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
2.5 V to 5.5 V
- Built-in Latch-type Protection Function by monitoring duty cycle (Fixed Delay Time Typ. 100ms)
- Oscillator Frequency 700 kHz
- High Accuracy Voltage Reference .................... $\pm 1.5 \%$
- 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 | $3,000 \mathrm{pcs}$ | Yes | Yes |

x: Designation of Mask Option
A version: fosc $=700 \mathrm{kHz}$, with External Phase Compensation for Channel 1

## PIN CONFIGURATION



## 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 $_{\text {FB1 }}$ | Feedback pin of Channel 1 |
| 6 | V FB2 | DTC2 |
| 7 | Vrefout | Meedback pin of Channel 2 |
| 8 | VIN | Veference Output Pin |
| 9 | EXT2 | External Transistor of Channel 2 Drive Pin (CMOS Output) |
| 10 |  |  |

## ABSOLUTE MAXIMUM RATINGS

| Symbol | Item | Rating | Unit |
| :---: | :---: | :---: | :---: |
| Vin | Vin Pin Voltage | 6.5 | V |
| Vexti,2 | Vexti,2 Pin Output Voltage | $-0.3 \sim \mathrm{~V}$ IN+0.3 | V |
| $V_{\text {ampout }}$ | AMPOUT1 Pin Voltage | -0.3~Vin+0.3 | V |
| Vdtci,2 | DTC1,2 Pin Voltage | -0.3~Vin+0.3 | V |
| Vrefout | Vrefout Pin Voltage | -0.3~VIN+0.3 | V |
| $V_{\text {FBB } 1,2}$ | $\mathrm{V}_{\text {FB1 } 1, \mathrm{~V}_{\text {FB2 }} \text { Pin Voltage }}$ | -0.3~VIN+0.3 | V |
| IExT1,2 | EXT1,2 Pin Output Current | $\pm 50$ | mA |
| PD | Power Dissipation | 250 | mW |
| Topt | Operating Temperature Range | -40 to +85 | ${ }^{\circ} \mathrm{C}$ |
| Tstg | Storage Temperature Range | -55 to +125 | ${ }^{\circ} \mathrm{C}$ |

## ELECTRICAL CHARACTERISTICS

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Vin | Operating Input Voltage |  | 2.5 |  | 5.5 | V |
| Vrefout | V Refout Voltage Tolerance | $\mathrm{V}_{\text {IN }}=3.3 \mathrm{~V}$, lout $=1 \mathrm{~mA}$ | 1.478 | 1.500 | 1.522 | V |
| Irout | Vrefout Output Current | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$ | 20 |  |  | mA |
|  | V ${ }_{\text {Refout }}$ Line Regulation | $2.5 \mathrm{~V} \leqq \mathrm{~V}^{\mathrm{IN}} \leqq 5.5 \mathrm{~V}$ |  | 2 | 6 | mV |
| $\Delta \mathrm{V}_{\text {REFOUT } / \Delta I \text { Iout }}$ | $V_{\text {refout }}$ Load Regulation | $1 \mathrm{~mA} \leqq \mathrm{I}_{\text {Rout }} \leqq 10 \mathrm{~mA} \mathrm{~V}_{\text {IN }}=3.3 \mathrm{~V}$ |  | 6 | 12 | mV |
| ILIm | Vrefout Short Current Limit | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$, $\mathrm{V}_{\text {refout }}=0 \mathrm{~V}$ |  | 25 |  | mA |
| $\Delta \mathrm{V}_{\text {Refout/ }} / \mathrm{T}$ | Vrefout Voltage <br> Temperature Coefficient | $-40^{\circ} \mathrm{C} \leqq$ Topt $\leqq 85^{\circ} \mathrm{C}$ |  | $\pm 150$ |  | ppm/ ${ }^{\circ} \mathrm{C}$ |
| $V_{\text {fb1 }}$ | VFB1 Voltage | $\mathrm{V}_{\text {IN }}=3.3 \mathrm{~V}$ | 0.985 | 1.000 | 1.015 | V |
| $\Delta \mathrm{V}_{\mathrm{FB1}} / \Delta \mathrm{T}$ | $V_{\text {FBI }}$ Voltage <br> Temperature Coefficient | $-40^{\circ} \mathrm{C} \leqq$ Topt $\leqq 85^{\circ} \mathrm{C}$ |  | $\pm 150$ |  | ppm/ ${ }^{\circ} \mathrm{C}$ |
| $\Delta \mathrm{V}_{\text {FB2 }} / \Delta \mathrm{T}$ | $V_{\text {Fb2 }}$ Voltage Temperature Coefficient | $-40^{\circ} \mathrm{C} \leqq$ Topt $\leqq 85^{\circ} \mathrm{C}$ |  | $\pm 150$ |  | ppm $/{ }^{\circ} \mathrm{C}$ |
| IVFB1,2 | $V_{\text {FB1,2 }}$ Input Current | $\mathrm{V}_{\mathrm{IN}}=5.5 \mathrm{~V}, \mathrm{~V}_{\mathrm{FB} 1}$ or $\mathrm{V}_{\mathrm{FB} 2}=0 \mathrm{~V}$ or 5.5 V | -0.1 |  | 0.1 | $\mu \mathrm{A}$ |
| fosc | Oscillator Frequency | EXT1,2 Pins at no load, $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$ | 595 | 700 | 805 | kHz |
| IdD1 | Supply Current | $\mathrm{V}_{\mathrm{IN}}=5.5 \mathrm{~V}$, EXT1,2 pins at no load |  | 1.4 | 3.0 | mA |
| Rexth1 | EXT1 "H" ON Resistance | $\mathrm{V}_{\mathrm{IN}=3.3 \mathrm{~V}, \mathrm{IEXT}=-20 \mathrm{~mA}}$ |  | 4.0 | 8.0 | $\Omega$ |
| Rextli | EXT1 "L" ON Resistance | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$, $\mathrm{IExT}=20 \mathrm{~mA}$ |  | 2.7 | 5.0 | $\Omega$ |
| Rexth2 | EXT2 "H" ON Resistance | $\mathrm{V}_{\text {In }}=3.3 \mathrm{~V}, \mathrm{IEXT}=-20 \mathrm{~mA}$ |  | 4.0 | 8.0 | $\Omega$ |
| Rextl2 | EXT2 "L" ON Resistance | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$, $\mathrm{IExT}=20 \mathrm{~mA}$ |  | 3.7 | 8.0 | $\Omega$ |
| Tdiy | Delay Time for Protection | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}, \mathrm{~V}_{\mathrm{FB} 1}=1.1 \mathrm{~V} \rightarrow 0 \mathrm{~V}$ | 60 | 100 | 140 | ms |
| Vuvlod | UVLO Detector Threshold |  | 2.10 | 2.20 | 2.35 | V |
| Vuvıo | UVLO Released Voltage |  |  | $\begin{aligned} & \hline \text { Vuvlod } \\ & +0.20 \end{aligned}$ | 2.48 | V |
| Vdtc10 | CH1 Duty=0\% | $\mathrm{V}_{\mathrm{I}}=3.3 \mathrm{~V}$ | 0.1 | 0.2 | 0.3 | V |
| VdTC1100 | CH1 Duty=100\% | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$ | 1.1 | 1.2 | 1.3 | V |
| Vdtcro | CH2 Duty=0\% | $\mathrm{V}_{\mathrm{in}}=3.3 \mathrm{~V}$ | 0.1 | 0.2 | 0.3 | V |
| VdTC2100 | CH2 Duty=100\% | V In $=3.3 \mathrm{~V}$ | 1.1 | 1.2 | 1.3 | V |
| Av1 | CH1 Open Loop Gain | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$ |  | 110 |  | dB |
| $\mathrm{F}_{\text {T1 }}$ | CH1 Single Gain Frequency Band | $\mathrm{V}_{\mathrm{in}}=3.3 \mathrm{~V}, \mathrm{Av} 1=0 \mathrm{~dB}$ |  | 1.9 |  | MHz |
| Vicr1 | CH1 Input Voltage Range | V In $=3.3 \mathrm{~V}$ |  | $\begin{gathered} \hline 0.7 \text { to } \\ \text { VIN } \\ \hline \end{gathered}$ |  | V |
| IAmpl | CH1 Sink Current | $\begin{array}{\|l\|} \hline \mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}, \\ \mathrm{~V}_{\text {AMPOUT1 } 1}=1.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{FB} 1}=\mathrm{V}_{\mathrm{FB} 1}+0.1 \mathrm{~V} \\ \hline \end{array}$ | 70 | 115 |  | $\mu \mathrm{A}$ |
| lamph | CH1 Source Current | $\begin{aligned} & \begin{array}{l} \mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}, \\ \mathrm{~V}_{\text {AMPOUT } 1}=1.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{FB} 1}=\mathrm{V}_{\text {FB1 }}-0.1 \mathrm{~V} \end{array} \end{aligned}$ |  | -1.4 | -0.7 | mA |
| Av2 | CH2 Open Loop Gain | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$ |  | 60 |  | dB |
| $\mathrm{F}_{\text {T2 }}$ | CH2 Single Gain Frequency Band | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}, \mathrm{Av} 2=0 \mathrm{~dB}$ |  | 600 |  | kHz |
| VICR2 | CH2 Input Voltage Range | V In $=3.3 \mathrm{~V}$ |  | $\begin{array}{\|l\|l} \hline-0.2 \text { to } \\ \text { Vin-1.3 } \end{array}$ |  | V |
| $\mathrm{V}_{\text {fb2 }}$ | CH2 Reference Voltage | $\mathrm{V}_{\mathrm{IN}}=3.3 \mathrm{~V}$ | 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 Vin, the current is Vin $\times \mathrm{t} / \mathrm{L}$.

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

$$
\text { Pon }=\int_{0}^{\text {Ton }} \mathrm{Vin}^{2} \times \mathrm{t} / \mathrm{L} \text { dt ................................................................................................ Formula } 1
$$

With the step-up circuit, electric power is supplied from power source also during off time. In this case, input current is described as $\left(\mathrm{Vout}^{-\mathrm{VIN}) \times t / L}\right.$, therefore electric power, Poff is described as in next formula.

$$
\text { Poff }=\int_{0}^{T f} \operatorname{VIN} \times\left(\text { Vout }^{\text {O }}-\mathrm{V}_{\text {IN }}\right) \mathrm{t} / \mathrm{L} d t .
$$

Formula 2

In this formula, Tf means the time of which the energy saved in the inductance is being emitted. Thus average electric power, $\mathrm{P}_{\mathrm{Av}}$ is described as in the next formula.

$$
P_{A V}=1 /(\text { Ton }+ \text { Toff }) \times\left\{\int_{0}^{T o n} V_{I N}{ }^{2} \times t / L d t+\int_{0}^{T f} V_{\text {IN }} \times\left(\text { Vout }-V_{\text {IN }}\right) t / L d t\right\}
$$

$\qquad$ Formula 3

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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.
$\qquad$
Vin $\times$ Ton $/ L=($ Vout - Vin $) \times$ Toff $/ L$
Formula 4

Further, the electric power, Pav is equal to output electric power, Voutxlout, thus,

$$
\text { lout }=\text { fosc } \times \mathrm{V}_{\text {In }}{ }^{2} \times \operatorname{Ton}^{2} /\{2 \times \mathrm{L} \times(\mathrm{Vout}-\mathrm{Vin})\}=\mathrm{V}^{2}{ }^{2} \times \operatorname{Ton} /(2 \times \mathrm{L} \times \mathrm{Vout})
$$

Formula 5

When lout becomes more than $\mathrm{V}_{\mathrm{IN}} \times \mathrm{Ton} \times \mathrm{Toff} /(2 \times \mathrm{L} \times$ (Ton+Toff)), the current flows through the inductor, then the mode becomes continuous. The continuous current through the inductor is described as

Iconst, then,

$$
\text { lout }=\text { fosc } \times \mathrm{Vin}^{2} \times \operatorname{Ton}^{2} /(2 \times \mathrm{L} \times(\mathrm{Vout}-\mathrm{V} \text { in }))+\mathrm{V}_{\text {In }} \times \text { Iconst } / \text { Vout }
$$

$\qquad$ Formula 6

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

$$
\text { ILxmax = Iconst +Vin×Ton/L ............................................................................................Formula } 7
$$

With the formula 4,6, and ILxmax is,

$$
\text { ILxmax }=\text { Vout }_{\text {/Vin } \times \text { lout }+ \text { Vin } \times \text { Ton } /(2 \times L) ~}^{2}
$$

Therefore, peak current is more than lout. Considering the value of ILxmax the condition of input and output, and external components should be selected.
In the formula 7, peak current ILxmax at discontinuous mode can be calculated. Put Iconst=0 in the formula.
The explanation above is based on the ideal calculation, and the loss caused by Lx switch and external components is not included. The actual maximum output current is between $50 \%$ and $80 \%$ of the calculation. Especially, when the ILx is large, or $\mathrm{V}_{\mathrm{IN}}$ is low, the loss of $\mathrm{V}_{\mathrm{IN}}$ is generated with the on resistance of the switch. As for Vout, Vf (as much as 0.3 V ) 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.


$$
\text { Discontinuous Mode }<\text { Current through L> }
$$

Continuous Mode
ILxmax



During on time of the transistor, when the voltage added on to the inductor is described as $\mathrm{V}_{\mathrm{in}}-\mathrm{Vout}$ the current is $\left(V_{\text {In }}-V_{\text {out }}\right) \times t / L$.

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

$$
\mathrm{P}=\int_{0}^{\text {Ton }} \mathrm{V}_{\text {IN }} \cdot(\mathrm{V} \text { In-Vout }) \cdot \mathrm{t} / \mathrm{L} \text { dt ....................................................................................... Formula } 9
$$

Thus average electric power in one cycle, $\mathrm{P}_{\mathrm{Av}}$ is described as in the next formula.

$$
\mathrm{P}_{\mathrm{AV}}=1 /(\text { Ton }+ \text { Toff }) \int_{0}^{\text {Ton }} \mathrm{V}_{\mathrm{IN}} \cdot\left(\mathrm{~V}_{\text {IN }}-\mathrm{V}_{\text {out }}\right) \cdot \mathrm{t} / \mathrm{Ldt}=\mathrm{V}_{\text {IN }} \cdot\left(\mathrm{V}_{\text {IN }}-\mathrm{Vout}\right) \cdot \operatorname{Ton}^{2} /(2 \cdot \mathrm{~L}(\text { Ton }+ \text { Toff })) \ldots \text { Formula } 10
$$

This electric power Pav equals to output electric power Vout $\times$ lout, thus,

$$
\text { lout }=\mathrm{VIN}_{\text {IN }} / \text { Voutx }(\mathrm{V} \text { IN }- \text { Vout })^{\prime} \operatorname{Ton}^{2} /(2 \times \mathrm{L} \times(\text { Ton }+ \text { Toff }))
$$

When lout 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,

$$
\left(\text { Vin }^{\text {- }} \text { Vout }\right) \times \text { Ton } / L=\text { Vout } \times \text { Toff } / L
$$

In this moment, the current flowing continuously through $L$, is assumed as Iconst, lout is described as in the next formula:

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lout=Iconst+Vout×Toff $/(2 \times \mathrm{L})$
In this moment, the peak current, ILxmax flowing through the inductor and the driver Tr . is described as follows:
IL×max $=$ lout + Vout $\times$ Toff $/(2 \times$ L $)$
Formula 14

With the formula 12,13 , ILxmax is,
Toff=(1-Vout/Vin)/fosc $\qquad$ Formula 15

Therefore, peak current is more than lout. Considering the value of ILxmax, the condition of input and output, and external components should be selected.

In the formula 14, peak current ILxmax at discontinuous mode can be calculated. Put Iconst=0 in the formula.
The explanation above is based on the ideal calculation, and the loss caused by Lx switch and external components is not included.

## TEST CIRCUITS



Test Circuit 1


Test Circuit 5


Test Circuit 2



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:
\(\mathrm{C} 1=4.7 \mu \mathrm{~F}, \mathrm{C} 2=1.0 \mu \mathrm{~F}\)
Efficiency \(\eta(\%)\) can be calculated with the next formula:
\(\eta=(\) Vout1 \(\times\) lout \(1+\) Vout \(2 \times\) lout 2\() /(\) Vin \(\times\) lin \() \times 100\)
```


## TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current (Topt $=25^{\circ} \mathrm{C}$ )

R1282D002A
$\mathrm{L} 1=6.8 \mu \mathrm{H}, \mathrm{C} 1=10 \mu \mathrm{~F}, \mathrm{Vout} 2=2.5 \mathrm{~V}$,lour $2=0 \mathrm{~mA}$


R1282D002A
$\mathrm{L} 2=6.8 \mu \mathrm{H}, \mathrm{C} 2=10 \mu \mathrm{~F}, \mathrm{Vout} 1=10 \mathrm{~V}$, lour $1=0 \mathrm{~mA}$

2) Efficiency vs. Output Current (Vin=3.3V, Topt $=25^{\circ} \mathrm{C}$ )

R1282D002A


R1282D002A

L2 $2=6.8 \mu \mathrm{H}, \mathrm{C} 2=10 \mu \mathrm{~F}$, Vout $1=10 \mathrm{~V}$, lout $1=0 \mathrm{~mA}$

3) Output Voltage vs. Temperature ( $\mathrm{V} \operatorname{\mathrm {I}=3.3\mathrm {V}\text {)})~(1)~}$

R1282D002A
$L 1=6.8 \mu \mathrm{H}, \mathrm{C} 1=10 \mu \mathrm{~F}$


R1282D002A
$\mathrm{L} 2=6.8 \mu \mathrm{H}, \mathrm{C} 2=10 \mu \mathrm{~F}$

4) Frequency vs. Temperature

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

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6) Vrefout Voltage vs. Temperature(Vin=3.3V) R1282D002A


R1282D002A

7) Vrefout Output Voltage vs. Output Current R1282D002A

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)

11) Output Sink Current vs. Temperature (Vin $=3.3 \mathrm{~V}$ ) R1282D002A


R1282D002A

12) Output Source Current vs. Temperature R1282D002A


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13) Load Transient Response (Step-up Side) Vin $=3.3 \mathrm{~V}$, L1 $=6.8 \mu \mathrm{H}$

14) Load Transient Response (Step-down Side) $\operatorname{Vin}=3.3 \mathrm{~V}, \mathrm{~L} 2=6.8 \mu \mathrm{H}$

R1282D002A


R1280D002A


## TYPICAL APPLICATION AND TECHNICAL NOTES



Components examples

| Inductor L1,2 | $6.8 \mu \mathrm{H}$ 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 100 kW or less.

| $\mathrm{R} 1=47 \mathrm{k} \Omega$ | $\mathrm{R} 2=5.1 \mathrm{k} \Omega$ | $\mathrm{R} 3=30 \mathrm{k} \Omega$ | $\mathrm{R} 4=20 \mathrm{k} \Omega$ |
| :--- | :--- | :--- | :--- |
| $\mathrm{R} 5=43 \mathrm{k} \Omega$ | $\mathrm{R} 6=10 \mathrm{~kW} \Omega$ |  |  |
| $\mathrm{R} 7=\mathrm{R} 9=22 \mathrm{k} \Omega$ | $\mathrm{R} 8=\mathrm{R} 10=43 \mathrm{k} \Omega$ | $\mathrm{R} 11=220 \mathrm{k} \Omega$ |  |

Capacitors Ceramic Type
$\mathrm{C} 1=\mathrm{C} 2=10 \mu \mathrm{~F} \quad \mathrm{C} 3=4.7 \mu \mathrm{~F}$
C4 $=0.22 \mu \mathrm{~F}$
$C 5=0.47 \mu \mathrm{~F}$
C6=120pF
C7=50pF
$\mathrm{C} 8=1 \mu \mathrm{~F}$
C9=1000pF

Note) Consider the ratings of external components including voltage tolerance. With the transistor in the circuit above, Vout $=15 \mathrm{~V}$ is the voltage setting limit.

## EXTERNAL COMPONENTS

1. How to set the output voltages

As for step-up side, feedback ( $\mathrm{V}_{\mathrm{FB} 1}$ ) pin voltage is controlled to maintain 1 V , therefore,
Vouti: R1+R2= VFB1: $^{\text {R2 }}$

Thus, Vout1 $=\mathrm{V}_{\text {FB1 }} \times(\mathrm{R} 1+\mathrm{R} 2) / \mathrm{R} 2$
Output Voltage is adjustable with R1 and R2.
As for Step-down side, Feedback ( $\mathrm{V}_{\mathrm{FB} 2}$ ) pin voltage follows the next formula,

$$
\text { Vоита: R3+R4=V }{ }_{\text {Fb2 }} \text { : R4 }
$$

Thus, $\mathrm{Vout}^{2}=\mathrm{V}_{\text {FB2 }} \times(\mathrm{R} 3+\mathrm{R} 4) / \mathrm{R} 4$
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, $\mathrm{T}_{\mathrm{ss1}}$ and $\mathrm{T}_{\mathrm{ss2}}$ are adjustable. Soft-start time can be set with the time constant of RC.
Soft-start time can be described as in next formula.

```
Tssı \(\cong \mathrm{RO} 1 \times \mathrm{C} 4\)
```

If $\mathrm{R} 10=0 \Omega$, then,
Tss2 $\cong R 9 \times$ C $5 \times \operatorname{In}(($ Vrefout-VDTC2 $) /$ 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 $\cong(R 8 /(R 7+R 8) \times V r e f o u t-0.2) /(1.2-0.2) \times 100$ (\%)
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.

## TECHNICAL NOTES on EXTERNAL COMPONENTS

- External components should be set as close to this IC as possible. Especially, wiring of the capacitor connected to Vin 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 $4.7 \mu \mathrm{~F}$.
- If the spike noise of $V_{\text {out }}$ is too large, the noise is feedback from $V_{\text {Fbi }}$ pin and operation might be unstable. In that case, use the resistor ranging from $10 \mathrm{k} \Omega$ to $50 \mathrm{k} \Omega$ as R5 and try to reduce the noise level. In the case of Voutr, use the resistor as much as $10 \mathrm{k} \Omega$ 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, ILx 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 C 1 and C 2 is as much as Ceramic $10 \mu \mathrm{~F}$. In case that the operation with the system of DC/DC converter would be unstable, add a series resister less than $0.5 \Omega$ to each output capacitor or use tantalum capacitors with appropriate ESR. If you choose too large ESR, ripple noise may be forced to $\mathrm{V}_{\text {FB1 }}$ and $\mathrm{V}_{\text {FB2 }}$, 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 ( $\mathrm{V}_{\mathrm{IN}}-0.3$ ) 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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