



NC2600 series

2A Low Quiescent Current PWM/PFM Step-down Switching Regulator

FEATURES

- Input Voltage Range (Maximum Rating): 2.3 V to 5.5 V (6.5 V)
- Operating Temperature Range: -40 °C to 85 °C
- Output Voltage Range:
 - Fixed Output Voltage Type: 0.6 V to 3.3 V
 - Adjustable Output Voltage Type: 0.6 V to 5.5 V
- Output Voltage Accuracy: $\pm 1.5\%$ ($V_{SET} \geq 1.2$ V)
 ± 18 mV ($V_{SET} < 1.2$ V)
- Feedback Voltage Accuracy: ± 9 mV
- Quiescent Current: Typ. 17 μ A
- Switching Frequency: Typ. 4.0 MHz ($V_{SET} = 1.8$ V)
- UVLO Detection Voltage: Typ. 2.0 V
- Soft-Start Time: Typ. 0.15 ms When CSS is open.
- Thermal Shutdown Function:
 - Detection Temperature Typ. 150 °C
 - Release Temperature Typ. 120 °C
- Auto Discharge Function
- Latch Protection Function

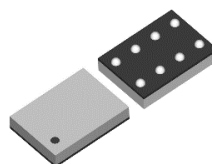
APPLICATIONS

- Portable Communication Devices: Mobile Phones / Smartphones
- Digital Cameras and Note-PCs
- Li-ion Battery-used Equipment

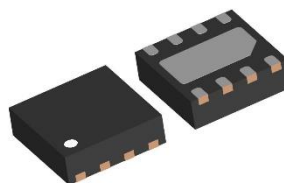
GENERAL DESCRIPTION

The NC2600 is a low quiescent current PWM / PFM 2A step-down switching regulator IC using CMOS-based.

The NC2600 is available in WLCSP-8-P11 and DFN2020-8-GT, and it is suitable for use in wearable and IoT devices that require miniaturization and long-lifetime of battery.

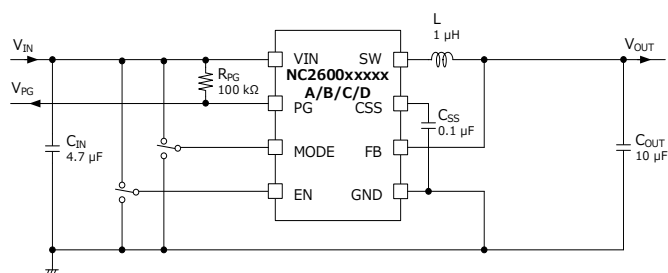


WLCSP-8-P11
1.62 x 0.98 x 0.4 (mm)

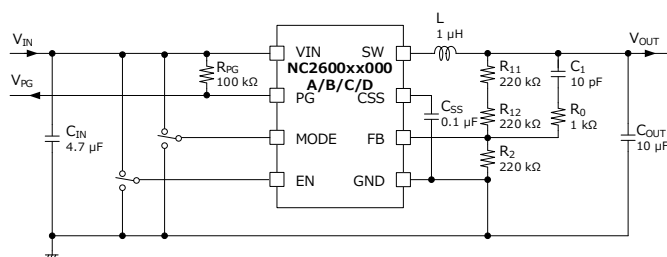


DFN2020-8-GT
2.0 x 2.0 x 0.6 (mm)

TYPICAL APPLICATIONS

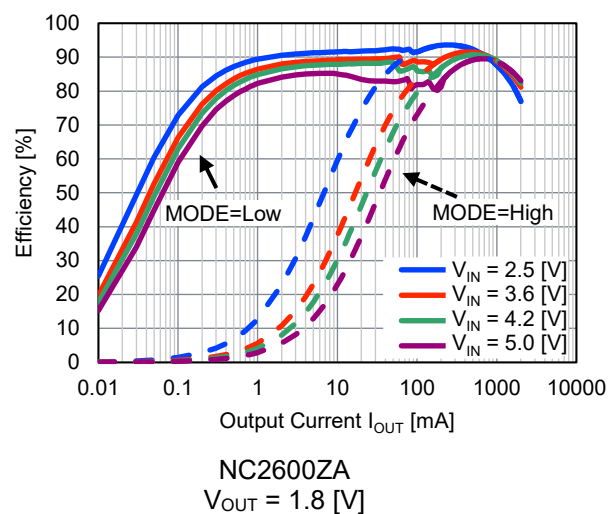


Fixed Output Voltage Type



Adjustable Output Voltage Type ($V_{SET} = 1.8$ V)

EFFICIENCY TYPICAL CHARACTERISTICS



PRODUCT NAME INFORMATION

NC2600 aa bbb c dd e

Description of configuration

| Composition | Item | Description |
|-------------|----------------|--|
| aa | Package Code | Indicates the package. Refer to the order information. |
| bbb | Output Voltage | Set Output Voltage (V_{SET}) Adjustable Output Voltage Type (000) The internal fixed output voltage type has a lineup of main voltages in the range of 0.6 V (060) to 3.3 V (330). |
| c | Version | Indicates the selection of auto discharge function and latch protection function. |
| dd | Packing | Refer to the packing specifications. |
| e | Grade | Indicates the quality grade. |

Version

| c | Latch Protection Function | Auto Discharge Function |
|---|---------------------------|-------------------------|
| A | Yes | Yes |
| B | Yes | No |
| C | No | Yes |
| D | No | No |

Grade

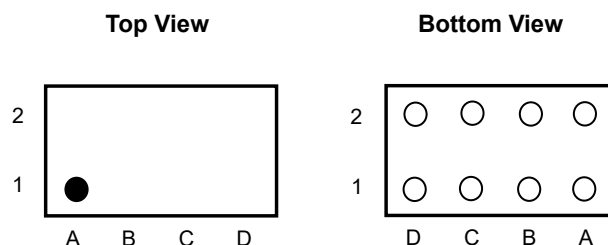
| e | Applications | Operating Temperature Range | Test Temperature |
|---|--------------|-----------------------------|------------------|
| S | Consumer | -40 °C to 85 °C | 25 °C |

ORDER INFORMATION

| PRODUCT NAME | PACKAGE | RoHS | HALOGEN-FREE | PLATING COMPOSITION | MARKING | WEIGHT (mg) | Quantity per Reel(pcs) |
|-------------------|--------------|------|--------------|---------------------|---------------------------|-------------|------------------------|
| NC2600ZA bbbc E2S | WLCSP-8-P11 | Yes | Yes | Sn3Ag0.5Cu | Reference | 1.1 | 10000 |
| NC2600GT bbbc E4S | DFN2020-8-GT | Yes | Yes | Sn | Reference | 7.0 | 3000 |

Refer to the marking specifications for a detailed lineup of set output voltage and versions.

PIN DESCRIPTIONS (NC2600ZA)



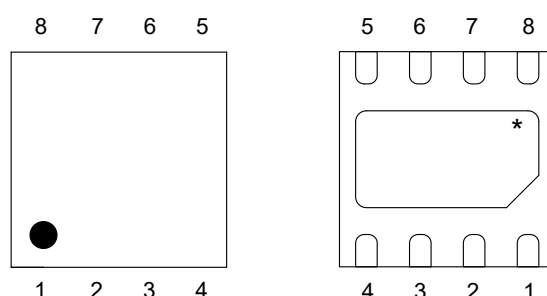
WLCSP-8-P11 Pin Configuration

NC2600ZA (WLCSP-8-P11) Pin Descriptions

| Pin No. | Pin Name | I/O | Description |
|---------|----------|-------|---|
| A1 | VIN | Power | Power Supply Input Pin |
| B1 | SW | O | Switching Output Pin Internal MOSFET Drain Connect the inductor between the VOUT node and the SW pin. |
| C1 | EN | I | Enable Pin Can set the active state with the "High" input and the shutdown state with the "Low" input. |
| D1 | PG | O | Power-good Output Pin NMOS open drain output. In normal operation, "High" (pull-up voltage) is output. |
| A2 | GND | - | Ground Pin |
| B2 | CSS | I | Soft-Start Adjustment Pin Soft-Start time can be adjusted by connecting a capacitor between the CSS pin and GND. |
| C2 | MODE | I | Mode Control Pin High: Forced PWM Control, Low: PWM/PFM Auto Switching Control. |
| D2 | FB | I | Feedback Pin When using NC2600xx000x (adjustable output voltage type), connect an external resistor as the feedback input pin for the error amplifier and set the output voltage. When using the internal fixed output voltage type, connect it to the VOUT node as an output voltage feedback pin. |

For details, refer to "[Typical Application Circuit](#)" and "[THEORY OF OPERATION](#)".

PIN DESCRIPTIONS (NC2600GT)



DFN2020-8-GT Pin Configuration

* The tab on the bottom of the package is the silicon substrate level. It is recommended to connect to GND level on the board.

NC2600GT (DFN2020-8-GT) Pin Descriptions

| Pin No. | Pin Name | I/O | Description |
|---------|----------|-------|---|
| 1 | GND | - | Ground pin |
| 2 | CSS | I | Soft-Start Adjustment Pin Soft-Start time can be adjusted by connecting a capacitor between the CSS pin and GND. |
| 3 | MODE | I | Mode Control Pin High: Forced PWM Control, Low: PWM/PFM Auto Switching Control. |
| 4 | FB | I | Feedback Pin When using NC2600xx000x (adjustable output voltage type), connect an external resistor as the feedback input pin for the error amplifier and set the output voltage. When using the internal fixed output voltage type, connect it to the VOUT node as an output voltage feedback pin. |
| 5 | PG | O | Power-good Output Pin NMOS open drain output. In normal operation, "High" (pull-up voltage) is output. |
| 6 | EN | I | Enable Pin Can set the active state with the "High" input and the shutdown state with the "Low" input. |
| 7 | SW | O | Switching Output Pin Internal MOSFET Drain Connect the inductor between the VOUT node and the SW pin. |
| 8 | VIN | Power | Power Supply Input Pin |

For details, refer to "[Typical Application Circuit](#)" and "[THEORY OF OPERATION](#)".

ABSOLUTE MAXIMUM RATINGS

| Parameter | Symbol | Ratings | Unit |
|-------------------------------|------------|------------------------|------|
| Input Voltage | V_{IN} | -0.3 to 6.5 | V |
| SW pin voltage | V_{SW} | -0.3 to $V_{IN} + 0.3$ | V |
| EN pin voltage | V_{EN} | -0.3 to 6.5 | V |
| CSS pin voltage | V_{CSS} | -0.3 to 6.5 | V |
| PG pin voltage | V_{PG} | -0.3 to 6.5 | V |
| MODE pin voltage | V_{MODE} | -0.3 to 6.5 | V |
| FB pin voltage | V_{FB} | -0.3 to 6.5 | V |
| Junction Temperature Range *1 | T_J | -40 to 125 | °C |
| Storage Temperature Range | T_{stg} | -55 to 125 | °C |

ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause permanent damage and may degrade the lifetime and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

*1 Calculate the power consumption of the IC from the operating conditions, and calculate the junction temperature with the thermal resistance.

Please refer to "[THERMAL CHARACTERISTICS](#)" for the thermal resistance under our measurement board conditions

THERMAL CHARACTERISTICS

| Package | Parameter | Measurement Result | Unit |
|--------------|--|--------------------|------|
| WLCSP-8-P11 | Thermal Resistance (θ_{ja}) | 131 | °C/W |
| | Thermal Characterization Parameter (ψ_{jt}) | 38 | |
| DFN2020-8-GT | Thermal Resistance (θ_{ja}) | 71 | |
| | Thermal Characterization Parameter (ψ_{jt}) | 33 | |

θ_{ja} : Junction-to-Ambient Thermal Resistance

ψ_{jt} : Junction-to-Top Thermal Characterization Parameter

The above values are reference data under measurement conditions based on JEDEC STD.51.

ELECTROSTATIC DISCHARGE RATINGS

| Parameter | Conditions | Protection Voltage |
|-----------|--------------------------------|--------------------|
| HBM | C = 100 pF, R = 1.5 k Ω | ±2000 V |
| CDM | | ±1000 V |

ELECTROSTATIC DISCHARGE RATINGS

The electrostatic discharge test is done based on JESD47.

In the HBM method, ESD is applied using the power supply pin and GND pin as reference pins.

RECOMMENDED OPERATING CONDITIONS

| Parameter | Symbol | Ratings | Unit |
|-----------------------------|----------|------------|------|
| Input Voltage | V_{IN} | 2.3 to 5.5 | V |
| Operating Temperature Range | T_a | -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.

ELECTRICAL CHARACTERISTICS

NC2600xx060x to 330x (Internal Fixed Output Voltage Type)

$V_{IN} = 3.6V$ ($V_{SET} \leq 2.6V$) or $V_{SET} + 1V$ ($V_{SET} > 2.6V$) unless otherwise specified.

For parameter that do not describe the temperature condition, the MIN / MAX value under the condition of $-40^\circ C \leq T_a \leq 85^\circ C$ is described.

| Parameter | Symbol | Conditions | | MIN | TYP | MAX | Unit |
|--|----------------------|---|--------------------------|------------------------|------------------------|------------------------|------|
| Output Voltage | V _{OUT} | Ta = 25 °C | V _{SET} ≥ 1.2 V | x 0.985 | - | x 1.015 | V |
| | | | V _{SET} < 1.2 V | −0.018 | - | +0.018 | |
| Switching Frequency | f _{OSC} | V _{MODE} =3.6 V | | - | 4.0 | - | MHz |
| Quiescent Current | I _Q | V _{FB} = V _{SET} × 1.05, V _{MODE} = 0 V, no switching | | - | 17 | 25 | μA |
| Shutdown current | I _{SD} | V _{IN} = 5.5 V, V _{EN} = 0 V | | - | 0 | 5 | μA |
| EN "H" Input Current | I _{ENH} | V _{IN} = V _{EN} = 5.5 V | | −1 | 0 | 1 | μA |
| EN "L" Input Current | I _{ENL} | V _{IN} = 5.5 V, V _{EN} = 0 V | | −1 | 0 | 1 | μA |
| MODE "H" Input Current | I _{MODEH} | V _{IN} = V _{MODE} = 5.5 V | | −1 | 0 | 1 | μA |
| MODE "L" Input Current | I _{MODEL} | V _{IN} = 5.5 V, V _{MODE} = 0 V | | −1 | 0 | 1 | μA |
| VFB "H" Input Current | I _{FBH} | V _{IN} = V _{FB} = 5.5 V, V _{EN} = 0 V | | −1 | 0 | 1 | μA |
| VFB "L" Input Current | I _{FBL} | V _{IN} = 5.5 V, V _{EN} = V _{FB} = 0 V | | −1 | 0 | 1 | μA |
| On-resistance for Discharger | R _{ONDIS} | NC2600xxxxxA/C | | - | 60 | - | Ω |
| EN pin "H" Input Voltage | V _{ENH} | V _{IN} = 5.5 V | | 1.0 | - | - | V |
| EN pin "L" Input Voltage | V _{ENL} | V _{IN} = 2.3 V | | - | - | 0.4 | V |
| MODE "H" Input Voltage | V _{MODEH} | V _{IN} = 5.5 V | | 1.0 | - | - | V |
| MODE "L" Input Voltage | V _{MODEL} | V _{IN} = 2.3 V | | - | - | 0.4 | V |
| On-resistance of High Side MOSFET | R _{ONH} | I _{SW} = 100 mA | NC2600ZA | - | 0.13 | - | Ω |
| | | | NC2600GT | - | 0.15 | - | Ω |
| On-resistance of Low Side MOSFET | R _{ONL} | I _{SW} = 100 mA | NC2600ZA | - | 0.09 | - | Ω |
| | | | NC2600GT | - | 0.12 | - | Ω |
| Soft-Start Time 1 | t _{START1} | CSS = OPEN | | - | 150 | 300 | μs |
| Soft-Start Time 2 | t _{START2} | CSS = 0.1 μF | | 15 | 30 | 45 | ms |
| SW Current Limit | I _{SWLIM} | | | 2.3 | - | 4.7 | A |
| Protection Delay Time | t _{PROT} | NC2600xxxxxA/B | | 10 | 20 | 40 | μs |
| UVLO Detection Voltage *1 | V _{UVLODET} | V _{IN} = Falling | | 1.85 | 2.00 | 2.20 | V |
| UVLO Release Voltage *1 | V _{UVLOREL} | V _{IN} = Rising | | 1.90 | 2.05 | 2.25 | V |
| On resistance at PG "L" Output | R _{ONPG} | V _{FB} = 0 V | | - | 45 | - | Ω |
| OV Detection Voltage | V _{OVD} | V _{FB} = Rising | | V _{SET} X 1.1 | V _{SET} X 1.2 | - | V |
| UV Detection Voltage | V _{UVD} | V _{FB} = Falling | | - | V _{SET} X 0.8 | V _{SET} X 0.9 | V |
| Thermal Shutdown Detection Temperature | T _{SDDET} | T _j = Rising | | - | 150 | - | °C |
| Thermal Shutdown Release Temperature | T _{SDREL} | T _j = Falling | | - | 120 | - | °C |

All electrical characteristic parameters that specify the minimum and maximum specifications are tested under the condition of $T_J \approx T_a = 25^\circ C$

*1 Due to the circuit configuration, $V_{UVLODET} \geq V_{UVLOREL}$ does not hold. The hysteresis is Typ.0.05 V.

NC2600xx000x (Adjustable Output Voltage Type)

$V_{IN} = 3.6V$ unless otherwise specified.

For parameter that do not describe the temperature condition, the MIN / MAX value under the condition of $-40\text{ }^{\circ}\text{C} \leq T_a \leq 85\text{ }^{\circ}\text{C}$ is described.

| Parameter | Symbol | Conditions | | MIN | TYP | MAX | Unit |
|--|----------------------|--|----------|-------|-------|-------|------|
| Feedback voltage | V _{FB} | Ta = 25 °C | | 0.591 | 0.600 | 0.609 | V |
| Switching Frequency | f _{OSC} | V _{MODE} =3.6 V | | - | 4.0 | - | MHz |
| Quiescent Current | I _Q | V _{FB} = 0.63 V, V _{MODE} = 0 V, no switching | | - | 17 | 25 | µA |
| Shutdown current | I _{SD} | V _{IN} = 5.5 V, V _{EN} = 0 V | | - | 0 | 5 | µA |
| EN "H" Input Current | I _{ENH} | V _{IN} = V _{EN} = 5.5 V | | -1 | 0 | 1 | µA |
| EN "L" Input Current | I _{ENL} | V _{IN} = 5.5 V, V _{EN} = 0 V | | -1 | 0 | 1 | µA |
| MODE "H" Input Current | I _{MODEH} | V _{IN} = V _{MODE} = 5.5 V | | -1 | 0 | 1 | µA |
| MODE "L" Input Current | I _{MODEL} | V _{IN} = 5.5 V, V _{MODE} = 0 V | | -1 | 0 | 1 | µA |
| FB "H" Input Current | I _{FBH} | V _{IN} = V _{FB} = 5.5 V, V _{EN} = 0 V | | -1 | 0 | 1 | µA |
| FB "L" Input Current | I _{FBL} | V _{IN} = 5.5 V, V _{EN} = V _{FB} = 0 V | | -1 | 0 | 1 | µA |
| On-resistance for Discharger | R _{ONDIS} | NC2600xx000A/C | | - | 60 | - | Ω |
| EN pin "H" Input Voltage | V _{ENH} | V _{IN} = 5.5 V | | 1.0 | - | - | V |
| EN pin "L" Input Voltage | V _{ENL} | V _{IN} = 2.3 V | | - | - | 0.4 | V |
| MODE "H" Input Voltage | V _{MODEH} | V _{IN} = 5.5 V | | 1.0 | - | - | V |
| MODE "L" Input Voltage | V _{MODEL} | V _{IN} = 2.3 V | | - | - | 0.4 | V |
| On-resistance of High Side MOSFET | R _{ONH} | I _{SW} = 100 mA | NC2600ZA | - | 0.13 | - | Ω |
| | | | NC2600GT | - | 0.15 | - | Ω |
| On-resistance of Low Side MOSFET | R _{ONL} | I _{SW} = 100 mA | NC2600ZA | - | 0.09 | - | Ω |
| | | | NC2600GT | - | 0.12 | - | Ω |
| Soft-Start Time 1 | t _{START1} | CSS = OPEN | | - | 150 | 300 | µs |
| Soft-Start Time 2 | t _{START2} | CSS = 0.1 µF | | 15 | 30 | 45 | ms |
| SW Current Limit | I _{SWLIM} | | | 2.3 | - | 4.7 | A |
| Protection Delay Time | t _{PROT} | NC2600xx000A/B | | 10 | 20 | 40 | µs |
| UVLO Detection Voltage *1 | V _{UVLODET} | V _{IN} = Falling | | 1.85 | 2.00 | 2.20 | V |
| UVLO Release Voltage *1 | V _{UVLOREL} | V _{IN} = Rising | | 1.90 | 2.05 | 2.25 | V |
| On resistance at PG "L" Output | R _{ONPG} | V _{FB} =0 V | | - | 45 | - | Ω |
| OV Detection Voltage | V _{OVD} | V _{FB} = Rising | | 0.66 | 0.72 | - | V |
| UV Detection Voltage | V _{UVD} | V _{FB} = Falling | | - | 0.48 | 0.54 | V |
| Thermal Shutdown Detection Temperature | T _{SDDET} | T _j = Rising | | - | 150 | - | °C |
| Thermal Shutdown Release Temperature | T _{SDREL} | T _j = Falling | | - | 120 | - | °C |

All electrical characteristic parameters that specify the minimum and maximum specifications are tested under the condition of $T_j \approx T_a = 25\text{ }^{\circ}\text{C}$

*1 Due to the circuit configuration, $V_{UVLODET} \geq V_{UVLOREL}$ does not hold. The hysteresis is Typ.0.05 V.

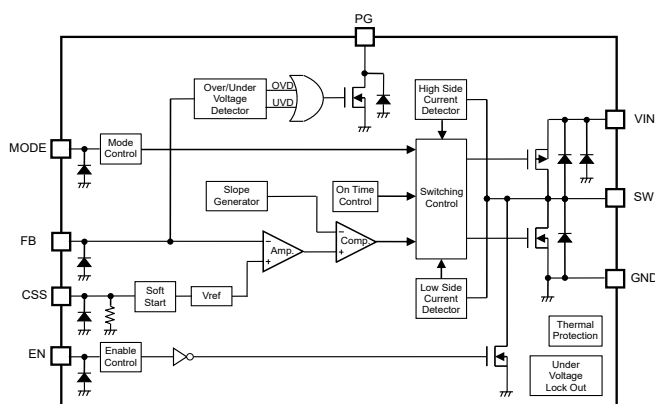
PRODUCT-SPECIFIC ELECTRICAL CHARACTERISTICS

| PRODUCT NAME | $V_{OUT} (T_a = 25\text{ }^{\circ}\text{C})$ | | | Unit |
|----------------|--|-----|-------|------|
| | MIN | TYP | MAX | |
| NC2600xx060xxx | 0.582 | 0.6 | 0.618 | V |
| NC2600xx070xxx | 0.682 | 0.7 | 0.718 | |
| NC2600xx080xxx | 0.782 | 0.8 | 0.818 | |
| NC2600xx090xxx | 0.882 | 0.9 | 0.918 | |
| NC2600xx100xxx | 0.982 | 1.0 | 1.018 | |
| NC2600xx110xxx | 1.082 | 1.1 | 1.118 | |
| NC2600xx120xxx | 1.182 | 1.2 | 1.218 | |
| NC2600xx130xxx | 1.280 | 1.3 | 1.320 | |
| NC2600xx140xxx | 1.379 | 1.4 | 1.421 | |
| NC2600xx150xxx | 1.477 | 1.5 | 1.523 | |
| NC2600xx160xxx | 1.576 | 1.6 | 1.624 | |
| NC2600xx170xxx | 1.674 | 1.7 | 1.726 | |
| NC2600xx180xxx | 1.773 | 1.8 | 1.827 | |
| NC2600xx190xxx | 1.871 | 1.9 | 1.929 | |
| NC2600xx200xxx | 1.970 | 2.0 | 2.030 | |
| NC2600xx210xxx | 2.068 | 2.1 | 2.132 | |
| NC2600xx220xxx | 2.167 | 2.2 | 2.233 | |
| NC2600xx230xxx | 2.265 | 2.3 | 2.335 | |
| NC2600xx240xxx | 2.364 | 2.4 | 2.436 | |
| NC2600xx250xxx | 2.462 | 2.5 | 2.538 | |
| NC2600xx260xxx | 2.561 | 2.6 | 2.639 | |
| NC2600xx270xxx | 2.659 | 2.7 | 2.741 | |
| NC2600xx280xxx | 2.758 | 2.8 | 2.842 | |
| NC2600xx290xxx | 2.856 | 2.9 | 2.944 | |
| NC2600xx300xxx | 2.955 | 3.0 | 3.045 | |
| NC2600xx310xxx | 3.053 | 3.1 | 3.147 | |
| NC2600xx320xxx | 3.152 | 3.2 | 3.248 | |
| NC2600xx330xxx | 3.250 | 3.3 | 3.350 | |

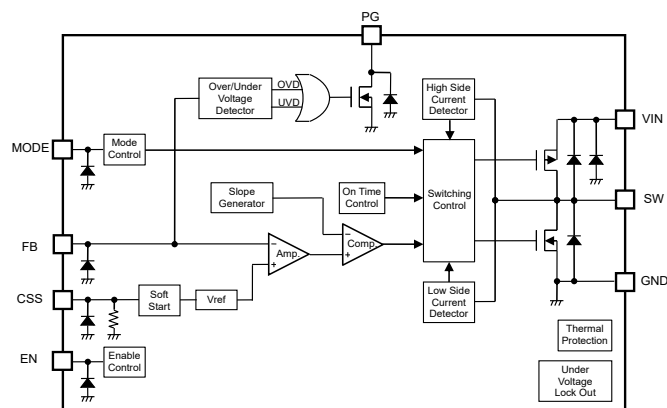
Above parameters are all tested under the following conditions:

$T_j \approx T_a = 25\text{ }^{\circ}\text{C}$

BLOCK DIAGRAMS



NC2600xxxxxA/C Block Diagram



NC2600xxxxxB/D Block Diagram

THEORY OF OPERATION

Enable Function

Forcing above designated "High" voltage to EN pin, the NC2600 becomes active. Forcing below designated "Low" voltage to EN pin shuts down the NC2600. In shutdown condition, all functions are disabled except auto discharge function. With auto discharge option, the MOSFET to discharge the output capacitor turns on and the output is pulled down to GND. Without auto discharge option, the output becomes "Hi-Z". EN pin can accept input range voltage regardless of the input of VIN pin.

Do not open the EN pin because it is not pulled up or down inside the IC.

If Enable function is not necessary, tie EN pin to VIN pin or other designated "High" voltage node at start-up.

For the NC2600 with the latch protection function, SW pin voltage must be 0.1 V or lower, when the NC2600 is activated by the enable function.

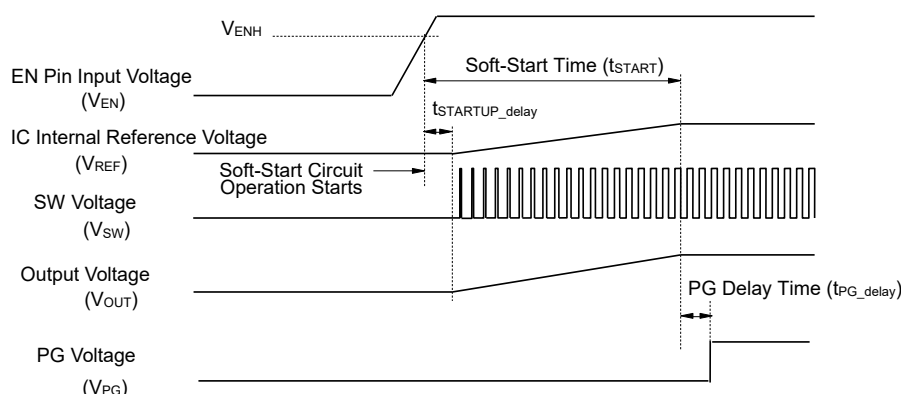
Auto Discharge Function

When turned off, the Vout voltage drops rapidly to near 0V by discharging the charge stored in the output capacitor through the MOSFET connected between the SW pin and GND pins. The auto discharge function is enabled when the EN pin = "low", UVLO detection or the thermal shutdown detection. On-resistance of MOSFET is Typ.60 Ω.

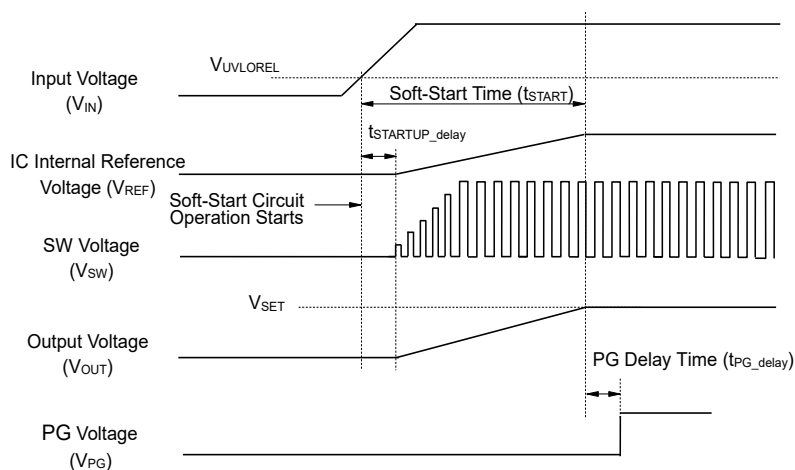
Soft-Start

When the input voltage (V_{IN}) exceeds the UVLO release voltage ($V_{UVLOREL}$) and the EN pin is input with a voltage higher than the EN "High" input voltage (V_{ENH}), the Soft-Start circuit starts operation. After the Soft-Start circuit starts operating and the delay time ($t_{STARTUP_delay}$) Typ.45 μ sec, the IC internal reference voltage (V_{REF}) starts rising, and after the Soft-Start time (t_{START})*¹, the V_{REF} reaches the specified value.

The output of the PG pin (V_{PG}) confirms that the output voltage (V_{OUT}) is between the UV detection voltage (V_{UVD}) and the OV detection voltage (V_{OVD}), and becomes "High" after the PG delay time (t_{PG_delay} =Typ.10 μ sec).



Timing Chart when Starting-up with EN pin



Timing Chart when Starting-up with $V_{IN} = EN$

The current limiting function, latch type protection function (NC2600xxxxxA/B), UVLO function, and thermal shutdown function are effective even during the Soft-Start time. When the thermal shutdown is released, the Soft-Start function is effective.

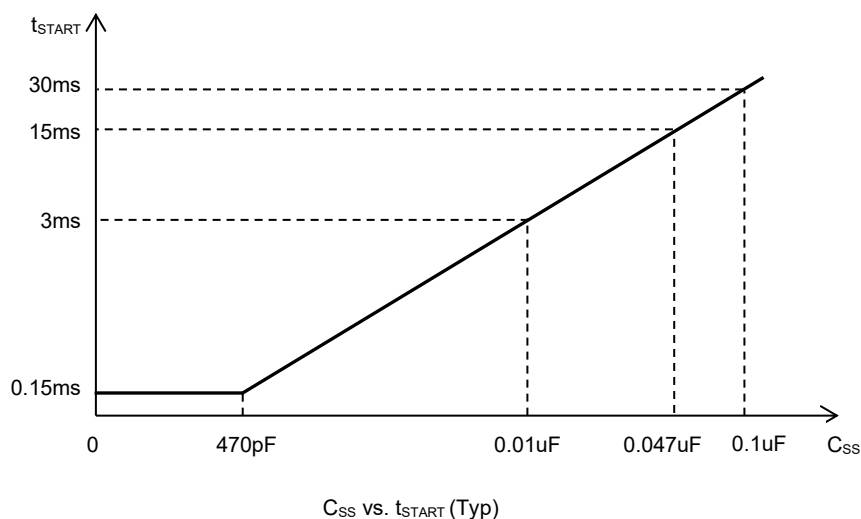
When starting with a large load current or when a large capacitance is used in the C_{OUT} , the above protection functions may be activated. In such a case, adjust the C_{SS} and increase the Soft-Start time in order to avoid such an abnormal situation.

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

Soft-Start Time Adjustment

Soft-Start time t_{START} can be adjusted as shown in the figure below by connecting a capacitor C_{SS} to the CSS pin. When C_{SS} is 0.1 μF , the Soft-Start time is Typ.30 ms. If you do not need to adjust the Soft-Start time, open the CSS pin to start up with the built-in Soft-Start time (Typ.0.15 ms). Soft-Start time can be calculated using the following equation. There is no limit to the capacitance value of the C_{SS} .

$$C_{SS} [\mu\text{F}] = t_{START} [\text{ms}] \times 0.0033$$



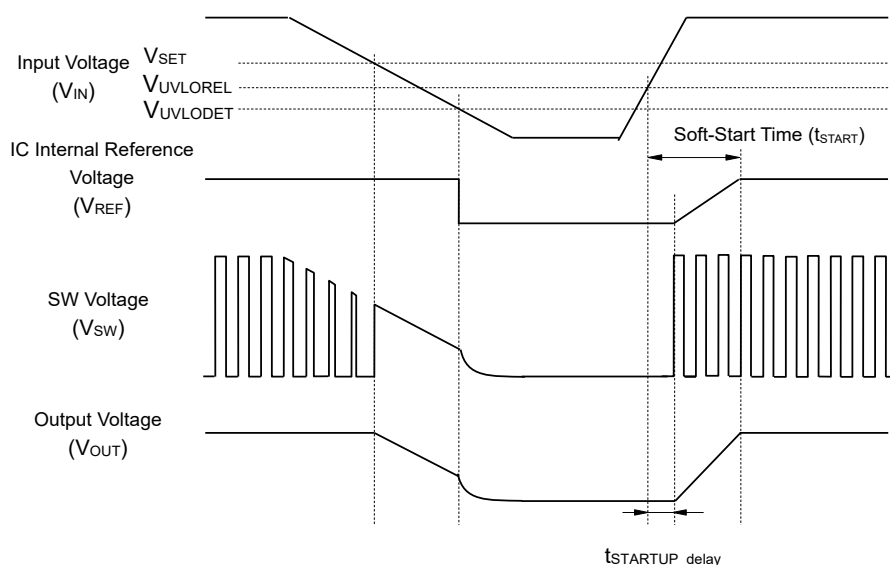
Under Voltage Lockout (UVLO) Circuit

When V_{IN} becomes lower than V_{SET} , the step-down switching regulator stops its switching operation and ON duty becomes 100%, then V_{OUT} gradually falls according to V_{IN} .

When the V_{IN} drops below the UVLO detection voltage ($V_{UVLODET}$), the UVLO operates, V_{REF} stops, and high side MOSFET and low side MOSFET turn "OFF".

As a result, the output voltage decreases according to the capacitance value of C_{OUT} , load current, and discharge FET on-resistance (NC2600xxxxxA/C).

To restart the operation, V_{IN} needs to exceed $V_{UVLOREL}$. The timing chart below shows the V_{OUT} voltage waveforms when the V_{IN} value is changed. Falling edge (detecting) 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} .

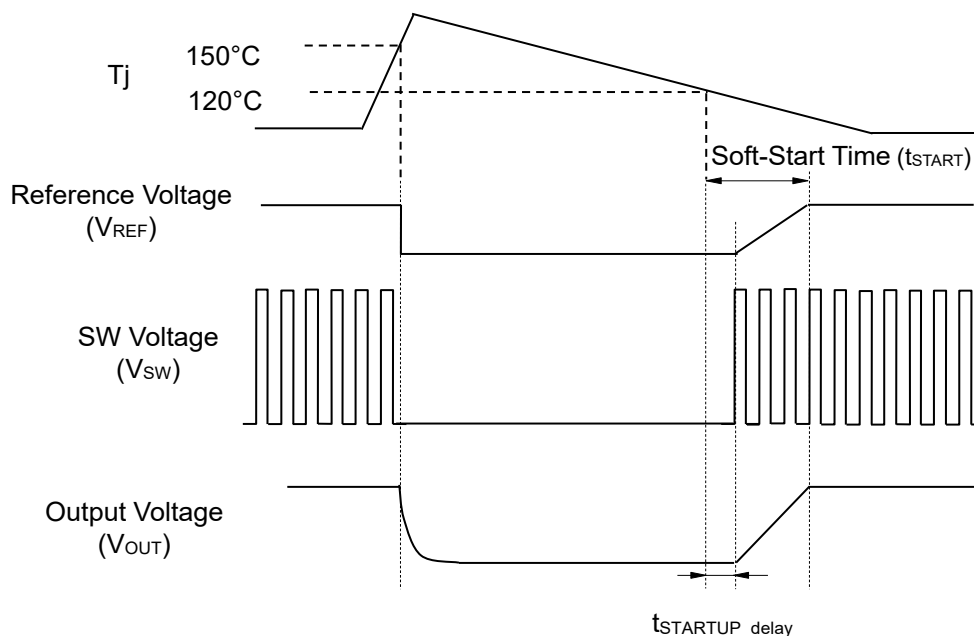


Timing Chart with Variations in Input Voltage (V_{IN})

Thermal Shutdown

When the junction temperature exceeds the thermal shutdown detection temperature (Typ.150°C), switching stops and self-heating is suppressed.

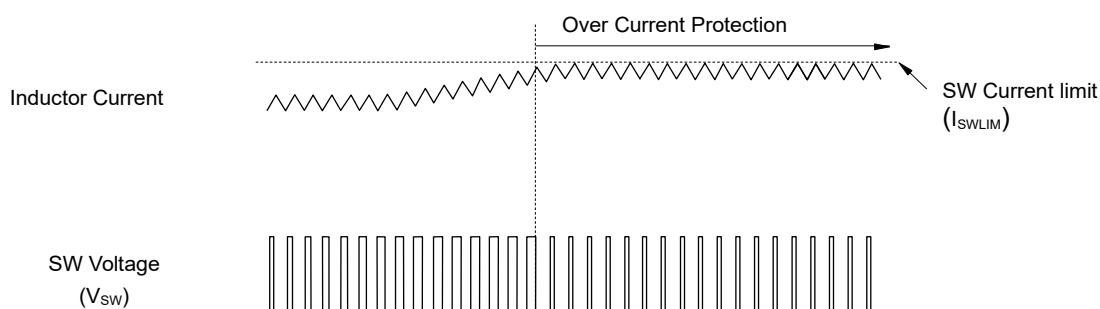
This IC will restart when the junction temperature drops below the thermal shutdown release temperature (Typ.120°C). Then, the Soft-Start function is activated.



Current Limit Circuit, Latch Type Protection Circuit

Current limit circuit supervises the peak current flowing through the inductor in each switching cycle. If the current exceeds the SW current limit (Typ.3.4 A), High Side MOSFET is turned off and the upper limit of the inductor peak current is imposed.

The latch-type protection circuit latches the built-in driver off and shuts down the switching regulator if this overcurrent condition lasts for the protection delay time (t_{PROT}). To release the latch type protection state, restart the device by inputting "Low" signal to the EN pin or making the Input Voltage lower than UVLO detection voltage ($V_{UVLODET}$).



Over-Current Protection Operation

Forced PWM Mode and PWM / PFM Auto Switching Mode

Output voltage controlling method is selectable between a forced PWM mode type and PWM/PFM Auto Switching mode. The operation mode can be set by the MODE pin. The forced PWM mode operates with fixed switching frequency to reduce noise in low output current. The PWM/PFM Auto Switching mode automatically enters PFM control to achieve high efficiency at light load current.

The above control types operate differently depending on the relationship between the load current (I_{OUT}) and the current ripple (ΔI_L) calculated by the following equation.

$$\Delta I_L = (V_{IN} - V_{OUT}) \times t_{ON} / L$$

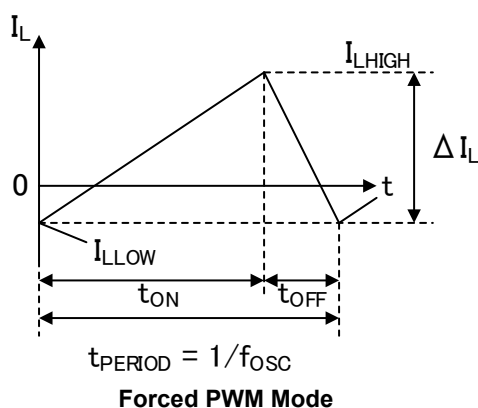
t_{ON} : ON time of high side MOSFET

Do not open the MODE pin because it is not pulled up or down inside the IC.

MODE = "High" (Forced PWM Mode)

When a "High" signal is input to the MODE pin, the device enters a forced PWM mode in which the high side MOSFET and low side MOSFET are turned on alternately. During this operation, it operates with fixed switching frequency regardless of the load current. This reduces output voltage ripple and responds quickly to load current transitions.

If $I_{OUT} < \Delta I_L / 2$, I_{LOW} becomes 0 A or less, and the charge stored in C_{OUT} flows back to the IC side. Refer to the figure below.



MODE = "Low" (PWM/PFM Auto Switching Mode)

When a "Low" signal is input to the MODE pin, when $I_L = 0$ A under a light load condition, the operation mode is set to $t_{OFF-OFF}$ which turns off the high side MOSFET and the low side MOSFET at the same time. Such an operation in which $t_{OFF-OFF}$ exists in one cycle is called PFM operation.

$t_{OFF-OFF}$ during PFM operation reduces power consumption by minimizing the operating circuits inside the IC.

This realizes highly efficient operation at light loads conditions.

The cycle during PFM operation is defined by the following equation.

$$t_{PERIOD} = t_{ON} + t_{OFF} + t_{OFF-OFF} = 1 / f_{OSC} \dots\dots\dots (1)$$

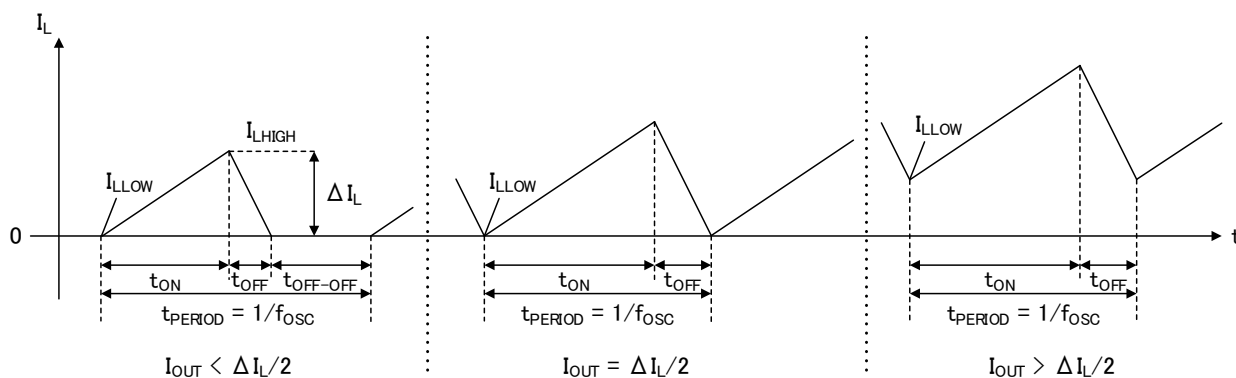
At light load conditions ($I_{OUT} < \Delta I_L / 2$), $I_{LLOW} = 0$ A and the I_L waveform is as shown on the left in the figure.

During PFM operation, if the load current is increases from a light load, $t_{OFF-OFF}$ becomes shorter.

When $t_{OFF-OFF}$ becomes 0 sec ($I_{OUT} = \Delta I_L / 2$), the IC enters PWM operation, and when the load current increases further, $I_{LLOW} > 0$ A.

Refer to the figure below.

In this way, when the MODE pin is fixed to "Low", PWM operation and PFM operation are automatically switched according to the load current.



PWM/PFM Auto Switching Mode

Switching Frequency

The minimum on-time / the minimum off-time for this product is determined by the circuit. If the on-time / the off-time calculated under the input/output voltage conditions at 4 MHz are less than the minimum on-time / minimum off-time determined by the circuit, the switching frequency falls below 4 MHz.

The on-time under no load is calculated by the following equation according to the input / output voltage conditions.

$$t_{ON} = 250 \text{ ns} \times V_{OUT} / V_{IN}$$

Example 1: Switching frequency with minimum on-time (60 ns) under the following input / output conditions.

condition1: $V_{IN} = 3.6 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$

$$1/4 \text{ MHz} \times 1.2 \text{ V} / 3.6 \text{ V} = 83 \text{ ns} > \text{minimum on-time (60 ns)}$$

Operates with 4 MHz.

condition2: $V_{IN} = 5.5 \text{ V}$, $V_{OUT} = 1.0 \text{ V}$

$$1/4 \text{ MHz} \times 1.0 \text{ V} / 5.5 \text{ V} = 55 \text{ ns} < \text{minimum on-time (60 ns)}$$

Switching frequency falls below 4 MHz.

Example 2: Switching frequency with minimum off-time (50 ns) under the following input / output conditions.

condition1: $V_{IN} = 5.0 \text{ V}$, $V_{OUT} = 3.3 \text{ V}$

$$1/4 \text{ MHz} \times (1 - 3.3 \text{ V} / 5.0 \text{ V}) = 77 \text{ ns} > \text{minimum off-time (50 ns)}$$

Operates with 4 MHz.

condition2: $V_{IN} = 4.0 \text{ V}$, $V_{OUT} = 3.3 \text{ V}$

$$1/4 \text{ MHz} \times (1 - 3.3 \text{ V} / 4.0 \text{ V}) = 44 \text{ ns} < \text{minimum off-time (50 ns)}$$

Switching frequency falls below 4 MHz.

Power Good Function

This product has a power good (PG) function, and the output type is NMOS FET open drain. When EN = "Low" is detected, the NMOS FET turns on and sets the power good output to "Low".

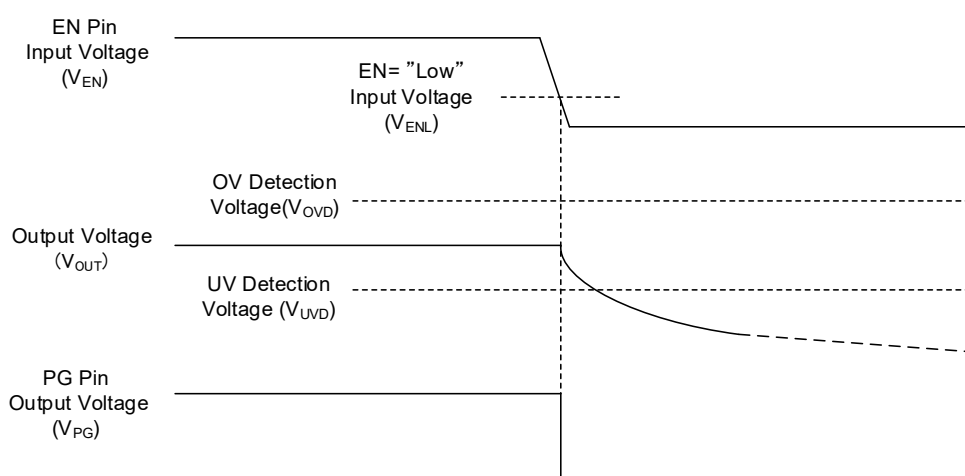
Figure: Refer to PG Output When EN = "Low".

Also, when the IC detects Over Voltage (OV) or Under Voltage (UV), the power good output is set to "Low" as well.

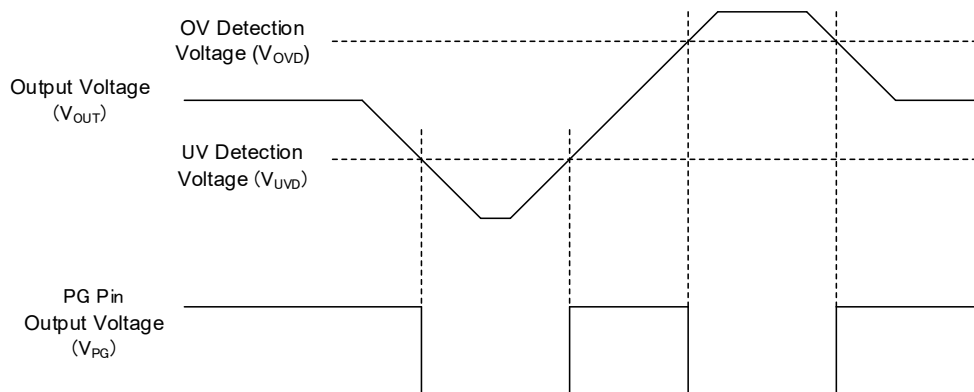
Figure: Refer to PG Output When OV or UV is Detected.

When the IC is released from these conditions, the NMOS FET is turned off and the power good output is set to "High".

The pull-up resistor (R_{PG}) of the PG pin should be between 10 k Ω and 100 k Ω . The PG pin must be open or connected to GND if the power good function is not used.



PG Output When EN = "Low"



PG Output When OV or UV is Detected

Pass-Through Mode

This product enters pass-through mode when the input / output voltage difference drops. In this operating state, the high side MOSFET is always on and the low side MOSFET is always off. This function helps to hold output voltage and to lengthen operation time of application longest even when battery voltage drops. In this operating state, the output voltage is calculated by the following equation using the on-resistance of the high side MOSFET (R_{ONP}) and the DC resistance of the inductor (R_L).

$$V_{OUT} = V_{IN} - (R_{ONP} + R_L) \times I_{OUT}$$

THERMAL CHARACTERISTICS (WLCSP-8-P11)

Thermal characteristics depend on mounting conditions. The thermal characteristics below are the results of measurements under measurement conditions determined by our company with reference to JEDEC STD. (JESD51).

Measurement Result

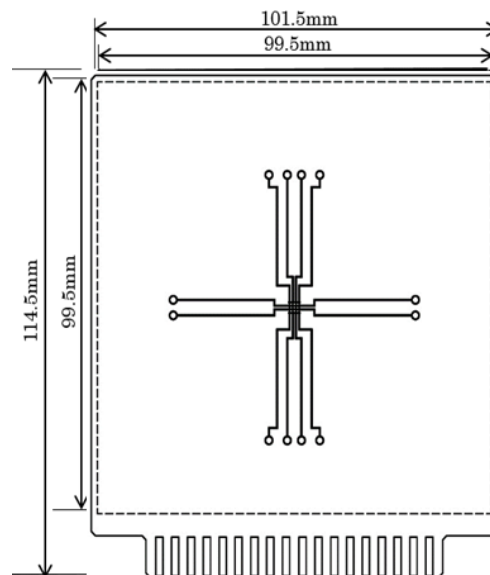
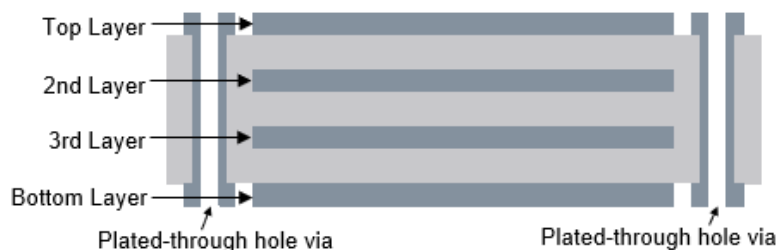
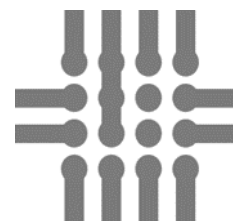
| Item | Measurement Result |
|--|--------------------|
| Thermal Resistance (θ_{ja}) | 131 °C/W |
| Thermal Characterization Parameter (ψ_{jt}) | 38 °C/W |

θ_{ja} : Junction-to-Ambient Thermal Resistance

ψ_{jt} : Junction-to-Top Thermal Characterization Parameter

Measurement Conditions

| Item | Specification |
|-----------------------|---|
| Measurement Condition | Mounting on Board (Still Air) |
| Board material | FR-4 |
| Board size | 101.5 mm × 114.5 mm × t 1.6 mm |
| Copper foil layer | 1 99.5 mm × 99.5 mm (coverage rate 5%), t 0.050 mm |
| | 2 99.5 mm × 99.5 mm (coverage rate 100%), t 0.035 mm |
| | 3 99.5 mm × 99.5 mm (coverage rate 100%), t 0.035 mm |
| | 4 99.5 mm × 99.5 mm (coverage rate 5%), t 0.050 mm |
| Thermal vias | None |

**Measurement Board Pattern****Cross section view of layers and vias****Enlarged view of IC mounting area****● CALCULATION METHOD OF JUNCTION TEMPERATURE**

The junction temperature (T_j) can be calculated from the following formula.

$$T_j = T_a + \theta_{ja} \times P$$

$$T_j = T_c (\text{top}) + \psi_{jt} \times P$$

T_a : Ambient temperature

$T_c (\text{top})$: Package mark side center temperature

P : Power consumption under user's conditions

$$P = (100 / \eta - 1) \times (V_{OUT} \times I_{OUT}) - DCR \times I_{OUT}^2$$

η : Efficiency under user's conditions [%]

V_{OUT} : Output Voltage [V]

I_{OUT} : Output Current [A]

DCR : DC resistance of external inductor [Ω]

THERMAL CHARACTERISTICS (DFN2020-8-GT)

Thermal characteristics depend on mounting conditions. The thermal characteristics below are the results of measurements under measurement conditions determined by our company with reference to JEDEC STD. (JESD51).

Measurement Result

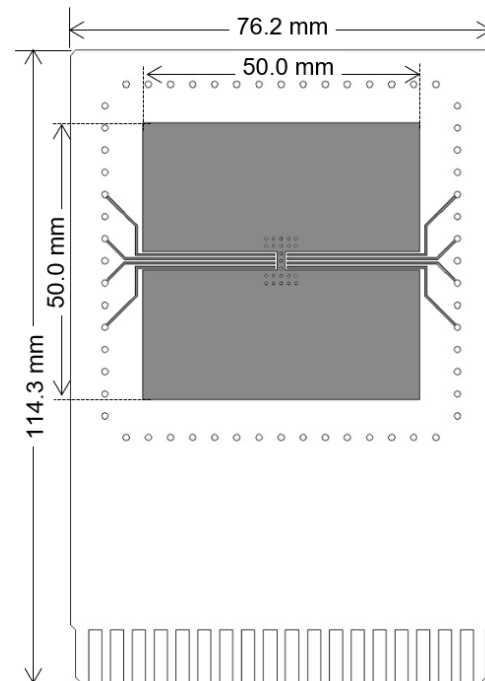
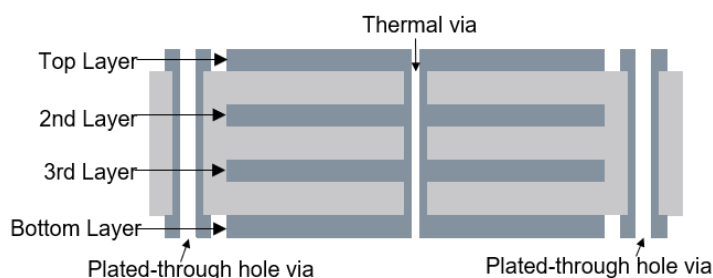
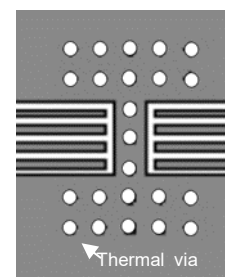
| Item | Measurement Result |
|--|--------------------|
| Thermal Resistance (θ_{ja}) | 71 °C/W |
| Thermal Characterization Parameter (ψ_{jt}) | 33 °C/W |

θ_{ja} : Junction-to-Ambient Thermal Resistance

ψ_{jt} : Junction-to-Top Thermal Characterization Parameter

Measurement Conditions

| Item | Specification |
|-----------------------|---|
| Measurement Condition | Mounting on Board (Still Air) |
| Board material | FR-4 |
| Board size | 76.2 mm × 114.3 mm × t 0.8 mm |
| Copper foil layer | 1 50 mm × 50 mm (coverage rate 95%), t 0.090 mm |
| | 2 50 mm × 50 mm (coverage rate 100%), t 0.035 mm |
| | 3 50 mm × 50 mm (coverage rate 100%), t 0.035 mm |
| | 4 50 mm × 50 mm (coverage rate 100%), t 0.090 mm |
| Thermal vias | ϕ 0.3 mm × 23 pcs |

**Measurement Board Pattern****Cross section view of layers and vias****Enlarged view of IC mounting area****● CALCULATION METHOD OF JUNCTION TEMPERATURE**

The junction temperature (T_j) can be calculated from the following formula.

$$T_j = T_a + \theta_{ja} \times P$$

$$T_j = T_c (\text{top}) + \psi_{jt} \times P$$

T_a : Ambient temperature

$T_c (\text{top})$: Package mark side center temperature

P : Power consumption under user's conditions

$$P = (100 / \eta - 1) \times (V_{OUT} \times I_{OUT}) - DCR \times I_{OUT}^2$$

η : Efficiency under user's conditions [%]

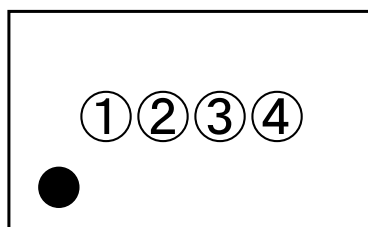
V_{OUT} : Output Voltage [V]

I_{OUT} : Output Current [A]

DCR : DC resistance of external inductor [Ω]

MARKING SPECIFICATION (NC2600ZA)

- ①②: Product Code
③④: Lot No. ... Alphanumerical Serial Number



WLCSP-8-P11 Marking

NOTICE

There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact our sales or distributor before attempting to use AOI.

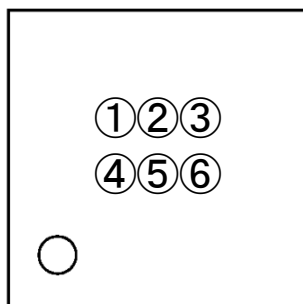
NC2600ZA Marking List

| Product Code | ① | ② | Product Code | ① | ② | Product Code | ① | ② |
|--------------|---|---|--------------|---|---|--------------|---|---|
| NC2600ZA000A | A | A | NC2600ZA150B | E | P | NC2600ZA250C | H | F |
| NC2600ZA060A | A | C | NC2600ZA160B | E | R | NC2600ZA260C | H | G |
| NC2600ZA070A | A | E | NC2600ZA170B | E | T | NC2600ZA270C | H | H |
| NC2600ZA080A | A | F | NC2600ZA180B | E | U | NC2600ZA280C | H | J |
| NC2600ZA090A | A | G | NC2600ZA190B | E | V | NC2600ZA290C | H | K |
| NC2600ZA100A | A | H | NC2600ZA200B | E | X | NC2600ZA300C | H | L |
| NC2600ZA110A | A | J | NC2600ZA210B | E | Y | NC2600ZA310C | H | N |
| NC2600ZA120A | A | K | NC2600ZA220B | F | A | NC2600ZA320C | H | P |
| NC2600ZA130A | A | L | NC2600ZA230B | F | C | NC2600ZA330C | H | R |
| NC2600ZA140A | A | N | NC2600ZA240B | F | E | NC2600ZA000D | J | A |
| NC2600ZA150A | A | P | NC2600ZA250B | F | F | NC2600ZA060D | J | C |
| NC2600ZA160A | A | R | NC2600ZA260B | F | G | NC2600ZA070D | J | E |
| NC2600ZA170A | A | T | NC2600ZA270B | F | H | NC2600ZA080D | J | F |
| NC2600ZA180A | A | U | NC2600ZA280B | F | J | NC2600ZA090D | J | G |
| NC2600ZA190A | A | V | NC2600ZA290B | F | K | NC2600ZA100D | J | H |
| NC2600ZA200A | A | X | NC2600ZA300B | F | L | NC2600ZA110D | J | J |
| NC2600ZA210A | A | Y | NC2600ZA310B | F | N | NC2600ZA120D | J | K |
| NC2600ZA220A | C | A | NC2600ZA320B | F | P | NC2600ZA130D | J | L |
| NC2600ZA230A | C | C | NC2600ZA330B | F | R | NC2600ZA140D | J | N |
| NC2600ZA240A | C | E | NC2600ZA000C | G | A | NC2600ZA150D | J | P |
| NC2600ZA250A | C | F | NC2600ZA060C | G | C | NC2600ZA160D | J | R |
| NC2600ZA260A | C | G | NC2600ZA070C | G | E | NC2600ZA170D | J | T |
| NC2600ZA270A | C | H | NC2600ZA080C | G | F | NC2600ZA180D | J | U |
| NC2600ZA280A | C | J | NC2600ZA090C | G | G | NC2600ZA190D | J | V |
| NC2600ZA290A | C | K | NC2600ZA100C | G | H | NC2600ZA200D | J | X |
| NC2600ZA300A | C | L | NC2600ZA110C | G | J | NC2600ZA210D | J | Y |
| NC2600ZA310A | C | N | NC2600ZA120C | G | K | NC2600ZA220D | K | A |
| NC2600ZA320A | C | P | NC2600ZA130C | G | L | NC2600ZA230D | K | C |
| NC2600ZA330A | C | R | NC2600ZA140C | G | N | NC2600ZA240D | K | E |
| NC2600ZA000B | E | A | NC2600ZA150C | G | P | NC2600ZA250D | K | F |
| NC2600ZA060B | E | C | NC2600ZA160C | G | R | NC2600ZA260D | K | G |
| NC2600ZA070B | E | E | NC2600ZA170C | G | T | NC2600ZA270D | K | H |
| NC2600ZA080B | E | F | NC2600ZA180C | G | U | NC2600ZA280D | K | J |
| NC2600ZA090B | E | G | NC2600ZA190C | G | V | NC2600ZA290D | K | K |
| NC2600ZA100B | E | H | NC2600ZA200C | G | X | NC2600ZA300D | K | L |
| NC2600ZA110B | E | J | NC2600ZA210C | G | Y | NC2600ZA310D | K | N |
| NC2600ZA120B | E | K | NC2600ZA220C | H | A | NC2600ZA320D | K | P |
| NC2600ZA130B | E | L | NC2600ZA230C | H | C | NC2600ZA330D | K | R |
| NC2600ZA140B | E | N | NC2600ZA240C | H | E | | | |

MARKING SPECIFICATION (NC2600GT)

①②③④: Product Code

⑤⑥: Lot No. ... Alphanumerical Serial Number



DFN2020-8-GT Part Markings

NOTICE

There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact our sales or our distributor before attempting to use AOI.

NC2600GT Marking List

| Product Code | ① ② ③ ④ |
|--------------|---------|
| NC2600GT000A | 1 A 0 0 |
| NC2600GT060A | 1 A 0 1 |
| NC2600GT070A | 1 A 0 2 |
| NC2600GT080A | 1 A 0 3 |
| NC2600GT090A | 1 A 0 4 |
| NC2600GT100A | 1 A 0 5 |
| NC2600GT110A | 1 A 0 6 |
| NC2600GT120A | 1 A 0 7 |
| NC2600GT130A | 1 A 0 8 |
| NC2600GT140A | 1 A 0 9 |
| NC2600GT150A | 1 A 1 0 |
| NC2600GT160A | 1 A 1 1 |
| NC2600GT170A | 1 A 1 2 |
| NC2600GT180A | 1 A 1 3 |
| NC2600GT190A | 1 A 1 4 |
| NC2600GT200A | 1 A 1 5 |
| NC2600GT210A | 1 A 1 6 |
| NC2600GT220A | 1 A 1 7 |
| NC2600GT230A | 1 A 1 8 |
| NC2600GT240A | 1 A 1 9 |
| NC2600GT250A | 1 A 2 0 |
| NC2600GT260A | 1 A 2 1 |
| NC2600GT270A | 1 A 2 2 |
| NC2600GT280A | 1 A 2 3 |
| NC2600GT290A | 1 A 2 4 |
| NC2600GT300A | 1 A 2 5 |
| NC2600GT310A | 1 A 2 6 |
| NC2600GT320A | 1 A 2 7 |
| NC2600GT330A | 1 A 2 8 |

| Product Code | ① ② ③ ④ |
|--------------|---------|
| NC2600GT000B | 1 B 0 0 |
| NC2600GT060B | 1 B 0 1 |
| NC2600GT070B | 1 B 0 2 |
| NC2600GT080B | 1 B 0 3 |
| NC2600GT090B | 1 B 0 4 |
| NC2600GT100B | 1 B 0 5 |
| NC2600GT110B | 1 B 0 6 |
| NC2600GT120B | 1 B 0 7 |
| NC2600GT130B | 1 B 0 8 |
| NC2600GT140B | 1 B 0 9 |
| NC2600GT150B | 1 B 1 0 |
| NC2600GT160B | 1 B 1 1 |
| NC2600GT170B | 1 B 1 2 |
| NC2600GT180B | 1 B 1 3 |
| NC2600GT190B | 1 B 1 4 |
| NC2600GT200B | 1 B 1 5 |
| NC2600GT210B | 1 B 1 6 |
| NC2600GT220B | 1 B 1 7 |
| NC2600GT230B | 1 B 1 8 |
| NC2600GT240B | 1 B 1 9 |
| NC2600GT250B | 1 B 2 0 |
| NC2600GT260B | 1 B 2 1 |
| NC2600GT270B | 1 B 2 2 |
| NC2600GT280B | 1 B 2 3 |
| NC2600GT290B | 1 B 2 4 |
| NC2600GT300B | 1 B 2 5 |
| NC2600GT310B | 1 B 2 6 |
| NC2600GT320B | 1 B 2 7 |
| NC2600GT330B | 1 B 2 8 |

NC2600GT Marking List

| Product Code | ① ② ③ ④ |
|--------------|---------|
| NC2600GT000C | 1 C 0 0 |
| NC2600GT060C | 1 C 0 1 |
| NC2600GT070C | 1 C 0 2 |
| NC2600GT080C | 1 C 0 3 |
| NC2600GT090C | 1 C 0 4 |
| NC2600GT100C | 1 C 0 5 |
| NC2600GT110C | 1 C 0 6 |
| NC2600GT120C | 1 C 0 7 |
| NC2600GT130C | 1 C 0 8 |
| NC2600GT140C | 1 C 0 9 |
| NC2600GT150C | 1 C 1 0 |
| NC2600GT160C | 1 C 1 1 |
| NC2600GT170C | 1 C 1 2 |
| NC2600GT180C | 1 C 1 3 |
| NC2600GT190C | 1 C 1 4 |
| NC2600GT200C | 1 C 1 5 |
| NC2600GT210C | 1 C 1 6 |
| NC2600GT220C | 1 C 1 7 |
| NC2600GT230C | 1 C 1 8 |
| NC2600GT240C | 1 C 1 9 |
| NC2600GT250C | 1 C 2 0 |
| NC2600GT260C | 1 C 2 1 |
| NC2600GT270C | 1 C 2 2 |
| NC2600GT280C | 1 C 2 3 |
| NC2600GT290C | 1 C 2 4 |
| NC2600GT300C | 1 C 2 5 |
| NC2600GT310C | 1 C 2 6 |
| NC2600GT320C | 1 C 2 7 |
| NC2600GT330C | 1 C 2 8 |

| Product Code | ① ② ③ ④ |
|--------------|---------|
| NC2600GT000D | 1 D 0 0 |
| NC2600GT060D | 1 D 0 1 |
| NC2600GT070D | 1 D 0 2 |
| NC2600GT080D | 1 D 0 3 |
| NC2600GT090D | 1 D 0 4 |
| NC2600GT100D | 1 D 0 5 |
| NC2600GT110D | 1 D 0 6 |
| NC2600GT120D | 1 D 0 7 |
| NC2600GT130D | 1 D 0 8 |
| NC2600GT140D | 1 D 0 9 |
| NC2600GT150D | 1 D 1 0 |
| NC2600GT160D | 1 D 1 1 |
| NC2600GT170D | 1 D 1 2 |
| NC2600GT180D | 1 D 1 3 |
| NC2600GT190D | 1 D 1 4 |
| NC2600GT200D | 1 D 1 5 |
| NC2600GT210D | 1 D 1 6 |
| NC2600GT220D | 1 D 1 7 |
| NC2600GT230D | 1 D 1 8 |
| NC2600GT240D | 1 D 1 9 |
| NC2600GT250D | 1 D 2 0 |
| NC2600GT260D | 1 D 2 1 |
| NC2600GT270D | 1 D 2 2 |
| NC2600GT280D | 1 D 2 3 |
| NC2600GT290D | 1 D 2 4 |
| NC2600GT300D | 1 D 2 5 |
| NC2600GT310D | 1 D 2 6 |
| NC2600GT320D | 1 D 2 7 |
| NC2600GT330D | 1 D 2 8 |

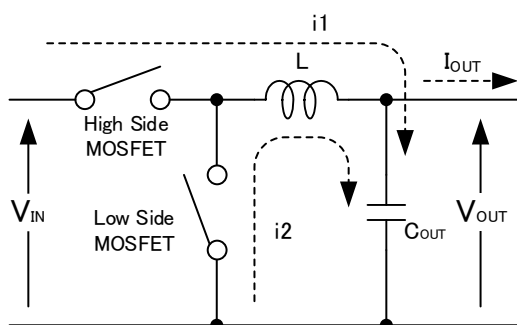
APPLICATION NOTES

Operation of Step-down Switching Regulator and Output Current

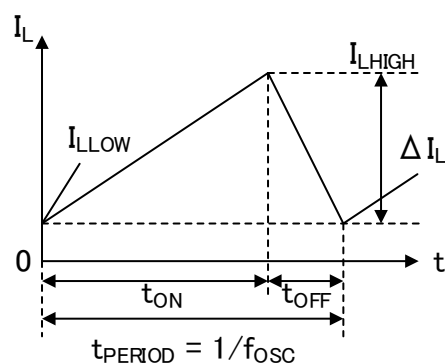
The operation of the step-down switching regulator is explained.

- Step1.** The high side MOSFET turns on and the inductor current $I_L = i1$ flows, storing energy in the inductor and at the same time charging to the C_{OUT} . Then, the inductor current $I_L = i1$ increases from I_{LLOW} in proportion to the time when the high side MOSFET turns on and reaches I_{LHIGH} .
- Step2.** When the high side MOSFET turns off and the low side MOSFET turns on, the inductor operates to hold the inductor current $I_L = I_{LHIGH}$. At this time, the inductor uses the energy stored in Step 1 to flow the inductor current $I_L = i2$.
- Step3.** $i2$ gradually decreases until the low side MOSFET is turned off. When the next cycle, it returns to Step 1 again and the high side MOSFET turns on.

By performing Step 1 to 3 above cyclically, an arbitrary output voltage is obtained according to the ratio of on time for one cycle.



Basic Circuit of Step-down Switching Regulator



Current Through Inductor

When the maximum current of the inductor is I_{LHIGH} and the minimum value is I_{LLOW} , the difference between I_{LHIGH} and I_{LLOW} ΔI_L is called the current ripple, $\Delta I_L = I_{LHIGH} - I_{LLOW}$. The current ripple ΔI_L during Step 1 is shown by using t_{ON} (on-time), V_{IN} , V_{OUT} , and L (inductor value) as follows.

$$\Delta I_L = (V_{IN} - V_{OUT}) \times t_{ON} / L \quad \dots\dots\dots (2)$$

On the other hand, during Step2, it is represented by the following equation using t_{OFF} (off-time).

$$\Delta I_L = V_{OUT} \times t_{OFF} / L \quad \dots\dots\dots (3)$$

Since in the static state, the values of equations (2) and (3) are the same,

$$(V_{IN} - V_{OUT}) \times t_{ON} / L = V_{OUT} \times t_{OFF} / L \quad \dots\dots\dots (4)$$

Therefore, t_{ON} / t_{PERIOD} is shown by following equation.

$$t_{ON} / t_{PERIOD} = V_{OUT} / V_{IN} \quad \dots\dots\dots (5)$$

Where t_{PERIOD} is the period and is shown by the following equation.

$$t_{PERIOD} = t_{ON} + t_{OFF} = 1 / f_{OSC} \quad \dots\dots\dots (6)$$

f_{OSC} is the switching frequency.

Duty is the ratio of the time that the high side MOSFET is on during one cycle and can be calculated by the following equation.

$$\text{Duty (\%)} = t_{ON} / t_{PERIOD} \times 100 = V_{OUT} / V_{IN} \times 100 \quad \dots\dots\dots (7)$$

Calculation Conditions of SW Pin Maximum Output Current (I_{SWMAX})

The following equations explain the calculation to determine I_{SWMAX} at the ideal operation of the ICs in continuous conduction mode.

The p-p value of the ripple current is I_{RP} , the on-resistance of the high side MOSFET and low side MOSFETs is R_{ONP} and R_{ONN} , respectively, and the DC resistance of the inductor is R_L .

First, define t_{ON} be the time when the high side MOSFET is on.

$$V_{IN} = V_{OUT} + (R_{ONP} + R_L) \times I_{OUT} + L \times I_{RP} / t_{ON} \quad (8)$$

Next, define t_{OFF} be the time when the high side MOSFET is off (low side MOSFET is on).

$$L \times I_{RP} / t_{OFF} = R_{ONN} \times I_{OUT} + V_{OUT} + R_L \times I_{OUT} \quad (9)$$

Put Equation (9) into Equation (8) to solve $D_{ON} = t_{ON} / (t_{OFF} + t_{ON})$ that is on-duty of high side MOSFET.

$$D_{ON} = (V_{OUT} + R_{ONN} \times I_{OUT} + R_L \times I_{OUT}) / (V_{IN} + R_{ONN} \times I_{OUT} - R_{ONP} \times I_{OUT}) \quad (10)$$

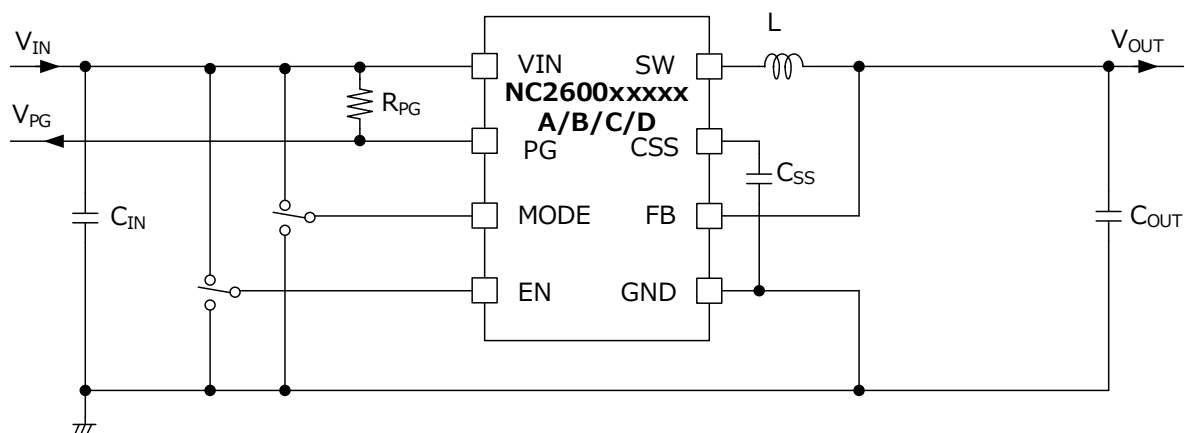
Ripple Current (I_{RP}) is as follows.

$$I_{RP} = (V_{IN} - V_{OUT} - R_{ONP} \times I_{OUT} - R_L \times I_{OUT}) \times D_{ON} / f_{OSC} / L \quad (11)$$

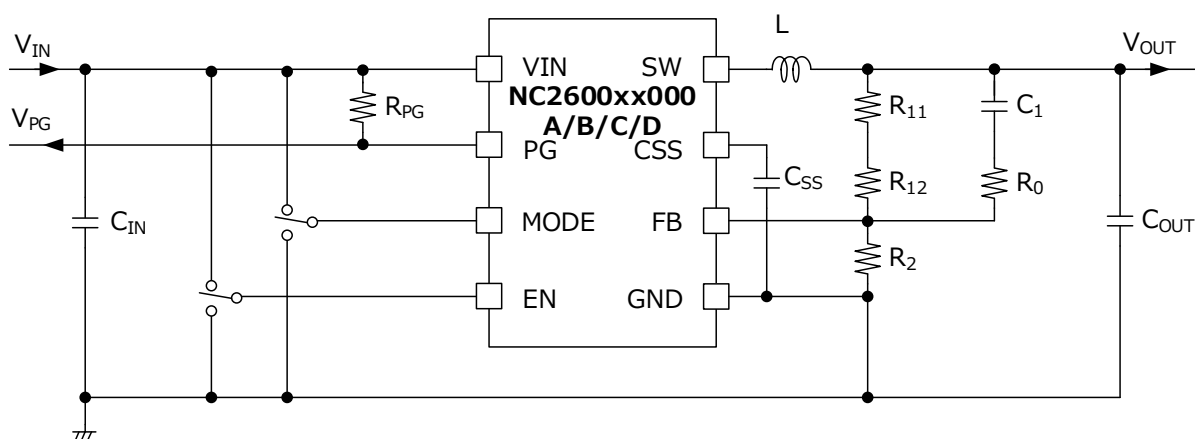
The peak current flowing through the inductor and high side MOSFET can be calculated by the following equation.

$$I_{SWMAX} = I_{OUT} + I_{RP} / 2 \quad (12)$$

Typical Application Circuit



NC2600xxxxx (Fixed Output Voltage Type)



NC2600xx000 (Adjustable Output Voltage Type)

Recommended external parts

| Symbol | Capacitance | Tolerance | Protection Voltage | Temperature characteristics |
|------------------|-------------|------------|--------------------|-----------------------------|
| C _{IN} | 4.7 μ F | $\pm 20\%$ | 6.3 V | X5R |
| C _{OUT} | 10 μ F | $\pm 20\%$ | 6.3 V | X5R |
| C _{SS} | - | $\pm 20\%$ | 6.3 V | X5R |

| Symbol | Inductance | Tolerance | Rated Current |
|--------|-------------|------------|---------------|
| L | 1.0 μ H | $\pm 20\%$ | 2.0A |

External Resistor for Setting Output Voltage (NC2600xx000x)

The output voltage can be set by the external resistors (R1, R2) connected to the FB pin as shown in the following equation.

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

$$R1 = R11 + R12$$

The reference voltage (V_{FB}) of this IC is set 0.6 V. The V_{FB} accuracy and output voltage setting range are as follows.

$$V_{FB} \text{ Accuracy} : 0.6 \text{ V} \pm 9 \text{ mV}$$

$$\text{Output Voltage Setting Range} : 0.6 \text{ V} \leq V_{SET} \leq 5.5 \text{ V}$$

Recommended values for R1, R2, and C1 are shown below.

Set Output Voltage (VSET) vs. R1,R2,C1 (Adjustable Output Voltage Type)

| V_{SET} [V] | R1 [k Ω] | R2 [k Ω] | C1 [pF] |
|--------------------------|---|------------------|---------|
| 0.6 | 0 | 220 | Open |
| $0.6 < V_{SET} \leq 2.1$ | $R1 = (V_{SET} / V_{FB} - 1) \times R2$ | 220 | 10 |
| $2.1 < V_{SET} \leq 4.0$ | | 47 | 6.8 |
| $4.0 < V_{SET} \leq 5.5$ | | 33 | 3.3 |

When using R2 other than the above table, adjust C1 according to the table below and check that there is no problem with the actual application.

Set Output Voltage (VSET) vs. R2/C1 (Adjustable Output Voltage Type)

| V_{SET} [V] | C1 [pF] |
|--------------------------|----------------------------|
| 0.6 | Open |
| $0.6 < V_{SET} \leq 2.1$ | $2200 / R2$ [k Ω] |
| $2.1 < V_{SET} \leq 4.0$ | $319.6 / R2$ [k Ω] |
| $4.0 < V_{SET} \leq 5.5$ | $108.9 / R2$ [k Ω] |

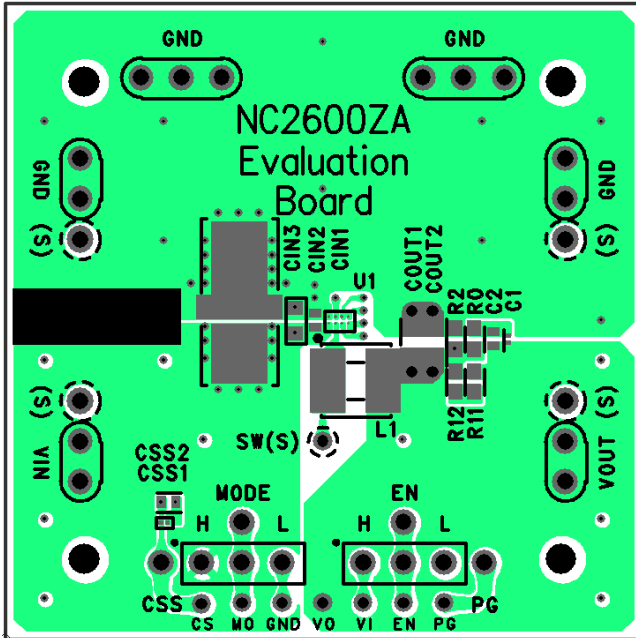
R0 prevents against the effects of noise. Noise varies depending on the board layout. R0 is not required for optimized boards, but if you are concerned about spikes, use about 1 k Ω .

Cautions for Selecting External Components

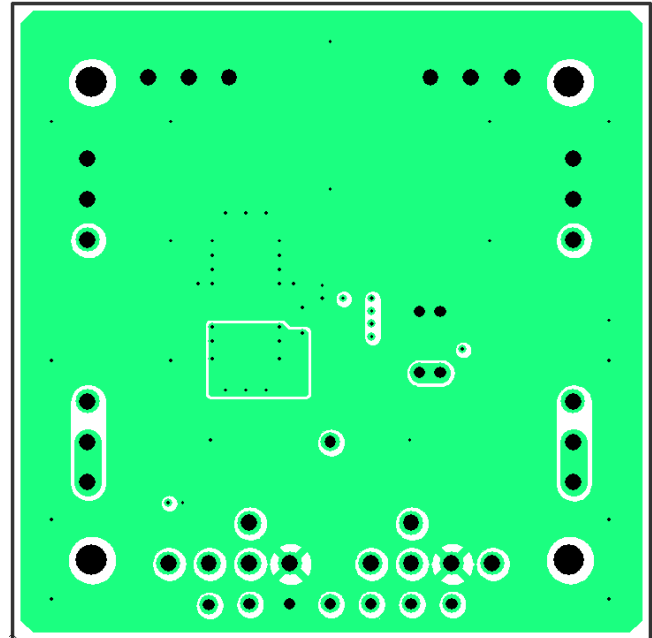
- Choose a low ESR ceramic capacitor. The input capacitor (C_{IN}) between VIN and GND should be more than 4.7 μ F, and the output capacitor (C_{OUT}) should be used of 10 μ F. Also, choose the capacitor with consideration for bias characteristics and input/output voltages.
Even when using a capacitor other than a ceramic capacitor such as aluminum electrolytic, connect a ceramic capacitor with shortest-distance wiring.
- The phase compensation of this device is designed according to the C_{OUT} and L values. The inductance value of an inductor should be 1.0 μ H to gain stability.
- Choose an inductor that has small DC resistance, has enough permissible current and is hard to cause magnetic saturation. If the inductance value of the inductor becomes extremely small under the load conditions, the peak current of inductor may increase along with the load current. As a result, the current limit circuit may start to operate before the peak current of inductor reaches to load current range. Therefore, choose an inductor with consideration for the value of I_{SWMAX} .
Refer to the data sheet "Calculation Conditions of SW Pin Maximum Output Current (I_{SWMAX})".

Evaluation Board / PCB Layout
NC2600ZA [WLCSP-8-P11]

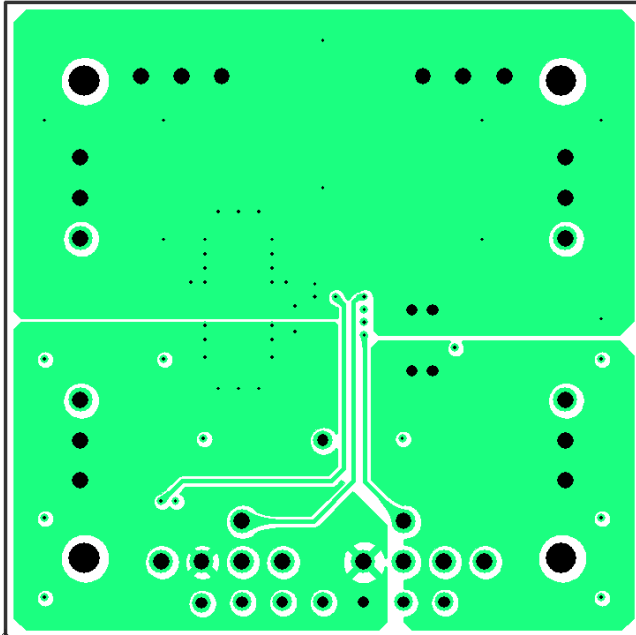
Layer 1



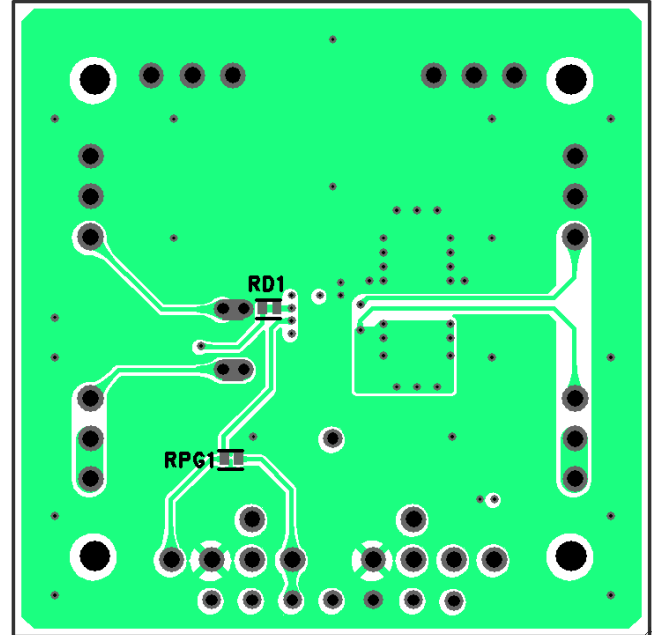
Layer 2



Layer 3

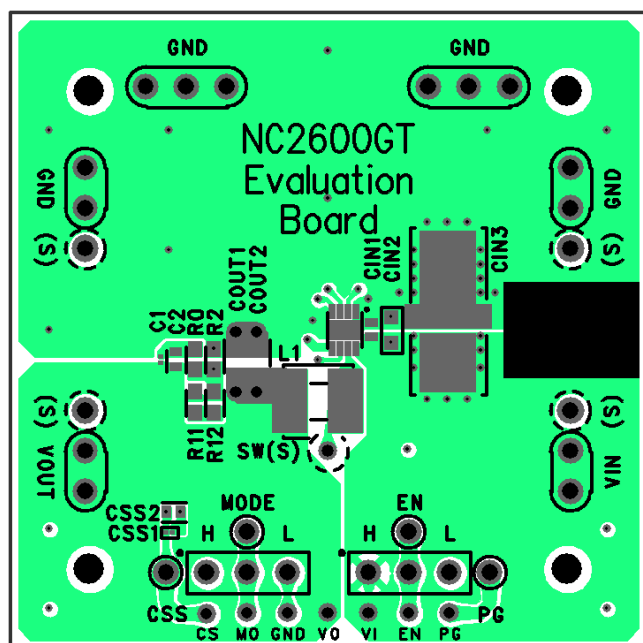


Layer 4

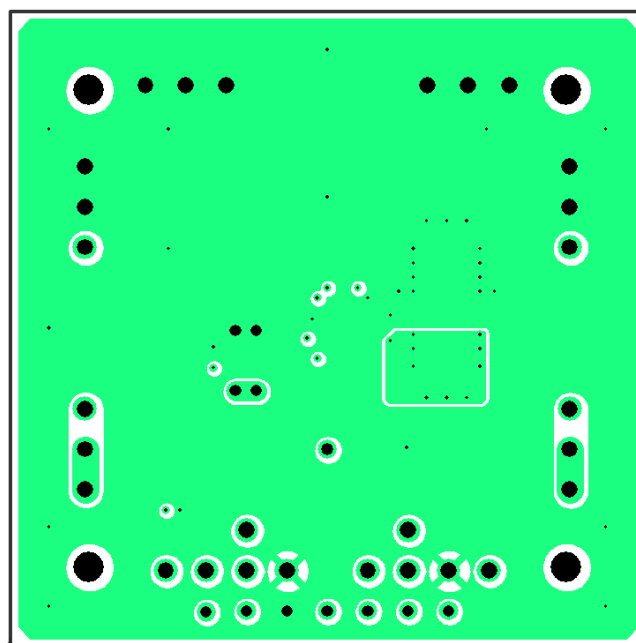


NC2600GT [DFN2020-8-GT]

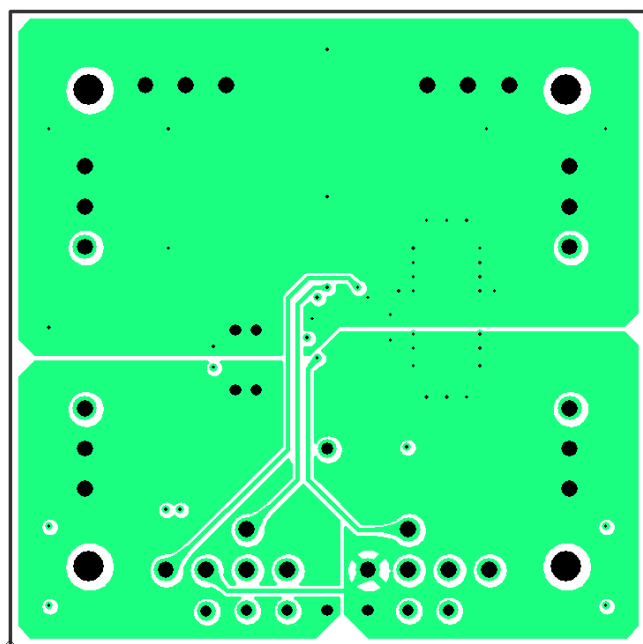
Layer 1



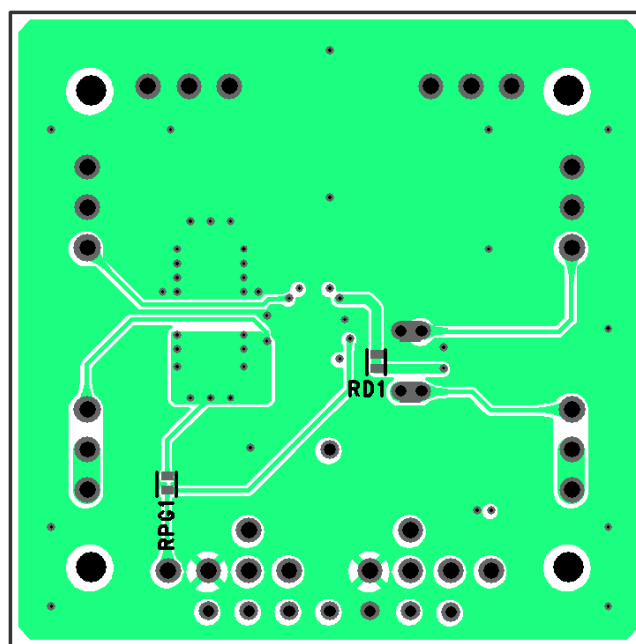
Layer 2



Layer 3



Layer 4



TECHNICAL NOTES

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

- External components must be connected as close as possible to the ICs and make wiring as short as possible and on the same side of the IC. Especially, the capacitor connected in between VIN pin and GND pin must be wiring the shortest.
- The VIN line, the GND line, and SW pin should make special considerations for the large switching current flows. If their impedance is high, internal voltage of the IC may shift by the switching current, and the operating may be unstable. Make the power supply and GND lines as wide and short as possible. The wiring from the SW pin to the inductor becomes a noise source, so ensure that the current capacity is secured and that the wiring is not wider or longer than necessary so that the noise does not increase.
- Connect C_{OUT} to the wiring between the FB pin and the inductor(L), or between the output voltage setting resistor (R1) and L. Also, keep them as far away as possible from noise sources such as inductors to prevent noise from being mixed in.
- The thermal shutdown function prevents the IC from fuming and ignition but does not ensure the IC's reliability or keep the IC below the absolute maximum ratings. The thermal shutdown function does not operate on the heat generated by other than the normal IC operation such as latch-up and overvoltage application. The thermal shutdown function operates in a state over the absolute maximum ratings, therefore the thermal shutdown function should not be used for a system design.
- The tab on the bottom side of the DFN-Package is recommended to be connected to GND. It will work even if it is open, but please note that the heat dissipation and mounting strength will decrease.

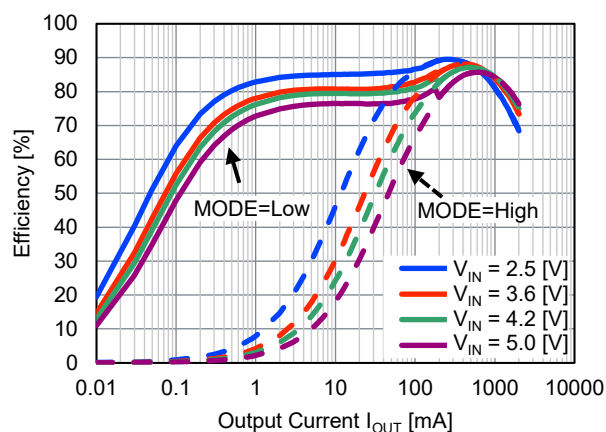
TYPICAL CHARACTERISTICS

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

1) Efficiency vs Output Current

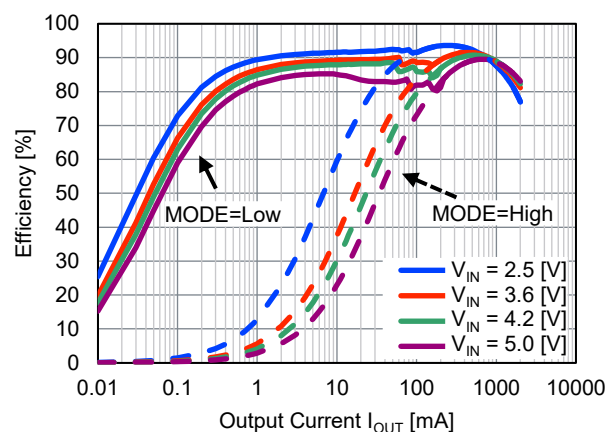
NC2600ZA

$V_{OUT} = 1.2 [V]$



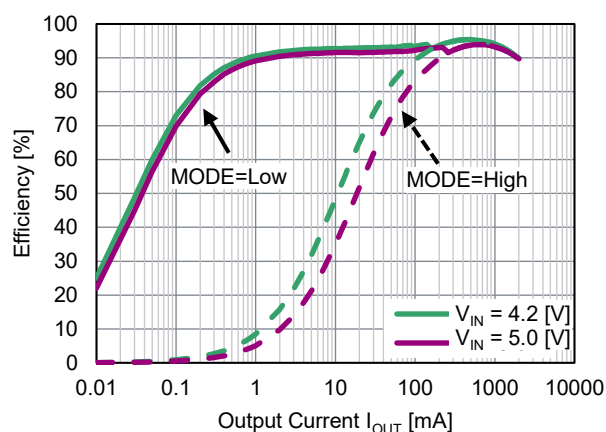
NC2600ZA

$V_{OUT} = 1.8 [V]$



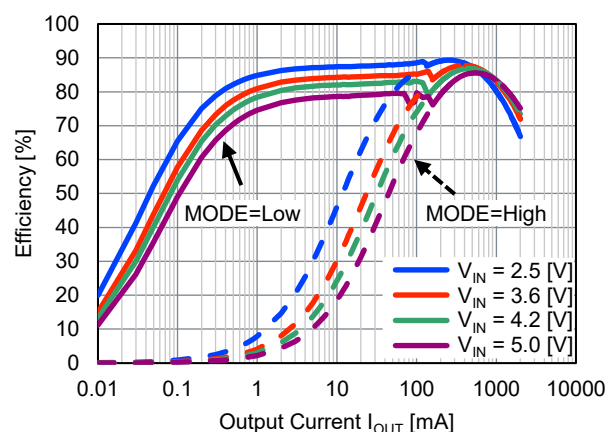
NC2600ZA

$V_{OUT} = 3.3 [V]$



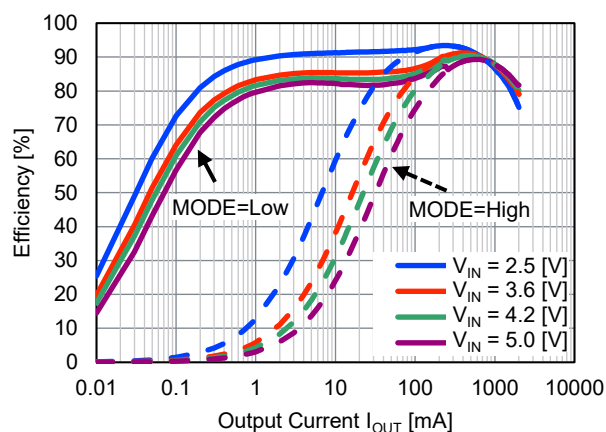
NC2600GT

$V_{OUT} = 1.2 [V]$



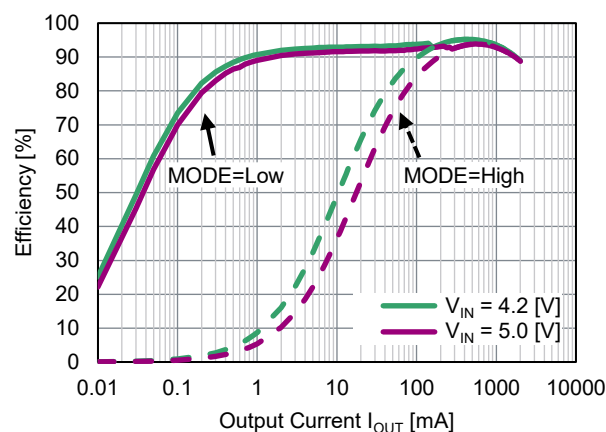
NC2600GT

$V_{OUT} = 1.8 [V]$



NC2600GT

$V_{OUT} = 3.3 [V]$

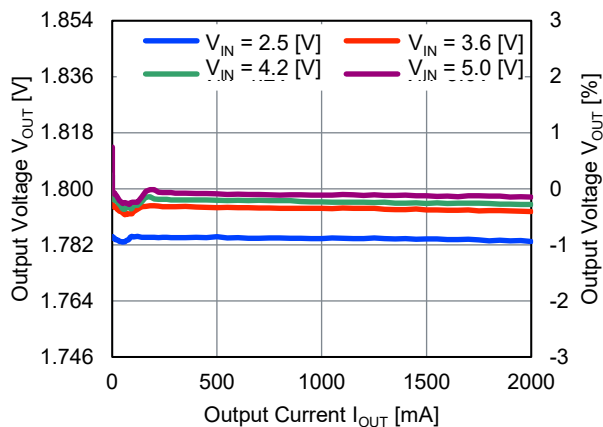


2) Output Voltage vs Output Current

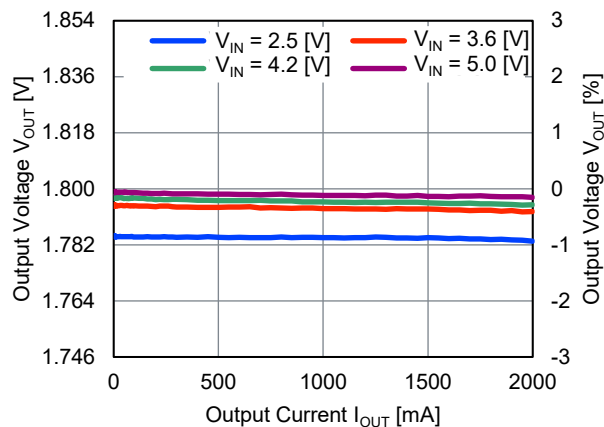
NC2600ZA

$V_{OUT} = 1.8$ [V]

MODE = Low



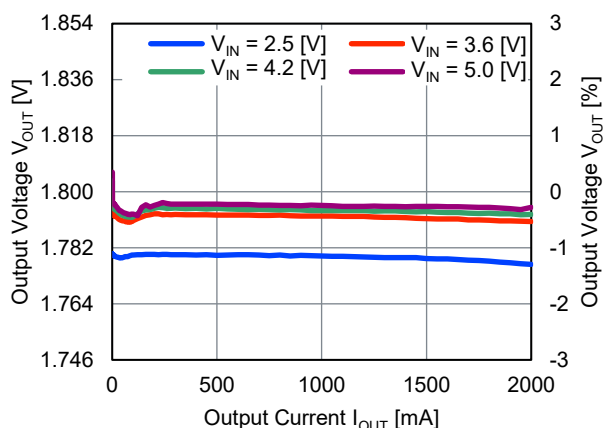
MODE = High



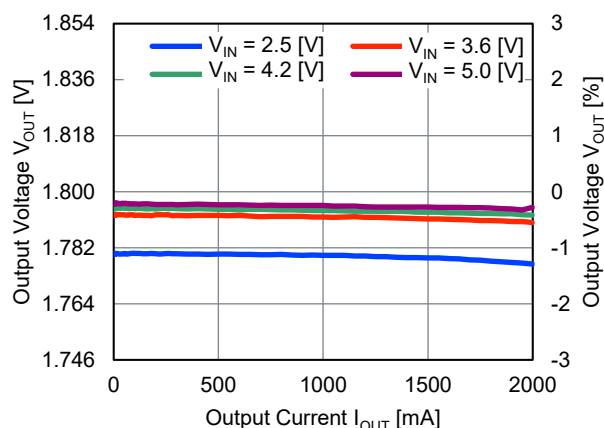
NC2600GT

$V_{OUT} = 1.8$ [V]

MODE = Low



MODE = High

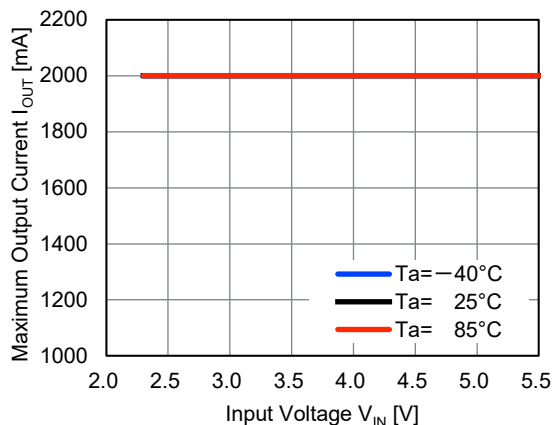


3) Maximum Output Current vs V_{IN}

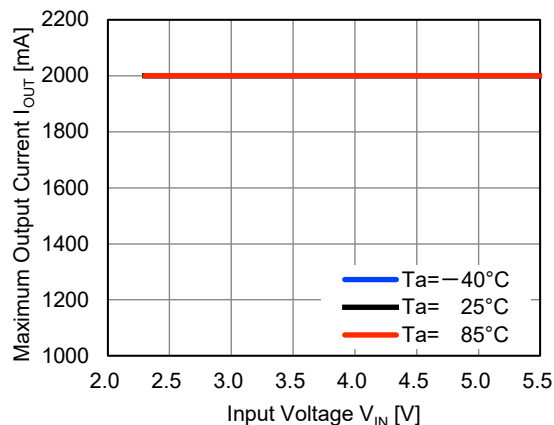
MODE = High

NC2600ZA

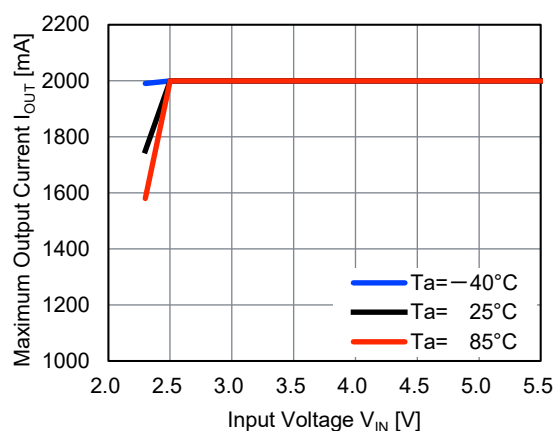
$V_{OUT} = 0.6$ [V]



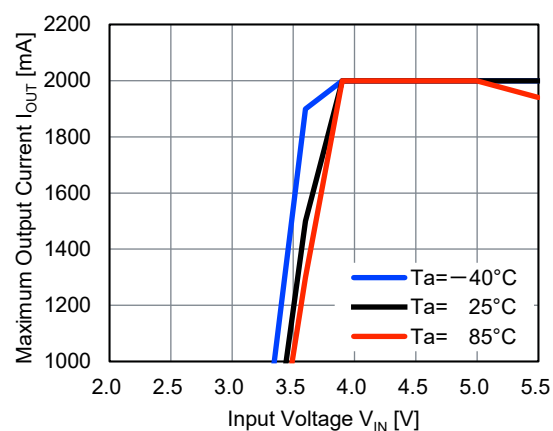
$V_{OUT} = 1.2$ [V]



$V_{OUT} = 1.8 [V]$

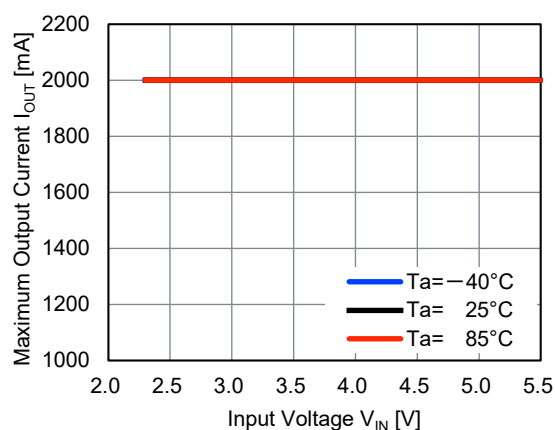


$V_{OUT} = 3.3 [V]$

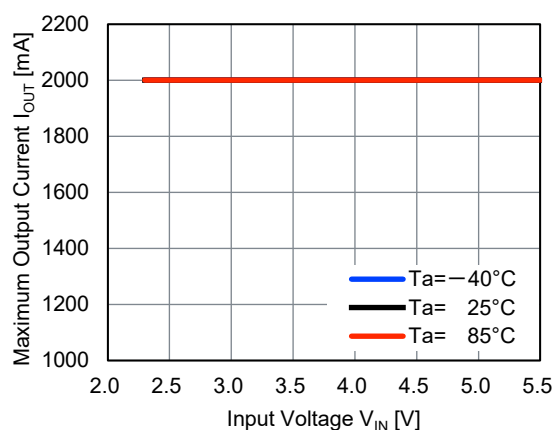


NC2600GT

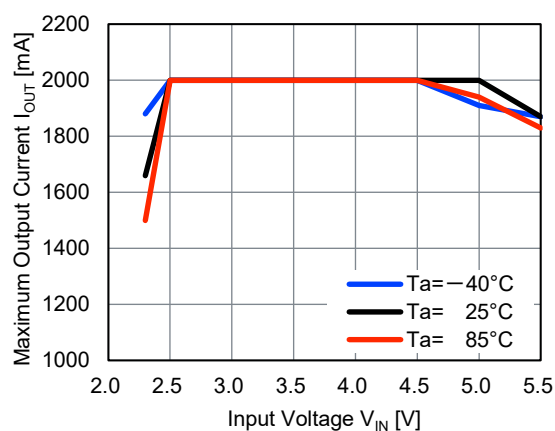
$V_{OUT} = 0.6 [V]$



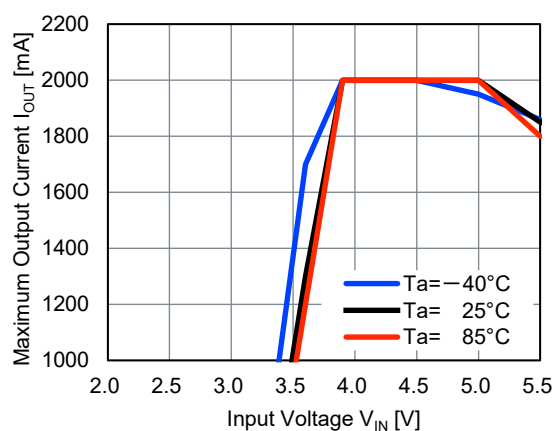
$V_{OUT} = 1.2 [V]$



$V_{OUT} = 1.8 [V]$

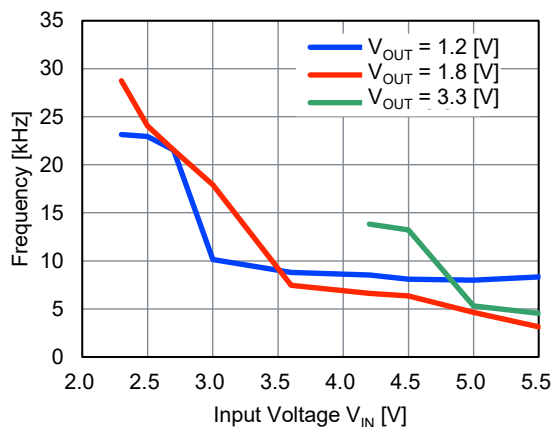


$V_{OUT} = 3.3 [V]$

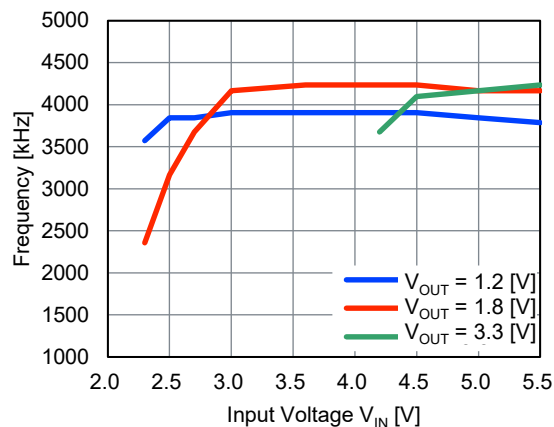


4) Switching Frequency vs Input Voltage

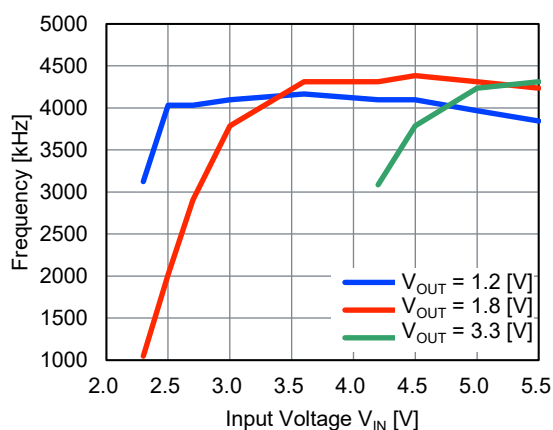
$I_{OUT} = 1 \text{ [mA]}$
MODE = Low



$I_{OUT} = 1 \text{ [mA]}$
MODE = High



$I_{OUT} = 1000 \text{ [mA]}$
MODE = Low

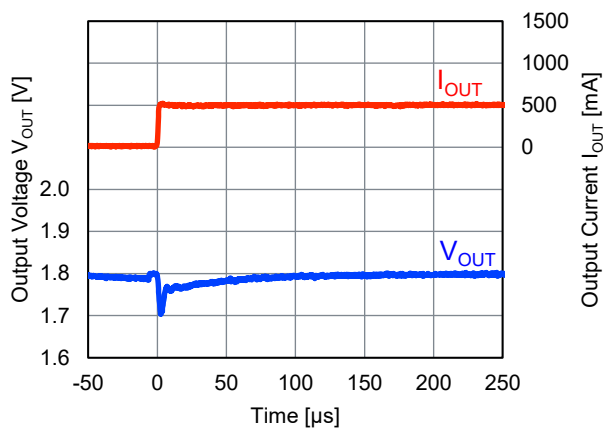


5) Load Transient Response

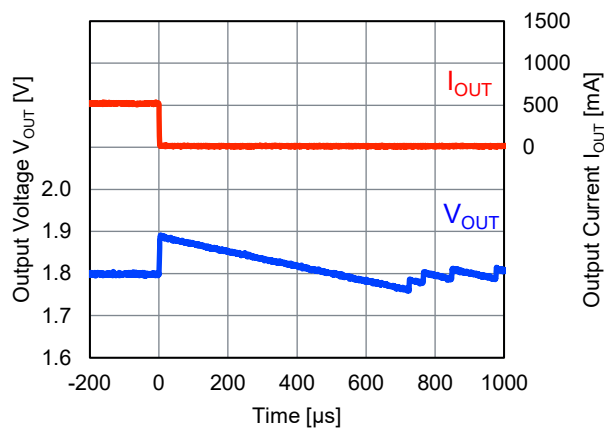
$V_{IN} = V_{EN} = 3.6 \text{ [V]}$, $V_{OUT} = 1.8 \text{ [V]}$

MODE = Low

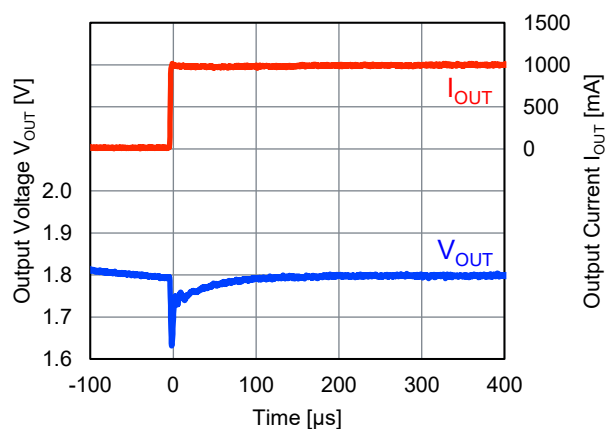
$I_{OUT} = 1 \text{ [mA]} \rightarrow 500 \text{ [mA]}$



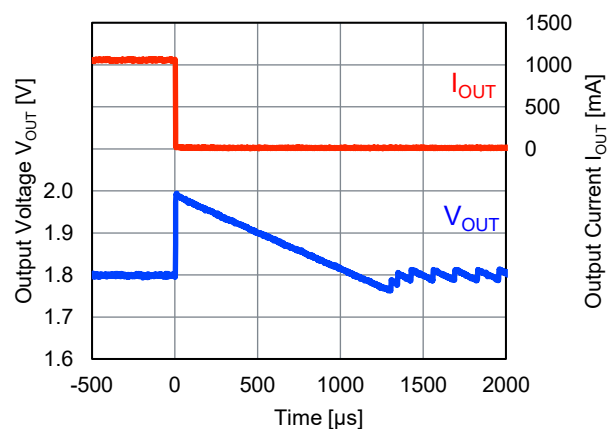
$I_{OUT} = 500 \text{ [mA]} \rightarrow 1 \text{ [mA]}$



$I_{OUT} = 1 \text{ [mA]} \rightarrow 1000 \text{ [mA]}$

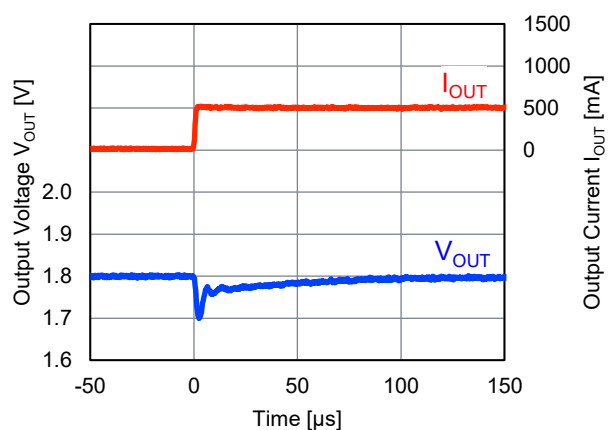


$I_{OUT} = 1000 \text{ [mA]} \rightarrow 1 \text{ [mA]}$

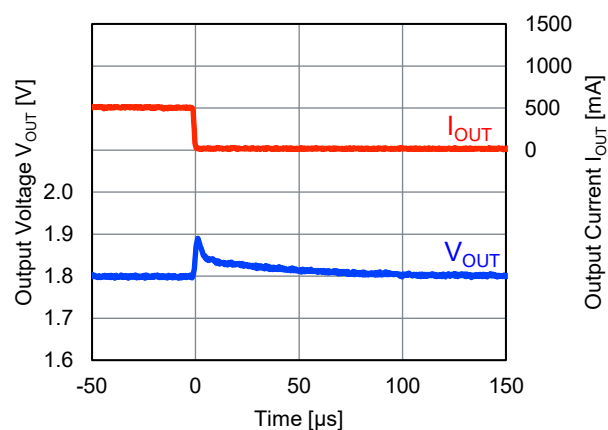


MODE = High

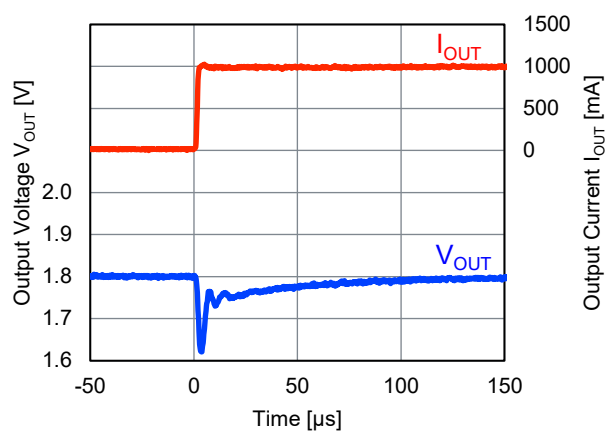
$I_{OUT} = 1 \text{ [mA]} \rightarrow 500 \text{ [mA]}$



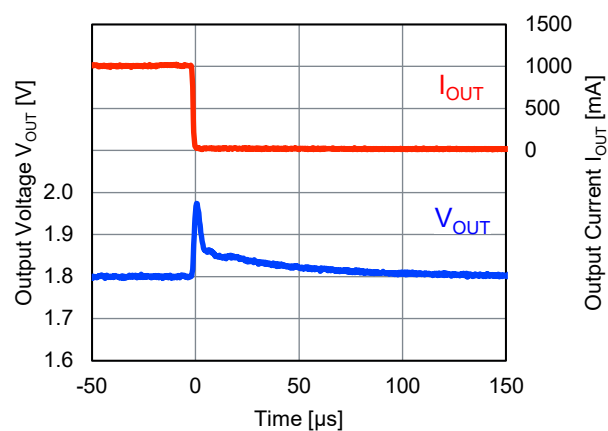
$I_{OUT} = 500 \text{ [mA]} \rightarrow 1 \text{ [mA]}$



$I_{OUT} = 1 \text{ [mA]} \rightarrow 1000 \text{ [mA]}$



$I_{OUT} = 1000 \text{ [mA]} \rightarrow 1 \text{ [mA]}$

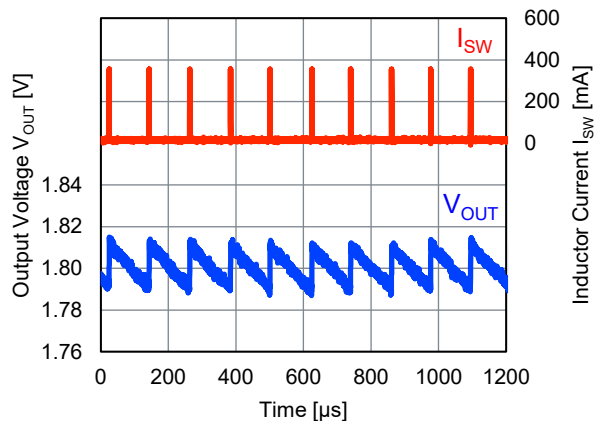


6)Output Voltage Waveform

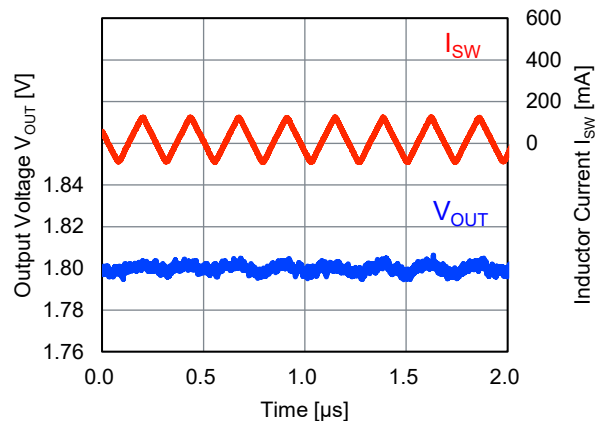
$V_{IN} = V_{EN} = 3.6 [V]$, $V_{OUT} = 1.8 [V]$

$I_{OUT} = 1 [mA]$

MODE = Low

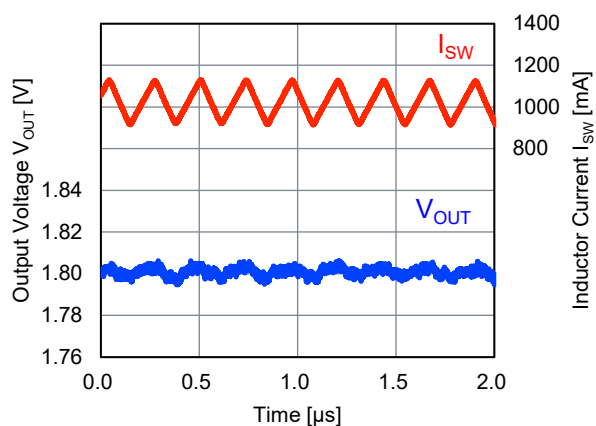


MODE = High

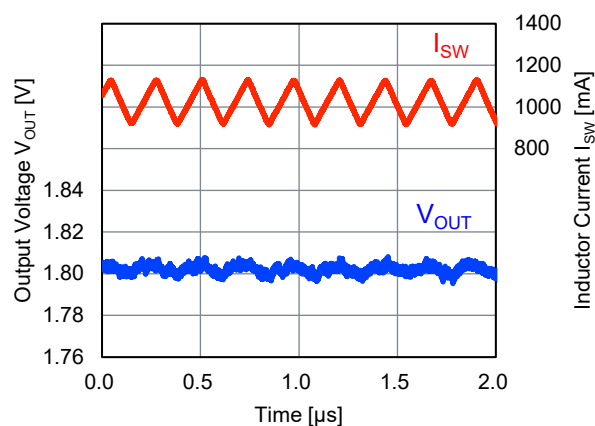


$I_{OUT} = 1000 [mA]$

MODE = Low



MODE = High

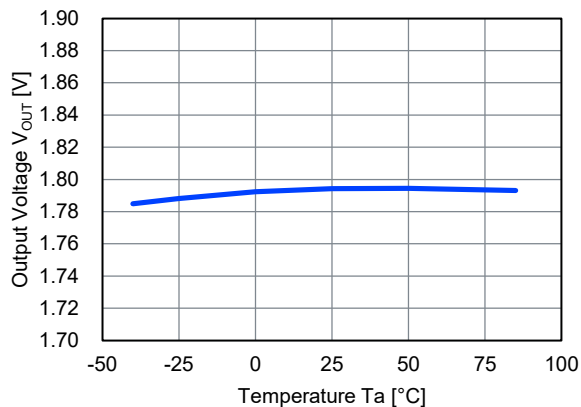


7)Output Voltage vs Temperature

$V_{IN} = V_{EN} = 3.6 [V]$, $V_{OUT} = 1.8 [V]$

$I_{OUT} = 0 [mA]$

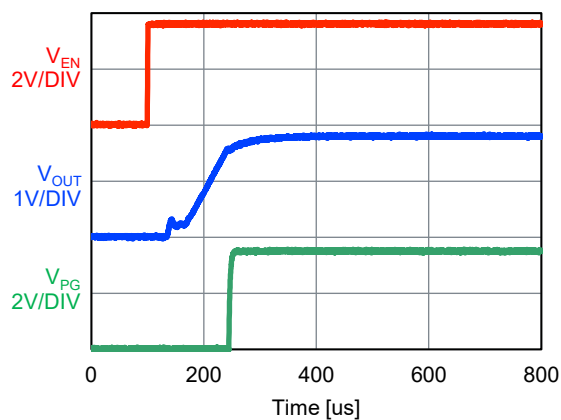
MODE = High



8) Soft-Start Waveform

$V_{OUT} = 1.8$ [V], MODE = High, $C_{SS} = \text{open}$, $I_{OUT} = 0$ [mA]

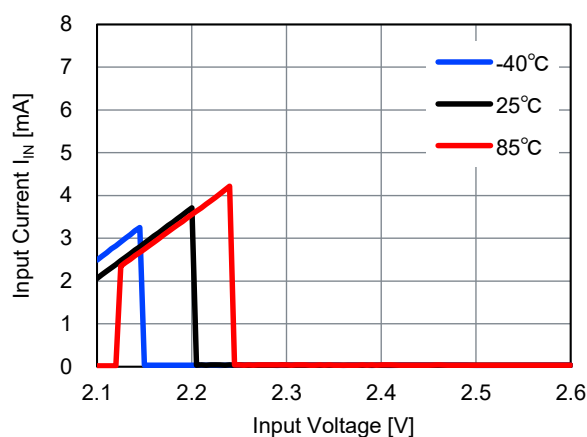
$V_{IN} = 3.6$ [V], $V_{EN} = 0 \rightarrow 3.6$ [V]



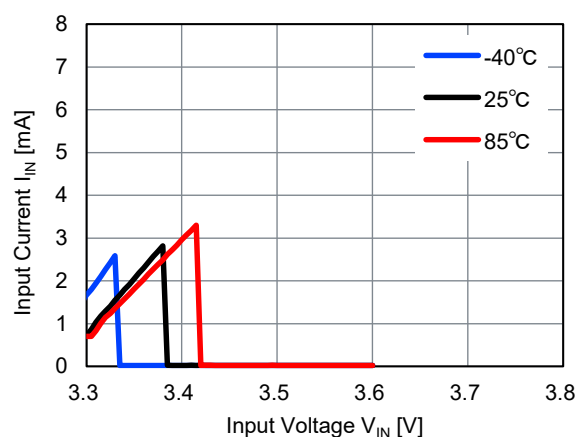
9) Input Current vs Input Voltage

MODE = Low

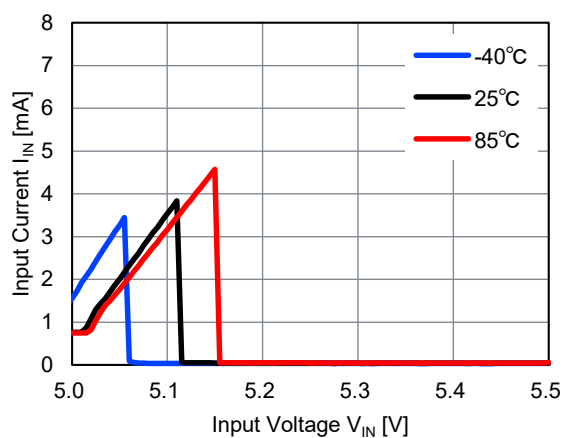
$V_{OUT} = 2.1$ [V]



$V_{OUT} = 3.3$ [V]

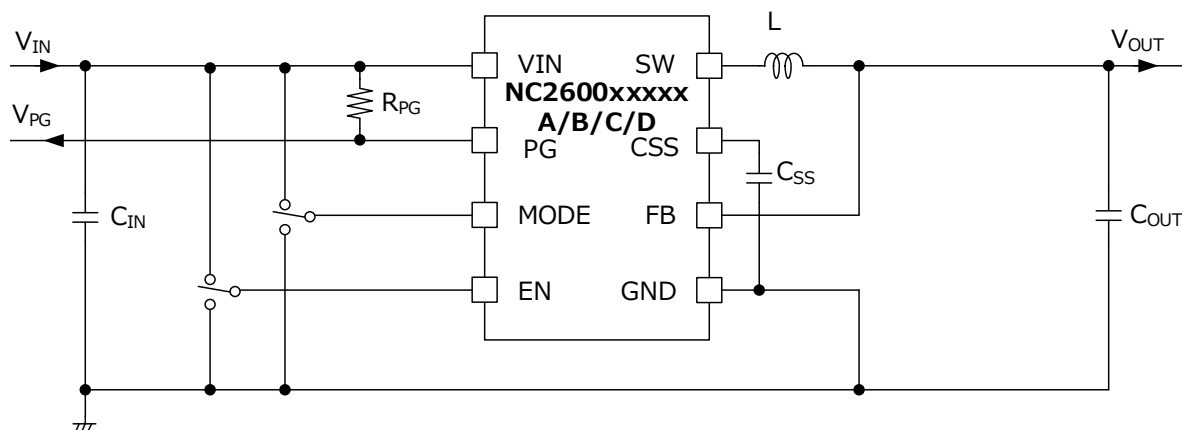


$V_{OUT} = 5.0$ [V]



*Note that if the voltage difference between V_{IN} and V_{OUT} decreases, switching current increases regardless of I_{OUT} .

TEST CIRCUIT



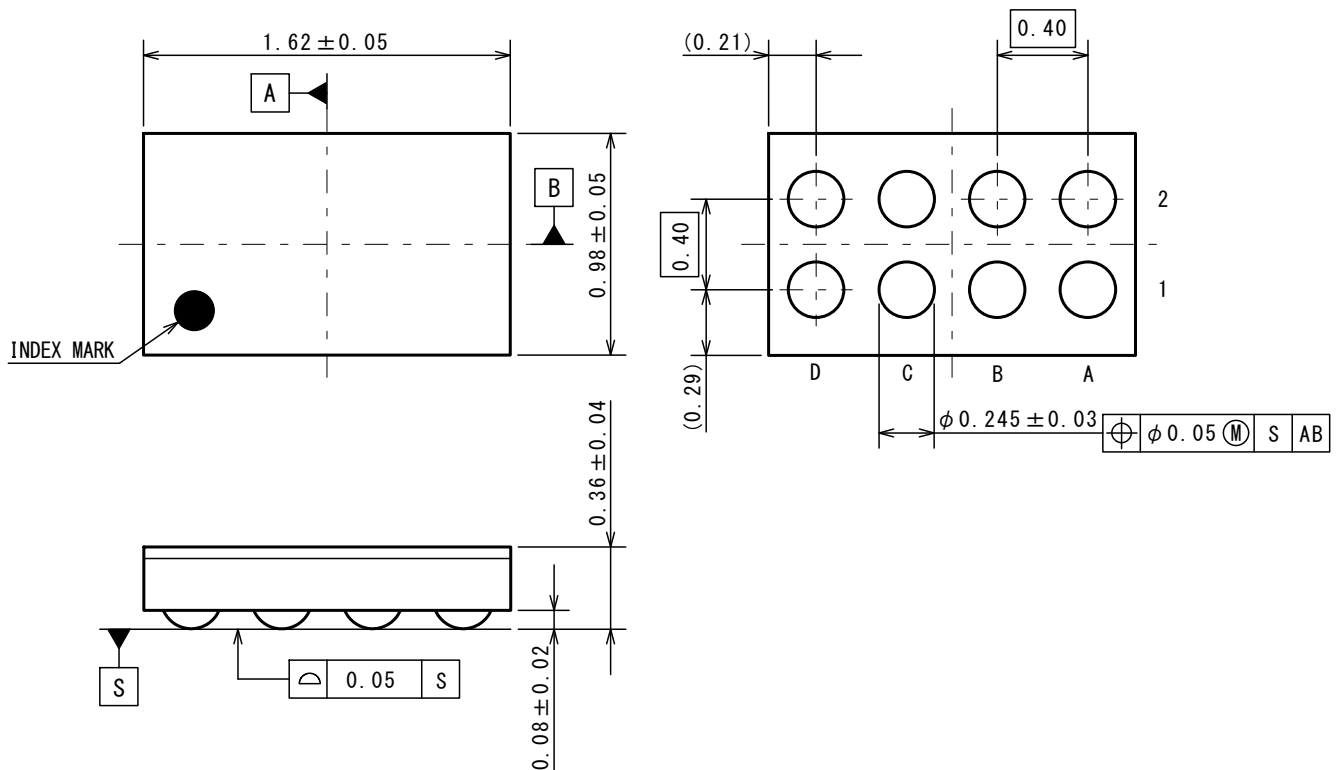
NC2600xxxxx (Fixed Output Voltage Type) Test Circuit

【Components List for Our Evaluation】

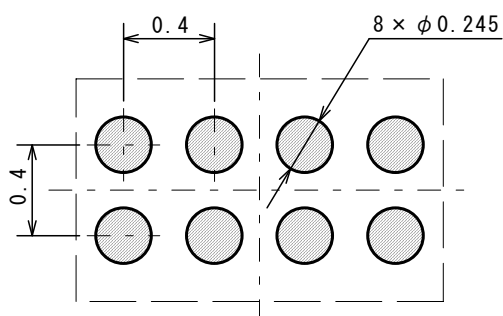
| Symbol | Specification | Parts Number |
|------------------|---------------|----------------------|
| C _{IN} | 4.7 μ F | GRM035R60J475ME |
| C _{OUT} | 10 μ F | GRM155R60J106ME44 |
| L | 1.0 μ H | TFM201610ALM-1R0MTAA |

■ PACKAGE DIMENSIONS

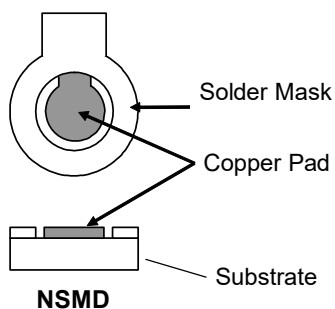
UNIT: mm



■ EXAMPLE OF SOLDER PADS DIMENSIONS



Recommended Land Pattern



| NSMD Pad Definition | | |
|-----------------------------------|------------|---------------------|
| Pad definition | Copper Pad | Solder Mask Opening |
| NSMD (Non-Solder Mask defined) | 0.245mm | MIN. 0.345mm |

*) Pad Layout and size can modify by customers material, equipment and method.

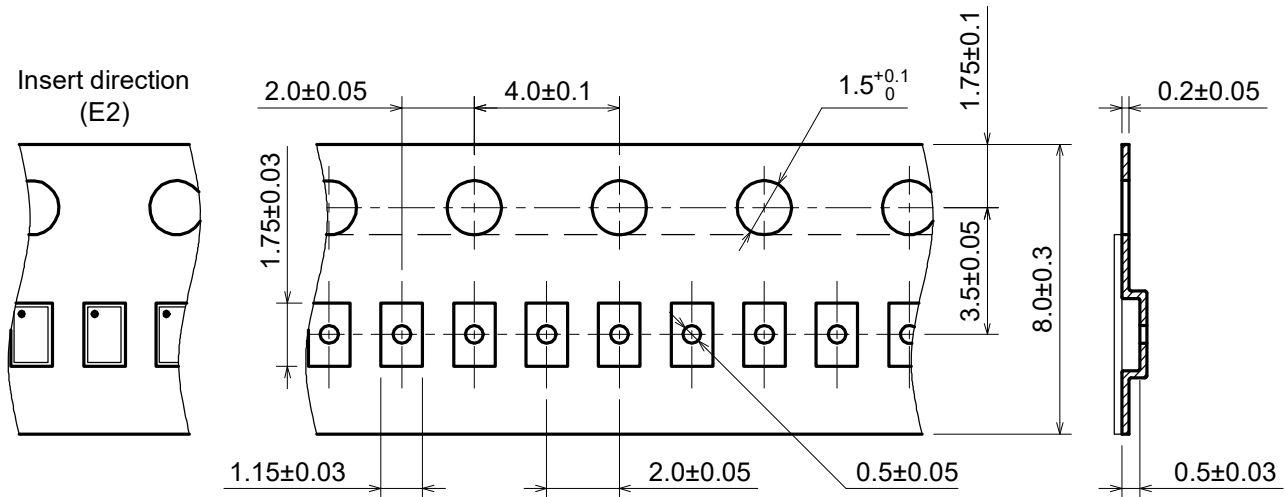
*) Please adjust pad layout according to your conditions.

*) Recommended Stencil Aperture Size: $\phi 0.245$ mm

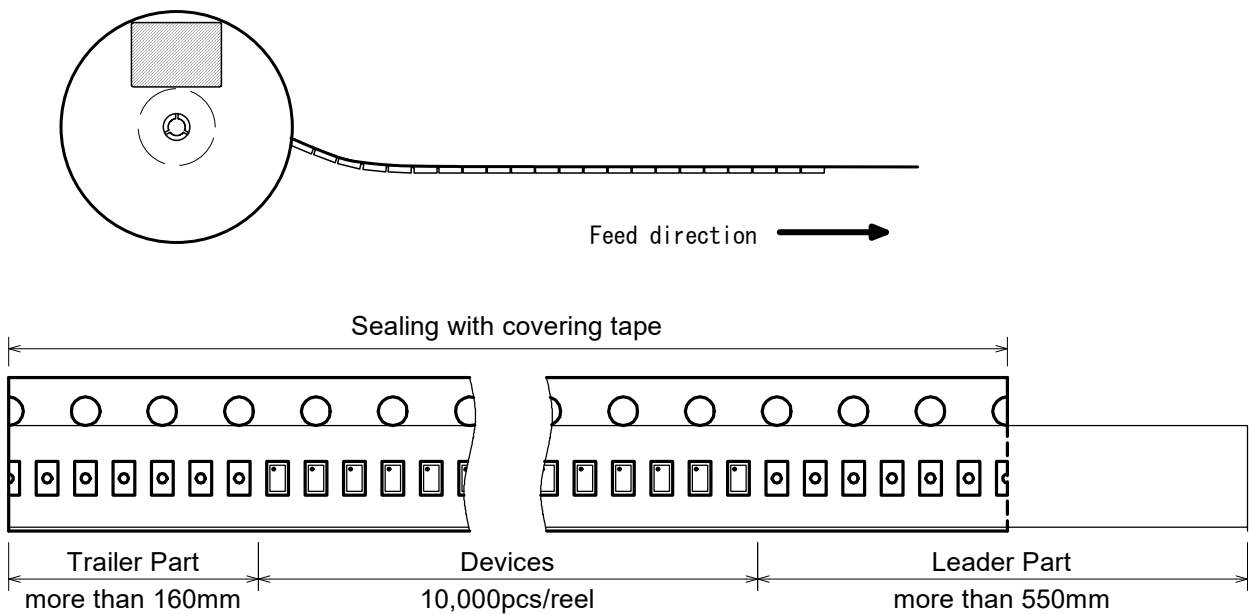
■ PACKING SPEC

UNIT: mm

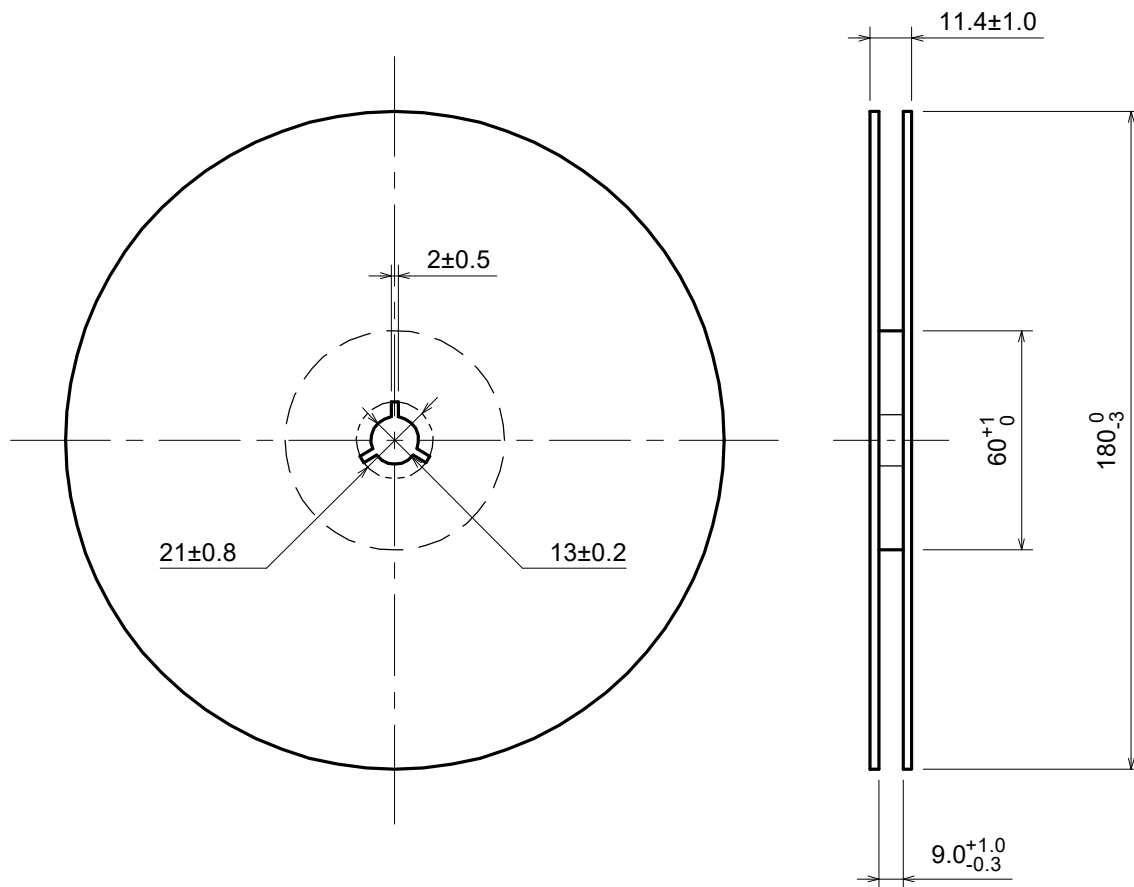
(1) Taping dimensions / Insert direction



(2) Taping state



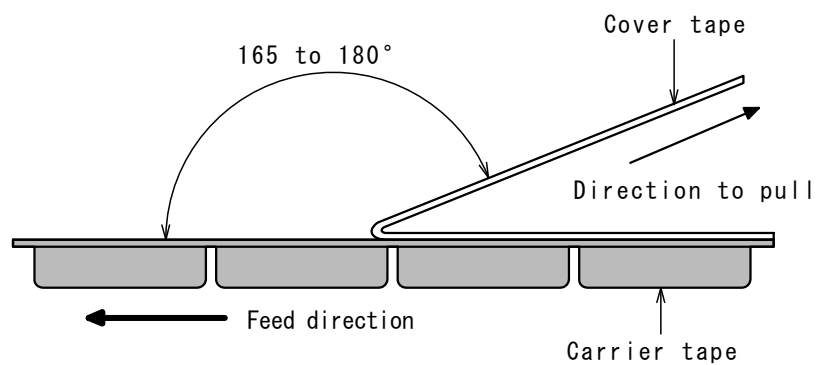
(3) Reel dimensions



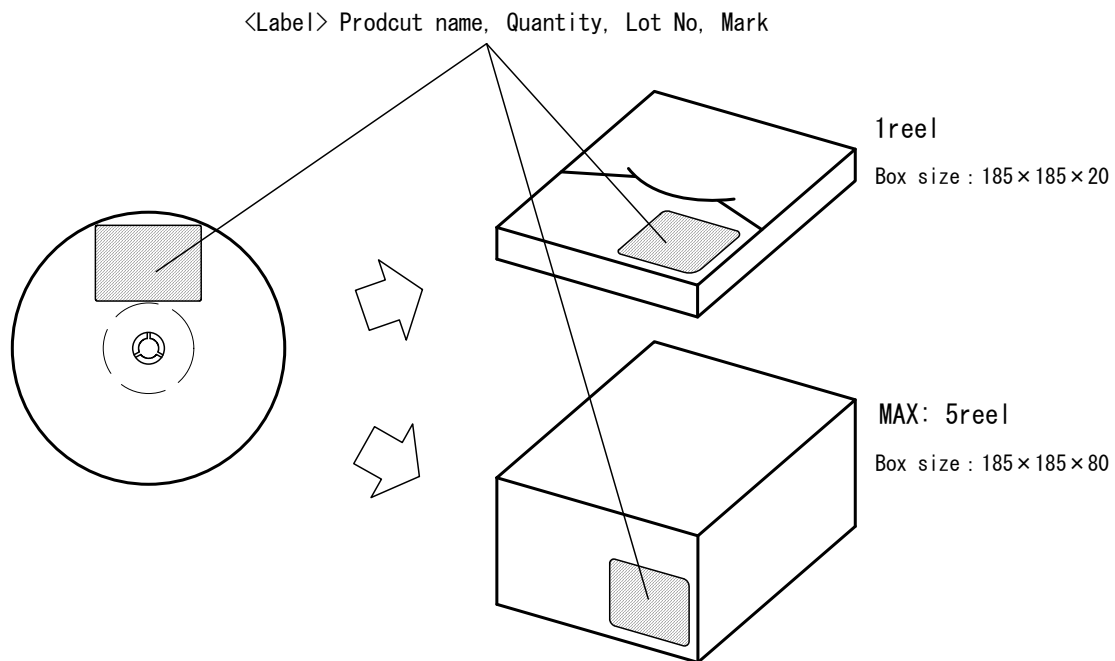
(4) Peeling strength

Peeling strength of cover tape

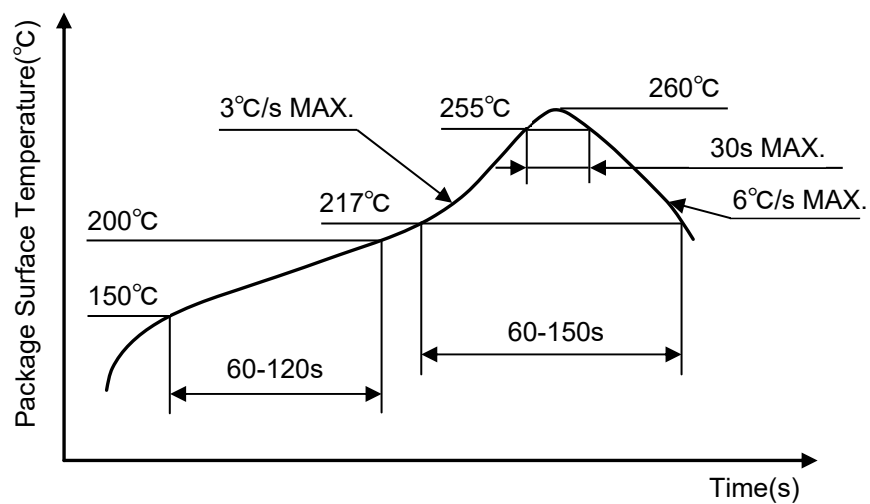
- Peeling angle: 165 to 180° degrees to the taped surface.
- Peeling speed: 300mm/min
- Peeling strength: 0.1 to 1.0N



(5) Packing state



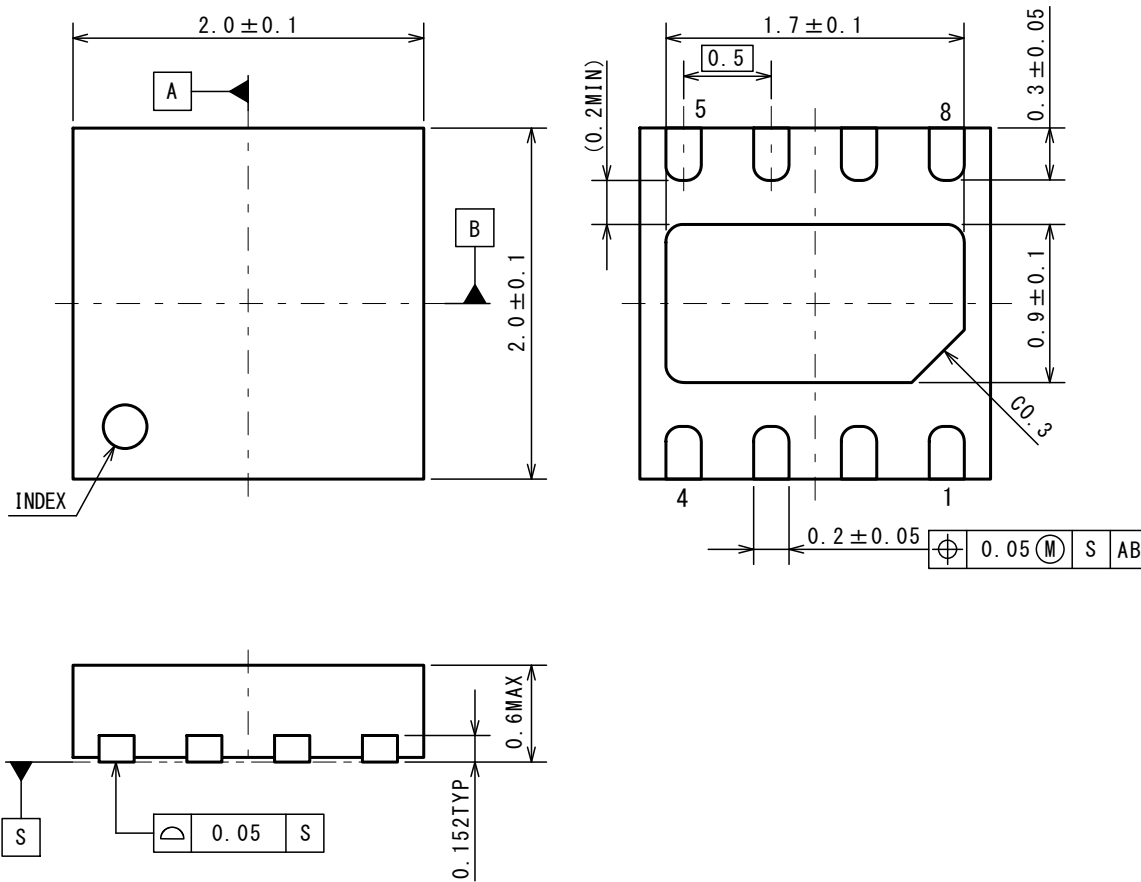
■ HEAT-RESISTANCE PROFILES



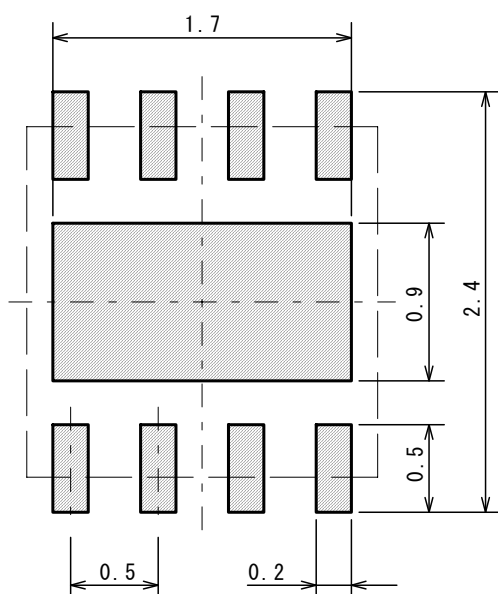
Reflow profile

■ PACKAGE DIMENSIONS

UNIT: mm



■ EXAMPLE OF SOLDER PADS DIMENSIONS



Nisshinbo Micro Devices Inc.

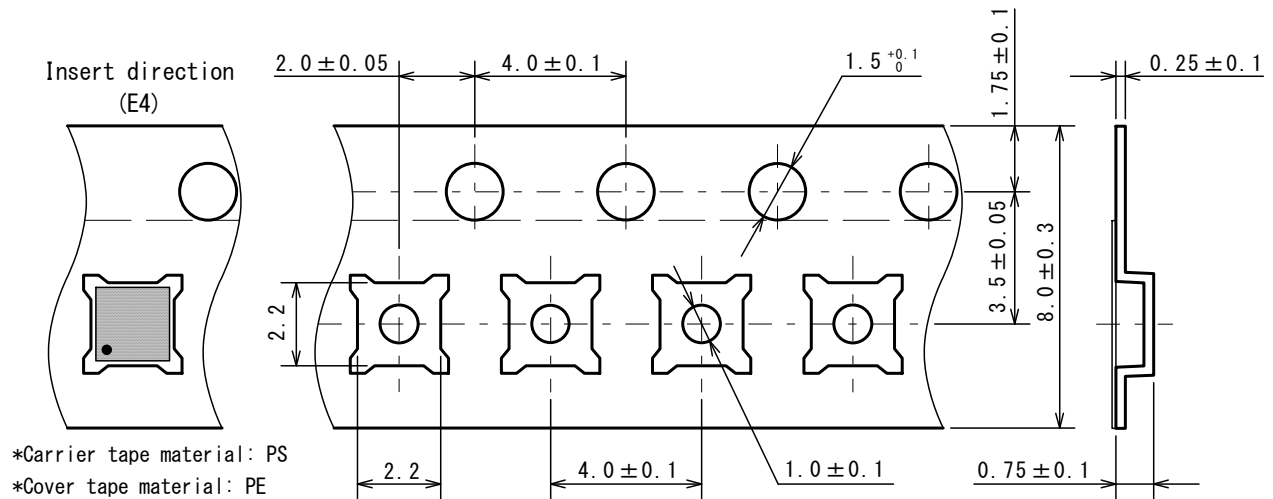
DFN2020-8-GT

PI-DFN2020-8-GT-E-A

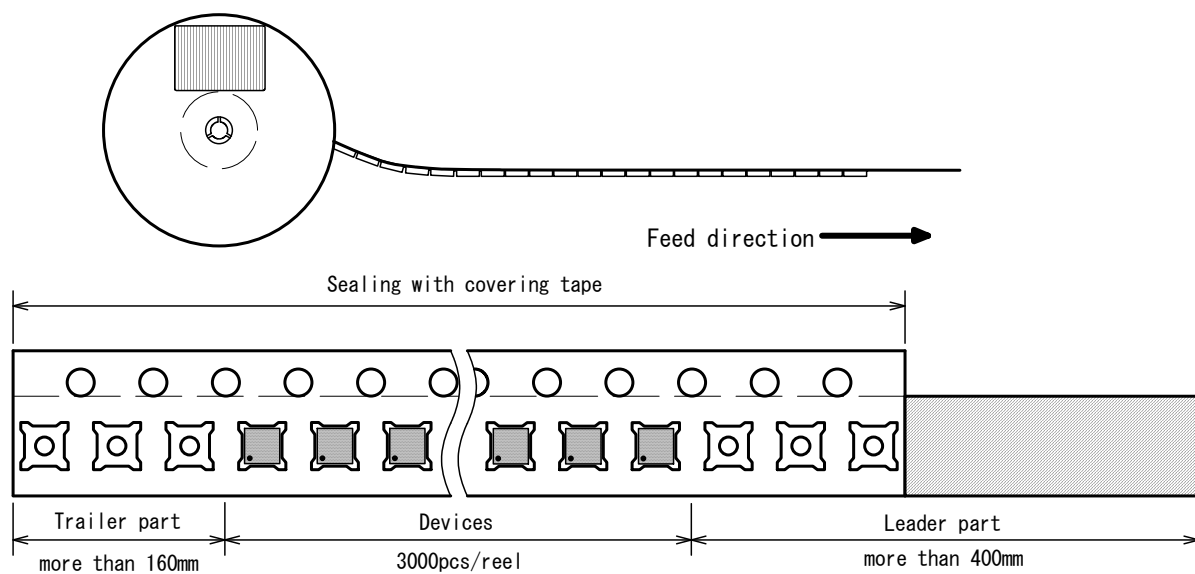
■ PACKING SPEC

UNIT: mm

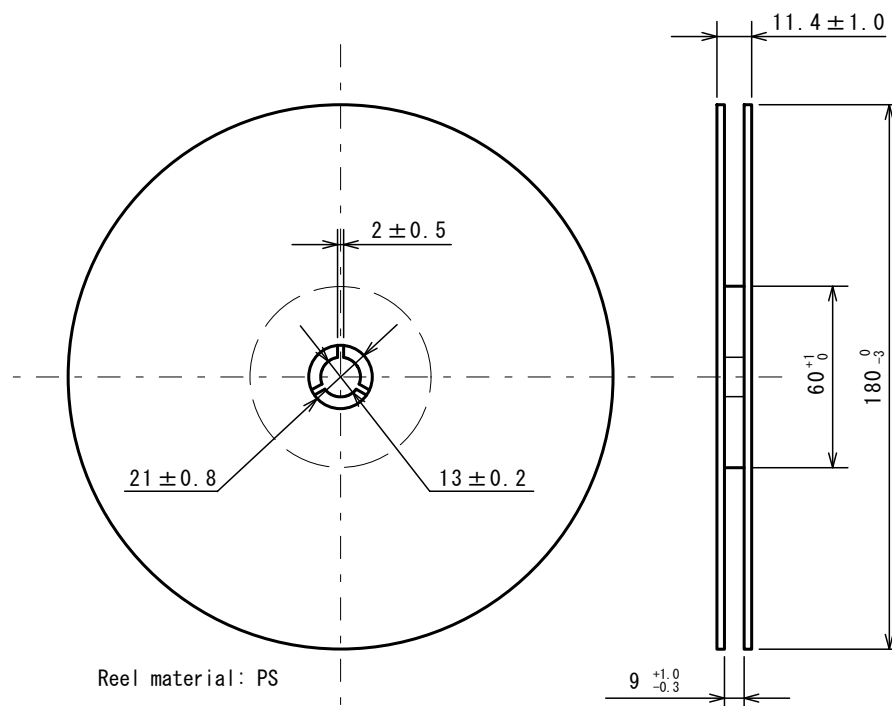
(1) Taping dimensions / Insert direction



(2) Taping state



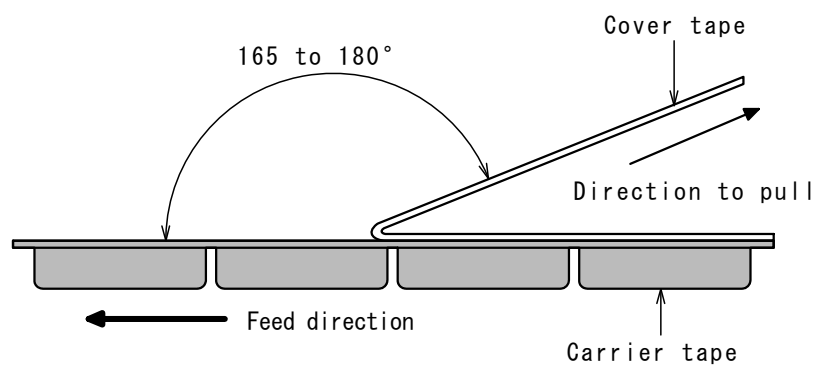
(3) Reel dimensions



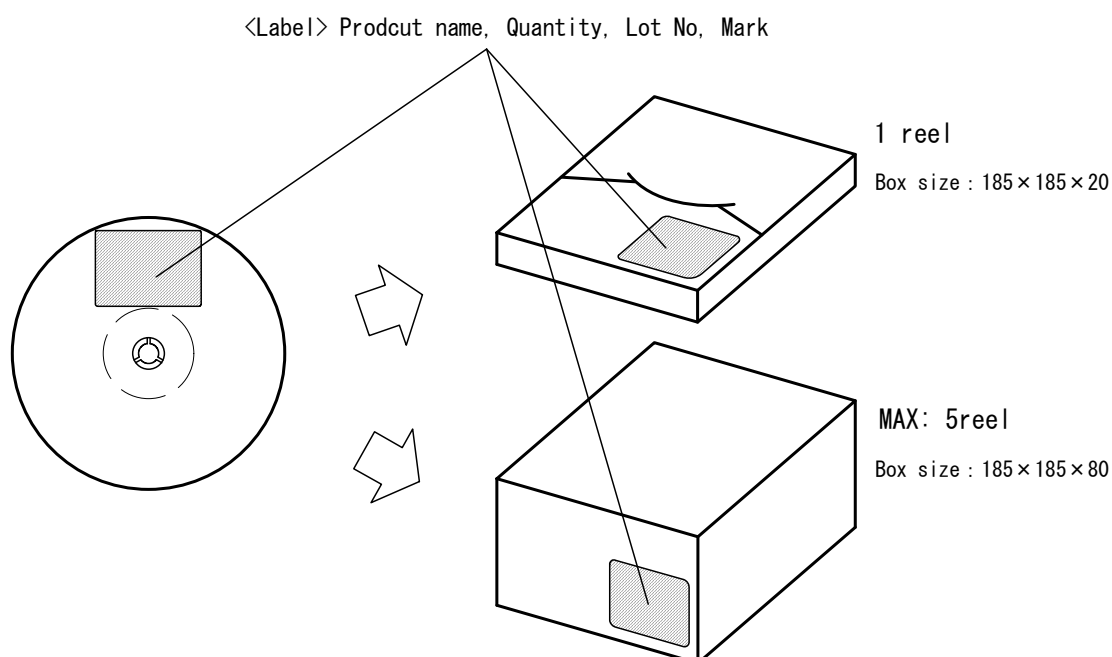
(4) Peeling strength

Peeling strength of cover tape

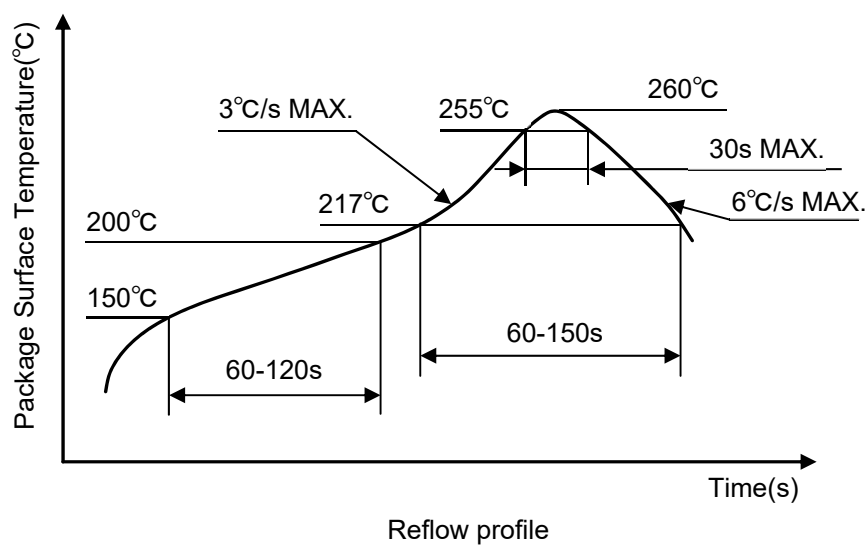
- Peeling angle: 165 to 180° degrees to the taped surface.
- Peeling speed: 300mm/min
- Peeling strength: 0.1 to 1.0N



(5) Packing state



■ HEAT-RESISTANCE PROFILES



Revision History

| Date | Version | Contents of Changes |
|-------------------|---------|--|
| August 26, 2022 | 1.0 | Initial release |
| October 18, 2022 | 1.1 | <ul style="list-style-type: none"> Corrected the size thickness of DFN2020-8-GT to 0.6 (mm). Added page for marking specification. |
| February 22, 2023 | 1.2 | <ul style="list-style-type: none"> In NC2600GT lineup added. In NC2600ZA, the mark specification was corrected (addition of NC2600ZA100B, correction of mark numbering) and the format was changed. |
| March 24, 2023 | 1.3 | <ul style="list-style-type: none"> In NC2600GT lineup added. In NC2600ZA, the mark specification was corrected (addition of NC2600ZA100B, correction of mark numbering) and the format was changed. |
| June 18, 2024 | 1.4 | <ul style="list-style-type: none"> In theory of operation section, Added the note about the SW pin voltage condition, when activating the NC2600 with the latch protection function by the enable function. Quantity per reel: 5000 → 1000 THERMAL CHARACTERISTICS : Format was changed. (The specification is no change.) PACKAGE INFORMATION : PI-WLCSP-8-P11-J-C → PI- WLCSP-8-P11-J-D (Taping dimensions/Insert direction, Taping state was changed) |

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 - Combustion equipment

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