# 2ch. PWM Step-up / Inverting DC/DC Converter with Synchronous Rectifier for AMOLED / LCD

NO.EA-283-191114

## OUTLINE

The R1286K 2ch DC/DC converter is designed for AMOLED display power source. It contains a step up DC/DC converter and an inverting DC/DC converter.
Step up DC/DC converter generates boosted output voltage to 4.6 V to 5.8 V (Selectable). Inverting DC/DC converter generates negative voltage down to -2.0 V to -6.0 V (Selectable) that is dynamically adjustable with single wire interface signal. R1286K consist of a voltage reference, error amplifiers, an oscillator, PWM control circuits, over current protection circuits, short protection circuits, an under voltage lockout circuit (UVLO), thermal shutdown circuit, a NMOS driver and a synchronous PMOS switch for boost converter, a PMOS driver and a synchronous NMOS switch for inverting converter, and so on. High efficiency boost and inverting DC/DC converters can be composed with two external inductors and three capacitors.

## FEATURES

- Operating Voltage ······································ 2.3 V to 5.5 V

**[Step-up DC/DC Converter (CH1)]**

- Selectable Output Voltage ($V_{OUTP}$) ····················· R1286KxxxX[1]: 4.6 V to 5.8 V (0.1V Step)
- Externally Adjustable Output Voltage ················ R1286K001B: 4.6 V to 5.8 V
- Maximum Output Current ······························ R1286K0xxX[1] / R1286K001B: 250 mA
  R1286K1xxX [1]: 300 mA
- VOUTP Voltage Load Regulation······························ Typ.± 5 mV
- VOUTP Voltage Line Transient Response········· Typ. ± 10 mV

**[Inverting DC/DC Converter (CH2)]**

- Dynamically Adjustable Output Voltage ($V_{OUTN}$) ··· -2.0 V to -6.0 V (Fixed Rate: 3.0 V, 0.1 V Step)
- Selectable Single Wire (S-Wire) I/F ················· R1286KxxxX[1]: Default value (0.1 V Step)
- Externally Adjustable Output Voltage ················ R1286K001B: -2.0 V to -6.0 V
- Maximum Output Current ······························ R1286K0xxX[1] / R1286K001B: 250 mA
  R1286K1xxX [1]: 300 mA
- VOUTN Voltage Load Regulation ······························ Typ.± 5 mV
- VOUTN Voltage Line Transient Response ········ Typ. ± 10 mV

**[Controller]**

- Internal Start-up Sequence Control with Soft-start Operation
- Auto Discharge Operation for Both Outputs
- Short circuit protection
- Internal timer-latch protection ............................... Typ. 16 ms or 40 ms
- Maximum duty cycle ............................................ Typ. 85% (CH1) / Typ. 90% (CH2)

[1] X : A to N (Provided except B and I)

- LX peak current limit ······································ R1286K0xxX(1) : Typ. 1.0 A (CH1), 1.5 A (CH2)
  R1286K1xxX(1) : Typ. 1.1 A (CH1)、1.8 A (CH2)
- UVLO(Under voltage lock out) protection ............. Typ. 2.05 V
- Thermal Shutdown ................................................ Typ. 150°C
- Operating Frequency ............................................ 1750kHz
- Package ................................................................. DFN(PLP)2730-12

## APPLICATION

- Fixed voltage power supply for portable equipment
- Fixed voltage power supply for AMOLED, LCD

# SELECTION GUIDE

The inverting output voltage ($V_{OUTN}$), the positive output voltage ($V_{OUTP}$) and the versions of the inverting output voltage are user-selectable options.

| Product Name | Package | Quantity per Reel | Pb Free | Halogen Free |
|---|---|---|---|---|
| R1286K$xx∗-TR | DFN(PLP)2730-12 | 5,000pcs | Yes | Yes |

$: Specify the delay time for timer latch [1].
(0) Typ.16msec
(1) Typ.40msec

xx: Specify the set output voltages ($V_{SET}$) for default value of $V_{OUTx}$ and $V_{ONDEF}$[2]

∗ : Specify setting methods for $V_{OUTN}$ and $V_{OUTP}$.
$V_{ONDEF}$ : $V_{OUTN}$ default value[3] (Internal fixed value at shipping)
$V_{ONMIN}$ : $V_{OUTN}$ minimum value with S-Wire
$V_{ONMAX}$ : $V_{OUTN}$ maximum value with S-Wire
$t_{TRA}$ : Variable time per 0.1V with S-Wire [4]

| ∗ | Designation for Settings of $V_{OUTx}$ | $V_{ONDEF}$ | $V_{ONMIN}$ | $V_{ONMAX}$ | $t_{TRA}$ |
|---|---|---|---|---|---|
| A | $V_{OUTP}$ / $V_{OUTN}$ Fixed Output Voltage type[5] | -5.4 V to -2.4 V | -5.4 V | -2.4 V | 10 ms |
| B | $V_{OUTP}$ / $V_{OUTN}$ Adjustable Output Voltage type | - | - | - | - |
| C | $V_{OUTP}$ / $V_{OUTN}$ Fixed Output Voltage type | -5.0 V to -2.4 V | -5.0 V | -2.0 V | 10 ms |
| D | | -5.2 V to -2.4 V | -5.2 V | -2.2 V | 10 ms |
| E | | -5.6 V to -2.6 V | -5.6 V | -2.6 V | 10 ms |
| F | | -5.8 V to -2.8 V | -5.8 V | -2.8 V | 10 ms |
| G | | -6.0 V to -3.0 V | -6.0 V | -3.0 V | 10 ms |
| H | | -5.0 V to -2.4 V | -5.0 V | -2.0 V | 360 μs |
| J | | -5.4 V to -2.4 V | -5.4 V | -2.4 V | 360 μs |
| K | | -5.6 V to -2.6 V | -5.6 V | -2.6 V | 360 μs |
| L | | -5.8 V to -2.8 V | -5.8 V | -2.8 V | 360 μs |
| M | | -6.0 V to -3.0 V | -6.0 V | -3.0 V | 360 μs |
| N | | -5.2 V to -2.4 V | -5.2 V | -2.2 V | 360 μs |

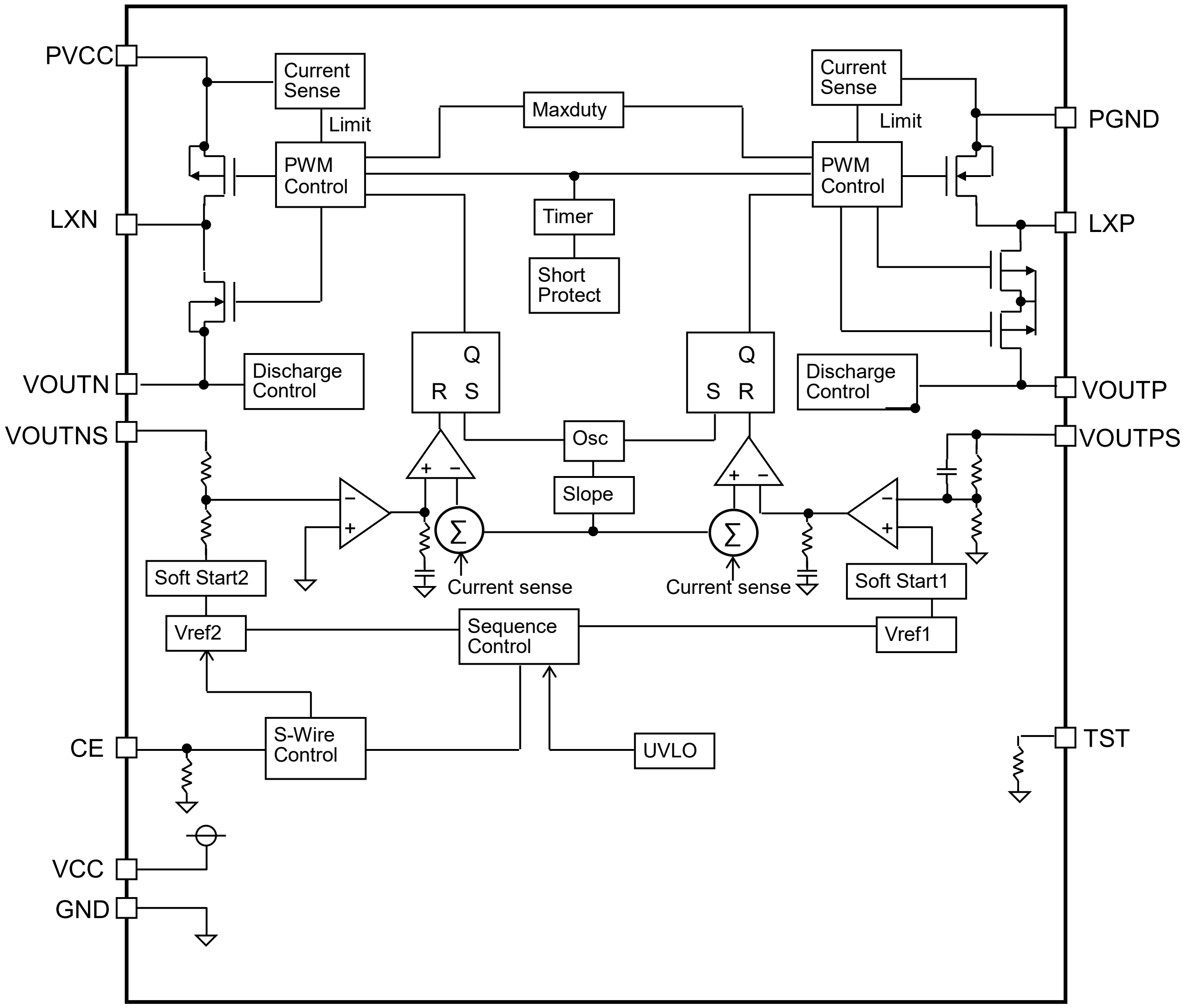
(1) Fixed Output Voltage type only can select the delay time of 40 msec (Typ).
(2) Refer to *Voltage Combination List* for details.
(3) Selectable in 0.1V step
(4) Refer to the *TIMING CHART of S-Wire* for details.
(5) Dynamically adjustable output voltage with S-Wire

**Output voltage combination list**

| $V_{SET}$ codes (xx) | $V_{OUTP}$ | $V_{ONDEF}$ |
|---|---|---|
| 01 | Setting by external resistor | Setting by external resistor |
| 02 | 4.6 V | -4.9 V |
| 03 | 5.8 V | -6.0 V |
| 04 | 4.8 V | -4.9 V |
| 05 | 5.4 V | -5.4 V |
| 06 | 5.0 V | -5.0 V |
| 07 | 5.0 V | -3.5 V |
| 08 | 5.6 V | -5.6 V |
| 09 | 5.8 V | -5.8 V |
| 10 | 5.5 V | -5.5 V |
| 11 | 4.6 V | -4.4 V |

# BLOCK DIAGRAMS

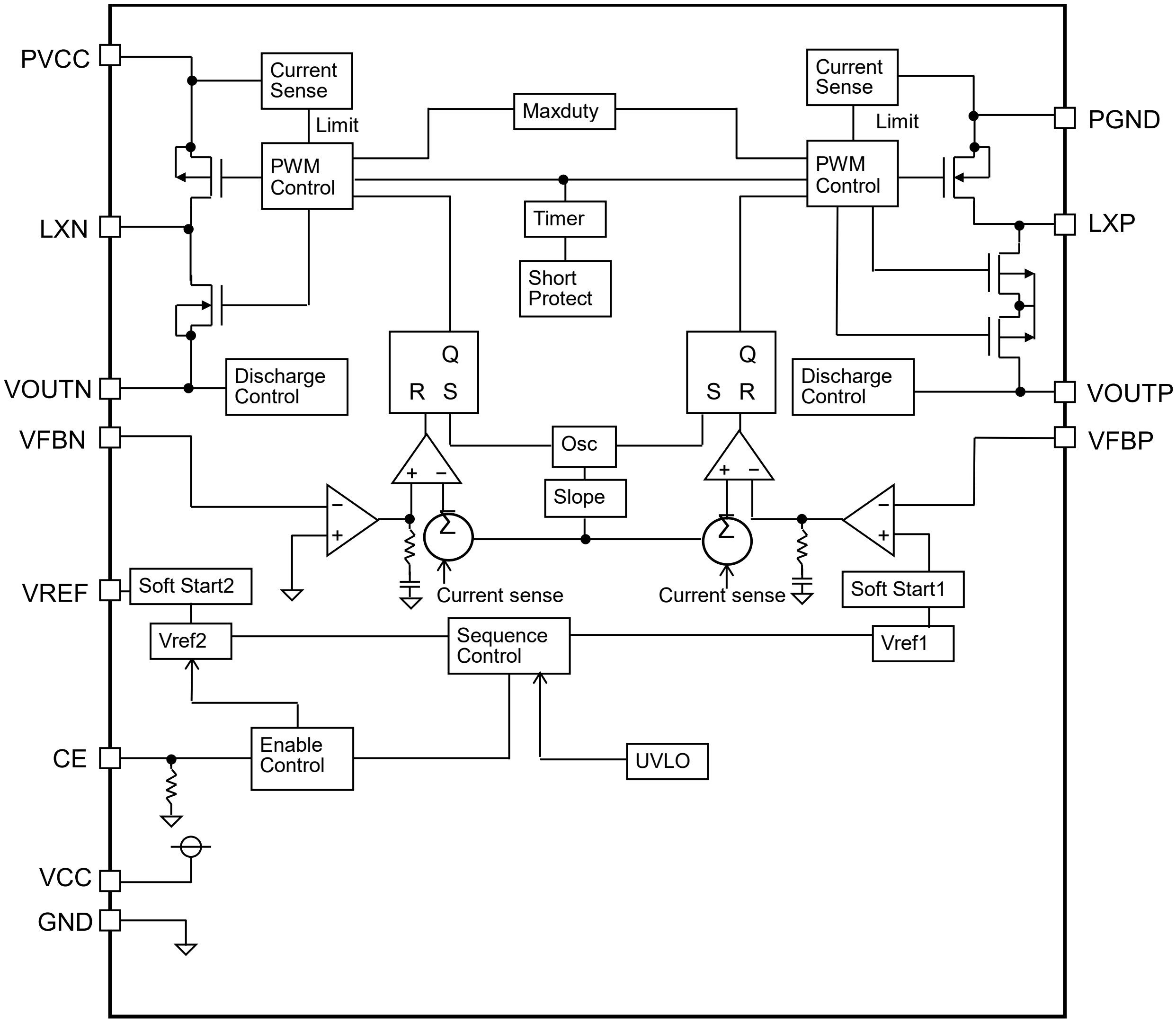
### R1286KxxxX[1] (Fixed Output Voltage Type)




**R1286KxxxX Block Diagram**

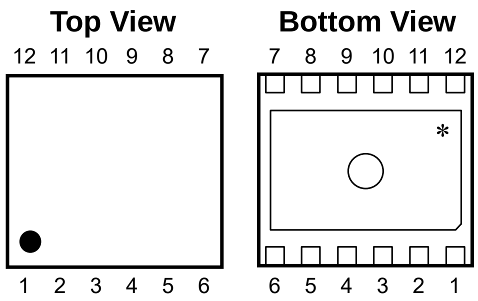
[1] X : A to N (Provided, except “B” and “I”)

**R1286K001B (Adjustable Output Voltage Type)**




**R1286K001B Block Diagram**

# PIN DESCRIPTION




**R1286K (DFN(PLP)2730-12) Pin Configuration**

**R1286K Pin Description**

| Pin No. | Symbol | | Description |
|---|---|---|---|
| | **R1286KxxxX[1]** | **R1286K001B** | |
| 1 | VOUTNS | VFBN | Feed Back Pin for Inverting DC/DC |
| 2 | VOUTN | VOUTN | Outout Pin for Inverting DC/DC |
| 3 | LXN | LXN | Switching Pin for Inverting DC/DC |
| 4 | PVCC | PVCC | Power Input Pin |
| 5 | VCC | VCC | Analog Power Input Pin |
| 6 | GND | GND | Analog GND Pin |
| 7 | PGND | PGND | Power GND Pin |
| 8 | LXP | LXP | Switching Pin for Step up DC/DC |
| 9 | VOUTP | VOUTP | Output Pin for Step up DC/DC |
| 10 | VOUTPS | VFBP | Feed Back Pin for Step up DC/DC |
| 11 | CE | CE | Chip Enable and S-Wire Control Input Pin (R1286KxxxX)<br>Chip Enable Pin (R1286KxxxB) |
| 12 | TST | VREF | TEST Pin [2] (R1286KxxxX)<br>Reference Voltage Output Pin for Inverting DC/DC (R1286KxxxB) |

∗ The tab on the bottom of the package is substrate level (GND). It is recommended that the tab be connected to the ground plane on the board.

[1] X : A to N (Provided, except “B” and “I”)

[2] TEST pin must be connected to the GND or leaving it open.

## ABSOLUTE MAXIMUM RATINGS

(GND = PGND = 0 V)

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| $V_{CC}$ | VCC / PVCC Pin Voltage | -0.3 to 6.0 | V |
| $V_{CE}$ | CE Pin Voltage | -0.3 to 6.0 | V |
| $V_{LXP}$ | LXP Pin Voltage | -0.3 to 6.5 | V |
| $V_{OUTP(S)}$ | VOUTP Pin Voltage | -0.3 to 6.5 | V |
| $V_{LXN}$ | LXN Pin Voltage | $V_{CC}$ - 14 to $V_{CC}$ + 0.3 | V |
| $V_{OUTN(S)}$ | VOUTN Pin Voltage | VCC - 14 to 0.3 | V |
| $V_{TST}$ | TST Pin Voltage [R1286kxxxx[1]] | -0.3 to 6.0 | V |
| $V_{FBP}$ | VFBP Pin Voltage [R1286K001B] | -0.3 to 6.0 | V |
| $V_{FBN}$ | VFBN Pin Voltage [R1286K001B] | -0.3 to VCC + 0.3 | V |
| $V_{REF}$ | VREF Pin Voltage [R1286K001B] | -0.3 to VCC + 0.3 | V |
| $P_D$ | Power Dissipation [2] (DFN(PLP)2730-12, JEDEC STD. 51-7) | 3100 | mW |
| Tj | Junction Temperature Range | −40 to 125 | °C |
| Tstg | Storage Temperature Range | -55 to 125 | ºC |

| ABSOLUTE MAXIMUM RATINGS |
|---|
| Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages and may degrade the lifetime and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured. |

## RECOMMENDED OPERATING CONDITIONS

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| $V_{CC}$ | Operating Input Voltage | 2.3 to 5.5 | V |
| Ta | Operating Temperature Range | −40 to 85 | °C |

| RECOMMENDED OPERATING CONDITIONS |
|---|
| All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if when they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions. |

[1] X : A to N (Provided, except “B” and “I”)
[2] Refer to *POWER DISSIPATION* for detailed information.

# ELECTRICAL CHARACTERISTICS

The specifications surrounded by [ ] are guaranteed by Design Engineering at - 40ºC ≤ Ta ≤ 85ºC.

**R1286K Electrical Characteristics** (Ta = 25ºC)

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $I_{CC}$ | VCC Consumption Current (at no switching) | $V_{CC}$=5.5V | | 1.2 | | mA |
| $I_{STANDBY}$ | Standby Current | $V_{CC}$=$V_{LXP}$=5.5V , $V_{CE}$=$V_{LXN}$=0V | | 0.1 | 5 | μA |
| $V_{UVLO1}$ | UVLO Detection Voltage | Falling | 1.95 | 2.05 | 2.15 | V |
| $V_{UVLO2}$ | UVLO Release Voltage | Rising | | $V_{UVLO1}$ +0.10 | 2.28 | V |
| $f_{OSC}$ | Oscillator Frequency | $V_{CC}$=3.7V | 1500 | 1750 | 2000 | kHz |
| $V_{CEH}$ | CE Pin Input Voltage, high | $V_{CC}$=5.5V | 1.2 | | | V |
| $V_{CEL}$ | CE Pin Input Voltage, low | $V_{CC}$=2.3V | | | 0.4 | V |
| $R_{CE}$ | CE Pin Pull-down Resistance | $V_{CC}$=3.7V | | 160 | | kΩ |
| $T_{TSD}$ | Thermal Shutdown Detection Temperature | $V_{IN}$=3.7V | | 150 | | °C |
| $T_{TSR}$ | Thermal Shutdown Release Temperature | $V_{IN}$=3.7V | | 125 | | °C |
| **[ R1286K0xxx]** | | | | | | |
| $t_{DLY}$ | Delay Time for Protection | $V_{CC}$=3.7V | 8 | 16 | 24 | ms |
| **[ R1286K1xxX[(1)]]** | | | | | | |
| $t_{DLY}$ | Delay Time for Protection | $V_{CC}$=3.7V | 32 | 40 | 48 | ms |

■ **Set-up DC/DC Converter (CH1)**

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Maxduty1 | Maximum Duty Cycle 1 | $V_{CC}$=3.7V | | 85 | | % |
| $I_{VOUTP}$ | $V_{OUTP}$ Discharge Current | $V_{CC}$=3.7V, $V_{OUTP}$=0.1V | | 1.1 | | mA |
| $t_{SSP}$ | CH1 Soft-start Time | $V_{CC}$=3.7V | 1.6 | 2.4 | 3.0 | ms |
| $R_{LXP}$ | LXP Pin On-resistance | $V_{CC}$=3.7V | | 400 | | mΩ |
| $R_{SYNCP}$ | Synchronous SW Pch.On-resistance | $V_{CC}$=3.7V | | 700 | | mΩ |
| **[ R1286K0xxx]** | | | | | | |
| $I_{LIMLXP}$ | LXP Pin Limit Current | $V_{CC}$=3.7V | | 1.0 | | A |
| **[ R1286K1xxX]** | | | | | | |
| $I_{LIMLXP}$ | LXP Pin Limit Current | $V_{CC}$=3.7V | | 1.1 | | A |
| **[ R1286KxxxX]** | | | | | | |
| $V_{OUTP}$ | $V_{OUTP}$ Voltage Tolerance | $V_{CC}$=3.7V | ×0.991 | $V_{SET}$ | ×1.009 | V |

(1) X : A to N (Provided, except “B” and “I”)

The specifications surrounded by [box] are guaranteed by Design Engineering at - 40ºC ≤ Ta ≤ 85ºC.

**R1286K Electrical Characteristics (Continued)** (Ta = 25ºC)

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **[ R1286K001B]** | | | | | | |
| $V_{FBP}$ | $V_{FBP}$ Voltage Tolerance | $V_{CC}$=3.7V | 0.985 | 1.000 | 1.015 | V |
| $I_{FBP}$ | $V_{FBP}$ Input Current | $V_{CC}$=5.5V, $V_{FBP}$=0V or 5.5V | -0.1 | | 0.1 | μA |

■ **Inverting DC/DC Converter (CH2)**

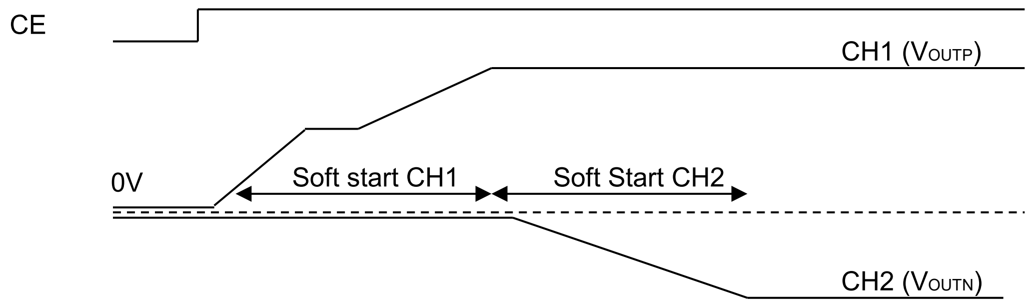
| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Maxduty2 | Maximum Duty Cycle 2 | $V_{CC}$=3.7V | | 90 | | % |
| $I_{VOUTN}$ | $V_{OUTN}$ Discharge Current | $V_{CC}$=3.7V, $V_{OUTN}$=-0.1 | | 0.3 | | mA |
| $R_{LXN}$ | LXN Pin On-resistance | $V_{CC}$=3.7V | | 400 | | mΩ |
| $R_{SYNCN}$ | Synchronous SW Nch.On-resistance | $V_{CC}$=3.7V | | 600 | | mΩ |
| **[ R1286K0xxx]** | | | | | | |
| $I_{LIMLXN}$ | LXN Pin Limit Current | $V_{CC}$=3.7V | | 1.5 | | A |
| **[ R1286K1xxX]** | | | | | | |
| $I_{LIMLXN}$ | LXN Pin Limit Current | $V_{CC}$=3.7V | | 1.8 | | A |
| **[ R1286KxxxX]** | | | | | | |
| $V_{ONDEF}$ | $V_{OUTN}$ Default Voltage Tolerance | $V_{CC}$=3.7V, selectable between $V_{ONMIN}$ and $V_{ONMAX}$ at shipping | $V_{SET}$ -70 | $V_{SET}$ | $V_{SET}$ +70 | mV |
| $V_{ONMIN}$ | $V_{OUTN}$ Minimum Voltage Tolerance | $V_{CC}$=3.7V, selectable between -2.0V and -3.0V at shipping | $V_{SET}$ -70 | $V_{SET}$ | $V_{SET}$ +70 | mV |
| $V_{ONMAX}$ | $V_{OUTN}$ Maximum Voltage Tolerance | $V_{CC}$=3.7V | $V_{SET}$ -70 | $V_{ONMIN}$ + 3.0V | $V_{SET}$ +70 | mV |
| $V_{OUTN}$ | $V_{OUTN}$ Voltage Tolerance (S-Wire) | $V_{CC}$=3.7V (Guaranteed by design engineering) | $V_{SET}$ -80 | $V_{SET}$ | $V_{SET}$ +80 | mV |
| $t_{SSN}$ | Soft-start Time for CH2 | $V_{CC}$=3.7V | 1.6x $V_{ONDEF}$/ -4.9 | 2.3x $V_{ONDEF}$/ -4.9 | 3.0x $V_{ONDEF}$/ -4.9 | ms |
| **[ R1286K001B]** | | | | | | |
| $V_{FBN}$ | $V_{FBN}$ Voltage Tolerance | $V_{CC}$=3.7V | -25 | 0 | 25 | mV |
| $V_{REF}$ | $V_{REF}$ Voltage Tolerance | $V_{CC}$=3.7V | 1.18 +$V_{FBN}$ | 1.2 +$V_{FBN}$ | 1.22 +$V_{FBN}$ | V |
| $I_{FBN}$ | $V_{FBN}$ Input Current | $V_{CC}$=5.5V, $V_{FBN}$ = 0V or 5.5V | -0.1 | | 0.1 | μA |
| $t_{SSN}$ | Soft-start Time for CH2 | $V_{CC}$=3.7V | 1.6 | 2.8 | 3.6 | ms |

All test items listed under *Electrical Characteristics* are done under the pulse load condition (Tj≈Ta=25ºC).

# THEORY OF OPERATION

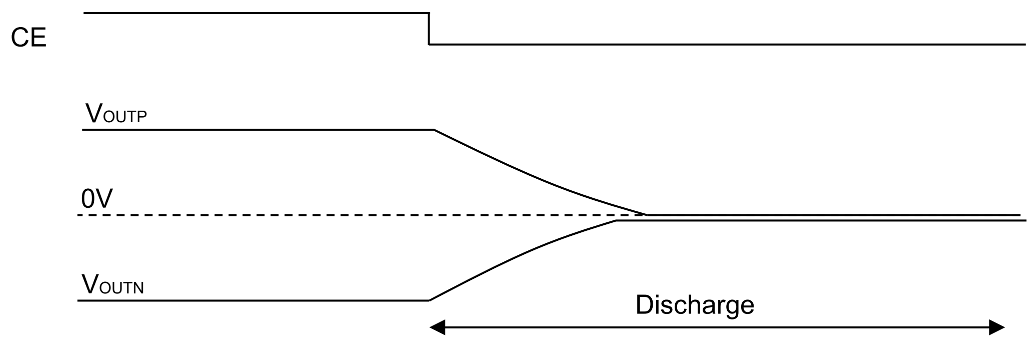
### Start-up Sequence

When CE level turns from ‘L’ to ‘H’ level, the softstart of CH1 starts the operation. After detecting output voltage of CH1($V_{OUTP}$)as the nominal level, the soft start of CH2 starts the operation.




### Auto Discharge Function

When CE level turns from ‘H’ to ‘L’ level, the R1286K goes into standby mode and switching of the outputs of $L_{XP}$ and $L_{XN}$ will stop. Then dischage switsh between $V_{OUTN}$ and GND and switch between $V_{OUTP}$ and GND turn on and discharge the negative output voltage and positive output voltage. The positive and negative output voltage is discharged to 0V in standby mode. If Vcc voltage became lower than UVLO detect voltage , discharge switches also turn on and discharge output voltage($V_{OUTN}$ and $V_{OUTP}$) .
In case of timer latch protection,discharge switches will keep off .




### Thermal Shutdown Protection

If the over temparature is detected, internal Mosfet will turn-off soon. And when the temparature get lower than the release temparature, IC is reset and restart the operation.

### Overcurrent Protection and Short-circuit Protection Circuit Timer

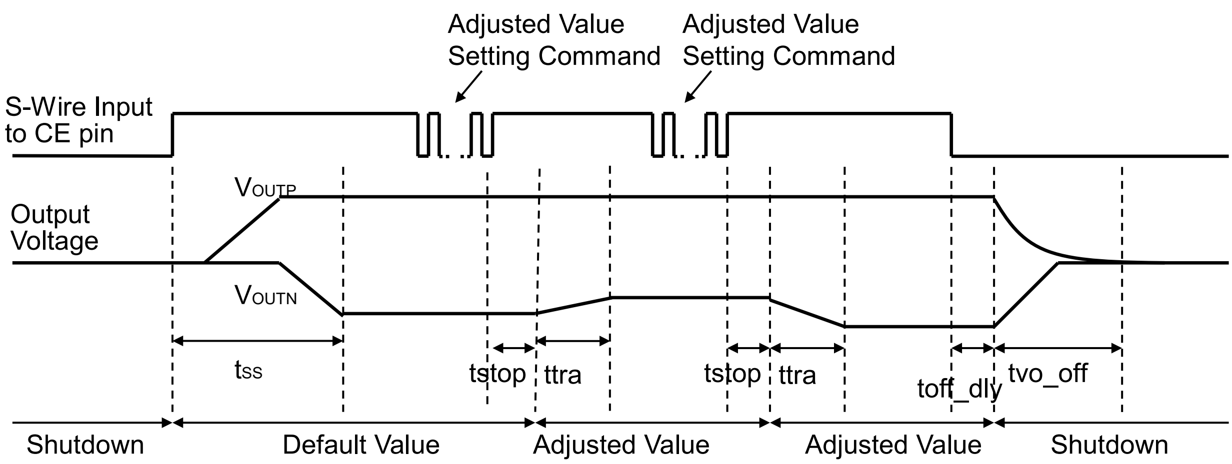
The over current protection circuit supervises the peak current of the inductor (The current passing through NMOS transistor of CH1 and PMOS transistor of CH2) with respect to each switching cycle. If the peak current exceeds the Lx current limit ($I_{LIMLXP}$ or $I_{LIMLXN}$), the over current protection circuit turns off the NMOS transistor of CH1 or PMOS transistor of CH2. If the over current continues more than the protection delay time ($T_{DLY}$), the short current protection circuit latches the built-in driver at OFF state and stops the operation of DC/DC converter.

∗ Lx limit current ($I_{LIMLXP}$ or $I_{LIMLXN}$) and the protection delay time ($T_{DLY}$) can be easily affected by self-heating and ambient environment. The drastic drop of output voltage or the unstable output voltage caused by the short-circuiting may affect the protection operation and the delay time.

To release the latch over current protection, reset the IC by inputting “L” into CE pin or by making the input voltage lower than the UVLO detector threshold ($V_{UVL01}$).

During the softstart operation of CH1 and CH2, the timer operates until detecting output voltage of CH2 ($V_{OUTN}$) as the nominal level. Therefore, even if the softstart cannot finish correctly because of the short circuit, the protection timer function will be able to work correctly.

### Sequence with S-Wire Control for $V_{OUTN}$ (R1286KxxxX[(1)])




■ **Default Value Driving**

$V_{OUTP}$ rises up first and secondarily $V_{OUTN}$ goes down. In this time $V_{OUTN}$ is set $V_{ONDEF}$.

Soft-start time ($t_{SS}$) =2.4ms + 2.3 x $V_{ONDEF}$/ -4.9 (Typ.)

(1) X : A to N (Provided, except “B” and “I”)

■ **Adjusted Value Driving**

After receiving the adjusted value setting command, $V_{OUTN}$ is changed to the target voltage in multiple steps method. Adjusted value is also selectable with pulse count (Please refer to *$V_{OUTN}$ VARIABLE TABLE*).

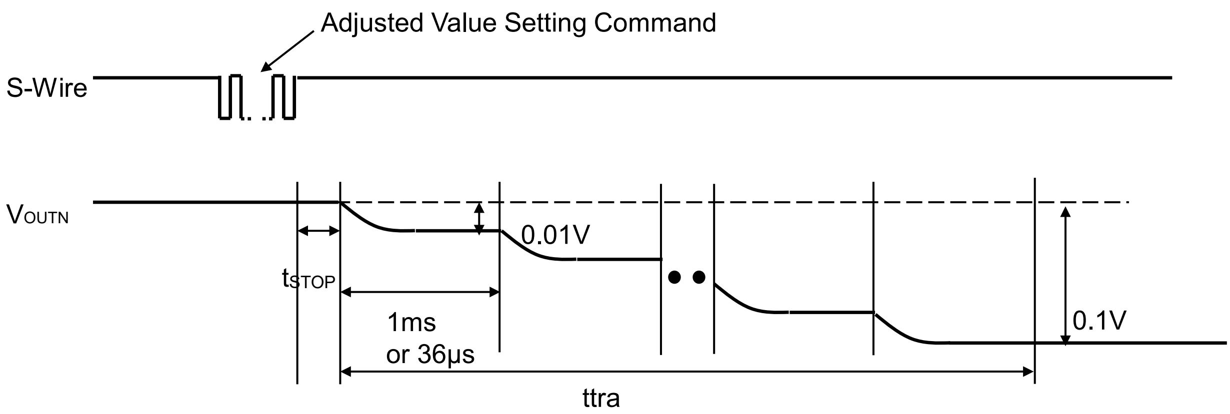
**In the case of R1286KxxxA/C/D/E/F/G,**

$V_{OUTN}$ change 0.01V step in every 1ms and it takes 10ms per 0.1V that is minimum step for $V_{OUTN}$ setting value.

**In the case of R1286KxxxH/J/K/L/M/N,**

$V_{OUTN}$ change 0.01V step in every 36us and it takes 360us per 0.1V that is minimum step for $V_{OUTN}$ setting value.

[Multiple steps method (In case of $\Delta V_{OUT}$ = 0.1V)]




・Multiple step rate : 0.01V / 1ms or 36μs

・Transient time (ttra) for minimum $\Delta V_{OUTN}$ : 10 ms or 0.36 ms

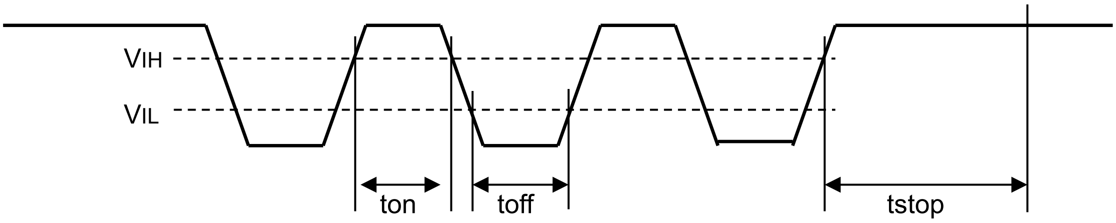
**$V_{OUTN}$ Variable Table**

The adjusted value setting command are operated with S-Wire input (pulse count) as the following table.

**$V_{OUTN}$ Variable Table (31 steps)**

| BIT (Pulse Count) | R1286KxxxA | R1286KxxxG |
|---|---|---|
| 0 (Default) | -2.4 to -5.4 | -3.0 to -6.0 |
| 1 | -5.4 | -6.0 |
| 2 | -5.3 | -5.9 |
| 3 | -5.2 | -5.8 |
| 4 | -5.1 | -5.7 |
| 5 | -5.0 | -5.6 |
| 6 | -4.9 | -5.5 |
| 7 | -4.8 | -5.4 |
| 8 | -4.7 | -5.3 |
| 9 | -4.6 | -5.2 |
| 10 | -4.5 | -5.1 |
| 11 | -4.4 | -5.0 |
| 12 | -4.3 | -4.9 |
| 13 | -4.2 | -4.8 |
| 14 | -4.1 | -4.7 |
| 15 | -4.0 | -4.6 |
| 16 | -3.9 | -4.5 |
| 17 | -3.8 | -4.4 |
| 18 | -3.7 | -4.3 |
| 19 | -3.6 | -4.2 |
| 20 | -3.5 | -4.1 |
| 21 | -3.4 | -4.0 |
| 22 | -3.3 | -3.9 |
| 23 | -3.2 | -3.8 |
| 24 | -3.1 | -3.7 |
| 25 | -3.0 | -3.6 |
| 26 | -2.9 | -3.5 |
| 27 | -2.8 | -3.4 |
| 28 | -2.7 | -3.3 |
| 29 | -2.6 | -3.2 |
| 30 | -2.5 | -3.1 |
| 31 | -2.4 | -3.0 |

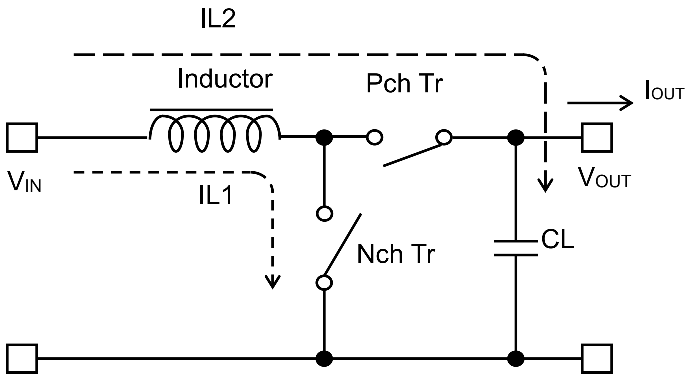
**Timing Chart for Commands with S-Wire**



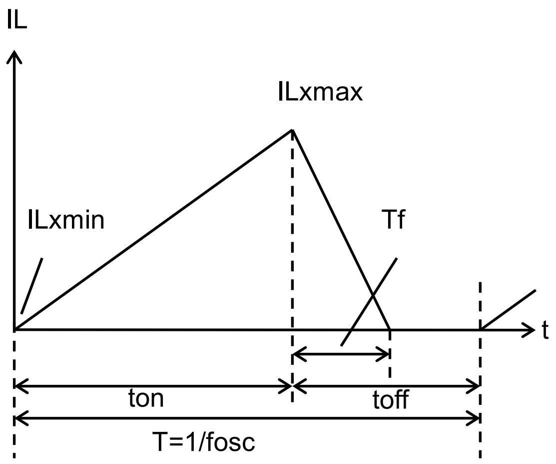

**Timing specification**

| Item | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| Soft-start time | tss | | tssp + tssn | | ms |
| $V_{OUTN}$ Transient time (1 step) | ttra | | 10 (R1286KxxxA/C/D/E/F/G)<br>0.36 (R1286KxxxH/J/K/L/M/N) | | ms |
| Turn-off delay time | toff_dly | 70 | 90 | 110 | μs |
| $V_{OUT}$ discharge time | tvo_off | | 2.0 | | ms |
| CE pin input voltage, high | $V_{IH}$ | 1.2 | | | V |
| CE pin input voltage, low | $V_{IL}$ | | | 0.4 | V |
| S-Wire time, high | ton | 2 | 10 | 20 | μs |
| S-Wire time, low | toff | 2 | 10 | 20 | μs |
| S-Wire command stop time | tstop | 70 | 90 | 110 | μs |

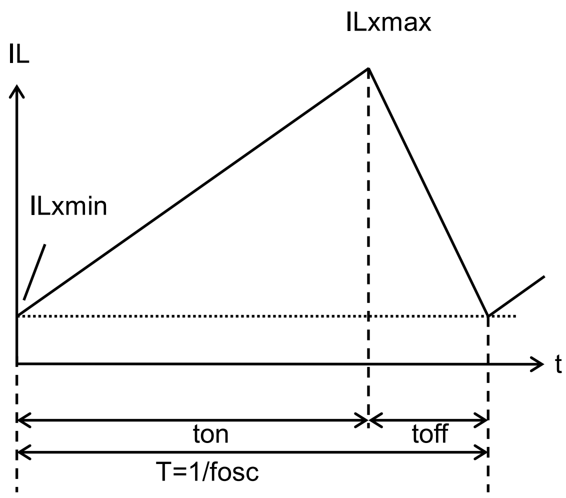
### Operation of Set-up DC/DC Converter (CH1) and Output Current




**Basic Circuit**




**Discontinuous Inductor Current Mode**




**Continuous Inductor Current Mode**

**Inductor Current Waveforms (IL) through Indictor (L)**

The PWM control type of CH1 has two operation modes characterized by the continuity of inductor current: discontinuous inductor current mode and continuous inductor current mode.

When a NMOS Tr. is in On-state, the voltage to be applied to the inductor (L) is described as $V_{IN}$. An increase in the inductor current (IL1) can be written as follows:

$IL1 = V_{IN} \times ton / L$ ········································································ Equation 1

In the CH1 circuit, the energy accumulated during the On-state is transferred into the capacitor even in the Off-state. A decrease in the inductor current (IL2) can be written as follows:

$IL2 = (V_{OUT} - V_{IN}) \times tf / L$ ································································ Equation 2

In the PWM control, IL1 and IL2 become continuous when tf = toff, which is called continuous inductor current mode. When the device is in continuous inductor current mode and operates in steady-state conditions, the variations of IL1 and IL2 are same:

$V_{IN}$ x ton / L = ($V_{OUT} - V_{IN}$) x toff / L ··· Equation 3

Therefore, the duty cycle in continuous inductor current mode is:

Duty = ton / (ton + toff) = ($V_{OUT} - V_{IN}$) / $V_{OUT}$ ··· Equation 4

If the input voltage ($V_{IN}$) is equal to $V_{OUT}$, the output current ($I_{OUT}$) is:

$I_{OUT} = V_{IN}^2$ x ton / (2 x L x $V_{OUT}$) ··· Equation 5

If $I_{OUT}$ is larger than Equation 5, the device switches to continuous inductor current mode. The $L_X$ peak current flowing through L (ILxmax) is:

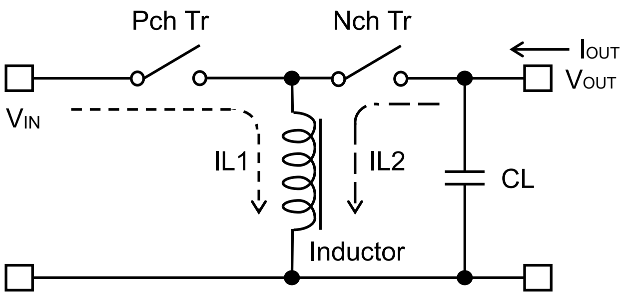
ILxmax = $I_{OUT}$ x $V_{OUT}$ / $V_{IN}$ + $V_{IN}$ x ton / (2 x L) ··· Equation 6

ILxmax = $I_{OUT}$ x $V_{OUT}$ / $V_{IN}$ + $V_{IN}$ x T x ($V_{OUT} - V_{IN}$) / (2 x L x $V_{OUT}$) ··· Equation 7

The $L_X$ peak current limit circuit operates in both modes if the ILxmax becomes more than the $L_X$ peak current limit. When considering the input and output conditions or selecting the external components, please pay attention to ILxmax.

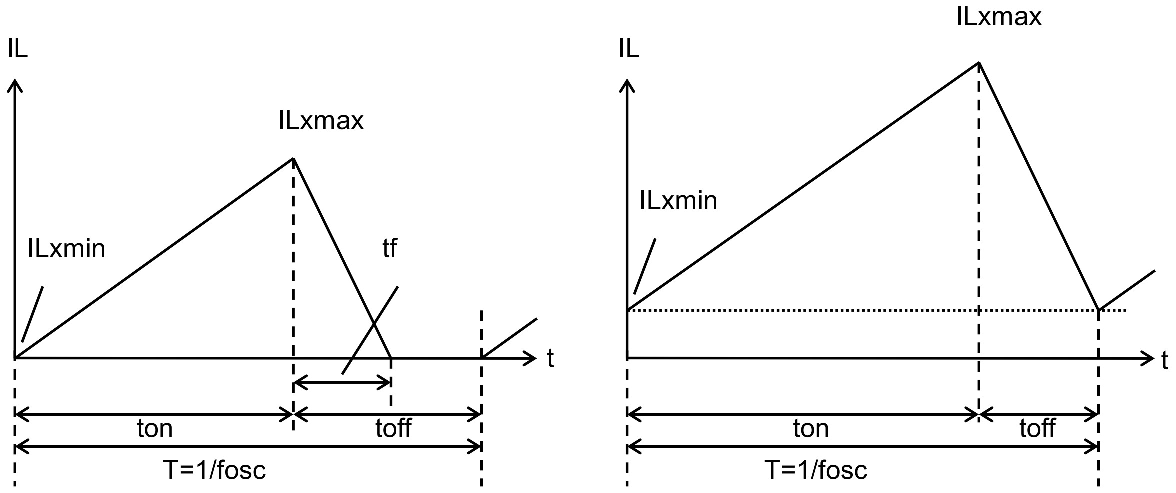
**Notes:** The above calculations are based on the ideal operation of the device. They do not include the losses caused by the external components or $L_X$ switch. The actual maximum output current will be 70% to 90% of the above calculation results. Especially, if IL is large or $V_{IN}$ is low, it may cause the switching losses.

## Operation of Inverting DC/DC Converter (CH2) and Output Current




**Basic Circuit**

**Discontinuous Inductor Current Mode** **Continuous Inductor Current Mode**




**Inductor Current Waveforms (IL) through Indictor (L)**

The PWM control type of CH2 has two operation modes characterized by the continuity of inductor current: discontinuous inductor current mode and continuous inductor current mode.
When a PMOS Tr. is in ON-state, the voltage to be applied to the inductor (L) is described as $V_{IN}$. An increase in the inductor current (IL1) can be written as follows:

$IL1 = V_{IN} \times ton / L$ ············ Equation 8

In the CH2 circuit, the energy accumulated during the On-state is transferred into the capacitor even in the Off-state. A decrease in the inductor current (IL2) can be written as follows:

$IL2 = |V_{OUT}| \times tf / L$ ············ Equation 9

In the PWM control type, when tf = toff, the inductor current will be continuous and the operation of CH2 will be continuous inductor current mode. When the device is in continuous inductor current mode and operates in steady-state conditions, the variation of IL1 and IL2 are same:

$V_{IN}$ x ton / L = $|V_{OUT}|$ x toff / L ······································································ Equation 10

Therefore, the duty cycle in continuous inductor current mode is:

Duty = ton / (ton + toff) = $|V_{OUT}|$ / ($|V_{OUT}|$ + $V_{IN}$) ················································ Equation 11

If the input voltage ($V_{IN}$) equal to $V_{OUT}$, the output current ($I_{OUT}$) is:

$I_{OUT} = V_{IN}^2$ x ton / (2 x L x $|V_{OUT}|$) ································································· Equation 12

If $I_{OUT}$ is larger than Equation 12, the device switches to continuous inductor current mode. The $L_X$ peak current flowing through L (ILxmax) is:

ILxmax = $I_{OUT}$ x ($|V_{OUT}|$ + $V_{IN}$) / $V_{IN}$ + $V_{IN}$ x ton / (2 x L) ············································ Equation 13

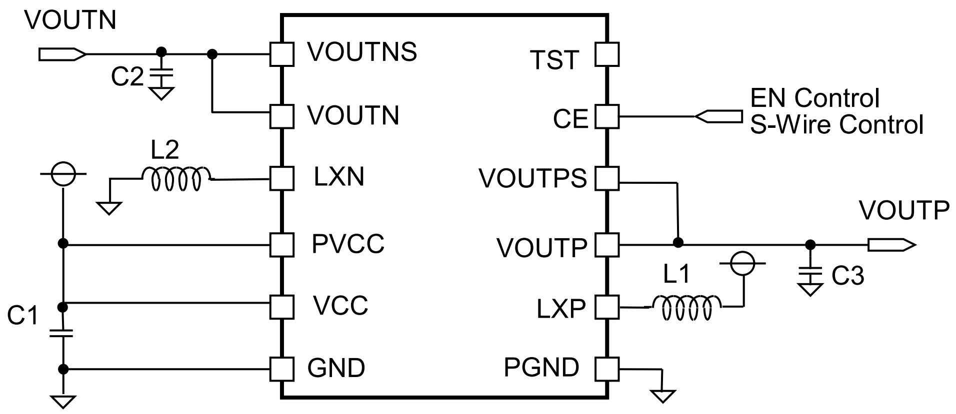
ILxmax = $I_{OUT}$ x ($|V_{OUT}|$ + $V_{IN}$) / $V_{IN}$ + $V_{IN}$ x $|V_{OUT}|$ x T / { 2 x L x ($|V_{OUT}|$ + $V_{IN}$) } ·················· Equation 14

The $L_X$ peak current limit circuit operates in both modes if the ILxmax becomes more than the $L_X$ peak current limit. When considering the input and output conditions or selecting the external components, please pay attention to ILxmax.

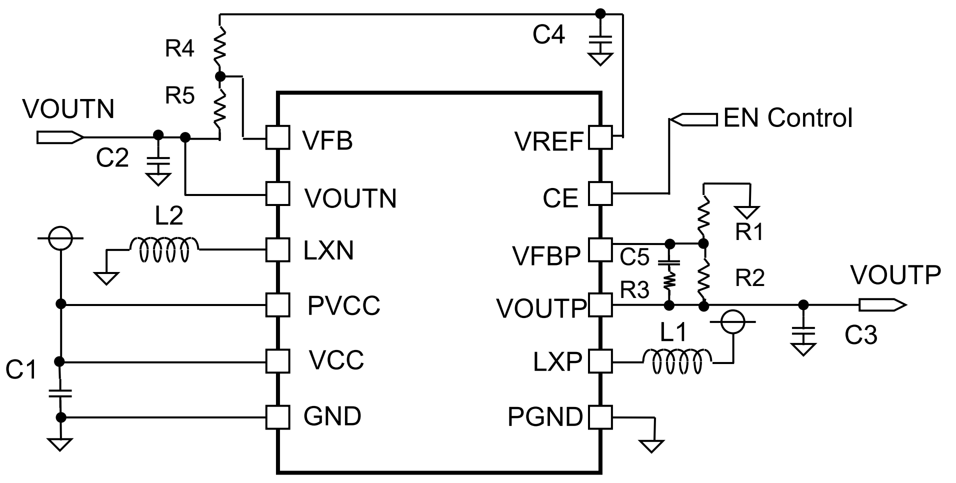
**Notes:** The above calculations are based on the ideal operation of the device. They do not include the losses caused by the external components or $L_X$ switch. The actual maximum output current will be 70% to 90% of the above calculation results. Especially, if IL is large or $V_{IN}$ is low, it may cause the switching losses.

# APPLICATION INFORMATION

### Typical Application Circuits




**R1286KxxxX (Fixed Output Voltage Type) Typical Application Circuit**




**R1286K001B (Adjustable Output Voltage Type) Typical application Circuit**

**Recommended External Components**

| Symbol | Description |
|---|---|
| L1 | VLF302510M-4R7M (TDK)、VLF3010S-4R7M (TDK) |
| L2 | VLF4012S-4R7M (TDK)、NR4012T4R7M (TAIYOYUDEN) |
| C1($C_{IN}$), C2($C_{OUTN}$), C3($C_{OUTP}$) | 4.7μF、 2012size X5R T=0.85max |
| C4 ($C_{REF}$)(1) | 0.1μF、 0603size |

(1) R1286K001B Only

## Precautions for Selecting External Components

- Place a ceramic capacitor of 4.7μF or more (C1) between VCC pin/PVCC pin and GND pin/ PGND pin.

- Place a ceramic capacitor of 4.7μF or more (C2, C3) between VOUTP pin / VOUTN pin and GND.

- Place a ceramic capacitor of 0.1μF to 2.2μF (C4) between VREF pin and GND. [ R1286K001B ]

- Step-up DC/DC Converter Output Voltage Setting [ R1286K001B ]

  The output voltage $V_{OUTP}$ of the step-up DC/DC converter is controlled with maintaining the $V_{FBP}$ as 1.0V. $V_{OUTP}$ can be set with adjusting the values of R1 and R2 as in the next formula.

  $$V_{OUTP} = V_{FBP} \times (R1 + R2) / R1$$

  $V_{OUTP}$ can be set from 4.6V to 5.8V. The appropriate value range of R1 is from 20kΩ to 60k Ω.

- **Inverting DC/DC Converter Output Voltage Setting [ R1286K001B ]**

  The output voltage $V_{OUTN}$ of the inverting DC/DC converter is controlled with maintaining the $V_{FBN}$ as 0V. $V_{OUTN}$ can be set with adjusting the values of R1 and R2 as in the next formula.

  $$V_{OUTN} = V_{FBN} - (V_{REF} - V_{FBN}) \times R5 / R4$$

  $V_{OUTN}$ can be set from -2.0V to -6.0V. The appropriate value range of R4 is from 2.5kΩ to 60kΩ.

- **Phase Compensation of Step-up DC/DC Converter [ R1286K001B ]**

  DC/DC converter's phase may lose 180 degree by external components of L and C and load current. Because of this, the phase margin of the system will be less and the stability will be worse. Therefore, the phase must be gained.

  Zero will be formed with R1 and C5.
  C5 [pF] = 300 / R1 [kΩ]

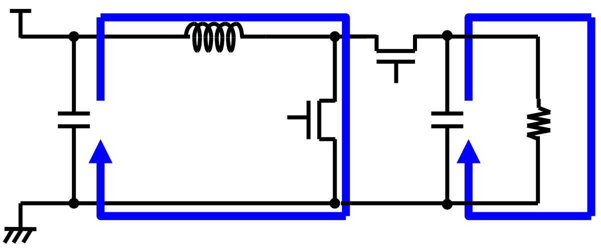
  If the noise of the system is large, the output noise affects the feedback and the operation may be unstable. In that case, another resistor R3 will be set. The appropriate value range is from 10Ω to 1kΩ.

# TECHNICAL NOTES

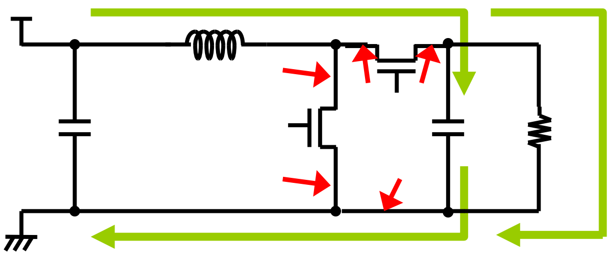
The performance of a power source circuit using this device is highly dependent on a peripheral circuit. A peripheral component or the device mounted on PCB should not exceed a rated voltage, a rated current or a rated power. When designing a peripheral circuit, please be fully aware of the following points.

- Wire the bypass capacitor (C1) between the VCC pin, the GND pin, or the PVCC pin as short as possible. The GND pin should be connected to the GND plane of the PCB.
- Wire the GND of the output capacitors (C2, C3) to the GND pin of the device as short as possible.
- The wiring among each GND line of C1, C2, and C3 and the GND pin of the device must be short as possible via the device.
- The wiring between $L_{XP}$ pin, $L_{XN}$ pin and inductor each should be as short as possible and mount output capacitors (C2 and C3) as close as possible to the $V_{OUTP}$, $V_{OUTN}$ each.
- Input impedance of VOUTPS pin, VOUTNS pin, VFBP pin, and VFBN pin is high, therefore, the external noise may affect the performance. The coupling capacitance between these nodes and switching lines must be as short as possible.
- As shown in the diagrams of the current paths of boost DC/DC converter and the current path of inverting DC/DC converter, the parasitic impedance, inductance, and the capacitance in the parts pointed with red arrows have an influence against the stability of the DC/DC converters and become a cause of the noise. Therefore, such parasitic elements must be made as small as possible. Wiring of the current paths must be short and thick.

【Set-up DCDC】

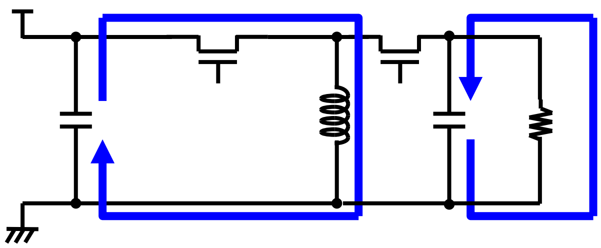


NMOSFET-ON

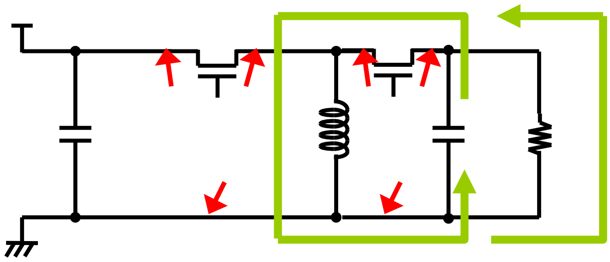


PMOSFET-ON

【Inverting DCDC】



PMOSFET-ON

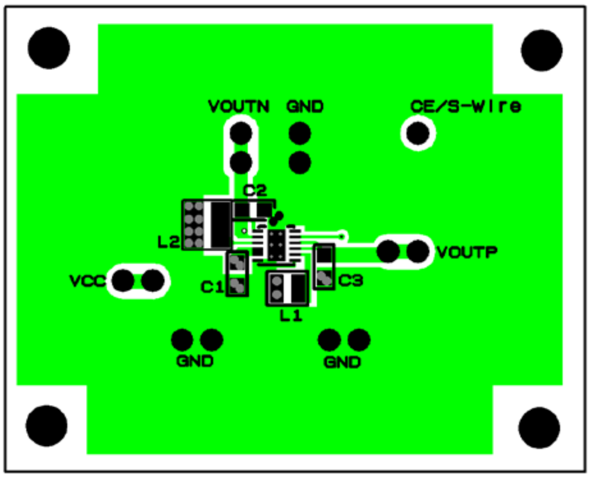


NMOSFET-ON

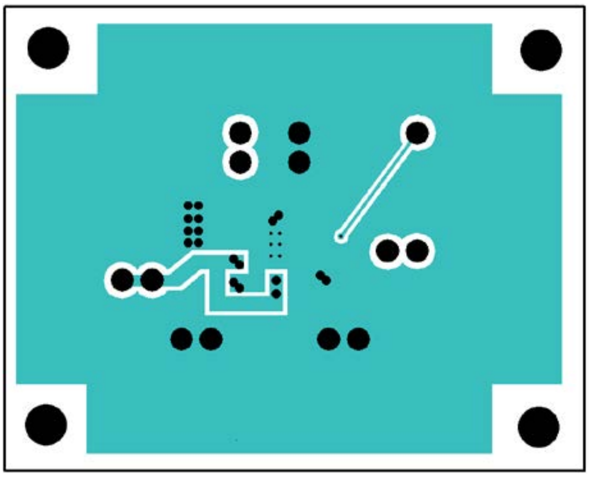
## PCB Layout

### R1286K Board Layout [PKG: DNF (PLP) 2730-12]

**Top Layer**

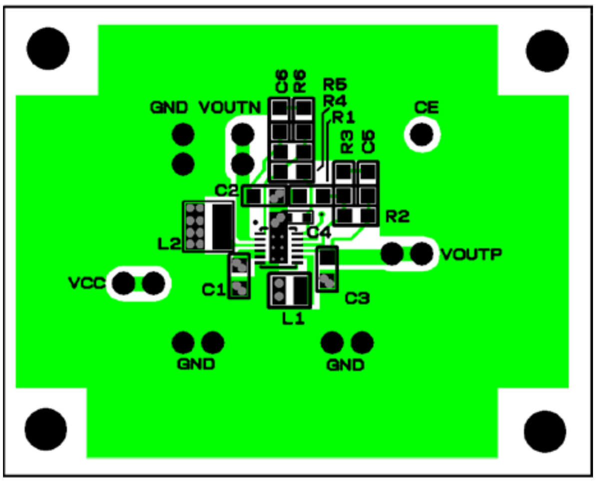



**Back Layer**

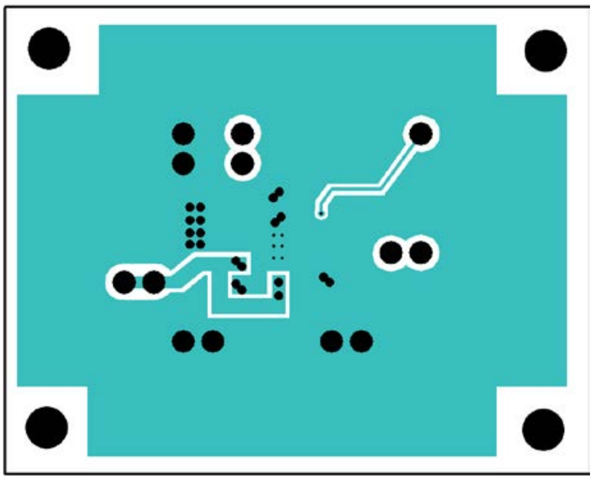


**R1286KxxxX[1]（Fixed Output Voltage Type）Board Layout**

**Top Layer**




**Back Layer**



**R1286K001B (Adjustable Output Voltage Type) Board Layout**

[1] X : A to N (Provided, except “B” and “I”)

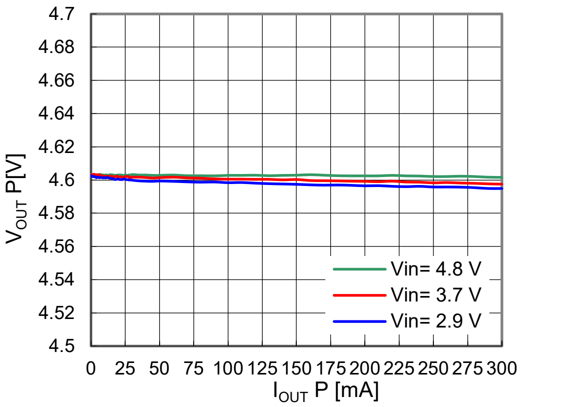
# TYPICAL CHARACTERISTICS

Typical Characteristics are intended to be used as reference data, they are not guaranteed.

### 1) Output Voltage vs. Output Current

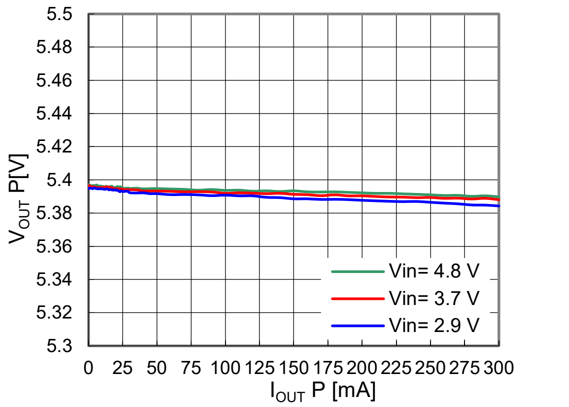
R1286KxxxX[(1)] ($V_{OUTP}$ = 4.6 V)

(Ta = 25°C)



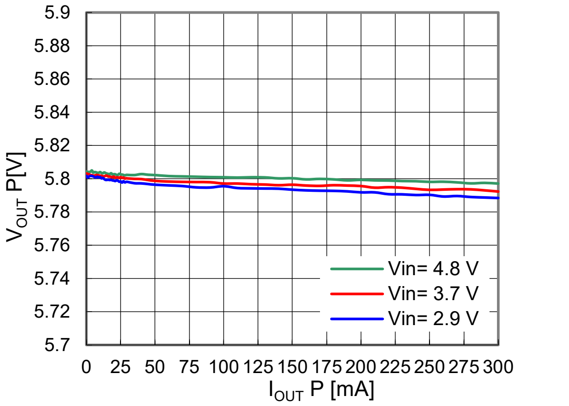

R1286KxxxX ($V_{OUTP}$ = 5.4 V)

(Ta = 25°C)



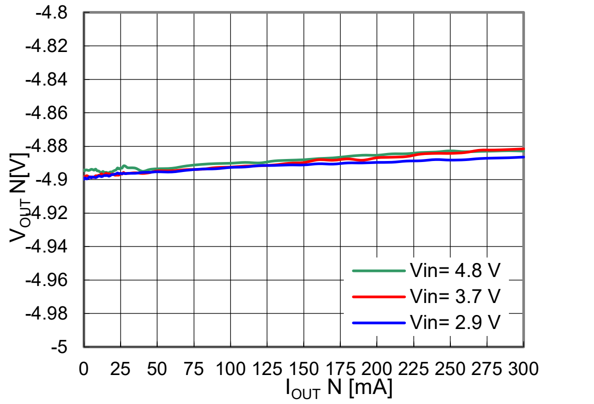

R1286KxxxX ($V_{OUTP}$ = 5.8 V)

(Ta = 25°C)



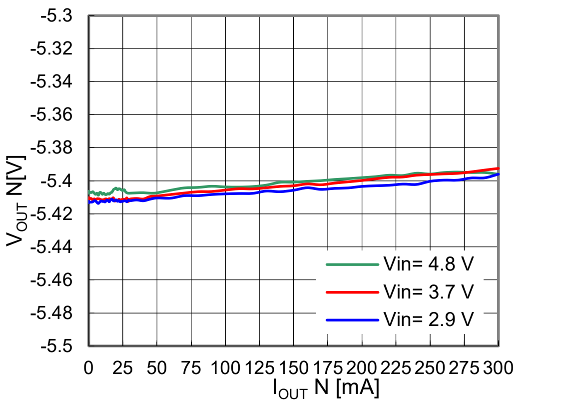

R1286KxxxX ($V_{OUTN}$ = -4.9 V)

(Ta = 25°C)



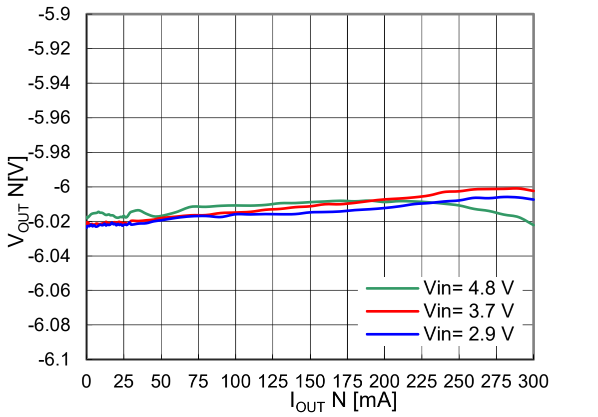

R1286KxxxX ($V_{OUTN}$ = -5.4 V)

(Ta = 25°C)




R1286KxxxX ($V_{OUTN}$ = -6.0 V)

(Ta = 25°C)

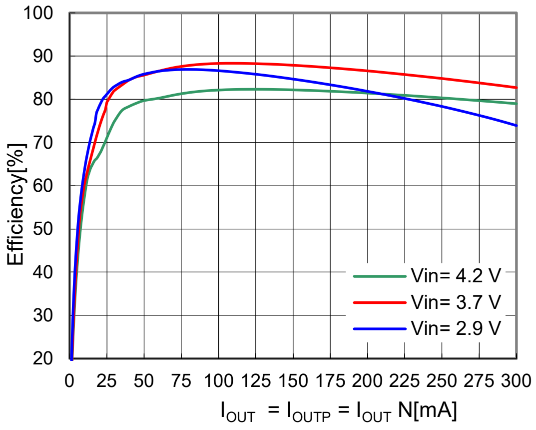



(1) X : A to N (Provided, except “B” and “I”)

**2) Efficiency vs. Output Current**

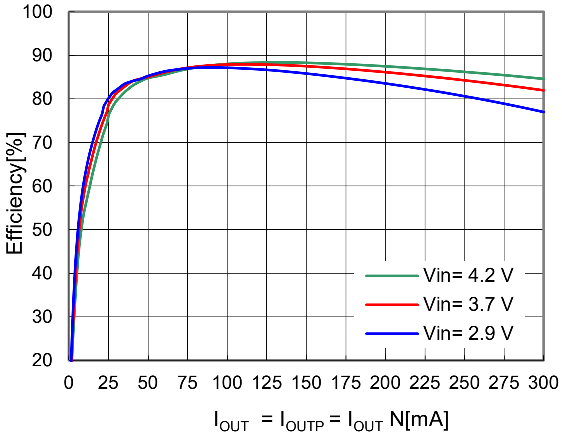
R1286KxxxX ($V_{OUTP}$ = 4.6 V, $V_{OUTN}$ = -4.9 V)

(Ta = 25°C)



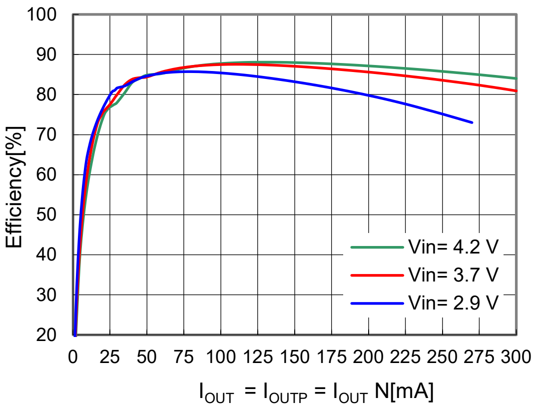

R1286KxxxX ($V_{OUTP}$ = 5.4 V, $V_{OUTN}$ = -5.4 V)

(Ta = 25°C)




R1286KxxxX ($V_{OUTP}$ = 5.8 V, $V_{OUTN}$ = -6.0 V)

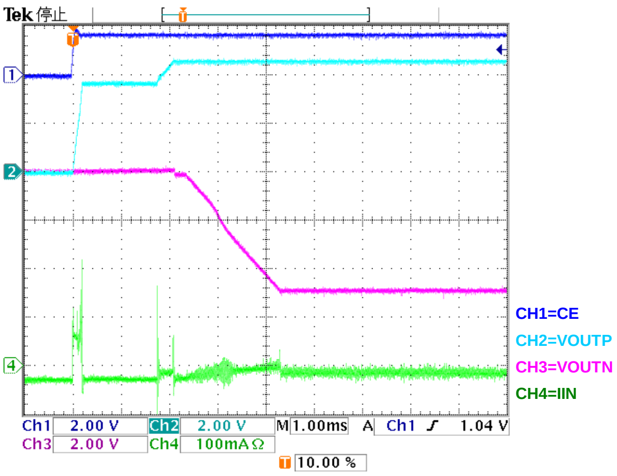
(Ta = 25°C)

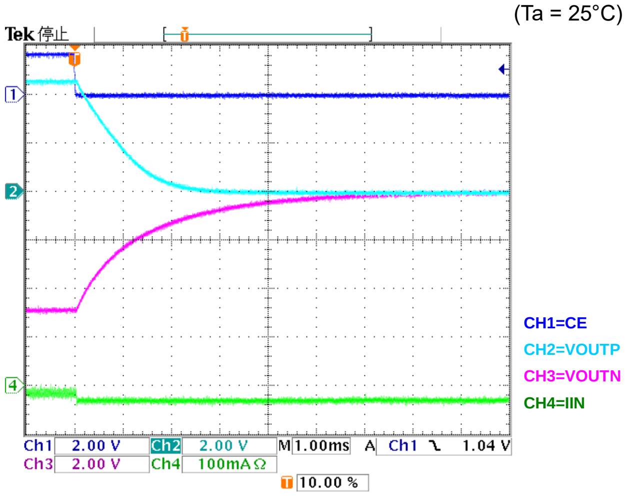


### 3) Turn-on/Turn-off Waveform by CE

R1286Kx02A ($V_{IN}$=3.7 V, $I_{OUTP}$ = $I_{OUTN}$ = 0 mA )

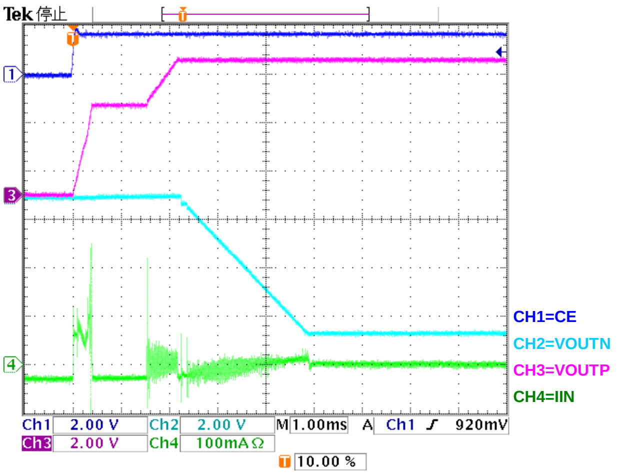
(Ta = 25°C)

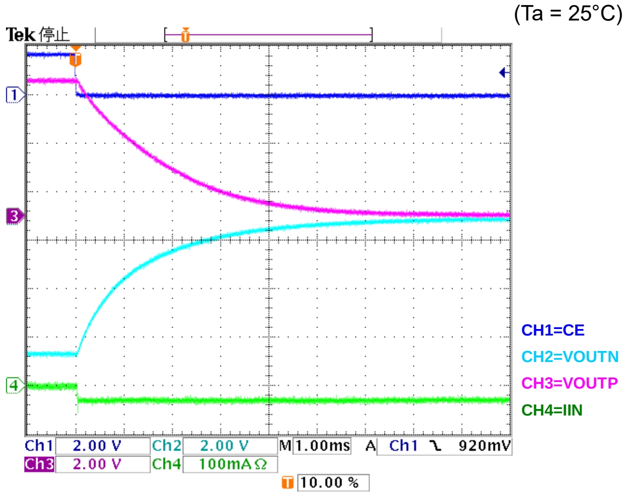



R1286Kx05A ($V_{IN}$=3.7 V, $I_{OUTP}$ = $I_{OUTN}$ = 0 mA, $C_{OUTP}$ = $C_{OUTN}$ = 4.7μF)

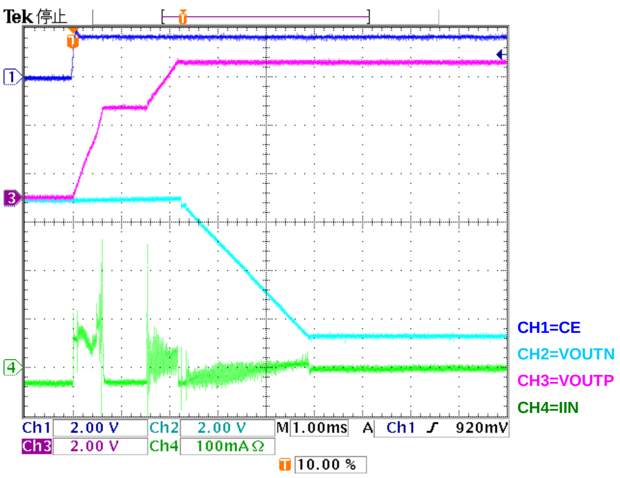
(Ta = 25°C)

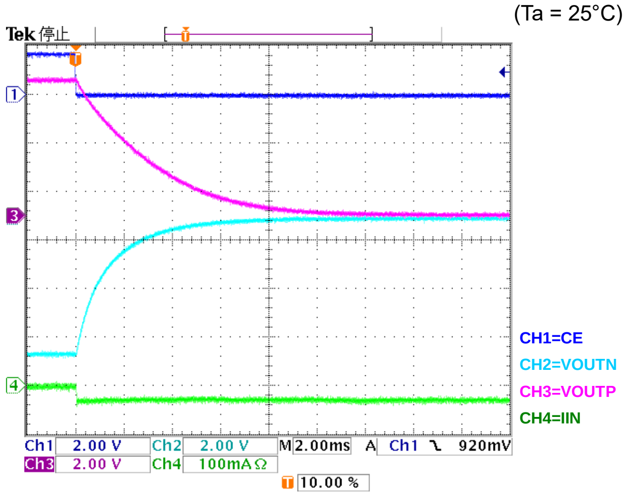



R1286Kx05A ($V_{IN}$=3.7 V, $I_{OUTP}$ = $I_{OUTN}$ = 0 mA, $C_{OUTP}$ = 10 μF x 2, $C_{OUTN}$ = 4.7μF)

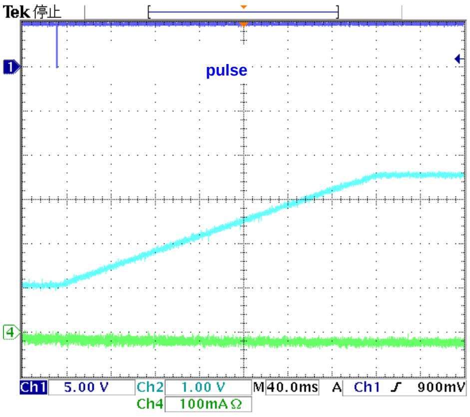
(Ta = 25°C)



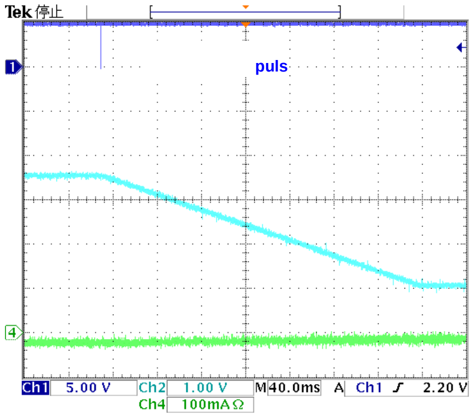
### 4) VOUTN Waveform with S-Wire Control

R1286Kx02A
(-4.9 V ≤ $V_{OUTN}$ ≤ -2.4 V, $I_{OUTP}$ = $I_{OUTN}$ = 0 mA )
(Ta = 25°C)




CH1=CE
CH2=VOUTN
CH4=IIN

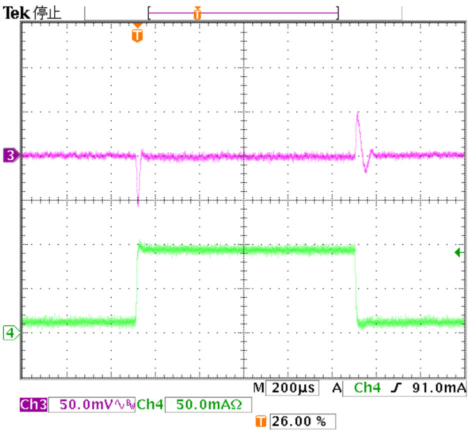
R1286Kx02A
(-2.4 V ≤ $V_{OUTN}$ ≤ -4.9 V, $I_{OUTP}$ = $I_{OUTN}$ = 0 mA )
(Ta = 25°C)




CH1=CE
CH2=VOUTN
CH4=IIN

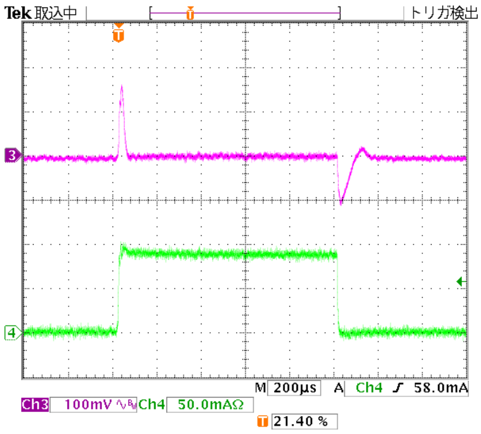
### 5) Load Transient Response

R1286KxxxX ($V_{OUTP}$ = 4.6 V)
(Ta = 25°C)




CH3=VOUTP
CH4=IOUT

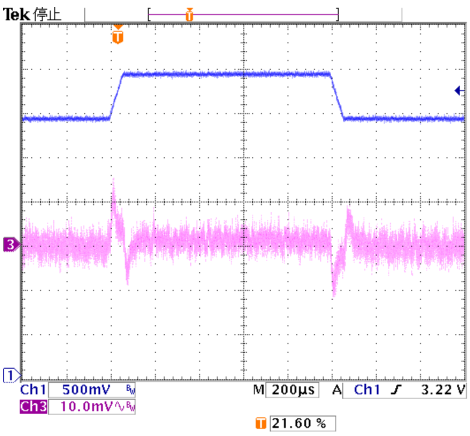
R1286KxxxX ($V_{OUTN}$ = -4.9 V)
(Ta = 25°C)




CH3=VOUTN
CH4=IOUT

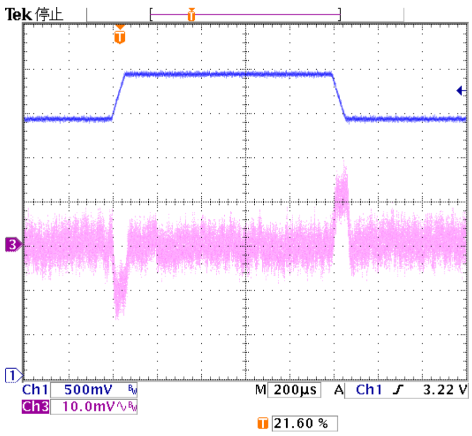
### 6) Line Transient Response

R1286KxxxX ($V_{OUTP}$ = 4.6 V, $I_{OUTP}$ = 100 mA)
(Ta = 25°C)




CH1=VIN
CH3=VOUTP

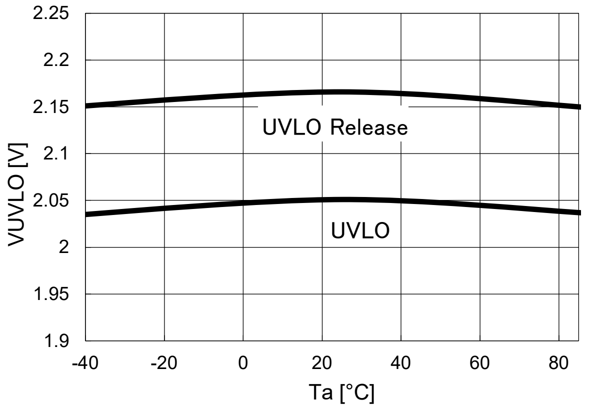
R1286KxxxX ($V_{OUTN}$ = -4.9 V, $I_{OUTN}$ = 100 mA)
(Ta = 25°C)




CH1=VIN
CH3=VOUTN

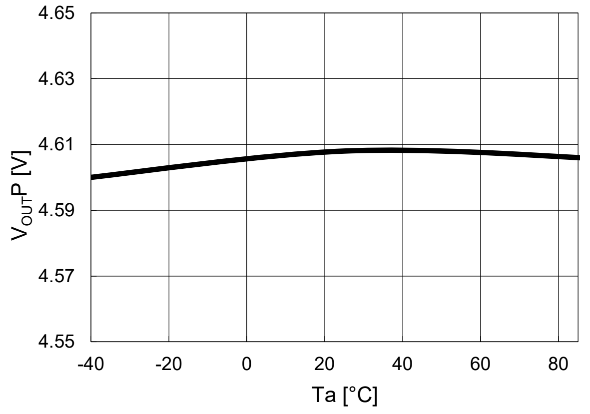
### 7) UVLO Voltage vs. Temperature

R1286KxxxX



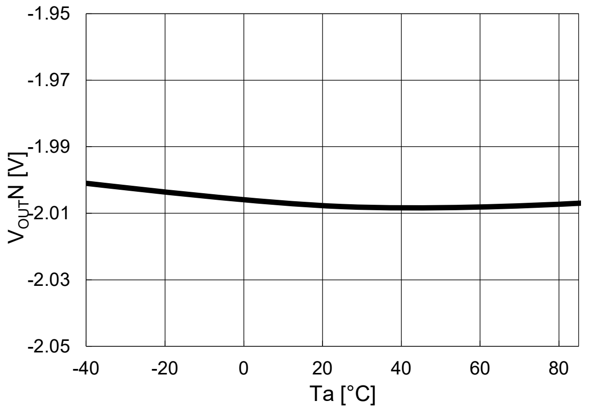

### 8) VOUTP Voltage vs. Temperature

R1286Kx02X

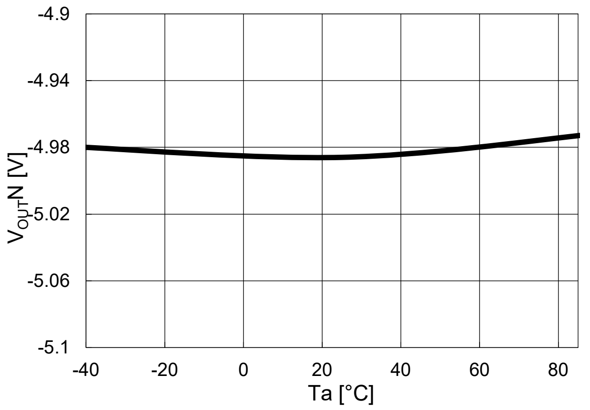



### 9) VOUTN Voltage vs. Temperature

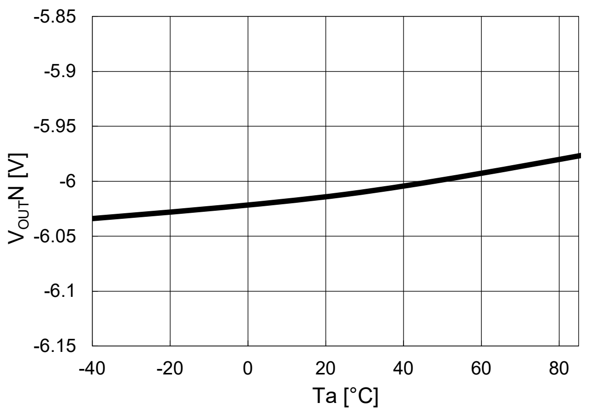
**R1286KxxxC**




**R1286KxxxX**

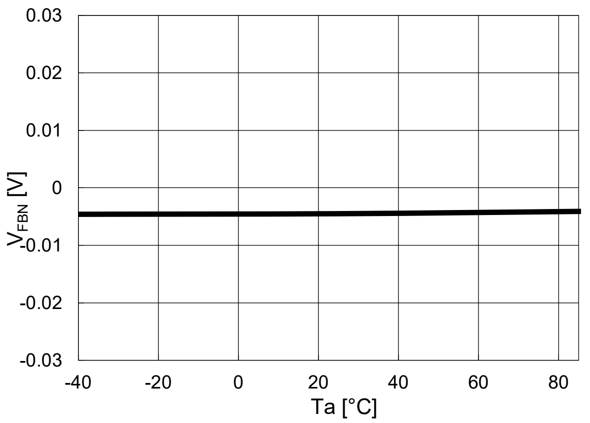



**R1286KxxxG**



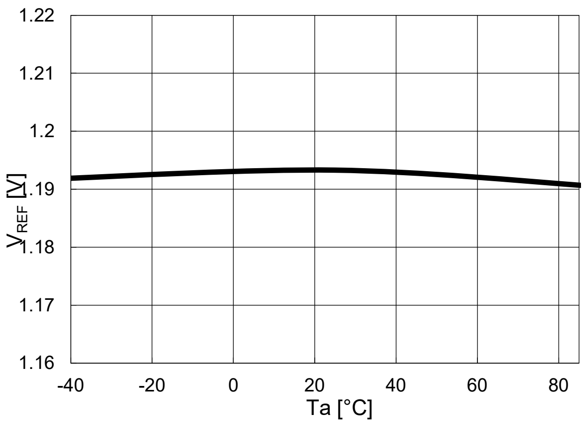
**10) VFBN Voltage vs. Temperature**

**R1286K001B**



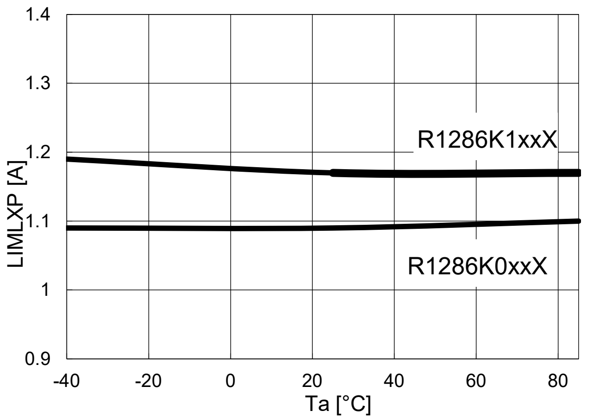

**11) VREF Voltage vs. Temperature**

**R1286K001B**



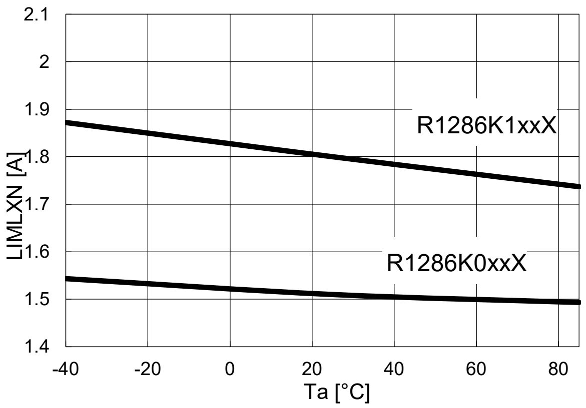

**12) LXP Current Limit vs. Temperature**

**R1286KxxxX**



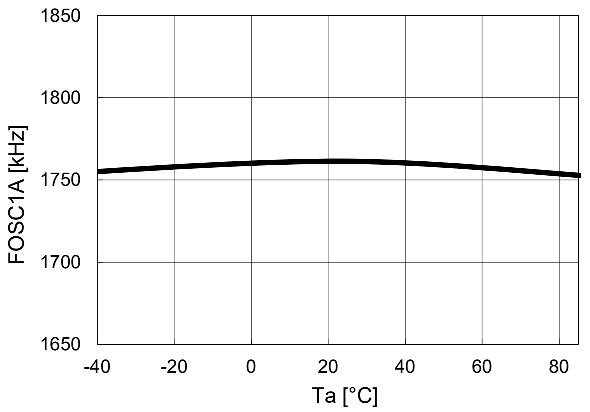

**13) LXN Limit Current vs. Temperature**

**R1286KxxxX**



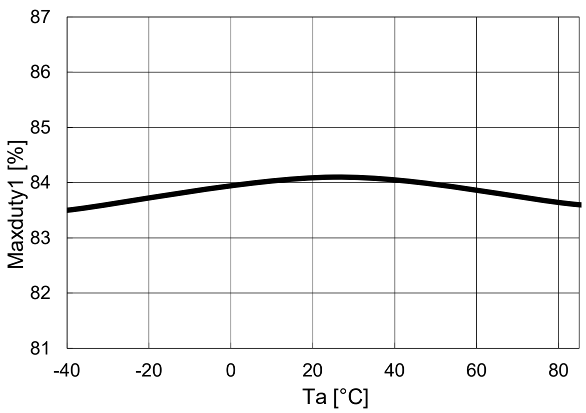

**14) Oscillator Frequency vs. Temperature**

**R1286KxxxX**



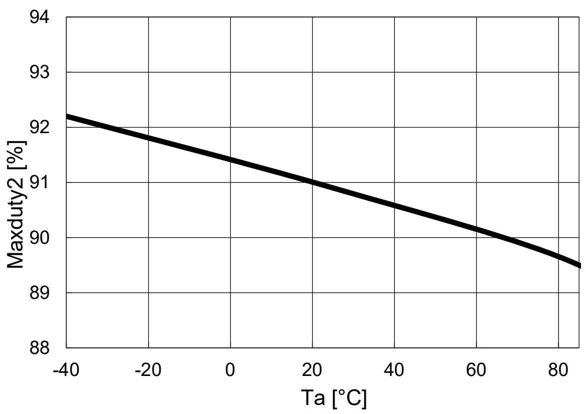
**15) Maxduty1 vs. Temperature**

R1286KxxxX



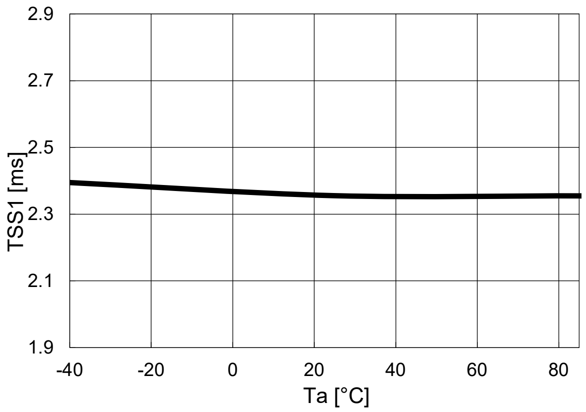

**16) Maxduty2 vs. Temperature**

R1286KxxxX



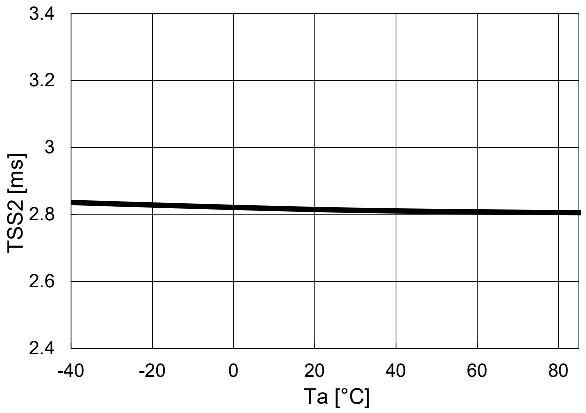

**17) CH1 Soft-start Time vs. Temperature**

**R1286KxxxX**



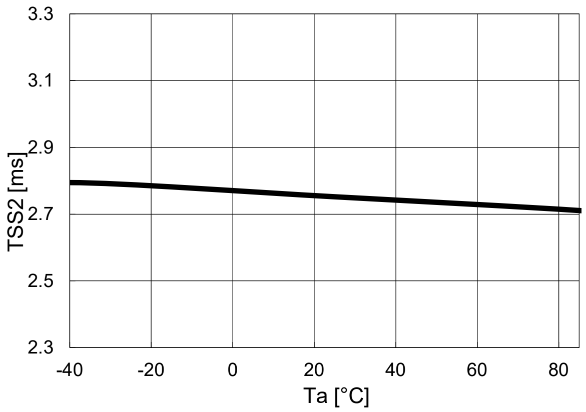

**18) CH2 Soft-start Time vs. Temperature**

**R1286KxxxG**



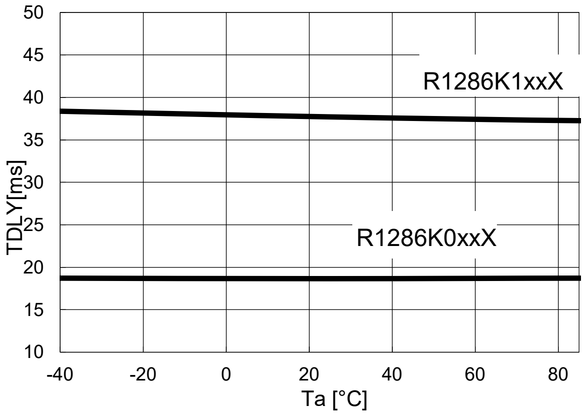

**19) CH2 Soft-start Time vs. Temperature**

**R1286K001B**




**20) Delay Time for Protection vs. Temperature**

**R1286KxxxX**



Ver. A

The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following measurement conditions are based on JEDEC STD. 51-7.

**Measurement Conditions**

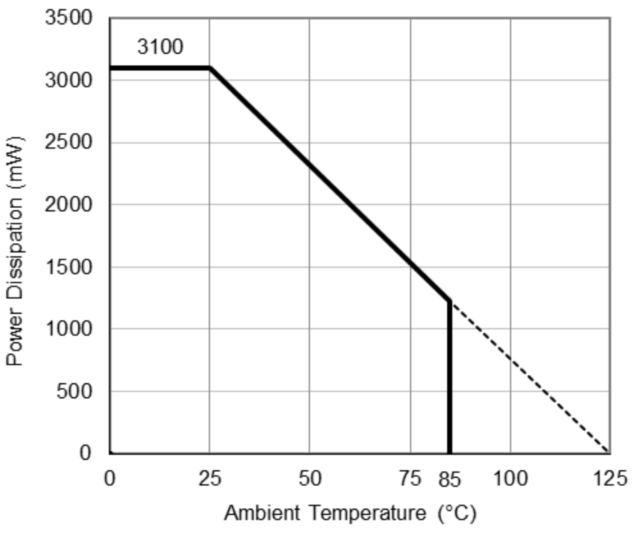
| Item | Measurement Conditions |
|---|---|
| Environment | Mounting on Board (Wind Velocity = 0 m/s) |
| Board Material | Glass Cloth Epoxy Plastic (Four-Layer Board) |
| Board Dimensions | 76.2 mm × 114.3 mm × 0.8 mm |
| Copper Ratio | Outer Layer (First Layer): Less than 95% of 50 mm Square<br>Inner Layers (Second and Third Layers): Approx. 100% of 50 mm Square<br>Outer Layer (Fourth Layer): Approx. 100% of 50 mm Square |
| Through-holes | ϕ 0.3 mm × 23 pcs |

**Measurement Result** (Ta = 25°C, Tjmax = 125°C)

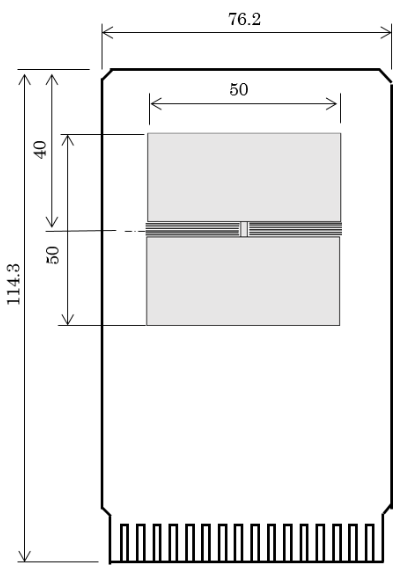
| Item | Measurement Result |
|---|---|
| Power Dissipation | 3100 mW |
| Thermal Resistance (θja) | θja = 32°C/W |
| Thermal Characterization Parameter (ψjt) | ψjt = 8°C/W |

θja: Junction-to-Ambient Thermal Resistance

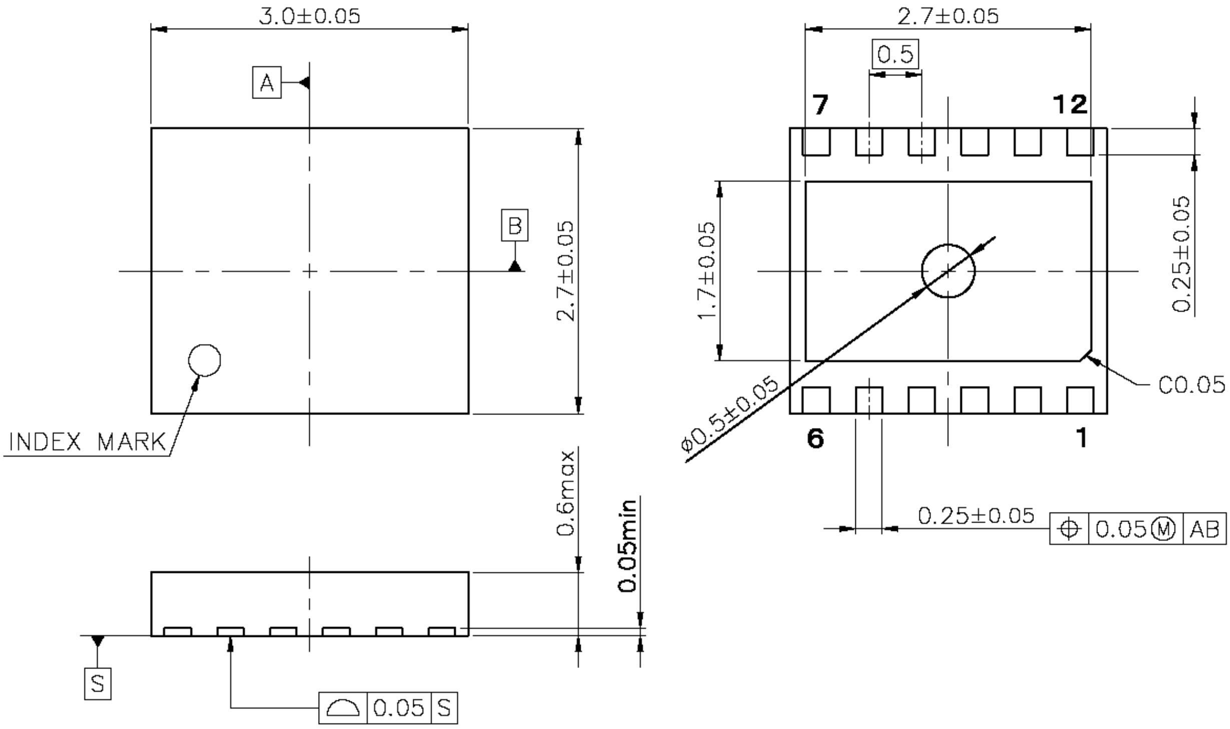
ψjt: Junction-to-Top Thermal Characterization Parameter




**Power Dissipation vs. Ambient Temperature**




**Measurement Board Pattern**




**DFN(PLP)2730-12 Package Dimensions (Unit: mm)**

NISSHINBO

Nisshinbo Micro Devices Inc.

**Official website**

https://www.nisshinbo-microdevices.co.jp/en/

**Purchase information**

https://www.nisshinbo-microdevices.co.jp/en/buy/