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R1282D002A SERIES

2CH PWM DC/DC CONTROLLER

NO.EA-086-160126

OUTLINE

The R1282D002A is a CMOS-based 2-channel PWM Step-up (as Channel 1)/Step-down (as Channel 2) DC/DC converter controller.

The R1282D002A 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/Step-down DC/DC converter can be composed of this IC with inductors, diodes, power MOSFETs, resisters, and capacitors. Each output voltage and maximum duty cycle can be adjustable with external resistors, while soft-start time can be adjustable with external capacitors and resistors.

As for a protection circuit, if Maximum duty cycle of either Step-up DC/DC converter side or Step-down DC/DC converter side is continued for a certain time, the R1280D002A latches 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).

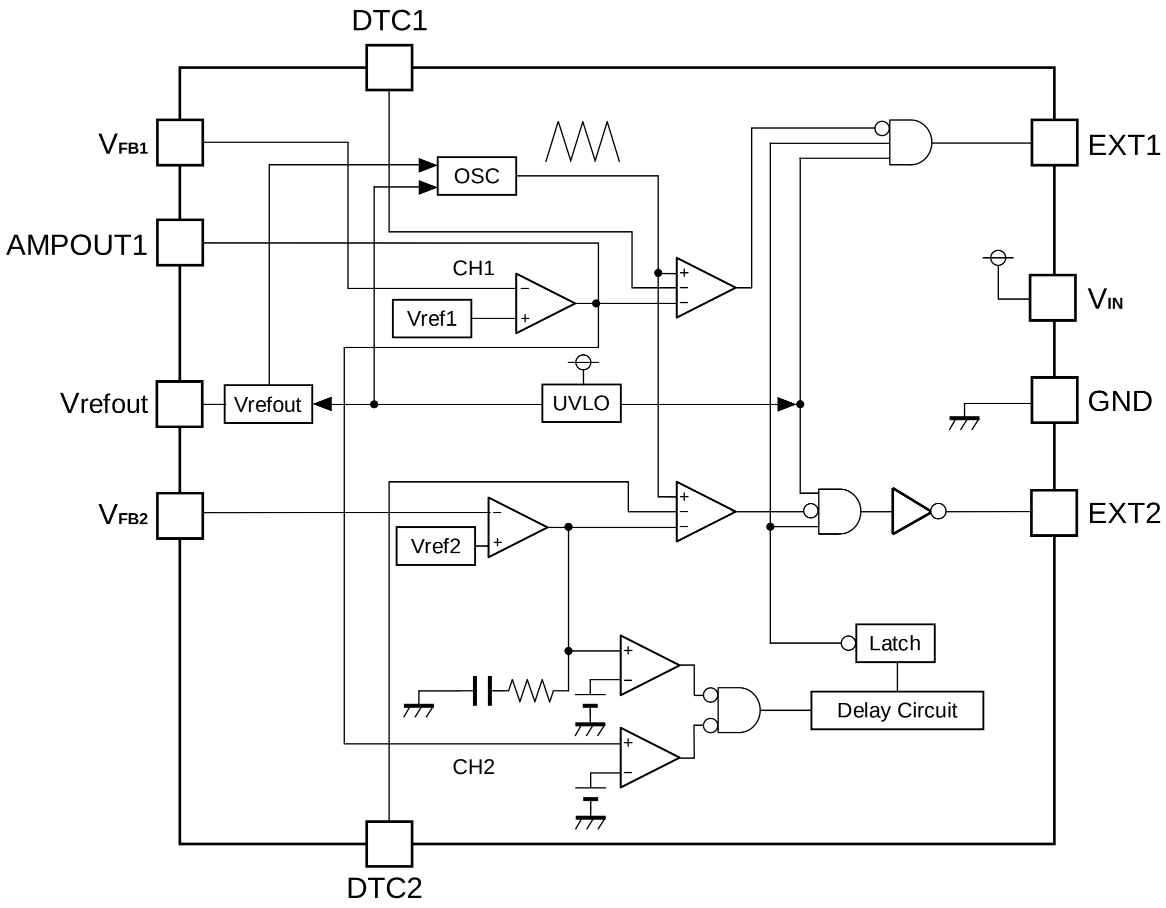
FEATURES

- 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
- High Accuracy Voltage Reference ....±1.5%
- U.V.L.O. Threshold..Typ. 2.2V (Hysteresis: Typ. 0.2V)
- 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



SELECTION GUIDE

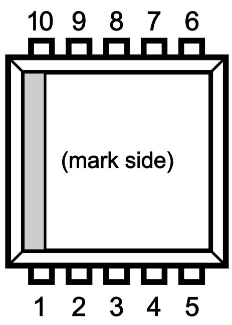
The selection can be made with designating the part number as shown below;

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1282D002x-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

PIN CONFIGURATION

● SON-10



PIN DESCRIPTION

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)

ABSOLUTE MAXIMUM RATINGS

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}, 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

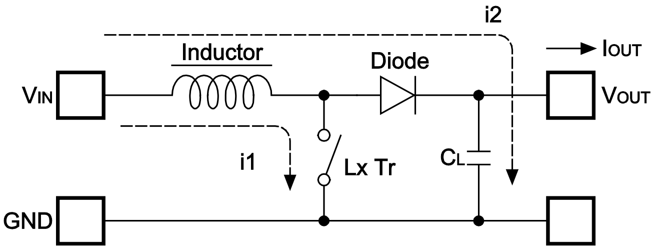
ELECTRICAL CHARACTERISTICS

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 $\leqq V_{IN} \leqq$ 5.5V		2	6	mV
$\Delta V_{REFOUT}/\Delta I_{OUT}$	V_{REFOUT} Load Regulation	1mA $\leqq I_{ROUT} \leqq$ 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
$\Delta V_{FB2}/\Delta T$	V_{FB2} Voltage Temperature Coefficient	−40°C ≦ Topt ≦ 85°C		±150		ppm/°C
$I_{VFB1,2}$	$V_{FB1,2}$ 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} +0.20	2.48	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_{T2}	CH2 Single Gain Frequency Band	V_{IN}=3.3V, A_{V2}=0dB		600		kHz
V_{ICR2}	CH2 Input Voltage Range	V_{IN}=3.3V		−0.2 to V_{IN}−1.3		V
V_{FB2}	CH2 Reference Voltage	V_{IN}=3.3V	0.985	1.000	1.015	V

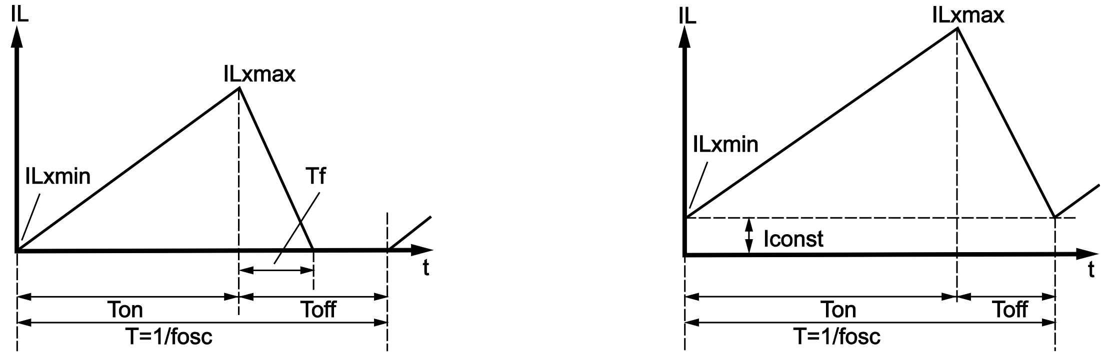
Output Current and Selection of External Components

<Basic Circuit>



<Current through L>

Discontinuous Mode | **Continuous Mode**



There are two modes, or discontinuous mode and continuous mode for the PWM step-up switching regulator depending on the continuous characteristic of inductor current.

During on time of the transistor, when the voltage added on to the inductor is described as V_{IN}, the current is $V_{IN} \times t/L$.

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

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

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

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

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

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

In PWM control, when Tf=Toff is true, the inductor current becomes 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, ILXmax flowing through the inductor and the driver Tr. is described as follows:

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

With the formula 4,6, and IL_Xmax is,

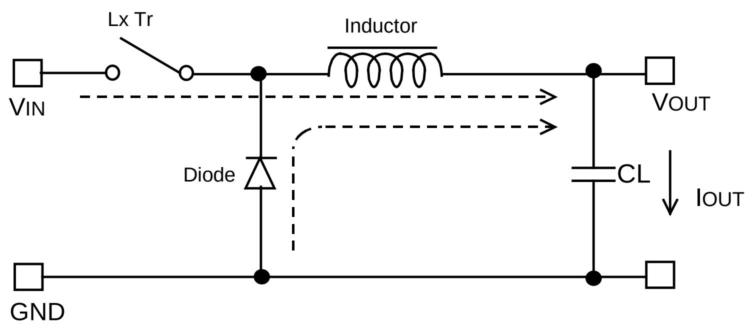
$IL_X max = V_{OUT}/V_{IN} \times I_{OUT} + V_{IN} \times Ton/(2 \times L)$ .... Formula 8

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.

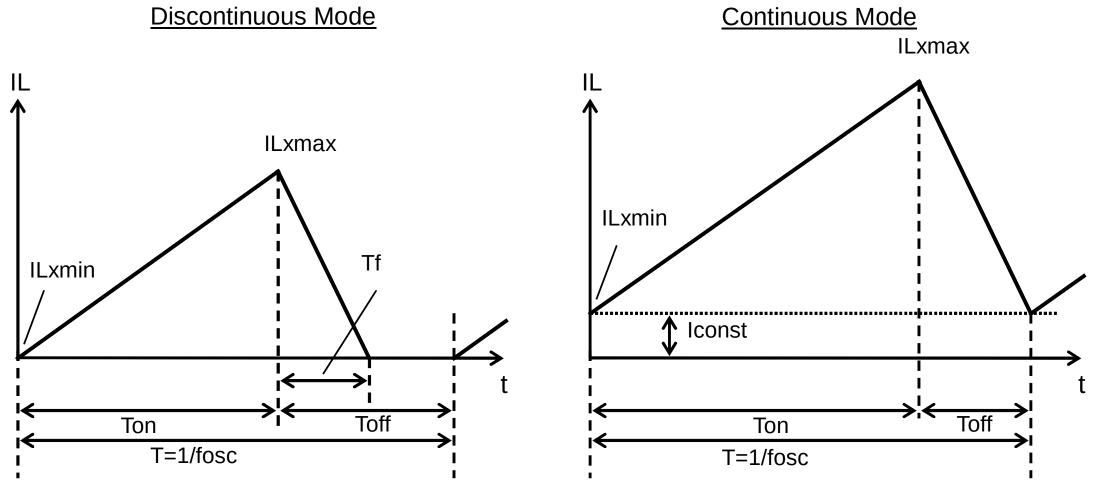
In the formula 7, peak current IL_Xmax at discontinuous mode can be calculated. Put Iconst=0 in the formula.

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.

There are also two modes, or discontinuous mode and continuous mode for the PWM step-down switching regulator depending on the continuous characteristic of inductor current.



<Current through L>



During on time of the transistor, when the voltage added on to the inductor is described as $V_{IN}- V_{OUT}$ the current is $(V_{IN}- V_{OUT}) \times t/L$.

Therefore, the electric power, P, which is supplied from the input side, can be described as in next formula.

$$P=\int_0^{Ton} V_{IN} \cdot (V_{IN}-V_{OUT}) \cdot t/L\,dt$$ .... Formula 9

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

$$P_{AV} = 1/(Ton+Toff) \int_0^{Ton} V_{IN} \cdot (V_{IN}-V_{OUT}) \cdot t/L\,dt = V_{IN} \cdot (V_{IN}-V_{OUT}) \cdot Ton^2 / (2 \cdot L\,(Ton+Toff))$$ ... Formula 10

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

$$I_{OUT} = V_{IN} / V_{OUT} \times (V_{IN} - V_{OUT}) \acute{} Ton^2/(2 \times L \times (Ton+Toff))$$ .... Formula 11

When I_{OUT} increases and 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,

$$(V_{IN}- V_{OUT}) \times Ton/L = V_{OUT} \times Toff/L$$ .... Formula 12

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

$I_{OUT}=I_{CONST}+V_{OUT}\times Toff/(2\times L)$ .... Formula 13

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

$IL_{X}max= I_{OUT}+V_{OUT}\times Toff/(2\times L)$ .... Formula 14

With the formula 12,13, $IL_{X}max$ is,

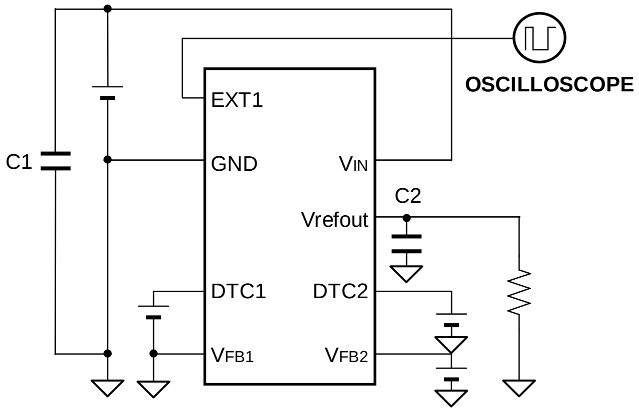
$Toff=(1-V_{OUT}/V_{IN})/fosc$ .... Formula 15

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.

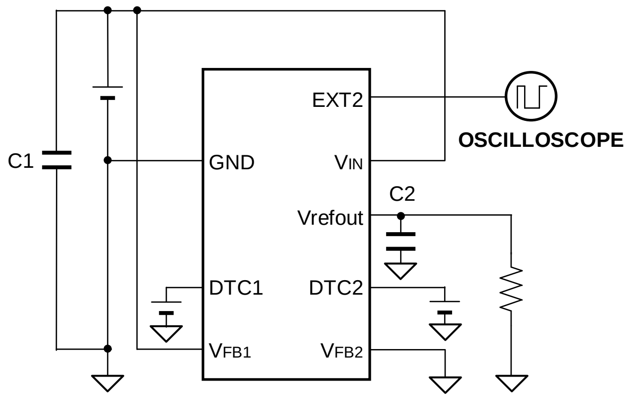
In the formula 14, peak current $IL_{X}max$ at discontinuous mode can be calculated. Put Iconst=0 in the formula.

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

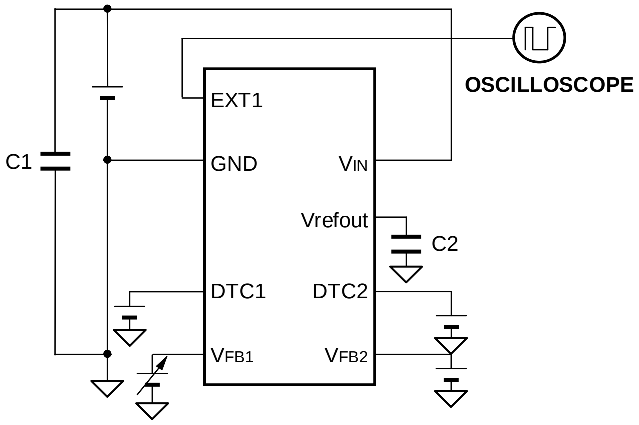
TEST CIRCUITS



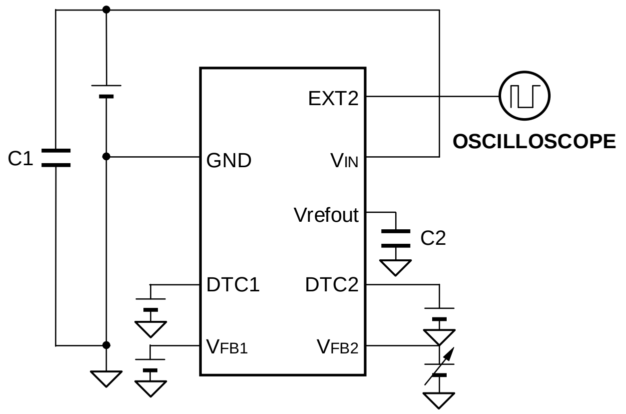
Test Circuit 1



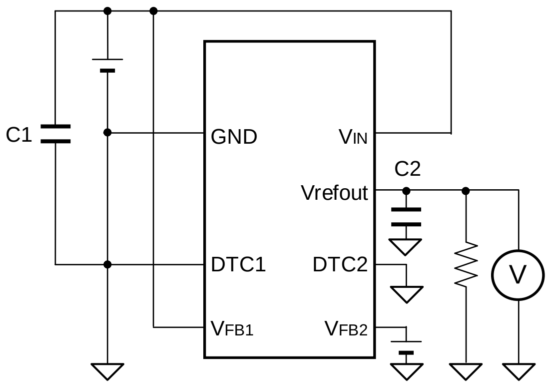
Test Circuit 2



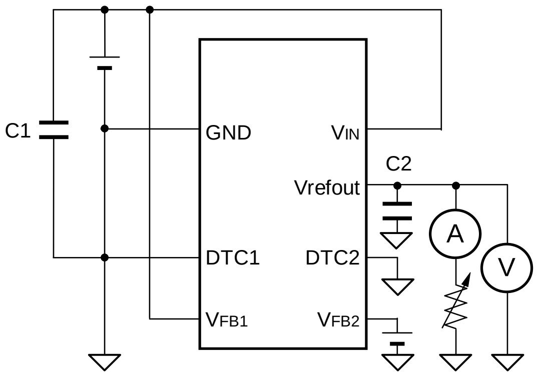
Test Circuit 3



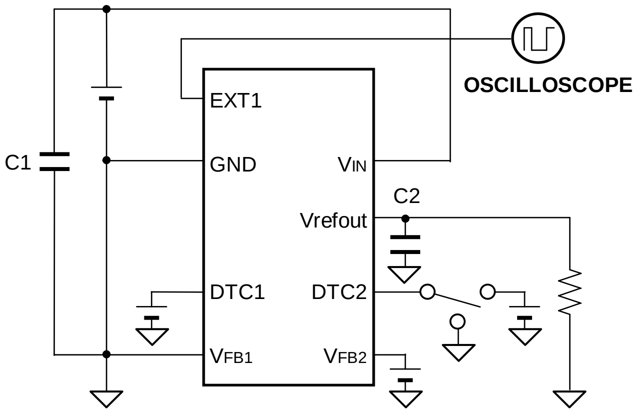
Test Circuit 4



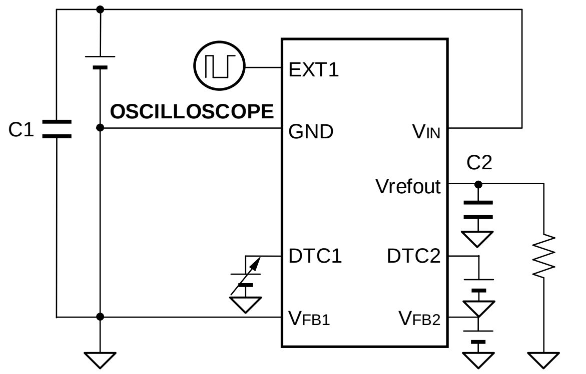
Test Circuit 5



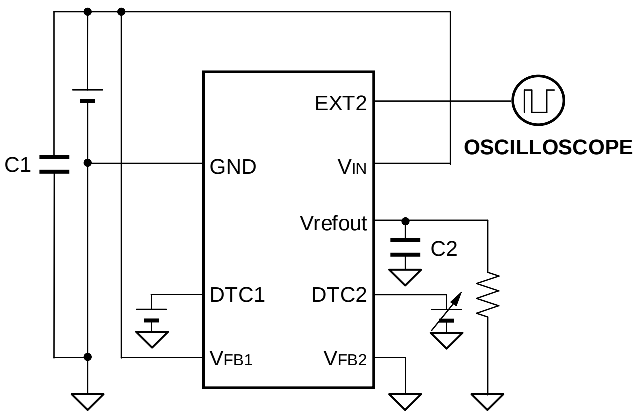
Test Circuit 6



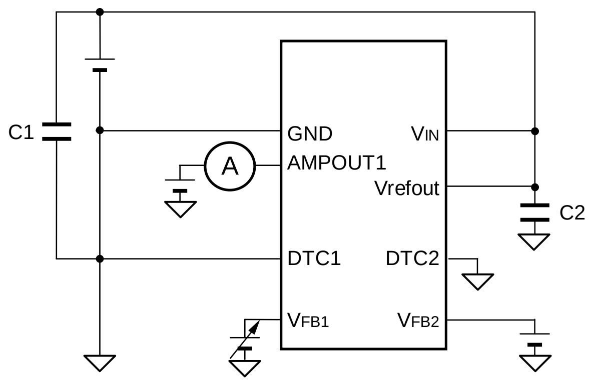
Test Circuit 7



Test Circuit 8



Test Circuit 9



Test Circuit 10

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

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

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

Efficiency η(%) can be calculated with the next formula:
$\eta=(V_{OUT1}\times I_{OUT1}+V_{OUT2}\times I_{OUT2})/(V_{IN}\times I_{IN})\times 100$

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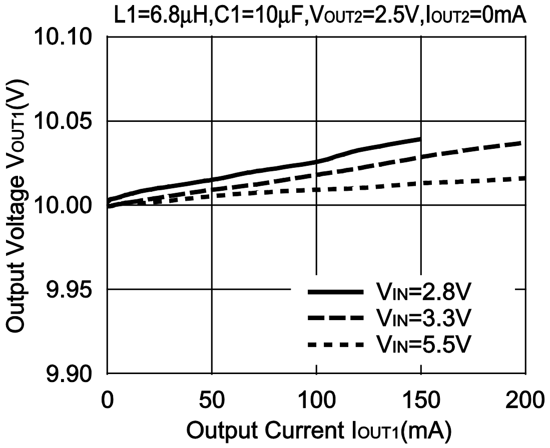
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current (Topt=25°C)

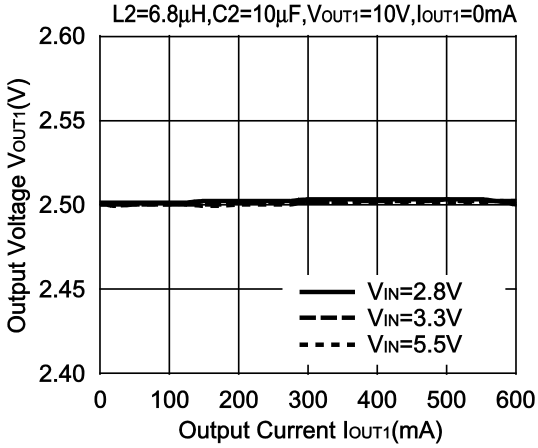
R1282D002A

L1=6.8µH,C1=10µF,VOUT2=2.5V,IOUT2=0mA



R1282D002A

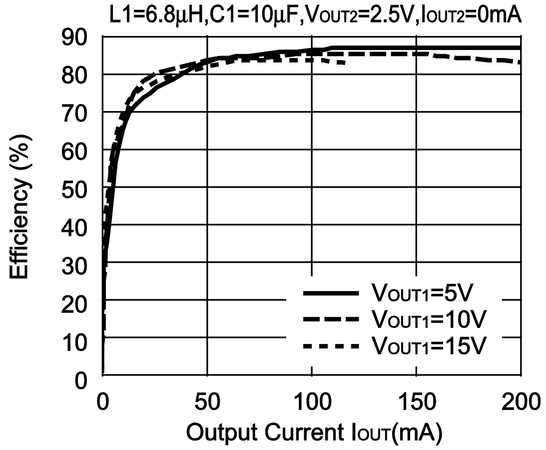
L2=6.8µH,C2=10µF,VOUT1=10V,IOUT1=0mA



2) Efficiency vs. Output Current (VIN=3.3V, Topt=25°C)

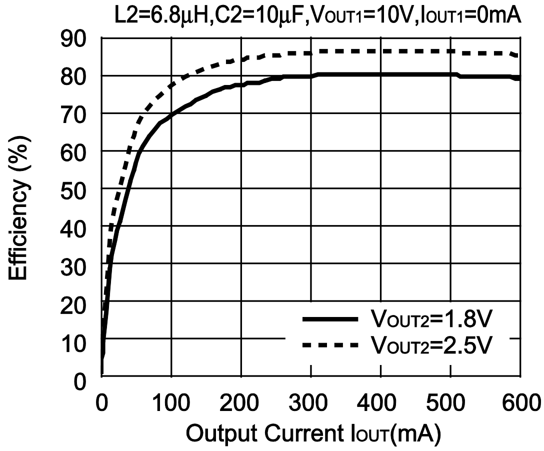
R1282D002A

L1=6.8µH,C1=10µF,VOUT2=2.5V,IOUT2=0mA



R1282D002A

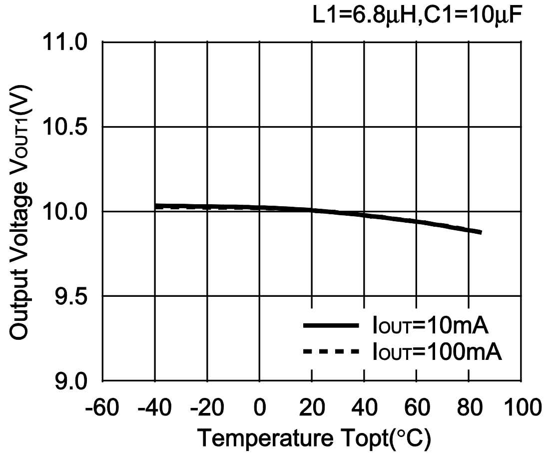
L2=6.8µH,C2=10µF,VOUT1=10V,IOUT1=0mA



3) Output Voltage vs. Temperature (VIN=3.3V)

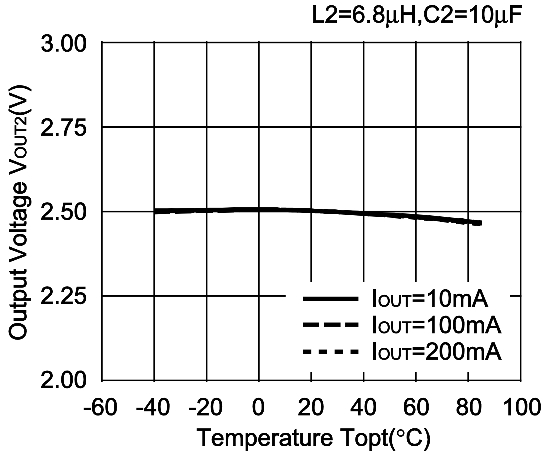
R1282D002A

L1=6.8µH,C1=10µF



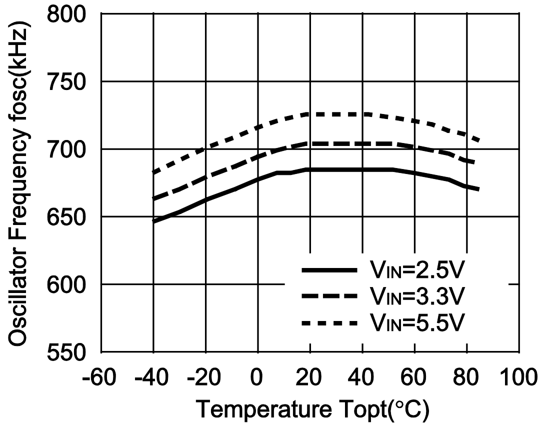
R1282D002A

L2=6.8µH,C2=10µF



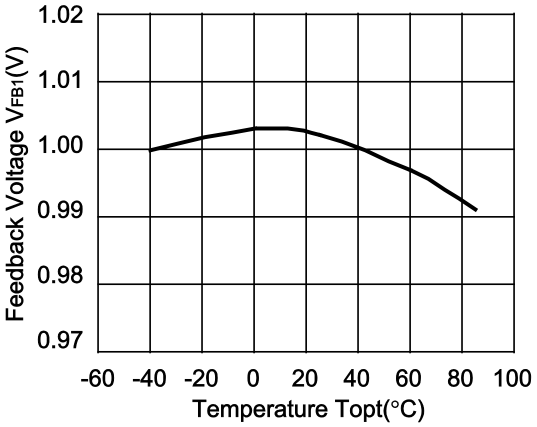
4) Frequency vs. Temperature

R1282D002A

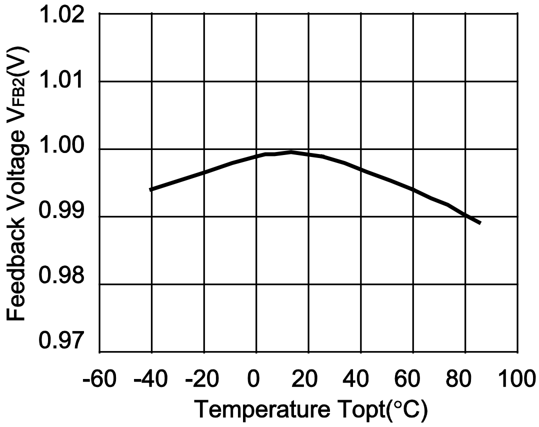


5) Feedback Voltage vs. Temperature (VIN=3.3V)

R1282D002A

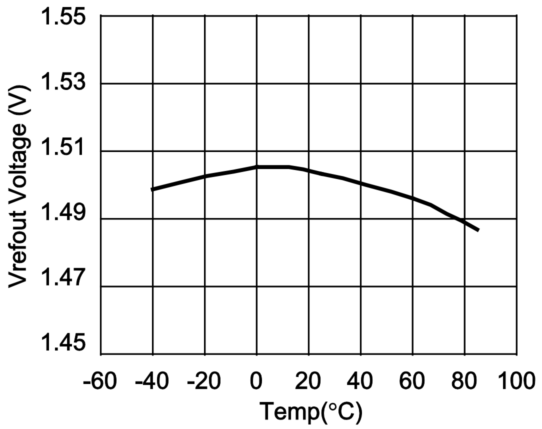


R1282D002A



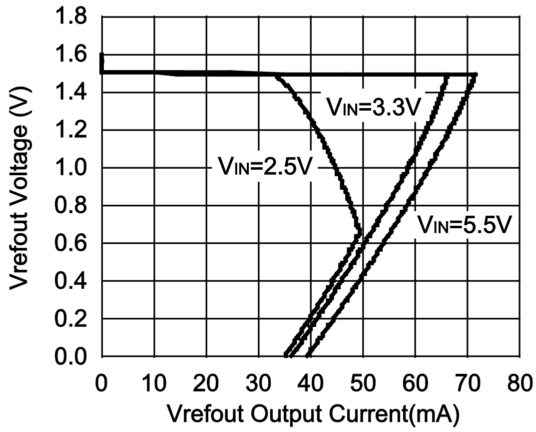
6) Vrefout Voltage vs. Temperature(VIN=3.3V)

R1282D002A



7) Vrefout Output Voltage vs. Output Current

R1282D002A



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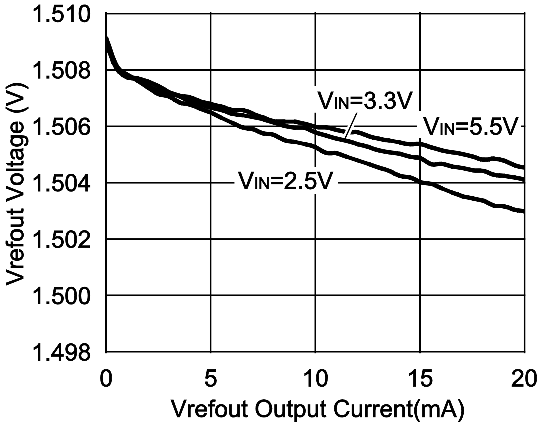
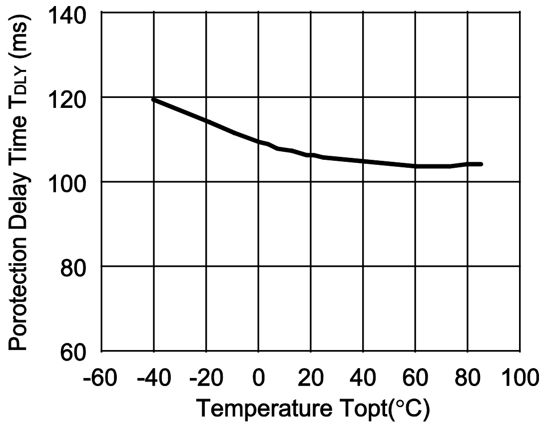
8) Vrefout Output Voltage vs. Output Current

R1282D002A



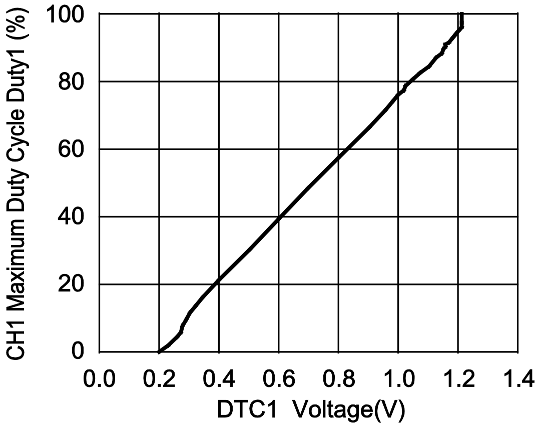
9) Protection Delay Time vs. Temperature (VIN=3.3V)

R1282D002A

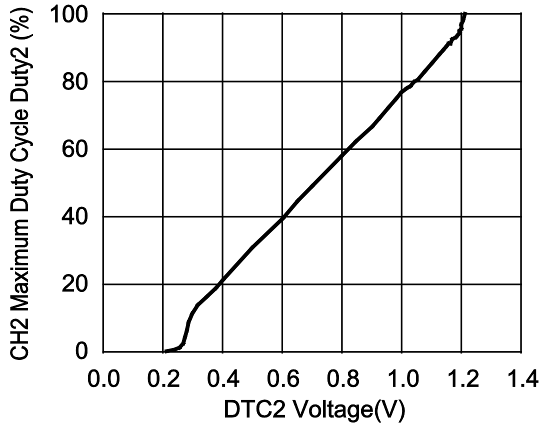


10) Maximum Duty Cycle vs. DTC Voltage (VIN=3.3V)

R1282D002A

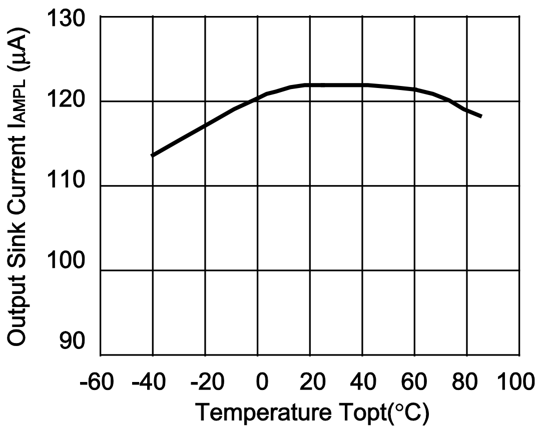


R1282D002A



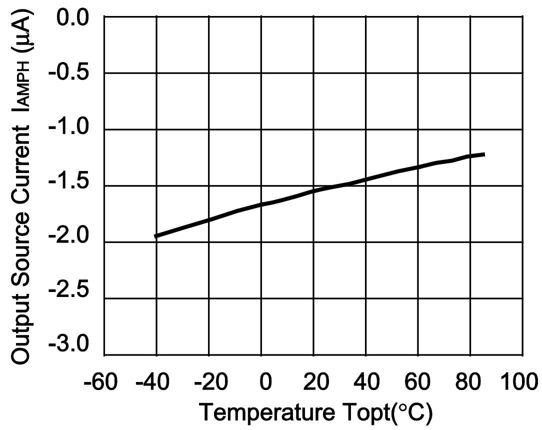
11) Output Sink Current vs. Temperature (VIN=3.3V)

R1282D002A

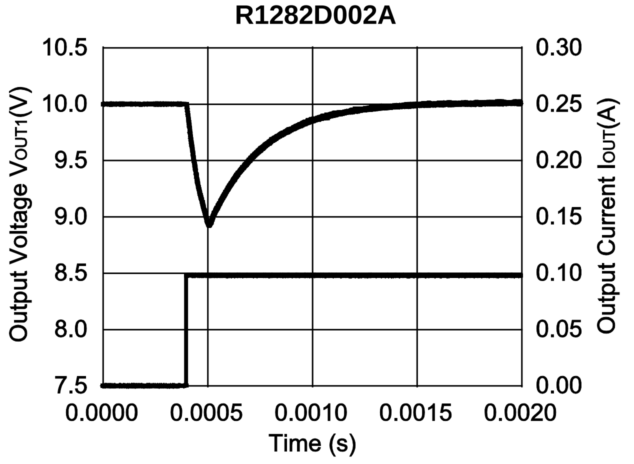


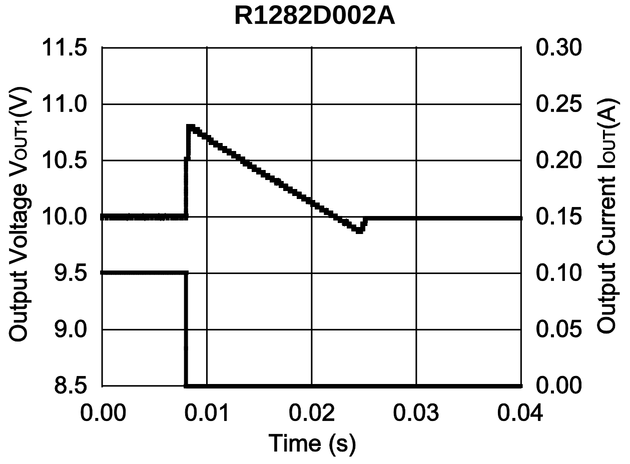
12) Output Source Current vs. Temperature

R1282D002A

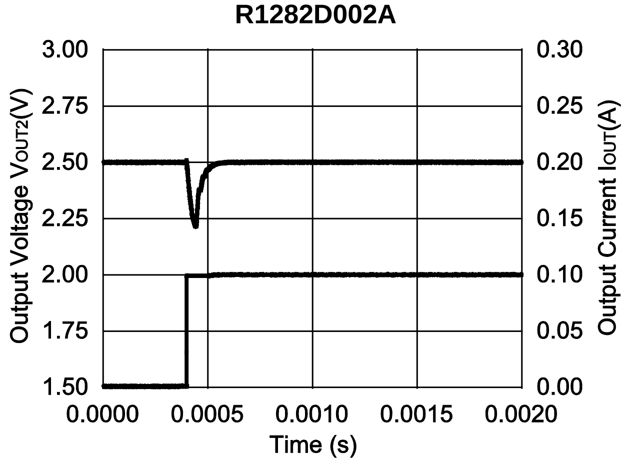


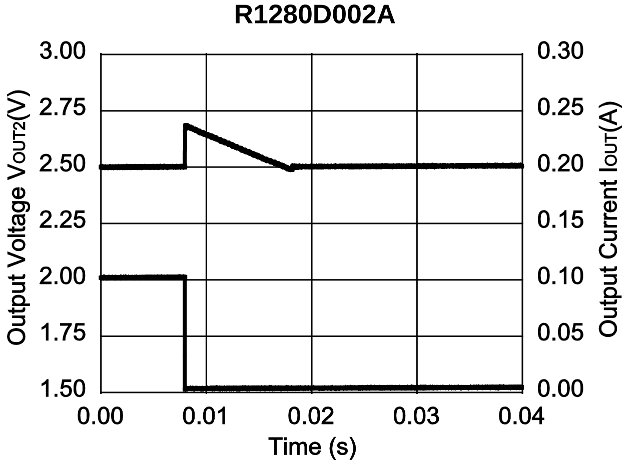
13) Load Transient Response (Step-up Side) V_{IN}=3.3V, L1=6.8μH





14) Load Transient Response (Step-down Side) V_{IN}=3.3V, L2=6.8μH





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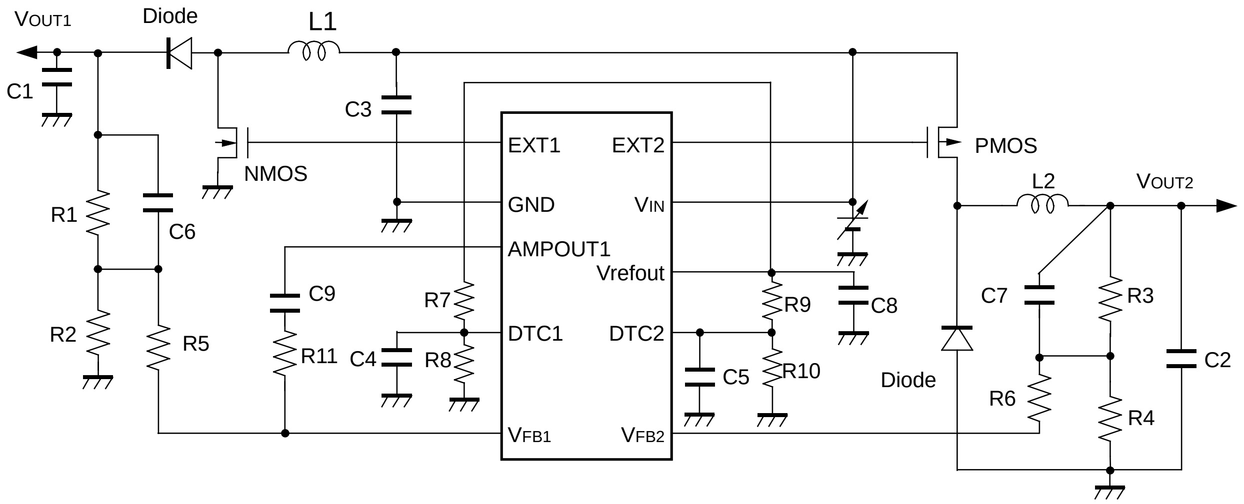
TYPICAL APPLICATION AND TECHNICAL NOTES



Components examples

Inductor L1,2	6.8μH VLF504012MT (TDK)
Diode	CRS10I30A (Toshiba)
PMOS	Si3443DV (Siliconix)
NMOS	IRF7601 (International Rectifier)

Resistance As setting resistors total value for the output voltage, R1+R2, R3+R4 recommendation value is 100kW or less.

R1=47kΩ	R2=5.1kΩ	R3=30kΩ	R4=20kΩ
R5=43kΩ	R6=10kWΩ		
R7=R9=22kΩ	R8=R10=43kΩ	R11=220kΩ	

Capacitors Ceramic Type

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

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.

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 Step-down side, Feedback (V_{FB2}) pin voltage follows the next formula,

   $$V_{OUT2}: R3+R4=V_{FB2} : R4$$

   Thus, $V_{OUT2}=V_{FB2}\times(R3+R4)/R4$
   Output Voltage is adjustable with R3 and R4.

2. How to set Soft-Start Time and Maximum Duty Cycle
   Soft-start time is adjustable with connecting resistors and 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.

   $$T_{SS1}\cong RO1\times C4$$

   If $R10=0\Omega$, then,

   $$T_{SS2}\cong R9\times C5\times \ln((Vrefout-V_{DTC2})/Vrefout)$$

   Maximum Duty Cycle is set with the voltage to DTC1 and DTC2.
   Maximum duty cycle is described as follows;
   CH1 (Step-up side)
   $Maxduty1\cong (R8/(R7+R8)\times Vrefout-0.2)/(1.2-0.2)\times 100$ (%)
   Step-up side maximum duty cycle should be set equal or less than 90%. If the maximum duty cycle is set at high percentage, operation will be unstable.

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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.
- If the spike noise of V_{OUT1} 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 fully large voltage tolerance of the capacitor.
- 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.
- 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.

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