NISSHINBO

RP508K Series

600 mA 6 MHz Synchronous Step-down DC/DC Converter

NO. EA-318-171106

OUTLINE

The RP508K is a low supply current PWM/VFM step-down DC/DC converter with synchronous rectifier featuring 600 mA[(1)] output current. Internally, a single converter consists of an oscillator, a reference voltage unit, an error amplifier, a switching control circuit, a mode control circuit, a soft-start circuit, an under-voltage lockout (UVLO) circuit, an over current protection circuit, a thermal shutdown circuit and switching transistors. By the adoption of the synchronous rectification circuit with built-in switching transistors, the RP508K works as efficient step-down DC/DC converter, without connecting external diodes. Using synchronous rectification not only increases circuit performance but also allows a design to reduce parts count.

Power controlling method can be selected from forced PWM control type or PWM/VFM auto switching control type by inputting a signal to the MODE pin. In low output current, forced PWM control switches at fixed frequency rate in order to reduce noise. Likewise, in low output current, PWM/VFM auto switching control automatically switches from PWM mode to VFM mode in order to achieve high efficiency.

Output voltage is internally fixed type which allows output voltages that range from 0.8 V to 3.3 V in 0.1 V step. The output voltage accuracy is as high as ±1.5% or ±18 mV.

Protection circuits included in the RP508K are over current protection circuit and thermal shutdown circuit. Over current protection circuit supervises the inductor peak current in each switching cycle, and if the current exceeds the L_X current limit (I_{LXLIM}), it turns off P-channel Tr. Thermal shutdown circuit detects overheating of the converter if the output pin is shorted to the ground pin (GND) etc. and stops the converter operation to protect it from damage if the junction temperature exceeds the specified temperature.

The RP508K is offered in a small and thin 6-pin DFN(PLP)1212-6F package which achieves the smallest possible footprint solution on boards where area is limited.

For an input capacitor (C_{IN}) and an output capacitor (C_{OUT}), the smaller sized 0402/1005 (inch/mm) capacitor can be used. For an inductor (L), the smaller sized 0603/1608 or 1005/2012 (inch/mm) inductor can be used.

FEATURES

- Input Voltage Range (V_{IN}) ······ 2.3 V to 5.5 V (Absolute Maximum Ratings: 6.5 V)
- Output Voltage Range (V_{OUT}) ······ 0.8 V to 3.3 V (Adjustable in 0.1 V steps)
- Supply Current (I_{DD2}) ······ Typ. 15 µA (VFM Mode with No-load)
- Standby Current (Istandby) ······ Typ. 0 µA
- Output Voltage Temperature Coefficient ($\Delta V_{OUT}/Ta$) ······ Typ. ±100 ppm/°C
- Oscillator Frequency (fosc) ······ Typ. 6.0 MHz
- Maximum Duty Cycle (Maxduty) ······ 100%
- Built-in Driver ON Resistance (R_{ONP}, R_{ONN}) ······ Typ. Pch. 0.33 Ω, Nch. 0.24 Ω (V_{IN} = 3.6 V)
- UVLO Detector Threshold (V_{UVLO01}) ······ Typ. 2.0 V
- Soft-start Time (tstart) ······ Typ. 90 µs

(1) This is an approximate value. The output current is dependent on conditions and external components.

- L_X Current Limit Circuit (I_{LXLIM})······························· Typ. 1.1 A
- Output Voltage Accuracy ···································· ±1.5% (V_{OUT} ≥ 1.2 V) or ±18 mV (V_{OUT} < 1.2 V)
- Package ·· DFN(PLP)1212-6F

APPLICATIONS

- Cellular Phones
- Smartphones
- Digital Still Camera
- Notebook PCs, PDA's
- Li-ion Battery-used Equipment

SELECTION GUIDE

The set output voltage and the auto discharge[(1)] function are user-selectable options.

Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
RP508Kxx1$-TR	DFN(PLP)1212-6F	5,000 pcs	Yes	Yes

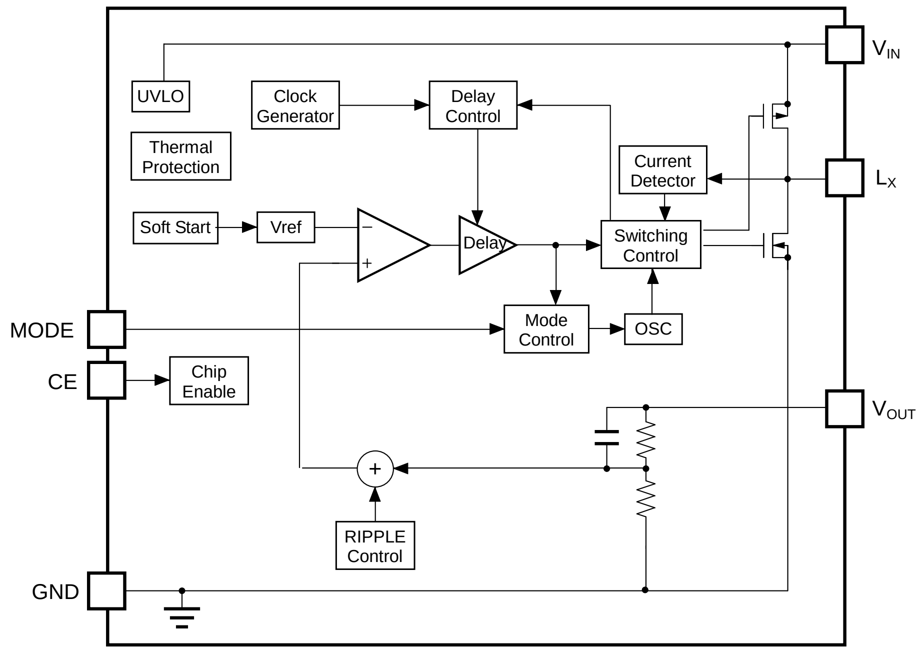
xx: Specify the set output voltage (V_{SET}) within the range of 0.8 V (08) to 3.3 V (33) in 0.1 V steps[(2)].

If the set output voltage includes the 3rd digit, indicate the digit of 0.01.
(1.05 V, 1.25 V, 1.35 V)
Ex. If the set output voltage is 1.05 V: RP508K101$5
If the set output voltage is 1.25 V: RP508K121$5
If the set output voltage is 1.35 V: RP508K131$5

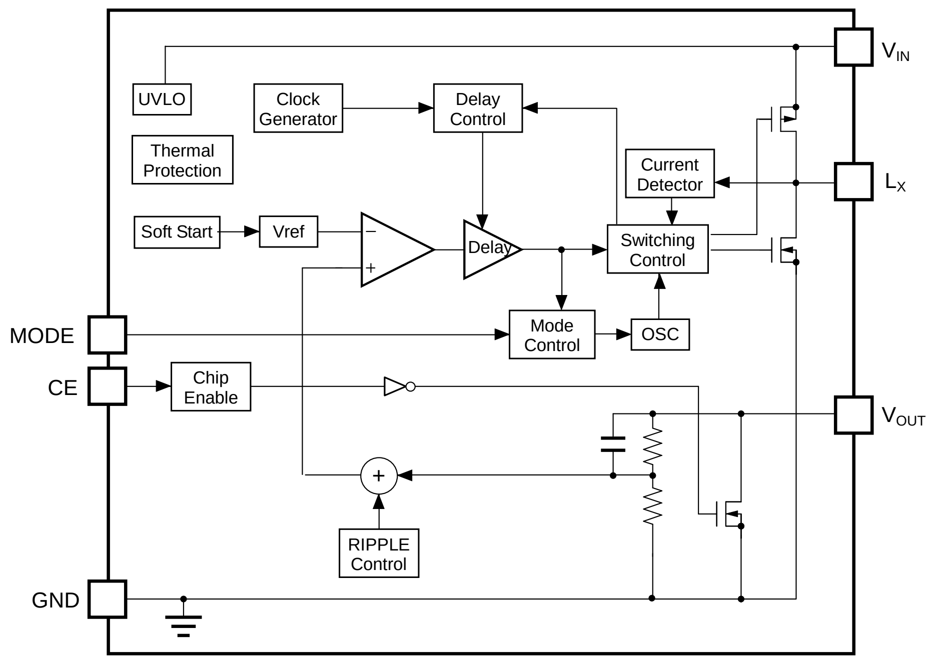
$: Specify the auto-discharge option.
A: Fixed output voltage type
B: Fixed output voltage type, auto-discharge function in shutdown mode

(1) Auto-discharge function quickly lowers the output voltage to 0 V, when the chip enable signal is switched from the active mode to the standby mode, by releasing the electrical charge accumulated in the external capacitor.
(2) 0.05 V step is also available as a custom code.

BLOCK DIAGRAM

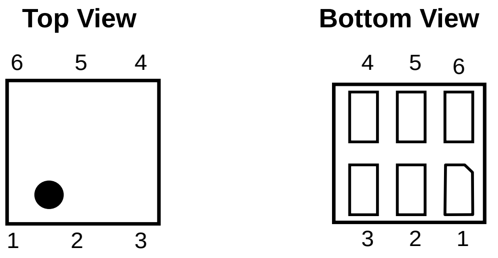


RP508Kxx1A Block Diagram



RP508Kxx1B Block Diagram

PIN DESCRIPTION



DFN(PLP)1212-6F Pin Configurations

Pin Description

Pin No.	Symbol	Pin Description
1	VOUT	Output Pin
2	MODE	Mode Control Pin (“H” forced PWM control, “L” PWM/VFM auto switching control)
3	CE	Chip Enable Pin ("H" active)
4	VIN	Input Pin
5	LX	LX Switching Pin
6	GND	Ground Pin

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings

Symbol	Item	Rating	Unit
V_{IN}	V_{IN} Input Voltage	−0.3 to 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 6.5	V
V_{MODE}	MODE Pin Input Voltage	−0.3 to 6.5	V
V_{OUT}	V_{OUT} Pin Voltage	−0.3 to 6.5	V
I_{LX}	L_X Pin Output Current	1300	mA
P_D	Power Dissipation(1) (JEDEC STD 51-7 Test Land Pattern)	666	mW
Tj	Junction Temperature Range	−40 to 125	°C
Tstg	Storage Temperature Range	−55 to 125	°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

Symbol	Item	Rating	Unit
V_{IN}	Input Voltage	2.3 to 5.5	V
Ta	Operating Temperature Range	−40 to 85	°C

RECOMMENDED OPERATING CONDITIONS

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

(1) Refer to *POWER DISSIPATION* for detailed information.

ELECTRICAL CHARACTERISTICS

RP508K Electrical Characteristics (Ta = 25°C)

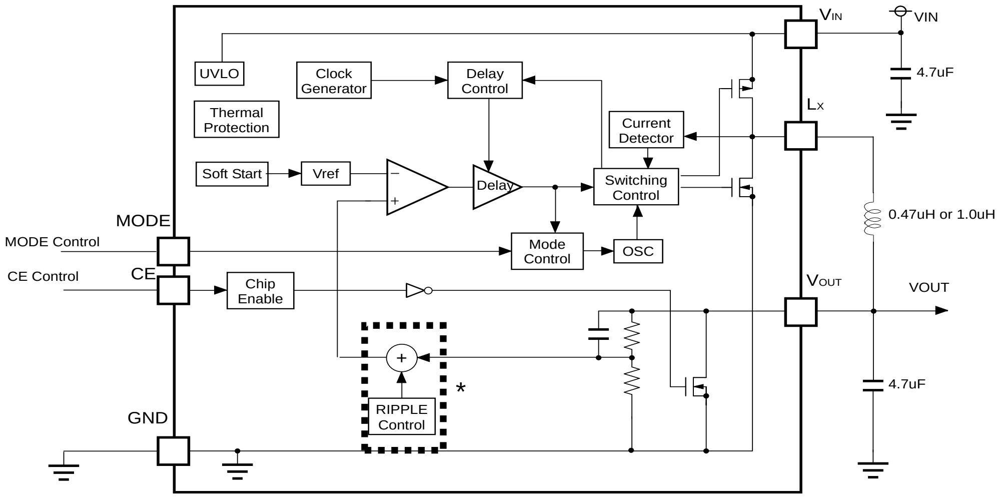
Symbol	Item	Conditions		Min.	Typ.	Max.	Unit
V_{OUT}	Output Voltage	$V_{IN} = V_{CE} = 3.6$ V	$V_{SET} \geq 1.2$ V	x0.985		x1.015	V
			$V_{SET} < 1.2$ V	−0.018		+0.018	V
fosc	Oscillator Frequency	$V_{IN} = V_{CE} = 3.6$ V ($V_{SET} \leq 2.6$ V), $V_{IN} = V_{CE} = V_{SET} + 1$ V ($V_{SET} > 2.6$ V)		5.4	6.0	6.6	MHz
I_{DD1}	Supply Current 1	$V_{IN} = V_{CE} = 5.5$ V, $V_{OUT} = V_{SET} \times 0.8$			1000	1300	µA
I_{DD2}	Supply Current 2	$V_{IN} = V_{CE} = V_{OUT}$ = 5.5 V	$V_{MODE} = 0$ V		15	25	µA
			$V_{MODE} = 5.5$ V		1000	1300	µA
Istandby	Standby Current	$V_{IN} = 5.5$ V, $V_{CE} = 0$ V			0	5	µA
I_{CEH}	CE "H" Input Current	$V_{IN} = V_{CE} = 5.5$ V		−1	0	1	µA
I_{CEL}	CE "L" Input Current	$V_{IN} = 5.5$ V, $V_{CE} = 0$ V		−1	0	1	µA
I_{MODEH}	Mode "H" Input Current	$V_{IN} = V_{MODE} = 5.5$ V, $V_{CE} = 0$ V		−1	0	1	µA
I_{MODEL}	Mode "L" Input Current	$V_{IN} = 5.5$ V, $V_{CE} = V_{MODE} = 0$ V		−1	0	1	µA
I_{VOUTH}	V_{OUT} "H" Input Current(1)	$V_{IN} = V_{OUT} = 5.5$ V, $V_{CE} = 0$ V		−1	0	1	µA
I_{VOUTL}	V_{OUT} "L" Input Current	$V_{IN} = 5.5$ V, $V_{CE} = V_{OUT} = 0$ V		−1	0	1	µA
R_{LOW}	On Resistance for Auto Discharge(2)	$V_{IN} = 3.6$ V, $V_{CE} = 0$ V			30		Ω
$I_{LXLEAKH}$	L_X Leakage Current "H"	$V_{IN} = V_{LX} = 5.5$ V, $V_{CE} = 0$ V		−1	0	5	µA
$I_{LXLEAKL}$	L_X Leakage Current "L"	$V_{IN} = 5.5$ V, $V_{CE} = V_{LX} = 0$ V		−5	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 "H" Input Voltage	$V_{IN} = V_{CE} = 5.5$ V		1.0			V
V_{MODEL}	Mode "L" Input Voltage	$V_{IN} = V_{CE} = 2.3$ V				0.4	V
R_{ONP}	On Resistance of Pch Tr.	$V_{IN} = 3.6$ V, $I_{LX} = -100$ mA			0.33		Ω
R_{ONN}	On Resistance of Nch Tr.	$V_{IN} = 3.6$ V, $I_{LX} = -100$ mA			0.24		Ω
Maxduty	Maximum Duty Cycle			100			%
tstart	Soft-start Time	Soft-start Time is between the rising edge of CE pin and $V_{OUT} \geq V_{SET}$ x 0.9.			90	150	µs
I_{LXLIM}	L_X Current Limit			900	1100		mA
V_{UVLO1}	UVLO Detector Threshold	$V_{IN} = V_{CE}$		1.9	2.0	2.1	V
V_{UVLO2}	UVLO Released Voltage	$V_{IN} = V_{CE}$		2.0	2.1	2.2	V
T_{TSD}	Thermal Shutdown Temperature	Junction Temperature			140		°C
T_{TSR}	Thermal Shutdown Released Temperature	Junction Temperature			100		°C

All test items listed under ELECTRICAL CHARACTERISTICS are done under the pulse load condition (Tj ≈ Ta = 25°C) except Output Voltage Temperature Coefficient.

(1) RP508Kxx1A only
(2) RP508Kxx1B only

THEORY OF OPERATION

Fast Frequency and Fast Response

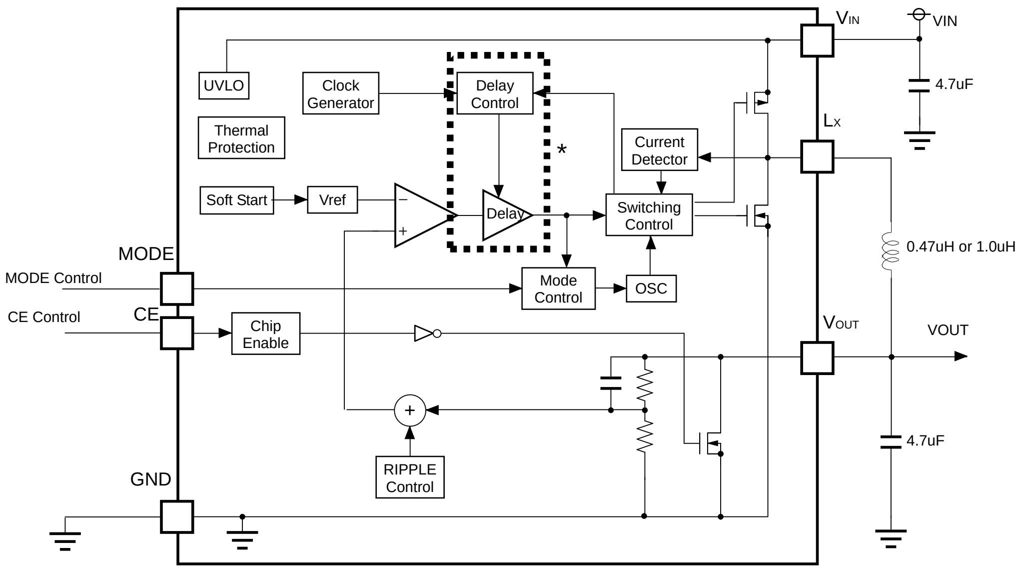


∗ Ripple is added and easy to detect and stabilize the system.

There are the following advantages when it operates at fast frequency (6 MHz).

- Inductance value can be reduced.
- The fluctuation of energy in one cycle is fast and small, as a result, the capacitance value of C_{OUT} can be also reduced.
- Small LC value reduced the feedback delay, then response frequency band can be wide and transient response is much improved compared with conventional line-up.

Maximum Frequency (6 MHz) Lock



∗ The frequency goes faster and faster without this.

Switching frequency in order to become reference frequency (6 MHz), delay time is included the output voltage feedback loop and locked the frequency (6 MHz).

Frequency Control for Minimum On/Off Time

Minimum on/off time/Minimum off time is set. (But 100% duty is available.) In the 6 MHz, based on the calculation of input/ output relation, on/off time can be calculated, and if it is not satisfy the minimum on time / minimum off time, the reference frequency must be reduced and switching frequency is reduced.

(Ex.) Min On Time (40 ns)

① V_{IN} = 3.6 V V_{OUT} = 1.0 V

1/6 MHz × 1.0 V / 3.6 V ≈ 46 ns > Min On Time (= 40 ns)

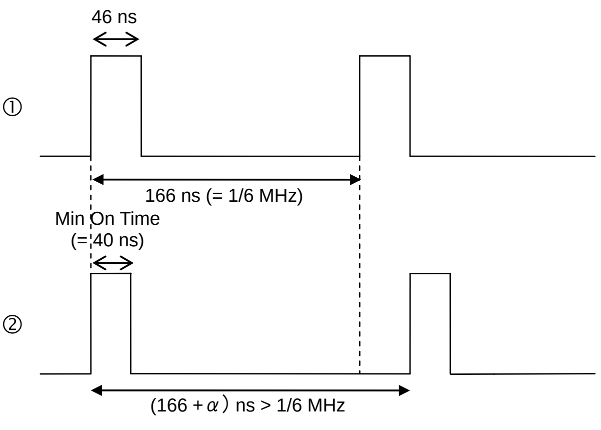
→6 MHz Switching OK

② V_{IN} =5.5V Vout=1.0V

1/6 MHz × 1.0 V / 5.5 V ≈ 30 ns < Min On Time (= 40 ns)

→It must be slow down from 6 MHz

LX Waveform



Cycle time becomes long in order to satisfy Min. on time. It is suitable with keeping the duty.

(Ex.) Min Off Time (40 ns)

① V_{IN} = 5.0 V V_{OUT} = 3.3 V

1/6 MHz × (1 - 3.3 V / 5.0 V) ≈ 57 ns > Min Off Time (= 40 ns)

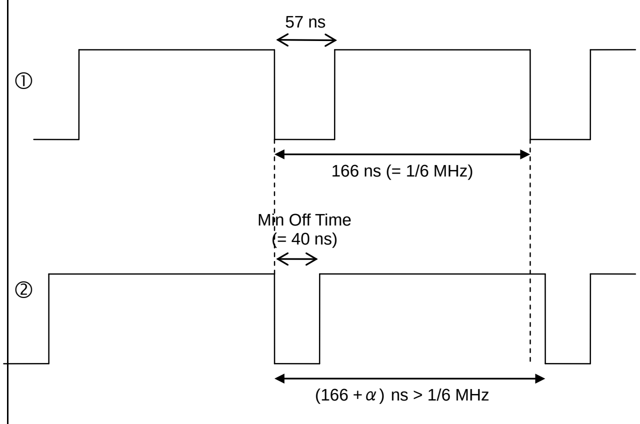
→6 MHz Switching OK

② V_{IN} =4.2 V V_{OUT} = 3.3 V

1/6 MHz × (1 - 3.3 V / 4.2 V) ≈ 36 ns < Min Off Time (= 40 ns)

→It must be slow down from 6 MHz

LX Waveform



Cycle time becomes long in order to satisfy Min. off time. It is suitable with keeping the duty.

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

The step-down DC/DC converter charges energy in the inductor when L_X Tr. turns “ON”, and discharges the energy from the inductor when L_X Tr. turns “OFF” and operates 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.

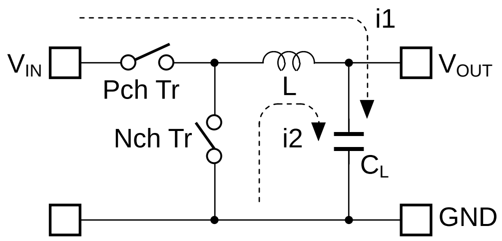


Figure 1. Basic Circuit

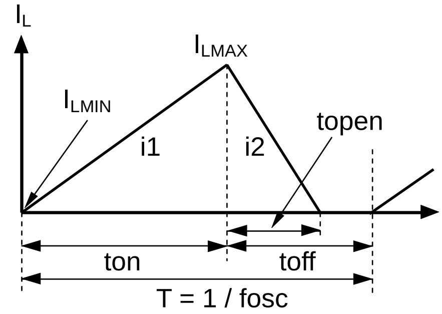


Figure 2. Inductor Current (I_L) flowing through Inductor

Step1. P-channel Tr. turns “ON” and the inductor current (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 (ton) of P-channel Tr.

Step2. When P-channel Tr. turns “OFF”, L tries to maintain I_L at I_{LMAX}, so L turns N-channel Tr. “ON” and the inductor current (I_L = i2) flows into L.

Step3. i2 decreases gradually and reaches I_{LMIN} after the open-time period (topen) of N-channel Tr., and then N-channel Tr. turns “OFF”. This is called discontinuous current mode.
As the output current (I_{OUT}) increases, the off-time period (toff) of P-channel Tr. runs out before I_L reaches I_{LMIN}. The next cycle starts, and P-channel Tr. turns “ON” and N-channel Tr. turns “OFF”, which means I_L starts increasing from I_{LMIN}. This is called continuous current mode.

In the case of PWM mode, V_{OUT} is maintained by controlling ton. During the PWM mode, the oscillator frequency (fosc) is constantly maintained.

As shown in Figure 2., when the step-down DC/DC operation is constant, I_{LMIN} and I_{LMAX} during ton of P-channel Tr. is same as the P-channel Tr. during toff.

The current differential between I_{LMAX} and I_{LMIN} is described as ΔI.

$$\Delta I = I_{LMAX} - I_{LMIN} = V_{OUT} \times topen / L = (V_{IN} - V_{OUT}) \times ton / L \cdots\cdots \text{Equation 1}$$

However,

$T = 1 / fosc = ton + toff$

$Duty (\%) = ton / T \times 100 = ton \times fosc \times 100$

$topen \leq toff$

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

Discontinuous Mode and Continuous Mode

As illustrated in Figure 3. when I_{OUT} is relatively small, topen < toff. In this case, the energy charged into L during ton will be completely discharged during toff, as a result, $I_{LMIN} = 0$. This is called discontinuous mode. When I_{OUT} is gradually increased, eventually topen = toff and when I_{OUT} is increased further, eventually I_{LMIN} > 0. This is called continuous mode.

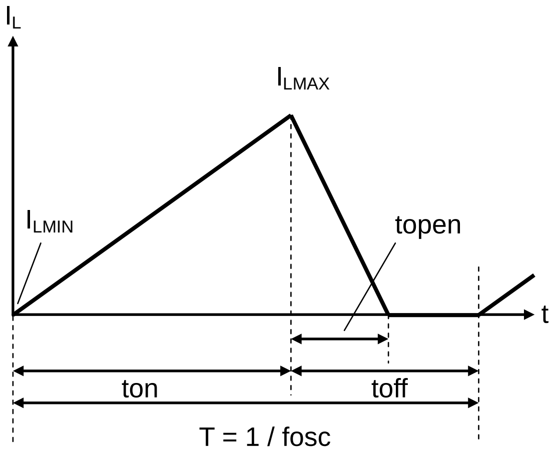


Figure 3. Discontinuous Mode

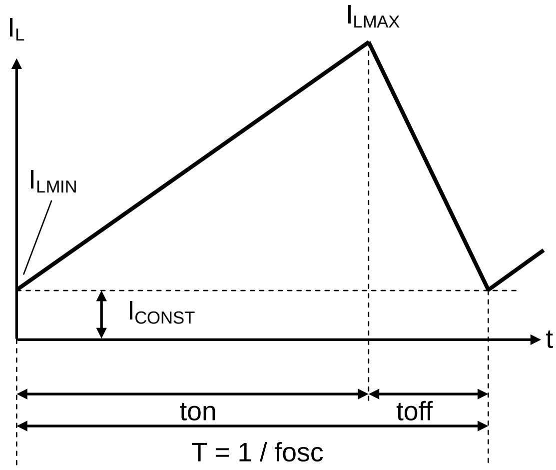


Figure 4. Continuous Mode

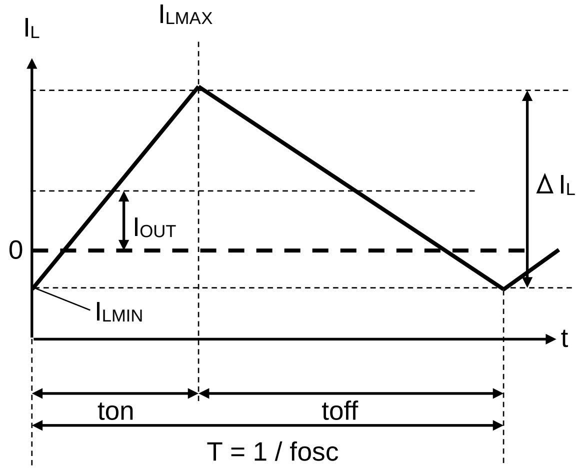
In the continuous mode, the solution of Equation 1 is described as tonc.

$$tonc = T \times V_{OUT} / V_{IN} \cdots\cdots \text{Equation 2}$$

When ton < tonc, it indicates discontinuous mode, and when ton ≥ tonc, it indicates continuous mode.

Forced PWM Mode

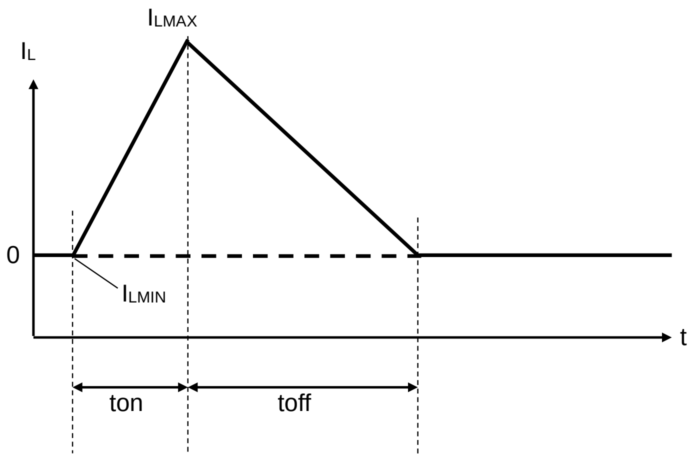
By setting the MODE pin to “H”, the RP508K switches on/off at the fixed frequency to reduce noise even under the light load. When IOUT is ∆IL / 2 or less, ILMIN becomes less than 0. That is, the accumulated electricity in CL is discharged through the IC side at IL increase period from ILMIN to "0" during ton and at IL decrease period from "0" to ILMIN during toff.



Forced PWM Mode

VFM MODE

By setting the MODE pin to “L”, in low output current, the IC automatically switches into VFM mode in order to achieve high efficiency. In VFM mode, a value of ton is determined by VIN and VOUT.



VFM Mode

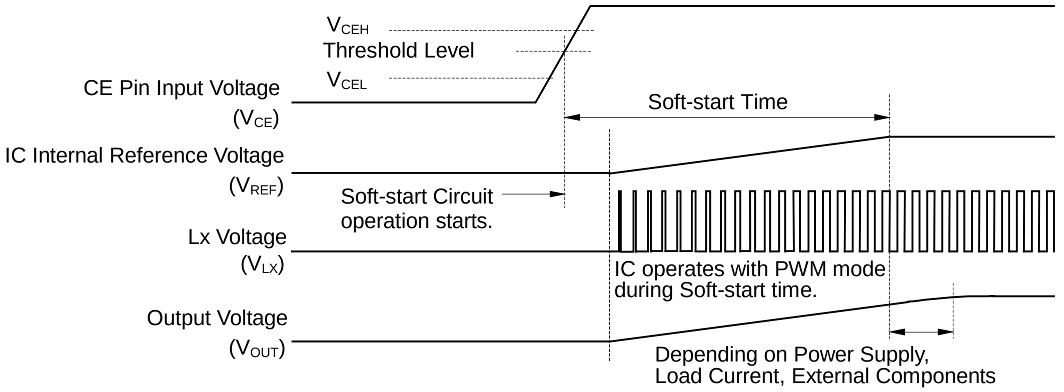
Timing Chart

1. Soft-Start Time

Starting-up with CE Pin

The IC starts to operate when the CE pin voltage (V_{CE}) exceeds the threshold voltage. The threshold voltage is preset between CE "H" input voltage (V_{CEH}) and CE "L" input voltage (V_{CEL}).

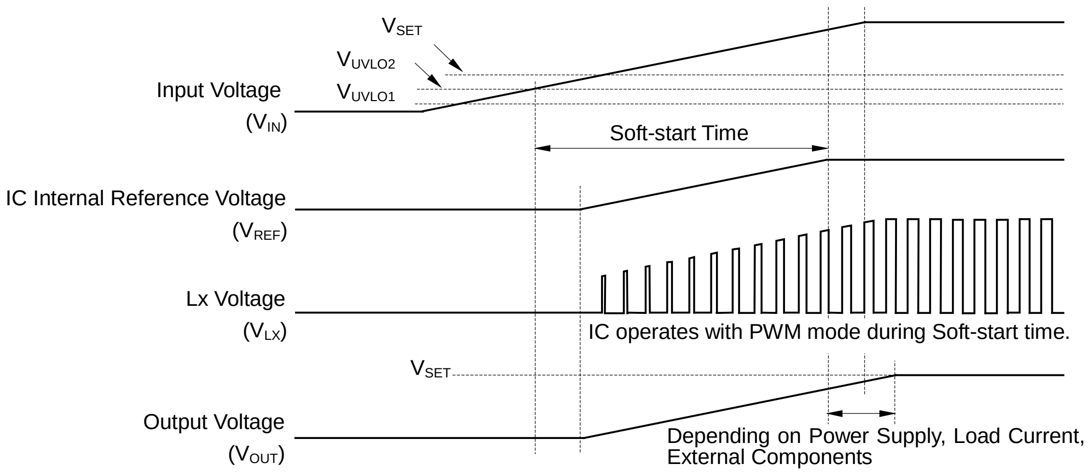
After the start-up of the IC, soft-start circuit starts to operate. Then, after a certain period of time, the reference voltage (V_{REF}) in the IC gradually increases up to the specified value.



Soft-start time starts when soft-start circuit is activated, and ends when the reference voltage reaches the specified voltage. Soft start time is not always equal to the turn-on speed of the step-down DC/DC converter. 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.

Starting-up with Power Supply

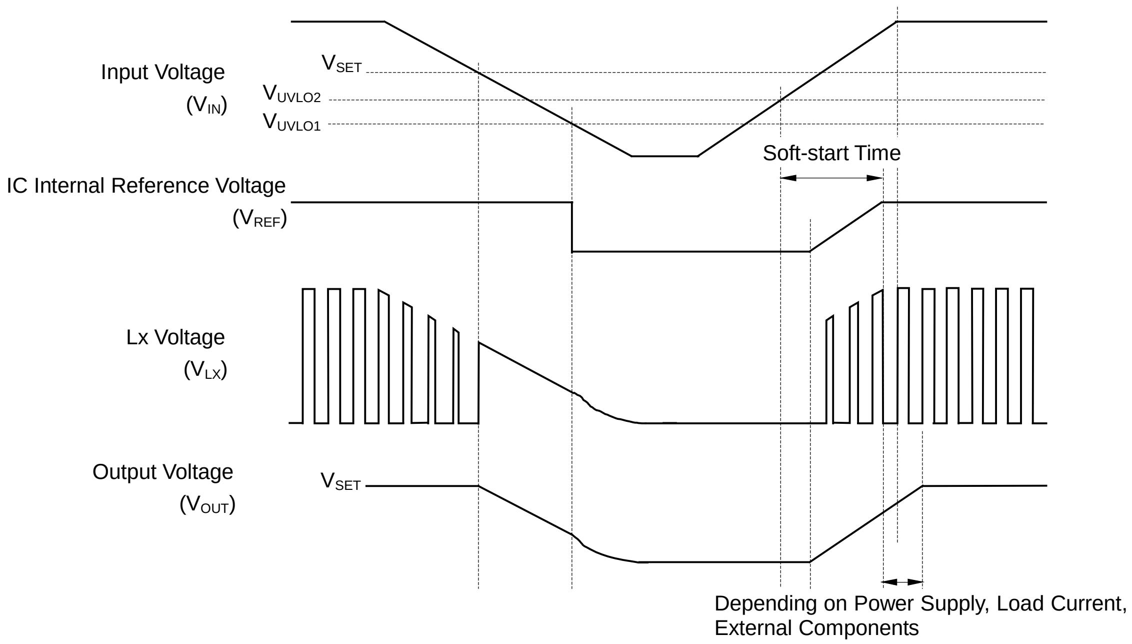
After the power-on, when V_{IN} exceeds the UVLO released voltage (V_{UVLO2}), the IC starts to operate. Then, soft-start circuit starts to operate and after a certain period of time, V_{REF} gradually increases up to the specified value. Soft-start time starts when soft-start circuit is activated, and ends when V_{REF} reaches the specified voltage.



Note that the turn-on speed of V_{OUT} could be affected by the power supply capacity, the output current, the inductance value, the C_{OUT} value and the turn-on speed of V_{IN} determined by C_{IN}.

2. Under Voltage Lockout (UVLO) Circuit

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} becomes lower than the UVLO detector threshold (V_{UVLO1}), the UVLO circuit starts to operate, V_{REF} stops, and P-channel and N-channel built-in switch transistors turn "OFF". As a result, V_{OUT} drops according to the C_{OUT} capacitance value and the load.
To restart the operation, V_{IN} needs to be higher than V_{UVLO2}. The timing chart below shows the voltage shifts of V_{REF}, V_{LX} and V_{OUT} when V_{IN} value is varied.

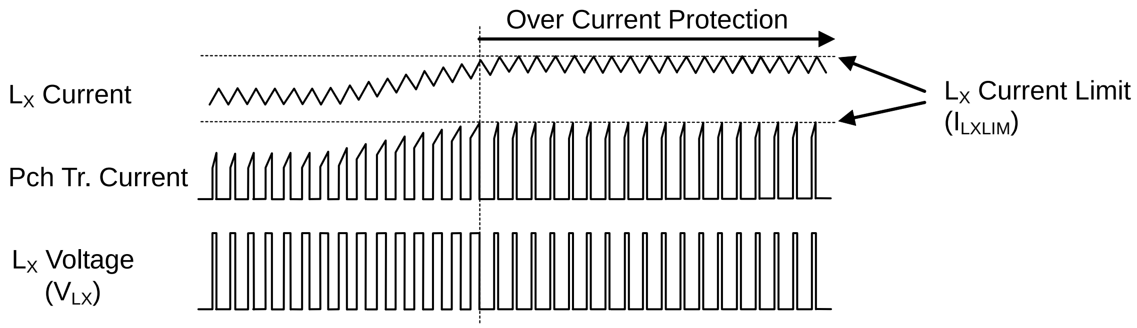


Falling edge (operating) and rising edge (releasing) waveforms of V_{OUT} could be affected by the initial voltage of C_{OUT} and the output current of V_{OUT}.

3. Over Current Protection Circuit

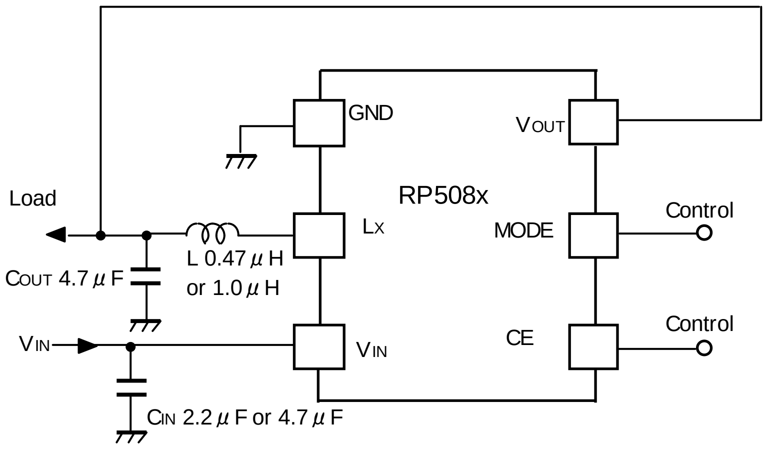
Over current protection circuit supervises the inductor peak current (the peak current flowing through P-channel Tr.) in each switching cycle. If the current exceeds the L_X current limit (I_{LXLIM}) of 1100 mA (Typ.), P-channel Tr. is turned off.

I_{LXLIM} 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 could be affected.



APPLICATION INFORMATION

Typical Application



RP508K Typical Application

Recommended Components

Symbol	Size	Type	Manufacturer
C_{IN}	2.2 µF	Ceramic	C1005JB0J225K (TDK)
	4.7 µF	Ceramic	C1005JB0J475K (TDK)
C_{OUT}	4.7 µF	Ceramic	C1005JB0J475K (TDK)
L	0.47 µH (0.5 µH)	Inductor	MIPSZ2012D0R5 (FDK)
			MDT1608CHR47N (TOKO)
	1.0 µH	Inductor	MIPSZ2012D1R0 (FDK)
			MDT1608CH1R0N (TOKO)

Cautions in Selecting External Components

- Ensure the V_{IN} and GND lines are sufficiently robust. A large switching current flows through the GND lines, the V_{DD} line, the V_{OUT} line, an inductor, and L_X. If their impedance is too high, noise pickup or unstable operation may result. Set the external components as close as possible to the IC and minimize the wiring between the components and the IC, especially between a capacitor (C_{IN}) and the V_{IN} pin. The wiring between V_{OUT} and load and between L and V_{OUT} should be separated.
- Choose a low ESR ceramic capacitor. The capacitance of C_{IN} should be more than or equal to 2.2 µF. The capacitance of a capacitor (C_{OUT}) should be between 4.7 µF to 10 µF.
- The Inductance value should be set within the range of 0.47 µH to 1.0 µH. However, the inductance value is limited by output voltage. Refer to the table below. The phase compensation of this IC is designed according to the C_{OUT} and L values. Choose an inductor that has small DC resistance, has enough allowable current and is hard to cause magnetic saturation. If the inductance value of an inductor is extremely small, the peak current of L_X may increase. The increased L_X peak current reaches "L_X limit current" to trigger over current protection circuit even if the load current is less than 600 mA.

Set Output Voltage Range vs. Inductance Range

Set Output Voltage (V)	Input Voltage (V)	Inductance	
V_{SET}	**V_{IN}**	**L = 0.47 µH**	**L = 1.0 µH**
0.8 to 1.2	up to 5.5	Recommended	Acceptable
1.3 to 1.5	up to 4.5	Recommended	Acceptable
	4.5 to 5.5	Acceptable	Recommended
1.6 to 2.6	up to 3.6	Recommended	Acceptable
	up to 4.5	Acceptable	Recommended
	4.5 to 5.5	-	Recommended
2.7 to 3.3	up to 4.5	Recommended	Acceptable
	4.5 to 5.5	-	Recommended

- Over current protection circuit may be affected by self-heating or power dissipation environment.
- The performance of power source circuits using this IC largely depends on the peripheral circuits. When selecting the peripheral components, consider the conditions of use. Do not allow each component, PCB pattern and the IC to exceed their respected rated values (voltage, current and power) when designing the peripheral circuits.

Output Current and Selection of External Components

The following equations explain the relationship between output current and peripheral components used in the diagrams in *TYPICAL APPLICATIONS*.

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

First, when P-channel Tr. Is “ON”, the following equation is satisfied.

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

Second, when P-channel Tr. is “OFF” (N-channel Tr. Is “ON”), the following equation is satisfied.

$$L \times I_{RP} / toff = R_{ONN} \times I_{OUT} + V_{OUT} + R_L \times I_{OUT} \cdots\cdots \text{Equation 4}$$

Put Equation 4 into Equation 3 to solve ON duty of P-channel Tr. (D_{ON} = ton / (toff + ton)):

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

Ripple Current is described as follows:

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

Peak current that flows through L, and L_X Tr. is described as follows:

$$I_{LXMAX} = I_{OUT} + I_{RP} / 2 \cdots\cdots \text{Equation 7}$$

Consider I_{LXMAX} when setting conditions of input and output, as well as selecting the external components.
The above calculation formulas are based on the ideal operation of the I_{CS} in continuous mode.

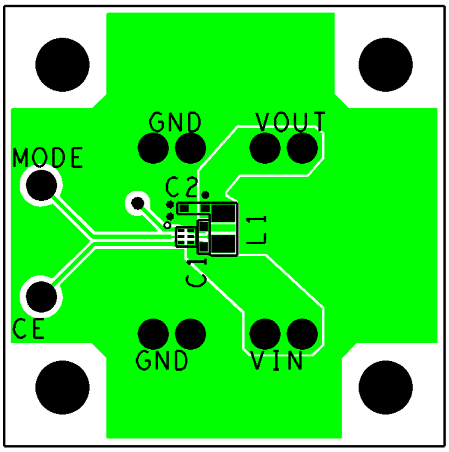
TECHNICAL NOTES

The performance of power source circuits using this IC largely depends on the peripheral circuits. When selecting the peripheral components, consider the conditions of use. Do not allow each component, PCB pattern and the IC to exceed their respected rated values (voltage, current and power) when designing the peripheral circuits.

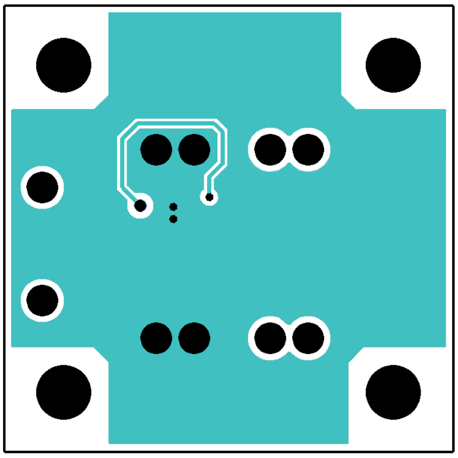
- Ensure the V_{IN} and GND lines are sufficiently robust. A large switching current flows through the GND lines, the V_{DD} line, the V_{OUT} line, an inductor, and L_X. If their impedance is too high, noise pickup or unstable operation may result. Set the external components as close as possible to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

Reference PCB Layout

Topside



Backside



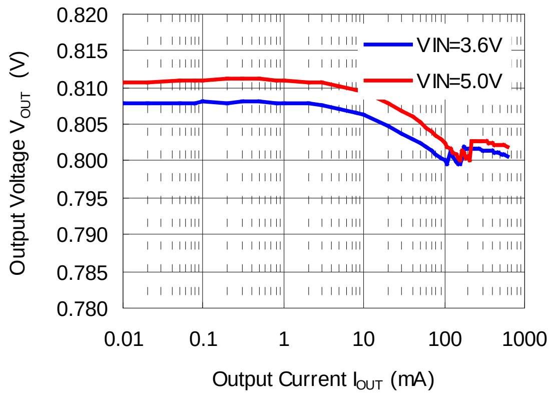
DFN1212-6 Typical Board Layout

TYPICAL CHARACTERISTICS

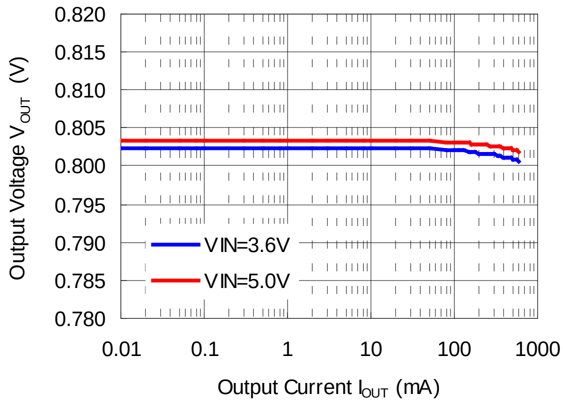
Note: Typical Characteristics are intended to be used as reference data; they are not guaranteed.

01) Output Voltage vs. Output Current

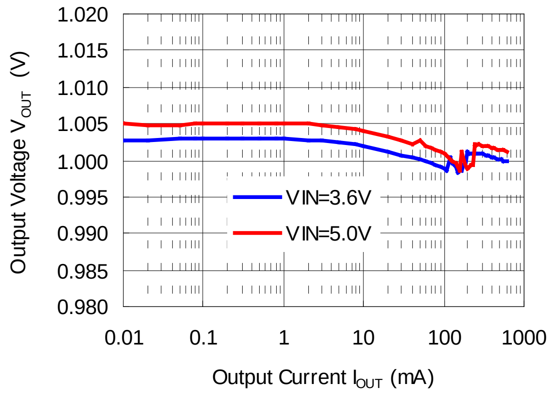
RP508K081x, V_{OUT} = 0.8 V
MODE = "L" PWM/VFM auto switching control



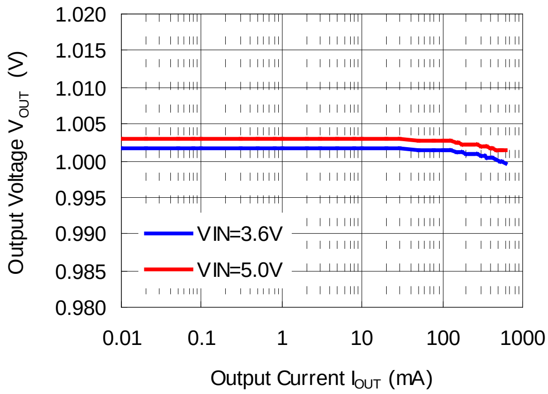
RP508K081x, V_{OUT} = 0.8 V
MODE = "H" forced PWM control



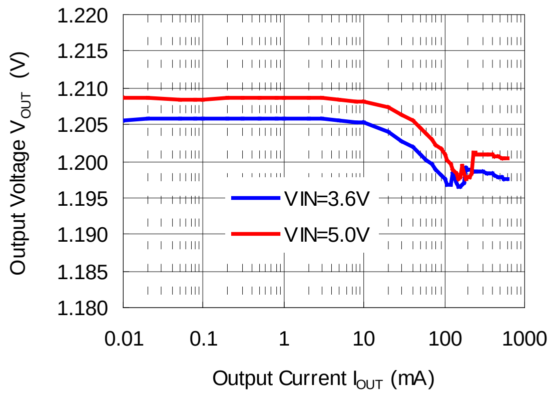
RP508K101x, V_{OUT} = 1.0 V
MODE = "L" PWM/VFM auto switching control



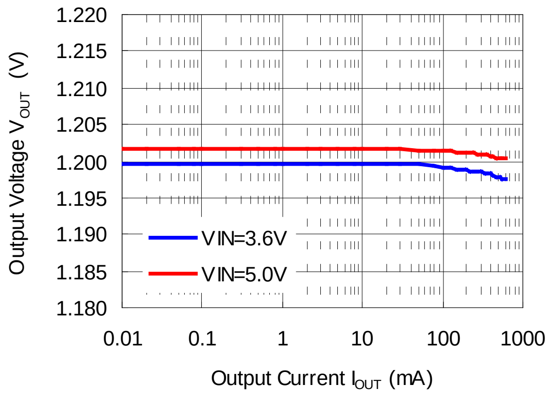
RP508K101x, V_{OUT} = 1.0 V
MODE = "H" forced PWM control



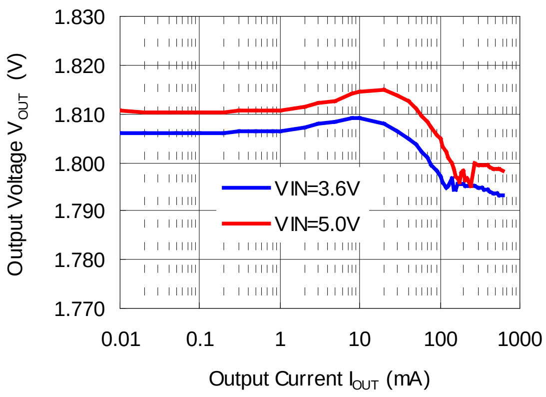
RP508K121x, V_{OUT} = 1.2 V
MODE = "L" PWM/VFM auto switching control



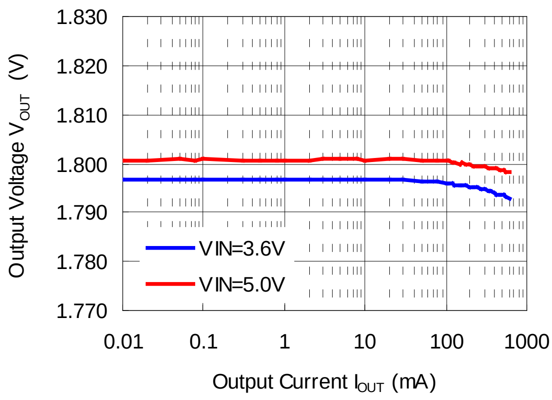
RP508K121x, V_{OUT} = 1.2 V
MODE = "H" forced PWM control



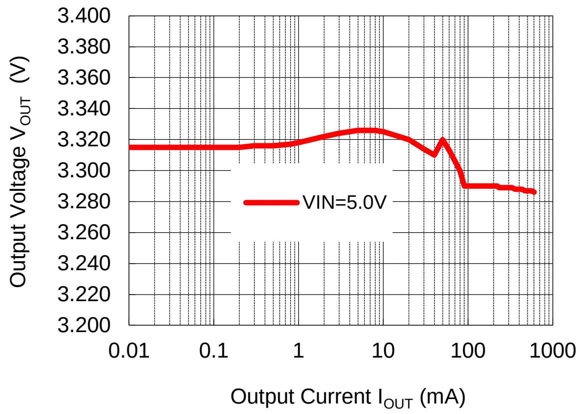
RP508K181x, V_{OUT} = 1.8 V
MODE = "L" PWM/VFM auto switching control



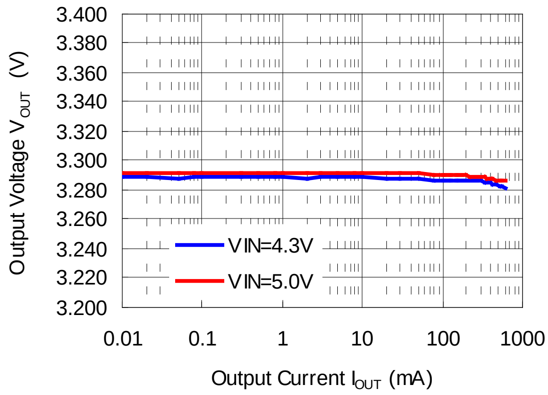
RP508K181x, V_{OUT} = 1.8 V
MODE = "H" forced PWM control



RP508K331x, V_{OUT} = 3.3 V
MODE = "L" PWM/VFM auto switching control

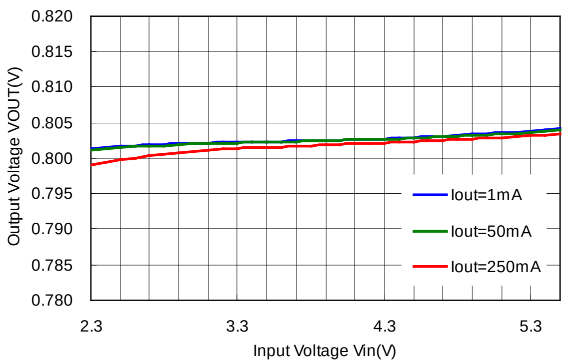


RP508K331x, V_{OUT} = 3.3 V
MODE = "H" forced PWM control

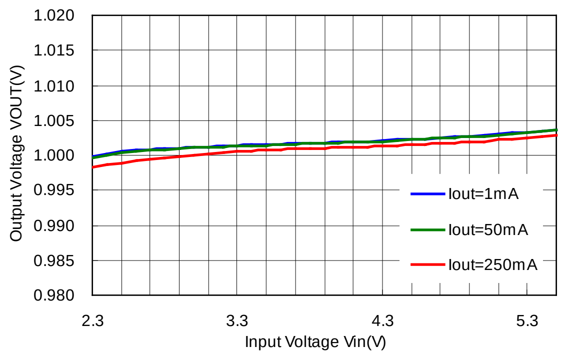


02) Output Voltage vs. Input Voltage

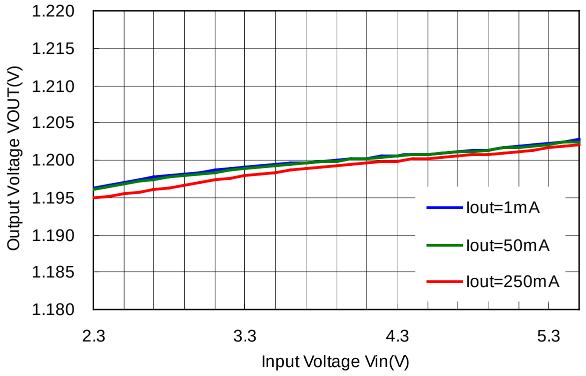
RP508K081x, V_{OUT} = 0.8 V
MODE = "H" forced PWM control



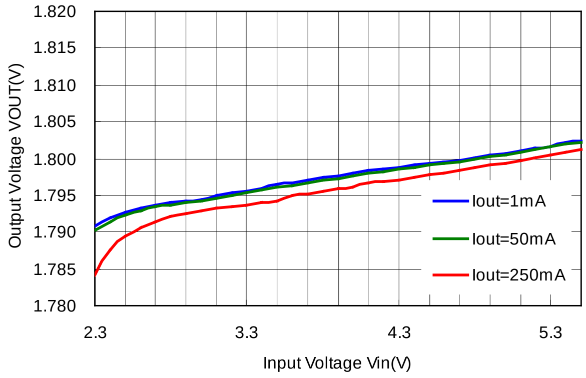
RP508K101x, V_{OUT} = 1.0 V
MODE = "H" forced PWM control



RP508K121x, V_{OUT} = 1.2 V
MODE = "H" forced PWM control

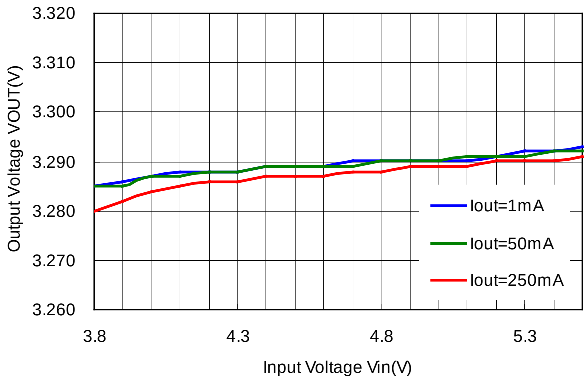


RP508K181x, V_{OUT} = 1.8 V
MODE = "H" forced PWM control

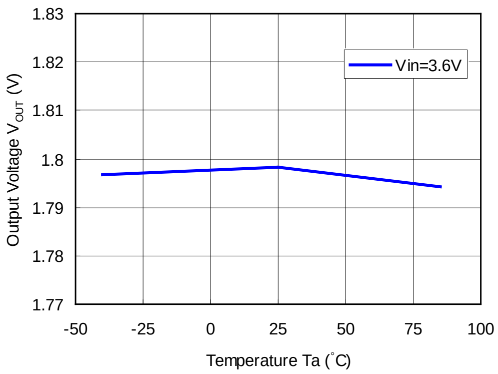


RP508K331x, V_{OUT} = 3.3 V

MODE = "H" forced PWM control

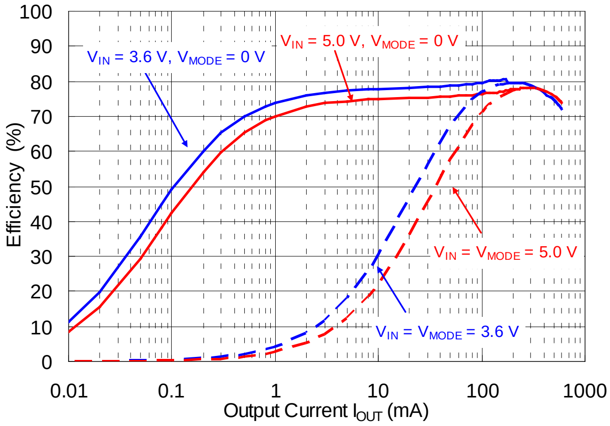


03) Output Voltage vs. Temperature

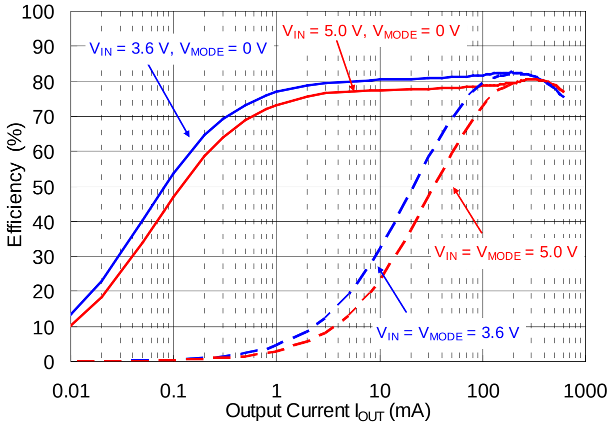


04) Efficiency vs. Output Current

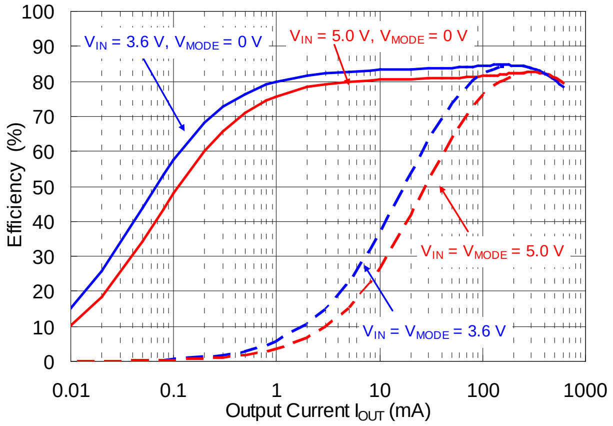
RP508K081x, V_{OUT} = 0.8 V
L = MIPSZ2012D0R5 (2012size_0.5 μH)



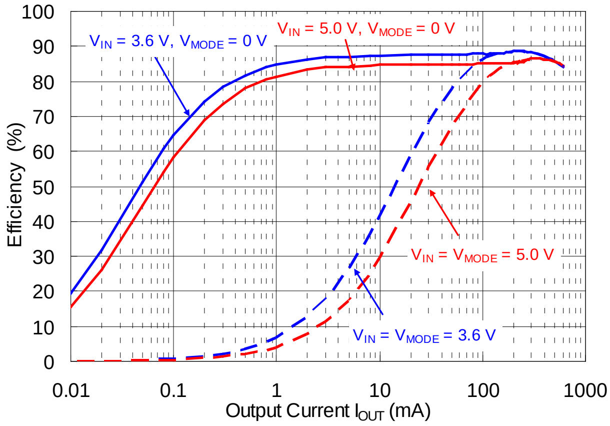
RP508K101x, V_{OUT} = 1.0 V
L = MIPSZ2012D0R5 (2012size_0.5 μH)



RP508K121x, V_{OUT} = 1.2 V
L = MIPSZ2012D0R5 (2012size_0.5 μH)

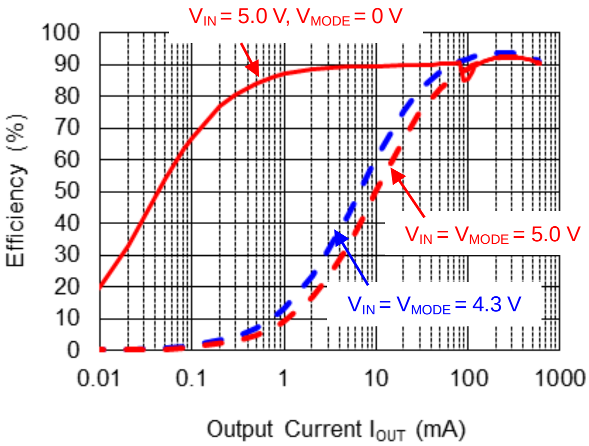


RP508K181x, V_{OUT} = 1.8 V
L = MIPSZ2012D0R5 (2012size_0.5 μH)



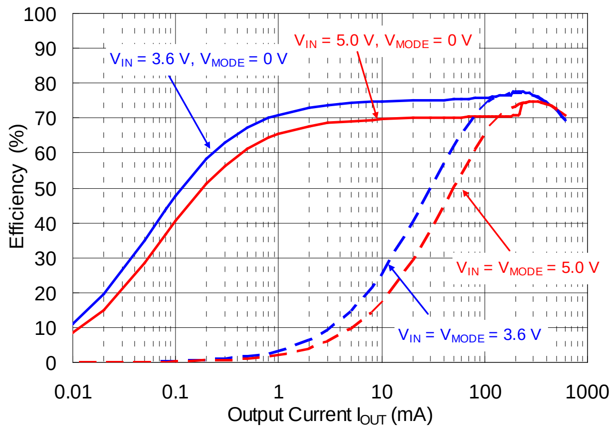
RP508K331x, V_{OUT} = 3.3 V

L = MIPSZ2012D1R0 (2012size_1.0 μH)



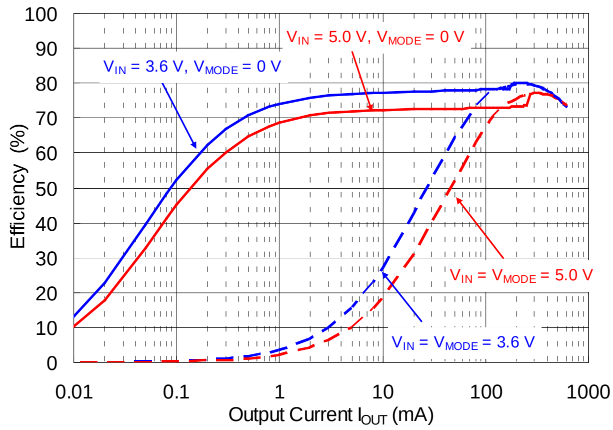
RP508K081x, V_{OUT} = 0.8 V

L = MDT1608CHR47N (1608size_0.47 µH)



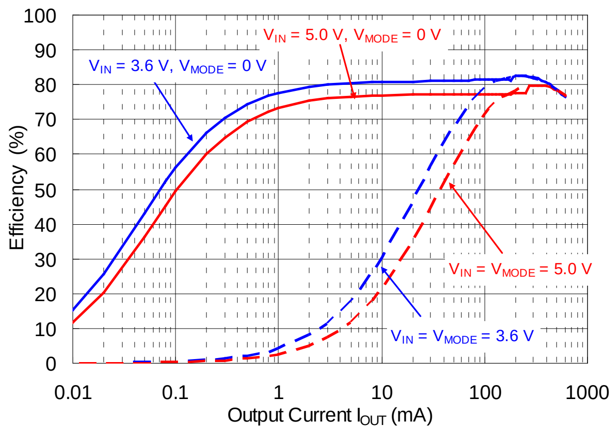
RP508K101x, V_{OUT} = 1.0 V

L = MDT1608CHR47N (1608size_0.47 µH)



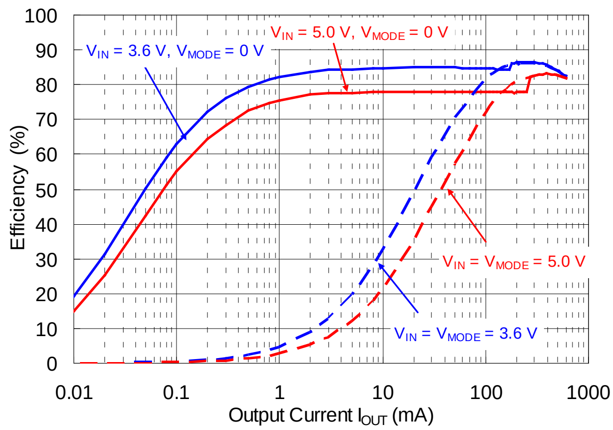
RP508K121x, V_{OUT} = 1.2 V

L = MDT1608CHR47N (1608size_0.47 µH)



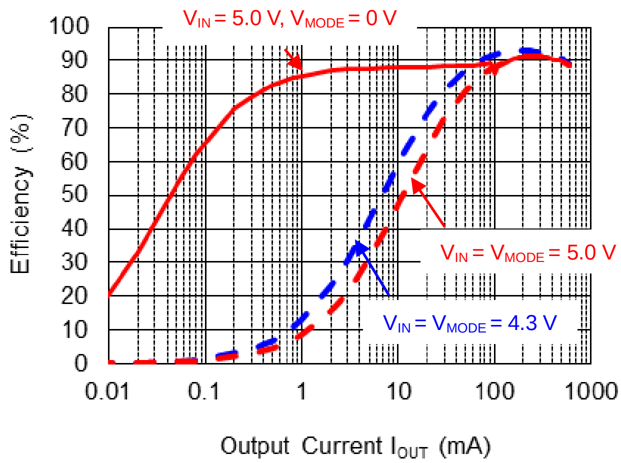
RP508K181x, V_{OUT} = 1.8 V

L = MDT1608CHR47N (1608size_0.47 µH)



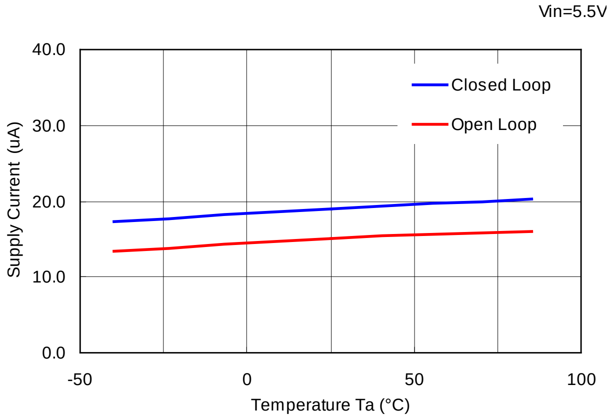
RP508K331x, V_{OUT} = 3.3 V

L = MDT1608CH1R0N (1608size_1.0 µH)



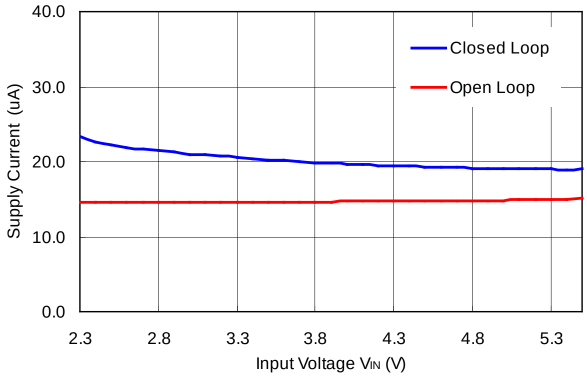
05) Supply Current vs. Temperature

RP508K181x, V_{OUT} = 1.8 V (V_{IN} = 5.5 V)
MODE = "L" PWM/VFM auto switching control



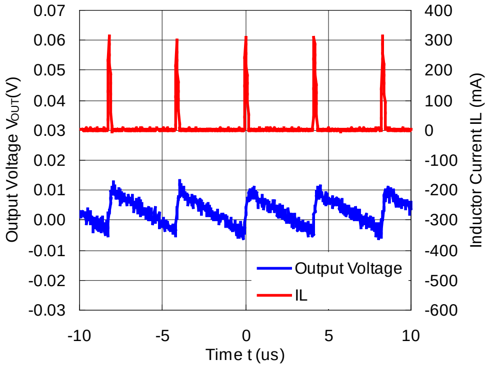
06) Supply Current vs. Input Voltage

RP508K181x, V_{OUT} = 1.8 V
MODE = "L" PWM/VFM auto switching control

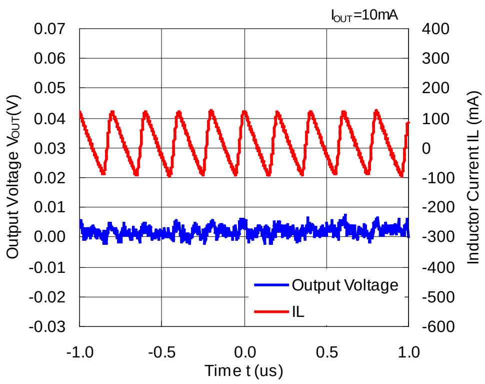


07) Output Voltage Waveform

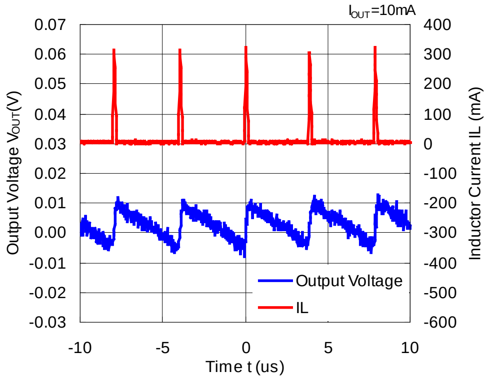
RP508K081x, V_{OUT} = 0.8 V (V_{IN} = 3.6 V)
MODE = "L" PWM/VFM auto switching control



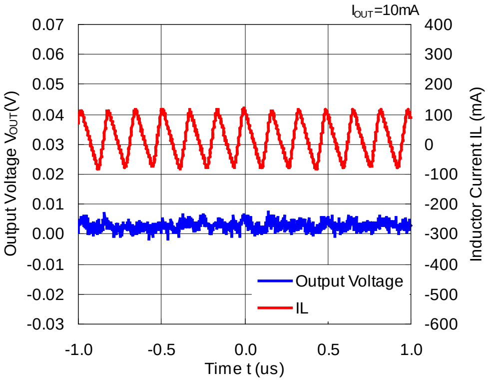
RP508K081x, V_{OUT} = 0.8 V (V_{IN} = 3.6 V)
MODE = "H" forced PWM control



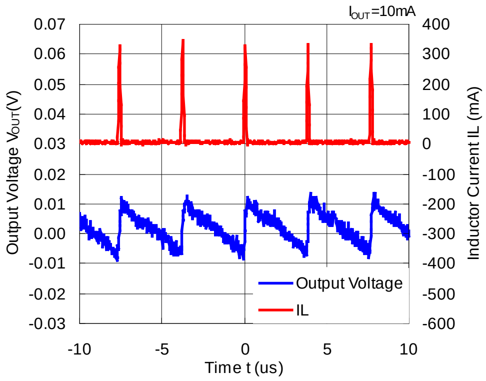
RP508K121x, V_{OUT} = 1.2 V (V_{IN} = 3.6 V)
MODE = "L" PWM/VFM auto switching control



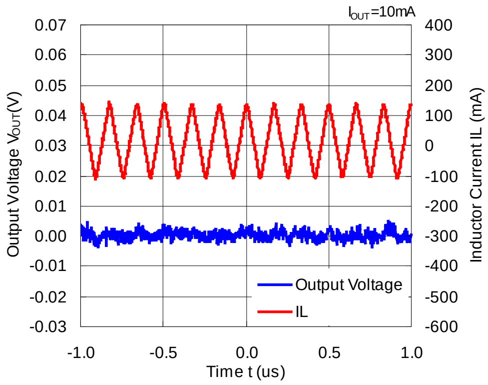
RP508K121x, V_{OUT} = 1.2 V (V_{IN} = 3.6 V)
MODE = H" forced PWM control



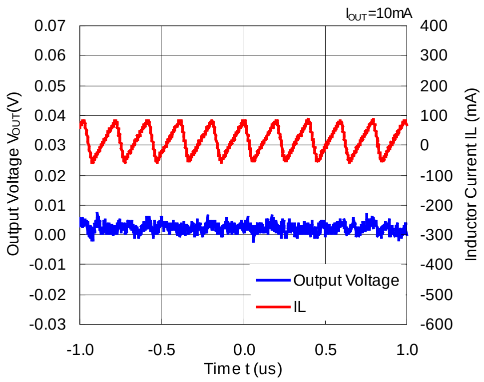
RP508K181x, V_{OUT} = 1.8 V (V_{IN} = 3.6 V)
MODE = "L" PWM/VFM auto switching control



RP508K181x, V_{OUT} = 1.8 V (V_{IN} = 3.6 V)
MODE = "H" forced PWM control



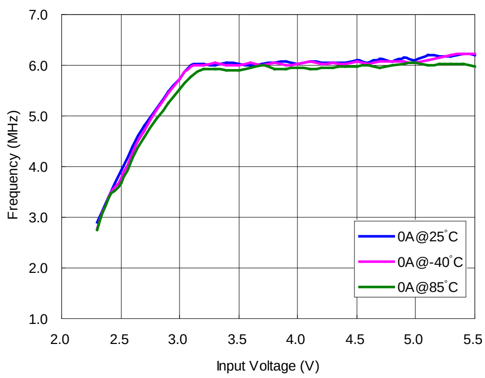
RP508K331x, V_{OUT} = 3.3 V (V_{IN} = 4.3 V)
MODE = "H" forced PWM control



08) Frequency vs. Input Voltage

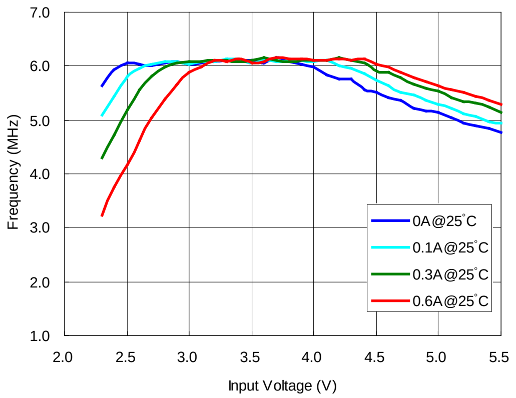
RP508K181x, V_{OUT} = 1.8 V

MODE = "H" forced PWM control

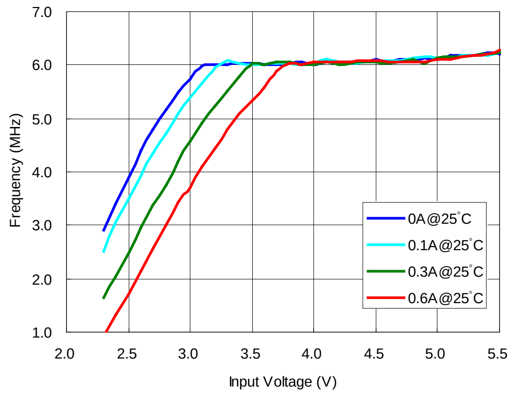


09) Frequency vs. Input Voltage with Various Output Currents

RP508K121x, V_{OUT} = 1.2 V
MODE = "H" forced PWM control

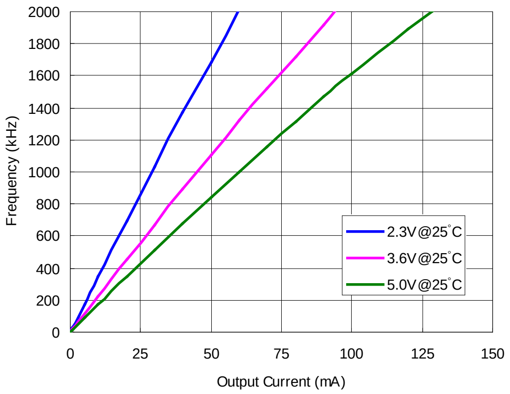


RP508K181x, V_{OUT} = 1.8 V
MODE = "H" forced PWM control

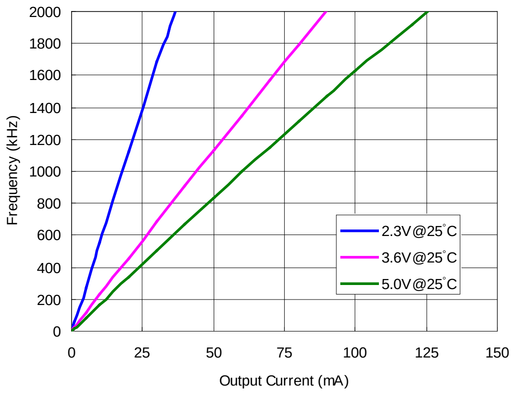


10) VFM Frequency vs. Output Current

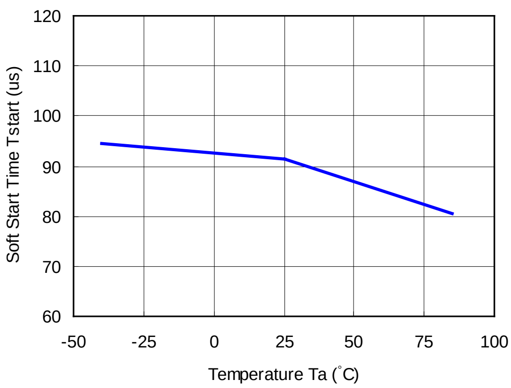
RP508K121x, V_{OUT} = 1.2 V
MODE = "L" PWM/VFM auto switching control



RP508K181x, V_{OUT} = 1.8 V
MODE = "L" PWM/VFM auto switching control

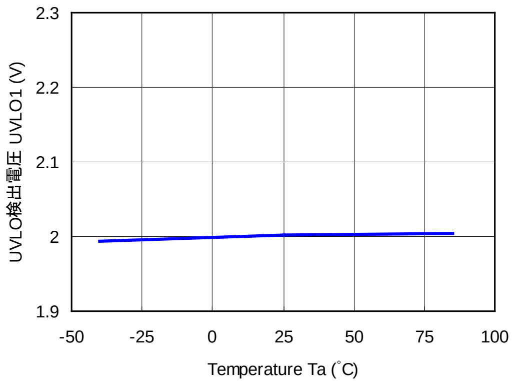


11) Soft-start Time vs. Temperature

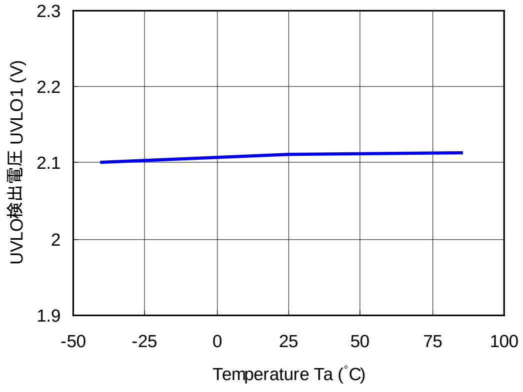


12) UVLO Detector Threshold/ Released Voltage vs. Temperature

UVLO Detector Threshold

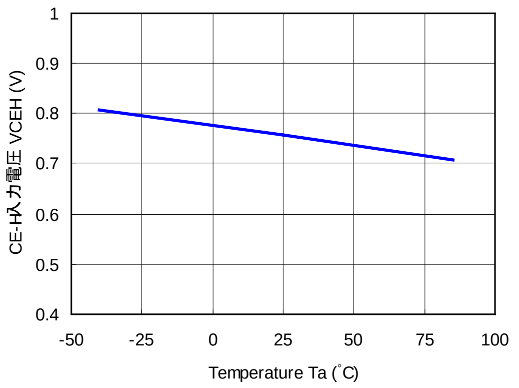


UVLO Release Voltage

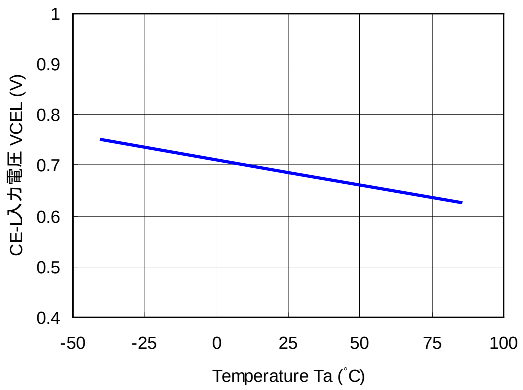


13) CE Input Voltage vs. Temperature

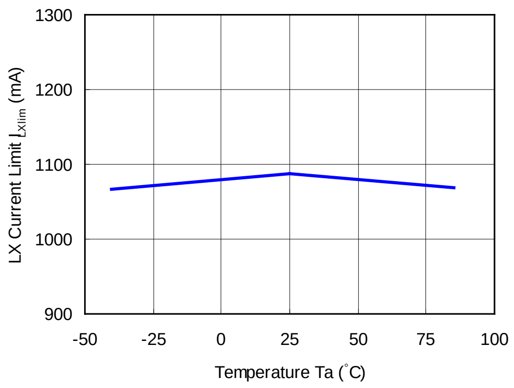
CE = "H" Input Voltage (V_{IN} = 5.5 V)



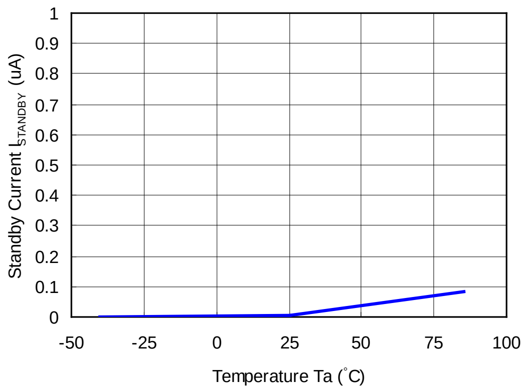
CE = "H" Input Voltage (V_{IN} = 2.3 V)



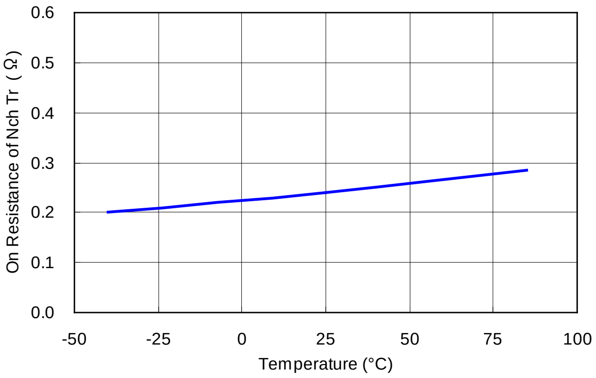
14) L_X Current Limit vs. Temperature



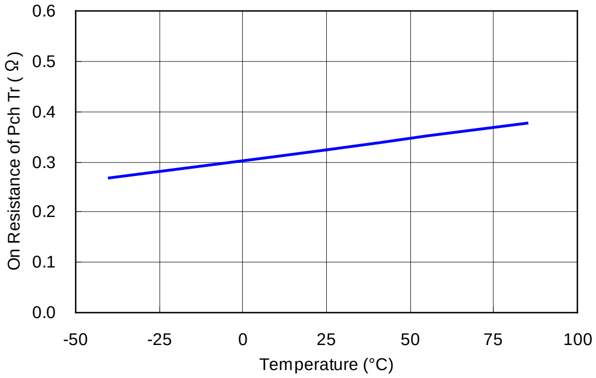
15) Standby Current vs. Temperature



16) Nch Transistor On Resistance vs. Temperature

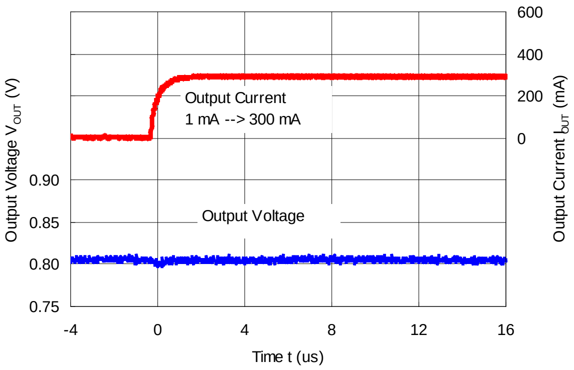


17) Pch Transistor On Resistance vs. Temperature

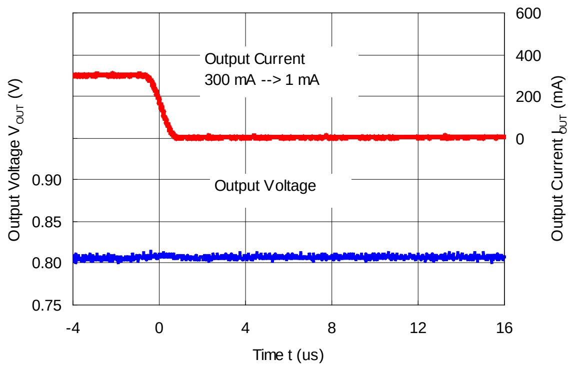


18) Load Transient Response (C_{OUT} = 4.7 µF, C1005X5R0J475M)

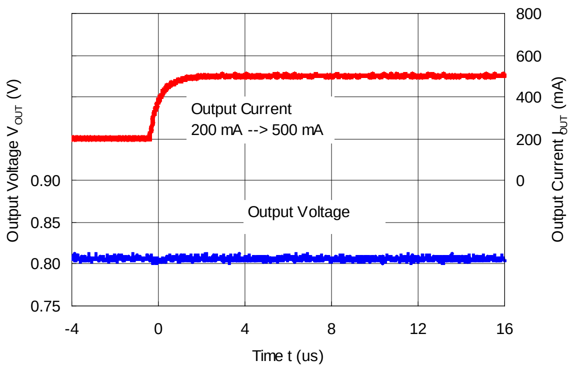
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



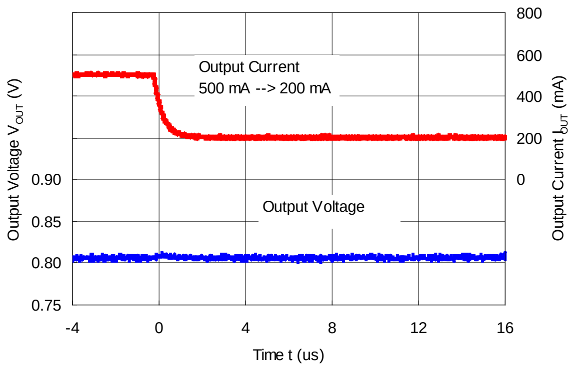
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



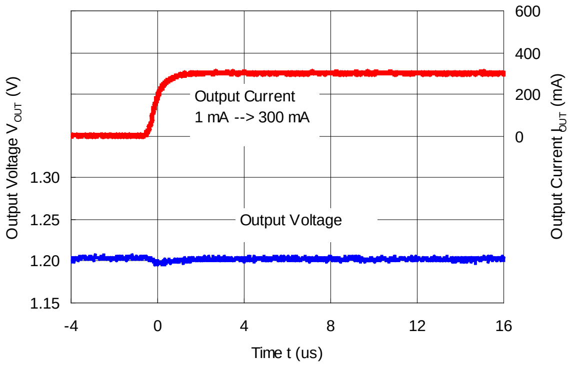
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



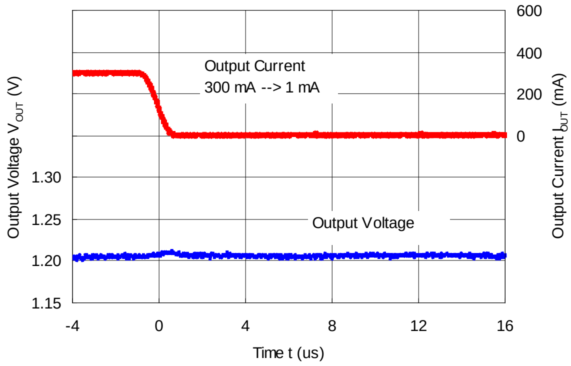
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



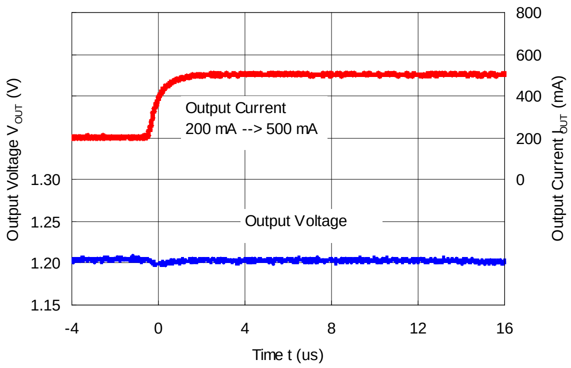
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



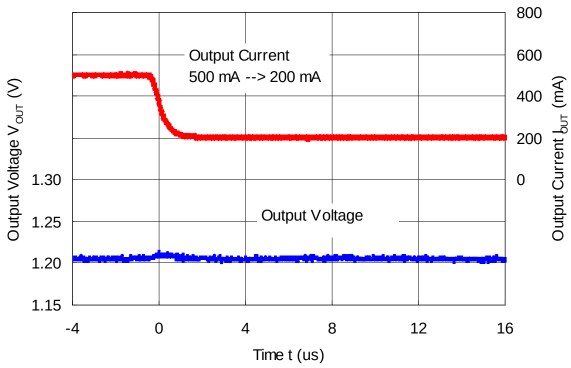
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



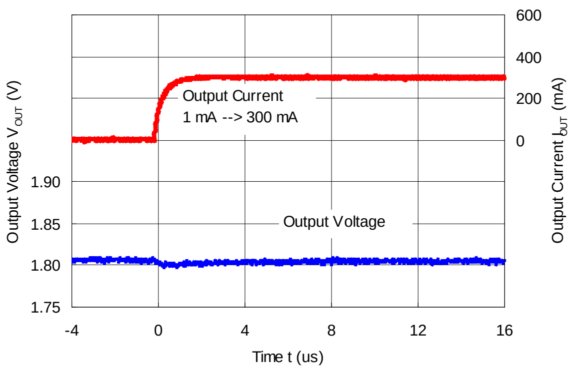
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



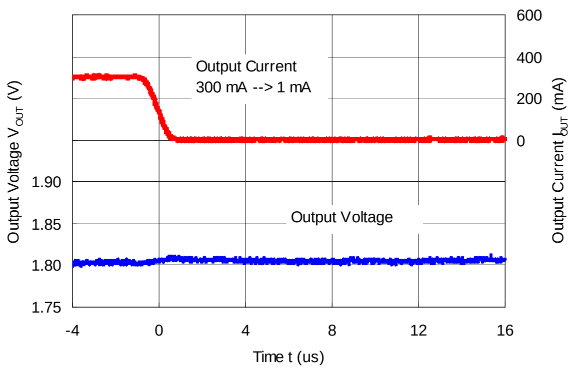
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



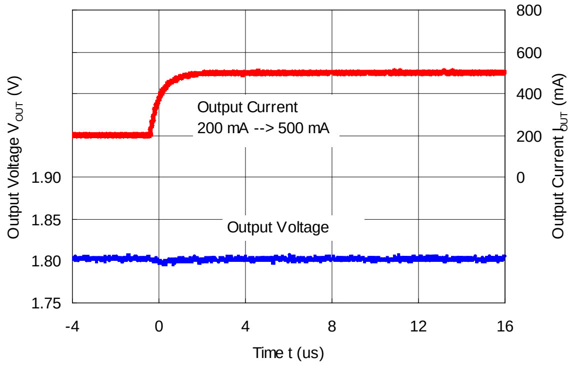
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



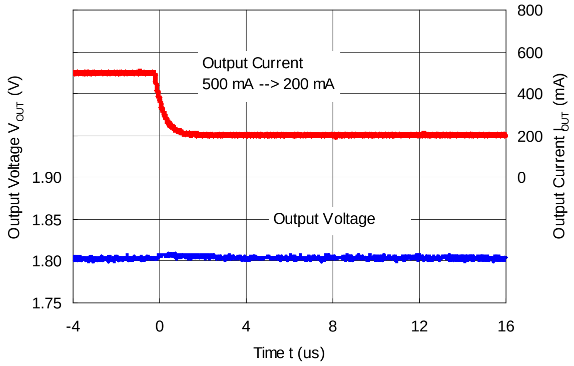
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



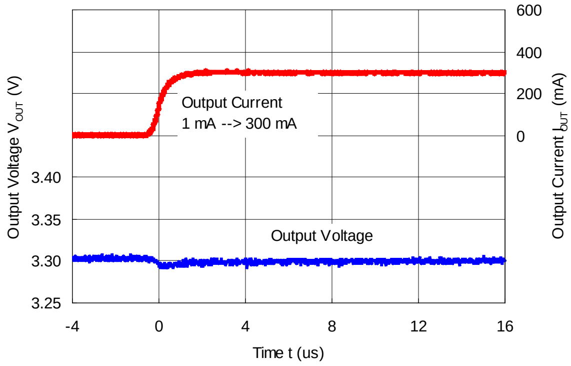
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



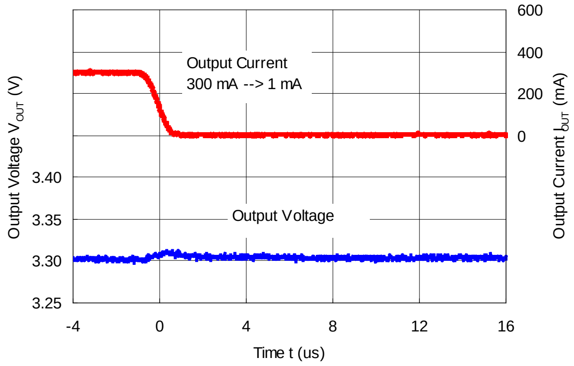
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "H" forced PWM control



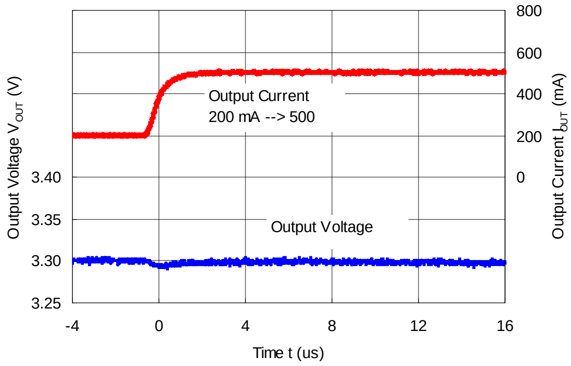
RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MIPSZ2012D1R0 (2012size_1.0 µH)
MODE = "H" forced PWM control



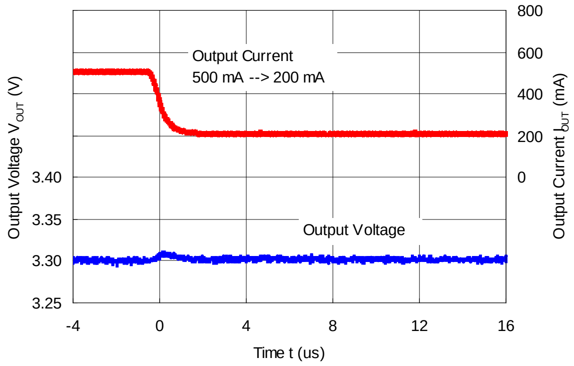
RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MIPSZ2012D1R0 (2012size_1.0 µH)
MODE = "H" forced PWM control



RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MIPSZ2012D1R0 (2012size_1.0 µH)
MODE = "H" forced PWM control

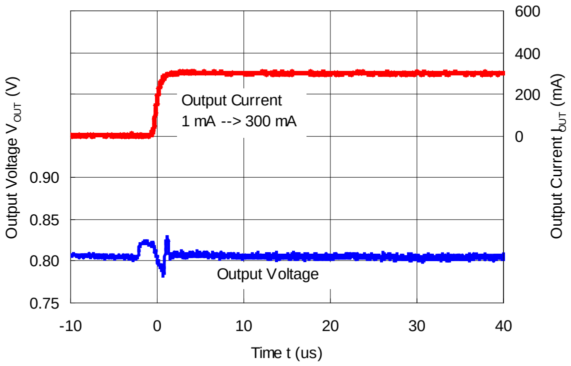


RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MIPSZ2012D1R0 (2012size_1.0 µH)
MODE = "H" forced PWM control

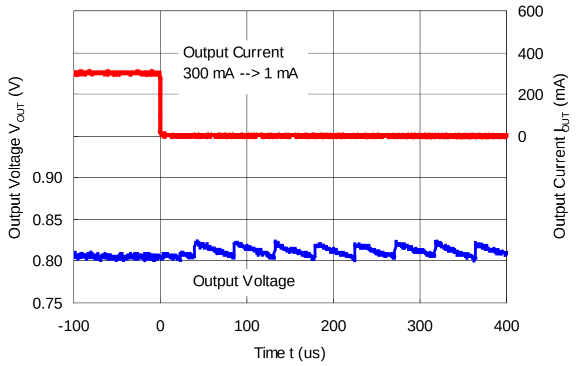


Load Transient Response (C_{OUT} = 4.7µF, C1005X5R0J475M)

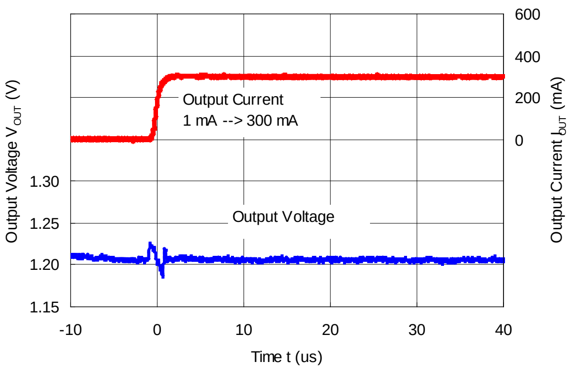
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "L" PWM/VFM auto switching control



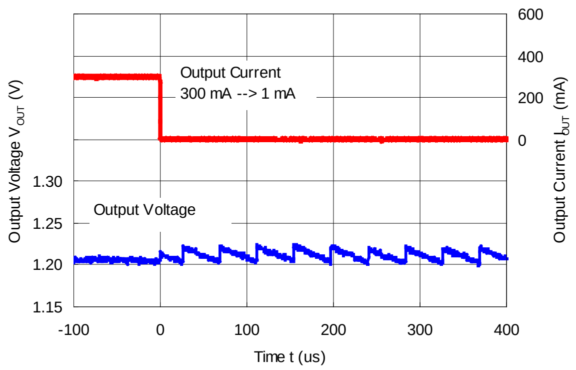
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "L" PWM/VFM auto switching control



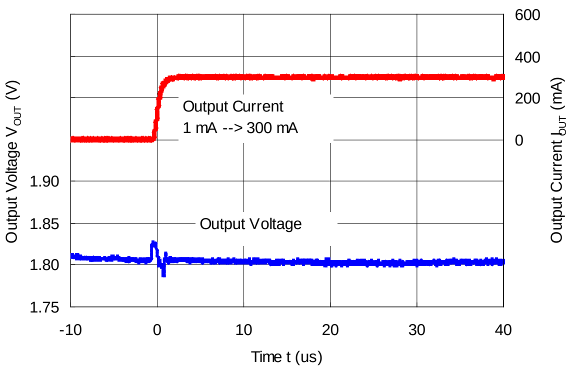
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "L" PWM/VFM auto switching control



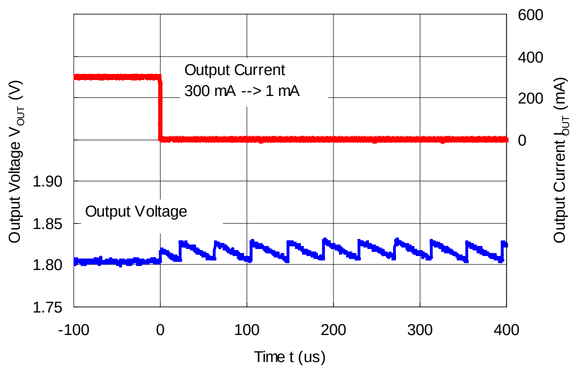
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "L" PWM/VFM auto switching control



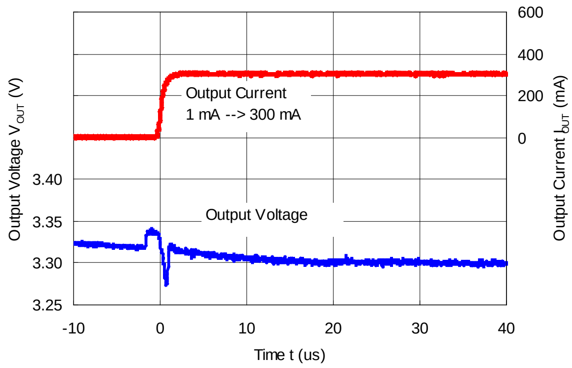
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "L" PWM/VFM auto switching control



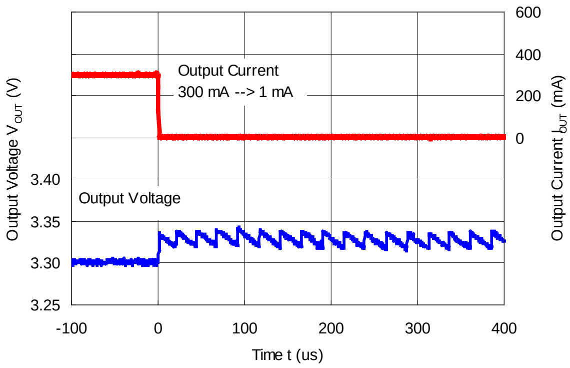
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MIPSZ2012D0R5 (2012size_0.5 µH)
MODE = "L" PWM/VFM auto switching control



RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MIPSZ2012D1R0 (2012size_1.0 µH)
MODE = "L" PWM/VFM auto switching control

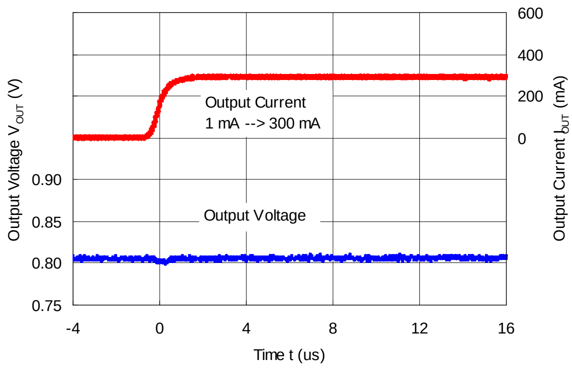


RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MIPSZ2012D1R0 (2012size_1.0 µH)
MODE = "L" PWM/VFM auto switching control

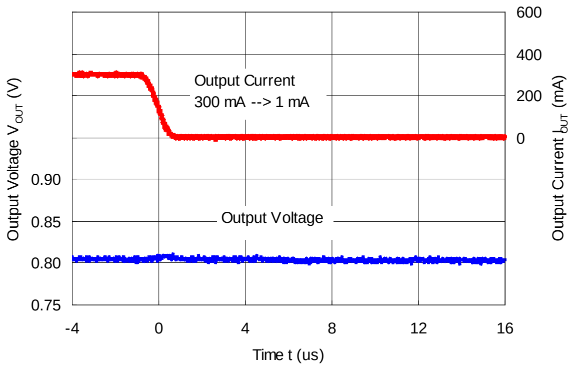


Load Transient Response (C_{OUT} = 4.7 µF, C1005X5R0J475M)

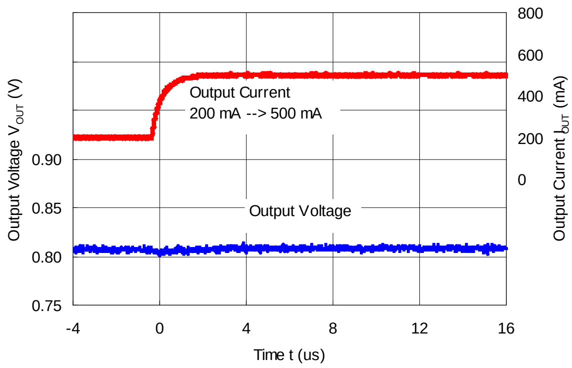
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



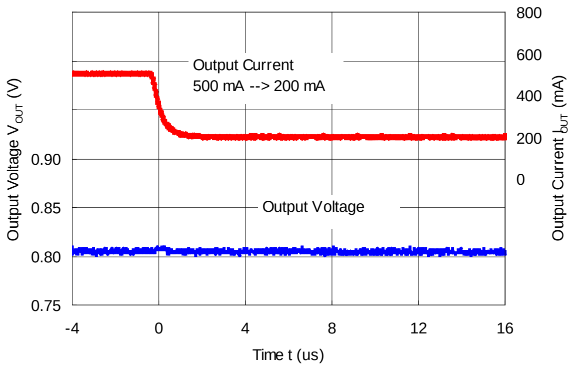
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



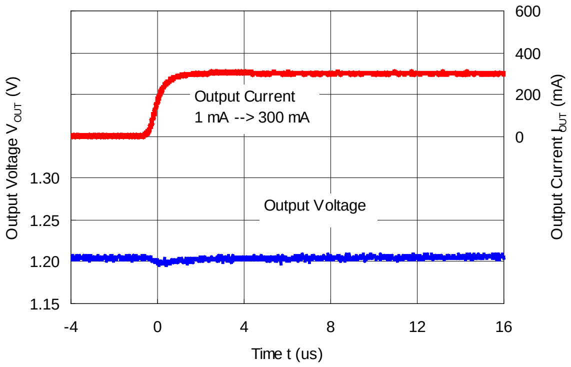
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



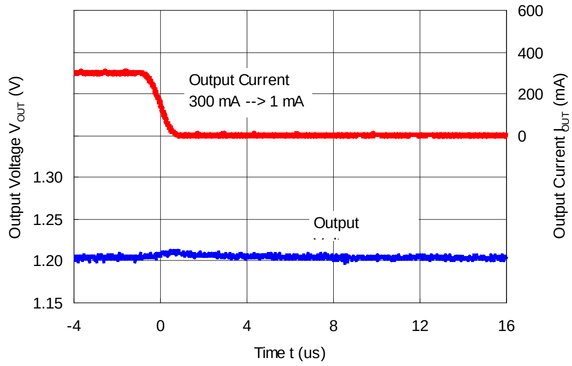
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



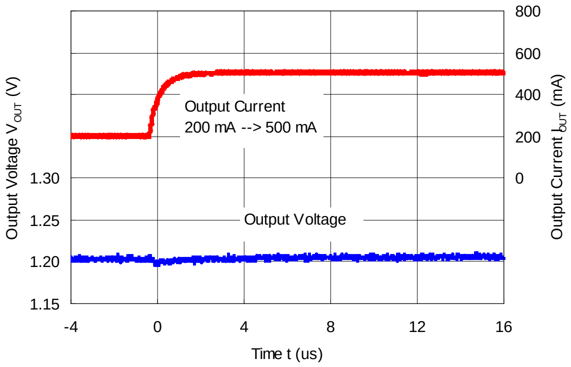
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



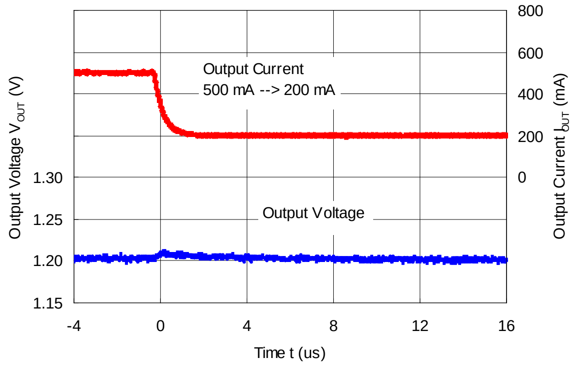
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



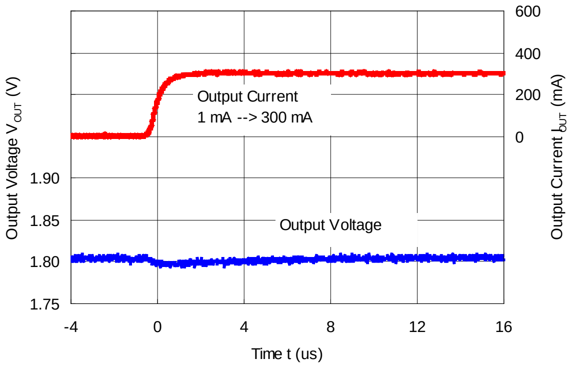
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



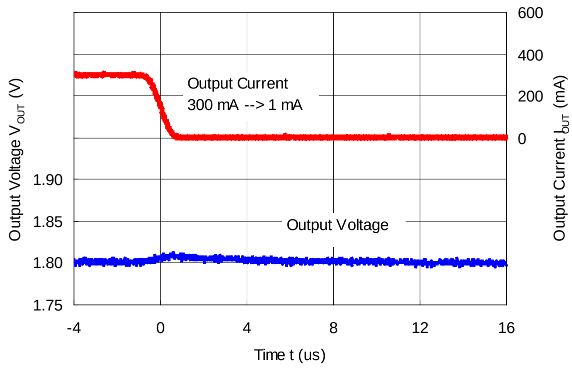
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



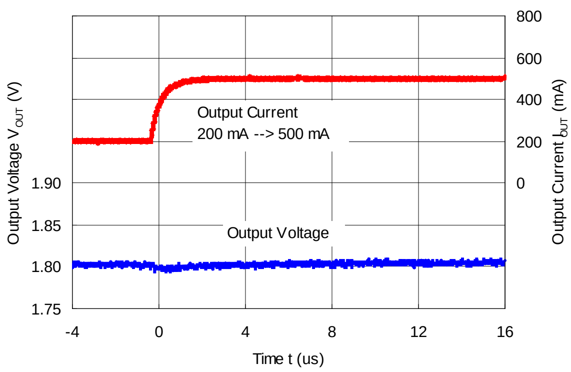
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



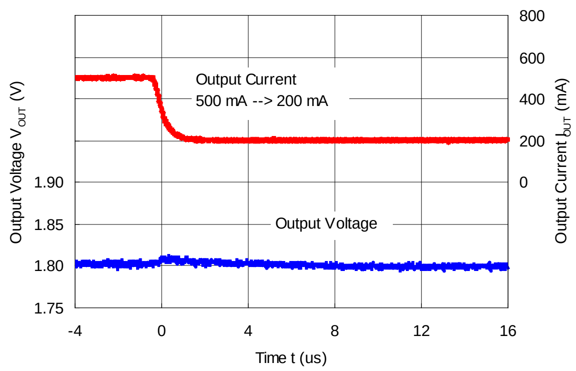
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



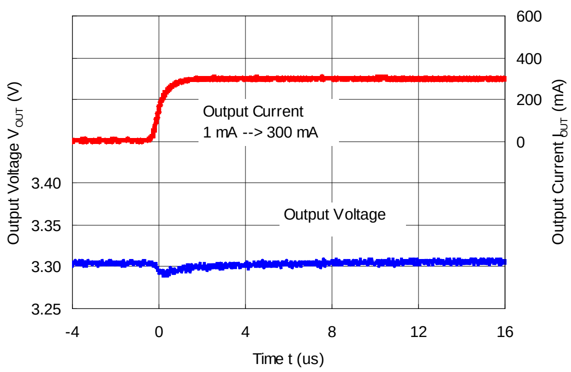
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



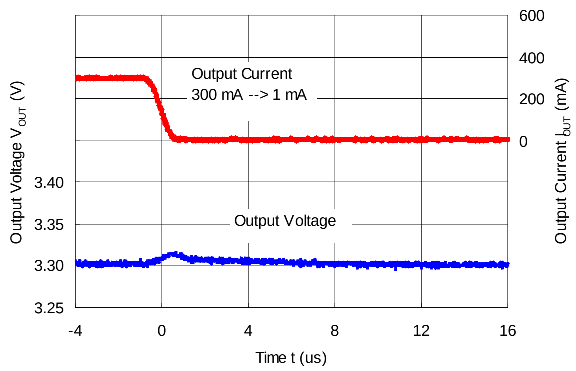
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "H" forced PWM control



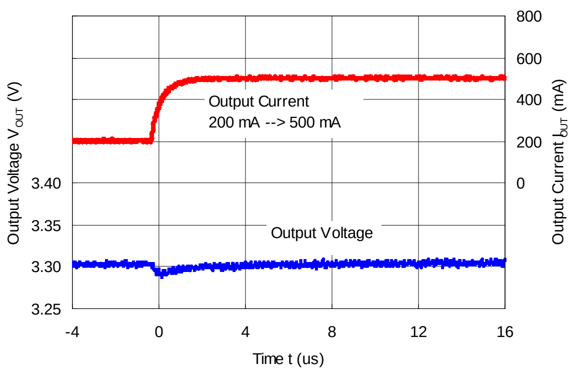
RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MDT1608CH1R0N(1608size_1.0 µH)
MODE = "H" forced PWM control



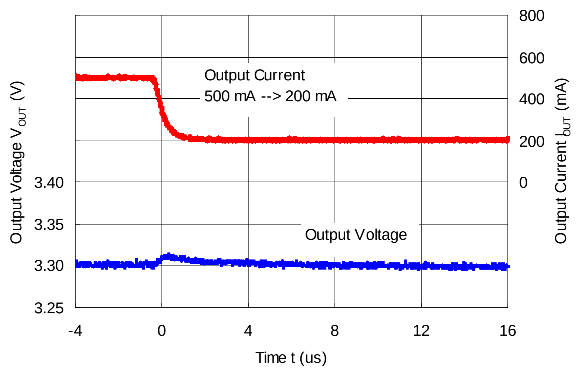
RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MDT1608CH1R0N (1608size_1.0 µH)
MODE = "H" forced PWM control



RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MDT1608CH1R0N (1608size_1.0 µH)
MODE = "H" forced PWM control

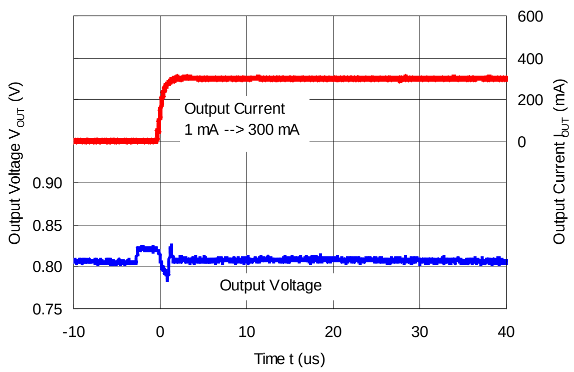


RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MDT1608CH1R0N (1608size_1.0 µH)
MODE = "H" forced PWM control

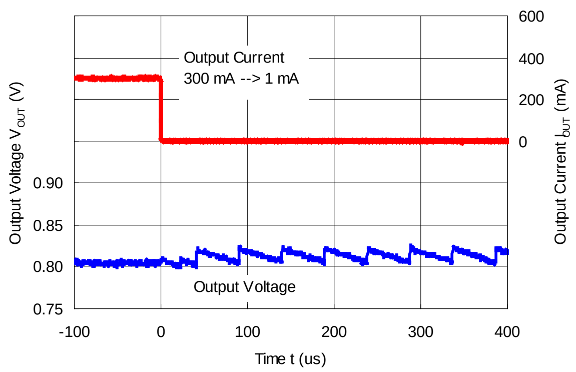


Load Transient Response (C_{OUT} = 4.7µF, C1005X5R0J475M)

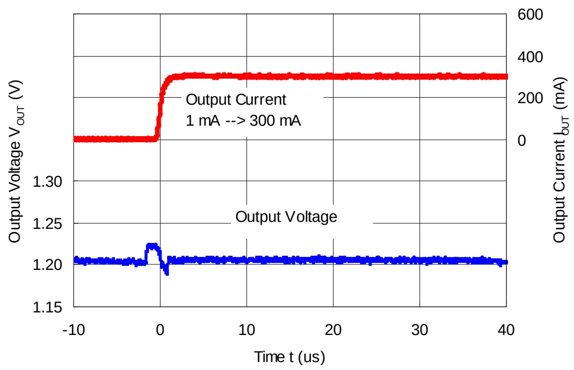
RP508K081x (V_{IN} = 3.6 V, V_{OUT} = 0.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "L" PWM/VFM auto switching control



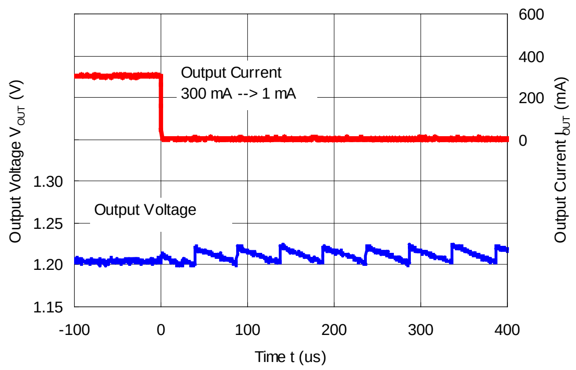
RP508K081x (V_{IN} = 3.6V, V_{OUT} = 0.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "L" PWM/VFM auto switching control



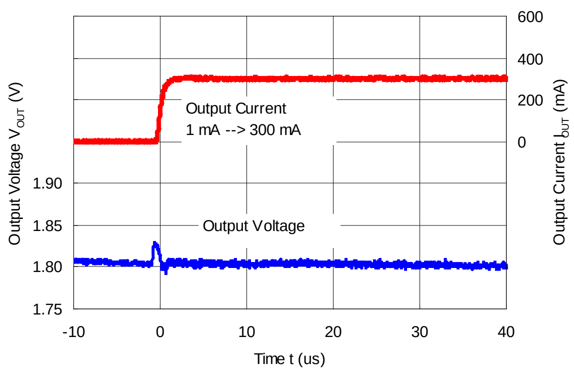
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "L" PWM/VFM auto switching control



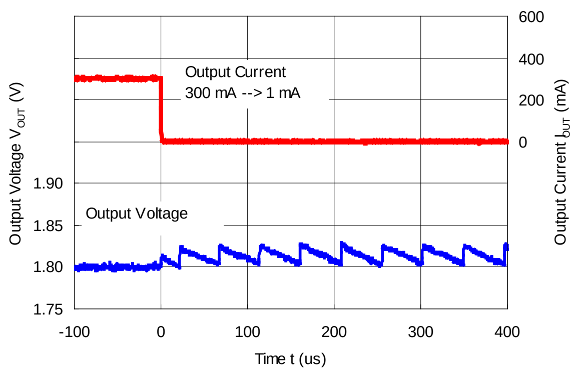
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "L" PWM/VFM auto switching control



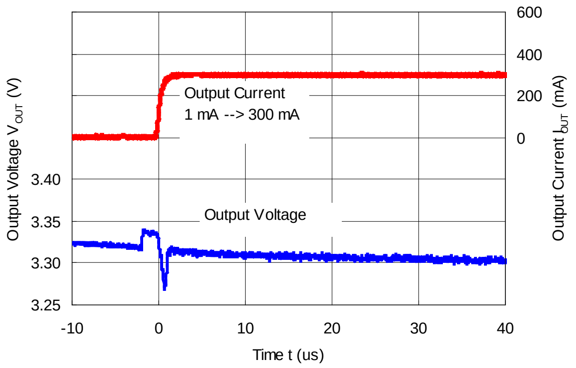
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "L" PWM/VFM auto switching control



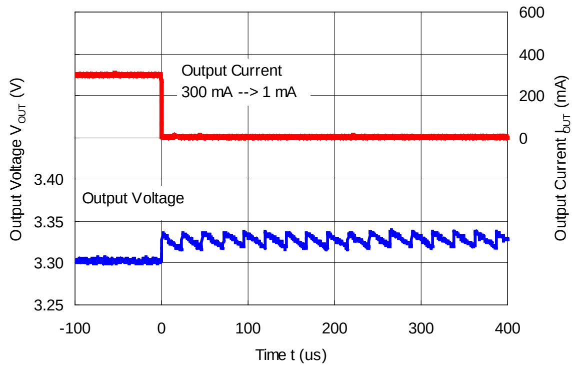
RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V)
L = MDT1608CHR47N (1608size_0.47 µH)
MODE = "L" PWM/VFM auto switching control



RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MDT1608CH1R0N (1608size_1.0 µH)
MODE = "L" PWM/VFM auto switching control

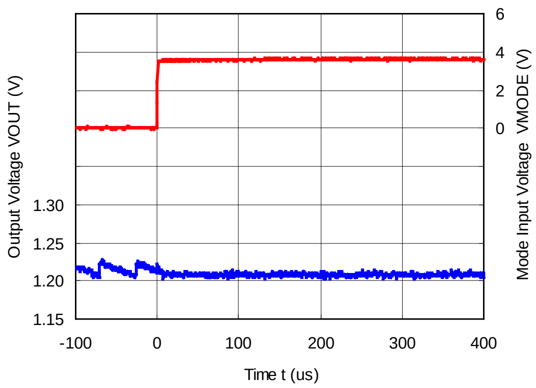


RP508K331x (V_{IN} = 5.0 V, V_{OUT} = 3.3 V)
L = MDT1608CH1R0N (1608size_1.0 µH)
MODE = "L" PWM/VFM auto switching control

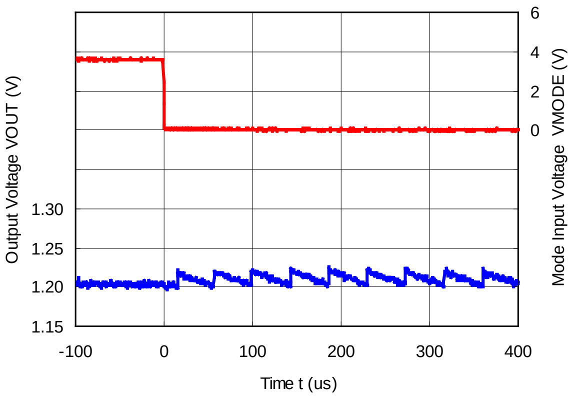


19) Mode Switching Waveform

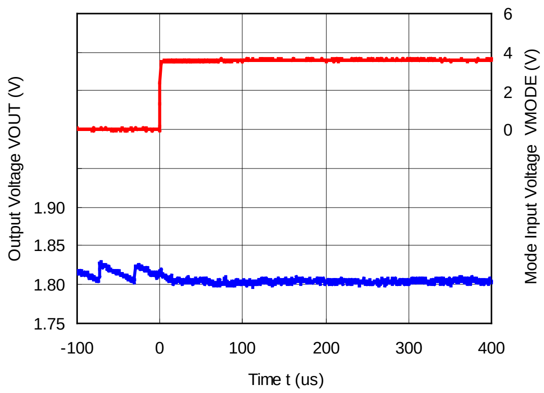
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V, I_{OUT} = 1 mA)
MODE = "L" → MODE = "H"



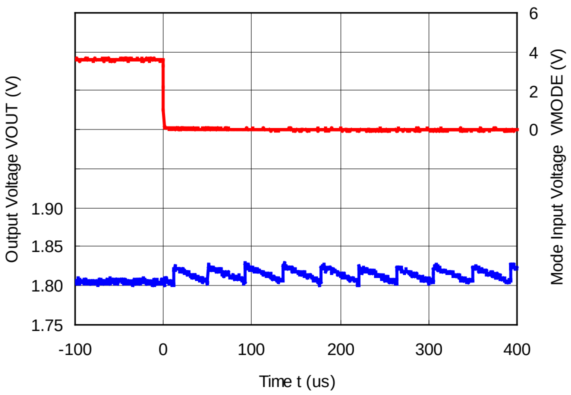
RP508K121x (V_{IN} = 3.6 V, V_{OUT} = 1.2 V, I_{OUT} = 1 mA)
MODE = "H" → MODE = "L"



RP508K181x (V_{IN} = 3.6 V, V_{OUT} = 1.8 V, I_{OUT} = 1 mA)
MODE = "L" → MODE = "H"



RP508K181x (V_{IN} = 3.6V, V_{OUT} = 1.8 V, I_{OUT} = 1 mA)
MODE = "H" → MODE = "L"



Ver. A

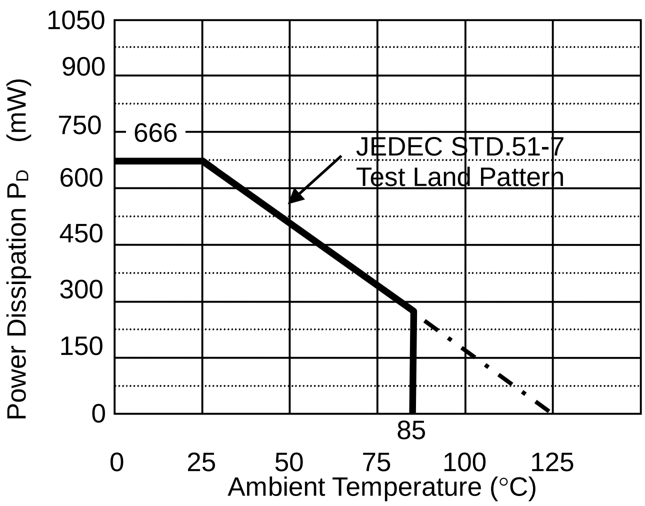
The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following conditions are used in this measurement.

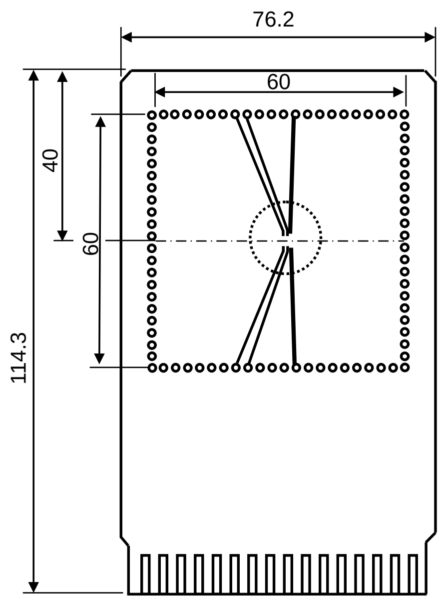
Measurement Conditions

	JEDEC STD.51-7 Test Land Pattern
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 1.6 mm
Copper Ratio	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	ϕ 0.85 mm × 44 pcs

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

	JEDEC STD.51-7 Test Land Pattern
Power Dissipation	666 mW
Thermal Resistance	θja = (125 − 25°C) / 0.666 W = 150°C/W θjc = 28°C/W



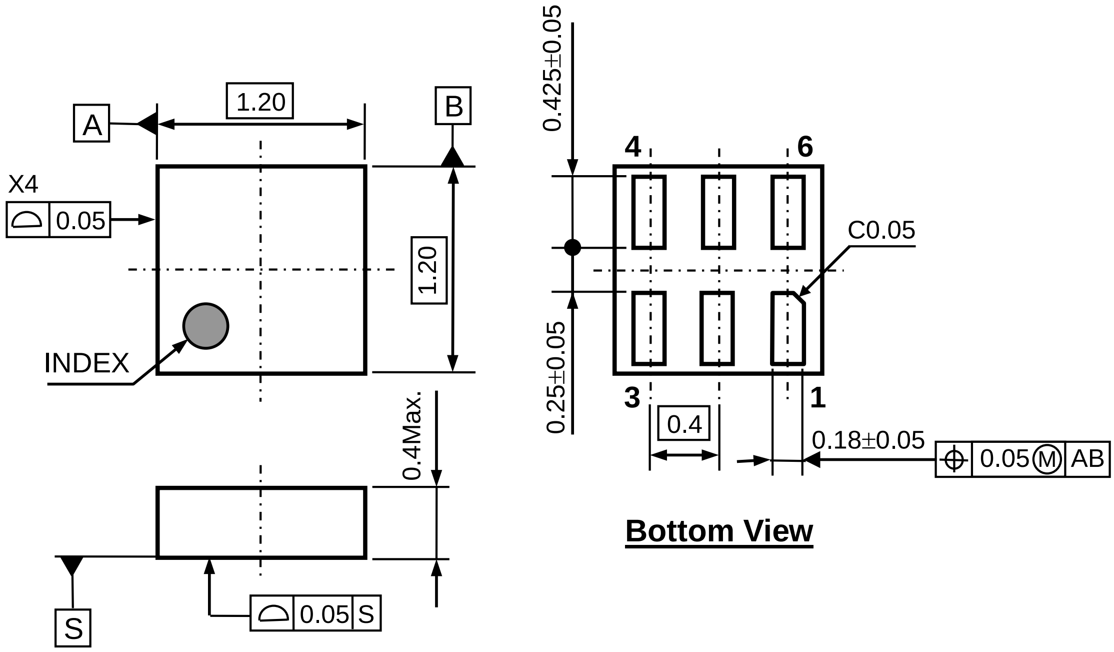


Measurement Board Pattern

IC Mount Area (mm)

Power Dissipation vs. Ambient Temperature

Measurement Board Pattern



DFN(PLP)1212-6F Package Dimensions (Unit: mm)

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