

# 2.7 V to 5.5 V Input, 1 A Single Synchronous Buck DC/DC Converter for Automotive

## BD9S100NUX-C

### General Description

BD9S100NUX-C is a synchronous buck DC/DC Converter with built-in low On Resistance power MOSFETs. It is capable of providing current up to 1 A. Small inductor is applicable due to high switching frequency of 2.2 MHz. It is a current mode control DC/DC Converter and features high-speed transient response. It has a built-in phase compensation circuit. Applications can be created with a few external components.

### Features

- AEC-Q100 Qualified<sup>(Note 1)</sup>
- Single Synchronous Buck DC/DC Converter
- Adjustable Soft Start Function
- Output Discharge Function
- 100 % ON Duty Cycle
- Power Good Output
- Input Under Voltage Lockout Protection (UVLO)
- Short Circuit Protection (SCP)
- Output Over Voltage Protection (OVP)
- Over Current Protection (OCP)
- Thermal Shutdown Protection (TSD)

(Note 1) Grade 1

### Applications

- Automotive Equipment
- Other Electronic Equipment

### Key Specifications

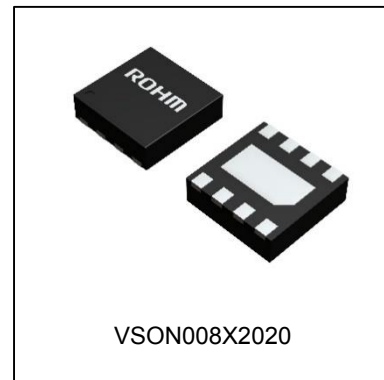
|                                |                   |
|--------------------------------|-------------------|
| ■ Input Voltage:               | 2.7 V to 5.5 V    |
| ■ Output Voltage Setting:      | 0.8 V to $V_{IN}$ |
| ■ Output Current:              | 1 A(Max)          |
| ■ Switching Frequency:         | 2.2 MHz(Typ)      |
| ■ High Side FET ON Resistance: | 270 mΩ(Typ)       |
| ■ Low Side FET ON Resistance:  | 180 mΩ(Typ)       |
| ■ Shutdown Circuit Current:    | 0 μA(Typ)         |
| ■ Operating Temperature:       | -40 °C to +125 °C |

### Package

VSON008X2020

W(Typ) x D(Typ) x H(Max)

2.00 mm x 2.00 mm x 0.60 mm



### Typical Application Circuit

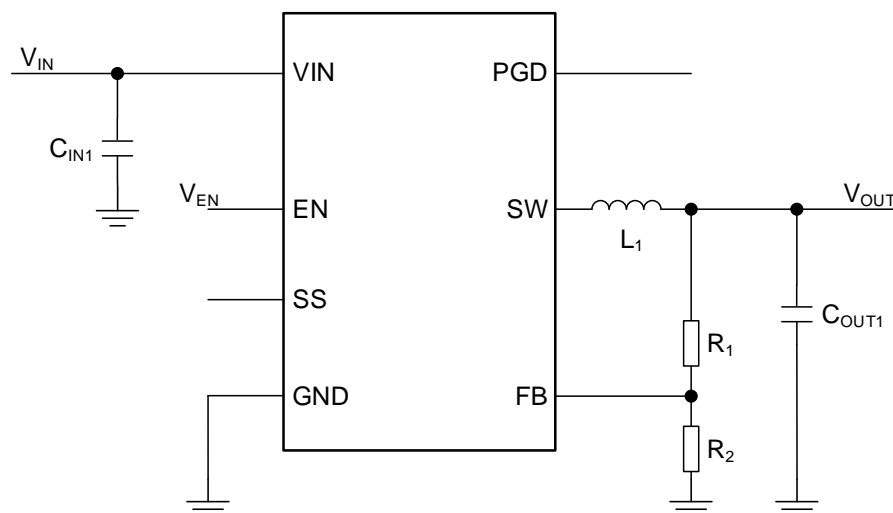
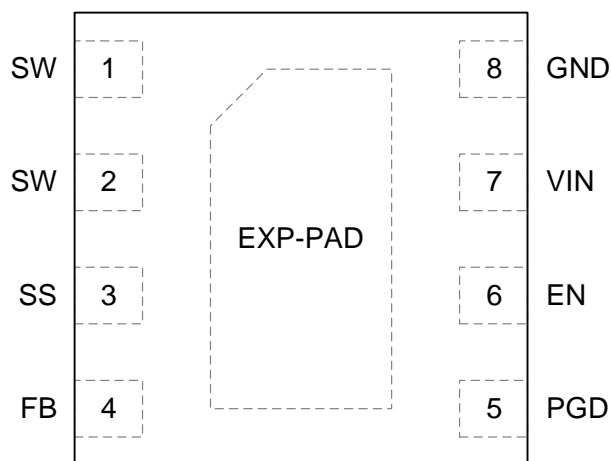


Figure 1. Application Circuit

## Pin Configuration



(TOP VIEW)

## Pin Descriptions

| Pin No. | Pin Name | Function  |
|---------|----------|---|
| 1, 2    | SW       | Switch pin. These pins are connected to the drain of the High Side FET and the Low Side FET.  |
| 3       | SS       | Pin for setting the soft start time. The rise time of the output voltage can be specified by connecting a capacitor to this pin. See <a href="#">page 17</a> on calculate the capacitance.                            |
| 4       | FB       | $V_{OUT}$ feedback pin. An inverting input node for the error amplifier. Connect output voltage divider to this pin to set the output voltage. See <a href="#">page 15</a> on how to compute for the resistor values. |
| 5       | PGD      | Power Good pin, an open drain output. Use of pull up resistor is needed. See <a href="#">page 11</a> on setting the resistance.   |
| 6       | EN       | Pin for controlling the device. Turning this pin signal Low forces the device to enter the shutdown mode. Turning this pin signal High makes the device to start up.  |
| 7       | VIN      | Power supply pin. Connecting a 10 $\mu$ F(Typ) ceramic capacitor is recommended. The detail of a selection is described in <a href="#">page 16</a> .  |
| 8       | GND      | Ground pin.   |
| -       | EXP-PAD  | A backside heat dissipation pad. Connecting to the internal PCB ground plane by using via provides excellent heat dissipation characteristics.  |

Block Diagram

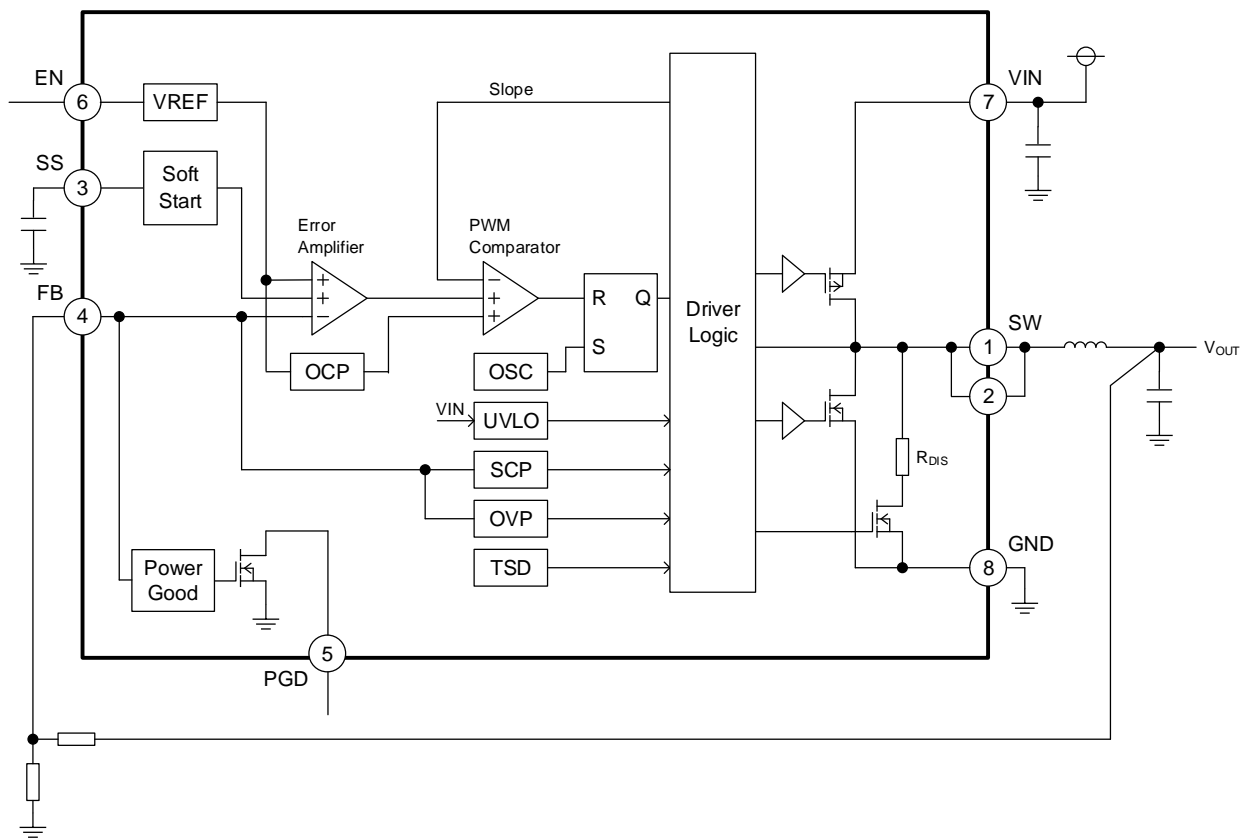


Figure 2. Block Diagram

## Description of Blocks

1. VREF  
The VREF block generates the internal reference voltage.
2. UVLO (Under Voltage Lockout)  
The UVLO block is for under voltage lockout protection. It will shutdown the device when the  $V_{IN}$  falls to 2.45 V(Typ) or lower. The threshold voltage has a hysteresis of 100 mV(Typ).
3. SCP (Short Circuit Protection)  
This is the short circuit protection circuit. After soft start is judged to be completed, if the FB pin voltage falls to 0.56 V(Typ) or less and remain in that state for 1 ms(Typ), output MOSFET will turn OFF for 14 ms(Typ) and then restart the operation.
4. OVP (Over Voltage Protection)  
This is the output over voltage protection circuit. When the FB pin voltage becomes 0.92 V(Typ) or more, it turns the output MOSFET OFF. After output voltage falls 0.88 V(Typ) or less, the output MOSFET returns to normal operation.
5. TSD (Thermal Shutdown)  
This is the thermal shutdown circuit. It will shutdown the device when the junction temperature ( $T_j$ ) reaches to 175 °C(Typ) or more. When the  $T_j$  falls below the TSD threshold, the circuits are automatically restored to normal operation with hysteresis of 25 °C(Typ).
6. OCP (Over Current Protection)  
The Over Current Protection function operates by limiting the current that flows through High Side FET at each cycle of the switching frequency.
7. Soft Start  
The Soft Start circuit slows down the rise of output voltage during startup, which allows the prevention of output voltage overshoot. The soft start time of the output voltage can be specified by connecting a capacitor to the SS pin. See [page 17](#) on calculate the capacitance. A built-in soft start function is provided and a soft start is initiated in 1 ms(Typ) when the SS pin is open.
8. Error Amplifier  
The Error Amplifier block is an error amplifier and its inputs are the reference voltage 0.8 V(Typ) and the FB pin voltage.
9. PWM Comparator  
The PWM Comparator block compares the output voltage of the Error Amplifier and the Slope signal to determine the switching duty.
10. OSC (Oscillator)  
This block generates the oscillating frequency.
11. Driver Logic  
This block controls switching operation and various protection functions.
12. Power Good  
When the FB pin voltage reaches 0.8 V(Typ) within  $\pm 10\%$ , the built-in Nch MOSFET turns OFF and the PGD output turns high. In addition, the PGD output turns low when the FB pin voltage reaches outside  $\pm 15\%$  of 0.8 V(Typ).

## Absolute Maximum Ratings

| Parameter                    | Symbol              | Rating           | Unit |
|------------------------------|---------------------|------------------|------|
| Input Voltage                | $V_{IN}$            | -0.3 to +7       | V    |
| EN Voltage                   | $V_{EN}$            | -0.3 to $V_{IN}$ | V    |
| PGD Voltage                  | $V_{PGD}$           | -0.3 to +7       | V    |
| FB, SS Voltage               | $V_{FB}$ , $V_{SS}$ | -0.3 to $V_{IN}$ | V    |
| Maximum Junction Temperature | $T_{jmax}$          | 150              | °C   |
| Storage Temperature Range    | $T_{stg}$           | -55 to +150      | °C   |

**Caution 1:** Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

**Caution 2:** Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, design a PCB boards with thermal resistance taken into consideration by increasing board size and copper area so as not to exceed the maximum junction temperature rating.

Thermal Resistance<sup>(Note 1)</sup>

| Parameter  | Symbol        | Thermal Resistance (Typ) |                          | Unit |
|--|---------------|--------------------------|--------------------------|------|
|  |               | 1s <sup>(Note 3)</sup>   | 2s2p <sup>(Note 4)</sup> |      |
| VSON008X2020   |               |                          |                          |      |
| Junction to Ambient  | $\theta_{JA}$ | 309.5                    | 77.1                     | °C/W |
| Junction to Top Characterization Parameter <sup>(Note 2)</sup> | $\Psi_{JT}$   | 53                       | 12                       | °C/W |

(Note 1) Based on JESD51-2A(Still-Air).

(Note 2) The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.

(Note 3) Using a PCB board based on JESD51-3.

(Note 4) Using a PCB board based on JESD51-5, 7.

| Layer Number of Measurement Board | Material | Board Size                   |
|-----------------------------------|----------|------------------------------|
| Single                            | FR-4     | 114.3 mm x 76.2 mm x 1.57 mm |

| Top                   |            |
|-----------------------|------------|
| Copper Pattern        | Thickness  |
| Footprints and Traces | 70 $\mu$ m |

| Layer Number of Measurement Board | Material | Board Size                  | Thermal Via <sup>(Note 5)</sup> |                |
|-----------------------------------|----------|-----------------------------|---------------------------------|----------------|
|                                   |          |                             | Pitch                           | Diameter       |
| 4 Layers                          | FR-4     | 114.3 mm x 76.2 mm x 1.6 mm | 1.20 mm                         | $\Phi$ 0.30 mm |

| Top                   |            | 2 Internal Layers |            | Bottom            |            |
|-----------------------|------------|-------------------|------------|-------------------|------------|
| Copper Pattern        | Thickness  | Copper Pattern    | Thickness  | Copper Pattern    | Thickness  |
| Footprints and Traces | 70 $\mu$ m | 74.2 mm x 74.2 mm | 35 $\mu$ m | 74.2 mm x 74.2 mm | 70 $\mu$ m |

(Note 5) This thermal via connects with the copper pattern of all layers.

## Recommended Operating Conditions

| Parameter              | Symbol        | Min                     | Max      | Unit |
|------------------------|---------------|-------------------------|----------|------|
| Input Voltage          | $V_{IN}$      | 2.7                     | 5.5      | V    |
| Operating Temperature  | $T_a$         | -40                     | +125     | °C   |
| Output Current         | $I_{OUT}$     | -                       | 1        | A    |
| Output Voltage Setting | $V_{OUT}$     | 0.8 <sup>(Note 1)</sup> | $V_{IN}$ | V    |
| SW Minimum ON Time     | $t_{ON\_MIN}$ | -                       | 80       | ns   |

(Note 1) Although the output voltage is configurable at 0.8 V and higher, it may be limited by the SW min ON pulse width. For the configurable range, please refer to [the Output Voltage Setting on page 15](#) in Selection of Components Externally Connected.

Electrical Characteristics (Unless otherwise specified Ta=Tj=-40 °C to +125 °C, V<sub>IN</sub>=5 V, V<sub>EN</sub>=5 V)

| Parameter   | Symbol    | Limit         |               |               | Unit | Conditions                           |
|---|-----------|---------------|---------------|---------------|------|--------------------------------------|
|   |           | Min           | Typ           | Max           |      |                                      |
| VIN   |           |               |               |               |      |                                      |
| Shutdown Circuit Current                                  | ISDN      | -             | 0             | 10            | μA   | VEN=0 V, Ta=25 °C                    |
| Circuit Current   | ICC       | 200           | 350           | 500           | μA   | IOUT=0 mA<br>Non-switching, Ta=25 °C |
| UVLO Detection Voltage                                    | VUVLO1    | 2.30          | 2.45          | 2.60          | V    | VIN Falling                          |
| UVLO Release Voltage                                      | VUVLO2    | 2.40          | 2.55          | 2.70          | V    | VIN Rising                           |
| UVLO Hysteresis Voltage                                   | VUVLO-HYS | 50            | 100           | 125           | mV   |                                      |
| ENABLE  |           |               |               |               |      |                                      |
| EN Threshold Voltage High                                 | VENH      | 1.0           | -             | VIN           | V    |                                      |
| EN Threshold Voltage Low                                  | VENL      | GND           | -             | 0.4           | V    |                                      |
| EN Input Current  | IEN       | 2             | 5             | 8             | μA   | VEN=5 V, Ta=25 °C                    |
| Reference Voltage   |           |               |               |               |      |                                      |
| FB Pin Voltage  | VFB       | 0.788         | 0.8           | 0.812         | V    |                                      |
| FB Input Current  | IFB       | -             | 0             | 0.2           | μA   | VFB=0.8 V, Ta=25 °C                  |
| Soft Start  |           |               |               |               |      |                                      |
| Soft Start Time   | tss       | 0.5           | 1.0           | 2.0           | ms   | VIN=5 V,<br>The SS Pin OPEN          |
|   |           | 0.6           | 1.2           | 2.4           | ms   | VIN=3.3 V,<br>The SS Pin OPEN        |
| SS Charge Current   | ISS       | -1.4          | -1.0          | -0.6          | μA   |                                      |
| Switching Frequency                                       |           |               |               |               |      |                                      |
| Switching Frequency                                       | fSW       | 2.0           | 2.2           | 2.4           | MHz  |                                      |
| Power Good  |           |               |               |               |      |                                      |
| PGD Falling (Fault) Voltage                               | VPGDTH_FF | VFB<br>x 0.80 | VFB<br>x 0.85 | VFB<br>x 0.90 | V    | VFB Falling                          |
| PGD Rising (Good) Voltage                                 | VPGDTH_RG | VFB<br>x 0.85 | VFB<br>x 0.90 | VFB<br>x 0.95 | V    | VFB Rising                           |
| PGD Rising (Fault) Voltage                                | VPGDTH_RF | VFB<br>x 1.10 | VFB<br>x 1.15 | VFB<br>x 1.20 | V    | VFB Rising                           |
| PGD Falling (Good) Voltage                                | VPGDTH_FG | VFB<br>x 1.05 | VFB<br>x 1.10 | VFB<br>x 1.15 | V    | VFB Falling                          |
| PGD Output Leakage Current                                | ILEAKPGD  | -             | 0             | 2             | μA   | VPGD=5 V, Ta=25 °C                   |
| PGD FET ON Resistance                                     | RPGD      | 30            | 60            | 120           | Ω    |                                      |
| PGD Output Low Level Voltage                              | VPGDL     | 0.03          | 0.06          | 0.12          | V    | IPGD=1 mA                            |
| Switch MOSFET   |           |               |               |               |      |                                      |
| High Side FET ON Resistance                               | RONH      | 120           | 270           | 470           | mΩ   | VIN=5 V                              |
|   |           | 150           | 330           | 550           | mΩ   | VIN=3.3 V                            |
| Low Side FET ON Resistance                                | RONL      | 80            | 180           | 300           | mΩ   | VIN=5 V                              |
|   |           | 100           | 210           | 350           | mΩ   | VIN=3.3 V                            |
| High Side FET Leakage Current                             | ILEAKSWH  | -             | 0             | 5             | μA   | VIN=5.5 V, VSW=0 V,<br>Ta=25 °C      |
| Low Side FET Leakage Current                              | ILEAKSWL  | -             | 0             | 5             | μA   | VIN=5.5 V, VSW=5.5 V,<br>Ta=25 °C    |
| SW Current of Over Current Protection <sup>(Note 1)</sup> | IOCP      | 1.2           | 2.0           | 2.8           | A    |                                      |
| SW Discharge Resistance                                   | RDIS      | 450           | 650           | 850           | Ω    |                                      |
| SCP, OVP  |           |               |               |               |      |                                      |
| Short Circuit Protection Detection Voltage                | VSCP      | 0.48          | 0.56          | 0.64          | V    |                                      |
| Output Over Voltage Protection Detection Voltage          | VOVP      | 0.88          | 0.92          | 0.96          | V    |                                      |

(Note 1) This is design value. Not production tested.

## Typical Performance Curves

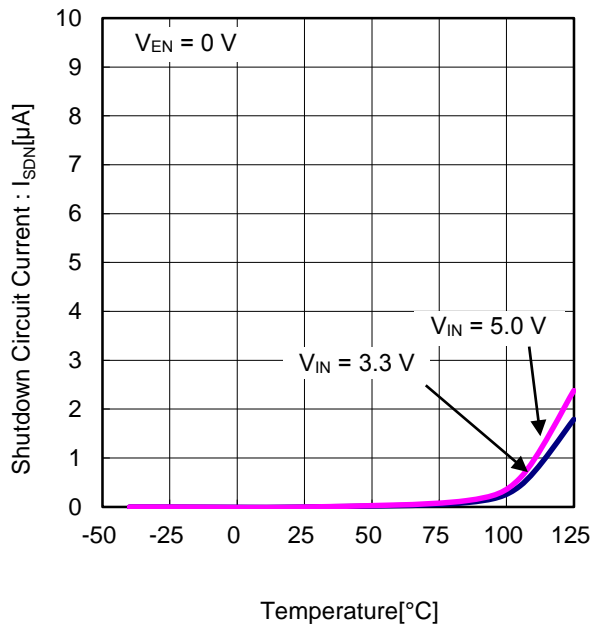
Unless otherwise specified  $V_{IN} = V_{EN}$ 

Figure 3. Shutdown Circuit Current vs Temperature

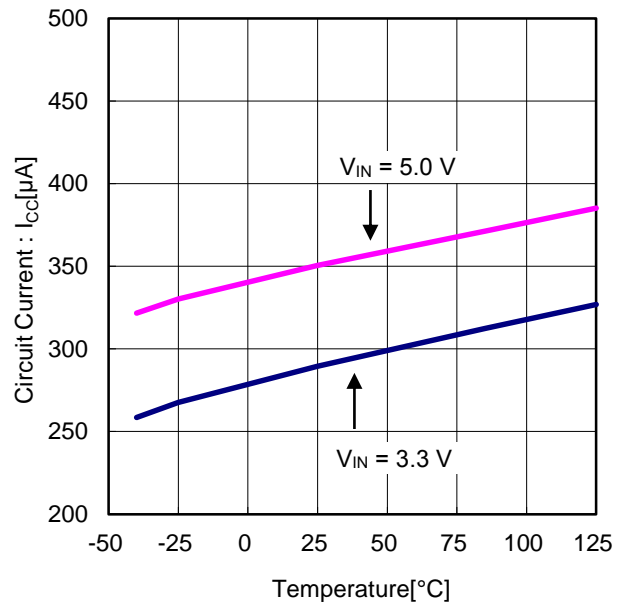


Figure 4. Circuit Current vs Temperature

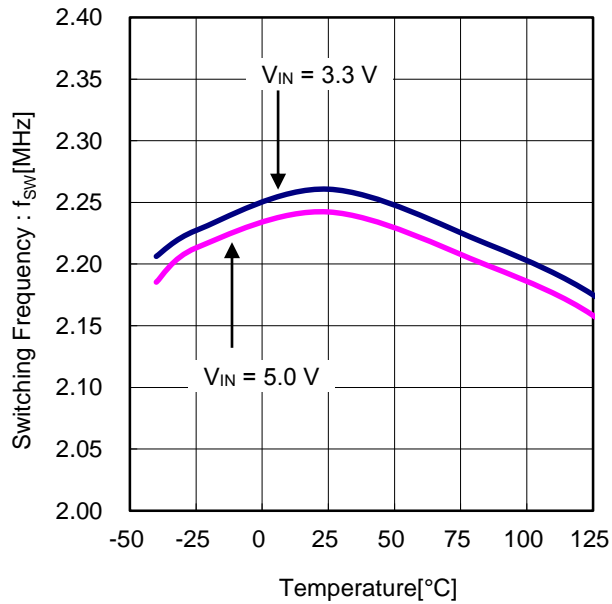


Figure 5. Switching Frequency vs Temperature

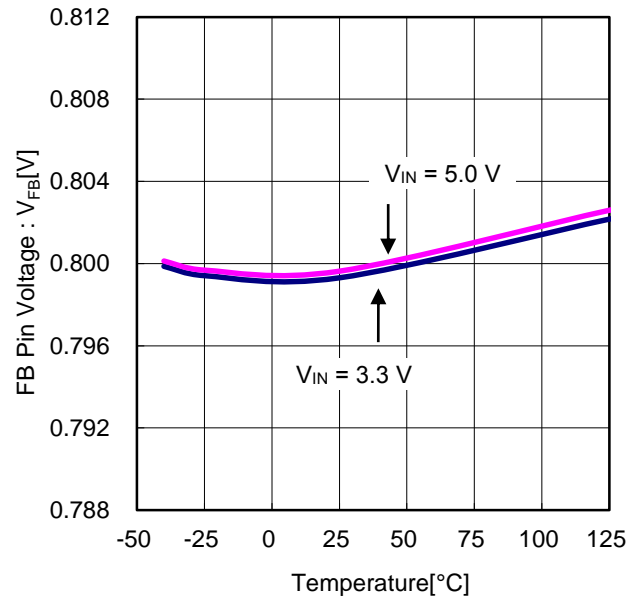


Figure 6. FB Pin Voltage vs Temperature

## Typical Performance Curves – continued

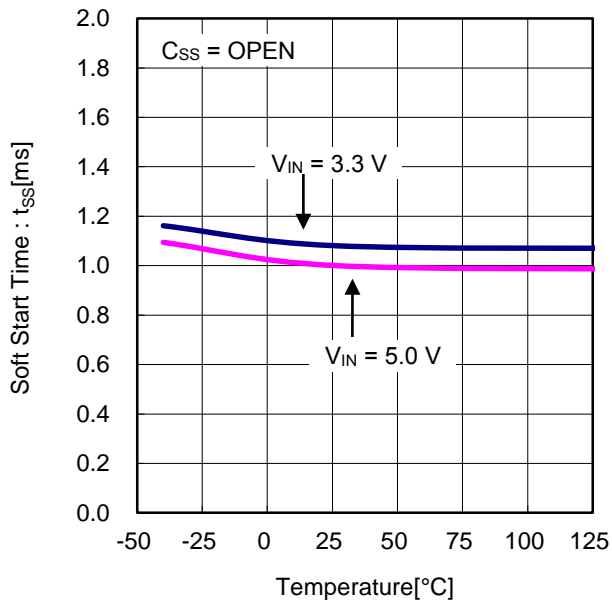


Figure 7. Soft Start Time vs Temperature

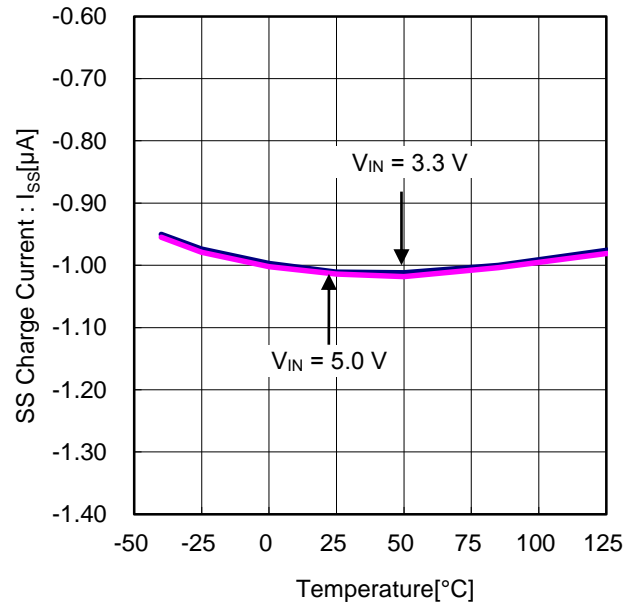


Figure 8. SS Charge Current vs Temperature

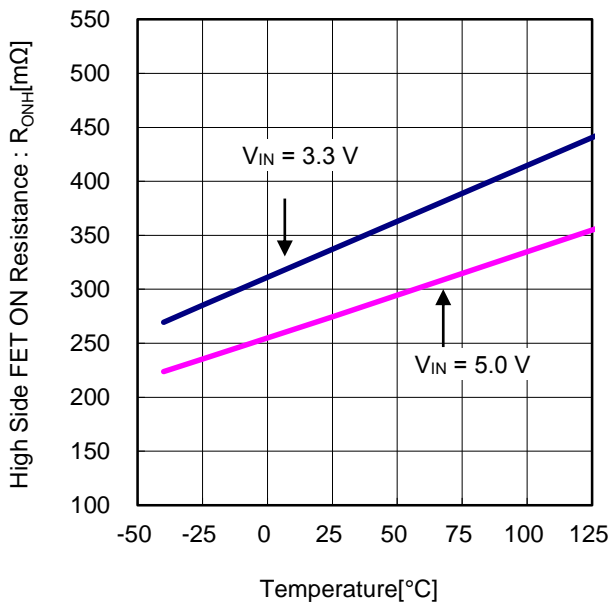


Figure 9. High Side FET ON Resistance vs Temperature

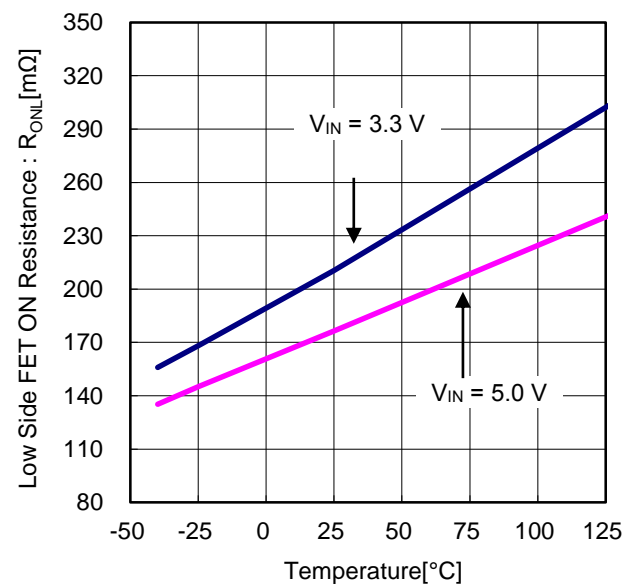


Figure 10. Low Side FET ON Resistance vs Temperature



Typical Performance Curves – continued

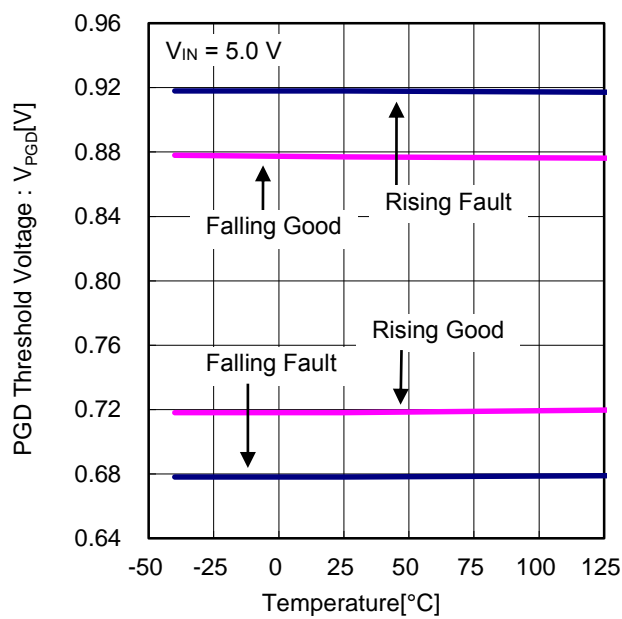


Figure 11. PGD Threshold Voltage vs Temperature

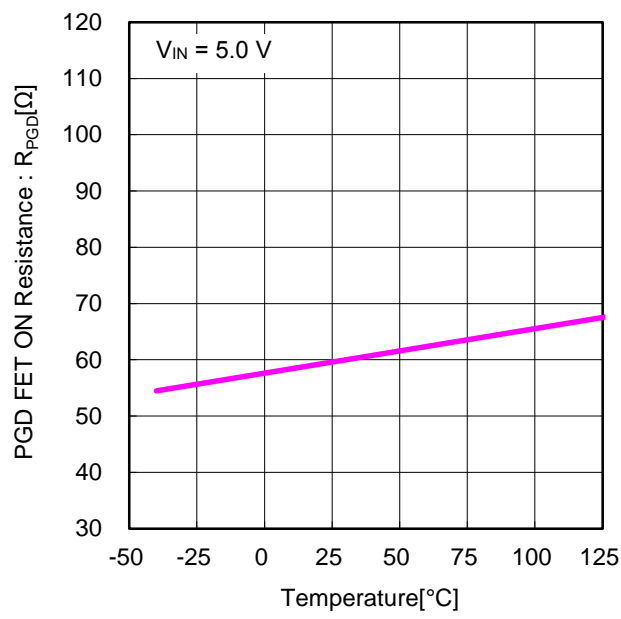


Figure 12. PGD FET ON Resistance vs Temperature

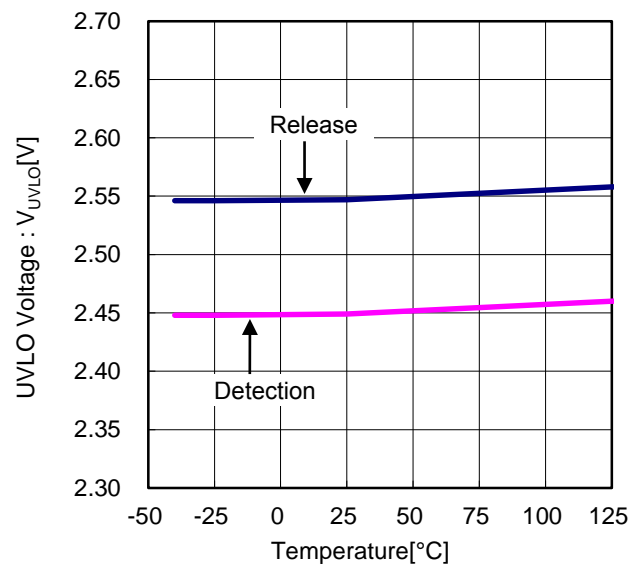


Figure 13. UVLO Voltage vs Temperature

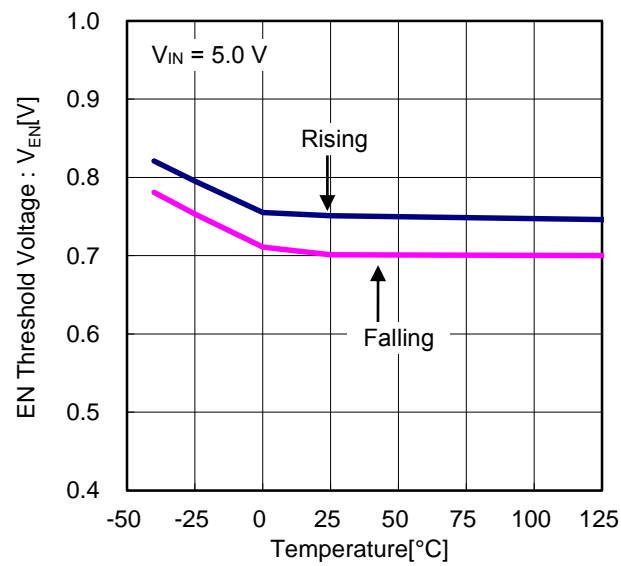


Figure 14. EN Threshold Voltage vs Temperature

## Typical Performance Curves – continued

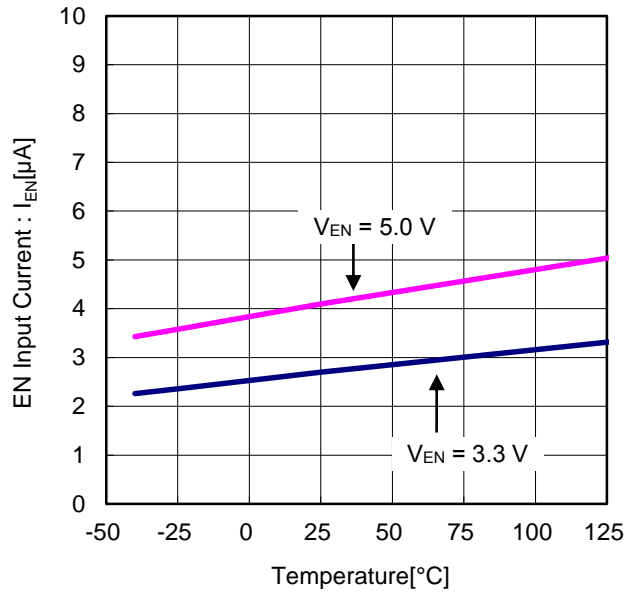


Figure 15. EN Input Current vs Temperature

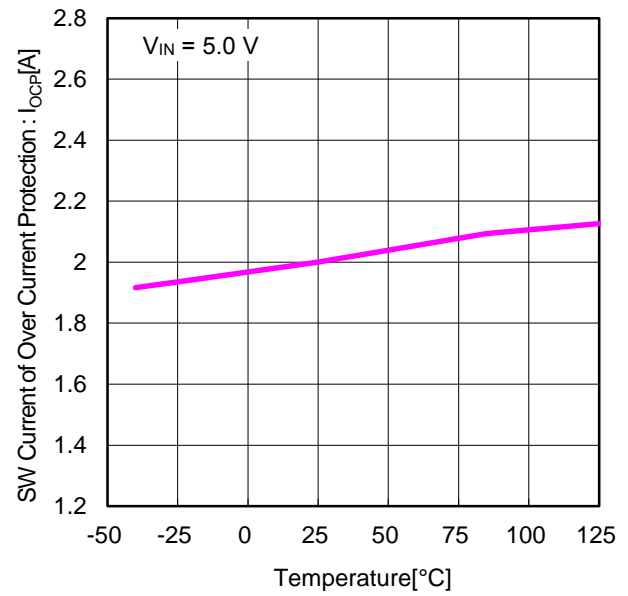


Figure 16 SW Current of Over Current Protection vs Temperature

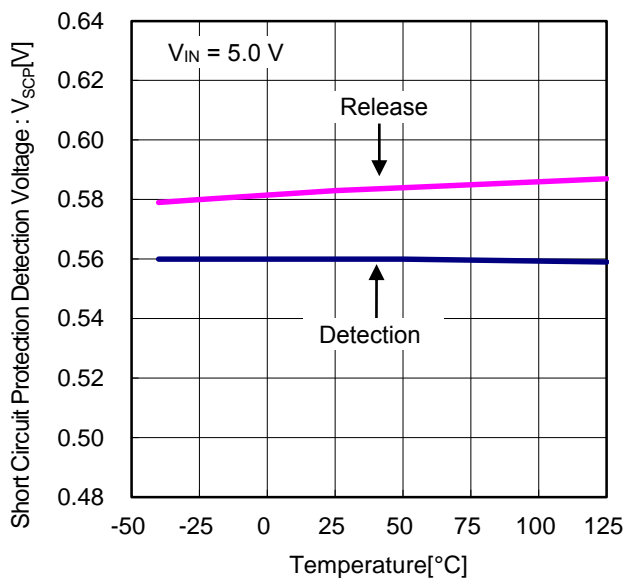


Figure 17. Short Circuit Protection Detection Voltage vs Temperature

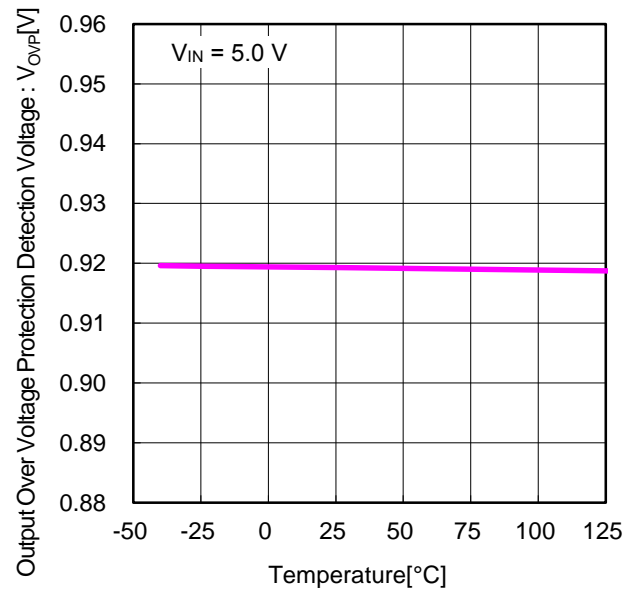


Figure 18. Output Over Voltage Protection Detection Voltage vs Temperature

## Function Explanations

## 1. Enable Control

The device shutdown can be controlled by the voltage applied to the EN pin. When  $V_{EN}$  becomes 1.0 V or more, the internal circuit is activated and the device starts up with soft start. When  $V_{EN}$  becomes 0.4 V or less, the device will be shutdown.

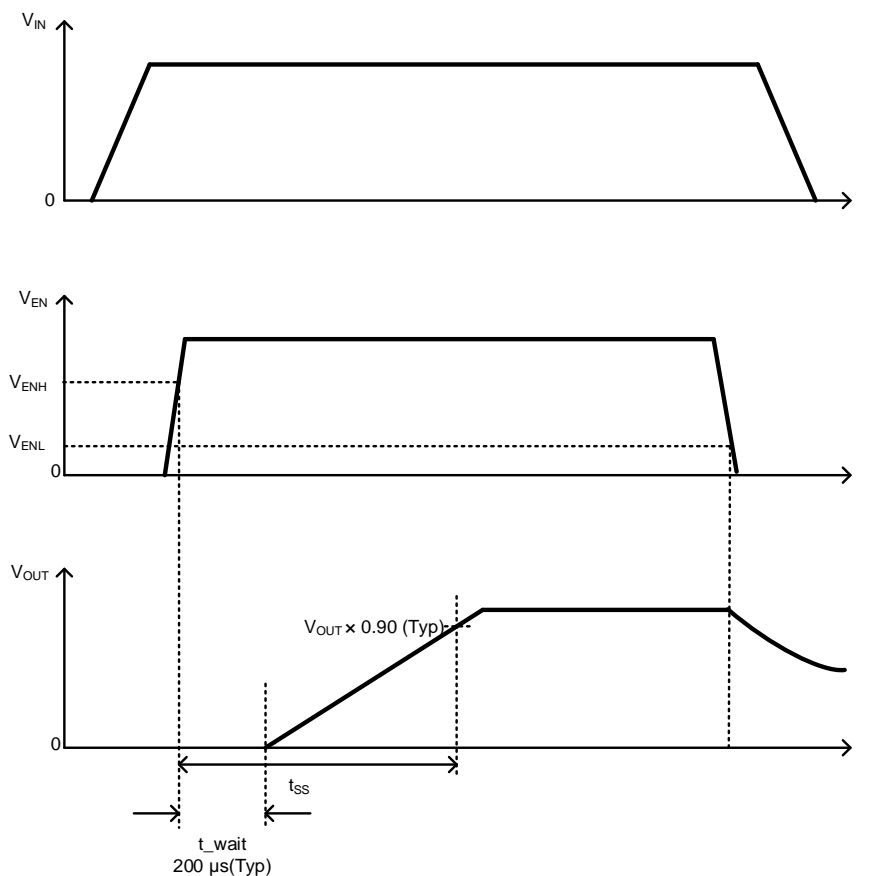


Figure 19. Enable ON/OFF Timing Chart

## 2. Power Good Function

When the FB pin voltage reaches 0.8 V(Typ) within  $\pm 10\%$ , the PGD pin open drain MOSFET turns OFF and the output turns high. In addition, when the FB pin voltage reaches outside  $\pm 15\%$  of 0.8 V(Typ), the PGD pin open drain MOSFET turns ON and the PGD pin is pulled down with impedance of 60  $\Omega$ (Typ). It is recommended to use a pull-up resistor of 2 k $\Omega$  to 100 k $\Omega$  for the power source

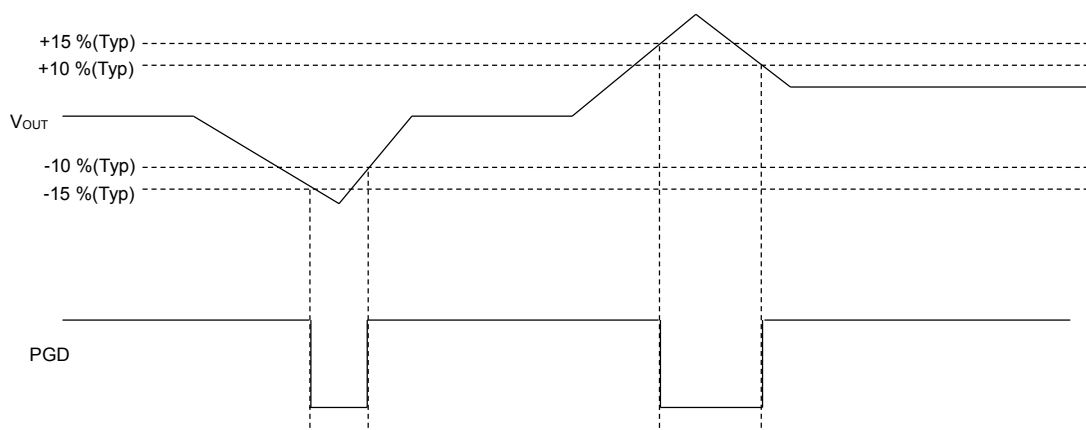


Figure 20. Power Good Timing Chart

**Function Explanations – continued****3. Output Discharge**

When even one of the following conditions is satisfied, output is discharged with 650  $\Omega$ (Typ) resistance through SW pin.

- $V_{EN}$  becomes 0.4 V or less
- $V_{IN}$  becomes 2.45 V(Typ) or less(UVLO)
- $V_{FB}$  becomes 0.56 V(Typ) or less and remains there for 1ms(Typ)(SCP)
- $V_{FB}$  becomes 0.92 V(Typ) or more(OVP)
- $T_j$  becomes 175 °C (Typ) or more(TSD)

When all of the above conditions are released, output discharge is stopped.

**4. 100 % ON Duty Cycle**

When the input voltage comes close to the setting output voltage, the High Side FET is turned on 100 % for one or more cycle in order to maintain the output voltage. With further decreasing the input voltage, the High Side FET is turned on completely.

The minimum input voltage to maintain the output voltage can be represented by following equation.

$$V_{IN(Min)} = V_{OUT} + I_{OUT(Max)} \times (R_{ONH(Max)} + R_{L(Max)}) \text{ [V]}$$

where

$V_{OUT}$  is the output voltage

$I_{OUT(Max)}$  is the maximum output current

$R_{ONH(Max)}$  is the High Side FET ON Resistance([Refer to page 6](#))

$R_{L(Max)}$  is the DC resistance of the inductor

## Protection

## 1. Short Circuit Protection (SCP)

The Short Circuit Protection block compares the FB pin voltage with the internal reference voltage VREF. When the FB pin voltage has fallen to 0.56 V(Typ) or less and remained there for 1 ms(Typ), SCP stops the operation for 14 ms(Typ) and subsequently initiates a restart. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the device should not be used in applications characterized by continuous operation of the protection circuit (e.g. when a load that significantly exceeds the output current capability of the chip is connected).

| The EN Pin      | The FB Pin                 | Short Circuit Protection | Short Circuit Protection Operation |
|-----------------|----------------------------|--------------------------|------------------------------------|
| 1.0 V or higher | $\leq 0.56 \text{ V(Typ)}$ | Enabled                  | ON                                 |
|                 | $\geq 0.60 \text{ V(Typ)}$ |                          | OFF                                |
| 0.4 V or lower  | -                          | Disabled                 | OFF                                |

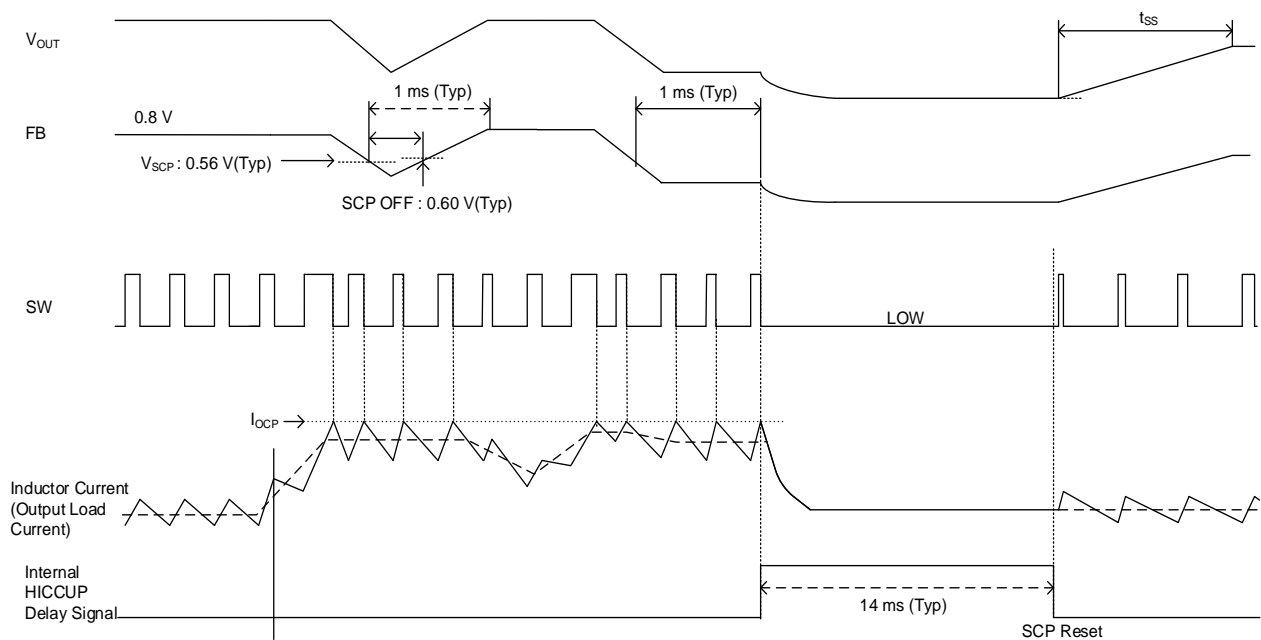


Figure 21. Short Circuit Protection (SCP) Timing Chart

## 2. Over Current Protection (OCP)

The Over Current Protection function operates by limiting the current that flows through High Side FET at each cycle of the switching frequency. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the device should not be used in applications characterized by continuous operation of the protection circuit (e.g. when a load that significantly exceeds the output current capability of the chip is connected).

## Protection – continued

## 3. Under Voltage Lockout Protection (UVLO)

It will shutdown the device when the VIN pin falls to 2.45 V(Typ) or lower. The threshold voltage has a hysteresis of 100 mV(Typ).

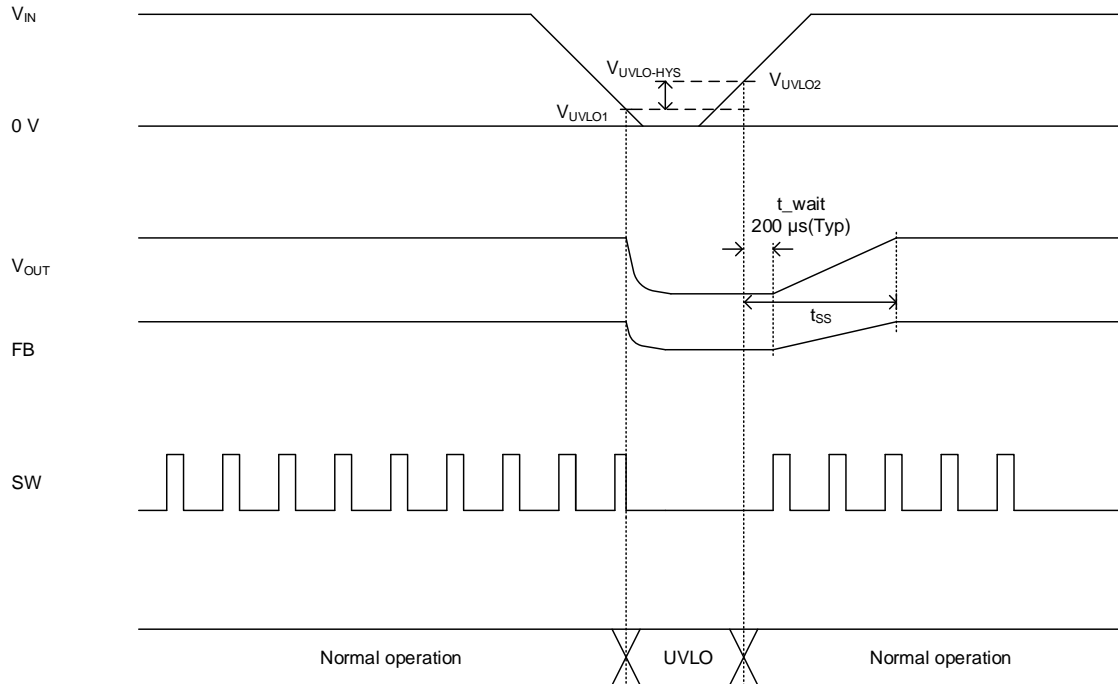


Figure 22. UVLO Timing Chart

## 4. Thermal Shutdown

This is the thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. However, if the rating is exceeded for a continued period, the junction temperature ( $T_j$ ) will rise which will activate the TSD circuit [ $T_j \geq 175^\circ\text{C}$  (Typ)] that will turn OFF output MOSFET. When the  $T_j$  falls below the TSD threshold, the circuits are automatically restored to normal operation. Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

## 5. Over Voltage Protection (OVP)

The device incorporates an over voltage protection circuit to minimize the output voltage overshoot when recovering from strong load transients or output fault conditions. If the FB pin voltage exceeds Output Over Voltage Protection Detection Voltage at 0.92 V(Typ), the MOSFET on the output stage is turned OFF to prevent the increase in the output voltage. After the detection, the switching operation resumes if the output decreases and the over voltage state is released. Output Over Voltage Protection Detection Voltage and release voltage have a hysteresis of 5 %.

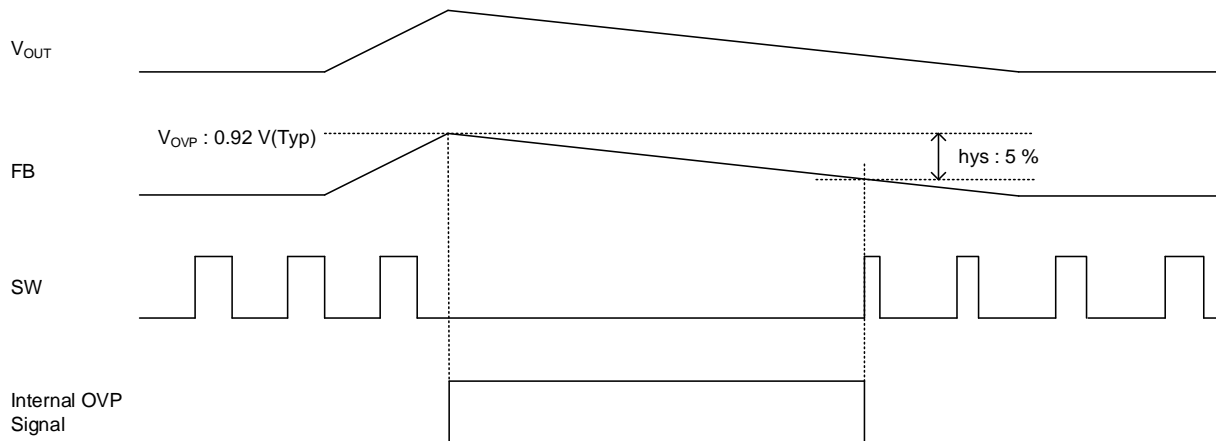


Figure 23. OVP Timing Chart

## Selection of Components Externally Connected

Contact us if not use the recommended constant in this section.

Necessary parameters in designing the power supply are as follows:

Table 1. Application Specification

| Parameter               | Symbol       | Example Value |
|-------------------------|--------------|---------------|
| Input Voltage           | $V_{IN}$     | 5.0 V         |
| Output Voltage          | $V_{OUT}$    | 1.2 V         |
| Switching Frequency     | $f_{SW}$     | 2.2 MHz(Typ)  |
| Inductor Ripple Current | $\Delta I_L$ | 0.25 A        |
| Output Capacitor        | $C_{OUT}$    | 10 $\mu$ F    |
| Soft Start Time         | $t_{SS}$     | 8.0 ms(Typ)   |
| Maximum Output Current  | $I_{OUTMAX}$ | 1.0 A         |

### Application Example

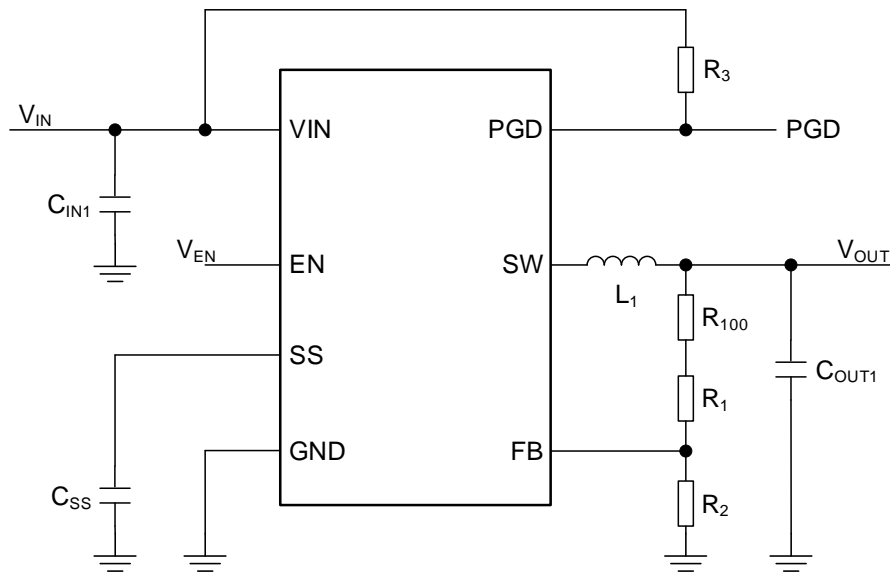


Figure 24. Typical Application

#### 1. Switching Frequency

The switching frequency  $f_{SW}$  is fixed at 2.2 MHz(Typ) inside the IC.

#### 2. Selection of Output Voltage Setting

The output voltage value can be set by the feedback resistance ratio.

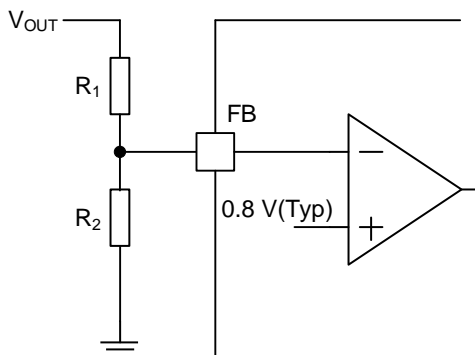


Figure 25. Feedback Resistor Circuit

$$V_{OUT} = \frac{R_1 + R_2}{R_2} \times 0.8 \text{ [V]}$$

SW Minimum ON Time that BD9S100NUX-C can output stably in the entire load range is 80 ns.

Use this value to calculate the input and output conditions that satisfy the following equation

$$80 \text{ [ns]} \leq \frac{V_{OUT}}{V_{IN} \times f_{SW}}$$

### Selection of Components Externally Connected – continued

#### 3. Selection of Input Capacitor

Please use ceramic type capacitor for the input capacitor  $C_{IN1}$ .  $C_{IN1}$  is used to suppress the input ripple noise and this capacitor is effective by being placed as close as possible to the VIN pin. Set the capacitor value for  $C_{IN1}$  so that it does not fall to 4.7  $\mu\text{F}$  against the capacitor value variances, temperature characteristics, DC bias characteristics, aging characteristics, and etc. Please use components which are comparatively same with the components used in “Application Example” on page 18. Moreover, factors like the PCB layout and the position of the capacitor may lead to IC malfunction. Please refer to “Notes on the PCB layout Design” on page 28 and 29. In addition, the capacitor with value 0.1  $\mu\text{F}$  can be added to suppress the high frequency noise as an option.

#### 4. Selection of Output LC Filter

In order to supply a continuous current to the load, the DC/DC converter requires an LC filter for smoothing the output voltage. Please use the inductor with value 1.0  $\mu\text{H}$  to 2.2  $\mu\text{H}$ .

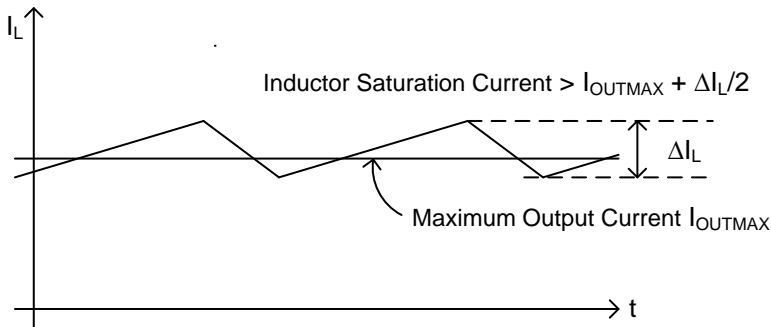


Figure 26. Waveform of Current Through Inductor

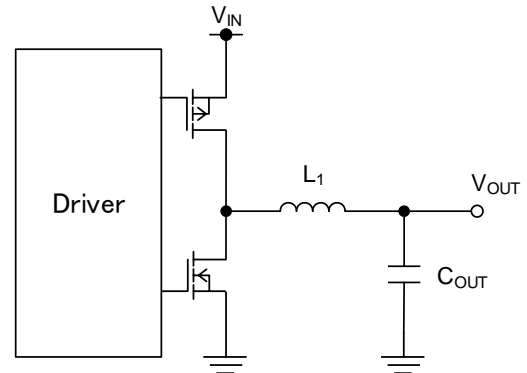


Figure 27. Output LC Filter Circuit

Inductor ripple current  $\Delta I_L$  can be represented by the following equation.

$$\Delta I_L = V_{OUT} \times (V_{IN} - V_{OUT}) \times \frac{1}{V_{IN} \times f_{SW} \times L_1} = 276 \text{ [mA]}$$

where

$V_{IN}$  is the 5.0 V

$V_{OUT}$  is the 1.2 V

$L_1$  is the 1.5  $\mu\text{H}$

$f_{SW}$  is the 2.2 MHz (Switching Frequency)

The rated current of the inductor must be larger than the sum of the maximum output current and 1/2 of the inductor ripple current  $\Delta I_L$ .

Please use ceramic type capacitor for the output capacitor  $C_{OUT}$ . The capacitance value of  $C_{OUT}$  is selected in the range between 10  $\mu\text{F}$  and 22  $\mu\text{F}$ .  $C_{OUT}$  affects the output ripple voltage characteristics.  $C_{OUT}$  must satisfy the required ripple voltage characteristics.

The output ripple voltage can be represented by the following equation.

$$\Delta V_{RPL} = \Delta I_L \times \left( R_{ESR} + \frac{1}{8 \times C_{OUT} \times f_{SW}} \right) \text{ [V]}$$

Where

$R_{ESR}$  is the Equivalent Series Resistance (ESR) of the output capacitor

The output ripple voltage  $\Delta V_{RPL}$  can be represented by the following equation.

$$\Delta V_{RPL} = 0.276 \text{ A} \times \left( 10 \text{ m}\Omega + \frac{1}{8 \times 10 \text{ }\mu\text{F} \times 2.2 \text{ MHz}} \right) = 4.33 \text{ [mV]}$$

where

$C_{OUT}$  is the 10  $\mu\text{F}$

$R_{ESR}$  is the 10 m $\Omega$



#### 4. Selection of Output LC Filter – continued

In addition, for the total value of capacitance in the output line  $C_{OUT(Max)}$ , choose a capacitance value less than the value obtained by the following equation.

$$C_{OUT(Max)} < \frac{(t_{SS(Min)} - 200 \mu s) \times (I_{OCP(Min)} - I_{SWSTART})}{V_{OUT}} \quad [F]$$

where:

$I_{SWSTART}$  is the maximum output current during startup  
 $I_{OCP(Min)}$  is the minimum OCP operation SW current 1.2 A  
 $t_{SS(Min)}$  is the minimum Soft Start Time  
 $V_{OUT}$  is the output voltage

Startup failure may happen if the limits from the above-mentioned are exceeded. Especially if the capacitance value is large, over current protection may be activated by the inrush current at startup and prevented to turn on the output. Please confirm this on the actual application.

Stable transient response and the loop is dependent to  $C_{OUT}$ . Actually, characteristics will vary depending on PCB layout, arrangement of wiring, kinds of parts used and use conditions(temperature, etc.). Please be sure to check stability and responsiveness with the actual application.

#### 5. Selection of Soft Start Capacitor

Turning the EN pin signal high activates the soft start function. This causes the output voltage to rise gradually while the current at startup is placed under control. This allows the prevention of output voltage overshoot and inrush current. The rise time  $t_{SS\_EXT}$  depends on the value of the capacitor connected to the SS pin. The capacitance value should be set to 0.1  $\mu F$  or less.

$$t_{SS\_EXT} = \frac{(C_{SS} \times V_{FB})}{I_{SS}} \quad [s]$$

where

$t_{SS\_EXT}$  is the Soft Start Time  
 $C_{SS}$  is the Capacitor connected to the SS pin  
 $V_{FB}$  is the FB pin Voltage 0.8 V(Typ)  
 $I_{SS}$  is the SS Charge Current 1.0  $\mu A$ (Typ)

With  $C_{SS}=0.01 \mu F$

$$t_{SS\_EXT} = \frac{(0.01 \mu F \times 0.8 V)}{1.0 \mu A} = 8.0 \quad [ms]$$

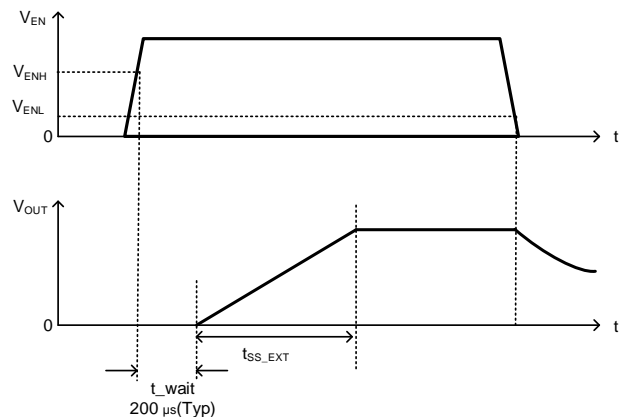


Figure 28. Soft Start Timing chart

Turning the EN pin High without connecting capacitor to the SS pin and keeping the SS pin either OPEN condition or 10 k $\Omega$  to 100 k $\Omega$  pull up condition to power source, the output will rise in 1 ms(Typ).

#### Recommended Parts Manufacturer List

Shown below is the list of the recommended parts manufacturers for reference.

Table 2

| Device | Type               | Manufacturer | URL  |
|--------|--------------------|--------------|--|
| C      | Ceramic capacitors | Murata       | <a href="http://www.murata.com">www.murata.com</a>       |
| C      | Ceramic capacitors | TDK          | <a href="http://product.tdk.com">product.tdk.com</a>     |
| L      | Inductors          | Coilcraft    | <a href="http://www.coilcraft.com">www.coilcraft.com</a> |
| L      | Inductors          | Cyntec       | <a href="http://www.cyntec.com">www.cyntec.com</a>       |
| L      | Inductors          | Murata       | <a href="http://www.murata.com">www.murata.com</a>       |
| L      | Inductors          | Sumida       | <a href="http://www.sumida.com">www.sumida.com</a>       |
| L      | Inductors          | TDK          | <a href="http://product.tdk.com">product.tdk.com</a>     |
| R      | Resistors          | ROHM         | <a href="http://www.rohm.com">www.rohm.com</a>           |

Application Example 1

Table 3. Specification Example 1

| Parameter                   | Symbol       | Example Value     |
|-----------------------------|--------------|-------------------|
| Product Name                | IC           | BD9S100NUX-C      |
| Supply Voltage              | $V_{IN}$     | 5.0 V, 3.3 V      |
| Output Voltage              | $V_{OUT}$    | 1.0 V             |
| Soft Start Time             | $t_{ss}$     | 1.0 ms(Typ)       |
| Maximum Output Current      | $I_{OUTMAX}$ | 1.0 A             |
| Operation Temperature Range | $T_a$        | -40 °C to +125 °C |

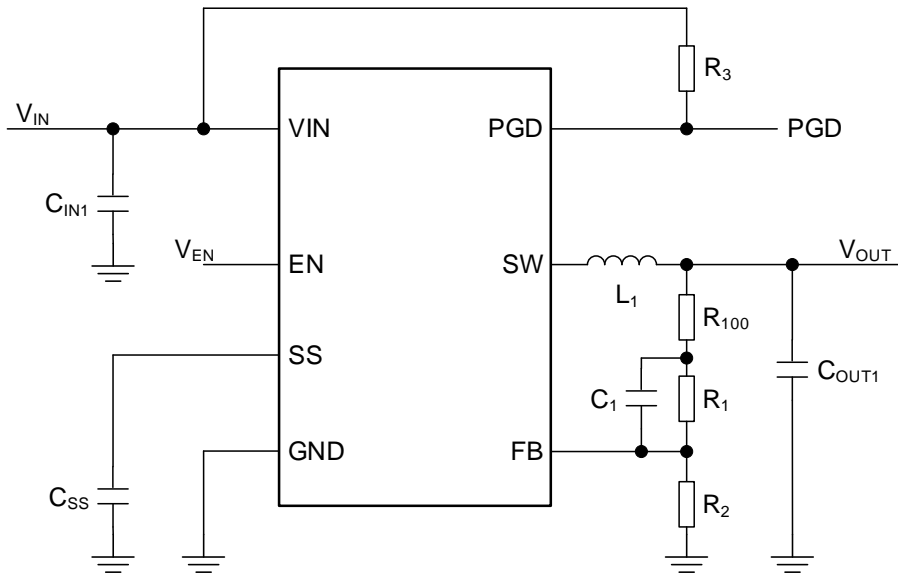


Figure 29. Reference Circuit 1

Table 4. Parts List 1

| No    | Package | Parameters                   | Part Name(Series) | Type              | Manufacturer |
|-------|---------|------------------------------|-------------------|-------------------|--------------|
| L1    | 2016    | 1.5 $\mu$ H                  | TFM201610ALMA1R5M | Inductor          | TDK          |
| COUT1 | 2012    | 10 $\mu$ F, X7R, 6.3 V       | GCM21BR70J106K    | Ceramic Capacitor | Murata       |
| CIN1  | 2012    | 10 $\mu$ F, X7R, 10 V        | GCM21BR71A106K    | Ceramic Capacitor | Murata       |
| R100  | -       | SHORT                        | -                 | -                 | -            |
| R1    | 1005    | 7.5 k $\Omega$ , 1 %, 1/16 W | MCR01MZPF7501     | Chip Resistor     | ROHM         |
| R2    | 1005    | 30 k $\Omega$ , 1 %, 1/16 W  | MCR01MZPF3002     | Chip Resistor     | ROHM         |
| R3    | 1005    | 100 k $\Omega$ , 1 %, 1/16 W | MCR01MZPF1003     | Chip Resistor     | ROHM         |
| CSS   | -       | -                            | -                 | -                 | -            |
| C1    | -       | -                            | -                 | -                 | -            |

Characteristic Data (Application Examples 1)

$V_{IN} = V_{EN}$ ,  $T_a = 25\text{ }^{\circ}\text{C}$

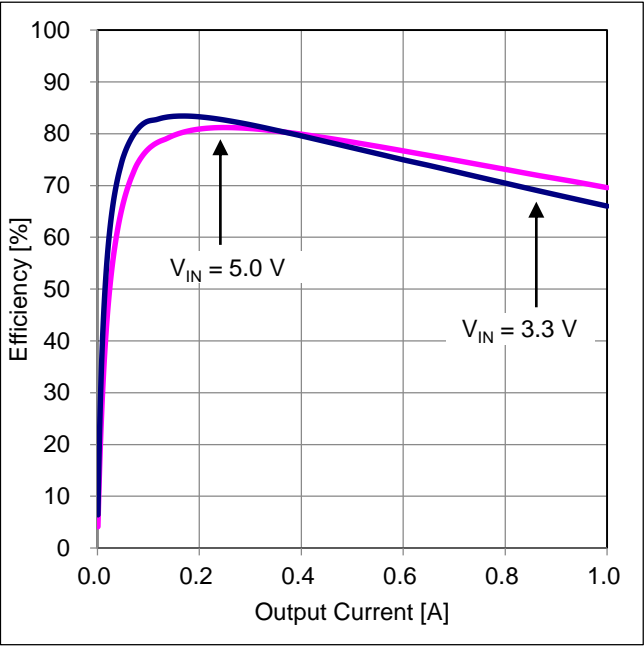


Figure 30. Efficiency vs Output Current

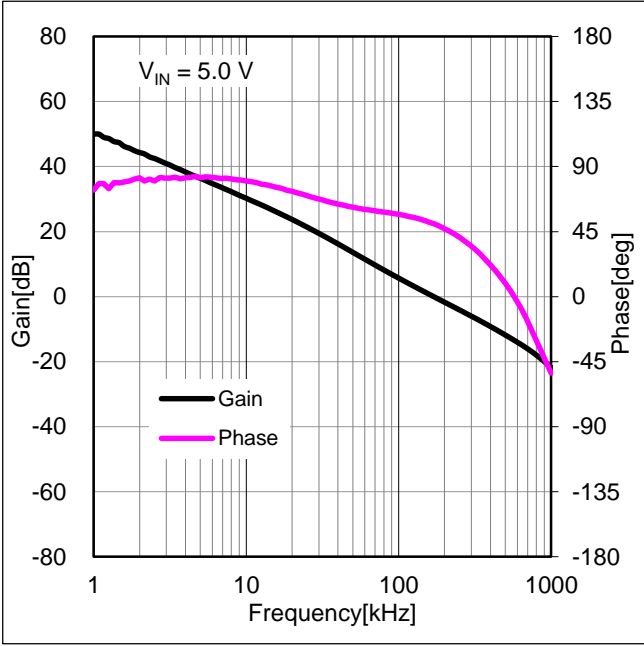


Figure 31. Frequency Characteristics  
( $I_{OUT}=1\text{ A}$ )

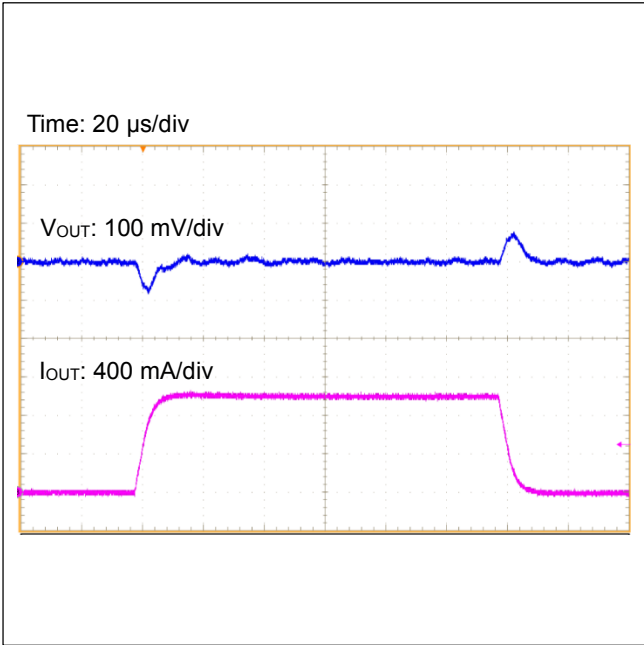


Figure 32. Load Transient Response  
( $I_{OUT}=0\text{ A} \leftrightarrow 1\text{ A}$ )

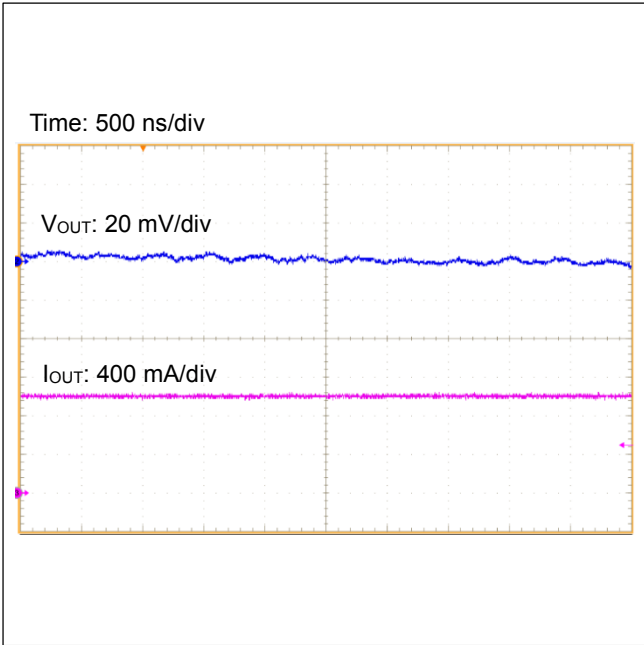


Figure 33. Output Ripple Voltage  
( $I_{OUT}=1\text{ A}$ )

Application Example 2

Table 5. Specification Example 2

| Parameter                   | Symbol              | Example Value     |
|-----------------------------|---------------------|-------------------|
| Product Name                | IC                  | BD9S100NXX-C      |
| Supply Voltage              | V <sub>IN</sub>     | 5.0 V, 3.3 V      |
| Output Voltage              | V <sub>OUT</sub>    | 1.2 V             |
| Soft Start Time             | t <sub>ss</sub>     | 1.0 ms(Typ)       |
| Maximum Output Current      | I <sub>OUTMAX</sub> | 1.0 A             |
| Operation Temperature Range | T <sub>a</sub>      | -40 °C to +125 °C |

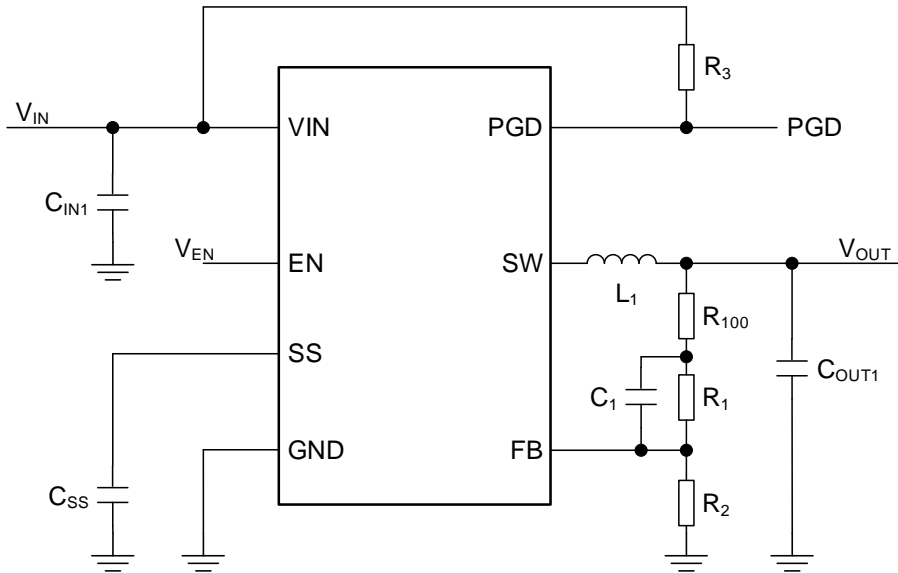


Figure 34. Reference Circuit 2

Table 6. Parts List 2

| No                | Package | Parameters                   | Part Name(Series) | Type              | Manufacturer |
|-------------------|---------|------------------------------|-------------------|-------------------|--------------|
| L <sub>1</sub>    | 2016    | 1.5 $\mu$ H                  | TFM201610ALMA1R5M | Inductor          | TDK          |
| C <sub>OUT1</sub> | 2012    | 10 $\mu$ F, X7R, 6.3 V       | GCM21BR70J106K    | Ceramic Capacitor | Murata       |
| C <sub>IN1</sub>  | 2012    | 10 $\mu$ F, X7R, 10 V        | GCM21BR71A106K    | Ceramic Capacitor | Murata       |
| R <sub>100</sub>  | -       | SHORT                        | -                 | -                 | -            |
| R <sub>1</sub>    | 1005    | 10 k $\Omega$ , 1 %, 1/16 W  | MCR01MZPF1002     | Chip Resistor     | ROHM         |
| R <sub>2</sub>    | 1005    | 20 k $\Omega$ , 1 %, 1/16 W  | MCR01MZPF2002     | Chip Resistor     | ROHM         |
| R <sub>3</sub>    | 1005    | 100 k $\Omega$ , 1 %, 1/16 W | MCR01MZPF1003     | Chip Resistor     | ROHM         |
| C <sub>SS</sub>   | -       | -                            | -                 | -                 | -            |
| C <sub>1</sub>    | -       | -                            | -                 | -                 | -            |

Characteristic Data (Application Examples 2)

$V_{IN} = V_{EN}$ ,  $T_a = 25\text{ }^{\circ}\text{C}$

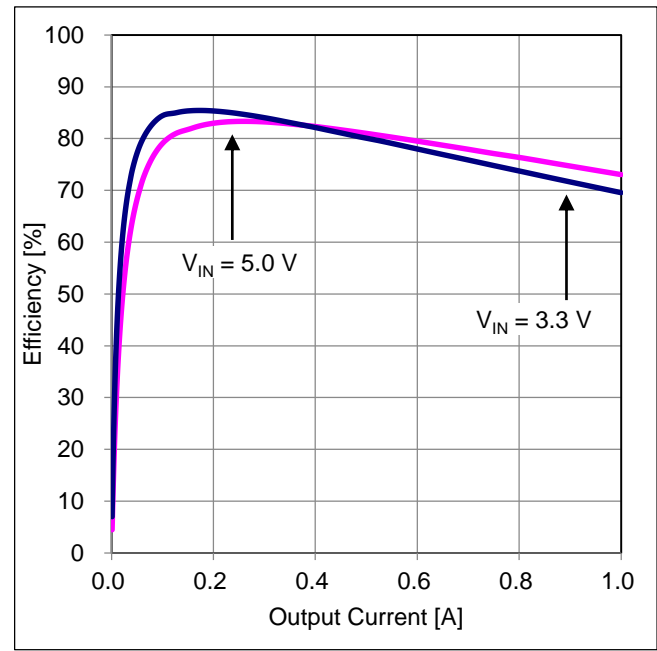


Figure 35. Efficiency vs Output Current

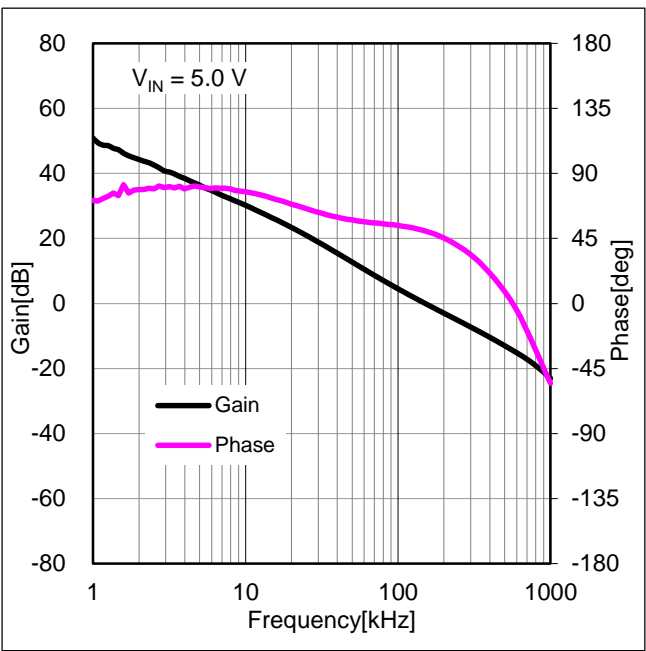


Figure 36. Frequency Characteristic  
( $I_{OUT} = 1\text{ A}$ )

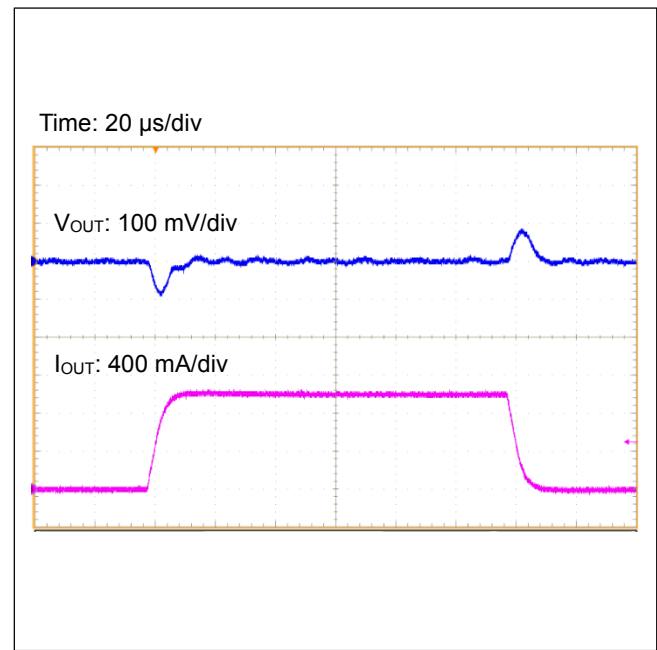


Figure 37. Load Transient Response  
( $I_{OUT} = 0\text{ A} \leftrightarrow 1\text{ A}$ )

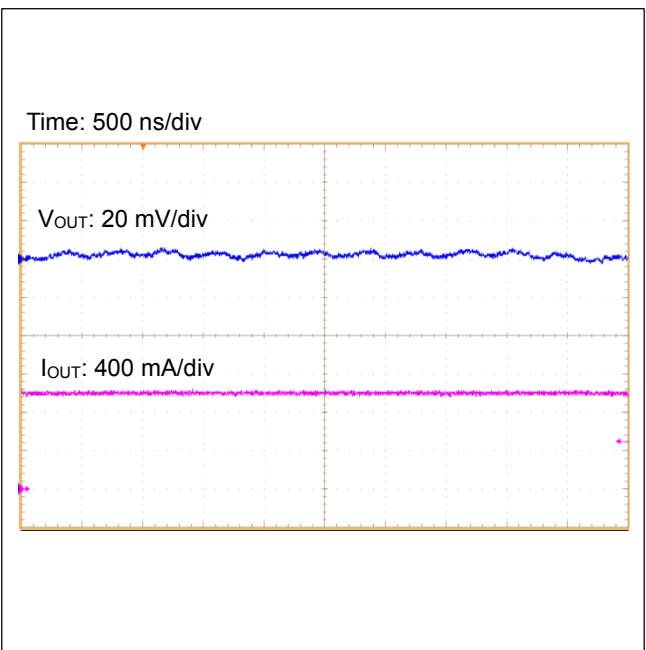


Figure 38. Output Ripple Voltage  
( $I_{OUT} = 1\text{ A}$ )

Application Example 3

Table 7. Specification Example 3

| Parameter                   | Symbol              | Example Value     |
|-----------------------------|---------------------|-------------------|
| Product Name                | IC                  | BD9S100NUX-C      |
| Supply Voltage              | V <sub>IN</sub>     | 5.0 V, 3.3 V      |
| Output Voltage              | V <sub>OUT</sub>    | 1.5 V             |
| Soft Start Time             | t <sub>ss</sub>     | 1.0 ms(Typ)       |
| Maximum Output Current      | I <sub>OUTMAX</sub> | 1.0 A             |
| Operation Temperature Range | T <sub>a</sub>      | -40 °C to +125 °C |

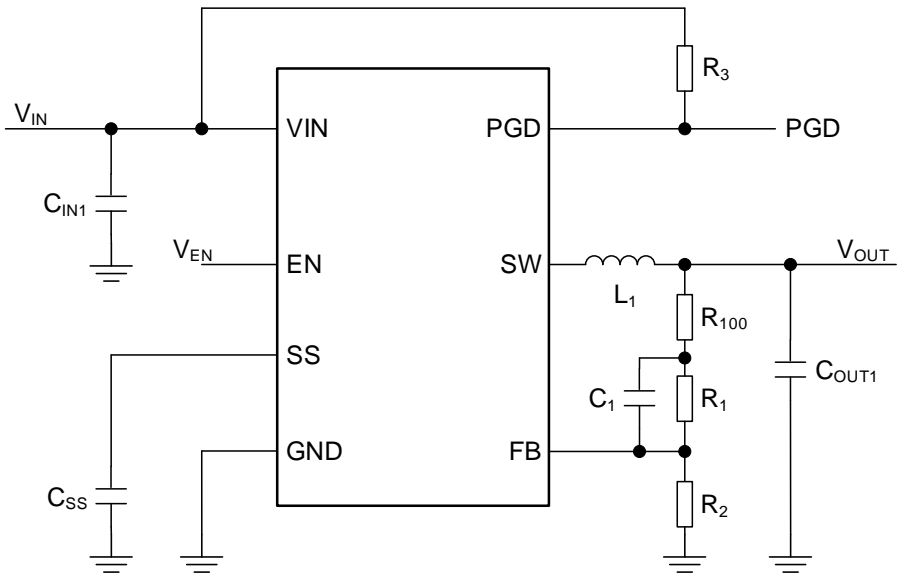


Figure 39. Reference Circuit 3

Table 8. Parts List 3

| No                | Package | Parameters                   | Part Name(Series) | Type              | Manufacturer |
|-------------------|---------|------------------------------|-------------------|-------------------|--------------|
| L <sub>1</sub>    | 2016    | 1.5 $\mu$ H                  | TFM201610ALMA1R5M | Inductor          | TDK          |
| C <sub>OUT1</sub> | 2012    | 10 $\mu$ F, X7R, 6.3 V       | GCM21BR70J106K    | Ceramic Capacitor | Murata       |
| C <sub>IN1</sub>  | 2012    | 10 $\mu$ F, X7R, 10 V        | GCM21BR71A106K    | Ceramic Capacitor | Murata       |
| R <sub>100</sub>  | -       | SHORT                        | -                 | -                 | -            |
| R <sub>1</sub>    | 1005    | 16 k $\Omega$ , 1 %, 1/16 W  | MCR01MZPF1602     | Chip Resistor     | ROHM         |
| R <sub>2</sub>    | 1005    | 18 k $\Omega$ , 1 %, 1/16 W  | MCR01MZPF1802     | Chip Resistor     | ROHM         |
| R <sub>3</sub>    | 1005    | 100 k $\Omega$ , 1 %, 1/16 W | MCR01MZPF1003     | Chip Resistor     | ROHM         |
| C <sub>SS</sub>   | -       | -                            | -                 | -                 | -            |
| C <sub>1</sub>    | -       | -                            | -                 | -                 | -            |

Characteristic Data (Application Examples 3)

$V_{IN} = V_{EN}$ ,  $T_a = 25\text{ }^{\circ}\text{C}$

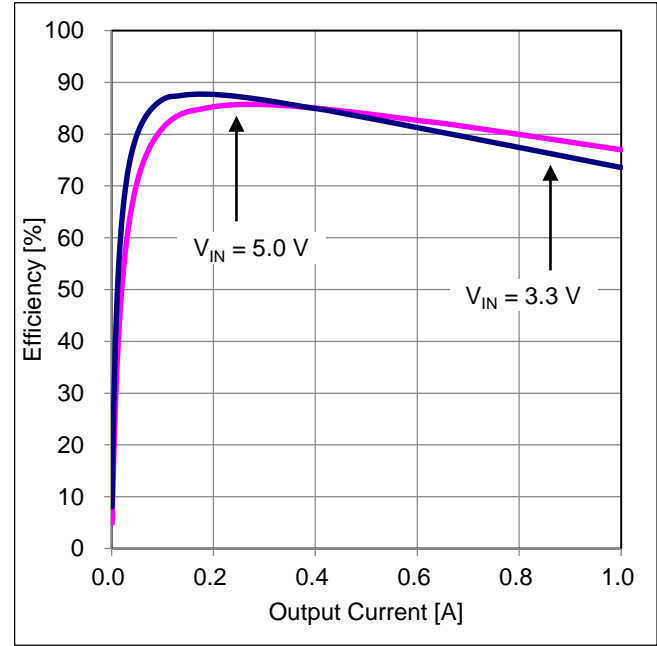


Figure 40. Efficiency vs Output Current

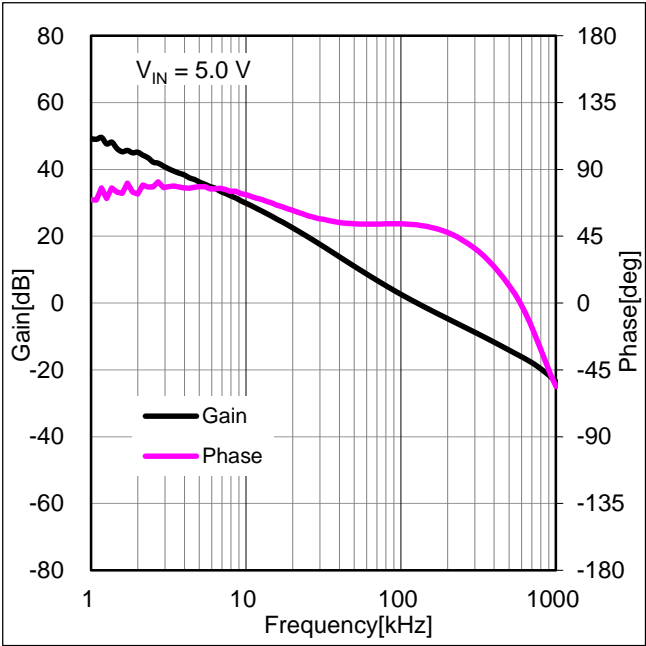


Figure 41. Frequency Characteristics  
( $I_{OUT} = 1\text{ A}$ )

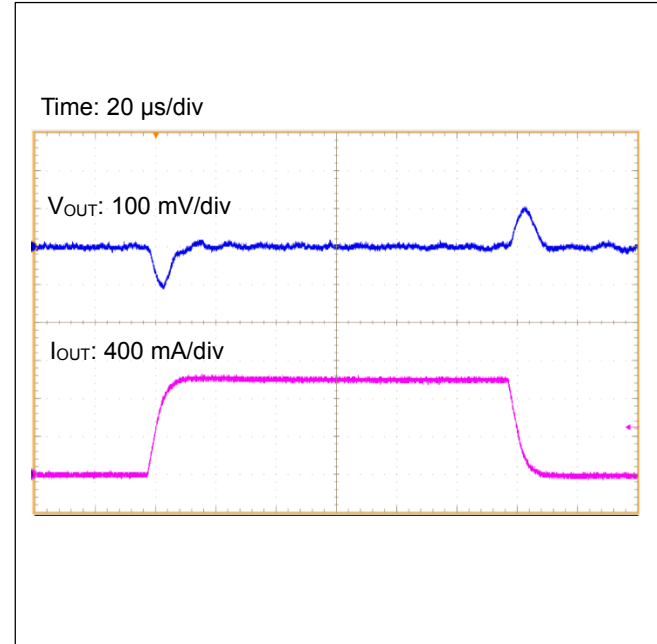


Figure 42. Load Transient Response  
( $I_{OUT} = 0\text{ A} \leftrightarrow 1\text{ A}$ )

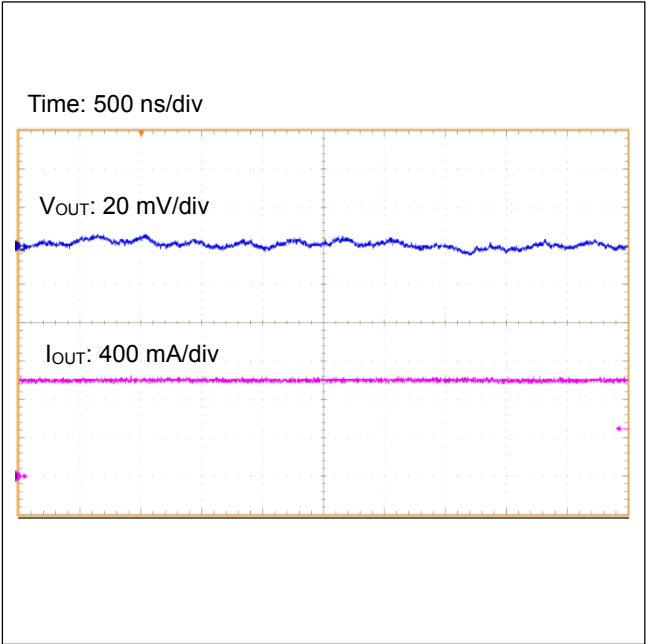


Figure 43. Output Ripple Voltage  
( $I_{OUT} = 1\text{ A}$ )

Application Example 4

Table 9. Specification Example 4

| Parameter                   | Symbol              | Example Value     |
|-----------------------------|---------------------|-------------------|
| Product Name                | IC                  | BD9S100NUX-C      |
| Supply Voltage              | V <sub>IN</sub>     | 5.0 V, 3.3 V      |
| Output Voltage              | V <sub>OUT</sub>    | 1.8 V             |
| Soft Start Time             | t <sub>ss</sub>     | 1.0 ms(Typ)       |
| Maximum Output Current      | I <sub>OUTMAX</sub> | 1.0 A             |
| Operation Temperature Range | T <sub>a</sub>      | -40 °C to +125 °C |

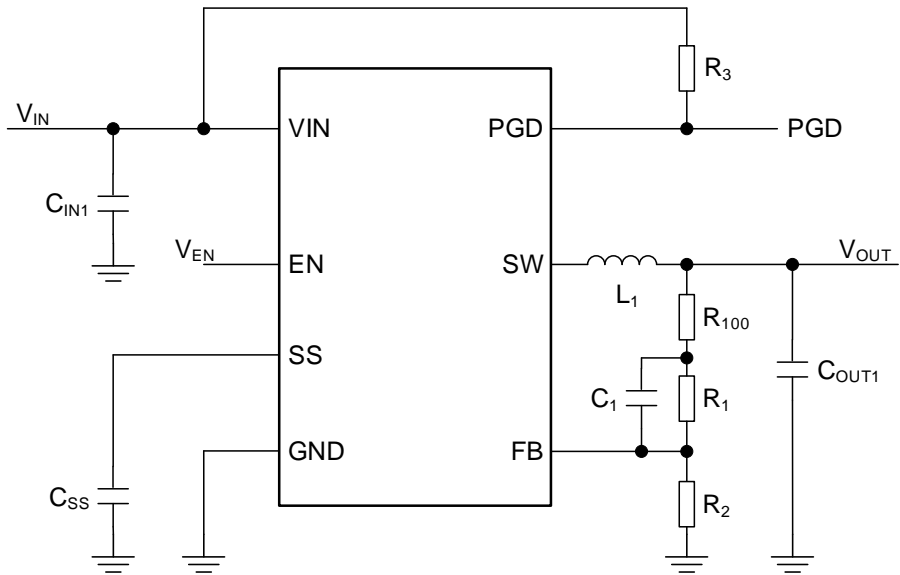


Figure 44. Reference Circuit 4

Table 10. Parts List 4

| No                | Package | Parameters          | Part Name(Series) | Type              | Manufacturer |
|-------------------|---------|---------------------|-------------------|-------------------|--------------|
| L <sub>1</sub>    | 2016    | 1.5 μH              | TFM201610ALMA1R5M | Inductor          | TDK          |
| C <sub>OUT1</sub> | 2012    | 10 μF, X7R, 6.3 V   | GCM21BR70J106K    | Ceramic Capacitor | Murata       |
| C <sub>IN1</sub>  | 2012    | 10 μF, X7R, 10 V    | GCM21BR71A106K    | Ceramic Capacitor | Murata       |
| R <sub>100</sub>  | -       | SHORT               | -                 | -                 | -            |
| R <sub>1</sub>    | 1005    | 30 kΩ, 1 %, 1/16 W  | MCR01MZPF3002     | Chip Resistor     | ROHM         |
| R <sub>2</sub>    | 1005    | 24 kΩ, 1 %, 1/16 W  | MCR01MZPF2402     | Chip Resistor     | ROHM         |
| R <sub>3</sub>    | 1005    | 100 kΩ, 1 %, 1/16 W | MCR01MZPF1003     | Chip Resistor     | ROHM         |
| C <sub>SS</sub>   | -       | -                   | -                 | -                 | -            |
| C <sub>1</sub>    | -       | -                   | -                 | -                 | -            |



## Characteristic Data (Application Examples 4)

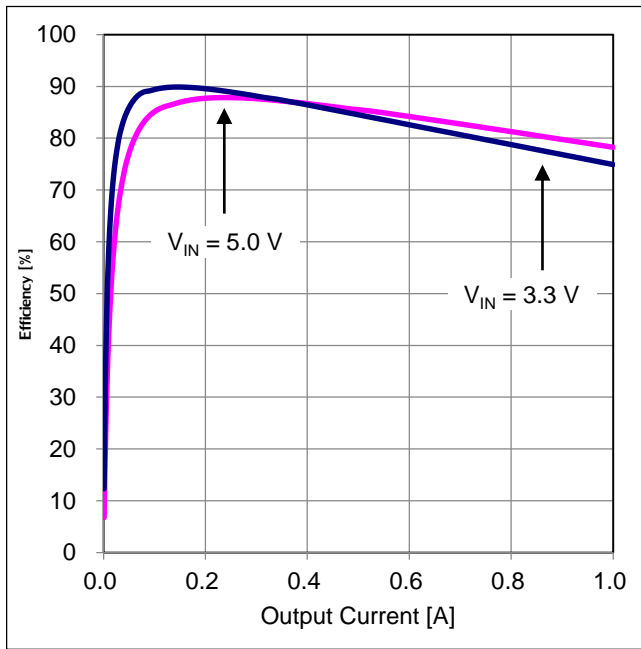
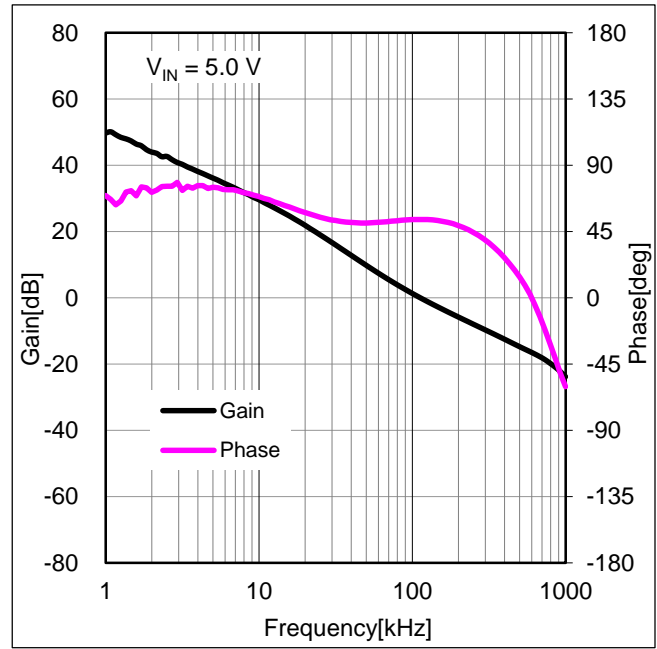
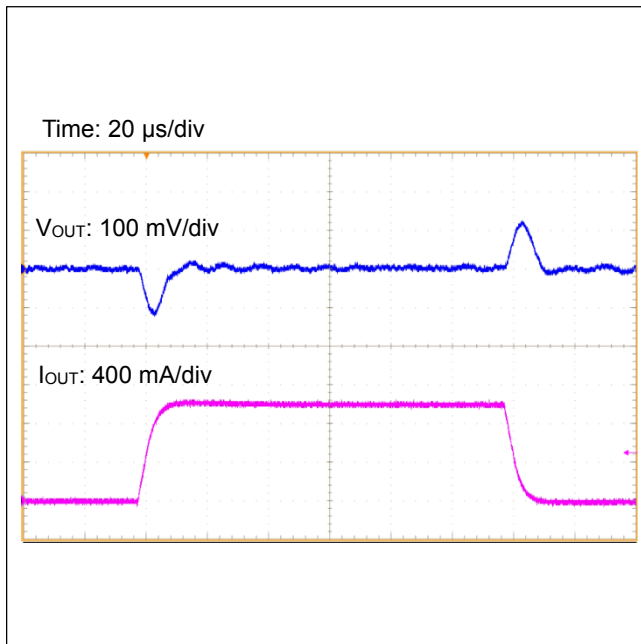
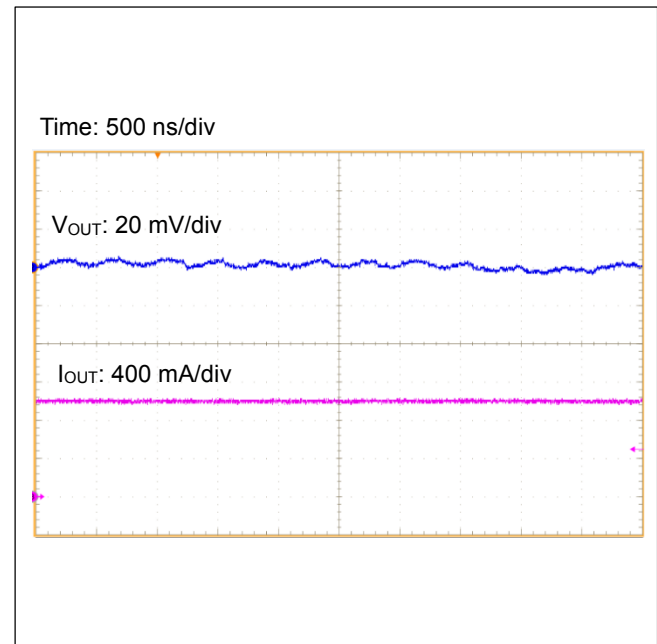
 $V_{IN} = V_{EN}$ ,  $T_a = 25^\circ\text{C}$ 

Figure 45. Efficiency vs Output Current

Figure 46. Frequency Characteristics  
( $I_{OUT} = 1\text{ A}$ )Figure 47. Load Transient Response  
( $I_{OUT} = 0\text{ A} \leftrightarrow 1\text{ A}$ )Figure 48. Output Ripple Voltage  
( $I_{OUT} = 1\text{ A}$ )

Application Example 5

Table 11. Specification Example 5

| Parameter                   | Symbol       | Example Value     |
|-----------------------------|--------------|-------------------|
| Product Name                | IC           | BD9S100NUX-C      |
| Supply Voltage              | $V_{IN}$     | 5.0 V             |
| Output Voltage              | $V_{OUT}$    | 3.3 V             |
| Soft Start Time             | $t_{ss}$     | 1.0 ms(Typ)       |
| Maximum Output Current      | $I_{OUTMAX}$ | 1.0 A             |
| Operation Temperature Range | $T_a$        | -40 °C to +125 °C |

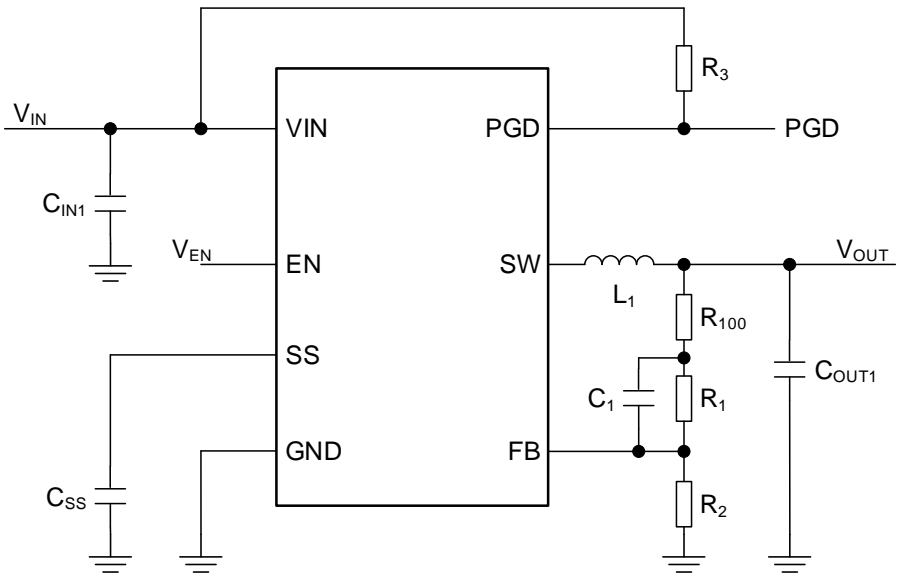


Figure 49. Reference Circuit 5

Table 12. Parts List 5

| No                | Package | Parameters                   | Part Name(Series) | Type              | Manufacturer |
|-------------------|---------|------------------------------|-------------------|-------------------|--------------|
| L <sub>1</sub>    | 2016    | 1.5 $\mu$ H                  | TFM201610ALMA1R5M | Inductor          | TDK          |
| C <sub>OUT1</sub> | 2012    | 10 $\mu$ F, X7R, 10 V        | GCM21BR71A106K    | Ceramic Capacitor | Murata       |
| C <sub>IN1</sub>  | 2012    | 10 $\mu$ F, X7R, 10 V        | GCM21BR71A106K    | Ceramic Capacitor | Murata       |
| R <sub>100</sub>  | -       | SHORT                        | -                 | -                 | -            |
| R <sub>1</sub>    | 1005    | 75 k $\Omega$ , 1 %, 1/16 W  | MCR01MZPF7502     | Chip Resistor     | ROHM         |
| R <sub>2</sub>    | 1005    | 24 k $\Omega$ , 1 %, 1/16 W  | MCR01MZPF2402     | Chip Resistor     | ROHM         |
| R <sub>3</sub>    | 1005    | 100 k $\Omega$ , 1 %, 1/16 W | MCR01MZPF1003     | Chip Resistor     | ROHM         |
| C <sub>SS</sub>   | -       | -                            | -                 | -                 | -            |
| C <sub>1</sub>    | -       | -                            | -                 | -                 | -            |

Characteristic Data (Application Examples 5)

$V_{IN} = V_{EN}$ ,  $T_a = 25\text{ }^{\circ}\text{C}$

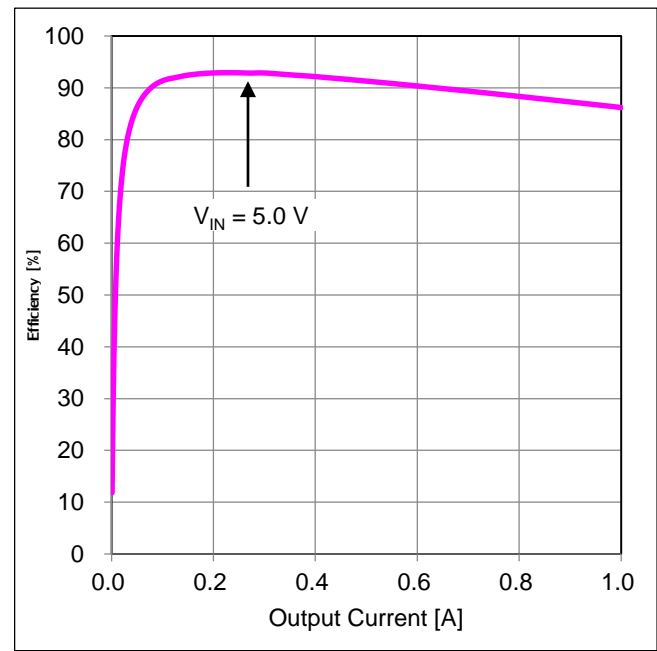


Figure 50. Efficiency vs Output Current

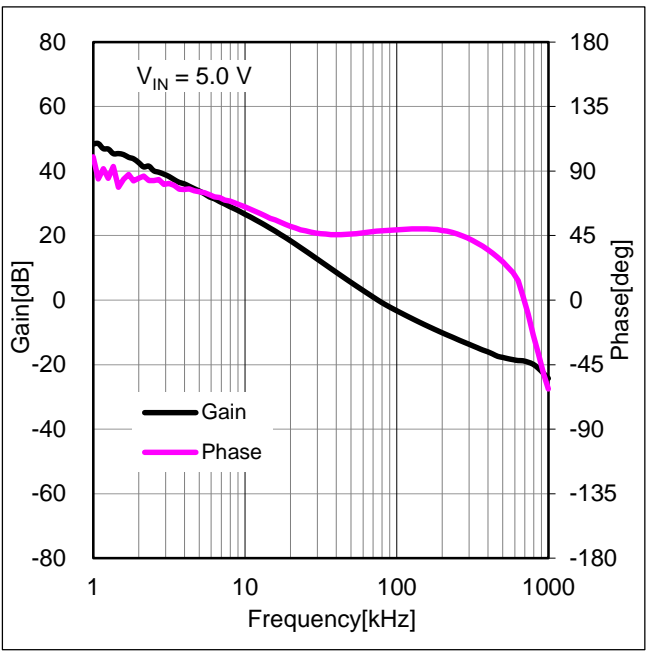


Figure 51. Frequency Characteristics  
( $I_{OUT}=1\text{ A}$ )

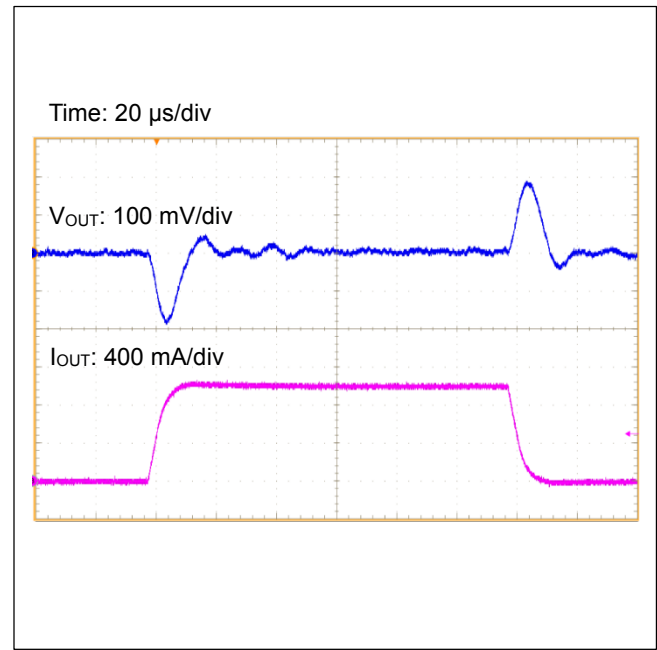


Figure 52. Load Transient Response  
( $I_{OUT}=0\text{ A}\leftrightarrow 1\text{ A}$ )

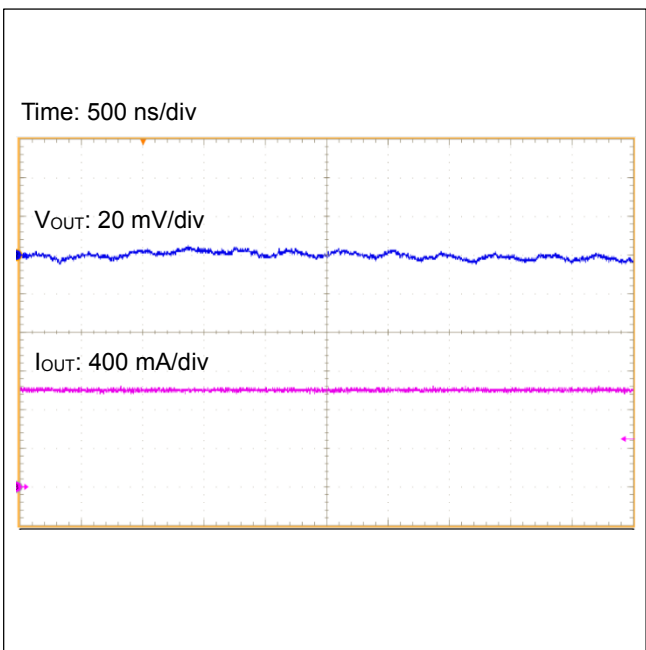


Figure 53. Output Ripple Voltage  
( $I_{OUT}=1\text{ A}$ )

## PCB Layout Design

PCB layout design for DC/DC converter is very important. Appropriate layout can avoid various problems concerning power supply circuit. Figure 54-a to 54-c show the current path in a buck DC/DC converter circuit. The Loop 1 in Figure 54-a is a current path when H-side switch is ON and L-side switch is OFF, the Loop 2 in Figure 54-b is when H-side switch is OFF and L-side switch is ON. The thick line in Figure 54-c shows the difference between Loop1 and Loop2. The current in thick line change sharply each time the switching element H-side and L-side switch change from OFF to ON, and vice versa. These sharp changes induce a waveform with harmonics in this loop. Therefore, the loop area of thick line that is consisted by input capacitor and IC should be as small as possible to minimize noise. For more details, refer to application note of switching regulator series "PCB Layout Techniques of Buck Converter".

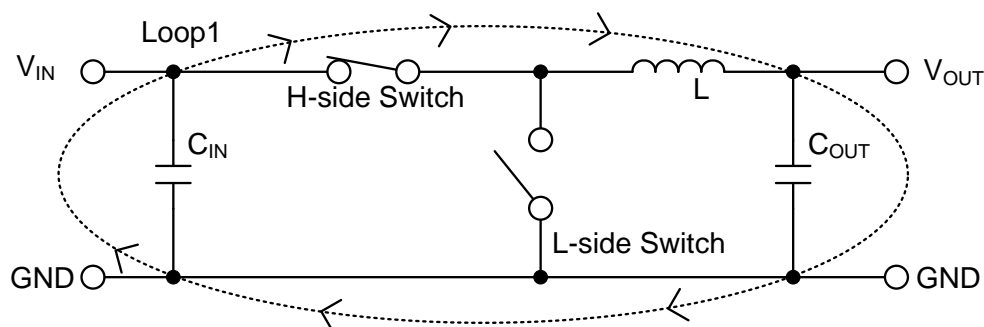


Figure 54-a. Current Path when H-side Switch = ON, L-side Switch = OFF

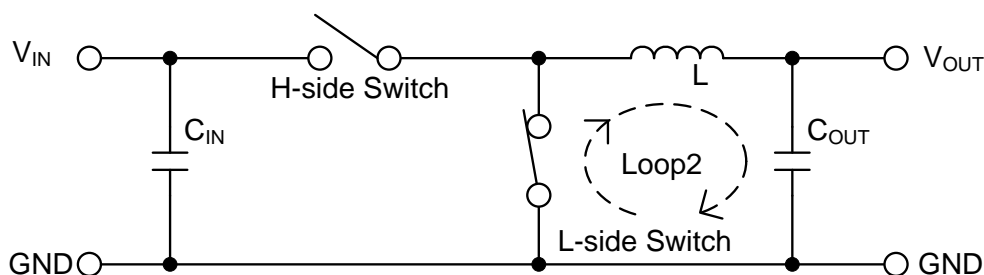


Figure 54-b. Current Path when H-side Switch = OFF, L-side Switch = ON

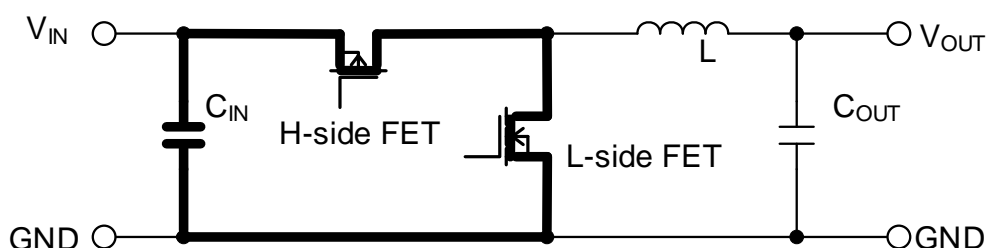
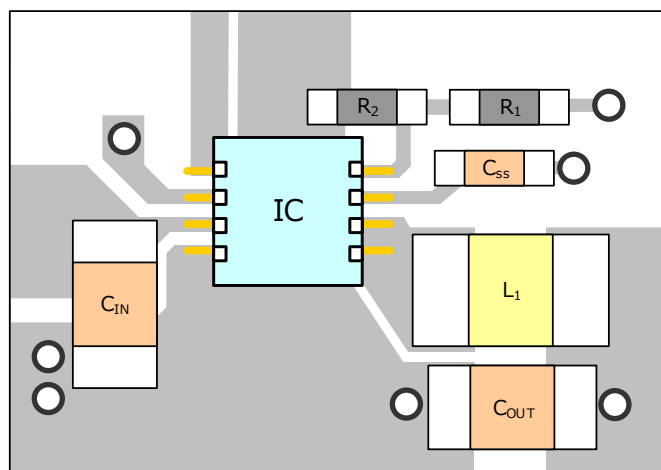


Figure 54-c. Difference of Current and Critical Area in Layout

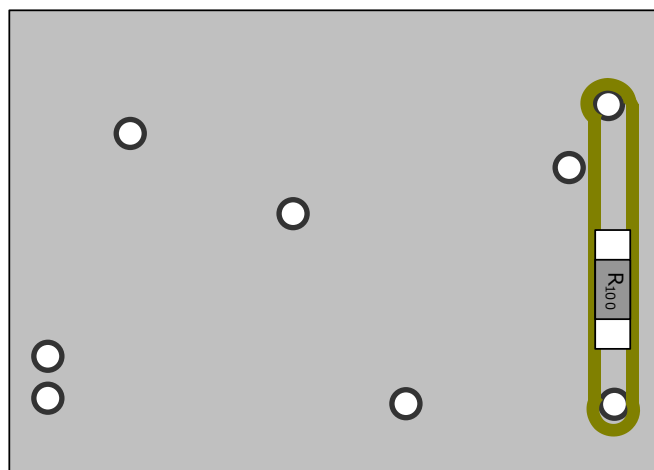
## PCB Layout Design – continued

When designing the PCB layout, please pay extra attention to the following points:

- Connect the input capacitor  $C_{IN}$  as close as possible to the VIN pin on the same plane as the IC.
- Switching nodes such as SW are susceptible to noise due to AC coupling with other nodes. Route the inductor pattern as thick and as short as possible.
- $R_1$  and  $R_2$  shall be located as close as possible to the FB pin and the wiring between  $R_1$  and  $R_2$  to the FB pin shall be as short as possible.
- Provide line connected to FB far from the SW nodes.
- $R_{100}$  is provided for the measurement of feedback frequency characteristics (optional). By inserting a resistor into  $R_{100}$ , it is possible to measure the frequency characteristics of feedback (phase margin) using FRA etc.  $R_{100}$  is short-circuited for normal use.



Example of Evaluation Board Layout (Top View)



Example of Evaluation Board Layout (Bottom View)

Figure 55. Example of Evaluation Board Layout

## Power Dissipation

For thermal design, be sure to operate the IC within the following conditions.  
(Since the temperatures described hereunder are all guaranteed temperatures, take margin into account.)

1. The ambient temperature  $T_a$  is to be 125 °C or less.
2. The chip junction temperature  $T_j$  is to be 150 °C or less.

The chip junction temperature  $T_j$  can be considered in the following two patterns:

1. To obtain  $T_j$  from the package surface center temperature  $T_t$  in actual use

$$T_j = T_t + \psi_{JT} \times W \text{ [}^\circ\text{C]}$$

2. To obtain  $T_j$  from the ambient temperature  $T_a$

$$T_j = T_a + \theta_{JA} \times W \text{ [}^\circ\text{C]}$$

Where:

$\psi_{JT}$  is junction to top characterization parameter ([Refer to page 5](#))

$\theta_{JA}$  is junction to ambient ([Refer to page 5](#))

The heat loss  $W$  of the IC can be obtained by the formula shown below:

$$W = R_{ONH} \times I_{OUT}^2 \times \frac{V_{OUT}}{V_{IN}} + R_{ONL} \times I_{OUT}^2 \left(1 - \frac{V_{OUT}}{V_{IN}}\right) + V_{IN} \times I_{CC} + \frac{1}{2} \times (tr + tf) \times V_{IN} \times I_{OUT} \times f_{SW} \text{ [W]}$$

Where:

$R_{ONH}$  is the High Side FET ON Resistance ([Refer to page 6](#)) [ $\Omega$ ]

$R_{ONL}$  is the Low Side FET ON Resistance ([Refer to page 6](#)) [ $\Omega$ ]

$I_{OUT}$  is the Output Current [A]

$V_{OUT}$  is the Output Voltage [V]

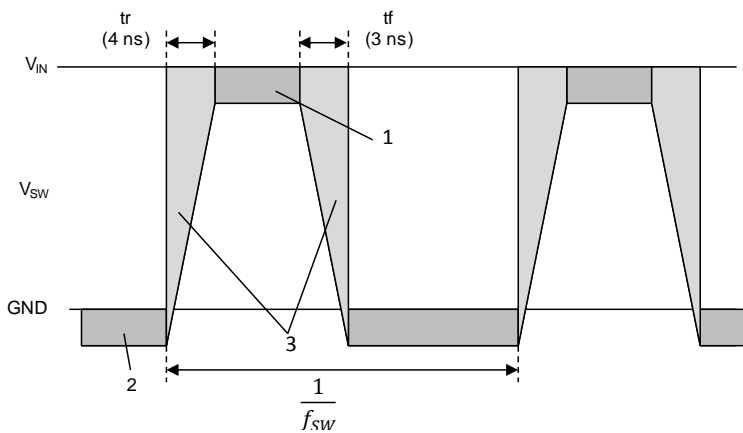
$V_{IN}$  is the Input Voltage [V]

$I_{CC}$  is the Circuit Current ([Refer to page 6](#)) [A]

$tr$  is the Switching Rise Time [s] (Typ:4 ns)

$tf$  is the Switching Fall Time [s] (Typ:3 ns)

$f_{SW}$  is the Switching Frequency ([Refer to page 6](#)) [Hz]



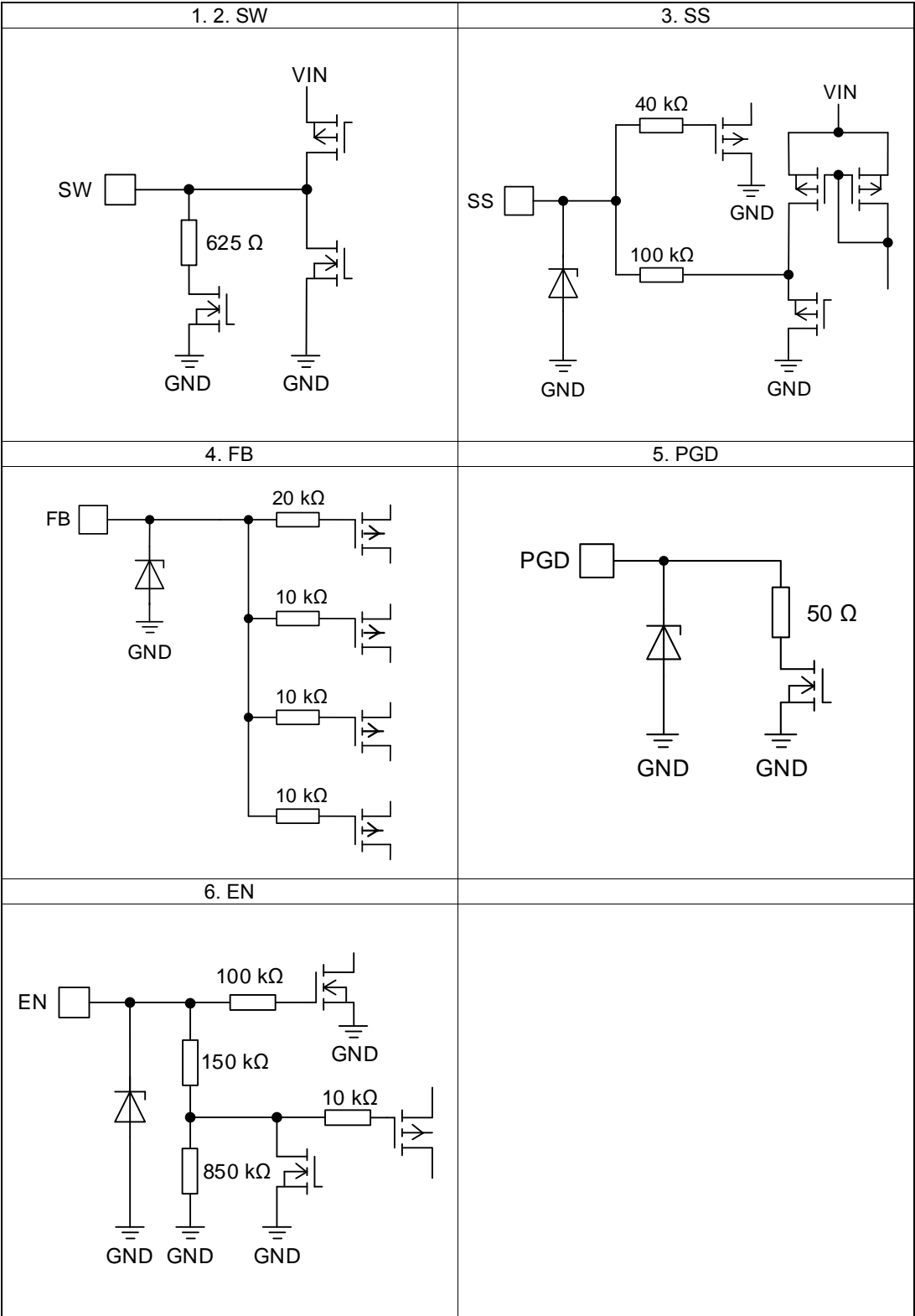
$$1. R_{ONH} \times I_{OUT}^2$$

$$2. R_{ONL} \times I_{OUT}^2$$

$$3. \frac{1}{2} \times (tr + tf) \times V_{IN} \times I_O \times f_{SW}$$

Figure 56. SW Waveform

I/O Equivalent Circuits<sup>(Note 1)</sup>



(Note 1) Resistance value is Typical.

## Operational Notes

### 1. Reverse Connection of Power Supply

Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

### 2. Power Supply Lines

Design the PCB layout pattern to provide low impedance supply lines. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

### 3. Ground Voltage

Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition. However, pins that drive inductive loads (e.g. motor driver outputs, DC-DC converter outputs) may inevitably go below ground due to back EMF or electromotive force. In such cases, the user should make sure that such voltages going below ground will not cause the IC and the system to malfunction by examining carefully all relevant factors and conditions such as motor characteristics, supply voltage, operating frequency and PCB wiring to name a few.

### 4. Ground Wiring Pattern

When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

### 5. Recommended Operating Conditions

The function and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions of each item specified by the electrical characteristics.

### 6. Inrush Current

When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

### 7. Testing on Application Boards

When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

### 8. Inter-pin Short and Mounting Errors

Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

### 9. Unused Input Pins

Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.



## Operational Notes – continued

**10. Regarding the Input Pin of the IC**

This monolithic IC contains P<sup>+</sup> isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.

When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

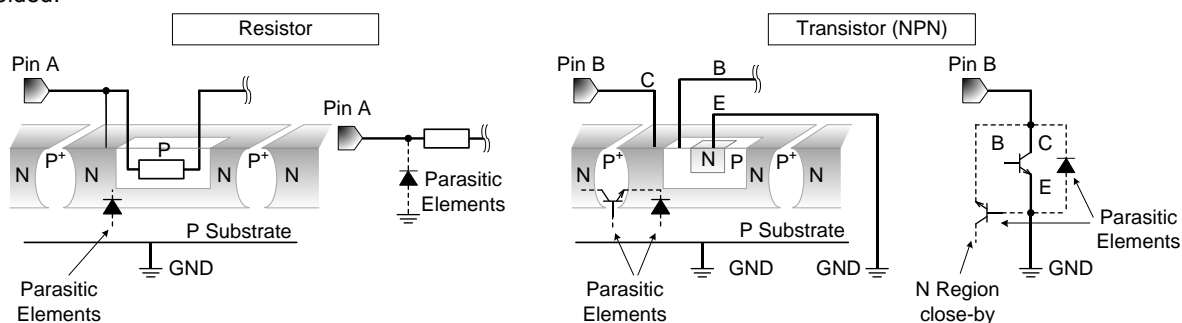


Figure 57. Example of monolithic IC structure

**11. Ceramic Capacitor**

When using a ceramic capacitor, determine a capacitance value considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

**12. Thermal Shutdown Circuit(TSD)**

This IC has a built-in thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature ( $T_j$ ) will rise which will activate the TSD circuit that will turn OFF power output pins. When the  $T_j$  falls below the TSD threshold, the circuits are automatically restored to normal operation.

Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

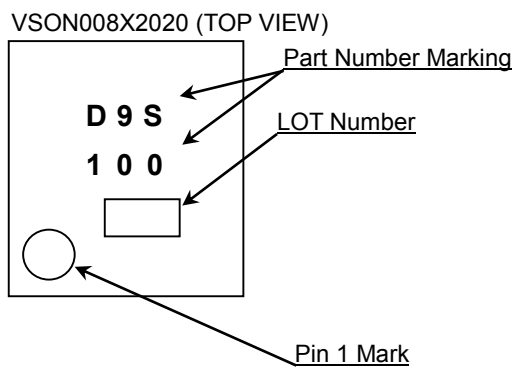
**13. Over Current Protection Circuit (OCP)**

This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.

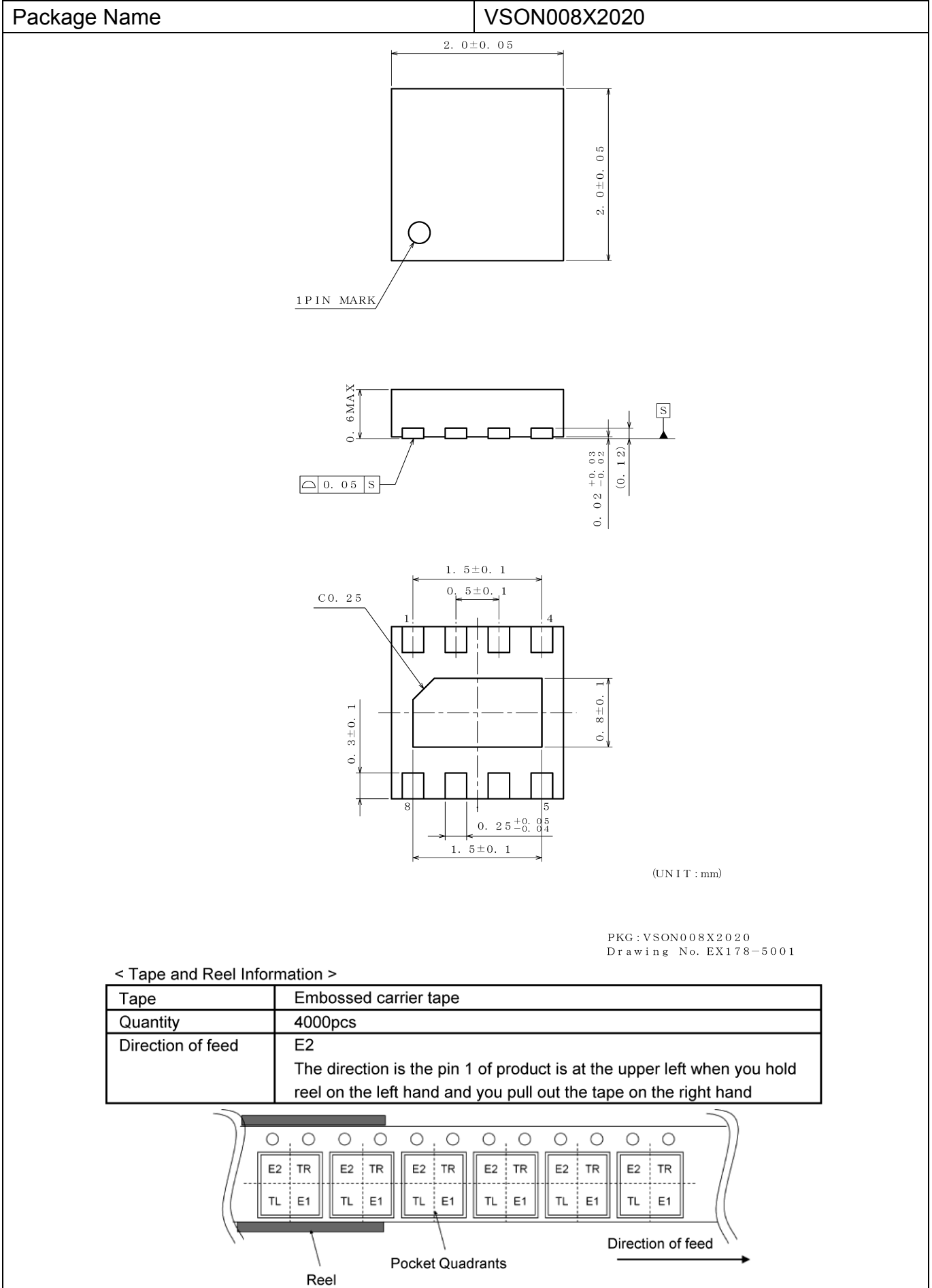
Ordering Information

|                     |  |  |  |  |  |  |  |  |  |                         |       |   |  |
|---------------------|--|--|--|--|--|--|--|--|--|-------------------------|-------|---|--|
| B D 9 S 1 0 0 N U X |  |  |  |  |  |  |  |  |  | -                       | C E 2 |   |  |
| Part Number         |  |  |  |  |  |  |  |  |  | Package<br>VSON008X2020 |       | Product class<br>C for Automotive applications<br>Packaging and forming specification<br>E2: Embossed tape and reel |  |

Marking Diagrams



## Physical Dimension and Packing Information



Revision History

| Date        | Revision | Changes     |
|-------------|----------|-------------|
| 08.May.2018 | 001      | New Release |

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