NJW1871A-T1

MOSFET DRIVE SWITCHING REGULATOR IC for BOOST / FLY-BACK CONVERTER

FEATURES

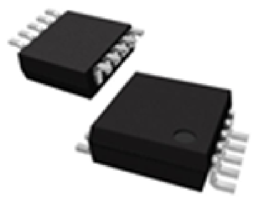
- AEC-Q100 Grade 1
- Wide Operating Voltage Range 4.5 to 40V
- Nch. MOSFET Drive Voltage 5.2V typ.
- Oscillating Frequency 1MHz to 2MHz
- Current Mode Control
- External Clock Synchronization
- PWM Control
- Soft Start Fixed 20ms typ.
- Adjustable Startup Voltage
- Overvoltage Protection
- Overcurrent Protection (Hiccup)
- Undervoltage Lockout (UVLO)
- Thermal Shutdown
- Standby Function
- Package MSOP10(VSP10)

APPLICATIONS

- Automotive
- Industrial Instruments
- Boost converter for small to middle range power supplies

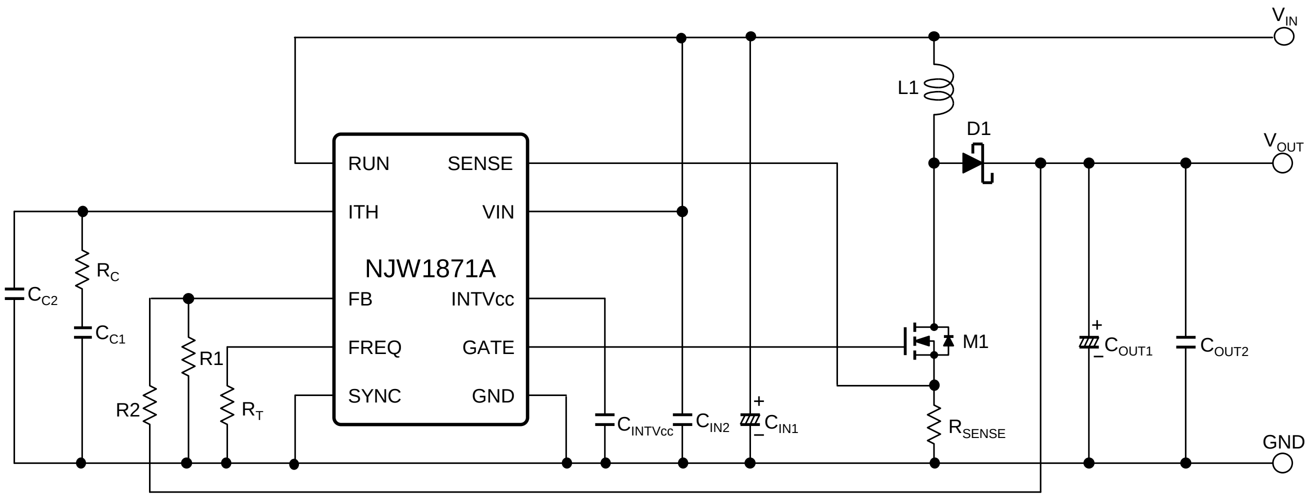
GENERAL DESCRIPTION

The NJW1871A is a MOSFET drive switching regulator IC for boost / fly-back converters that operates wide operating voltage range from 4.5V to 40V.
The internal Nch MOSFET driver circuit provides high efficiency driving, makes this device ideal for high output current applications.
The protection function is equipped with pulse-by-pulse overcurrent detection to limit the switching current at overload. Automatic recovery of switching is possible upon recovery of load abnormalities.
In addition, the high Oscillating frequency support allows AM band noise avoidance and small inductors to be used.
The NJW1871A is suitable for boost / fly-back applications such as automotive and industrial instruments and so on.



MSOP10(VSP10)
2.9×4.0×1.1(mm)

TYPICAL APPLICATION



■ PRODUCT NAME INFORMATION

NJW1871A R - T1 (TE2)

Part Number

Package
R: VSP

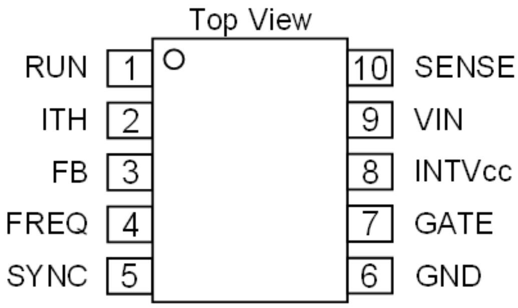
Grade
T1:Automotive

Taping Form

■ ORDER INFORMATION

PRODUCT NAME	PACKAGE	AUTO MOTIVE	RoHS	HALOGEN -FREE	PLATING COMPOSITION	WEIGHT (mg)	QUANTITY PER REEL (pcs/reel)
NJW1871AR-T1 (TE2)	MSOP10(VSP10)	○	Yes	Yes	Sn2Bi	21	2000

■ PIN DESCRIPTIONS



MSOP10(VSP10) Pin Configuration

Pin No.	Pin Name	Description
1	RUN	Start up control pin. ON/OFF control pin H level input : normal operation L level input : standby In addition, it is possible to set the startup voltage by dividing and inputting from the power supply line.
2	ITH	Error amplifier output pin. The capacitor and resistor for phase compensation should be connected between ITH pin and GND pin.
3	FB	Voltage feedback input. This pin detects the output voltage. The output voltage is divided and input so that the FB pin voltage becomes 0.8V typ.
4	FREQ	Oscillating frequency setting. Oscillation frequency setting pin to connect the timing resistor Set the oscillation frequency between 1MHz and 2MHz.
5	SYNC	When a clock signal is input from the outside, it operates at an oscillation frequency synchronized with this clock signal.
6	GND	Ground pin
7	GATE	Output pin for Power MOSFET driving
8	INTVcc	Internal 5.2V regulator output pin The capacitor of 0.01μF to 1μF should be connected between INTVcc pin and GND pin.
9	VIN	Power supply input pin Insert a bypass capacitor close to VIN pin - GND pin in order to lower the power supply line impedance.
10	SENSE	Current sensing pin When difference voltage between SENSE pin and GND pin exceeds 150mV typ., the over current protection operates.

■ ABSOLUTE MAXIMUM RATINGS

	Symbol	Ratings	Unit
Supply Voltage	V_{IN}	−0.3 to 45	V
INTVcc Pin Voltage	V_{INTVcc}	−0.3 to 11(1)	V
INTVcc Pin Output Current	I_{INTVcc}	50	mA
GATE Pin Voltage	V_{GATE}	−0.3 to V_{INTVcc} 0.3	V
GATE Pin Peak Current	I_{GATE_PEAK+} I_{GATE_PEAK-}	1800 (Source) 1500 (Sink)	mA
FB Pin Voltage	V_{FB}	−0.3 to 6	V
RUN Pin Voltage	V_{RUN}	−0.3 to 45	V
SYNC Pin Voltage	V_{SYNC}	−0.3 to 6	V
SENSE Pin Voltage	V_{SENSE}	−0.3 to 45	V
Junction Temperature Range*1	T_j	−40 to 150	°C
Storage Temperature Range	T_{stg}	−50 to 150	°C

(1) When Supply voltage is less than 11V, the absolute maximum INTVcc pin voltage is same to the Supply voltage.

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.

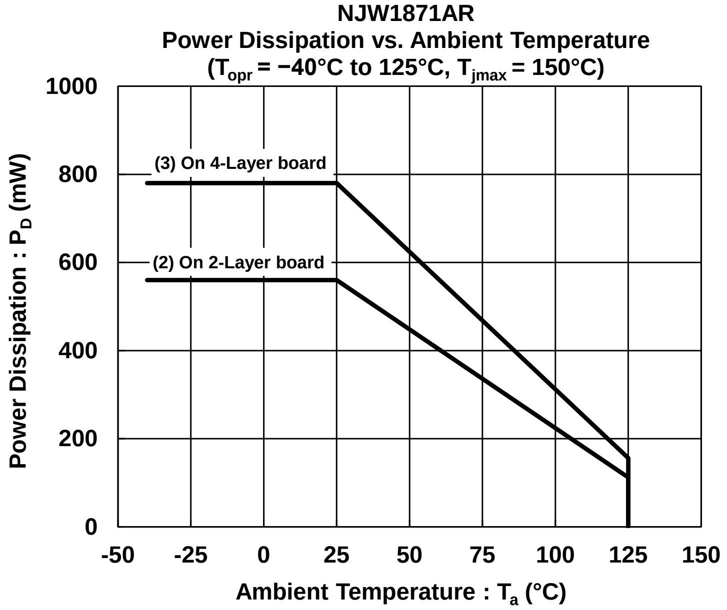
Please refer to "*THERMAL CHARACTERISTICS*" for the thermal resistance under our measurement board conditions.

■ THERMAL CHARACTERISTICS

Item	Symbol	Value	Unit
Junction-To-Ambient Thermal Resistance MSOP10(VSP10)	θ_{ja}	2-Layer / 4-Layer 224(2) / 159(3)	°C/W
Junction-To-Top of Package Characterization Parameter MSOP10(VSP10)	ψ_{jt}	2-Layer / 4-Layer 40(2) / 31(3)	°C/W

θja : Junction-to-Ambient Thermal Resistance
ψjt : Junction-to-Top Thermal Characterization Parameter

■ POWER DISSIPATION vs. AMBIENT TEMPERATURE



(2) 2-Layer: Mounted on glass epoxy board (76.2 mm × 114.3 mm × 1.6 mm: based on EIA/JEDEC standard, 2-layer FR-4).
(3) 4-Layer: Mounted on glass epoxy board (76.2 mm × 114.3 mm × 1.6 mm: based on EIA/JEDEC standard, 4-layer FR-4).

■ 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 EIAJ ED-4701. In the HBM method, ESD is applied using the power supply pin and GND pin as reference pins.

■ RECOMMENDED OPERATING CONDITIONS

	Symbol	Ratings	Unit
Supply Voltage	V_{IN}	4.5 to 40	V
Timing Resistor	R_T	10 to 23.2	kΩ
Operating Frequency	f_{OSC}	1000 to 2000	kHz
External Clock Input Range	f_{SYNC}	f_{OSC} × 0.9 to f_{OSC} × 1.9(4)	kHz
INTVcc Capacitor	C_{INTVcc}	0.01 to 1 (0.1µF typ.)	µF
Operating Temperature	T_{opr}	−40 to 125	°C

(4) The maximum value is 2800kHz.

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

V_{IN} = V_{INTVcc} = 5V, V_{RUN} = 1.5V, V_{SENSE} = 0V, V_{SYNC} = 0V, R_T = 10kΩ, T_a=25°C unless otherwise specified.

Parameter	Symbol	Test Conditions	MIN	TYP	MAX	Unit
GENERAL CHARACTERISTICS						
Quiescent Current	I_Q	V_{IN} = 12V, V_{FB} = 0.9V	-	1.2	1.7	mA
		V_{IN} = 12V, V_{FB} = 0.9V, T_a = −40°C to 125°C	-	-	1.7	
Standby Current	I_{Q_STBY}	V_{RUN} = 0V	-	10	20	μA
		V_{RUN} = 0V, T_a = −40°C to 125°C	-	-	20	
RUN CONTROL						
ON Threshold Voltage	V_{RUN+}	V_{RUN} = L → H	1.298	1.348	1.398	V
		V_{RUN} = L → H, T_a = −40°C to 125°C	1.298	-	1.398	
OFF Threshold Voltage	V_{RUN-}	V_{RUN} = H → L	1.223	1.248	1.273	V
		V_{RUN} = H → L, T_a = −40°C to 125°C	1.198	-	1.298	
Hysteresis Voltage	V_{RUN_HYS}		50	100	150	mV
Input Bias Current	I_{RUN}		-	1	60	nA
		T_a = −40°C to 125°C	-	-	60	
ERROR AMPLIFIER						
Reference Voltage	V_{FB}		−1.0%	0.8	+1.0%	V
		T_a = −40°C to 125°C	−2.0%	-	+2.0%	
Input Bias Current	I_{FB}		−0.1	-	0.1	μA
		T_a = −40°C to 125°C	−0.1	-	0.1	
Over Voltage Lockout	ΔV_{FB_OV}	V_{FB_OV} − V_{FB} in percent	2.5	6.0	10.0	%
		V_{FB_OV} − V_{FB} in percent, T_a = −40°C to 125°C	2.5	-	10.0	
Transconductance	gm	I_{TH} = ±5μA	-	650	-	μmho

■ ELECTRICAL CHARACTERISTICS

V_{IN} = V_{INTVcc} = 5V, V_{RUN} = 1.5V, V_{SENSE} = 0V, V_{SYNC} = 0V, R_T = 10kΩ, T_a=25°C unless otherwise specified.

Parameter	Symbol	Test conditions	MIN	TYP	MAX	Unit
SOFT START						
Soft Start Time	t_{SS}	V_{FB} = 0.75V	8	16	24	ms
		V_{FB} = 0.75V, T_a = −40°C to 125°C	5	-	35	
CURRENT SENSE						
Current Sense Threshold Voltage	V_{SENSE}		−8%	150	+8%	mV
		T_a = −40°C to 125°C	−12%	-	+12%	
Low Level Input Current	I_{SENSE_L}	V_{SENSE} = 0V	-	2	4	μA
		V_{SENSE} = 0V, T_a = −40°C to 125°C	-	-	4	
High Level Input Current	I_{SENSE_H}	V_{SENSE} = 30V	-	0.1	5	μA
		V_{SENSE} = 30V, T_a = −40°C to 125°C	-	-	5	
COOL DOWN Time	t_{COOL}		-	80	-	ms
OSCILLATOR						
Oscillating Frequency 1	f_{OSC1}	R_T = 23.2kΩ	900	1000	1100	kHz
		R_T = 23.2kΩ, T_a = −40°C to 125°C	900	-	1100	
Oscillating Frequency 2	f_{OSC2}	R_T = 10kΩ	1860	2000	2140	kHz
		R_T = 10kΩ, T_a = −40°C to 125°C	1860	-	2140	
PWM COMPARATOR						
Maximum Duty Cycle 1	D_{MAX1}	R_T = 23.2kΩ, V_{FB} = 0.7V, V_{ITH} = OPEN	89.5	93.5	96.5	%
		R_T = 23.2kΩ, V_{FB} = 0.7V, V_{ITH} = OPEN, T_a = −40°C to 125°C	89.5	-	96.5	
Maximum Duty Cycle 2	D_{MAX2}	R_T = 10kΩ, V_{FB} = 0.7V, V_{ITH} = OPEN	80.0	87.0	93.5	%
		R_T = 10kΩ, V_{FB} = 0.7V, V_{ITH} = OPEN, T_a = −40°C to 125°C	80.0	-	93.5	
Minimum ON Time	t_{ON_min}		-	70	120	ns
		T_a = −40°C to 125°C	-	-	130	
SYNC CONTROL						
Minimum Input Pulse Width	t_{SYNC_MIN}	V_{SYNC} = 0V → 5V	-	25	-	ns
Maximum Input Pulse Width	t_{SYNC_MAX}	V_{SYNC} = 0V → 5V	-	0.8 / f_{OSC}	-	ns
Low Level Input Voltage	V_{IL_SYNC}		0	-	0.5	V
		T_a = −40°C to 125°C	0	-	0.5	
High Level Input Voltage	V_{IH_SYNC}		1.2	-	5.5	V
		T_a = −40°C to 125°C	1.2	-	5.5	
Pull Down Resistance	R_{SYNC}		−30%	50	+30%	kΩ

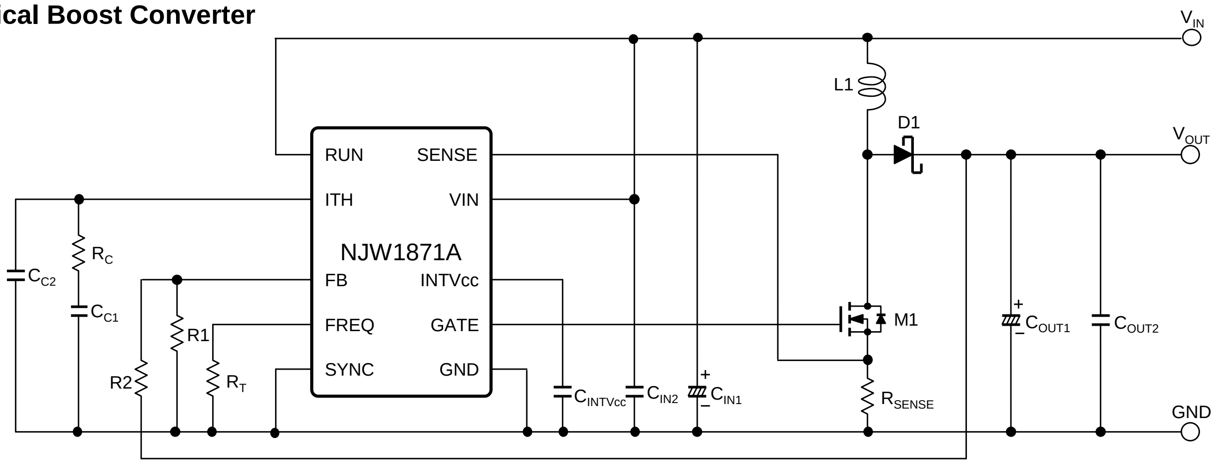
■ ELECTRICAL CHARACTERISTICS

VIN = VINTVcc = 5V, VRUN = 1.5V, VSENSE = 0V, VSYNC = 0V, RT = 10kΩ, Ta=25°C unless otherwise specified.

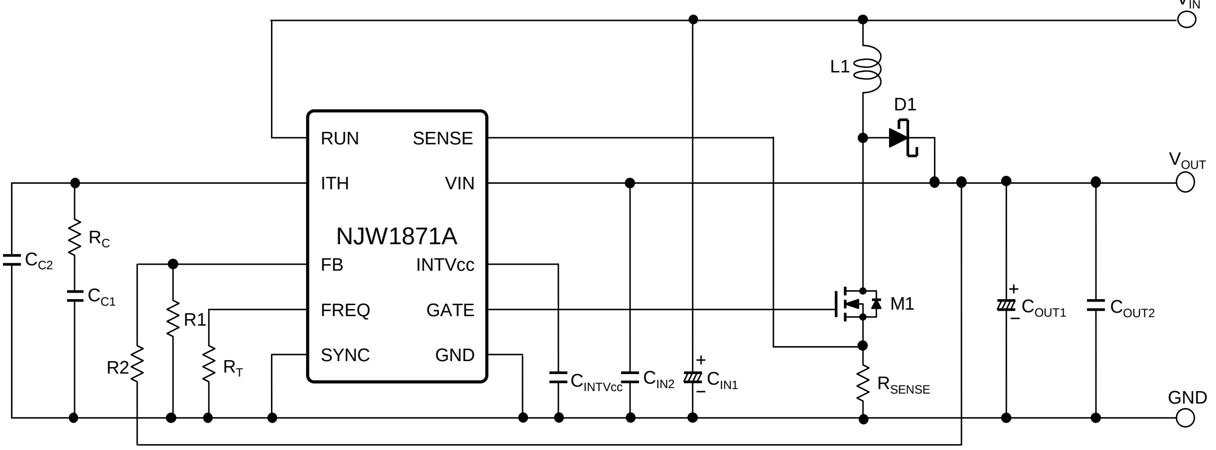
Parameter	Symbol	Test Conditions	MIN	TYP	MAX	Unit
LDO REGULATOR						
Output Voltage	V_{INTVcc}	V_{IN} = 7.5V	5.0	5.2	5.4	V
		V_{IN} = 7.5V, T_a = −40°C to 125°C	5.0	-	5.4	
UVLO OFF Threshold Voltage	V_{T_OFF}	V_{INTVcc} = L → H	4.0	4.2	4.5	V
		V_{INTVcc} = L → H, T_a = −40°C to 125°C	4.0	-	4.5	
UVLO ON Threshold Voltage	V_{T_ON}	V_{INTVcc} = H → L	3.5	3.7	4.0	V
		V_{INTVcc} = H → L, T_a = −40°C to 125°C	3.5	-	4.0	
UVLO Hysteresis Voltage	V_{HYS}		-	500	-	mV
Dropout Voltage	$V_{DROPOUT}$	V_{IN} = 5V, I_{INTVcc} = 20mA	110	210	400	mV
		V_{IN} = 5V, I_{INTVcc} = 20mA, T_a = −40°C to 125°C	50	-	500	
Bootstrap Mode INTVcc Quiescent Current	I_{INTVcc}	V_{RUN} = 0V, V_{SENSE} = 5V	-	10	20	μA
		V_{RUN} = 0V, V_{SENSE} = 5V, T_a = −40°C to 125°C	-	-	20	
GATE DRIVER						
High Side ON Resistance	R_{GATEH}	I_{GATE} = 50mA (Source)	-	1.5	3.0	Ω
		I_{GATE} = 50mA (Source), T_a = −40°C to 125°C	-	-	3.0	
Low Side ON Resistance	R_{GATEL}	I_{GATE} = 50mA (Sink)	-	1.1	2.5	Ω
		I_{GATE} = 50mA (Sink), T_a = −40°C to 125°C	-	-	2.5	
Pull Down Resistance	$R_{PD\text{-}GATE}$		-	500	-	kΩ

■ TYPICAL APPLICATION CIRCUIT

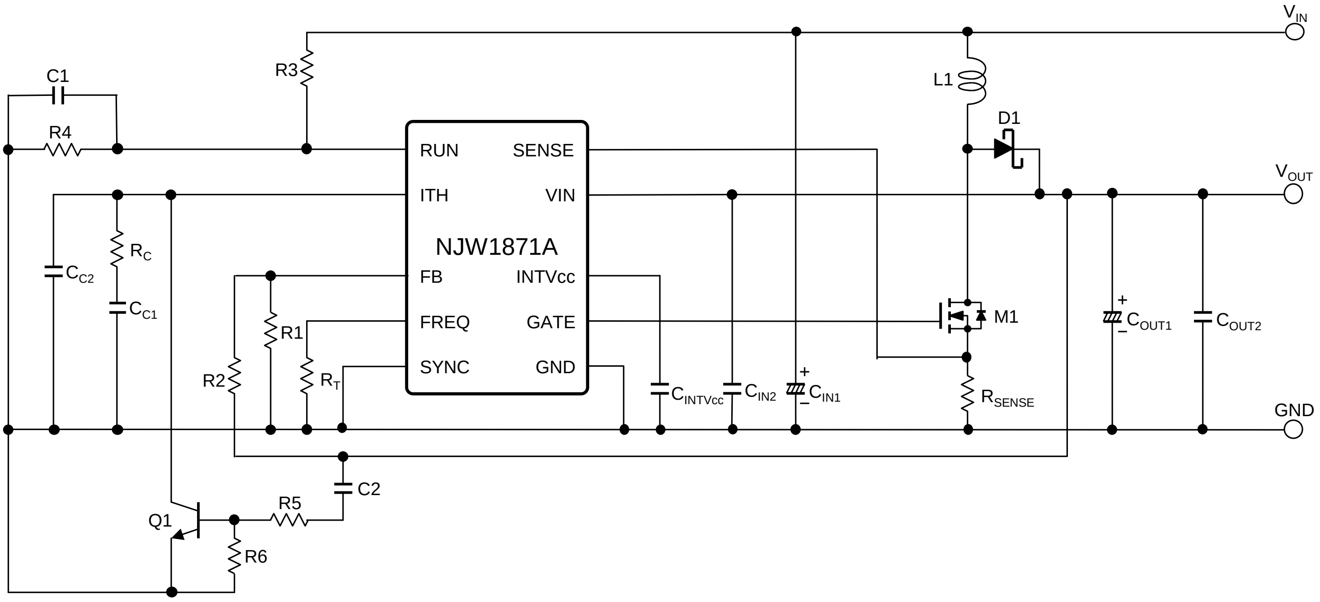
● Typical Boost Converter



● Power supply from the output voltage to the IC



● Adjustable start-up voltage and soft-start circuit

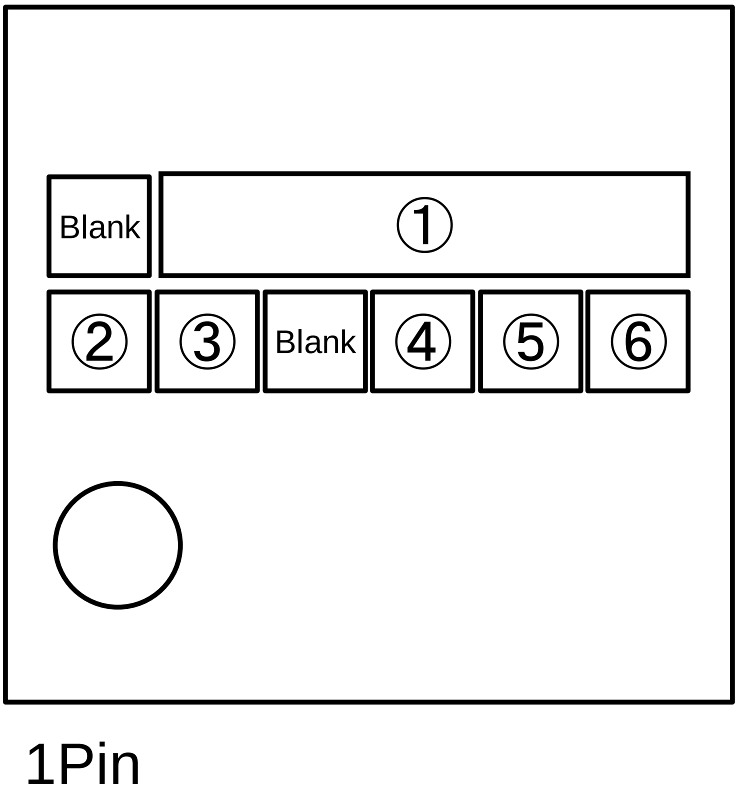


■ MARKING SPECIFICATION

①: Product code … Refer to *Part Marking List*

②③: Automotive device… Refer to *Part Marking List*

④⑤⑥: Lot Number … Alphanumeric Serial Number



MSOP10(VSP10) 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.

Part Marking List

Product Name	①	②	③	④	⑤	⑥
	1871A	T	1	P	0	1

■ FUNCTION DESCRIPTION

1. Basic Function

● Error Amplifier Section (Error AMP)

0.8V±1% high precision reference voltage is connected to non-inverted input of this section. The output voltage can be set by connection of converter's output to inverted input of this section (FB pin).

● Oscillating Circuit Section (OSC), PWM Comparator Section (PWM)

Oscillating frequency can be set by inserting resistor between the FREQ pin and GND. Table1 shows example of oscillating frequency and timing resistor. The resistor can be selected from E24 series or E96 series.

Table 1. NJW1871A oscillating frequency and timing resistor

Oscillating Frequency (kHz)	Timing Resistor (kΩ)	Oscillating Frequency (kHz)	Timing Resistor (kΩ)
1000	23.2	1600	13.3
1100	21	1700	12.4
1200	19.1	1800	11.5
1300	17.4	1900	10.7
1400	15.8	2000	10
1500	14.3		

When the switching regulator operates at high oscillating frequency, the application can use a small inductor and capacitor. If oscillating frequency is high, consider subject to efficiency reduction of the application and a restriction by minimum ON time. Since the minimum ON time of NJW1871A designed 70ns typ., it needs to select the oscillation frequency at which the ON time of the boost application become over 70ns.
The ON time of boost converter is calculated the following formula.

$$t_{ON} = \frac{V_{OUT} - V_{IN}}{V_{OUT} \times f_{OSC}} \ [s]$$

When the ON time of boost application becomes below in 70ns typ., it can cause duty fluctuation and pulse skipping in order to maintain output voltage at a stable state.

● **Driver Circuit, 5.2V Regulator (GATE pin, INTVcc pin)**

The output driver circuit is configured a totem pole type, it can efficiently drive an Nch. MOSFET switching device. When the output is high level, the GATE pin voltage is clamped with 5.2V typ. by the internal regulator to protect gate of the Nch. MOSFET.

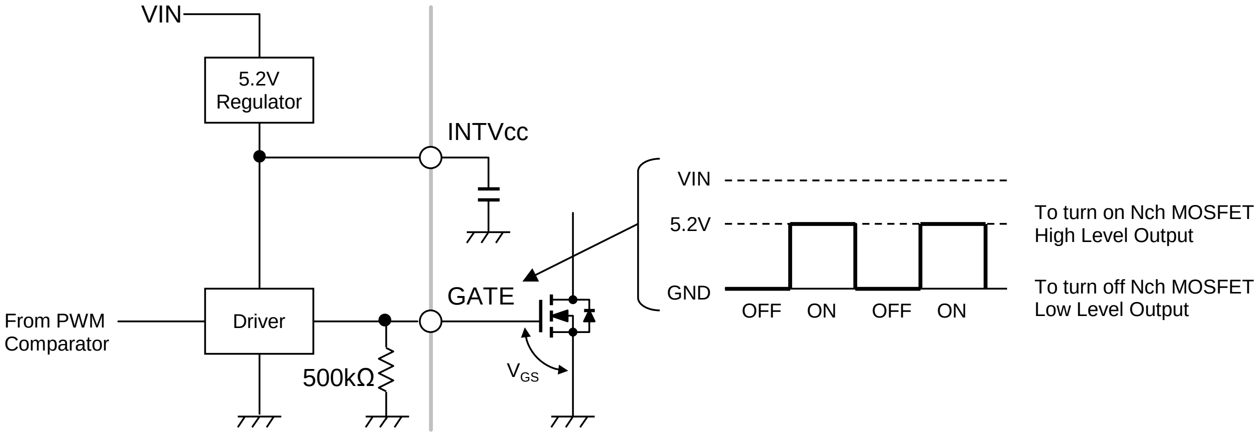


Figure 1. Driver Circuit and GATE Pin Voltage

Although gate drive voltage output from the gate pin decrease due to decrease supply voltage, the gate pin voltage is kept gate drive voltage by passing the internal regulator around supply voltage 5.2V. Figure 2 shows the example of the gate pin voltage vs. supply voltage characteristics. The optimum drive ability of MOSFET depends on the oscillation frequency and the gate capacitance of MOSFET.

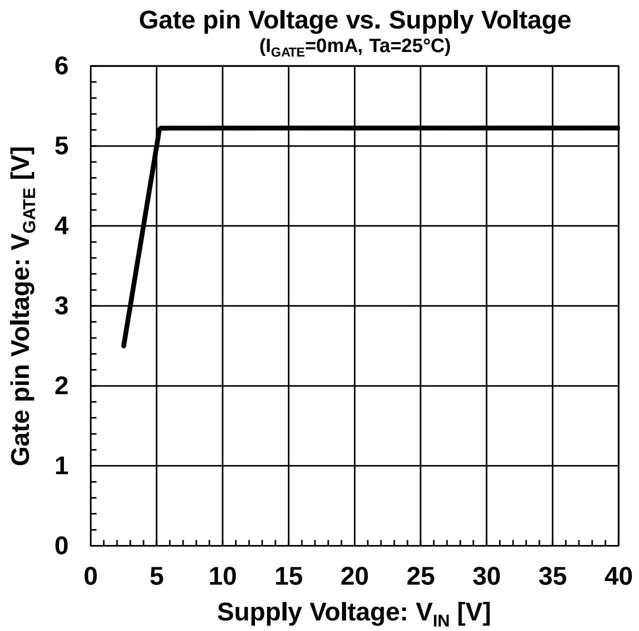


Figure 2. Gate Pin Voltage vs. Supply Voltage

2. Protection Function

● Overvoltage Protection (OVP)

Prevent the overvoltage when normal control of output voltage isn't performed due to any reasons. While FB pin voltage exceeds 0.848V typ., driving of the power MOSFET is stopped.

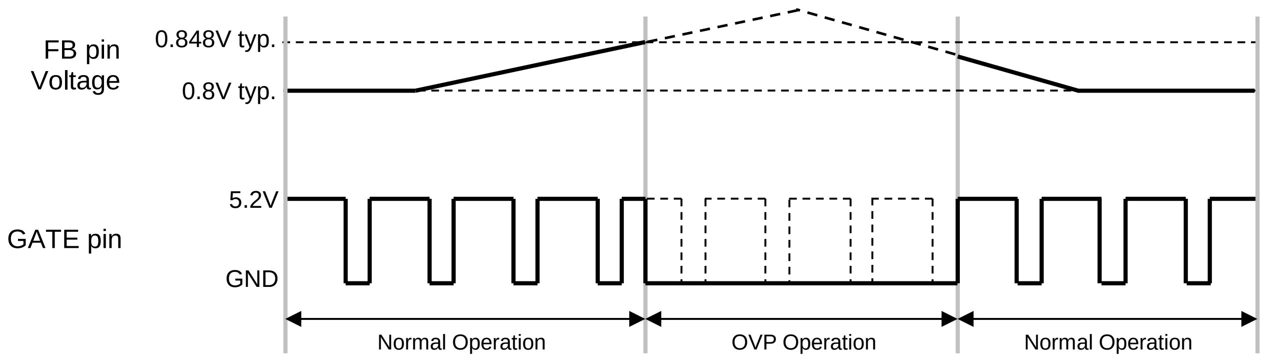


Figure 3. OVP Timing Chart (Assumes function stop of Error AMP)

● Undervoltage Lockout (UVLO)

When the voltage value of the internal regulator output (VINTVcc) becomes lower than a certain level due to the input of a low power supply voltage, etc., the operation other than the internal regulator circuit is stopped by UVLO circuit. The UVLO circuit is released when the internal regulator output voltage (VINTVcc) exceeds 4.2V typ., and returns to normal operation. There is 500mV typ. hysteresis voltage between detection and release to prevent the malfunction.

● Thermal Shutdown (TSD)

When Junction temperature exceeds the 160°C typ., switching operation is stopped by internal thermal shutdown circuit.
When junction temperature decreases to 145°C typ. or less, switching operation is returned with soft start function.
The thermal shutdown function is a preliminary circuit to prevent thermal runaway of the IC at high temperature and not to compensate for inappropriate thermal design. Thermal design should be designed with a margin to operate within IC junction temperature (up to 150°C).

● Overcurrent Protection (OCP)

When the potential difference between the SENSE pin and the GND pin becomes 150mV typical or more, the overcurrent protection circuit stops the switch output. The switching current is detected by inserted current sensing resistor (RSENSE) between the SENSE pin and the GND pin. The NJW1871A contains hiccup overcurrent protection and decrease heat generation at the overload. Then, output voltage of the switching regulator returns automatically when recovering from an abnormal state. If the overcurrent is detected continuously for 8 pulses while the FB pin voltage is 0.6V typ. or less, the overcurrent protection function turns off the MOSFET. After stopping, NJW1871A restarts with soft start after the cool down time of 60ms typ.

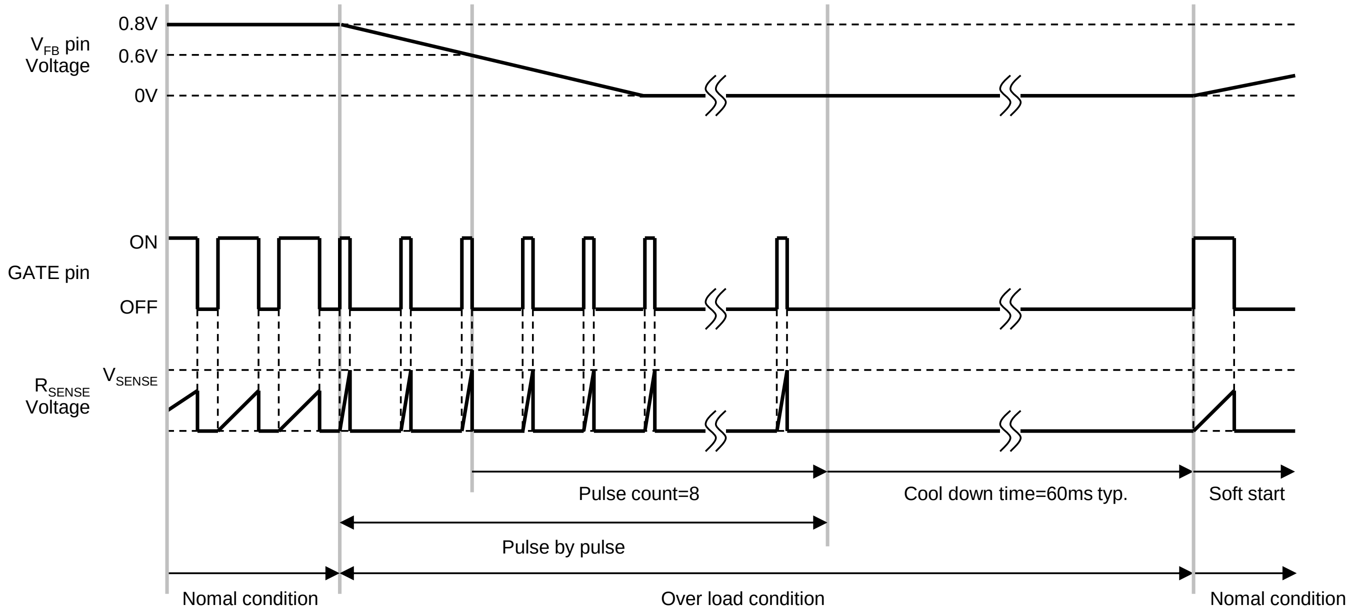


Figure 4. OCP Timing Chart

The current waveform contains high frequency superimposed noises due to the parasitic elements of MOSFET, the inductor and the others. Depending on the application, inserting RC low-pass filter between current sensing resistor (RSENSE) and the SENSE pin to prevent the malfunction due to such noise. The time constant of RC low-pass filter should be equivalent to the spike width ($t \leq R \times C$) as a rough guide.

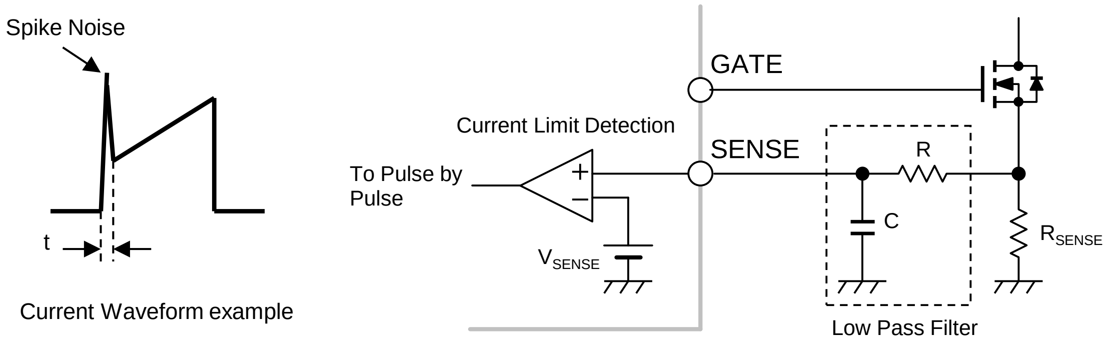


Figure 5. Current Waveform and Filter Circuit

3. Additional Function

● Soft Start

The output voltage rises gradually to the setting value by the soft start function. The soft start time is 20ms typ. and it is defined as the time until error amplifier reference voltage reaches 0V to 0.75V. The soft start circuit operates under the following conditions.

- After releasing UVLO
- After restoration from thermal shutdown
- After restoration from standby state
- After restoration from the cool down state

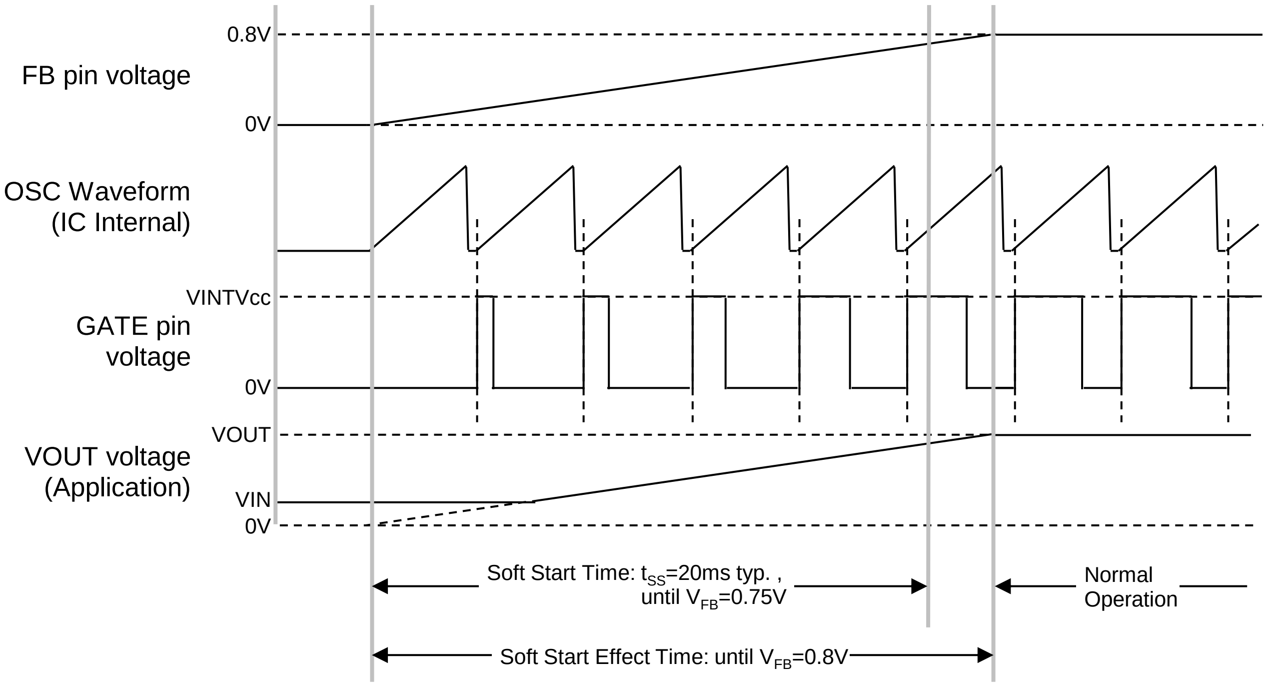


Figure 6. Soft Start Timing Chart

● Standby Function (RUN pin)

The standby function controls standby state by the RUN pin. The device turns into standby mode when the input voltage at the RUN pin is below the threshold voltage (1.248V typ.). As shown in the application circuit example (startup voltage change circuit), startup voltage of input voltage can be adjusted by setting the voltage dividing resistors R3 and R4 from the power supply line.

$$V_{IN(OFF)} = 1.248V \times \left(1 + \frac{R_3}{R_4}\right)$$

$$V_{IN(ON)} = 1.348V \times \left(1 + \frac{R_3}{R_4}\right)$$

If standby function is not required, connect the RUN pin to the VIN pin.

● INTVcc pin

The internal power supply regulator outputs 5.2V and supplies power to the gate driver in the NJW1871A. The internal power supply regulator can supply up to 50mA. Insert a ceramic capacitor to GND nearby the INTVcc pin. The INTVcc pin and VIN pin can be shorted directly if the input power does not exceed the absolute maximum ratings. When the INTVcc pin and VIN pin are shorted, 10μA flows to the INTVcc pin even the device is in the standby mode. Therefore, do not connect the INTVcc and the VIN pins in applications where standby current needs to be minimized. In addition, it is also necessary to insert a ceramic capacitor nearby the INTVcc pin when shorting the INTVcc pin and the VIN pin.

● External Synchronous

By inputting a square-wave to the SYNC pin, the oscillator of the NJW1871A can be synchronized to the external frequency. The square-wave needs to meet the specifications in Table 2.

Table 2. Square-Wave Inputs to the SYNC Pin

Item	Conditions
Input Frequency	f_{OSC}× 0.9 to f_{OSC} ×1.9(Upper limit is 2800 kHz)
Input Pulse Width	25ns to 0.8/f_{OSC}
Input Voltage AM plitude	Over than 1.2(High Level) Less than 0.5V(Low Level)

Switching operation during external synchronization is triggered on the rising edge of the SYNC input signal. In order to prevent a malfunction, a delay time is provided for switching between the asynchronous operation and external synchronous operation. Table 3 shows the delay time with respect to the oscillation frequency, and Figure 7 shows the timing chart.

Table 3. Oscillating Frequency and Delay Time

Oscillating Frequency(kHz)	Delay Time
1000	3μs to 12μs
2000	2μs to 6μs

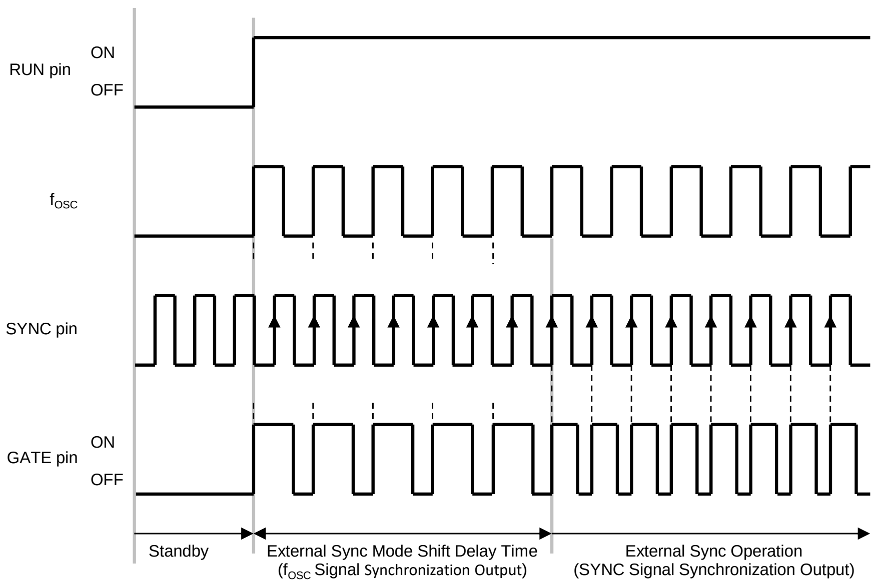


Figure 7. Switching Operation by External Synchronized Clock

● Inductor

Since large current flows in the inductor, it is necessary to have current capability that does not saturate. In the case of small inductor value, the peak current increases and conversion efficiency tends to decrease. The peak current is calculated by the following formula.

$$I_{IN} = \frac{V_{OUT} \times I_{OUT}}{\eta \times V_{IN}} \text{ [A]}$$

$$\Delta I_L = \frac{(V_{OUT} - V_{IN}) \times V_{IN}}{L \times V_{OUT} \times f_{OSC}} \text{ [A]}$$

$$I_{PK} = I_{IN} + \frac{\Delta I_L}{2} \text{ [A]}$$

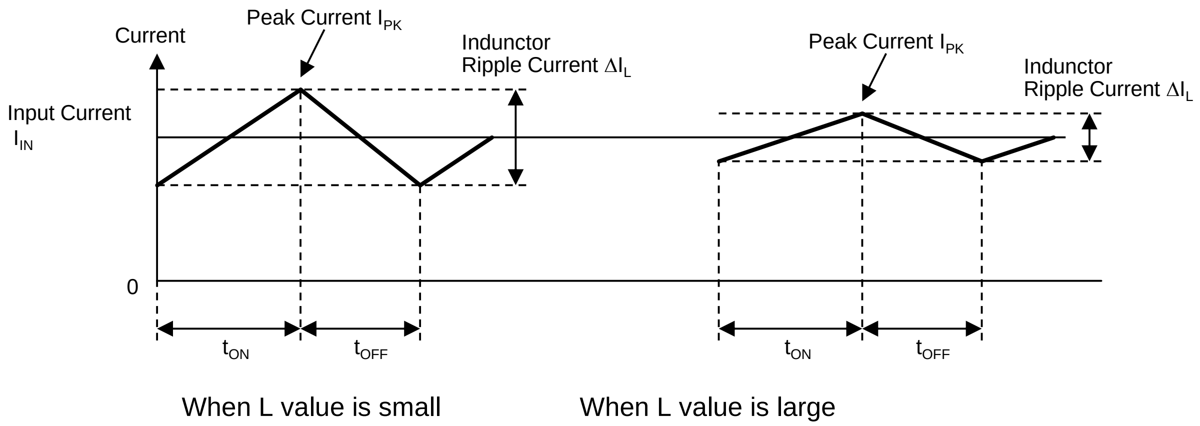


Figure 8. Inductor Current State Transition (Continuous Conduction Mode)

In many cases, the value of the inductor is determined by input voltage, output voltage, oscillation voltage, and RSENSE. The inductor value is calculated by the following formula.

Lower Limit Value of Inductance : $(4.79\ V_{OUT} - 7.27\ V_{IN}) \times \frac{R_{SENSE}}{f_{OSC}}$
Higher Limit Value of Inductance : $(26.79\ V_{OUT} - 7.27\ V_{IN}) \times \frac{R_{SENSE}}{f_{OSC}}$

The Inductor value is the theoretical value. This value varies depending on application specifications and applications, adjusting it on the actual device.

● Setting of Output voltage

The output voltage V_{OUT} is determined by the relative resistances of R1 and R2.The currents flowing through R1 and R2 need to be sufficiently larger than the bias current of the error amplifier. The output voltage is calculated by the following formula.

$$V_{OUT} = \left[\frac{R2}{R1} + 1\right] \times V_{FB} \text{ [V]}$$

■ APPLICATION NOTE

● Input Capacitor

Transient current depending on the frequency flows at the input section of the switching regulator. If the power supply line impedance is high, it will lead to input voltage fluctuations and the performance of the NJW1871A cannot be fully drawn out. Therefore, insert an input capacitor as close to the IC as possible. A ceramic capacitor is the optimal for input capacitor. The ripple input current is calculated by the following formula.

$$I_{RMS\_CIN} = 0.3 \times \Delta I_L \text{ [A]}$$

● Output Capacitor

The output capacitor is responsible for storing power from the inductor and for stabilizing the supply voltage to the output. To select the output capacitor, consider the characteristics of ESR (Equivalent Series Resistance), ripple current, and breakdown voltage.
In most cases, either one type of capacitor, ceramic or electrolytic, will be sufficient to operate the application.
Ceramic capacitors have a low ESR and can reduce ripple voltage.
However, since their capacitance decreases with DC voltage application and temperature change, please check their characteristics with the specification sheet.
Electrolytic capacitors are used in applications that require large output capacitance because they are relatively small even with large capacitance.
Select components with low ESR characteristics to reduce ripple voltage.
However, since ESR is higher than that of ceramic capacitors, check the ripple voltage when using them.
If the ripple voltage is higher than required, connect ceramic capacitors in parallel to lower the ripple voltage.
The capacitance of a ceramic capacitor is calculated by the following formula.

$$C_{OUT} = \frac{30}{V_{OUT} \times f_{OSC}} \times 10^6 \text{ [μF]}$$

The output ripple voltage is calculated by the following formula.

$$V_{ripple(p-p)} = ESR \times I_{PK} + \frac{I_{OUT}}{C_{OUT}} \times t_{ON} \text{ [V]}$$

The effective value of ripple current is calculated by the following formula.

$$I_{RMS\_CONT} = I_{OUT} \times \sqrt{\frac{V_{OUT} - V_{IN}}{V_{IN}}} \text{ [A]}$$

● Power Supply, GND pin (VIN pin, GND pin)

With the switching operation, switching current flows into the IC depends on oscillation frequency. If the impedance of power supply line is high, IC performance will not be drawn out due to input voltage fluctuation. Therefore insert an input capacitor close to the VIN pin - the GND pin connection in order to lower high frequency impedance.

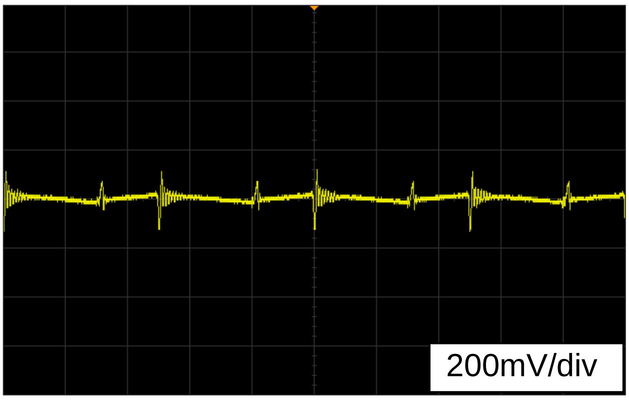
● Catch Diode

During the OFF cycle of the power MOSFET, the power stored in the inductor flows through the catch diode into the output capacitor. Therefore, electric current depending on the load current flows into the diode every OFF cycle. Since a diode's forward saturation voltage and the current accumulation cause power loss, a SBD (Schottky Barrier Diode) which has a low forward saturation voltage is the most suitable. During the ON cycle of the MOSFET, reverse voltage is applied to the diode. Considering the margin for the withstand voltage of the diode with respect to the output voltage. The SBD has a large increase in reverse current characteristics at high temperatures compared to general diodes. Depending on the operating conditions of the application, efficiency may be improved by emphasizing reverse current characteristics rather than forward saturation voltage.

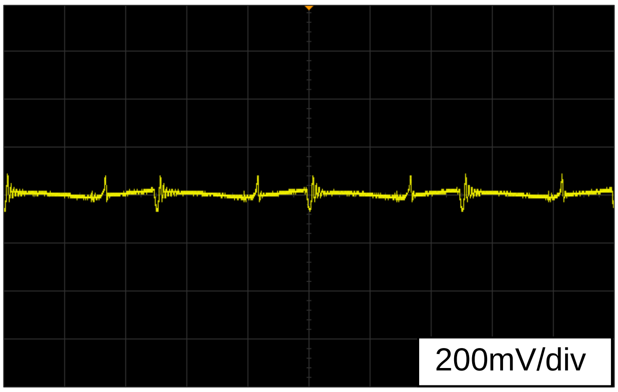
● **Switching Element**

For switching element, use Nch MOSFET specified for switching applications. The GATE pin voltage of NJW1871A is limited to 5.2V typ., thus select a MOSFET with a gate-source voltage less than 5.2V and a sufficiently low drain-source ON resistance. The gate drive voltage output from the GATE pin decreases as the power supply voltage of the NJW1871A becomes lower; therefore, determine MOSFET usage according to the input voltage range. A large gate capacity leads to reduction in efficiency. Switching loss will occur due to delay of the time rising/falling by discharging current to gate capacity. Additionally, a parasitic inductance component may cause spike noise when the gate capacitance charge/discharge is accompanied by a rapid current change. If the gate capacitance is small, insert a resistor R_G between a GATE pin and a gate to limit the current moderately. When inserting a gate resistor, 10Ω is recommended; provided that the waveform is blunted due to a resistance and the efficiency is reduced, determine the optimum value by actual machine evaluation.

<Output Voltage Spike Waveform (at V_{IN}=5V, V_{OUT}=12V, I_{OUT}=2A, f_{OSC}=2MHz)>

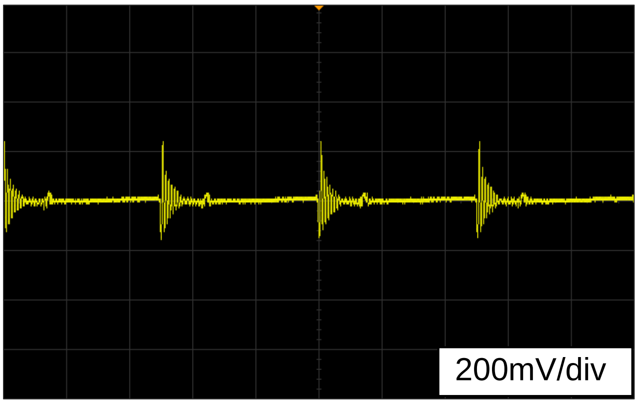


No Gate Resistance

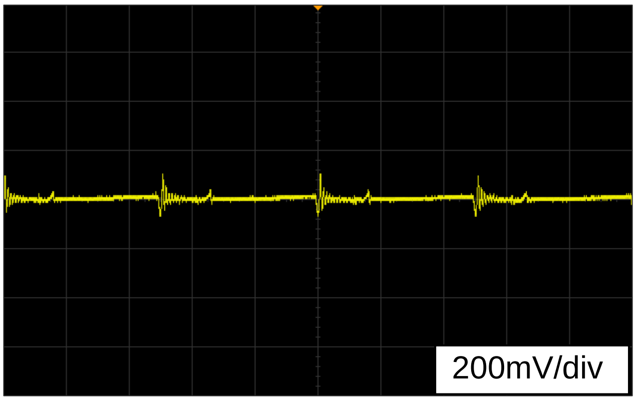


With Gate Resistance 10Ω

<Output Voltage Spike Waveform (at V_{IN}=9V, V_{OUT}=12V, I_{OUT}=2A, f_{OSC}=2MHz)>

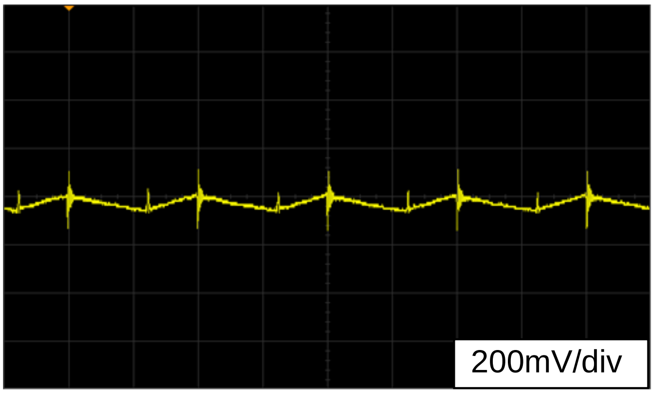


No Gate Resistance

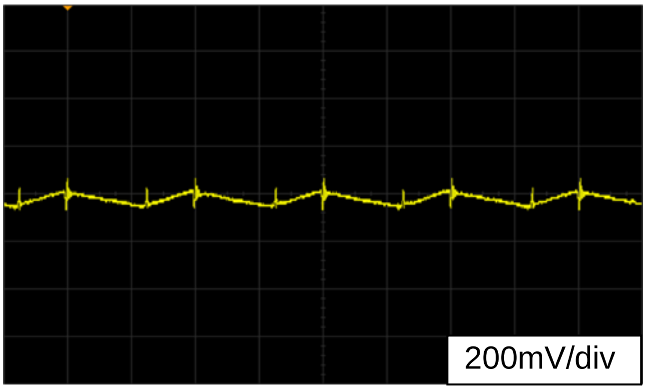


With Gate Resistance 10Ω

<Output Voltage Spike Waveform (at V_{IN}=5V, V_{OUT}=12V, I_{OUT}=2A, f_{OSC}=1MHz)>

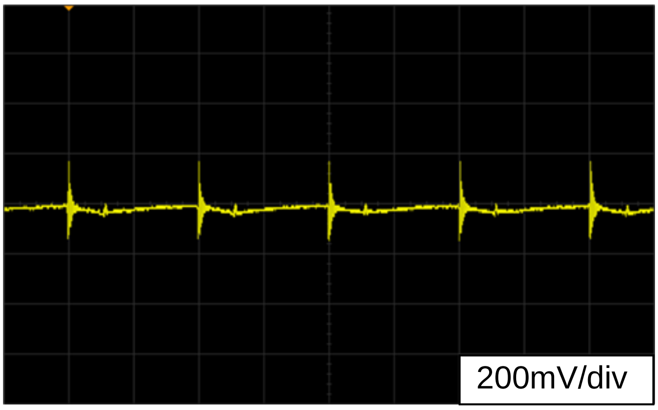


No Gate Resistance

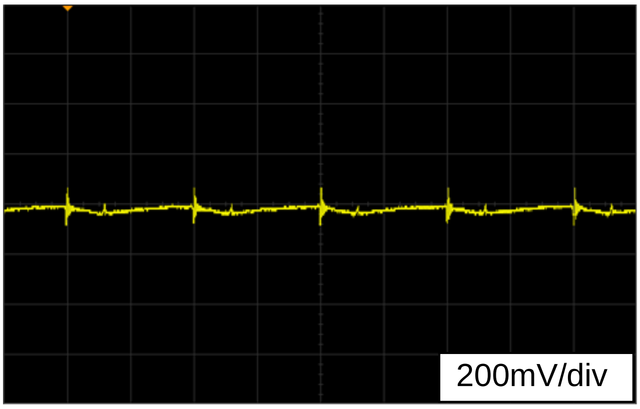


With Gate Resistance 10Ω

<Output Voltage Spike Waveform (at V_{IN}=9V, V_{OUT}=12V, I_{OUT}=2A, f_{OSC}=1MHz)>

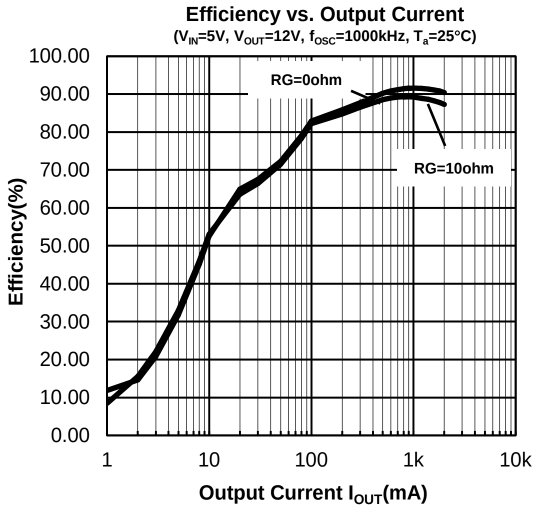


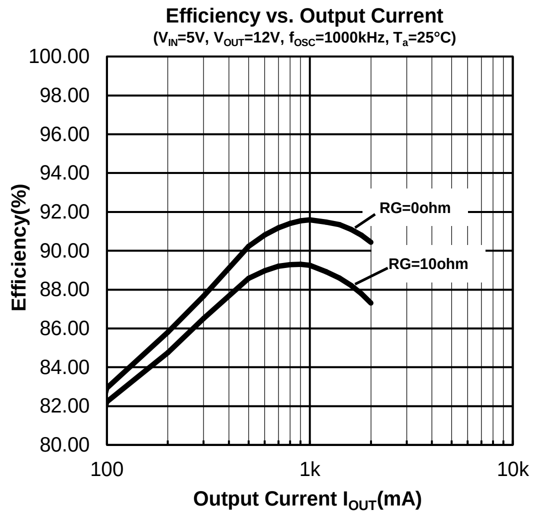
No Gate Resistance

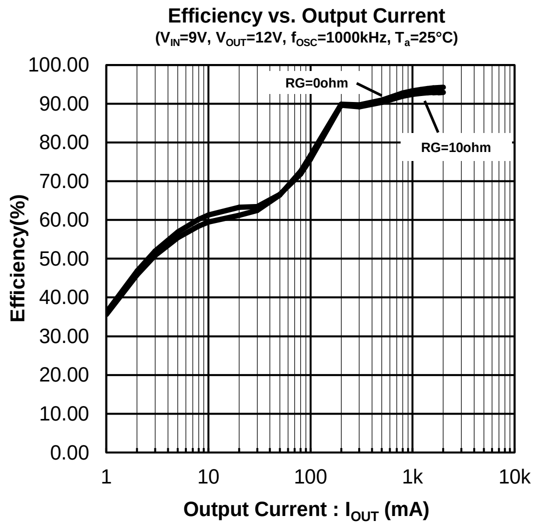


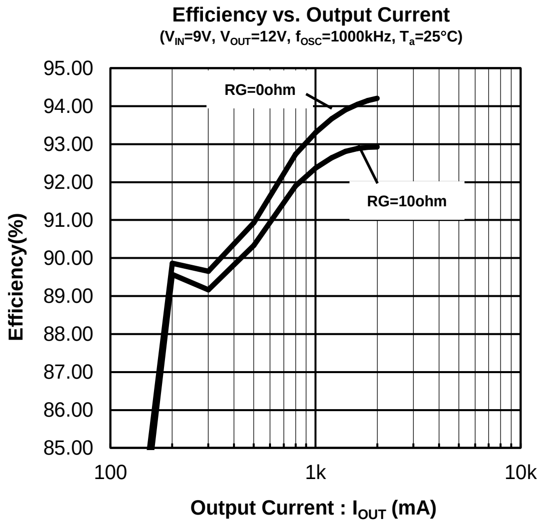
With Gate Resistance 10Ω

<Efficiency Characteristics>









● Phase Compensation design example

A switching regulator needs a feedback circuit to stabilize the output voltage. Frequency characteristics of the application change due to inductance and output capacitor. It is ideal phase compensation design that can obtain the maximum bandwidth while ensuring the phase margin necessary for stable operation. For the phase compensation designs, actual machine adjustment is also important. Ultimately please select a constant while considering the application specification.

● Feedback and Stability

The feedback loop should be designed the open loop phase shift less than −180 ° at frequency where the loop gain is 0dB. Also, the loop characteristics should have margin in consideration of ringing and immunity to oscillation during load fluctuations. The NJW1871A can arbitrarily design the feedback circuit; it is possible to optimize the placement of Pole and Zero that are important for loop compensation. The characteristics of the Pole and Zero are shown in Figure 9.

Pole: The gain has a slope of −20 dB/dec, and the phase shifts −90°.
Zero: The gain has a slope of +20 dB/dec, and the phase shifts +90°.

If the number of factors constituting Pole is “n”, the gain phase change will also be “n”-fold. It is the same for Zero. The Pole and Zero are in a reciprocal relationship, if there is one factor for each Pole and Zero, they will cancel each other.

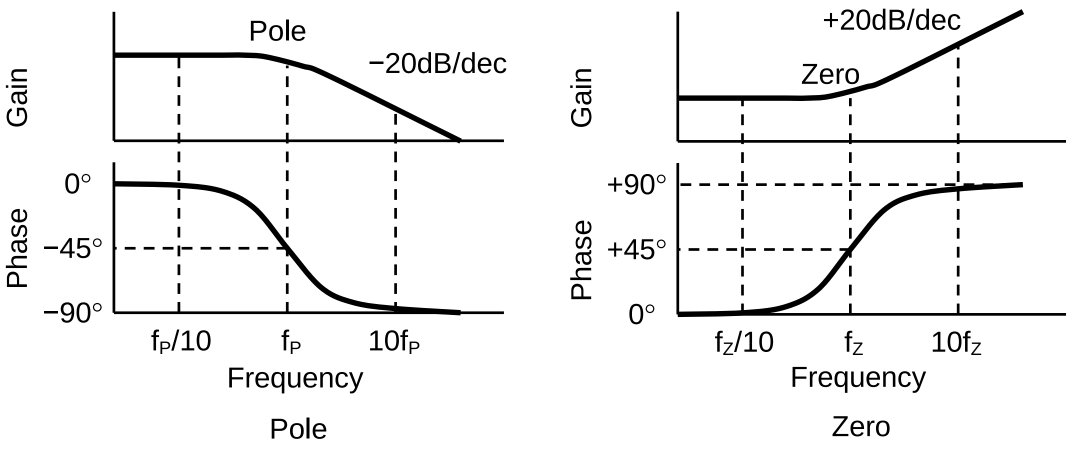


Figure 9. Pole and Zero Characteristics

● Setting of Pole and Zero

The position of the Pole and Zero are determined by the application condition and error amplifier setting. Figure 10 shows phase compensation circuit and Table 4 shows setting of Pole and Zero.

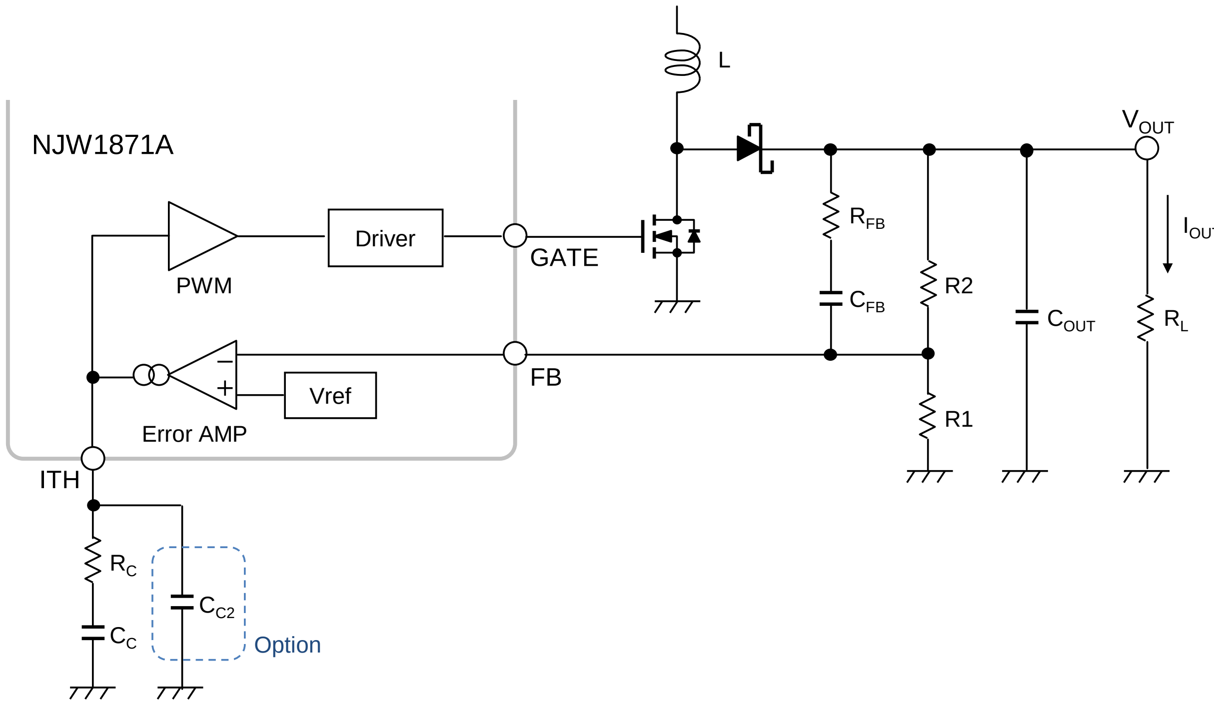


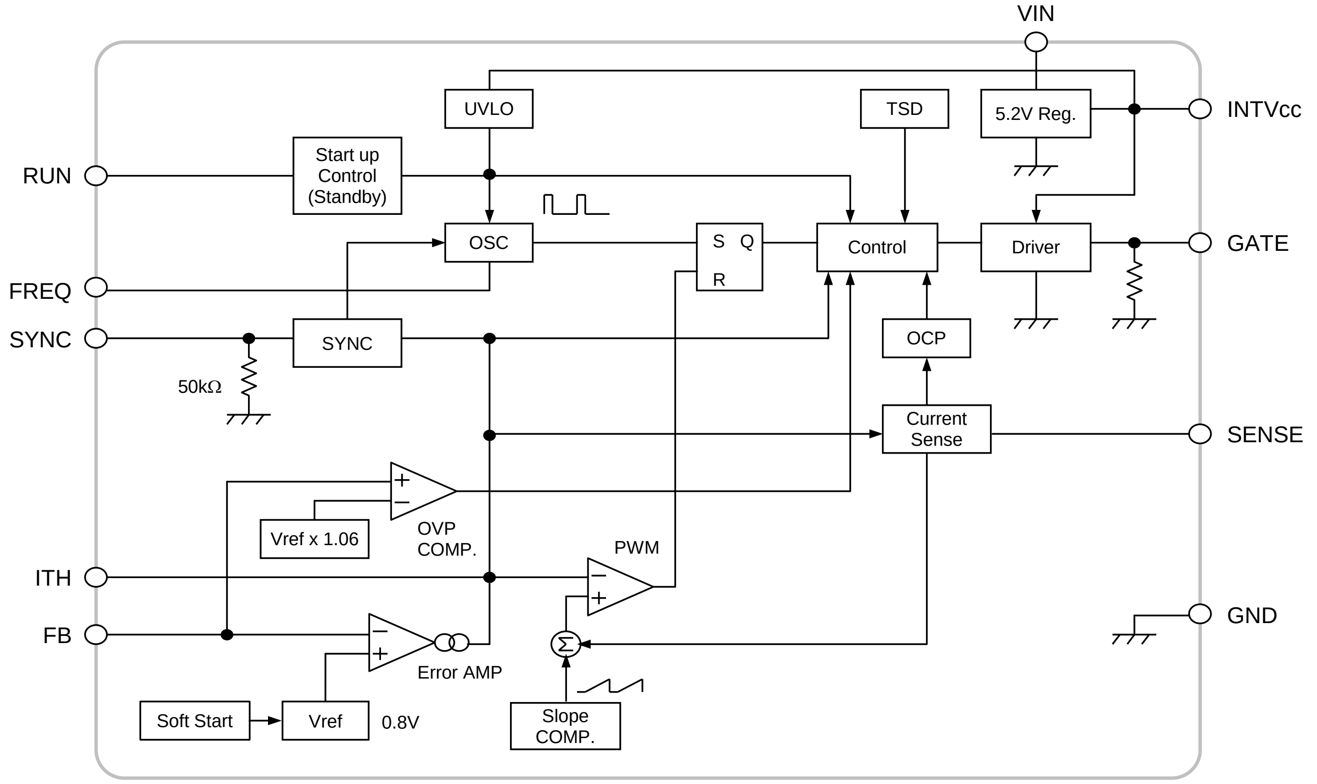
Figure 10. Phase Compensation Circuit Configuration

Table 4. Setting of Pole and Zero

Symbol	Calculating formula	Setting example	Description
f_{P1}	$f_{P1} = \dfrac{1}{2\times\pi\times\frac{A_V}{gm}\times C_C}$	$f_{P1} < \dfrac{f_{ZRPH}}{10000}$ to $\dfrac{f_{ZRPH}}{5000}$	A position of 1st pole f_{P1} is fixed by C_C connected to the output of the error amplifire
f_{ZRPH}	$f_{ZRPH} = \dfrac{(1-D)^2\times\frac{V_{OUT}}{I_{OUT}}}{2\times\pi\times L}$		The position of f_{ZRPH} is determined by input / output condition, L value and load current. It is recommended to limit the f_{0dB} frequency of the loop gain to the upper limit of 1/5 to 1/10 of f_{ZRPH}.
f_{POUT}	$f_{POUT} = \dfrac{1}{2\times\pi\times\frac{V_{OUT}}{I_{OUT}}\times C_{OUT}}$	$1 < \dfrac{f_{Z1}}{f_{POUT}} < 15$	The pole f_{POUT} is caused by capacitor and load resistance connected to the output. In the case, the load resistance asumes a maximum load current and calculates. When it uses a ceramic capacitor for C_{OUT}, it us realistic to calculate at effective capacitance in consideration of DC bias.
f_{Z1}	$f_{Z1} = \dfrac{1}{2\times\pi\times R_C\times C_C}$		A position of zero f_{Z1} is fixed by R_C and C_C connected to the output of the error amplifire
f_{Z2}	$f_{Z2} = \dfrac{1}{2\times\pi\times R2\times C_{FB}}$	20kHz to 60kHz	It should be set when it is difficult to secure phase margin.

Various Poles are occurred at hundreds of kHz or more, the 0dB frequency of the loop gain is set to 1/5 to 1/10 of the oscillation frequency as the upper limit. If the oscillation frequency is high, the loop gain 0dB frequency should be set around 100 kHz in order to ensure sufficient phase margin. When the loop gain is affected by the stability in the high frequency region, adjust the actual equipment using RFB, CC2.

■ BLOCK DIAGRAM

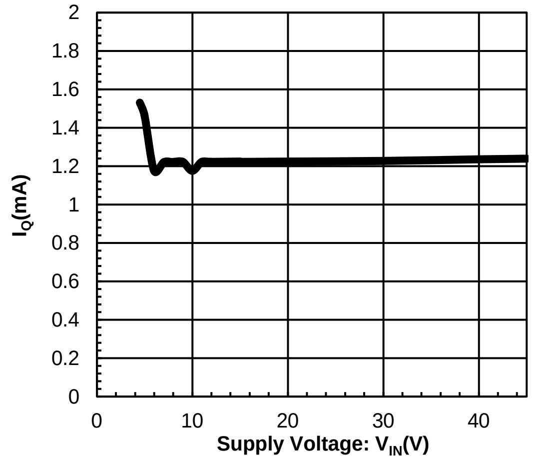


NJW1871A Block Diagram

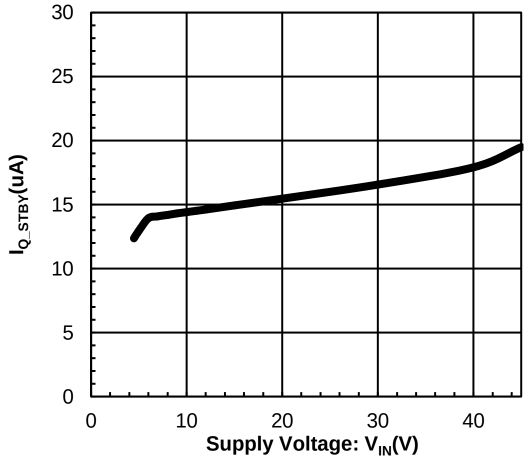
■ TYPICAL CHARACTERISTICS

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

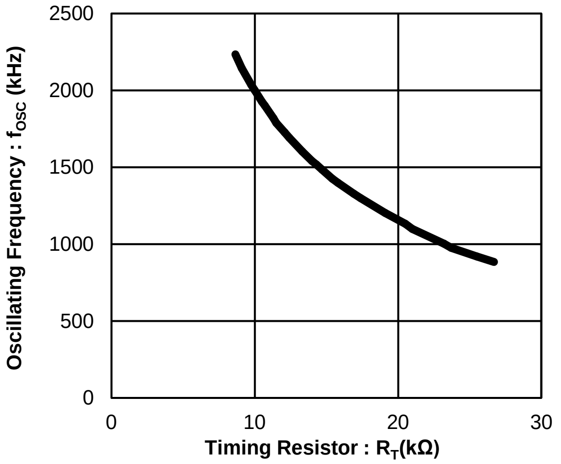
Quiescent Current vs. Supply Voltage
(V_{IN}=4.5 to 45V, V_{ITH}=OPEN, T_a=25°C)



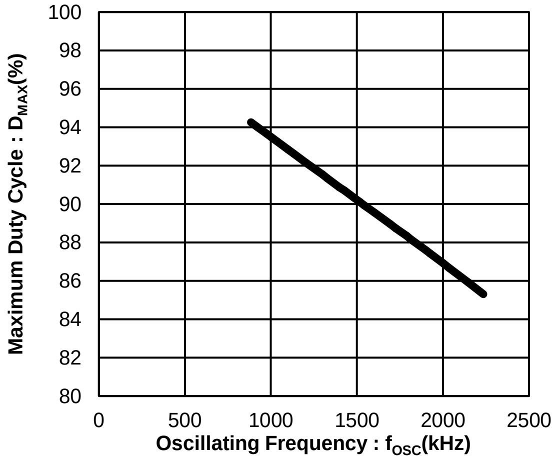
Standby Current vs. Supply Voltage
(V_{IN}=2.5 to 45V, V_{RUN}=0V, Ta=25°C)



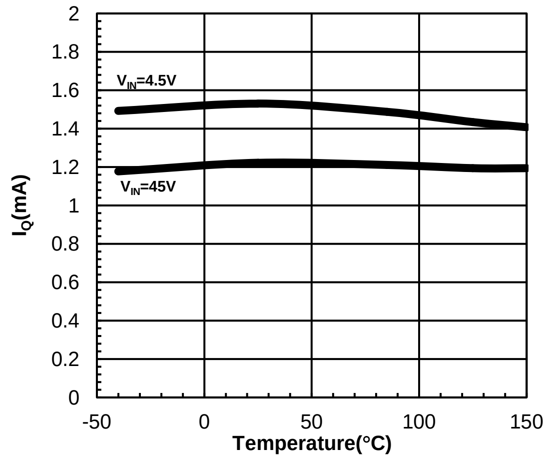
Oscillating Frequency vs. Timing Resistor
(V_{IN}=9V, V_{OUT}=12V, f_{OSC}=1000kHz, T_a=25°C)



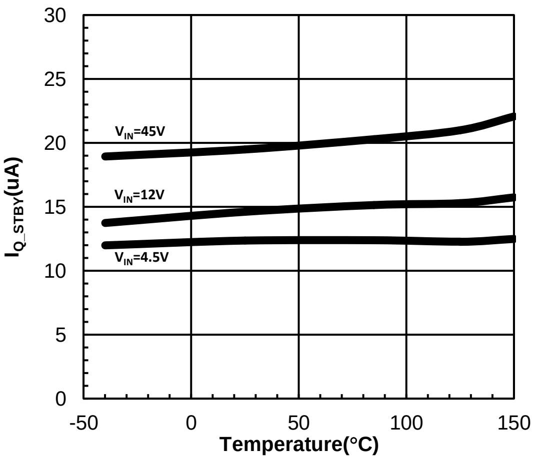
Maximum Duty Cycle vs. Oscillating Frequency
(V_{IN}=5V)



Current Consumption vs. Temperature
(V_{IN}=4.5 to 45V, V_{ITH}=OPEN)



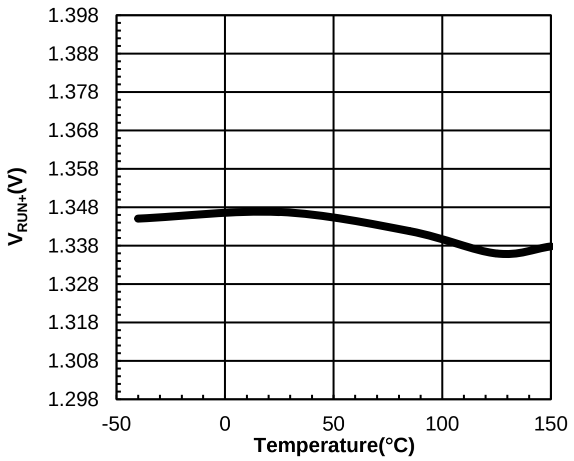
Standby Current Consumption vs. Temperature
(V_{IN}=4.5 to 45V, V_{RUN}=0V)



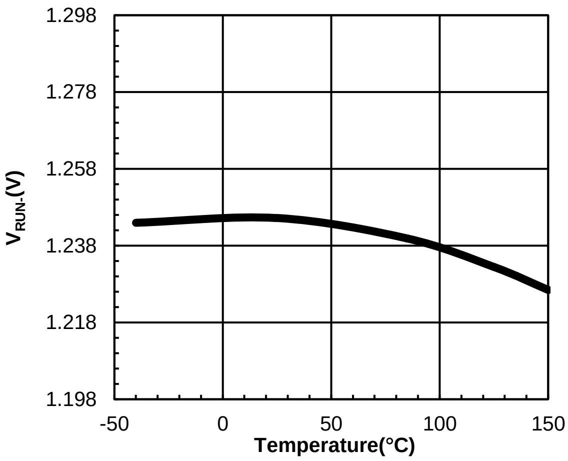
■ TYPICAL CHARACTERISTICS

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

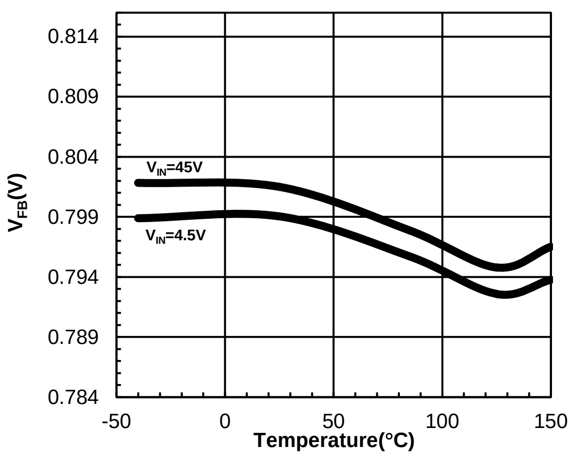
UVLO ON Threshold Voltage vs. Temperature
(V_{IN}=4.5 to 45V, V_{RUN}=L → H)



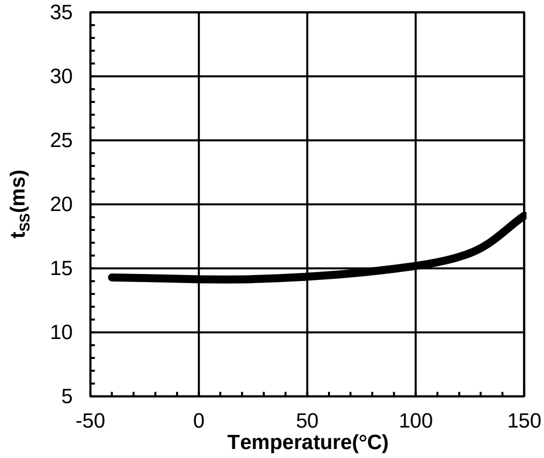
UVLO OFF Threshold Voltage vs. Temperature
(V_{IN}=4.5 to 45V, V_{RUN}=H → L)



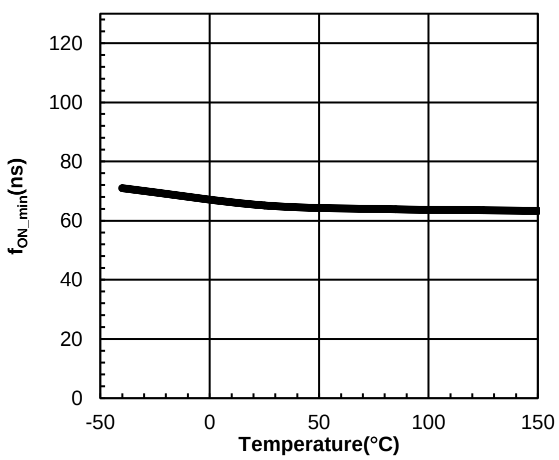
Reference Voltage vs. Temperature
(V_{IN}=4.5 to 45V, V_{ITH}=V_{FB})



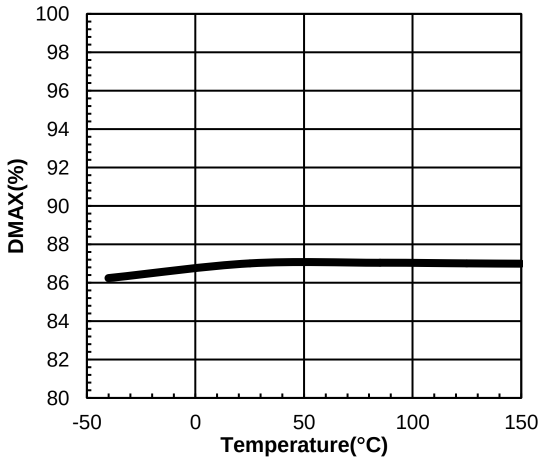
Soft Start Time vs. Temperature
(V_{IN}=4.5 to 45V)



Minimum ON Time vs. Temperature
(V_{IN}=4.5 to 45V, R_T=10kΩ, V_{FB}=0.7V, V_{ITH}=0.3V approx.)

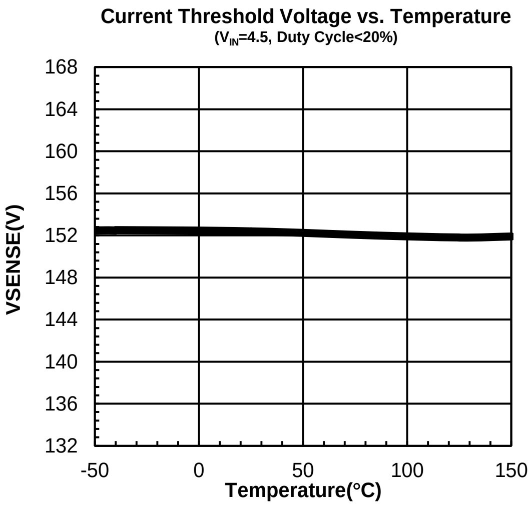


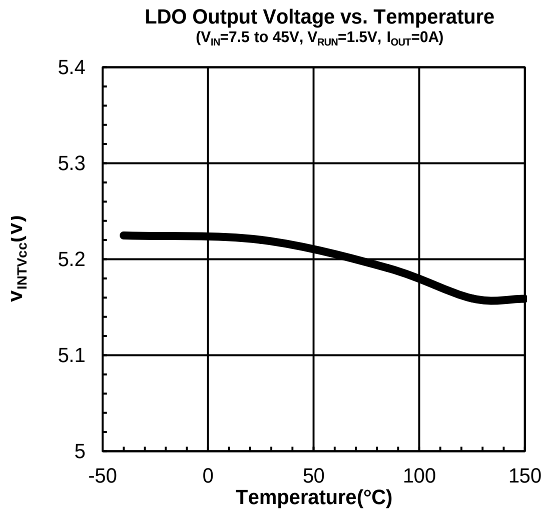
Maximum Duty Cycle vs. Temperature
(V_{IN}=4.5 to 45V, R_T=10kΩ, ITH=OPEN)

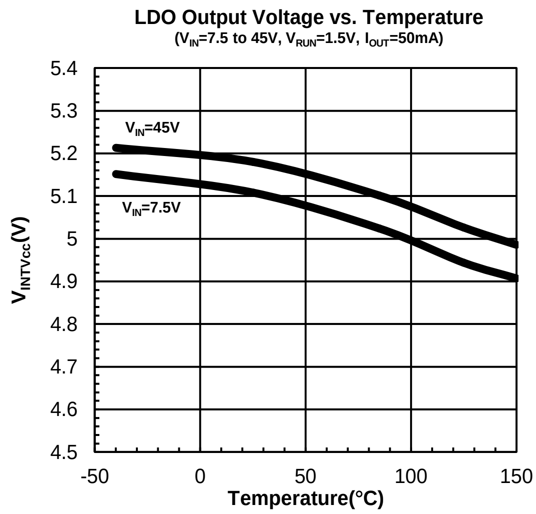


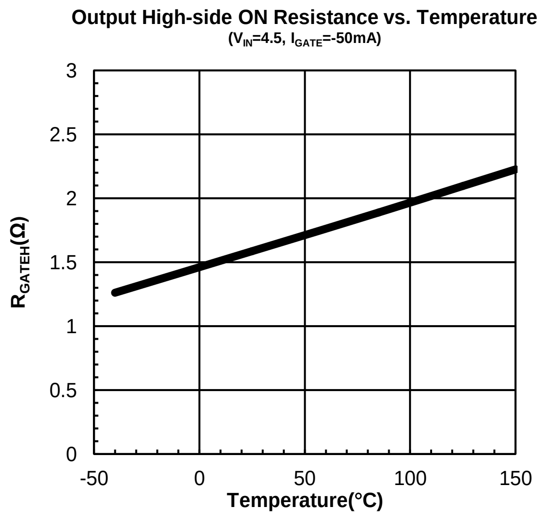
■ TYPICAL CHARACTERISTICS

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









■ TYPICAL CHARACTERISTICS

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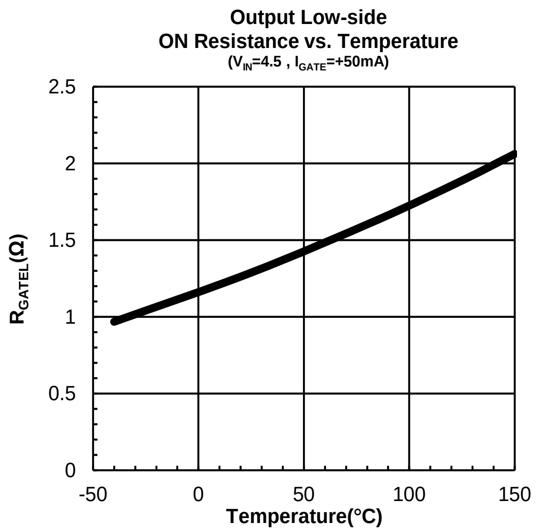
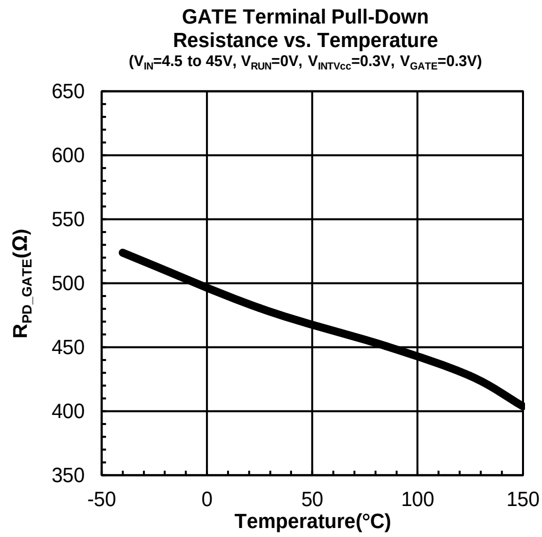
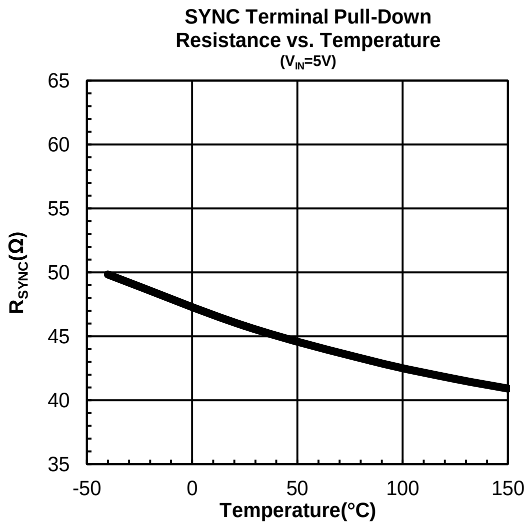
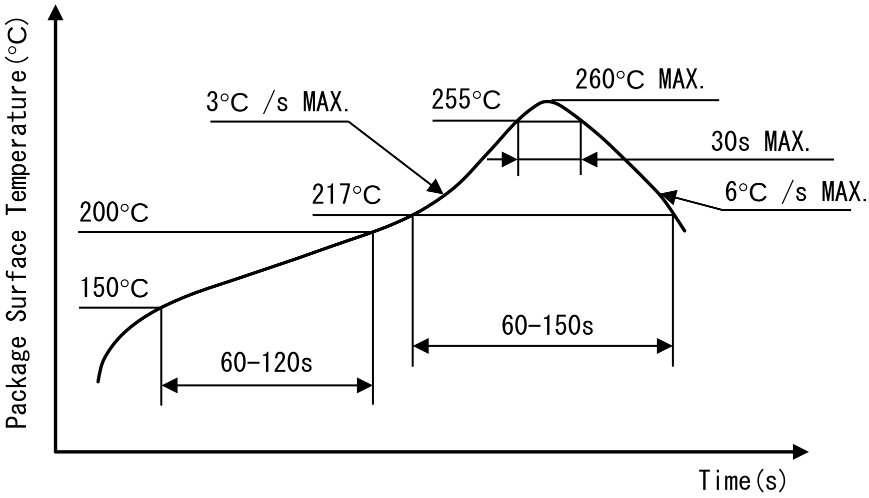






■ HEAT-RESISTANCE PROFILES



Reflow profile

■ REVISION HISTORY

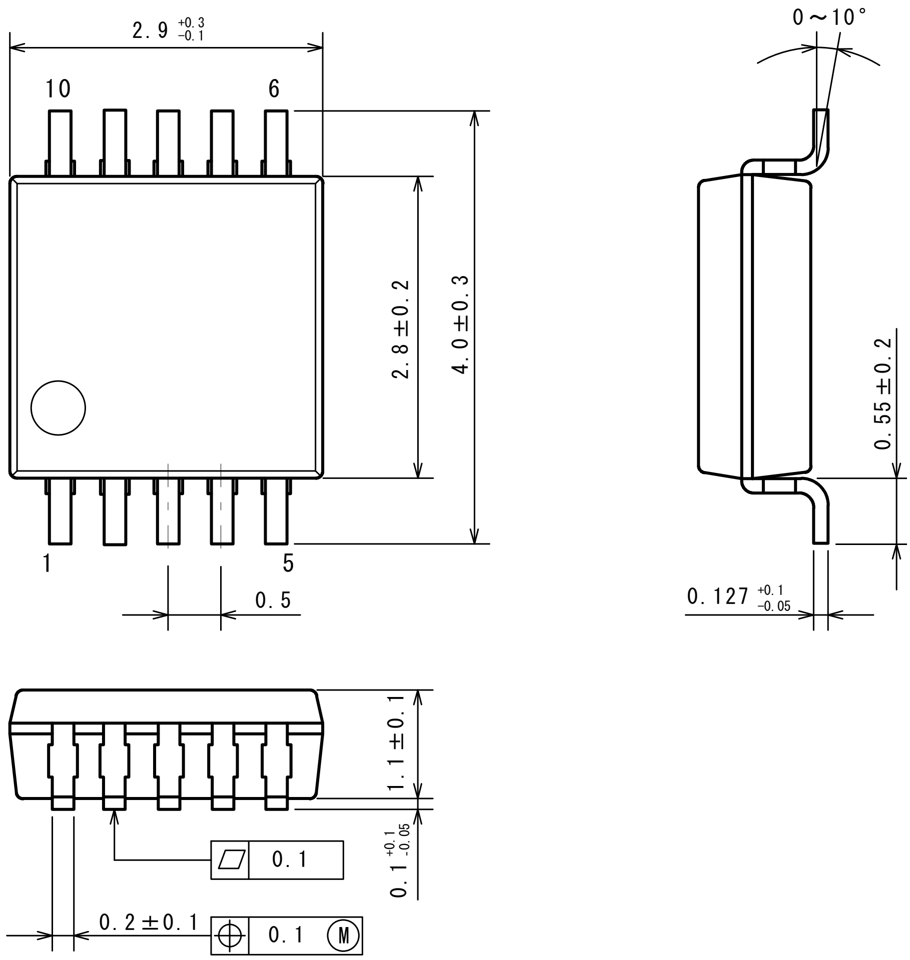
Date	Revision	Changes
Jan 24, 2024	Ver. 1.0	Initial release

MSOP10 MEET JEDEC MO-187-DA (VSP10)

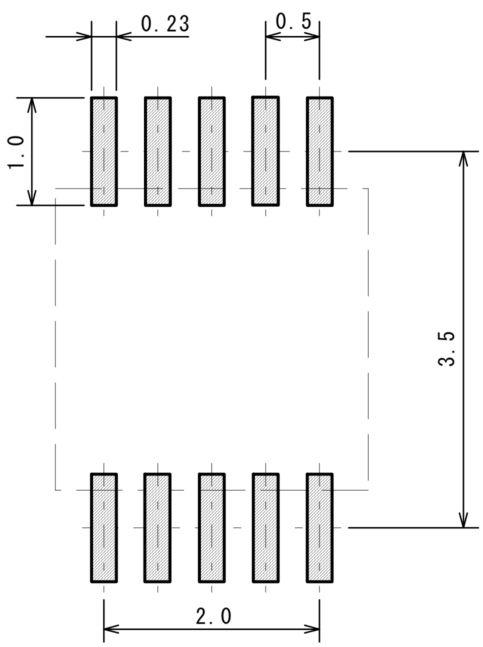
PI-MSOP10-E-B

■ PACKAGE DIMENSIONS

UNIT: mm



■ EXAMPLE OF SOLDER PADS DIMENSIONS

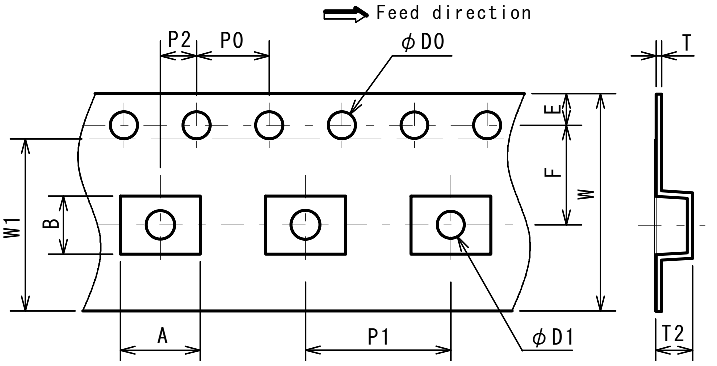


MSOP10 MEET JEDEC MO-187-DA (VSP10)

■ PACKING SPEC

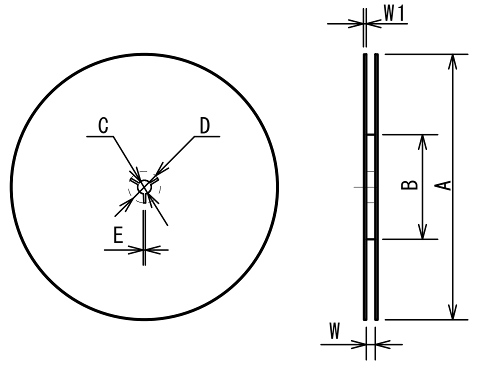
UNIT: mm

TAPING DIMENSIONS



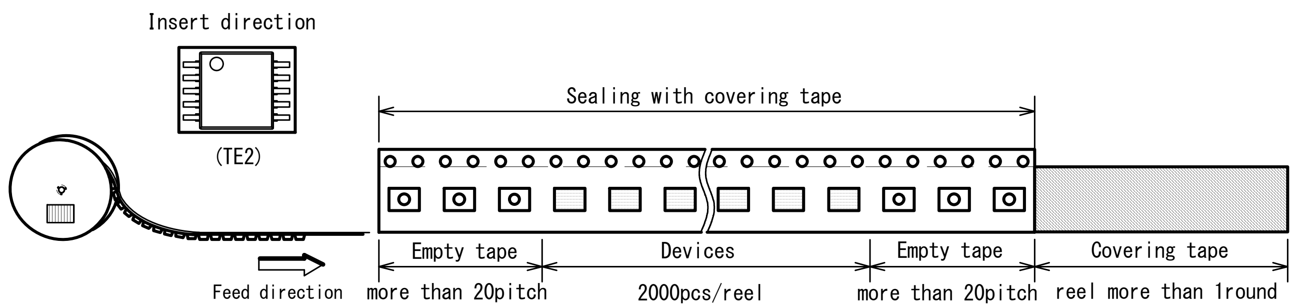
SYMBOL	DIMENSION	REMARKS
A	4.4	BOTTOM DIMENSION
B	3.2	BOTTOM DIMENSION
D0	$1.5^{+0.1}_{0}$	
D1	$1.5^{+0.1}_{0}$	
E	1.75±0.1	
F	5.5±0.05	
P0	4.0±0.1	
P1	8.0±0.1	
P2	2.0±0.05	
T	0.30±0.05	
T2	2.0 (MAX.)	
W	12.0±0.3	
W1	9.5	THICKNESS 0.1max

REEL DIMENSIONS

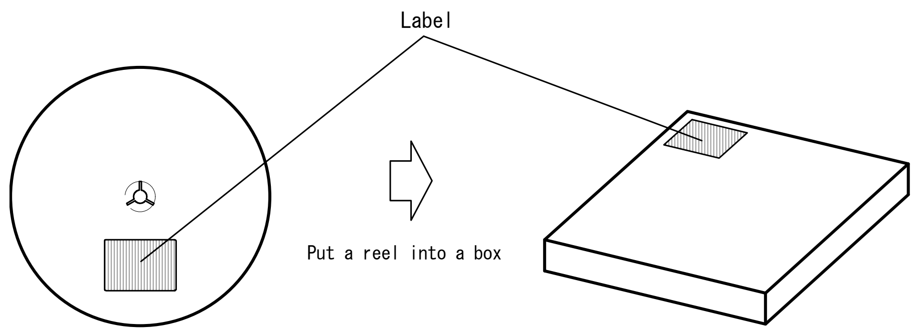


SYMBOL	DIMENSION
A	φ254±2
B	φ100±1
C	φ 13±0.2
D	φ 21±0.8
E	2±0.5
W	13.5±0.5
W1	2.0±0.2

TAPING STATE



PACKING STATE



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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.
4. The technical information described in this document shows typical characteristics and example application circuits for the products. The release of such information is not to be construed as a warranty of or a grant of license under our or any third party's intellectual property rights or any other rights.
5. The products listed in this document are intended and designed for automotive applications. Those customers intending to use a product in an application requiring extreme quality and reliability, for example, in a highly specific application where the failure or misoperation of the product could result in human injury or death should first contact us.
    - Aerospace Equipment
    - Equipment Used in the Deep Sea
    - Power Generator Control Equipment (nuclear, steam, hydraulic, etc.)
    - Life Maintenance Medical Equipment
    - Fire Alarms / Intruder Detectors
    - Vehicle Control Equipment (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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Nisshinbo Micro Devices Inc.

Official website

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

Purchase information

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