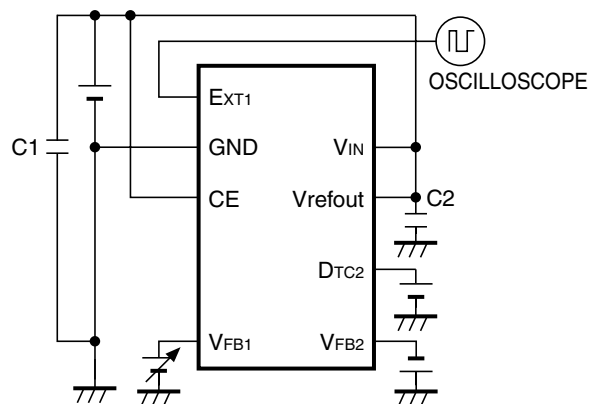
Test Circuit 9



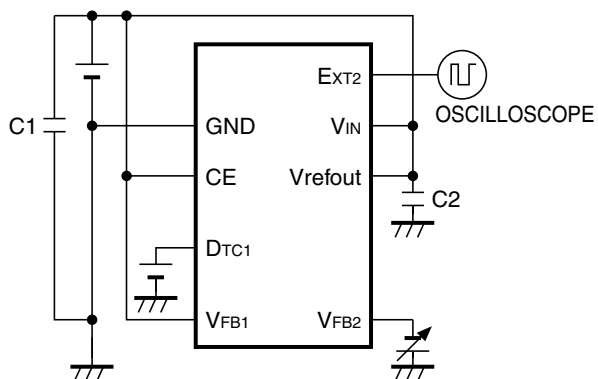
Test Circuit 10



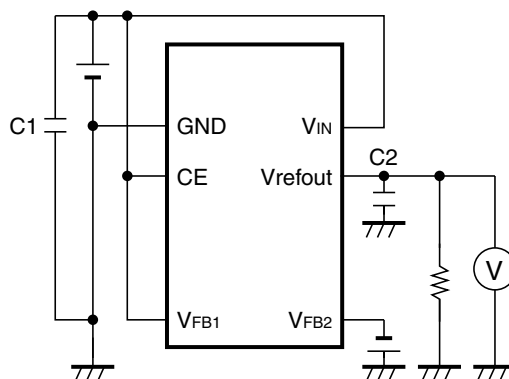
Test Circuit 11



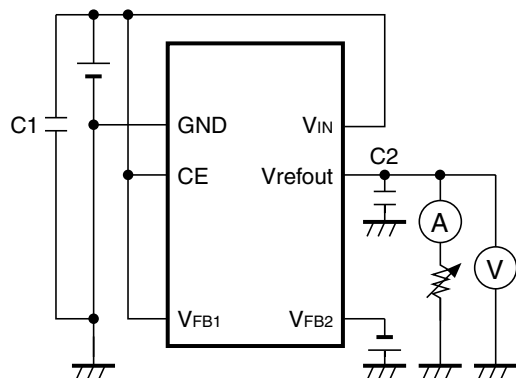
Test Circuit 12



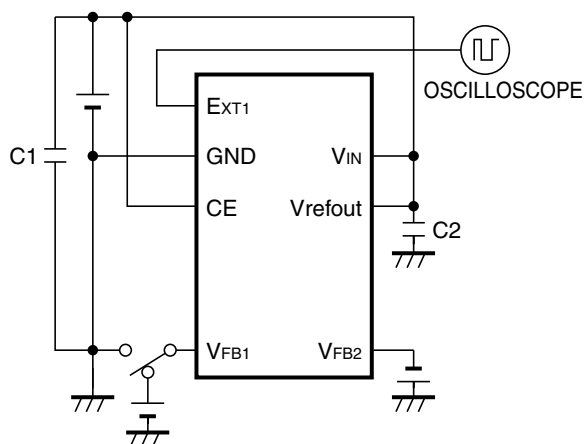
Test Circuit 13



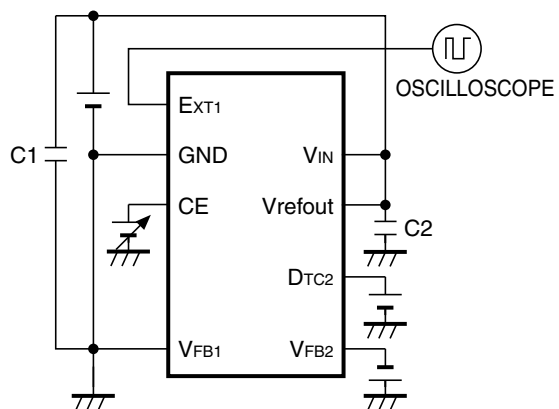
Test Circuit 14



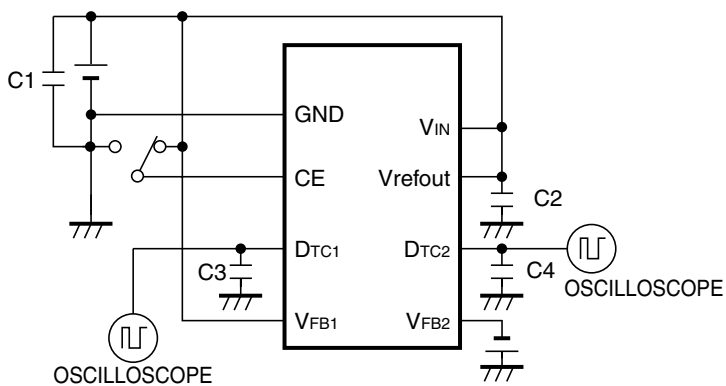
Test Circuit 15



Test Circuit 16



Test Circuit 17



Test Circuit 18

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

- **R1280D002A/C**

Test Circuit 1,2 :	Typical 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:

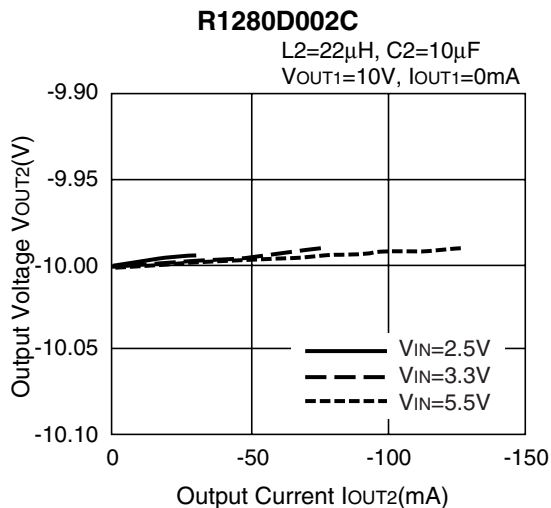
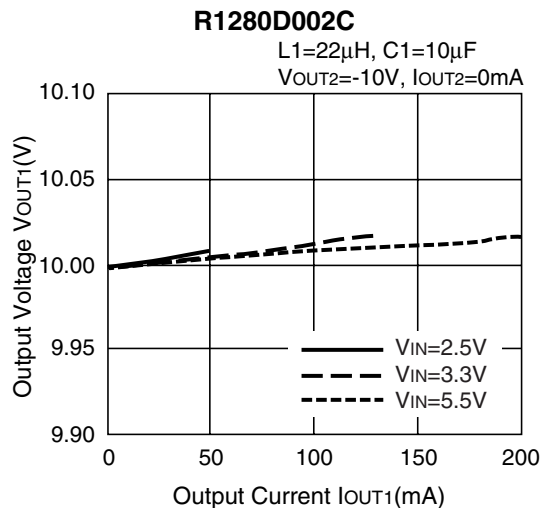
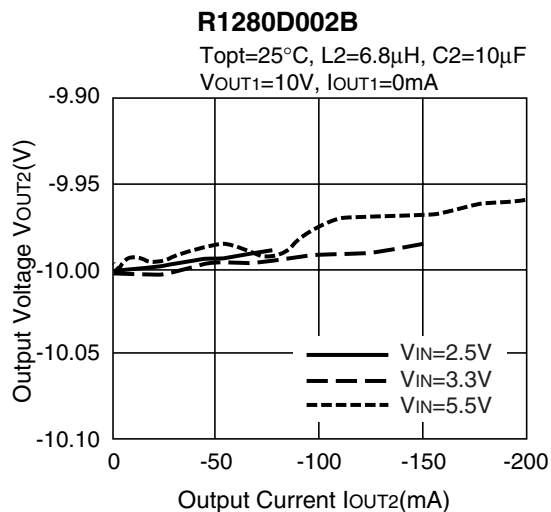
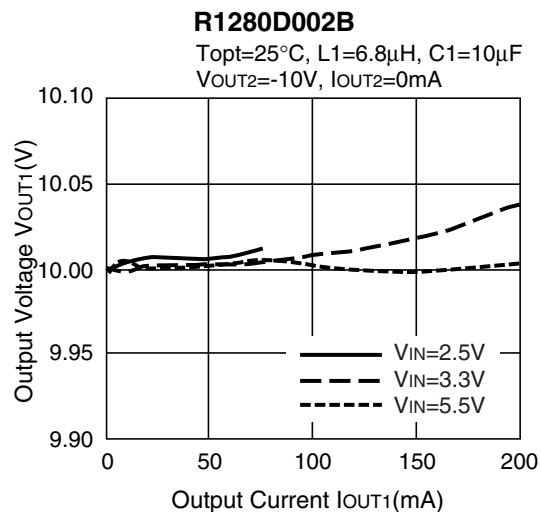
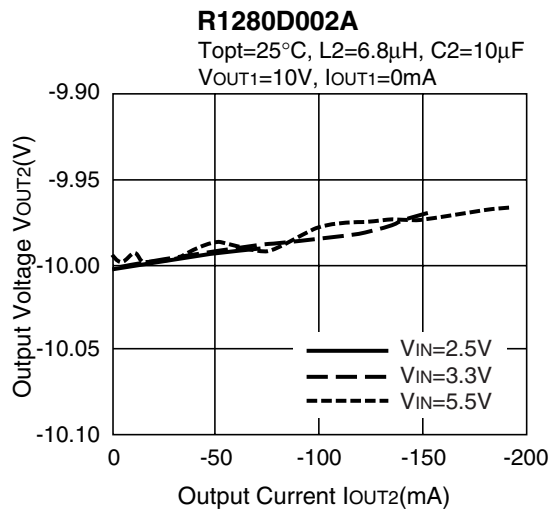
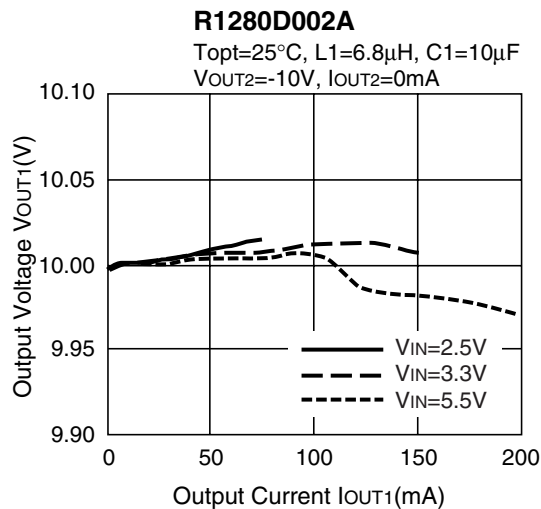
C1=4.7μF, C2=1.0μF, C3=C4=1000pF

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

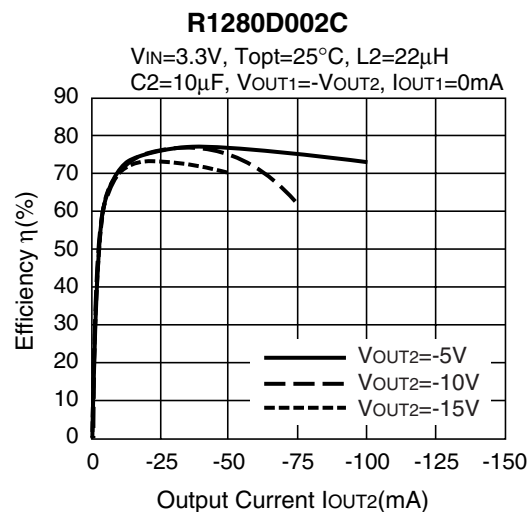
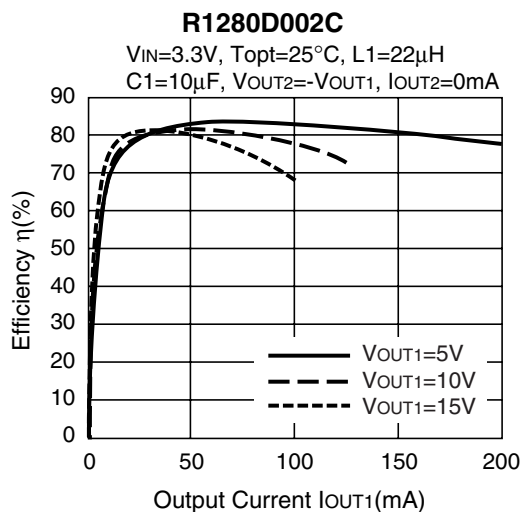
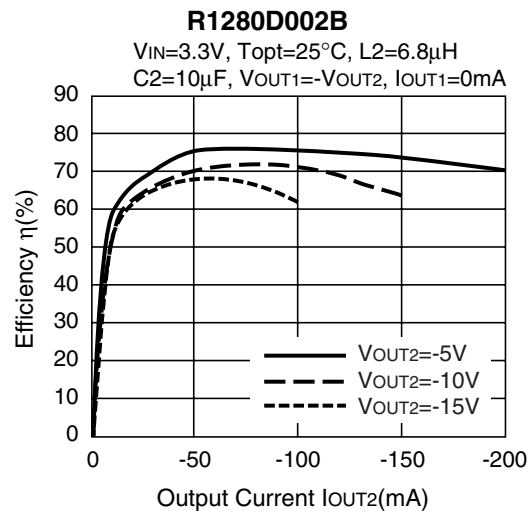
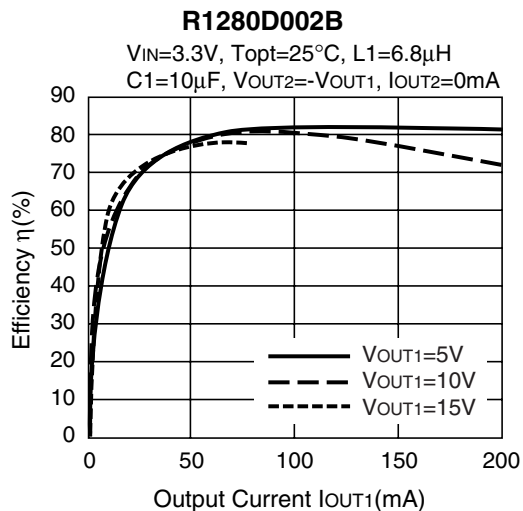
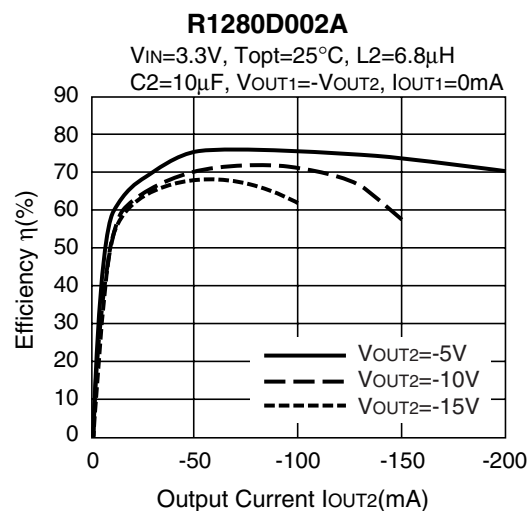
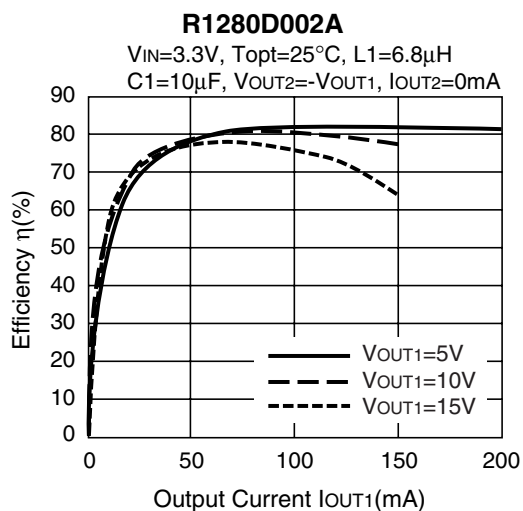
$$\eta = (V_{OUT1} \times I_{OUT1} + V_{OUT2} \times I_{OUT2}) / (V_{IN} \times I_{IN}) \times 100$$

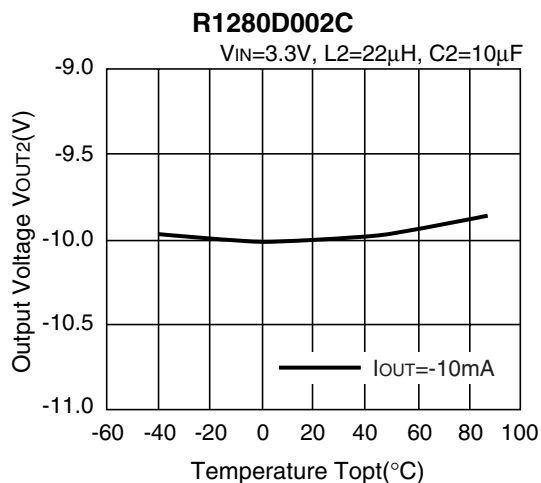
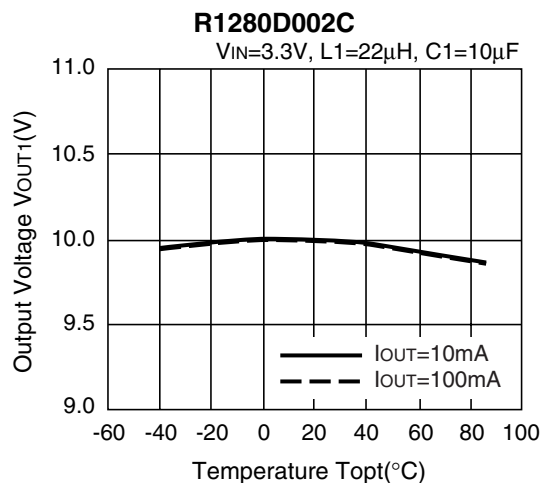
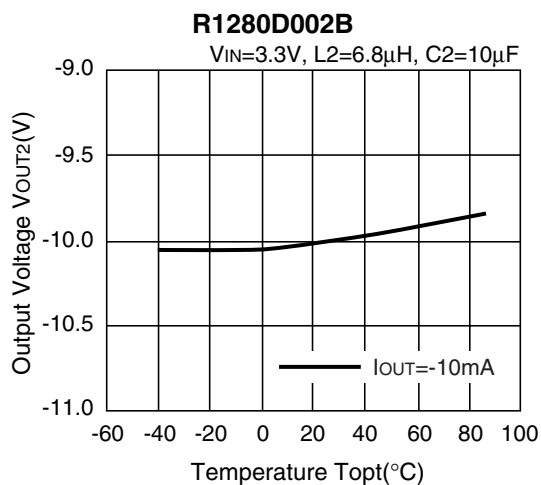
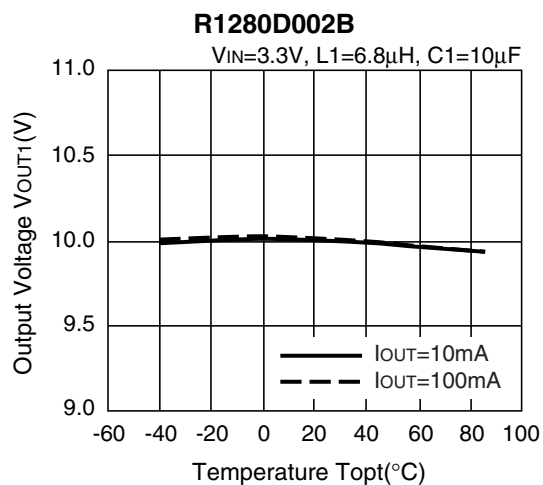
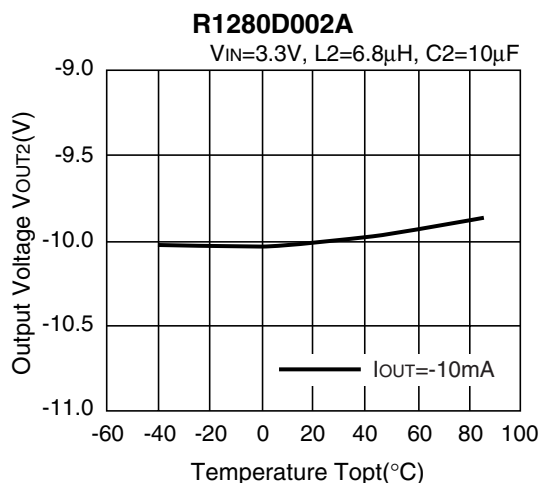
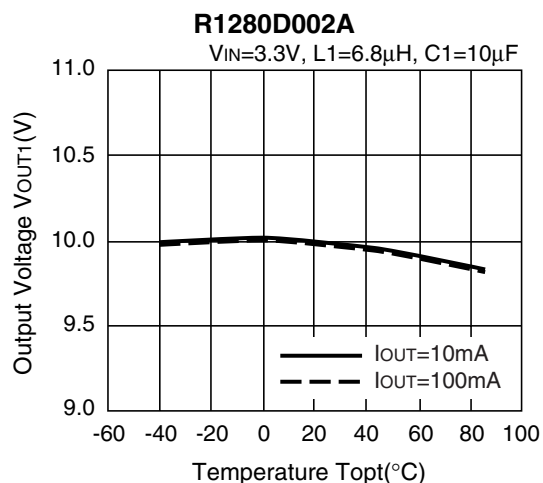
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current

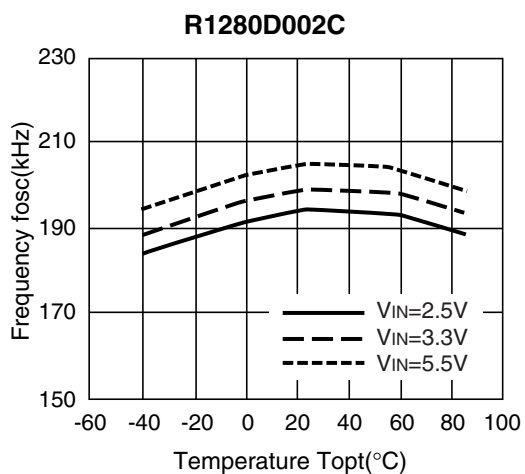
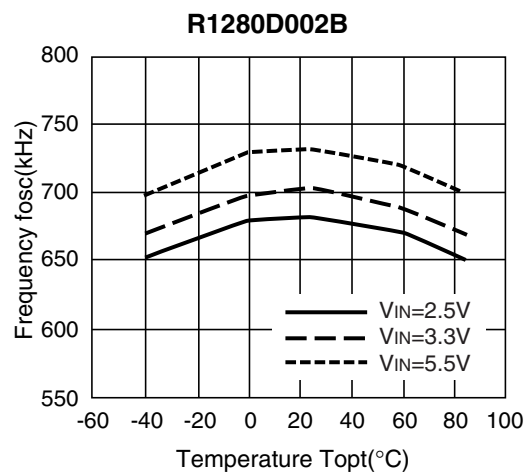
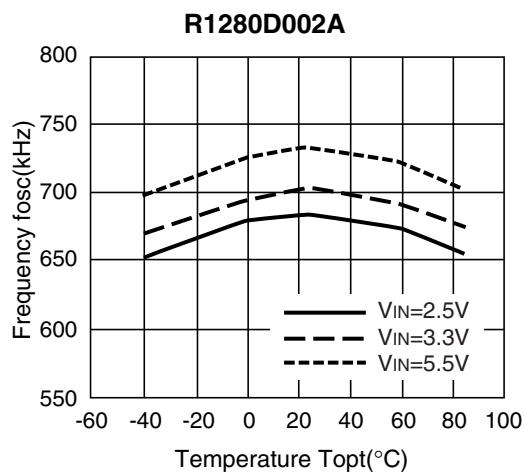


2) Efficiency vs. Output Current

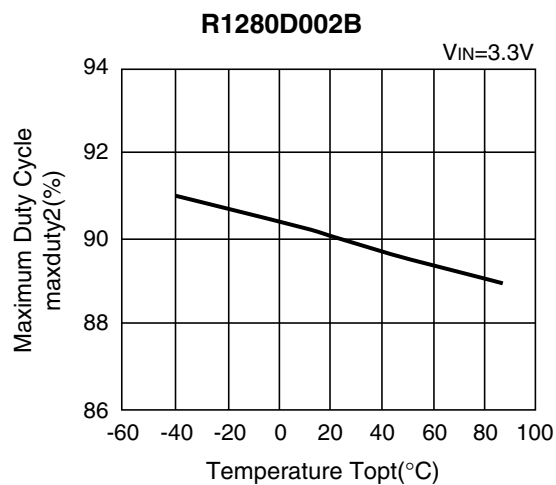
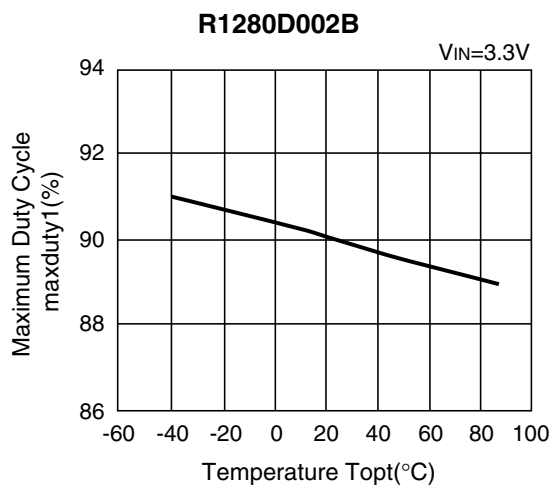


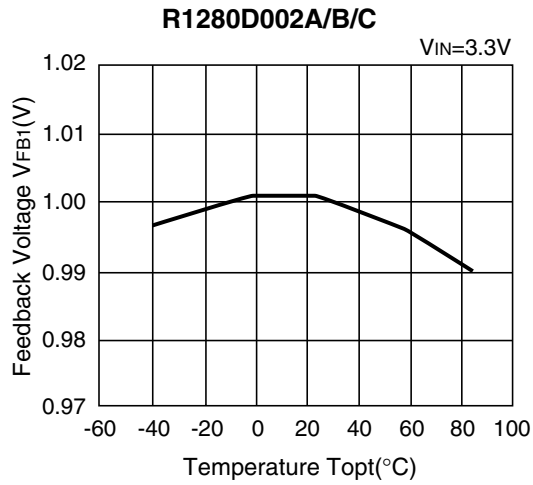
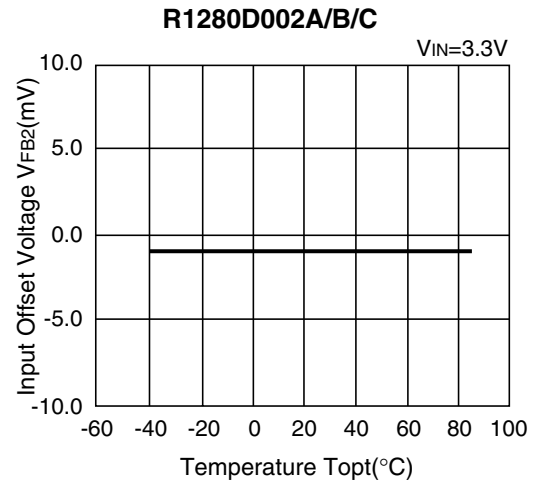
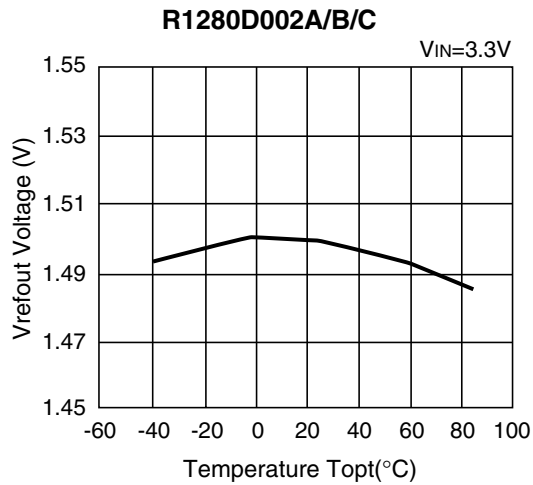
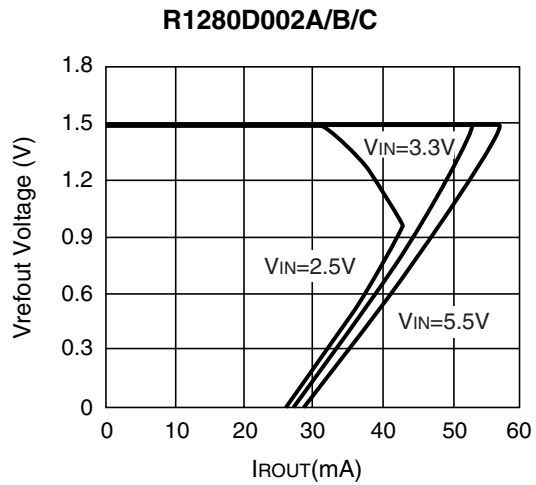
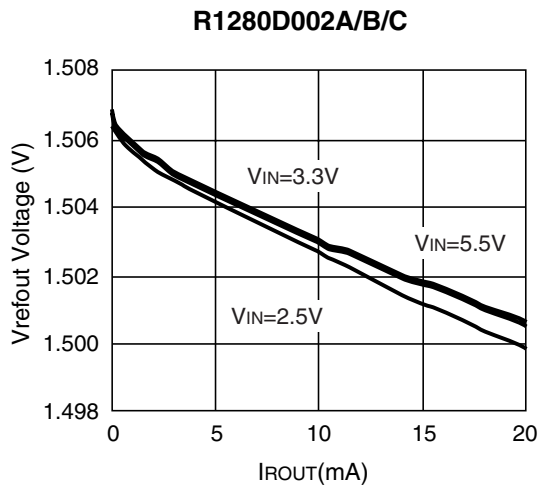
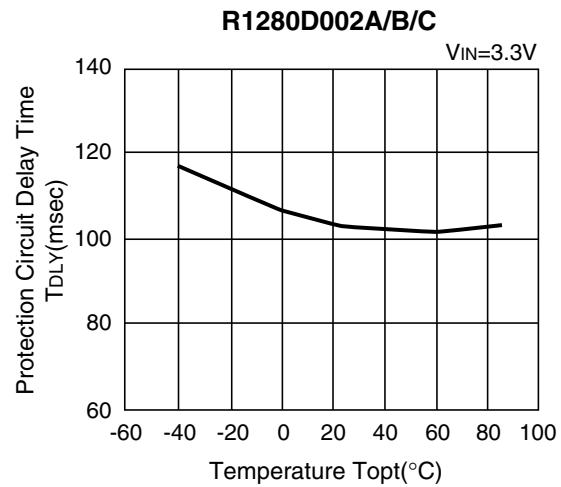
3) Output Voltage vs. Temperature


4) Frequency vs. Temperature

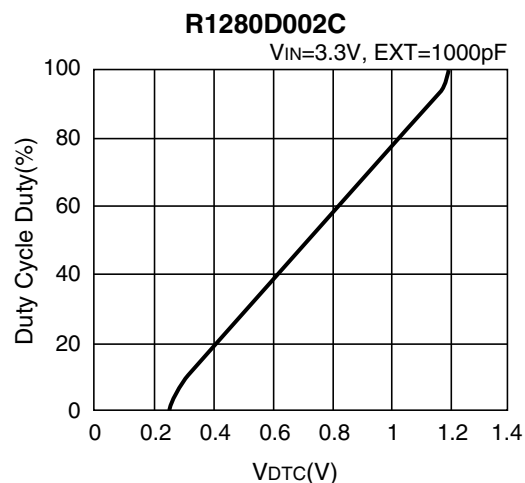
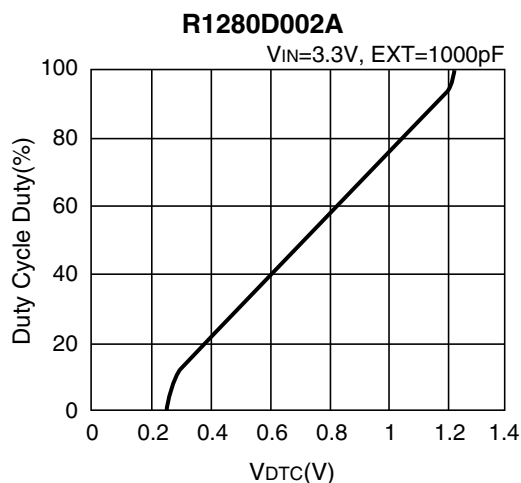


5) Maximum Duty Cycle vs. Temperature

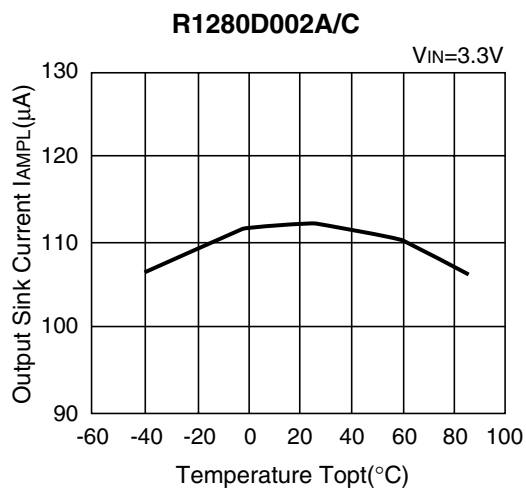


6) Feedback Voltage vs. Temperature

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


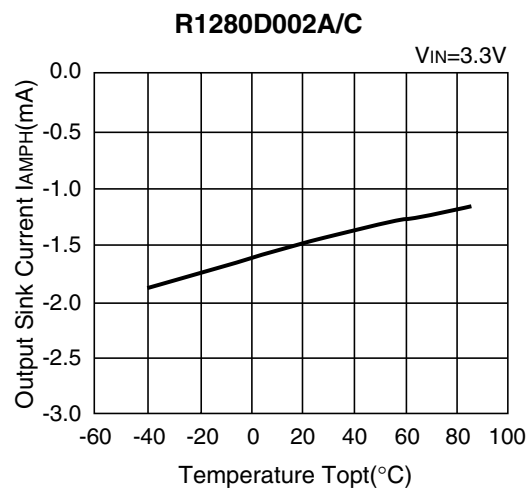
12) Duty Cycle vs. DTC Voltage



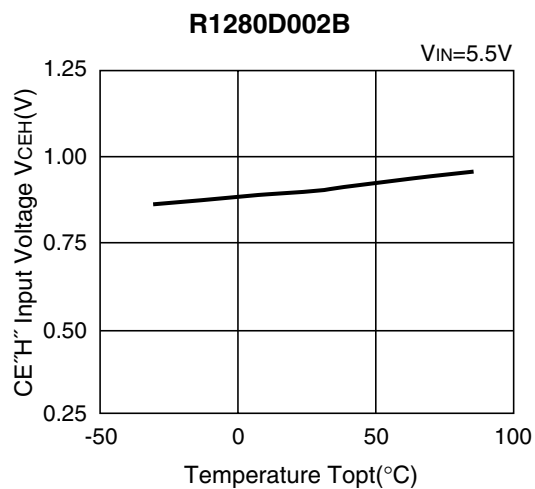
13) Output Sink Current vs. Temperature



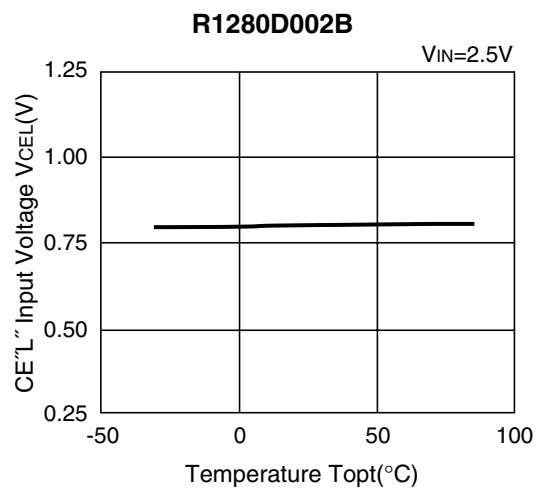
14) Output Source Current vs. Temperature



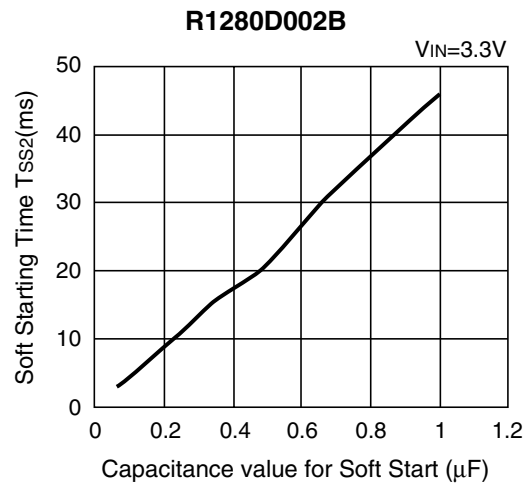
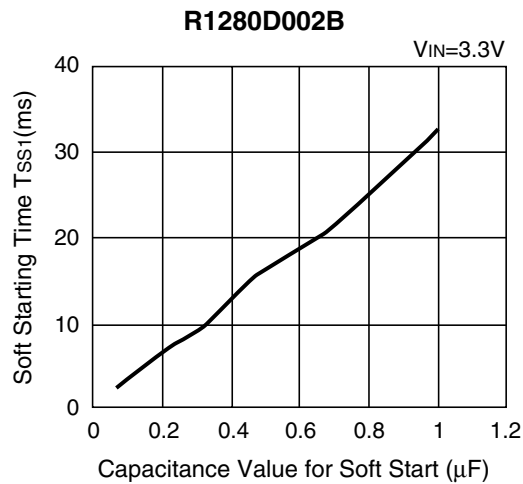
15) CE "H" Input Voltage vs. Temperature



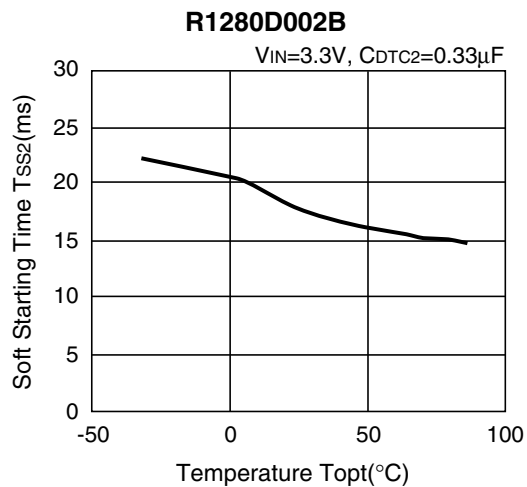
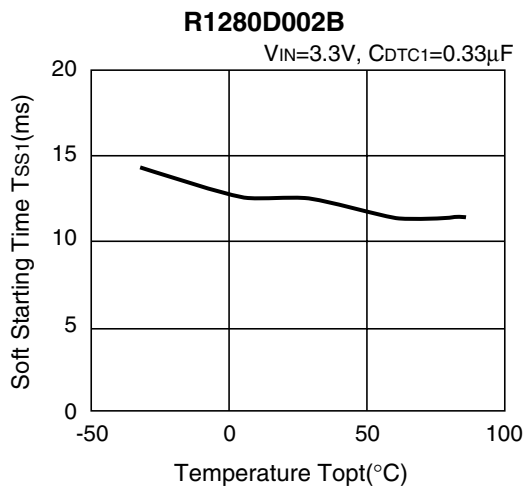
16) CE "L" Input Voltage vs. Temperature



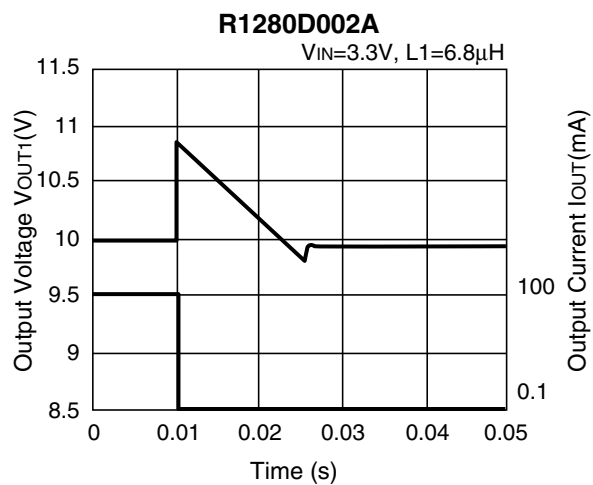
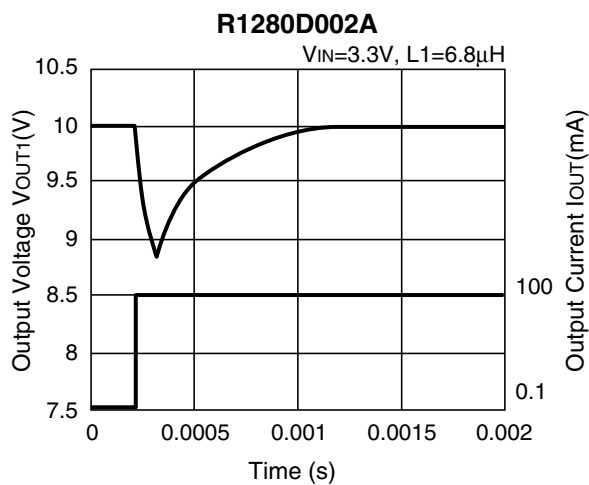
17) Soft Starting Time vs. Capacitance value

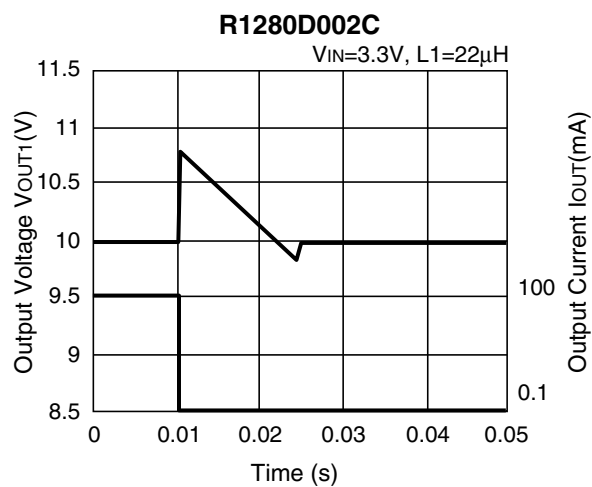
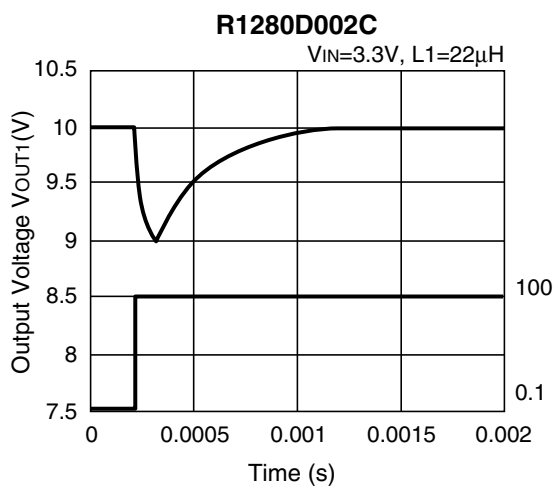
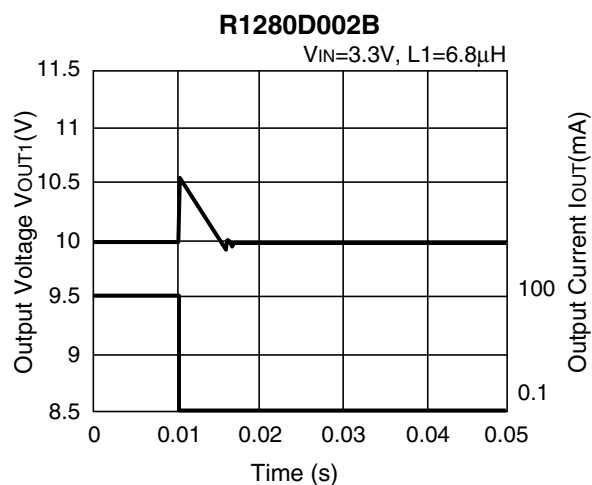
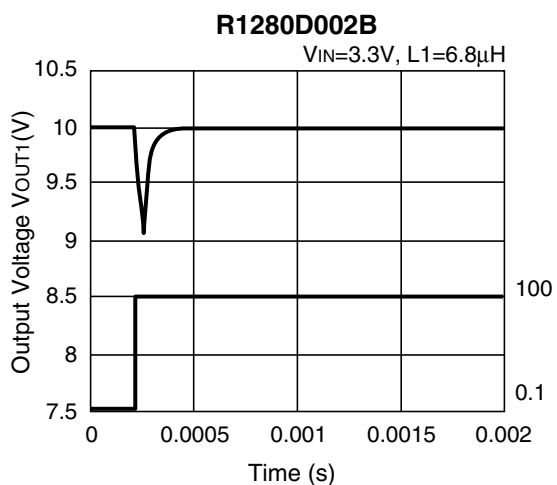


18) Soft Starting Time vs. Temperature

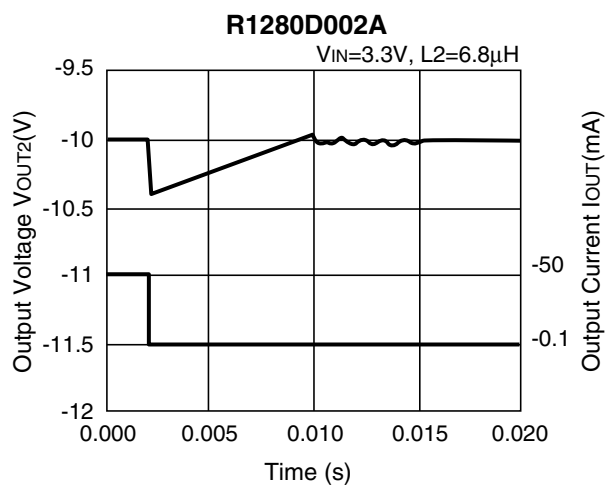
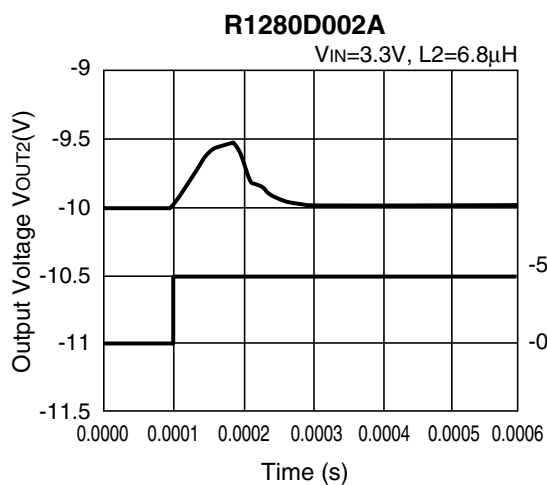


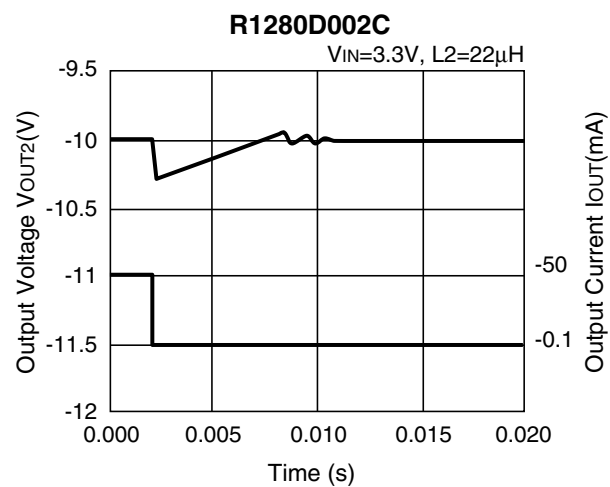
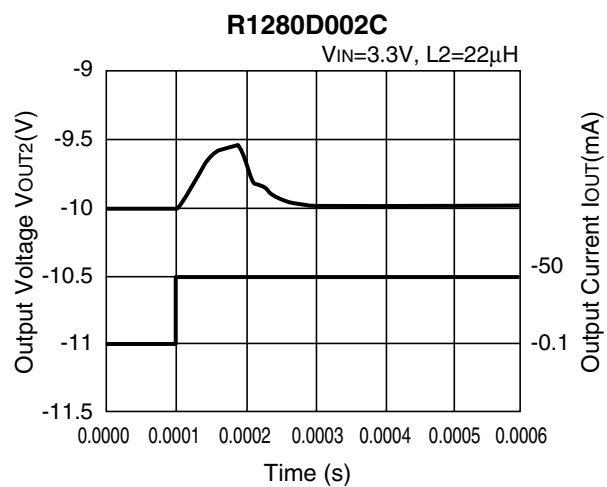
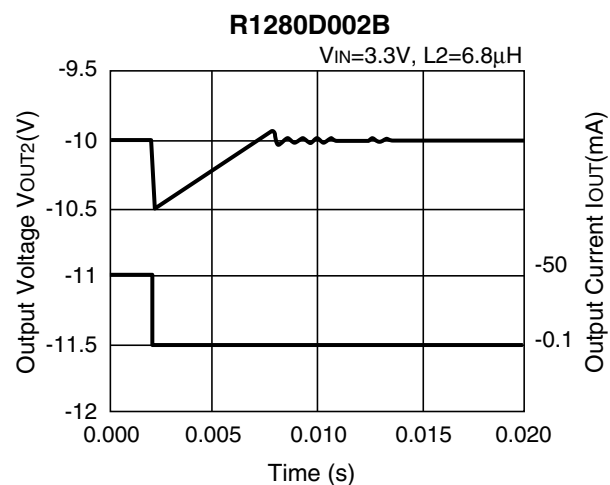
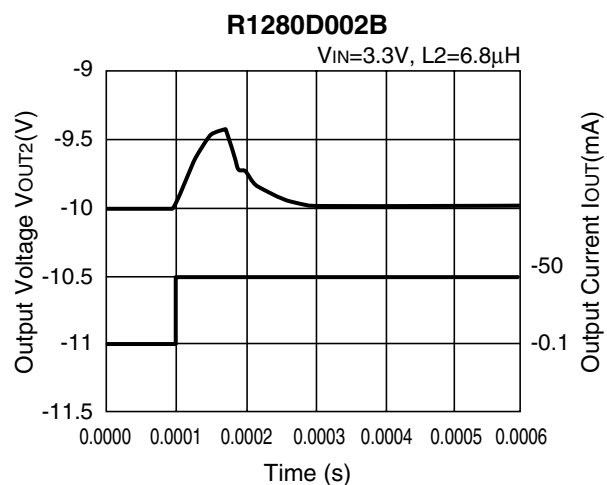
19) Load Transient Response(Step-up Side)





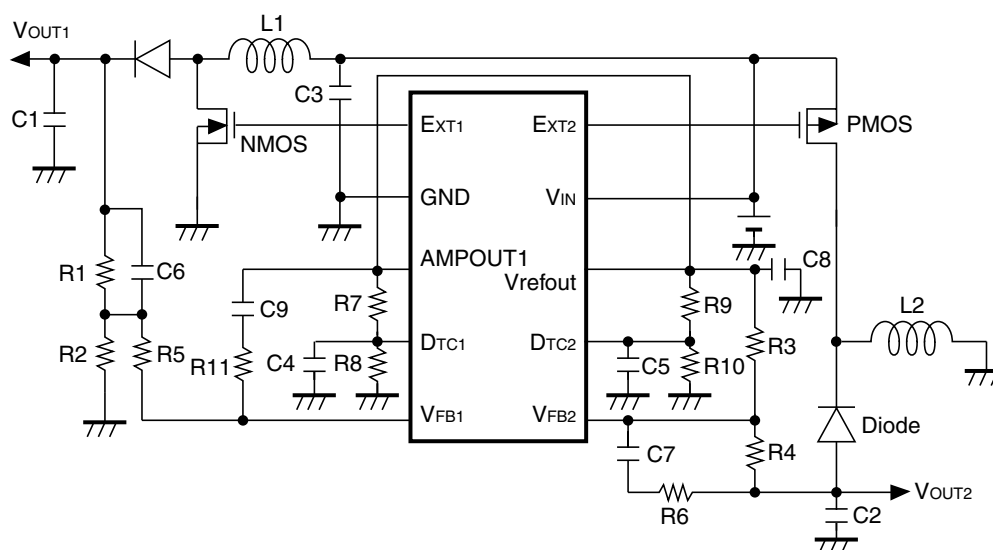
20) Load Transient Response (Inverting Side)





TYPICAL APPLICATION AND TECHNICAL NOTES

• R1280D002A/C



External Components

Inductor L1,2: 6.8μH, LDR655312T (TDK) for A type, 22μH for C type

Diode: FS1J3 (Origin Electronics)

NMOS: IRF7601 (International Rectifier)

PMOS: Si3443DV (Siliconix)

Resistors: R1, R2, R3, and R4 are for Setting Output Voltage. Recommendation values are
 $R1+R2 \leq 100k\Omega$ or $R3+R4 \leq 100k\Omega$
 $R5=43k\Omega$, $R6=10k\Omega$, $R7=R9=22k\Omega$, $R8=R10=43k\Omega$, $R11=220k\Omega$

Capacitors: Ceramic Capacitor

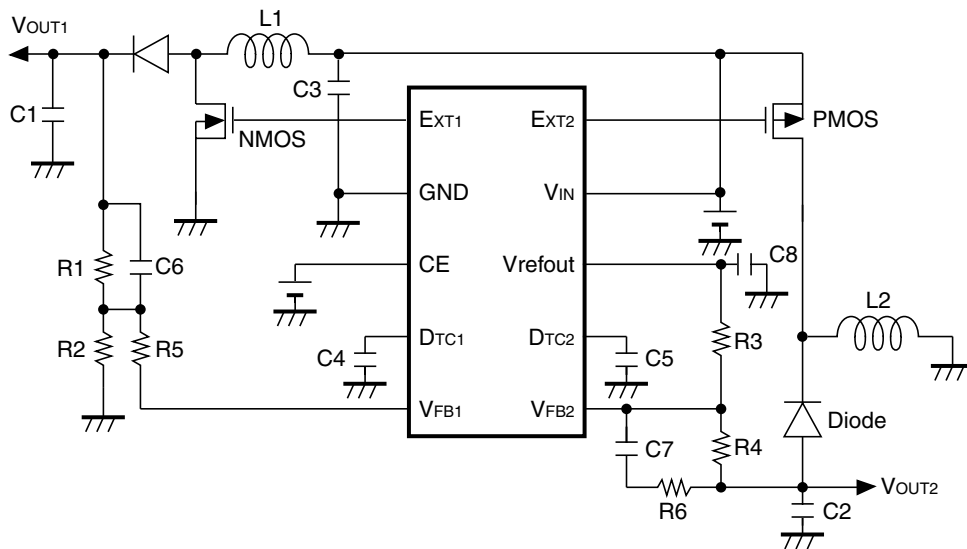
(Example)

R1280D002A: $C1=C2=10\mu F$, $C3=4.7\mu F$, $C4=0.22\mu F$, $C5=0.47\mu F$, $C6=120pF$, $C7=50pF$,
 $C8=1\mu F$, $C9=1000pF$

R1280D002C: $C1=C2=10\mu F$, $C3=4.7\mu F$, $C4=0.22\mu F$, $C5=0.47\mu F$, $C6=220pF$, $C7=330pF$,
 $C8=1\mu F$, $C9=1000pF$

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

R1280D002B



External Components

Inductor L1,2: 6.8μH, LDR655312T (TDK)

Diode: FS1J3 (Origin Electronics)

NMOS: IRF7601 (International Rectifier)

PMOS: Si3443DV (Siliconix)

Resistors: R1, R2, R3, and R4 are for Setting Output Voltage. Recommendation values are $R1+R2 \leq 100k\Omega$ or $R3+R4 \leq 100k\Omega$
 $R5=43k\Omega$, $R6=10k\Omega$

Capacitors: Ceramic Capacitor

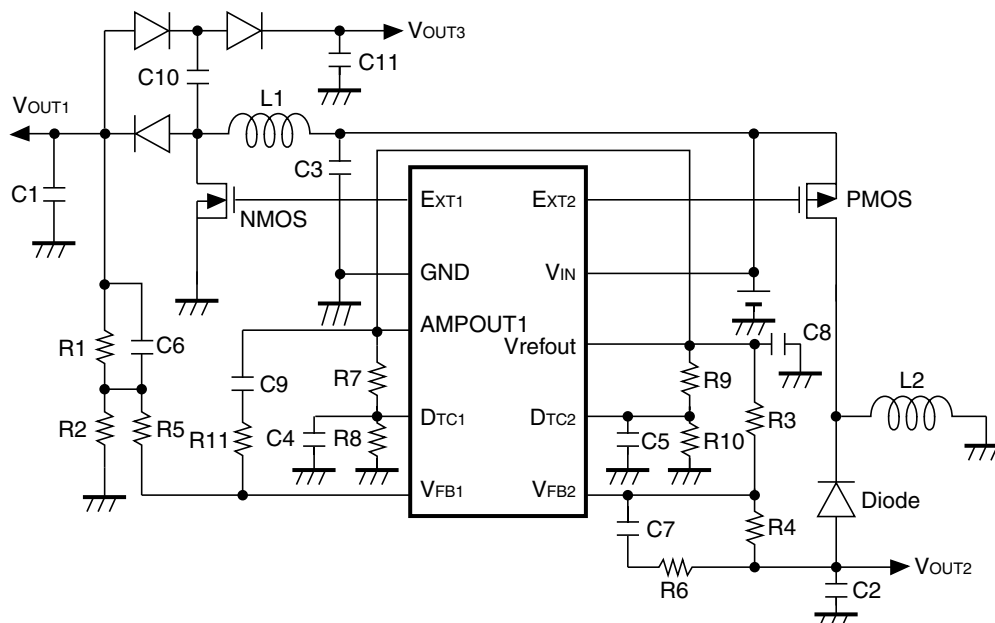
(Example)

$C1=C2=10\mu F$, $C3=4.7\mu F$, $C4=0.33\mu F$, $C5=0.33\mu F$, $C6=120pF$, $C7=50pF$, $C8=1\mu F$

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

APPLICATION EXAMPLE

• R1280D002A/C



External Components

Inductor L1,2: 6.8μH, LDR655312T (TDK) for A version, 22μH for R1280D002C

Diode: FS1J3 (Origin Electronics)

NMOS: IRF7601 (International Rectifier)

PMOS: Si3443DV (Siliconix)

Resistors: R1, R2, R3, and R4 are for Setting Output Voltage. Recommendation values are $R1+R2 \leq 100k\Omega$ or $R3+R4 \leq 100k\Omega$

R5=43kΩ, R6=10kΩ, R7=R9=22kΩ, R8=R10=43kΩ, R11=220kΩ

Capacitors: Ceramic Capacitor

(Example)

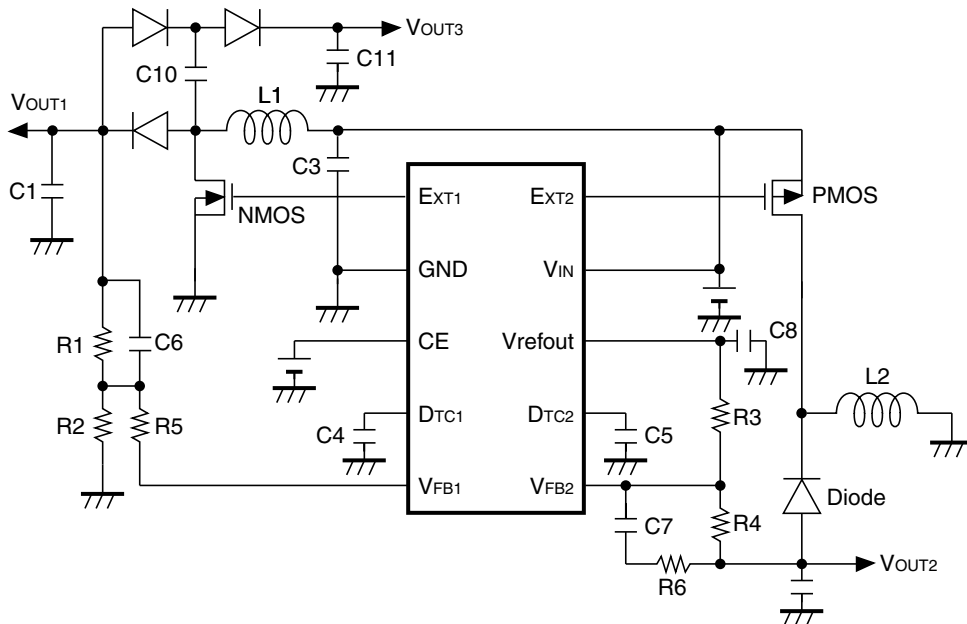
R1280D002A: C1=C2=10μF, C3=4.7μF, C4=0.22μF, C5=0.47μF, C6=120pF, C7=50pF, C8=C10=C11=1μF, C9=1000pF

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. $V_{OUT3} = 2 \times V_{OUT1} - V_f$

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, LDR655312T (TDK)

Diode: FS1J3 (Origin Electronics)

NMOS: IRF7601 (International Rectifier)

PMOS: Si3443DV (Siliconix)

Resistors: R1, R2, R3, and R4 are for Setting Output Voltage. Recommendation values are $R1+R2 \leq 100k\Omega$ or $R3+R4 \leq 100k\Omega$, $R5=43k\Omega$, $R6=10k\Omega$,

Capacitors: Ceramic Capacitor

(Example)

R1280D002B: $C1=C2=10\mu F$, $C3=4.7\mu F$, $C4=0.22\mu F$, $C5=0.33\mu F$, $C6=120pF$, $C7=50pF$, $C8=C10=C11=1\mu F$

This IC can be used 3 Output TFT Bias Circuit as shown above. $V_{OUT3}=2 \times V_{OUT1}-V_f$

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}

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,

$$V_{refout} : R3 = |-V_{OUT2}| : R4$$

Thus, $|-V_{OUT2}| = V_{refout} \times R4 / R3$

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. ($T_{opt} = 25^\circ\text{C}$)

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

In the above formulas, RS1 value is Typ. 32k Ω , while RS2 value is Typ. 45k Ω . Tolerance of these values is $\pm 25\%$ 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 $4.7\mu\text{F}$. 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 $10\text{k}\Omega$ to $50\text{k}\Omega$ as R5 and try to reduce the noise level. In the case of V_{OUT2} , use the resistor as much as $10\text{k}\Omega$ 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, I_{Lx} 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 $10\mu\text{F}$. In case that the operation with the system of DC/DC converter would be unstable, add a series resistor 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 $(V_{IN}-0.3)\text{V}$ 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.