RICHTEK®

RT6050/RT6052

High-Side Measurement Current Shunt Monitor with Comparator

1 General Description

The RT6050/RT6052 device is a high-side current-shunt monitor that contains a current-sense amplifier, a bandgap reference, and a comparator with a latching output. The RT6050/RT6052 senses voltage drops across shunts at common-mode voltages ranging from 2V to 80V. The RT6050/RT6052 series supports two output voltage scales: 20V/V, and 100V/V.

The RT6050 and RT6052 include an open-drain comparator and an internal reference providing a 0.6V threshold. External dividers set the current trip point. The comparator features a latching capability, which can be easily enabled by grounding (or leaving open) the RESET pin.

The RT6050/RT6052 is available in a small 8-pins MSOP package. The recommended junction temperature range is –40°C to 125°C, and the ambient temperature range is –40°C to 85°C.

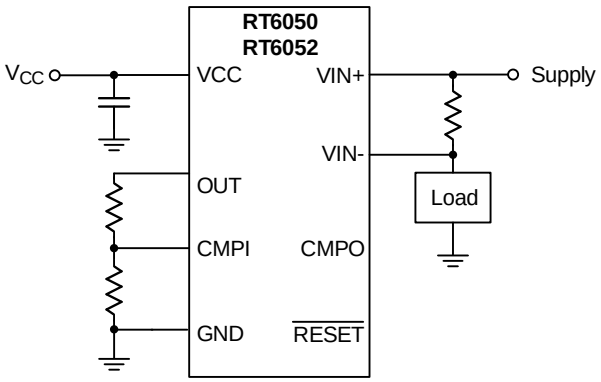
2 Features

- **High Accuracy Current Sensing**
- **3.5% Maximum Error Over-Temperature**
- **2.9V to 18V Power-Supply Range**
- **Two Gain Options Available**
  - **RT6050 = 20V/V**
  - **RT6052 = 100V/V**
- **Common-Mode Range: 2V to 80V**
- **0.6V Internal Voltage Reference**
- **Internal Open-Drain Comparator**
- **Latching Capability on Comparator**
- **Packages: MSOP-8**

3 Applications

- Server, Storage and Network Equipment
- Portable, Battery-Powered Systems
- Point of Load (POL) Power Modules
- Notebook Computers
- High End Digital TVs

4 Simplified Application Circuit



5 Ordering Information

RT605 □ □ □

Package Type(1)
F: MSOP-8

Lead Plating System
G: Richtek Green Policy Compliant(2)

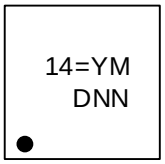
Gain Options
0: 20V/V
2: 100V/V

Note 1.

- Marked with (1) indicated: Compatible with the current requirements of IPC/JEDEC J-STD-020.
- Marked with (2) indicated: Richtek products are Richtek Green Policy compliant.

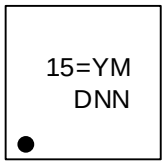
6 Marking Information

RT6050GF



14= : Product Code
YMDNN : Date Code

RT6052GF



15= : Product Code
YMDNN : Date Code

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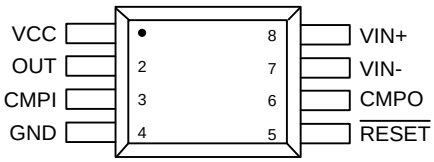
7 Pin Configuration

(TOP VIEW)

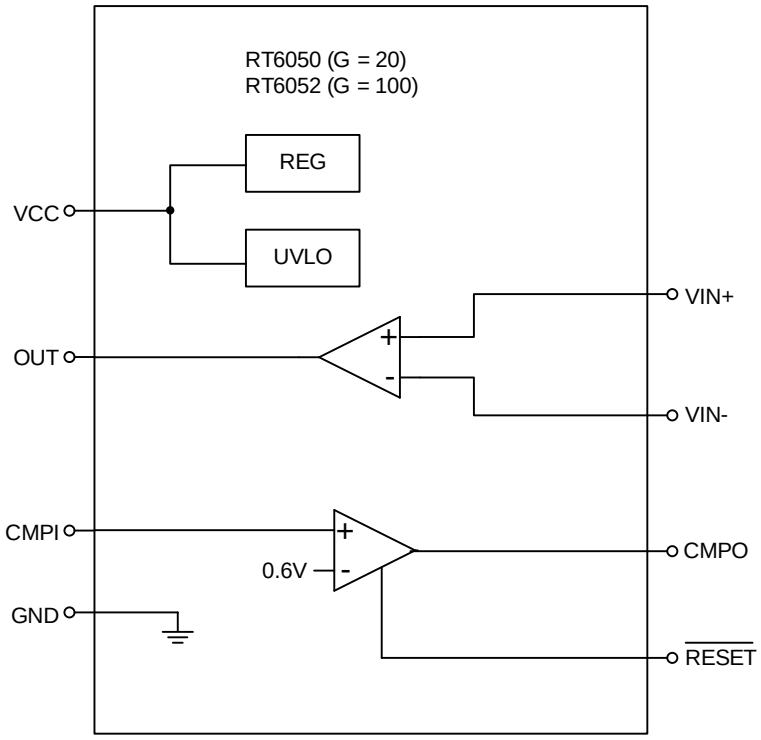


MSOP-8

8 Functional Pin Description

Pin No.	Pin Name	Pin Function
1	VCC	Power input. Connect a 0.1μF capacitor as close to the VCC pin as possible.
2	OUT	Voltage output. V_{OUT} is proportional to V_{SENSE} (VIN+ – VIN-).
3	CMPI	Comparator input. Positive input of an internal comparator. The negative terminal is connected to a 0.6V internal reference.
4	GND	Ground.
5	$\overline{\text{RESET}}$	Reset input pin. Reset the output latch of the comparator, active low.
6	CMPO	Open-drain comparator output. Connect $\overline{\text{RESET}}$ to GND to disable the latch.
7	VIN-	Negative current-sensing input. Connect load side to external sense resistor.
8	VIN+	Positive current-sensing input. Connect power side to external sense resistor.

9 Functional Block Diagram



10 Absolute Maximum Ratings

(Note 2)

- Supply Input Voltage, V_{CC} ---------- –0.3V to 19.8V
- Power Sensing PINS, VIN+, VIN- (Common Mode), V_{CM} ---------- –6V to 88V
- Power Sensing PINS, VIN+ -VIN- (Differential Mode), V_{SENSE} ---------- –6V to 18V
- Other Pins, CMPI, CMPO, OUT, $\overline{RESET}$ ---------- –0.3V to 19.8V
- Power Dissipation, P_D @ T_A = 25°C

  MSOP-8 ---------- 0.27W
- Package Thermal Resistance (Note 3)

  MSOP-8, θ_{JA} ---------- 361.6°C/W

  MSOP-8, θ_{JC} ---------- 90.4°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 4)

  HBM (Human Body Model) ---------- 4kV

Note 2. Stresses beyond those listed under “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 3. θ_{JA} is simulated 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.

Note 4. Devices are ESD sensitive. Handling precautions are recommended.

11 Recommended Operating Conditions

(Note 5)

- Supply Input Voltage, V_{CC} ---------- 2.9V to 18V
- Common mode input range, V_{CM} ---------- 2V to 80V
- Ambient Temperature Range ---------- –40°C to 85°C
- Junction Temperature Range ---------- –40°C to 125°C

Note 5. The device is not guaranteed to function outside its operating conditions.

12 Electrical Characteristics

(V_{CC} = 12V, V_{CM} = 12V, T_A = 25°C, unless otherwise specified)

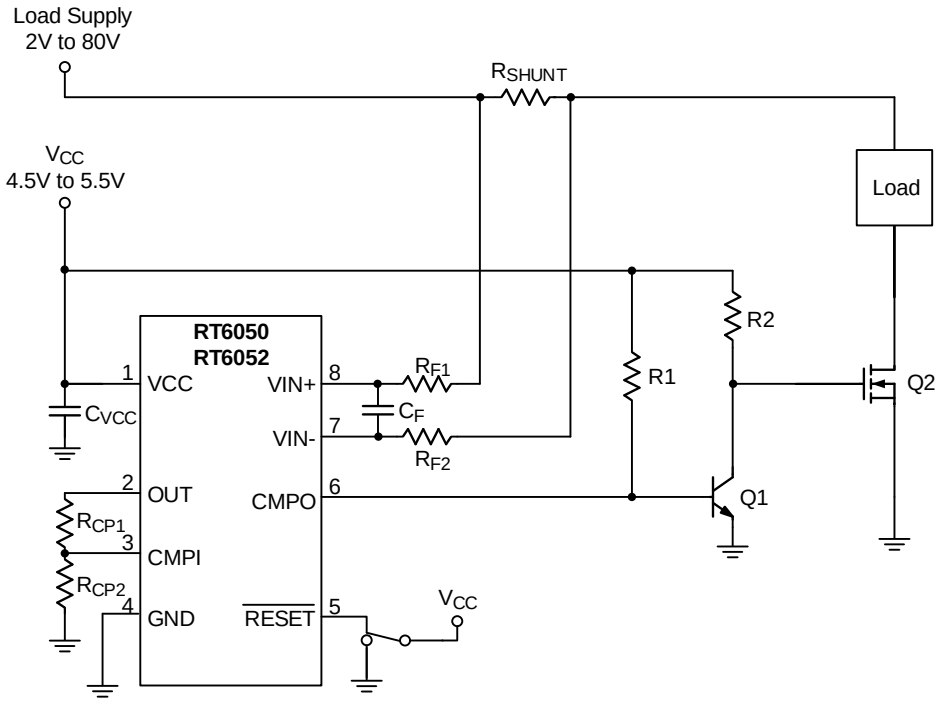
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Supply						
Operating Power Supply	V_{CC}		2.9	--	18	V
Quiescent Current	I_Q	V_{OUT} = 2V, T_A = –40°C to 125°C	--	--	1200	μA
		V_{SENSE} = 0mV, T_A = –40°C to 125°C	--	--	500	
POR Rising Threshold	V_{POR_R}		2.7	2.75	2.85	V

Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
POR Falling Threshold	V_{POR_F}			--	2.55	--	V
Current Sense							
Full Scale Sense Input Voltage				--	0.15	--	V
Common Mode Input Range	V_{CM}			2	--	80	V
Common Mode Rejection (Note 6)	CMR	V_{IN+} = 2V to 80V		80	100	--	dB
Offset Voltage, RTI	V_{OS}	T_A = 25°C		--	±0.5	±2.5	mV
PSR of Offset Voltage, RTI	PSR	V_{OUT} = 2V, V_{IN+} = 18V, V_{CC} = 2.9V T_A = –40°C to 125°C		--	2.5	100	µV/V
Input Bias Current	I_B	VIN- pin		--	13	--	µA
Gain	G	RT6050		--	20	--	V/V
		RT6052		--	100	--	V/V
Gain Error	GE%	V_{SENSE} = 20mV to 100mV		--	±0.2	±1	%
Total Output Error	ΔV_{OUT}%	V_{SENSE} = 120mV, V_{CC} = 16V		--	±0.75	±2.2	%
Nonlinearity Error (Note 6)	NLIN%	V_{SENSE} = 20mV to 100mV		--	0.1	--	%
Maximum Capacitive Load (Note 6)		No sustained oscillation		--	10	--	nF
Output Voltage Range H		V_{IN-} =11V, V_{IN+}= 12V T_A = –40°C to 125°C		--	V_{CC} –0.15	--	V
Output Voltage Range L		V_{IN-} = 0V, V_{IN+} = –0.5V T_A = –40°C to 125°C	RT6050	--	4	100	mV
			RT6052	--	4	350	
Bandwidth (Note 6)	BW	GAIN = 20, C_{LOAD} = 5pF, unity gain		--	160	--	kHz
		GAIN = 100, C_{LOAD} = 5pF, unity gain		--	36	--	kHz
Phase Margin (Note 6)	P.M	C_{LOAD} < 10nF		--	40	--	°
Slew Rate	SR	RT6050		--	0.5	--	V/µs
		RT6052		--	1.5	--	
Settling Time	T_{ST}	V_{SENSE} = 10mV to 100mV 10%~90% V_{OUT} C_{LOAD} = 5pF	RT6050	--	2	--	µs
			RT6052	--	6	--	
Noise Density, RTI (Note 6)		Frequency = 10k		--	40	--	nV/√Hz
Comparator							
Threshold	V_{TH}	T_A = –40°C to 125°C		585	600	615	mV
Hysteresis	V_{HYS}	T_A = –40°C to 85°C		--	–8	--	mV
Input Bias Current	I_{B_CM}	T_A = 25°C		--	0.005	10	nA
		T_A = –40°C to 125°C		--	--	15	nA
Maximum Input				--	V_{CC} –1.5	--	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Output Open-Drain						
Voltage Gain (Note 6)	CMP_{GAIN}		--	200	--	V/mV
Leakage Current	I_{LEAK}		--	0.0001	1	μA
Dropout Voltage	V_{DROP}	I_{LOAD} = 2.35mA	--	125	220	mV
Response Time	T_{RS}	R_L to 5V, C_L = 15pF 100mV input step with 10mV overdrive	--	1.3	--	μs
$\overline{\text{RESET}}$						
$\overline{\text{RESET}}$ Pin Threshold	V_{RST_H}	High Level	1	--	--	V
	V_{RST_L}	Low Level	--	--	0.4	V
$\overline{\text{RESET}}$ Input Impedance			--	2	--	MΩ
$\overline{\text{RESET}}$ Minimum Pulse Width			--	1.5	--	μs
$\overline{\text{RESET}}$ Propagation Delay	t_{DLY_PD}		--	1.6	--	μs

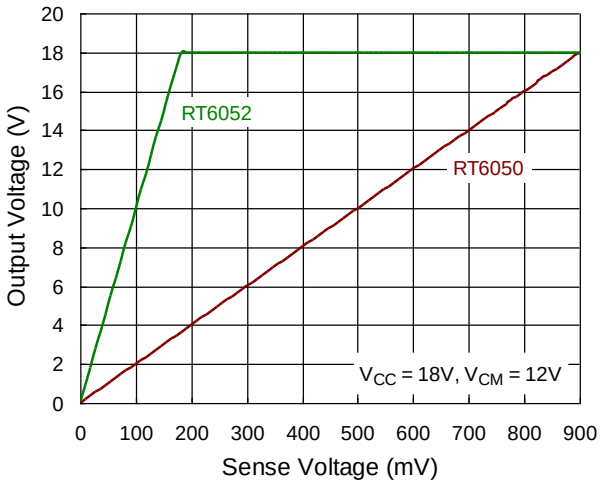
Note 6. Specifications are guaranteed by design, not production tested.

13 Typical Application Circuit

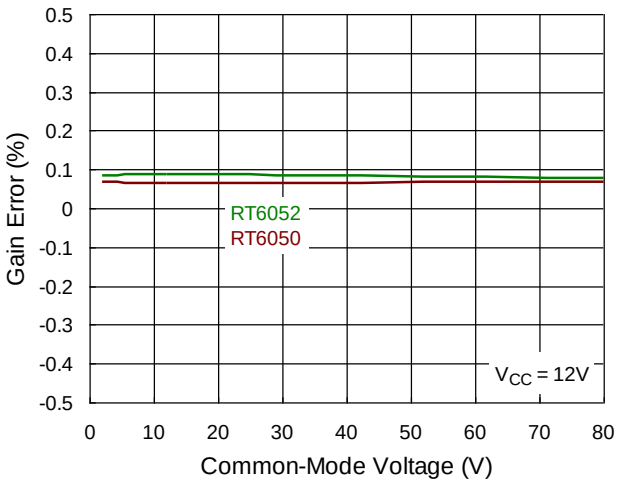


14 Typical Operating Characteristics

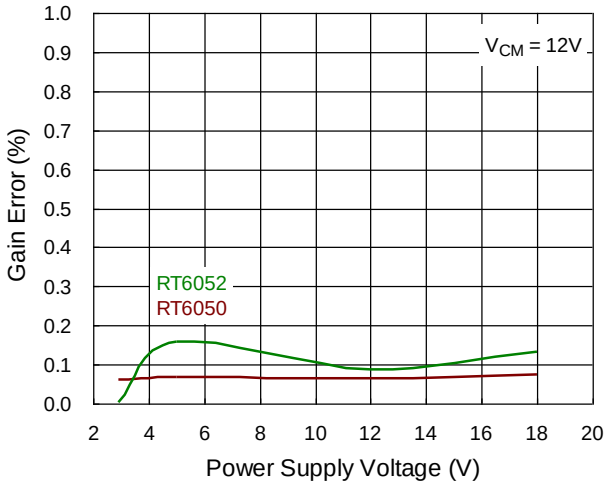
Output Voltage vs. Sense Voltage



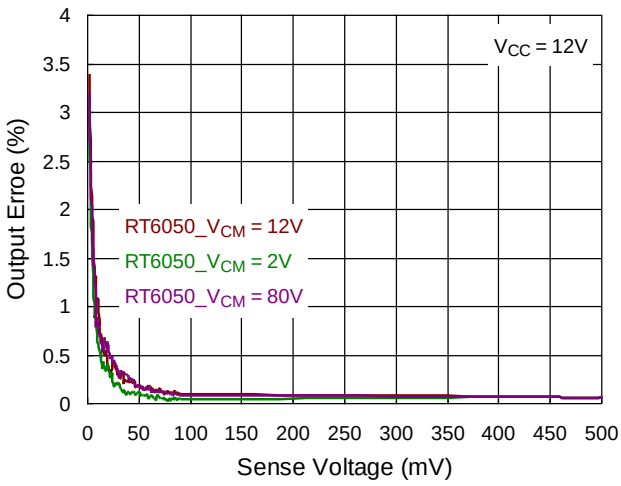
Gain Error vs. Common-Mode Voltage



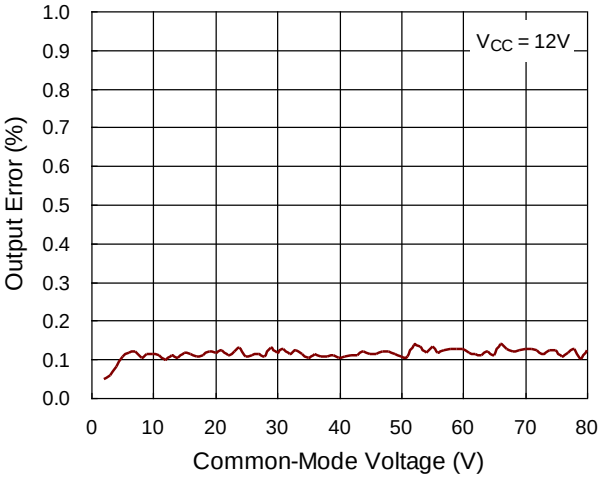
Gain Error vs. Power Supply Voltage



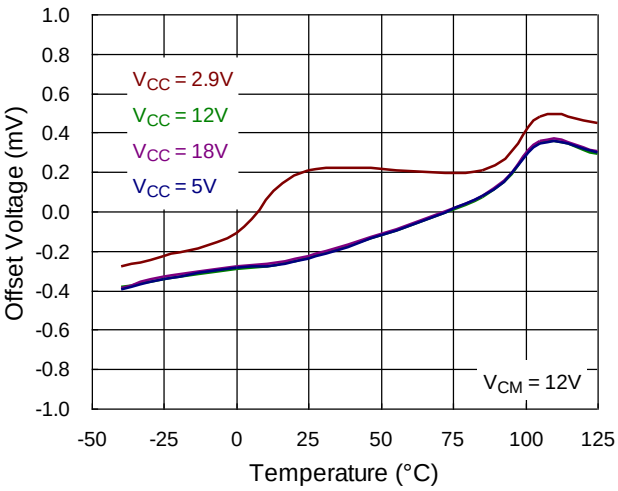
Output Error vs. Sense Voltage



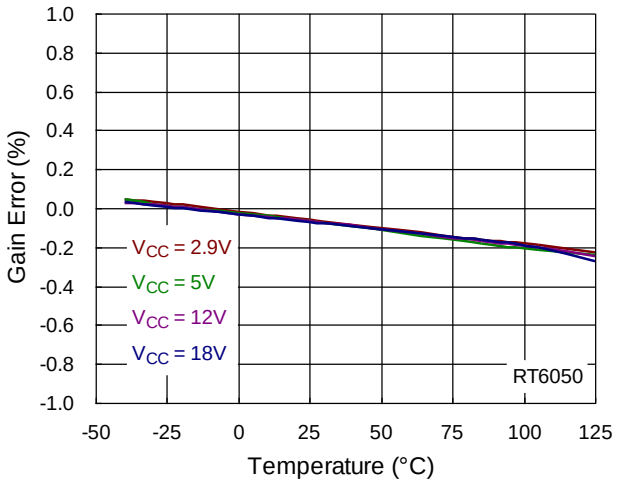
Output Error vs. Common-Mode Voltage



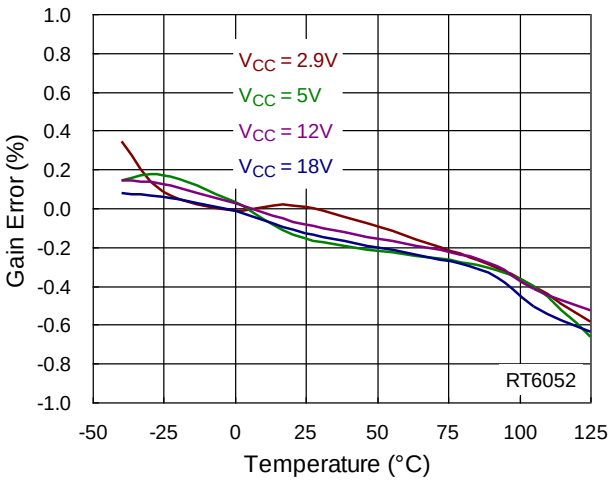
Offset Voltage vs. Temperature



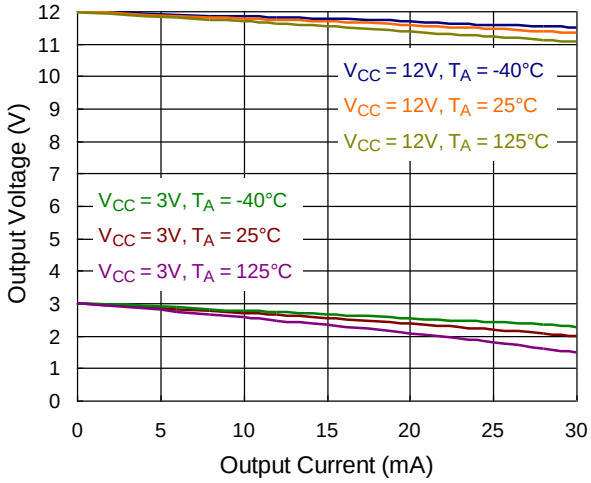
Gain Error vs. Temperature



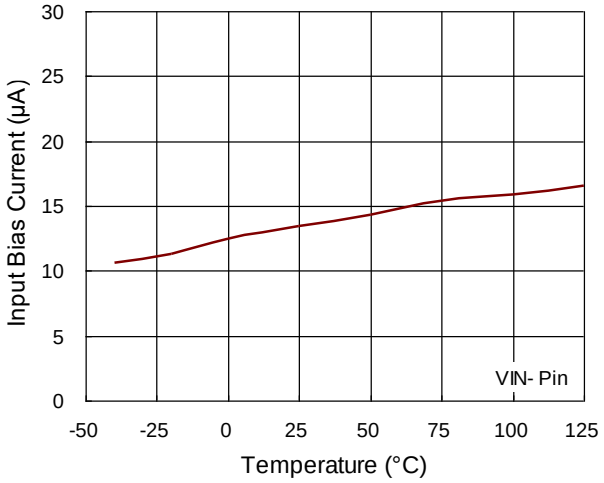
Gain Error vs. Temperature



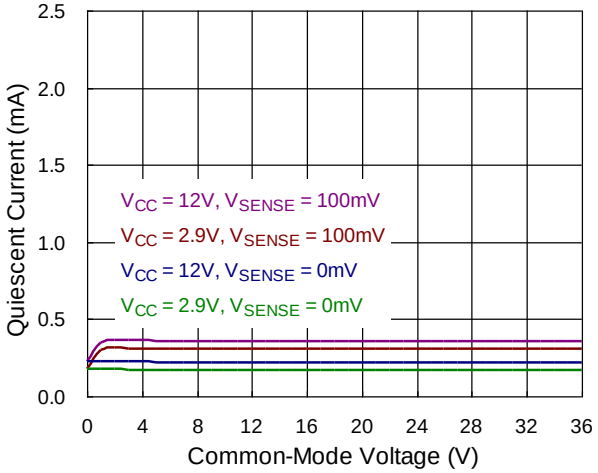
Output Voltage vs. Output Current



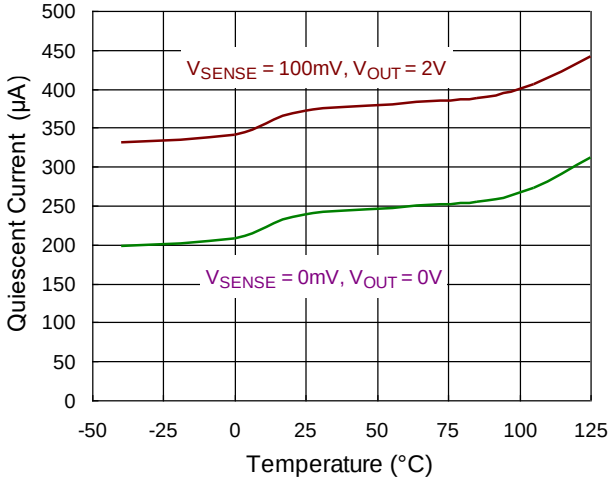
Input Bias Current vs. Temperature

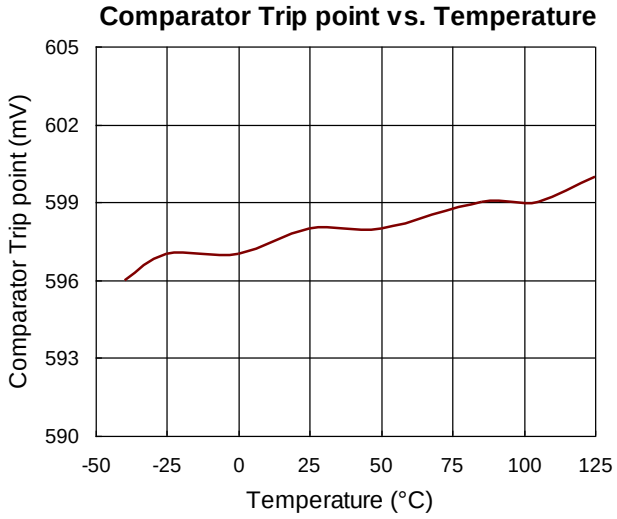


Quiescent Current vs. Common-Mode Voltage



Quiescent Current vs. Temperature





15 Operation

The RT6050/RT6052 devices are high-side, unidirectional, current-shunt monitors with a high common-mode input range from 2V to 80V. The devices are available with two output voltage scales: 20V/V and 100V/V, with up to 500kHz bandwidth. The overcurrent protection is also available by internal comparator; when the voltage at CMPI pin is higher than internal reference 0.6V, the CMPO pulls high to indicate overcurrent situation. Connect a divider from the OUT pin to CMPI pin to set the overcurrent trip point, the devices provide an open-drain comparator with a latching function that allows the output signal of comparator to be latched or non-latched by $\overline{\text{RESET}}$ pin setting.

15.1 Comparator and Reset

The RT6050/RT6052 devices incorporate an open-drain comparator. This comparator typically has 1.3μs (typical) response time. The output of the comparator latches and is reset through the $\overline{\text{RESET}}$ pin. From Figure 1, the control logic is described in 3 stages.

Stage1. V_{CMPO} goes high after V_{CMPI} increases and eventually exceeds 0.6V.

Stage2. When V_{RESET} is high, V_{CMPO} is kept high even if V_{CMPI} decreases and falls below 0.6V; when the V_{RESET} goes low, V_{CMPO} also goes low.

Stage3. When V_{RESET} is low, V_{CMPO} goes high/low depending on V_{CMPI} higher/lower than 0.6V.

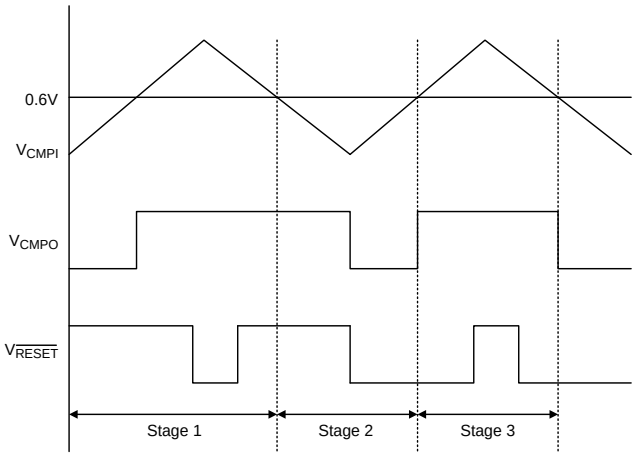
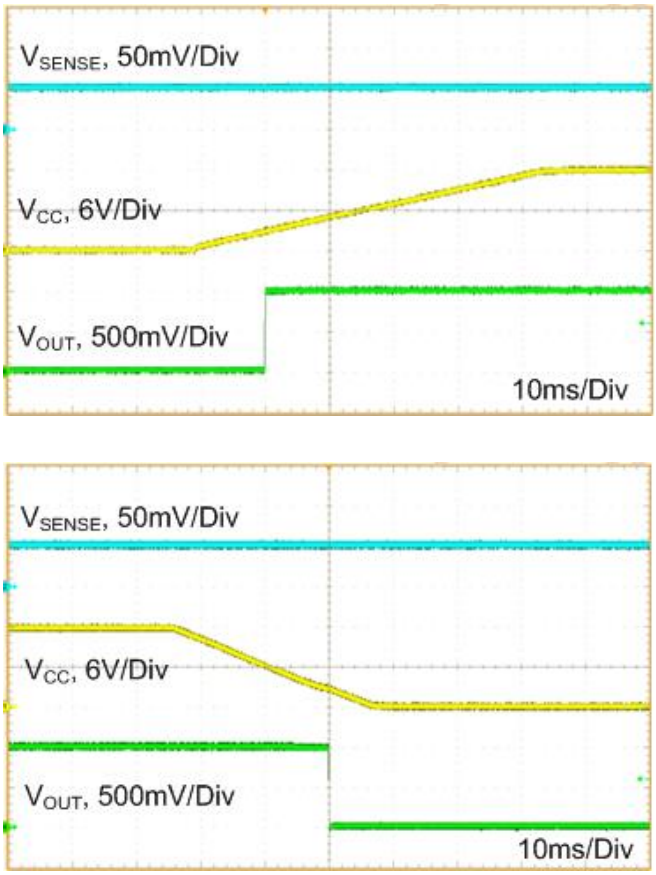


Figure 1. Comparator Latching and Reset Logic

15.2 Power On

The RT6050/RT6052 implements a power-on reset (POR) function to prevent operation without fully turning on the internal control circuit. When VCC increases and eventually becomes higher than the POR rising threshold (2.75V, typical), the device starts outputting voltage; in contrast, when VCC is lower than the POR falling threshold (2.55V, typical), the device stops outputting voltage.



15.3 Gain Error and Input Offset Voltage

Using a two-step method to characterize gain error and offset voltage, the gain can first be obtained by measuring the output voltage at different sense voltages.

$$G = \frac{V_{OUT1} - V_{OUT2}}{100mV\text{-}20mV}$$

Where

- V_{OUT1} = output voltage with V_{SENSE} = 100mV
- V_{OUT2} = output voltage with V_{SENSE} = 20 V

Then the offset voltage is measured at V_{SENSE} = 100mV, and is referred to the input (RTI) of the current shunt monitor, as shown in Electrical Characteristics: Current-Shunt Monitor.

$$VRTI\ (\text{Referred-To-Input}) = \left(\frac{V_{OUT1}}{G}\right) - 100mV$$

16 Application Information

(Note 7)

16.1 Selecting the Shunt Resistor

The selected value for the shunt resistor, R_{SHUNT}, depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High values of R_{SHUNT} provide better accuracy at lower currents by minimizing the effects of offset, while low values of R_{SHUNT} minimize voltage loss in the supply line. For best performance, select R_{SHUNT} to provide approximately 50mV to 100mV of sense voltage for the full-scale current in each application. Maximum input voltage for accurate measurements is 500mV, but output voltage is limited by supply voltage V_{CC}.

16.2 Input Filtering

In some applications, the current being measured may be inherently noisy. In the case of a noisy signal, filtering after the output of the current sense amplifier is often simpler; however, this location negates the advantage of the low output impedance of the internal buffer.

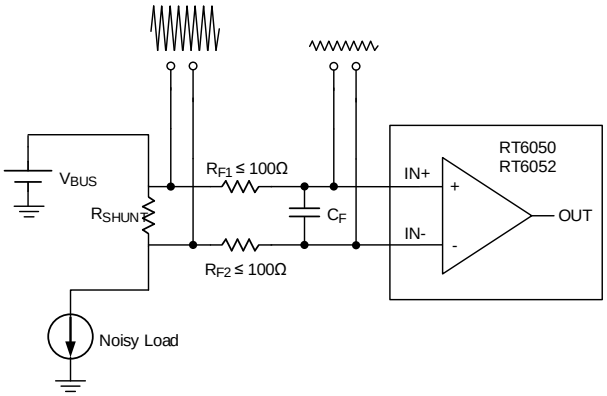


Figure 2. Input Filter

Other applications may require filtering at the input of the current sense amplifier. Figure 2 shows the recommended schematic for input filtering.

Input filtering is complicated by the fact that the mismatch between added resistance of the filter resistors and the associated resistance can adversely affect gain, CMR, and offset voltage, V_{OS}. The effect on V_{OS} is partly due to input bias currents as well. As a result, the value of the input resistors should be limited to 100Ω or less.

16.3 Total Error Analysis

To optimize the design, the first is to analyze each error contributed; the main influences of sense voltage errors can be identified as follows:

- The tolerance of the shunt resistor (R_{SHUNT})
- Sense offset voltage, V_{OS}. When the sense voltage is low, particularly at low load currents and small shunt resistance, the error is dominated by the input offset error.
- Gain Error, GE%
- Power supply rejection (PSR) of the offset voltage, PSR
- Common mode rejection, CMR
- The offset voltage caused by input bias current
- Nonlinearity Error, NLIN%

16.4 Maximum Output Error Estimation

Here is an example. The system bus voltage V_{CM_SYS} connects to VIN+ = 18V, system supply voltage V_{CC_SYS} = 5V, shunt resistor accuracy is 1%, 10mΩ 1.5W, the load current is 10A. To set the design goals, the maximum output voltage errors are calculated in the following sections.

16.5 Input Offset Voltage Error

The rate of offset error in the total error can be estimated directly from the specification table. The input offset voltage is 2.5mV at T_A = 25°C. The error due to offset can be obtained using the following equation:

$$V_{OS\_err} = \frac{V_{OS(max)}}{V_{SENSE}} \times 100\% = \frac{2.5mV}{10m\Omega \times 10A} \times 100\% = 2.5\%$$

16.6 Shunt Voltage Gain Error

From the Electrical Characteristics, the maximum gain error is 1%

16.7 PSR Error

The PSR error estimates the error caused by different supply voltages. The RT6050/RT6052 device specification provides the specified power supply voltage for the input offset voltage specification as V_{CC_DS} = 2.9V. When the system supply voltage is not exactly 2.9V, it may result in an additional error. The RT6050/RT6052 device specifies the maximum PSR as 100μV/V. Calculate the PSR error using the equation below:

$$PSR\_err = \frac{\left|V_{CC\_DS} - V_{CC\_SYS}\right| \times PSR}{V_{SENSE}} \times 100\%$$

$$= \frac{\left|2.9 - 5\right| \times 100 \frac{\mu V}{V}}{10m\Omega \times 10A} \times 100\% = 0.21\%$$

16.8 CMR Error

The CMR error means the input offset error is influenced by variations of the common-mode voltage. In real conditions, calculate the maximum input offset by determining the actual common-mode voltage as applied to the RT6050/RT6052. According to the RT6050/RT6052 device specification, the minimum common-mode rejection ratio is given as 80dB (100μV/V). The offset voltage in the datasheet is specified with a common-mode voltage, V_{CM_DS}, of 12V. To calculate the actual common-mode error at the system bus voltage:

$$80dB = \frac{1}{10^{\left(\frac{80dB}{20}\right)}} \times 10^6 \times \frac{\mu V}{V} = 100 \frac{\mu V}{V}$$

$$CMR\_err = \frac{\left|V_{CM\_DS} - V_{CM\_SYS}\right| \times CMR}{V_{SENSE}} \times 100\%$$

$$= \frac{\left|12 - 18\right| \times 100 \frac{\mu V}{V}}{10m\Omega \times 10A} \times 100\% = 0.6\%$$

16.9 Input Bias Current Error

The input bias current flowing through the shunt resistor causes an additional offset; this error is calculated with respect to the ideal voltage across the sense voltage

$$I_{B\_err} = \frac{I_B \times R_{SHUNT}}{V_{SENSE}} \times 100\% = \frac{13\mu A \times 10m\Omega}{10m\Omega \times 10A} \times 100\%$$

$$= 0.00013\%$$

16.10 Nonlinearity Error

The nonlinearity error, as shown in Figure 3, is the difference between the actual gain and the ideal value. In ideal cases, the voltage gain is constant over the full sense range, but in real applications, the voltage gain is not exactly constant. The nonlinearity gain may cause additional errors. In the specification, the RT6050/RT6052 gives the nonlinearity error as 0.1% over a sense voltage range from 20mV to 100mV.

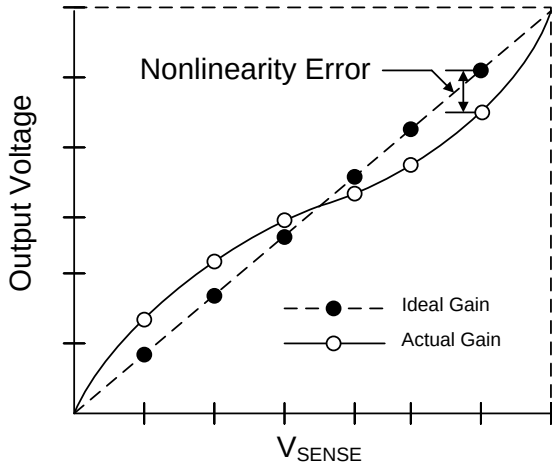


Figure 3. Nonlinearity Error

16.11 Total Error

Use the following equation to calculate the worst case of total error:

$$Total\_err = \sqrt{(GE\%)^2 + (R\%)^2 + (V_{OS\_err})^2 + (PSR\_err)^2 + (CMR\_err)^2 + (I_{B\_err})^2 + (NLIN\%)^2}$$

$$= \sqrt{(1\%)^2 + (1\%)^2 + (2.5\%)^2 + (0.21\%)^2 + (0.6\%)^2 + (0.0013\%)^2 + (0.1\%)^2}$$

$$= 2.94\%$$

16.12 Layout Guidelines

- A Kelvin sense arrangement is required for best performance. Connect the input pins (VIN+ and VIN-) to the sensing resistor using a 4-wire connection.
- PCB trace resistance from the sense resistor to the VIN+ and VIN- pins can affect the power measurement accuracy. Place the sense resistors as close as possible to the RT6050/RT6052 and do not use minimum width PCB traces.
- Place the power-supply bypass capacitor 0.1μF as close as possible to the supply and ground pins.

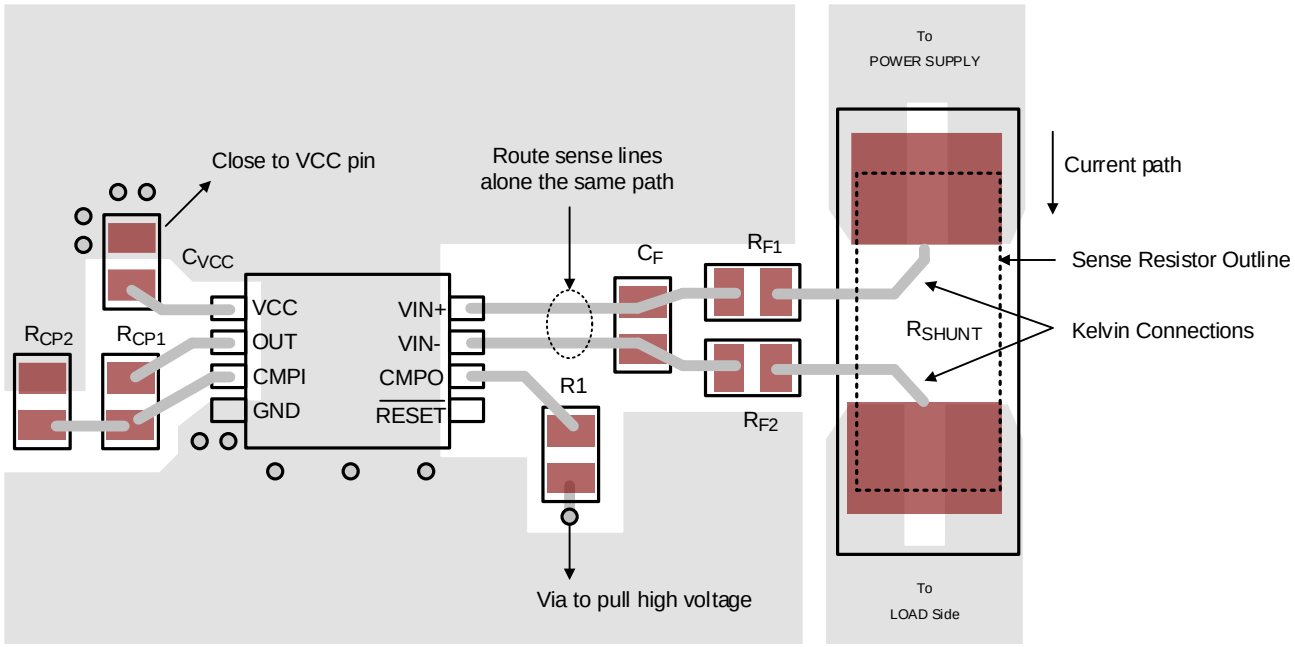
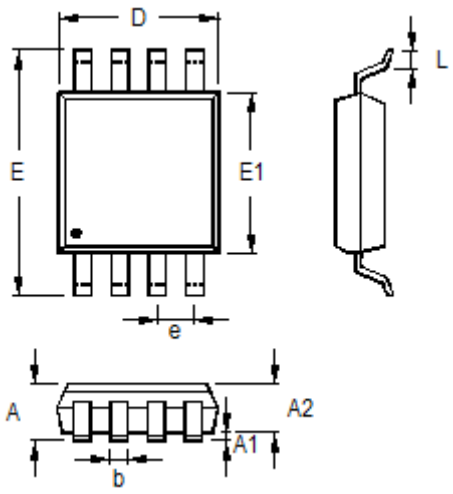


Figure 4. PCB Layout Guide

Note 7. The information provided in this section is for reference only. The customer is solely responsible for the designing, validating, and testing your product incorporating Richtek's product and ensure such product meets applicable standards and any safety, security, or other requirements.

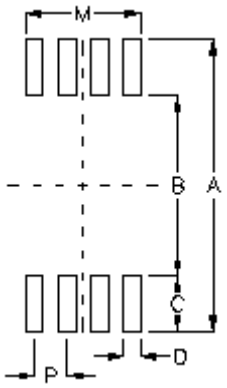
17 Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.810	1.100	0.032	0.043
A1	0.000	0.150	0.000	0.006
A2	0.750	0.950	0.030	0.037
b	0.220	0.380	0.009	0.015
D	2.900	3.100	0.114	0.122
e	0.650		0.026	
E	4.800	5.000	0.189	0.197
E1	2.900	3.100	0.114	0.122
L	0.400	0.800	0.016	0.031

8-Lead MSOP Plastic Package

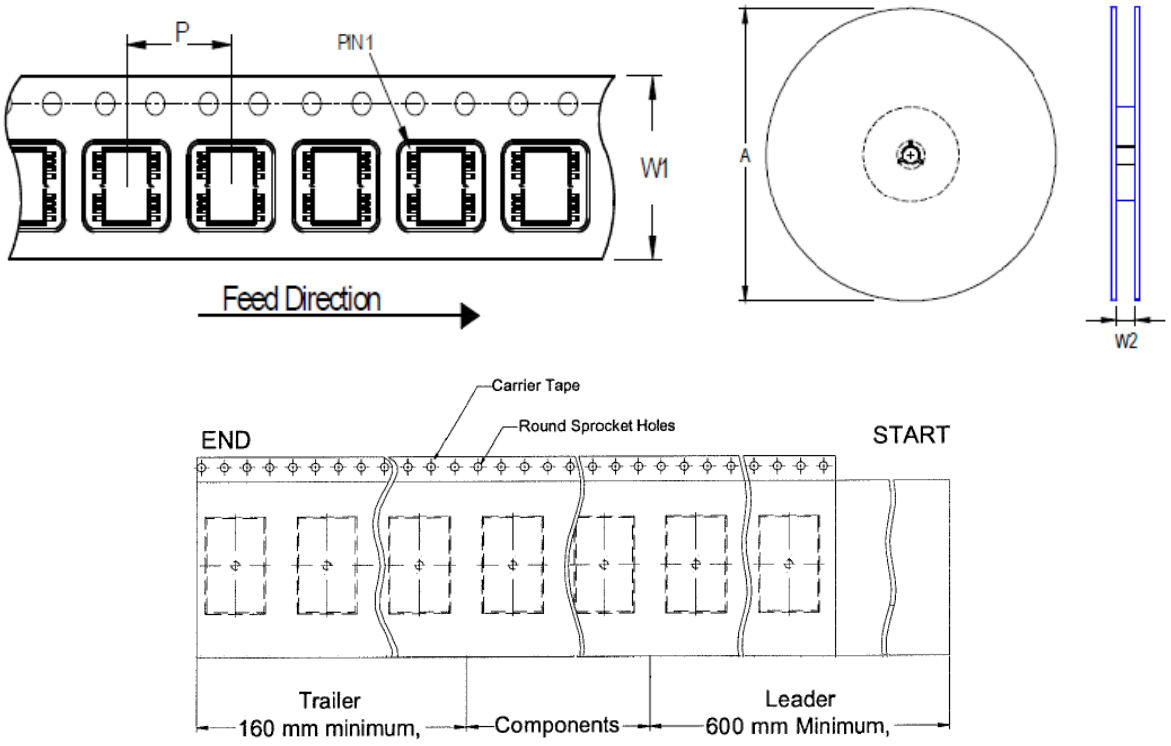
18 Footprint Information



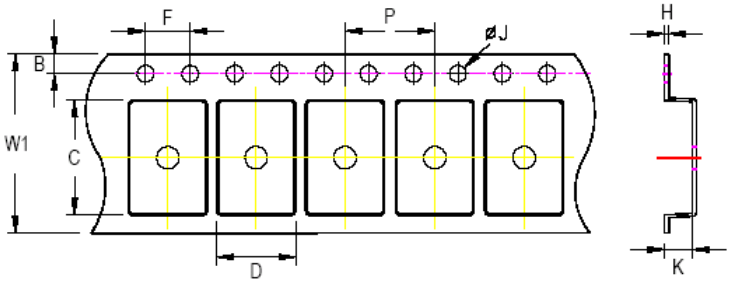
Package	Number of Pin	Footprint Dimension (mm)						Tolerance
		P	A	B	C	D	M	
MSOP-8	8	0.65	5.80	3.60	1.10	0.35	2.30	±0.10

19 Packing Information

19.1 Tape and Reel Data



Package Type	Tape Size (W1) (mm)	Pocket Pitch (P) (mm)	Reel Size (A)		Units per Reel	Trailer (mm)	Leader (mm)	Reel Width (W2) Min./Max. (mm)
			(mm)	(in)				
MSOP-8	12	8	330	13	2,500	160	600	12.4/14.4



C, D and K are determined by component size. The clearance between the components and the cavity is as follows:

- For 12mm carrier tape: 1.0mm max.

Tape Size	W1	P		B		F		ØJ		K		H
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Max.
12mm	12.3mm	7.9mm	8.1mm	1.65mm	1.85mm	3.9mm	4.1mm	1.5mm	1.6mm	1.5mm	1.7mm	0.6mm

19.2 Tape and Reel Packing

Step	Photo/Description	Step	Photo/Description
1	 Reel 13”	4	 1 reel per inner box **Box G**
2	 HIC & Desiccant (2 Unit) inside	5	 6 inner boxes per outer box
3	 Caution label is on backside of Al bag	6	 Outer box **Carton A**

Container / Package	Reel		Box			Carton		
	Size	Units	Item	Reels	Units	Item	Boxes	Units
MSOP-8	13”	2,500	Box G	1	2,500	Carton A	6	15,000

19.3 Packing Material Anti-ESD Property

Surface Resistance	Aluminum Bag	Reel	Cover tape	Carrier tape	Tube	Protection Band
Ω/cm^2	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**

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20 Datasheet Revision History

Version	Date	Description	Item
00	2022/2/16	Final	
01	2022/11/23	Modify (add RT6050)	*General Description on page 1* *Features on page 1* *Applications on page 1* *Simplified Application Circuit on page 1* *Ordering Information on page 2* *Marking Information on page 2* *Functional Block Diagram on page 4* *Operation on page 4* *Electrical Characteristics on page 6* *Typical Application Circuit on page 9* *Typical Operating Characteristics on page 10* *Application Information on page 13*
02	2025/1/22	Modify	*General Description on page 1* *Ordering Information on page 2* *Functional Block Diagram on page 4* *Application Information on page 14, 17* *Packing Information on page 20 to 22*