USB Type-C Power Delivery Controller

BD93W21F

General Description

BD93W21F is a USB Type-C Power Delivery (PD) Controller for AC adaptor applications. It is compatible with USB Type-C Specification and Power Delivery Specification.
BD93W21F includes support for the USBPD policy engine and be able to operate independently.

Features

- USB Type-C Specification Compatible
- USBPD Specification Compatible (BMC-PHY)
- Power Path N-ch MOSFET Control Driver
- SCP Function
- Support Receptacle Application
- Support Sleep Mode
- Support Temperature Detection for OTP
- Variable OVP Function
- Variable OCP for Peak Power Control
- Variable Output Voltage Error Amplifier
- Output Voltage Compensation
- Built-in VCC and VBUS Discharge Switches
- Built-in VCC and VBUS Voltage Monitors
- EC-less Operation (Auto mode)

Key Specifications

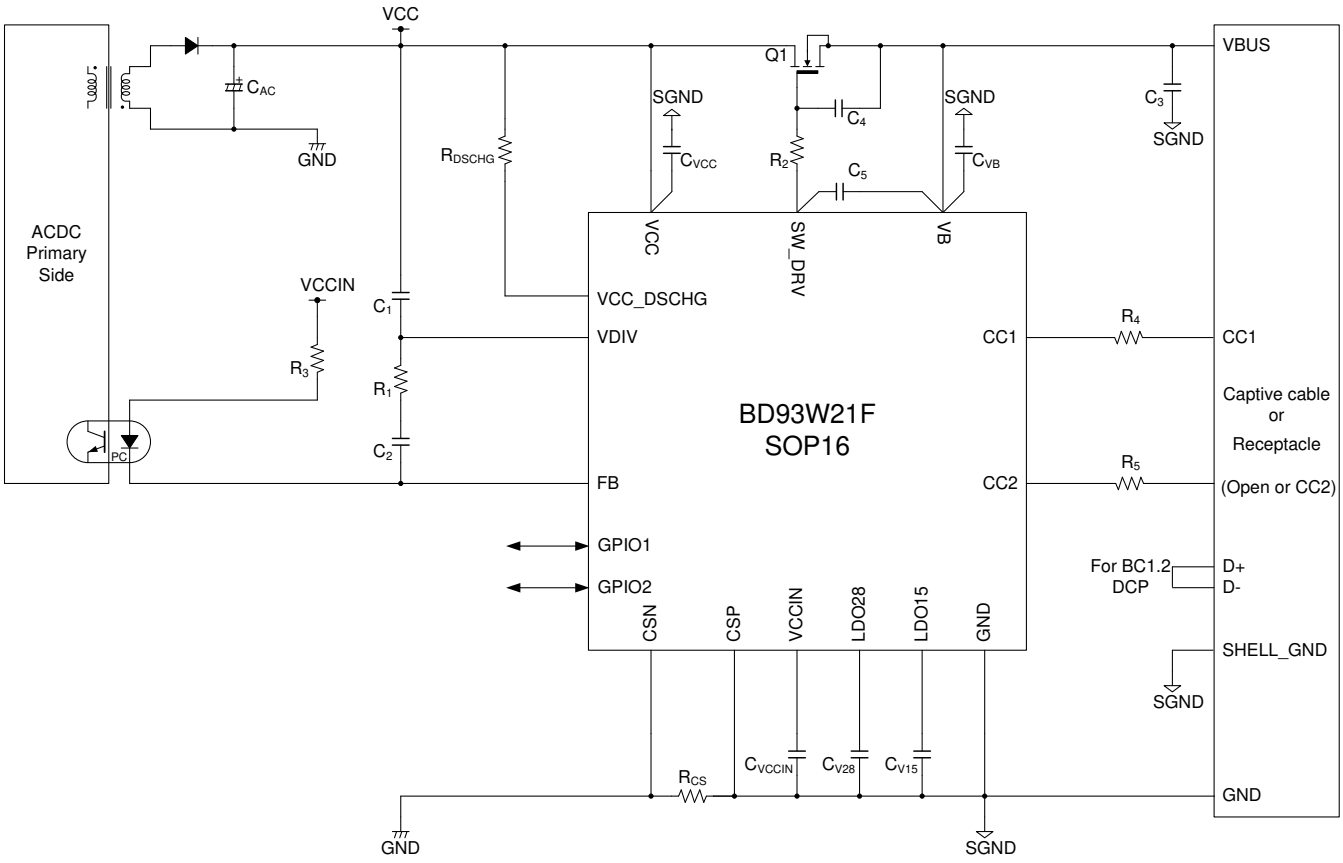
- VCC Voltage Range: 4.75 V to 20 V
- Power Source Voltage Range: 4.75 V to 20 V
- Power Consumption at Sleep Power: 1.8 mW (Typ)
- Operating Temperature Range: -30 °C to +105 °C

Applications

- Consumer Applications AC Adaptors

Package	W (Typ) x D (Typ) x H (Max)
SOP16	10.00 mm x 6.20 mm x 1.71 mm

Typical Application Circuit



Contents

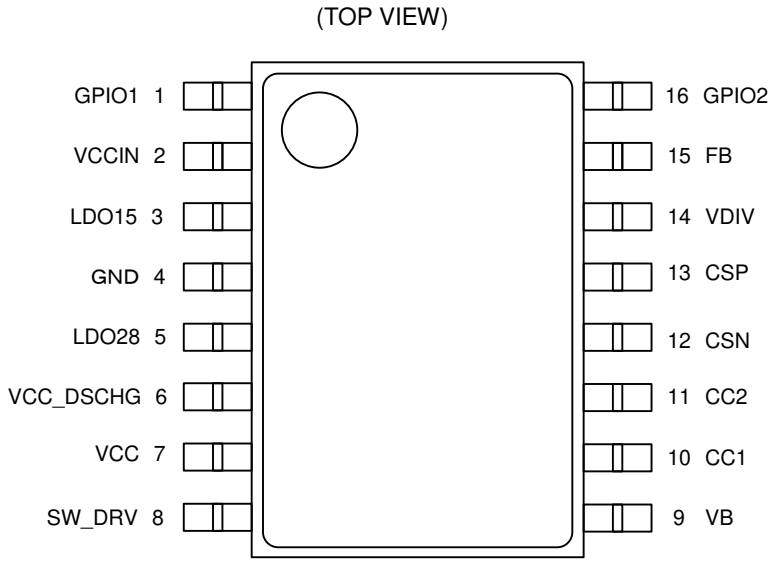
Notation

Category	Notation	Description
Unit	V	Volt (Unit of voltage)
	A	Ampere (Unit of current)
	Ω, Ohm	Ohm (Unit of resistance)
	F	Farad (Unit of capacitance)
	deg., degree	degree Celsius (Unit of temperature)
	Hz	Hertz (Unit of frequency)
	s (lower case)	second (Unit of time)
	min	minute (Unit of time)
	b, bit	bit (Unit of digital data)
	B, byte	1 byte=8 bits
Unit prefix	M, mega-, mebi-	2^{20}=1,048,576 (used with “bit” or “byte”)
	M, mega-, million-	10^{6}=1,000,000 (used with “Ω” or “Hz”)
	K, kilo-, kibi-	2^{10}=1,024 (used with “bit” or “byte”)
	k, kilo-	10^{3}=1,000 (used with “Ω” or “Hz”)
	m, milli-	10^{-3}
	µ, micro-	10^{-6}
	n, nano-	10^{-9}
	p, pico-	10^{-12}
Numeric value	xx h, xx H	Hexadecimal number. “x”: any alphanumeric of 0 to 9 or A to F.
	xx b	Binary number; “b” may be omitted. “x”: a number, 0 or 1 “_” is used as a nibble (4 bit) delimiter. (e.g. “0011_0101b”=“35 h”)
Address	#xx h	Address in a hexadecimal number. “x”: any alphanumeric of 0 to 9 or A to F.
Data	bit[n]	n-th single bit in the multi-bit data.
	bit[n:m]	Bit range from bit[n] to bit[m].
Signal level	“H”, High	High level (over V_{IH} or V_{OH}) of logic signal.
	“L”, Low	Low level (under V_{IL} or V_{OL}) of logic signal.
	“Z”, “Hi-Z”	High impedance state of 3-state signal.

Reference

Name	Reference Document	Release Date	Publisher
USB Type-C	“USB Type-C Specification Revision 1.2”	March. 2016	USB.org
USBPD	“Power Delivery Specification Revision 3.0 Version 1.0a”	March. 2016	USB.org

Pin Configuration

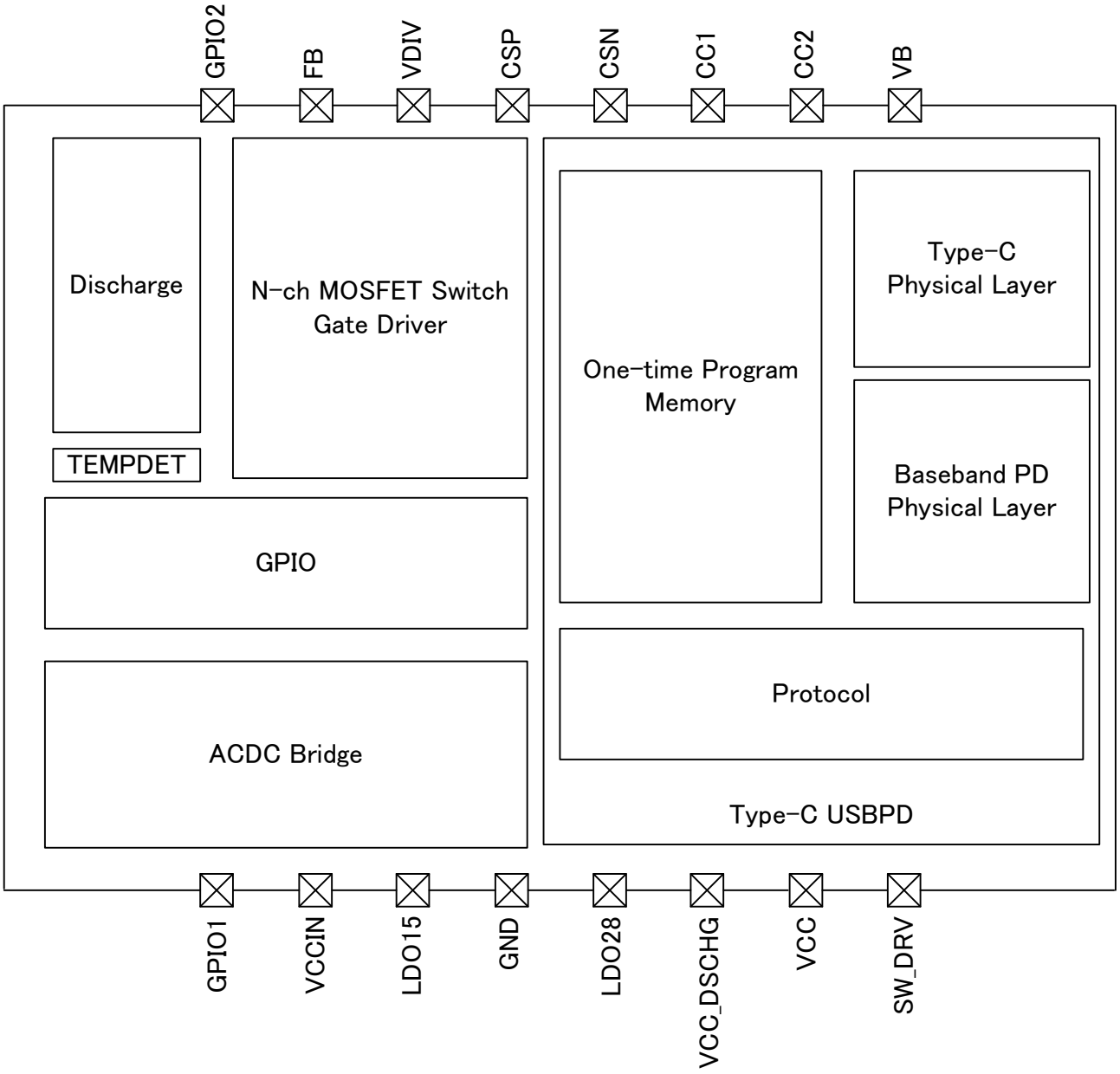


Pin Description

Pin No.	Pin Name	I/O	Type	Digital I/O Level	Description
1	GPIO1	IO	Digital	VCCIN	General purpose I/O port 1
2	VCCIN	O	Analog	-	Voltage regulator output (Need capacitor)
3	LDO15	O	Analog	-	Internal LDO 1.5 V (Need capacitor)
4	GND	I	GND	-	Ground
5	LDO28	O	Analog	-	Internal LDO 2.8 V for analog (Need capacitor)
6	VCC_DSCHG	O	Analog	-	VCC discharge N-ch MOSFET open drain
7	VCC	I	Power	-	Power supply
8	SW_DRV	I	Analog	-	Power path N-ch MOSFET gate control
9	VB	I	Power	-	VBUS voltage monitor
10	CC1	IO	Analog	-	Configuration channel 1 for Type-C
11	CC2	IO	Analog	-	Configuration channel 2 for Type-C
12	CSN	I	Analog	-	Current sense voltage input negative
13	CSP	I	Analog	-	Current sense voltage input positive
14	VDIV	O	Analog	-	Phase compensation
15	FB	O	Analog	-	Error AMP output
16	GPIO2	IO	Digital	VCCIN	General purpose I/O port 2

Block Diagram

BD93W21F is USB Type-C PD controller for AC adapter applications that supports Type-C DFP port control and USB Power Delivery using baseband communication. It is compatible with USB Type-C Specification and USB Power Delivery Specification. And it has ACDC Bridge which is constructed in Error Amplifier (for Fly-back AC adapter system) and Current Sense (for variable OCP function). It supports Type-C source only.
BD93W21F includes the following functional blocks: Type-C Physical Layer (baseband PHY), BMC encoder/decoder, USBPD Protocol engine, a N-ch MOSFET switch gate driver, OVP and Discharge.



Absolute Maximum Ratings (Ta=25 °C)

Parameter	Symbol	Rating	Unit	Conditions
Maximum Input Voltage 1	V_{IN1}	-0.3 to +28	V	VCC, VB, SW_DRV, VCC_DSCHG
Maximum Input Voltage 2	V_{IN2}	-0.3 to +6.0	V	GPIO1, GPIO2, VDIV, FB, CSP, CSN, CC1*(Note 1)*, CC2*(Note 1)*, VCCIN, LDO28
Maximum Input Voltage 3	V_{IN3}	-0.3 to +2.0	V	LDO15
Maximum VBUS Voltage When Shorted to CC1 or CC2	V_B	-0.3 to +22	V	-
Maximum Junction Temperature	Tjmax	150	°C	-
Storage Temperature Range	Tstg	-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 with thermal resistance taken into consideration by increasing board size and copper area so as not to exceed the maximum junction temperature rating.*

(Note 1) For the DC input voltage, when VBUS is shorted to CC1 or CC2, maximum short voltage becomes “VB”.

Thermal Resistance*(Note 2)*

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s*(Note 4)*	2s2p*(Note 5)*	
SOP16				
Junction to Ambient	θ_{JA}	169.7	115.4	°C/W
Junction to Top Characterization Parameter *(Note 3)*	Ψ_{JT}	21	20	°C/W

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

(Note 3) 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 4) Using a PCB board based on JESD51-3.

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

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

Top	
Copper Pattern	Thickness
Footprints and Traces	70 µm

Layer Number of Measurement Board	Material	Board Size
4 Layers	FR-4	114.3 mm x 76.2 mm x 1.6 mmt

Top		2 Internal Layers		Bottom	
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70 µm	74.2 mm x 74.2 mm	35 µm	74.2 mm x 74.2 mm	70 µm

Recommended Operating Conditions

Item	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
VCC Voltage	V_{CC}	4.75	-	20	V	USB VBUS voltage
Operating Temperature	Topr	-30	+25	+105	°C	-

Electrical Characteristics

1. Circuit Power Characteristics

(Ta=25 °C, V_{CC}=5.0 V)

Item	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Sleep Power	P_{SL}	-	1.8	-	mW	*(Note 6)*
Standby Mode Current	I_{ST}	-	3.2	-	mA	*(Note 7)*

(Note 6) Sleep power: Power consumption at unattached plug. The current of the photo-coupler is not included.
(Note 7) Standby Mode Current: Current consumption at attached plug. The current of the photo-coupler is not included. USB Type-C pull-up current of 330µA is included.

2. Digital Pin DC Characteristics

(Ta=25 °C, V_{CC} =5.0 V)

Item	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Digital pin: GPIO1, GPIO2 Unless otherwise specified C_{VCCIN}=4.7 µF(Ceramic), C_{V15} =2.2 µF(Ceramic), C_{VCC}= C_{V28}=1 µF(Ceramic) , C_{VB} =0.1 µF(Ceramic)						
Input "H" Level	V_{IH}	0.8x V_{CCIN}	-	V_{CCIN} + 0.3	V	-
Input "L" Level	V_{IL}	-0.3	-	0.2 x V_{CCIN}	V	-
Input Leak Current	I_{LC}	-5	0	+5	µA	Power: VCCIN
Output Voltage “H” (GPIOs)	V_{OH}	0.7x V_{CCIN}	-	-	V	Source=1 mA
Output Voltage “L” (GPIOs)	V_{OL}	-	-	0.3	V	Sink=1 mA

3. Internal Power Source Characteristics

BD93W21F has internal power sources. These power sources are intended to be used for internal circuit operation. It should not be used externally. As exception, it is allowed to use VCCIN for the anode of the photo-coupler and LDO28 for the reference voltage of thermistor circuit.

(Ta=25 °C, V_{CC} =5.0 V)

Item	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Unless otherwise specified C_{VCCIN}=4.7 µF(Ceramic), C_{V15} =2.2 µF(Ceramic), C_{VCC}= C_{V28}=1 µF(Ceramic) , C_{VB} =0.1 µF(Ceramic)						
VCCIN Voltage	V_{CCIN}	-	5.0	-	V	No external load
LDO28 Voltage	V_{28}	-	2.8	-	V	No external load
LDO15 Voltage	V_{15}	-	1.6	-	V	No external load

Electrical Characteristics - continued

4. CC_PHY

CC_PHY has below functions of USB Type-C (Refer to USB Type-C Specification):
- Defining Current: High current (High or Medium or USB default)
- DFP-to-UFP Attach/Detach Detection
- Plug Orientation/Cable Twist Detection
- USB Type-C VBUS Voltage Detection and Usage
- VCONN (Supply for SOP') Control
- Baseband Power Delivery Communication (BBPD Communication)

(Ta=25 °C, V_{CC}=5.0 V)

Item	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Unless otherwise specified C_{VCCIN}=4.7 µF(Ceramic), C_{V15} =2.2 µF(Ceramic), C_{VCC}= C_{V28}=1 µF(Ceramic) , C_{VB} =0.1 µF(Ceramic)						
USB Default Current	I_{PUP1}	64	80	96	µA	-
Medium Current (1.5 A)	I_{PUP2}	166	180	194	µA	-
High Current (3.0 A)	I_{PUP3}	304	330	356	µA	-
CC Pin Input Impedance	Z_{CCIN}	126	-	-	kΩ	-
RX Threshold Voltage	V_{THRX}	0.233	0.55	0.892	V	-
VCONN Supply Voltage	V_{CON}	4.75	5	-	V	I_L=20 mA

Electrical Characteristics - continued

5. Voltage Detection for OVP

BD93W21F has a voltage detection for OVP (Over Voltage Protection)

(Ta=25 °C, V_{CC}=5.0 V, V_{GND}=0 V)

Item	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Unless otherwise specified C_{VCCIN}=4.7 µF(Ceramic), C_{V15} =2.2 µF(Ceramic), C_{VCC}= C_{V28}=1 µF(Ceramic) , C_{VB} =0.1 µF(Ceramic)						
Detection Voltage Tolerance	R_{DET}	-5	-	+5	%	-

6. VCC/VBUS Discharge

N-ch MOSFET switch is prepared for VCC and VBUS discharging.

(Ta=25 °C, V_{CC}=5.0 V)

Item	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Unless otherwise specified C_{VCCIN}=4.7 µF(Ceramic), C_{V15} =2.2 µF(Ceramic), C_{VCC}= C_{V28}=1 µF(Ceramic) , C_{VB} =0.1 µF(Ceramic)						
VCC Discharge Resistance *(Note 8)*	R_{VCC}	-	2.0	-	Ω	V_{CC_DSCHG}=0.2 V
VBUS Discharge Resistance	R_{BUS}	-	2.5	-	kΩ	-

(Note 8) When an output capacitor of ACDC is above 1680µF, please use an external discharge circuit.

7. Power FET Gate Driver

FET Gate Driver is the external N-ch MOSFET switch driver for power line switch.

(Ta=25 °C, V_{CC}=5.0 V)

Item	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Unless otherwise specified C_{VCCIN}=4.7 µF(Ceramic), C_{V15} =2.2 µF(Ceramic), C_{VCC}= C_{V28}=1 µF(Ceramic) , C_{VB} =0.1 µF(Ceramic)						
N-ch MOSFET Control Voltage Between Gate and Source	V_{GS}	-	5.4	-	V	SW_DRV – VB

Electrical Characteristics – continued

8. TEMPDET

GPIO1 has TEMPDET mode. It functions as temperature detection by applying voltage set by an external thermistor and resistor divider network. The ACDC system can have temperature detection by this function using external thermistor circuit.

(Ta=25 °C, V_{CC}=5.0 V)

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Unless otherwise specified C_{VCCIN}=4.7 µF(Ceramic), C_{V15} =2.2 µF(Ceramic), C_{VCC}= C_{V28}=1 µF(Ceramic) , C_{VB} =0.1 µF(Ceramic)						
Detection Voltage Setting Range	V_{TEMP}	0	-	2.8	V	-
Detection Voltage Setting Step	V_{STEMP}	-	43.75	-	mV	-

9. ACDC Bridge

ACDC Bridge Block has an error amplifier and current sensing comparator.

(Ta=25 °C, V_{CC}=5.0 V)

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Unless otherwise specified C_{VCCIN}=4.7 µF(Ceramic), C_{V15} =2.2 µF(Ceramic), C_{VCC}= C_{V28}=1 µF(Ceramic) , C_{VB} =0.1 µF(Ceramic) VNOM=PD Negotiation Voltage, INOM= PD Negotiation Current						
PDO Voltage Setting Range	V_{RPDO}	5	-	20	V	-
PDO Voltage Setting Step	V_{SPDO}	-	50	-	mV	-
Feedback Current Threshold Tolerance	V_{THFB}	-2	-	+2	%	Standard voltage=VNOM
Maximum Feedback Current	I_{FBMAX}	2	-	-	mA	-
OCP Current Setting Range	I_{RPDO}	1.0	-	10	A	*(Note 9)*
OCP Current Setting Step	I_{SPDO}	-	10	-	mA	*(Note 9)*
OCP Detection Tolerance	R_{OCPDET}	-10	-	+10	%	*(Note 9)*

(Note 9) (OCP detection current) = (OCP detection voltage) / (External current sense resistor). This item prescribes OCP detection voltage. For example, when INOM is set less than 2A, the tolerance does not become smaller than ±2mV (When external current sense resistor is 10mΩ, the OCP level tolerance converted into current is equivalent to ±0.2A).

Parameter Information

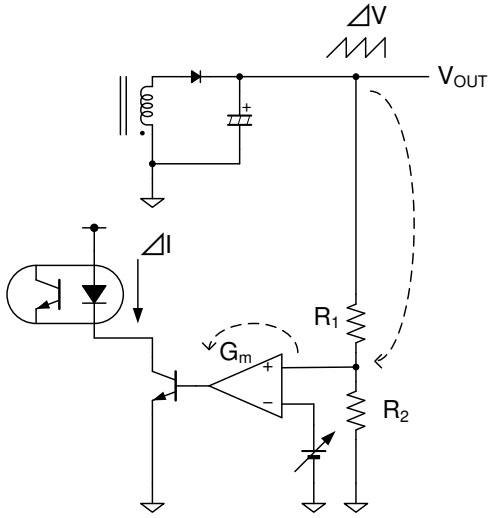
This IC supports the following functions by FW program. The function that is not set below not be supported.

Item	Symbol	Description	Parameters	Setting Value
Type-C Voltage	V_{TC}	Output Voltage at Type-C Connection	5 V	5 V
Type-C Current	I_{TC}	Output Current Mode at Type-C Connection	0.9 A / 1.5 A / 3 A	3 A
PDO1 (Voltage)	V_{PDO1}	Voltage of PDO1	5 V to 20 V / 0.05 V step	5 V
PDO2 (Voltage)	V_{PDO2}	Voltage of PDO2	5 V to 20 V / 0.05 V step	9 V
PDO3 (Voltage)	V_{PDO3}	Voltage of PDO3	5 V to 20 V / 0.05 V step	12 V
PDO4 (Voltage)	V_{PDO4}	Voltage of PDO4	5 V to 20 V / 0.05 V step	15 V
PDO5 (Voltage)	V_{PDO5}	Voltage of PDO5	5 V to 20 V / 0.05 V step	20 V
PDO6 (Voltage)	V_{PDO6}	Voltage of PDO6	5 V to 20 V / 0.05 V step	-
PDO7 (Voltage)	V_{PDO7}	Voltage of PDO7	5 V to 20 V / 0.05 V step	-
PDO1 (Current)	I_{PDO1}	Current of PDO1	0 A to 5 A / 0.01 A step	3 A
PDO2 (Current)	I_{PDO2}	Current of PDO2	0 A to 5 A / 0.01 A step	3 A
PDO3 (Current)	I_{PDO3}	Current of PDO3	0 A to 5 A / 0.01 A step	3 A
PDO4 (Current)	I_{PDO4}	Current of PDO4	0 A to 5 A / 0.01 A step	3 A
PDO5 (Current)	I_{PDO5}	Current of PDO5	0 A to 5 A / 0.01 A step	2.25 A
PDO6 (Current)	I_{PDO6}	Current of PDO6	0 A to 5 A / 0.01 A step	-
PDO7 (Current)	I_{PDO7}	Current of PDO7	0 A to 5 A / 0.01 A step	-
OVP Voltage	V_{OVP}	OVP Detection Voltage at PDO	5 V to 25.5 V / 0.025 V step	V_{PDO} x 1.2
OCP1 Current	I_{OCP1}	OCP Detection Current at PDO	1 A to 10 A / 0.01 A step	I_{PDO} x 1.2
OCP2 Current	I_{OCP2}	Peak Current Detection Value	(100 % or 110 % or 125 % or 150 % or 175 % or 200 %) of I_{OCP1}	110 %
Wake-up SCP	F_{SCP}	Wake-up SCP	Enable / Disable	Disable
OVP Latch	F_{OVP}	Processing after OVP Detection	Latch / Auto Recovery	Auto Recovery
OCP Latch	F_{OCP}	Processing after OCP Detection	Latch / Auto Recovery	Auto Recovery
SCP Latch	F_{SCP}	Processing after SCP Detection	Latch / Auto Recovery	Auto Recovery
OCP1 Wait Time	t_{OCP1}	Detection Wait Time of OCP1	0 ms to 2040 ms / 1 ms step	300 ms
OCP2 Wait Time	t_{OCP2}	Detection Wait Time of OCP2	0 ms to 510 ms / 1 ms step	10 ms
DCR Value	VAL_{DCR}	Cable Resistor Setting	40 mΩ to 180 mΩ / 20 mΩ step	Disable
GPIO1 Setting	FU_{GPIO1}	Function of GPIO1 Selection	Function1: Fixed “L” Function2: OVP Detection (H: OVP / L: Normal) Function3: OCP Detection (H: OCP / L: Normal) Function4: OVP or OCP Detection (H: OVP or OCP / L: Normal) Function5: Type-C Connection Detection (H: Attached / L: Detached) Function6: Thermistor Voltage Input Function7: Serial Bus I/F Mode	Function1: Fixed “L”
GPIO2 Setting	FU_{GPIO2}	Function of GPIO2 Selection	Function1: Fixed ”L” Function2: Serial Bus I/F Mode	Function1: Fixed ”L”

Function Description

1. **PDOs (Power Data Object)**
   BD93W21F can have up to seven PDOs. Voltage and current values of PDO are defined by Parameter Setting.

2. **ACDC Bridge Control**
   Error amplifier is integrated. It changes the target value automatically in conjunction with PDO.
   Without depending on the output voltage, the gain of the error amplifier becomes fixed. The influence by which the output voltage gives to a frequency response is reduced by this.

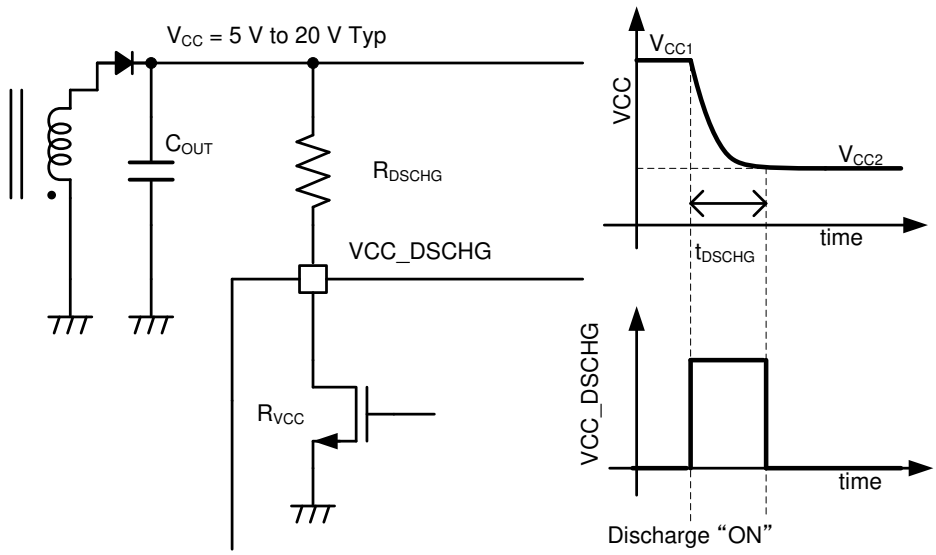


$$\triangle I = (R_2 / (R_1 + R_2)) \times G_m \times \triangle V$$

R1 and R2 need not change these value for changing VOUT Voltage. So a transfer response from VOUT to IFB is constant.

During VB output, a feedback point of ACDC is changed from VCC to VB automatically. In this way, voltage drop out by the impedance of the output switch is reduced.

3. **ACDC Discharge Control**
   Discharge switch for ACDC output voltage is integrated. Discharge time (t_{DSCHG}) must be less than 275 ms as defined by the USBPD Specification and must be less than 275 ms. Select discharge capacitor and resistor to satisfy USBPD Specification. t_{DSCHG} can be obtained by the following equation.



$$t_{DSCHG} = (R_{VCC} + R_{DSCHG}) \times C_{OUT} \times ln(\frac{V_{CC2}}{V_{CC1}})$$

t_{DSCHG} is the VCC discharge time.
R_{VCC} is the internal resistance.
R_{DSCHG} is the VCC discharge resistor.
C_{OUT} is the output capacitor for secondary side ACDC.
V_{CC1} is the old voltage.
V_{CC2} is the new voltage

When an output capacitor of ACDC is beyond 1680 µF, use an external discharge circuit.

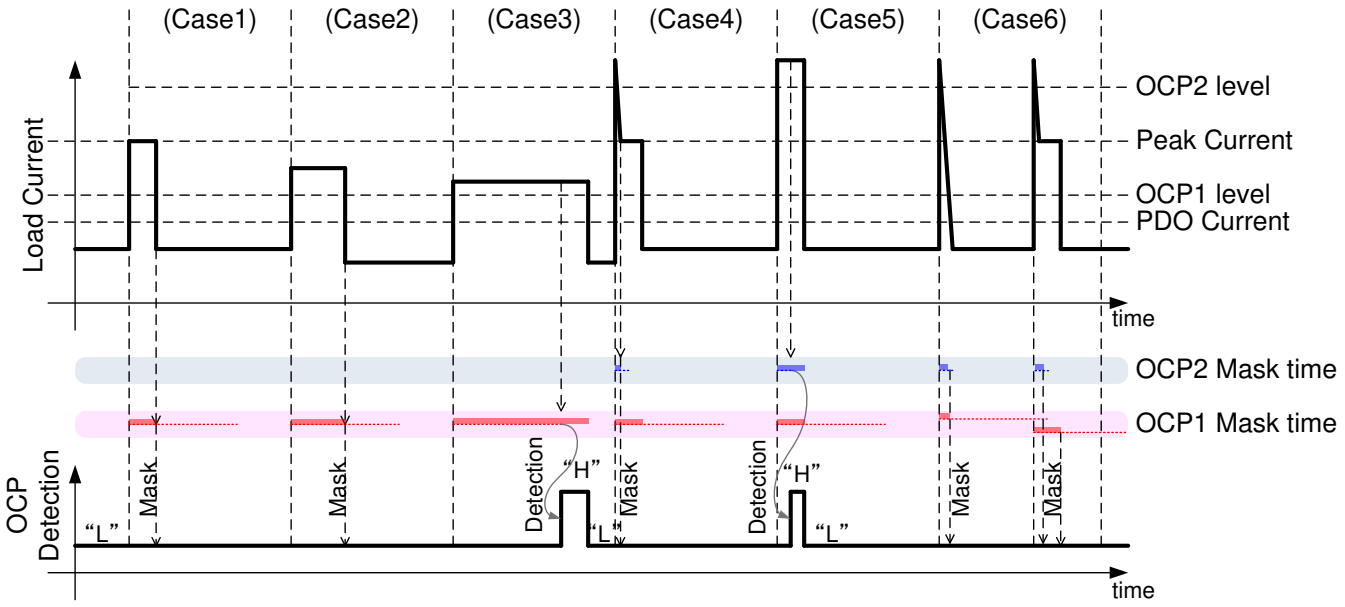
Function Description – continued

4. **Emergency Control**
When an external abnormal factor occurs as well as a prescribed abnormality state such as OVP and OCP continuously, the IC stops action automatically.

5. **Watchdog Timer**
BD93W21F has watchdog timer function. When fault occurs for FW program action, the IC detects this and resets the system.

6. **OVP/OCP/SCP Function**
BD93W21F is integrated with OVP, OCP, and SCP. The detection level changes with PDO automatically.
Each protection function is defined by Parameter Setting.

7. **Safety Peak Power**
When PDO reaches Peak Current as shown below, OCP detection mask is OFF.
This prevents OCP to Peak Current miss-detection.

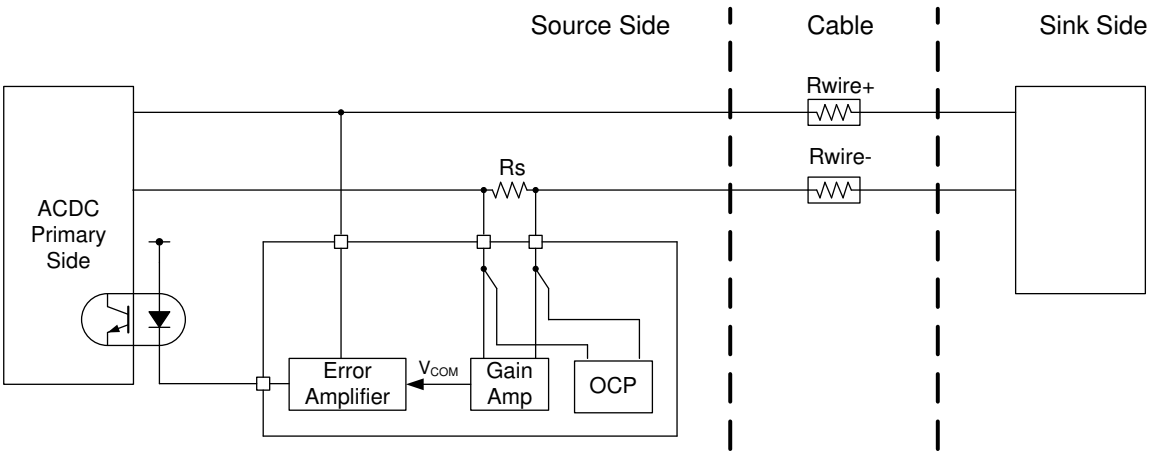


8. **Wake-up SCP Function**
The short circuit sensing of the VBUS line is carried out before outputting voltage to VBUS. When SCP is detected, VBUS has no output. The function can be enabled/disabled by Parameter Setting.

Function Description – continued

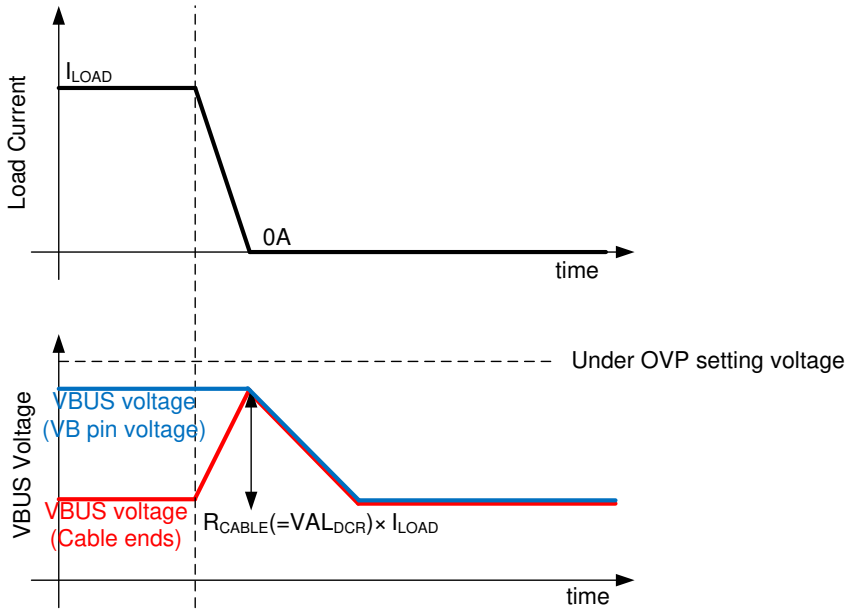
9. Output Voltage Compensation

By sensing the voltage drop at the detection resistance at the GND, the output voltage is compensated.



The compensation value is changed by Parameter Setting. When the cable impedance (DCR) and the compensation value have difference, the IR Drop (V_{IR}) will be different from the expected value.

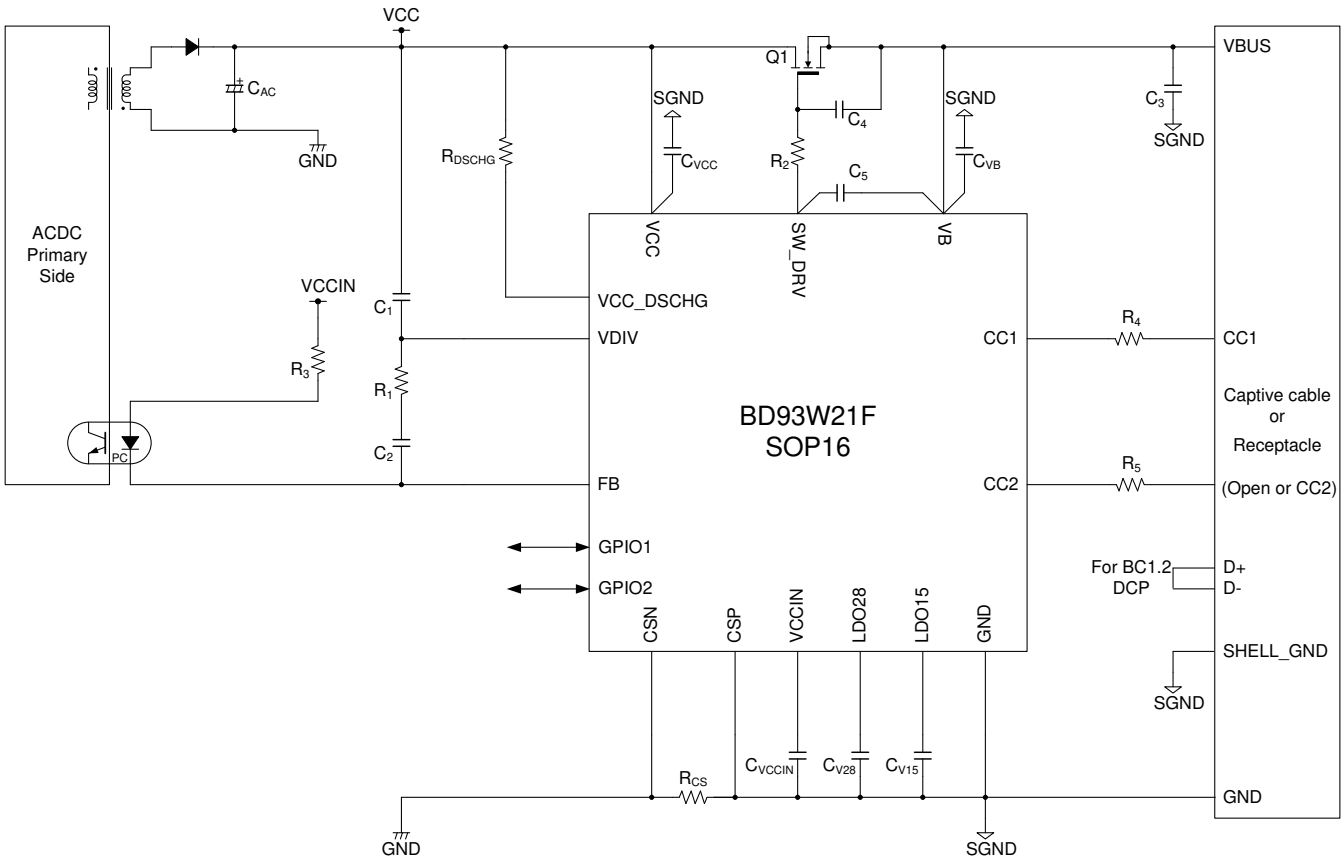
As shown in the figure below, when load current changes to a no-load state, depending on the value of the load current and the set value of DCR, VBUS voltage will overshoot momentarily.
Please set the OVP voltage so that the overshoot voltage does not exceed OVP.



10. External Thermal Monitor

GPIO1 is multi-function pin. It is possible to change function to temperature detection by sensing the voltage from an external thermistor circuit. This function becomes effective only for Type-C attached state.

Application Example

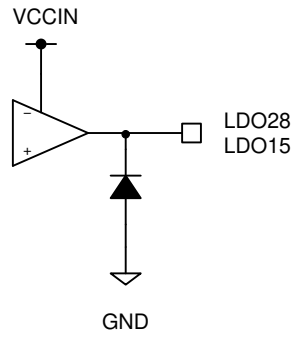
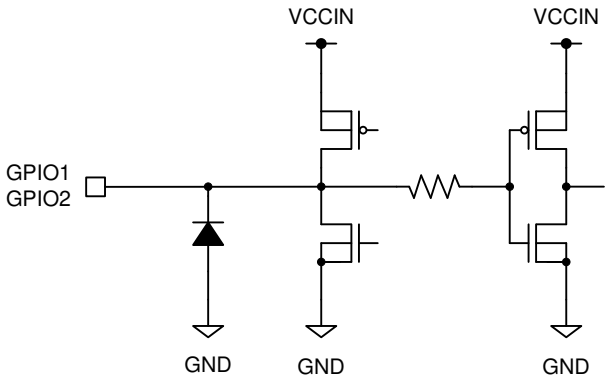
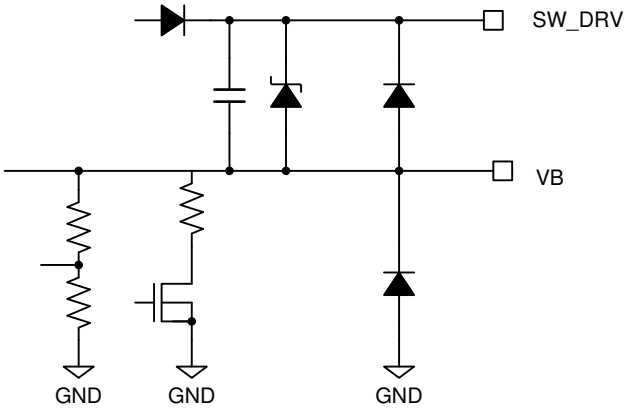
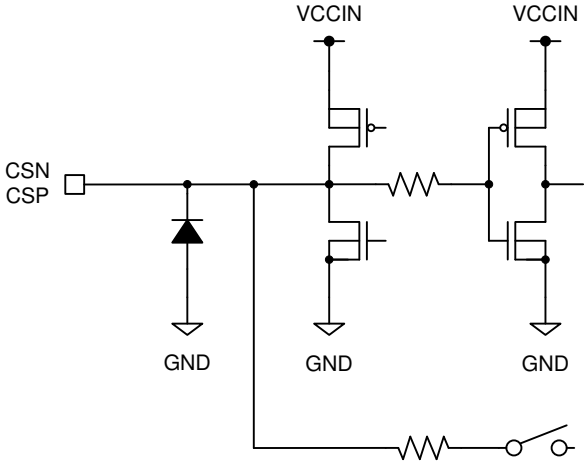


Selection of Components Externally Connected

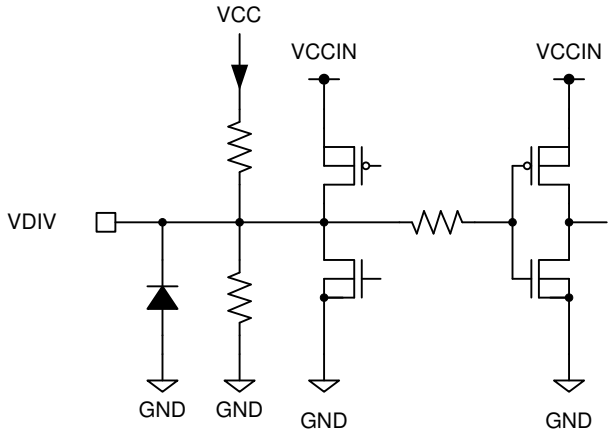
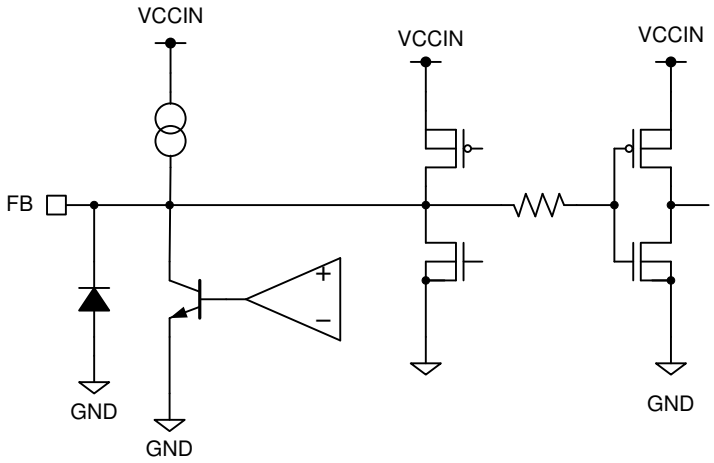
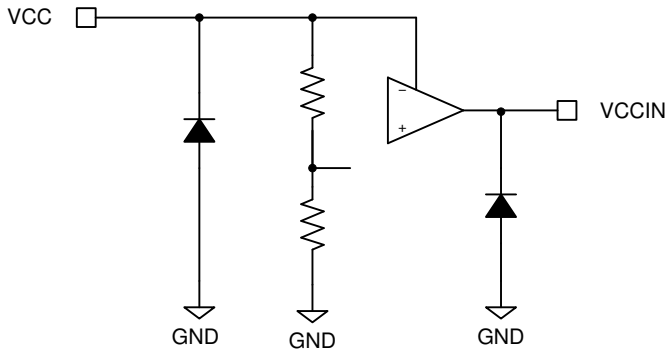
Item	Symbol	Limit			Unit	Comment
		Min	Typ	Max		
VCC Bypass Capacitor *(Note 10)*	C_{VCC}	0.47	1.0	2.2	µF	Ceramic capacitor
VB Bypass Capacitor *(Note 10)*	C_{VB}	0.047	0.1	0.22	µF	Ceramic capacitor
VCCIN Capacitor *(Note 10)*	C_{VCCIN}	0.60	4.7	10	µF	Ceramic capacitor
LDO28 Capacitor *(Note 10)*	C_{V28}	0.47	1.0	2.2	µF	Ceramic capacitor
LDO15 Capacitor *(Note 10)*	C_{V15}	1.0	2.2	4.7	µF	Ceramic capacitor
System Phase Compensation Capacitor 1 *(Note 10)*	C_1	-	-	-	F	Choose value suitable for the ACDC system.
System Phase Compensation Capacitor 2 *(Note 10)*	C_2	-	-	-	F	
VB Capacitor *(Note 10)*	C_3	-	-	-	F	Refer to USBPD Specification.
Capacitor for the VBUS Setup Timing	C_4	-	-	-	F	Choose value suitable for the ACDC system.
Phase Compensation Capacitor	C_5	0.00022	-	0.5	µF	In the case of R_2=0 Ω, please coordinate C_4 and C_5 so that the sum is within the limit.
Current Sense Resistor	R_{CS}	-	10	-	mΩ	This resistance tolerance influences OCP detection accuracy. Please consider the tolerance that you can permit.
System Phase Compensation Resistor	R_1	-	-	-	Ω	Choose value suitable for the ACDC system.
Resistor for the VBUS Setup Timing	R_2	-	-	-	Ω	
Current Limit Resistor	R_3	-	-	-	Ω	
CC1 Pin Resistor	R_4	0	-	-	Ω	Refer to USB Type-C and USBPD Specification.
CC2 Pin Resistor	R_5					
VCC Discharge Resistor	R_{DSCHG}	110	-	*(Note 11)*	Ω	Choose the resistor value suitable for the ACDC system. *(Note 12)*
ACDC Input Capacitor	C_{AC}	-	-	1680	µF	-

(Note 10) Please set the capacitance not less than the minimum requirement after considering temperature and DC characteristics.
(Note 11) Maximum value of R_{DSCHG} depends on output capacitance. Please refer to 3. ACDC Discharge Control.
(Note 12) The power consumed by a resistor is the square of the voltage divided by resistance. A resistor with enough power rating should be chosen.

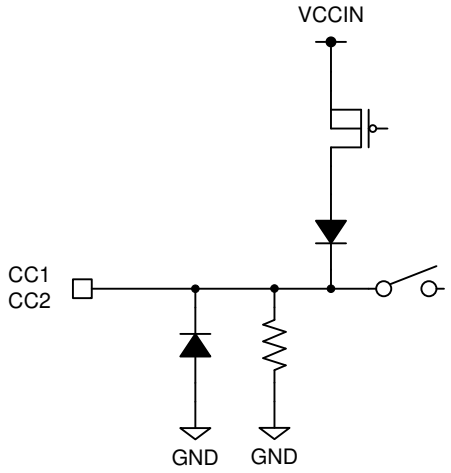
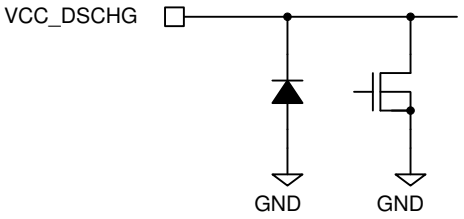
I/O Equivalence Circuit

Pin No.	Pin Name	Equivalence Circuit Diagram
3, 5	LDO15, LDO28	
1, 16	GPIO1, GPIO2	
8, 9	SW_DRV, VB	
12, 13	CSN, CSP	

I/O Equivalence Circuit - continued

Pin No.	Pin Name	Equivalence Circuit Diagram
14	VDIV	
15	FB	
2,7	VCCIN, VCC	

I/O Equivalence Circuit - continued

Pin No.	Pin Name	Equivalence Circuit Diagram
10, 11	CC1, CC2	
6	VCC_DSCHG	

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. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. 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.

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.

Operational Notes - continued

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

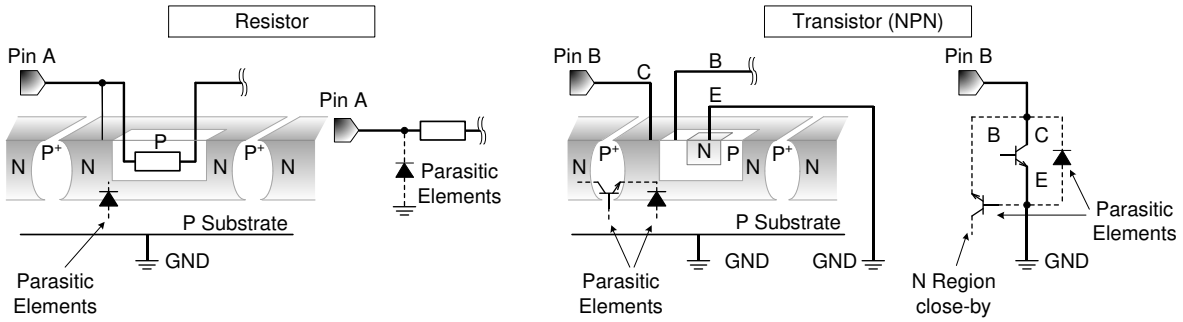
Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect 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.

10. Regarding the Input Pin of the IC

This monolithic IC contains P+ 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.



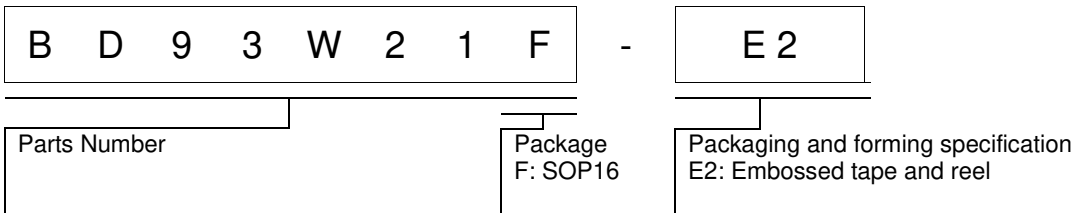
11. Ceramic Capacitor

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.

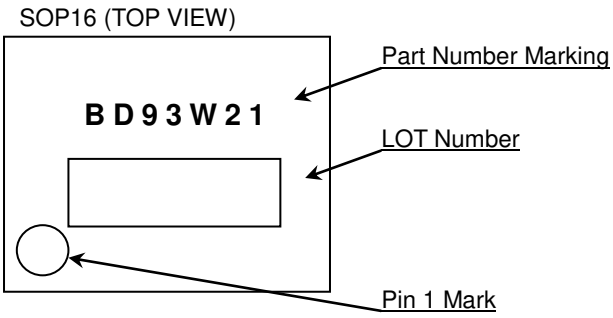
12. Over Current Protection Circuit (OCP)

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

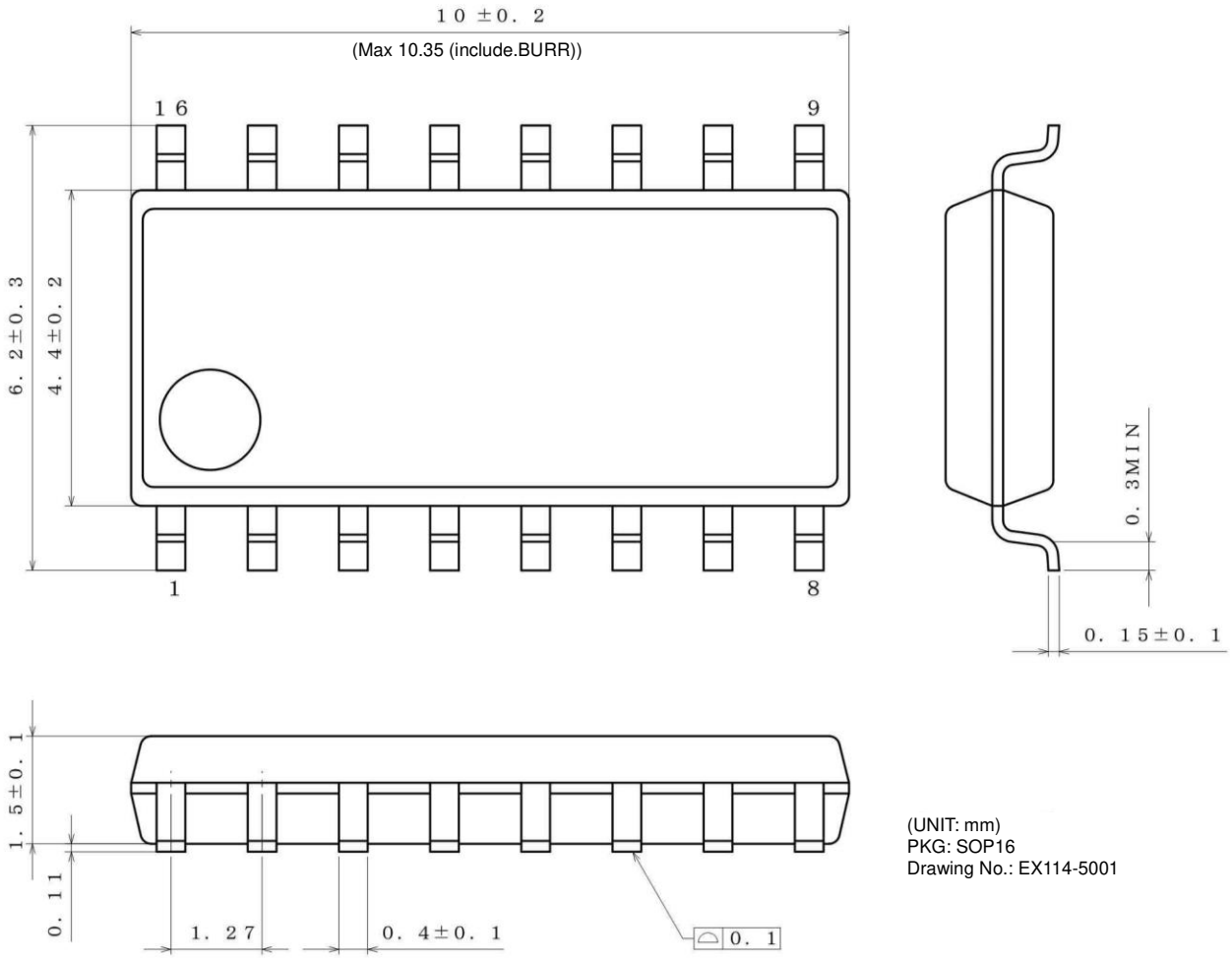


Marking Diagram



Physical Dimension and Packing Information

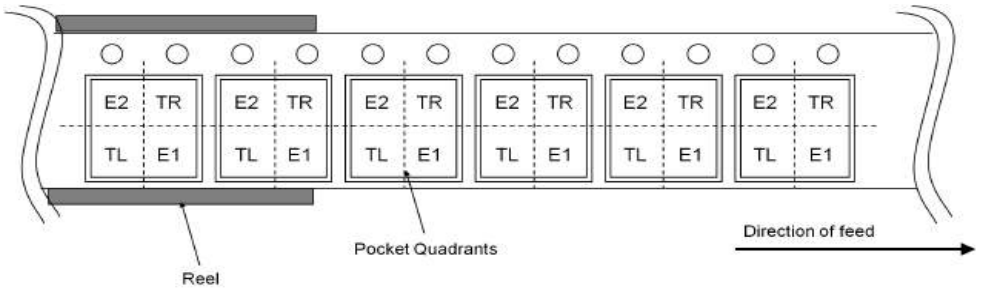
Package Name	SOP16



(UNIT: mm)
PKG: SOP16
Drawing No.: EX114-5001

<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)



Revision History

Date	Revision	Changes
12.Oct.2018	001	New Release

Notice

Precaution on using ROHM Products

1. Our Products are designed and manufactured for application in ordinary electronic equipment (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 depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction 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 on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

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

A two-dimensional barcode 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.

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Since concerned goods might be fallen under listed items of export control prescribed by Foreign exchange and Foreign trade act, please consult with ROHM in case of export.

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