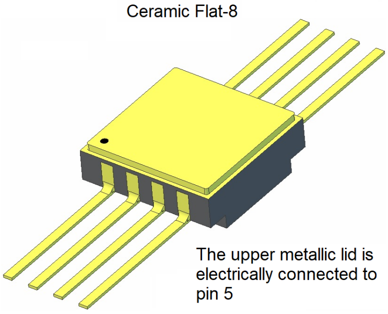
RHF350A

Datasheet

Rad-hard 550 MHz low noise operational amplifier



Features

- Bandwidth: 550 MHz (unity gain)
- Quiescent current 4 mA
- Slew rate: 940 V/µs
- Input noise: 1.5 nV/√ Hz
- Distortion: SFDR = -66 dBc (10 MHz, 1 V_{pp})
- 2.8 V_{pp} minimum output swing on a 100 Ω load for a 5 V supply
- 5 V power supply
- ELDRS free up to 300 krad
- SEL immune at 110 MeV.cm^2/mg
- SET characterized
- SMD pin: 5962F07232
- Mass: 0.45 g

Applications

- Space data acquisition systems
- Aerospace instrumentation
- Harsh environments
- ADC drivers

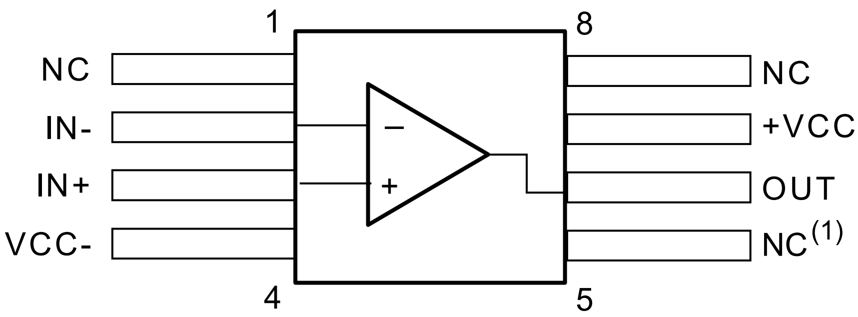
Product status link
RHF350A

Description

The RHF350A device is a current feedback, single operational amplifier that uses very high-speed complementary technology to provide a bandwidth of up to 550 MHz while drawing only 4 mA of quiescent current. With a slew rate of 940 V/µs and an output stage optimized for driving a standard 100 Ω load, this circuit is highly suitable for applications where speed and power-saving are the main requirements. The RHF350A is mounted in a Flat-8 hermetic package.

1 Pin description

Figure 1. **Pin connections of ceramic Flat-8 (top view)**



1. The upper metallic lid is electrically connected to pin 5

2 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings

Symbol	Parameter		Value	Unit
V_{CC}	Supply voltage (voltage difference between $-V_{CC}$ and V_{CC} pins) (1)		6	V
V_{id}	Differential input voltage (2)		±0.5	
V_{in}	Input voltage range (3)		±2.5	
T_{stg}	Storage temperature		-65 to 150	°C
T_j	Maximum junction temperature		150	
R_{thja}	Thermal resistance junction to ambient area		150	°C/W
R_{thjc}	Thermal resistance junction to case		22	
P_{max}	Maximum power dissipation (at T_{amb} = 25 °C) for T_j = 150 °C (4)		830	mW
ESD	HBM: human body model (5)	Pins 1, 4, 5, 6, 7 and 8	2	kV
		Pins 2 and 3	0.5	
	MM: machine model (6)	Pins 1, 4, 5, 6, 7 and 8	200	V
		Pins 2 and 3	60	
	CDM: charged device model (7)	Pins 1, 4, 5, 6, 7 and 8	1.5	kV
		Pins 2 and 3	1.5	
	Latch-up immunity		200	mA

1. *All voltage values are measured with respect to the ground pin.*
2. *The differential voltage is the non-inverting input terminal with respect to the inverting input terminal.*
3. *The magnitude of the input and output voltage must never exceed V_{CC} + 0.3 V.*
4. *Short-circuits can cause excessive heating. Destructive dissipation can result from short circuits on amplifiers.*
5. *Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.*
6. *This is a minimum value. Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω). This is done for all couples of connected pin combinations while the other pins are floating.*
7. *Charged device model: all pins and package are charged together to the specified voltage and then discharged directly to ground through only one pin. This is done for all pins.*

Table 2. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	4.5 to 5.5	V
V_{icm}	Common-mode input voltage	$-V_{CC}$ + 1.5 V to V_{CC} - 1.5 V	
T_{amb}	Operating free-air temperature range (1)	-55 to 125	°C

1. *Tj must never exceed 150 °C. $P = (T_j - T_{amb} / R_{thja} = (T_j - T_{case}) / R_{thjc}$ where P is the power that the RHF350A must dissipate in the application.*

3 Electrical characteristics

Table 3. Electrical characteristics for V_{CC} = ±2.5 V, T_{amb} = 25 °C (unless otherwise specified)

Symbol	Parameter	Test conditions [(1)]		Min.	Typ.	Max.	Unit
DC performance							
V_{io}	Input offset voltage		125 °C	-4	1	4	mV
			25 °C	-4	0.4	4	
			-55 °C	-4	0.8	4	
I_{ib+}	Non-inverting input bias current		125 °C		8.5	35	µA
			25 °C		9	35	
			-55 °C		9	35	
I_{ib-}	Inverting input bias current		125 °C		2.5	25	
			25 °C		2	20	
			-55 °C		1.8	25	
CMR	Common mode rejection ratio, 20 log ($\Delta V_{ic}/\Delta V_{io}$)	ΔV_{ic} = ±1 V	125 °C	50	55		dB
			25 °C	54	57		
			-55 °C	50	58		
SVR	Supply voltage rejection ratio, 20 log ($\Delta V_{CC}/\Delta V_{io}$)	ΔV_{CC} = 3.5 V to 5 V	125 °C	55	87		
			25 °C	68	87		
			-55 °C	55	88		
PSRR	Power supply rejection ratio, 20 log ($\Delta V_{CC}/\Delta V_{out}$)	ΔV_{CC} = 200 mV_{pp} at 1 kHz	25 °C		51		
I_{CC}	Supply current	No load	125 °C		3.8	4.9	mA
			25 °C		4	4.9	
			-55 °C		4	4.9	
Dynamic performance and output characteristics							
R_{OL}	Transimpedance	ΔV_{out} = ±1 V, R_L = 100 Ω	125 °C	150	244		kΩ
			25 °C	170	260		
			-55 °C	150	276		
Bw	Small signal -3 dB bandwidth	R_L = 100 Ω, A_V = 1	25 °C		550		MHz
		R_L = 100 Ω, A_V = 2	25 °C		390		
		R_L = 100 Ω, A_V = 10	25 °C		125		
		R_L = 100 Ω, A_V = -2	25 °C		425		
SR	Slew rate [(2)]	V_{out} = 2 V_{pp}, A_V = 2, R_L = 100 Ω	25 °C	700	940		V/µs
V_{OH}	High level output voltage	R_L = 100 Ω	125 °C	1.3	1.6		V
			25 °C	1.44	1.55		
			-55 °C	1.3	1.5		
V_{OL}	Low level output voltage	R_L = 100 Ω	125 °C		-1.6	-1.3	
			25 °C		-1.55	-1.44	
			-55 °C		-1.5	-1.3	

Symbol	Parameter	Test conditions (1)		Min.	Typ.	Max.	Unit
I_{sink}	Output sink current	Output to GND	125 °C	135	210		mA
			25 °C	135	225		
			-55 °C	135	225		
I_{source}	Output source current	Output to GND	125 °C		-200	-140	
			25 °C		-225	-140	
			-55 °C		-240	-140	

1. *T_{min} < T_{amb} < T_{max}: worst case of the parameter on a standard sample across the temperature range. The evaluation is done on 50 units in the SO8 plastic package.*
2. *Guaranteed by characterization of initial design release and upon design or process changes which affect this parameter.*

Table 4. Closed-loop gain and feedback components

Gain (V/V)	+ 1	- 1	+ 2	- 2	+ 10	- 10
R_{fb} (Ω)	820	300	300	300	300	300

4 Electrical characteristic curves

Figure 2. Frequency response, positive gain

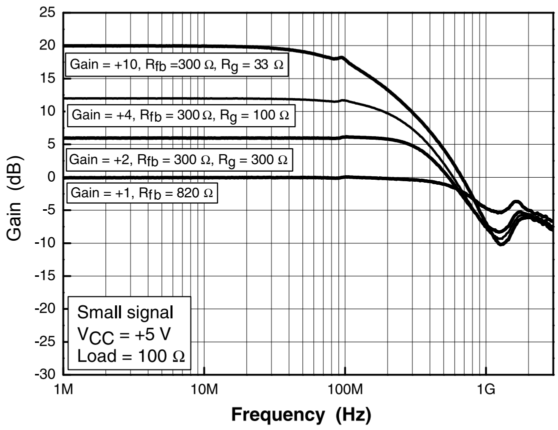


Figure 3. Flatness, gain = 1

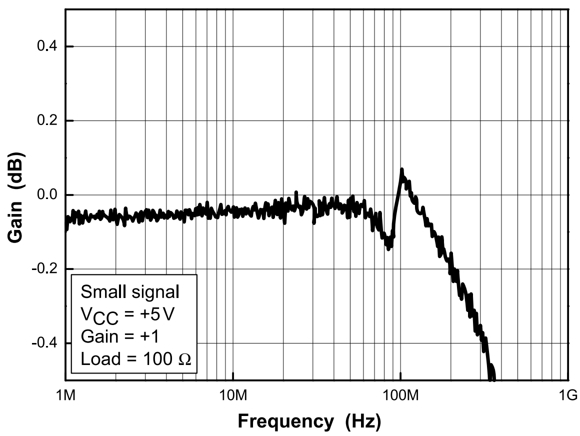


Figure 4. Flatness, gain = 2

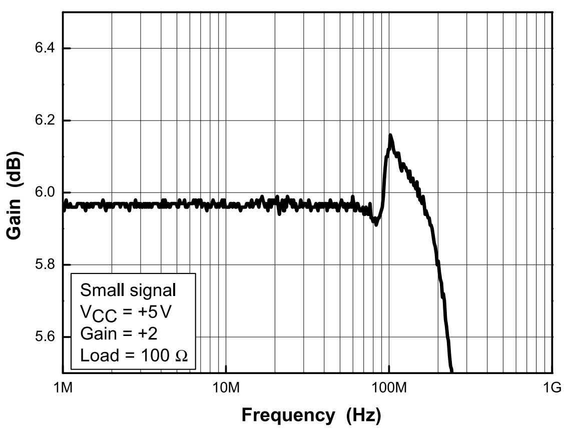


Figure 5. Flatness, gain = 4

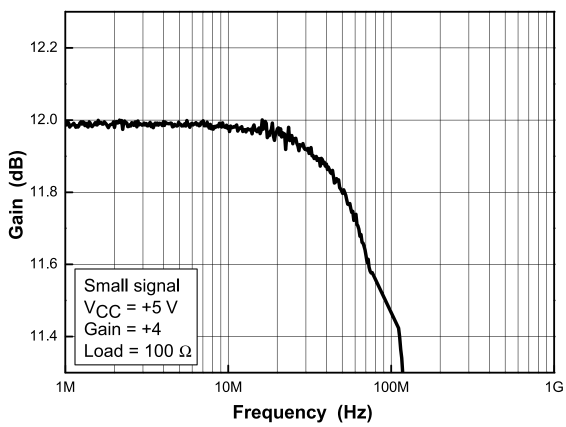


Figure 6. **Flatness, gain = 10**

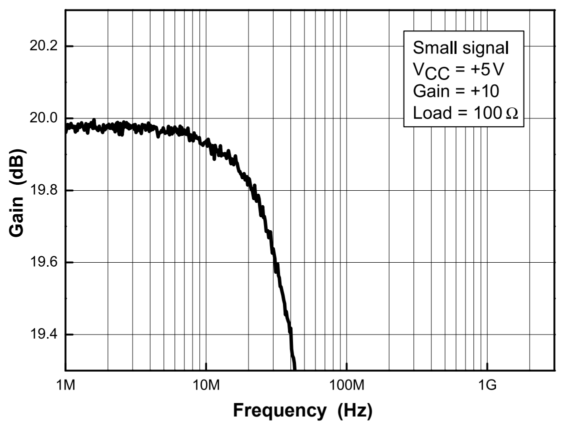


Figure 7. **Slew rate**

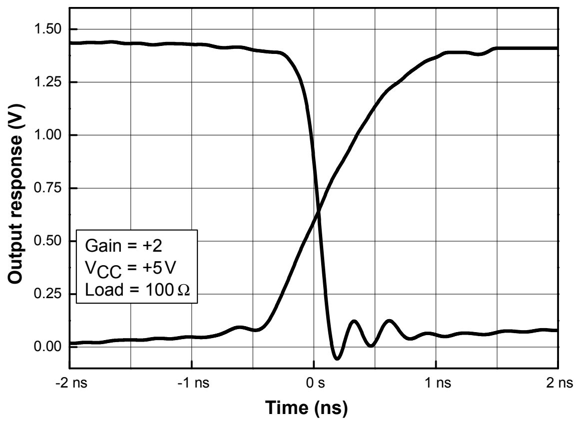


Figure 8. **I_{sink}**

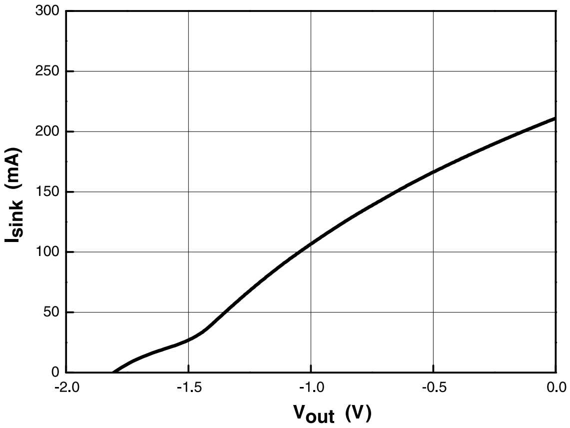


Figure 9. **I_{source}**

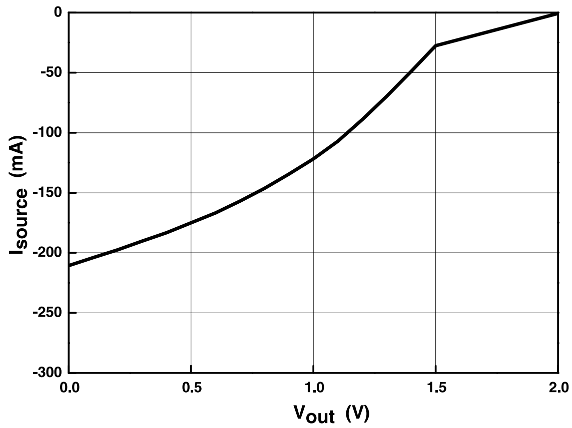


Figure 10. **Input current noise vs. frequency**

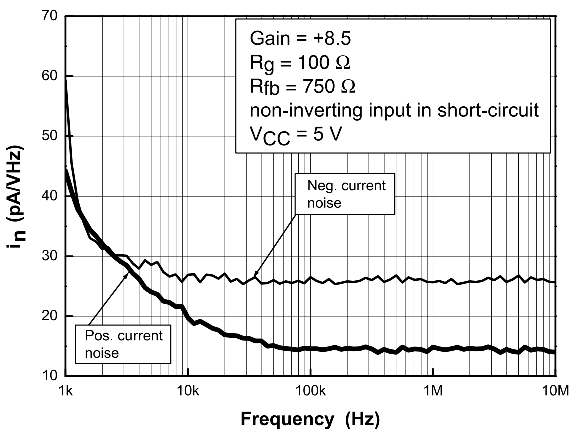


Figure 11. **Input voltage noise vs. frequency**

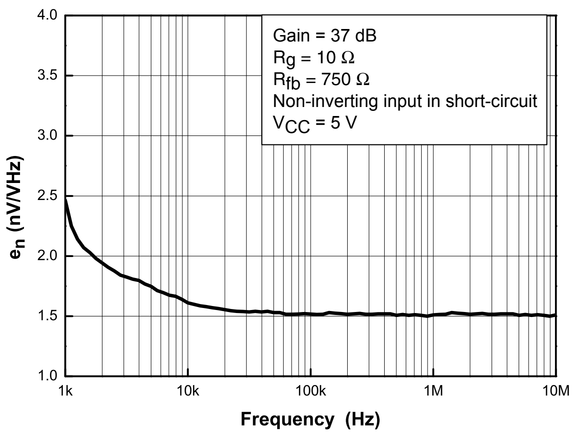


Figure 12. Quiescent current vs. V_{CC}

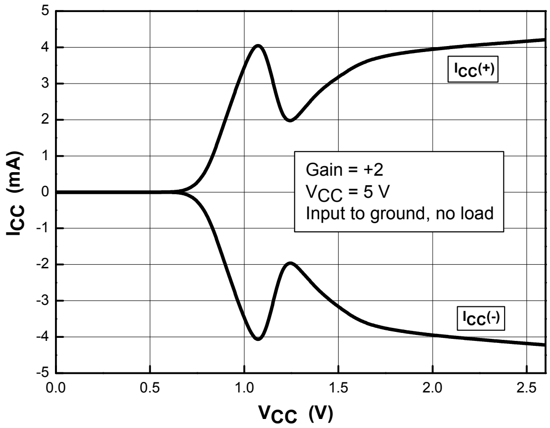


Figure 13. Noise

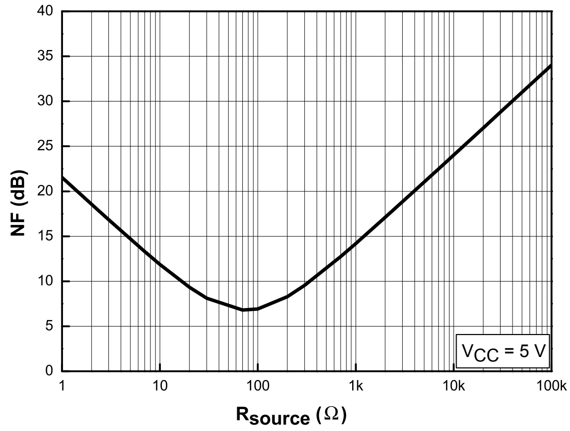


Figure 14. Distortion vs. output amplitude

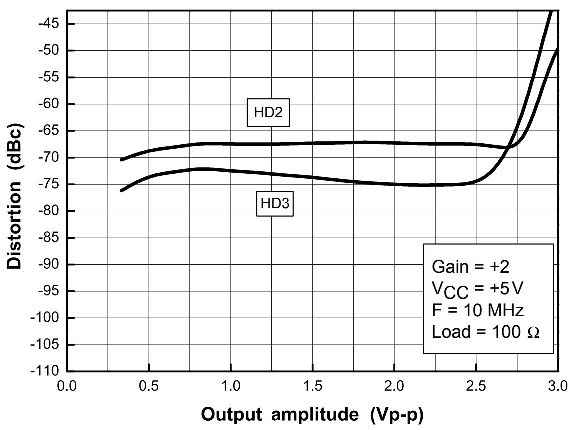


Figure 15. Output amplitude vs. load

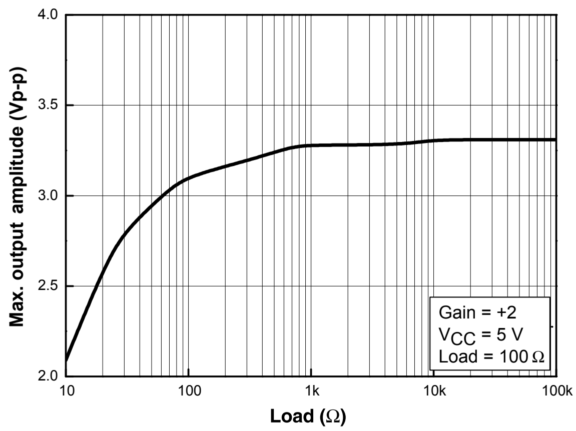


Figure 16. Reverse isolation vs. frequency

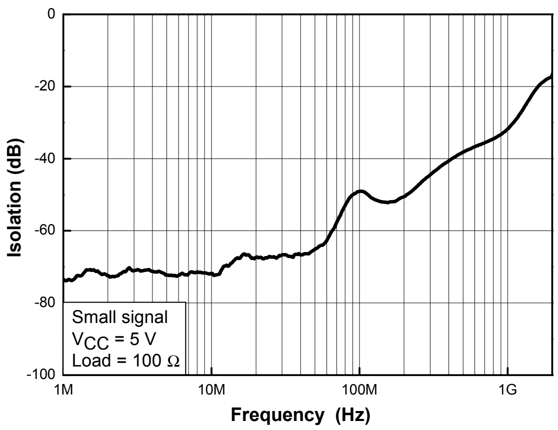


Figure 17. SVR vs. temperature

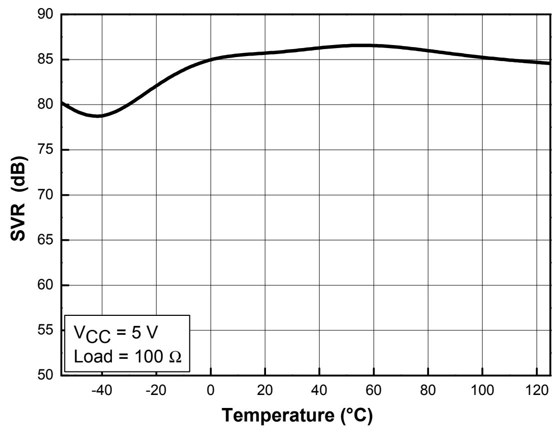


Figure 18. I_{out} **vs. temperature**

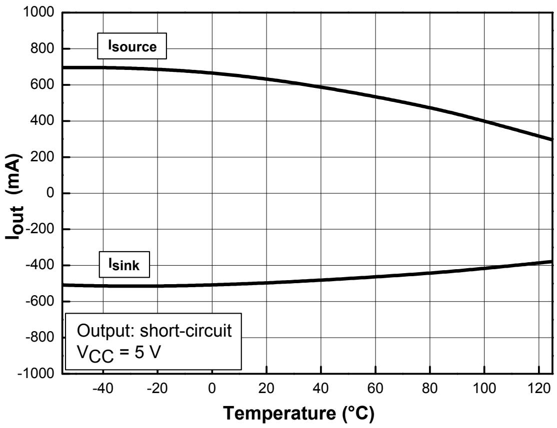


Figure 19. R_{OL} **vs. temperature**

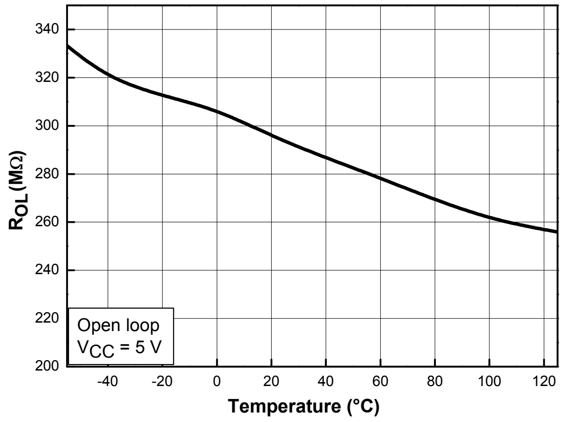


Figure 20. CMR vs. temperature

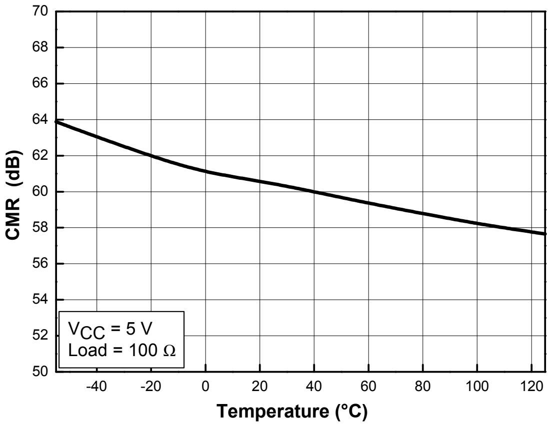


Figure 21. I_{bias} **vs. temperature**

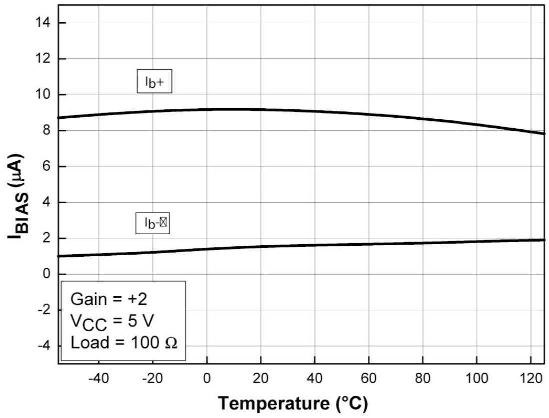


Figure 22. V_{io} **vs. temperature**

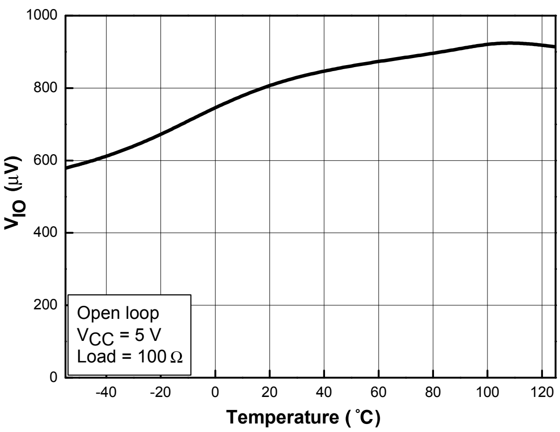
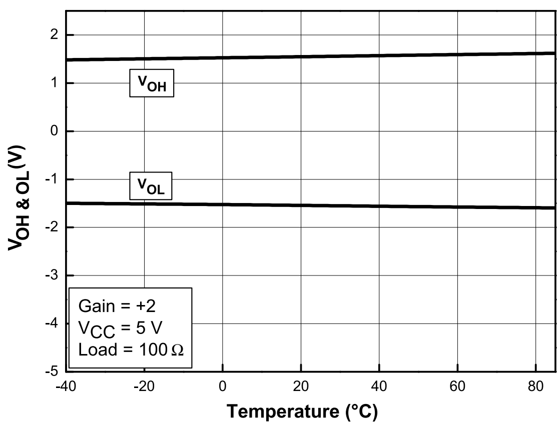


Figure 23. V_{OH} **and** V_{OL} **vs. temperature**



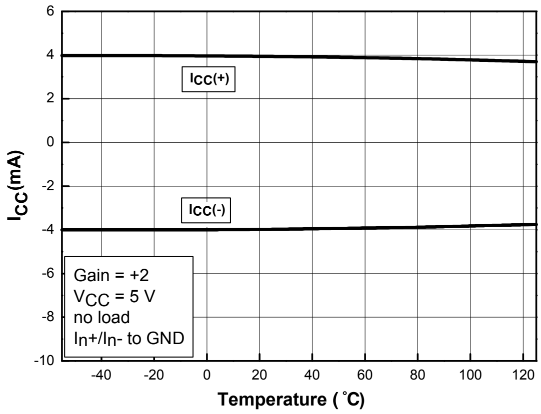


Figure 24. I_{CC} **vs. temperature**

5 Radiations

5.1 Introduction

Table 5. Radiations summarizes the radiation performance of the RHF350A.

Table 5. Radiations

<table>
<tr><th>Type</th><th colspan="2">Features</th><th>Value</th><th>Unit</th></tr>
<tr><td rowspan="3">TID</td><td colspan="2">High-dose rate</td><td>300</td><td rowspan="3">krad</td></tr>
<tr><td colspan="2">Low-dose rate</td><td>300</td></tr>
<tr><td colspan="2">ELDRS</td><td>300</td></tr>
<tr><td rowspan="7">Heavy ions</td><td colspan="2">SEL immunity (at 125 °C) up to:</td><td>110</td><td>MeV.cm²/mg</td></tr>
<tr><td rowspan="6">SET characterized</td><td rowspan="2">Inverting</td><td>LET_{th} = 19</td><td>MeV.cm²/mg</td></tr>
<tr><td>σ = 4.00E-06</td><td>cm²/device</td></tr>
<tr><td rowspan="2">Non-inverting</td><td>LET_{th} = 18</td><td>MeV.cm²/mg</td></tr>
<tr><td>σ = 2.00E-06</td><td>cm²/device</td></tr>
<tr><td rowspan="2">Subtracting</td><td>LET_{th} = 1</td><td>MeV.cm²/mg</td></tr>
<tr><td>σ = 6.00E-04</td><td>cm²/device</td></tr>
</table>

5.2 Total ionizing dose (TID)

The products guaranteed in radiation within the RHA QML-V system fully comply with the MIL-STD-883 test method 1019 specification.

The RHF350A is RHA QML-V qualified, and is tested and characterized in full compliance with the MIL-STD-883 specification. It uses a mixed bipolar and CMOS technology and is tested both below 10 mrad/s (low dose rate) and between 50 and 300 rad/s (high dose rate).

- The ELDRS characterization is performed in qualification only on both biased and unbiased parts, on a sample of ten units from two different wafer lots.
- Each wafer lot is tested at high-dose rate only, in the worst bias case condition, based on the results obtained during the initial qualification.

5.3 Heavy ions

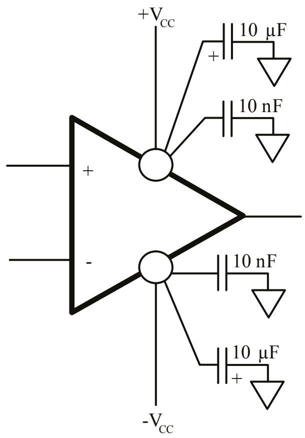
Note: The heavy ion trials are performed on qualification lots only. No additional test is performed.

6 Device description and operation

6.1 Power supply considerations

Correct power supply bypassing is very important for optimizing the performance of the device in high-frequency ranges. The bypass capacitors should be placed as close as possible to the IC pins to improve high-frequency bypassing. A capacitor greater than 1 µF is necessary to minimize the distortion. For better quality bypassing, a capacitor of 10 nF can be added, which should also be placed as close as possible to the IC pins. The bypass capacitors must be incorporated for both the negative and positive supply.

Figure 25. Circuit for power supply bypassing



6.1.1 Single power supply

If you use a single-supply system, biasing is necessary to obtain a positive output dynamic range between the 0 V and V_{CC} supply rails. Considering the values of V_{OH} and V_{OL}, the amplifier provides an output swing from 0.9 V to 4.1 V on a 100 Ω load.

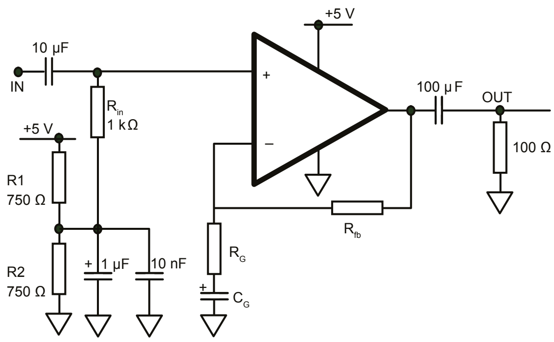
The amplifier must be biased with a mid-supply (nominally $V_{CC}/2$) in order to maintain the DC component of the signal at this value. Several options are possible to provide this bias supply, such as a virtual ground using an operational amplifier or a two-resistance divider (which is the cheapest solution). A high resistance value is required to limit the current consumption. On the other hand, the current must be high enough to bias the non-inverting input of the amplifier. If we consider this bias current (35 µA maximum) as 1 % of the current through the resistance divider, two resistances of 750 Ω can be used to maintain a stable mid-supply.

The input provides a high-pass filter with a break frequency below 10 Hz, which is necessary to remove the original 0 V DC component of the input signal and to set it at $V_{CC}/2$.

Figure 27. Circuit for 5 V single supply illustrates a 5 V single power supply configuration.

A capacitor C_G is added in the gain network to ensure a unity gain at low frequencies to keep the right DC component at the output. C_G contributes to a high-pass filter with $R_{fb}//R_G$ and its value is calculated with regard to the cut-off frequency of this low-pass filter.

Figure 26. Circuit for 5 V single supply

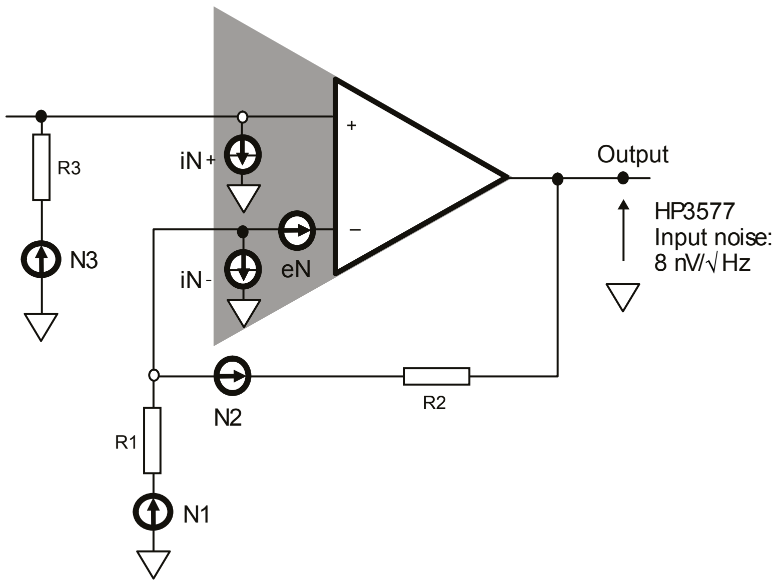


6.2 Noise measurements

The noise model is shown in Figure 28. Noise model.

- eN: input voltage noise of the amplifier
- iNn: negative input current noise of the amplifier
- iNp: positive input current noise of the amplifier

Figure 27. Noise model



The thermal noise of a resistance R is:

$$\sqrt{4kTR\Delta F}$$

Where ΔF is the specified bandwidth, and k is the Boltzmann's constant, equal to 1,374.10-23J/°K. T is the temperature (°K).

On a 1 Hz bandwidth the thermal noise is reduced to:

$$\sqrt{4kTR}$$

The output noise eNo is calculated using the superposition theorem. However, eNo is not the simple sum of all noise sources but rather the square root of the sum of the square of each noise source, as shown in Equation 1.

Equation 1

$$eNo = \sqrt{V1^2 + V2^2 + V3^2 + V4^2 \; V5^2 + V6^2}$$

Equation 2

$$eNo^2 = eN^2 \cdot g^2 + iNn^2 \cdot R2^2 + iNp^2 \cdot R3^2 \cdot g^2 + \frac{R2^2}{R1} \cdot 4kTR1 + 4kTR2 + 1 \; \frac{R2^2}{R1} \cdot 4kTR3$$

The input noise of the instrumentation must be extracted from the measured noise value. The real output noise value of the driver is shown in Equation 3.

Equation 3

$$eNo = \sqrt{(Measured)^2 - (instrumentation)^2}$$

The input noise is called **equivalent input noise** because it is not directly measured but is evaluated from the measurement of the output divided by the closed loop gain (eNo/g).

After simplification of the fourth and fifth terms of Equation 2, you obtain Equation 4.

Equation 4

$$eNo^2 = eN^2 \cdot g^2 + iNn^2 \cdot R2^2 + iNp^2 \cdot R3^2 \cdot g^2 + g \cdot 4kTR2 + 1 \; \frac{R2^2}{R1} \cdot 4kTR3$$

6.2.1 Measurement of the input voltage noise eN

Assuming a short-circuit on the non-inverting input (R3 = 0), from Equation 4 you can derive Equation 5.

Equation 5

$$eNo = \sqrt{eN^2 \cdot g^2 + iNn^2 \cdot R2^2 + g \cdot 4kTR2}$$

To easily extract the value of eN, the resistance R2 must be as low as possible. On the other hand, the gain must be high enough. R3 = 0 and gain (g) = 100.

6.2.2 Measurement of the negative input current noise iNn

To measure the negative input current noise iNn, R3 is set to zero and Equation 5 is used. This time, the gain must be lower in order to decrease the thermal noise contribution. R3 = 0 and gain (g) = 10.

6.2.3 Measurement of the positive input current noise iNp

To extract iNp from Equation 3, a resistance R3 is connected to the non-inverting input. The value of R3 must be selected so that its thermal noise contribution is as low as possible against the iNp contribution. R3 = 100 Ω and gain (g) = 10.

6.3 Intermodulation distortion product

The non-ideal output of the amplifier can be described by the following series of equations.

$$V_{out} = C_0 + C_1 V_{in} + C_2 V^2{}_{in} + \ldots + C_n V^n{}_{in}$$

Where the input is V_{in} = Asinωt, C_0 is the DC component, $C_1(V_{in})$ is the fundamental and C_n is the amplitude of the harmonics of the output signal V_{out}.

A one-frequency (one-tone) input signal contributes to harmonic distortion. A two-tone input signal contributes to harmonic distortion and to the intermodulation product.

The study of the intermodulation and distortion for a two-tone input signal is the first step in characterizing the driving capability of multi-tone input signals.

In this case:

$$V_{in} = A\sin\omega_1 t + A\sin\omega_2 t$$

Therefore:

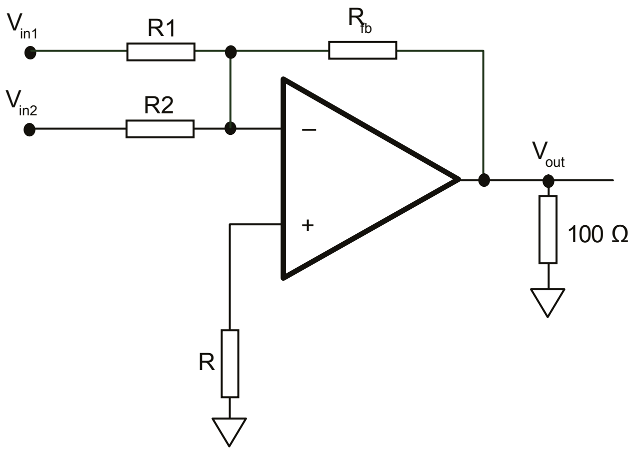
$$V_{out} = C_0 + C_1(A\sin\omega_1 t + A\sin\omega_2 t) + C_2(A\sin\omega_1 t + A\sin\omega_2 t)^2 \ldots + C_n(A\sin\omega_1 t + A\sin\omega_2 t)^n$$

From this expression, we can extract the distortion terms and the intermodulation terms from a single sine wave.

- Second-order intermodulation terms IM2 by the frequencies (ω_1-ω_2) and (ω_1+ω_2) with an amplitude of $C2A^2$.
- Third-order intermodulation terms IM3 by the frequencies ($2\omega_1$-ω_2), ($2\omega_1$+ω_2), (-ω_1+$2\omega_2$) and (ω_1+$2\omega_2$) with an amplitude of $(3/4)C3A^3$.

The intermodulation product of the driver is measured by using the driver as a mixer in a summing amplifier configuration (Figure 29. Inverting summing amplifier). In this way, the non-linearity problem of an external mixing device is avoided.

Figure 28. Inverting summing amplifier



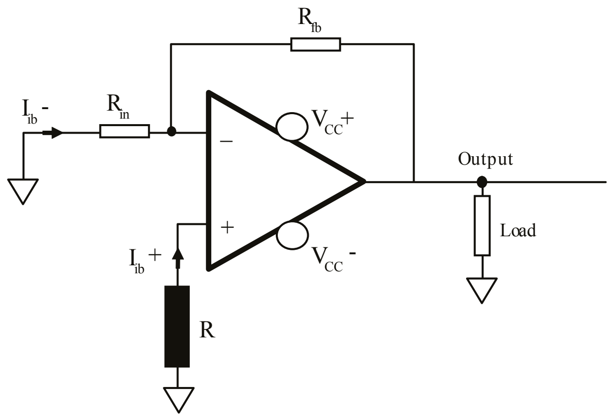
6.4 Bias of an inverting amplifier

A resistance is necessary to achieve good input biasing, such as resistance R shown in Figure 30. Compensation of the input bias current.

The value of this resistance is calculated from the negative and positive input bias current. The aim is to compensate for the offset bias current, which can affect the input offset voltage and the output DC component. Assuming I_{ib-}, I_{ib+}, R_{in}, R_{fb} and a 0 V output, the resistance R is:

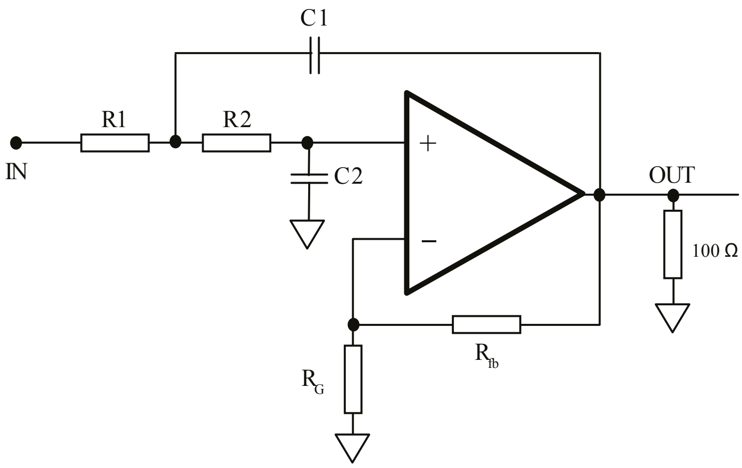
$$R = \frac{R_{in} \cdot R_{fb}}{R_{in} + R_{fb}}$$

Figure 29. Compensation of the input bias current



6.5 Active filtering

Figure 30. Low-pass active filtering, Sallen-Key



From the resistors R_{fb} and R_G it is possible to directly calculate the gain of the filter in a classic non-inverting amplification configuration.

$$A_V = g = 1 + \frac{R_{fb}}{R_g}$$

The response of the system is assumed to be:

$$T_{j\omega} = \frac{Vout_{j\omega}}{Vin_{j\omega}} = \frac{g}{1+2\zeta\frac{j\omega}{\omega_c}+\frac{(j\omega)^2}{\omega_c^2}}$$

The cut-off frequency is not gain-dependent and so becomes:

$$\omega_C = \frac{1}{\sqrt{R1R2C1C2}}$$

The damping factor is calculated using the following expression.

$$\zeta = \frac{1}{2}\omega_C(C_1R_1 + C_1R_2 + C_2R_1 - C_1R_1g)$$

The higher the gain, the more sensitive the damping factor. When the gain is higher than 1, it is preferable to use very stable resistor and capacitor values. In the case of R1 = R2 = R:

$$\zeta = \frac{2C_2 - C_1\frac{R_{fb}}{R_g}}{2\sqrt{C_1C_2}}$$

Due to a limited selection of capacitor values in comparison with the resistors, you can set C1 = C2 = C, so that:

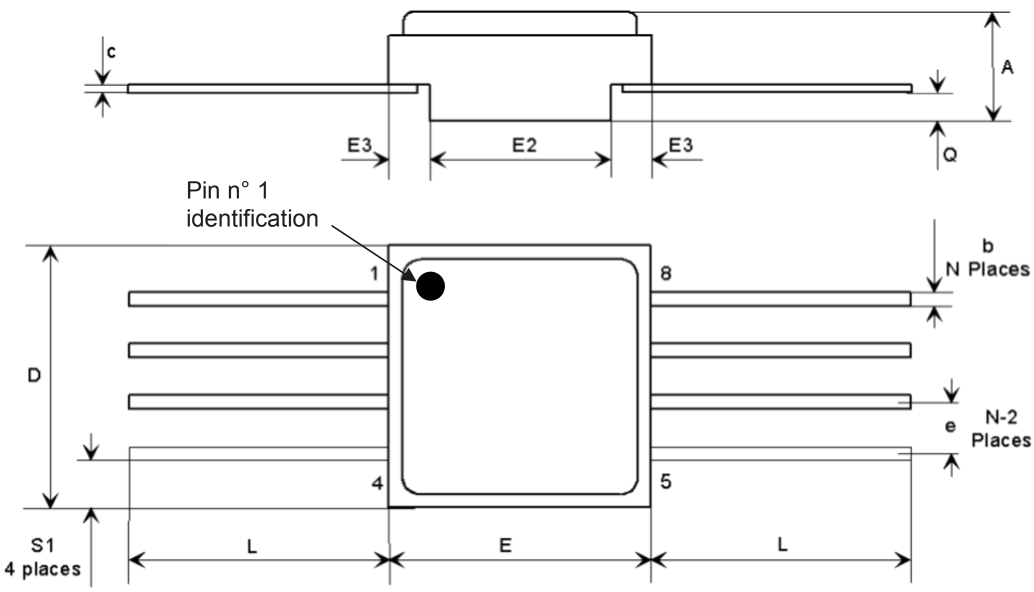
$$\zeta = \frac{2R_2 - R_1\frac{R_{fb}}{R_g}}{2\sqrt{R_1R_2}}$$

7 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

7.1 Ceramic Flat-8 package information

Figure 31. Ceramic Flat-8 package outline



Note: The upper metallic lid is electrically connected to pin 5. No other pin is electrically connected to the metallic lid nor to the IC die inside the package.

Table 6. Ceramic Flat-8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	2.24	2.44	2.64	0.088	0.096	0.104
b	0.38	0.43	0.48	0.015	0.017	0.019
c	0.10	0.13	0.16	0.004	0.005	0.006
D	6.35	6.48	6.61	0.250	0.255	0.260
E	6.35	6.48	6.61	0.250	0.255	0.260
E2	4.32	4.45	4.58	0.170	0.175	0.180
E3	0.88	1.01	1.14	0.035	0.040	0.045
e		1.27			0.050	
L	6.51		7.38	0.256		0.291
Q	0.66	0.79	0.92	0.026	0.031	0.036
S1	0.92	1.12	1.32	0.036	0.044	0.052
N	08			08		

8 Ordering information

Table 7. Ordering information

Order codes	SMD [1]	Quality level	Package	Finishing	Marking [2]	Packing
RHF350AK1	—	Engineering model	Flat-8	Gold	RHF350AK1	Strip pack
RHF350AK01V	5962F07232	QML-V flight			5962F0723202VYC	

1. *Standard microcircuit drawing*
2. *Specific marking only. Complete marking includes the following:*
   - *ST logo*
   - *Date code (date the package was sealed) in YYWWA (year, week, and lot index of week)*
   - *Country of origin (FR = France)*

Other information

The date code is structured as shown below:

- EM xyywwz
- QML-V yywwz

  where:
  - x (EM only) = 3 and the assembly location is Rennes, France
  - yy = last two digits of the year
  - ww = week digits
  - z = lot index in the week

Product documentation

Each product shipment includes a set of associated documentation within the shipment box. This documentation depends on the quality level of the products, as detailed in the table below.

The certificate of conformance is provided on paper whatever the quality level. For QML parts, complete documentation, including the certificate of conformance, is provided on a CDROM.

Table 8. Product documentation

Quality level	Item
Engineering model	Certificate of conformance including : Customer name Customer purchase order number ST sales order number and item ST part number Quantity delivered Date code Reference to ST datasheet Reference to TN1181 on engineering models ST Rennes assembly lot ID
QML-V Flight	Certificate of Conformance including: Customer name Customer purchase order number ST sales order number and item ST part number Quantity delivered

Quality level	Item
QML-V Flight	Date code Serial numbers Group C reference Group D reference Reference to the applicable SMD ST Rennes assembly lot ID
	Quality control inspection (groups A, B, C, D, E)
	Screening electrical data in/out summary
	Precap report
	PIND (particle impact noise detection) test
	SEM (scanning electronic microscope) inspection report
	X-ray plates

Revision history

Table 9. Document revision history

Date	Revision	Changes
20-May-2009	1	Initial release
12-Jul-2010	2	Added Mass in Features on cover page. Added Table 1: Device summary on cover page, with full ordering information. Changed temperature limits in Table 4: Radiations
27-Jul-2011	3	Added note to the Package information section and in the Pin connections diagram on the coverpage.
03-Aug-2012	4	Updated Table 4: Radiations with values after radiations. Replaced note in the Package information section with a footnote. Minor corrections throughout document.
06-Feb-2015	5	Replaced package name with “Flat-8S” instead of “Flat-8” Replaced package silhouette and added marker to show the position of pin 1 on package silhouette, pinout and drawing. Updated Features Updated Table 1: Device summary Removed Table 4: Radiations from Section 2: Electrical characteristics. Added Section 3: Radiations Added Section 4: Device description and operation and updated document layout accordingly. Updated Section 6: Ordering information Added Section 7: Other information
06-Apr-2016	6	Updated document layout Table 1: "Device summary": updated footnote 1, SMD = standard microcircuit drawing.
05-Apr-2017	7	Added part number RHF350A Replaced cover image Updated Features Updated Applications Updated Description Added Section 1: "Pin description" Table 2: "Absolute maximum ratings": updated Rthja and Rthjc values. Table 4: updated Bw and SR parameters; updated footnote 2. Section 5.2: "Total ionizing dose (TID)": corrected typos Added Section 7.2: "Ceramic Flat-8 package information" Table 9: "Order codes": updated table title, removed column “EPPL”, added order codes RHF350AK1 and RHF350AK01V, and updated footnotes.
12-Feb-2020	8	Removed the part number RHF350 and all its references due to the obsolete status.

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