

PWM/VFM Step-Down DC/DC CONVERTER with Synchronous Rectifier

NO.EA-137-070221

OUTLINE

The R1234D Series are CMOS-based PWM step-down DC/DC Converters with synchronous rectifier, low supply current.

Each of these ICs consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a soft-start circuit, protection circuits, a protection against miss operation under low voltage (UVLO), PWM/VFM alternative circuit, a chip enable circuit, and a driver transistor. A low ripple, high efficiency step-down DC/DC converter can be easily composed of this IC with only a few kinds of external components, or an inductor and capacitors. (As for R1234D001C/D types, divider resistors are also necessary.) In terms of Output Voltage, it is fixed internally in the R1234Dxx1A/B types. While in the R1234D001C/D types, Output Voltage is adjustable with external divider resistors.

PWM/VFM alternative circuit is active with Mode Pin of the R1234D Series. Thus, when the load current is small, the operation can be switching into the VFM operation from PWM operation by the logic of MODE pin and the efficiency at small load current can be improved. As protection circuits, Current Limit circuit which limits peak current of Lx at each clock cycle, and Latch type protection circuit which works if the term of Over-current condition keeps on a certain time in PWM mode exist. Latch-type protection circuit works to latch an internal driver with keeping it disable. To release the condition of protection, after disable this IC with a chip enable circuit, enable it again, or restart this IC with power-on or make the supply voltage at UVLO detector threshold level or lower than UVLO.

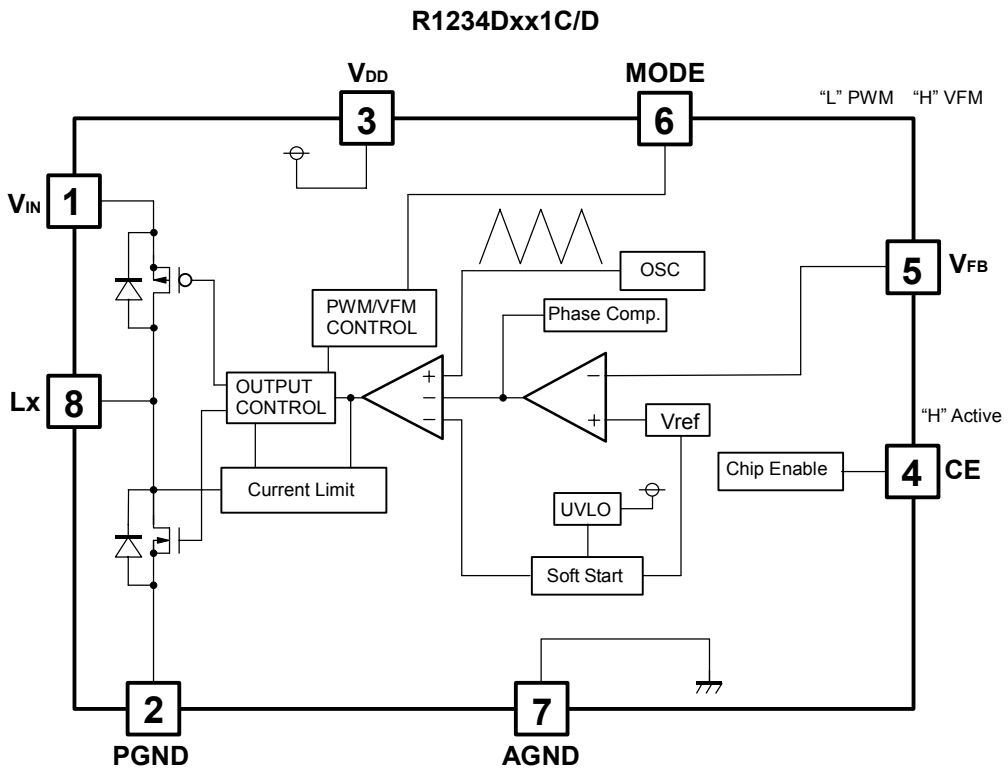
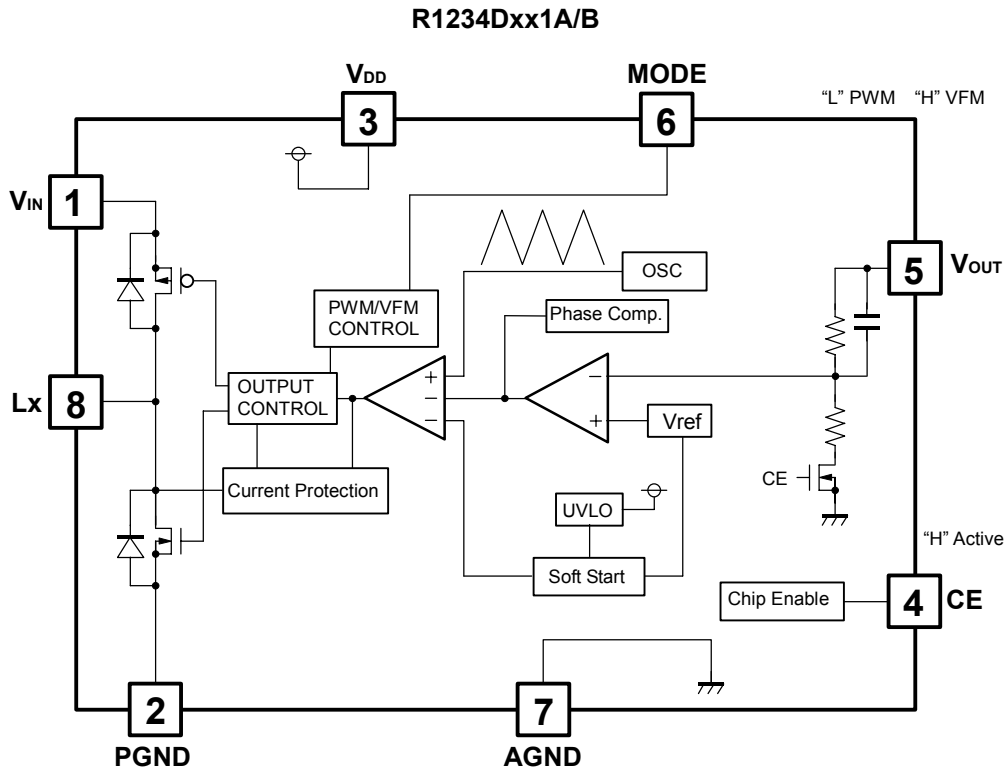
FEATURES

- Supply Current Typ. 230 μ A (R1234Dxx1A/C)
Typ. 250 μ A (R1234Dxx1B/D)
- Standby Current Typ. 0 μ A
- Input Voltage Range 2.4V to 5.5V (ABSOLUTE MAXIMUM : 6.5V)
- Output Voltage Range..... 2.2V to 3.3V (R1234Dxx1A/B)
0.8V to V_{IN} (R1234Dxx1C/D)
- Output Voltage Accuracy..... \pm 2.0% (R1234DxxA/B)
- Oscillator Frequency Typ. 500kHz (R1234Dxx1A/C)
Typ. 800kHz (R1234Dxx1B/D)
- Built-in Driver ON Resistance Pch 0.4 Ω ,Nch 0.6 Ω (V_{IN}=3V)
- Control mode switch MODE pin="L": PWN
MODE pin="H": VFM
- Efficiency Typ. 90%
- Package SON-8
- Built-in Soft-start Function..... Typ. 1.5ms
- Latch-type Protection Function Typ. 1.5ms
- Built-in Current Limit Circuit

APPLICATIONS

- Power source for portable equipment.

BLOCK DIAGRAM



SELECTION GUIDE

In the R1234D Series, the output voltage, the oscillator frequency, and the taping type for the ICs can be selected at the user's request.

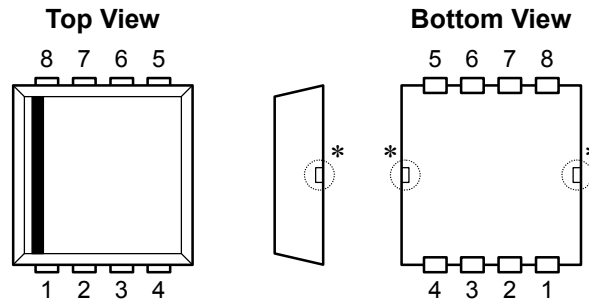
The selection can be made with designating the part number as shown below;

R1234Dxx1x-xx-X ← Part Number
 ↑ ↑ ↑ ↑ ↑ ↑
 a b c d e f

Code	Contents
a	Designation of Package Type; D: SON-8
b	Setting Output Voltage (V_{OUT}): Stepwise setting with a step of 0.1V in the range of 1.2V to 3.3V is possible for A/B version. "00" is for Output Voltage Adjustable C/D version (0.8V to)
c	1: fixed
d	Designation of Optional Function A: 500kHz, Fixed Output Voltage B: 800kHz, Fixed Output Voltage C: 500kHz, Adjustable Output Voltage D: 800kHz, Adjustable Output Voltage
e	Designation of Taping Type; (Refer to Taping Specification)"TR" is prescribed as a standard.
f	Designation of Composition of pin plating -F: Lead free plating


PIN CONFIGURATIO

• SON-8



PIN DESCRIPTION

Pin No	Symbol	Pin Description
1	V_{IN}	Voltage Supply Pin
2	PGND	Power Ground Pin
3	V_{DD}	Voltage Supply Pin
4	CE	Chip Enable Pin (active with "H")
5	V_{OUT}/V_{FB}	Output/Feedback Pin
6	MODE	Mode changer Pin ("L"=PWM, "H"=VFM)
7	AGND	Analogue Ground Pin
8	L_X	L_X Pin (CMOS)

* Tab in the  parts have GND level. (They are connected to the reverse side of this IC.)
Do not connect to other wires or land patterns.

ABSOLUTE MAXIMUM RATINGS

Symbol	Item	Rating	Unit
V_{IN}	V_{IN} Supply Voltage	6.5	V
V_{DD}	V_{DD} Pin Voltage	6.5	V
V_{LX}	L_X Pin Voltage	-0.3 to $V_{IN} + 0.3$	V
V_{CE}	CE Pin Input Voltage	-0.3 to $V_{IN} + 0.3$	V
V_{MODE}	MODE Pin Input Voltage	-0.3 to $V_{IN} + 0.3$	V
V_{FB}	V_{FB} Pin Input Voltage	-0.3 to $V_{IN} + 0.3$	V
I_{LX}	L_X Pin Output Current	-0.8	A
P_D	Power Dissipation (SON-8)	480	mW
T_{opt}	Operating Temperature Range	-40 to +85	°C
T_{stg}	Storage Temperature Range	-55 to +125	°C

*) For Power Dissipation, please refer to PACKAGE INFORMATION to be described.

ELECTRICAL CHARACTERISTICS

• R1234DxxxA

T_{opt}=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V _{IN}	Operating Input Voltage		2.4		5.5	V
V _{OUT}	Step-down Output Voltage	V _{IN} =V _{CE} =V _{SET} +1.5V, V _{MODE} =0V, I _{OUT} =10mA	Typ. ×0.98	V _{SET}	Typ. ×1.02	V
ΔV _{OUT} /ΔT _{opt}	Step-down Output Voltage Temperature Coefficient	-40°C ≤ T _{opt} ≤ 85°C		±150		ppm/ °C
fosc	Oscillator Frequency	V _{IN} =V _{CE} =V _{SET} +1.5V	425	500	575	kHz
I _{DD}	Supply Current	V _{IN} =V _{CE} =V _{SET} +1.5V, V _{OUT} =V _{MODE} =0V		230	300	μA
I _{standby}	Standby Current	V _{IN} =5.5V, V _{CE} =V _{OUT} =0V		0	5	μA
R _{ONP}	ON Resistance of Pch Transistor	V _{IN} =5.0V	0.2	0.4	0.9	Ω
R _{ONN}	ON Resistance of Nch Transistor	V _{IN} =5.0V	0.2	0.6	0.9	Ω
I _{LXleak}	Lx Leakage Current	V _{IN} =5.5V, V _{CE} =0V, V _{LX} =0V or 5.5V	-5.0	0.0	5.0	μA
I _{VOUTleak}	V _{OUT} Leakage Current	V _{IN} =5.5V, V _{CE} =0V, V _{LX} =0V or 5.5V	-0.1	0.0	0.1	μA
I _{CE}	CE Input Current	V _{IN} =5.5V, V _{MODE} =0V, V _{CE} =5.5V or 0V	-0.1	0.0	0.1	μA
I _{MODE}	MODE Pin Input Current	V _{IN} =5.5V, V _{CE} =0V, V _{MODE} =5.5V or 0V	-0.1		0.1	μA
V _{CEH}	CE "H" Input Voltage	V _{IN} =5.5V, V _{OUT} =0V	1.5			V
V _{CEL}	CE "L" Input Voltage	V _{IN} =2.4V, V _{OUT} =0V			0.3	V
V _{MODEH}	MODE "H" Input Voltage	V _{IN} =V _{CE} =5.5V, V _{OUT} =0V	1.5			V
V _{MODEL}	MODE "L" Input Voltage	V _{IN} =V _{CE} =2.4V, V _{OUT} =0V			0.3	V
Maxduty	Oscillator Maximum Duty Cycle	V _{MODE} =0V	100			%
t _{start}	Delay Time by Soft-Start function	at no load, V _{IN} =V _{CE} =V _{SET} +1.5V	0.5	1.5	2.5	ms
V _{LXlim}	Lx Limit Voltage	V _{MODE} =V _{OUT} =0V, V _{IN} =V _{CE} =3.0V	V _{IN} -0.15	V _{IN} -0.35	V _{IN} -0.65	V
T _{prot}	Delay Time for protection circuit	V _{IN} =V _{CE} =V _{SET} +1.5V, V _{MODE} =0V	0.5	1.5	2.5	ms
V _{UVLO1}	UVLO Threshold Voltage	V _{IN} =V _{CE} =2.5V→1.5V, V _{OUT} =0V	1.8	2.1	2.2	V
V _{UVLO2}	UVLO Released Voltage	V _{IN} =V _{CE} =1.5V→2.5V, V _{OUT} =0V	1.9	2.2	2.3	V
V _{FMDuty}	VFM Duty Cycle	V _{IN} =V _{CE} =V _{MODE} =2.4V, V _{OUT} =0V	55	65	85	%

R1234D

• R1234DxxxB

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

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		2.4		5.5	V
V_{OUT}	Step-down Output Voltage	$V_{IN}=V_{CE}=V_{SET}+1.5\text{V}$, $V_{MODE}=0\text{V}$, $I_{OUT}=10\text{mA}$	Typ. $\times 0.98$	V_{SET}	Typ. $\times 1.02$	V
$\Delta V_{OUT}/\Delta T_{opt}$	Step-down Output Voltage Temperature Coefficient	$-40^{\circ}\text{C} \leq T_{opt} \leq 85^{\circ}\text{C}$		± 150		ppm/ $^{\circ}\text{C}$
fosc	Oscillator Frequency	$V_{IN}=V_{CE}=V_{SET}+1.5\text{V}$	680	800	920	kHz
I_{DD}	Supply Current	$V_{IN}=V_{CE}=V_{SET}+1.5\text{V}$, $V_{OUT}=V_{MODE}=0\text{V}$		250	450	μA
$I_{standby}$	Standby Current	$V_{IN}=5.5\text{V}$, $V_{CE}=V_{OUT}=0\text{V}$		0	5	μA
R_{ONP}	ON Resistance of Pch Transistor	$V_{IN}=5.0\text{V}$	0.2	0.4	0.9	Ω
R_{ONN}	ON Resistance of Nch Transistor	$V_{IN}=5.0\text{V}$	0.2	0.6	0.9	Ω
I_{Lxleak}	Lx Leakage Current	$V_{IN}=5.5\text{V}$, $V_{CE}=0\text{V}$, $V_{LX}=0\text{V}$ or 5.5V	-5.0	0.0	5.0	μA
$I_{VOUTleak}$	V_{OUT} Leakage Current	$V_{IN}=5.5\text{V}$, $V_{CE}=0\text{V}$, $V_{LX}=0\text{V}$ or 5.5V	-0.1	0.0	0.1	μA
I_{CE}	CE Input Current	$V_{IN}=5.5\text{V}$, $V_{MODE}=0\text{V}$, $V_{CE}=5.5\text{V}$ or 0V	-0.1	0.0	0.1	μA
I_{MODE}	MODE Pin Input Current	$V_{IN}=5.5\text{V}$, $V_{CE}=0\text{V}$, $V_{MODE}=5.5\text{V}$ or 0V	-0.1		0.1	μA
V_{CEH}	CE "H" Input Voltage	$V_{IN}=5.5\text{V}$, $V_{OUT}=0\text{V}$	1.5			V
V_{CEL}	CE "L" Input Voltage	$V_{IN}=2.4\text{V}$, $V_{OUT}=0\text{V}$			0.3	V
V_{MODEH}	MODE "H" Input Voltage	$V_{IN}=V_{CE}=5.5\text{V}$, $V_{OUT}=0\text{V}$	1.5			V
V_{MODEL}	MODE "L" Input Voltage	$V_{IN}=V_{CE}=2.4\text{V}$, $V_{OUT}=0\text{V}$			0.3	V
Maxduty	Oscillator Maximum Duty Cycle	$V_{MODE}=0\text{V}$	100			%
tstart	Delay Time by Soft-Start function	at no load, $V_{IN}=V_{CE}=V_{SET}+1.5\text{V}$	0.5	1.5	2.5	ms
V_{Lxlim}	Lx Limit Voltage	$V_{MODE}=V_{OUT}=0\text{V}$, $V_{IN}=V_{CE}=3.0\text{V}$	V_{IN} -0.15	V_{IN} -0.35	V_{IN} -0.65	V
Tprot	Delay Time for protection circuit	$V_{IN}=V_{CE}=V_{SET}+1.5\text{V}$, $V_{MODE}=0\text{V}$	0.5	1.5	2.5	ms
V_{UVLO1}	UVLO Threshold Voltage	$V_{IN}=V_{CE}=2.5\text{V} \rightarrow 1.5\text{V}$, $V_{OUT}=0\text{V}$	1.8	2.1	2.2	V
V_{UVLO2}	UVLO Released Voltage	$V_{IN}=V_{CE}=1.5\text{V} \rightarrow 2.5\text{V}$, $V_{OUT}=0\text{V}$	1.9	2.2	2.3	V
VFMduty	VFM Duty Cycle	$V_{IN}=V_{CE}=V_{MODE}=2.4\text{V}$, $V_{OUT}=0\text{V}$	55	65	85	%

• R1234DxxxC

T_{opt}=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V _{IN}	Operating Input Voltage		2.7		5.5	V
V _{FB}	Feedback Voltage	V _{IN} =V _{CE} =V _{SET} +1.5V, V _{MODE} =0V, I _{OUT} =10mA	0.776	0.800	0.824	V
ΔV _{FB} /ΔT _{opt}	Feedback Voltage Temperature Coefficient	-40°C ≤ T _{opt} ≤ 85°C		±300		ppm/ °C
fosc	Oscillator Frequency	V _{IN} =V _{CE} =V _{SET} +1.5V	425	500	575	kHz
I _{DD}	Supply Current	V _{IN} =V _{CE} =V _{SET} +1.5V, V _{FB} =V _{MODE} =0V		230	300	μA
I _{standby}	Standby Current	V _{IN} =5.5V, V _{CE} =V _{FB} =0V		0	5	μA
R _{ONP}	ON Resistance of Pch Transistor	V _{IN} =5.0V	0.2	0.4	0.9	Ω
R _{ONN}	ON Resistance of Nch Transistor	V _{IN} =5.0V	0.2	0.6	0.9	Ω
I _{LXleak}	L _x Leakage Current	V _{IN} =5.5V, V _{CE} =0V, V _{LX} =0V or 5.5V	-5.0	0.0	5.0	μA
I _{VFBleak}	V _{FB} Leakage Current	V _{IN} =5.5V, V _{CE} =0V, V _{FB} =0V or 5.5V	-0.1	0.0	0.1	μA
I _{CE}	CE Input Current	V _{IN} =5.5V, V _{MODE} =0V, V _{CE} =5.5V or 0V	-0.1	0.0	0.1	μA
I _{MODE}	MODE Pin Input Current	V _{IN} =5.5V, V _{CE} =0V, V _{MODE} =5.5V or 0V	-0.1		0.1	μA
V _{CEH}	CE "H" Input Voltage	V _{IN} =5.5V, V _{FB} =0V	1.5			V
V _{CEL}	CE "L" Input Voltage	V _{IN} =2.4V, V _{FB} =0V			0.3	V
V _{MODEH}	MODE "H" Input Voltage	V _{IN} =V _{CE} =5.5V, V _{FB} =0V	1.5			V
V _{MODEL}	MODE "L" Input Voltage	V _{IN} =V _{CE} =2.4V, V _{FB} =0V			0.3	V
Maxduty	Oscillator Maximum Duty Cycle	V _{MODE} =0V	100			%
t _{start}	L _x Limit Voltage	at no load, V _{IN} =V _{CE} =V _{SET} +1.5V	0.5	1.5	2.5	ms
V _{LXlim}	Delay Time by Soft-Start function	V _{MODE} =V _{FB} =0V, V _{IN} =V _{CE} =3.0V	V _{IN} -0.15	V _{IN} -0.35	V _{IN} -0.65	V
T _{prot}	Delay Time for protection circuit	V _{IN} =V _{CE} =3.6V, V _{MODE} =0V	0.5	1.5	2.5	ms
V _{UVLO1}	UVLO Threshold Voltage	V _{IN} =V _{CE} =2.5V→1.5V, V _{MODE} =0V	1.95	2.20	2.45	V
V _{UVLO2}	UVLO Released Voltage	V _{IN} =V _{CE} =1.5V→2.7V, V _{FB} =0V	2.20	2.40	2.65	V
V _{FMDuty}	VFM Duty Cycle	V _{IN} =V _{CE} =V _{MODE} =2.4V, V _{FB} =0V	55	65	85	%

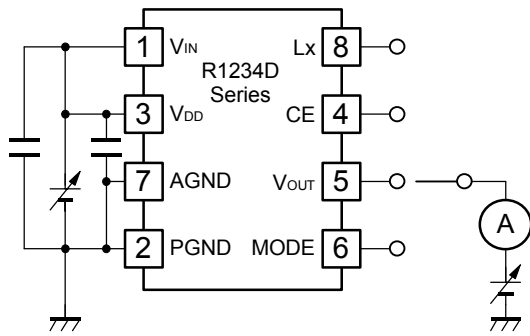
R1234D

• R1234DxxxD

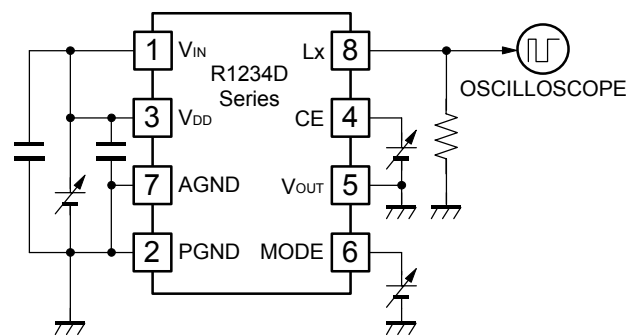
T_{opt}=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V _{IN}	Operating Input Voltage		2.7		5.5	V
V _{FB}	Feedback Voltage	V _{IN} =V _{CE} =V _{SET} +1.5V, V _{MODE} =0V, I _{OUT} =10mA	0.776	0.800	0.824	V
ΔV _{FB} /ΔT _{opt}	Feedback Voltage Temperature Coefficient	-40°C ≤ T _{opt} ≤ 85°C		±300		ppm/ °C
fosc	Oscillator Frequency	V _{IN} =V _{CE} =V _{SET} +1.5V	680	800	920	kHz
I _{DD}	Supply Current	V _{IN} =V _{CE} =V _{SET} +1.5V, V _{FB} =V _{MODE} =0V		250	400	μA
I _{standby}	Standby Current	V _{IN} =5.5V, V _{CE} =V _{FB} =0V		0	5	μA
R _{ONP}	ON Resistance of Pch Transistor	V _{IN} =5.0V	0.2	0.4	0.9	Ω
R _{ONN}	ON Resistance of Nch Transistor	V _{IN} =5.0V	0.2	0.6	0.9	Ω
I _{LXleak}	L _x Leakage Current	V _{IN} =5.5V, V _{CE} =0V, V _{LX} =0V or 5.5V	-5.0	0.0	5.0	μA
I _{VFBleak}	V _{FB} Leakage Current	V _{IN} =5.5V, V _{CE} =0V, V _{FB} =0V or 5.5V	-0.1	0.0	0.1	μA
I _{CE}	CE Input Current	V _{IN} =5.5V, V _{MODE} =0V, V _{CE} =5.5V or 0V	-0.1	0.0	0.1	μA
I _{MODE}	MODE Pin Input Current	V _{IN} =5.5V, V _{CE} =0V, V _{MODE} =5.5V or 0V	-0.1		0.1	μA
V _{CEH}	CE "H" Input Voltage	V _{IN} =5.5V, V _{FB} =0V	1.5			V
V _{CEL}	CE "L" Input Voltage	V _{IN} =2.4V, V _{FB} =0V			0.3	V
V _{MODEH}	MODE "H" Input Voltage	V _{IN} =V _{CE} =5.5V, V _{FB} =0V	1.5			V
V _{MODEL}	MODE "L" Input Voltage	V _{IN} =V _{CE} =2.4V, V _{FB} =0V			0.3	V
Maxduty	Oscillator Maximum Duty Cycle	V _{MODE} =0V	100			%
t _{start}	L _x Limit Voltage	at no load, V _{IN} =V _{CE} =V _{SET} +1.5V	0.5	1.5	2.5	ms
V _{LXlim}	Delay Time by Soft-Start function	V _{MODE} =V _{FB} =0V, V _{IN} =V _{CE} =3.0V	V _{IN} -0.15	V _{IN} -0.35	V _{IN} -0.65	V
T _{prot}	Delay Time for protection circuit	V _{IN} =V _{CE} =3.6V, V _{MODE} =0V	0.5	1.5	2.5	ms
V _{UVLO1}	UVLO Threshold Voltage	V _{IN} =V _{CE} =2.5V→1.5V, V _{MODE} =0V	1.95	2.20	2.45	V
V _{UVLO2}	UVLO Released Voltage	V _{IN} =V _{CE} =1.5V→2.7V, V _{FB} =0V	2.20	2.40	2.65	V
V _{FMDuty}	VFM Duty Cycle	V _{IN} =V _{CE} =V _{MODE} =2.4V, V _{FB} =0V	55	65	85	%

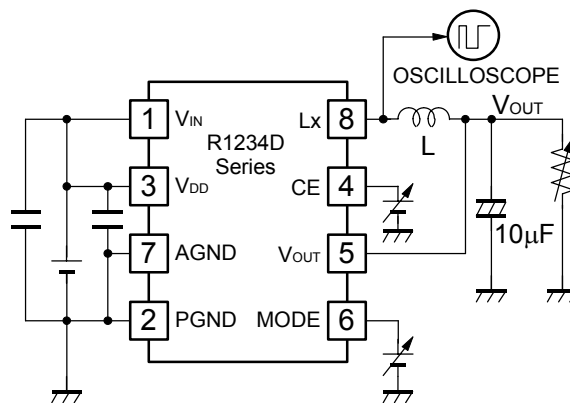
TEST CIRCUITS



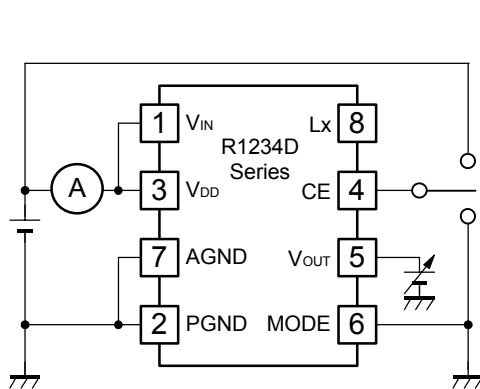
Test Circuit for Input Current and Leakage Current



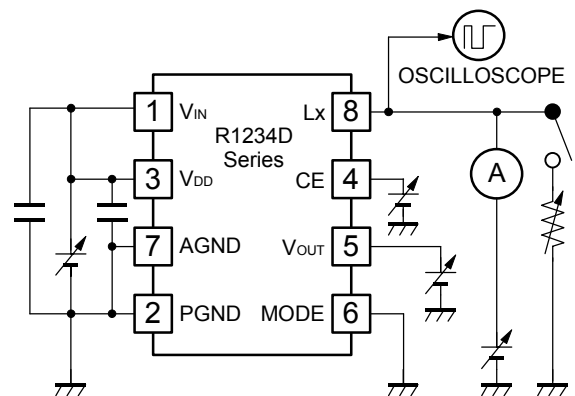
Test Circuit for Input Voltage and UVLO voltage



Test Circuit for Output Voltage, Oscillator Frequency, Soft-Starting Time



Test Circuit for Supply Current and Standby Current

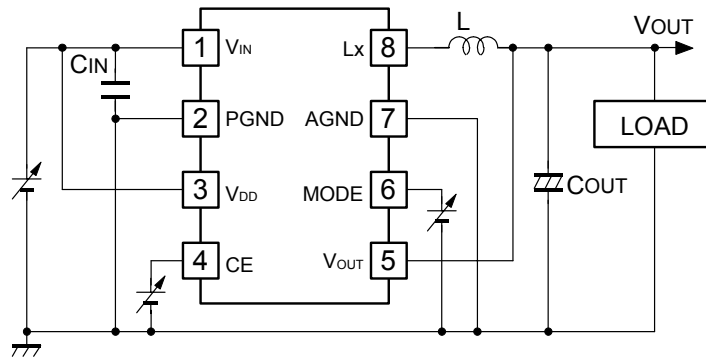


Test Circuit for ON resistance of L_x,
Limit Voltage, Delay Time of Protection Circuit

The bypass capacitor between power supply and GND is a ceramic capacitor 10µF.

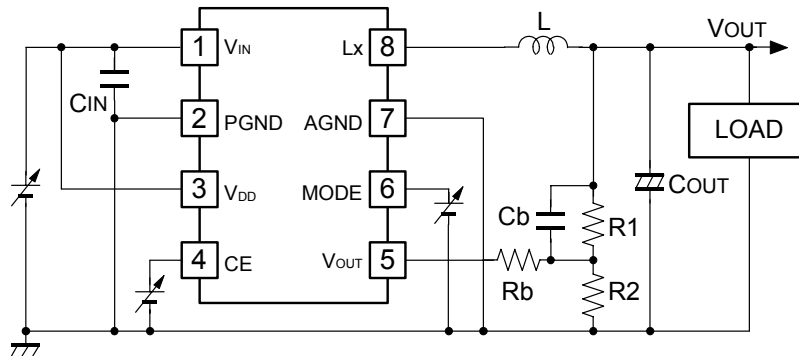
TYPICAL APPLICATION AND TECHNICAL NOTES

1) Fixed Output Voltage Type



C_{IN}	10 μ F C3216JB0J106M (TDK)
C_{OUT}	10 μ F ECSTOJX106R (Panasonic)
L	10 μ H LQH3C100K54 (Murata)

2) Adjustable Output Voltage Type



C_{IN}	10 μ F C3216JB0J106M (TDK)
C_{OUT}	10 μ F ECSTOJX106R (Panasonic)
L	10 μ H LQH3C100K54 (Murata)

VFM mode may work with a parasitic diode, but we recommend that VFM mode used with an external diode in between L_x and GND. As for PWM mode, an external diode is not necessary.

As for how to choose C_b , R_b , R_1 , and R_2 values, refer to the technical notes.

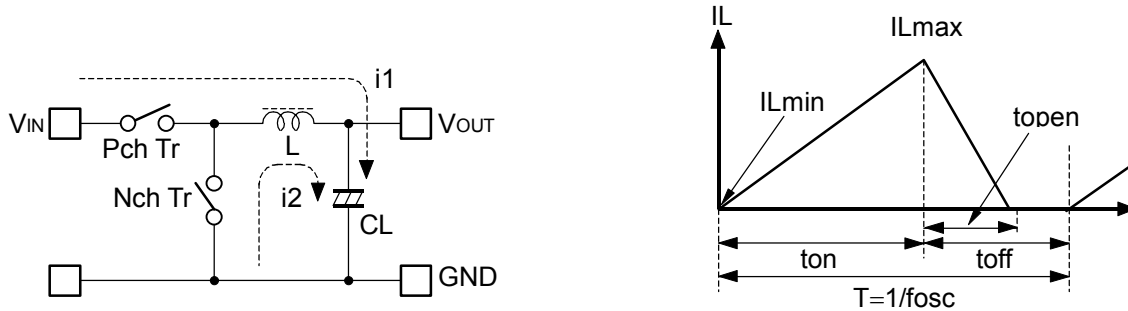
When you use these ICs, consider the following issues;

- Input same voltage into the power supply pins, V_{IN} and V_{DD} . Set the same level as AGND and PGND.
- When you control the CE pin and MODE pin by another power supply, do not make its "H" level more than the voltage level of V_{IN}/V_{DD} pin.
- Set external components such as an inductor, C_{IN} , C_{OUT} as close as possible to the IC, in particular, minimize the wiring to V_{IN} pin and PGND pin.
- At stand by mode, (CE="L"), the L_X output is Hi-Z, or both P-channel transistor and N-channel transistor of L_X pin turn off.
- Use an external capacitor C_{OUT} with a capacity of 10 μ F or more, and with good high frequency characteristics such as tantalum capacitors.
- At VFM mode, (MODE="H"), Latch protection circuit does not operate.
- If the mode is switched over into PWM mode from VFM mode during the operation, change the mode at light load current. If the load current is large, output voltage may decline.
- Reinforce the V_{IN} , PGND, and V_{OUT} lines sufficiently. Large switching current may flow in these lines. If the impedance of V_{IN} and PGND lines is too large, the internal voltage level in this IC may shift caused by the switching current, and the operation might be unstable.

The performance of power source circuits using these ICs extremely depends upon the peripheral circuits. Pay attention in the selection of the peripheral circuits. In particular, design the peripheral circuits in a way that the values such as voltage, current, and power of each component, PCB patterns and the IC do not exceed their respected rated values.

OPERATION of step-down DC/DC converter and Output Current

The step-down DC/DC converter charges energy in the inductor when L_x transistor is ON, and discharges the energy from the inductor when L_x transistor is OFF and controls with less energy loss, so that a lower output voltage than the input voltage is obtained. The operation will be explained with reference to the following diagrams:



- Step 1: P-channel Tr. turns on and current $I_L (=i1)$ flows, and energy is charged into CL. At this moment, I_L increases from $I_{Lmin} (=0)$ to reach I_{Lmax} in proportion to the on-time period (t_{on}) of P-channel Tr.
- Step 2: When P-channel Tr. turns off, Synchronous rectifier N-channel Tr. turns on in order that L maintains I_L at I_{Lmax} , and current $I_L (=i2)$ flows.
- Step 3: $I_L (=i2)$ decreases gradually and reaches $I_L=I_{Lmin}=0$ after a time period of t_{open} , and N-channel Tr. Turns off. Provided that in the continuous mode, next cycle starts before I_L becomes to 0 because t_{off} time is not enough. In this case, I_L value increases from this $I_{Lmin} (>0)$.

In the case of PWM control system, the output voltage is maintained by controlling the on-time period (t_{on}), with the oscillator frequency (f_{osc}) being maintained constant.

• Discontinuous Conduction Mode and Continuous Conduction Mode

The maximum value (I_{Lmax}) and the minimum value (I_{Lmin}) of the current flowing through the inductor are the same as those when P-channel Tr. turns on and off.

The difference between I_{Lmax} and I_{Lmin} , which is represented by ΔI ;

$$\Delta I = I_{Lmax} - I_{Lmin} = V_{OUT} \times t_{open} / L = (V_{IN} - V_{OUT}) \times t_{on} / L \dots \dots \dots \text{Equation 1}$$

Where, $t = 1/f_{osc} = t_{on} + t_{off}$
 duty (%) = $t_{on} / t \times 100 = t_{on} \times f_{osc} \times 100$
 $t_{open} \leq t_{off}$

In Equation 1, $V_{OUT} \times t_{open} / L$ and $(V_{IN} - V_{OUT}) \times t_{on} / L$ are respectively shown the change of the current at ON, and the change of the current at OFF.

When the output current (I_{OUT}) is relatively small, $t_{open} < t_{off}$ as illustrated in the above diagram. In this case, the energy is charged in the inductor during the time period of t_{on} and is discharged in its entirely during the time period of t_{off} , therefore I_{Lmin} becomes to zero ($I_{Lmin}=0$). When I_{OUT} is gradually increased, eventually, t_{open} becomes to t_{off} ($t_{open}=t_{off}$), and when I_{OUT} is further increased, I_{Lmin} becomes larger than zero ($I_{Lmin}>0$). The former mode is referred to as the discontinuous mode and the latter mode is referred to as continuous mode.

In the continuous mode, when Equation 1 is solved for t_{on} and assumed that the solution is t_{onc}

$$t_{onc} = t \times V_{OUT} / V_{IN} \dots \dots \dots \text{Equation 2}$$

When $t_{on} < t_{onc}$, the mode is the discontinuous mode, and when $t_{on} = t_{onc}$, the mode is the continuous mode.

OUTPUT CURRENT AND SELECTION OF EXTERNAL COMPONENTS

When P-channel Tr. of L_x is ON:

(Wherein, Ripple Current P-P value is described as I_{RP} , ON resistance of P-channel Tr. and N-channel Tr. of L_x are respectively described as R_{ONP} and R_{ONN} , and the DC resistor of the inductor is described as R_L .)

$$V_{IN} = V_{OUT} + (R_{ONP} + R_L) \times I_{OUT} + L \times I_{RP} / t_{on} \dots \dots \dots \text{Equation 3}$$

When P-channel Tr. of L_x is "OFF" (N-channel Tr. is "ON"):

$$L \times I_{RP} / t_{off} = V_F + V_{OUT} + R_{ONN} \times I_{OUT} \dots \dots \dots \text{Equation 4}$$

Put Equation 4 to Equation 3 and solve for ON duty of P-channel transistor, $D_{ON} = t_{on} / (t_{off} + t_{on})$,

$$D_{ON} = (V_{OUT} - R_{ONN} \times I_{OUT} + R_L \times I_{OUT}) / (V_{IN} + R_{ONN} \times I_{OUT} - R_{ONP} \times I_{OUT}) \dots \dots \dots \text{Equation 5}$$

Ripple Current is as follows;

$$I_{RP} = (V_{IN} - V_{OUT} - R_{ONP} \times I_{OUT} - R_L \times I_{OUT}) \times D_{ON} / f_{osc} / L \dots \dots \dots \text{Equation 6}$$

wherein, peak current that flows through L, and L_x Tr. is as follows;

$$I_{Lmax} = I_{OUT} + I_{RP} / 2 \dots \dots \dots \text{Equation 7}$$

Consider I_{Lmax} , condition of input and output and select external components.

★ The above explanation is directed to the calculation in an ideal case in continuous mode.

How to Adjust Output Voltage and about Phase Compensation

As for Adjustable Output type, feedback pin (V_{FB}) voltage is controlled to maintain 0.8V.

Output Voltage, V_{OUT} is as following equation;

$$V_{OUT} R1 + R2 = V_{FB} : R2$$
$$V_{OUT} = V_{FB} \times (R1 + R2) / R2$$

Thus, with changing the value of R1 and R2, output voltage can be set in the specified range.

In the DC/DC converter, with the load current and external components such as L and C, phase might be behind 180 degree. In this case, the phase margin of the system will be less and stability will be worse. To prevent this, phase margin should be secured with proceeding the phase. A pole is formed with external components L and C_{OUT} .

$$f_{pole} \sim 1/2\pi\sqrt{LC_{OUT}}$$

A zero (signal back to zero) is formed with R1 and C_b .

$$\cong f_{zero} \sim 1/(2\pi \times R1 \times C_b)$$

First, choose the appropriate value of R1, R2 and C_b .

Set $R1+R2$ value 100k Ω or less.

For example, if $L=10\mu H$, $C_{OUT}=10\mu F$, the cut off frequency of the pole is approximately 16kHz.

To make the cut off frequency of the zero higher than 16kHz, set $R1=42k\Omega$ and $C_b=100pF$.

If V_{OUT} is set at 1.5V, $R2=48k\Omega$ is appropriate.

If a ceramic capacitor is desirable as C_{OUT} in your application, nonetheless of the usage of both the fixed output voltage type and adjustable output type, add 0.2 Ω or more resistance to compensate the ESR. Further, if a ceramic capacitor is desirable to use as C_{OUT} without adding another resistor to compensate the ESR, phase should be back drastically. To make it, R2 value should be smaller compared to R1. As a result, the set output voltage may be large. For example, to make $V_{OUT}=1.5V$, constants are $R1=42k\Omega$, $R2=48k\Omega$, and $C_b=100pF$. If the ceramic capacitor is used, under the heavy load condition, oscillation may be result. On the other hand, if $R2 = 12k\Omega$ and $V_{OUT}=3.6V$, phase back becomes also large, and even if the device is used with a heavy load, the operation will be stable.

R_b is effective for reducing the noise on V_{FB} . However, it is not always necessary. If it is necessary, use a resistance as much as 30k Ω as R_b .

External Components

1. Inductor

Select an inductor that peak current does not exceed I_{Lmax} . If larger current than allowable current flows, magnetic saturation occurs and makes transform efficiency be worse.

Supposed that the load current is at the same, the smaller value of L is used, the larger the ripple current is.

Provided that the allowable current is large in that case and DC current is small, therefore, for large output current, efficiency is better than using an inductor with a large value of L and vice versa.

2. Capacitor

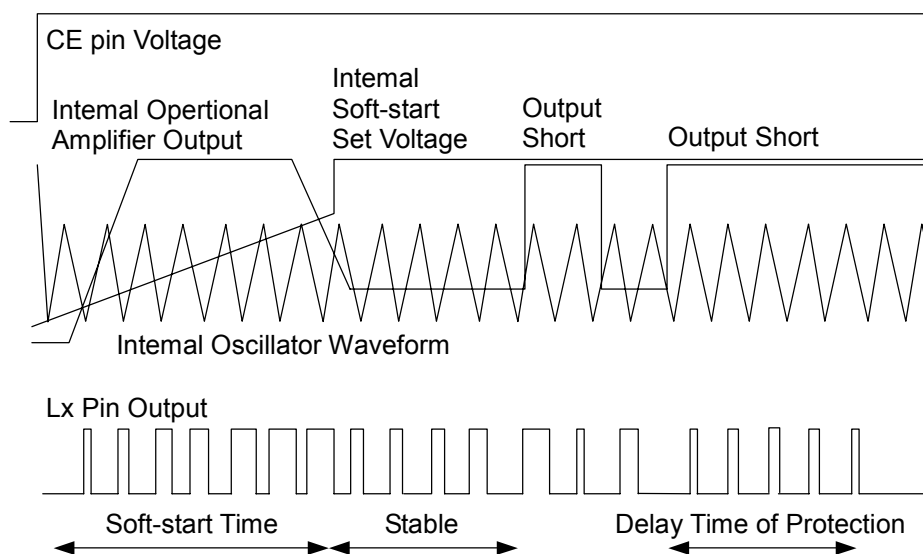
As for C_{IN} , use a capacitor with low ESR (Equivalent Series Resistance) Ceramic type of a capacity at least $10\mu F$ for stable operation.

C_{OUT} can reduce ripple of Output Voltage, therefore as much as $10\mu F$ ceramic type is recommended.

3. Diode

If VFM mode is chosen at light load, use a Schottky diode with small V_F . A diode with small V_F makes the efficiency of the circuit improved. Small reverse direction current, I_R is an important factor, however, V_F has more important priority than I_R .

TIMING CHART



The timing chart as shown above describes the waveforms starting from the IC is enabled with CE and latched with protection. During the soft-start time, until the level is rising up to the internal soft-start set voltage, the duty cycle of L_x is gradually wider and wider to prevent the over-shoot of the voltage. During the term, the output of amplifier is "H". After the output voltage reaches the set output voltage, they are balanced well. Herein, if the output pin would be short circuit, the output of amplifier would become "H" again, and the condition would continue for 2.0ms (Typ.), latch circuit would work and the output of L_x would be latched with "OFF". (Output ="High-Z")

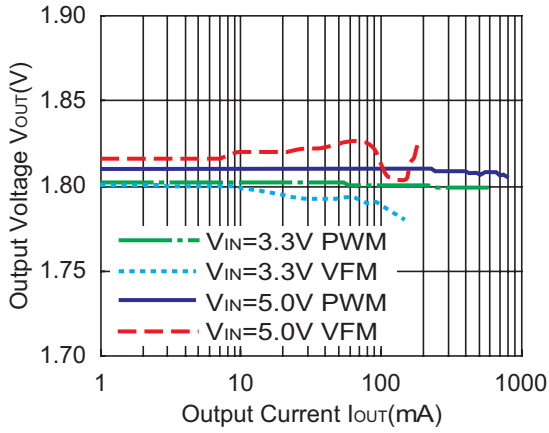
If the output short is released before the latch circuit works (within 2ms after output shorted), the output of amplifier is balanced in the stable state again.

Once the IC is latched, to release the protection, input "L" with CE pin, or make the supply voltage at UVLO level or less.

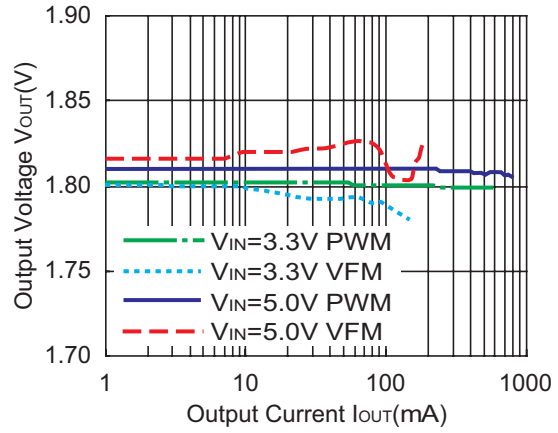
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current

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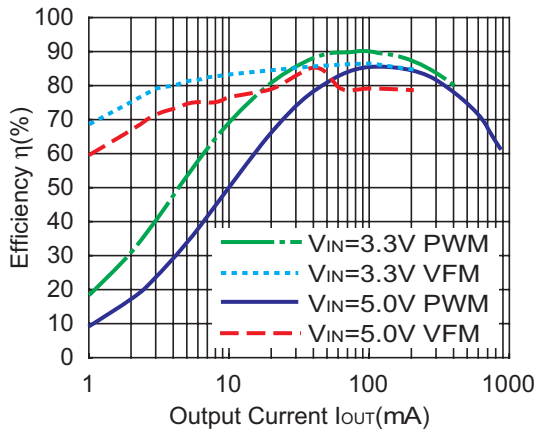


R1234D181B

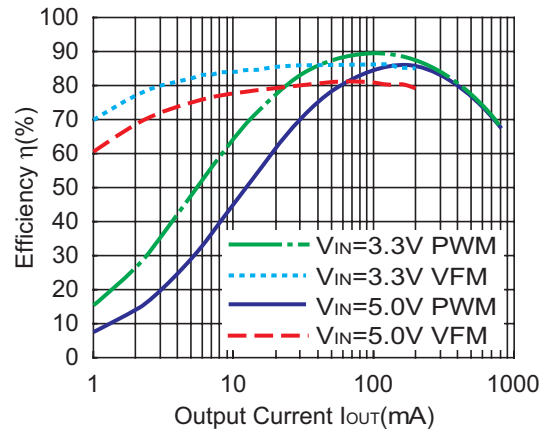


2) Efficiency vs. Output Current

R1234D181A



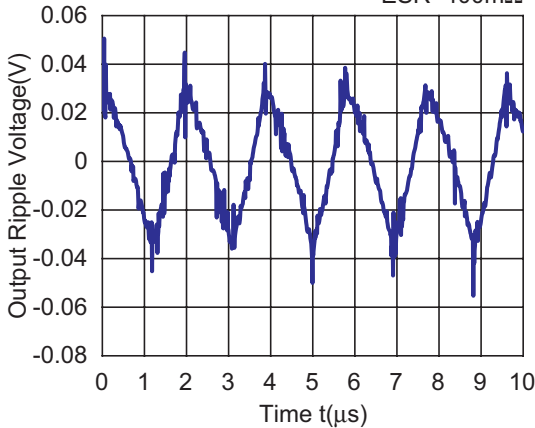
R1234D181B



3) Output Waveform (C_{OUT}=10μF, tantalum, PWM)

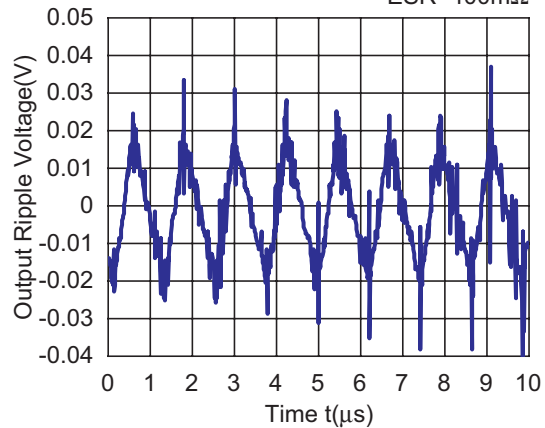
R1234D181A

V_{IN}=5V, I_{OUT}=200mA
ESR=400mΩ

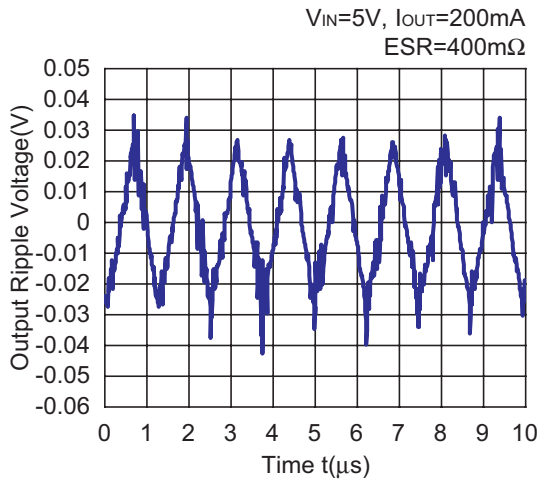


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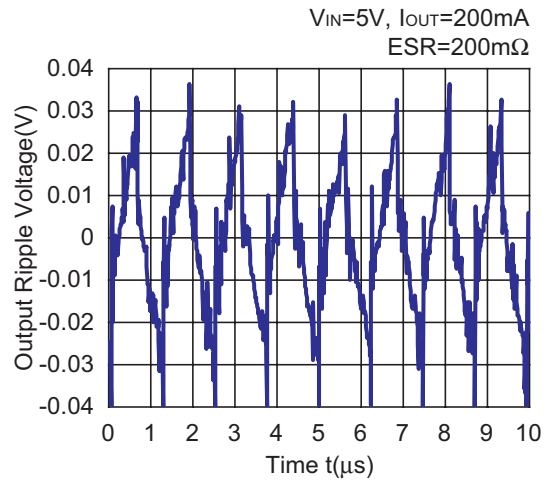
V_{IN}=5V, I_{OUT}=10mA
ESR=400mΩ



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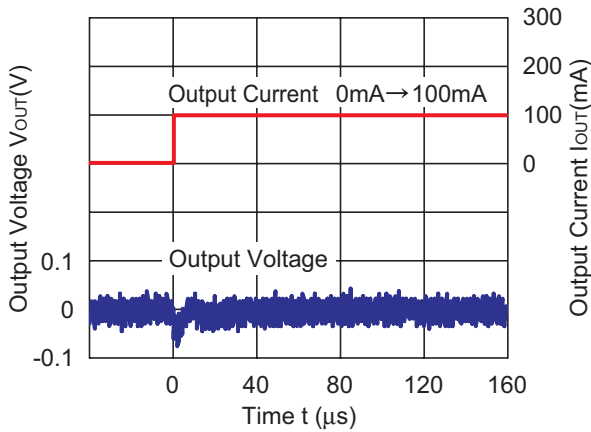


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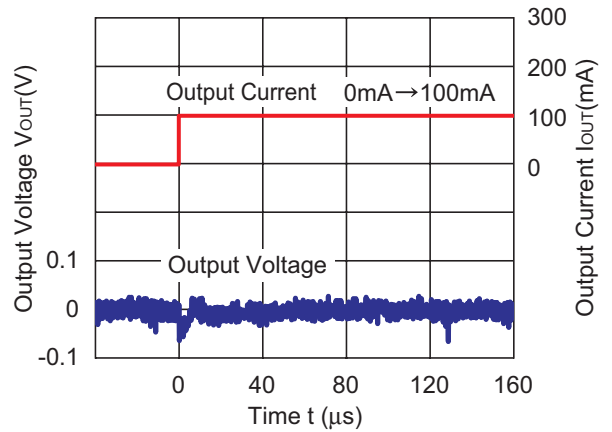


4) Load Transient Response ($V_{IN}=5.0V$, PWM)

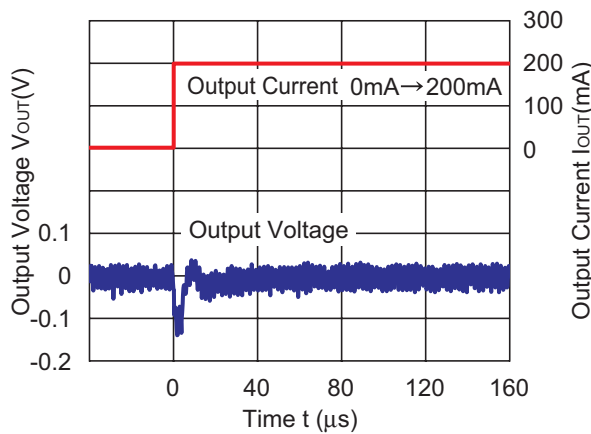
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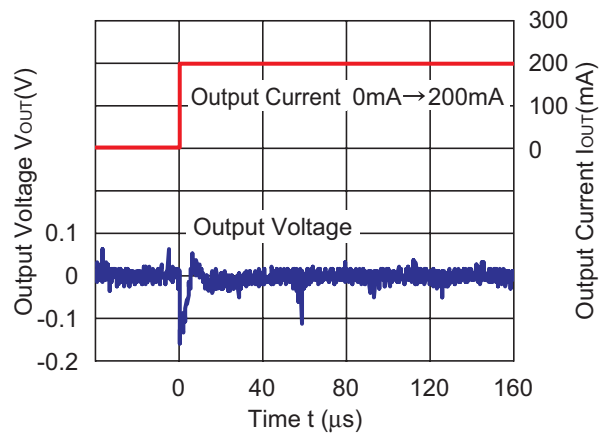
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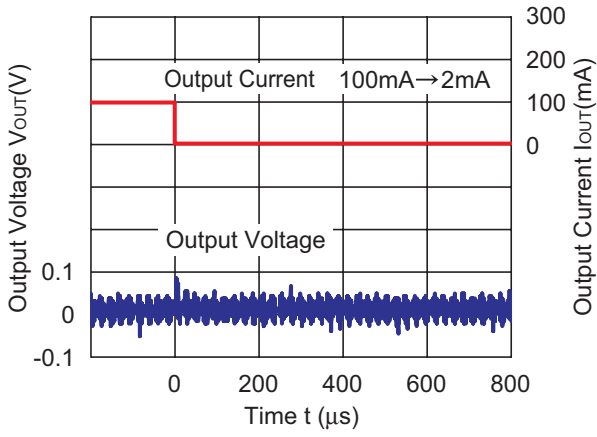
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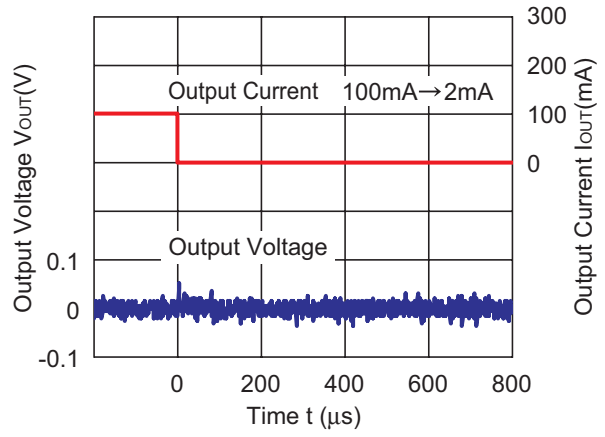
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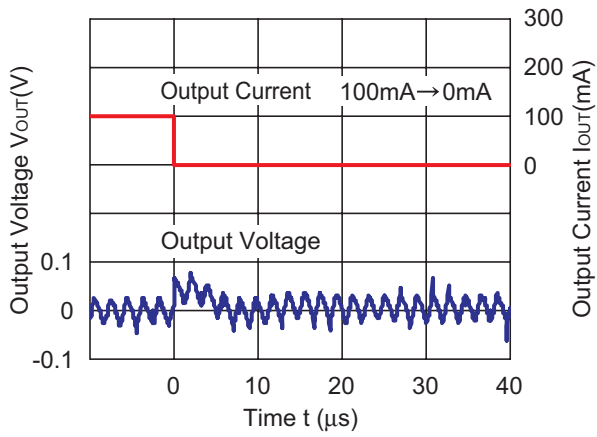
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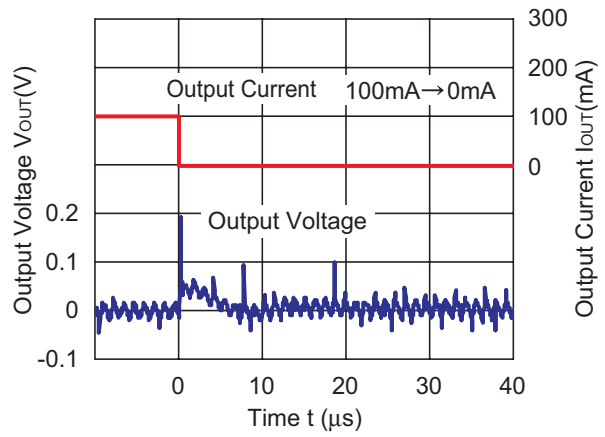
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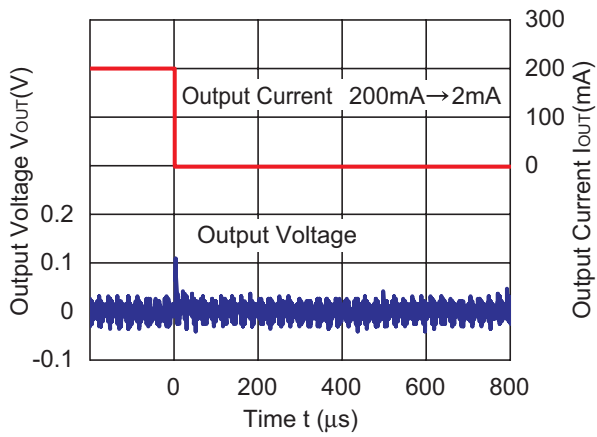
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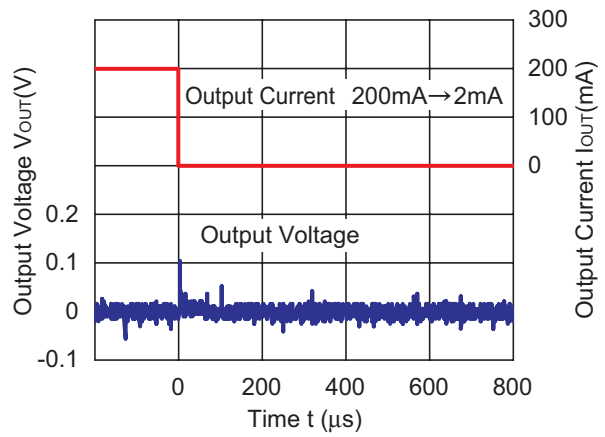
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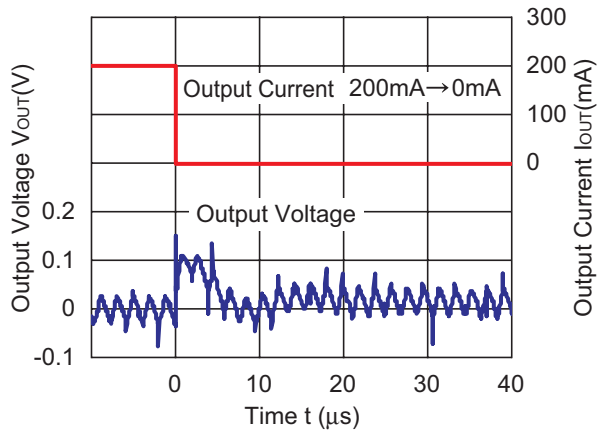
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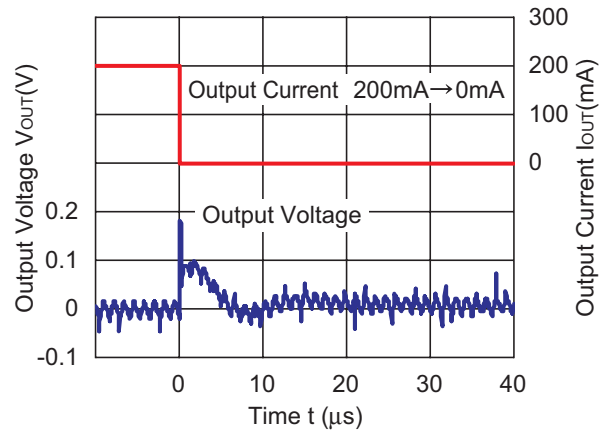
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R1234D181A

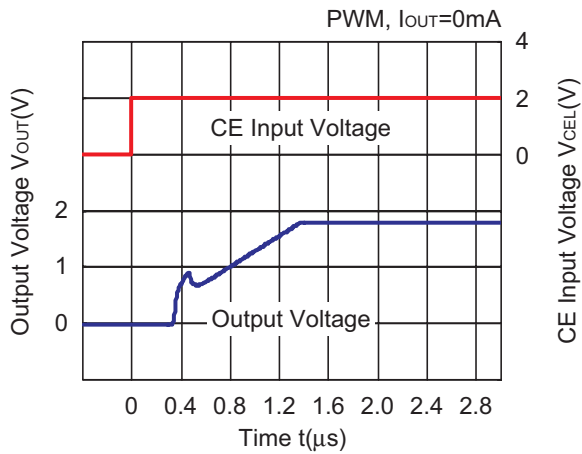


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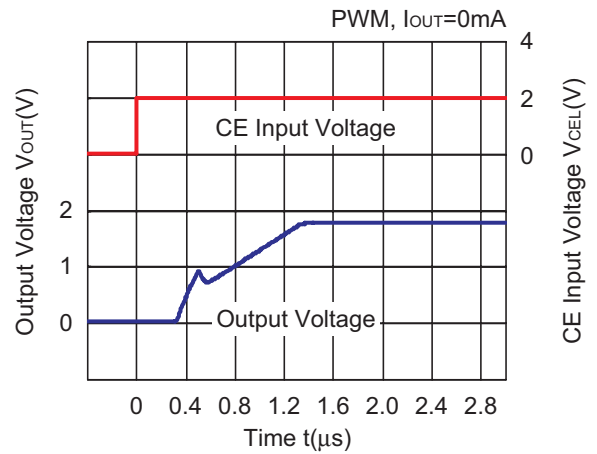


5) Turn on speed with CE pin

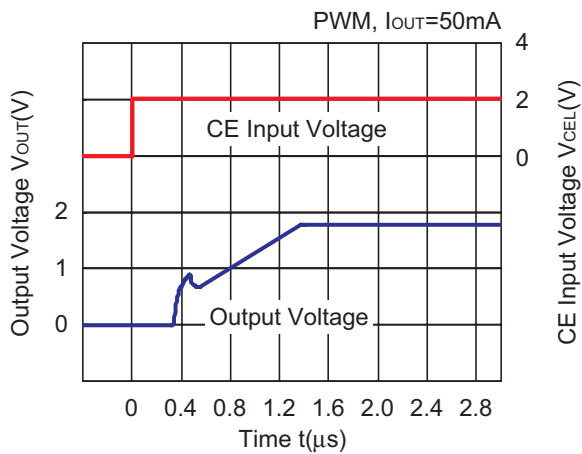
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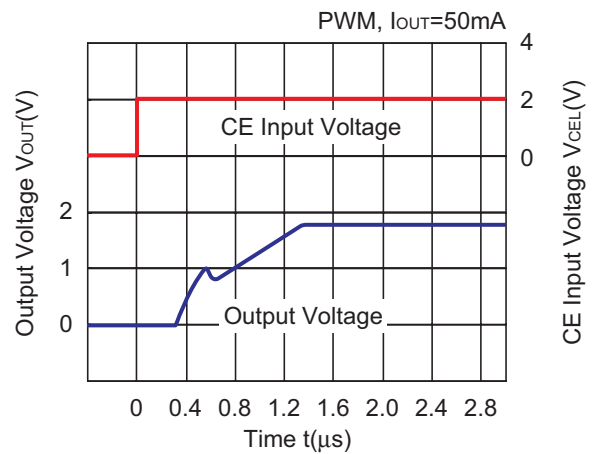
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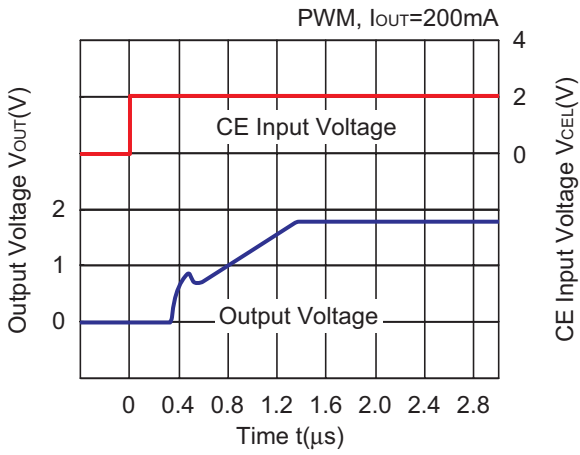
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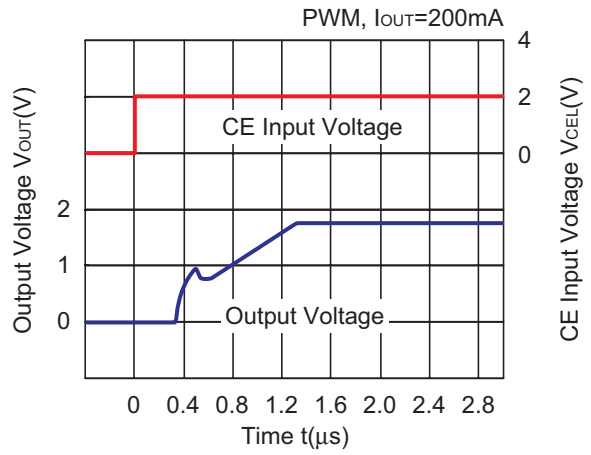
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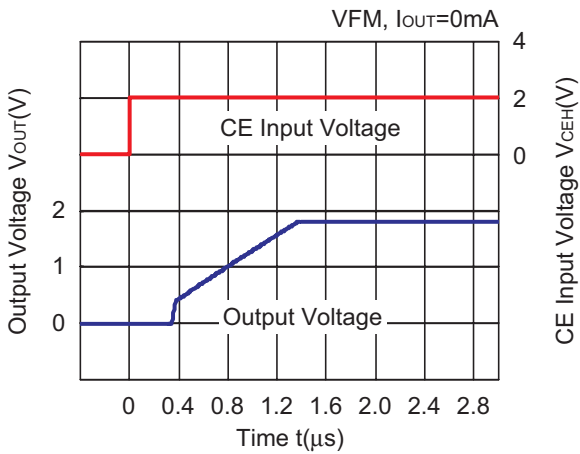
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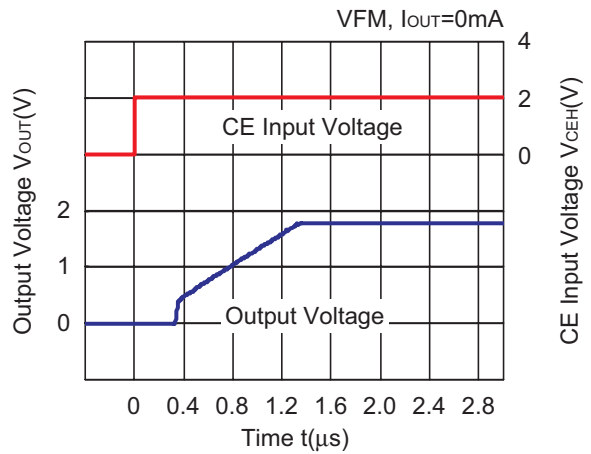
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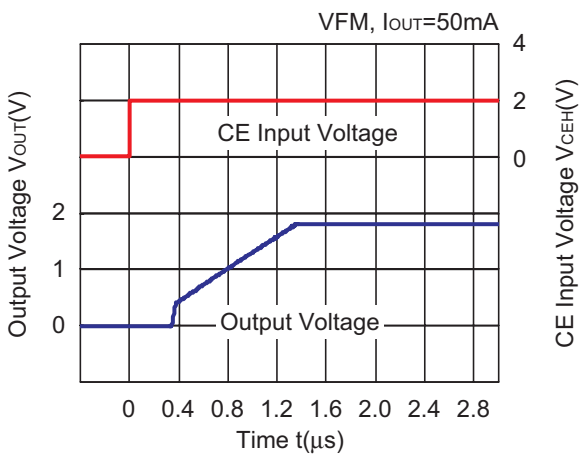
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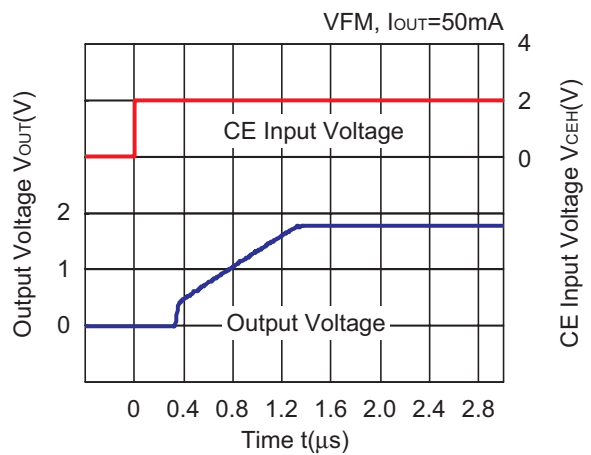
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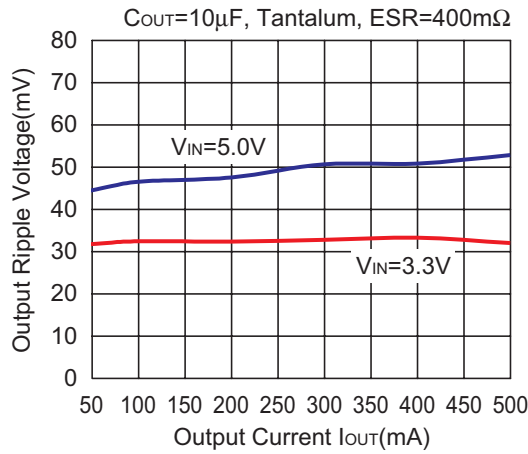


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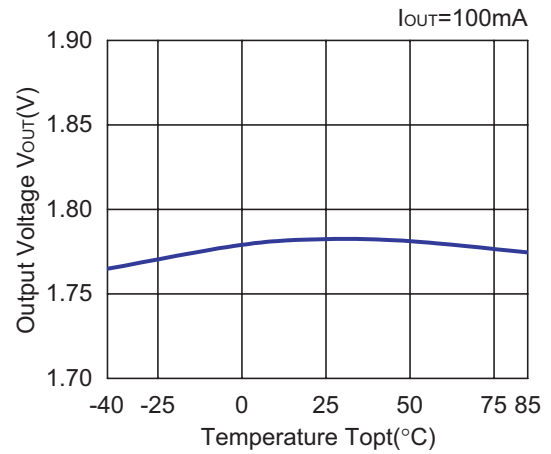
6) Output Ripple Voltage vs. Output Current

R1234D181B



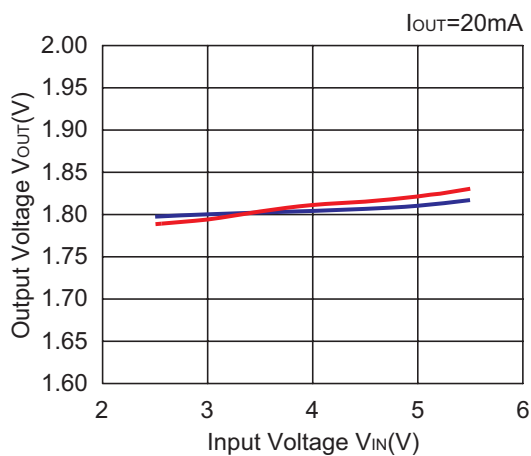
7) Output Voltage vs. Temperature

R1234D181B

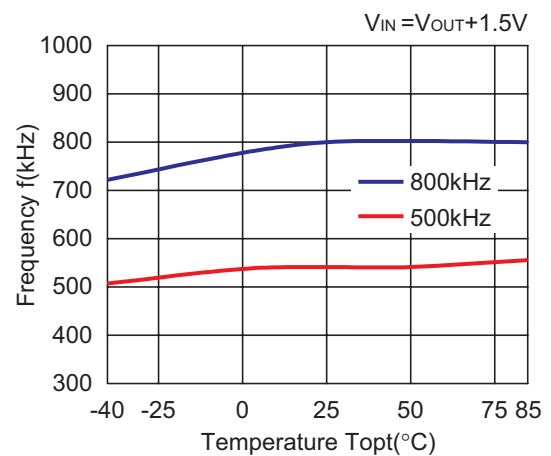


8) Output Voltage vs. Input Voltage

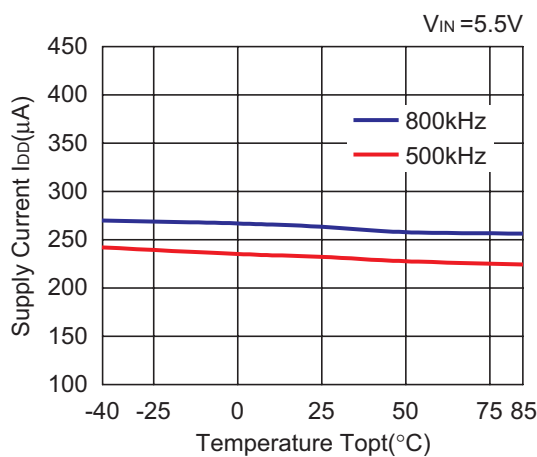
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9) Frequency vs. Temperature

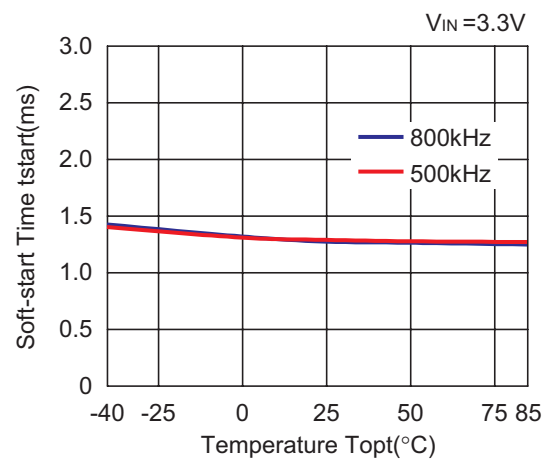


10) Supply Current vs. Temperature

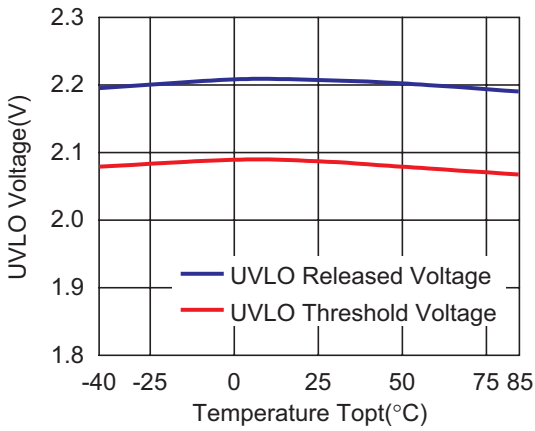


11) Soft-start Time vs. Temperature

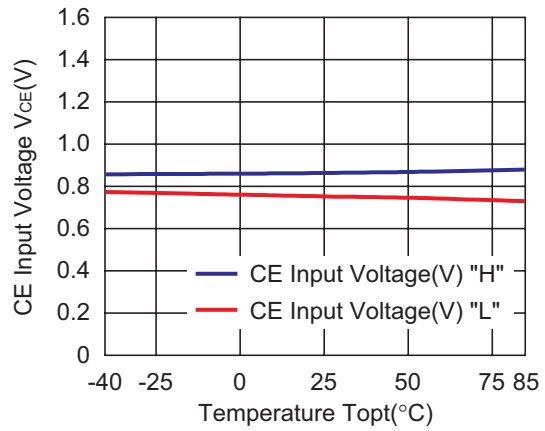
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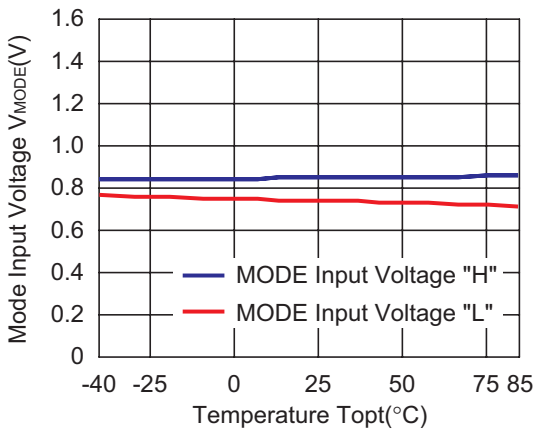
12) UVLO Threshold vs. Temperature



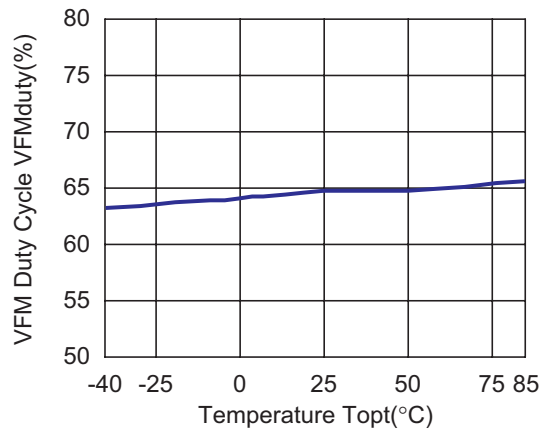
13) CE Input Voltage vs. Temperature



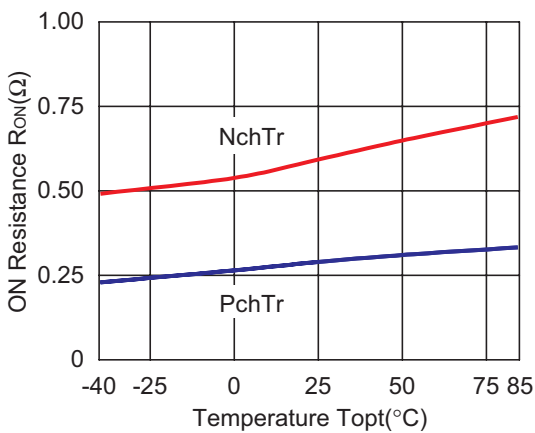
14) Mode Input Voltage vs. Temperature



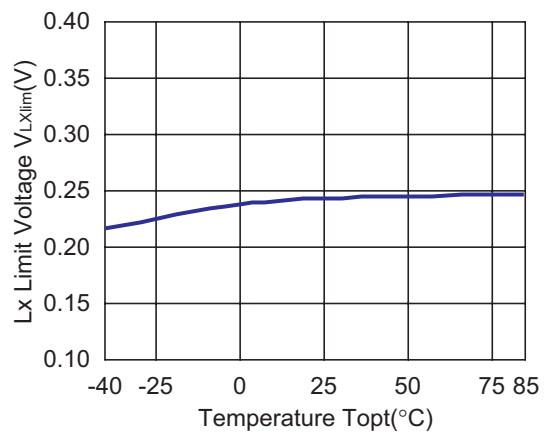
15) Maximum Duty Cycle at VFM Mode vs. Temperature

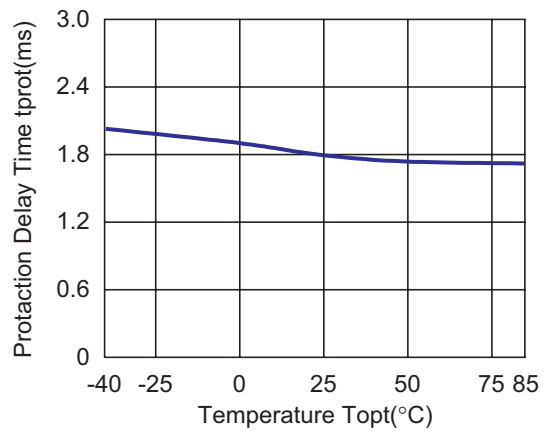


16) Lx Transistor On Resistance vs. Temperature



17) Lx Limit Voltage vs. Temperature

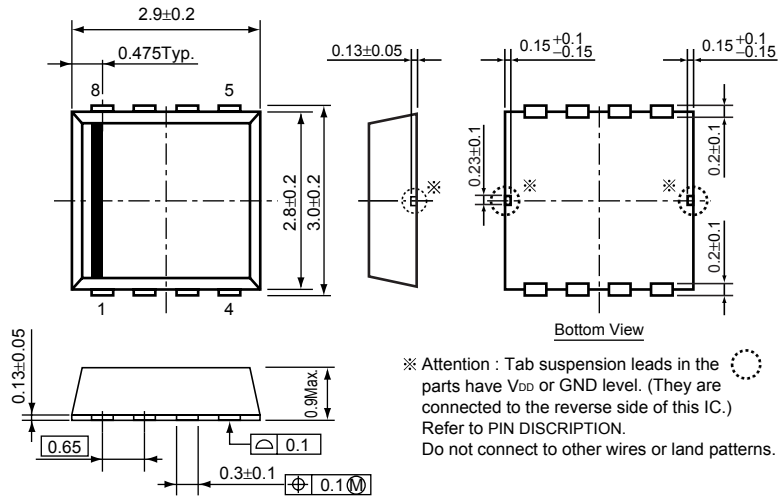


18) Protection Delay Time vs. Temperature

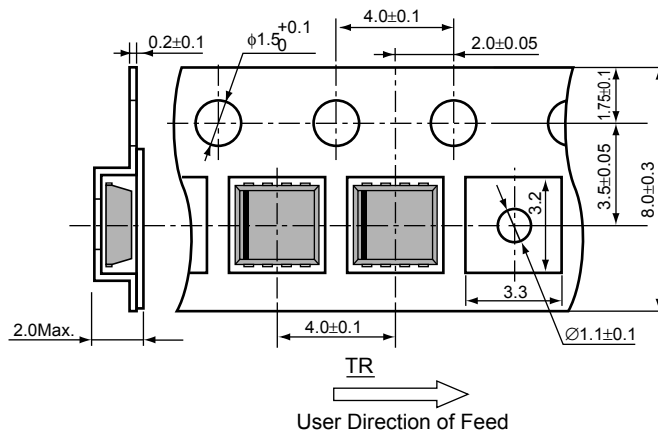
• SON-8

Unit: mm

PACKAGE DIMENSIONS

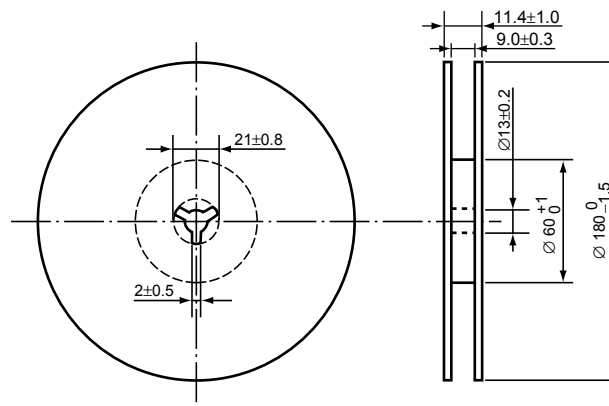


TAPING SPECIFICATION



TAPING REEL DIMENSIONS REUSE REEL (EIAJ-RRM-08Bc)

(1reel=3000pcs)



POWER DISSIPATION (SON-8)

This specification is at mounted on board. Power Dissipation (P_D) depends on conditions of mounting on board. This specification is based on the measurement at the condition below:

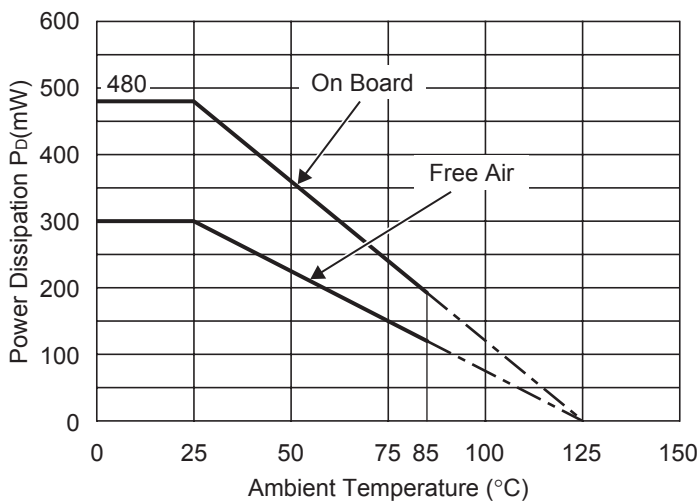
Measurement Conditions

	Standard Land Pattern
Environment	Mounting on Board (Wind velocity=0m/s)
Board Material	Glass cloth epoxy plactic (Double sided)
Board Dimensions	40mm × 40mm × 1.6mm
Copper Ratio	Top side : Approx. 50% , Back side : Approx. 50%
Through-hole	φ0.5mm × 44pcs

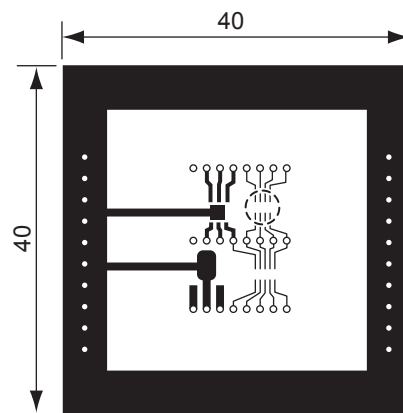
Measurement Result

($T_{opt}=25^{\circ}C, T_{jmax}=125^{\circ}C$)

	Standard Land Pattern	Free Air
Power Dissipation	480mW	300mW
Thermal Resistance	$\theta_{ja}=(125-25^{\circ}C)/0.48W=208^{\circ}C/W$	333 $^{\circ}C/W$



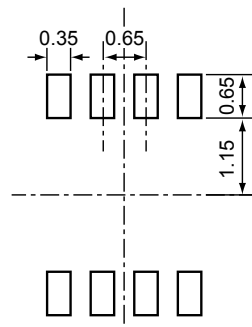
Power Dissipation



Measurement Board Pattern

○ IC Mount Area (Unit : mm)

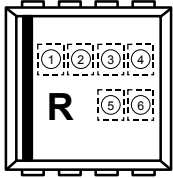
RECOMMENDED LAND PATTERN



(Unit: mm)

R1234D SERIES MARK SPECIFICATION

• SON-8



① to ④ : Product Code (refer to Part Number vs. Product Code)

⑤, ⑥ : Lot Number

• Part Number vs. Product Code

Part Number	Product Code			
	①	②	③	④
R1234D121A	H	1	2	A
R1234D131A	H	1	3	A
R1234D141A	H	1	4	A
R1234D151A	H	1	5	A
R1234D161A	H	1	6	A
R1234D171A	H	1	7	A
R1234D181A	H	1	8	A
R1234D191A	H	1	9	A
R1234D201A	H	2	0	A
R1234D211A	H	2	1	A
R1234D221A	H	2	2	A
R1234D231A	H	2	3	A
R1234D241A	H	2	4	A
R1234D251A	H	2	5	A
R1234D261A	H	2	6	A
R1234D271A	H	2	7	A
R1234D281A	H	2	8	A
R1234D291A	H	2	9	A
R1234D301A	H	3	0	A
R1234D311A	H	3	1	A
R1234D321A	H	3	2	A
R1234D331A	H	3	3	A

Part Number	Product Code			
	①	②	③	④
R1234D121B	H	1	2	B
R1234D131B	H	1	3	B
R1234D141B	H	1	4	B
R1234D151B	H	1	5	B
R1234D161B	H	1	6	B
R1234D171B	H	1	7	B
R1234D181B	H	1	8	B
R1234D191B	H	1	9	B
R1234D201B	H	2	0	B
R1234D211B	H	2	1	B
R1234D221B	H	2	2	B
R1234D231B	H	2	3	B
R1234D241B	H	2	4	B
R1234D251B	H	2	5	B
R1234D261B	H	2	6	B
R1234D271B	H	2	7	B
R1234D281B	H	2	8	B
R1234D291B	H	2	9	B
R1234D301B	H	3	0	B
R1234D311B	H	3	1	B
R1234D321B	H	3	2	B
R1234D331B	H	3	3	B

Part Number	Product Code			
	①	②	③	④
R1234D001C	H	0	1	C
R1234D001D	H	0	1	D