# 1A Step-down DC/DC Converters with Synchronous Rectifier

No.EA-273-210909

## OUTLINE

The RP505K Series are low supply current CMOS-based 1A[*1] step-down DC/DC Converters with synchronous rectifier. Each of these ICs consists of an oscillator, a reference voltage unit, an error amplifier, a switching control circuit, a mode control circuit, a soft-start circuit, a latch type protection circuit, an under voltage lock out (UVLO) circuit, a thermal shutdown circuit, and a switching transistors. A low ripple, high efficiency synchronous rectifier step-down DC/DC converter can be easily composed of this IC with only an inductor and capacitors. Since the package is DFN(PL)2020-8, high density mounting on boards is possible.

In the RP505K series, as for the A version and B version, since feedback resistors are built-in, the voltage is fixed internally. 0.1V step output can be set by laser-trim and ±1.5%($V_{OUT}$≥1.2V) or 18mV($V_{OUT}$<1.2V) tolerance is guaranteed. As for the C version, output voltage is adjustable with external divider resisters.

By inputting a signal to MODE pin, the RP505K Series can choose PWM/VFM alternative mode or forced PWM mode. In low output current, PWM/VFM alternative mode automatically switches from PWM to VFM in order to achieve high efficiency. Likewise, in low output current, Forced PWM mode switches at fixed frequency in order to reduce noise.

As protection circuits, the RP505K Series contain a current limit circuit which limits the Lx peak current in each clock cycle, and a latch type protection circuit which latches the built-in driver to the OFF state if the load current exceeds the limit value or the output short continues for a specified time (the protection delay time). The latch protective circuit can be released by once putting the IC into the standby mode with the CE pin and then into the active mode, or, by turning the power off and back on. Setting the supply voltage lower than the UVLO detector threshold can also release the latch protective circuit. The RP505K Series also contain a thermal shutdown circuit which detects the overheating and resets the IC when the junction temperature of the RP505K Series exceeds the specified temperature.

[*1] This is an approximate value, because output current depends on conditions and external parts.

## FEATURES

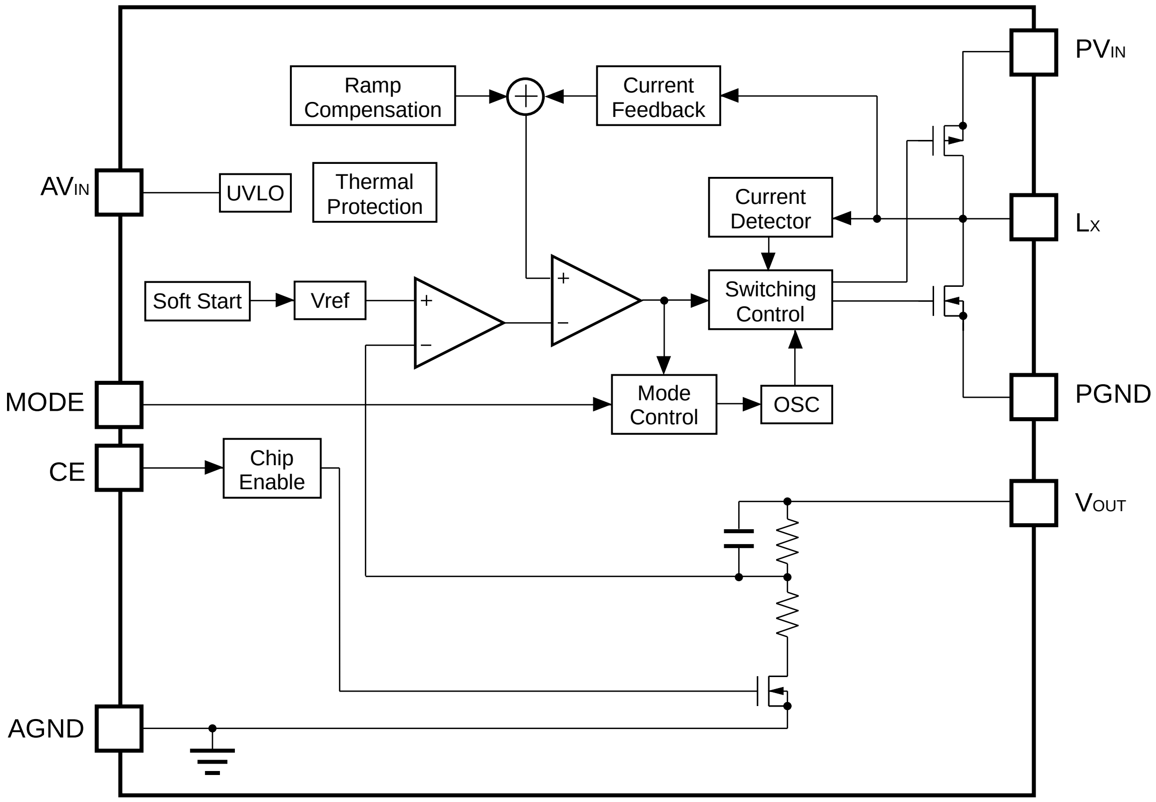
- Supply Current ...................... Typ. 40μA (VFM mode with no-load)
- Standby Current ...................... Max. 5μA
- Input Voltage Range ...................... 2.3V to 5.5V (Absolute maximum rating: 6.5V)
- Output Voltage Range (Ver.A,B) ...................... 0.6V to 3.3V (Adjustable in 0.1V steps.
  Note: As for 0.8V or less, input voltage range is limited.)
  (Ver.C) ...................... 0.8V to 3.3V
- Output Voltage Accuracy (Ver.A,B) ...................... ±1.5% ($V_{OUT}$≥1.2V), ±18mV ($V_{OUT}$<1.2V)
- Feedback Voltage Accuracy (Ver.C) ...................... ±9mV ($V_{FB}$=0.6V)
- Temperature-Drift Coefficient of Output Voltage/ Feedback
  ...................... Typ. ±100ppm/°C
- Oscillator Frequency ...................... Typ. 2.25MHz
- Oscillator Maximum Duty Cycle ...................... Min. 100%
- Built-in Driver ON Resistance ...................... Typ. Pch. 0.23Ω, Nch. 0.20Ω ($V_{IN}$=3.6V)
- UVLO Detector Threshold ...................... Typ. 2.0V
- Soft-start Time ...................... Typ. 0.15ms
- $L_X$ Current Limit Circuit ...................... Typ. 1.7A
- Latch Type Protection Circuit ...................... Typ. 1.5ms
- Package ...................... DFN(PL)2020-8

## APPLICATIONS

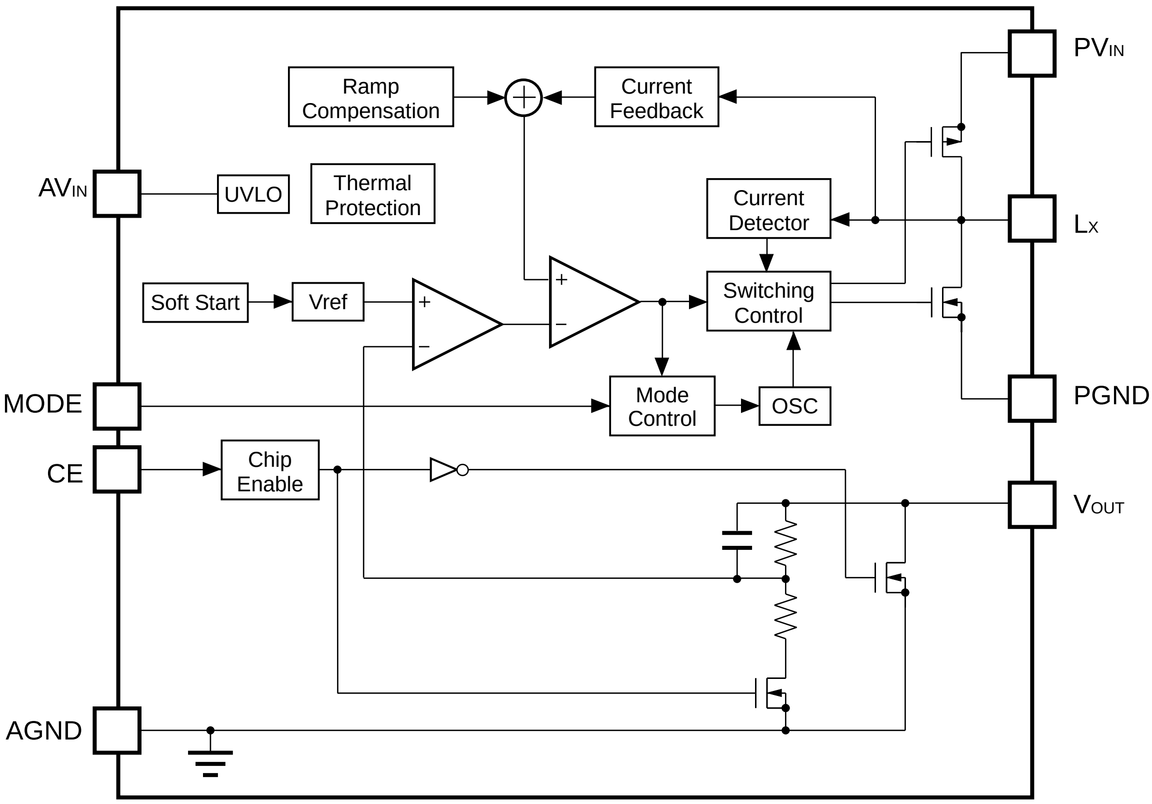
- Power source for portable equipment such as cellular, PDA, DSC, Notebook PC
- Power source for HDD, WLAN.
- Power source for Li-ion battery-used equipment

## BLOCK DIAGRAMS

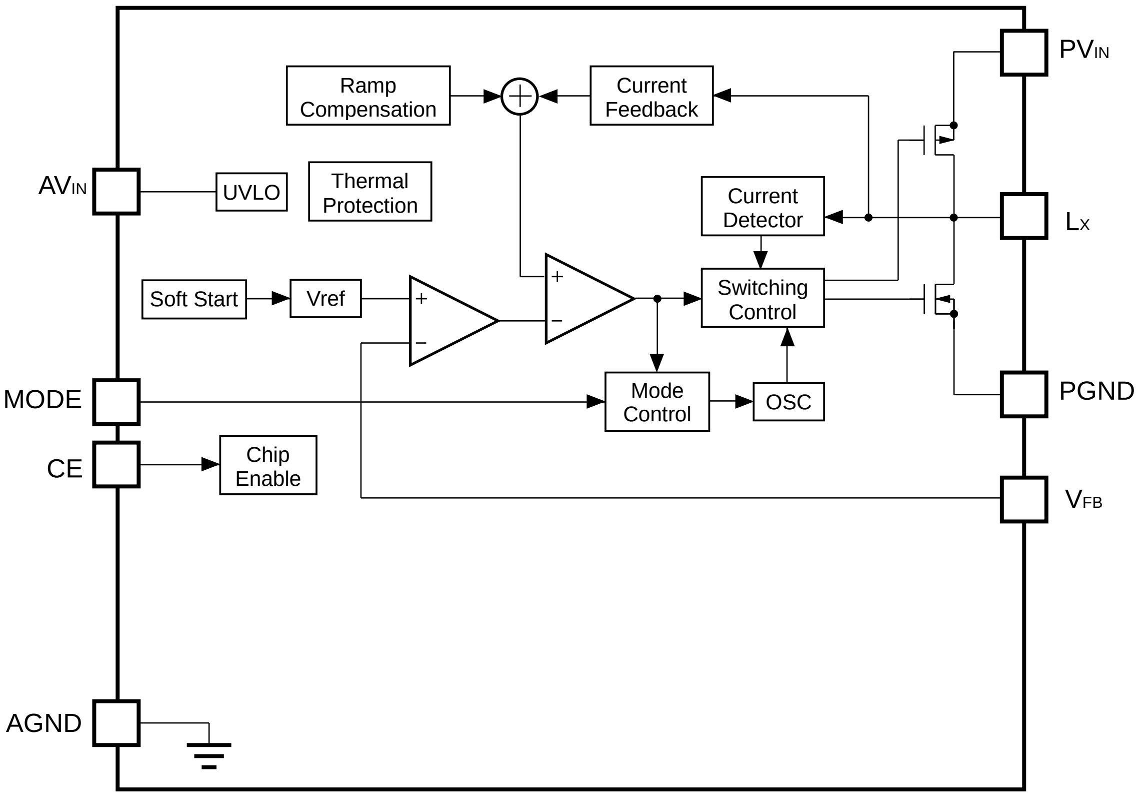
**RP505Kxx1A**



**RP505Kxx1B**




**RP505K001C**



## SELECTION GUIDE

In the RP505K Series, output voltage, and auto discharge function for the IC are selectable at the user's request.

| Product Name | Package | Quantity per Reel | Pb Free | Halogen Free |
|---|---|---|---|---|
| RP505Kxx1$-TR | DFN(PL)2020-8 | 5,000pcs | Yes | Yes |

xx : The output voltage can be designated in the range from 0.6V(06) to 3.3V(33) in 0.1V*1 steps.
The output voltage adjustable type: xx=00
(For other voltages, please refer to MARK INFORMATIONS.)

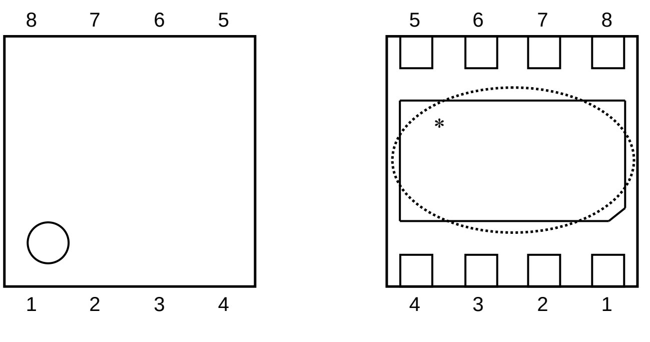
$ : Designation of Mask Option
A) Fixed output voltage type, without auto-discharge function at off state
B) Fixed output voltage type, with auto-discharge function at off state
C) Adjustable output voltage type, without auto-discharge function at off state

Auto-discharge function quickly lowers the output voltage to 0V, 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.
*1 0.05V step is also available as a custom code.

## PIN CONFIGURATIONS

• **DFN(PL)2020-8**

**Top View** **Bottom View**



# PIN DESCRIPTIONS

- **RP505K: DFN(PL)2020-8**

| Pin No. | Symbol | Description |
|---|---|---|
| 1 | MODE | Mode Control Pin (“H” Forced PWM Mode, “L” PWM/VFM Alternative Mode) |
| 2 | CE | Chip Enable Pin ("H" Active) |
| 3 | $AV_{IN}$ | Input Pin[*1] |
| 4 | $PV_{IN}$ | Input Pin[*1] |
| 5 | $L_X$ | $L_X$ Switching Pin |
| 6 | PGND | Ground Pin[*1] |
| 7 | AGND | Ground Pin[*1] |
| 8 | $V_{OUT}/V_{FB}$ | Output Pin / Feedback Pin |

Tab is GND level. (They are connected to the reverse side of this IC.) The tab is better to be connected to the GND, but leaving it open is also acceptable.

[*1] No.3 pin and No.4 pin, and also No.6 pin and No.7 pin must be wired each other when mounted on boards.

# ABSOLUTE MAXIMUM RATINGS

(AGND=PGND=0V)

| Symbol | Item | Rating | Unit |
|---|---|---|---|
| $A/PV_{IN}$ | $AV_{IN}/PV_{IN}$ Input Voltage | -0.3 to 6.5 | V |
| $V_{LX}$ | $L_X$ Pin Voltage | -0.3 to $A/PV_{IN}$ + 0.3 | V |
| $V_{CE}$ | CE Pin Input Voltage | -0.3 to 6.5 | V |
| $V_{OUT}/V_{FB}$ | $V_{OUT}/V_{FB}$ Pin Voltage | -0.3 to 6.5 | V |
| $V_{MODE}$ | MODE Pin Voltage | −0.3 to 6.5 | V |
| $I_{LX}$ | $L_X$ Pin Output Current | 1.7 | A |
| $P_D$ | Power Dissipation (Standard Test Land Pattern)*[1] | 880 | mW |
| Ta | Operating Temperature Range | -40 to 85 | °C |
| Tstg | Storage Temperature Range | -55 to 125 | °C |

[*1] For Power Dissipation and Standard Test Land Pattern, please refer to PACKAGE INFORMATION.

| 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 is not assured. |

| RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS) |
|---|
| 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. |

# ELECTRICAL CHARACTERISTICS

- **RP505Kxx1A/B**

(Ta=25°C)

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $A/PV_{IN}$ | Operating Input Voltage | $0.8V \leqq V_{OUT} \leqq 3.3V$ | 2.3 | | 5.5 | V |
| | | $0.7V \leqq V_{OUT} < 0.8V$ | 2.3 | | 4.4 | |
| | | $0.6V \leqq V_{OUT} < 0.7V$, MODE="L"[*1] | 2.3 | | 4.2 | |
| $V_{OUT}$ | Output Voltage | Refer to the conditions below.[*2] $V_{OUT} \geq 1.2V$ | -1.5% | | +1.5% | V |
| | | Refer to the conditions below.[*2] $V_{OUT} < 1.2V$ | -0.018 | | +0.018 | |
| $\Delta V_{OUT}/\Delta T$ | Output Voltage Temperature Coefficient | $-40°C \leqq Ta \leqq 85°C$ | | ±100 | | ppm/°C |
| fosc | Oscillator Frequency | Refer to the conditions below.[*2] | 2.00 | 2.25 | 2.50 | MHz |
| $I_{DD1}$ | Supply Current 1 | $A/PV_{IN}=V_{CE}=5.5V$, $V_{OUT}=V_{SET}\times0.8$ | | 500 | 840 | μA |
| $I_{DD2}$ | Supply Current 2 | $A/PV_{IN}=V_{CE}=V_{OUT}=5.5V$, $V_{MODE}=0V$ | | 40 | 60 | μA |
| | | $A/PV_{IN}=V_{CE}=V_{OUT}=5.5V$, $V_{MODE}=5.5V$ | | 500 | 840 | |
| Istandby | Standby Current | $A/PV_{IN}=5.5V, V_{CE}=0V$ | | 0 | 5 | μA |
| $I_{CEH}$ | CE "H" Input Voltage | $A/PV_{IN}=V_{CE}=5.5V$ | -1 | 0 | 1 | μA |
| $I_{CEL}$ | CE "L" Input Voltage | $A/PV_{IN}=5.5V, V_{CE}=0V$ | -1 | 0 | 1 | μA |
| $I_{MODEH}$ | Mode "H" Input Current | $A/PV_{IN}=V_{MODE}=5.5V, V_{CE}=0V$ | -1 | 0 | 1 | μA |
| $I_{MODEL}$ | Mode "L" Input Current | $A/PV_{IN}=5.5V, V_{CE}=V_{MODE}=0V$ | -1 | 0 | 1 | μA |
| $I_{VOUTH}$ | VOUT "H" Input Current[*3] | $A/PV_{IN}=V_{OUT}=5.5V, V_{CE}=0V$ | -1 | 0 | 1 | μA |
| $I_{VOUTL}$ | VOUT "L" Input Current | $A/PV_{IN}=5.5V, V_{CE}=V_{OUT}=0V$ | -1 | 0 | 1 | μA |
| $R_{LOW}$ | Nch On Resistance for Auto Discharge[*4] | $A/PV_{IN}=3.6V, V_{CE}=0V$ | | 30 | | Ω |
| $I_{LXLEAKH}$ | LX Leakage Current "H" | $A/PV_{IN}=V_{LX}=5.5V, V_{CE}=0V$ | -1 | 0 | 5 | μA |
| $I_{LXLEAKL}$ | LX Leakage Current "L" | $A/PV_{IN}=5.5V, V_{CE}=V_{LX}=0V$ | -5 | 0 | 1 | μA |
| $V_{CEH}$ | CE "H" Input Voltage | $A/PV_{IN}=5.5V$ | 1.0 | | | V |
| $V_{CEL}$ | CE "L" Input Voltage | $A/PV_{IN}=2.3V$ | | | 0.4 | V |
| $V_{MODEH}$ | Mode "H" Input Voltage | $A/PV_{IN}=V_{CE}=5.5V$ | 1.0 | | | V |
| $V_{MODEL}$ | Mode "L" Input Voltage | $A/PV_{IN}=V_{CE}=2.3V$ | | | 0.4 | V |
| $R_{ONP}$ | On Resistance of Pch Tr. | $A/PV_{IN}=3.6V$, $I_{LX}=-100mA$ | | 0.23 | | Ω |
| $R_{ONN}$ | On Resistance of Nch Tr. | $A/PV_{IN}=3.6V$, $I_{LX}=-100mA$ | | 0.20 | | Ω |
| Maxduty | Oscillator Maximum Duty Cycle | | 100 | | | % |
| tstart | Soft-start Time | Refer to the conditions below.[*2] | | 150 | 300 | μs |
| $I_{LXlim}$ | Lx Current Limit | Refer to the conditions below.[*2] | 1400 | 1700 | | mA |
| tprot | Protection Delay Time | Refer to the conditions below.[*2] | 0.5 | 1.5 | 5 | ms |
| $V_{UVLO1}$ | UVLO Detector Threshold | $A/PV_{IN}=V_{CE}$ | 1.9 | 2.0 | 2.1 | V |
| $V_{UVLO2}$ | UVLO Released Voltage | $A/PV_{IN}=V_{CE}$ | 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 |

Note: Test circuit is "OPEN LOOP" and AGND=PGND=0V unless otherwise specified.
[*1] $0.6V \leqq V_{OUT} < 0.7V$: MODE="L"PWM/VFM Alternative Mode.
[*2] $A/PV_{IN}=V_{CE}=3.6V$ ($V_{SET} \leqq 2.6V$), $A/PV_{IN}=V_{CE}=V_{SET}+1V$ ($V_{SET}>2.6V$)
[*3] with no auto discharge version only
[*4] with auto discharge version only

- **RP505K001C**

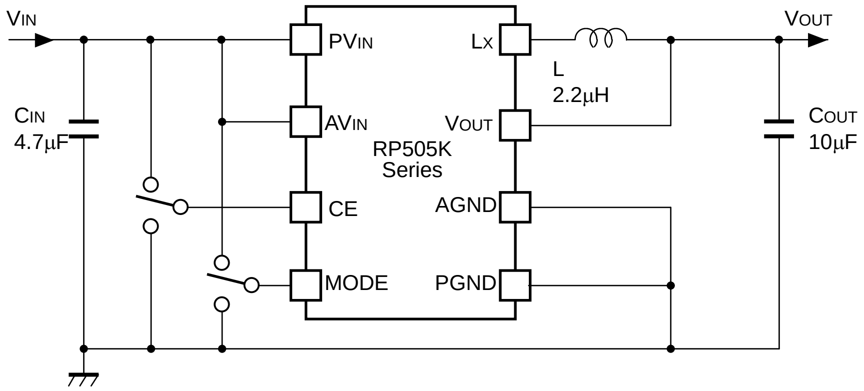
(Ta=25°C)

| Symbol | Item | Conditions | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| $A/PV_{IN}$ | Operating Input Voltage | | | 2.3 | | 5.5 | V |
| $V_{FB}$ | Feedback Output Voltage | $A/PV_{IN}=V_{CE}=3.6V$ | | 0.591 | 0.600 | 0.609 | V |
| $\Delta V_{FB}/\Delta T$ | Feedback Output Voltage Temperature Coefficient | $-40°C \leqq Ta \leqq 85°C$ | | | ±100 | | ppm/°C |
| fosc | Oscillator Frequency | Refer to the conditions below. *1 | | 2.00 | 2.25 | 2.50 | MHz |
| $I_{DD1}$ | Supply Current 1 | $A/PV_{IN}=V_{CE}=5.5V$, $V_{FB}=0.48V$ | | | 500 | 840 | μA |
| $I_{DD2}$ | Supply Current 2 | $A/PV_{IN}=V_{CE}=V_{OUT}=5.5V$ | $V_{MODE}=0V$ | | 40 | 60 | μA |
| | | | $V_{MODE}=5.5V$ | | 500 | 840 | |
| Istandby | Standby Current | $A/PV_{IN}=5.5V, V_{CE}=0V$ | | | 0 | 5 | μA |
| $I_{CEH}$ | CE "H" Input Voltage | $A/PV_{IN}=V_{CE}=5.5V$ | | -1 | 0 | 1 | μA |
| $I_{CEL}$ | CE "L" Input Voltage | $A/PV_{IN}=5.5V, V_{CE}=0V$ | | -1 | 0 | 1 | μA |
| $I_{MODEH}$ | Mode "H" Input Current | $A/PV_{IN}=V_{MODE}=5.5V, V_{CE}=0V$ | | -1 | 0 | 1 | μA |
| $I_{MODEL}$ | Mode "L" Input Current | $A/PV_{IN}=5.5V, V_{CE}=V_{MOD}E=0V$ | | -1 | 0 | 1 | μA |
| $I_{VFBH}$ | VFB "H" Input Current | $A/PV_{IN}=V_{OUT}=5.5V, V_{CE}=0V$ | | -1 | 0 | 1 | μA |
| $I_{VFBL}$ | VFB "L" Input Current | $A/PV_{IN}=5.5V, V_{CE}=V_{OUT}=0V$ | | -1 | 0 | 1 | μA |
| $I_{LXLEAKH}$ | LX Leakage Current "H" | $A/PV_{IN}=V_{LX}=5.5V, V_{CE}=0V$ | | -1 | 0 | 5 | μA |
| $I_{LXLEAKL}$ | LX Leakage Current "L" | $A/PV_{IN}=5.5V, V_{CE}=V_{LX}=0V$ | | -5 | 0 | 1 | μA |
| $V_{CEH}$ | CE "H" Input Voltage | $A/PV_{IN}=5.5V$ | | 1.0 | | | V |
| $V_{CEL}$ | CE "L" Input Voltage | $A/PV_{IN}=2.3V$ | | | | 0.4 | V |
| $V_{MODEH}$ | Mode "H" Input Voltage | $A/PV_{IN}=V_{CE}=5.5V$ | | 1.0 | | | V |
| $V_{MODEL}$ | Mode "L" Input Voltage | $A/PV_{IN}=V_{CE}=2.3V$ | | | | 0.4 | V |
| $R_{ONP}$ | On Resistance of Pch Tr. | $A/PV_{IN}=3.6V$, $I_{LX}=-100mA$ | | | 0.23 | | Ω |
| $R_{ONN}$ | On Resistance of Nch Tr. | $A/PV_{IN}=3.6V$, $I_{LX}=-100mA$ | | | 0.20 | | Ω |
| Maxduty | Oscillator Maximum Duty Cycle | | | 100 | | | % |
| tstart | Soft-start Time | Refer to the conditions below. *1 | | | 150 | 300 | μs |
| $I_{LXlim}$ | LX Current Limit | Refer to the conditions below. *1 | | 1400 | 1700 | | mA |
| tprot | Protection Delay Time | Refer to the conditions below. *1 | | 0.5 | 1.5 | 5 | ms |
| $V_{UVLO1}$ | UVLO Detector Threshold | $A/PV_{IN}=V_{CE}$ | | 1.9 | 2.0 | 2.1 | V |
| $V_{UVLO2}$ | UVLO Released Voltage | $A/PV_{IN}=V_{CE}$ | | 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 |

Test circuit is "OPEN LOOP" and AGND=PGND=0V unless otherwise specified.
*1 $A/PV_{IN}=V_{CE}=3.6V$ ($V_{SET} \leqq 2.6V$), $A/PV_{IN}=V_{CE}=V_{SET}+1V$ ($V_{SET}>2.6V$)

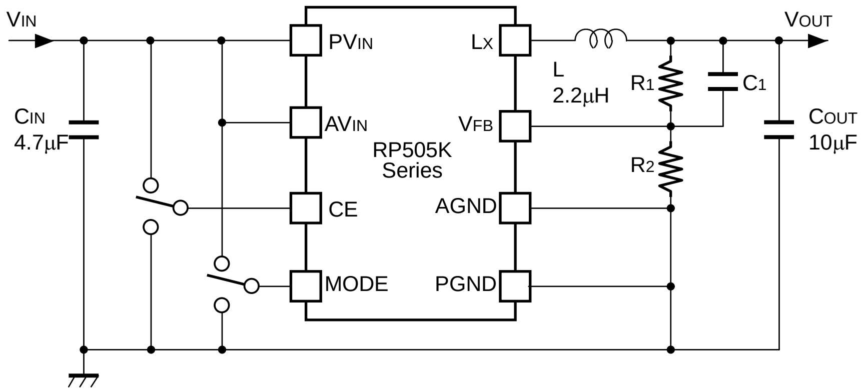
# TYPICAL APPLICATION

(Fixed Output Voltage Type)




∗) MODE=“H” Forced PWM Mode
MODE=“L” PWM/VFM Alternative Mode

(Adjustable Output Voltage Type)




∗) MODE=“H” Forced PWM Mode
MODE=“L”PWM/VFM Alternative Mode

| Symbol | Recommendation components | | |
|---|---|---|---|
| $C_{IN}$ | 4.7µF | Ceramic | C1608JB0J475K(TDK) |
| $C_{OUT}$ | 10µF | Ceramic | C1608JB0J106M(TDK) |
| L | 2.2µH | Inductor | MIPSA2520D2R2(FDK) |

# TECHNICAL NOTES

When you use these ICs, consider the following issues:

- Set the same level as AGND and PGND.
- Set the same level as $AV_{IN}$ and $PV_{IN}$.
- Place the external parts as close as possible to the IC by using a short as possible wiring. Especially, place the capacitor as close as possible to the $PV_{IN}$ and PGND pins. Ensure the $V_{DD}$ and GND lines are sufficiently robust. If their impedances are too high, the electrical potential of the inside of the IC could be fluctuated by switching current, and noise pickup or unstable operation could be the results. Please note that the large switching current flows through the $V_{DD}$ line, the GND line, an inductor, the $L_X$, and the $V_{OUT}$ line. Separate the line between the $V_{OUT}$ pin and an inductor (A and B versions), and the line between a resistor for setting output voltage (R1) and an inductor (C version), from the line connected to the load. Use a ceramic capacitor with the small ESR value.
- The recommended capacitance value for the $C_{IN}$ capacitor connected between the $PV_{IN}$ and PGND pins is 4.7µF or more. Also, the recommended capacitance value for the $C_{OUT}$ capacitor is 10µF.
- The Inductance value should be set within the rage of 1.0 to 2.2µH. However, the inductance value is limited by output voltage, so please refer to the table below. For stable operation, the phase compensation is set according to the specified inductance value and the specified $C_{OUT}$ capacitance value. Select the inductor with low DC resistance, with large permissive current, with high resistant to magnetic saturation. Select the inductance value considering the load current by the conditions of use. If the inductance value is small, the $L_X$ peak current may increase along with the increase of load current. When the $L_X$ peak current reaches to the "$L_X$ limit current", the current limit circuit may be activated.

**【Inductance Range vs. Output Voltage Range】**

| $V_{OUT}$ [V] | L=1.0µH | L=1.5µH | L=2.2µH |
|---|---|---|---|
| 0.6~1.55 | ○ | ○ | ○ |
| 1.6~2.3 | × | ○ | ○ |
| 2.35~3.3 | × | × | ○ |

- Please note that Current limit circuit and Latch type protection circuit could be affected by self-heating or heat dissipation environment.
- For adjustable output voltage type (C version), the output voltage ($V_{OUT}$) is adjustable by changing the $R_1$ and $R_2$ values as follows.

$$V_{OUT} = V_{FB} \times (R_1 + R_2) / R_2 \qquad (0.8V \leqq V_{OUT} \leqq 3.3V)$$

If the $R_1$ and $R_2$ values are large, the impedances of the $V_{FB}$ pin become large and could be easily affected by noise. Therefore, set the $R_2$ value to 220kΩ or less. If the operation becomes unstable due to the high impedance, the impedance should be decreased. The $C_1$ value can be calculated by the following formula. Please use the value close to the calculation result.

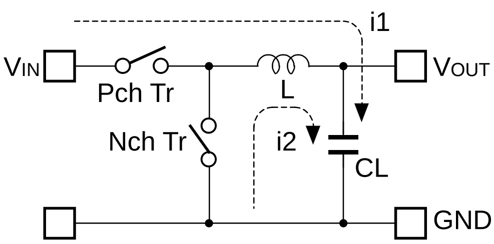
$$C_1 = 4.84 \times 10^{-6} / R_2 \text{ [F]}$$

∗ The performance of power supply circuits using this IC largely depends on the peripheral circuits. Please be very careful when setting the peripheral parts. When designing the peripheral circuits of each part, PCB patterns, and this IC, please do not exceed the rated values (Voltage, Current, Power).

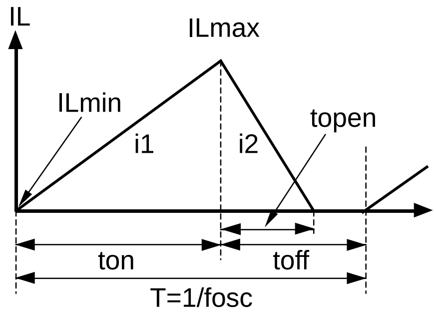
# Operation of Step-down DC/DC Converter and Output Current

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

**<Basic Circuit>**




**<Current through L>**




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

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

The maximum value ($IL_{max}$) and the minimum value ($IL_{min}$) of the current flowing through the inductor are the same as those when Pch Tr. turns on and off.
The difference between $IL_{max}$ and $IL_{min}$, which is represented by $\Delta I$:

$$\Delta I = IL_{max} - IL_{min} = V_{OUT} \times t_{open} / L = (V_{IN} - V_{OUT}) \times t_{on} / L \quad \text{.......................................Equation 1}$$

Wherein,

$T = 1 / f_{osc} = t_{on} + t_{off}$

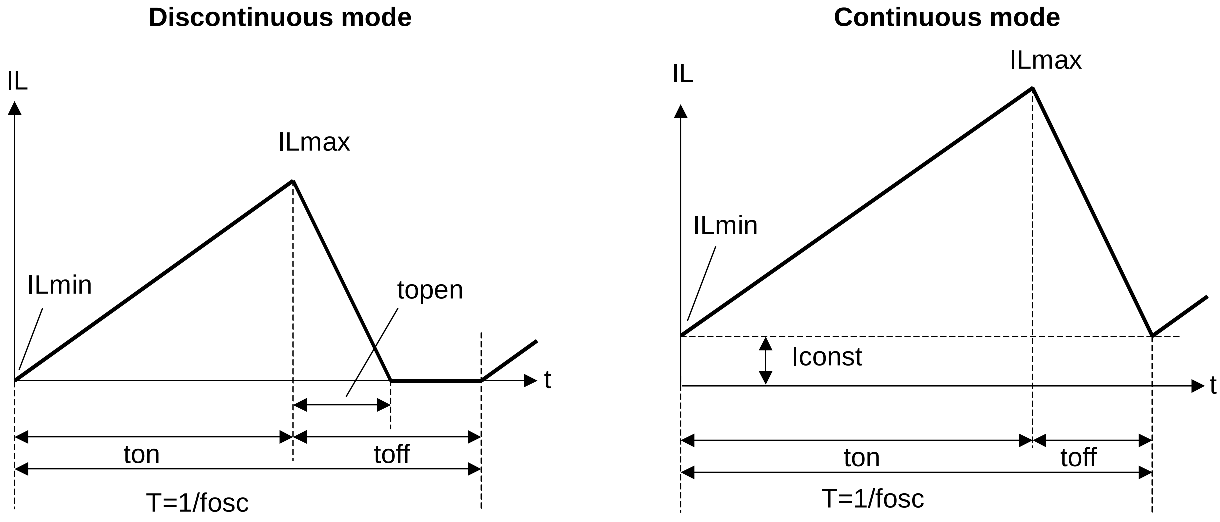
duty (%)= $t_{on} / T \times 100 = t_{on} \times f_{osc} \times 100$

$t_{open} \leq t_{off}$

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

## Discontinuous mode and Continuous mode

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




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

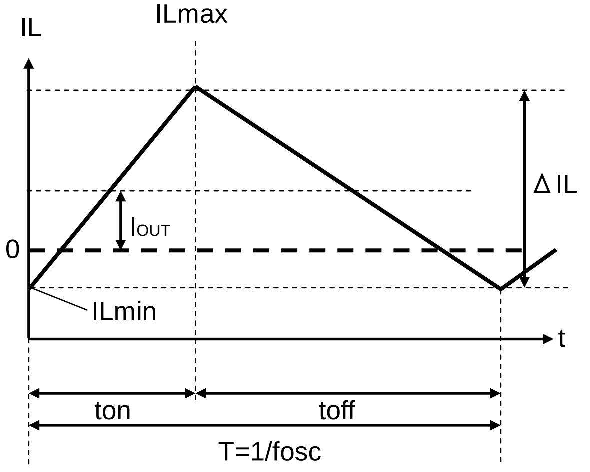
$$t_{onc} = T \times V_{OUT} / V_{IN} \quad \text{.......... Equation 2}$$

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

**Forced PWM Mode Control and VFM Mode Control**

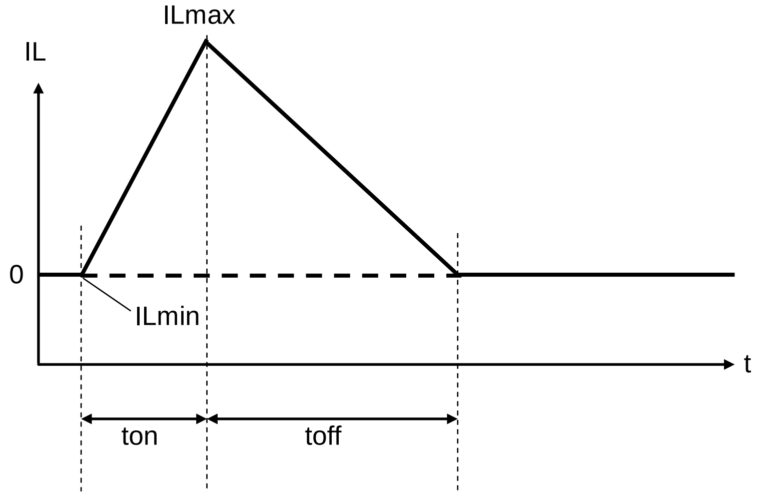
By setting the Mode pin to H, the IC switches the frequency at the fixed rate to reduce noise even when output load is light. Therefore, when $I_{OUT}$ is ΔIL/2 or less, $IL_{min}$ becomes less than 0. That is, the IC discharges the electrical charge in CL to the IC side until the IL changes from $IL_{min}$ to 0 during $t_{on}$ time, and the IL changes from 0 to $IL_{min}$ during $t_{off}$ time.

**Forced PWM Mode Control**




By setting the Mode pin to L, the IC automatically switches into VFM mode for high efficiency when output load is light. Under VFM mode, $t_{on}$ indicates the time until the IC reaches to the pre-set $IL_{max}$. With the RP505K Series, $IL_{max}$ during VFM control is pre-set to 280mA or so. However, even if the IC is not reached to $IL_{max}$ yet, $t_{on}$ turns off when it becomes around 1.5 times of T=1/$f_{osc}$.

**VFM Mode Control**



## Output Current and Selection of External Components

The relation between the output current and external components is as follows:

(Wherein, Ripple Current p-p value is described as $I_{RP}$, ON resistance of Pch Tr. and Nch Tr. of $L_X$ are respectively described as $R_{ONP}$ and $R_{ONN}$, and the DC resistor of the inductor is described as $R_L$.)

When Pch Tr. of $L_X$ is ON:

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

When Pch Tr. of $L_X$ is "OFF" (Nch Tr. is "ON"):

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

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

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

Ripple Current is as follows:

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

wherein, peak current that flows through L, and $L_X$ Tr. is as follows:

$$IL_{xmax} = I_{OUT} + I_{RP} / 2 \quad \text{...... Equation 7}$$

∗Consider $IL_{xmax}$, condition of input and output and select external components.

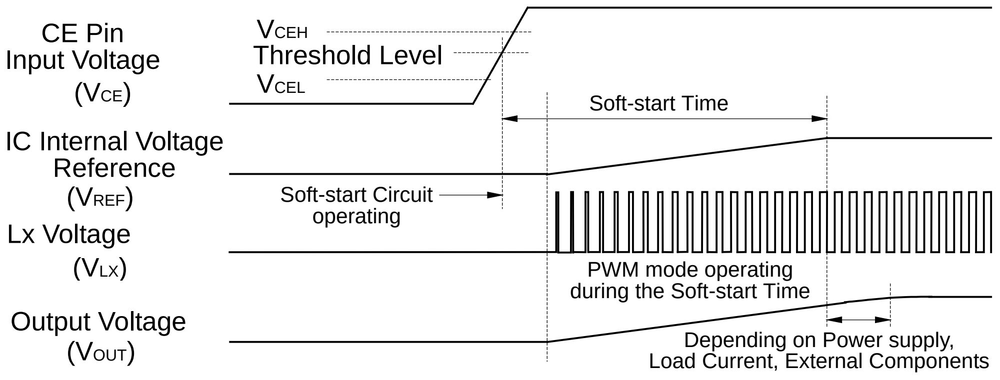
∗The above explanation is directed to the calculation in an ideal case in continuous mode.

## TIMING CHART

### (1) Soft-start Time

- **In the case of starting this IC with CE**

In the case of starting this IC with CE, the operation can be as in the timing chart below.
When the voltage of CE pin ($V_{CE}$) is beyond the threshold level, the operation of the IC starts. The threshold voltage of CE pin is in between CE "H" input voltage ($V_{CEH}$) and CE "L" input voltage ($V_{CEL}$) described in the electrical characteristics table. Soft-start circuit operates, and after the certain time, the reference voltage inside the IC ($V_{REF}$) is rising gradually up to the constant value.

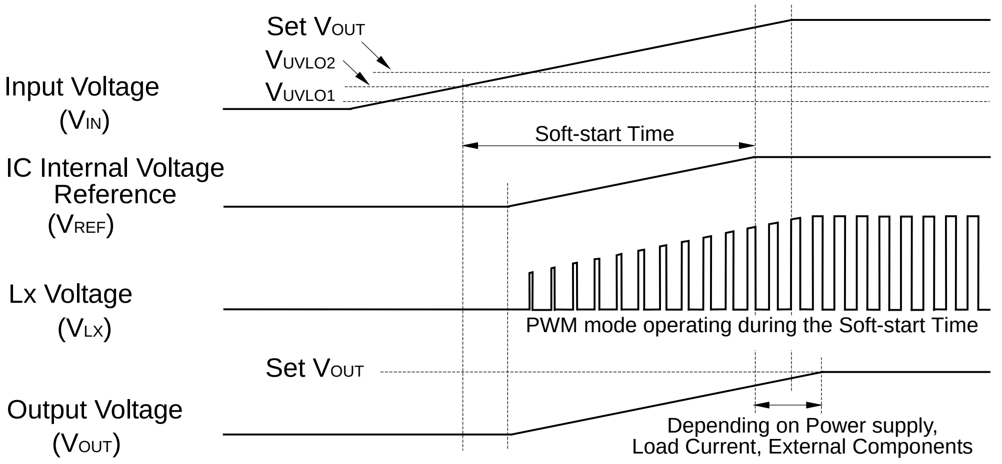



Soft-start time is the time interval from soft-start circuit starting point to the reference voltage level reaching point up to this constant level.

∗Soft-start time is not always equal to the turn-on speed of DC/DC converter.
The power supply capacity for this IC, load current, inductance and capacitance values affect the turn-on speed.

- **In the case of starting with power supply**

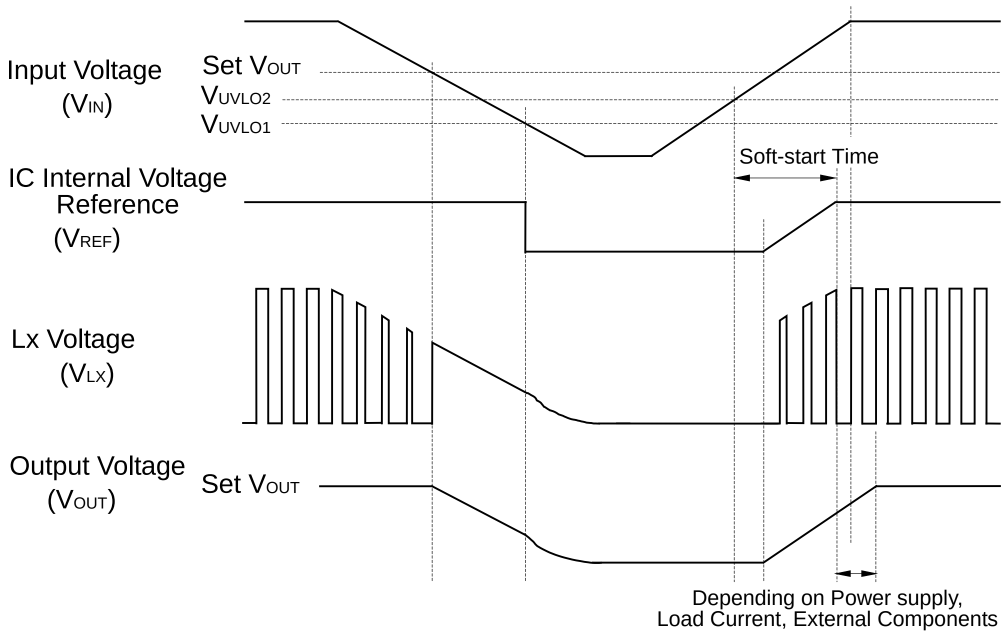
In the case of starting with power supply, when the input voltage ($V_{IN}$) is larger than UVLO released voltage ($V_{UVLO2}$), soft-start circuit operates, and after that, the same explanation above is applied to the operation.
Soft-start time is the time interval from soft-start circuit starting point to the reference voltage level reaching point up to this constant level.




∗Turn-on speed is affected by next conditions;
(a) Input Voltage ($V_{IN}$) rising speed depending on the power supplier to the IC and input capacitor $C_{IN}$.
(b) Output Capacitor $C_{OUT}$ value and load current value.

### (2) Under Voltage Lockout (UVLO) Circuit

The step-down DC/DC converter stops and ON duty becomes 100%, if input voltage ($V_{IN}$) becomes less than the set output voltage (Set $V_{OUT}$), the output voltage ($V_{OUT}$) gradually drops according to the input voltage ($V_{IN}$). If the input voltage drops more and becomes less than UVLO detector threshold ($V_{UVLO1}$), the under voltage lockout circuit (UVLO) operates, the IC internal reference voltage ($V_{REF}$) stops, switching transistors turn off and the output voltage drops according to the load and output capacitor $C_{OUT}$ value.
To restart the normal operation, the input voltage ($V_{IN}$) must be more than the UVLO released voltage ($V_{UVLO2}$).
The timing chart below describes the operation with varying the input voltage ($V_{IN}$).



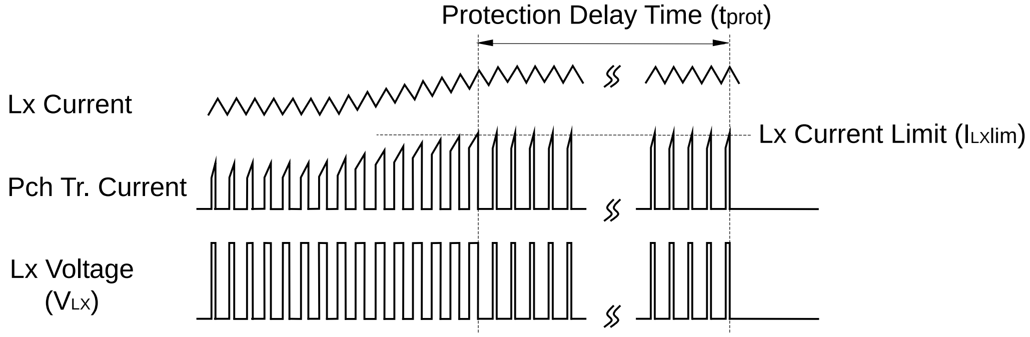

∗Actually, the waveform of $V_{OUT}$ at UVLO working and releasing varies depending on the initial voltage of $C_{OUT}$ and load current situation.

### (3) Over Current Protection Circuit, Latch Type Protection Circuit

Over current protection circuit supervises the inductor peak current (the current flowing through Pch transistor) in each switching cycle, and if the current exceeds the $L_X$ current limit ($I_{LXlim}$), turns off Pch transistor. The $L_X$ current limit of RP505K is Typ.1700mA.

Latch type protection circuit latches the built-in driver to the OFF state and stops the operation of DC/DC converter if the over current status continues or the output voltage continues being the half of the setting voltage for equal or longer than protection delay time ($t_{prot}$).

∗$L_X$ current limit ($I_{LXlim}$) and protection delay time ($t_{prot}$) could be easily affected by self-heating or ambient environment. If the input voltage ($V_{IN}$) drops drastically or becomes unstable due to short-circuit, the protection operation and protection delay time may be affected.

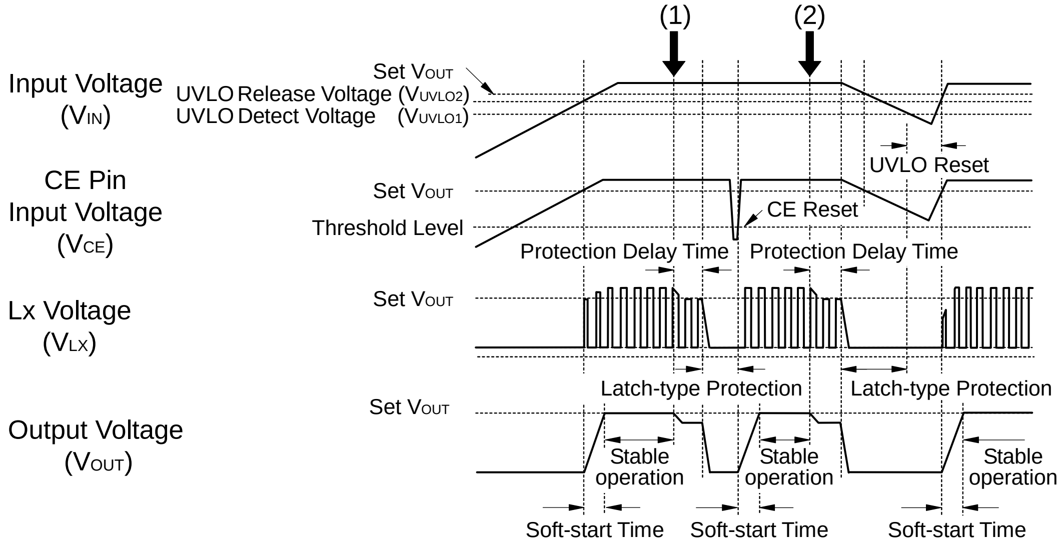



To release the condition of latch type protection, restart this IC by inputting "L" signal to CE pin, or restart this IC with power-on or make the supply voltage lower than UVLO detector threshold ($V_{UVLO1}$) level.

The timing chart shown below describes the changing process of input voltage rising, stable operating, operating with large current, reset with CE pin, stable operating, input voltage falling, input voltage recovering, and stable operating.

Point(1) : If the large current flows through the circuit or the IC goes into low output voltage condition due to short-circuit or other reasons, the latch type protection circuit latches the built-in driver to OFF state after the protection delay time ($t_{prot}$). Then, $V_{LX}$ becomes "L" and the output voltage turns OFF. In this timing chart below, the latch protective circuit can be released by once putting the IC into "L" with the CE pin and then into "H" again.

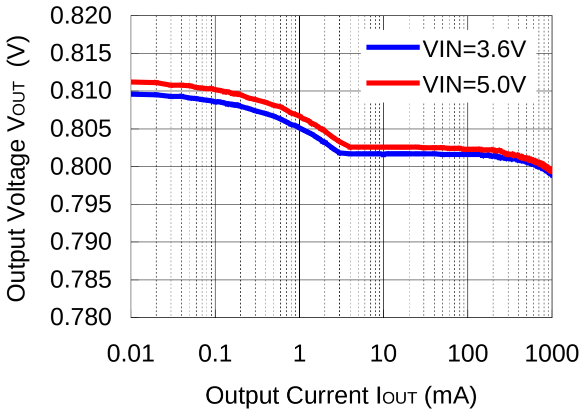
Point(2) : The latch type protection can be released by UVLO reset by making the input voltage lower than the UVLO detector threshold(VUVLO1)



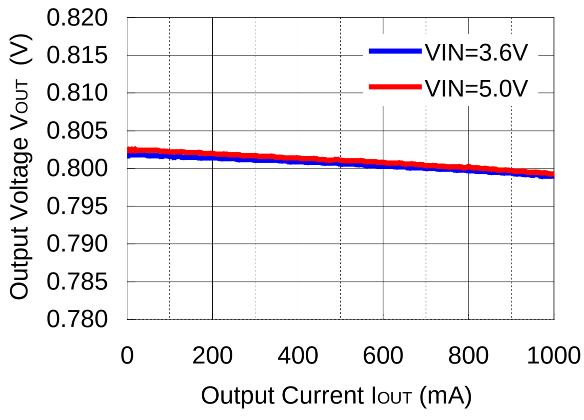
# TYPICAL CHARACTERISTICS

## 1) Output Voltage vs. Output Current

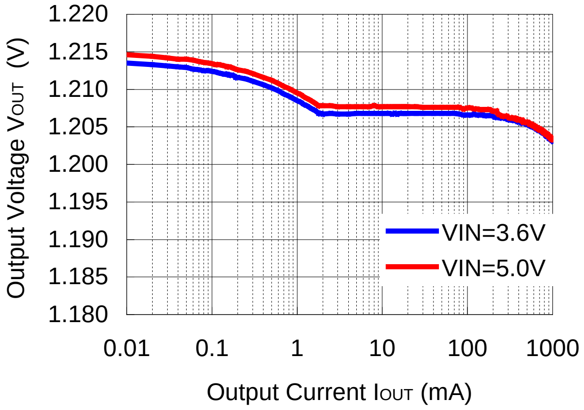
**RP505K $V_{OUT}$=0.8V**
**MODE="L"PWM/VFM automatic shift**



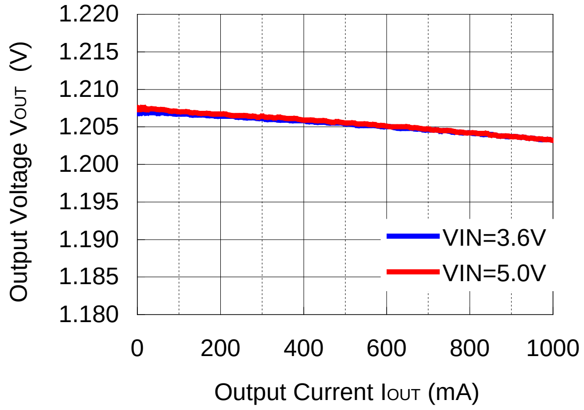

**RP505K $V_{OUT}$=0.8V**
**MODE="H" forced PWM**



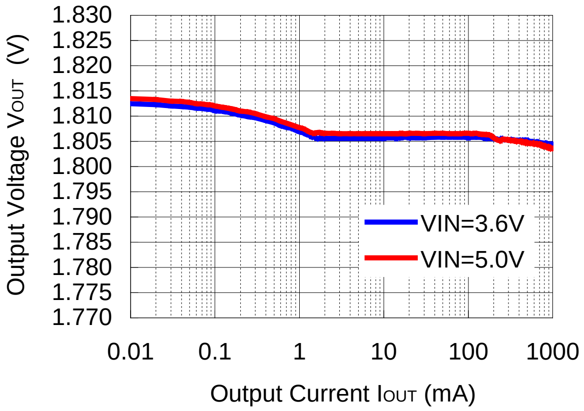

**RP505K $V_{OUT}$=1.2V**
**MODE="L"PWM/VFM automatic shift**



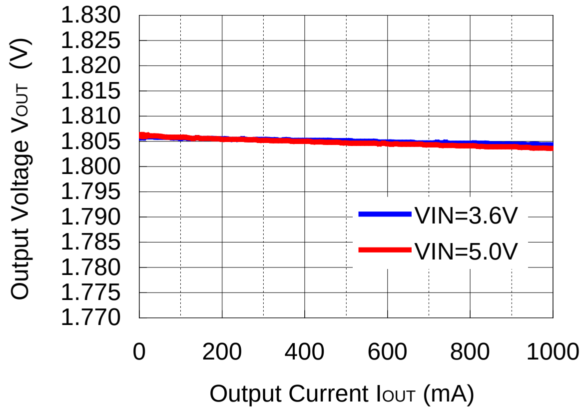

**RP505K $V_{OUT}$=1.2V**
**MODE="H" forced PWM**

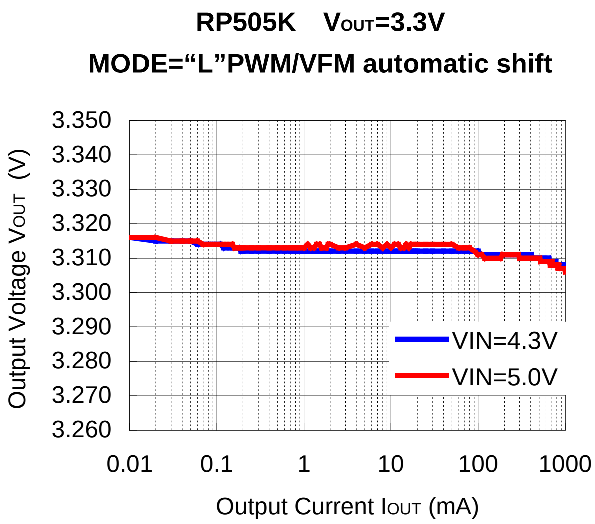


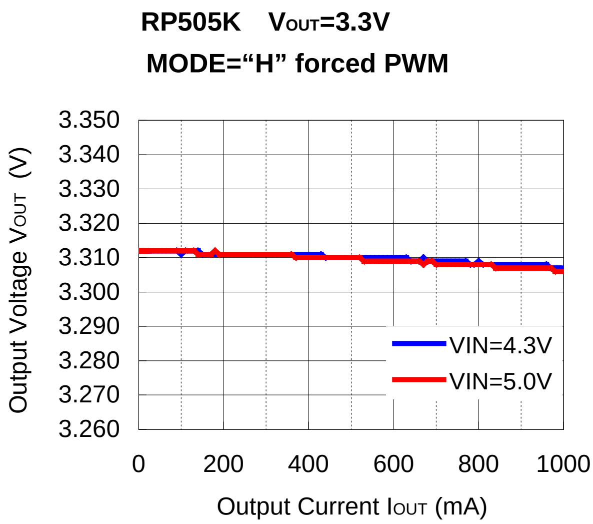

**RP505K $V_{OUT}$=1.8V**
**MODE="L"PWM/VFM automatic shift**



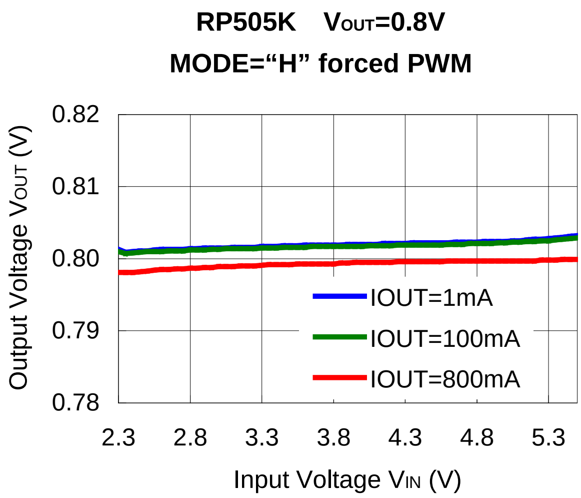

**RP505K $V_{OUT}$=1.8V**
**MODE="H" forced PWM**

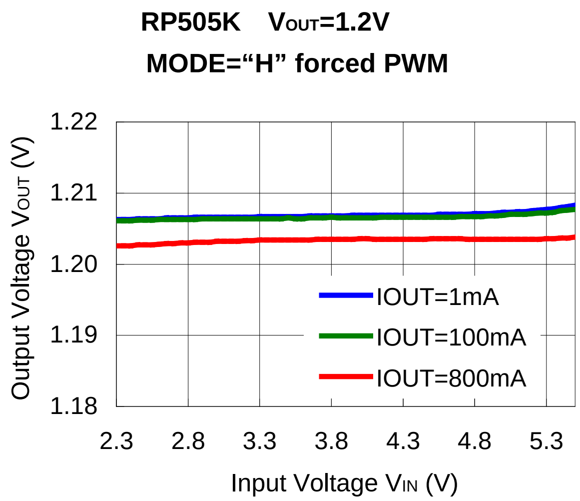


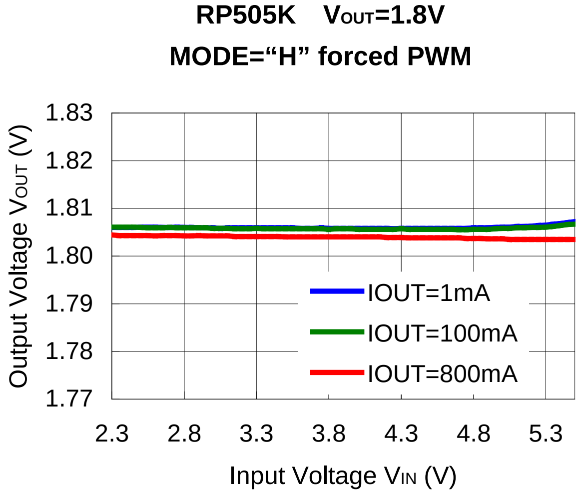


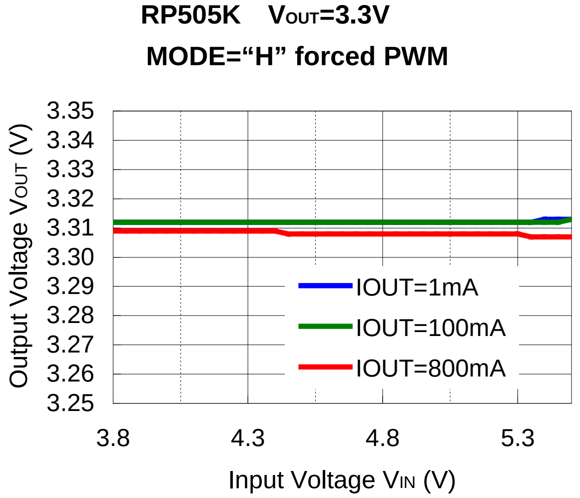




## 2) Output Voltage vs. Input Voltage



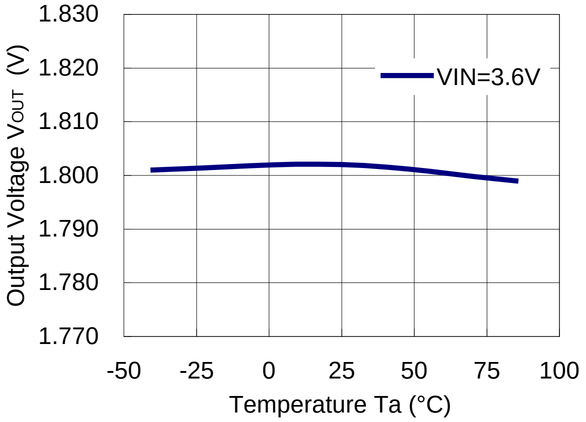



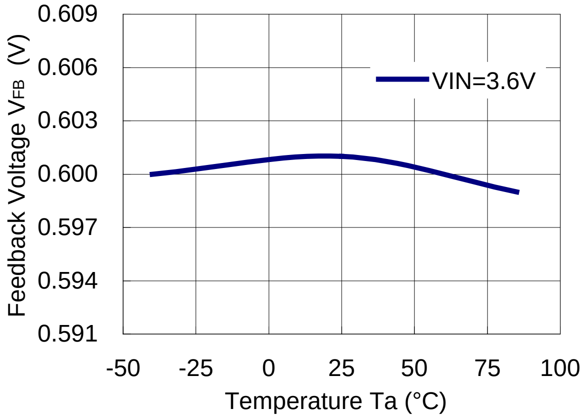
### 3) Output Voltage vs. Temperature

**RP505K181A/B**



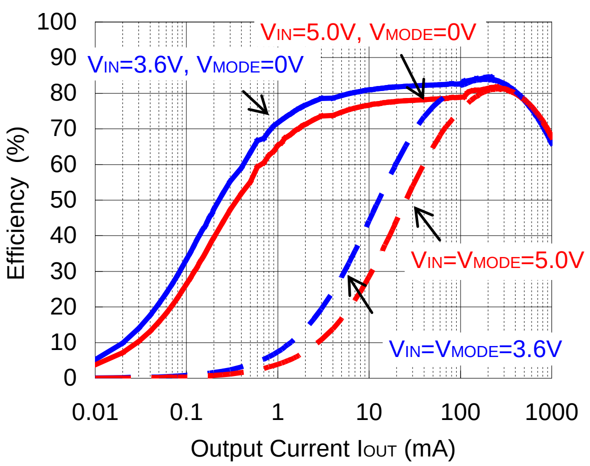

### 4) Feedback Voltage vs. Temperature

**RP505K001C**

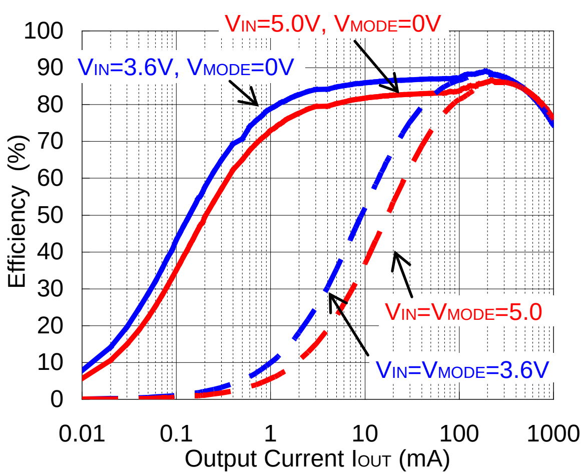



### 5) Efficiency vs. Output Current

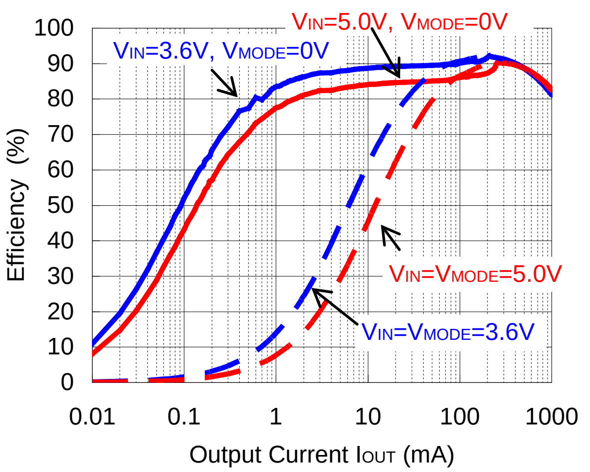
**RP505K VOUT=0.8V**



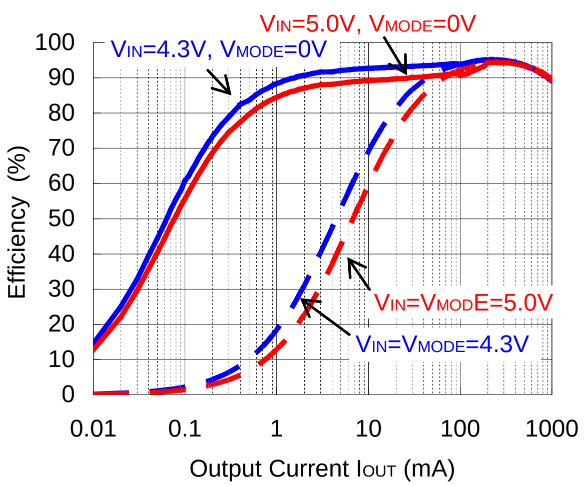

**RP505K VOUT=1.2V**




**RP505K VOUT=1.8V**

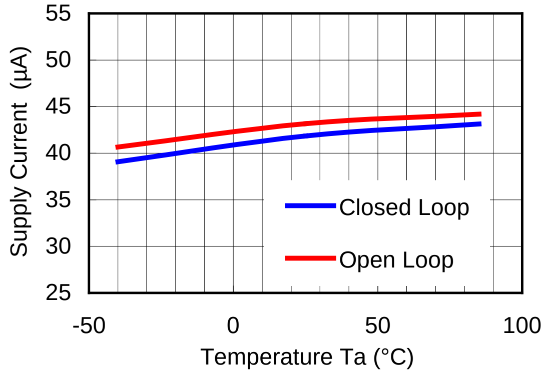



**RP505K VOUT=3.3V**



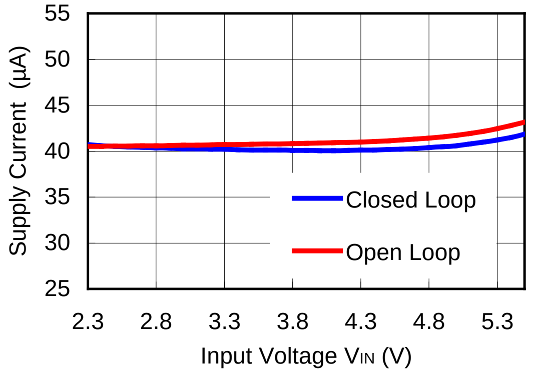
### 6) Supply Current vs. Temperature

**RP505K $V_{OUT}$=1.8V($V_{IN}$=5.5V)**
**MODE="L"PWM/VFM automatic shift**



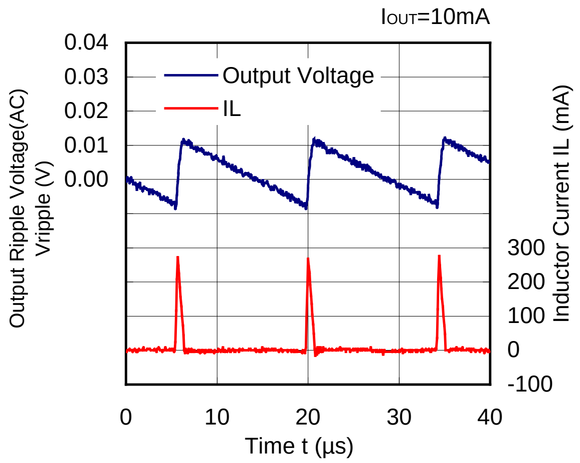

### 7) Supply Current vs. Input Voltage

**RP505K $V_{OUT}$=1.8V**
**MODE="L"PWM/VFM automatic shift**

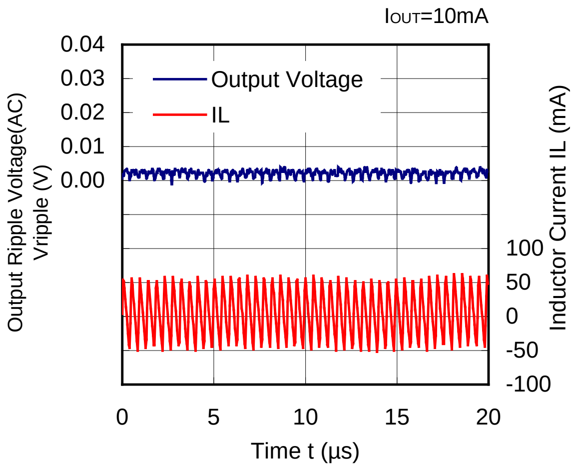



### 8) DC/DC Output Waveform

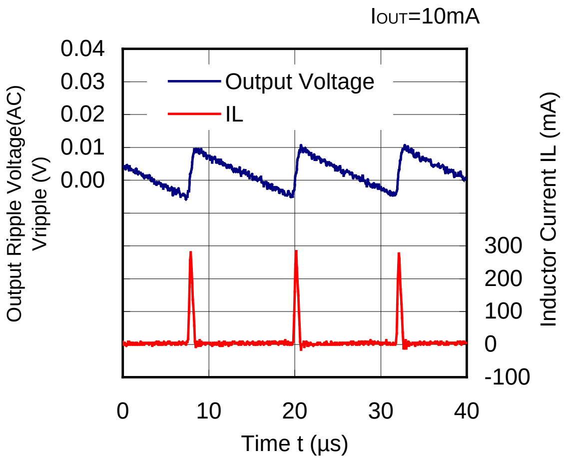
**RP505K $V_{OUT}$=0.8V($V_{IN}$=3.6V)**
**MODE="L"PWM/VFM automatic shift**



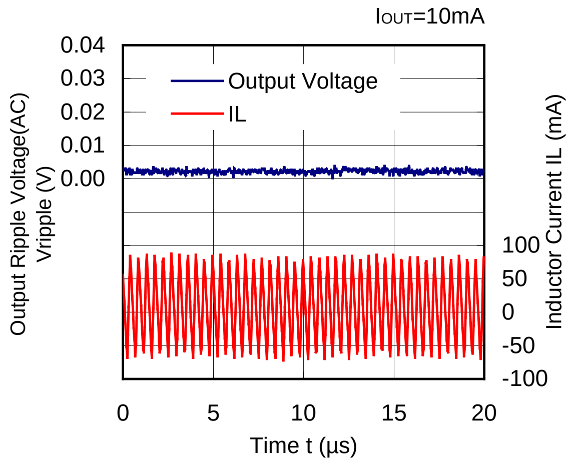

**RP505K $V_{OUT}$=0.8V($V_{IN}$=3.6V)**
**MODE="H" forced PWM**



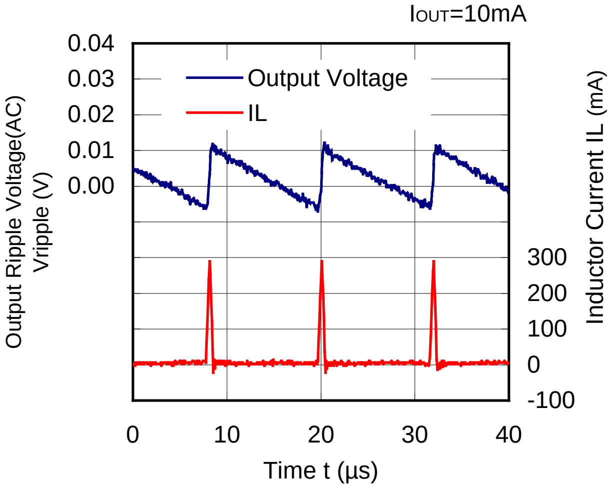

**RP505K $V_{OUT}$=1.2V($V_{IN}$=3.6V)**
**MODE="L"PWM/VFM automatic shift**



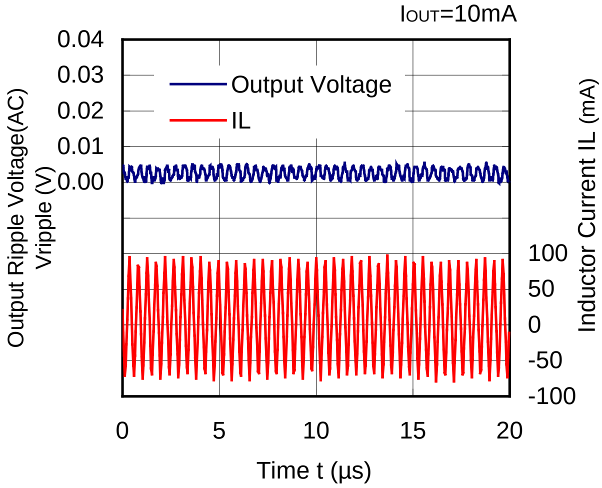

**RP505K $V_{OUT}$=1.2V($V_{IN}$=3.6V)**
**MODE="H" forced PWM**



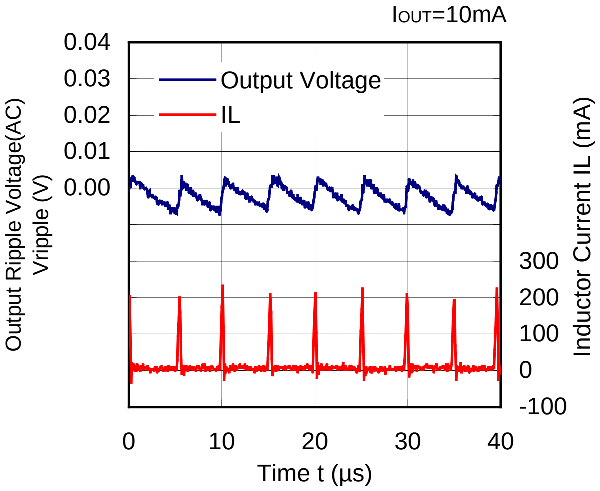
**RP505K $V_{OUT}$=1.8V($V_{IN}$=3.6V)**
**MODE="L"PWM/VFM automatic shift**



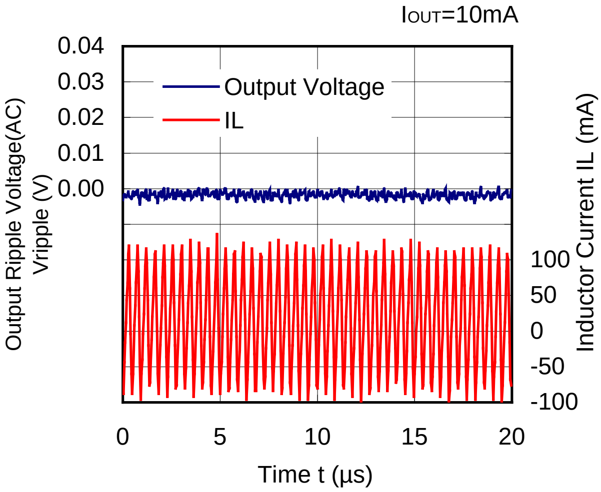

**RP505K $V_{OUT}$=1.8V($V_{IN}$=3.6V)**
**MODE="H" forced PWM**



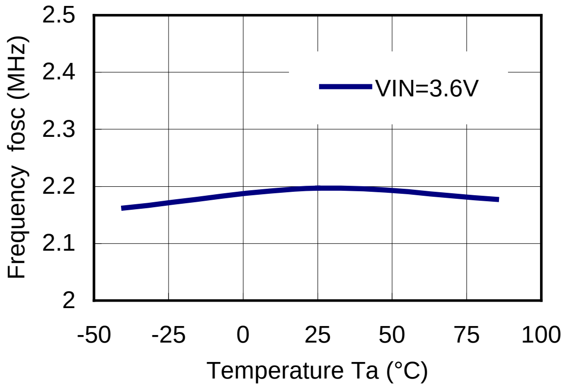

**RP505K $V_{OUT}$=3.3V($V_{IN}$=5.0V)**
**MODE="L"PWM/VFM automatic shift**



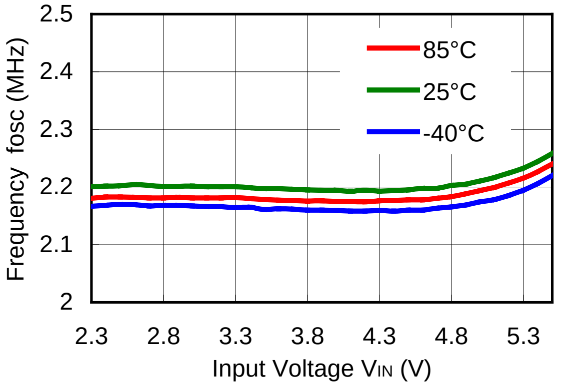

**RP505K $V_{OUT}$=3.3V($V_{IN}$=5.0V)**
**MODE="H" forced PWM**



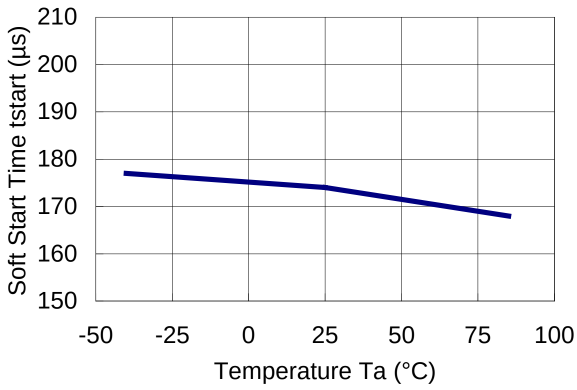
### 9) Oscillator Frequency vs. Temperature




### 10) Oscillator Frequency vs. Input Voltage

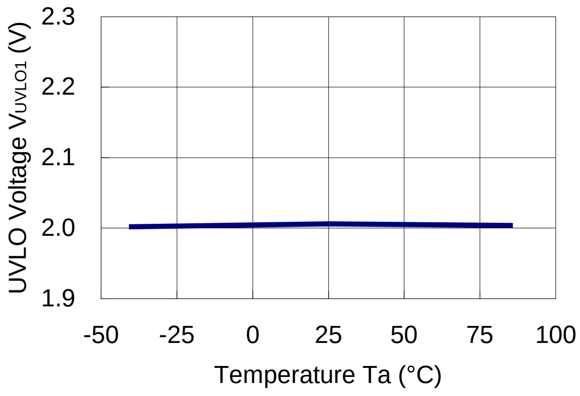



### 11) Soft-start Time vs. Temperature

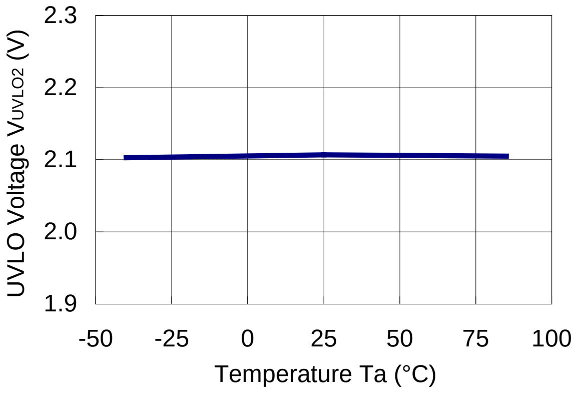



### 12) UVLO Detector Threshold / Released Voltage vs. Temperature

**UVLO Detector Threshold**

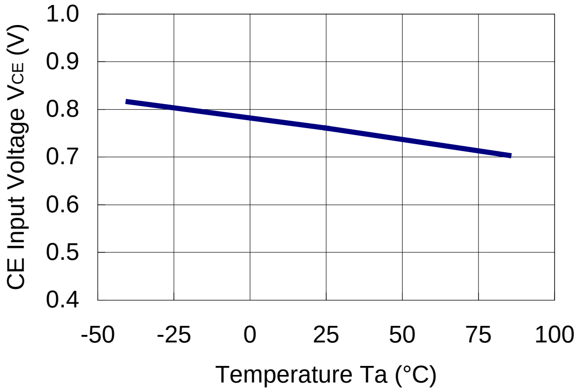



**UVLO Released Voltage**

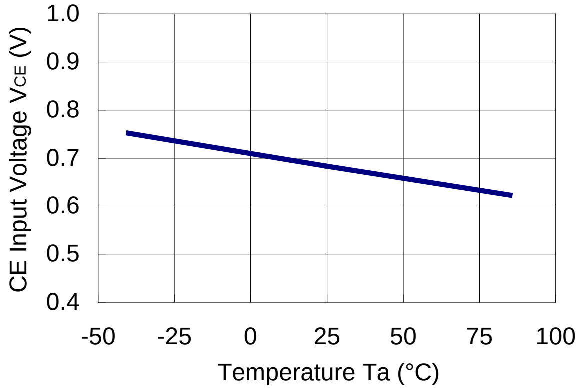


### 13) CE Input Voltage vs. Temperature

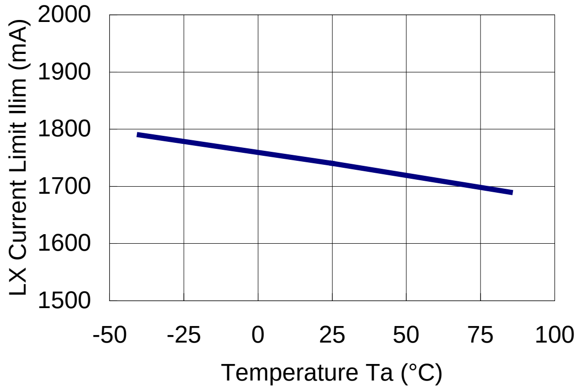
CE“H” Input Voltage($V_{IN}$=5.5V)



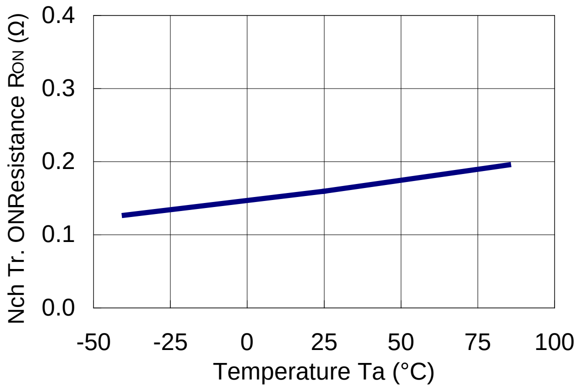

CE“L” Input Voltage ($V_{IN}$=2.3V)



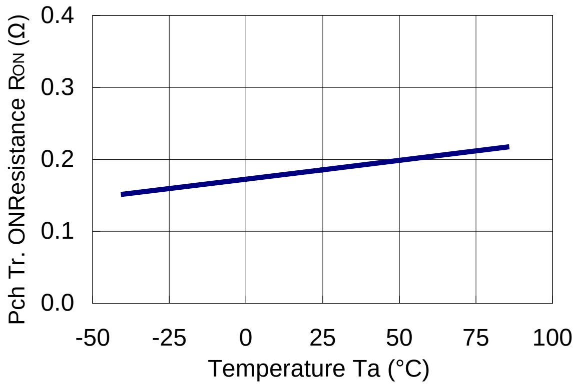

### 14) $L_X$ Current Limit vs. Temperature




### 15）Nch Tr. ON Resistance vs. Temperature

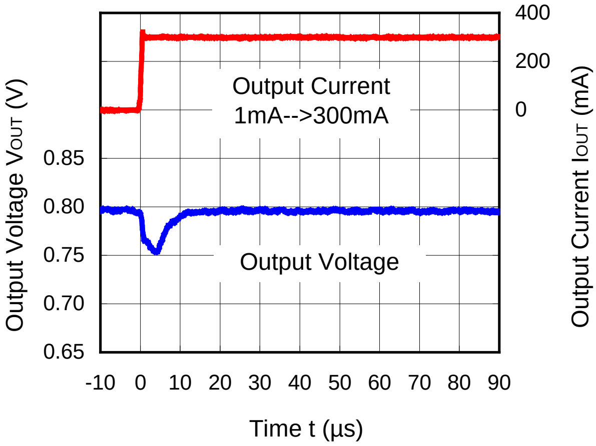



### 16）Pch Tr. ON Resistance vs. Temperature

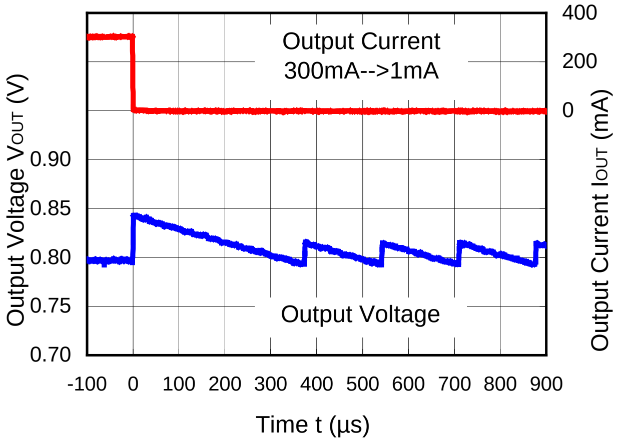


## 17) Load Transient Response

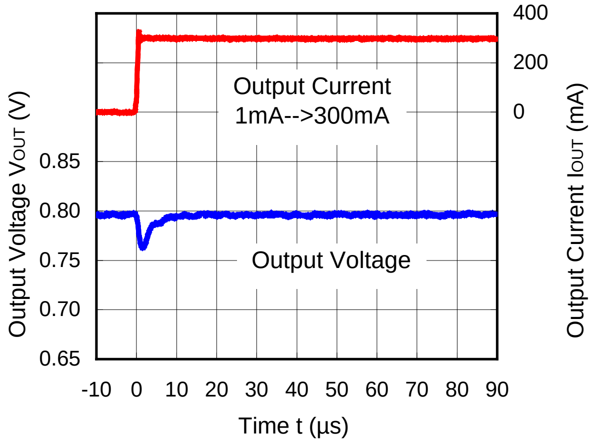
**RP505K081A/B ($V_{IN}$=3.6V)**
**MODE="L"PWM/VFM automatic shift**



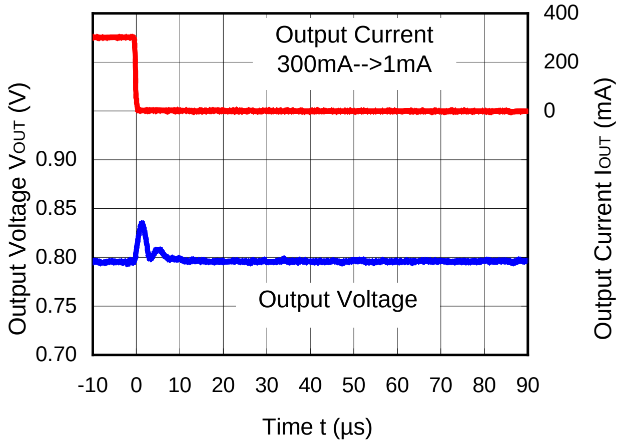

**RP505K081A/B ($V_{IN}$=3.6V)**
**MODE="L"PWM/VFM automatic shift**



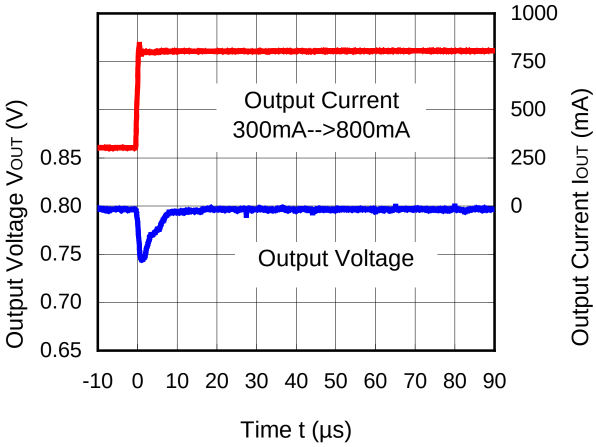

**RP505K081A/B ($V_{IN}$=3.6V)**
**MODE="H" forced PWM**



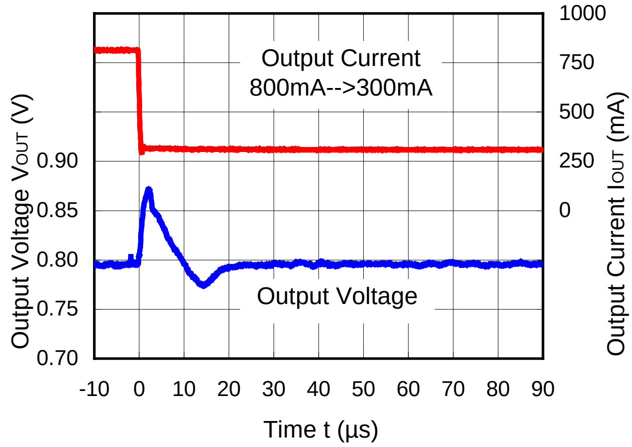

**RP505K081A/B ($V_{IN}$=3.6V)**
**MODE="H" forced PWM**



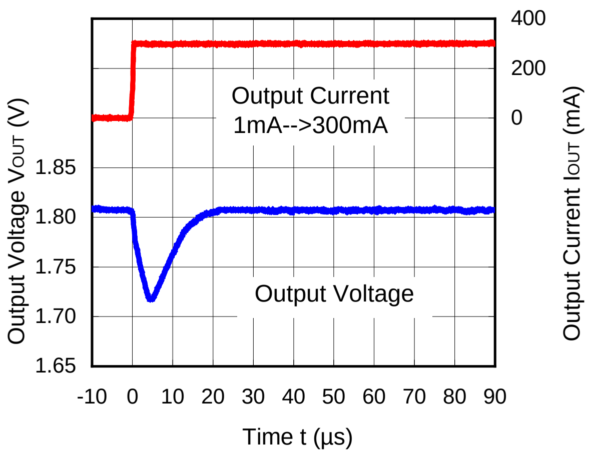

**RP505K081A/B ($V_{IN}$=3.6V)**



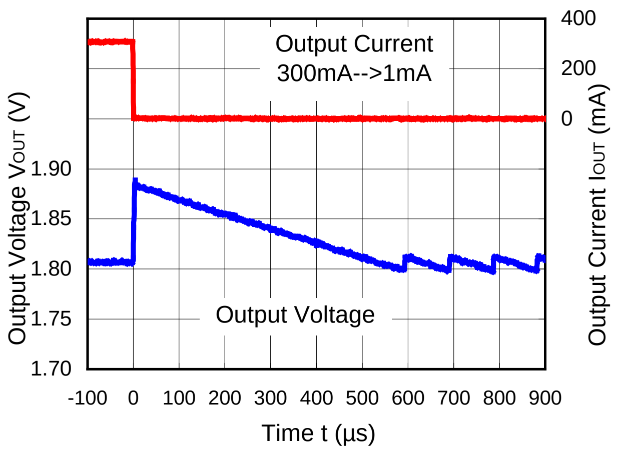

**RP505K081A/B ($V_{IN}$=3.6V)**



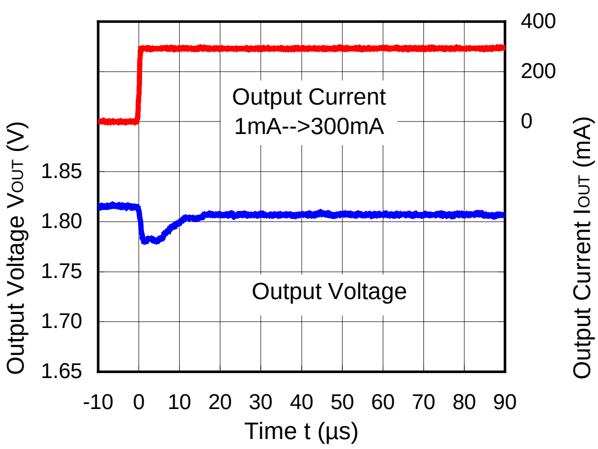
**RP505K181A/B (VIN=3.6V)**
**MODE="L"PWM/VFM automatic shift**



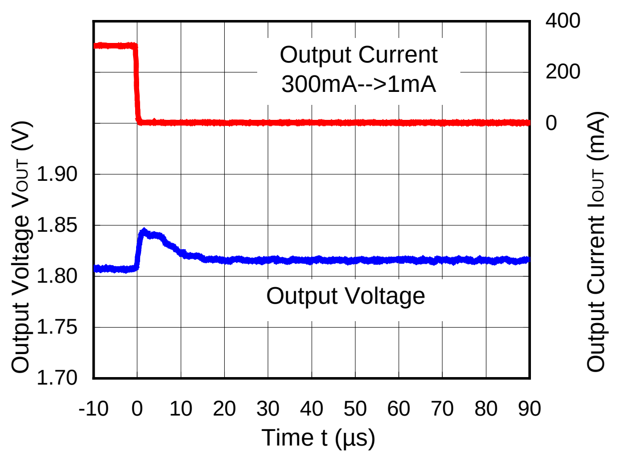

**RP505K181A/B (VIN=3.6V)**
**MODE="L"PWM/VFM automatic shift**



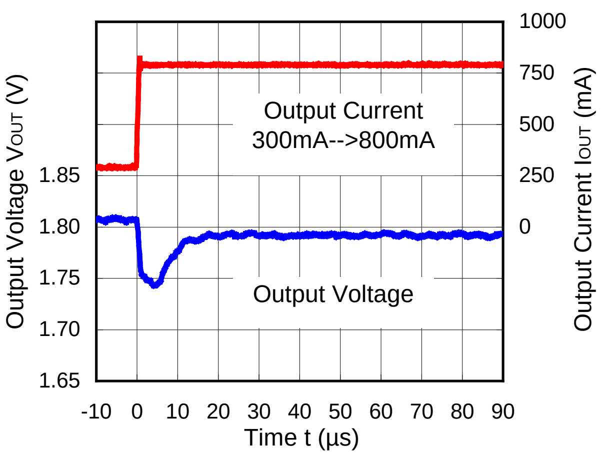

**RP505K181A/B (VIN=3.6V)**
**MODE="H" forced PWM**



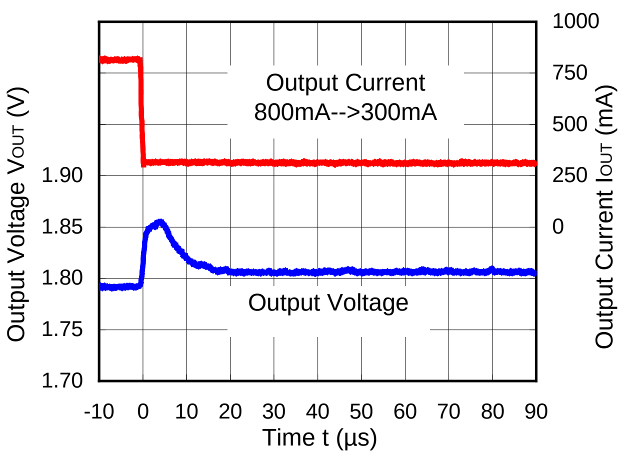

**RP505K181A/B (VIN=3.6V)**
**MODE="H" forced PWM**

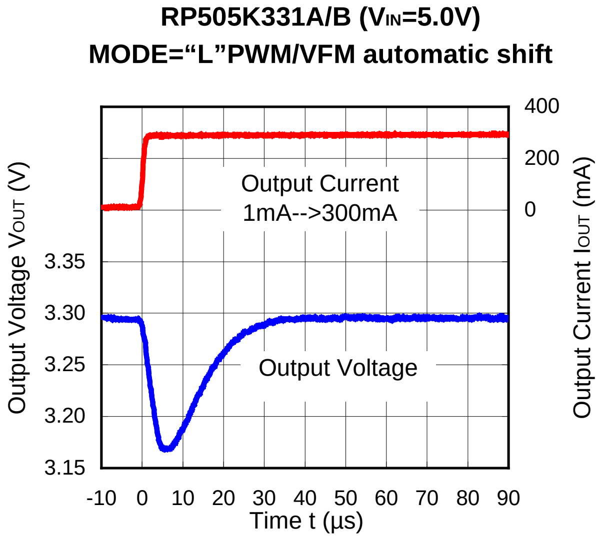


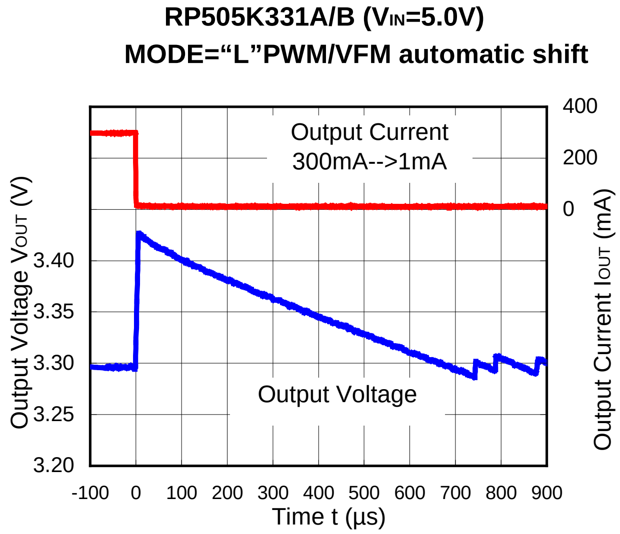

**RP505K181A/B (VIN=3.6V)**

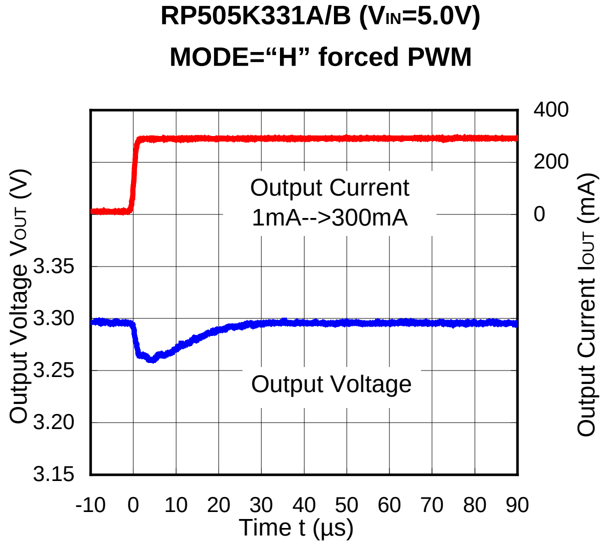


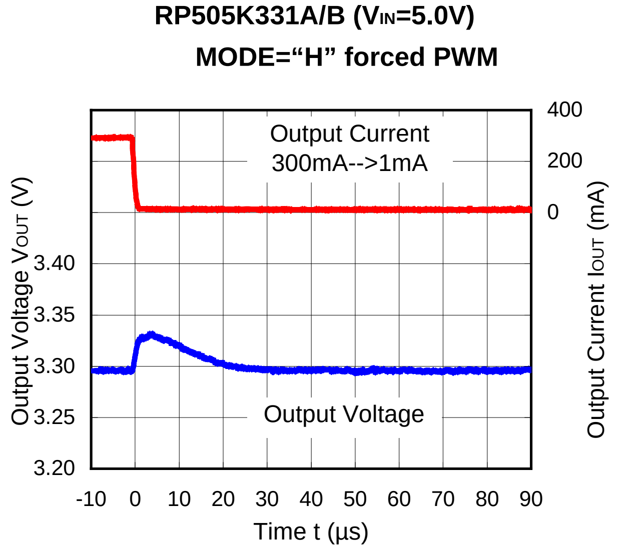

**RP505K181A/B (VIN=3.6V)**

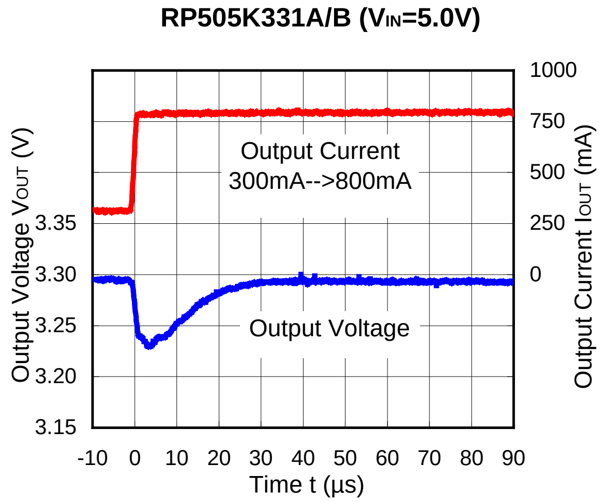


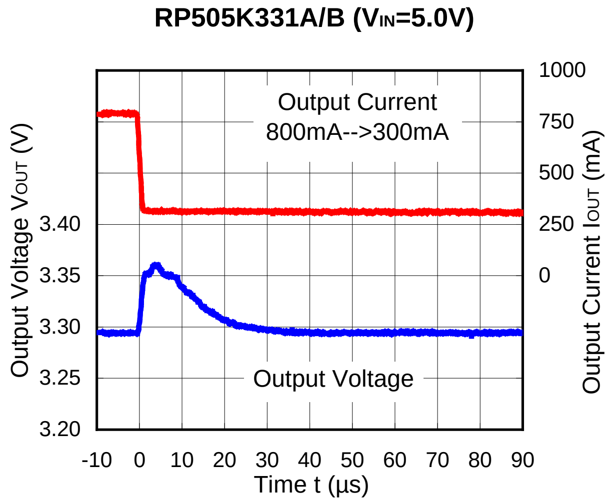

RP505K331A/B (VIN=5.0V)
MODE="L"PWM/VFM automatic shift
Output Current
1mA-->300mA
Output Voltage
Output Voltage VOUT (V)
Output Current IOUT (mA)
Time t (µs)


RP505K331A/B (VIN=5.0V)
MODE="L"PWM/VFM automatic shift
Output Current
300mA-->1mA
Output Voltage
Output Voltage VOUT (V)
Output Current IOUT (mA)
Time t (µs)

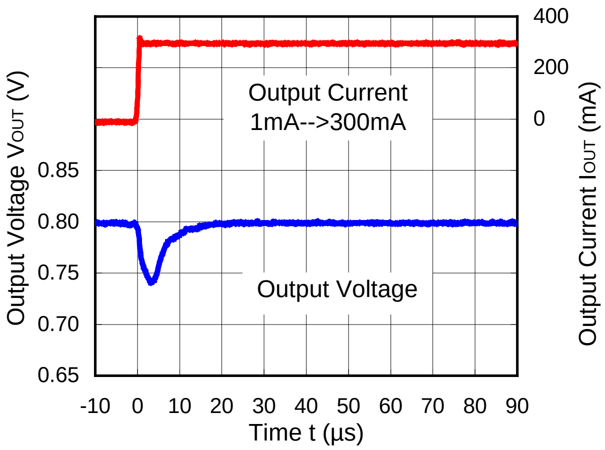

RP505K331A/B (VIN=5.0V)
MODE="H" forced PWM
Output Current
1mA-->300mA
Output Voltage
Output Voltage VOUT (V)
Output Current IOUT (mA)
Time t (µs)


RP505K331A/B (VIN=5.0V)
MODE="H" forced PWM
Output Current
300mA-->1mA
Output Voltage
Output Voltage VOUT (V)
Output Current IOUT (mA)
Time t (µs)

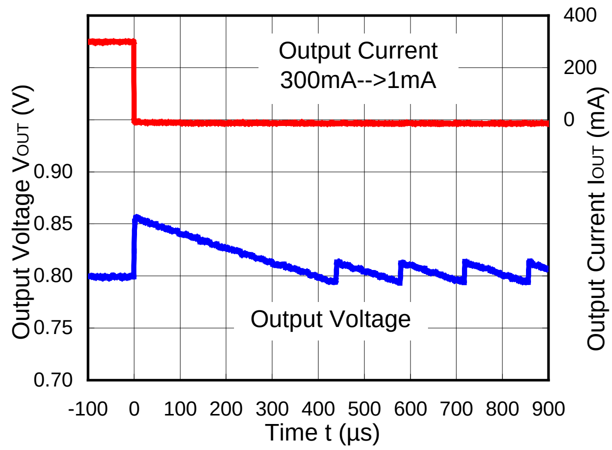

RP505K331A/B (VIN=5.0V)
Output Current
300mA-->800mA
Output Voltage
Output Voltage VOUT (V)
Output Current IOUT (mA)
Time t (µs)


RP505K331A/B (VIN=5.0V)
Output Current
800mA-->300mA
Output Voltage
Output Voltage VOUT (V)
Output Current IOUT (mA)
Time t (µs)

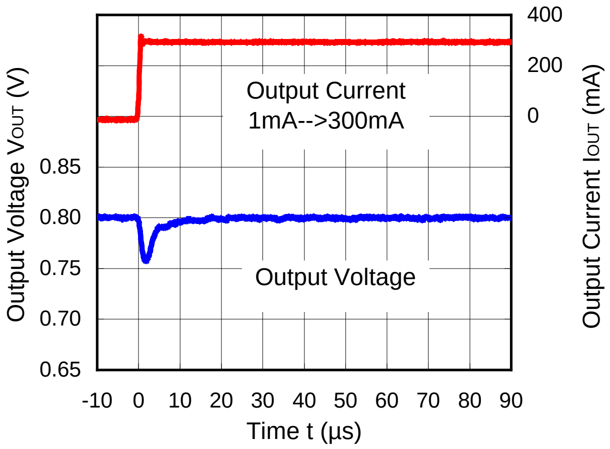
**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=0.8V)**
**MODE="L"PWM/VFM automatic shift**



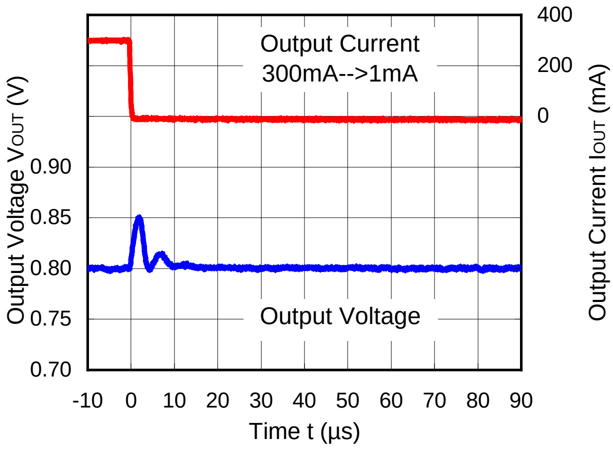

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=0.8V)**
**MODE="L"PWM/VFM モード自動切替え**



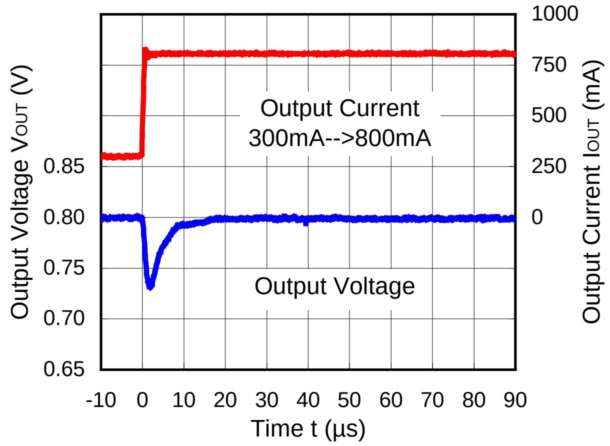

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=0.8V)**
**MODE="H" forced PWM**



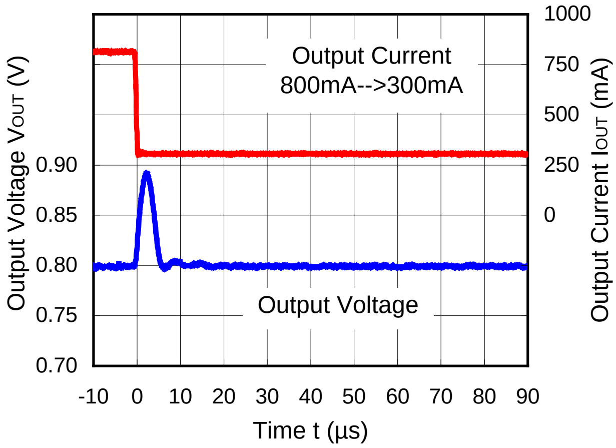

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=0.8V)**
**MODE="H" forced PWM**



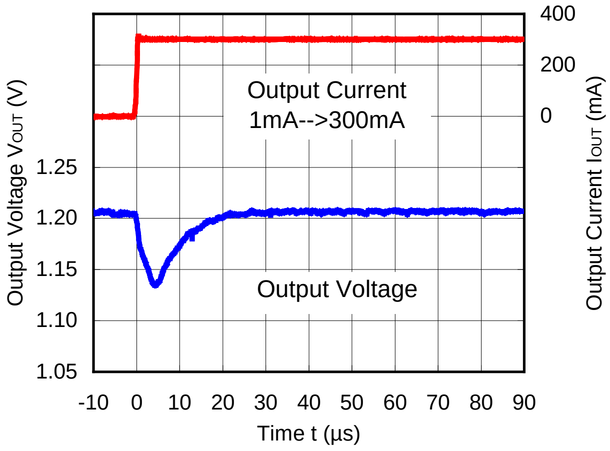

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=0.8V)**



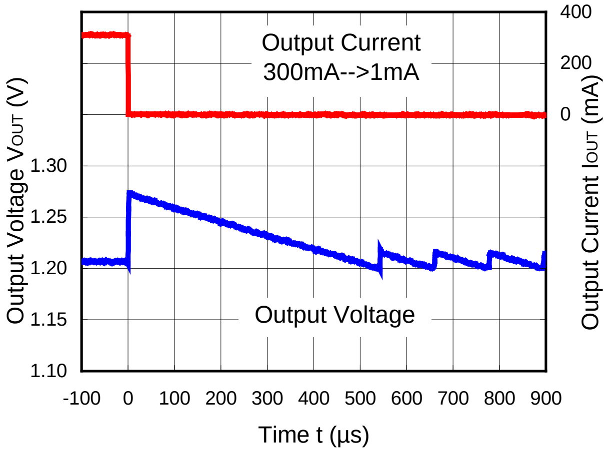

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=0.8V)**



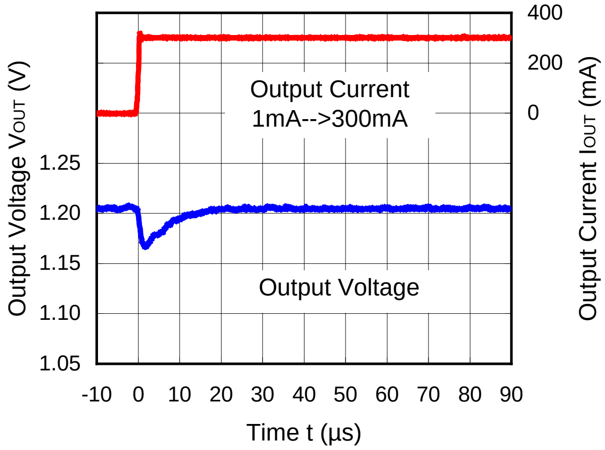
**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.2V)**
**MODE="L"PWM/VFM automatic shift**



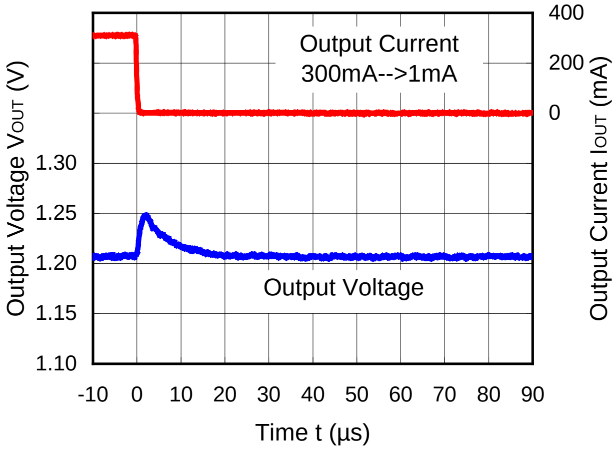

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.2V)**
**MODE="L"PWM/VFM automatic shift**



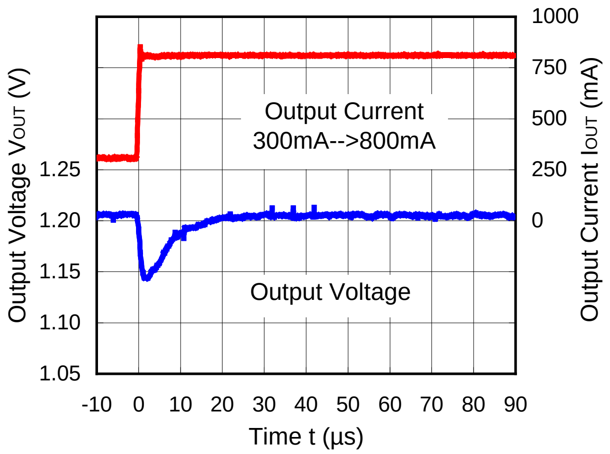

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.2V)**
**MODE="H" forced PWM**



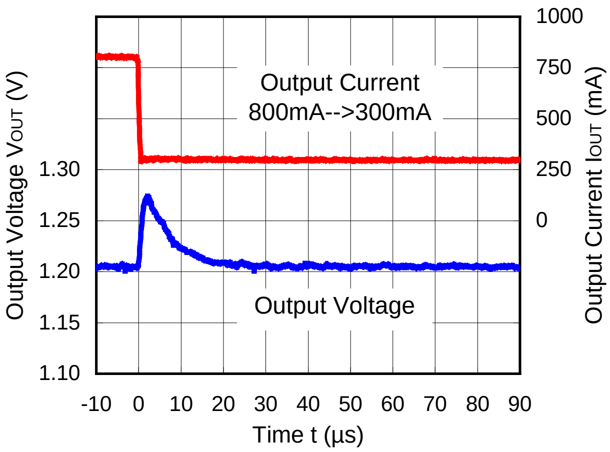

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.2V)**
**MODE="H" forced PWM**



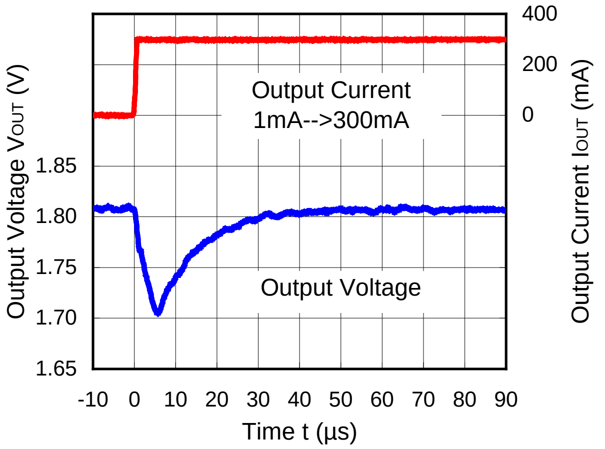

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.2V)**



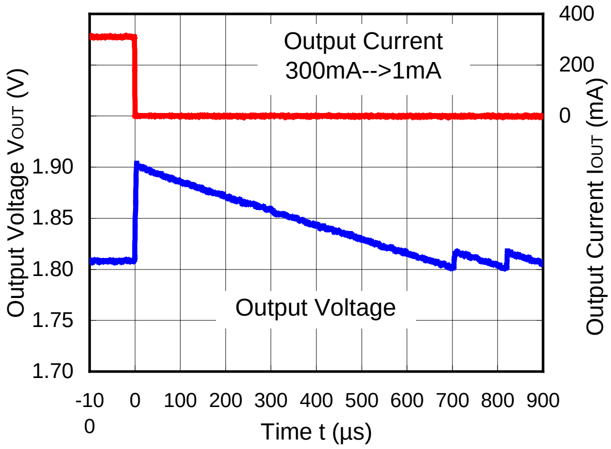

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.2V)**



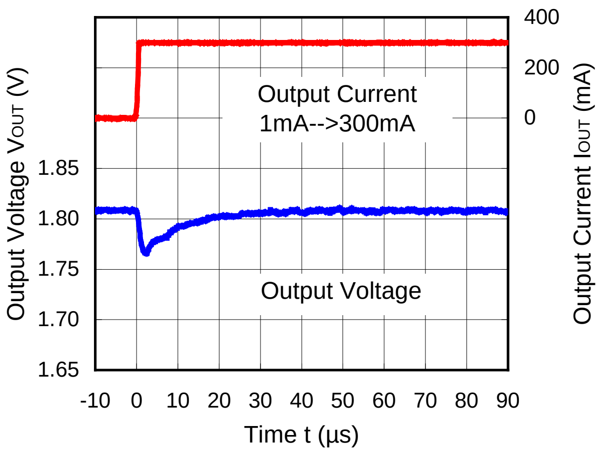
RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.8V)
MODE="L"PWM/VFM automatic shift



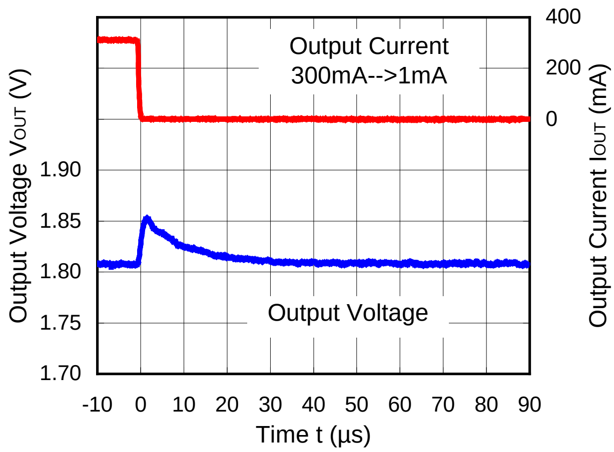

RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.8V)
MODE="L"PWM/VFM automatic shift



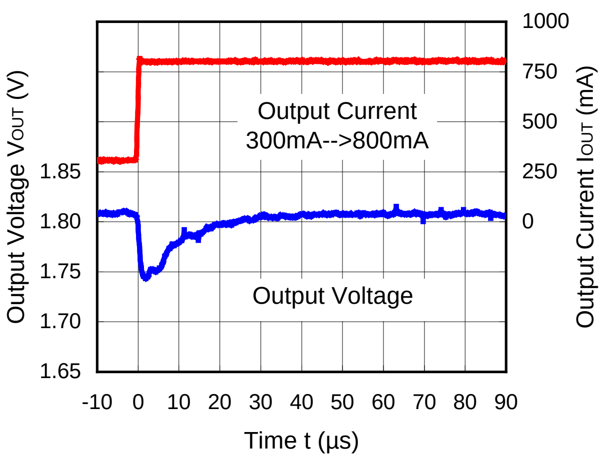

RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.8V)
MODE="H" forced PWM



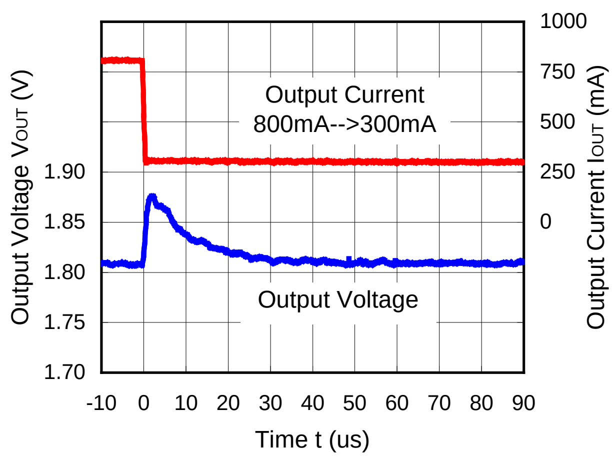

RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.8V)
MODE="H" forced PWM



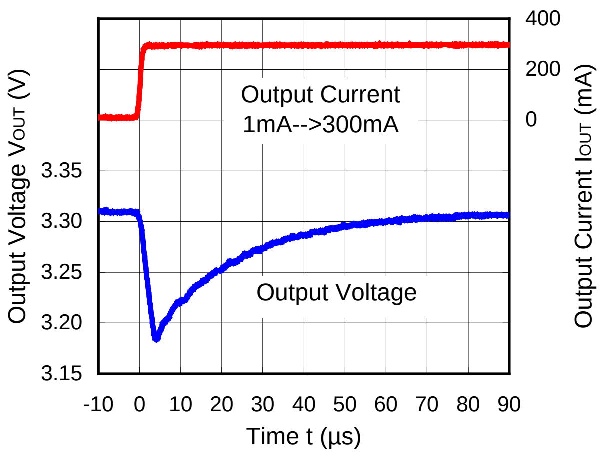

RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.8V)



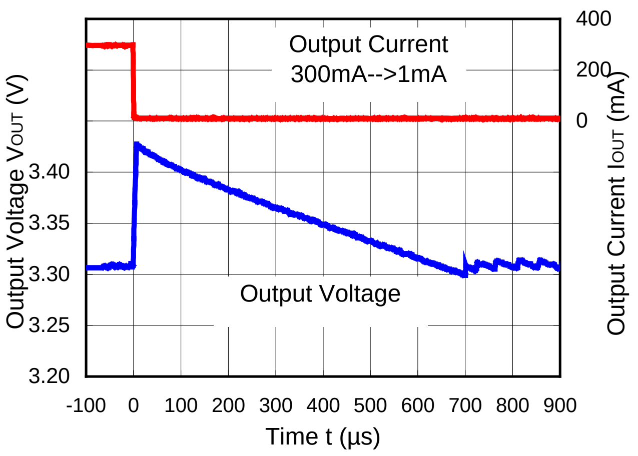

RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.8V)



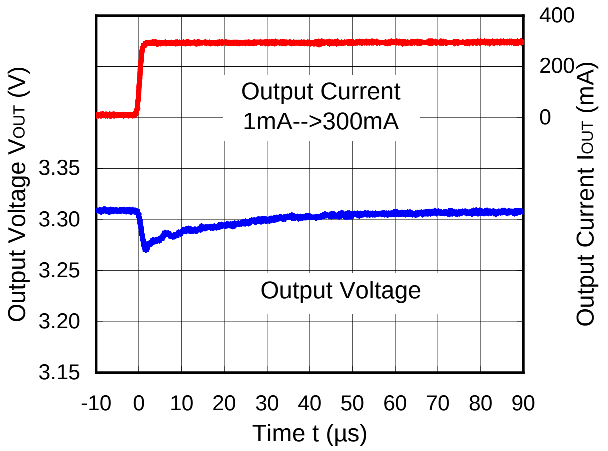
**RP505K001C ($V_{IN}$=5.0V, $V_{OUT}$=3.3V)**
**MODE="L"PWM/VFM automatic shift**



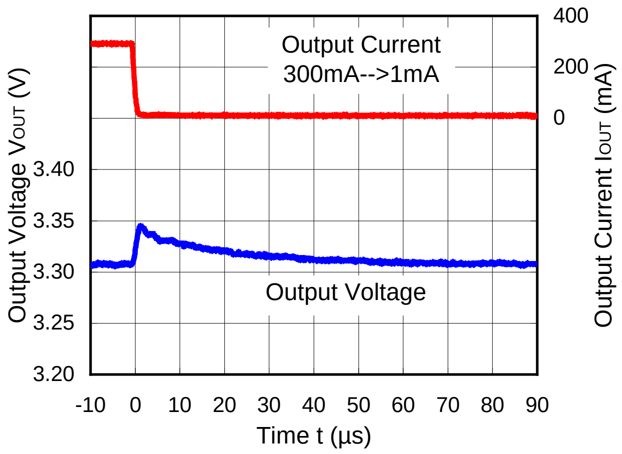

**RP505K001C ($V_{IN}$=5.0V, $V_{OUT}$=3.3V)**
**MODE="L"PWM/VFM automatic shift**



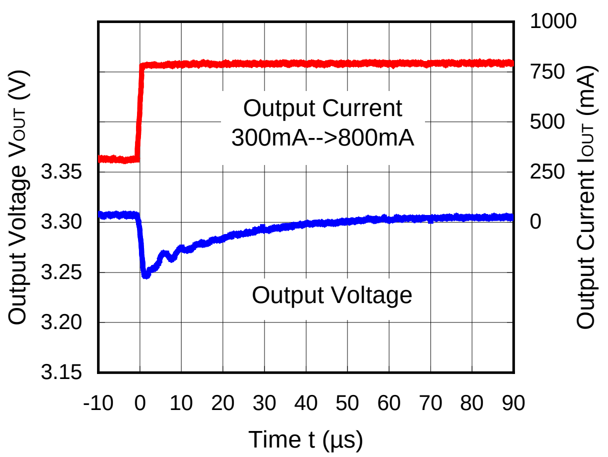

**RP505K001C ($V_{IN}$=5.0V, $V_{OUT}$=3.3V)**
**MODE="H" forced PWM**



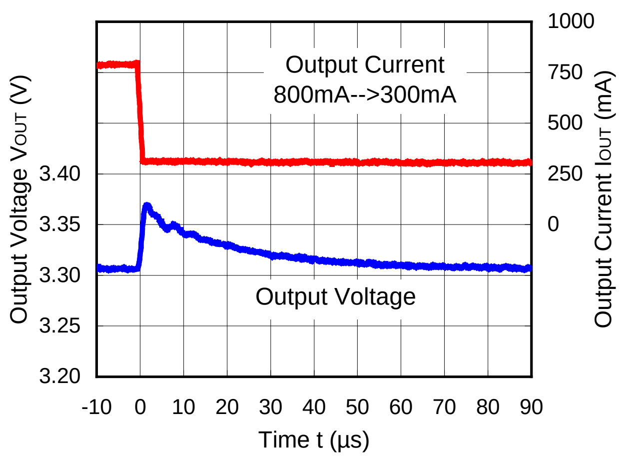

**RP505K001C ($V_{IN}$=5.0V, $V_{OUT}$=3.3V)**
**MODE="H" forced PWM**




**RP505K001C ($V_{IN}$=5.0V, $V_{OUT}$=3.3V)**

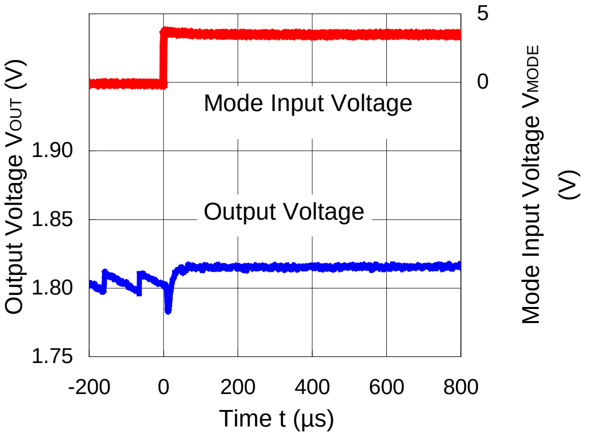



**RP505K001C ($V_{IN}$=5.0V, $V_{OUT}$=3.3V)**

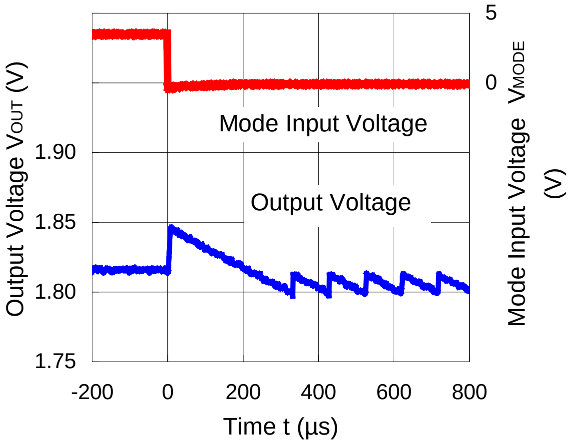


### 18) Mode Switching Waveform

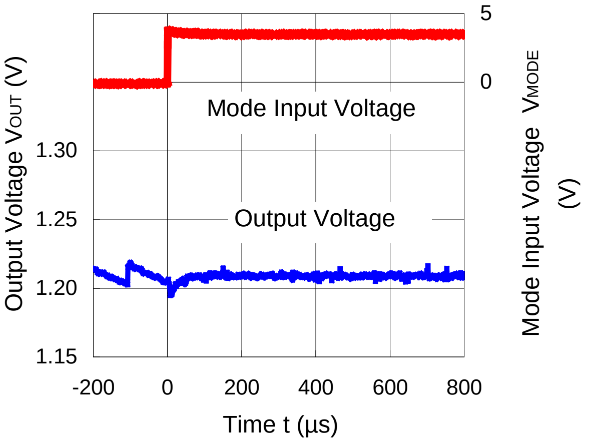
**RP505K181A/B ($V_{IN}$=3.6V, $I_{OUT}$=1mA)**
**MODE="L" --> MODE="H"**



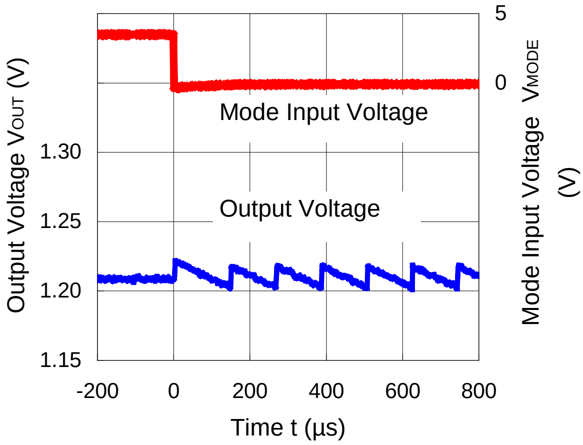

**RP505K181A/B ($V_{IN}$=3.6V, $I_{OUT}$=1mA)**
**MODE="H" --> MODE="L"**



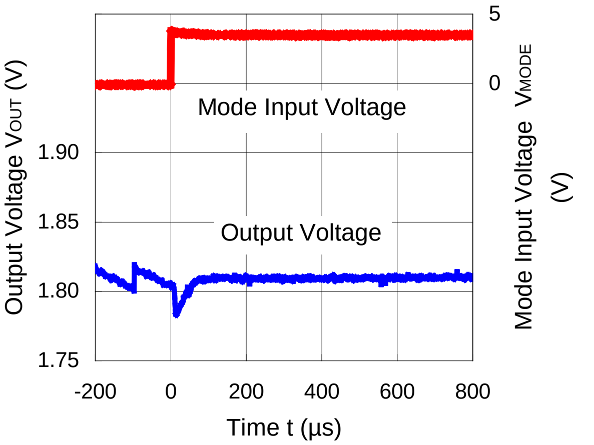

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.2V, $I_{OUT}$=1mA)**
**MODE="L" --> MODE="H"**



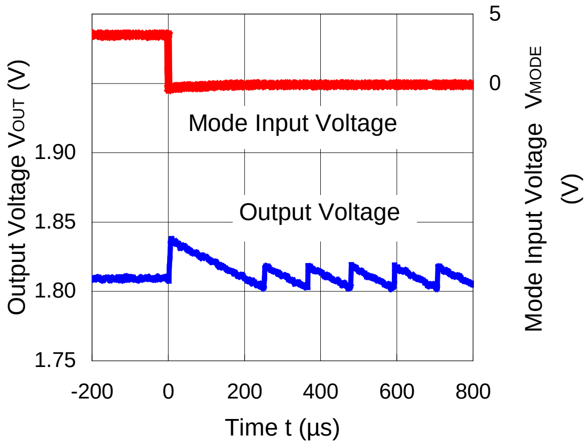

**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.2V, $I_{OUT}$=1mA)**
**MODE="H" --> MODE="L"**




**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.8V, $I_{OUT}$=1mA)**
**MODE="L" --> MODE="H"**




**RP505K001C ($V_{IN}$=3.6V, $V_{OUT}$=1.8V, $I_{OUT}$=1mA)**
**MODE="H" --> MODE="L"**



# PACKAGE INFORMATION

## Power Dissipation (DFN(PL)2020−8)

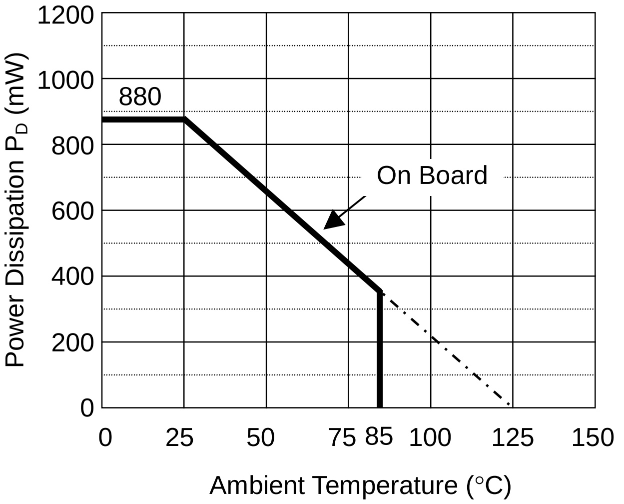
Power Dissipation ($P_D$) depends on conditions of mounting on board. This specification is based on the measurement at the condition below:

Measurement Conditions

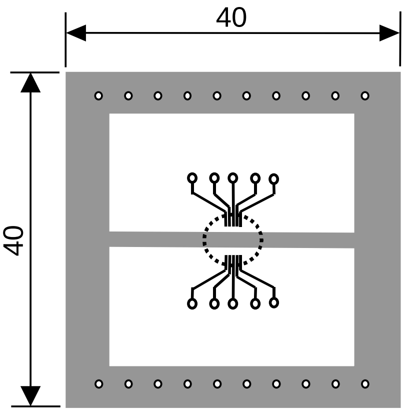
| | Standard Test Land Pattern |
|---|---|
| Environment | Mounting on Board (Wind velocity=0m/s) |
| Board Material | Glass cloth epoxy plastic (Double sided) |
| Board Dimensions | 40mm*40mm*1.6mm |
| Copper Ratio | Top side: Approx. 50%, Back side: Approx. 50% |
| Through-holes | ϕ 0.54mm * 30pcs |

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

| | Standard Test Land Pattern |
|---|---|
| Power Dissipation | 880mW |
| Thermal Resistance | θja = (125-25 °C)/0.88W = 114 °C/W |



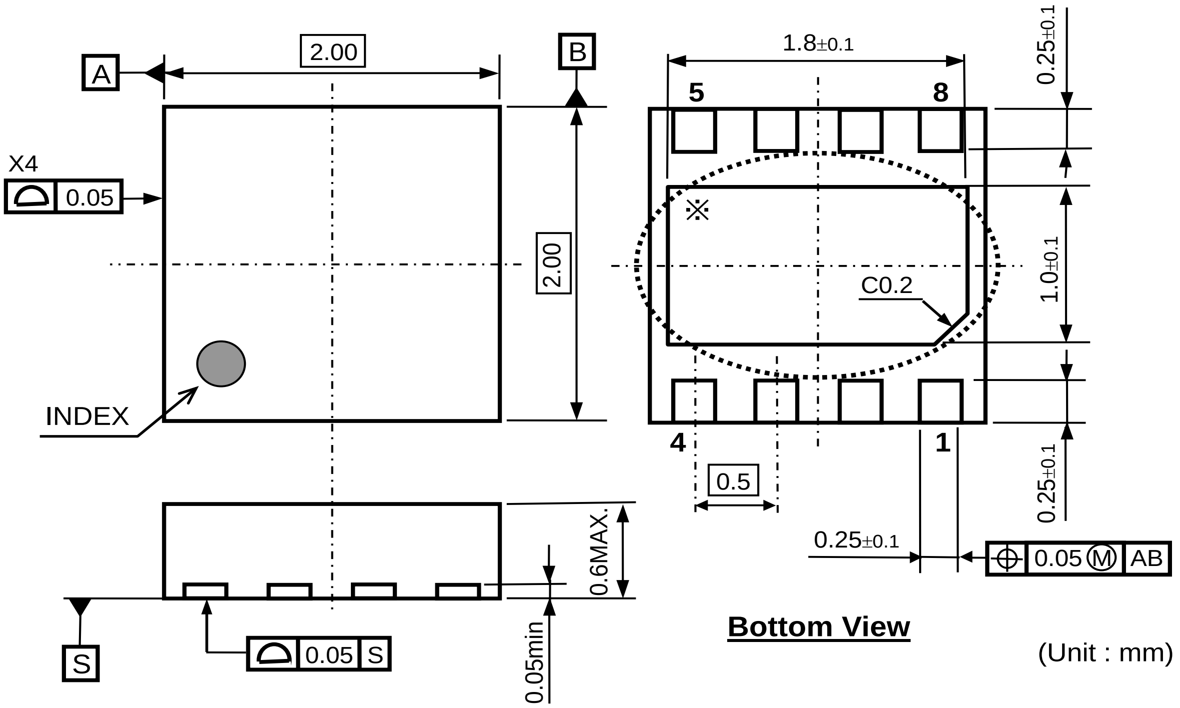

**Power Dissipation**




**Measurement Board Pattern**

IC Mount Area (Unit : mm)

**Package Dimensions (DFN(PL)2020−8)**

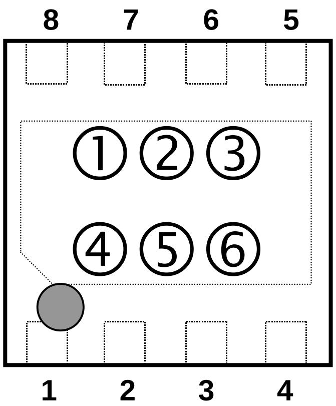



※) Tab is GND level (they are connected to the reverse side of this IC).
The tab is better to be connected to the GND, but leaving it open is also acceptable.

**Mark Specification (DFN(PL)2020−8)**

①②③④: Product Code … **Please refer to the RP505K Series Mark Specification Table.**

⑤⑥: Lot Number … Alphanumeric Serial Number



# RP505K Series Mark Specification

PKG: DFN(PL)2020−8

**RP505Kxx1A**

| Product Name | ①②③④ |
|---|---|
| RP505K061A | **CU06** |
| RP505K071A | **CU07** |
| RP505K081A | **CU08** |
| RP505K091A | **CU09** |
| RP505K101A | **CU10** |
| RP505K111A | **CU11** |
| RP505K121A | **CU12** |
| RP505K131A | **CU13** |
| RP505K141A | **CU14** |
| RP505K151A | **CU15** |
| RP505K161A | **CU16** |
| RP505K171A | **CU17** |
| RP505K181A | **CU18** |
| RP505K191A | **CU19** |
| RP505K201A | **CU20** |
| RP505K211A | **CU21** |
| RP505K221A | **CU22** |
| RP505K231A | **CU23** |
| RP505K241A | **CU24** |
| RP505K251A | **CU25** |
| RP505K261A | **CU26** |
| RP505K271A | **CU27** |
| RP505K281A | **CU28** |
| RP505K291A | **CU29** |
| RP505K301A | **CU30** |
| RP505K311A | **CU31** |
| RP505K321A | **CU32** |
| RP505K331A | **CU33** |
| RP505K121A5 | **CU01** |

**RP505Kxx1B**

| Product Name | ①②③④ |
|---|---|
| RP505K061B | **CV06** |
| RP505K071B | **CV07** |
| RP505K081B | **CV08** |
| RP505K091B | **CV09** |
| RP505K101B | **CV10** |
| RP505K111B | **CV11** |
| RP505K121B | **CV12** |
| RP505K131B | **CV13** |
| RP505K141B | **CV14** |
| RP505K151B | **CV15** |
| RP505K161B | **CV16** |
| RP505K171B | **CV17** |
| RP505K181B | **CV18** |
| RP505K191B | **CV19** |
| RP505K201B | **CV20** |
| RP505K211B | **CV21** |
| RP505K221B | **CV22** |
| RP505K231B | **CV23** |
| RP505K241B | **CV24** |
| RP505K251B | **CV25** |
| RP505K261B | **CV26** |
| RP505K271B | **CV27** |
| RP505K281B | **CV28** |
| RP505K291B | **CV29** |
| RP505K301B | **CV30** |
| RP505K311B | **CV31** |
| RP505K321B | **CV32** |
| RP505K331B | **CV33** |
| RP505K121B5 | **CV01** |

**RP505K001C**

| Product Name | ①②③④ |
|---|---|
| RP505K001C | **CW00** |

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