IC Card Interface ICs

IC Card Interface ICs with Built-in Low Noise LDO Regulator

BD8918F,BD8918FV,BD8919F,BD8919FV

No.09056EDT01

●Overview

This is an interface IC for a 5V smart card.
It works as a bidirectional signal buffer between a smart card and a controller. Also, it supplies 5V power to a smart card.
With an electrostatic breakdown voltage of more than HBM; ±6000V, it protects the card contact pins.

●Features

1) 1 half duplex bidirectional buffers
2) Protection against short-circuit for all the card contact pins
3) 5V power source for the card (VCC)
4) Over-current protection for card power source
5) Built-in thermal shutdown circuit
6) Built-in supply voltage detector
7) Automatic activation/deactivation sequence function for card contact pin
   Activation sequence: driven by a signal from controller (CMDVCCB↓)
   Deactivation sequence: driven by a signal from controller (CMDVCCB↑) and fault detection (card removal, short circuit of card power, IC overheat detection, VDD or VDDP drop)
8) Card contact pin ESD voltage ≧ ±6000V
9) Recommend frequency of crystal oscillator: 8MHz (BD8918F/FV), 16MHz (BD8919F/FV)
10) Programmable for card clock division of output signal: 1/1 and 1/2(BD8918F/FV), 1/2 and 1/4(BD8919F/FV).
11) RST output control by RSTIN input signal (positive output)
12) One multiplexed card status output by OFFB signal

●Applications

Interface for CLASS A smart cards
Interface for B-CAS cards

●Line up matrix

Part No	Card clock Ratio of dividing frequency	Package
BD8918F	1/1f, 1/2f	SOP16
BD8918FV		SSOP-B16
BD8919F	1/2f, 1/4f	SOP16
BD8919FV		SSOP-B16

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

●Absolute maximum ratings (Ta=25°C)

Parameter	Symbol	Ratings	Unit	Notes
VDD Input Voltage	V_{DD}	-0.3 ~ 6.5	V	
VDDP Input Voltage	V_{DDP}	-0.3 ~ 6.5	V	
I/O Pin Voltage	V_{MIN} V_{MOUT}	-0.3 ~ +6.5	V	Pin: XTAL1, XTAL2, CLKSEL, RSTIN, IO_U CMDVCCB, OFFB
Card Contact Pin Voltage	V_{CD}	-0.3 ~ +6.5	V	Pin: PRES, CLK, RST, IO_C
Junction Temperature	T_{jmax}	+150	°C	
Storage Temperature	T_{stg}	-55 ~ +150	°C	
Power Dissipation	P_{tot}	0.375 *1 0.500 *2	W	T = -20 ~ +85°C (Refer to the following package power dissipation)

*1 BD8918F/BD8919F, *2 BD8918FV/BD8919FV

- This product is not designed to be radiation tolerant.
- Absolute maximum ratings are not meant for guarantee of operation.

●Operating Conditions (Ta=25°C)

Parameter	Symbol	Ratings			Unit	Notes
		MIN	TYP	MAX		
VDD Input Voltage	V_{DD}	2.7	-	5.5	V	
VDDP Input Voltage	V_{DDP}	4.75	-	5.5	V	VCC ≥ 4.55V
Operating Temperature	T_{opr}	-40	-	+85	°C	

●Package Power Dissipation

The power dissipation of a simple package in case of a boadless will be as follows.
Use of this device beyond the following the power dissipation may cause permanent damage.

BD8918F/BD8919F Pd=375mW; however, reduce 3mW per 1°C when used at Ta ≥ 25°C.
BD8918FV/BD8919FV Pd=500mW; however, reduce 4mW per 1°C when used at Ta ≥ 25°C.

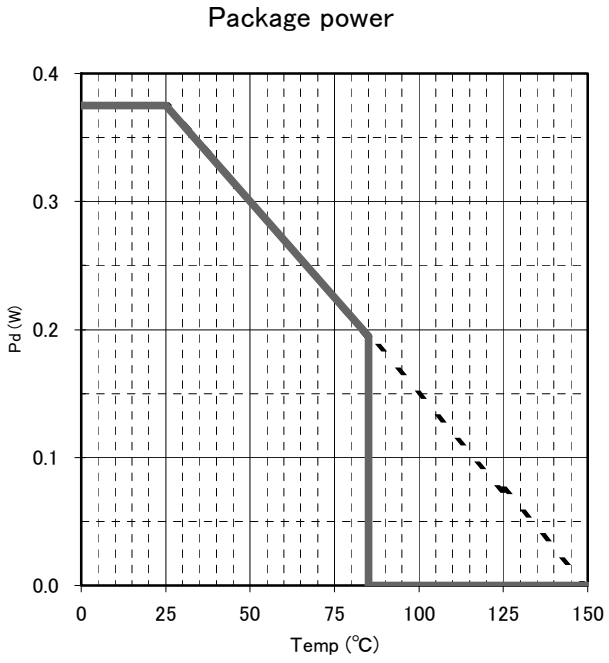


Fig. 1.1 BD8918F/BD8919F Power Dissipation

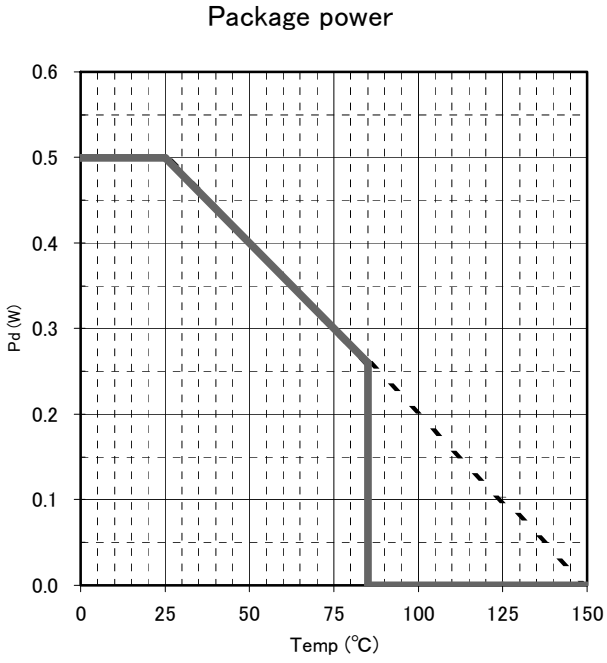


Fig. 1.2 BD8918FV/BD8919FV Power Dissipation

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

●Block Diagram

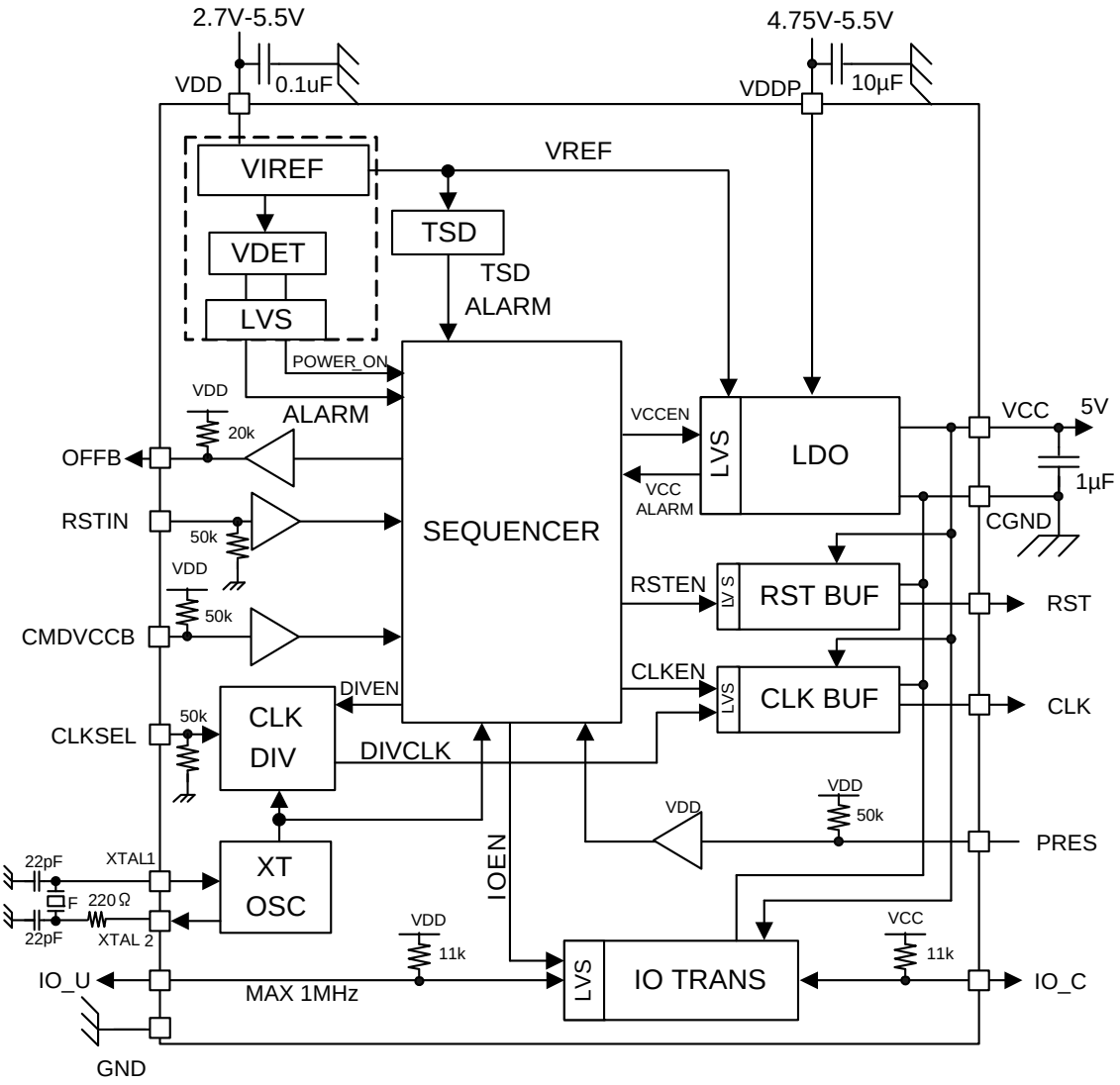


Fig. 2

BD8918F/FV F=8MHz
BD8919F/FV F=16MHz

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

●**Pin Description**

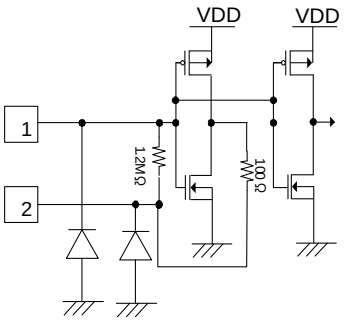
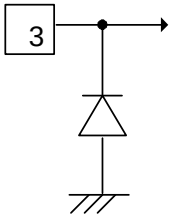
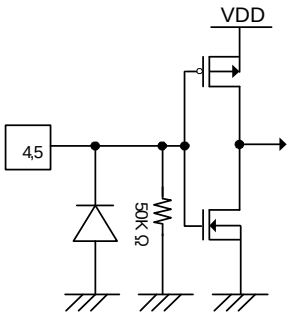
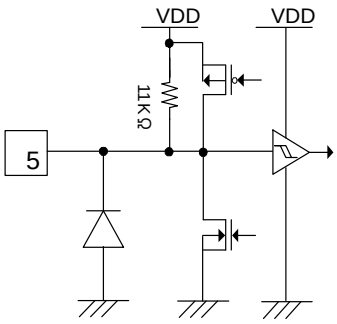
Pin No.	Pin Name	I/O	Signal Level	Pin Function	
1	XTAL1	I	VDD	Crystal connection or input for external clock	
2	XTAL2	O	VDD	Crystal connection (leave open pin when external clock source is used)	
3	VDD	S	VDD	3.3 V power source pin for host interface. Connect 0.1µF capacitor between the VDD and GND pins.	
4	CLKSEL	I	VDD	Input for clock frequency division setting. Pulled down to GND with a 50kΩ resistor.	BD8918F/FV H: 1/1 division; L: 1/2 division. BD8919F/FV H: 1/2 division; L: 1/4 division.
5	RSTIN	I	VDD	Card reset signal input. Pulled down to GND with a 50kΩ resistor.	
6	IO_U	I/O	VDD	Host data I/O line; Pulled up to VDD with an 11kΩ resistor	
7	CGND	S	GND	GND	
8	IO_C	I/O	VCC	I/O data line on the card side. Pulled up to VCC with an 11kΩresistor.	
9	RST	O	VCC	Card reset output	
10	CLK	O	VCC	Card clock output	
11	VCC	O	VCC	Card supply voltage. Connect 1µF capacitor between VCC and the CGND pins.	
12	VDDP	S	VDDP	5V power source pin for card power feed. Connect 10µF capacitor between the VDDP and CGND pins.	
13	PRES	I	VDD	Card presence contact input (“H” active). Pulled up to VDD with a 50kΩ resistor. Connected to a switch where GND level is inputted when no card is inserted and OPEN is inputted when a card is inserted. When “H” level is detected, a card is assumed to be inserted and waits for the CMDVCCB input for the confirmation, after the debounce time of typ. 8ms.	
14	OFFB	O	VDD	Alarm output pin (“L” active). NMOS open drain output. Pulled up to VDD with a 20kΩ resistor.	
15	CMDVCCB	I	VDD	Activation sequence command input; The activation sequence starts by signal input (H→L) from the host	
16	GND	S	GND	GND	

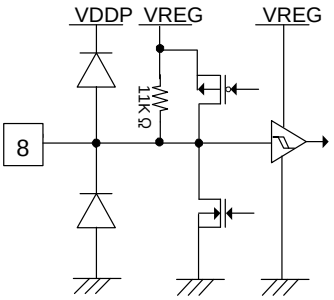
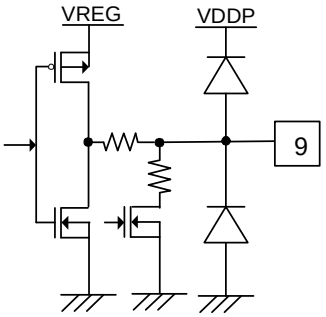
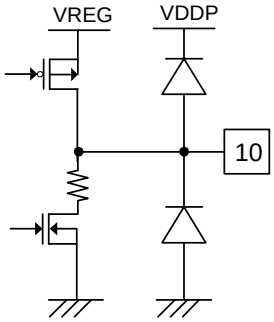
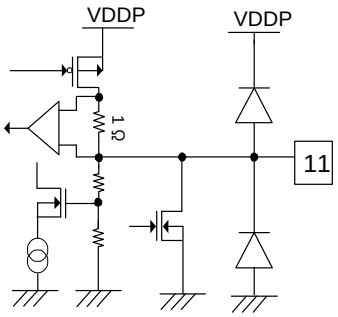
*Capacitors to be connected to VDD, VDDP and VCC should be placed immediately next to the pins (ESR<100mΩ).

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

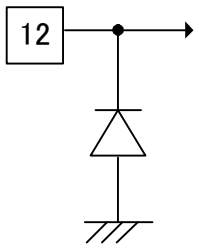
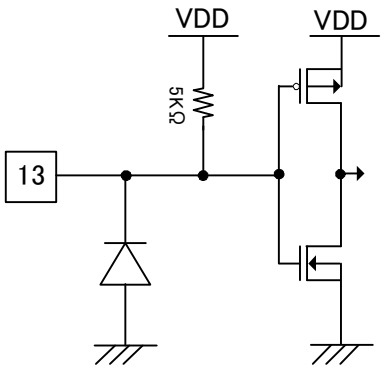
●**Pin Function Diagram**

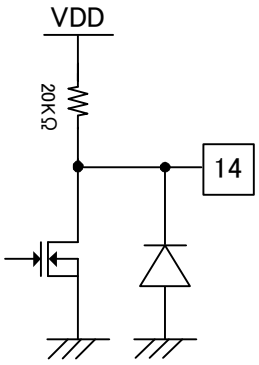
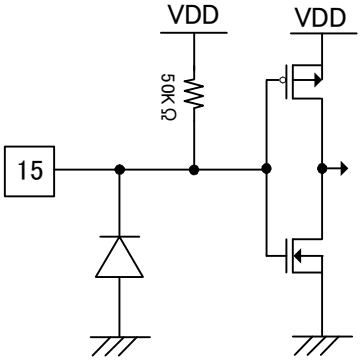
Pin No.	Pin Name	Pin function Diagram
1	XTAL1	
2	XTAL2	
3	VDD	
4	CLKSEL	
5	RSTIN	
6	IO_U	
7	CGND	----------

Pin No.	Pin Name	Pin function Diagram
8	IO_C	
9	RST	
10	CLK	
11	VCC	

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

Pin No.	Pin Name	Pin function Diagram
12	VDDP	
13	PRES	

Pin No.	Pin Name	Pin function Diagram
14	OFFB	
15	CMDVCCB	
16	GND	----------

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

●**Package**

Package Name: SOP16

Note : X is 8 or 9.

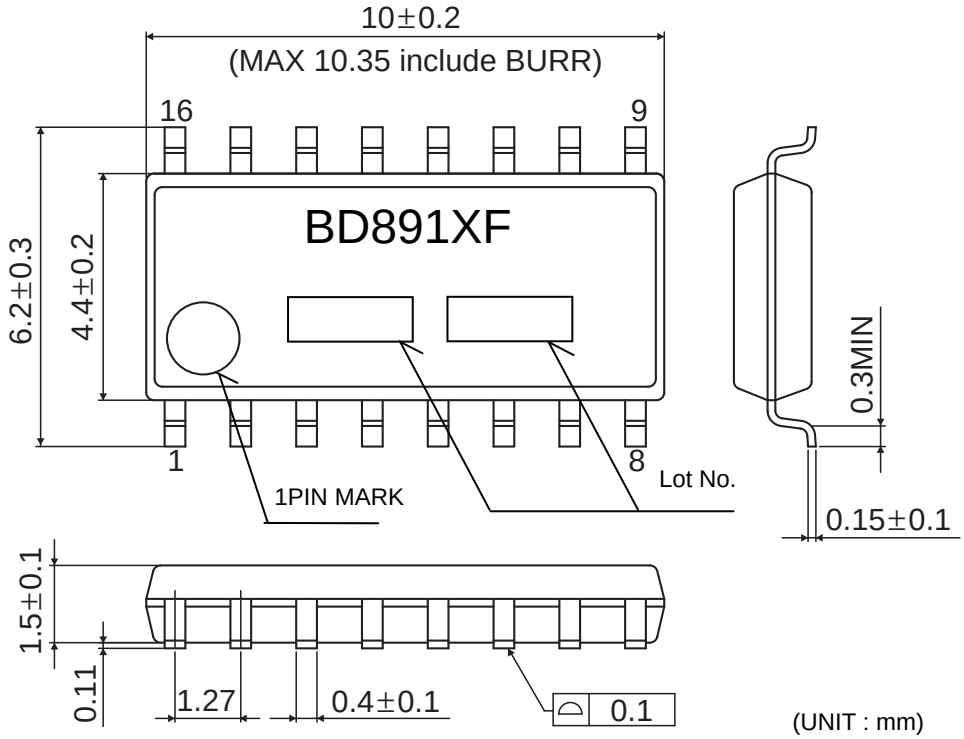


Fig. 3.1 SOP16 Package Dimension

Package Name: SSOP-B16

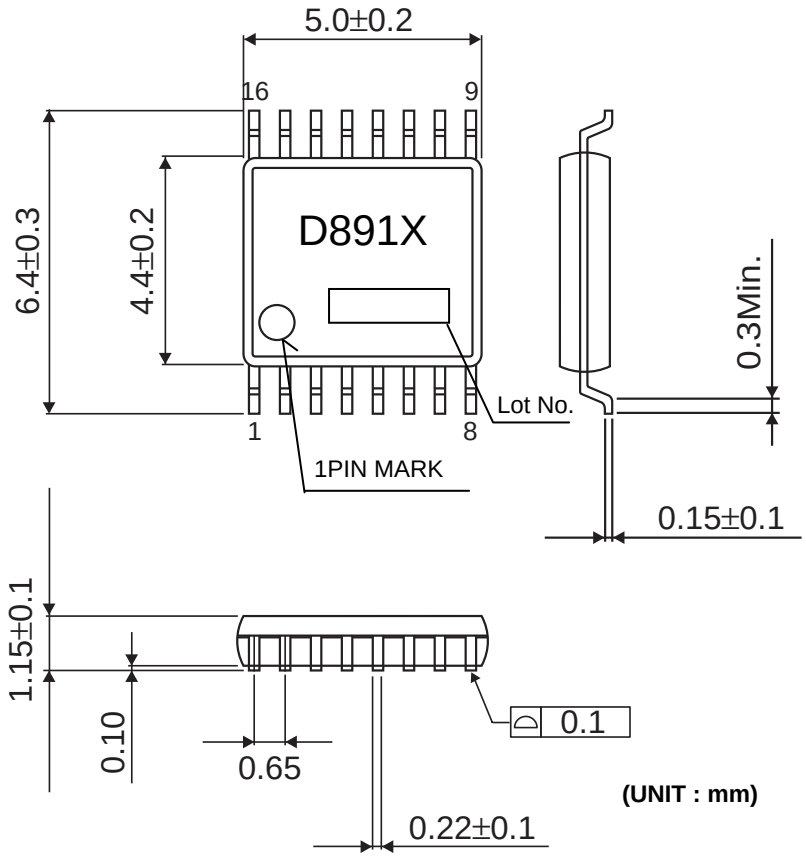


Fig. 3.2 SSOP-B16 Package Dimension

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

●Function

1) Power supply

Power supply pins are VDD and VDDP. Set VDD at the same voltage as the signal from the system controller side.
VDDP and CGND are for the 5V power source and GND, respectively, on the card side.

2) Input voltage detector

The IC remains in wait mode until the power on reset is released 16ms after the VDD supply voltage is increased over Vthd and the VDDP supply voltage is increased over Vthp, making the CMDVCCB signal turn from H to L.

Vthd=1.7V(typ) Vthp=2.25V(typ)

3) Operation sequence

3-1) Wait mode

The IC remains in wait mode until the power on reset is released after the VDD supply voltage is increased over Vthd and the VDDP supply voltage is increased over Vthp, making the CMDVCCB signal turn from H to L.
In this mode, the VDD and VDDP supply voltage detector (VDET), thermal shutdown circuit (TSD), reference circuit (VREF) and crystal oscillation circuit (XT OSC) are activated.
IO_U is pulled up to VDD with an 11kΩ resistor and all the card contact pins are at Lo level.

3-2) Card presence

Card presence is detected by PRES pin. When the PRES pin is active, a card is assumed to be present.

Table 1

PRES	“High” active

When a card is present in wait mode, the card insertion identification pin, PRES (“H” active) becomes active and OFFB becomes “H” after approx. 8ms (debounce time).
If a card is present before the VDD and VDDP power sources are applied and the internal reset is released, it is internally reset and OFFB becomes “H” after the debounce time.
The PRES pin is pulled up to VDD with a 50kΩ resistor.

Descriptions of transition times (example. Debounce time: 8msec) for the operation sequences are adapted in the conditions of the following input frequency.

8MHz (BD8918F/ FV), 16MHz (BD8919F/ FV)

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

3-3) Activation sequence

When OFFB is in the “High” state and the CMDVCCB signal from the controller turns from H to L, the activation sequence starts to activate each functional block in the following order:

The RST outputs signals based on the RSTIN input, being reset approximately 472∝sec after the CMDVCCB signal turns from H to L. The RSTIN input becomes effective approximately 48∝s after I/O TRANS turns ON. If RSTIN becomes Lo after RSTIN becomes effective and the RST output is released, the CLK signal is output. If RSTIN is High when the RST output is released, the CLK signal is output as soon as the RST output is released. (Refer to Fig. 4-1, 4-2 and 4-3)

LDO ON (VCC output)
↓
I/O TRANS ON (IO_C, IO_U Bus: Pull-up)
↓
↓ (RSTIN≠Always High) ↓ (RSTIN=Always High)
↓ ↓
CLK BUF ON (CLK output) CLK, RST BUF ON (CLK output, RST release)
↓
RST BUF ON (RST release)

[Activation sequence under different RSTIN input timings]

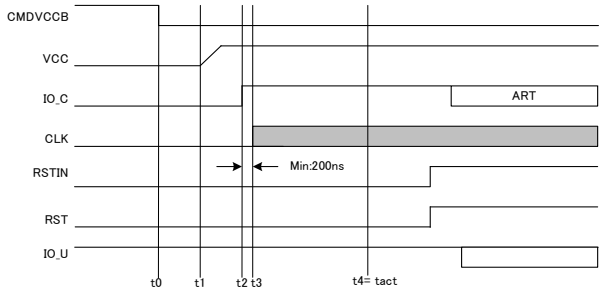


Fig. 4-1 Activation sequence 1

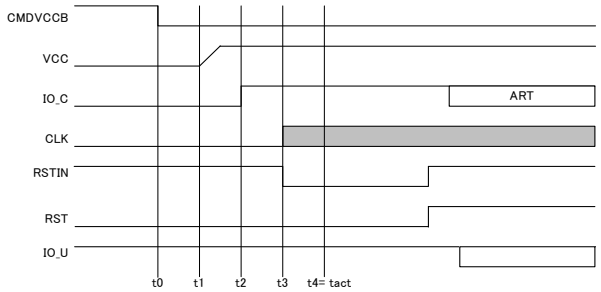


Fig. 4-2 Activation sequence 2

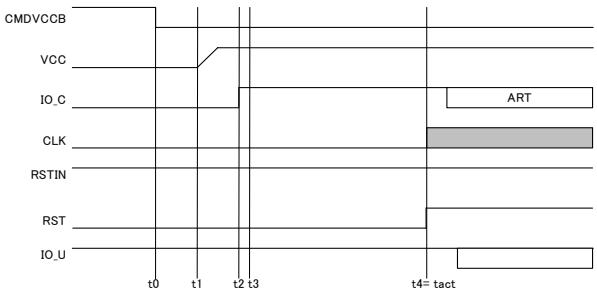


Fig. 4-3 Activation sequence 3

(RSTIN input sequence not specified by ISO7816)

t1: LDO startup time = typ. 24µs
t2: I/O ON time = typ. 424µs
t3: CLK output release time (t3-t2) = Min. 200ns
t4: RST release time = typ,472µs, max. 481µs
(Activation time)

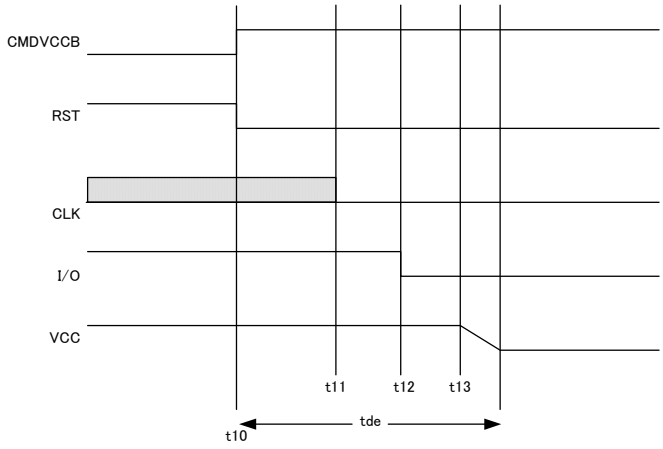
© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

3-4) Deactivation sequence

When the CMDVCCB input turns from L to H or the alarm signal (described later) is detected, the following deactivation sequence is initiated in the following order, transitioning to the wait mode.

RST BUF OFF (RST: Lo)
↓
CLK BUF OFF (CLK: Lo)
↓
I/O TRANS OFF (I/O Bus on the controller side: Pull-up)
↓ (I/O Bus on the card side: Lo)
↓
LDO OFF (VCC: Lo)



t11: CLK OFF time = typ. 10µs
t12: I/O OFF time = typ. 20µs
t13: Starting time of VCC fall = typ. 30µs
tde: Operational sequence completion time =Max. 200µs

Fig. 5 Deactivation sequence

4) LDO

LDO supplies power to the IC card through VCC pin.
This regulator has a built-in over-current limiter circuit. It generates an internal alarm with a load current of approximately 140mA or more and enters into the deactivation sequence. Also, the output voltage is regarded as abnormal if it drops to less than 1.6V and the output current is shut off; an internal alarm signal is generated and the deactivation sequence is initiated.
Connect a capacitor of 1µF or 2.2µF between VCC and CGND as close as possible to the VCC pin, in order to reduce the output voltage variation as much as possible. Also, ensure that ESR is kept at less than 100mΩ.
LDO output is also a power source for CLK, RST and IO_C output. Therefore, the CLK, RST and IO_C output level is the same as the VCC output level.

5) I/O data transitions

The data line, IO_C - IO_U, transmits/receives two-way data.
The IO_U pin for the controller side is pulled up with an 11kΩ resistor to High (VDD voltage) and card contact pins IO_C is set to Lo until I/O TRANS becomes ON by the activation sequence.
When I/O TRANS becomes On, IC becomes idle mode and the I/O pin is pulled up with an 11kΩ resistor to keep the IO_U pin to VDD voltage (High) and the IO_C pin to VCC voltage (High).

The pin which turns to L from H first becomes the master and the other output side becomes the slave between the pins on the controller side and card contact pins. Then the data are transferred from the master side to the slave side.
When the both signal levels become High, they become idle mode.
When the signal transits from L to H and it passes over a threshold, an active pull-up (100 ns or less) works to drive the data High at high speed. After the active pull-up is completed, the pin is pulled up with an 11kΩ resistor. After the active pull-up is completed, the pin is pulled up with an 11kΩ resistor. This function enables signal transmission up to 1MHz. Also, an over-current limiter of 30mA in the card contact pin, IO_C.

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

6) Card clock supply

Card clock is supplied from the CLK pin dividing the input frequency of XTAL1 pin with the CLKSEL pin setting. The clock division switching time is within the 8 clocks of the XTAL1 signal.
The input signal to the XTAL1 pin is made by a crystal oscillator (BD8918F/FV:8Hz, BD8919F/FV:16MHz) between the XTAL1 pin and XTAL2 pin or external pulse signal.
When a crystal oscillator is used, the voltage between XTAL1 and XTAL2 may decrease to become close to “-1V”, which is not a problem.
When an external pulse signal is applied to the XTAL1 pin (except for signal input by crystal oscillation), the duty of the XTAL1 pin should be 48% - 52% and the transition time of the XTAL1 pin should be within 5% of the signal cycle to ensure the duty factor of 45% - 55% at the CLK pin.

Table 2 Clock frequency selection (f_{XTAL}: Frequency at XTAL1)

	CLKSEL	f_{clk}
BD8918F/FV	1	f_{XTAL}
	0	$\frac{f_{XTAL}}{2}$

	CLKSEL	f_{clk}
BD8919F/FV	1	$\frac{f_{XTAL}}{2}$
	0	$\frac{f_{XTAL}}{4}$

7) RSTIN input, RST output

The RSTIN input becomes effective after the CMDVCCB signal input turns to L from H, activation sequence is initiated and approximately 48∝s after I/O TRANS turns ON. The RST output is released in approximately 472∝sec (max. 481∝sec) after the CMDVCCB signal turns from H to L to output a signal based on the RSTIN input.

8) Fault detection

When the following fault state is detected, the circuit enters the wait mode after it generates an internal alarm signal and is deactivated.
If a card is not present, it remains in the wait mode.

- When the VCC pin becomes less than 1.6V, or is loaded high current (TYP: 140mA)
- When VDDP voltage is less than the threshold voltage (detected by supply voltage detector)
- When a high temperature is detected by the thermal shutdown circuit
- When the card is removed during operation or the card is not present from the beginning (PRES=L)

9) OFFB output

The OFFB output pin indicates the IC is ready to operate. It is pulled up to VDD with a 20kΩ resistor.
When the IC is in the ready state, OFFB is High.
After activation, the OFFB outputs OFF state (Lo) when a fault state is detected.
When a card is present and CMDVCCB becomes High, the internal alarm is released and the OFFB output becomes High.

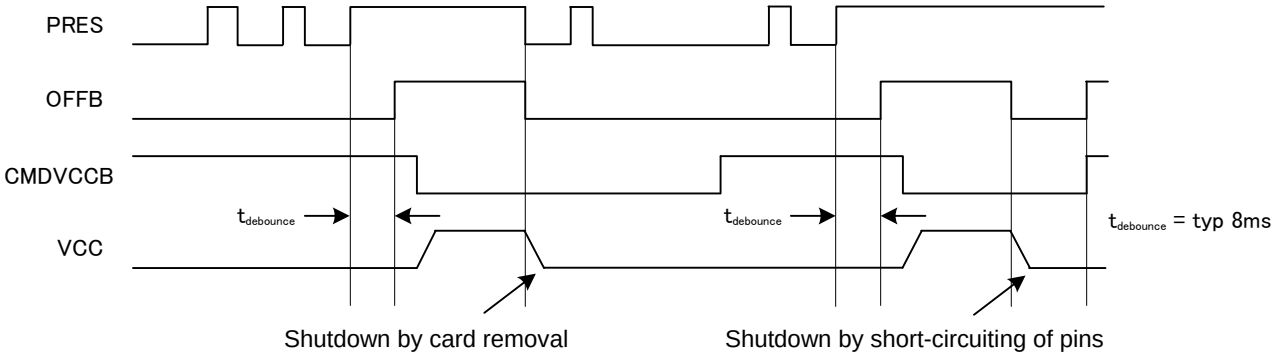


Fig. 6 OFFB, CMDVCCB, PRES, VCC operation

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

●**An example of software control**

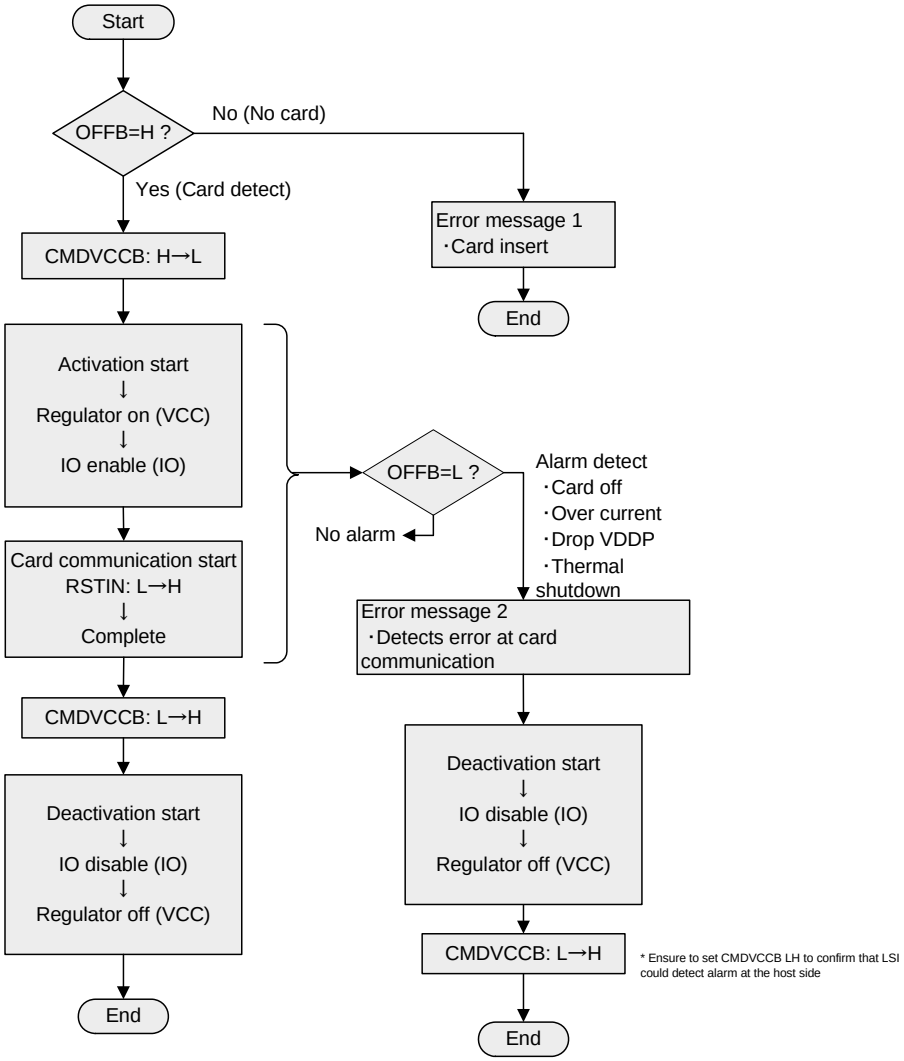


Fig. 7 An example of software control

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

●Application examples

BD8918F/FV application examples

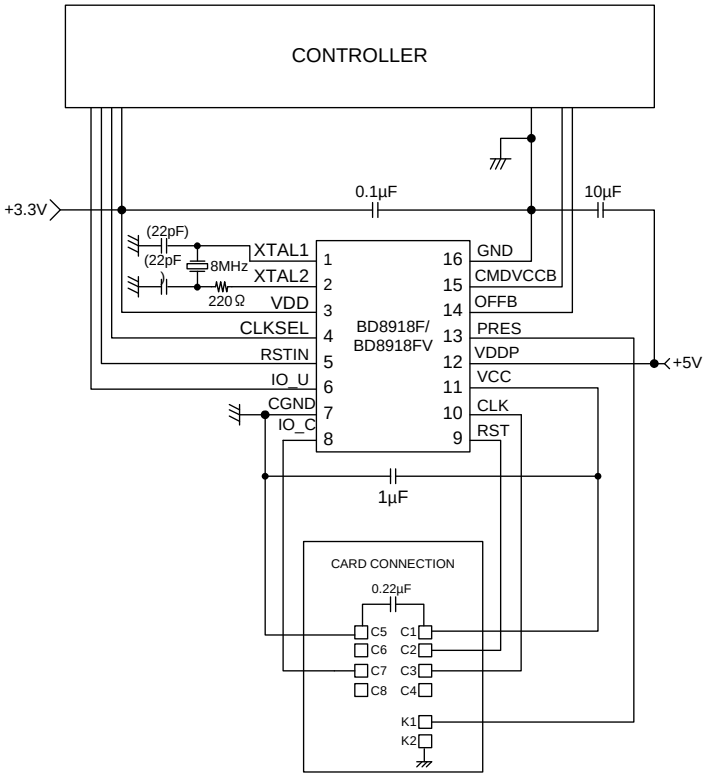


Fig.8

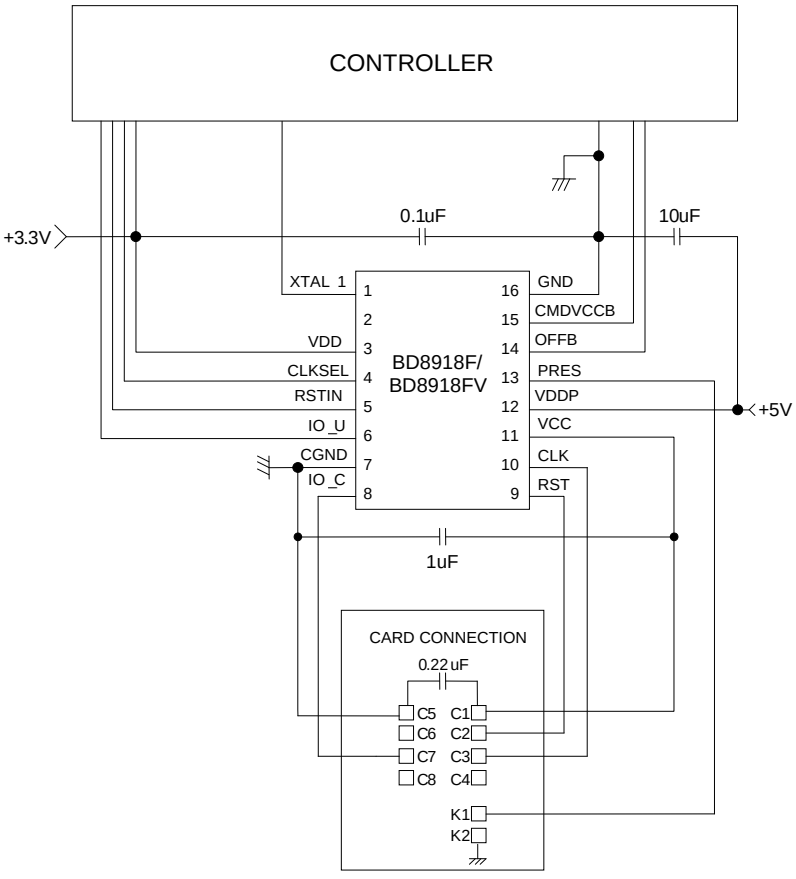
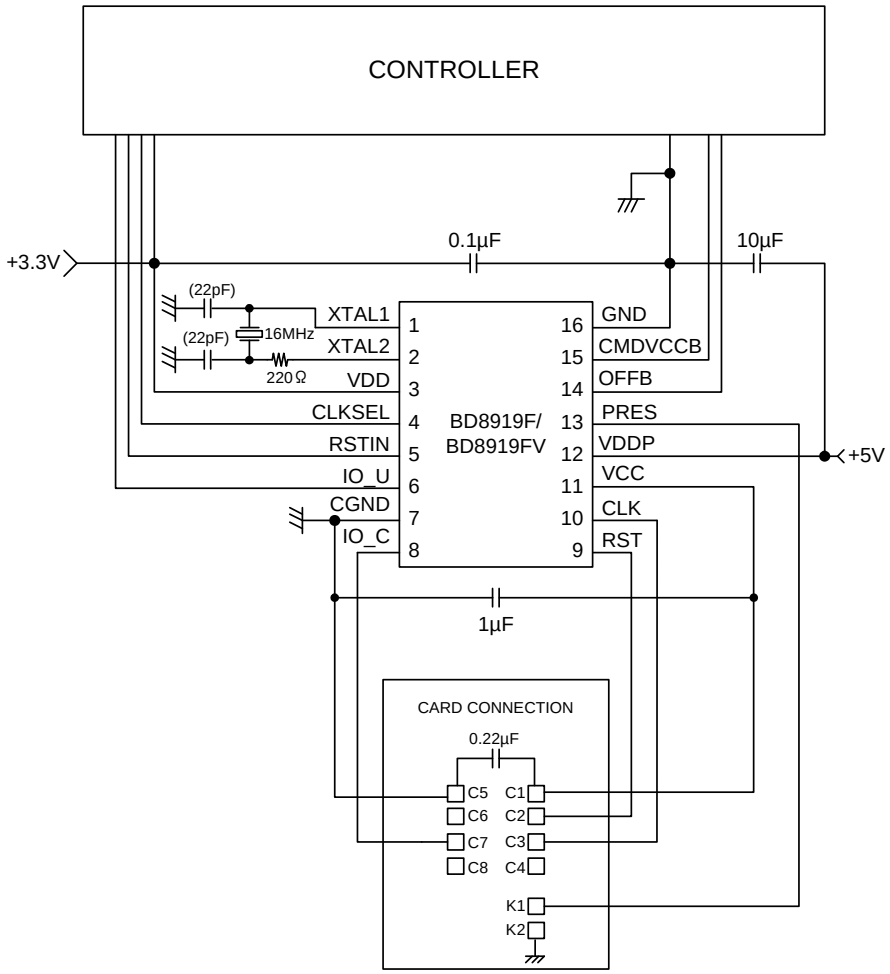


Fig.9

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

BD8919F/FV application examples



●Precautions for use

1) The capacitor for the VCC pin should be placed as close as possible to the IC between VCC and CGND so that the ESR becomes less than 100Ω
2) Connect a capacitor of over 0.1µF for VDD and over 10µF for VDDP as close as possible to the IC so that the ESR becomes less than 100mΩ to reduce the power line noise. We recommend the use of capacitors with the largest possible capacitance.

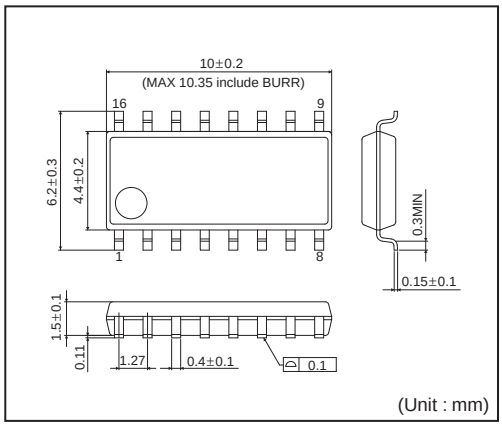
© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

● **Ordering part number**

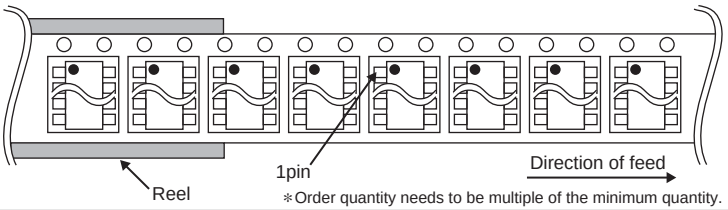
B	D		8	9	1	8		F	V	-	E	2
Part No.			Part No. 8918 8919					Package F: SOP16 FV: SSOP-B16			Packaging and forming specification E2: Embossed tape and reel	

SOP16



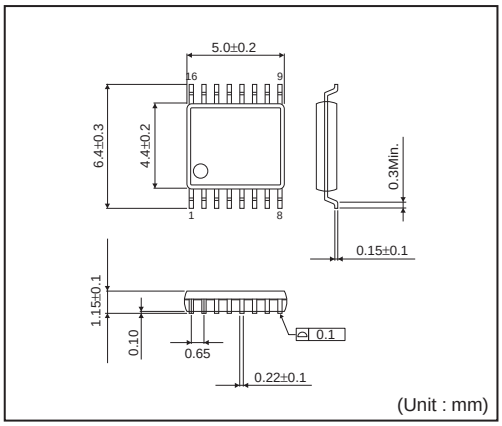
<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	E2 (The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand)



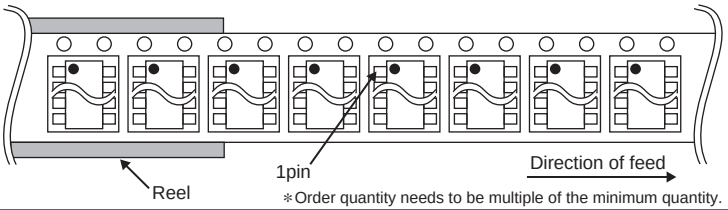
∗Order quantity needs to be multiple of the minimum quantity.

SSOP-B16



<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	E2 (The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand)



∗Order quantity needs to be multiple of the minimum quantity.

© 2009 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

Notice

Precaution on using ROHM Products

1. Our Products are designed and manufactured for application in ordinary electronic equipments (such as AV equipment, OA equipment, telecommunication equipment, home electronic appliances, amusement equipment, etc.). If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), transport equipment, traffic equipment, aircraft/spacecraft, nuclear power controllers, fuel controllers, car equipment including car accessories, safety devices, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property ("Specific Applications"), please consult with the ROHM sales representative in advance. Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any ROHM's Products for Specific Applications.

(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

2. ROHM designs and manufactures its Products subject to strict quality control system. However, semiconductor products can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against the physical injury, damage to any property, which a failure or malfunction of our Products may cause. The following are examples of safety measures:
   [a] Installation of protection circuits or other protective devices to improve system safety
   [b] Installation of redundant circuits to reduce the impact of single or multiple circuit failure

3. Our Products are designed and manufactured for use under standard conditions and not under any special or extraordinary environments or conditions, as exemplified below. Accordingly, ROHM shall not be in any way responsible or liable for any damages, expenses or losses arising from the use of any ROHM's Products under any special or extraordinary environments or conditions. If you intend to use our Products under any special or extraordinary environments or conditions (as exemplified below), your independent verification and confirmation of product performance, reliability, etc, prior to use, must be necessary:
   [a] Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
   [b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
   [c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
   [d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
   [e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
   [f] Sealing or coating our Products with resin or other coating materials
   [g] Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
   [h] Use of the Products in places subject to dew condensation

4. The Products are not subject to radiation-proof design.

5. Please verify and confirm characteristics of the final or mounted products in using the Products.

6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse. is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.

7. De-rate Power Dissipation (Pd) depending on Ambient temperature (Ta). When used in sealed area, confirm the actual ambient temperature.

8. Confirm that operation temperature is within the specified range described in the product specification.

9. ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

Precaution for Mounting / Circuit board design

1. When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.

2. In principle, the reflow soldering method must be used; if flow soldering method is preferred, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

© 2014 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.

2. You agree that application notes, reference designs, and associated data and information contained in this document are presented only as guidance for Products use. Therefore, in case you use such information, you are solely responsible for it and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of such information.

Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of Ionizer, friction prevention and temperature / humidity control).

Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
   - [a] the Products are exposed to sea winds or corrosive gases, including Cl2, H2S, NH3, SO2, and NO2
   - [b] the temperature or humidity exceeds those recommended by ROHM
   - [c] the Products are exposed to direct sunshine or condensation
   - [d] the Products are exposed to high Electrostatic

2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.

3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.

4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

Precaution for Product Label

QR code printed on ROHM Products label is for ROHM's internal use only.

Precaution for Disposition

When disposing Products please dispose them properly using an authorized industry waste company.

Precaution for Foreign Exchange and Foreign Trade act

Since our Products might fall under controlled goods prescribed by the applicable foreign exchange and foreign trade act, please consult with ROHM representative in case of export.

Precaution Regarding Intellectual Property Rights

1. All information and data including but not limited to application example contained in this document is for reference only. ROHM does not warrant that foregoing information or data will not infringe any intellectual property rights or any other rights of any third party regarding such information or data. ROHM shall not be in any way responsible or liable for infringement of any intellectual property rights or other damages arising from use of such information or data.:

2. No license, expressly or implied, is granted hereby under any intellectual property rights or other rights of ROHM or any third parties with respect to the information contained in this document.

Other Precaution

1. This document may not be reprinted or reproduced, in whole or in part, without prior written consent of ROHM.

2. The Products may not be disassembled, converted, modified, reproduced or otherwise changed without prior written consent of ROHM.

3. In no event shall you use in any way whatsoever the Products and the related technical information contained in the Products or this document for any military purposes, including but not limited to, the development of mass-destruction weapons.

4. The proper names of companies or products described in this document are trademarks or registered trademarks of ROHM, its affiliated companies or third parties.

© 2014 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.

General Precaution

1. Before you use our Products, you are requested to carefully read this document and fully understand its contents. ROHM shall not be in any way responsible or liable for failure, malfunction or accident arising from the use of any ROHM's Products against warning, caution or note contained in this document.

2. All information contained in this document is current as of the issuing date and subject to change without any prior notice. Before purchasing or using ROHM's Products, please confirm the latest information with a ROHM sales representative.

3. The information contained in this document is provided on an "as is" basis and ROHM does not warrant that all information contained in this document is accurate and/or error-free. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties resulting from inaccuracy or errors of or concerning such information.

© 2014 ROHM Co., Ltd. All rights reserved.

Downloaded from Arrow.com.