RICOH

R1286K SERIES

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)

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(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

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(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.

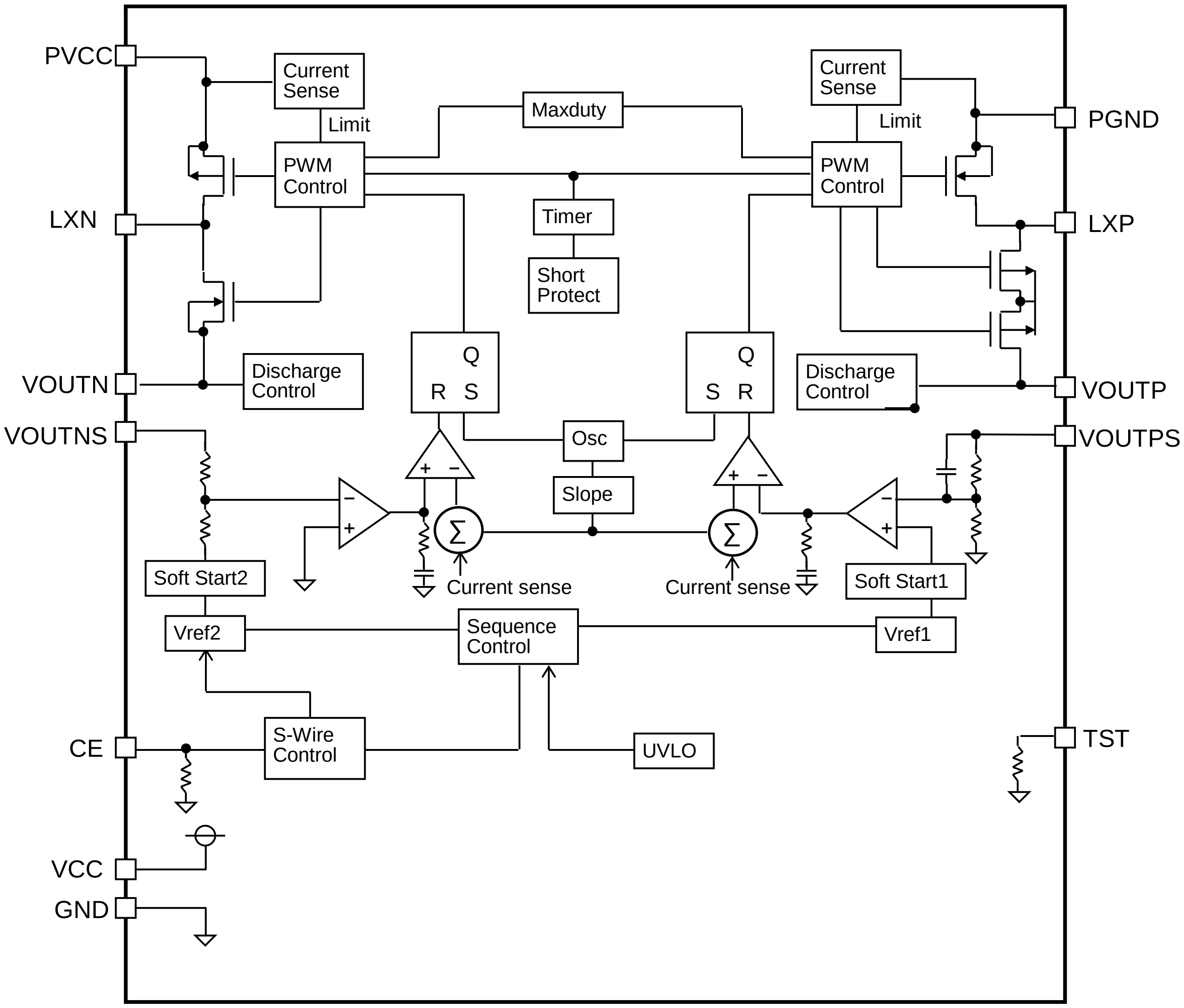
(5) Dynamically adjustable output voltage with S-Wire

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

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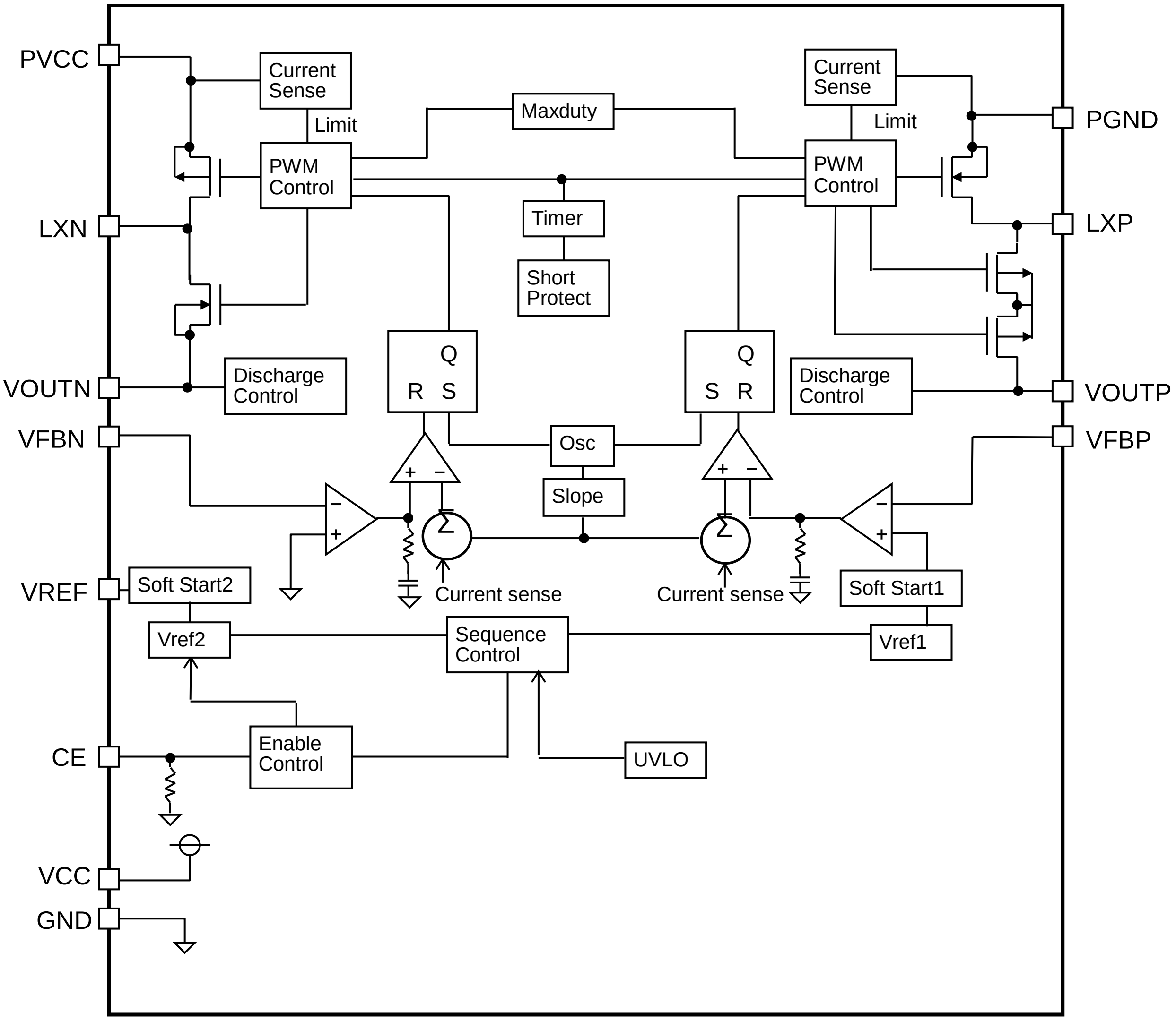
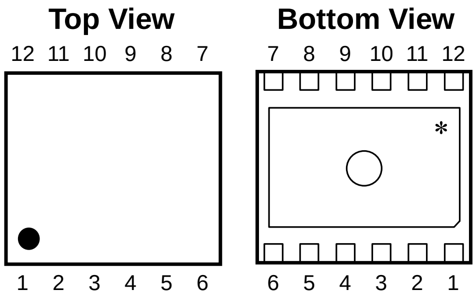
[1] X : A to N (Provided, except “B” and “I”)

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) Chip Enable Pin (R1286KxxxB)
12	TST	VREF	TEST Pin[2] (R1286KxxxX) 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.

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[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.

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(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)

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

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

The specifications surrounded by ☐ 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)

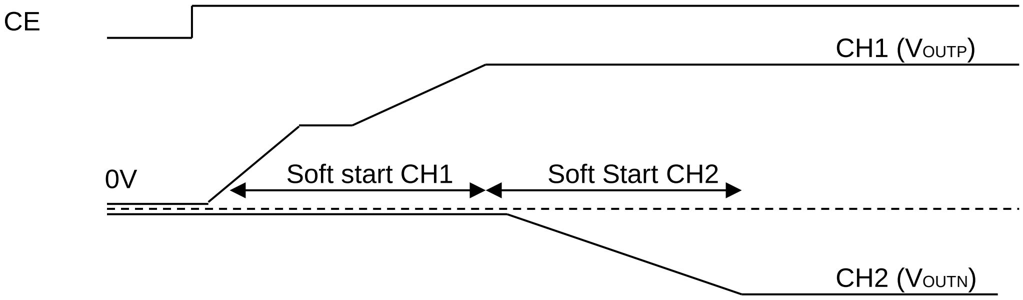
Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Maxduty2	Maximum Duty Cycle 2	V_{CC}=3.7V		90		%
I_{VOUTN}	V_{OUTN} Discharge Current	V_{CC}=3.7V, V_{OUTN}=-0.1		0.3		mA
R_{LXN}	LXN Pin On-resistance	V_{CC}=3.7V		400		mΩ
R_{SYNCN}	Synchronous SW Nch.On-resistance	V_{CC}=3.7V		600		mΩ
[R1286K0xxx]						
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

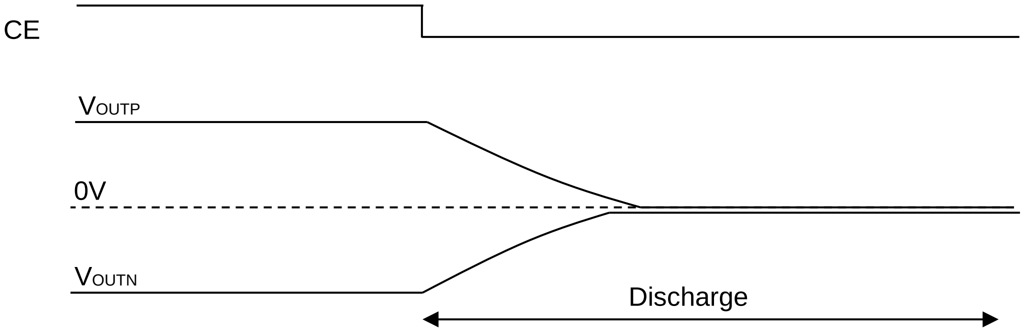
When CE level turns from 'L' to 'H' level, the softstart of CH1 starts the operation. After detecting output voltage of CH1(V_{OUTP})as the nominal level, the soft start of CH2 starts the operation.



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

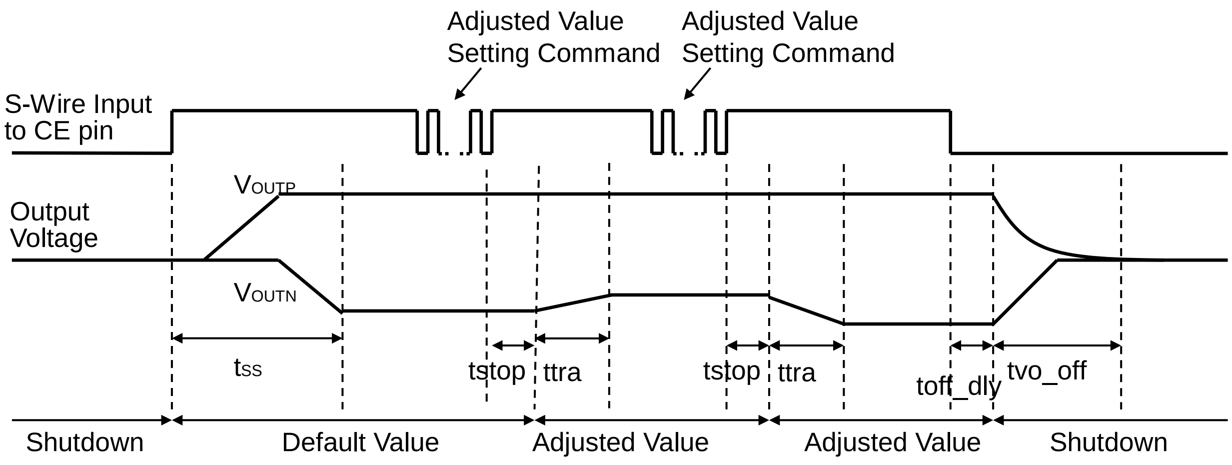
The over current protection circuit supervises the peak current of the inductor (The current passing through NMOS transistor of CH1 and PMOS transistor of CH2) with respect to each switching cycle. If the peak current exceeds the L_X current limit (I_{LIMLXP} or I_{LIMLXN}), the over current protection 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.

∗ L_X 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.)

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[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*).

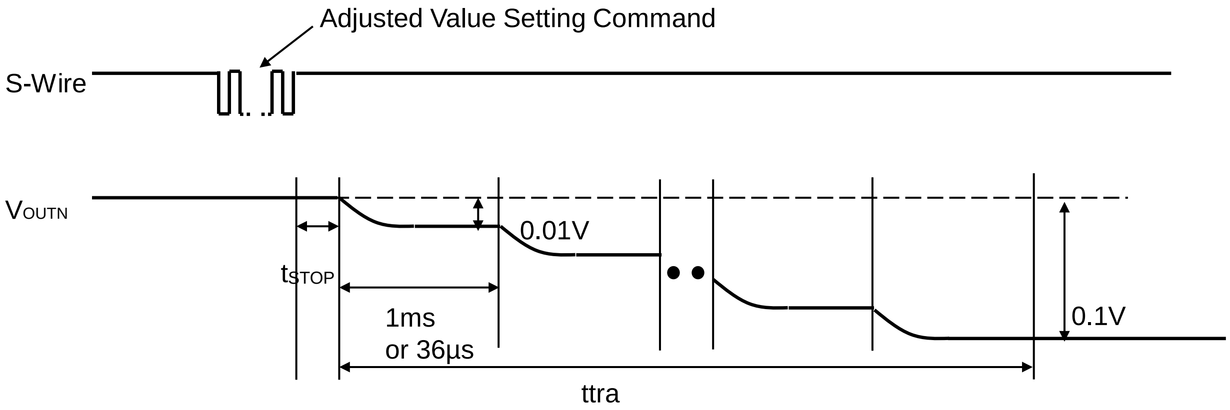
In the case of R1286KxxxA/C/D/E/F/G,

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 ΔV_{OUTN} : 10 ms or 0.36 ms

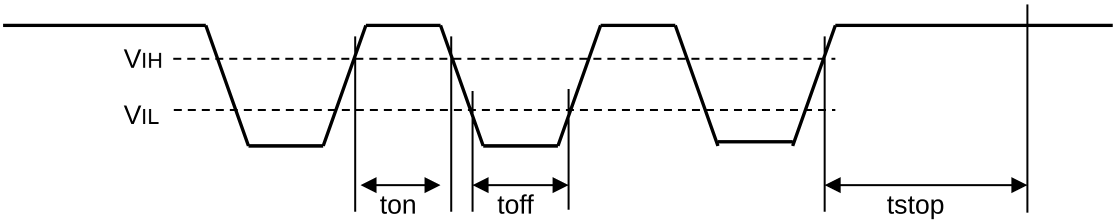
V_{OUTN} Variable Table

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

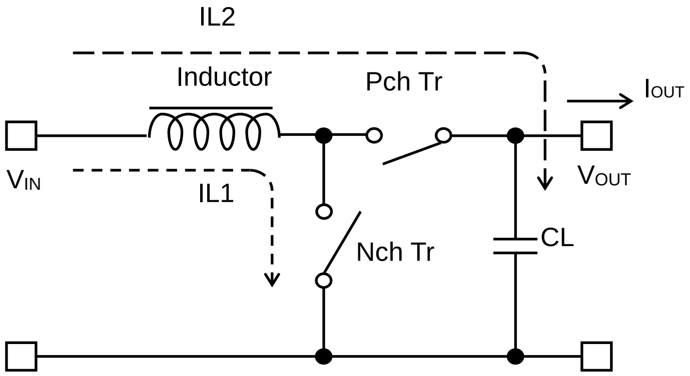
Timing Chart for Commands with S-Wire



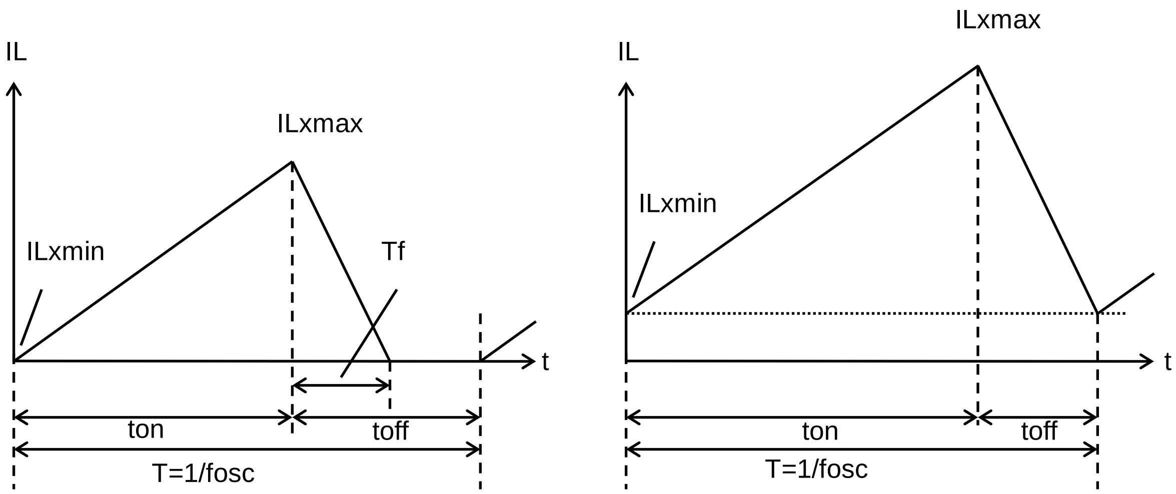
Timing specification

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) 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:

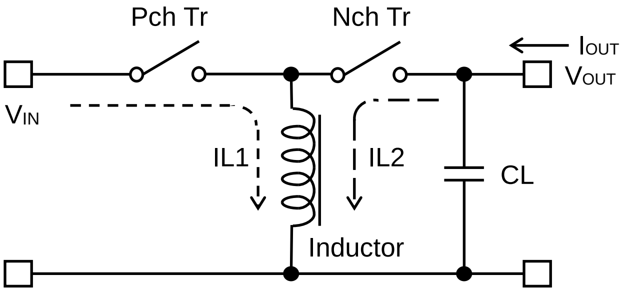
ILxmax = I_{OUT} x V_{OUT} / V_{IN} + V_{IN} x ton / (2 x L) ··Equation 6

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

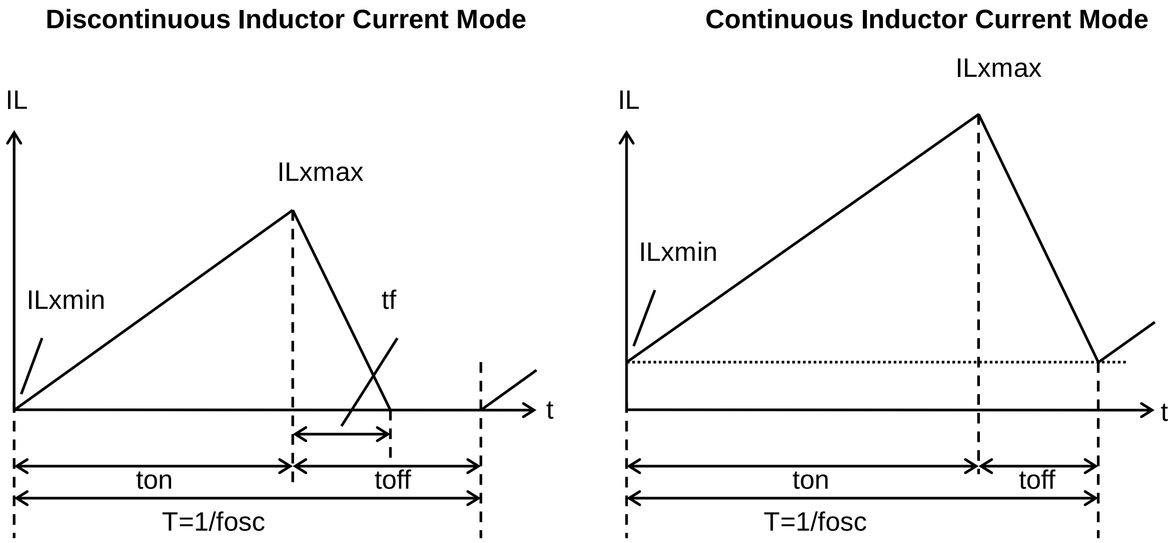
The L_X peak current limit circuit operates in both modes if the ILxmax becomes more than the L_X peak current limit. When considering the input and output conditions or selecting the external components, please pay attention to ILxmax.

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



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

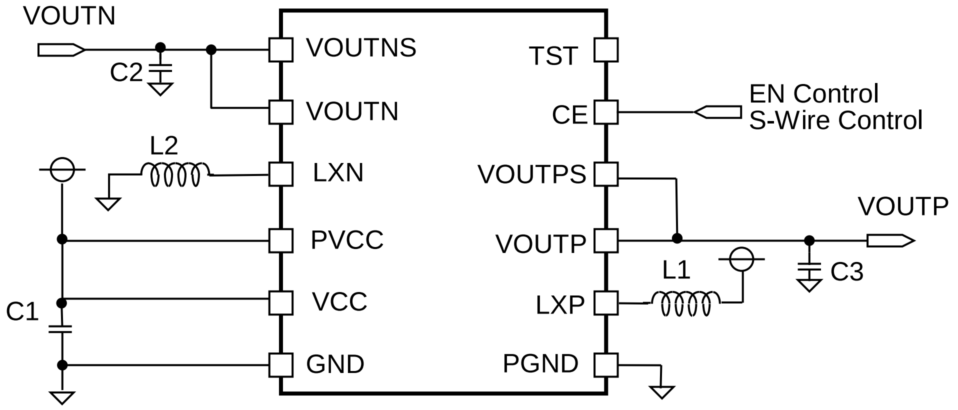
ILxmax = I_{OUT} x ($|V_{OUT}|$ + V_{IN}) / V_{IN} + V_{IN} x $|V_{OUT}|$ x T / { 2 x L x ($|V_{OUT}|$ + V_{IN}) } ·························· Equation 14

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.

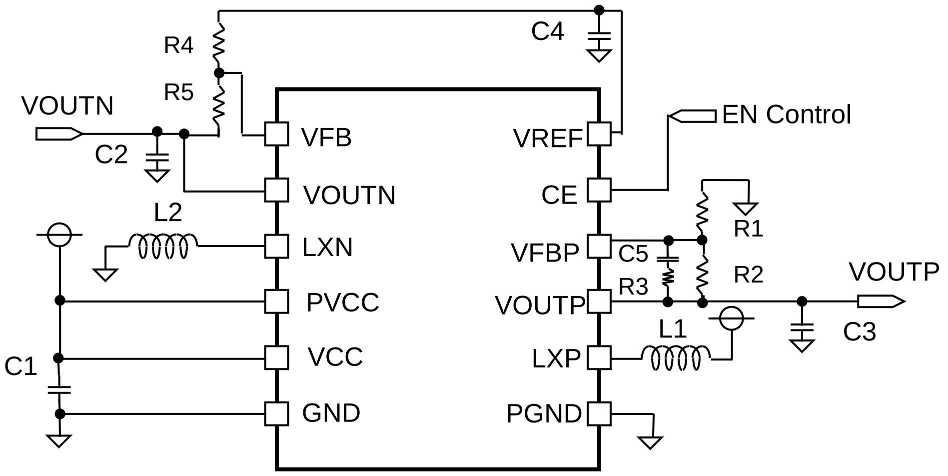
Notes: The above calculations are based on the ideal operation of the device. They do not include the losses caused by the external components or L_X switch. The actual maximum output current will be 70% to 90% of the above calculation results. Especially, if IL is large or V_{IN} is low, it may cause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

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(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]

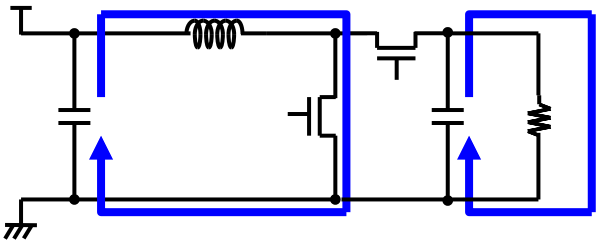
  If the noise of the system is large, the output noise affects the feedback and the operation may be unstable. In that case, another resistor R3 will be set. The appropriate value range is from 10Ω to 1kΩ.

TECHNICAL NOTES

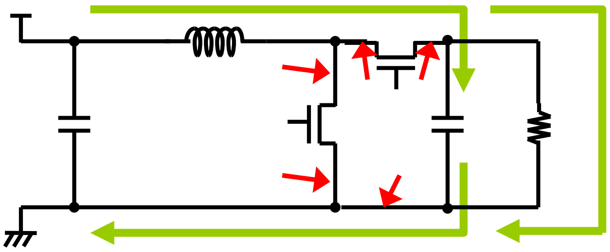
The performance of a power source circuit using this device is highly dependent on a peripheral circuit. A peripheral component or the device mounted on PCB should not exceed a rated voltage, a rated current or a rated power. When designing a peripheral circuit, please be fully aware of the following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

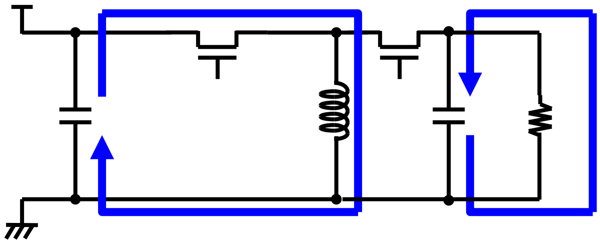


NMOSFET-ON

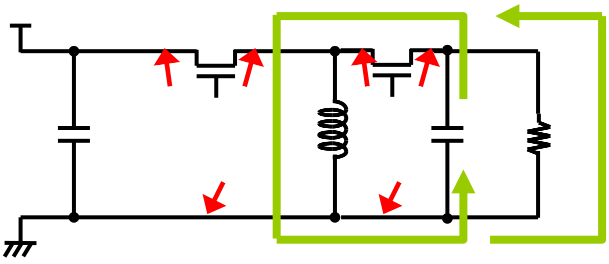


PMOSFET-ON

【Inverting DCDC】



PMOSFET-ON

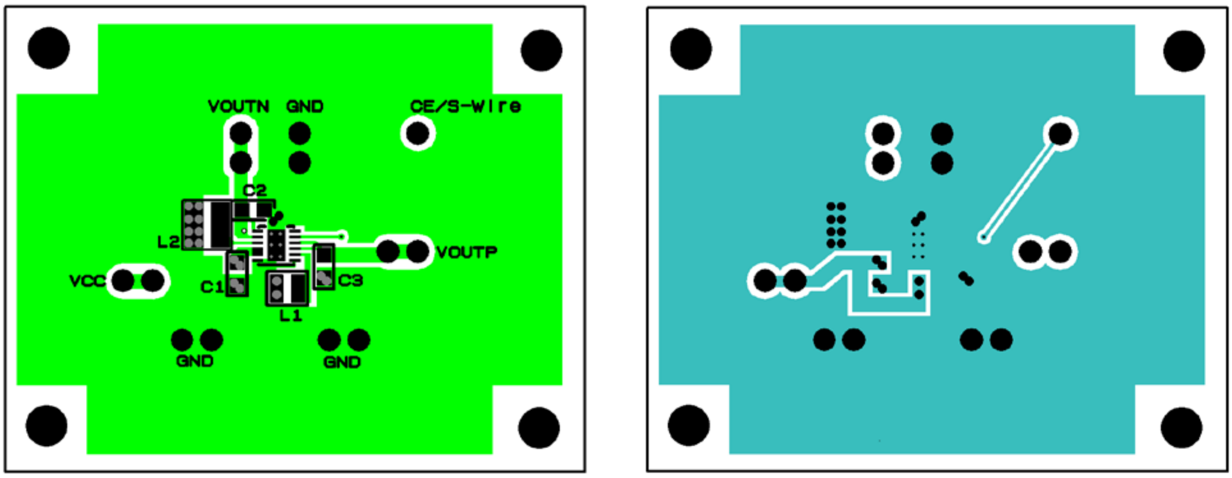


NMOSFET-ON

PCB Layout

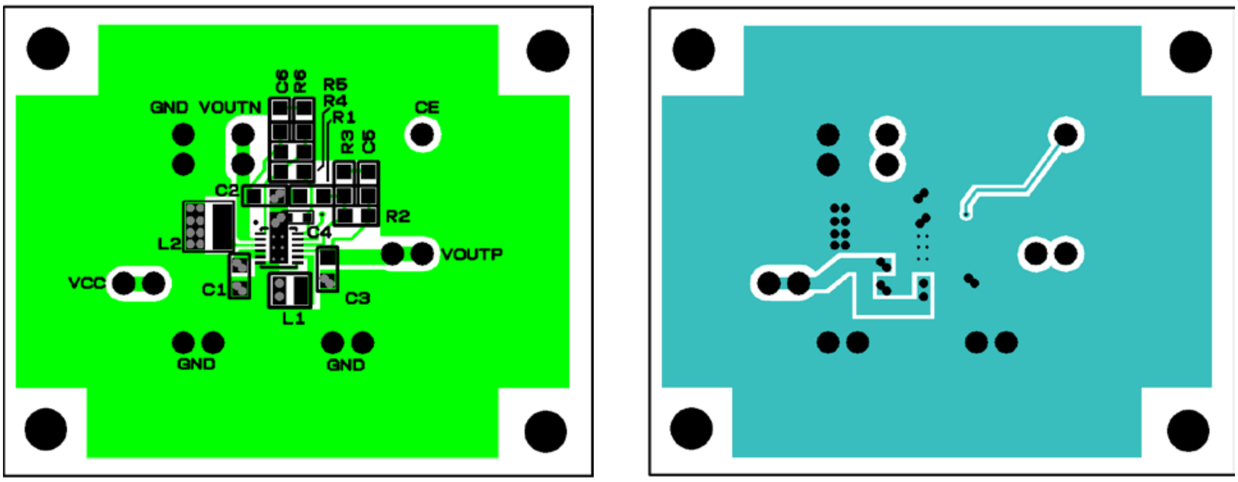
R1286K Board Layout [PKG: DNF (PLP) 2730-12]

Top Layer Back Layer



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

Top Layer Back Layer



R1286K001B (Adjustable Output Voltage Type) Board Layout

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

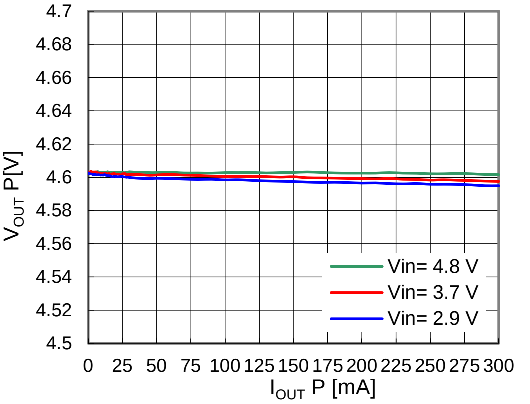
TYPICAL CHARACTERISTICS

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

1) Output Voltage vs. Output Current

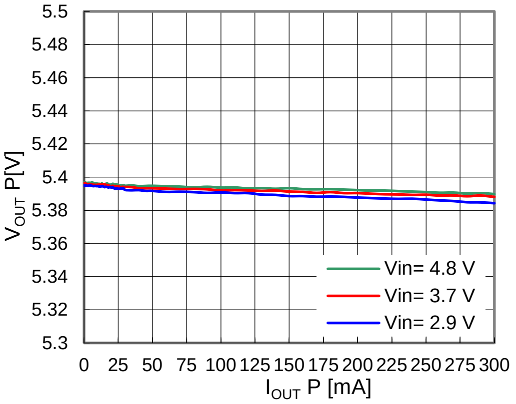
R1286KxxxX[1] (V_{OUTP} = 4.6 V)

(Ta = 25°C)



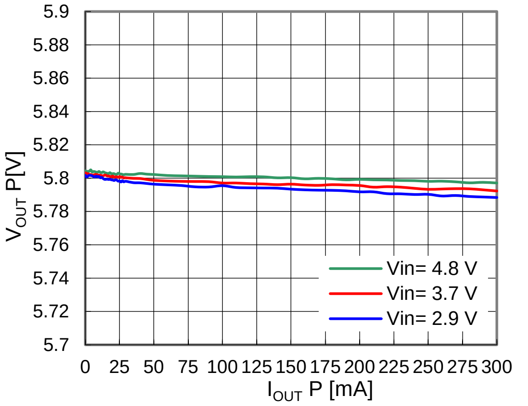
R1286KxxxX (V_{OUTP} = 5.4 V)

(Ta = 25°C)



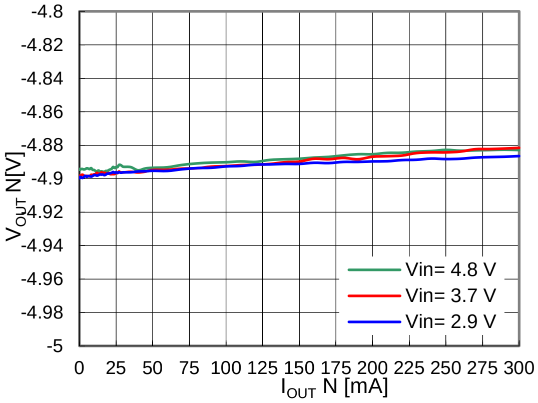
R1286KxxxX (V_{OUTP} = 5.8 V)

(Ta = 25°C)



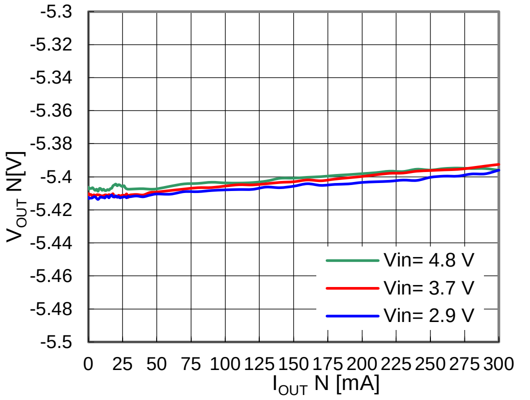
R1286KxxxX (V_{OUTN} = -4.9 V)

(Ta = 25°C)



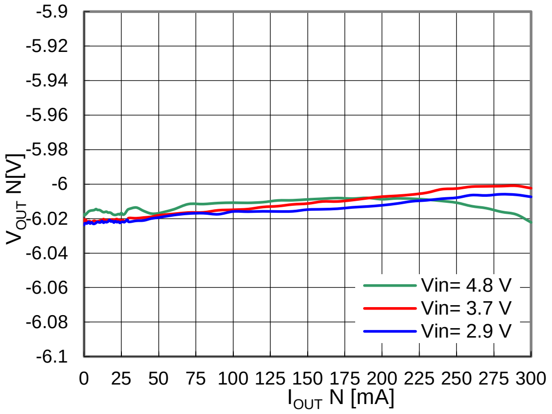
R1286KxxxX (V_{OUTN} = -5.4 V)

(Ta = 25°C)



R1286KxxxX (V_{OUTN} = -6.0 V)

(Ta = 25°C)



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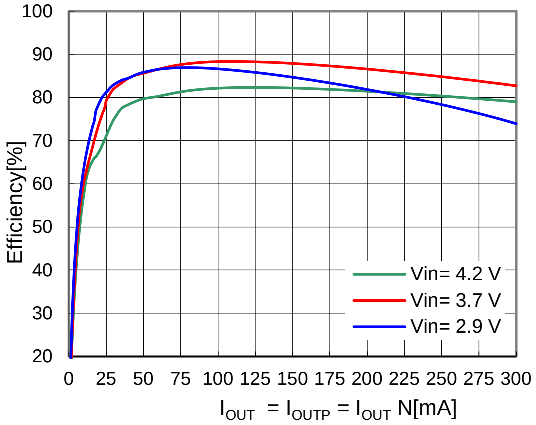
(1)X : A to N (Provided, except “B” and “I”)

2) Efficiency vs. Output Current

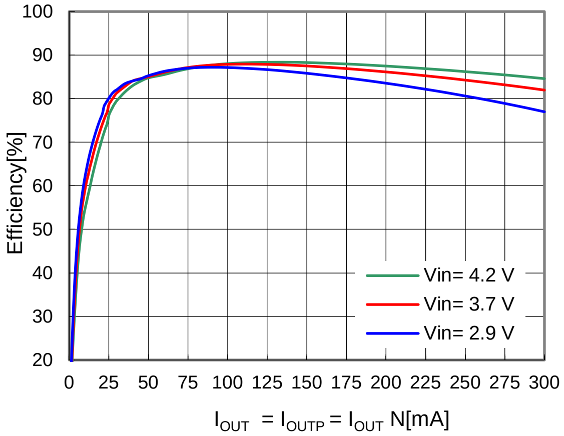
R1286KxxxX (V_{OUTP} = 4.6 V, V_{OUTN} = -4.9 V)

(Ta = 25°C)



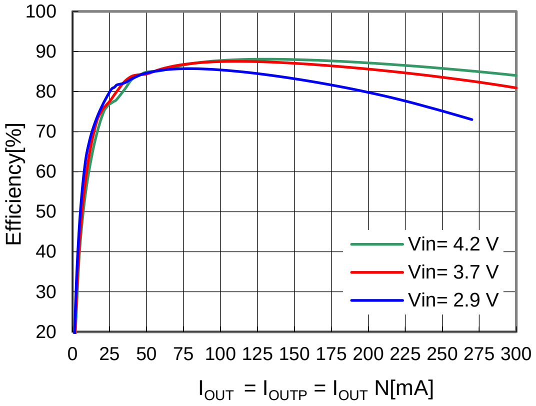
R1286KxxxX (V_{OUTP} = 5.4 V, V_{OUTN} = -5.4 V)

(Ta = 25°C)



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

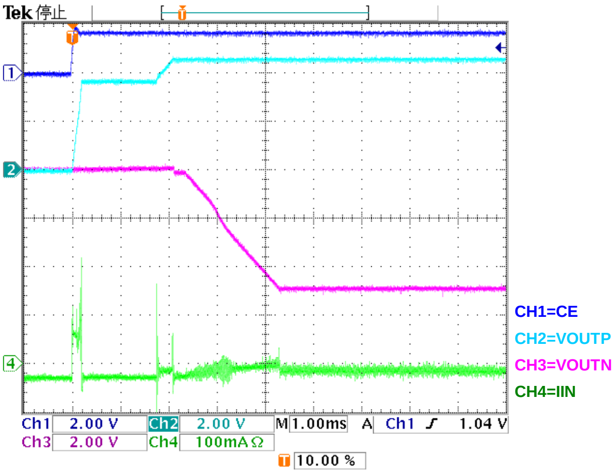
(Ta = 25°C)

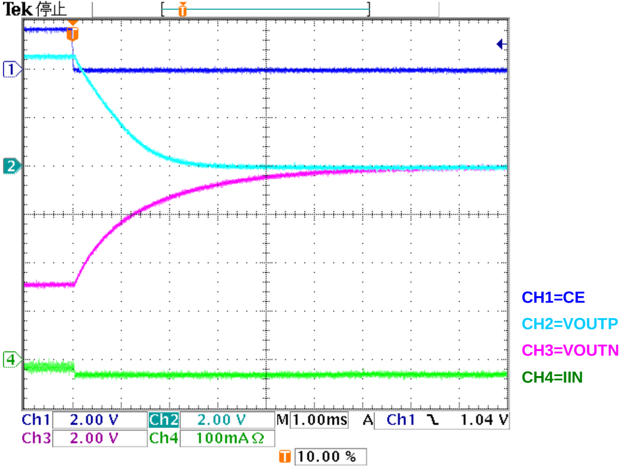


3) Turn-on/Turn-off Waveform by CE

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

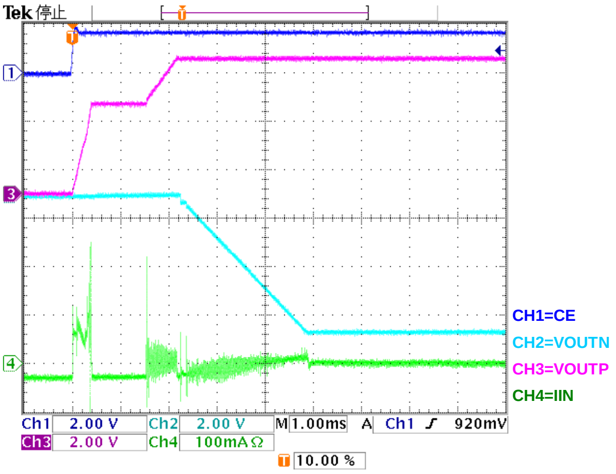
(Ta = 25°C)

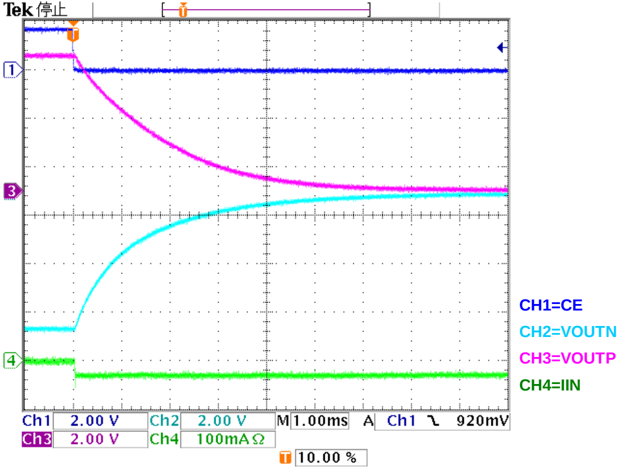




R1286Kx05A (V_{IN}=3.7 V, I_{OUTP} = I_{OUTN} = 0 mA, C_{OUTP} = C_{OUTN} = 4.7µF)

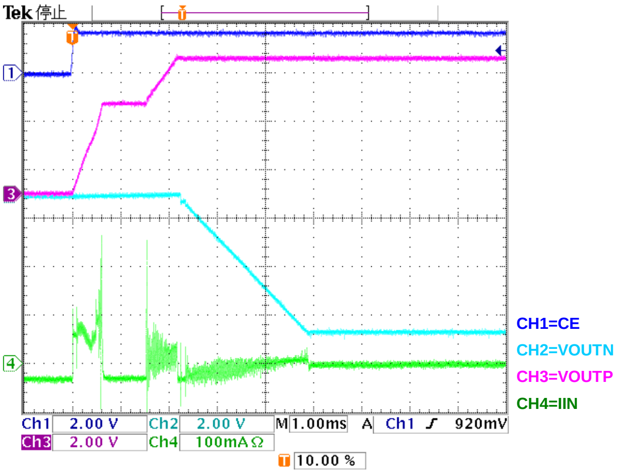
(Ta = 25°C)

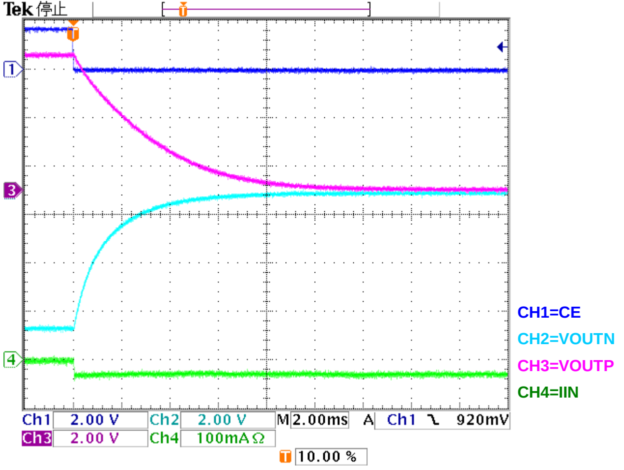




R1286Kx05A (V_{IN}=3.7 V, I_{OUTP} = I_{OUTN} = 0 mA, C_{OUTP} = 10 µF x 2, C_{OUTN} = 4.7µF)

(Ta = 25°C)



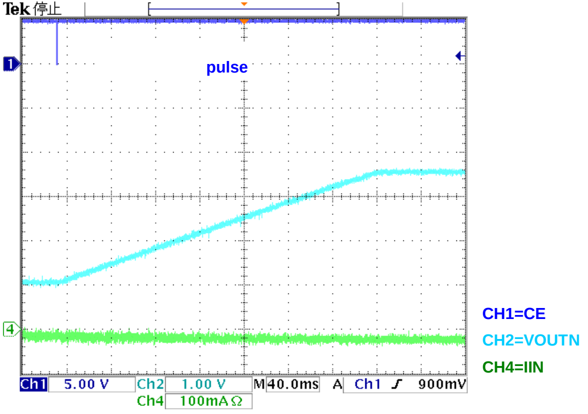


4) VOUTN Waveform with S-Wire Control

R1286Kx02A

(-4.9 V ≤ V_{OUTN} ≤ -2.4 V, I_{OUTP} = I_{OUTN} = 0 mA)

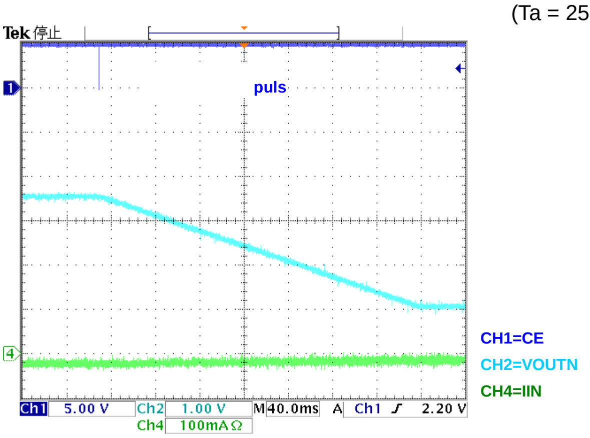
(Ta = 25°C)



R1286Kx02A

(-2.4 V ≤ V_{OUTN} ≤ -4.9 V, I_{OUTP} = I_{OUTN} = 0 mA)

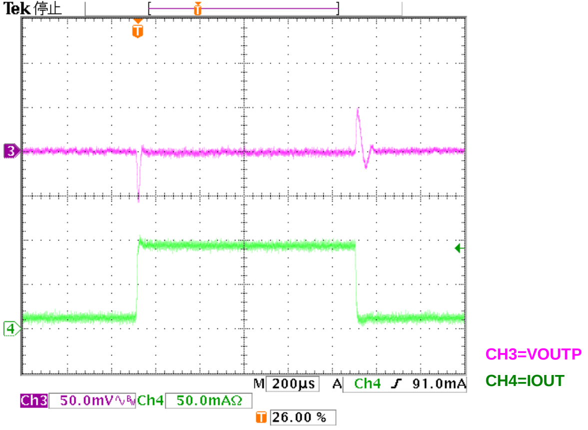
(Ta = 25°C)



5) Load Transient Response

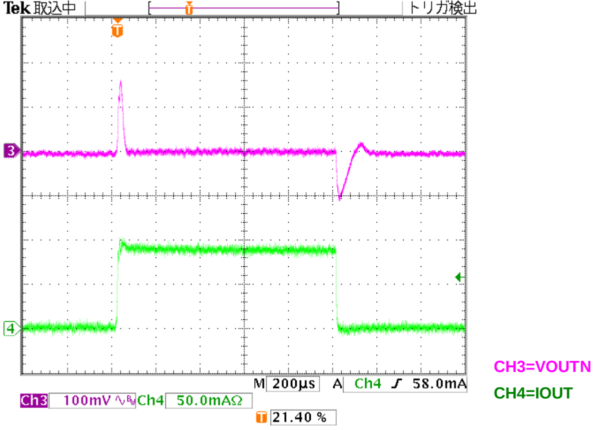
R1286KxxxX (V_{OUTP} = 4.6 V)

(Ta = 25°C)



R1286KxxxX (V_{OUTN} = -4.9 V)

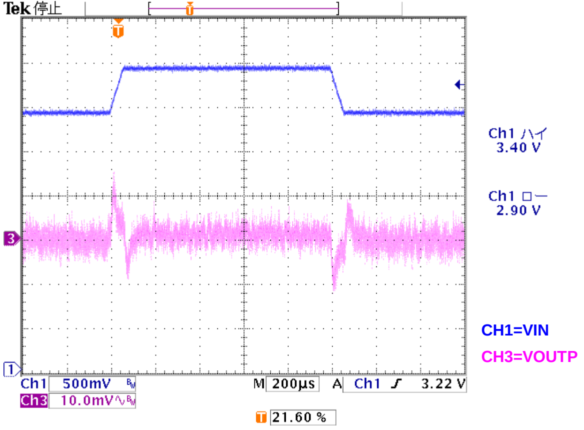
(Ta = 25°C)



6) Line Transient Response

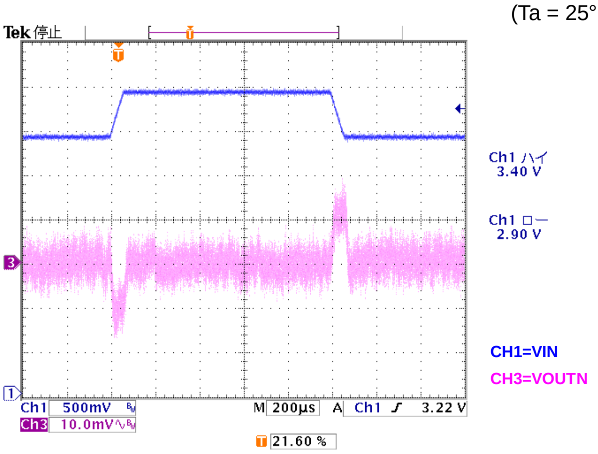
R1286KxxxX (V_{OUTP} = 4.6 V, I_{OUTP} = 100 mA)

(Ta = 25°C)



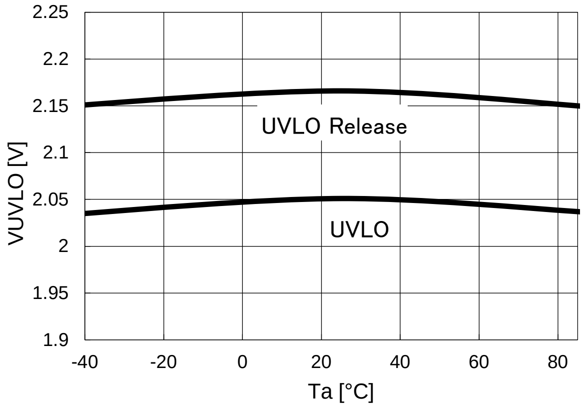
R1286KxxxX (V_{OUTN} = -4.9 V, I_{OUTN} = 100 mA)

(Ta = 25°C)



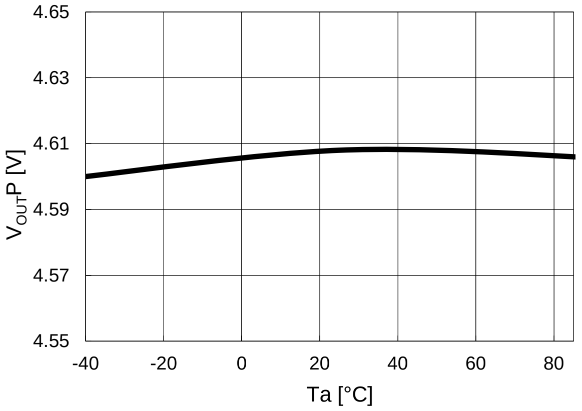
7) UVLO Voltage vs. Temperature

R1286KxxxX



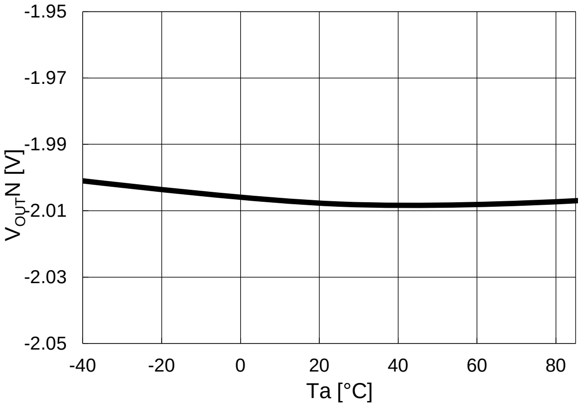
8) VOUTP Voltage vs. Temperature

R1286Kx02X

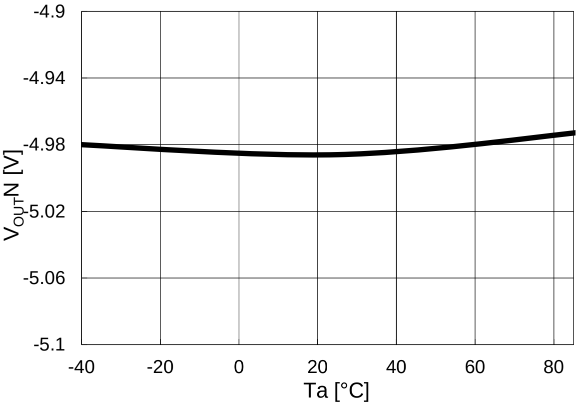


9) VOUTN Voltage vs. Temperature

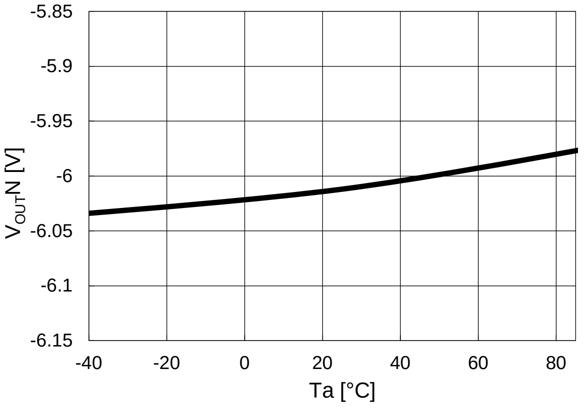
R1286KxxxC



R1286KxxxX

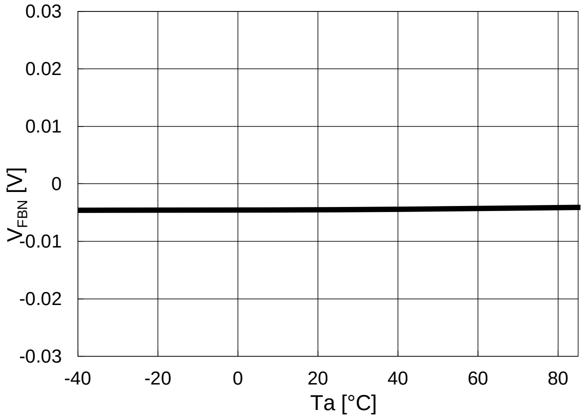


R1286KxxxG



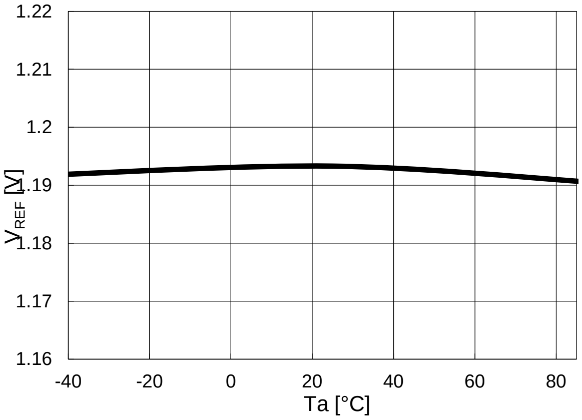
10) VFBN Voltage vs. Temperature

R1286K001B



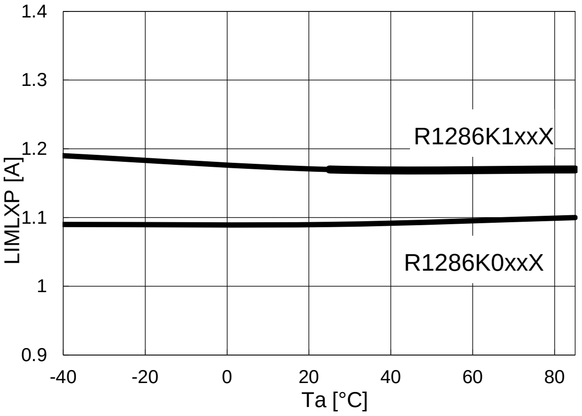
11) VREF Voltage vs. Temperature

R1286K001B



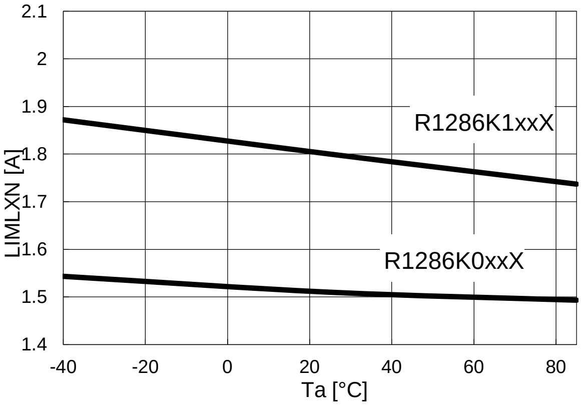
12) LXP Current Limit vs. Temperature

R1286KxxxX



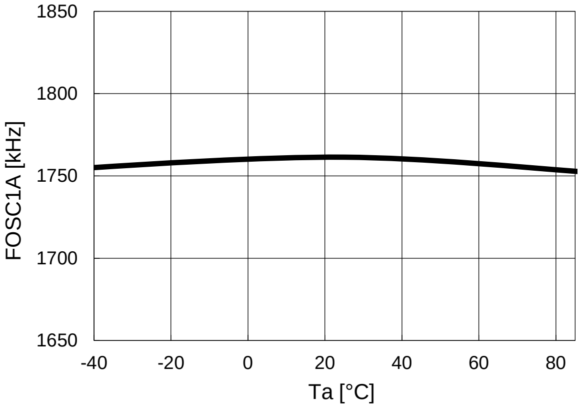
13) LXN Limit Current vs. Temperature

R1286KxxxX



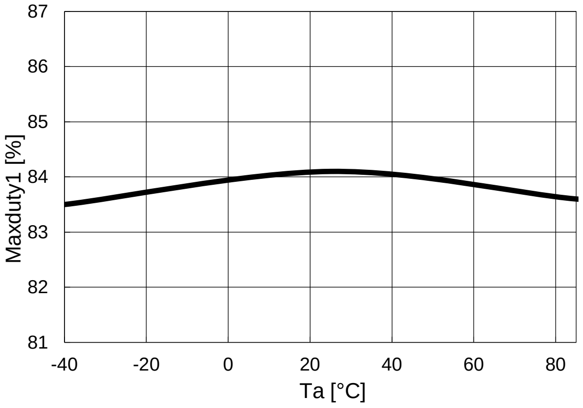
14) Oscillator Frequency vs. Temperature

R1286KxxxX



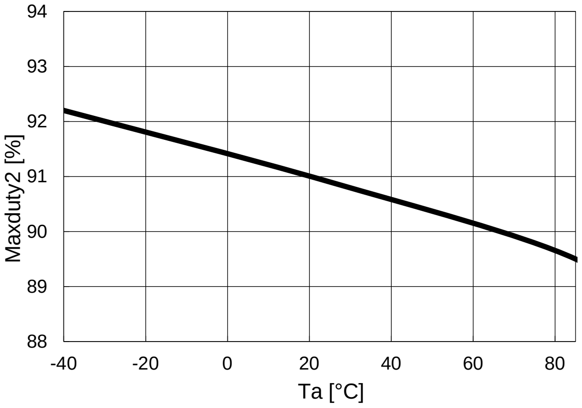
15) Maxduty1 vs. Temperature

R1286KxxxX



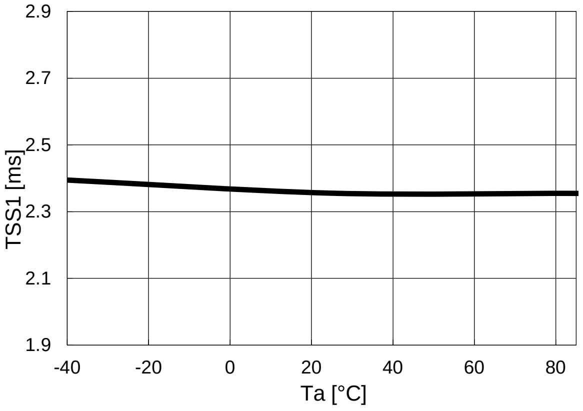
16) Maxduty2 vs. Temperature

R1286KxxxX



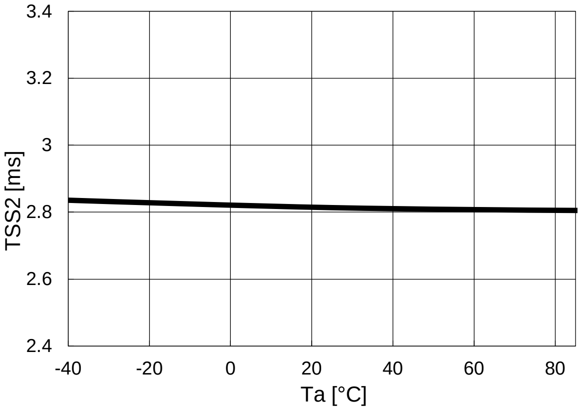
17) CH1 Soft-start Time vs. Temperature

R1286KxxxX



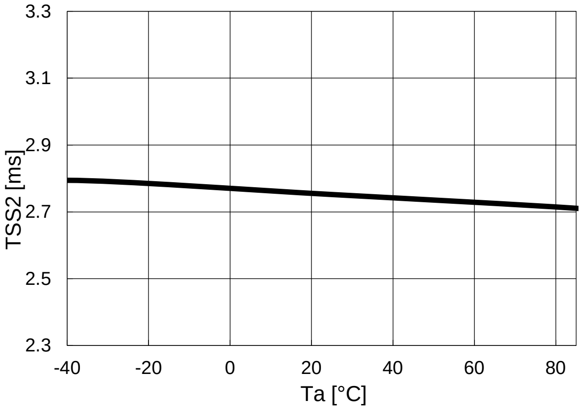
18) CH2 Soft-start Time vs. Temperature

R1286KxxxG



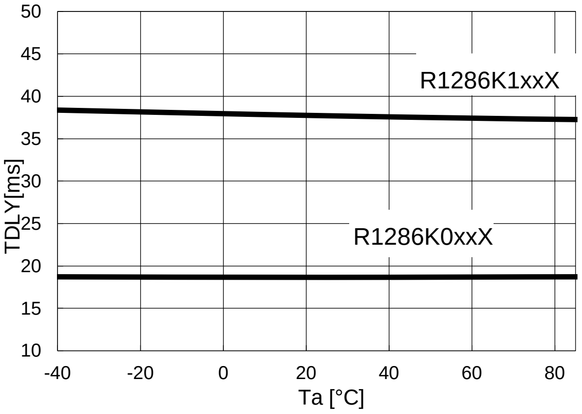
19) CH2 Soft-start Time vs. Temperature

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

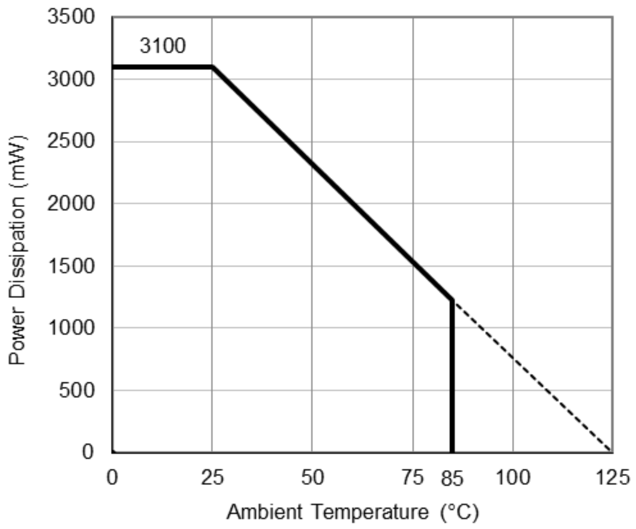
Item	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 0.8 mm
Copper Ratio	Outer Layer (First Layer): Less than 95% of 50 mm Square Inner Layers (Second and Third Layers): Approx.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

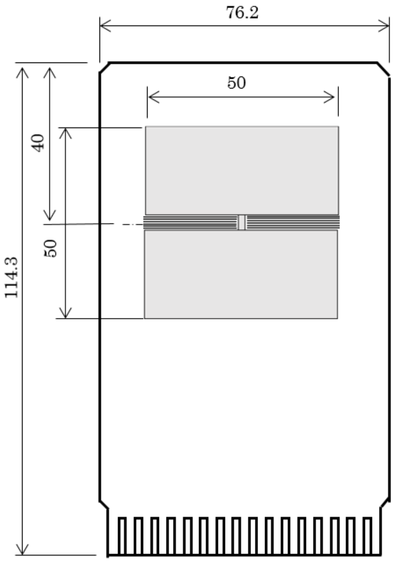
Item	Measurement Result
Power Dissipation	3100 mW
Thermal Resistance (θja)	θja = 32°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 8°C/W

θja: Junction-to-Ambient Thermal Resistance

ψjt: Junction-to-Top Thermal Characterization Parameter



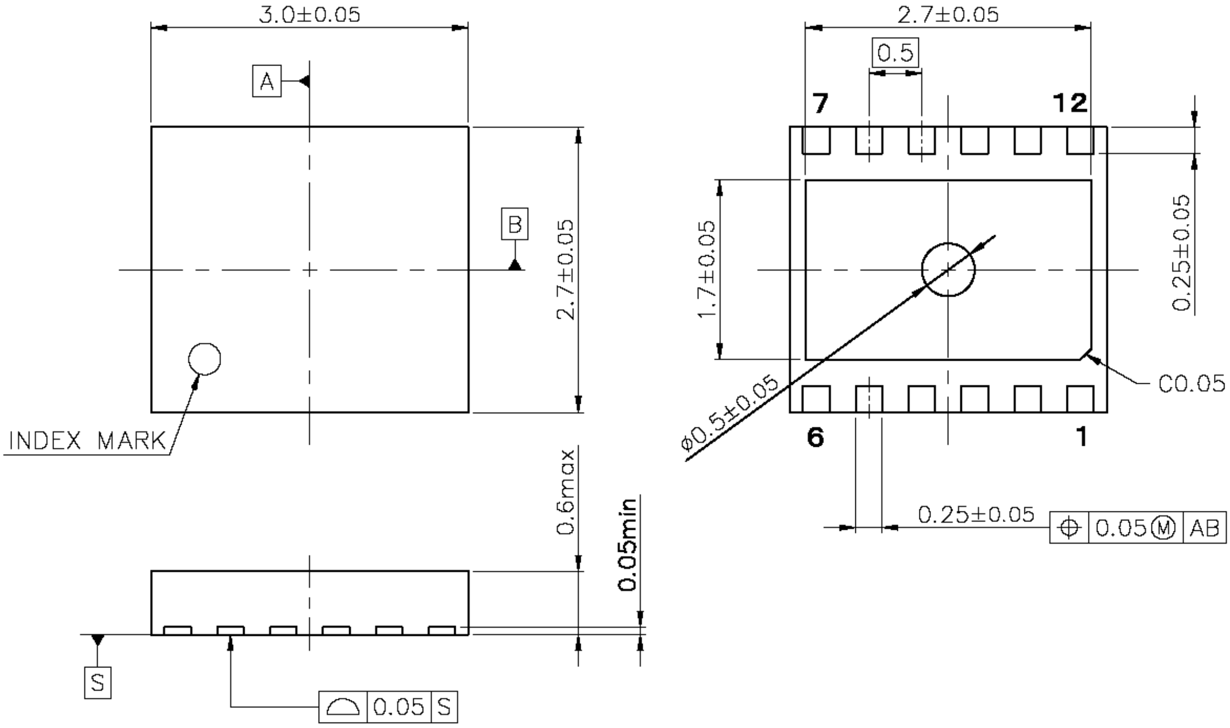
Power Dissipation vs. Ambient Temperature



Measurement Board Pattern

PACKAGE DIMENSIONS DFN(PLP)2730-12

DM-DFN(PNP)2730-12-JE-B



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

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