1 A PWM/VFM Dual Step-down DC/DC Converter with Synchronous Rectifier for Industrial Applications

NO. EY-285-170518

OUTLINE

The RP550L001B is a 1 A[1] dual step-down DC/DC converter with synchronous rectifier. Replacing diodes with built-in switching transistors improves the efficiency of rectification. Therefore, by simply using two inductors, resistors and capacitors as the external components, a low ripple high efficiency synchronous rectifier step-down DC/DC converter can be easily configured.
Protection functions include a current limit function, a latch-off overcurrent protection function, a thermal shutdown function, and so on.
Output Voltage Control Methods have two operating modes: Forced PWM mode and PWM/VFM Auto-switching mode. By inputting a signal to the MODE pin, the RP550L001B can select from between two modes. When the both converters are in PWM control, the converters operate with 180° turn-on phase shift of the switching transistors.
This is a high-reliability semiconductor device for industrial applications (-Y) that has passed both the screening at high temperature and the reliability test with extended hours.

FEATURES

- Input Voltage Range (Maximum Rating)
  - $0.6\ V \le V_{SET}$[2] $< 0.8\ V$ ··························· 2.3 V to 4.5 V (6.5 V),
  - $0.8 \le V_{SET}$ ··························· 2.3 V to 5.5 V (6.5 V)
- Operating Temperature Range ··························· −40°C to 105°C
- Supply Current ··························· Typ. 45 μA (VFM mode at no load per 1 channel)
- Standby Current ··························· Typ. 0 μA
- Adjustable Output Voltage Range[3] ··························· 0.6 V to 3.3 V
- Feedback Voltage Accuracy ··························· ±9 mV (V_{FB} = 0.6 V)
- Output Voltage Temperature Coefficient ··························· ±100 ppm/°C
- Oscillator Frequency ··························· Typ. 2.3 MHz
- Oscillator Maximum Duty ··························· Min. 100%
- Built-in Driver ON Resistance ··························· Typ. Pch. 0.25 Ω, Nch. 0.21 Ω (V_{IN} = 3.6 V)
- UVLO Detector Threshold ··························· Typ. 2.0 V
- Soft Start Time ··························· Typ. 0.2 ms
- LX Current Limit Circuit ··························· Typ. 1900 mA/ channel
- Latch Type Protection Circuit ··························· Typ. 1.5 ms
- Package ··························· DFN3030-12 (3.0 mm x 3.0 mm)

[1] This is an approximate value, because output current depends on conditions and external components.
[2] V_{SET}: Set Output Voltage
[3] Output voltage is settable by external resistor. Recommended range is up to 3.3 V.

APPLICATIONS

- Industrial equipments such as FAs and smart meters
- Equipments used under high-temperature conditions such as surveillance camera and vending machine
- Equipments accompanied by self-heating such as motor and lighting

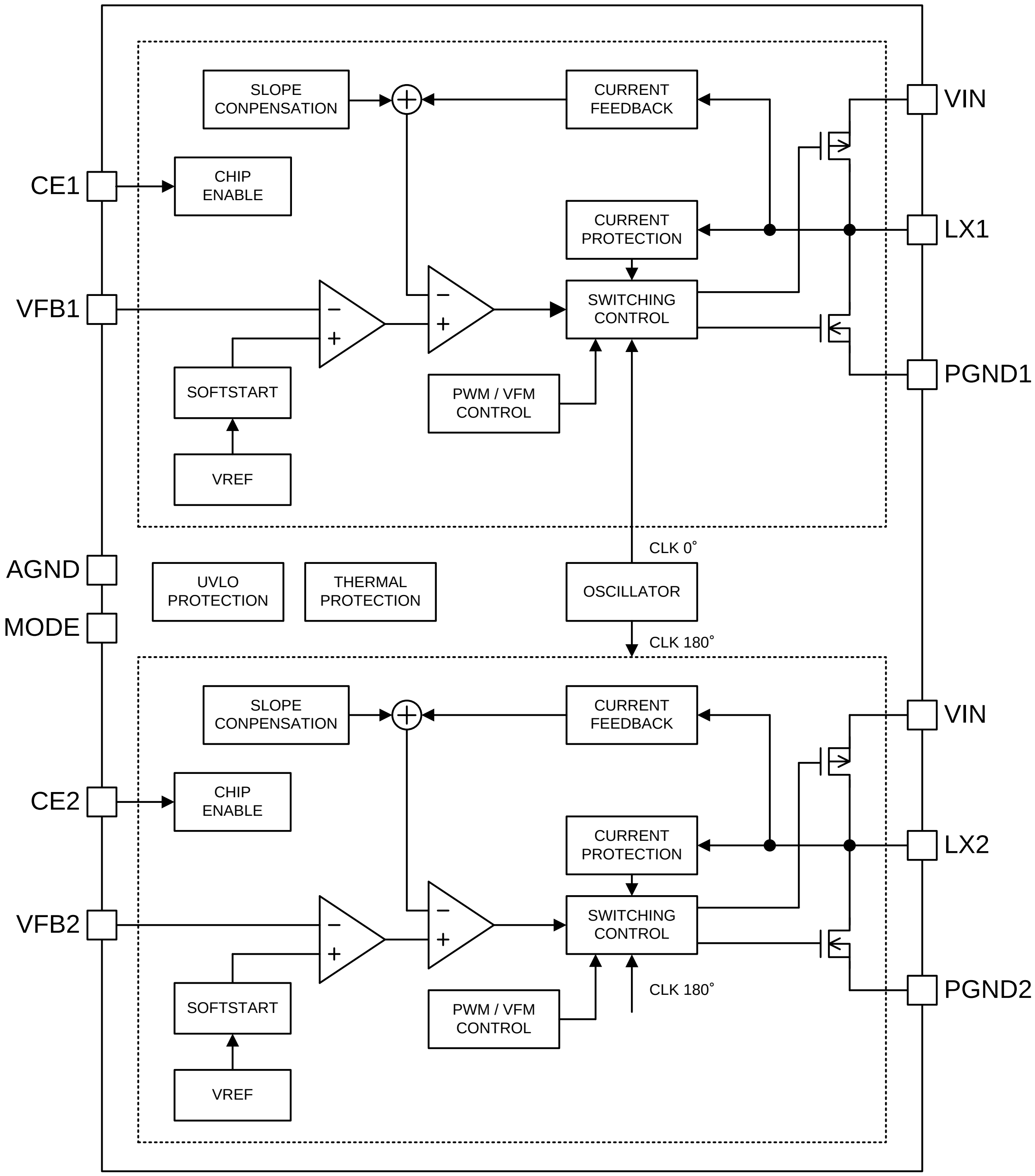
SELECTION GUIDE

Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
RP550L001B-TR-Y	DFN3030-12	3,000 pcs	Yes	Yes

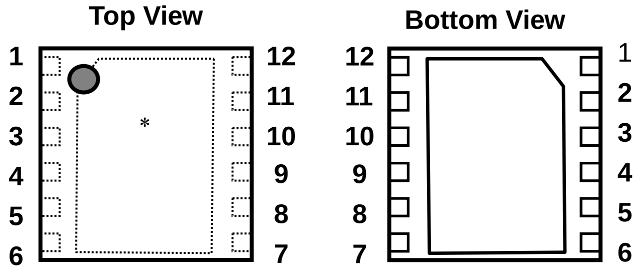
Set output voltage (V_{SET}) is adjustable with external divider resistors.
The recommended V_{SET} range is from 0.6 V to 3.3 V.

BLOCK DIAGRAM



RP550L001B Block Diagram

PIN DESCRIPTIONS



DFN3030-12 Pin Configuration

Pin Descriptions

Pin No.	Symbol	Description
1	VFB2	Channel 2 Feedback Pin
2	MODE	Mode Control Pin ("H" forced PWM mode, "L" PWM/VFM auto switching mode)
3	VIN (1)	Input Pin
4	VIN (1)	Input Pin
5	AGND (2)	Analog Ground Pin
6	VFB1	Channel 1 Feedback Pin
7	CE1	Channel 1 Chip Enable Pin ("H" active)
8	LX1	Channel 1 LX Switching Pin
9	PGND1 (2)	Channel 1 Power Ground Pin
10	PGND2 (2)	Channel 2 Power Ground Pin
11	LX2	Channel 2 LX Switching Pin
12	CE2	Channel 2 Chip Enable Pin ("H" active)

∗ The exposed tab on the bottom of the package enhances thermal performance and is electrically connected to GND (substrate level). It is recommended that the exposed tab be connected to the ground plane on the board or otherwise be left open.

(1) V_{IN} pin (No.3 and No.4) must be wired to the V_{IN} plane when mounting on boards.
(2) GND pin (No.5, No.9, and No.10) must be wired to the GND plane when mounting on boards.

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings (AGND = PGND1 = PGND2 = 0 V)

Symbol	Item		Rating	Unit
V_{IN}	VIN Pin Voltage		−0.3 to 6.5	V
V_{LX1}, V_{LX2}	LX1 / LX2 Pin Voltage		−0.3 to V_{IN} + 0.3	V
V_{CE1}, V_{CE2}	CE1 / CE2 Pin Voltage		−0.3 to 6.5	V
V_{MODE}	MODE Pin Voltage		−0.3 to 6.5	V
V_{FB1}, V_{FB2}	VFB1 / VFB2 Pin Voltage		−0.3 to 6.5	V
I_{LX1}, I_{LX2}	LX1 / LX2 Pin Output Current		1.9	A
P_D	Power Dissipation(1) (DFN3030-12)	Standard Test Land Pattern	1250	mW
		JEDEC STD. 51-7 Test Land Pattern	2440	mW
Tj	Junction Temperature Range		−40 to 150	°C
Tstg	Storage Temperature Range		−55 to 150	°C

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

RECOMMENDED OPERATING CONDITIONS

Recommended Operating Conditions

Symbol	Item	Rating	Unit
V_{IN}	Input Voltage (0.6 V ≤ V_{SET} (2) < 0.8 V)	2.3 to 4.5	V
	Input Voltage (0.8 ≤ V_{SET} (2))	2.3 to 5.5	V
Ta	Operating Temperature Range	−40 to 105	°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 ratings 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) Refer to *POWER DISSIPATION* for detailed information.
(2) V_{SET}: Set Output Voltage

ELECTRICAL CHARACTERISTICS

Test Circuit is “OPEN LOOP” and Test Condition is AGND = PGND1 = PGND2 = 0 V, unless otherwise noted.
The specifications surrounded by ☐ are guaranteed by design engineering at –40°C ≤ Ta ≤ 105°C.

RP550L001B Electrical Characteristics (Ta = 25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{FB}	Feedback Voltage	V_{IN} = V_{CE1} = V_{CE2} = 3.6V, Ta = 25°C	0.591	0.600	0.609	V
		V_{IN} = V_{CE1} = V_{CE2} = 3.6V, –40°C ≤ Ta ≤ 105°C	0.588		0.612	
f_{OSC}	Oscillator Frequency	V_{IN} = V_{CE1} = V_{CE2} = 3.6 V	2.05	2.30	2.55	MHz
I_{DD1}	Supply Current 1 (1)	V_{IN} = V_{CE1} = V_{CE2} = 5.5 V, V_{FB1} = V_{FB2} = 0.45 V, V_{MODE} = 0 V		800	1100	µA
I_{DD2}	Supply Current 2 (1)	V_{IN} = V_{CE1} = V_{CE2} = 5.5 V, V_{FB1} = V_{FB2} = 0.75 V, V_{MODE} = 0 V		45	60	µA
I_{DD3}	Supply Current 3 (1)	V_{IN} = V_{CE1} = V_{CE2} = 5.5 V, V_{FB1} = V_{FB2} = 0.75 V, V_{MODE} = 5.5 V		800	1100	µA
Istandby	Standby Current (2)	V_{IN} = 5.5 V, V_{CE1} = V_{CE2} = 0 V		0	10	µA
I_{CEH}	CE “High” Input Current (1)	V_{IN} = 5.5 V, V_{CE1} = V_{CE2} = 5.5 V	-1	0	1	µA
I_{CEL}	CE “Low” Input Current (1)	V_{IN} = 5.5 V, V_{CE1} = V_{CE2} = 0 V	-1	0	1	µA
I_{MODEH}	MODE “H” Input Current	V_{IN} = V_{MODE} = 5.5 V	-1	0	1	µA
I_{MODEL}	MODE “L” Input Current	V_{IN} = 5.5V, V_{MODE} = 0V	-1	0	1	µA
I_{FBH}	V_{FB} “High” Input Current (1)	V_{IN} = V_{FB1} = V_{FB2} = 5.5 V, V_{CE1} = V_{CE2} = 0 V	-1	0	1	µA
I_{FBL}	V_{FB} “Low” Input Current (1)	V_{IN} = 5.5 V, V_{CE1} = V_{CE2} = V_{FB1} = V_{FB2} = 0 V	-1	0	1	µA
$I_{LXLEAKH}$	Lx Leakage Current “High” (1)	V_{IN} = V_{LX1} = V_{LX2} = 5.5 V, V_{CE1} = V_{CE2} = 0 V	-1	0	5	µA
$I_{LXLEAKL}$	Lx Leakage Current “Low” (1)	V_{IN} = 5.5 V, V_{CE1} = V_{CE2} = V_{LX1} = V_{LX2} = 0 V	-6	0	1	µA
V_{CEH}	CE “H” Input Voltage	V_{IN} = 5.5 V	1.0			V
V_{CEL}	CE “L” Input Voltage	V_{IN} = 2.3 V			0.4	V
V_{MODEH}	MODE “High” Input Voltage	V_{IN} = 5.5 V	1.0			V
V_{MODEL}	MODE “Low” Input Voltage	V_{IN} = 2.3 V			0.4	V
R_{ONP}	Pch.Transistor ON Resistance	V_{IN} = 3.6 V, I_{LX1} = I_{LX2} = –100 mA		0.25		Ω
R_{ONN}	Nch.Transistor ON Resistance	V_{IN} = 3.6 V, I_{LX1} = I_{LX2} = –100 mA		0.21		Ω
Tstart	Soft-start Time	V_{IN} = V_{CE1} = V_{CE2} = 3.6 V		200	300	µs
I_{LXLIM}	LX Limit Current	V_{IN} = V_{CE1} = V_{CE2} = 3.6 V	1400	1900		mA
t_{PROT}	Protection Delay Time	V_{IN} = V_{CE1} = V_{CE2} = 3.6 V	0.5	1.5	5	ms
V_{UVLO1}	UVLO Threshold Voltage	V_{IN} = V_{CE1} = V_{CE2}, Falling	1.9	2.0	2.1	V
V_{UVLO2}		V_{IN} = V_{CE1} = V_{CE2}, Rising	2.0	2.1	2.2	V
T_{TSD}	Thermal Shutdown Threshold Temperature	Tj, Rising		165		°C
T_{TSR}		Tj, Falling		125		°C

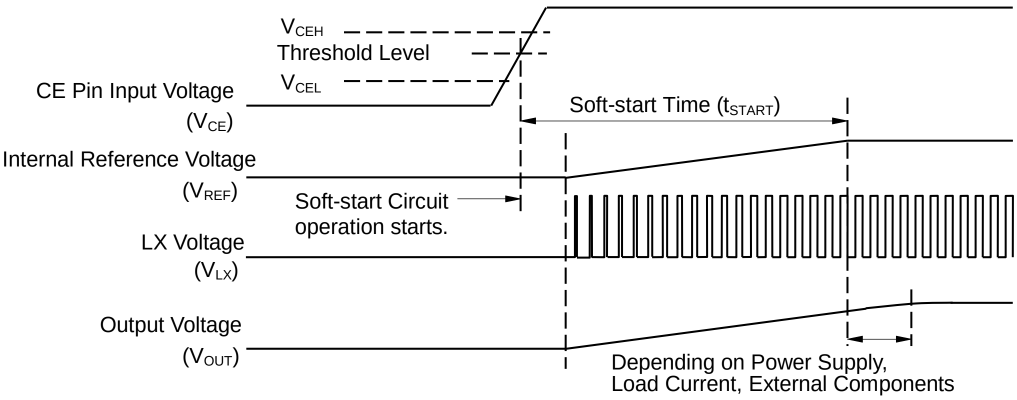
(1) Either Channel 1 value or Channel 2 value is indicated.
(2) The sum of Channel 1 and Channel 2 is indicated.

THEORY OF OPERATION

Soft-start

Starting-up with CE Pin

RP550L starts to operate when the CE pin voltage (V_{CE}) exceeds the threshold voltage. The threshold voltage is preset between CE "High" input voltage (V_{CEH}) and CE "Low" input voltage (V_{CEL}). The soft-start circuit also starts to operate after the device start-up. Then, after a certain period of time, the reference voltage (V_{REF}) in the device gradually increases up to the specified value.
Notes: Soft start time (t_{START})[1] might not be always equal to an actual turn-on speed of the step-down DC/DC converter. Please note that the turn-on speed could be affected by the power supply capacity, the output current, the inductance value, and the C_{OUT} value.



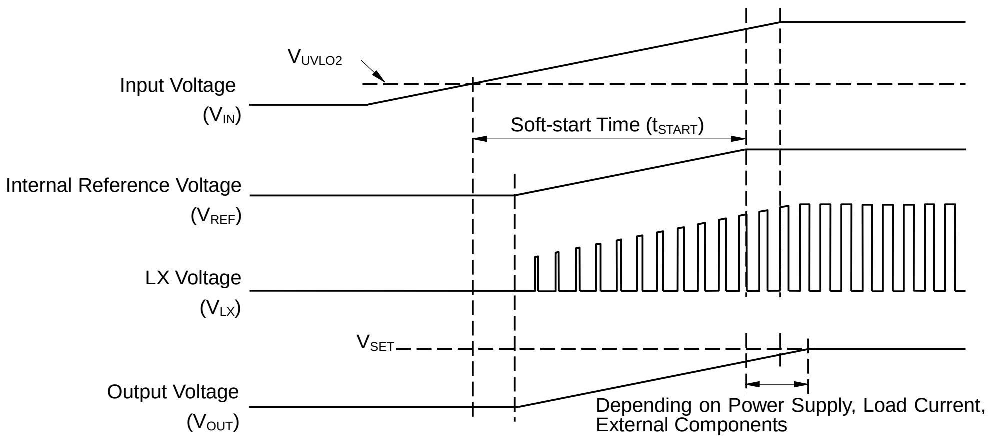
Timing Chart when Starting-up with CE Pin

Starting-up with Power Supply

After the power-on, the device starts to operate when V_{IN} exceeds the UVLO released voltage (V_{UVLO2}). The soft-start circuit also starts to operate. Then after a certain period of time, V_{REF} gradually increases up to the specified value.
Notes: Please note that the turn-on speed of V_{OUT} could be affected by the following conditions.

1. Power supply capacity and Turn-on speed of V_{IN} determined by C_{IN}
2. Output current and Output capacity of C_{OUT}

[1] Soft-start time (t_{START}) indicates the duration until the reference voltage (V_{REF}) reaches the specified voltage after soft-start circuit's activation.



Timing Chart when Starting-up with Power Supply

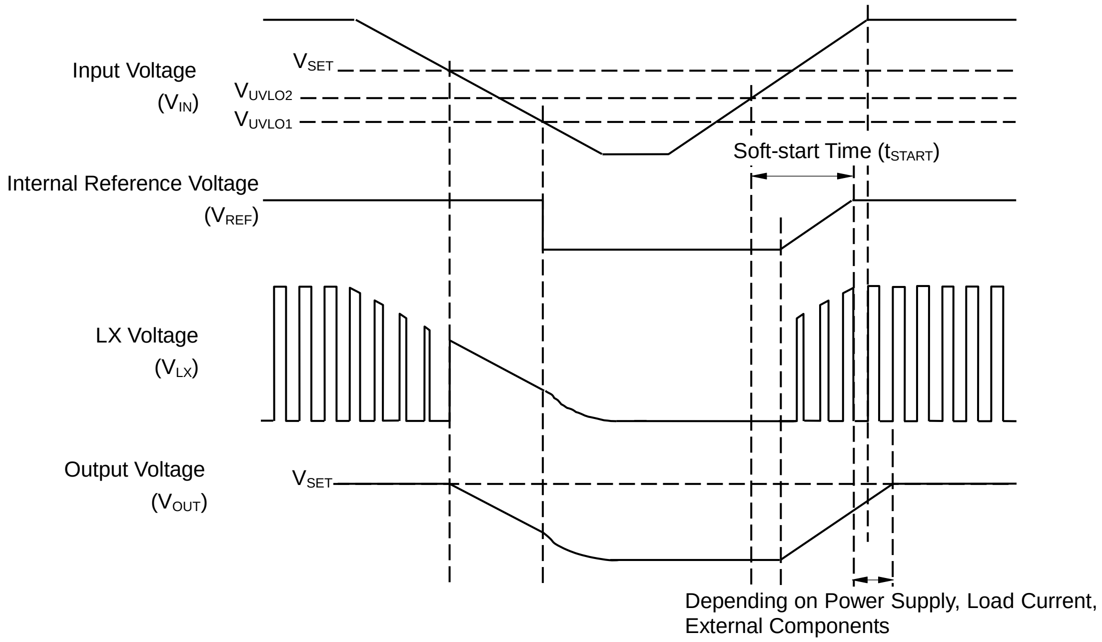
Under Voltage Lockout (UVLO)

If V_{IN} becomes lower than V_{SET}, the step-down DC/DC converter stops the switching operation and ON duty becomes 100%, and then V_{OUT} gradually drops according to V_{IN}.

If the V_{IN} drops more and becomes lower than the UVLO detector threshold (V_{UVLO1}), the UVLO circuit starts to operate, V_{REF} stops, and Pch. and Nch. built-in transistors become the OFF state. As a result, V_{OUT} drops according to the C_{OUT} capacitance value and the load.

To restart the operation, V_{IN} is required to be higher than V_{UVLO2}. The timing chart below shows the voltage shifts of V_{REF}, V_{LX} and V_{OUT} in response to variation of the V_{IN} value.

Notes: Falling edge (operating) and rising edge (releasing) waveforms of V_{OUT} might be affected by the initial voltage of C_{OUT} and the output current of V_{OUT}.



Timing Chart with Variations in Input Voltage (V_{IN})

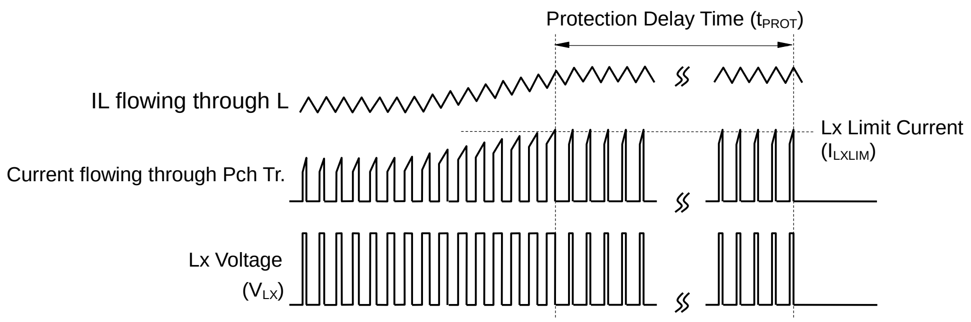
Current limit Function

Current limit circuit supervises the inductor peak current (the current flowing through Pch. transistor) in each switching cycle, and if the current exceeds the LX current limit (I_{LXLIM}), Pch. transistor is turned off. I_{LXLIM} of the RP550L001B is Typ.1.9 A.

Latch Type Protection

Latch type protection circuit latches the built-in driver in the OFF state and stops the operation of the step-down DC/DC converter, if the over current status or V_{OUT} being dropped to the half of the setting voltage due to shorting continues for the protection delay time (t_{PROT}).
To release the latch type protection circuit, restart the device by inputting "L" signal to the CE pin or making the supply voltage lower than V_{UVLO1}.

Notes: I_{LXLIM} and t_{PROT} could be easily affected by self-heating or ambient environment. If the V_{IN} drops dramatically or becomes unstable due to short-circuit, protection operation and t_{PROT} could be affected.



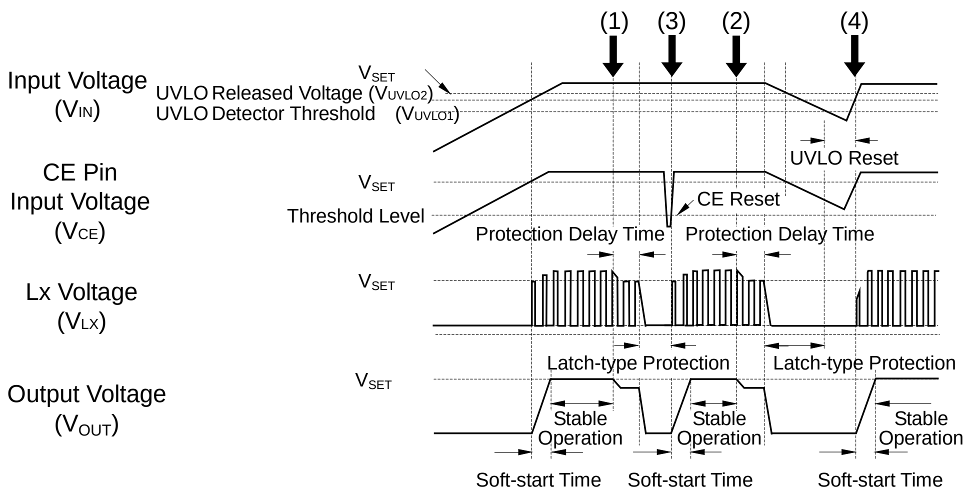
Protection Delay Time

The timing chart below shows the voltage shift of V_{CE}, V_{LX} and V_{OUT} when the device status is changed by the following orders: V_{IN} rising → stable operation → high load → CE reset → stable operation → V_{IN} falling → V_{IN} recovering (UVLO reset) → stable operation.

(1)(2) If the large current flows through the circuit or the device goes into low V_{OUT} condition due to short-circuit or other reasons, the latch type protection circuit latches the built-in driver to "OFF" state after t_{PROT}. Then, V_{LX} becomes "L" and V_{OUT} turns "OFF".

(3) The latch type protection circuit is released by CE reset, which puts the device into "L" once with the CE pin and back into "H".

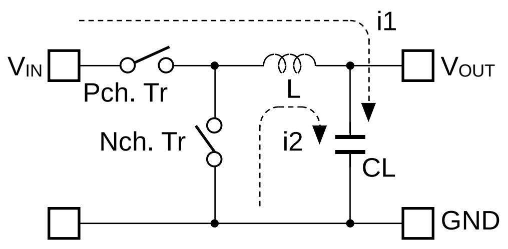
(4) The latch type protection circuit is released by UVLO reset, which makes V_{IN} lower than V_{UVLO1}.



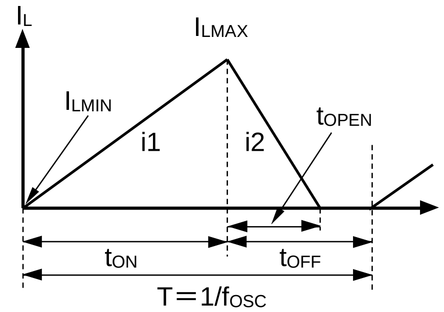
Timing Chart

Operation of Step-down DC/DC Converter and Output Current

The step-down DC/DC converter charges energy in the inductor when LX transistor turns “ON”, and discharges the energy from the inductor when LX transistor turns “OFF” and controls with less energy loss, so that a lower output voltage (V_{OUT}) than the input voltage (V_{IN}) can be obtained. The operation of the step-down DC/DC converter is explained in the following figures.



Basic Circuit



Inductor Current (IL) flowing through Inductor (L)

Step1. Pch. transistor turns “ON” and I_L (i1) flows, L is charged with energy. At this moment, i1 increases from the minimum inductor current (I_{LMIN}), which is 0 A, and reaches the maximum inductor current (I_{LMAX}) in proportion to the on-time period (t_{ON}) of Pch. transistor.

Step2. When Pch. transistor turns “OFF”, L tries to maintain I_L at I_{LMAX}, so L turns Nch. transistor “ON” and I_L (i2) flows into L.

Step3. i2 decreases gradually and reaches I_{LMIN} after the open-time period (t_{OPEN}) of NMOS transistor, and then Nch. transistor turns “OFF”. This is called discontinuous current mode.
As the output current (I_{OUT}) increases, the off-time period ($t_{OFF)}$ of Pch. transistor runs out before I_L reaches I_{LMIN}. The next cycle starts, and Pch. transistor turns “ON” and Nch. transistor turns “OFF”, which means I_L starts increasing from I_{LMIN}. This is called continuous current mode.

In PWM mode, V_{OUT} is maintained by controlling t_{ON}. The oscillator frequency (f_{OSC}) is maintained constant during PWM mode.
When the step-down DC/DC operation is constant, I_{LMIN} and I_{LMAX} during t_{ON} of Pch. transistor would be same as during t_{OFF} of Pch. transistor. The current differential between I_{LMAX} and I_{LMIN} is described as ΔI, as the following equation 1.

$$\Delta I = I_{LMAX} - I_{LMIN} = V_{OUT} \times t_{OPEN} / L = (V_{IN} - V_{OUT}) \times t_{ON} / L \quad \cdots\cdots \text{Equation 1}$$

The above equation is predicated on the following requirements.

$T = 1 / f_{OSC} = t_{ON} + t_{OFF}$
duty (%) = $t_{ON} / T \times 100 = t_{ON} \times f_{OSC} \times 100$
$t_{OPEN} \leq t_{OFF}$

In Equation 1, “$V_{OUT} \times t_{OPEN} / L$” shows the amount of current change in "OFF" state. Also, “$(V_{IN} - V_{OUT}) \times t_{ON} / L$” shows the amount of current change at "ON" state.

Discontinuous Mode and Continuous Mode

As illustrated in Figure A., when I_{OUT} is relatively small, $t_{OPEN} < t_{OFF}$. In this case, the energy charged into L during t_{ON} will be completely discharged during t_{OFF}, as a result, $I_{LMIN} = 0$. This is called discontinuous mode. When I_{OUT} is gradually increased, eventually $t_{OPEN} = t_{OFF}$ and when I_{OUT} is increased further, eventually $I_{LMIN} > 0$ as illustrated in Figure B. This is called continuous mode.

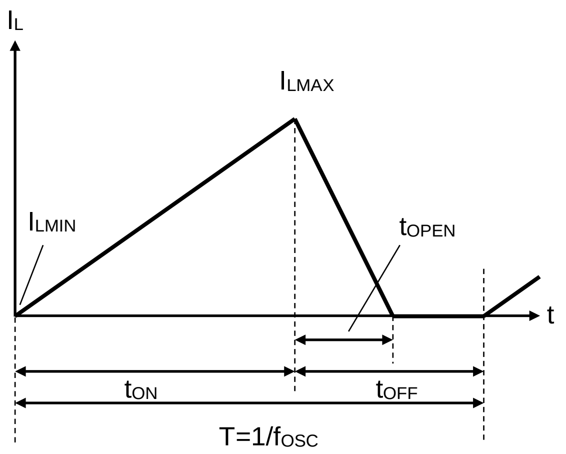


Figure A. Discontinuous Mode

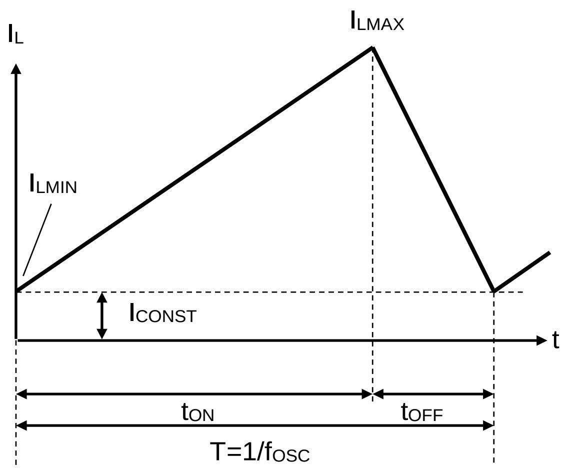


Figure B. Continuous Mode

In the continuous mode, the solution of Equation 1 is described as t_{ONC}.

$t_{ONC} = T \times V_{OUT} / V_{IN}$ ··· Equation 2

When $t_{ON} < t_{ONC}$, it is discontinuous mode, and when $t_{ON} = t_{ONC}$, it is continuous mode.

Forced PWM Mode and VFM Mode

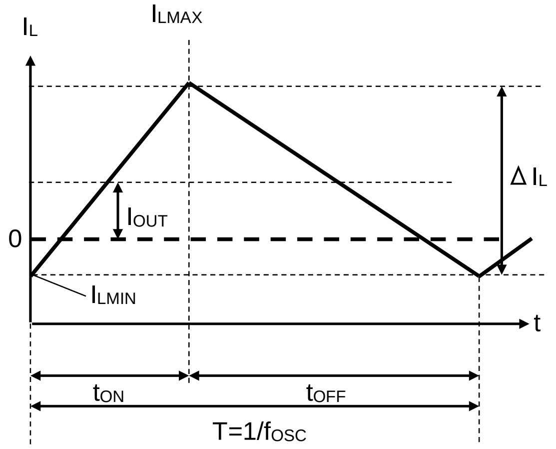
Operating mode to control the output voltage is selectable between a forced PWM mode and a PWM/VFM auto-switching mode, and can be set by the MODE pin. The forced PWM control switches at fixed frequency rate in order to reduce noise in low output current. The PWM/VFM auto-switching control automatically switches from PWM mode to VFM mode in order to achieve high efficiency in low output current.

Forced PWM Mode

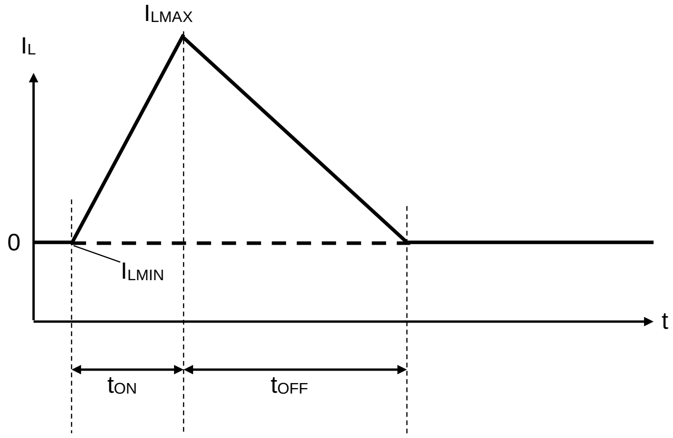
By setting the MODE pin to "H", the device switches the frequency at the fixed rate to reduce noise even when the output load is light. Therefore, when I_{OUT} is $\Delta I_L/2$ or less, I_{LMIN} becomes less than "0". That is, the accumulated charge in C_{OUT} is discharged through the internal transistor while I_L is increasing from I_{LMIN} to "0" during t_{ON}, and also while I_L is decreasing from "0" to I_{LMIN} during t_{OFF}.

VFM Mode

By setting the MODE pin to "L", in low output current, the device automatically switches into VFM mode in order to achieve high efficiency. In VFM mode, t_{ON} is forced to end when the inductor current reaches the pre-set I_{LMAX}. In the VFM mode, I_{LMAX} is typically set to 280 mA for the RP550L001B. When t_{ON} reaches 1.5 times of T = 1 / f_{OSC}, t_{ON} will be forced to end even if the inductor current is not reached I_{LMAX}.



Forced PWM Mode

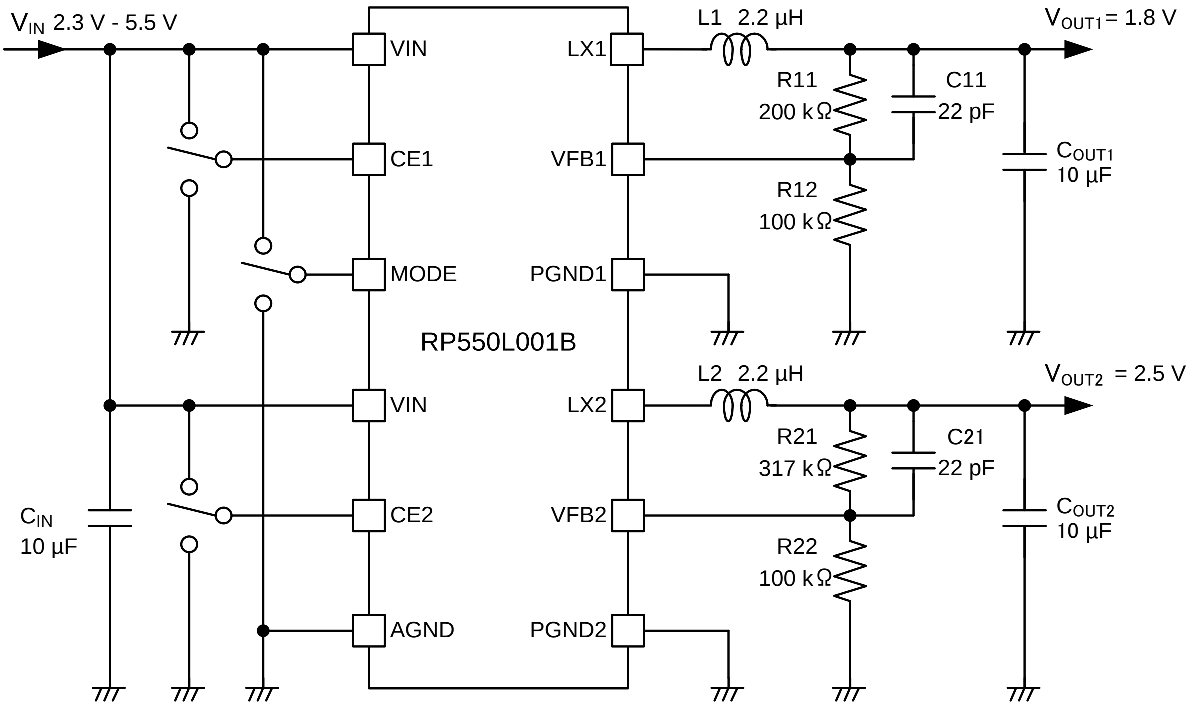


VFM Mode

APPLICATION INFORMATION

Typical Application Circuit

Notes: MODE = “H” forced PWM mode, MODE = “L” PWM/VFM auto switching mode



RP550L001B Typical Application Circuit

Recommended External Components

Table 1. Recommended External Components: 0.8 V ≤ V_{SET} ≤ 3.3 V

Symbol	Value	Components	Part Number
C_{IN}	10 µF	Ceramic Capacitor	CGA4J1X7R0J106K125AC (TDK)
C_{OUT}	10 µF	Ceramic Capacitor	CGA4J1X7R0J106K125AC (TDK)
L	2.2 µH	Inductor	VLS3012ET-2R2M-CA (TDK)

Table 2. Recommended External Components: 0.6 V ≤ V_{SET} < 0.8 V

Symbol	Value	Components	Part Number
C_{IN}	10 µF	Ceramic Capacitor	CGA4J1X7R0J106K125AC (TDK)
C_{OUT}	10 µF × 2	Ceramic Capacitor	CGA4J1X7R0J106K125AC (TDK)
L	1.5 µH	Inductor	VLS3012ET-1R5N-CA (TDK)

Cautions in selecting external parts

- Choose a low ESR ceramic capacitor. The ceramic capacitance of a capacitor (C_{IN}) connected between V_{IN} and GND should be more than or equal to 10 µF. The ceramic capacitance of a capacitor (C_{OUT}) connected between V_{OUT} and GND should be 10 µF to 20 µF. Please be aware of the characteristics of bias dependence and temperature fluctuation of ceramic capacitor.

- Choose an inductor that has small DC resistance, has enough permissible current and is hard to cause magnetic saturation. If the inductance value of the inductor becomes extremely small under the load conditions, the peak current of LX may increase along with the load current. As a result, over current protection circuit may start to operate when the peak current of LX reaches to LX limit current. Therefore, choose an inductor with consideration for the value of I_{LXMAX}.

- The output voltage (V_{OUT1}, V_{OUT2}) is adjustable by changing the resistance values of resistors (R11 and R12, R21 and R22) as follows.

$V_{OUT1} = 0.6 \times (R11 + R12) / R12$ (Recommended rage: $0.6\text{ V} \leq V_{OUT1} \leq 3.3\text{ V}$)
$V_{OUT2} = 0.6 \times (R21 + R22) / R22$ (Recommended rage: $0.6\text{ V} \leq V_{OUT2} \leq 3.3\text{ V}$)

If R11, R12, R21, and R22 are too large, the impedances of V_{FB1} and V_{FB2} also become large, as a result, the device could be easily affected by noise. For this reason, R12 and R22 should be 100kΩ or less. If the operation becomes unstable dues to the high impedances, the impedances should be decreased.
C11 and C21 can be calculated by the following equations. Please use the value close to the calculation result.

$C11 = 2.2 \times 10^{-6} / R12\ [F]$ ($0.6\text{ V} \leq V_{OUT1} \leq 3.3\text{ V}$)
$C21 = 2.2 \times 10^{-6} / R22\ [F]$ ($0.6\text{ V} \leq V_{OUT2} \leq 3.3\text{ V}$)

The recommended resistance values for R11, R12, R21, R22, C11, and C21 are as follows.

Recommended Resistor and Capacitor Values

Output Voltage V_{OUT1}, V_{OUT2} [V]	Resistor [kΩ]		Capacitor [pF]
	R11, R21	R12, R22	C11, C21
0.6	0	100	-
0.7	16.7	100	22
0.8	33.3	100	22
1.2	100	100	22
1.8	200	100	22
2.5	317	100	22
3.3	450	100	22

Calculation Conditions of LX Pin Maximum Output Current (I_{LXMAX})

The following equations explain the relationship to determine I_{LXMAX} at the ideal operation of the device in continuous mode.

I_{RP} : Ripple Current P-P value
R_{ONP} / R_{ONN} : ON resistance of Pch. / Nch. transistor
R_L : DC resistor of the inductor

First, when the Pch. transistor is “ON”, Equation 1 is satisfied.

$V_{IN} = V_{OUT} + (R_{ONP} + R_L) \times I_{OUT} + L \times I_{RP} / t_{ON}$ ············ Equation 1

Second, when the Pch. transistor is "OFF" (the Nch. transistor is "ON"), Equation 2 is satisfied.

$L \times I_{RP} / t_{OFF} = R_{ONN} \times I_{OUT} + V_{OUT} + R_L \times I_{OUT}$ ············ Equation 2

Put Equation 2 into Equation 1 to solve ON duty of the Pch. transistor ($D_{ON} = t_{ON} / (t_{OFF} + t_{ON})$):

$D_{ON} = (V_{OUT} + R_{ONN} \times I_{OUT} + R_L \times I_{OUT}) / (V_{IN} + R_{ONN} \times I_{OUT} - R_{ONP} \times I_{OUT})$ ············ Equation 3

Ripple Current is described as follows:

$I_{RP} = (V_{IN} - V_{OUT} - R_{ONP} \times I_{OUT} - R_L \times I_{OUT}) \times D_{ON} / f_{OSC} / L$ ············ Equation 4

Peak current that flows through L, and LX transistor is described as follows:

$I_{LXMAX} = I_{OUT} + I_{RP} / 2$ ············ Equation 5

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.

- AGND, PGND1 and PGND2 must be wired to the GND plane when mounting on boards.

- The VIN pins must be wired to the V_{IN} plane when mounting on boards.

- Ensure the V_{IN} and GND lines are sufficiently robust. A large switching current flows through the GND line, the V_{DD} line, the V_{OUT} line, an inductor, and LX. If their impedance is too high, noise pickup or unstable operation may result. Set external components as close as possible to the device and minimize the wiring between the components and the device, especially between a capacitor and the VIN pin. The wiring between V_{FB} and load and between L and V_{OUT} should be separated.

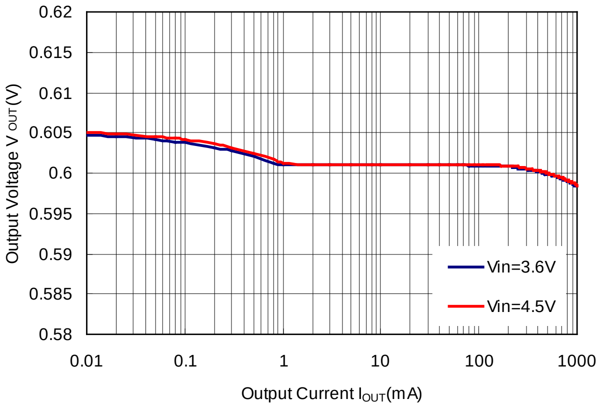
- Over current protection circuit and latch type protection circuit may be affected by self-heating or power dissipation environment.

TYPICAL CHARACTERISTICS

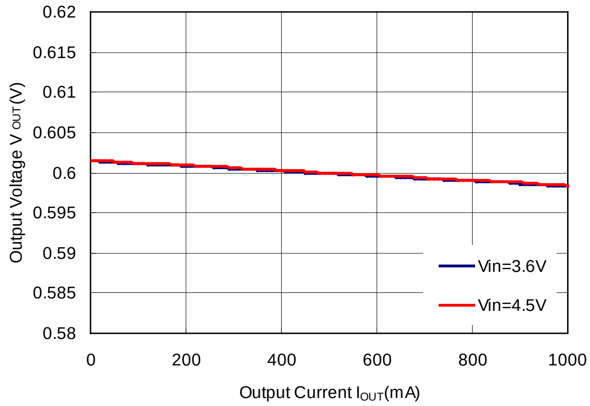
Typical Characteristics are intended to be used as reference data, they are not guaranteed.

1) Output Voltage vs. Output Current

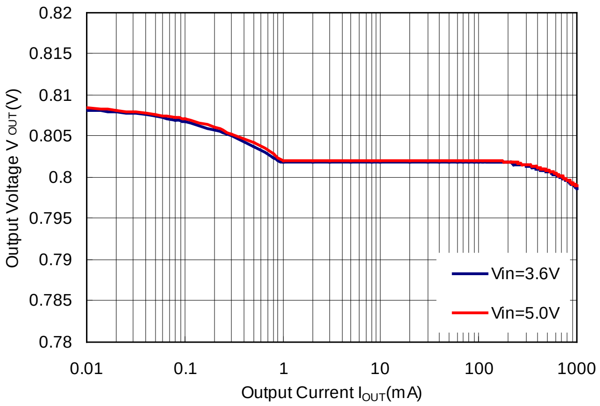
RP550L001B V_{OUT} = 0.6 V
MODE = “L”, PWM/VFM Auto-Switching Control



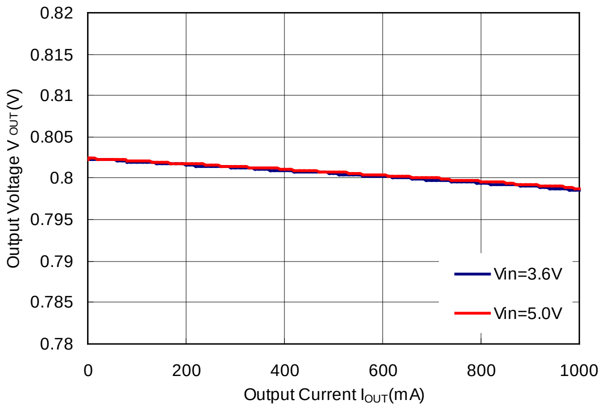
RP550L001B V_{OUT} = 0.6 V
MODE = “H”, Forced PWM Control



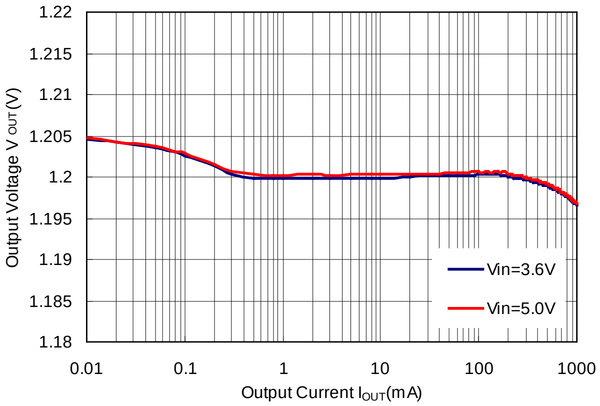
RP550L001B V_{OUT} = 0.8 V
MODE = “L”, PWM/VFM Auto-Switching Control



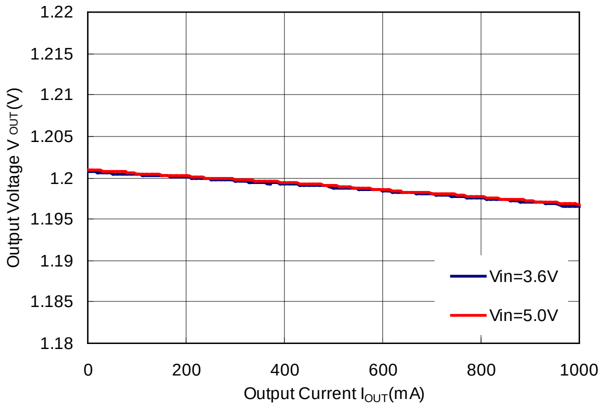
RP550L001B V_{OUT} = 0.8 V
MODE = “H”, Forced PWM Control



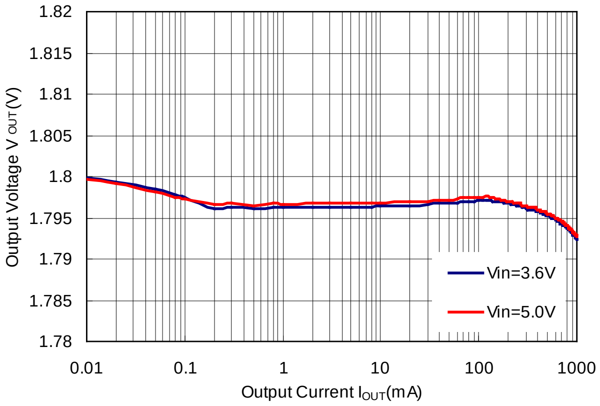
RP550L001B V_{OUT} = 1.2 V
MODE = “L”, PWM/VFM Auto-Switching Control



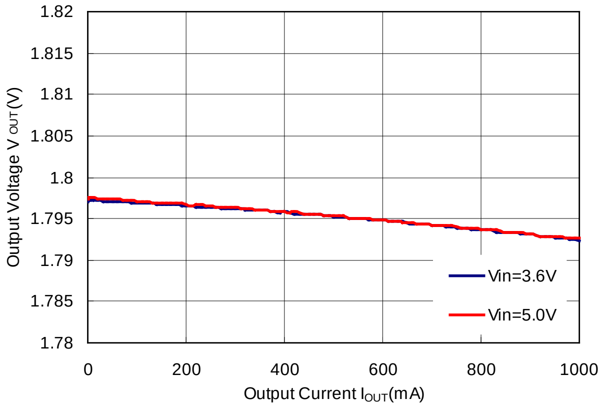
RP550L001B V_{OUT} = 1.2 V
MODE = “H”, Forced PWM Control



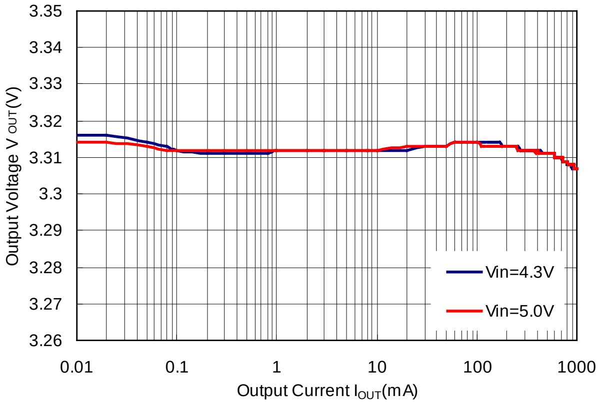
RP550L001B V_{OUT} = 1.8 V
MODE = "L", PWM/VFM Auto-Switching Control



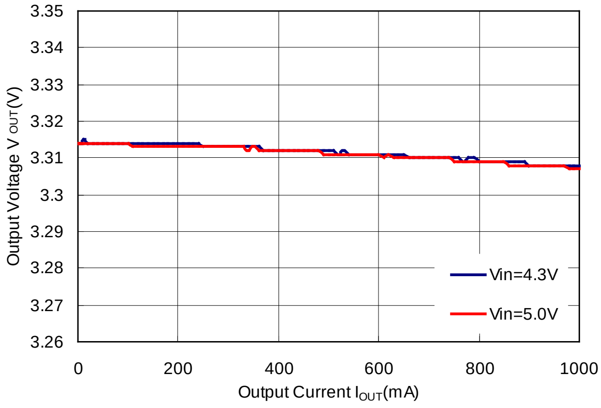
RP550L001B V_{OUT} = 1.8 V
MODE = "H", Forced PWM Control



RP550L001B V_{OUT} = 3.3 V
MODE = "L", PWM/VFM Auto-Switching Control

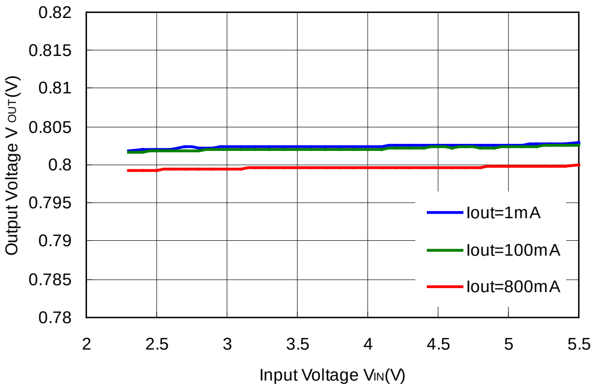


RP550L001B V_{OUT} = 3.3 V
MODE = "H", Forced PWM Control

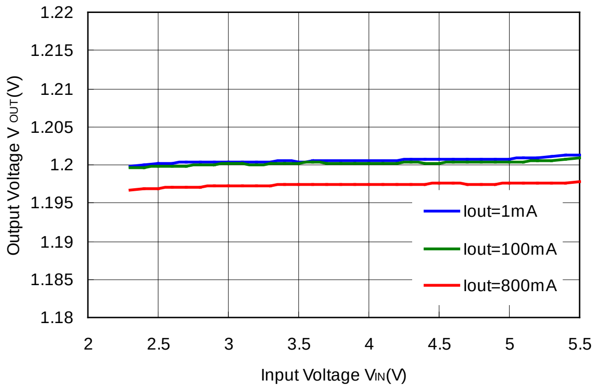


2) Output Voltage vs. Input Voltage

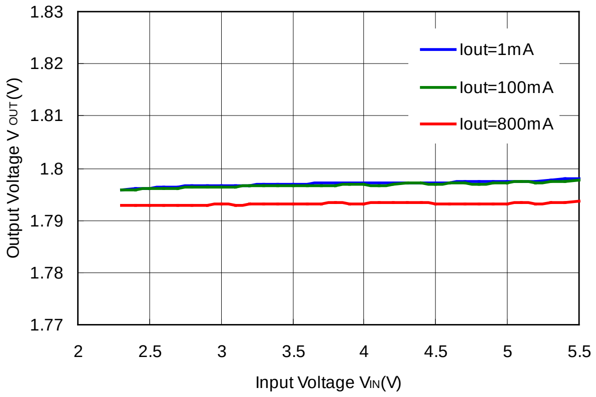
RP550L001B V_{OUT} = 0.8 V
MODE = "H", Forced PWM Control



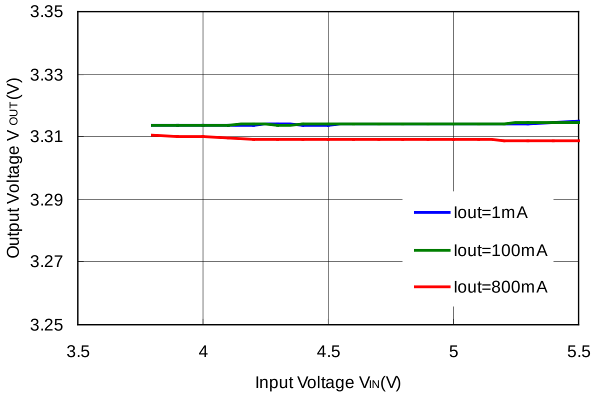
RP550L001B V_{OUT} = 1.2 V
MODE = "H", Forced PWM Control



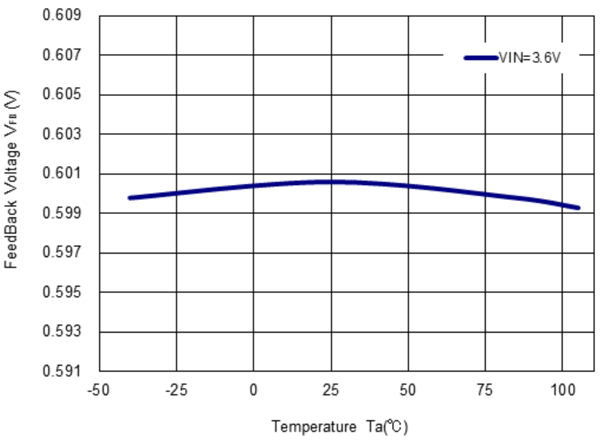
RP550L001B V_{OUT} = 1.8 V
MODE = “H”, Forced PWM Control



RP550L001B V_{OUT} = 3.3 V
MODE = “H”, Forced PWM Control

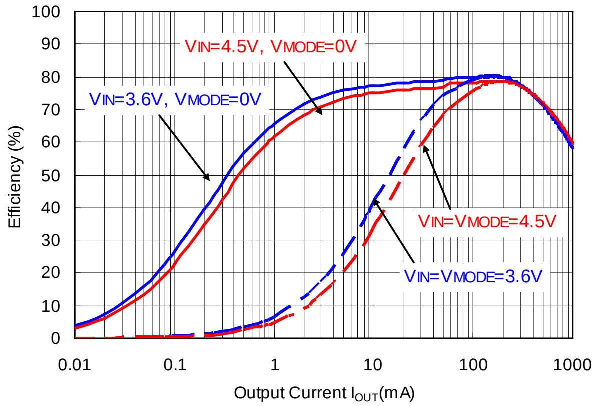


3) Feedback Voltage vs. Ambient Temperature

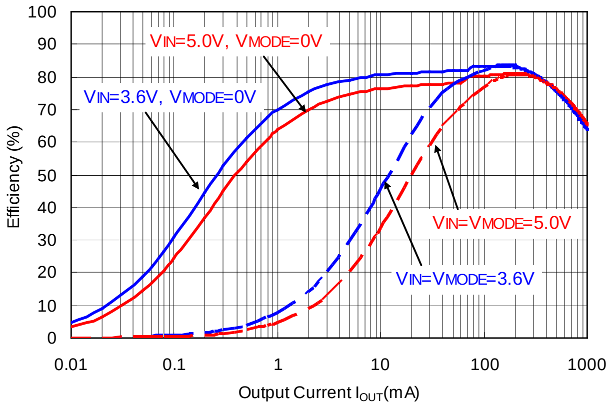


4) Efficiency vs. Output Current

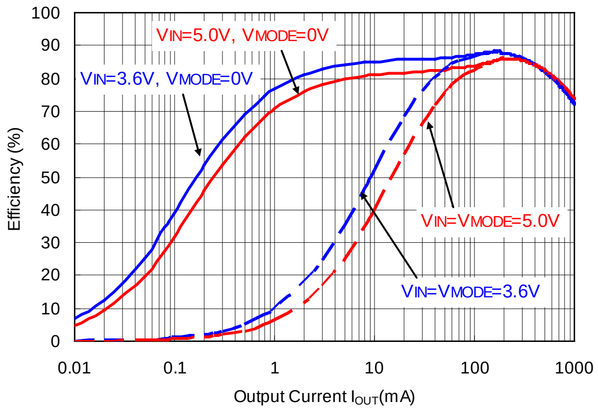
RP550L001B V_{OUT} = 0.6 V



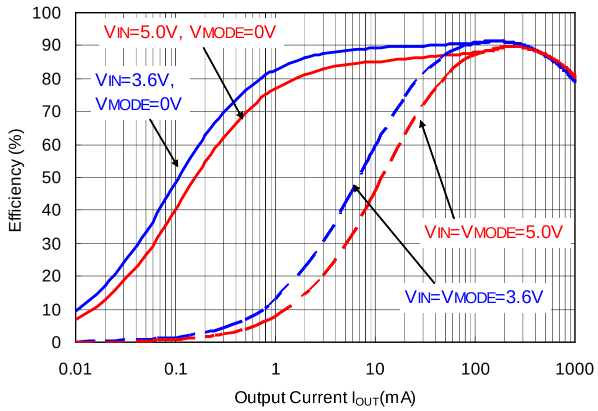
RP550L001B V_{OUT} = 0.8 V



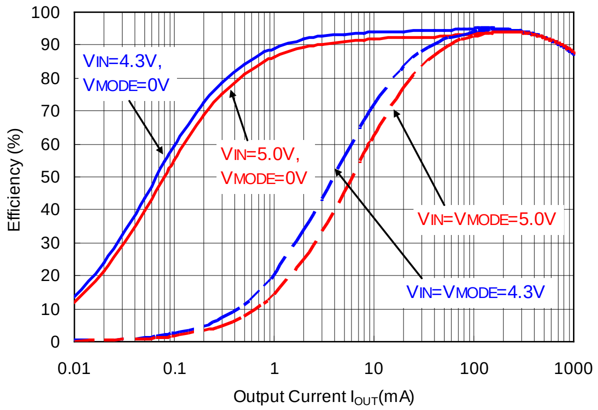
RP550L001B V_{OUT} = 1.2 V



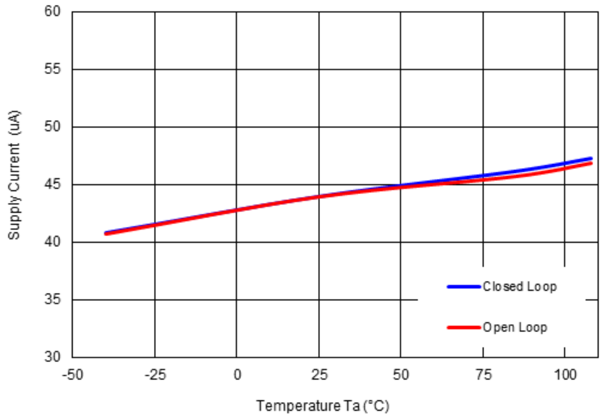
RP550L001B V_{OUT} = 1.8 V



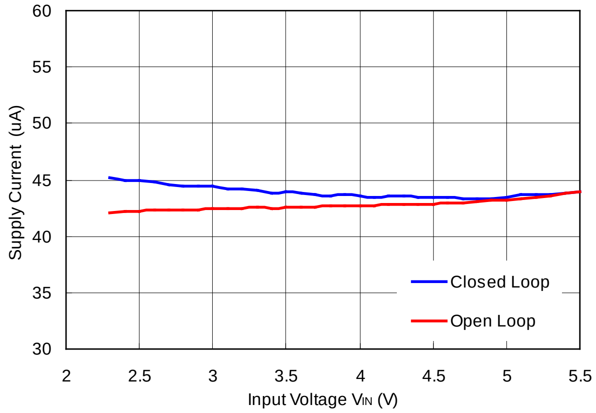
RP550L001B V_{OUT} = 3.3 V



5) Supply Current vs. Ambient Temperature
RP550L001B V_{OUT} = 1.8 V (V_{IN} = 5.5 V)
MODE = “L”, PWM/VFM Auto-Switching Control

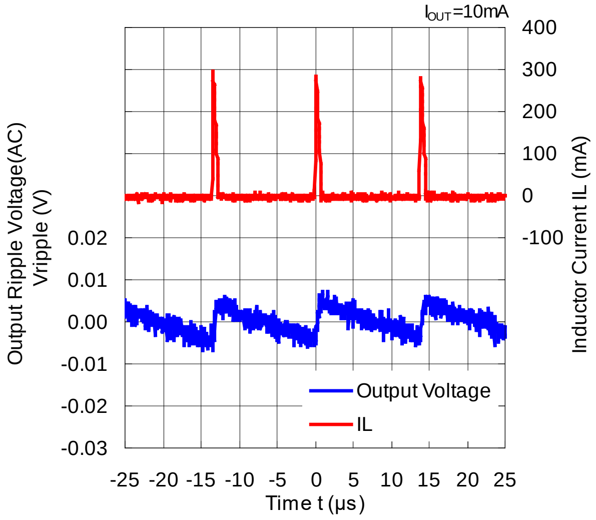


6) Supply Current vs. Input Voltage
RP550L001B V_{OUT} = 1.8 V
MODE = “L”, PWM/VFM Auto-Switching Control

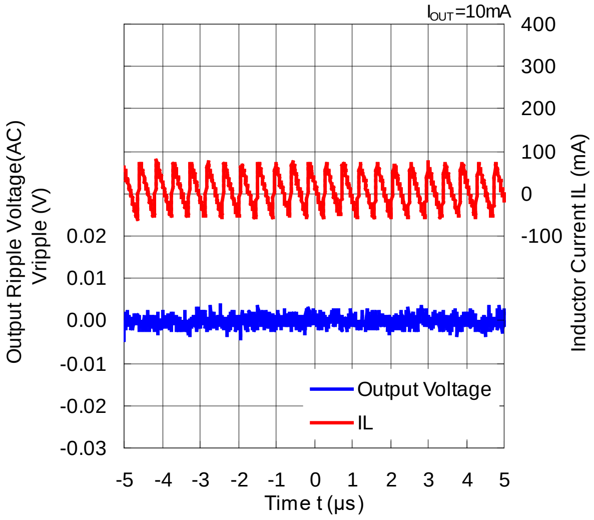


7) Output Voltage Waveform

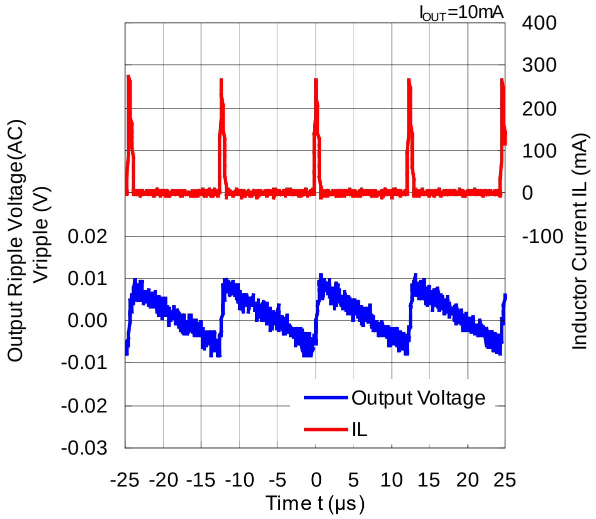
RP550L001B V_{OUT} = 0.6 V (V_{IN} = 3.6 V)
MODE = "L", PWM/VFM Auto-Switching Control



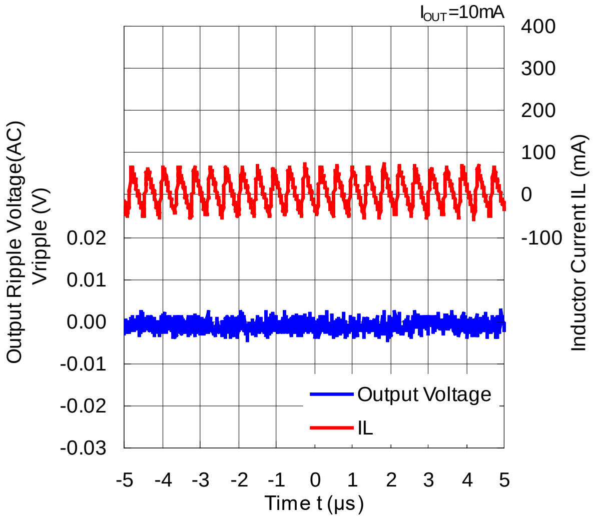
RP550L001B V_{OUT} = 0.6 V (V_{IN} = 3.6 V)
MODE = "H", Forced PWM Control



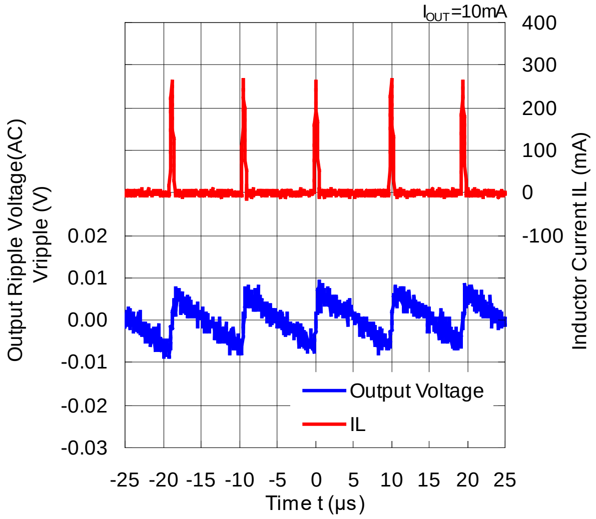
RP550L001B V_{OUT} = 0.8 V (V_{IN} = 3.6 V)
MODE = "L", PWM/VFM Auto-Switching Control



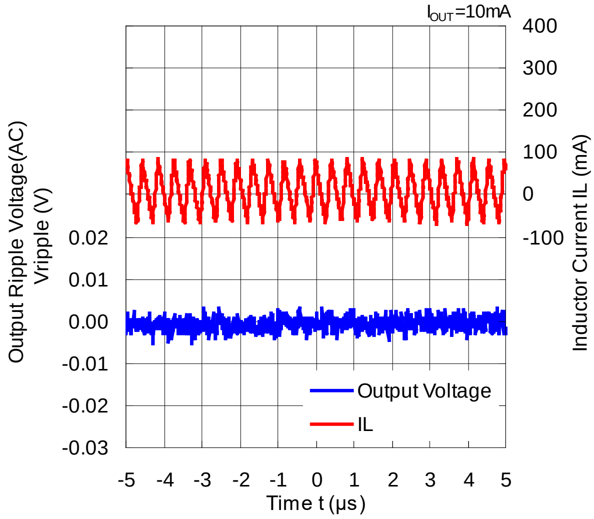
RP550L001B V_{OUT} = 0.8 V (V_{IN} = 3.6 V)
MODE = "H", Forced PWM Control



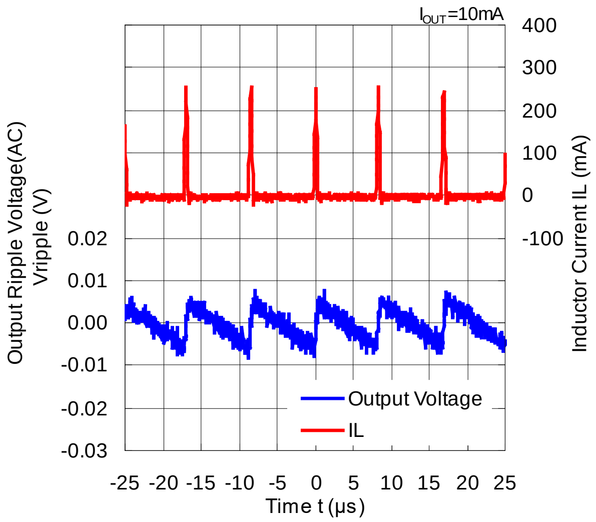
RP550L001B V_{OUT} = 1.2 V (V_{IN} = 3.6 V)
MODE = "L", Auto-Switching Control



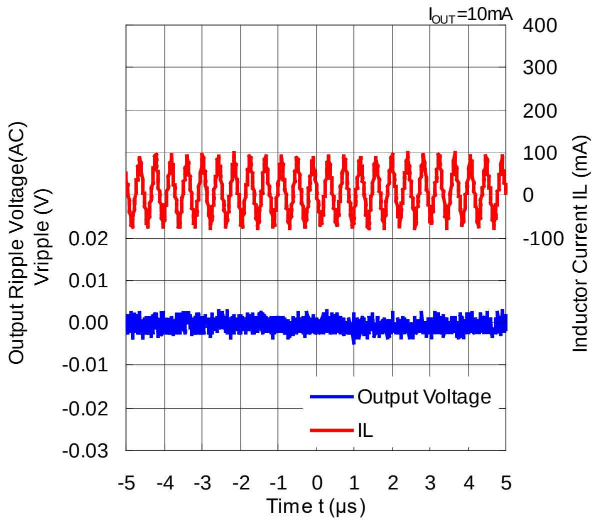
RP550L001B V_{OUT} = 1.2 V (V_{IN} = 3.6 V)
MODE = "H", Forced PWM Control



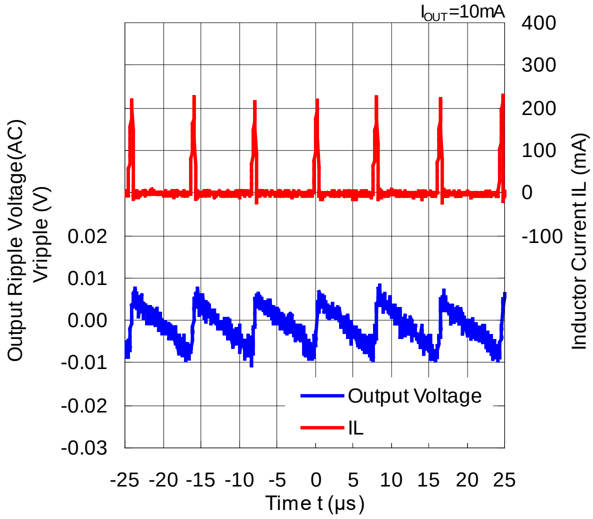
RP550L001B V_{OUT} = 1.8 V (V_{IN} = 3.6 V)
MODE = "L", PWM/VFM Auto-Switching Control



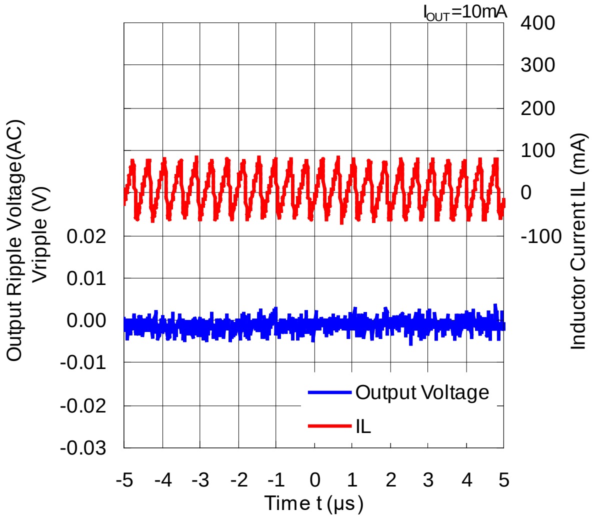
RP550L001B V_{OUT} = 1.8 V (V_{IN} = 3.6 V)
MODE = "H", Forced PWM Control



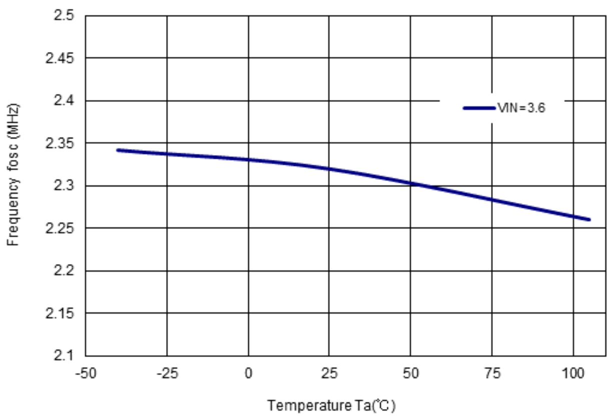
RP550L001B V_{OUT} = 3.3 V (V_{IN} = 4.3 V)
MODE = "L", PWM/VFM Auto-Switching Control



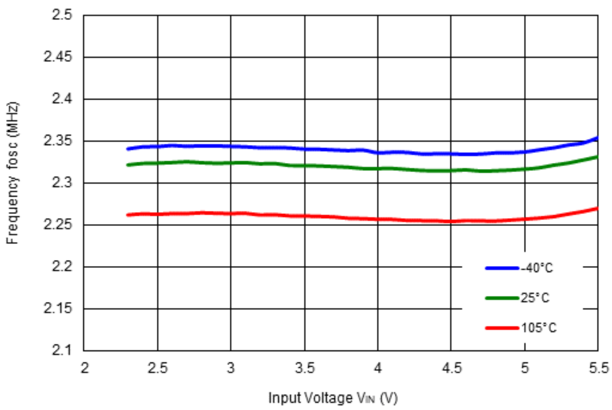
RP550L001B V_{OUT} = 3.3 V (V_{IN} = 4.3 V)
MODE = "H", Forced PWM Control



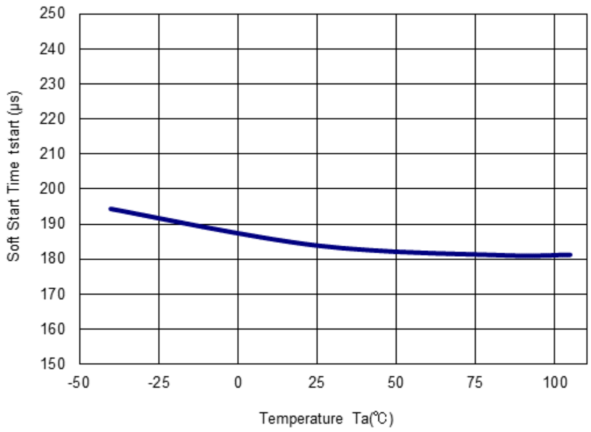
8) Oscillator Frequency vs. Ambient Temperature



9) Oscillator Frequency vs. Input Voltage

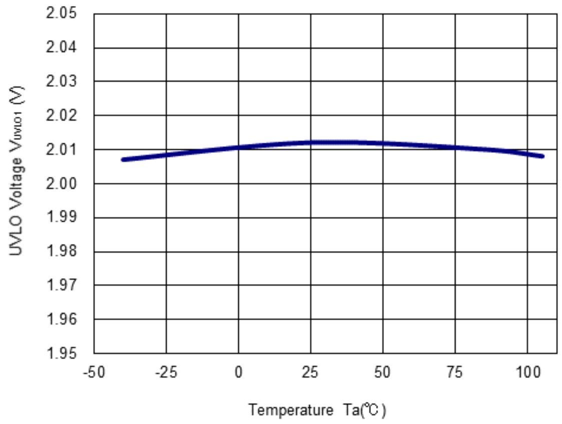


10) Soft-start Time vs. Ambient Temperature

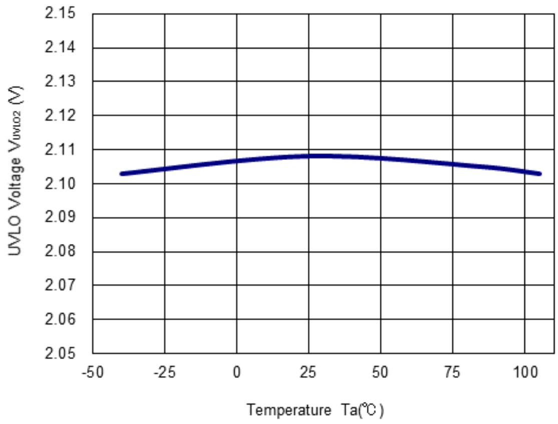


11) UVLO Detector/ Released Threshold vs. Ambient Temperature

UVLO Detector Threshold

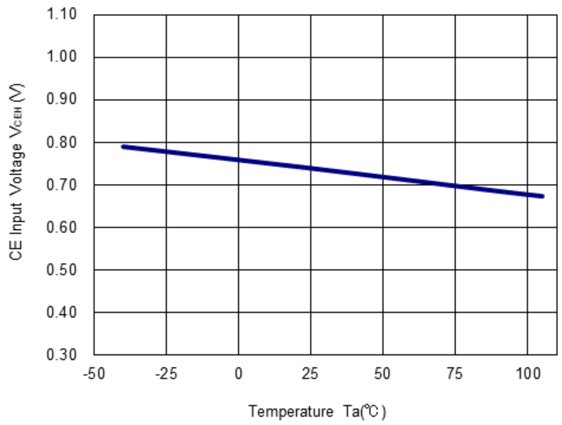


UVLO Released Threshold

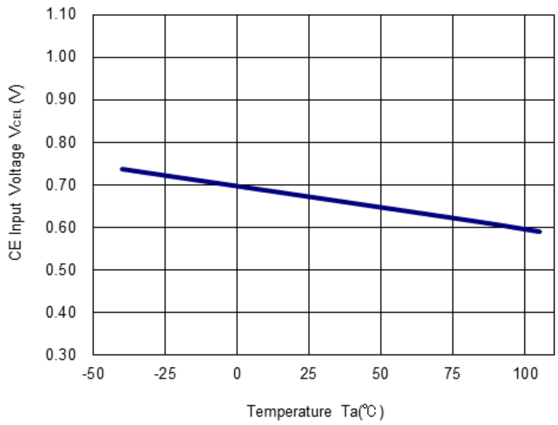


12) CE Input Voltage vs. Ambient Temperature

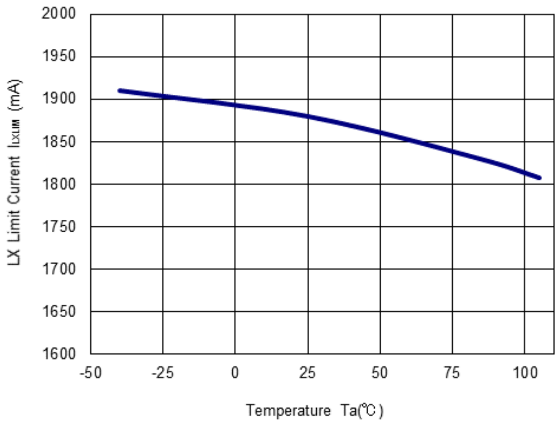
CE ”H” Input Voltage (V_{IN} = 5.5 V)



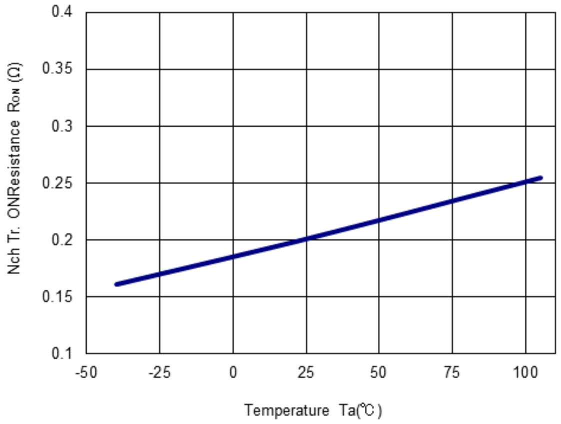
CE ”L” Input Voltage (V_{IN} = 2.3 V)



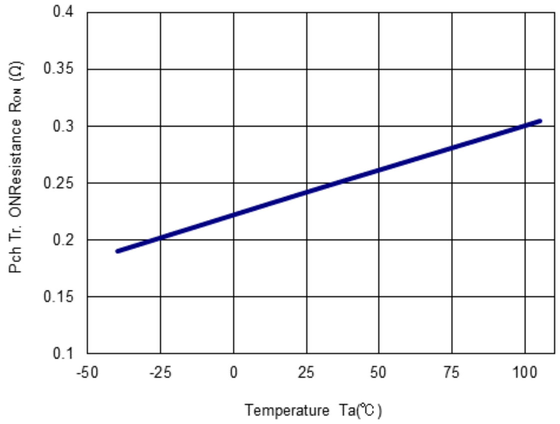
13) LX Limit Current vs. Ambient Temperature



14) Nch. Transistor ON Resistance vs. Ambient Temperature

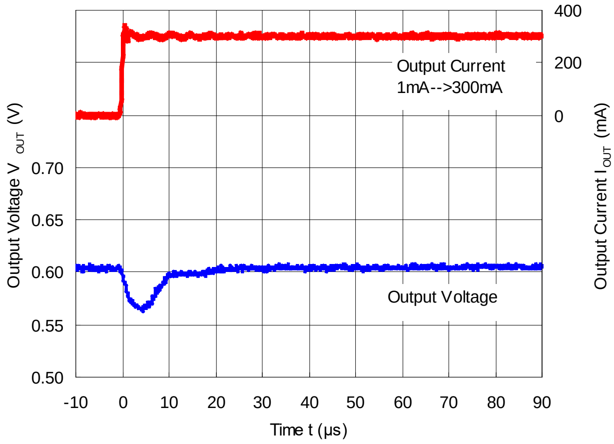


15) Pch. Transistor ON Resistance vs. Ambient Temperature

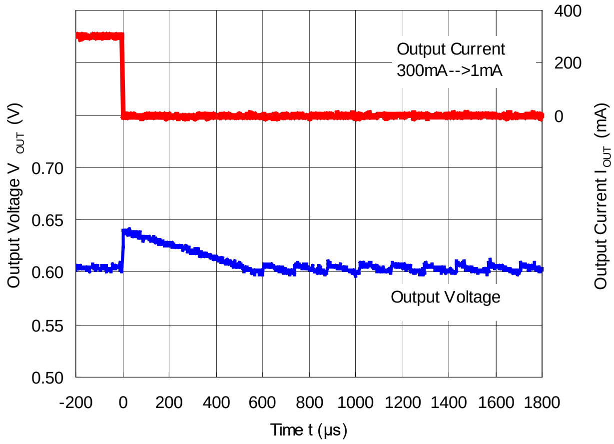


16) Load Transient Response

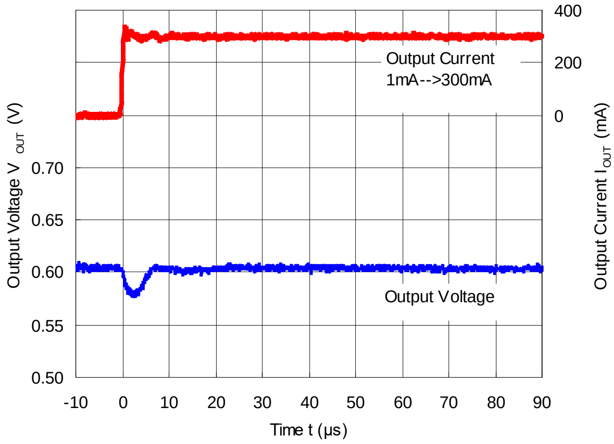
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.6 V)
MODE = "L", PWM/VFM Auto-Switching Control



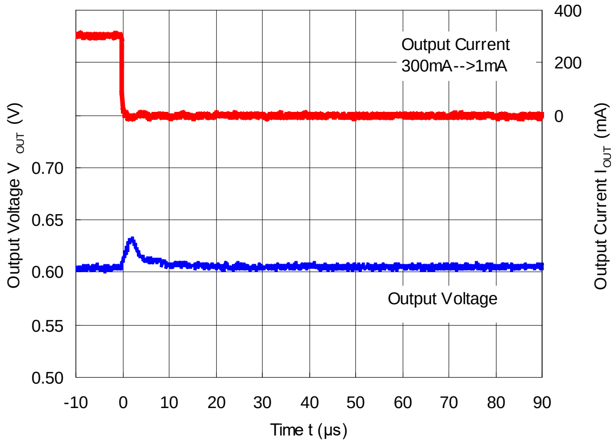
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.6 V)
MODE = "L", PWM/VFM Auto-Switching Control



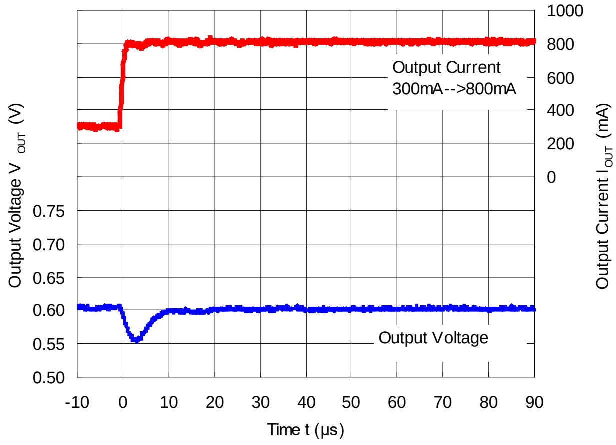
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.6 V)
MODE = "H", Forced PWM Control



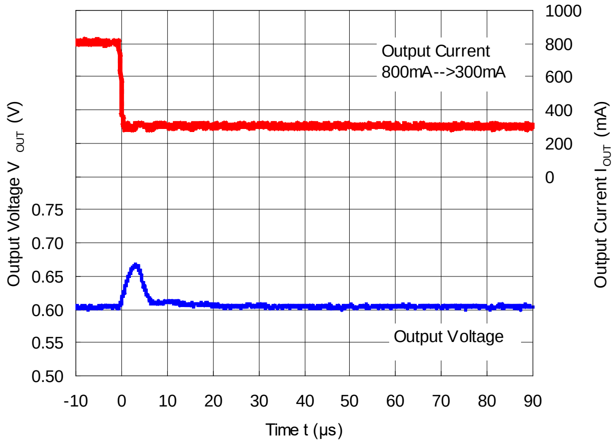
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.6 V)
MODE = "H", Forced PWM Control



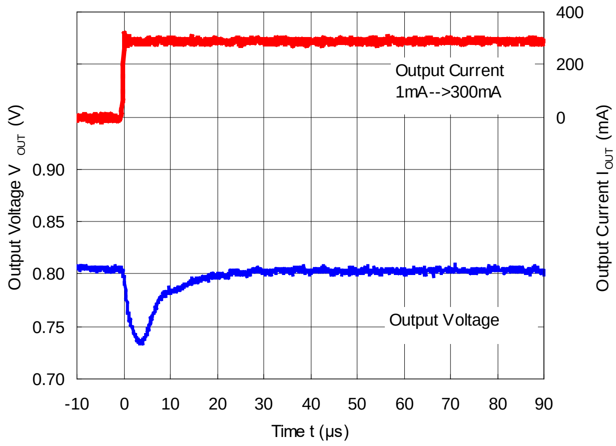
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.6 V)



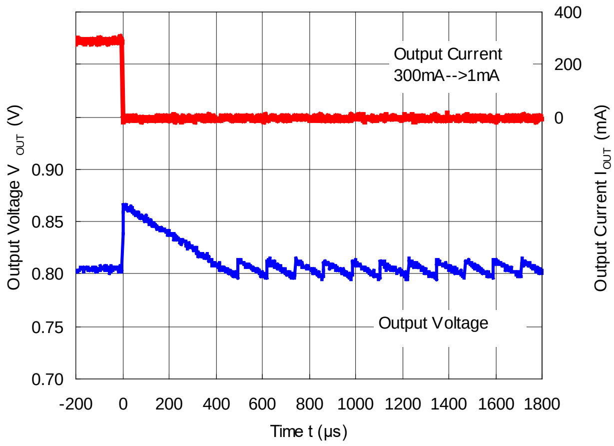
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.6 V)



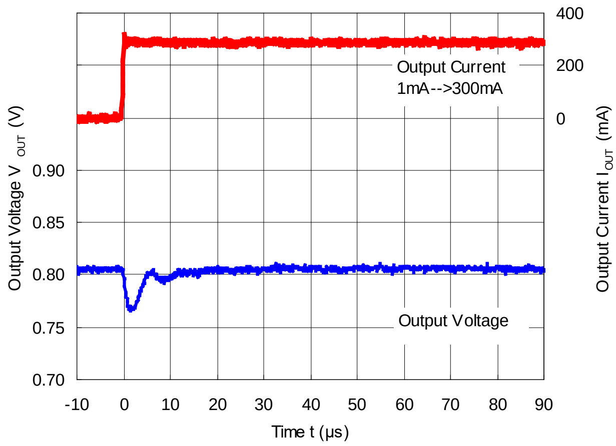
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
MODE = “L”, PWM/VFM Auto-Switching Control



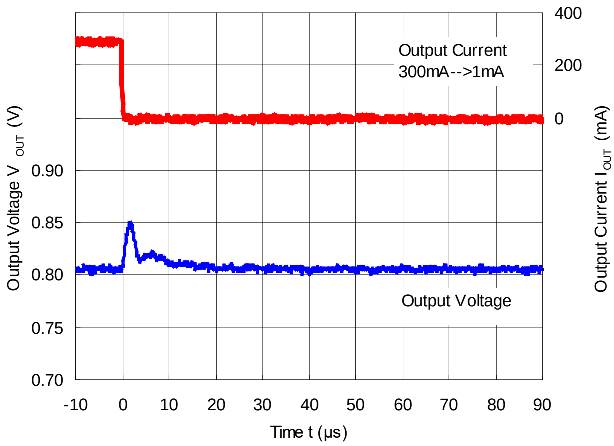
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
MODE = “L”, PWM/VFM Auto-Switching Control



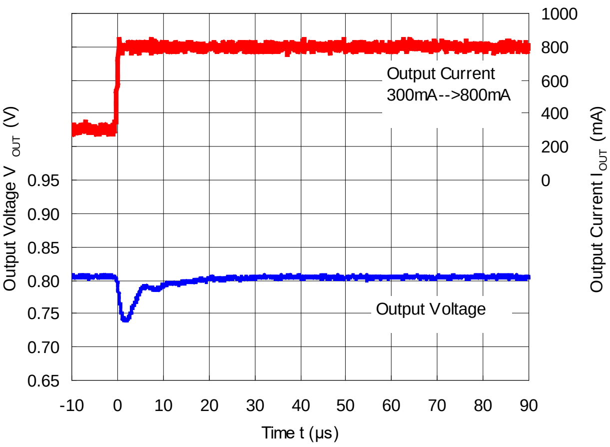
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
MODE = “H”, Forced PWM Control



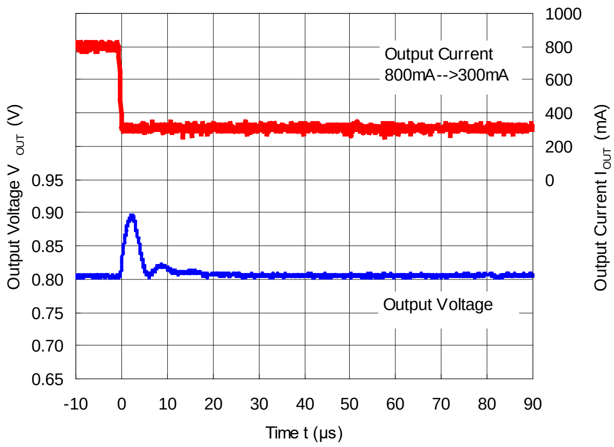
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
MODE = “H”, Forced PWM Control



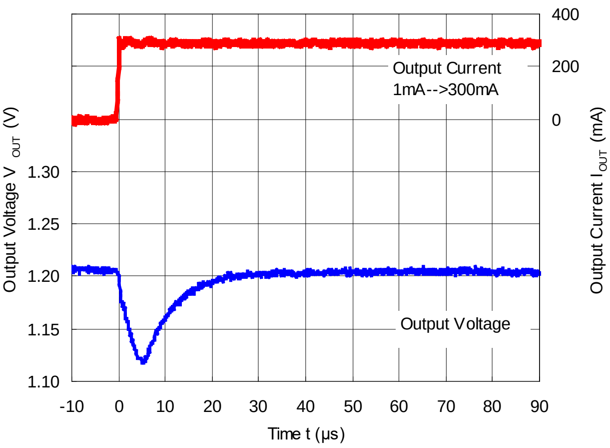
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)



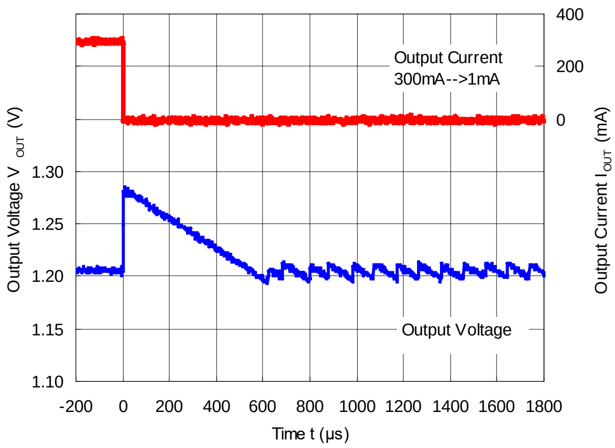
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)



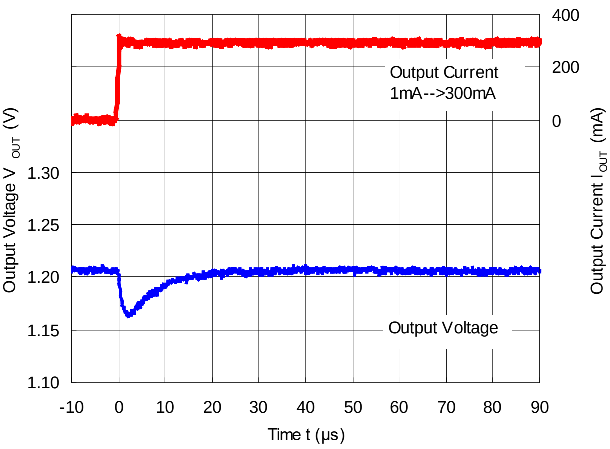
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
MODE = “L”, PWM/VFM Auto-Switching Control



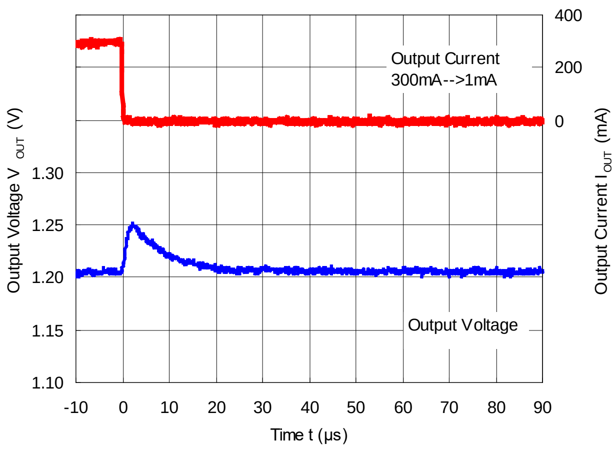
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
MODE = “L”, PWM/VFM Auto-Switching Control



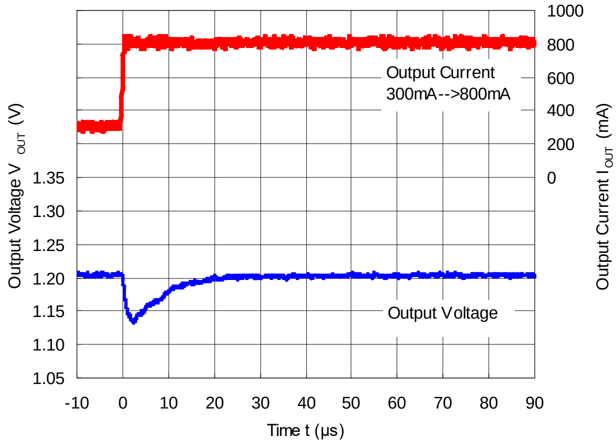
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
MODE = “H”, Forced PWM Control



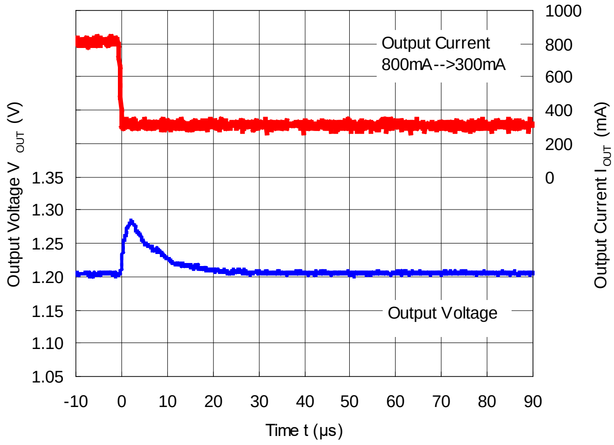
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
MODE = “H”, Forced PWM Control



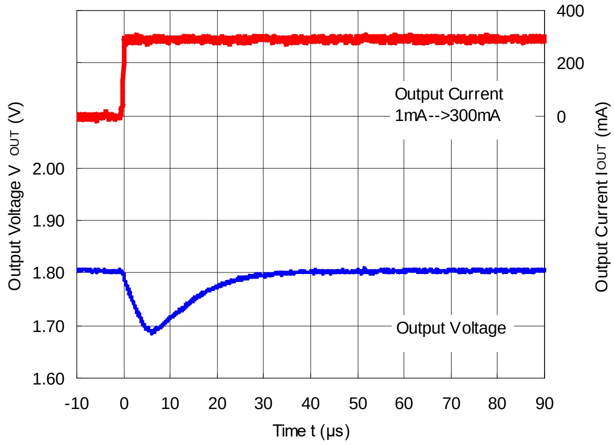
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)



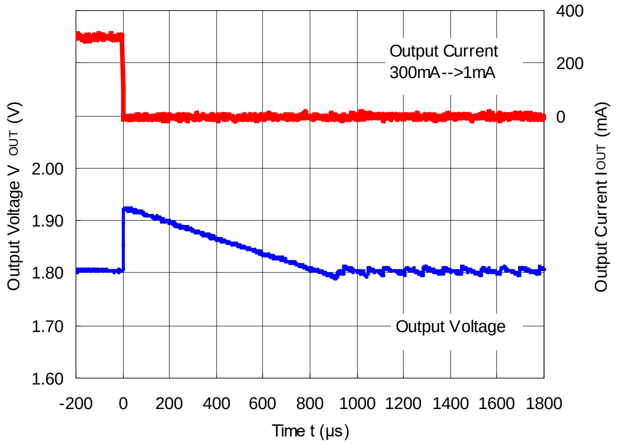
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)



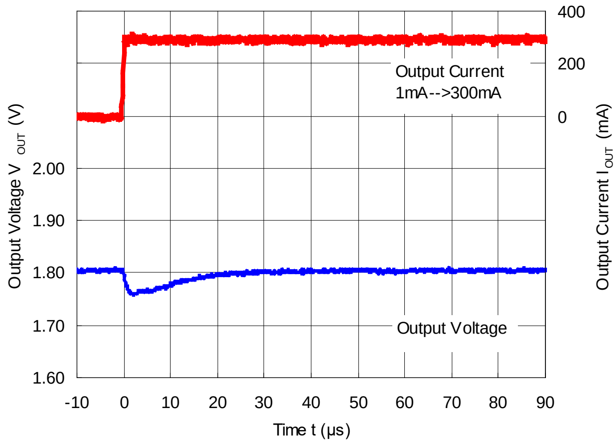
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
MODE = “L”, PWM/VFM Auto-Switching Control



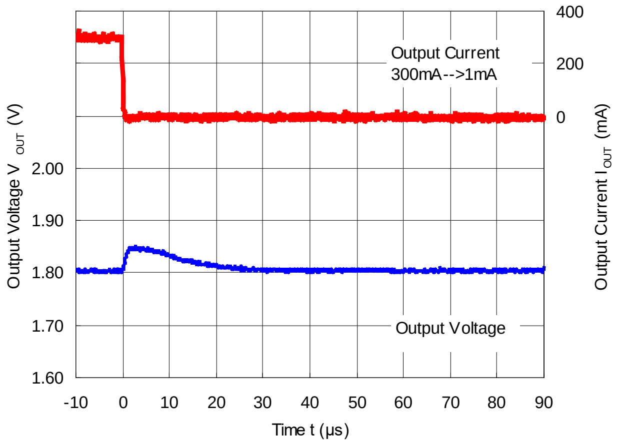
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
MODE = “L”, PWM/VFM Auto-Switching Control



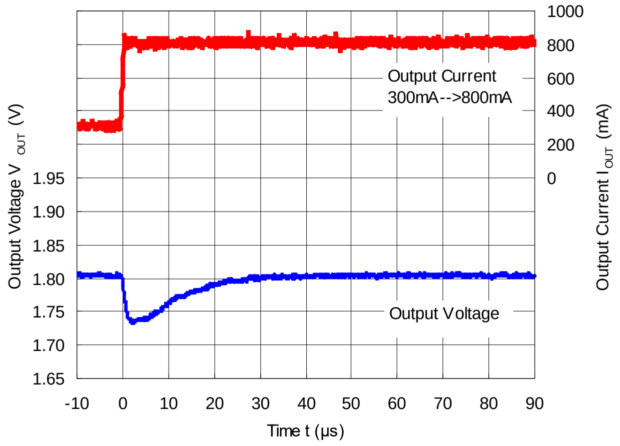
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
MODE = “H”, Forced PWM Control



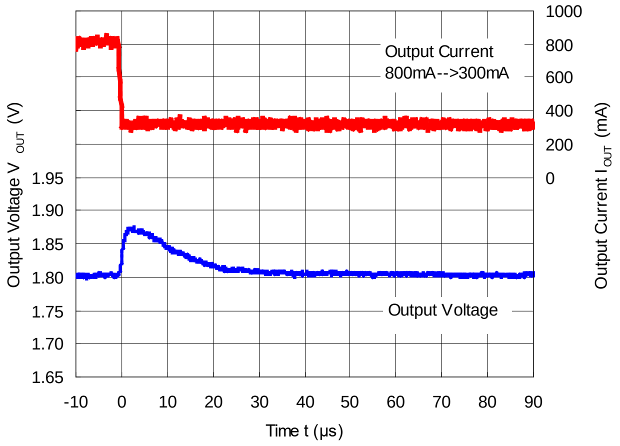
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
MODE = “H”, Forced PWM Control



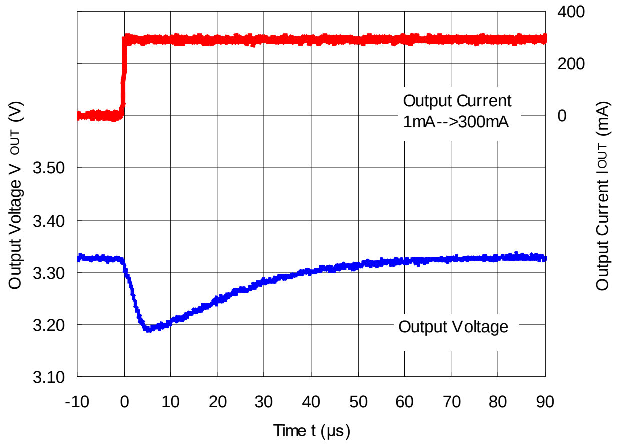
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)



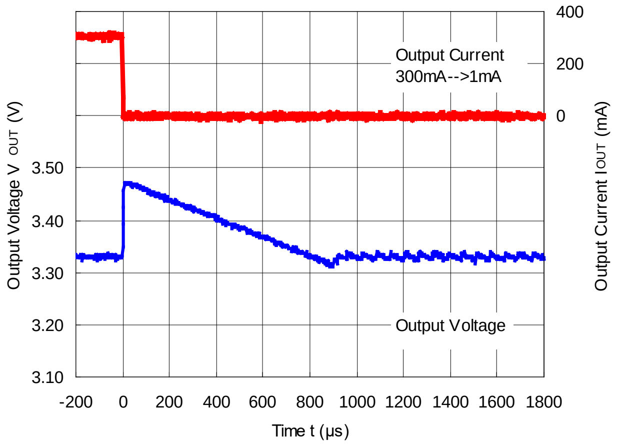
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)



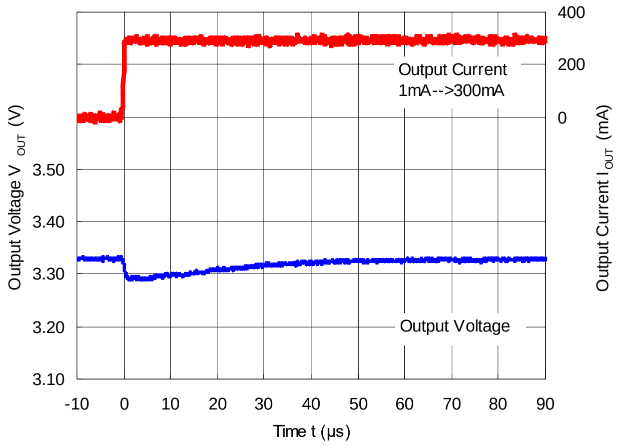
RP550L001B (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
MODE = “L”, PWM/VFM Auto-Switching Control



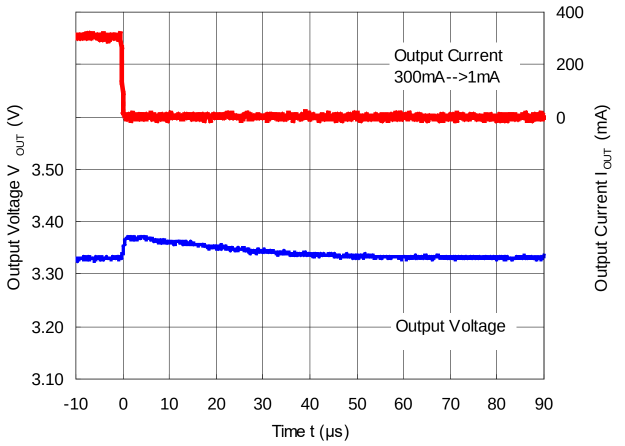
RP550L001B (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
MODE = “L”, PWM/VFM Auto-Switching Control



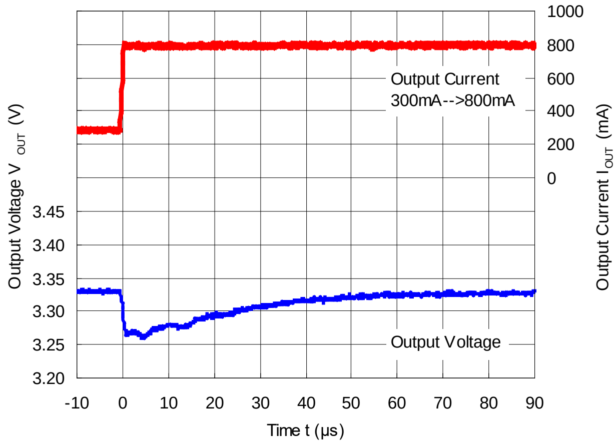
RP550L001B (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
MODE = “H”, Forced PWM Control



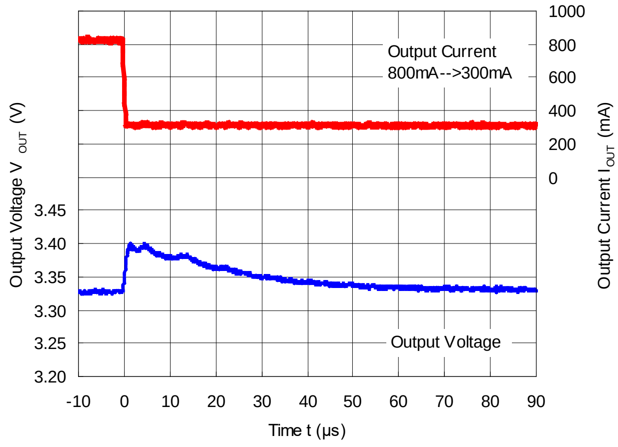
RP550L001B (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
MODE = “H”, Forced PWM Control



RP550L001B (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)

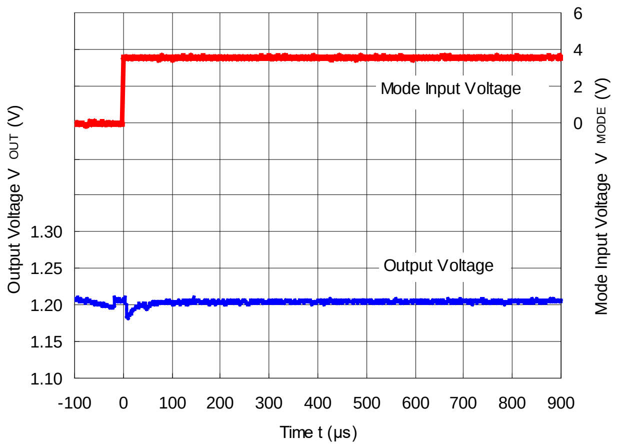


RP550L001B (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)

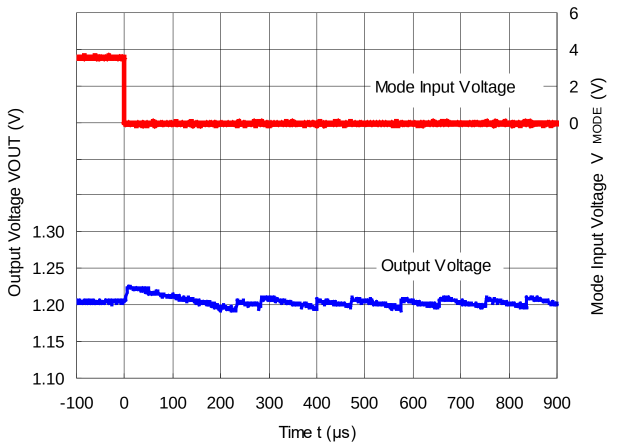


17) Mode Switching

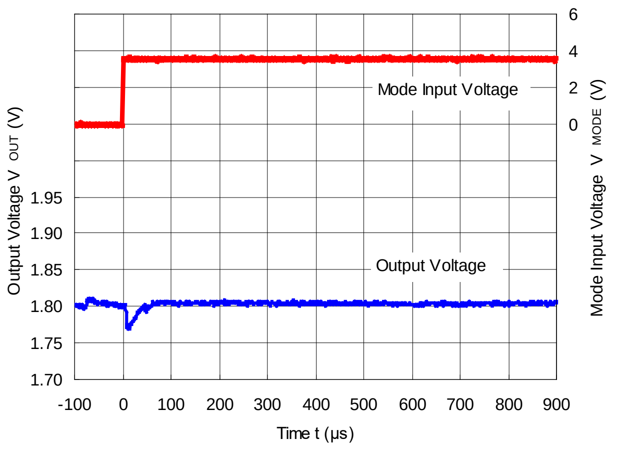
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.2 V, I_{OUT} = 1 mA)
MODE = “L” → MODE = “H”



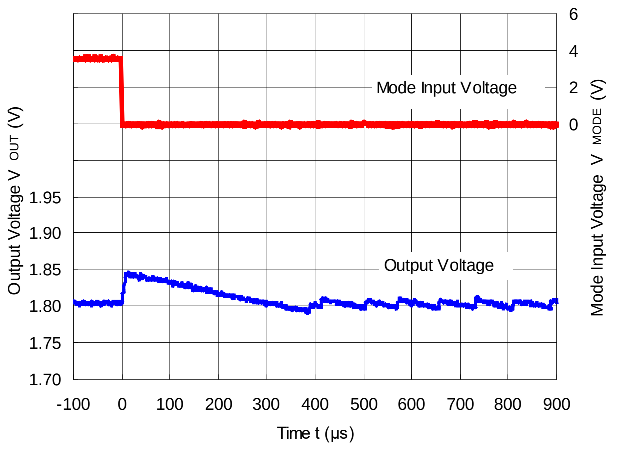
RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.2 V, I_{OUT} = 1 mA)
MODE = “H” → MODE = “L”



RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.8 V, I_{OUT} = 1 mA)
MODE = “L” → MODE = “H”



RP550L001B (V_{IN} = 3.6 V, V_{OUT} = 1.8 V, I_{OUT} = 1 mA)
MODE = “H” → MODE = “L”



Ver. A

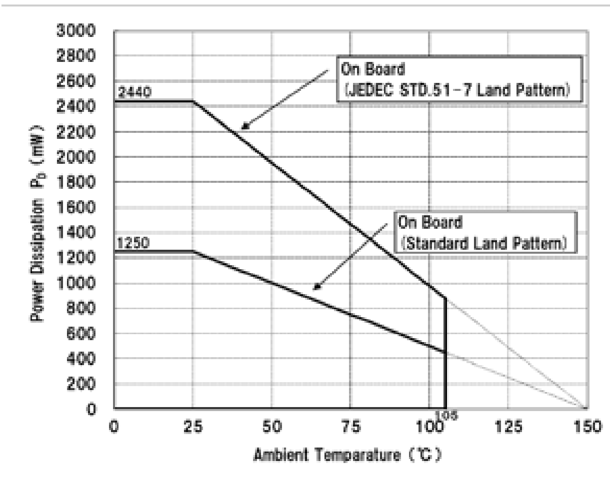
The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following conditions are used in this measurement.

Measurement Conditions

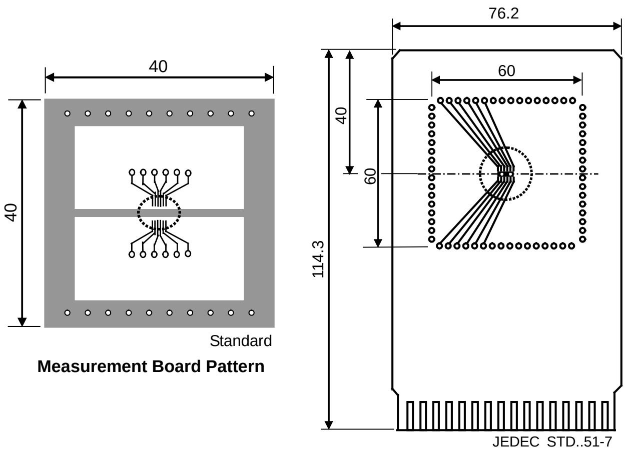
	Standard Test Land Pattern	JEDEC STD.51-7 Test Land Pattern
Environment	Mounting on Board (Wind Velocity=0m/s)	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass cloth epoxy plastic (Double sided)	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	40mm x 40mm x 1.6mm	76.2 mm × 114.3 mm × 1.6 mm
Copper Ratio	Top side: Approx. 50%, Back side: Approx. 50%	Outer Layers (First and Fourth Layers): Less than 10% of 60 mm Square Inner Layers (Second and Third Layers): 100% of 74.2 mm Square
Through-holes	f 0.54mm x 32pcs	f 0.85 mm × 64 pcs * The land pattern of Tab (Heat spreader), the inner layers and the backside pattern are connected by 0.3mm through-hole.

Measurement Result (Ta = 25°C, Tjmax = 150°C)

	Standard Test Land Pattern	JEDEC STD.51-7 Test Land Pattern
Power Dissipation	1250mW	2440 mW
Thermal Resistance	qja = (150-25°C)/1.25W = 100°C/W qjc = 18°C/W	qja = (150 − 25°C) / 2.44 W = 51.2°C/W qjc = 5.9°C/W



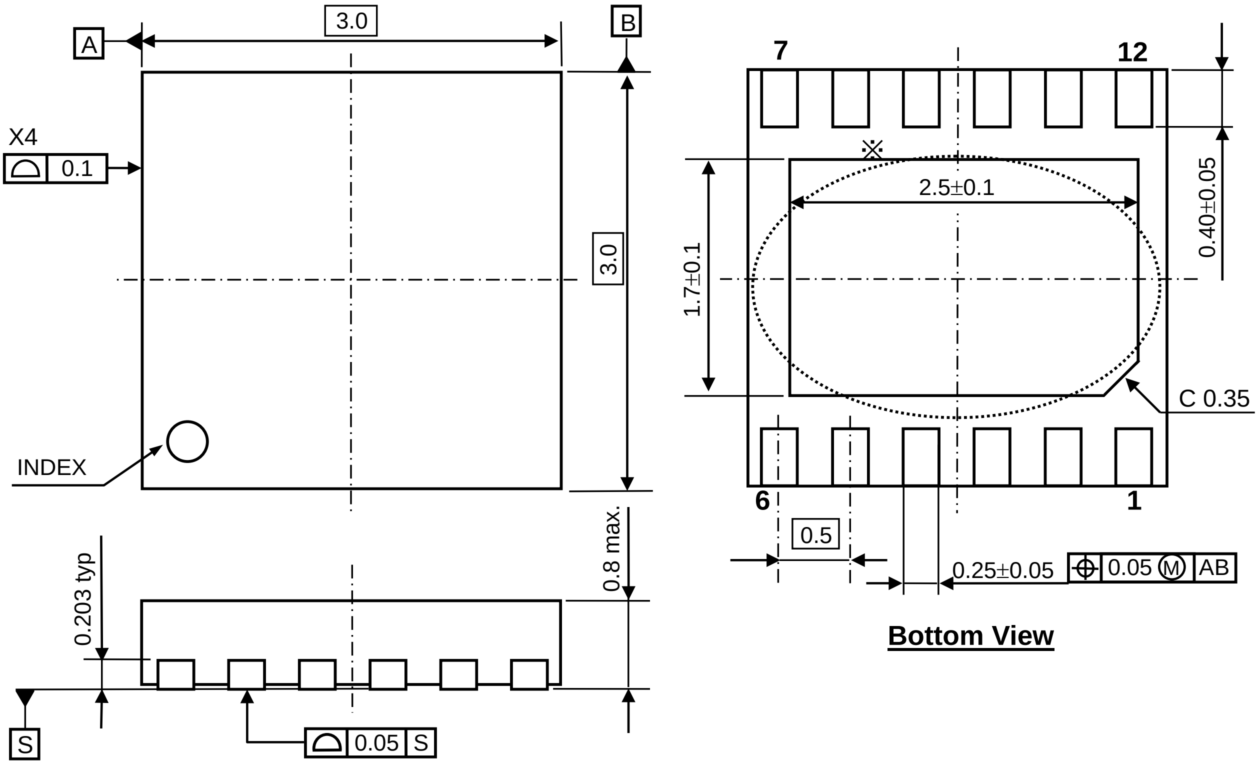
Power Dissipation vs. Ambient Temperature



IC Mount Area (mm)

Measurement Board Pattern

Ver. A



DFN3030-12 Package Dimensions (Unit: mm)

∗ 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, or otherwise be left floating.

1. The products and the product specifications described in this document are subject to change or discontinuation of production without notice for reasons such as improvement. Therefore, before deciding to use the products, please refer to our sales representatives for the latest information thereon.
2. The materials in this document may not be copied or otherwise reproduced in whole or in part without prior written consent of our company.
3. Please be sure to take any necessary formalities under relevant laws or regulations before exporting or otherwise taking out of your country the products or the technical information described herein.
4. The technical information described in this document shows typical characteristics of and example application circuits for the products. The release of such information is not to be construed as a warranty of or a grant of license under our company's or any third party's intellectual property rights or any other rights.
5. The products listed in this document are intended and designed for use as general electronic components in standard applications (office equipment, telecommunication equipment, measuring instruments, consumer electronic products, amusement equipment etc.). Those customers intending to use a product in an application requiring extreme quality and reliability, for example, in a highly specific application where the failure or misoperation of the product could result in human injury or death (aircraft, spacevehicle, nuclear reactor control system, traffic control system, automotive and transportation equipment, combustion equipment, safety devices, life support system etc.) should first contact us.
6. We are making our continuous effort to improve the quality and reliability of our products, but semiconductor products are likely to fail with certain probability. In order to prevent any injury to persons or damages to property resulting from such failure, customers should be careful enough to incorporate safety measures in their design, such as redundancy feature, fire containment feature and fail-safe feature. We do not assume any liability or responsibility for any loss or damage arising from misuse or inappropriate use of the products.
7. Anti-radiation design is not implemented in the products described in this document.
8. The X-ray exposure can influence functions and characteristics of the products. Confirm the product functions and characteristics in the evaluation stage.
9. WLCSP products should be used in light shielded environments. The light exposure can influence functions and characteristics of the products under operation or storage.
10. There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact our sales or our distributor before attempting to use AOI.
11. Please contact our sales representatives should you have any questions or comments concerning the products or the technical information.

NISSHINBO

Nisshinbo Micro Devices Inc.

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

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