



Industrial NC2701MA

28V Synchronous Buck 10A Switching Regulator with Built-in Inductor/MOSFET

FEATURES

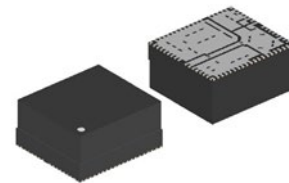
- Input Voltage (Maximum Rating): 4.0 V to 28 V (29 V)
- Operating Temperature Range: -40 °C to 85 °C
- Start-Up Voltage: 4.5 V
- Output Voltage: 0.7 V to 5.3 V
- Feedback Voltage Tolerance: $0.64 \text{ V} \pm 1 \%$
- Oscillation Frequency: 250 kHz to 1 MHz
- Minimum On-Time: Typ. 100 ns
- Minimum OFF-Time: Typ. 120 ns (at regulation mode)
At dropout, actual minimum off-time is reduced.
- Duty-Over: Min. 1/4
- Soft-Start
- Power-Good
- Thermal Shutdown
- Under Voltage Lockout (UVLO) Function:
VCC = 3.3 V (Typ.)
- Overvoltage Detection (OVD),
Undervoltage Detection (UVD)
- High-Side MOSFET ON-Resistance: 9.7mΩ
- Low-Side MOSFET ON-Resistance: 4.7mΩ

APPLICATIONS

- POL converter of FPGA
- Communication Base Stations, Network Servers
- Industrial Embedded Control Equipment, Medical Embedded Control Equipment

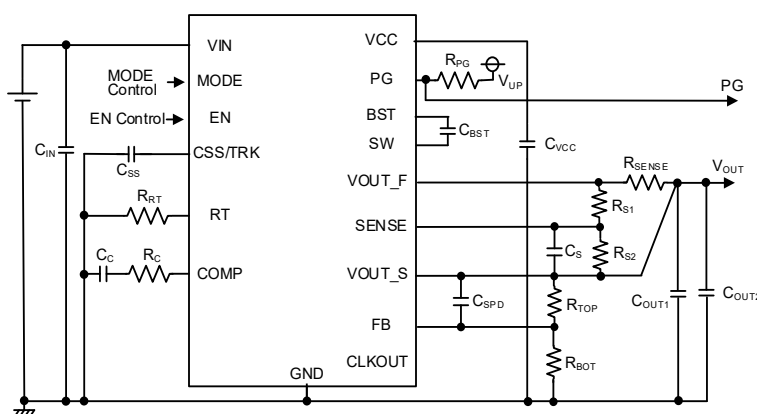
GENERAL DESCRIPTION

The NC2701MA is a 10 A synchronous step-down switching regulator module with a maximum input of 28 V that incorporates CMOS-based DC / DC controller IC, MOSFETs, and 1.0μH (DCR Typ. 4.6 mΩ) inductor. The space-saving power supply design is easy with the NC2701MA. Also, the switching frequency can be adjusted in the range from 250 kHz to 1 MHz by an external resistor. This product is a high-reliability device for industrial application, that has passed both the inspection at high temperature and the reliability test for considering industrial equipment.



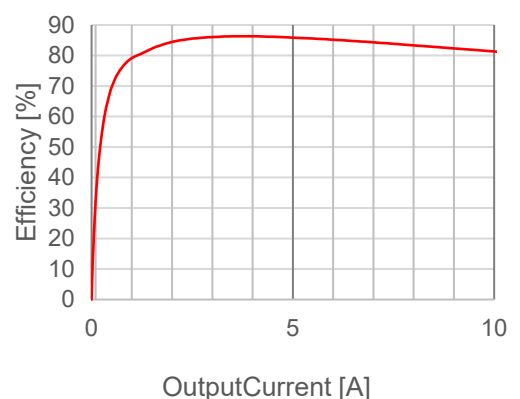
QFN0910-65-MA
10.0 x 9.0 x 4.8mm

TYPICAL APPLICATIONS



NC2701MA TYPICAL APPLICATIONS

EFFICIENCY TYPICAL CHARACTERISTICS



NC2701MA Efficiency Characteristics
V_{IN}=12V V_{OUT}=1V F_{osc}=400kHz

PRODUCT NAME INFORMATION

NC2701 aa bbb c dd e

Description of Configuration

Composition	Item	Description
aa	Package code	Indicates the package. Please refer to the ORDER INFORMATION. MA: MCM Type Module
bbb	Output Voltage	External Setting Type: 000 only
c	Version	Select the Overcurrent Protection type
dd	Packing	Taping direction. Refer to the packing specifications.
e	Grade	Indicates the quality grade. D: Industrial Equipment

Version

c	Overcurrent Protection
A	Non-Latch Type (Hiccup)
B	Latch Type

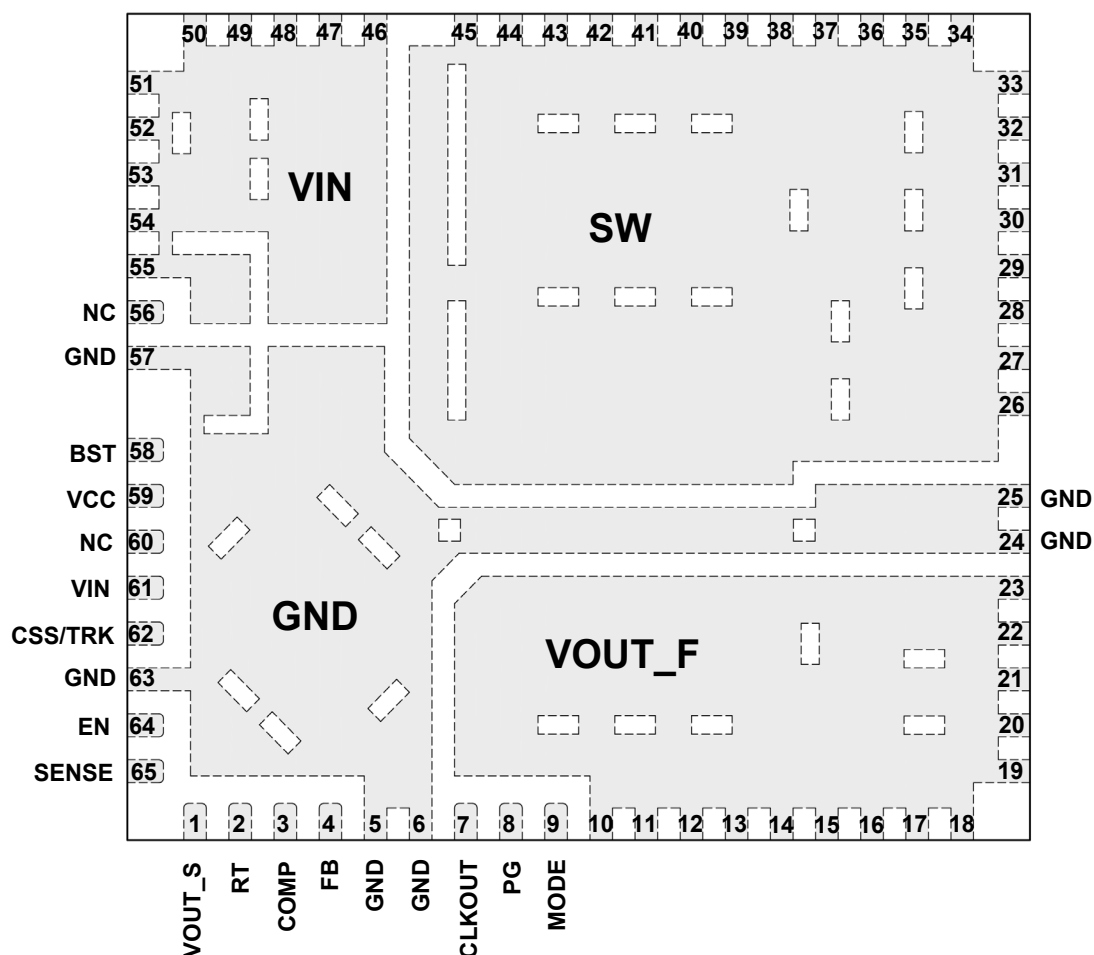
Grade

e	Applications	Operating Temperature Range	Test Temperature
D	Industrial Equipment and Social Infrastructures	-40°C to 85°C	25°C, 85°C

ORDER INFORMATION

PRODUCT NAME	PACKAGE	RoHS	HALOGEN-FREE	PLATING COMPOSITION	WEIGHT (mg)	QUANTITY (pcs/reel)
NC2701MA000AE2D	QFN0910-65-MA	Yes	Yes	Sn2Bi	1616	250
NC2701MA000BE2D	QFN0910-65-MA	Yes	Yes	Sn2Bi	1616	250

PIN DESCRIPTIONS



QFN0910-65-MA Pin Configuration

※This is a pin layout image diagram (Top view)

Pin Descriptions

Pin No.	Pin Name	I/O	Description
1	VOUT_S	I	Output Voltage Feedback Input Pin
2	RT	I	Oscillation Adjustment Pin Connecting a resistor to ground from this pin sets the switching frequency. Switching frequency range is from 250 kHz to 1 MHz.
3	COMP	I	A Phase Compensation network connected Pin. Connect a capacitor and a resistor to compensate the loop.
4	FB	I	Feedback Input Pin Set the output voltage by connecting an external resistor.
5, 6	GND	-	GND Pin ※Be sure to tie these pins on the board.
7	CLKOUT	O	Clock Output Pin Clock output pin synchronized with internal switching frequency. CMOS output with VCC as power supply.
8	PG	O	Power-Good Output Pin NMOS open drain pin. Output that is pulled-up node "High" in normal state.
9	MODE	I	Mode-Select Input Pin High: to select Forced PWM Control, External Clock Synchronization with PLL Input. Low: prohibited
10 to 23	VOUT_F	O	Power Output Pin Mount the RSENSE for Peak Current Limit between the Vout load and these pins .
24, 25	GND	—	GND Pin ※ Connect these pins together on the board.
26 to 45	SW	O	Switching Pin The inductor is connected inside the IC to this pin. To enforce the power dissipation, refer to the footprint and PCB layout.
46 to 55	VIN	Power	Power Supply Input Pin ※ Be sure to connect the VIN pins together on the board.
56, 60	NC	—	No Connection It is recommended to be left open to reduce the risk of adjacent pins' short.
57, 63	GND	—	GND Pin ※Be sure to connect the GND pins together on the board.
58	BST	I	Bootstrapped Pin By connecting a capacitor (C_{BST}) between the SW and BST pin, the voltage between the SW and BST pin is controlled to Typ.5V.
59	VCC	O	VCC Output Pin
61	VIN	Power	Power Supply Input Pin ※ Be sure to connect the VIN pins together on the board.
62	CSS/TRK	I	Soft-Start Adjustment Pin Soft-start time can be adjusted by connecting a capacitor between this pin and GND.
64	EN	I	Enable Pin ("High" active) Input "Low" to this pin shuts down the IC. Input "High" to this pin enables the IC.
65	SENSE	I	Sense Pin for Inductor Current

For details, refer to "[TYPICAL APPLICATION CIRCUIT](#)" and "[THEORY OF OPERATION](#)".

ABSOLUTE MAXIMUM RATINGS

	Symbol	Ratings	Unit
Input Voltage	V_{IN}	-0.3 to 29	V
EN Pin Input Voltage	V_{EN}	-0.3 to $V_{IN} + 0.3 \leq 29$	V
CSS/TRK Pin Input Voltage	$V_{CSS/TRK}$	-0.3 to 3	V
VOUT_S Pin Voltage	V_{OUT_S}	-0.3 to 6	V
VOUT_F Pin Voltage	V_{OUT_F}	-0.3 to 6	V
SENSE Pin Voltage	V_{SENSE}	-0.3 to 6	V
RT Pin Voltage	V_{RT}	-0.3 to 3	V
COMP Pin Voltage	V_{COMP}	-0.3 to $V_{CC} + 0.3 \leq 6$	V
FB Pin Voltage	V_{FB}	-0.3 to 3	V
VCC Pin Voltage	V_{CC}	-0.3 to 6	V
Output Current for VCC Pin		Internally limited	mA
BST Pin Voltage	V_{BST}	SW-0.3 to SW+6	V
SW Pin Voltage	V_{SW}	-0.3 to $V_{IN} + 0.3 \leq 29$	V
MODE Pin Voltage	V_{MODE}	-0.3 to 6	V
PG Pin Voltage	V_{PG}	-0.3 to 6	V
CLKOUT Pin Voltage	V_{CLKOUT}	-0.3 to $V_{CC} + 0.3 \leq 6$	V
Junction Temperature ^{*1}	T_j	-40 to 150	°C
Storage Temperature Range	T_{stg}	-55 to 150	°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.

ELECTROSTATIC DISCHARGE RATINGS

	Conditions	Protection Voltage
HBM	C = 100 pF, R = 1.5 kΩ	±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

	Symbol	Ratings	Unit
Input Voltage	V _{IN}	4.0 to 28	V
Operating Temperature Range	T _a	–40 to 85	°C
Output Voltage	V _{OUT}	0.7 to 5.3	V
Output Current (NC2701MA)	I _{OUT}	0 to 10	A

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 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

$V_{IN} = 12\text{ V}$, $V_{EN} = V_{IN}$ unless otherwise specified.

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

NC2701MA000xE2D

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Start-Up Voltage	V_{START}				4.5	V
VCC Pin Voltage (VCC-GND)	V_{CC}	$V_{IN} = 28\text{ V}$, $-40^{\circ}\text{C} \leq T_a \leq 85^{\circ}\text{C}$	4.9	5.1	5.3	V
Shutdown Current	I_{sd}	$V_{IN} = 28\text{ V}$, $V_{EN} = 0\text{ V}$		3	20	μA
Quiescent Current at no switching in PWM Mode	I_Q	$V_{IN} = 12\text{ V}$, $V_{FB} = 0.672\text{ V}$, $V_{OUT_S} = V_{SENSE} = 1.5\text{ V}$, $V_{SW} = 1.5\text{ V}$		1.2	1.9	mA
UVLO Release Voltage	$V_{UVLOREL}$	$V_{IN} = V_{CC} = \text{Low to High}$	3.85	4.0	4.2	V
UVLO Detection Voltage	$V_{UVLODET}$	$V_{IN} = V_{CC} = \text{High to Low}$	3.1	3.3	3.4	V
FB Voltage Accuracy	V_{FB}	$V_{IN} = 12\text{ V}$, $T_a = 25^{\circ}\text{C}$	0.6336	0.64	0.6464	V
		$-40^{\circ}\text{C} \leq T_a \leq 85^{\circ}\text{C}$	0.6272		0.6528	
Oscillation Frequency 0	f_{OSC0}	$R_{RT} = 135\text{ k}\Omega$	225	250	275	kHz
Oscillation Frequency 1	f_{OSC1}	$R_{RT} = 32\text{ k}\Omega$	900	1000	1100	kHz
Minimum OFF Time	t_{OFF}	$V_{IN} = 5\text{ V}$, $V_O = 5\text{ V}$		120	190	ns
Minimum ON Time	t_{ON}	$V_{IN} = 5\text{ V}$, $V_O = 0.7\text{ V}$		100	120	ns
Synchronizing Frequency	f_{SYNC}	f_{OSC} Criteria	$f_{osc} \times 0.5$		$f_{osc} \times 1.5$	kHz
			250		1000	kHz
Soft-Start Time 1	t_{SS1}	$V_{IN} = 12\text{ V}$, $CSS/TRK = \text{OPEN}$	0.4		0.75	ms
Soft-Start Time 2	t_{SS2}	$V_{IN} = 12\text{ V}$, $C_{SS} = 4.7\text{ nF}$	1.4		2.0	ms
Charge Current for Soft-Start Pin	I_{TSS}	$V_{IN} = 12\text{ V}$, $V_{CSS/TRK} = 0\text{ V}$	1.8	2	2.2	μA
CSS/TRK Pin Voltage at End of Soft-Start	V_{SSEND}		V_{FB}	$V_{FB} + 0.03$	$V_{FB} + 0.06$	V
Discharge FET On-resistance for CSS/TRK Pin	R_{ONDISD_CSS}	$V_{IN} = 4.5\text{ V}$, $V_{EN} = 0\text{ V}$, $V_{CSS/TRK} = 3\text{ V}$	2.0	3.0	5.0	k Ω

All electrical characteristic parameters that specify the minimum and maximum specifications are tested under the condition of $T_j \approx T_a = 25^{\circ}\text{C} / 85^{\circ}\text{C}$

$V_{IN} = 12\text{ V}$, $V_{EN} = V_{IN}$ unless otherwise specified.

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

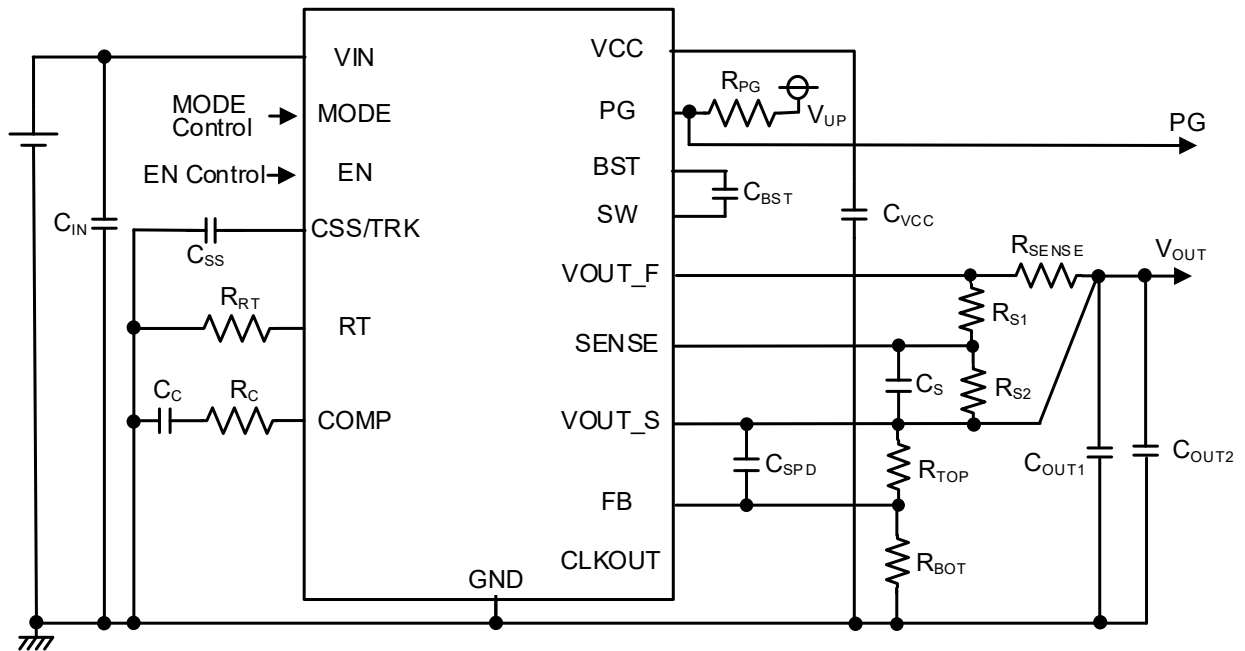
NC2701MA000xE2D

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Current Limit Threshold Voltage (SENSE – VOUT_S)	V_{LIMIT}		40	50	60	mV
Reverse Current Sense Threshold Voltage (SENSE – VOUT_S)	$V_{IREVLIMIT}$		40	50	60	mV
SW Short to GND Detector Threshold Voltage (VIN – SW)	$V_{SWSHORTDET}$		0.345	0.43	0.520	V
SW Short to VCC Detector Threshold Voltage (SW – GND)	$V_{SWSHORTDET}$		0.330	0.43	0.515	V
EN Input High Voltage	V_{ENH}	$V_{IN} = V_{CE} = 28\text{ V}$	1.30			V
EN Input Low Voltage	V_{ENL}	$V_{IN} = 28\text{ V}$, $V_{CE} = 0\text{ V}$			1.10	V
EN Input High Current	I_{ENH}	$V_{EN} = 28\text{ V}$	0.20		2.45	μA
FB Input High Current	I_{FBH}	$V_{IN} = 28\text{ V}$, $V_{FB} = 3\text{ V}$	-0.1	0	0.1	μA
FB Input Low Current	I_{FBL}	$V_{IN} = 28\text{ V}$, $V_{FB} = 0\text{ V}$	-0.1	0	0.1	μA
MODE Input High Voltage	V_{MODEH}	$V_{IN} = 28\text{ V}$	1.33			V
MODE Input High Current	I_{MODEH}	$V_{IN} = 28\text{ V}$, $V_{MODE} = 6\text{ V}$	1.00		6.60	μA
CLKOUT Output High Voltage	$V_{CLKOUTH}$	CLKOUT = Hi-Z	4.7		VCC	V
CLKOUT Output Low Voltage	$V_{CLKOUTL}$	CLKOUT = Hi-Z	0		0.1	V
PG Output Low Voltage	V_{PGOFF}	$V_{IN} = 4.0\text{ V}$, $I_{PG} = 1\text{ mA}$		0.26	0.54	V
PG Pin Leakage Current	I_{PGOFF}	$V_{IN} = 28\text{ V}$, $V_{PG} = 6\text{ V}$	-0.1	0	0.1	μA
FB Pin OVD Threshold Voltage	$V_{FBOVDDET}$	$V_{IN} = 5.0\text{ V}$, $V_{FB} = \text{Low to High}$	0.680	$V_{FB} \times 1.10$	0.740	V
	$V_{FBOVDREL}$	$V_{IN} = 5.0\text{ V}$, $V_{FB} = \text{High to Low}$	0.664	$V_{FB} \times 1.07$	0.712	V
FB Pin UVD Threshold Voltage	$V_{FBUVDDET}$	$V_{IN} = 5.0\text{ V}$, $V_{FB} = \text{High to Low}$	0.556	$V_{FB} \times 0.90$	0.604	V
	$V_{FBUVDREL}$	$V_{IN} = 5.0\text{ V}$, $V_{FB} = \text{Low to High}$	0.574	$V_{FB} \times 0.93$	0.628	V
Thermal Shutdown Detection Temperature	T_{SDDET}	$T_j^{*1} = \text{Low to High}$	-	130	-	$^{\circ}\text{C}$
Thermal Shutdown Release Temperature	T_{SDREL}	$T_j^{*1} = \text{High to Low}$	-	110	-	$^{\circ}\text{C}$

All electrical characteristic parameters that specify the minimum and maximum specifications are tested under the condition of $T_j \approx T_a = 25^{\circ}\text{C} / 85^{\circ}\text{C}$

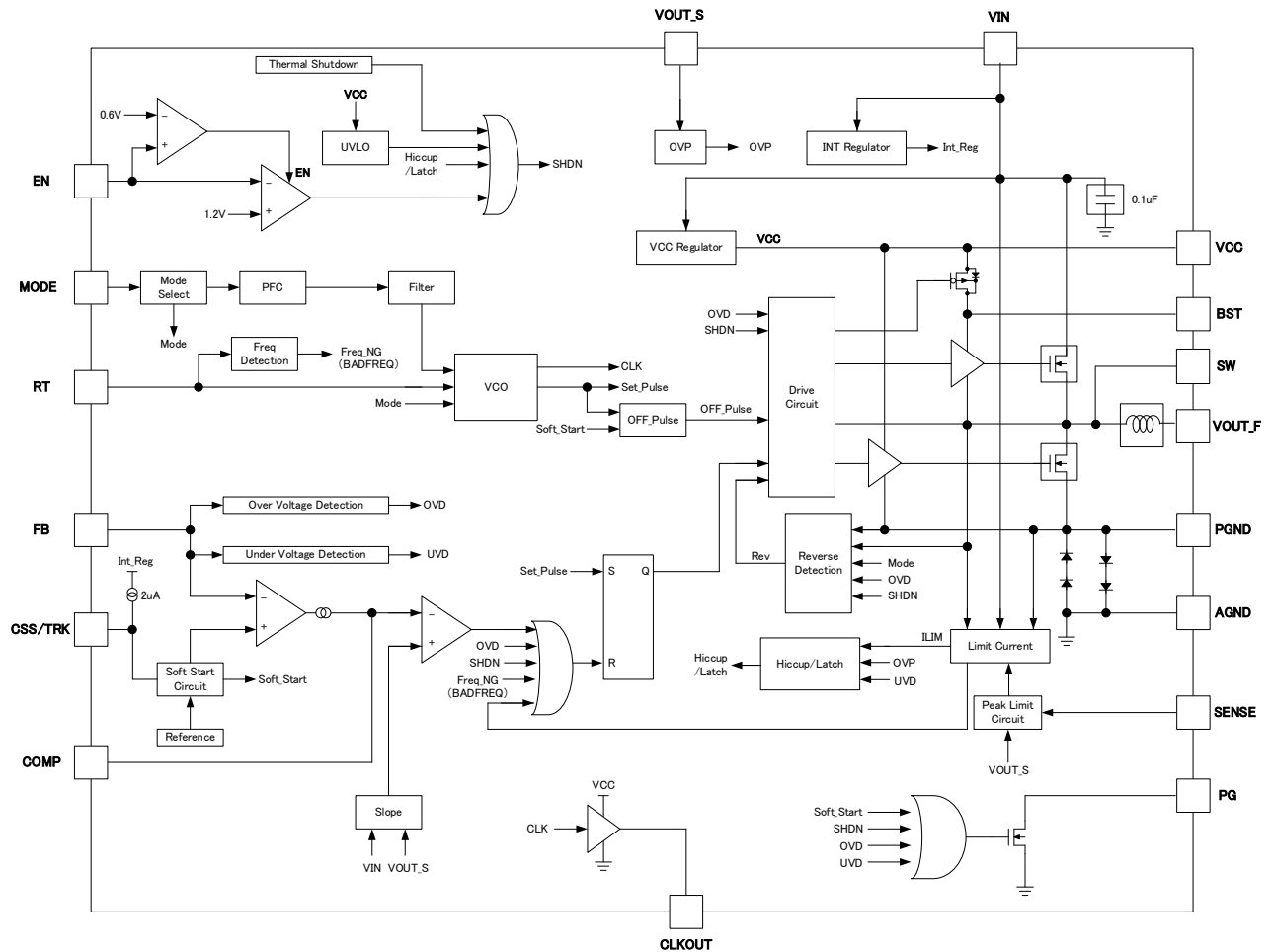
*1 This product is a module product. T_j is the junction temperature of the controller chip.

TYPICAL APPLICATION CIRCUIT



NC2701MA Typical Application Circuit

BLOCK DIAGRAMS

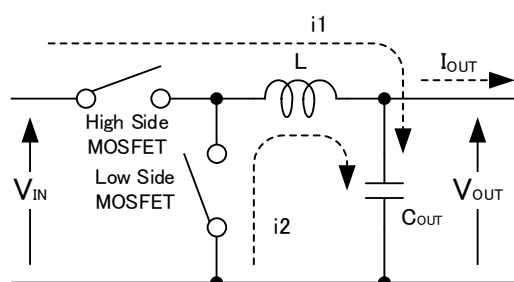


NC2701MA Block Diagram

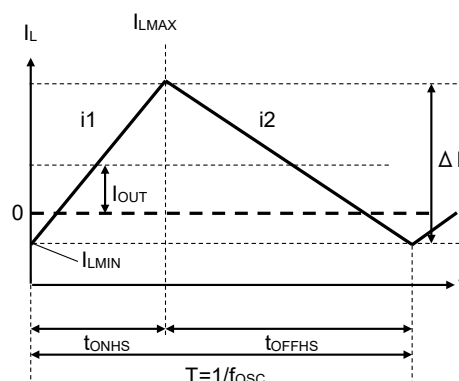
THEORY OF OPERATION

Operation of Step-Down Switching Regulator

A basic step-down switching regulator is illustrated in the following figures. This switching regulator charges energy in the inductor when the high-side MOSFET turns on and discharges the energy from the inductor when the high-side MOSFET turns off and controls with less energy loss, so that a lower output voltage than the input voltage is obtained.



Basic Circuit



Current Through Inductor

- Step1. The high-side MOSFET turns on and current $I_L (= i1)$ flows, and energy is charged into C_{OUT} . At this moment, I_L increases from $I_{LMIN} (= 0)$ to reach I_{LMAX} in proportion to the on-time period (t_{on}) of the high-side MOSFET turns on and current $I_L (= i1)$ flows, and energy is charged into C_{OUT} . At this moment, I_L increases from $I_{LMIN} (= 0)$ to reach I_{LMAX} in proportion to the on-time period (t_{ONHS}) of the high-side MOSFET.
- Step2. When the high-side MOSFET turns off, the low-side MOSFET turns on in order to maintain I_L at I_{LMAX} , and current $I_L (= i2)$ flows
- Step3. The low-side MOSFET is turned on until the next cycle. That is, the low-side MOSFET must keep turning on to meet. $I_L = I_{LMIN} < 0$, when reaches $I_L = I_{LMIN} = 0$ after a time of t_{OPEN} .

In the PWM mode, the output voltage is maintained constant by controlling t_{ONHS} with the constant switching frequency (f_{osc}).

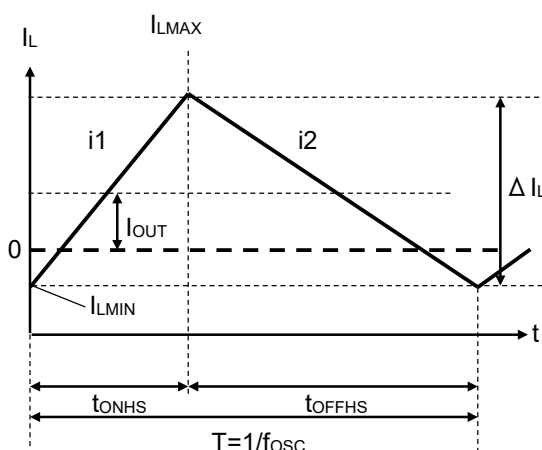
MODE Pin Function

The forced PWM mode is selected when the voltage of the MODE pin is more than 1.33 V, and the PWM works regardless of a load current. By inputting a clock signal, PLL synchronous mode appears and always operates in PWM regardless of the load current. (The "Low" level input is prohibited.)

See Forced PWM mode for details and Frequency Synchronization Function for the operation on connecting an external clock.

Forced PWM Mode

Forced PWM mode is selected by setting the fixing the MODE pin to 1.33V or higher or by applying an external clock signal. This mode can reduce the output noise since the frequency is fixed even if the light load conditions. Thus, $I_{L\min}$ becomes less than "0" when I_{OUT} is less than $\Delta I_L / 2$. That is, the electric charged to C_{OUT} , is discharged via MOSFET for the durations – when I_L reaches "0" from $I_{L\min}$ and when I_L reaches $I_{L\min}$ from "0". But, pulse skip is occurred to prevent the overvoltage if high-side MOSFET is turned on when the output voltage is more than the set output voltage.



Forced PWM Mode

Frequency Synchronization Function

The NC2701MA can synchronize to the external clock being inputted via the MODE pin, with using a PLL (Phase-locked loop). In this case, the forced PWM mode is also in valid. Each High/Low period of the external clock is required at least 100 ns or more. The allowable range of oscillation frequency is from 0.5 to 1.5 times of the set frequency⁽²⁾, and the operating guaranteed frequency is in the 250 kHz to 1 MHz range⁽³⁾. The NC2701MA can synchronize to the external clock also during the soft start. That is, the NC2701MA executes the soft-start with the synchronization functions if an external clock is input to the MODE pin and started up. However, if the device is on the maximum duty or the duty-over state caused by small difference between input and output voltages, the device may run at asynchronous to the MODE pin, and it may operate in the frequency in the range from one-fourth to same as the external clock frequency. Likewise, the CLKOUT pin becomes asynchronous to the MODE pin. If making synchronization to the MODE pin, consideration of the minimum difference between input and output voltage for this function is necessary.

Output Voltage Setting

The output voltage (V_{OUT}) can be set by adjustable values of R_{TOP} and R_{BOT} . The value of V_{OUT} can be calculated by Equation 1.

$$V_{OUT} = V_{FB} \times (R_{TOP} + R_{BOT}) / R_{BOT} \quad (\text{Equation 1})$$

For example, when setting $V_{OUT} = 3.3 \text{ V}$ and setting $R_{BOT} = 22 \text{ k}\Omega$, R_{TOP} can be calculated by substituting them to Equation 1. As a result of the expanding Equation 2, R_{TOP} can be set to 91.4 k Ω . To make 91.4 k Ω with using the E24 type resistors, the connecting use of 91 k Ω and 0.39 k Ω resistors in series is required. If the tolerance level of the set output voltage is wide, using a resistor of 91 k Ω to R_{TOP} can reduce the number of components.

$$\begin{aligned} R_{TOP} &= (3.3 \text{ V} / 0.64 \text{ V} - 1) \times 22 \text{ k}\Omega \\ &= 91.4 \text{ k}\Omega \quad (\text{Equation 2}) \end{aligned}$$

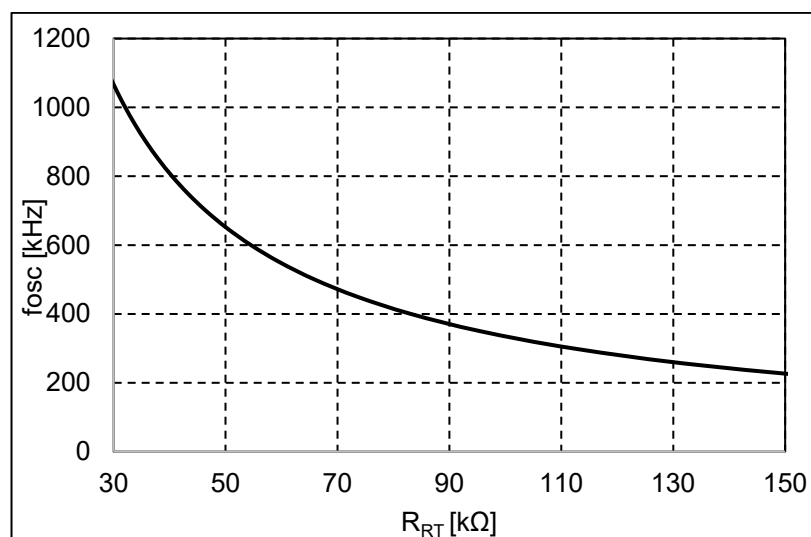
⁽²⁾ See *Oscillation Frequency Setting* for details of the set frequency.

⁽³⁾ The adjustable oscillation frequency range becomes $250\text{kHz} \leq f_{OSC} \leq 600\text{kHz}$ when $0.7 \text{ V} \leq V_{OUT} < 1.35\text{V}$.

Oscillation Frequency Setting

Connecting the oscillation frequency setting resistor (R_{RT}) between the RT pin and GND can control the oscillation frequency in the range of 250 kHz to 1 MHz^{*4}. For example, using the resistor of 66 kΩ can set the frequency of about 500 kHz.

The Electrical Characteristics guarantees the oscillation frequency for f_{OSC0} (at $R_{RT} = 135 \text{ k}\Omega$) and f_{OSC1} (at $R_{RT} = 32 \text{ k}\Omega$).



$$R_{RT} [\text{k}\Omega] = 41993 \times f_{osc} [\text{kHz}]^{-1.039}$$

NC2701MA Oscillation Frequency Setting Resistor (R_{RT}) vs. Oscillation Frequency (f_{osc})

Duty-Over Function

When the input voltage is down by cranking, the operating frequency is reduced until one-fourth of the set frequency with being linearly proportional to time in order to maintain the output voltage. Exploiting the ON duty to exceed the maxduty value at normal operation can allow the small difference between input and output voltages.

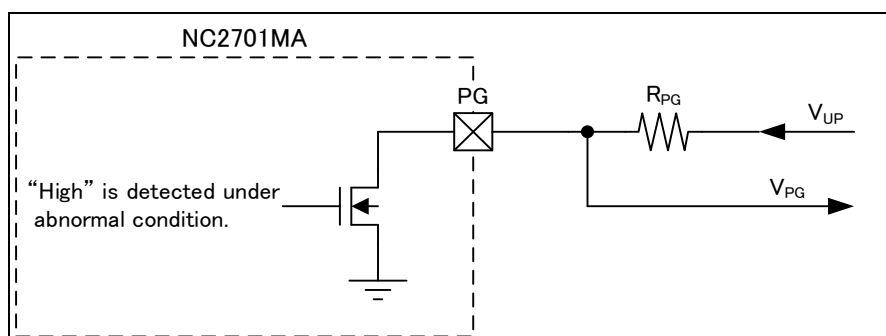
Power Good Output Function

The power good function with using an NMOS open drain output can detect the following states of the NC2701MA. The NMOS turns on and the PG pin being Low, when detecting the items shown below. After the NC2701MA returns to the normal state, the NMOS turns off and the PG pin outputs High (PG Input Voltage: V_{UP}).

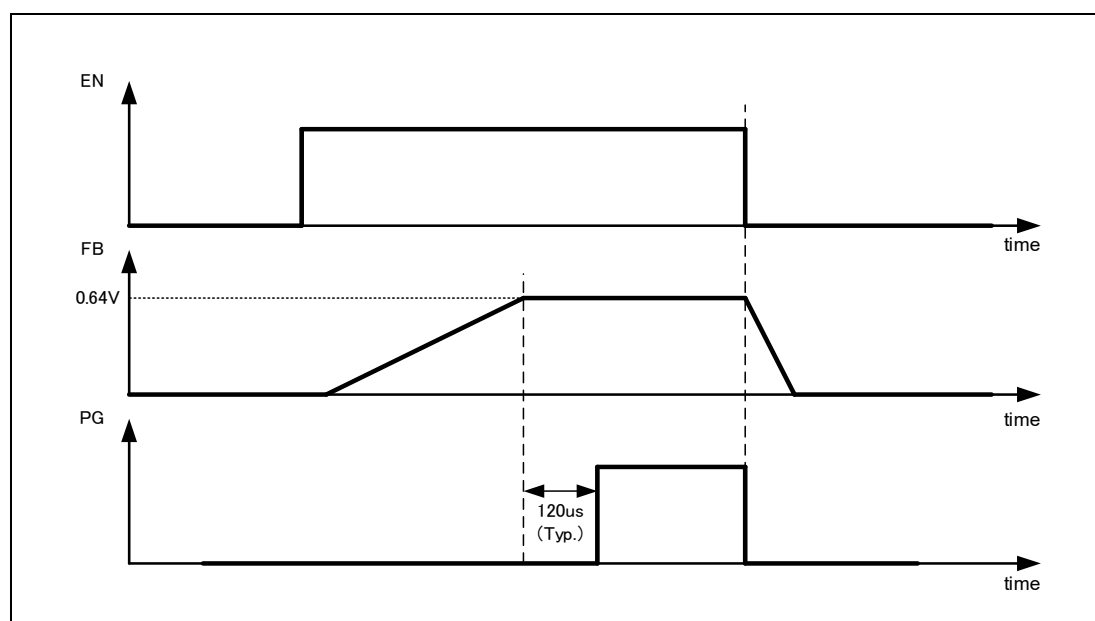
- EN = "Low" (Shut Down)
- UVLO(Shut Down)
- Thermal Shut Down
- Soft-Start Time
- At UVD Threshold Voltage Detection
- At OVD Threshold Voltage Detection
- At Hiccup-Type Protection (when hiccup mode is selected)
- At Latch-Type Protection (when latch mode is selected)

^{*4} The adjustable oscillation frequency range becomes $250 \text{ kHz} \leq f_{osc} \leq 600 \text{ kHz}$ if $.7 \text{ V} \leq V_{OUT} < 1.35 \text{ V}$.

The PG pin is designed to become 0.54 V or less in Low level when the current flowing to the PG pin is 1 mA. The use of the PG input voltage (V_{UP}) of 5.5 V or less and the pull-up resistor (R_{PG}) of 10 k Ω to 100 k Ω are recommended. If not using the PG pin, connect it to GND or left open.



Power Good Output Pin Connecting Diagram

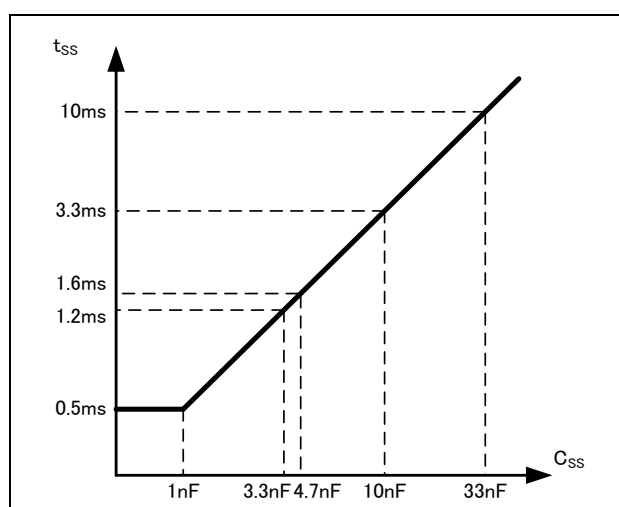


Rising / Falling Sequence of Power Good Circuit

Soft-Start Function

The soft-start time is a time between a rising edge ("High" level) of the EN pin and the timing when the output voltage reaches the set output voltage. Connecting a capacitor (C_{SS}) to the CSS / TRK pin can adjust the soft-start time (t_{ss}) – provided the internal soft-start time of 500 μs (Typ.) as a lower limit. The adjustable soft-start time is 1.6 ms (Typ.) when connecting an external capacitor of 4.7 nF. The time is for charging a capacitor up to 0.64V(Typ.) with the charging current of 2.0 μA (Typ.). If not required to adjust the soft-start time, by the CSS / TRK pin being "Open", the internal soft-start time of 500 μs (Typ.) is set. If connecting a large capacitor to an output signal, the overcurrent protection or the SW GND short protection might run. To avoid these protections caused by starting abruptly when reducing the amount of power current, soft-start time must be set as long as possible.

Each of soft-start time (t_{ss1}/ t_{ss2}) is guaranteed under the conditions described in the chapter of "Electrical Characteristics".

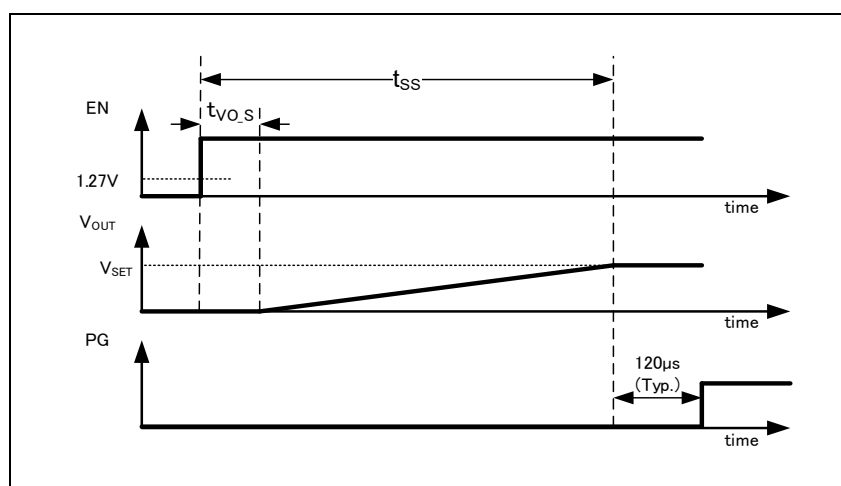


$$C_{SS} [nF] = (t_{ss} - t_{VO_S}) / 0.64 \times 2.0$$

t_{ss}: Soft-Start Time (ms)

t_{VO_S}: Time period from EN = "High" to V_{OUT}'s rising
(Typ. 0.160ms)

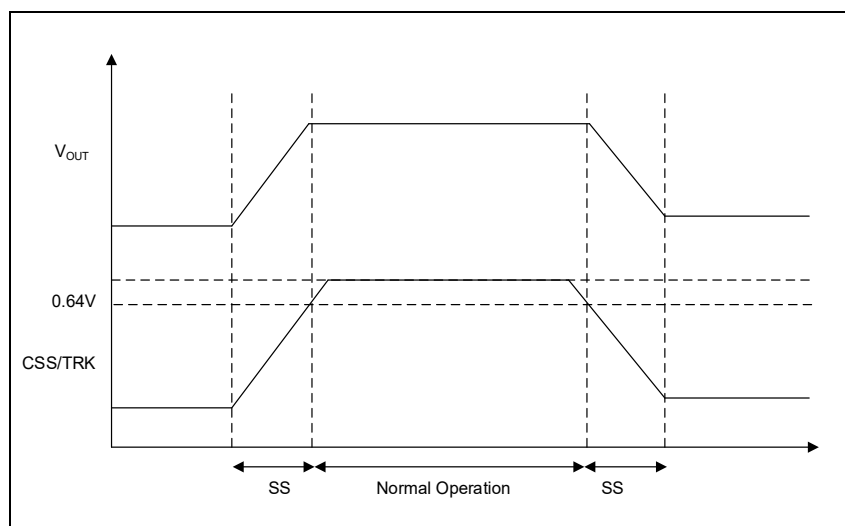
Soft-Start Time Adjustable Capacitor (C_{SS}) vs. Soft-Start Time (t_{ss})



Soft-Start Sequence

Tracking Function

Applying an external tracking voltage to the CSS / TRK pin can control the soft-start sequence – provided that the lowest internal soft-start time is limited to 500 μ s (Typ.). Since the FB pin voltage, V_{FB} becomes nearly equal to $V_{CSS/TRK}$ at tracking, the complex start timing and soft-start can be easily designed. The available voltage at tracking is between 0 V and 0.64 V. If the tracking voltage is over 0.64 V, the internal reference voltage of 0.64 V is enabled. Also, an arbitrary falling waveform can be generated by reducing $V_{CSS/TRK}$ to 0.64 V (Typ.) or less, because the NC2701MA supports both of up- and down- tracking.



Tracking Sequence

Min. ON-Time

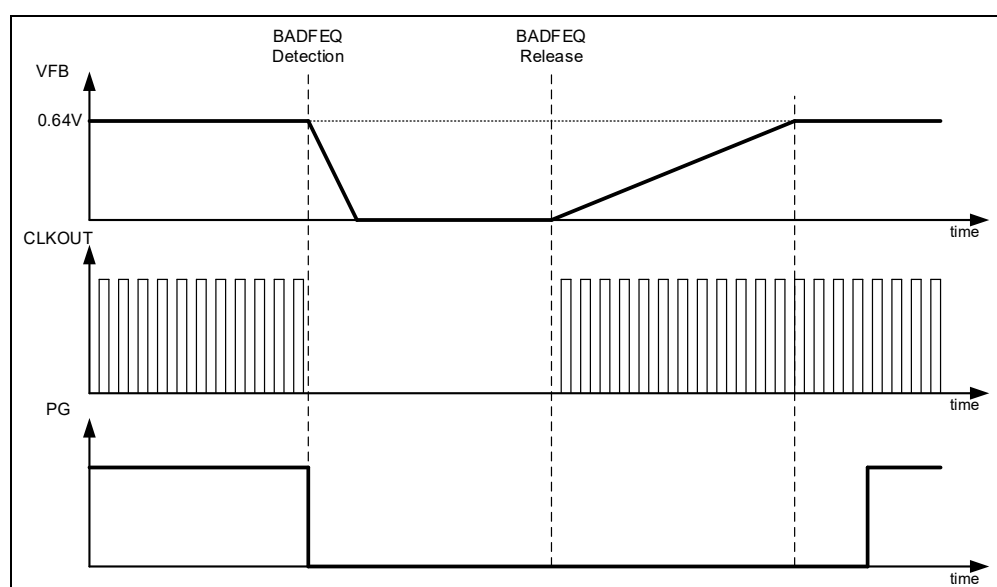
The min. ON time (Max. 120 ns), which is determined in the NC2701MA internal circuit, is a minimum time to turn high-side MOSFET on. The NC2701MA cannot generate a pulse width less than the min. ON time. Therefore, settings of the output set voltage and the oscillator frequency are required so that the minimum step-down ratio [$V_{OUT}/V_{IN} \times (1 / f_{OSC})$] does not stay below 120ns. If staying below 120 ns, the pulse skipping operation appears to stabilize the output voltage. The ripple current and the output voltage ripple will be large under the pulse skipping condition.

Min. OFF-Time

By the adoption of bootstrap circuit, the high-side MOSFET, which is used as the NC2701MA, is used an NMOS. The sufficient voltage to drive the high-side MOSFET must be charged. Therefore, the min. OFF time is determined from the required time to charge the voltage. By the function of the frequency's reduction by one-quarter of a set value (Min.) if the input-output difference voltage becomes small or drastic load transient may happen, the OFF period can be caused once in four-cycle period of normal cycle. As a result, the min. OFF time becomes 30 ns (Typ.) against the nominal clock, substantially, and the maximum duty cycle can be improved.

Bad Frequency (BADFREQ) Protection

If a current equivalent to 2 MHz (Typ.) or more or 125 kHz (Typ.) or less flows to the RT pin when the resistor of the RT pin is in open / short, the NC2701MA will stop switching to protect the IC and the internal state becomes back to before the soft start. The CLKOUT pin is fixed to "Low" while the bad frequency is detected. The NC2701MA will restart under the normal control with soft start when recover from the abnormal condition.



BADFREQ Detection / Release Sequence

PROTECTION FUNCTION

Thermal Shutdown

When the junction temperature exceeds the thermal shutdown detection temperature (Typ.130°C), switching stops. Then, this IC will restart when the junction temperature drops below the thermal shutdown release temperature (Typ.110°C). The NC2701MA is a product in which a switching regulator controller chip and high-side/low-side MOSFETs are built in one package, and a thermal shutdown circuit is built into the switching regulator controller chip. High-side and low-side MOSFETs junction temperatures cannot be sensed directly. Also, the temperature rises rapidly, specifically over 16 W loss, the MOSFETs may be damaged before the thermal shutdown. If VIN is 22V or more, please implement protection by the current limit function.

SW Power Supply (VIN Short) / GND (GND Short) Protection

In addition to normal current limit, the NC2701MA provides the SW power supply / GND short protection to monitor the voltage between the MOSFET's drain and source. Since the current limit function is controlled with a sense resistance, the current limit function cannot work for a shoot-through current through the MOSFETs and an overcurrent by shorten the SW pin to VDD/GND. The detecting current can be calculated by SW shot to VDD/GND detector threshold voltage (MOSFET_ON-Resistance x Current, Typ.0.43 V).

Current Limit Function

The current limit function limits the peak current to turn the high-side MOSFET off if the difference between SENSE pin voltage and VOUT_S pin voltage is over the current limit threshold voltage. The current limit detection method and current limit threshold can be set by connecting external components.

The current limit value is detected with the voltage across a sense resistance connected to the internal inductor connected pin in series. By connecting a high precision resistance, the current limit with high accuracy can be realized. Be careful that the power loss caused by the current and R_{SENSE} . The peak current in the current limit inductor can be calculated by the following equation.

$$\text{Peak current in Current limit inductor (A)} = \text{Current limit threshold voltage (mV)} / R_{SENSE} \text{ (m}\Omega\text{)}$$

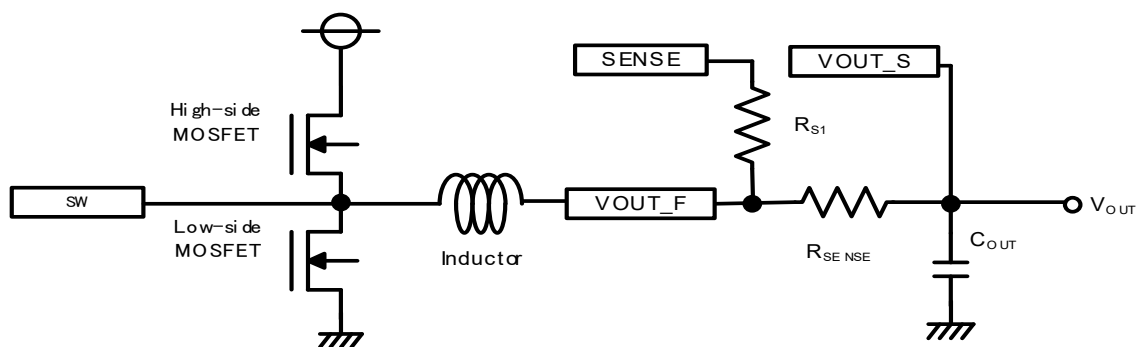


Figure A Detection with Sense Resistance 1

When the load current, I_{OUT} is large, the sense resistance, R_{SENSE} should be small, in such a case, current limit threshold may shift by the effect of wiring resistance. The countermeasure against it is by connecting R_{S1} and R_{S2} resistances to SENSE pin shown in Figure B as close as possible to R_{SENSE} , the fine current limit level is possible compared with adjustment by only R_{SENSE} . In this case, the inductor peak current limit can be calculated by the next equation.

$$\text{Peak Current limit (A)} = \text{Current limit threshold voltage (mV)} / (R_{S0} \times R_{SENSE} \text{ (m}\Omega\text{)})$$

$$R_{S0} = R_{S2} / (R_{S1} + R_{S2})$$

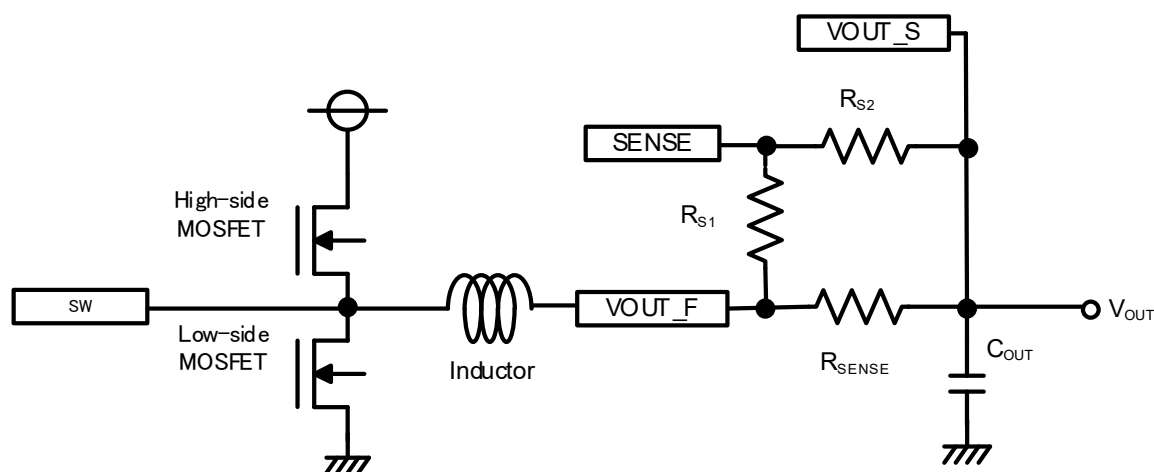


Figure B Detection with Sense Resistance 2

Instead of the SENSE resistor, it is possible to control the current limit value using the DCR of the internal inductor, but it is not recommended due to the drastic deterioration of the accuracy.

Reverse Current Limit Function

The reverse current limit function works when the reverse current is over the threshold. When the over current beyond the limit is detected, the low-side MOSFET is turned OFF to limit the reverse current. The reverse current limit value is determined by the voltage between the VOUT_S pin and the SENSE pin. The detector threshold is same as the current limit. This function is useful for the output is shortened to the higher voltage node than the set output voltage.

Under Voltage Detection (UVD)

The UVD function indirectly monitors the output voltage with using the FB pin. The PG pin outputs "Low" when the UVD detector threshold is 90% (Typ.) of V_{FB} for more than 30 μs (Typ.). When V_{FB} is over 93% (Typ.) of 0.64 V, the PG pin outputs "High" after the delay time (Typ. 120 μs). The hiccup- / latch-type overcurrent protection works when detecting an overcurrent, an SW shortened to GND, or an over output voltage protection (OVP) during the UVD detection.

Over Voltage Detection (OVD)

The OVD function indirectly monitors the output voltage with using the FB pin. Switching stops when detecting the over voltage of V_{FB} but the internal circuit keeps active. The PG pin outputs "Low" when the OVD detector threshold is 110% (Typ.) of V_{FB} for more than 30 μs (Typ.). When V_{FB} is under 107% (Typ.) of V_{FB} , which is the OVD released voltage, the switching goes back to the normal and the PG pin outputs "High" after the delay time (Typ. 120 μs). The over voltage protection works when an error is occurred by peripheral circuits for the FB pin such as output feedback resistance network.

Over Voltage Protection (OVP)

The OVP function monitors the voltage of VOUT_S pin to reduce an over voltage when an error is caused in peripheral circuits for the FB pin. Switching stops when V_{OUT} is over the OVP detector threshold, but the internal circuit keeps active. When V_{OUT} is under the OVP detector threshold, switching is back to the normal operation. If the UVD for FB pin is detected during the OVP detect state, the error is detected and hiccup- / latch-type protection will work. However, the operation is not guaranteed because the OVP detector threshold is set beyond the absolute maximum rating of the VOUT_S pin.

Hiccup-Type / Latch-Type Overcurrent Protection

There are the hiccup-type / latch-type overcurrent protections. When UVD can work during the current limit or OVP, or the SW short protection to GND. The latch-type protection can release by the following procedure. After removing the cause, set the EN pin to "Low" or tie V_{IN} input voltage below the UVLO detector threshold and start again. The hiccup type protection stops switching and releases the circuit automatically after the protection delay time (Typ. 3.5 ms). Since the hiccup type protection is auto-release, the EN pin control to release the protection is unnecessary. When the output is shortened to GND, turning on and off is repeated until the abnormal condition is released.

THERMAL CHARACTERISTICS 1

Thermal characteristics depend on the mounting conditions.
The following measurement conditions are based on JEDEC STD. 51.

Measurement Conditions

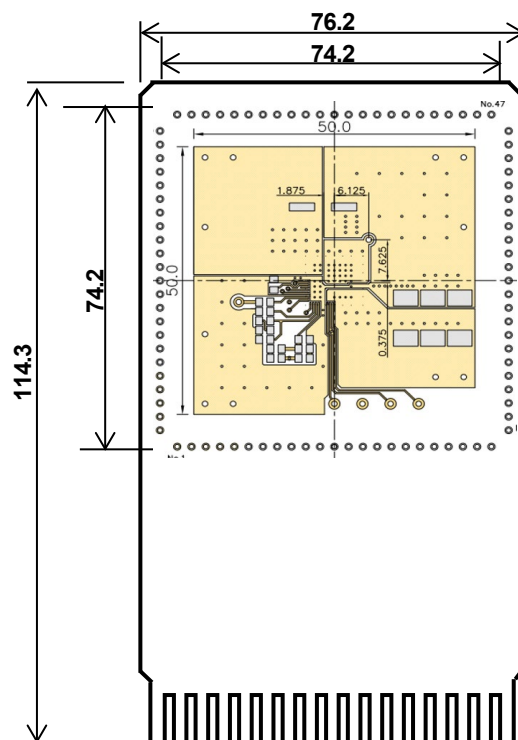
Parameter	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 1.6 mm
Copper Ratio	Outer Layer (First and Fourth Layers) : 90% or more Inner Layers (Second and Third Layers) : 95% or more

Measurement Result

Parameter	Measurement Result
Thermal Resistance (θ_{ja})	$\theta_{ja} = 24^{\circ}\text{C/W}$
Thermal Characterization Parameter (ψ_{jt})	$\psi_{jt} = 6.8^{\circ}\text{C/W}$

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

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



Measurement Board Pattern

CALCULATION METHOD OF JUNCTION TEMPERATURE

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

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

$$T_j = T_{c(top)} + \psi_{jt} \times P$$

T_a : Ambient temperature.

$T_{c(top)}$: Package mark side center temperature

P : $P_{IN} - P_{OUT} = (V_{IN} \times I_{IN}) - (V_{OUT} \times I_{OUT})$ (Power consumption under user's conditions.)

THERMAL CHARACTERISTICS 2

Thermal characteristics depend on the mounting conditions.

The following thermal characteristics are measurement data using our evaluation board.

Measurement Conditions

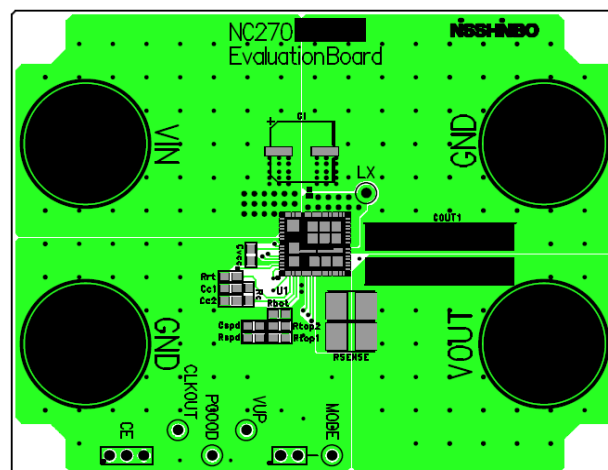
Parameter	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	70 mm × 90 mm × 1.6 mm
Copper Ratio	Outer Layer (First and Fourth Layers) : 90% or more Inner Layers (Second and Third Layers) : 95% or more

Measurement Result

Parameter	Measurement Result
Thermal Resistance (θ_{ja})	$\theta_{ja} = 16^{\circ}\text{C/W}$
Thermal Characterization Parameter (ψ_{jt})	$\psi_{jt} = 2.41^{\circ}\text{C/W}$

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

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



Measurement Board Pattern

CALCULATION METHOD OF JUNCTION TEMPERATURE

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

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

$$T_j = T_{c(top)} + \psi_{jt} \times P$$

T_a : Ambient temperature.

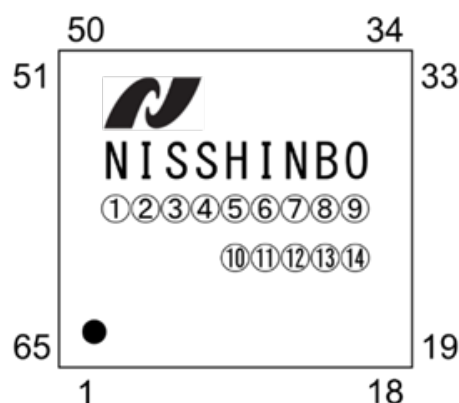
$T_{c(top)}$: Package mark side center temperature

P : $P_{IN} - P_{OUT} = (V_{IN} \times I_{IN}) - (V_{OUT} \times I_{OUT})$ (Power consumption under user's conditions.)

MARKING SPECIFICATION

①②③④⑤⑥⑦⑧⑨ : Product Code ... Refer to the following table

⑩⑪⑫⑬⑭ : Lot Number ... Alphanumeric Serial Number



QFN0910-65-MA Part Markings

NOTICE

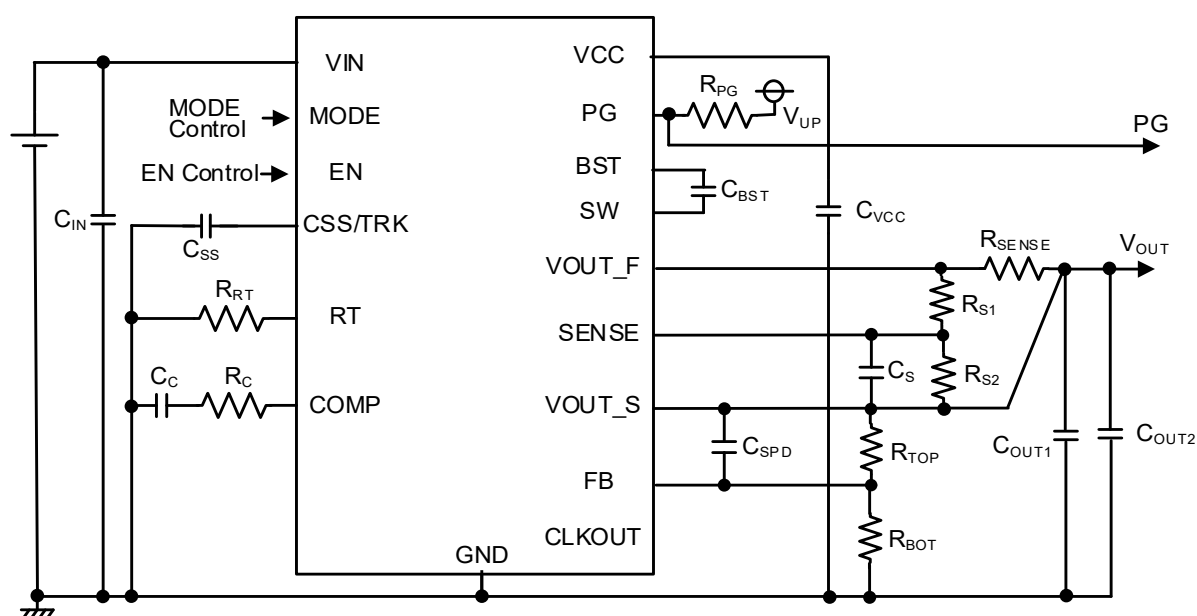
There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact our sales or distributor before attempting to use AOI.

NC2701MA Marking List

Product Name	①②③④⑤⑥⑦⑧⑨
NC2701MA000A	NC2701MAA
NC2701MA000B	NC2701MAB

APPLICATION NOTE

Cautions in Selecting External Components



NC2701MA Typical Application Circuit

Inductor

The inductor built in the NC2701MA: $L = 1.0 \mu\text{H}$, $\text{DCR} = \text{Typ. } 4.6 \text{ m}\Omega$.

Capacitor

Choose a capacitor that has a sufficient margin to the voltage ratings with consideration of the DC bias characteristics and the temperature characteristics.

The use of a ceramic capacitor for C_{IN} is recommended. When both a ceramic capacitor and an electrolyte capacitor are used, the stability of the operation will be improved. Choose the electrolyte capacitor with the possible lowest ESR with consideration of the allowable ripple current rating (I_{RMS}). I_{RMS} can be calculated by the following equation.

$$I_{\text{RMS}} \approx I_{\text{OUT}} / V_{\text{IN}} \times \sqrt{V_{\text{OUT}} \times (V_{\text{IN}} - V_{\text{OUT}})}$$

Table of Constants

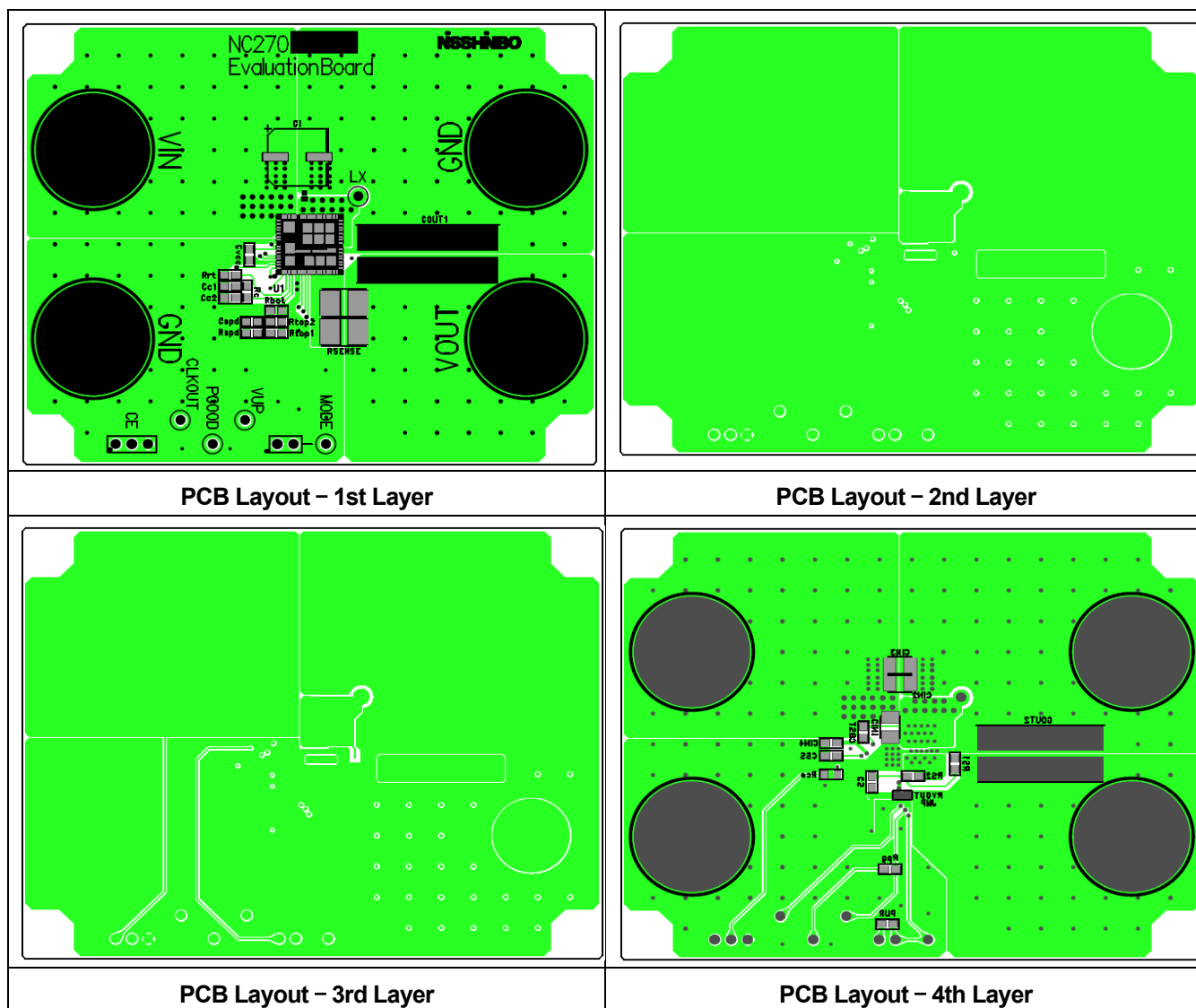
$R_{BOT}=22k\Omega$, $C_{VCC}=2.2\mu F$, $C_{BST}=0.22\mu F$ should be used in all conditions.

NC2701MA

V_{IN} (V)	V_{OUT} (V)	C_{OUT1} (μF)	C_{OUT2} (μF)	R_{RT} ($k\Omega$)	R_C ($k\Omega$)	C_C (μF)	R_{TOP} ($k\Omega$)	C_{SPD} (pF)	C_{SS} (nF)	R_{S1} ($k\Omega$)	R_{S2} ($k\Omega$)	C_S (pF)	R_{SENSE} (m Ω)
5	0.8	47*3	120*3	83.1	6.8	4.7	5.6	330	3.3	0.22	2.2	100	4
5	1	47*2	120*3	83.1	6.8	4.7	12.4	330	3.3	0.22	2.2	100	4
5	1.8	47*2	120	54.5	2.7	4.7	39.9	220	3.3	0.22	2.2	100	4
5	2.5	47*3	-	54.5	2.7	4.7	64	100	3.3	0.22	2.2	100	4
5	3.3	47*3	-	54.5	2.7	4.7	91.4	100	3.3	0.22	2.2	100	4
12	0.8	47*3	120*3	83.1	6.8	4.7	5.6	330	3.3	0.22	2.2	100	4
12	1	47*2	120*3	83.1	6.8	4.7	12.4	330	3.3	0.22	1	100	4
12	1.8	47*2	120	54.5	3.3	4.7	39.9	220	3.3	0.22	1	100	4
12	2.5	47*3	-	54.5	4.7	6.8	64	100	3.3	0.22	0.82	100	4
12	3.3	47*3	-	40.5	5.1	2.2	91.4	100	3.3	0.22	0.82	100	4
12	5	47*2	-	32	5.1	2.2	150	68	3.3	0.22	0.82	100	4
24	3.3	47*2	-	32	2.7	1	91.4	100	3.3	1	-	100	4
24	5	47*2	-	32	2.7	1	150	68	3.3	1	-	100	4

※The "-" indicate OPEN.

Evaluation Board / PCB Layout

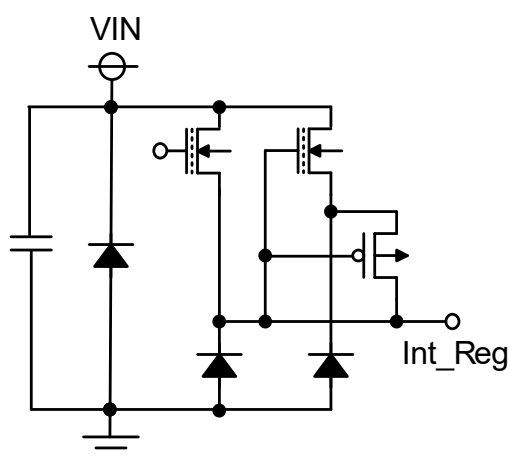


Technical Notes

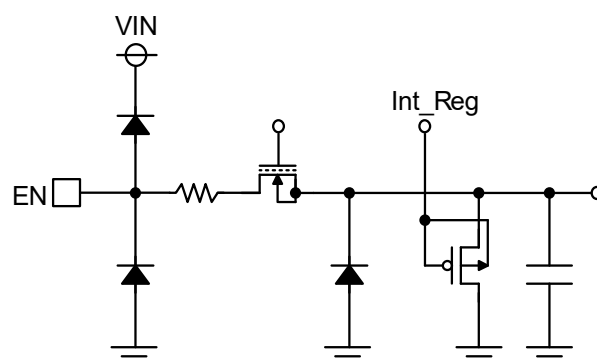
The performance of power source circuits using this IC largely depends on peripheral circuits. When selecting the peripheral components, please consider the conditions of use. Do not allow each component, PCB pattern or the IC to exceed their respected rated values (voltage, current, and power) when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

- External components must be connected as close as possible to the ICs and make wiring as short as possible. Especially, the capacitor connected in between VIN pin and GND pin must be wiring the shortest. 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 sufficient.
- Put a capacitor (C_{OUT}) to keep a distance from C_{IN} to avoid the high-frequency noise by input.
- Put a capacitor (C_{BST}) as close as possible to the SW pin and the BST pin. If controlling a slew rate of the high-side MOSFET for EMI, a resistor (R_{BST}) should be in series between the BST pin and the capacitor (C_{BST}).
- Do not use the MODE pin with “open” or “Low”.
- If V_{OUT} is a negative voltage, start-up may not impossible.
- 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 state over the absolute maximum ratings; therefore, the thermal shutdown function should not be used for a system design.
- The connection between GND pins should be near the IC in common to avoid impedance difference.
- When the load current, I_{OUT} is large, the sense resistance, R_{SENSE} should be small, in such a case, current limit threshold may shift by the effect of wiring resistance. The countermeasure against it is by connecting R_{S1} and R_{S2} resistances to SENSE pin as close as possible to R_{SENSE} . Refer to the explanation of “Current Limit Function”.
- As a noise filter, setting a capacitor, C_S between SENSE pin and V_{OUT_S} as close as possible to the IC is also recommended.

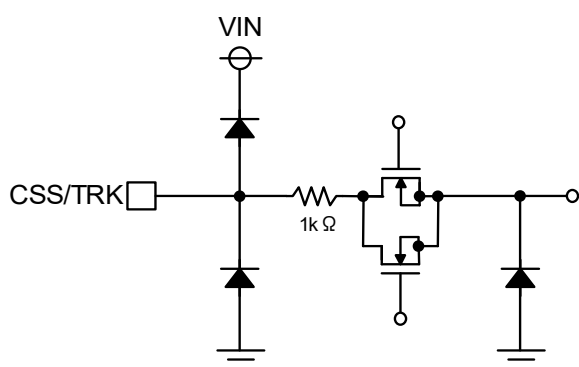
INTERNAL EQUIVALENT CIRCUIT FOR EACH PIN



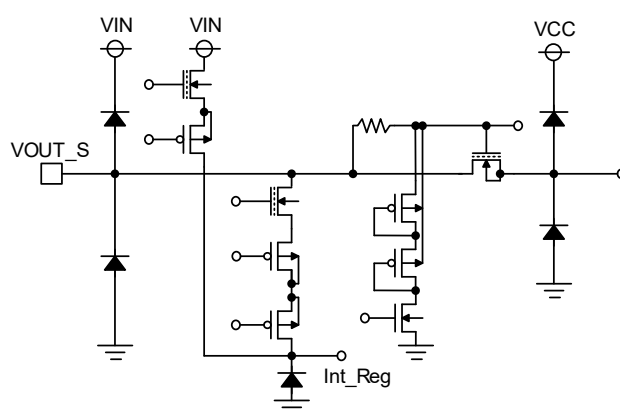
VIN Pin



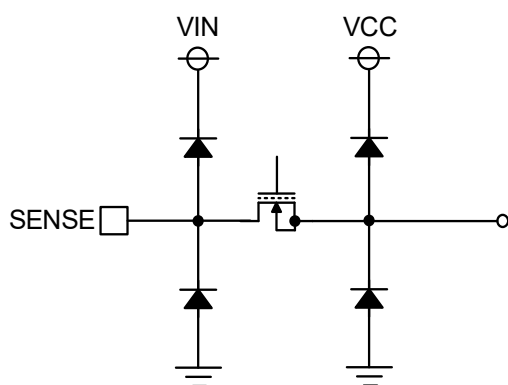
EN Pin



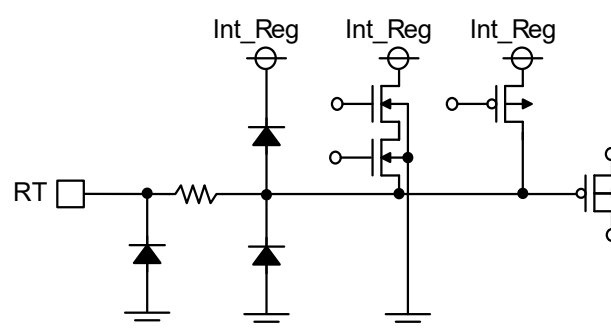
CSS/TRK Pin



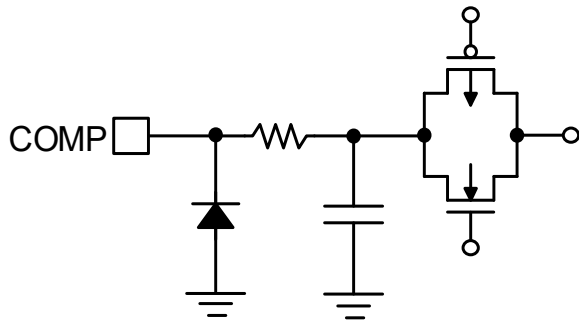
VOUT_S Pin



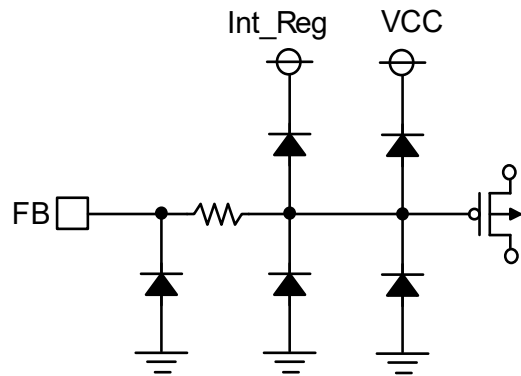
SENSE Pin



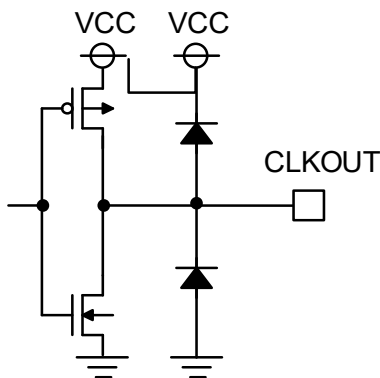
RT Pin



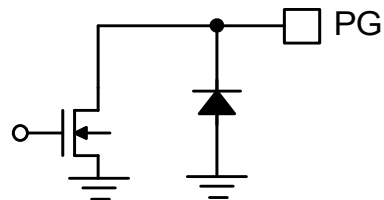
COMP Pin



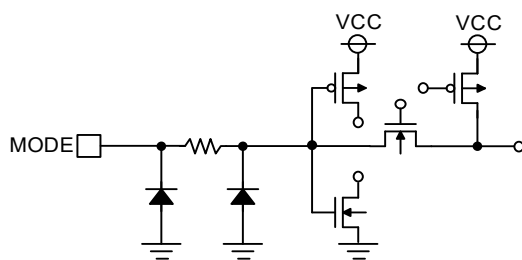
FB Pin



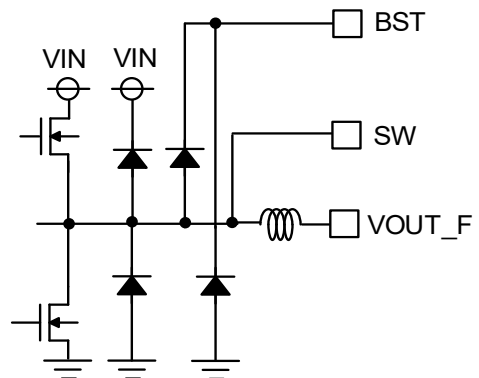
CLKOUT Pin



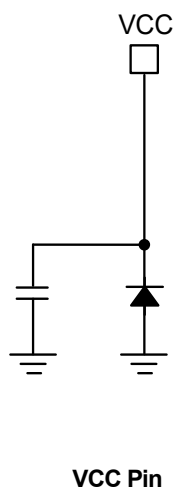
PG Pin



MODE Pin



SW Pin, VOUT_F, BST Pin



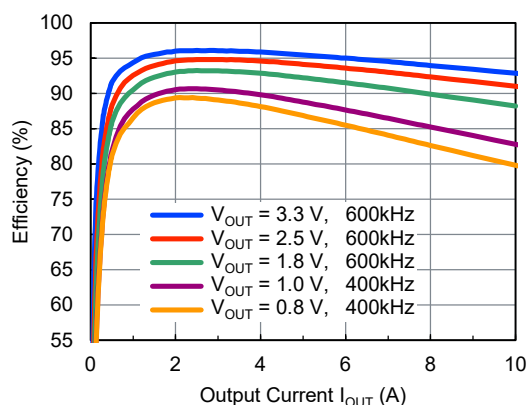
TYPICAL CHARACTERISTICS

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

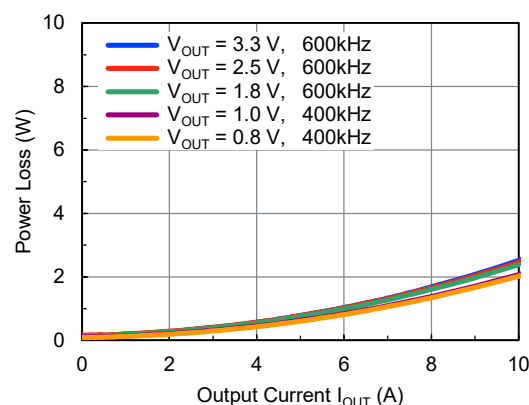
1) Efficiency and Power Loss vs Output Current

$V_{IN} = 5\text{ V}$

Efficiency vs Output Current

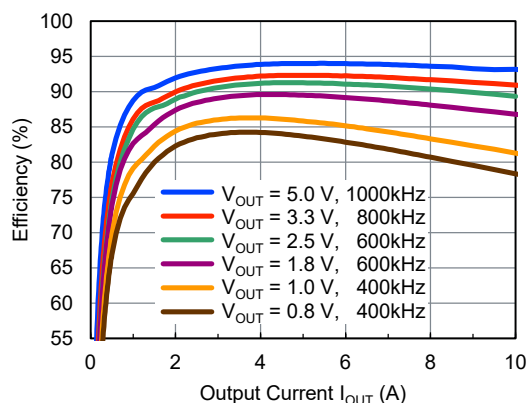


Power Loss vs Output Current

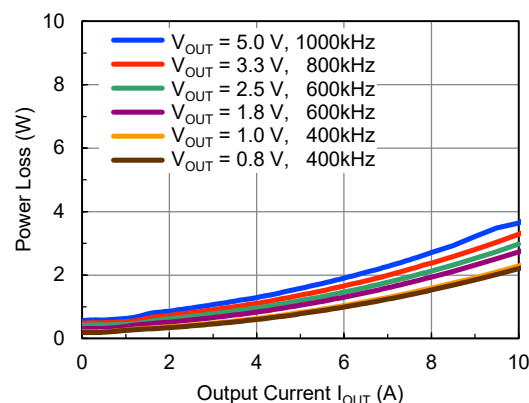


$V_{IN} = 12\text{ V}$

Efficiency vs Output Current

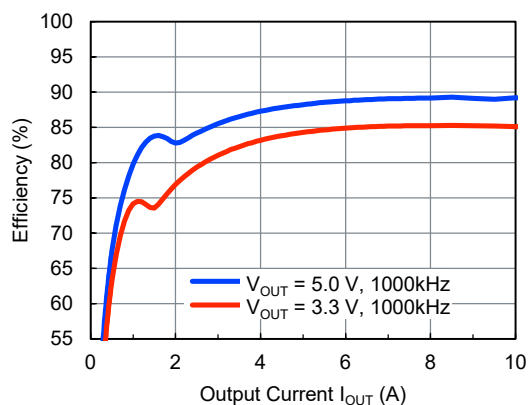


Power Loss vs Output Current

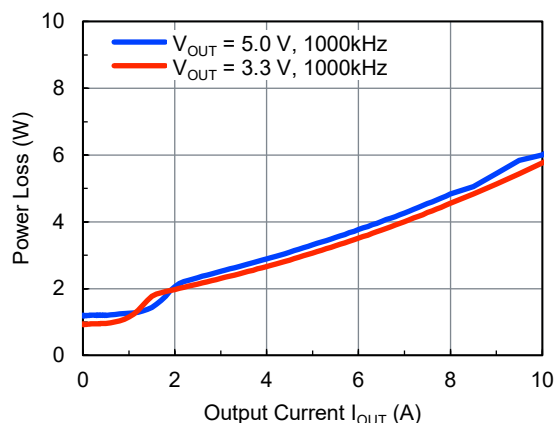


$V_{IN} = 24\text{ V}$

Efficiency vs Output Current

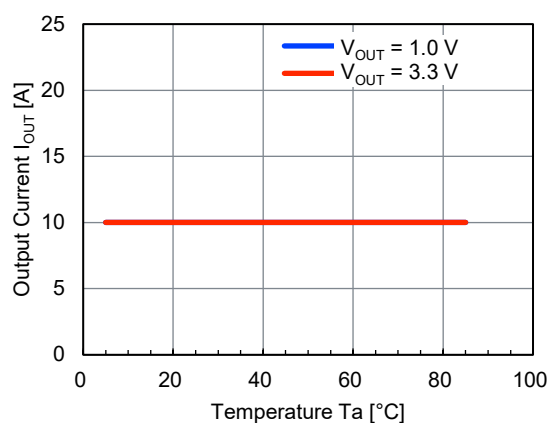


Power Loss vs Output Current

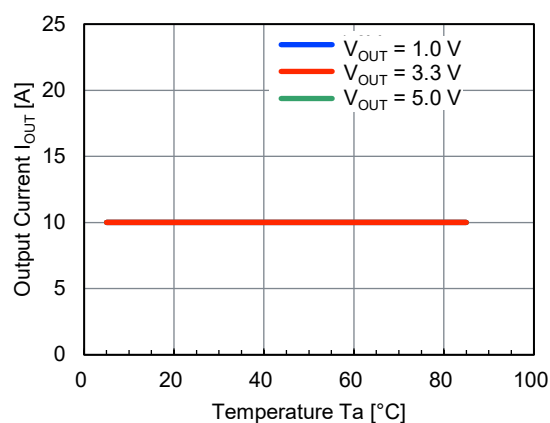


2) Maximum Current Temperature Dearthening

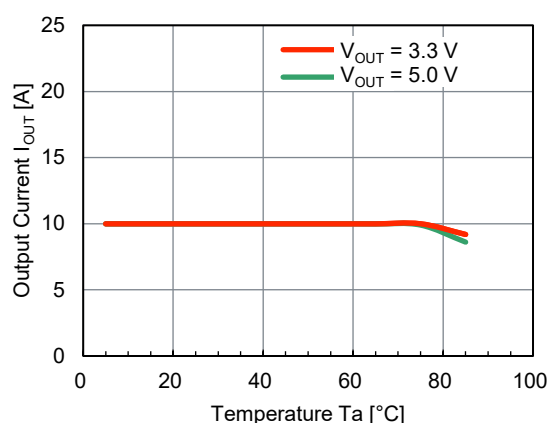
$V_{IN} = 5\text{ V}$



$V_{IN} = 12\text{ V}$



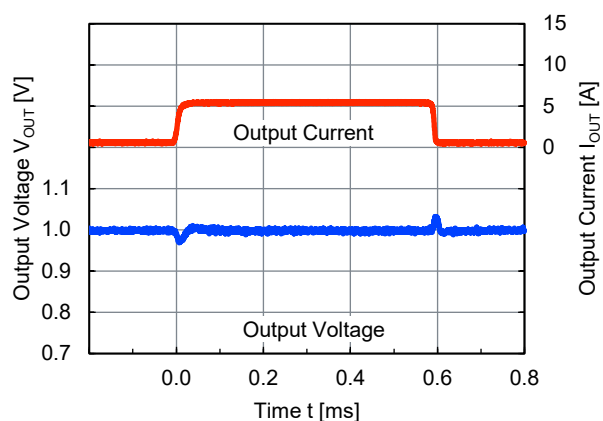
$V_{IN} = 24\text{ V}$



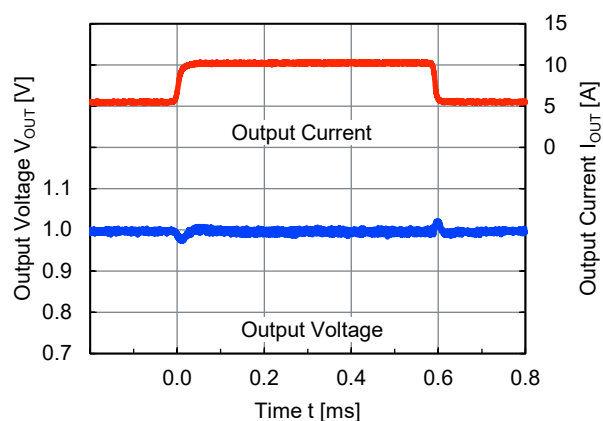
3) Load Transient Response

$V_{IN} = 5\text{ V}$, $V_{OUT} = 1\text{ V}$

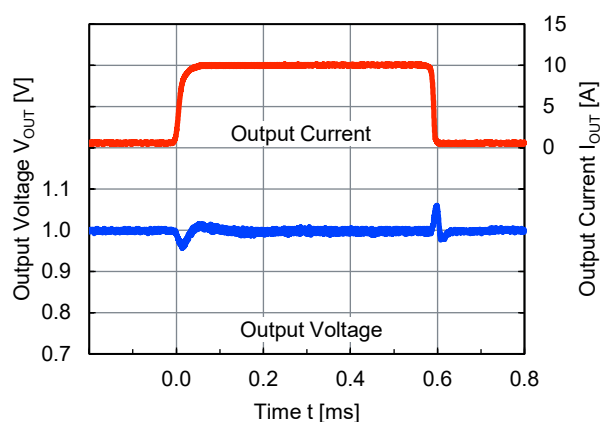
$I_{OUT} = 0\text{ A} \leftrightarrow 5\text{ A}$



$I_{OUT} = 5\text{ A} \leftrightarrow 10\text{ A}$

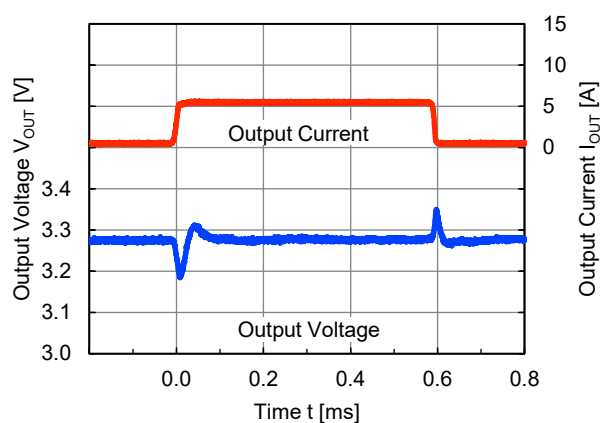


$I_{OUT} = 0\text{ A} \Leftrightarrow 10\text{ A}$

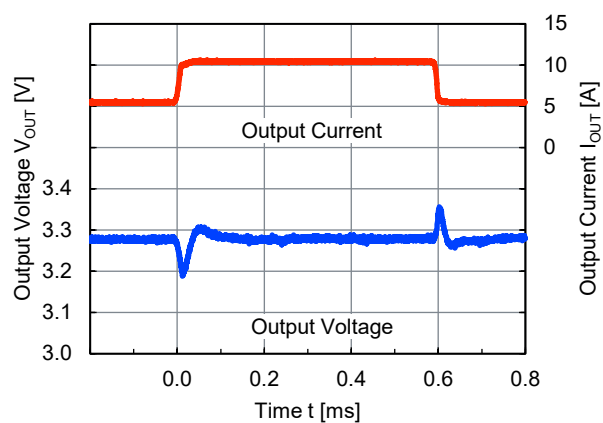


$V_{IN} = 5\text{ V}, V_{OUT} = 3.3\text{ V}$

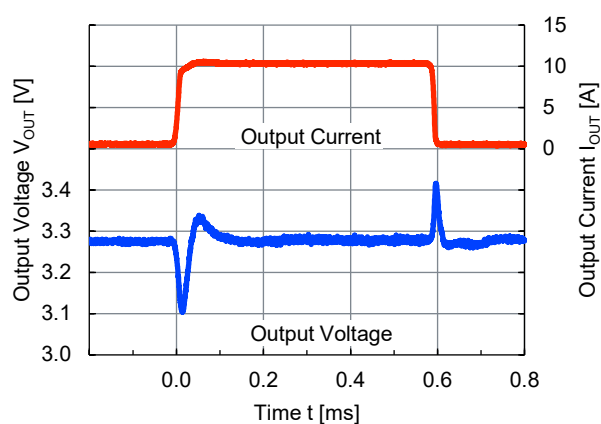
$I_{OUT} = 0\text{ A} \Leftrightarrow 5\text{ A}$



$I_{OUT} = 5\text{ A} \Leftrightarrow 10\text{ A}$

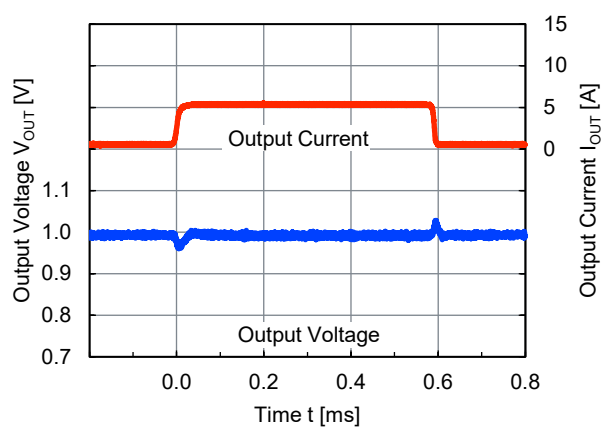


$I_{OUT} = 0\text{ A} \Leftrightarrow 10\text{ A}$

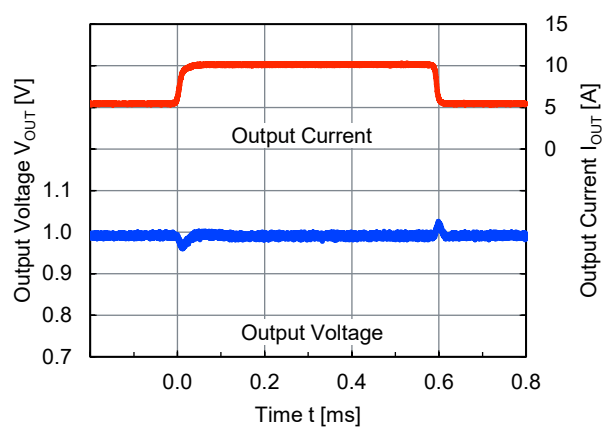


$V_{IN} = 12\text{ V}$, $V_{OUT} = 1\text{ V}$

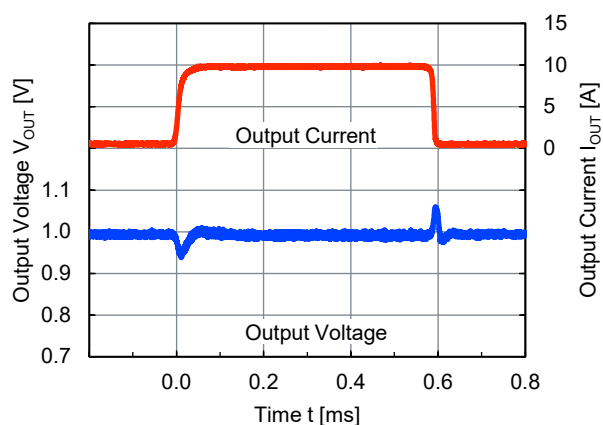
$I_{OUT} = 0\text{ A} \Leftrightarrow 5\text{ A}$



$I_{OUT} = 5\text{ A} \Leftrightarrow 10\text{ A}$

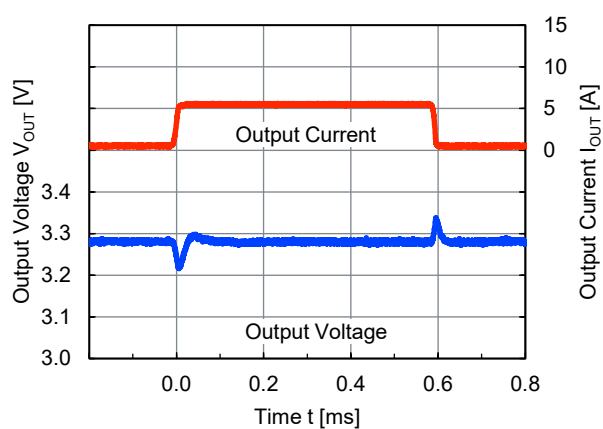


$I_{OUT} = 0\text{ A} \Leftrightarrow 10\text{ A}$

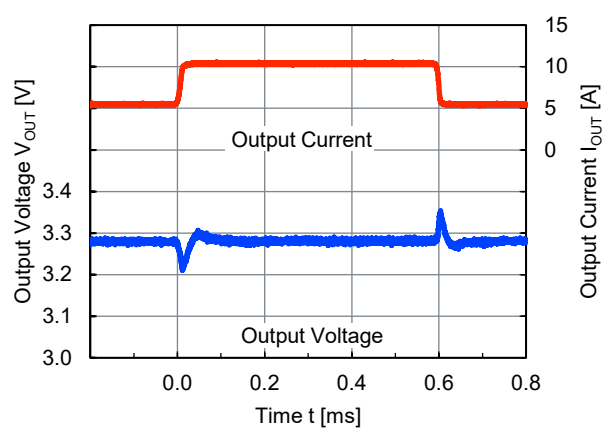


$V_{IN} = 12\text{ V}$, $V_{OUT} = 3.3\text{ V}$

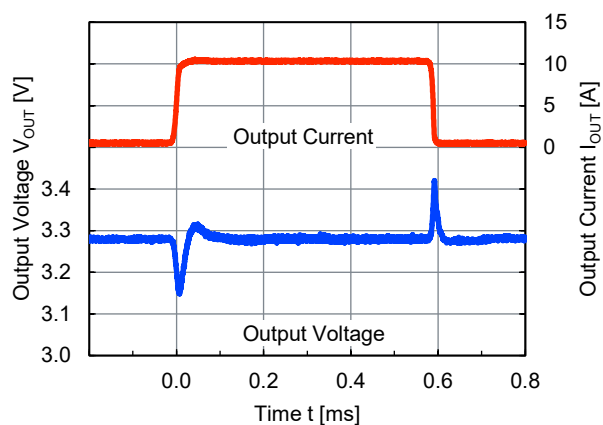
$I_{OUT} = 0\text{ A} \Leftrightarrow 5\text{ A}$



$I_{OUT} = 5\text{ A} \Leftrightarrow 10\text{ A}$



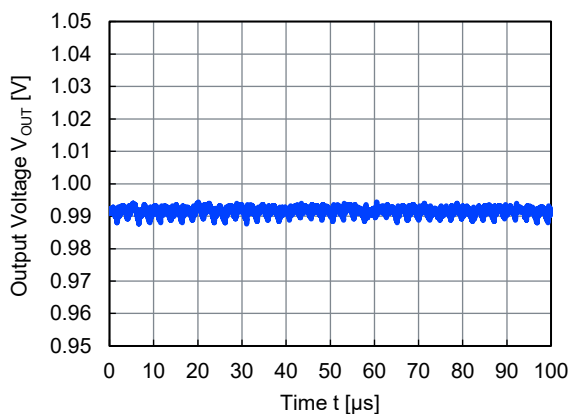
$I_{OUT} = 0\text{ A} \leftrightarrow 10\text{ A}$



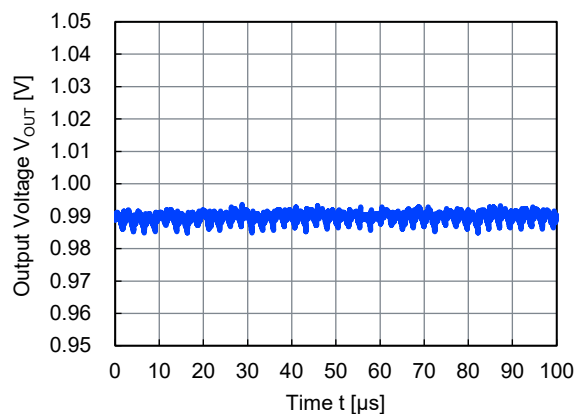
4) Output Voltage vs Time

$V_{IN} = 12\text{ V}$, $V_{OUT} = 1\text{ V}$

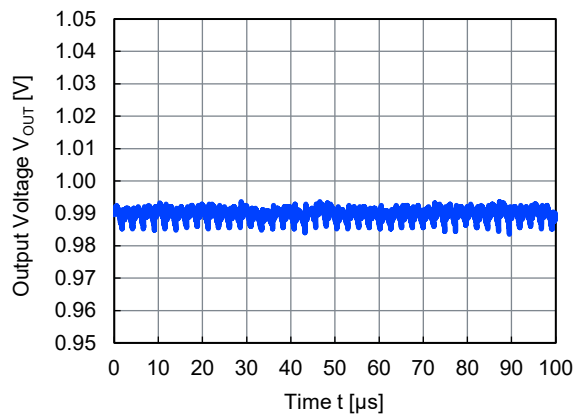
$I_{OUT} = 0\text{ A}$



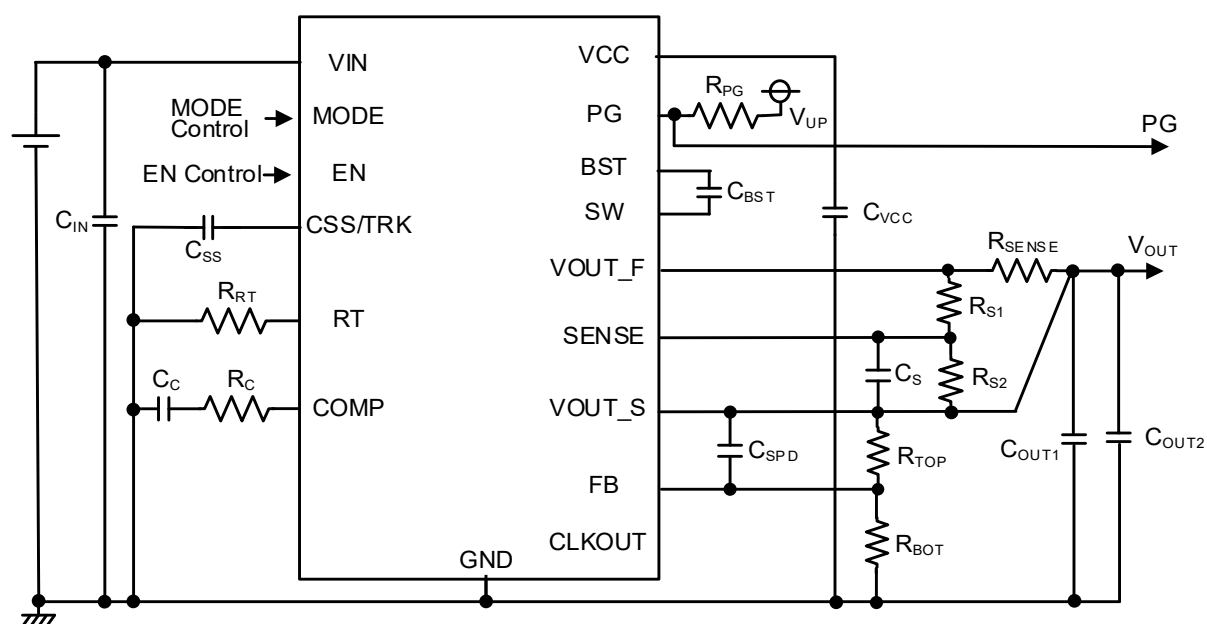
$I_{OUT} = 5\text{ A}$



$I_{OUT} = 10\text{ A}$



TEST CIRCUIT



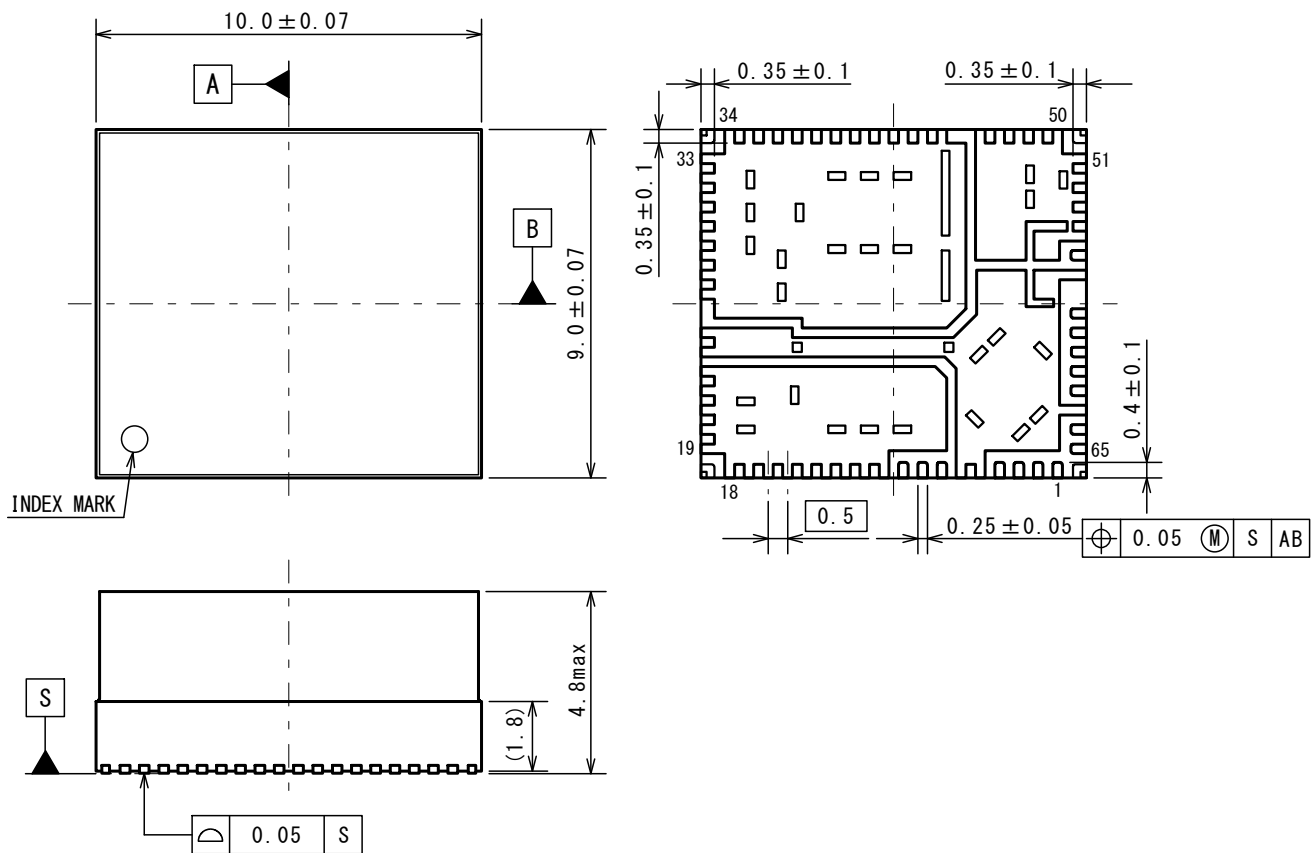
NC2701MA Test Circuit

Components List

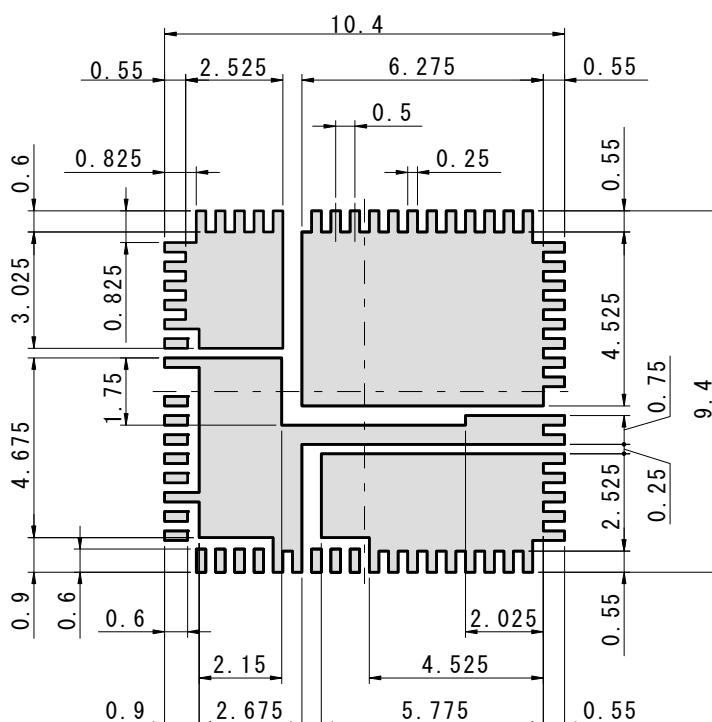
Symbol	Specification	Parts Number
C _{IN}	10 μ F	CGA6P3X7S1H106K
C _{OUT1}	47 μ F	C3225X7S1A476M
C _{OUT2}	120 μ F	EEFSX0J121E7
C _{VCC}	2.2 μ F	GCM21BR71E225KA73L
C _{BST}	0.22 μ H	GCM188R71E224KA55D

■ PACKAGE DIMENSIONS

UNIT: mm



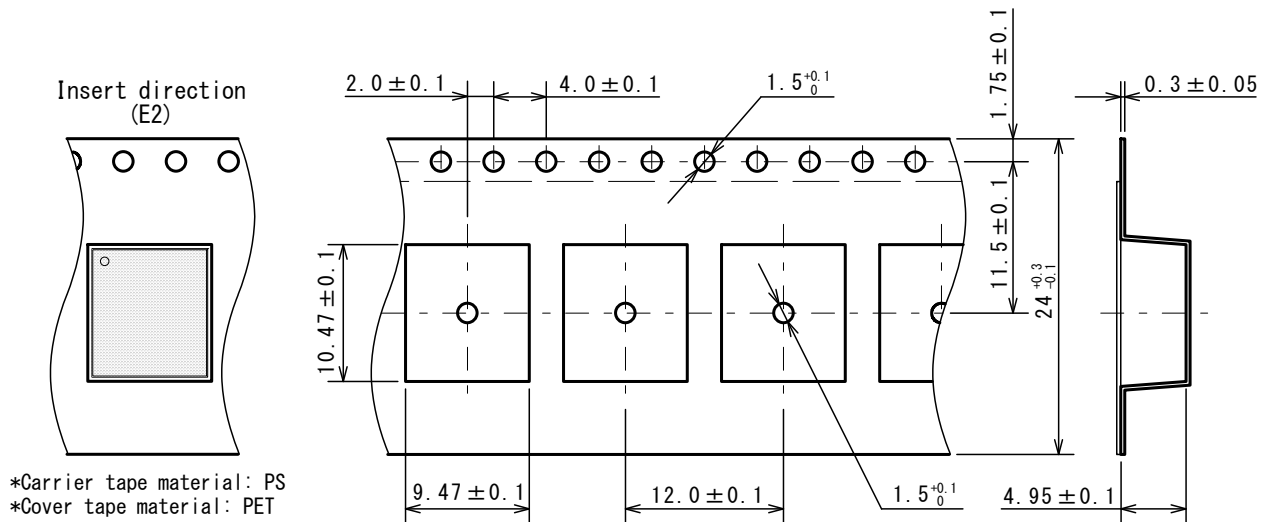
■ EXAMPLE OF SOLDER PADS DIMENSIONS



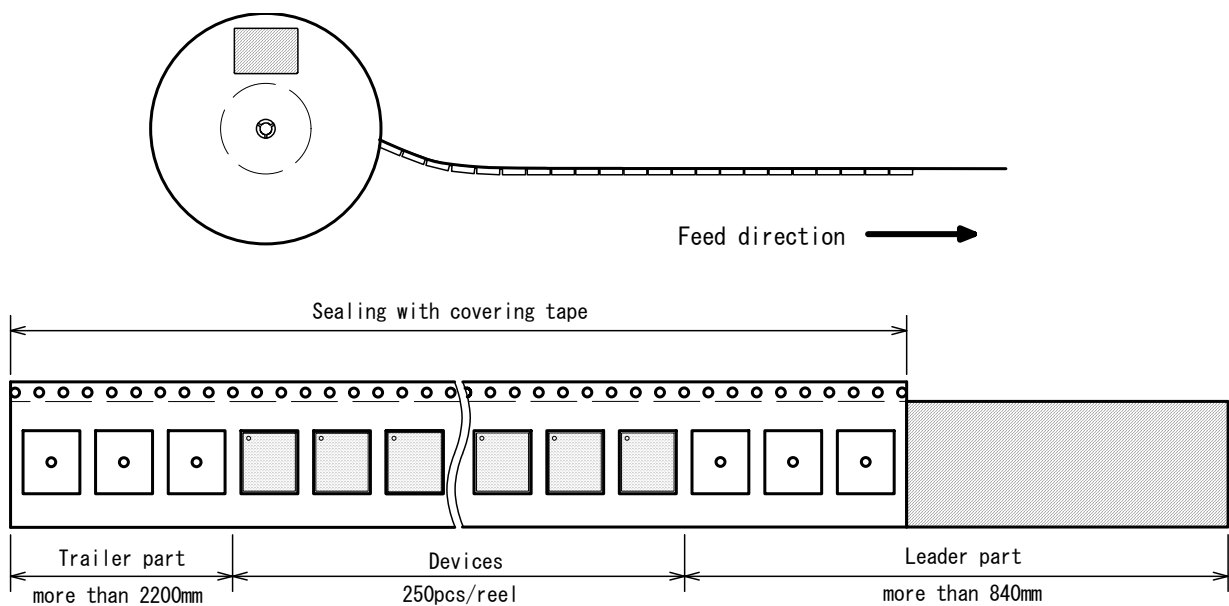
■ PACKING SPEC

UNIT: mm

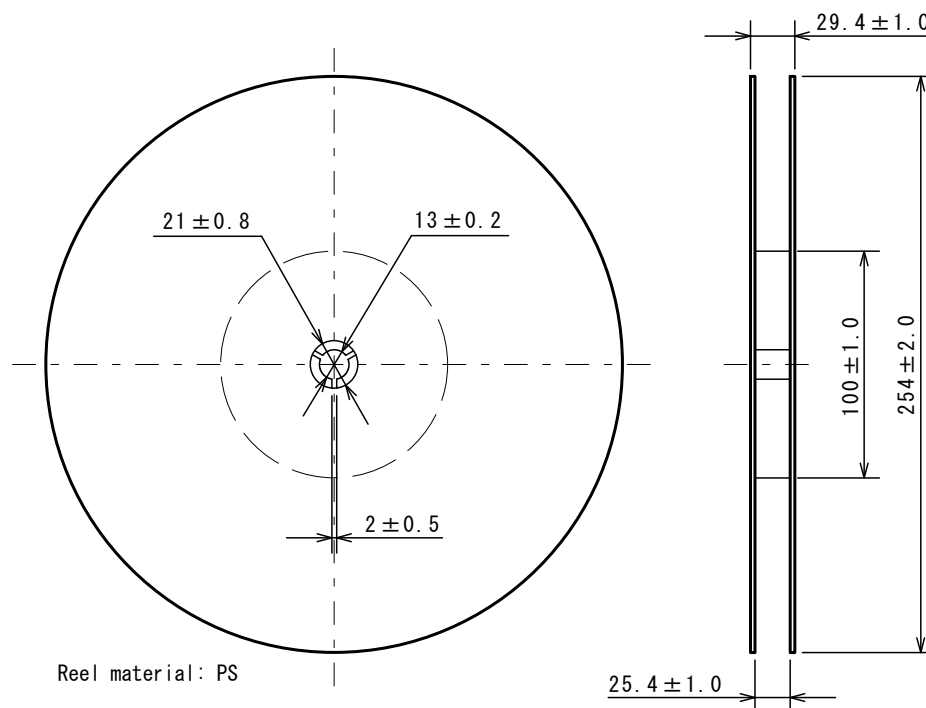
(1) Taping dimensions / Insert direction



(2) Taping state



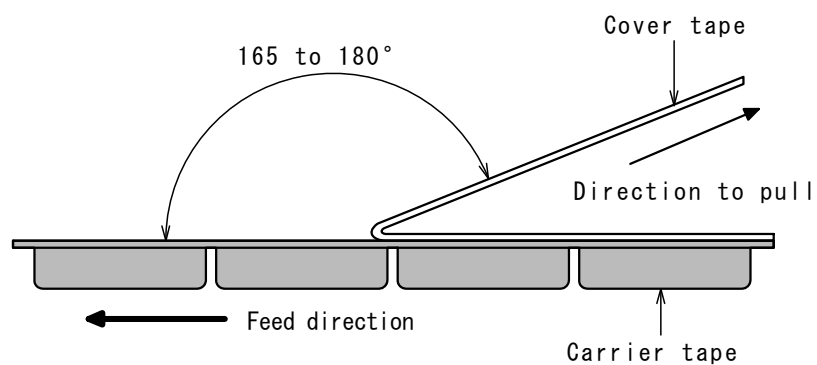
(3) Reel dimensions



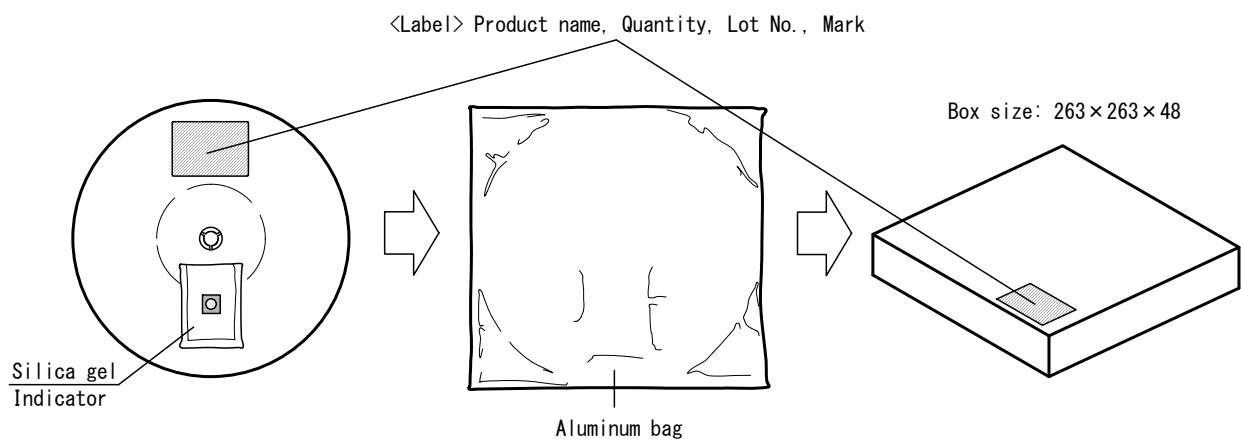
(4) Peeling strength

Peeling strength of cover tape

- Peeling angle 165 to 180° degrees to the taped surface.
- Peeling speed 300mm/min
- Peeling strength 0.1 to 1.3N

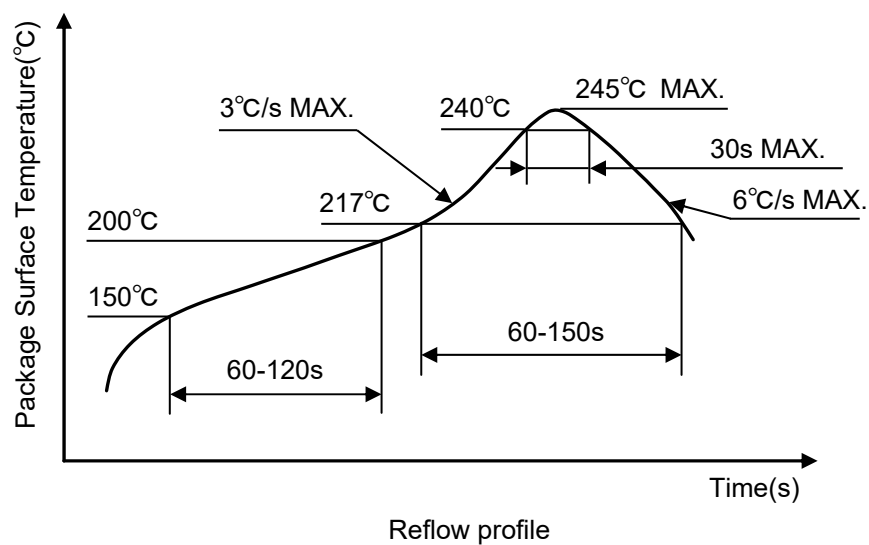


(5) Packing state



■ HEAT-RESISTANCE PROFILES

Reflow and Repair soldering method shall be within three times.



■ STORAGE CONDITION

1. Storage conditions

Before opening	Temperature:	5 to 40 (°C)
	Humidity:	45 to 90 (%)
After opening	Temperature:	5 to 30 (°C)
	Humidity:	45 to 60 (%)

Be sure to use within 1weeks (168h) after the open the anti-humidity seal.

2. Notes of IC storage

- (1) Do not use water for the tap for humidifiers, but use pure water or boiled water.
- (2) Do not store the devices in a corrosive-gas atmosphere.
- (3) Do not store the devices in a dusty place.
- (4) Do not expose devices to direct sunlight.
- (5) Maintain the temperature of the storage place stabilized.
- (6) Keep away from excessive load and impact.
- (7) Keep away from excessive electromagnetic radiation exposure.
- (8) When storing the tape packaging product which is used partially, do not roll up with excessive tension because it can influence the taping quality.

3. Storage period

Please mount devices within a year after delivering.

For the devices have stored longer than a year, check the corrosion of leads and solderability before using.

4. Baking Requirements

Baking prior to soldering reflow is required if the above storage term has been exceeded.

This package has a structure that makes it difficult to dehumidify. Please bake under the following baking conditions.

Baking condition at **125°C for 72hrs** should be used.

However, the tape and reel of the taping package of this product are not heat resistant.

Transfer to a heat-resistant container with a temperature of 125°C or higher before use.

<Notes>

Baking is limited to two times.

If more than three times baking is performed, be sure to confirm the solderability before use.

Package cracks may occur when reflow mounting a product that has absorbed moisture.

5. Moisture Sensitivity Levels

JEDEC: Level 3

Revision History

Date	Revision	Contents of Changes
Jun.12.2023	Ver. 1.0	Initial release

1. The products and the product specifications described in this document are subject to change or discontinuation of production without notice for reasons such as improvement. Therefore, before deciding to use the products, please refer to our sales representatives for the latest information thereon.
2. The materials in this document may not be copied or otherwise reproduced in whole or in part without the prior written consent of us.
3. This product and any technical information relating thereto are subject to complementary export controls (so-called KNOW controls) under the Foreign Exchange and Foreign Trade Law, and related politics ministerial ordinance of the law. (Note that the complementary export controls are inapplicable to any application-specific products, except rockets and pilotless aircraft, that are insusceptible to design or program changes.) Accordingly, when exporting or carrying abroad this product, follow the Foreign Exchange and Foreign Trade Control Law and its related regulations with respect to the complementary export controls.
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 - Power Generator Control Equipment (nuclear, steam, hydraulic, etc.)
 - Life Maintenance Medical Equipment
 - Fire Alarms / Intruder Detectors
 - Vehicle Control Equipment (automotive, airplane, railroad, ship, etc.)
 - Various Safety Devices
 - Traffic control system
 - Combustion equipment

In case your company desires to use this product for any applications other than general electronic equipment mentioned above, make sure to contact our company in advance. Note that the important requirements mentioned in this section are not applicable to cases where operation requirements such as application conditions are confirmed by our company in writing after consultation with your company.

6. We are making our continuous effort to improve the quality and reliability of our products, but semiconductor products are likely to fail with certain probability. In order to prevent any injury to persons or damages to property resulting from such failure, customers should be careful enough to incorporate safety measures in their design, such as redundancy feature, fire containment feature and fail-safe feature. We do not assume any liability or responsibility for any loss or damage arising from misuse or inappropriate use of the products.
7. The products have been designed and tested to function within controlled environmental conditions. Do not use products under conditions that deviate from methods or applications specified in this datasheet. Failure to employ the products in the proper applications can lead to deterioration, destruction or failure of the products. We shall not be responsible for any bodily injury, fires or accident, property damage or any consequential damages resulting from misuse or misapplication of the products.
8. **Quality Warranty**
 - 8-1. **Quality Warranty Period**
In the case of a product purchased through an authorized distributor or directly from us, the warranty period for this product shall be one (1) year after delivery to your company. For defective products that occurred during this period, we will take the quality warranty measures described in section 8-2. However, if there is an agreement on the warranty period in the basic transaction agreement, quality assurance agreement, delivery specifications, etc., it shall be followed.
 - 8-2. **Quality Warranty Remedies**
When it has been proved defective due to manufacturing factors as a result of defect analysis by us, we will either deliver a substitute for the defective product or refund the purchase price of the defective product.
Note that such delivery or refund is sole and exclusive remedies to your company for the defective product.
 - 8-3. **Remedies after Quality Warranty Period**
With respect to any defect of this product found after the quality warranty period, the defect will be analyzed by us. On the basis of the defect analysis results, the scope and amounts of damage shall be determined by mutual agreement of both parties. Then we will deal with upper limit in Section 8-2. This provision is not intended to limit any legal rights of your company.
9. Anti-radiation design is not implemented in the products described in this document.
10. The X-ray exposure can influence functions and characteristics of the products. Confirm the product functions and characteristics in the evaluation stage.
11. WLCSP products should be used in light shielded environments. The light exposure can influence functions and characteristics of the products under operation or storage.
12. Warning for handling Gallium and Arsenic (GaAs) products (Applying to GaAs MMIC, Photo Reflector). These products use Gallium (Ga) and Arsenic (As) which are specified as poisonous chemicals by law. For the prevention of a hazard, do not burn, destroy, or process chemically to make them as gas or power. When the product is disposed of, please follow the related regulation and do not mix this with general industrial waste or household waste.
13. Please contact our sales representatives should you have any questions or comments concerning the products or the technical information.



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