High Accuracy Current/Voltage Sensing and Protection IC

General Description

The RT9553B is designed for over-current detection and over-/under-voltage protection.

It provides users to set over-current threshold by the ILIM pin to compare that senses dropping voltage between CSP pin and CSN pin. Moreover, users can set over-/under-voltage threshold by the OVSET pin/UVSET pin to compare with the CSP voltage. The RT9553B is available in the WDFN-10L 3x3 package.

Features

- **Common Mode Input Range up to 24V**
- **VCC Operating Current : 200μA**
- **VCC Shutdown Current : 10μA (under S3/S4/S5)**
- **Programmable Over-Current Level**
- **One Shot $\overline{\text{PROCHOT}}$ Signal when OCP**
- **Pull Low RESET Signal when OVP/UVP**
- **OVP/UVP with 8% Recover Hysteresis Range**
- **Programmable OVP/UVP De-glitch Time**

Ordering Information

RT9553B □□

- Package Type
  QW : WDFN-10L 3x3 (W-Type)
- Lead Plating System
  G : Green (Halogen Free and Pb Free)

Note :

Richtek products are :

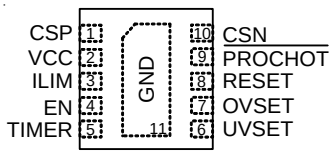
- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Applications

- Notebook

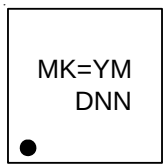
Pin Configuration

(TOP VIEW)



WDFN-10L 3x3

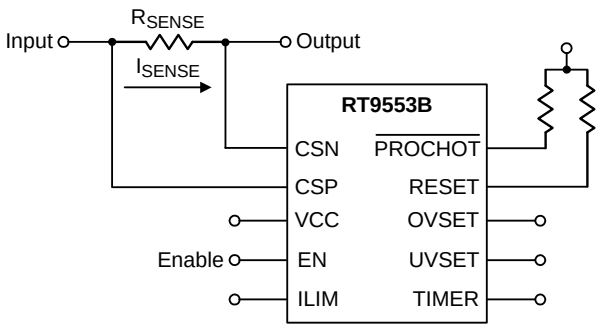
Marking Information



MK= : Product Code

YMDNN : Date Code

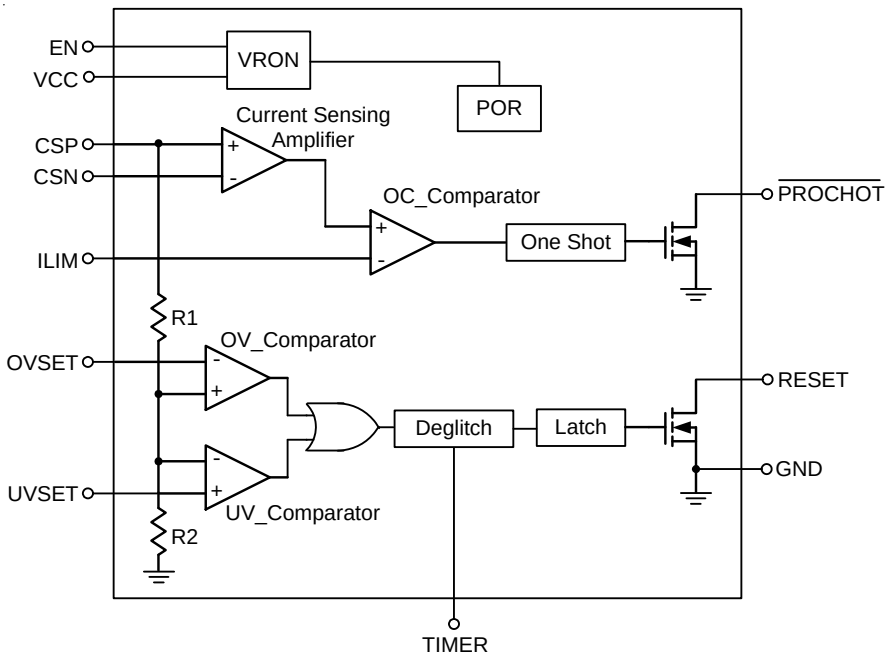
Simplified Application Circuit



Functional Pin Description

Pin No.	Pin Name	Pin Function
1	CSP	Positive current sense input.
2	VCC	Power supply input. Connect this pin to 5V and place a minimum 0.1μF decoupling capacitor. The decoupling capacitor should be placed to this pin as close as possible.
3	ILIM	Over-current trip point setting input. The setting range is from 0.4V to 2V.
4	EN	Enable control input.
5	TIMER	Deglitch time setting of OV/UV protection. Connect a resistor from this pin tied to GND to set deglitch time. Do not parallel any filter capacitor to this pin.
6	UVSET	Under-voltage trip point setting input. The setting range is from 0.55V to 3V.
7	OVSET	Over-voltage trip point setting input. The setting range is from 0.55V to 3V.
8	RESET	Open-drain output. Connect to an external resistor to pull high. When OV/UV occurs, this pin will be pulled low.
9	$\overline{\text{PROCHOT}}$	Open-drain output. Connect to an external resistor to pull high. When OC occurs, this pin will be pulled low.
10	CSN	Negative current sense input.
11 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.

Functional Block Diagram



Operation

The RT9553B consists of a current sensing amplifier, and two comparators, and it provides the following functions : over-current protection, over-voltage protection and under-voltage protection.

Over-Current Protection

With mΩ order of resistor shunts between CSP and CSN, the current sensing amplifier multiplies the voltage between CSP and CSN by 100 and compares the result with the ILIM voltage. If the output voltage of current sensing amplifier is larger than the ILIM voltage, the $\overline{\text{PROCHOT}}$ voltage is pulled low.

OVP/UVP Deglitch Time

The output signal of OV_comoparator or UV_comparator is delayed by deglitch timer. The delayed time is decided by the resistor (see spec.) connected to the TIMER pin.

Over-/Under-Voltage Protection

The OVSET voltage is set by users and it compares with the voltage which is 1/9 of CSP voltage with OV_comparator. The UVSET voltage is set by users and it also compares with the voltage which is 1/9 of CSP voltage with UV_comparator. Either the output of OV_comoparator or UV_comparator is high, the RESET voltage is pulled low.

Absolute Maximum Ratings (Note 1)

- CSP/CSN to GND ---------- –0.3V to 28V
- VCC, ILIM, EN, UVSET, OVSET, RESET, $\overline{\text{PROCHOT}}$ to GND ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  WDFN-10L 3x3 ---------- 3.27W
- Package Thermal Resistance (Note 2)
  WDFN-10L 3x3, θ_{JA} ---------- 30.5°C/W
  WDFN-10L 3x3, θ_{JC} ---------- 7.5°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV

Recommended Operating Conditions (Note 4)

- High-Side Voltage, VCSP/VCSN ---------- 5V to 24V
- Supply Voltage, VCC ---------- 4.5V to 5.5V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{CC} = 5V, T_A = 25°C, unless otherwise specified)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
CSN CSP Input							
Input Voltage Range		V_{CSP}, V_{CSN}		5	--	24	V
I_{CSN} + I_{CSP}			VCC = 5V, EN high	--	50	--	μA
			VCC = 5V, EN low	--	--	5	
VCC Input							
VCC Operating Current		I_{VCC}		--	200	--	μA
VCC Shutdown Current		I_{VCC_shd}		--	--	10	μA
VCC POR Rising Voltage		V_{IN_POR}	Rising	2.8	--	3.7	V
			Hysteresis	--	400	--	mV
Enable							
Enable Input Voltage	Logic-High	V_{IH}		0.7	--	--	V
	Logic-Low	V_{IL}		--	--	0.3	
Over-Current Protection							
System Response Time				--	50	--	μs
Open-Drain Output Duration		$T_{\overline{\text{PROCHOT}}}$		10	--	18	ms
Open-Drain Output R_{ON}		$R_{ON\_\overline{\text{PROCHOT}}}$		--	--	10	Ω

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Current Sensing Accuracy	OC_{acc}	V_{ILIM} = 0.4V to 2V	--	--	6.5	%
$\overline{PROCHOT}$ Leakage Current	$I_{leak\_\overline{PROCHOT}}$	EN Low	--	--	5	μA
ILIM Leakage Current	I_{leak_ILIM}	EN Low	--	--	5	μA
ILIM Operation Range	V_{ILIM}		0.4	--	2	V
Over-/Under-Voltage Protection						
OVP Accuracy	OVP_{acc}	V_{OVSET} = 0.55V to 3V	--	--	5	%
OVP Recover Hysteresis Range		V_{OVSET} = 0.55V to 3V	--	8	--	%
UVP Accuracy	UVP_{acc}	V_{UVSET} = 0.55V to 3V	--	--	5	%
UVP Recover Hysteresis Range		V_{UVSET} = 0.55V to 3V	--	8	--	%
Open Drain Output R_{ON}	R_{ON_RESET}	I_{Sink} = 10mA	--	--	10	Ω
RESET Leakage Current	I_{leak_RESET}	EN Low	--	--	5	μA
OVP/UVP De-glitch Time	t_{Timer}	R_{Timer} = 375k	--	15	--	μs
		R_{Timer} = 125k	--	5	--	

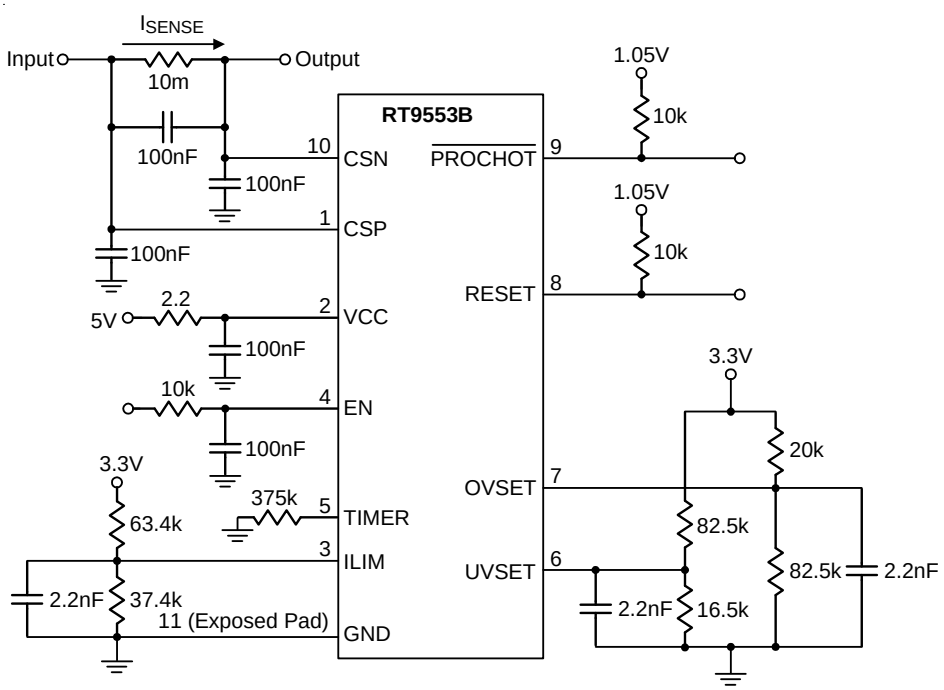
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured under natural convection (still air) at T_A = 25°C with the component mounted on a high effective-thermal-conductivity four-layer test board on a JEDEC 51-7 thermal measurement standard. θ_{JC} is measured at the exposed pad of the package.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

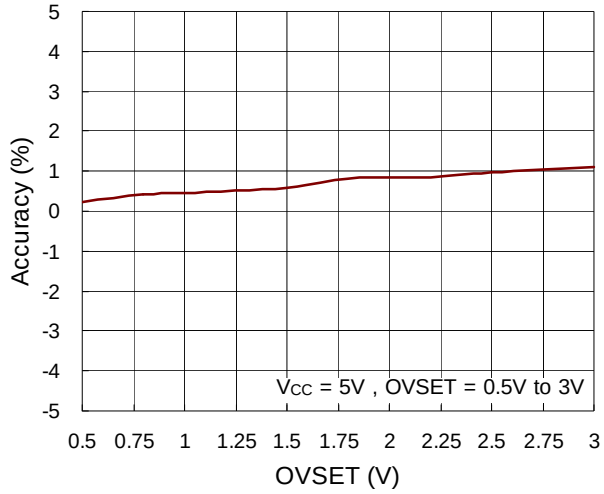
Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Application Circuit

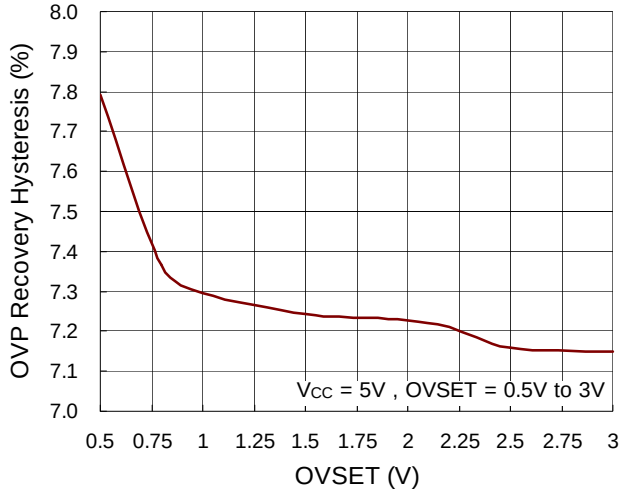


Typical Operating Characteristics

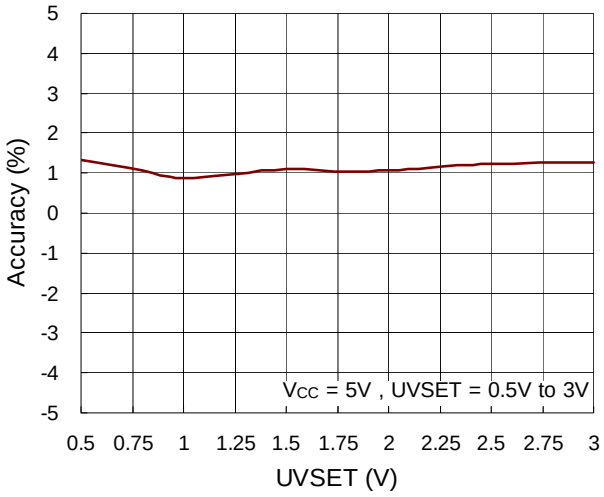
OVP Accuracy



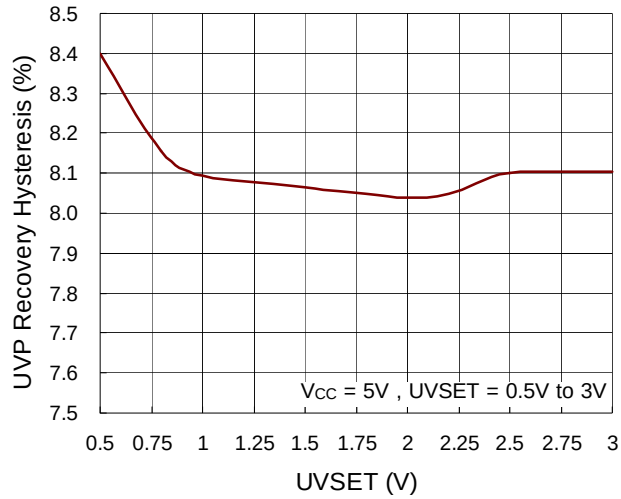
OVP Recovery Hysteresis



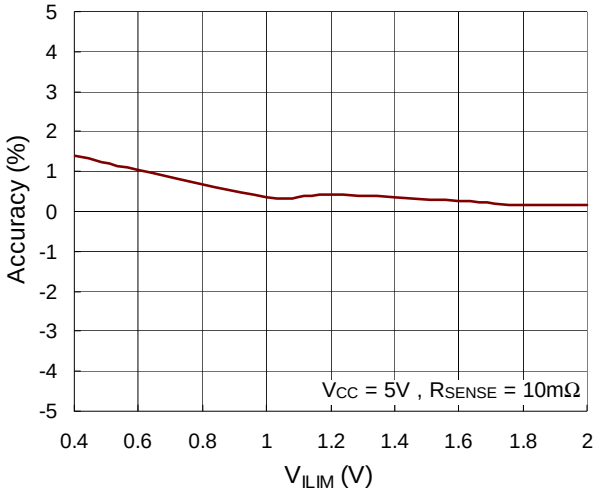
UVP Accuracy



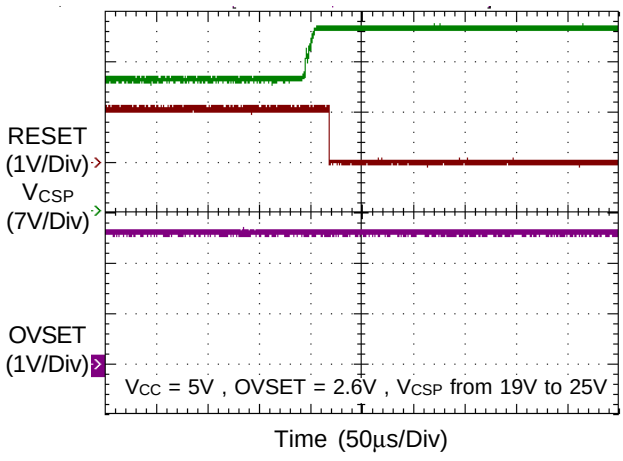
UVP Recovery Hysteresis



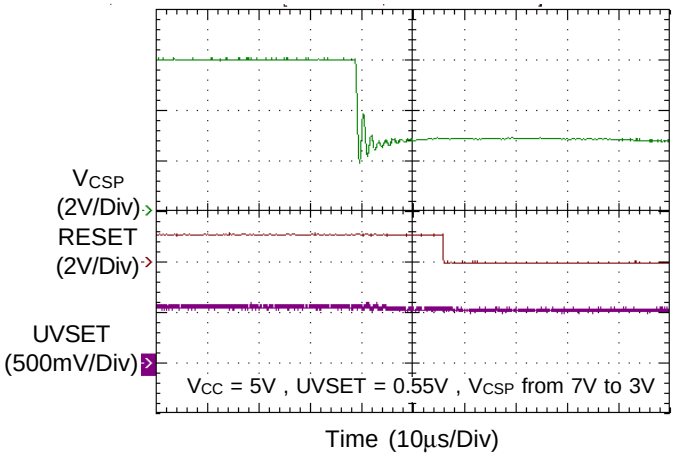
OCP Accuracy



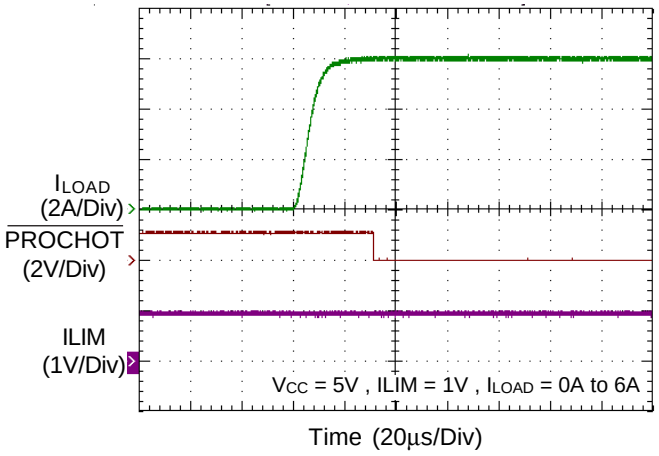
OVP vs. Reset Behavior



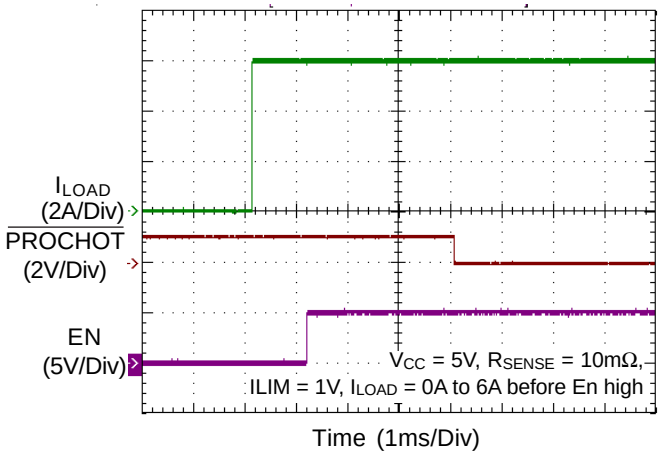
UVP vs. Reset Behavior



OCP vs. $\overline{\text{PROCHOT}}$ Behavior



Mask Time



Application Information

The RT9553B provides OVP, UVP, OCP protection functions with RESET, $\overline{\text{PROCHOT}}$ indicator to inform system. It can be operated minimize external components of switching power supply systems to achieve protection. For easily using and increasing PCB space utilization, the RT9553B is used in notebook applications.

Over-Voltage Protection (OVP)

The CSP pin voltage can be continuously monitored for over-voltage condition.

When the CSP pin voltage exceeds the setting threshold at the OVSET pin, the over-voltage protection will be triggered, and the RESET pin will be pull low after a deglitch time, the RESET is resumed when the CSP pin voltage down to 8% hysteresis.

For more details, please refer to the following information.

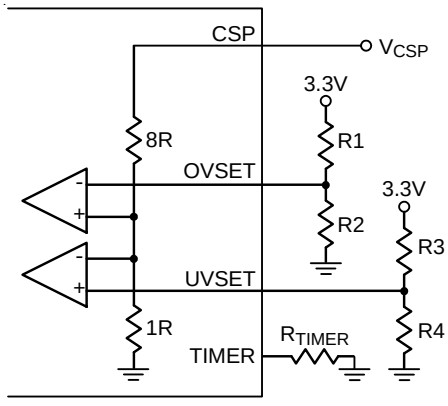
The equation of over-voltage setting threshold is shown as below :

$$V_{OVSET} = 3.3V \times \frac{R2}{R1+R2}$$

$$V_{CSP} = 3.3V \times \frac{R2}{R1+R2} \times 9$$

We suggest that the total resistance of divider network should be higher than 100kΩ.

V_{CSP} is over-voltage protection trigger point.



Fighre1.Setting Network of Over-Voltage Protection and Under-Voltage Protection

Under-Voltage Protection (UVP)

The principle of under-voltage protection is the same as over-voltage protection function. The under-voltage protection threshold is set by the UVSET pin.

When the CSP pin voltage is lower the setting threshold at the UVSET pin, the under-voltage protection will be triggered, and the RESET pin will be pull low after a deglitch time, the RESET is resumed when the CSP pin voltage up to 8% hysteresis.

Over-Current Protection (OCP)

As an industry standard, high accuracy current sense amplifier is used to monitor the input current that flows through current sense resistor. The RT9553B detects CSP-CSN differential voltage across the current sense resistor to monitor input current. The equation of over-current protection is shown as below :

$$V_{ILIM} = 3.3V \times \frac{R6}{R5+R6}$$

$$(I_{SENSE} \times R_{SENSE}) \times 100 = V_{ILIM}$$

$$I_{SENSE} = \frac{V_{ILIM}}{100 \times R_{SENSE}}$$

We suggest that the total resistance of divider network should be higher than 100kΩ.

I_{SENSE} is over-current protection trigger point.

The 100 is amplification of internal error amplifier.

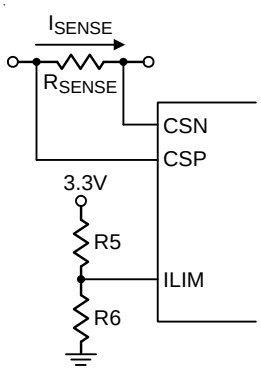


Figure 2. Setting Network of Over-Current Protection

RESET/Timer

The RESET pin is an open-drain output, and requires to be connected to a pull-up resistor. When over-voltage or under-voltage occurs, the RESET pin will be pulled low and resume to high with a hysteresis.

Users can set the deglitch time of RESET by adjusting the TIMER pin, and there are two choices of deglitch time, 15μs and 5μs. When the R_{TIMER} is 375kΩ, the deglitch time is 15μs; when the R_{TIMER} is 125kΩ, the deglitch time is 5μs. Users can choose a suitable deglitch time to avoid protection false triggering.

$\overline{\text{PROCHOT}}$

The $\overline{\text{PROCHOT}}$ pin is an open-drain output, and requires to be connected to a pull-up resistor. When over-current is detected, $\overline{\text{PROCHOT}}$ will be pulled low within 50μs for 15ms. If over-current condition keeps longer than 15ms, $\overline{\text{PROCHOT}}$ maintains low status until over-current protection is released.

Figure 3, Figure 4, Figure5 illustrates RESET and $\overline{\text{PROCHOT}}$ indicator signals.

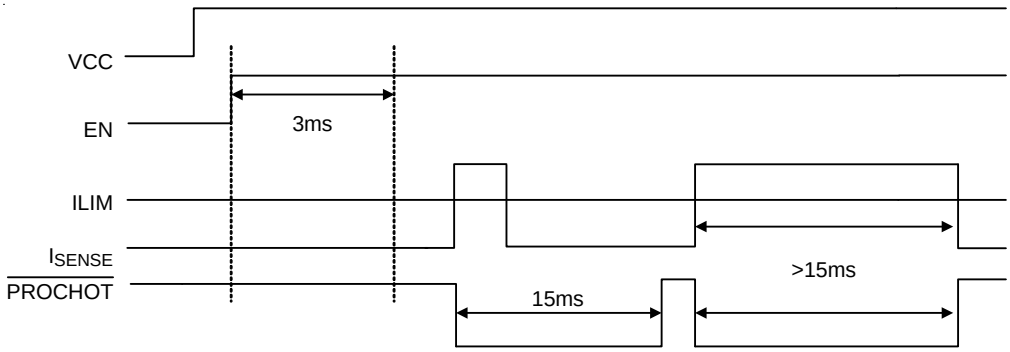


Figure 3. RESET and $\overline{\text{PROCHOT}}$ Indicator Illustration

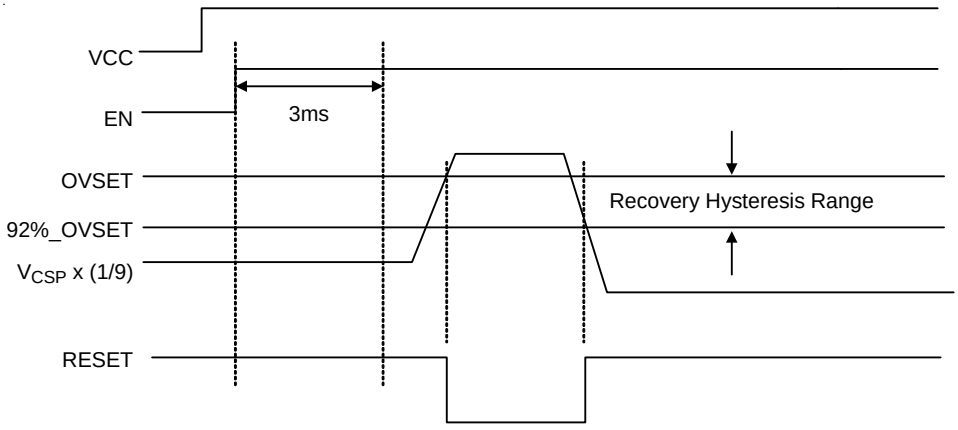


Figure 4. OVP and RESET Indicator Illustrator

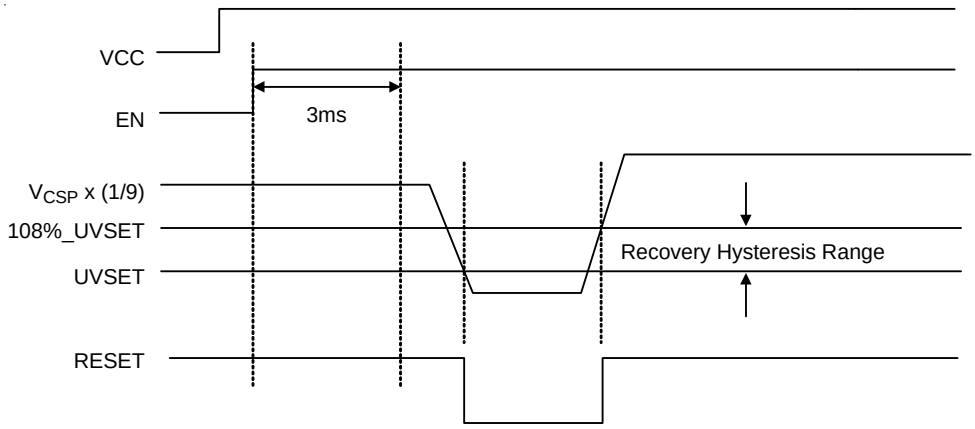


Figure 5. UVP and RESET Indicator Illustrator

Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature $T_{J(MAX)}$, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using the following formula :

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance.

For continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, θ_{JA}, is highly package dependent. For a WDFN-10L 3x3 package, the thermal resistance, θ_{JA}, is 30.5°C/W on a standard JEDEC 51-7 high effective-thermal-conductivity four-layer test board. The maximum power dissipation at T_A = 25°C can be calculated as below :

$P_{D(MAX)}$ = (125°C – 25°C) / (30.5°C/W) = 3.27W for a WDFN-10L 3x3 package.

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(MAX)}$ and the thermal resistance, θ_{JA}. The derating curves in Figure 6 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

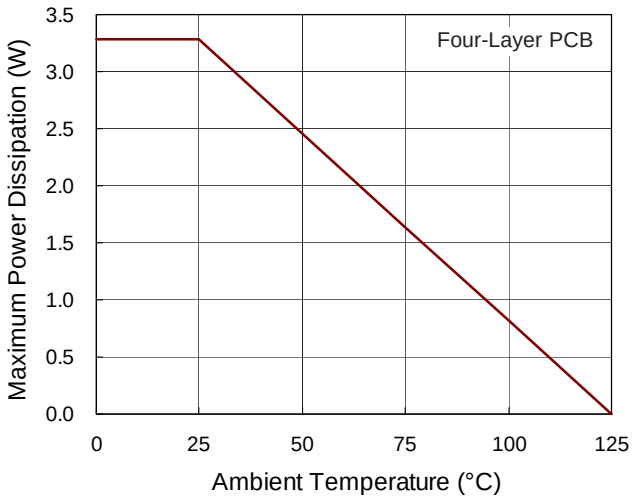


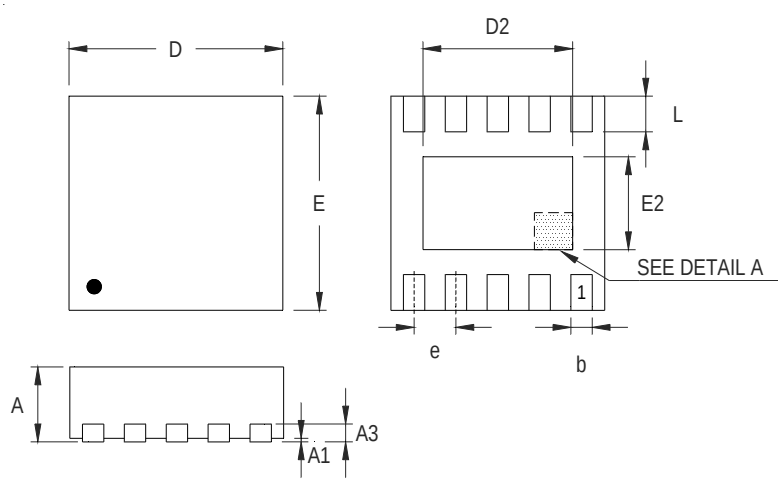
Figure 6. Derating Curve of Maximum Power Dissipation

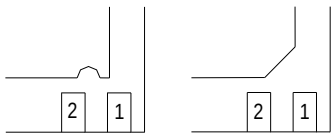
Layout Considerations

Layout is very important in the RT9553B, if designed improperly, the PCB may radiate excessive noise. Certain points must be considered before starting a layout for the RT9553B.

- Connect a RC low pass filter to VCC. The recommended BOM of RC filter is 2.2Ω and 0.1μF. Place the filter capacitor close to the IC.
- Current sense connections must always be made using Kelvin connections to ensure an accurate signal with the current limit resistor located at the device.
- All sensitive analog traces and components such as CSP, CSN, VCC, EN, $\overline{\text{PROCHOT}}$, RESET and ILIM should be placed away form high voltage switching nodes to avoid coupling.

Outline Dimension





DETAIL A

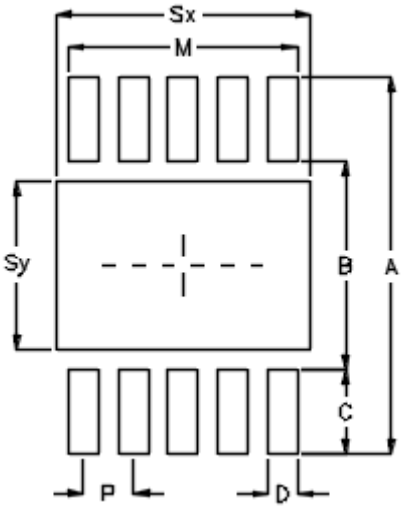
Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.180	0.300	0.007	0.012
D	2.950	3.050	0.116	0.120
D2	2.300	2.650	0.091	0.104
E	2.950	3.050	0.116	0.120
E2	1.500	1.750	0.059	0.069
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

W-Type 10L DFN 3x3 Package

Footprint Information



Package	Number of Pin	Footprint Dimension (mm)								Tolerance
		P	A	B	C	D	Sx	Sy	M	
V/W/U/X/ZDFN3*3-10	10	0.50	3.80	2.10	0.85	0.30	2.55	1.70	2.30	±0.05

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