AC/DC Converter
PWM Types DC/DC Converter IC
BD28C5xFJ-LB Series

General Description
This product is a rank product for the industrial equipment market. This is the best product for use in these applications.
The PWM type DC/DC converter for AC/DC provides an optimal system for all products that require an electrical outlet. This IC supports both isolated and non-isolated devices and enables simpler designs of various types of a low power consumption electrical converters.
This IC has a lineup of VDD UVLO that support both Si and SiC of MOSFET.
Power supplies can be designed flexibly by connecting a current detection resistor for the switching externally. Current is restricted in each cycle and excellent performances are demonstrated in a bandwidth and transient response since a current mode control is utilized.
The switching frequency can be set by external resistor and capacitor on the RTCT pin.

Features
- PWM Current Mode Method
- Low Power Consumption
- The VDD Pin UVLO Function
- Over Current Protection Function per Cycle
- Switching Frequency Setting Pin

Applications
- Industrial Equipment
- PV Inverter

Key Specifications
- Input Voltage Range : 6.90 V to 28.00 V
- Circuit Current: 2.0 mA (Max)
- Startup Current: 60 µA (Typ)
- Operating Temperature Range: -40 °C to +125 °C

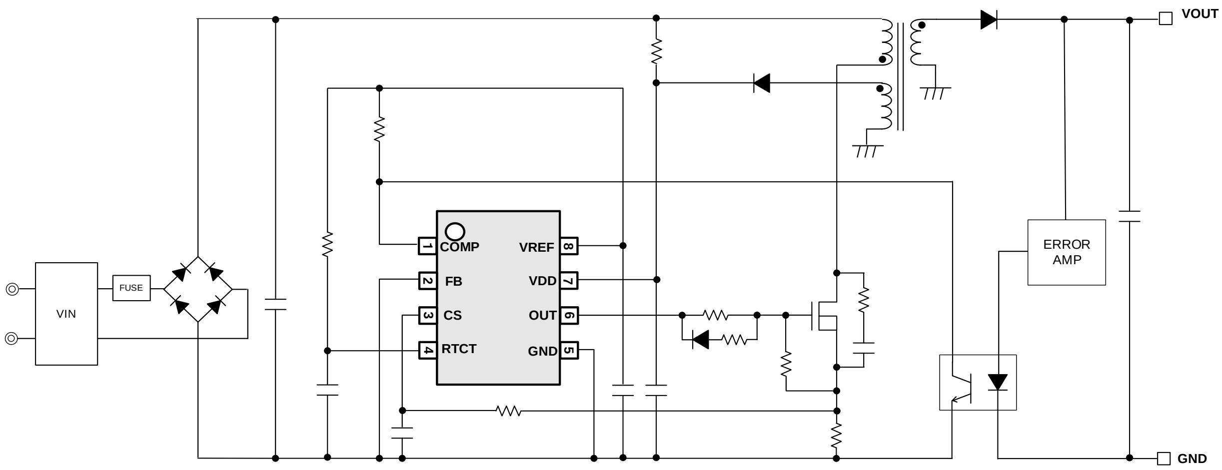
Package
W (Typ) x D (Typ) x H (Max)

SOP-J8 4.9 mm x 6.0 mm x 1.65 mm
Pitch 1.27 mm

Lineup

Product Name	VDD UVLO	Max ON Duty
BD28C52FJ-LB	14.5 V / 9.0 V	100 %
BD28C53FJ-LB	8.4 V / 7.6 V	
BD28C56HFJ-LB	18.8 V / 15.5 V	
BD28C56LFJ-LB	18.8 V / 14.5 V	
BD28C58FJ-LB	16.0 V / 12.5 V	
BD28C50FJ-LB	7.0 V / 6.6 V	
BD28C54FJ-LB	14.5 V / 9.0 V	50 %
BD28C55FJ-LB	8.4 V / 7.6 V	
BD28C57HFJ-LB	18.8 V / 15.5 V	
BD28C57LFJ-LB	18.8 V / 14.5 V	
BD28C59FJ-LB	16.0 V / 12.5 V	
BD28C51FJ-LB	7.0 V / 6.6 V	

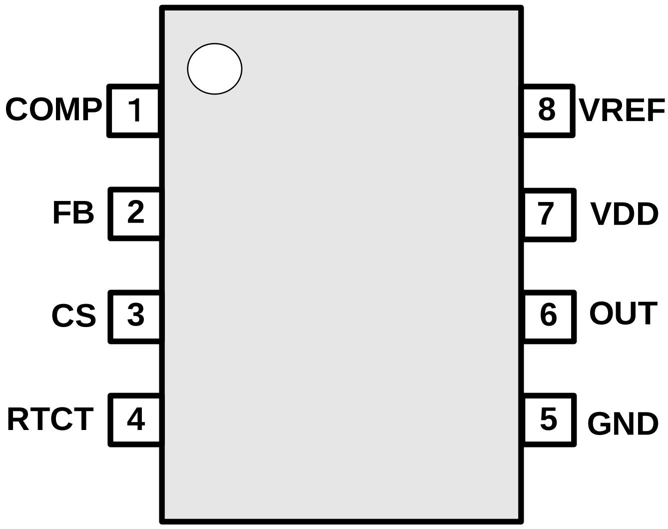
Typical Application Circuit



○Product structure: Silicon integrated circuit ○This product has no designed protection against radioactive rays.

Pin Configuration

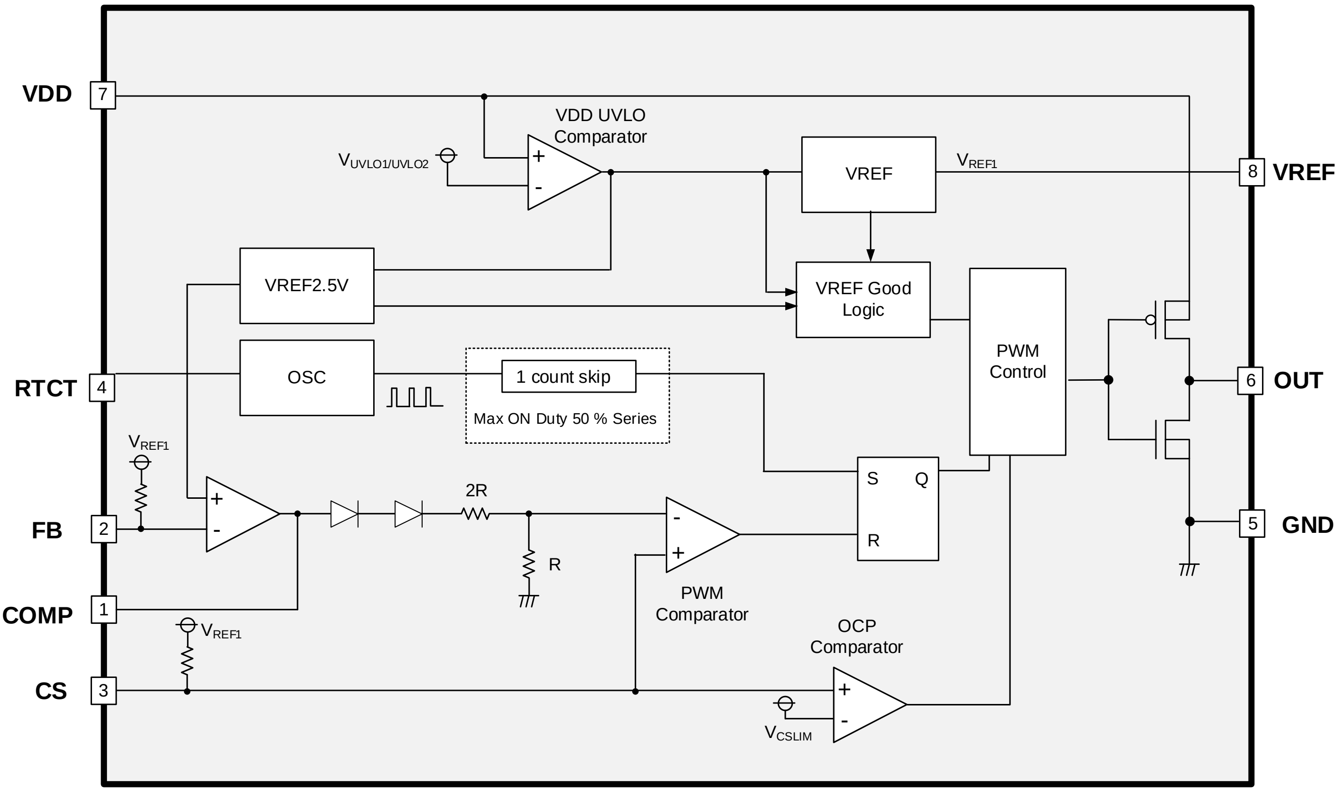
(TOP VIEW)



Pin Descriptions

Pin No.	Pin Name	I/O	Function
1	COMP	O	Error amplifier output pin
2	FB	I	Feedback signal input pin
3	CS	I	Primary current sense pin
4	RTCT	I/O	Switching frequency setting pin
5	GND	-	GND pin
6	OUT	O	External MOS driving pin
7	VDD	I	Power supply input pin
8	VREF	O	5 V output pin

Block Diagram



Description of Blocks

1. Startup Sequence

The startup sequence is shown in Figure 1. Each is described in more detail in each chapter.

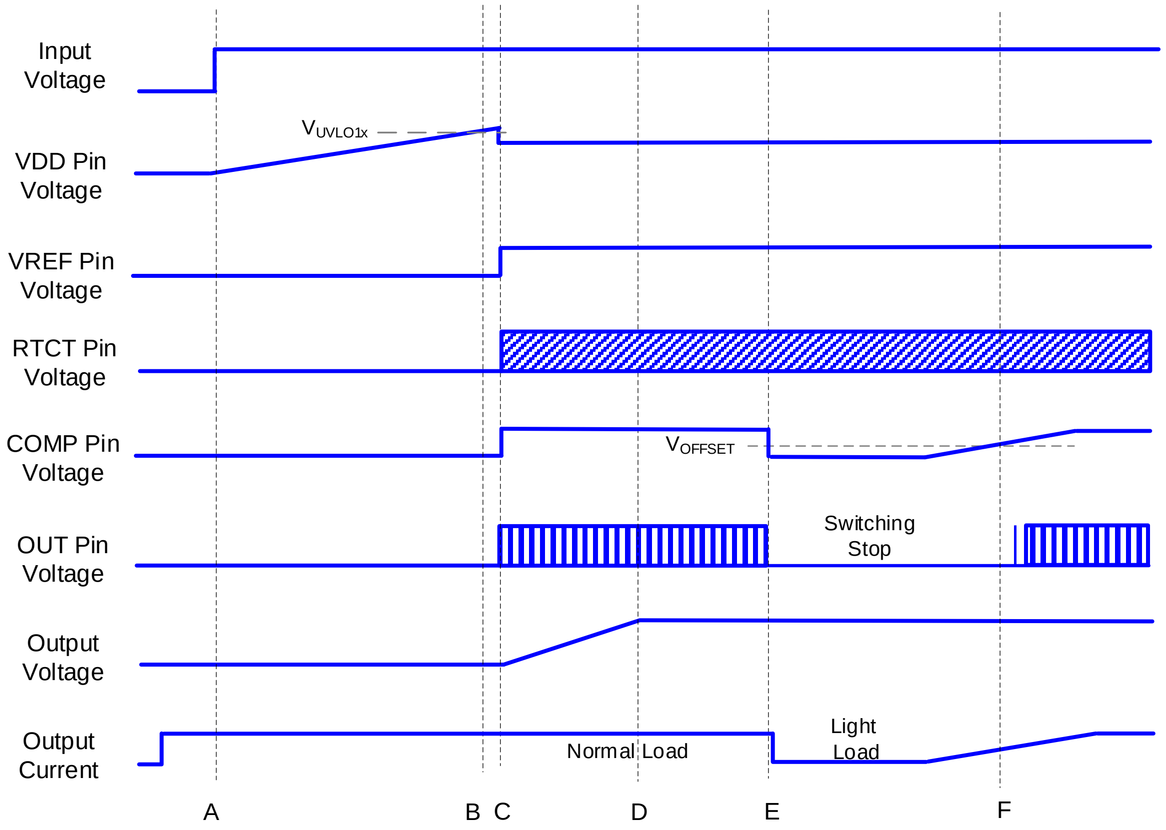


Figure 1. Startup Sequence Timing Chart

A: The VDD pin voltage rises after applying the input voltage.
B: When the VDD pin voltage > V_{UVLO1x}, VDD UVLO is released, and IC start to operate.
C: After VDD UVLO is released, the VREF pin and the COMP pin voltage rise, and IC starts switching operation.
D: The output voltage rises and becomes constant.
E: At light load, when the COMP pin voltage < V_{OFFSET}, the burst operation starts to reduce the power consumption, and switching operation is stopped.
F: When the COMP pin voltage > V_{OFFSET}, switching operation starts.

V_{UVLO1x} means to V_{UVLO1A} to V_{UVLO1F}.

Description of Blocks - continued

2. VDD

VDD is a power input pin.
Connect R_{START} to the VDD pin to activate it. Before VDD UVLO is released, I_{START} flows through R_{START}, so set an appropriate resistance. The lower R_{START}, the higher the standby power and the shorter the startup time. Conversely, increasing R_{START} reduces the standby power and increases the startup time.
R_{START} and the VDD pin capacitance C_{VDD} should be configured by checking the application evaluation.

ex) Startup resistor R_{START} setting.

$$R_{START} = (V_{MIN} - V_{UVLO1x}(max))/I_{START}(max) \qquad [\Omega]$$

where:

R_{START} is the startup resistor
V_{MIN} is the minimum input DC voltage
V_{UVLO1x} is the VDD UVLO voltage1x
I_{START} is the startup current

Since this IC has no built-in clamps, ground the zener protective diode D_Z between the VDD pin and the GND pin so that the absolute maximum rating voltage 30 V is not exceeded. Set D_Z so that the minimum value including temperature characteristic variation > V_{UVLO1x}.
As a countermeasure against noises, C_{VDDBP} is installed between the VDD pin and the GND pin to filter the VDD pin voltage. Position C_{VDDBP} as close to the VDD pin and the GND pin as possible.

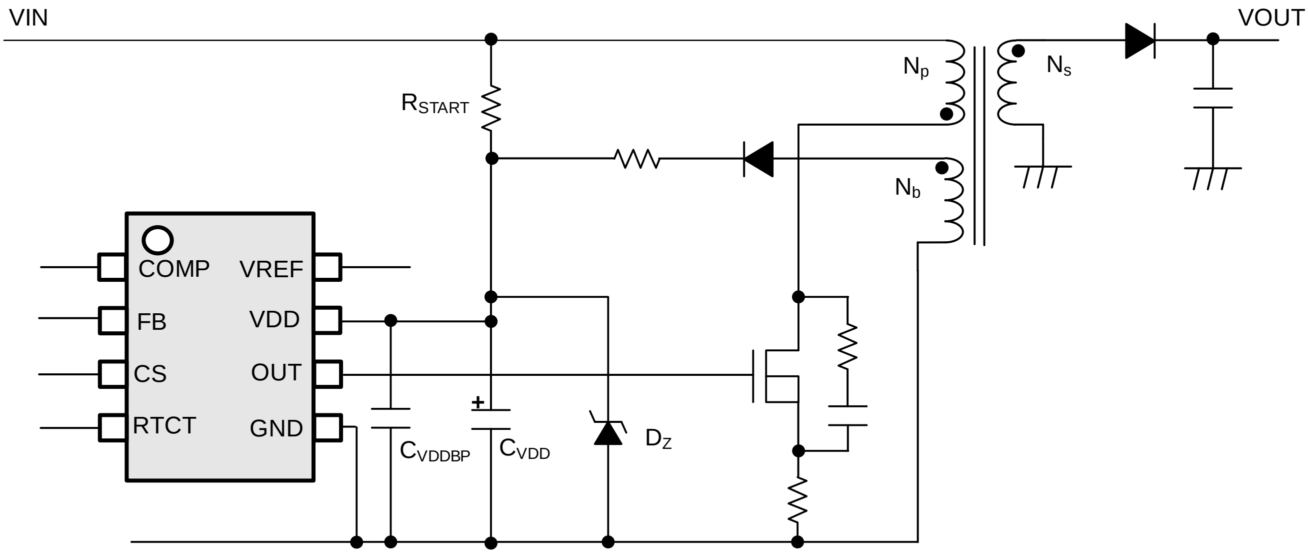


Figure 2. VDD Setup Circuit

2. VDD - continued

2.1 VDD UVLO (Under Voltage Lockout)

VDD UVLO is the auto recovery type comparator having voltage hysteresis. When VDD pin voltage > V_{UVLO1x}, VDD UVLO function is released and IC starts operating. When the VDD pin voltage < V_{UVLO2x}, VDD UVLO function detects and IC stops operating.
V_{UVLO1x} means to V_{UVLO1A} to V_{UVLO1F}. V_{UVLO2x} means to V_{UVLO2A} to V_{UVLO2F}.

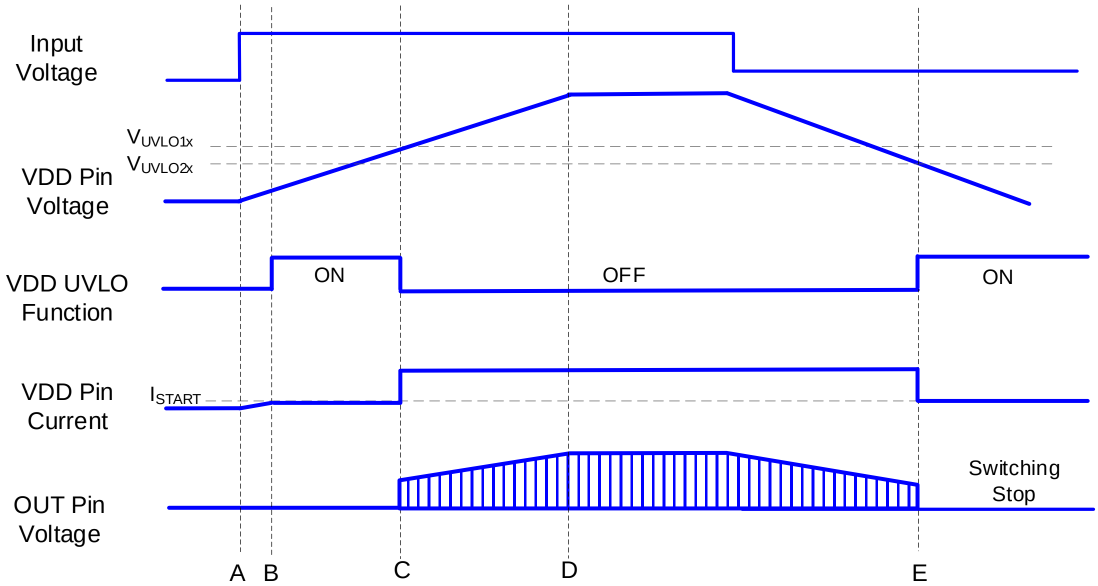


Figure 3. VDD UVLO Timing Chart

A: The VDD pin voltage rises after applying the input voltage.
B: When the internal comparator starts, VDD UVLO function is detected and I_{START} starts to flow.
C: When the VDD pin voltage > V_{UVLO1x}, VDD UVLO function is released and switching operation starts.
D: The High voltage of the OUT pin rises following the VDD pin voltage.
E: When the VDD pin voltage < V_{UVLO2x}, VDD UVLO function is detected, and the switching operation is stopped.

The following lineups are available in this series.

Table 1. VDD UVLO Lineup

Product Name	VDD UVLO1	VDD UVLO2
BD28C52FJ-LB / BD28C54FJ-LB	14.5 V	9.0 V
BD28C53FJ-LB / BD28C55FJ-LB	8.4 V	7.6 V
BD28C56HFJ-LB / BD28C57HFJ-LB	18.8 V	15.5 V
BD28C56LFJ-LB / BD28C57LFJ-LB	18.8 V	14.5 V
BD28C58FJ-LB / BD28C59FJ-LB	16.0 V	12.5 V
BD28C50FJ-LB / BD28C51FJ-LB	7.0 V	6.6 V

2.2 TSD (Thermal Shutdown)

The TSD stops switching operation if the junction temperature > T_{SD1} state continues for t_{PROT}.
When the junction temperature < T_{SD2}, the switching operation resumes.

Description of Blocks - continued

3. VREF

The VREF pin is used for outputting V_{REF1}. This voltage can be used for various functions such as frequency setting and soft start function.
C_{VREF} is required to ensure reference stability and to prevent noise problems caused by fast switching transients.
Place a ceramic capacitor of 0.1 µF or more as close as possible to the VREF pin and GND pin.
Connecting the VREF pin to GND pin may cause I_{REF} to flow, causing excessive heat to IC and damage. Do not connect the VREF pin to GND pin as the way to stop switching.
V_{REF} achieves the accuracy of V_{REF1} at normal temperature. The accuracy of V_{REF2} is achieved over the entire condition range of the V_{REF_LINE} of Line Regulation, the V_{REF_LOAD} of Load Regulation, and the V_{REF_TEMP} of temperature characteristics.

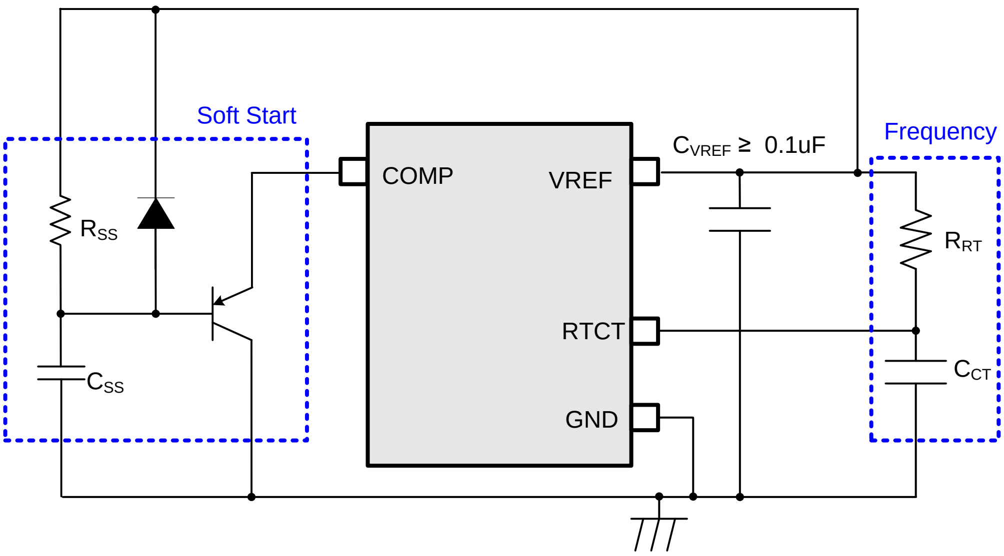


Figure 4. VREF Application

4. FB

The FB pin is used to control the feedback loop.
The V_{FB} achieves the accuracy of V_{FB1} at normal temperature and V_{FB2} over the entire temperature range.
Keep the wires to the FB pin as short as possible and reduce the parasitic capacitance of the FB pin to ensure stable operation.

Description of Blocks - continued

5. **RTCT**

The RTCT pin is used to set the switching frequency and max ON duty using the external component R_{RT} and C_{CT}. R_{RT} is connected to the VREF pin by pull-up. C_{CT} is connect to GND pin with a pull-down.
Use R_{RT} with a precision of 1 % or less, and C_{CT} with a precision of 5 % or less. Also, C_{CT} recommends the flat temperature coefficients. Keep cabling to C_{CT} and GND pin as short as possible.

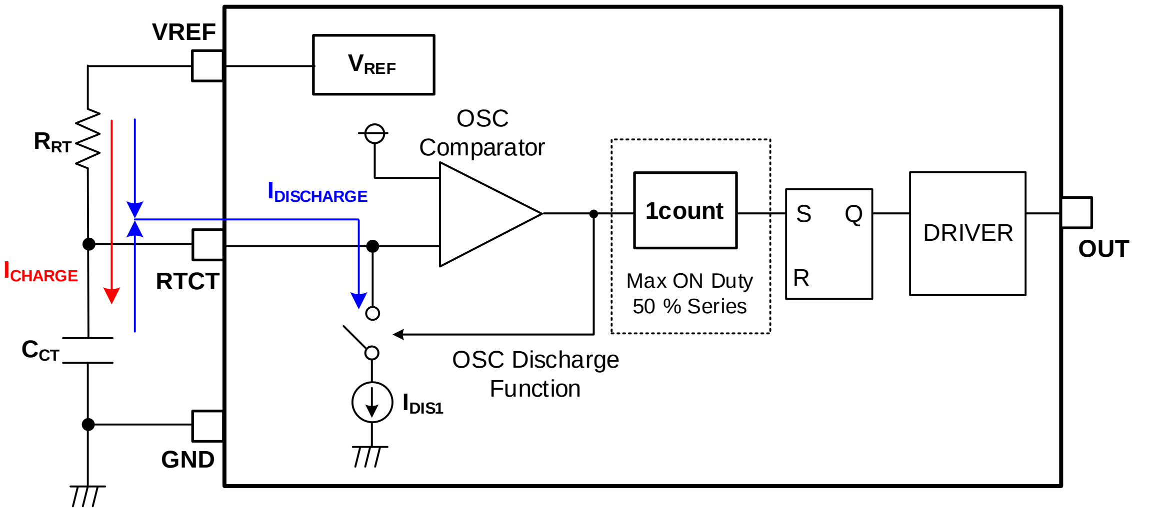


Figure 5. RTCT Circuit

When the RTCT pin voltage reaches V_{DIS2}, the OUT pin voltage switches from low to high.
The max ON duty is controlled by V_{DIS1}.

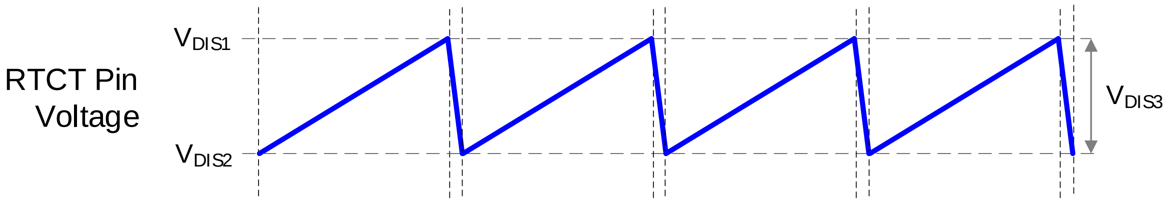


Figure 6. RTCT function

This series has two types of max ON duty.
The max ON duty of 50 % skips one switch of the OUT pin voltage from low to high, so the switching frequency is half of a max ON duty of 100 %.

Table 2. Max ON Duty Lineup

Product Name	Max ON Duty
BD28C52FJ-LB	100 %
BD28C53FJ-LB	
BD28C56HFJ-LB	
BD28C56LFJ-LB	
BD28C58FJ-LB	
BD28C50FJ-LB	
BD28C54FJ-LB	50 %
BD28C55FJ-LB	
BD28C57HFJ-LB	
BD28C57LFJ-LB	
BD28C59FJ-LB	
BD28C51FJ-LB	

5. RTCT - continued

5.1 Max ON Duty 100 %

The switching frequency is shown in Figure 7, the max ON duty is shown in Figure 8.
Set C_{CT} and R_{RT} referring to Figure 7 and Figure 8.
For C_{CT} = 3300 pF, and R_{RT} = 10 kΩ, the switching frequency is f_{SW1A}, and the max ON duty is D_{MAX1A}

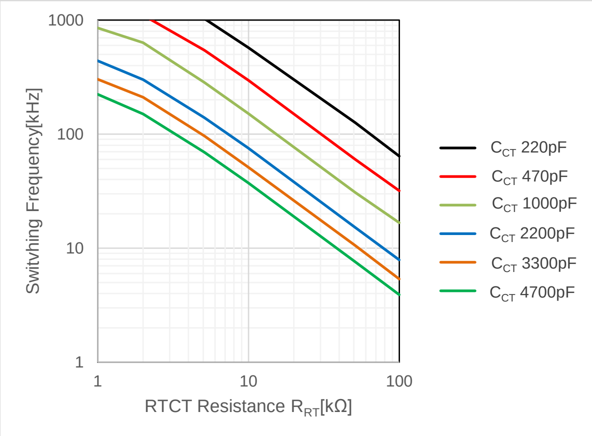


Figure 7. Switching Frequency vs R_{RT}
(Max ON Duty 100 %)

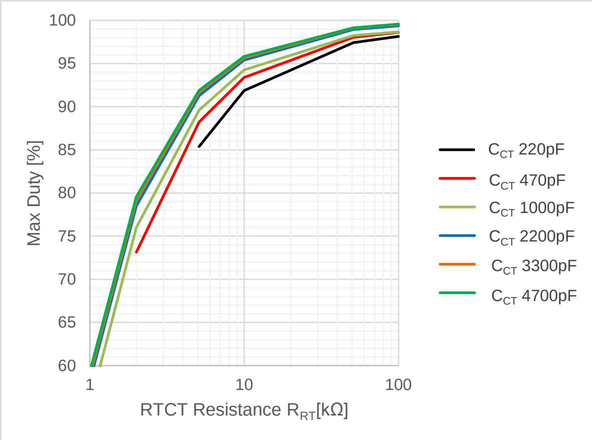


Figure 8. Max ON Duty vs R_{RT}

5.2 Max ON Duty 50 %

The switching frequency is shown in Figure 9, the max ON duty is shown in Figure 10.
Set C_{CT} and R_{RT} referring to Figure 9 and Figure 10.
For C_{CT} = 3300 pF and R_{RT} = 10 kΩ, the switching frequency is f_{SW1B} and the max ON duty is D_{MAX1B}

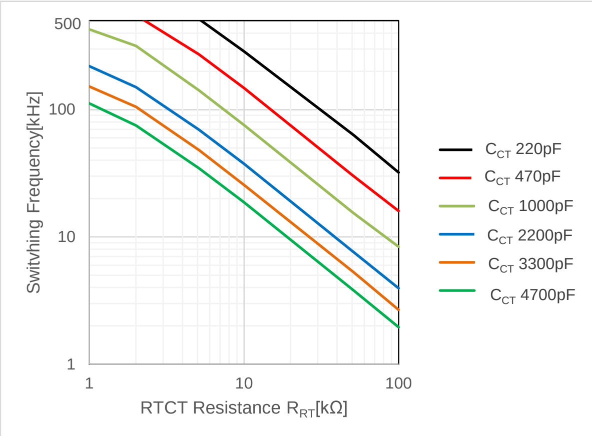


Figure 9. Switching Frequency vs R_{RT}
(Max ON Duty 50 %)

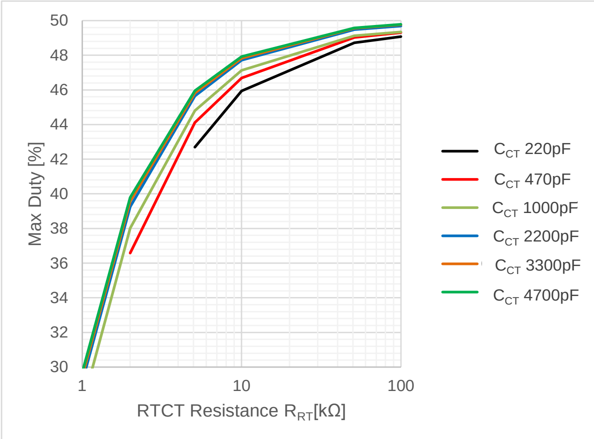


Figure 10. Max ON Duty vs R_{RT}

Description of Blocks - continued

6. COMP

The COMP pin is the output pin of the IC's error amplifier.

6.1 PWM Comparators

The cycle-by-cycle pulse-width modulation performed by PWM comparator compares the error amplifier output with the CS pin voltage.
The error amplifier gain is A_{CS}.

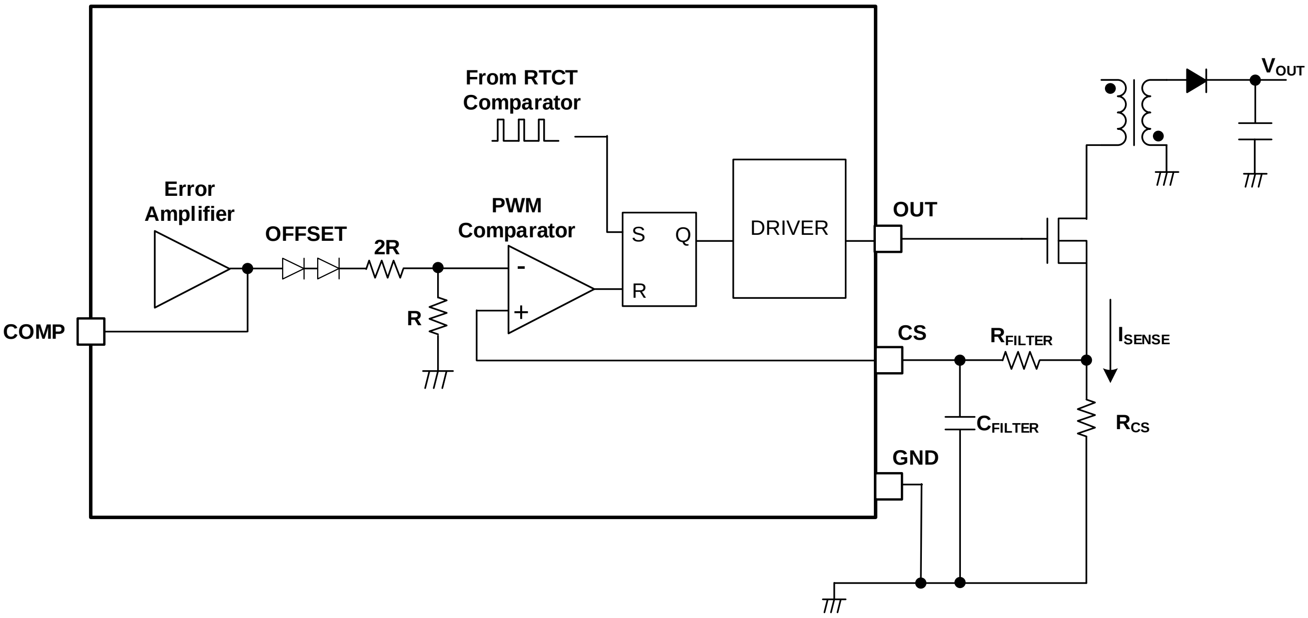


Figure 11. PWM COMP Circuit

PWM comparators have an offset.
When the CS pin voltage = 0 V, and the COMP pin voltage < V_{OFFSET}, PWM comparator does not drive, and switching is off. The offset of PWM comparator has no hysteresis.

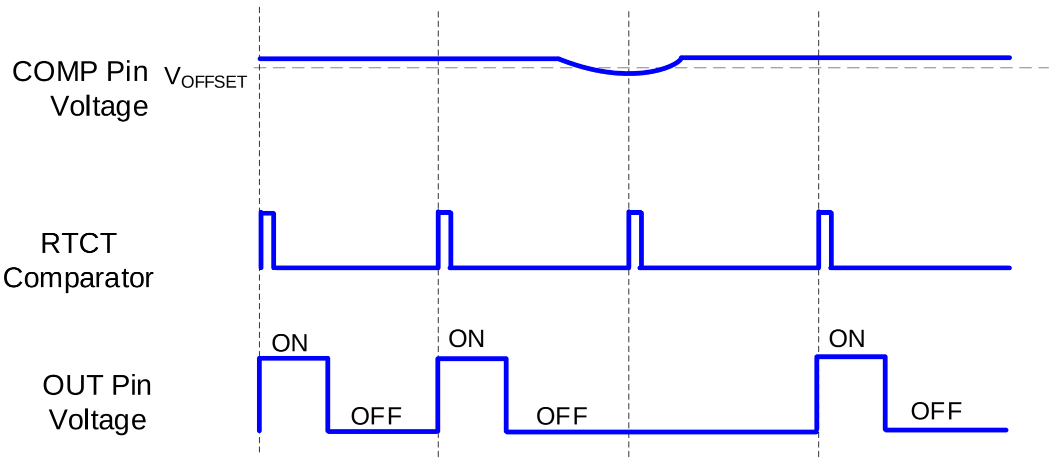


Figure 12. Offset Function

6. COMP - continued

6.2 Soft Start Function

When AC power supply is turned on, a large current flows normally to ACDC power supply. This IC can prevent large changes in output voltage and output current during startup by using application circuitry like a Figure 13. This function is called the soft start function.
At startup, the current I_{SS} flows from the COMP pin current through the PNP transistor, the COMP pin voltage rises slowly. This operation gradually increases the ON duty from zero to control the peak current rise.
The diode is required to operate the soft start function again when IC is restarted. Without a diode, C_{SS} is not discharged and PNP transistor is not re-driven, so the soft start function does not operate. When a diode is added, VDD UVLO is detected and C_{SS} is discharged. After VDD UVLO is released, the soft start function operates.
The soft start time is set by R_{SS} and C_{SS}. Use a large capacitor with a C_{SS} of 1 μF or more.

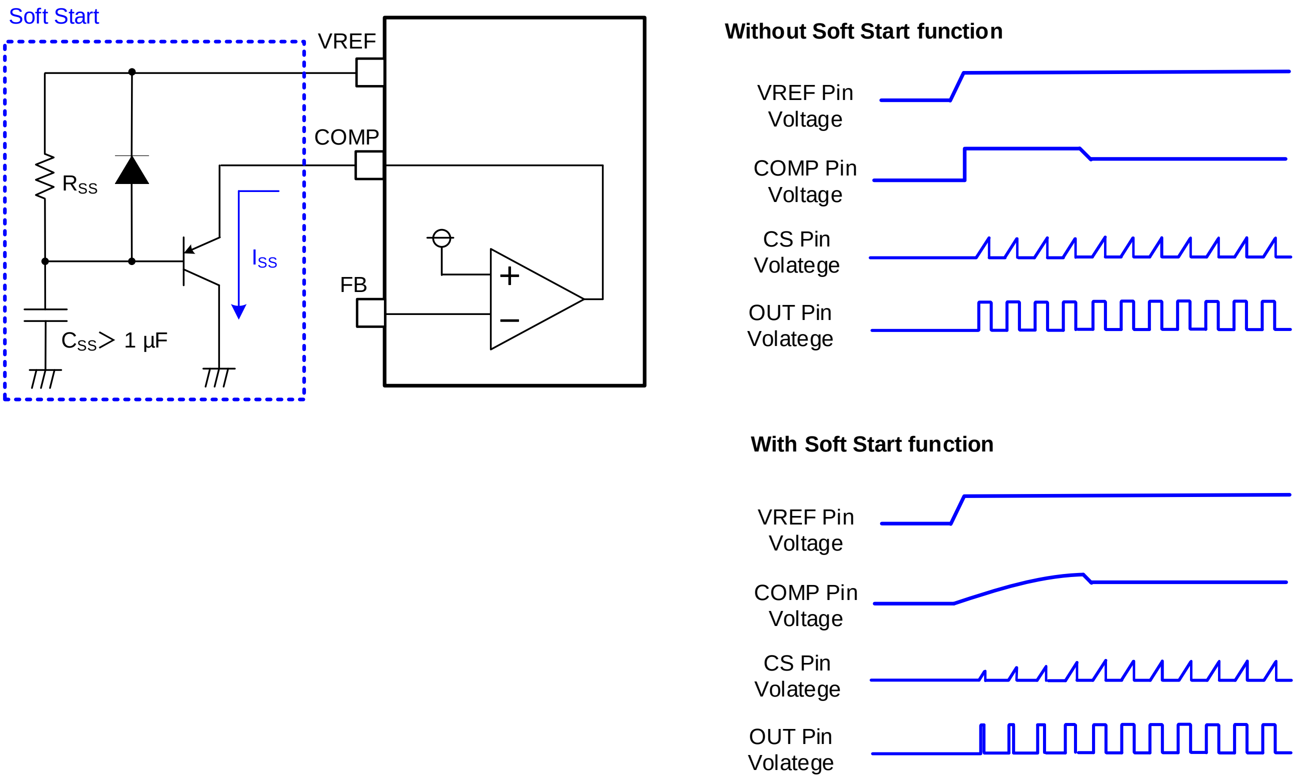


Figure 13. Soft Start Circuit

6.3 Enable and Disable

As shown in Figure 14, PWM comparator can be fixed to L by applying a Disable signal to COMP pin with an external transistor.

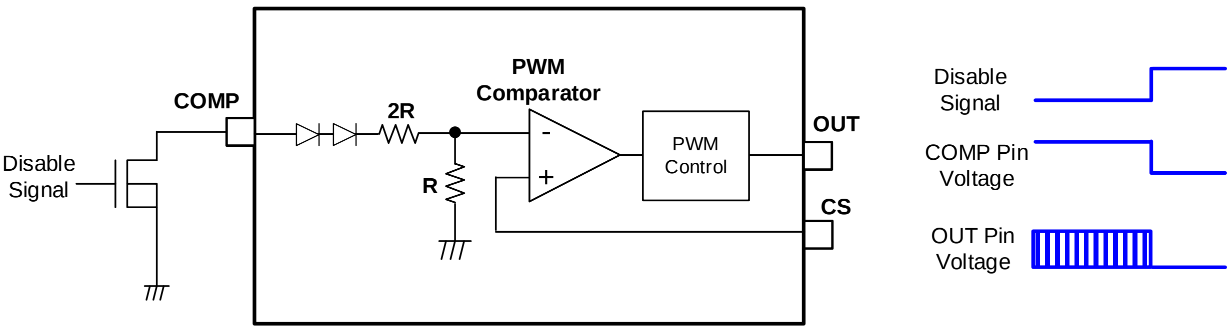


Figure 14. Disable Circuit

Description of Blocks - continued

7. CS

The CS pin is a current sense-input pin. The sense resistor R_{CS} senses the current, converts the current to voltage and input the CS pin.
A voltage-mode control configuration is also available by applying a triangular wave at the RTCT pin to this pin.
RC filters may be required to prevent false detection due to Leading Edge.

7.1 Over Current Protection Function (OCP)

This IC has a built-in over current protection function for each switching cycle. When CS pin voltage is > V_{OCP}, switching is stopped after t_{DELAY} regardless of the output voltage of the error amplifier. The peak current I_{SENSE} is calculated by the following equation:

$$I_{SENSE} = \frac{V_{OCP}}{R_{CS}}$$

where:

I_{SENSE}	is the peak current
V_{OCP}	is the over current protection voltage
R_{CS}	is the sense resistor

When designing, consider the accuracy of the sense resistor R_{CS} and the coil in addition to the accuracy of the over current protective voltage.
RC filters may be required to suppress switching transients caused by reverse-recovery of the secondary-diode or capacitive loads. The time constant of the filter should be smaller than the switching period of the converter.

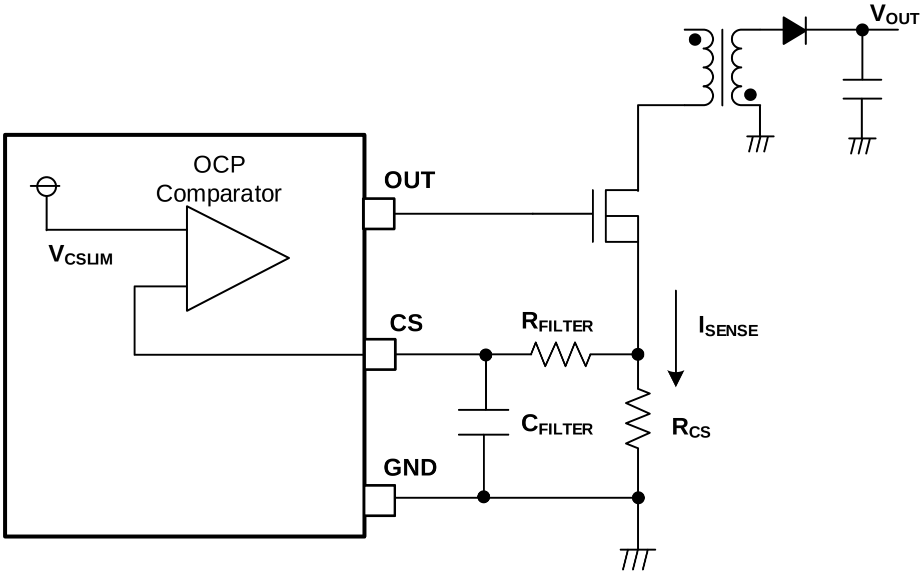


Figure 15. OCP Circuit

7. **CS - continued**

7.2 Voltage Mode Control

As shown in Figure 16, the triangular wave of the RTCT pin is converted and inputted to the CS pin, which enables driving with voltage mode control.
The RTCT pin voltage charging interval rises exponentially. When using this function, make R_{RT} larger and C_{CT} smaller to approximate a linear waveform.
Also, set the peak voltage at the CS pin to be smaller than the minimum value of V_{OCP}.

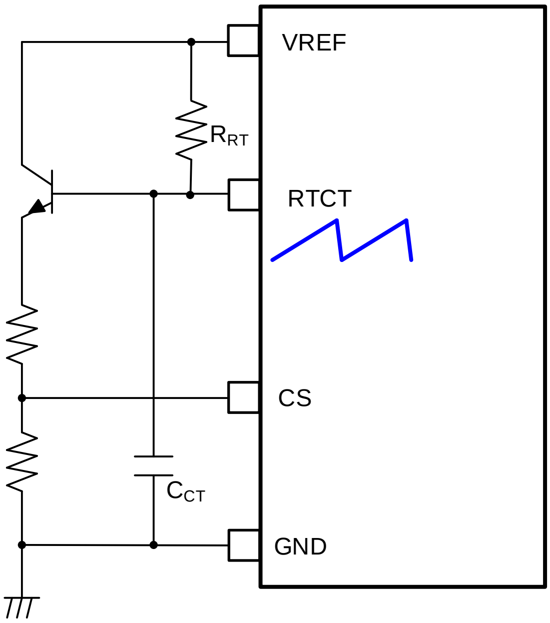


Figure 16. Voltage Mode Control Circuit

Description of Blocks - continued

8. Operation Mode of the Protection Function

The operation modes of each protection function are shown in Table 3.

Table 3. Operation Modes of Protection Functions

Parameter	Description	Protection Operation			
		Detection Method	Operation at Detection	How to Release	Operation at Release
VDD UVLO	VDD pin under voltage protection	VDD < V_{UVLO2x} (when VDD drops)	Switching stop	VDD > V_{UVLO1x} (when VDD rises)	Startup operation start
OCP	Over current protection function	CS > V_{OCP} (when CS rises)	OUT pin voltage = L	per Cycle	Normal operation
TSD	Thermal shutdown protection	Tj > T_{SD1}	Switching stop	Tj < T_{SD2}	Startup operation start

Absolute Maximum Ratings

Parameter	Symbol	Rating	Unit	Conditions
Maximum Applied Voltage 1	V_{MAX1}	-0.3 to +30.0	V	VDD pin, OUT pin
Maximum Applied Voltage 2	V_{MAX2}	-0.3 to +6.5	V	COMP pin, CS pin, FB pin, RTCT pin
Maximum Applied Voltage 3	V_{MAX3}	-0.3 to +7.0	V	VREF pin
OUT Pin Output Peak Current	I_{OUT_PEAK}	±1.0	A	
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.*

Thermal Resistance *(Note 1)*

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s*(Note 3)*	2s2p*(Note 4)*	
SOP-J8				
Junction to Ambient	θ_{JA}	149.3	76.9	°C/W
Junction to Top Characterization Parameter*(Note 2)*	Ψ_{JT}	18	11	°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 JESD51-7.

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

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Power Supply Voltage Range 1	VDD	6.90	-	28.00	V	VDD pin voltage
Power Supply Voltage Range 2	V_{OUT}	-	-	28	V	OUT pin voltage
VREF Pin Output Current	I_{OUT_REF}	-	-	20	mA	
Operating Temperature	Topr	-40	+25	+125	°C	

Recommended Range of the External Component

Parameter	Symbol	Rating	Unit
VREF Pin Connection Capacity	C_{VREF}	0.1 or more	μF
RTCT Pin Connection Capacity	C_{CT}	220 to 4700	pF
RTCT Pin Connection Resistor	R_{RT}	1 to 100	kΩ

Electrical Characteristics (Unless otherwise specified, VDD = 20 V, Ta =-40 °C to +125 °C)

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
[Circuit Current]						
Circuit Current 1	I_{ON1}	-	1.1	2.0	mA	
Startup Current	I_{START}	-	60	75	μA	VDD = 6.5 V
[VDD Pin Protective Function]						
VDD UVLO Voltage 1	V_{UVLO1A}	13.78	14.50	15.22	V	BD28C52FJ-LB BD28C54FJ-LB
	V_{UVLO1B}	7.98	8.40	8.82	V	BD28C53FJ-LB BD28C55FJ-LB
	V_{UVLO1C}	17.86	18.80	19.74	V	BD28C56HFJ-LB BD28C57HFJ-LB
	V_{UVLO1D}	17.86	18.80	19.74	V	BD28C56LFJ-LB BD28C57LFJ-LB
	V_{UVLO1E}	15.2	16.0	16.8	V	BD28C58FJ-LB BD28C59FJ-LB
	V_{UVLO1F}	6.5	7.0	7.5	V	BD28C50FJ-LB BD28C51FJ-LB
VDD UVLO Voltage 2	V_{UVLO2A}	8.55	9.00	9.45	V	BD28C52FJ-LB BD28C54FJ-LB
	V_{UVLO2B}	7.22	7.60	7.98	V	BD28C53FJ-LB BD28C55FJ-LB
	V_{UVLO2C}	14.73	15.50	16.30	V	BD28C56HFJ-LB BD28C57HFJ-LB
	V_{UVLO2D}	13.78	14.50	15.20	V	BD28C56LFJ-LB BD28C57LFJ-LB
	V_{UVLO2E}	11.88	12.50	13.10	V	BD28C58FJ-LB BD28C59FJ-LB
	V_{UVLO2F}	6.27	6.60	6.90	V	BD28C50FJ-LB BD28C51FJ-LB
Thermal Shutdown Temperature 1	T_{SD1}	155	175	195	°C	
Thermal Shutdown Temperature 2	T_{SD2}	130	150	170	°C	
Protective Mask Time	t_{PROT}	-	100	-	μs	
[VREF Block]						
VREF Reference Voltage 1	V_{REF1}	4.95	5.00	5.05	V	I_{OUT} = 1 mA, Ta = 25 °C
VREF Reference Voltage Line Regulation	V_{RERF_LINE}	-	0.2	20.0	mV	12 V ≤ VDD ≤ 25 V
VREF Reference Voltage Load Regulation	V_{RERF_LOAD}	-	3.0	25.0	mV	1 mA to 20 mA
VREF Reference Voltage Temperature Characteristics	V_{RERF_TEMP}	-	0.2	0.4	mV/°C	*(Note 1)*
VREF Reference Voltage 2	V_{REF2}	4.85	5.00	5.15	V	Total (V_{REF1},V_{REF_LINE},V_{REF_LOAD}, Ta = -40 °C to +125 °C)
VREF Output Short	I_{REF}	-65	-30	-22	mA	

(Note 1) Measurements are not made

Electrical Characteristics (Unless otherwise specified, VDD = 20 V, Ta =-40 °C to +125 °C) – continued

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
[FB Block]						
Feedback Voltage 1	V_{FB1}	2.48	2.50	2.53	V	Ta = 25 °C
Feedback Voltage 2	V_{FB2}	2.45	2.50	2.55	V	
FB Input Bias Current	I_{FB}		0.1	2.0	μA	V_{FB} = 5.0 V
FB Open-Loop Gain	Avol	-	90	-	dB	2 V ≤ V_{OUT} ≤ 4 V *(Note 1)*
Unity Gain Bandwidth	f_T	-	1.5	-	MHz	*(Note 1)*
FB PSRR	$PSRR_{FB}$	60	-	-	dB	12 V ≤ VDD ≤ 25 V *(Note 1)*
[COMP Block]						
COMP Sinking Current	I_{COMP_SINK}	2.0	14.0	-	mA	V_{FB} = 2.7 V, V_{COMP} = 1.1 V
COMP Sourcing Current	I_{COMP_SOURCE}	-1.5	-1.0	-0.5	mA	V_{FB} = 2.3 V, V_{COMP} = 5 V
COMP High Voltage	V_{COMPH}	V_{REF2} -0.2	-	-	V	V_{FB} = 2.3 V, R_{COMP} = 15 kΩ COMP to GND
COMP Low Voltage	V_{COMPL}	-	0.1	1.1	V	V_{FB} = 2.7 V, R_{COMP} = 15 kΩ COMP to VREF
PWM COMP Offset Voltage	V_{OFFSET}	-	1.15	-	V	CS = 0 V
[RTCT Block]						
Switching Frequency 1A (Max ON Duty = 100 % series)	f_{SW1A}	-	53.0	-	kHz	Ta = 25 °C *(Note 2) (Note 4)*
Switching Frequency 2A (Max ON Duty = 100 % series)	f_{SW2A}	35.0	37.0	39.0	kHz	Ta = 25 °C *(Note 3) (Note 4)*
Switching Frequency 1B (Max ON Duty = 50 % series)	f_{SW1B}	-	26.5	-	kHz	Ta = 25 °C *(Note 2) (Note 5)*
Switching Frequency 2B (Max ON Duty = 50 % series)	f_{SW2B}	20.5	23.0	25.5	kHz	Ta = 25 °C *(Note 3) (Note 5)*
Switching Frequency Line Regulation	f_{SW_LINE}	-	0.2	1.0	%	12 V ≤ VDD ≤ 25 V *(Note 3)*
Switching Frequency Temperature Characteristics	f_{SW_TEMP}	-	1.0	2.5	%	*(Note 1) (Note 2)*
Discharge Stop Voltage	V_{DIS1}	-	2.5	-	V	
Discharge Start Voltage	V_{DIS2}	-	0.8	-	V	
Discharge Hysteresis	V_{DIS3}	-	1.7	-	V	
Discharge Current 1	I_{DIS1}	7.7	8.4	9.0	mA	Ta = 25 °C, V_{RTCT} = 2 V
Discharge Current 2	I_{DIS2}	7.2	8.4	9.5	mA	V_{RTCT} = 2 V
Max ON Duty 1A	D_{MAX1A}	-	96	-	%	V_{FB} < 2.4 V *(Note 2) (Note 4)*
Max ON Duty 2A	D_{MAX2A}	94	96	100	%	V_{FB} < 2.4 V *(Note 3) (Note 4)*
Max ON Duty 1B	D_{MAX1B}	-	48	-	%	V_{FB} < 2.4 V *(Note 2) (Note 5)*
Max ON Duty 2B	D_{MAX2B}	47	48	50	%	V_{FB} < 2.4 V *(Note 3) (Note 5)*
Min ON Duty	D_{MIN}	-	-	0	%	V_{FB} > 2.6 V
[CS Block]						
Over Current Protection Voltage	V_{OCP}	0.95	1.00	1.05	V	V_{FB} < 2.4 V
CS Gain	A_{CS}	-	3.00	-	V/V	
CS Input Bias Current	I_{CS}	-	2.5	4.0	μA	V_{CS} = 0 V
CS PSRR	$PSRR_{CS}$	-	73	-	dB	*(Note 1)*
CS Output Delay Time	t_{DELAY}	-	35	-	ns	
[DRIVER Block]						
OUT Pull-down Resistor	R_{PDOUT}	-	5.5	15	Ω	I_{SINK} = 30 mA
OUT Pull-up Resistor	R_{PUOUT}	-	10	15	Ω	I_{SOURCE} = -30 mA
OUT Rise Time	t_{RISE}	-	25	50	ns	Ta = 25 °C, C_{OUT} = 1 nF
OUT Fall Time	t_{FALL}	-	20	40	ns	Ta = 25 °C, C_{OUT} = 1 nF

(Note 1) Measurements are not made
(Note 2) R_{RT} = 10 kΩ, C_{CT} = 3300 pF
(Note 3) R_{RT} = 10 kΩ, C_{CT} = 4000 pF
(Note 4) BD28C52FJ-LB, BD28C53FJ-LB, BD28C56HFJ-LB, BD28C56LFJ-LB, BD28C58FJ-LB, BD28C50FJ-LB
(Note 5) BD28C54FJ-LB, BD28C55FJ-LB, BD28C57HFJ-LB, BD28C57LFJ-LB, BD28C59FJ-LB, BD28C51FJ-LB

Typical Performance Curves
(Reference data)

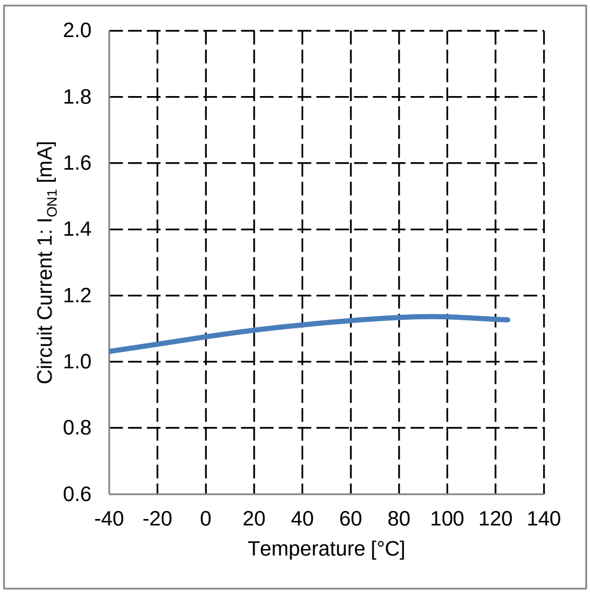


Figure 17. Circuit Current 1 vs Temperature

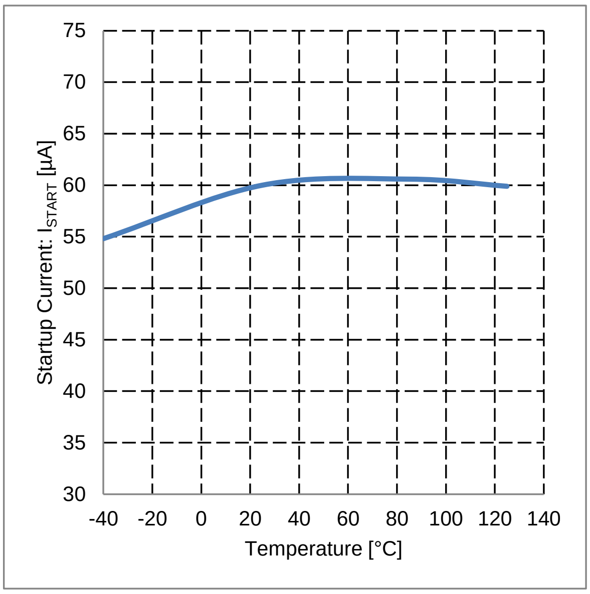


Figure 18. Startup Current vs Temperature

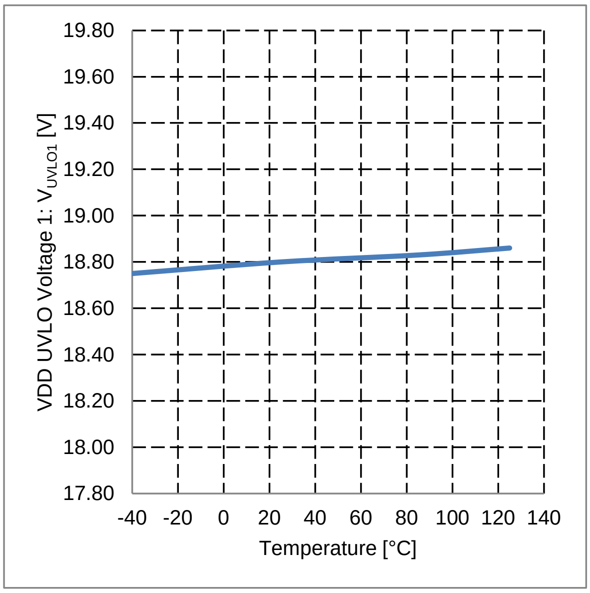


Figure 19. VDD UVLO Voltage 1 vs Temperature

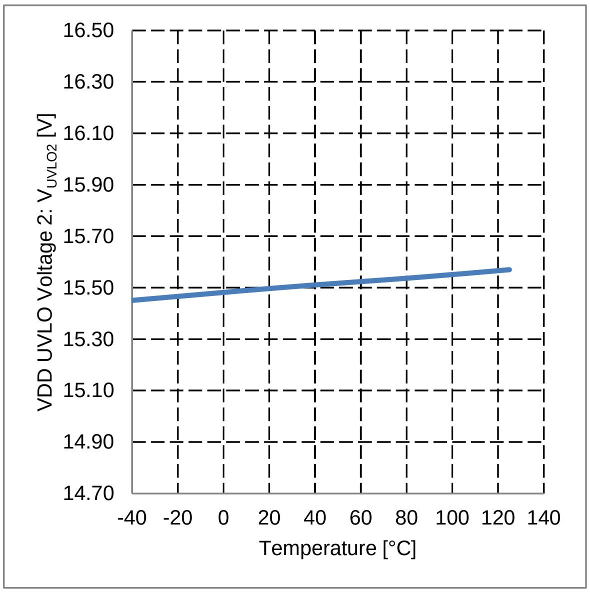


Figure 20. VDD UVLO Voltage 2 vs Temperature

Typical Performance Curves – continued
(Reference data)

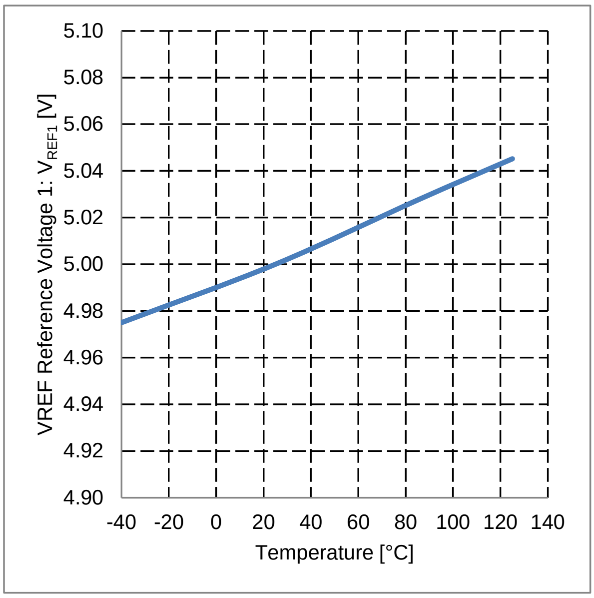


Figure 21. VREF Reference Voltage 1 vs Temperature

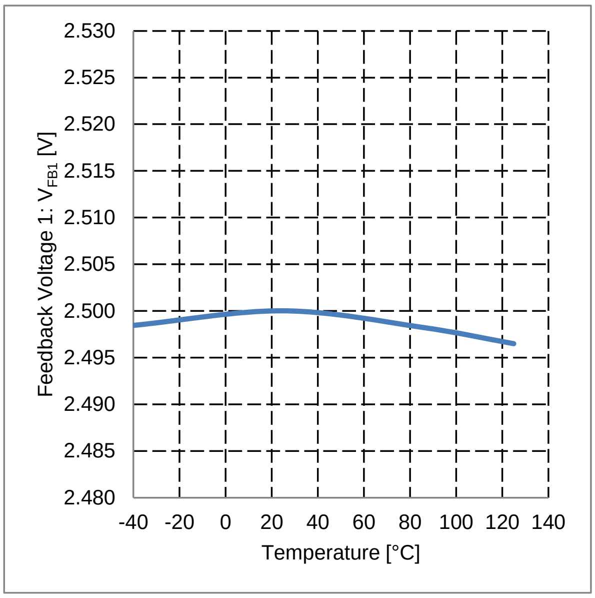


Figure 22. Feedback Voltage 1 vs Temperature

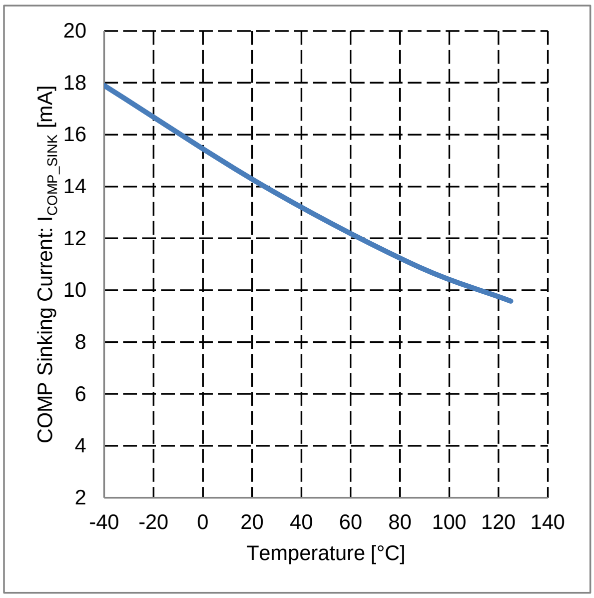


Figure 23. COMP Sinking Current vs Temperature

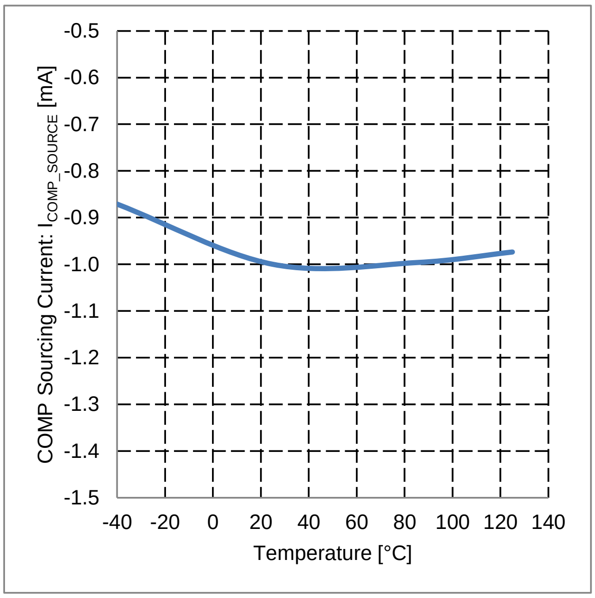


Figure 24. COMP Sourcing Current vs Temperature

Typical Performance Curves – continued
(Reference data)

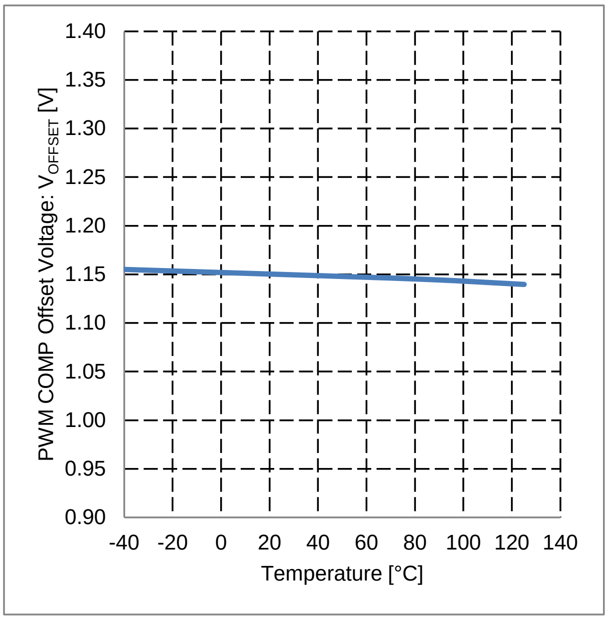


Figure 25. PWM COMP Offset Voltage vs Temperature

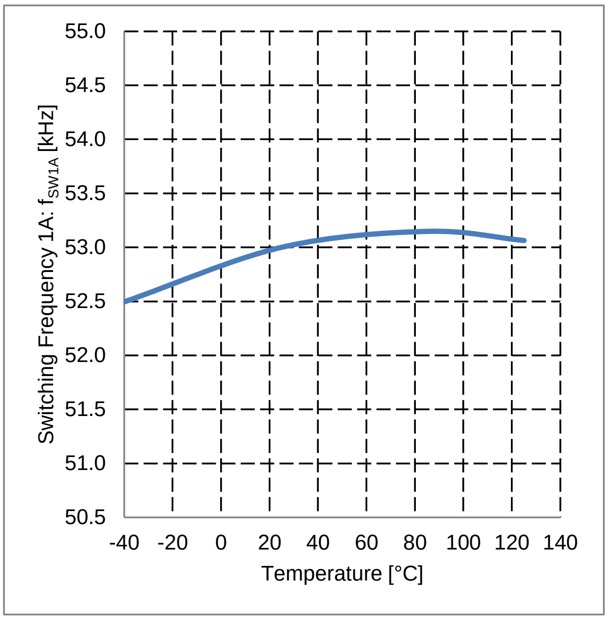


Figure 26. Switching Frequency 1A vs Temperature

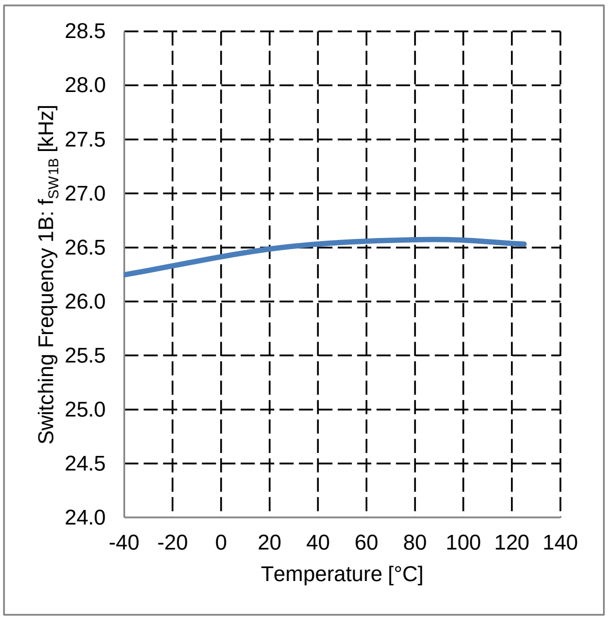


Figure 27. Switching Frequency 1B vs Temperature

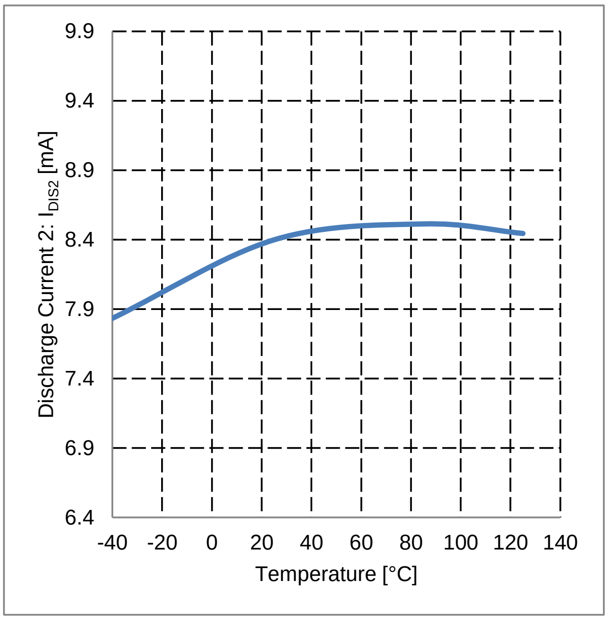


Figure 28. Discharge Current 2 vs Temperature

Typical Performance Curves – continued
(Reference data)

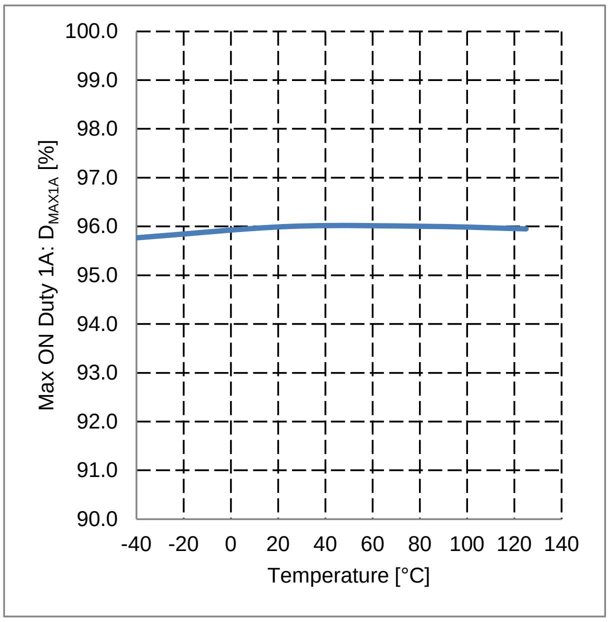


Figure 29. Max ON Duty 1A vs Temperature

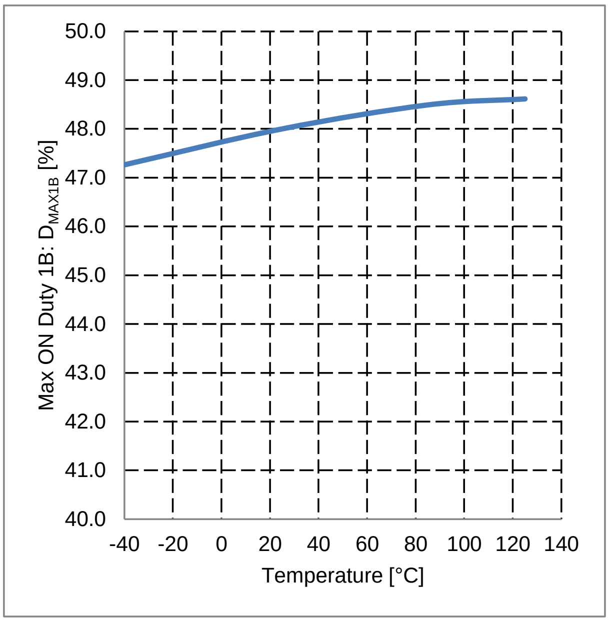


Figure 30. Max ON Duty 1B vs Temperature

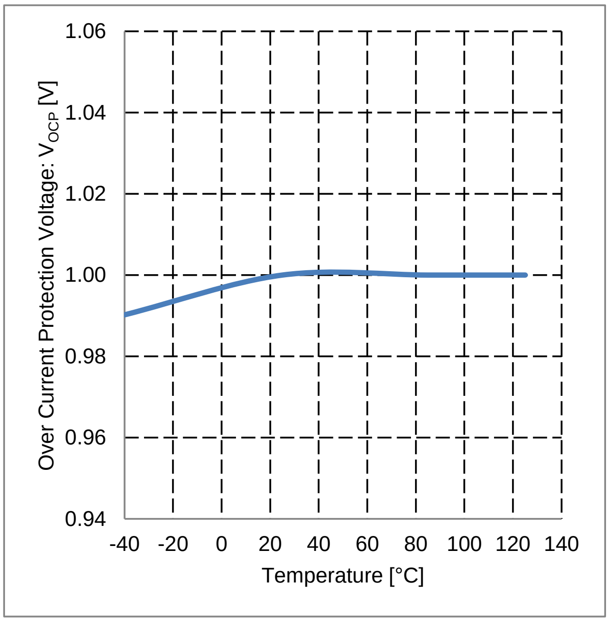


Figure 31. Over Current Protection Voltage vs Temperature

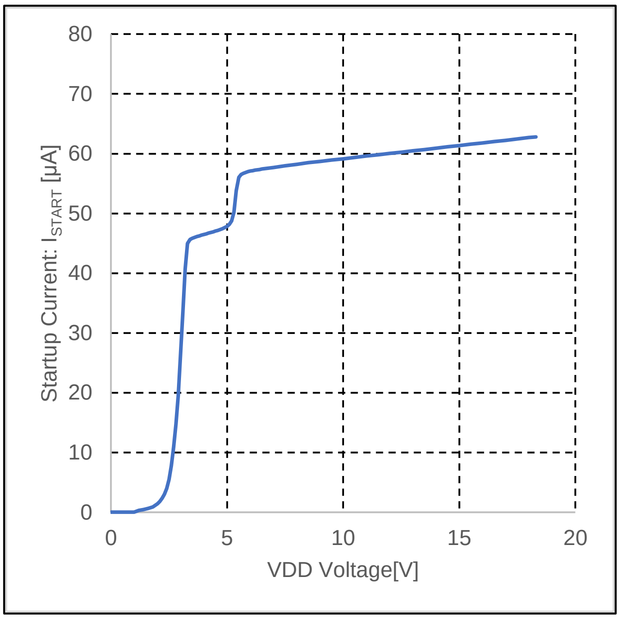


Figure 32. Startup Current vs VDD Voltage

Application Examples

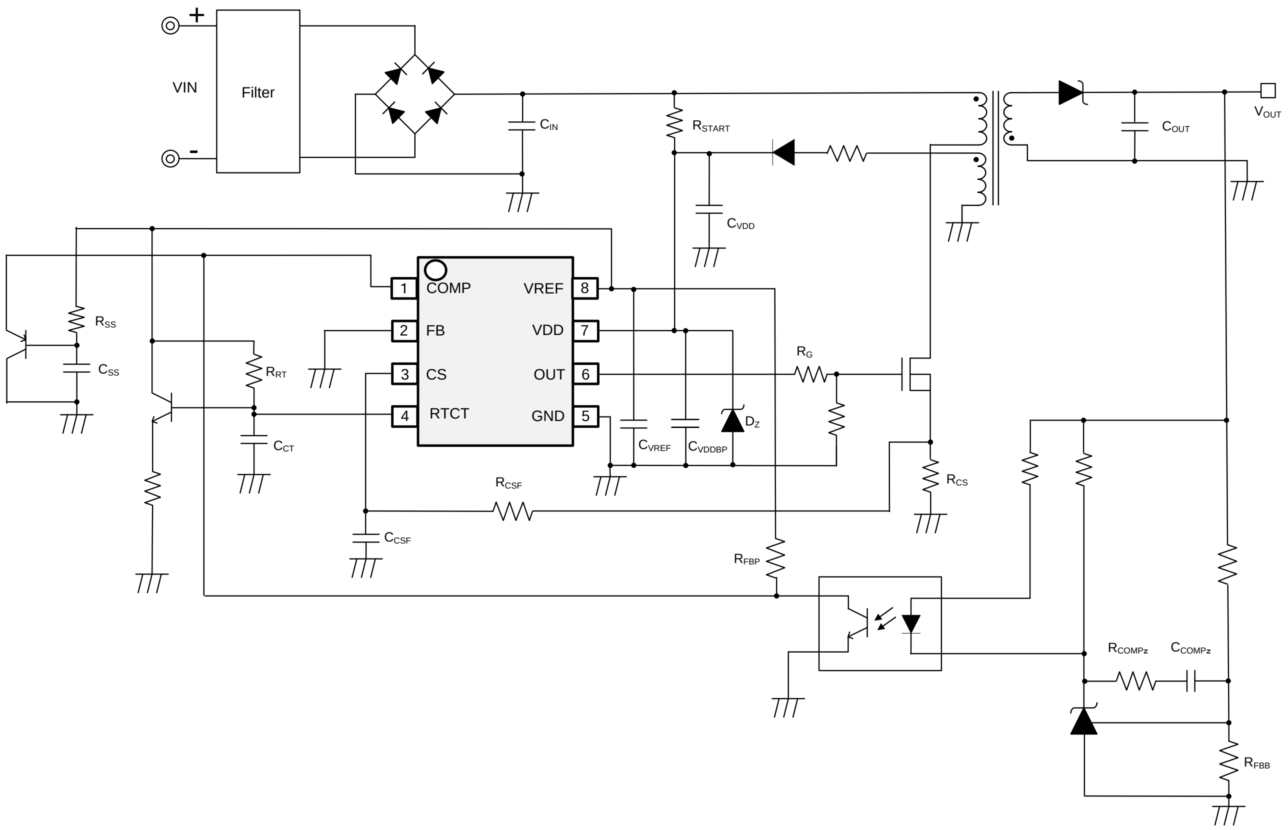


Figure 33. Application Circuit 1

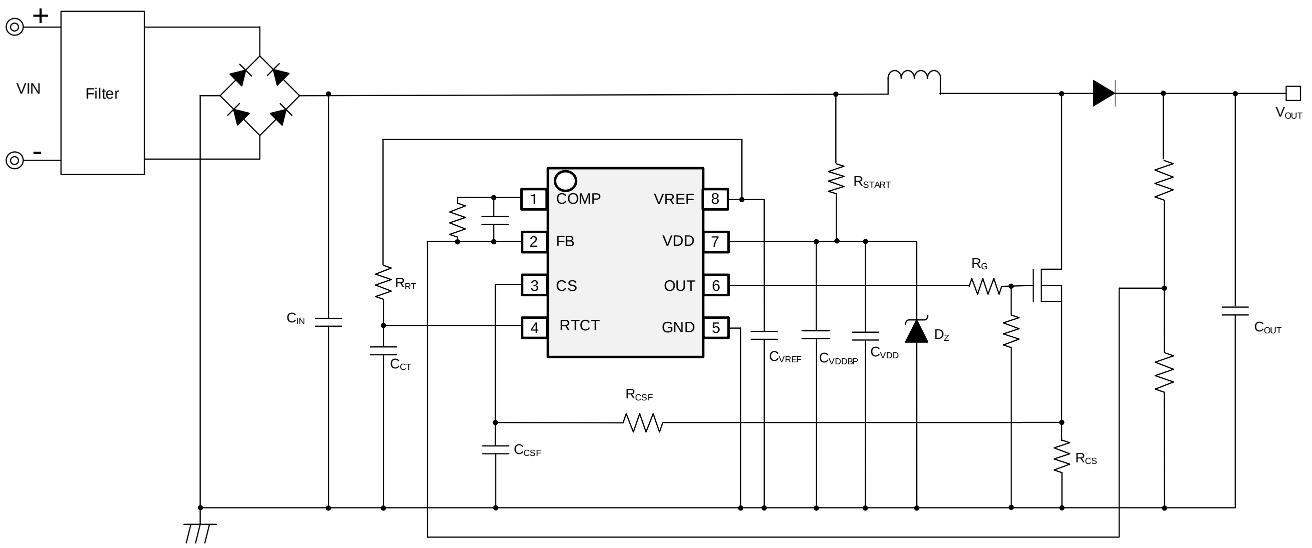
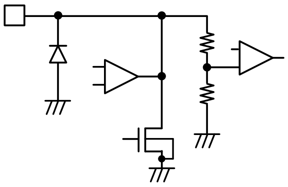
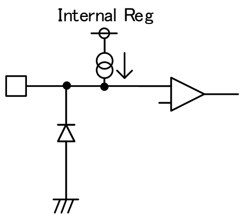
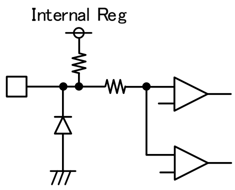
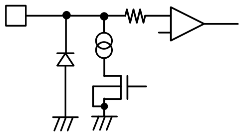
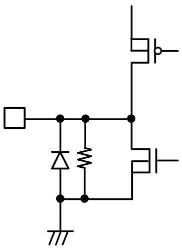
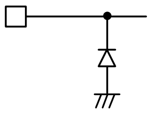
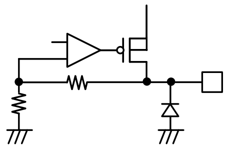


Figure 34. Application Circuit 2

I/O Equivalence Circuits

1	COMP	2	FB	3	CS	4	RTCT
							
5	GND	6	OUT	7	VDD	8	VREF
							

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**
Except for pins the output and the input of which were designed to go below ground, 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.

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+ 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.

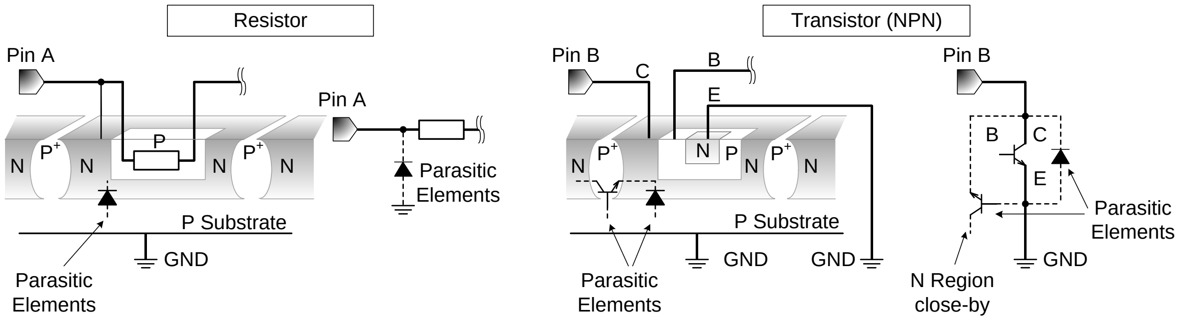


Figure 35. Example of Monolithic IC Structure

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 (Tj) will rise which will activate the TSD circuit that will turn OFF power output pins. When the Tj 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 over current 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 2 8 C 5 x F J - LB E 2

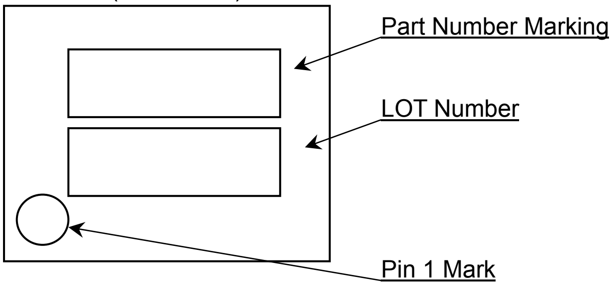
x: VDD UVLO voltage
2: 14.5 V / 9.0 V
3: 8.4 V / 7.6 V
6H: 18.8 V / 15.5 V
6L: 18.8 V / 14.5 V
8: 16.0 V / 12.5 V
0: 7.0 V / 6.6 V
4: 14.5 V / 9.0 V
5: 8.4 V / 7.6 V
7H: 18.8 V / 15.5 V
7L: 18.8 V / 14.5 V
9: 16.0 V / 12.5 V
1: 7.0 V / 6.6 V

Package
FJ: SOP-J8

Product Class
LB: for Industrial Applications
Packaging and Forming Specifications
E2: Embossed Tape and Reel

Marking Diagram

SOP-J8 (TOP VIEW)

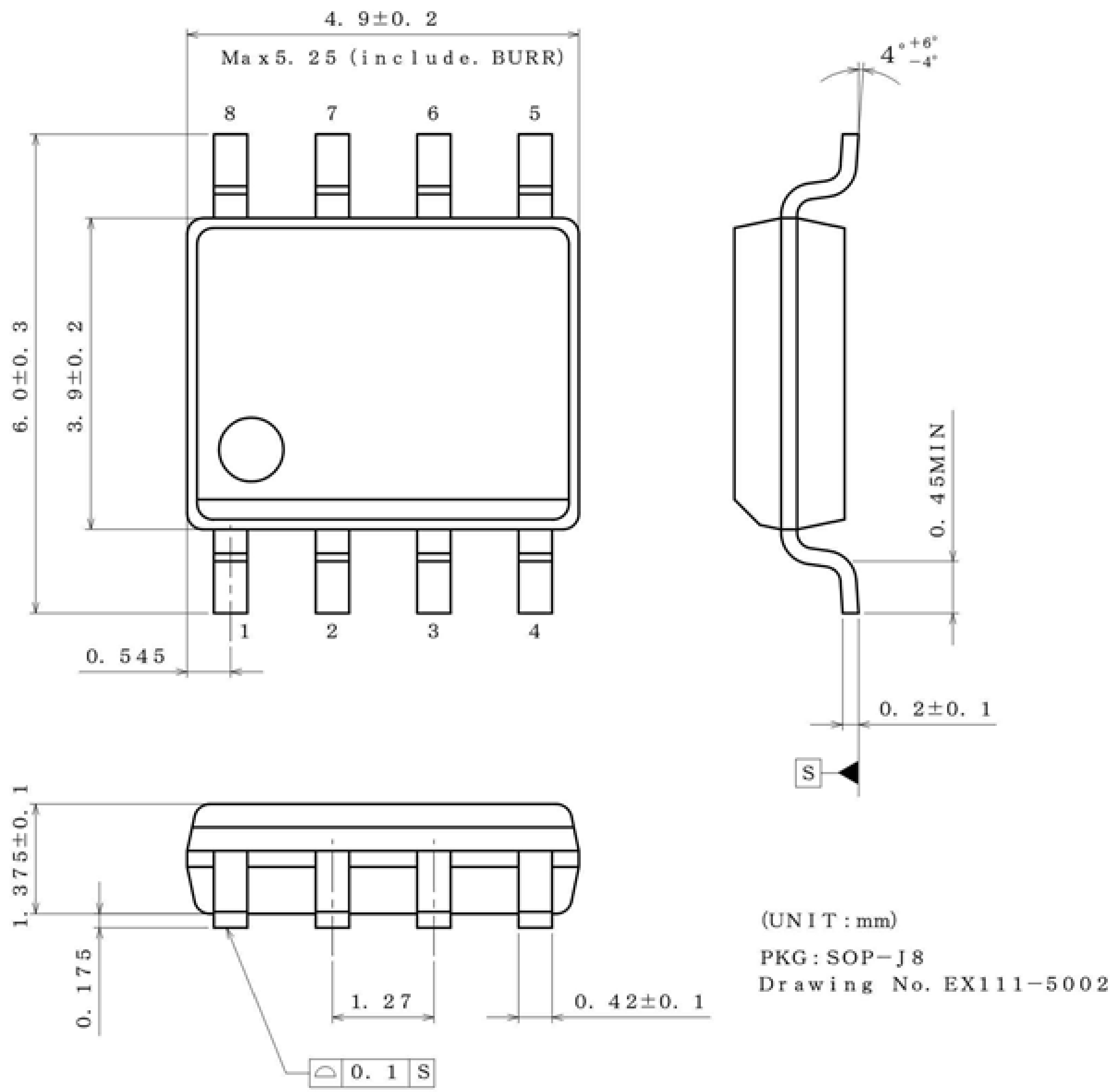


Lineup

Part Number Marking	Orderable Part Number	VDD UVLO	Max ON Duty
8C52	BD28C52FJ-LBE2	14.5 V / 9.0 V	100 %
8C53	BD28C53FJ-LBE2	8.4 V / 7.6 V	
8C56H	BD28C56HFJ-LBE2	18.8 V / 15.5 V	
8C56L	BD28C56LFJ-LBE2	18.8 V / 14.5 V	
8C58	BD28C58FJ-LBE2	16.0 V / 12.5 V	
8C50	BD28C50FJ-LBE2	7.0 V / 6.6 V	
8C54	BD28C54FJ-LBE2	14.5 V / 9.0 V	50 %
8C55	BD28C55FJ-LBE2	8.4 V / 7.6 V	
8C57H	BD28C57HFJ-LBE2	18.8 V / 15.5 V	
8C57L	BD28C57LFJ-LBE2	18.8 V / 14.5 V	
8C59	BD28C59FJ-LBE2	16.0 V / 12.5 V	
8C51	BD28C51FJ-LBE2	7.0 V / 6.6 V	

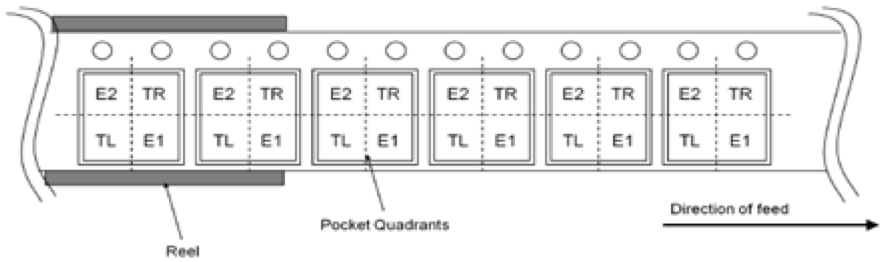
Physical Dimension and Packing Information

Package Name	SOP-J8



< Tape and Reel Information >

Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	E2 The direction is the pin 1 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	Edition	Changes
19.Feb.2024	001	New Release
28.Mar.2025	002	Addition to the lineup. P3. Updating Block Diagram. P7. Updating Figure 4. P8, P9. Updating RTCT description. P10, P11. Updating COMP description. P15. Addition to OUT Pin Output Peak Current. P16. Addition to VREF Pin Output Current. P16. Updating VREF Reference Voltage Line Regulation conditions. P17. Addition to FB Input Bias Current. P17. Addition to FB Open-Loop Gain. P17. Addition to Unity Gain Bandwidth. P17. Updating Switching Frequency Line Regulation conditions. P17. Addition to FB PSRR. P17. Addition to CS Input Bias Current. P17. Addition to CS PSRR. P22.Updating Figure 33.

Notice

Precaution on using ROHM Products

1. If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), aircraft/spacecraft, nuclear power controllers, 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 not designed 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 (Exclude cases where no-clean type fluxes is used. However, recommend sufficiently about the residue.); 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 Cl_2, H_2S, NH_3, SO_2, and NO_2
   [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

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