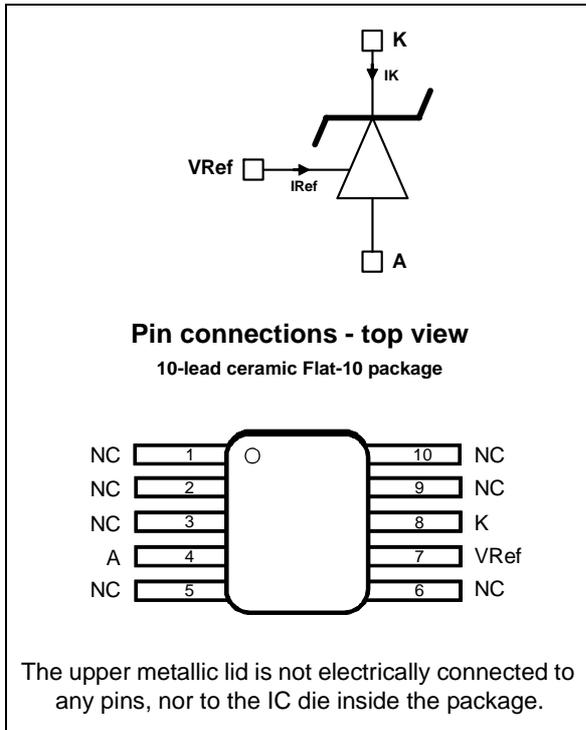


## Rad-hard adjustable 2.5 V/5.5 V precision shunt V-ref

Datasheet - production data



- ELDRS-free up to 300 krad
- 300 krad high/low dose rate
- SEL-free up to 120 MeV.cm<sup>2</sup>/mg
- SET characterized

### Applications

- Space systems
- Space data acquisition systems
- Aerospace instrumentation
- ADC references

### Description

The RHF1009A is a low-power adjustable 2.5 V voltage reference, specifically designed to sustain radiations in space applications.

Mounted in a Flat-10 ceramic package, the RHF1009A uses a dedicated architecture and design rules to provide the best immunity against heavy-ions.

A very low operating current and very good stability over a wide temperature range of -55 °C to +125 °C make the RHF1009A particularly suitable for precision and power saving.

### Features

- Adjustable shunt, 2.5 V to 5.5 V
- High precision  $\pm 0.2\%$  at 2.5 V at 25 °C
- Wide operating current: 60  $\mu$ A to 12 mA
- 30 ppm/°C maximum temperature range at 2.5 V
- Stable on capacitive load

**Table 1. Device summary**

Reference	SMD pin <sup>(1)</sup>	Quality level	Package	Lead finish	Mass	Temp. range
RHF1009AK1		Engineering model	Flat-10	Gold	0.50 g	-55 °C to 125 °C
RHF1009AK01V	5962F14222	QML-V flight				

1. SMD stands for standard microcircuit drawing.

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# 1 Absolute maximum ratings and operating conditions

**Table 2. Absolute maximum ratings**

Symbol	Parameter	Value	Unit
$I_K$	Reverse breakdown current	15	mA
$I_F$	Forward current	20	mA
$V_{KA}$	Reverse breakdown voltage in standby mode ( $V_{Ref} = V_A$ )	6	V
$T_{stg}$	Storage temperature	-65 to +150	°C
$T_j$	Maximum junction temperature	150	°C
$R_{thja}$	Thermal resistance junction ( $T_j$ ) to ambient ( $T_{amb}$ )	140	°C/W
$R_{thjc}$	Thermal resistance junction to case	40	°C/W
ESD	HBM: human body model <sup>(1)</sup>	2	kV
	MM: machine model <sup>(2)</sup>	200	V
	CDM: charged device model <sup>(3)</sup>	1.5	kV

- 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 left floating.
- 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 left floating.
- Charged device model: all pins and package are charged together to the specified voltage and then discharged directly to ground through only one pin.

**Table 3. Operating conditions**

Symbol	Parameter	Value	Unit
$I_{Kmin}$	Minimum operating current [ $V_K \geq V_K (I_K = 100 \mu A, T_a = 25 \text{ °C}) - 100 \mu V$ $V_K = V_{Ref}$ ]	60	μA
$V_{KA}$	Reverse breakdown voltage in operating mode: in standby mode ( $V_{Ref} = V_A$ ):	2.5 to 5.5 2.5 to 5.5	V
$I_{Kmax}$	Maximum operating current [ $V_K \geq V_K (I_K = 100 \mu A, T_a = 25 \text{ °C}) + 2 \text{ mV}$ $V_K = V_{Ref}$ ]	12	mA
$T_{oper}$	Operating ambient temperature range	-55 to +125	°C

## 2 Electrical characteristics

Parameters tested before radiation are shown in [Table 4](#).

**Table 4. Anode is connected to Gnd (0 V),  $V_K$  is in reference to anode voltage.  $C_K$  (between anode and cathode) = 100 nF,  $R_1 = 0$  and  $R_2$  not connected unless otherwise specified**

Symbol	Parameter	Test conditions	Temp.	Min.	Typ.	Max.	Unit
<b>DC performance</b>							
$V_{Ref}$	Reference input voltage	$I_K = 100 \mu A$ $V_K = V_{Ref}$	+25 °C		2.5		V
$\Delta V_{Ref}$	Reference input voltage tolerance	$I_K = 100 \mu A$ $V_K = V_{Ref}$	+25 °C	-5		+5	mV
$I_{Kmin}$	Minimum operating current	$[V_K \geq V_K (I_K = 100 \mu A,$ $T_a = 25^\circ C) - 100 \mu V]$ $V_K = V_{Ref}$	-55 °C +25 °C +125 °C			60 60 60	$\mu A$
$I_{Koff}$	Off state cathode current	$V_{Ref} = V_A$ $V_{KA} = 2.5 V$	-55 °C +25 °C +125 °C			1 1 1	$\mu A$
$I_{Ref}$	Reference input current	$I_K = 100 \mu A$ to 10 mA $V_K = V_{Ref}$ on $R_1 =$ 10 k $\Omega$	-55 °C +25 °C +125 °C			1 1 1	$\mu A$
$\Delta V_{Ref}/\Delta T$	Average temperature coefficient $\frac{V_{Refmax} - V_{Refmin}}{180^\circ C \times V_{Ref}(25^\circ C)} \times 10^6$	$I_K = 100 \mu A$ $V_K = V_{Ref}$	-55 °C to +125 °C			30	ppm/ °C
		$I_K = 10 mA$ $V_K = V_{Ref}$	-55 °C to +125 °C			30	
$\Delta V_{Ref}/\Delta V_{KA}$	Reference voltage versus cathode voltage variation	$I_K = 100 \mu A$ $V_{KA} = 2.5 V$ to 5.5 V $R_1 = 10 k\Omega, R_2$ Variable	-55 °C to +125 °C		1.5	2.5	mV/V
		$I_K = 10 mA$ $V_{KA} = 2.5 V$ to 5.5 V $R_1 = 10 k\Omega, R_2$ Variable	-55 °C to +125 °C		1.5	2.5	
$\Delta V_{Ref}/\Delta I_K$	Reference voltage versus cathode current variation	$I_{Kmin} \leq I_K \leq 1 mA$ $V_K = V_{Ref}$	-55 °C +25 °C +125 °C		0.075 0.08 0.15	0.15 0.16 0.3	mV
		$1 mA \leq I_K \leq 12 mA$ $V_K = V_{Ref}$	-55 °C +25 °C +125 °C		0.65 0.7 1	1.3 1.4 2	
$R_{KA}$	Reverse static impedance	$\Delta I_K = I_{Kmin}$ to 10 mA $V_K = V_{Ref}$	-55 °C +25 °C +125 °C		0.05 0.06 0.1	0.1 0.12 0.2	$\Omega$
$Z_{KA}$	Reverse dynamic impedance	$I_K = 1 mA$ to 1.1 mA $V_K = V_{Ref}, F \leq 1 kHz$ No capacitive load	-55 °C +25 °C +125 °C		0.4 0.4 0.5		$\Omega$

**Table 4. Anode is connected to Gnd (0 V),  $V_K$  is in reference to anode voltage.  $C_K$  (between anode and cathode) = 100 nF,  $R_1 = 0$  and  $R_2$  not connected unless otherwise specified (continued)**

Symbol	Parameter	Test conditions	Temp.	Min.	Typ.	Max.	Unit
$K_{vh}^{(1)}$	Long-term stability $\frac{ V_k(0hr) - V_k(1000hrs) }{V_k(0hr)} \times 10^6$	$I_K = 100 \mu A$ $V_K = V_{Ref}$ $t = 1000 \text{ hrs}$	-55 °C +25 °C +125 °C		100 100 100		ppm
$K_{vhd}$	Stability in radiation $\frac{ V_k(0rad) - V_k(300krad) }{V_k(0rad)} \times 10^6$	$I_K = 100 \mu A$ $V_K = V_{Ref}$ Total dose = 300 krad Dose rate = 0.01 rad/s	-55 °C +25 °C +125 °C		1000 1000 1000		ppm
en	Voltage noise	$I_K = 100 \mu A$ $V_K = V_{Ref}$ $F = 1 \text{ kHz}$	-55 °C +25 °C +125 °C		760 880 980		nV/ $\sqrt{\text{Hz}}$

1. Reliability verified with a cathode current setting  $I_K = 10 \text{ mA}$

### 3 Radiation

#### Total ionizing dose (MIL-STD-883 TM 1019)

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

The RHF1009A is RHA QML-V, tested and characterized in full compliance with the MIL-STD-883 specification, both below 10 mrad/s and between 50 and 300 rad/s, as follows:

- All tests are performed in accordance with MIL-PRF-38535 and the test method 1019 of MIL-STD-883 for total ionizing dose (TID).
- 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.

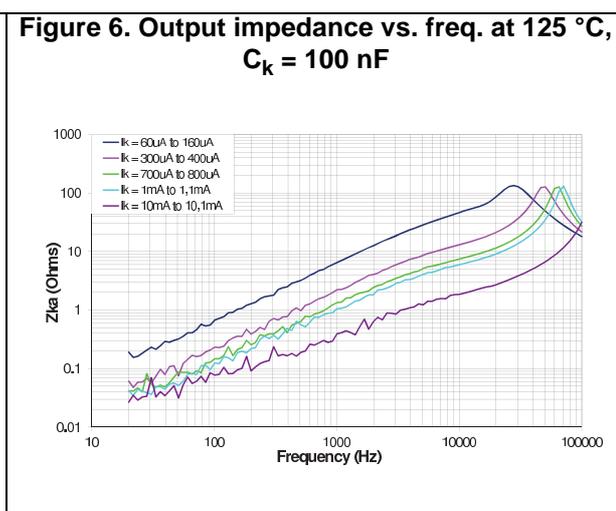
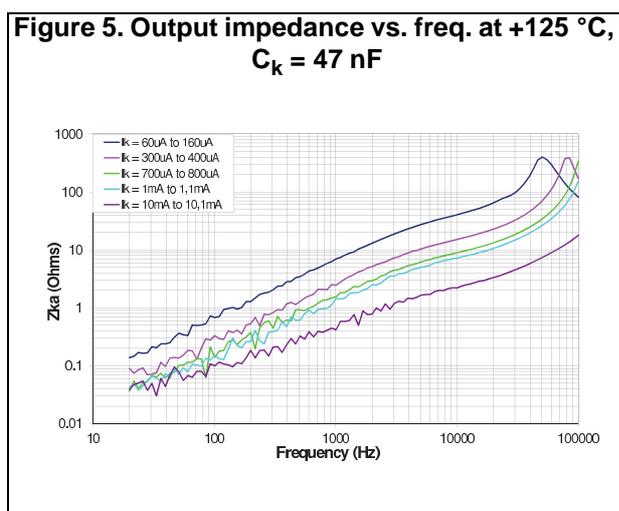
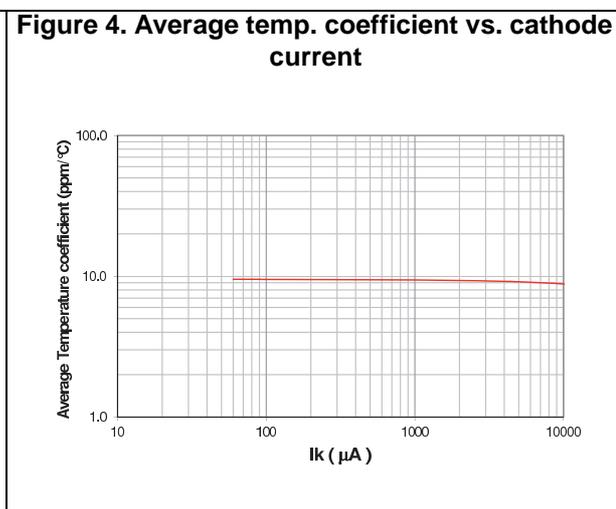
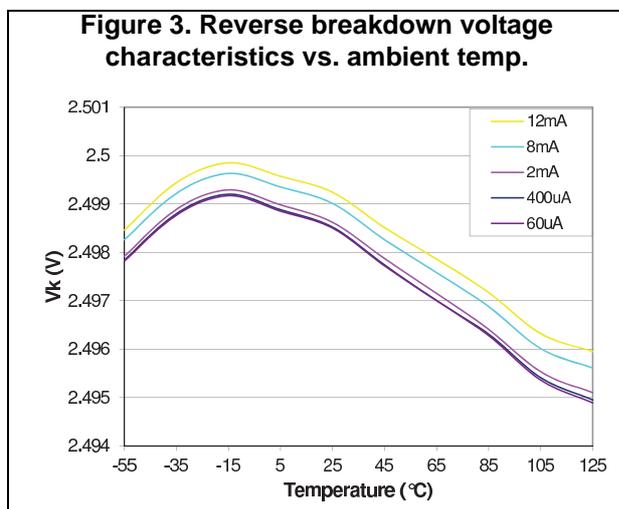
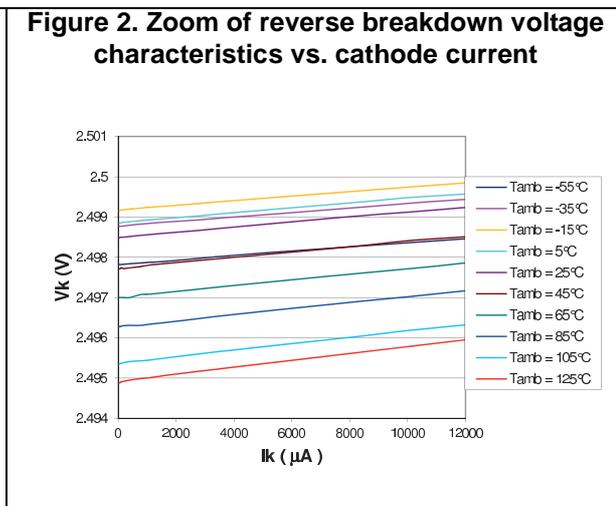
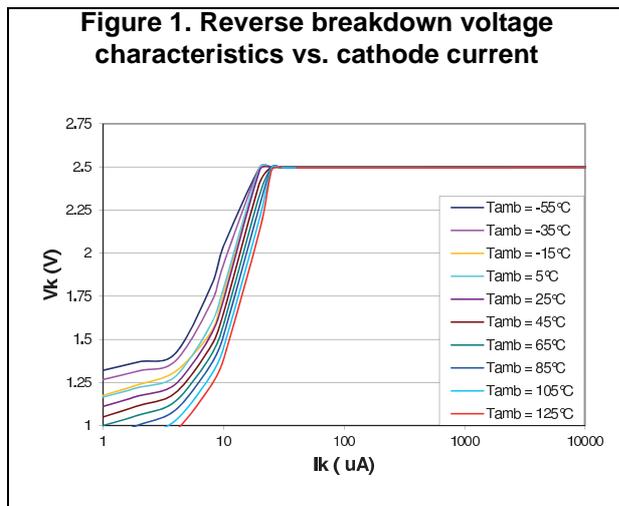
#### Heavy-ions

The behavior of the product when submitted to heavy-ions is not tested in production. Heavy-ion trials are performed on qualification lots only.

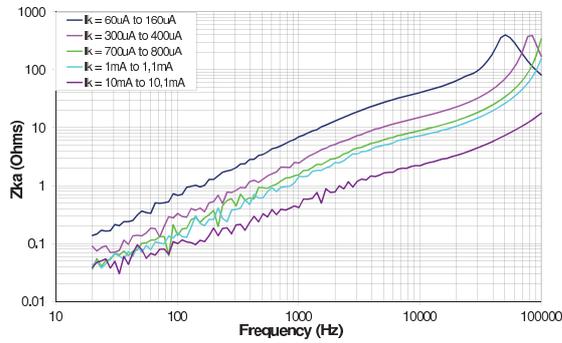
**Table 5. Radiations**

Type	Characteristics	Value	Unit
TID	180 krad/h high-dose rate (50 rad/s) up to:	300	krad
	ELDRS-free up to:	300	
	36 rad/h low-dose rate (0.01 rad/s) up to:	300	
Heavy-ions	SEL immunity up to: (at 125 °C, with a particle angle of 60 °)	120	MeV.cm <sup>2</sup> /mg
	SEL immunity up to: (at 125 °C, with a particle angle of 0 °)	60	
	SET (at 25 °C)	Characterized	

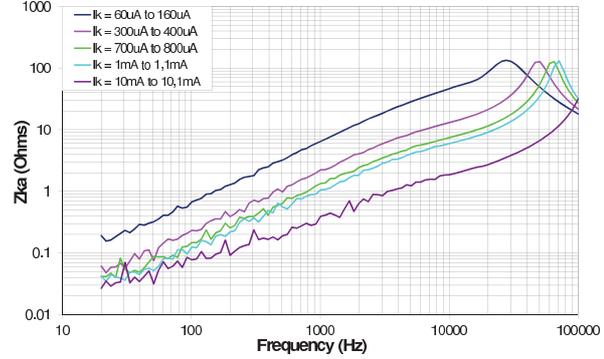
Note: In Figure 1 to 24, temp. = temperature, freq. = frequency, and resp. = response.



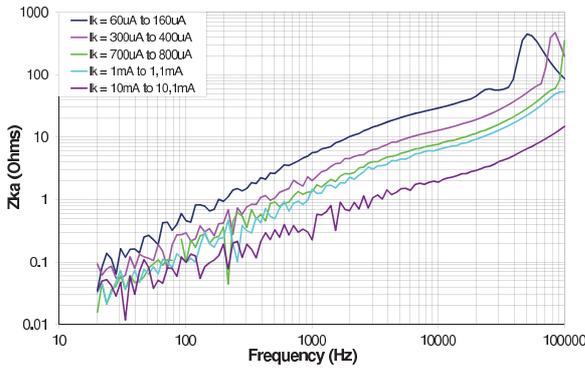
**Figure 7. Output impedance vs. freq. at +25 °C,  $C_k = 47\text{ nF}$**



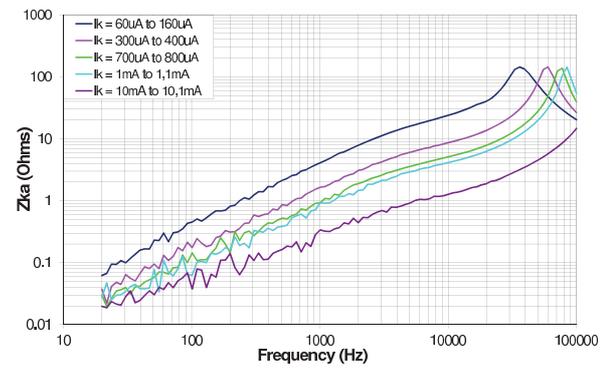
**Figure 8. Output impedance vs. freq. at 25 °C,  $C_k = 100\text{ nF}$**



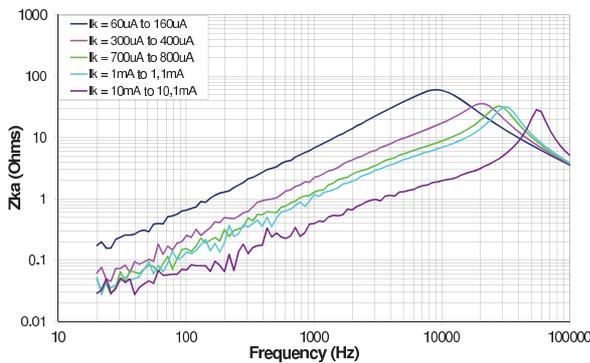
**Figure 9. Output impedance vs. freq. at -55 °C,  $C_k = 47\text{ nF}$**



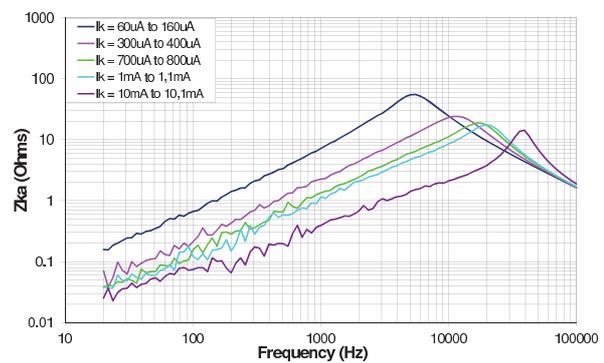
**Figure 10. Output impedance vs. freq. at -55 °C,  $C_k = 100\text{ nF}$**



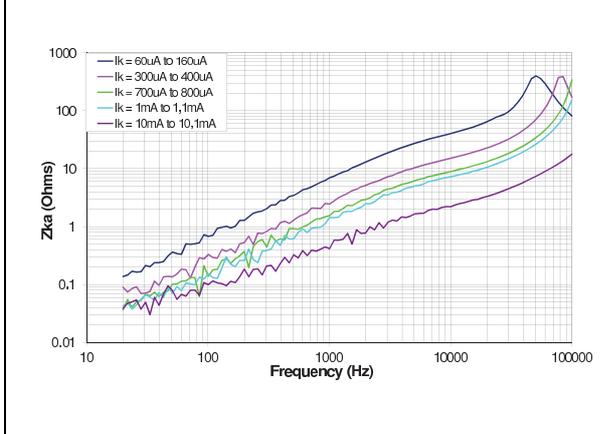
**Figure 11. Output impedance vs. freq. at +125 °C,  $C_k = 470\text{ nF}$**



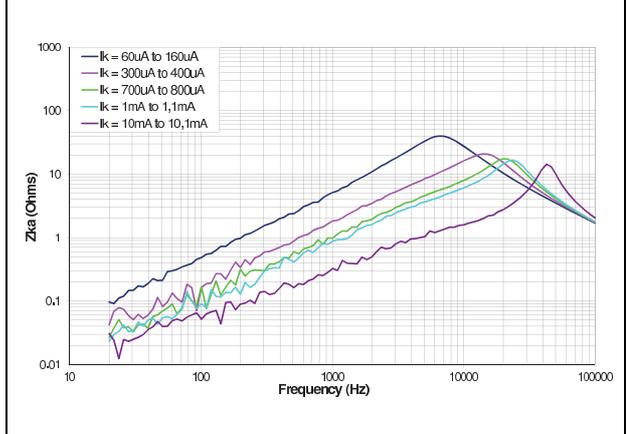
**Figure 12. Output impedance vs. freq. at +125 °C,  $C_k = 1\text{ }\mu\text{F}$**



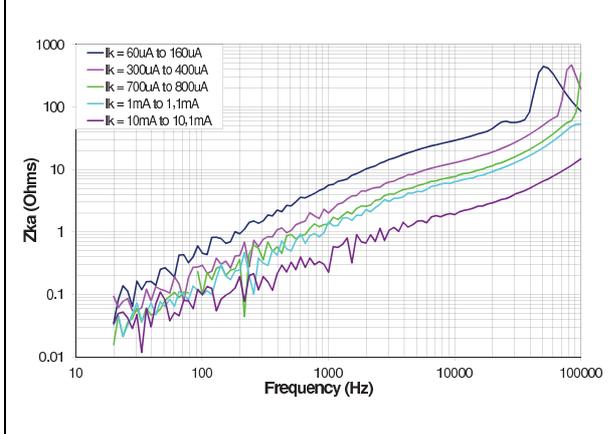
**Figure 13. Output impedance vs. freq. at +25 °C,  $C_k = 470 \text{ nF}$**



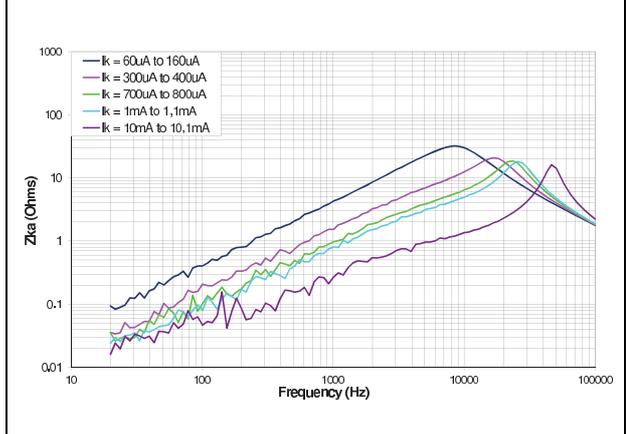
**Figure 14. Output impedance vs. freq. at +25 °C,  $C_k = 1 \mu\text{F}$**



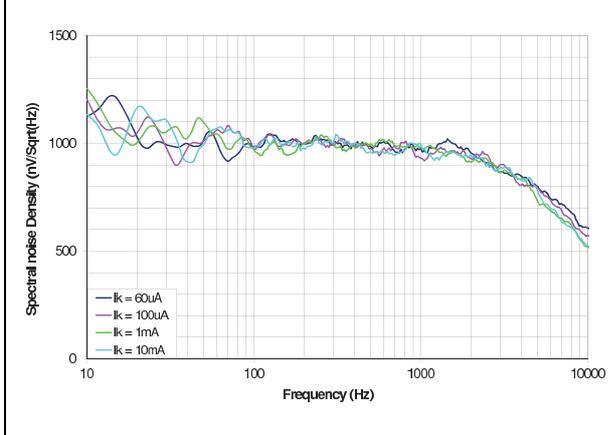
**Figure 15. Output impedance vs. freq. at -55 °C,  $C_k = 470 \text{ nF}$**



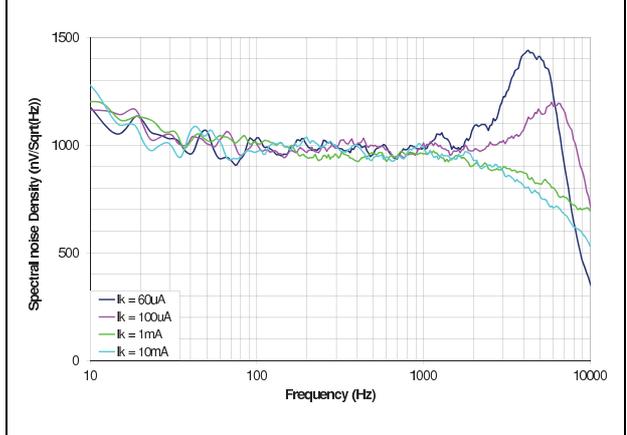
**Figure 16. Output impedance vs. freq. at -55 °C,  $C_k = 1 \mu\text{F}$**



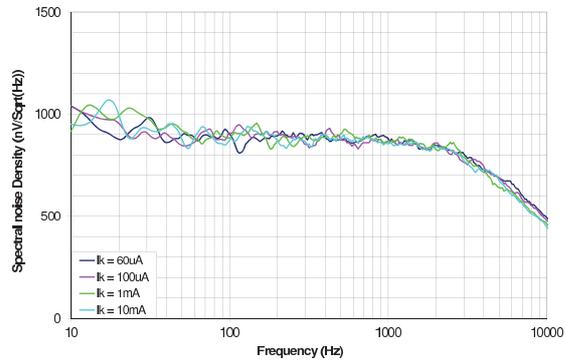
**Figure 17. Spectral noise density vs. freq. at +125 °C,  $C_k = 100 \text{ nF}$**



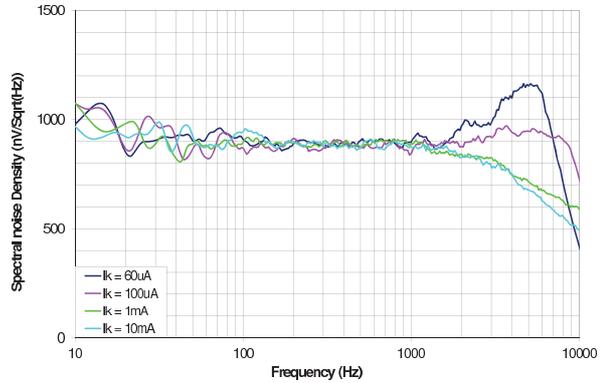
**Figure 18. Spectral noise density vs. freq. at +125 °C,  $C_k = 1 \mu\text{F}$**



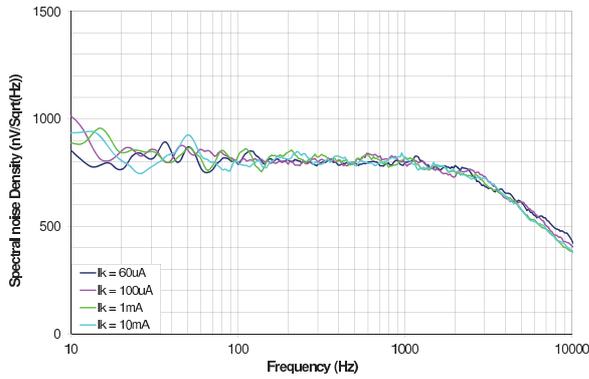
**Figure 19. Spectral noise density vs. freq. at +25 °C, C<sub>k</sub> = 100 nF**



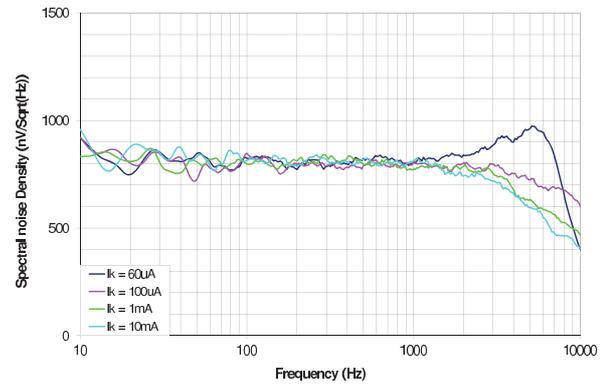
**Figure 20. Spectral noise density vs. freq. at +25 °C, C<sub>k</sub> = 1 μF**



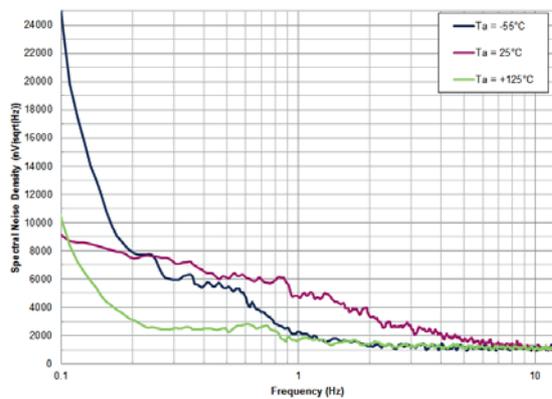
**Figure 21. Spectral noise density vs. freq. at -55 °C, C<sub>k</sub> = 100 nF**



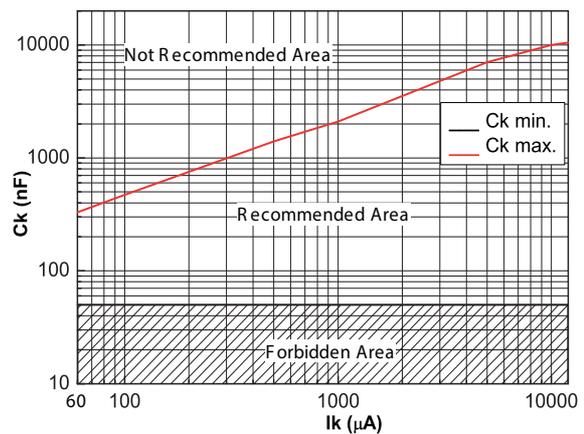
**Figure 22. Spectral noise density vs. freq. at -55 °C, C<sub>k</sub> = 1 μF**



**Figure 23. Low freq. spectral noise density vs. freq. C<sub>k</sub> = 100 nF to 1 μF, I<sub>k</sub> = 60 μA to 10 mA**



**Figure 24. Recommended operating area**



## 4 Design information

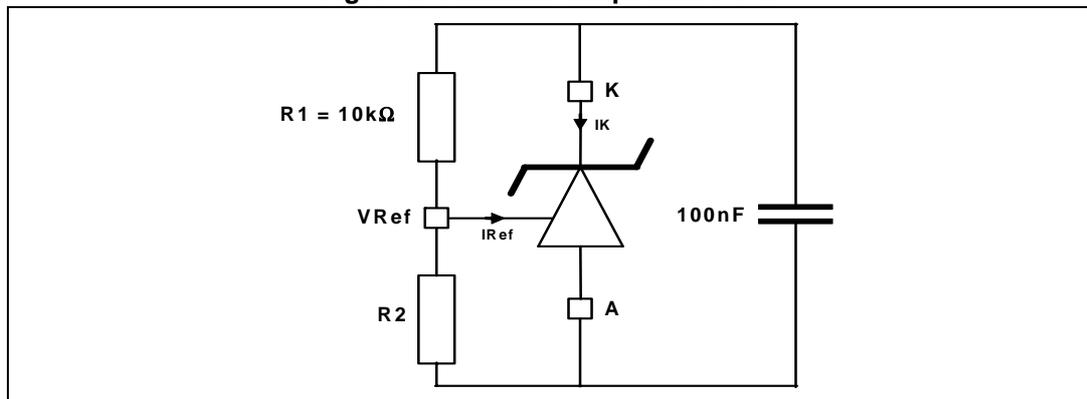
### 4.1 Introduction

The RHF1009A is a programmable voltage reference. It can be set from 2.5 V to 5.5 V by a bridge of 2 resistors (see [Figure 25](#)).

From -55 °C to +125 °C, the cathode current capability of the RHF1009A ranges from 60 µA up to 12 mA.

Internal double bonding allows the RHF1009A to have an equivalent output resistance as low as 110 mΩ. Consequently, the RHF1009A has very good load regulation.

**Figure 25. Electrical implementation**



$$V_{KA} = V_{Ref} \times \left(1 + \frac{R_1}{R_2}\right) + R_1 \times I_{Ref}$$

### 4.2 Average temperature coefficient

The RHF1009A is designed with a second order compensation in temperature. This gives an S-shaped curve for the  $V_k$  variation over the temperature range.

For the RHF1009A, the average temperature coefficient is calculated as shown in [Equation 1](#).

#### Equation 1

$$\text{Average temperature coefficient} = \frac{V_{kmax} - V_{kmin}}{(T_{max} - T_{min}) \times v_k(25^\circ\text{C})} \times 10^6$$

where  $T_{max} = +125$  °C and  $T_{min} = -55$  °C.

For each sample, use [Equation 1](#) and the procedure below:

- Set a cathode current ( $I_k$ )
- Measure  $V_k$  at  $I_k$  with an ambient temperature of 25 °C
- Measure  $V_k$  at  $I_k$  with the following ambient temperatures: -55 °C, -15 °C, +75 °C, and +125 °C.
- For the above five temperature measurements, find the  $V_k$  maximum and minimum
- Apply [Equation 1](#)

The average temperature coefficient is evaluated during product qualification on the above five temperature measurements and is guaranteed on production tests with three temperature measurements: -55 °C, +25 °C, and +125 °C.

## 4.3 Minimum and maximum cathode current

### 4.3.1 Minimum operating cathode current

The minimum operating cathode current ( $I_{kmin.}$ ) is a combination of parameters (such as reference voltage, stability, noise, and process drift) that are taken over the ambient temperature range. For the RHF1009A,  $I_{kmin.}$  is 60  $\mu$ A.

$I_{kmin.}$  is guaranteed over the ambient temperature range by [Equation 2](#).

$$\text{Equation 2: } V_k(I_k = 60 \mu\text{A}) \geq V_k(I_k = 100 \mu\text{A}, 25 \text{ }^\circ\text{C}) - 100 \mu\text{V}$$

### 4.3.2 Maximum operating cathode current ( $I_{kmax.}$ )

The maximum operating cathode current ( $I_{kmax.}$ ) is limited by the output ballast current capabilities and process drift. For the RHF1009A,  $I_{kmax.}$  is 12 mA.

$I_{kmax.}$  is guaranteed by the  $\Delta V_k$  vs.  $\Delta I_k$  parameter (see [Table 4](#)) and by [Equation 3](#) (at  $T_{amb} = 25 \text{ }^\circ\text{C}$ ).

$$\text{Equation 3: } V_k(I_k = 12 \text{ mA}) \leq V_k(I_k = 100 \mu\text{A}, 25 \text{ }^\circ\text{C}) + 3 \text{ mV}$$

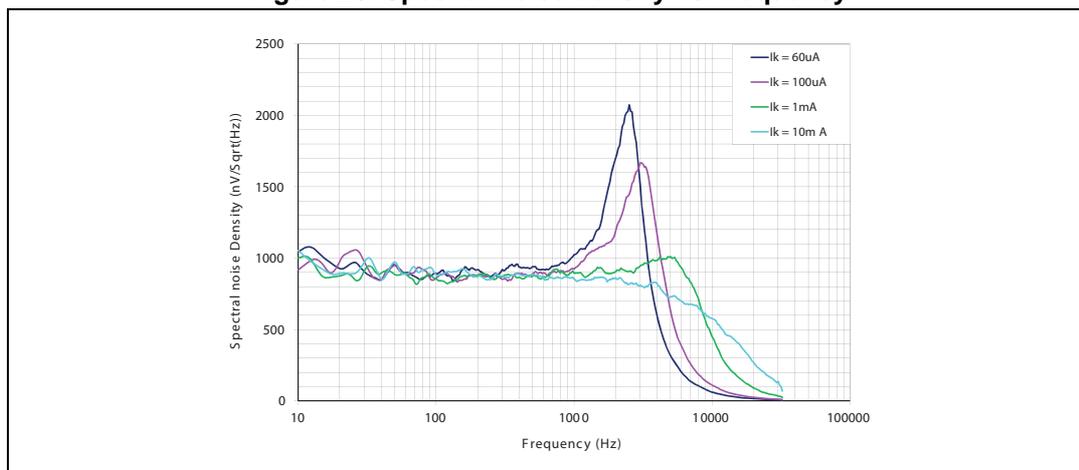
## 4.4 Capacitive load considerations

The RHF1009A can oscillate for a small  $I_k$  and no  $C_k$ . This is why we recommend a minimum capacitive load of 47 nF. The RHF1009A is designed to be stable with a capacitive load ( $C_k$ ) over the cathode current range (60  $\mu$ A to 12 mA) and ambient temperature range (-55 °C to +125 °C).

If an oscillation amplitude less than 2 mVrms is acceptable, this device can be considered usable with any capacitive load given in [Figure 24: Recommended operating area](#).

[Figure 26: Spectral noise density vs. frequency](#) shows the spectral noise density measurements vs. frequency. For example, with a capacitive load of 4.7  $\mu$ F and  $I_k = 60 \mu$ A, there is a noise peak at about 2500 Hz. For the reverse breakdown voltage ( $V_k$ ), this peaking corresponds to a micro-oscillation, with jitter, centered at 2500 Hz.

Figure 26. Spectral noise density vs. frequency



## 5 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK<sup>®</sup> packages, depending on their level of environmental compliance. ECOPACK<sup>®</sup> specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK<sup>®</sup> is an ST trademark.

## 5.1 Ceramic Flat-10 package information

Figure 27. Ceramic Flat-10 package outline

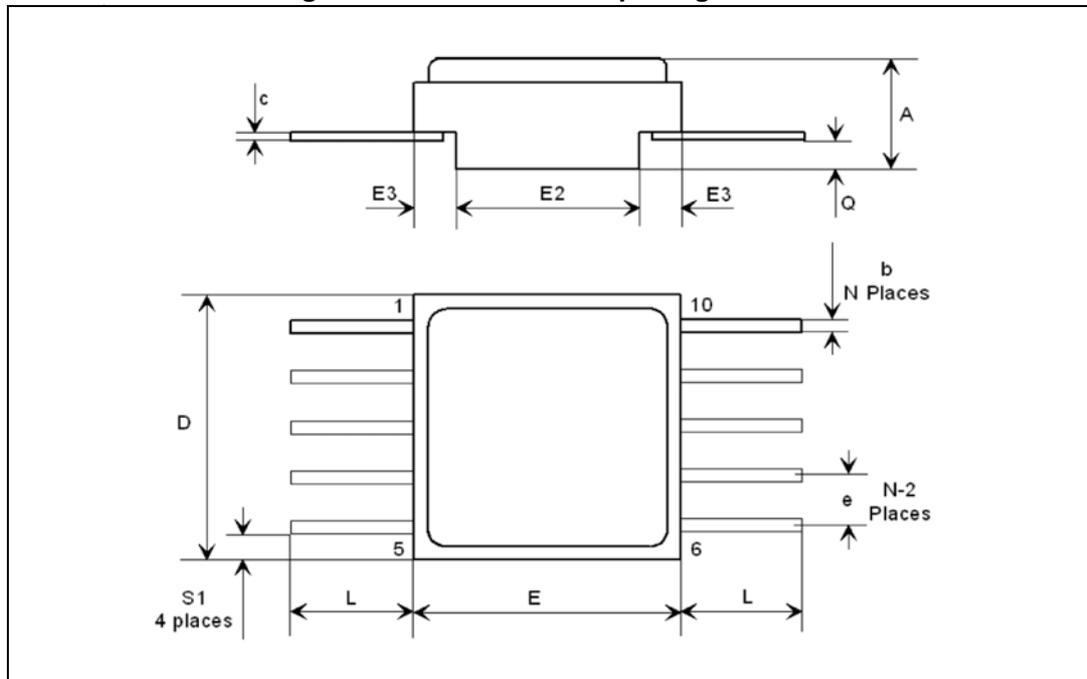


Table 6. Ceramic Flat-10 mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	2.26	2.44	2.62	0.089	0.096	0.103
b	0.38	0.43	0.48	0.015	0.017	0.019
c	0.102	0.127	0.152	0.004	0.005	0.006
D	6.35	6.48	6.60	0.250	0.255	0.260
E	6.35	6.48	6.60	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	6.35		9.40	0.250		0.370
Q	0.66	0.79	0.92	0.026	0.031	0.036
S1	0.16	0.485	0.81	0.006	0.019	0.032
N	10			10		

**Note:** The upper metallic lid is not electrically connected to any pins, nor to the IC die inside the package.

## 6 Ordering information

Table 7. Order code

Order code	Description	Temp. range	Package	Marking <sup>(1)</sup>	Packing
RHF1009AK1	Engineering model	-55 °C to 125 °C	Flat-10	RHF1009AK1	Strip pack
RHF1009AK01V	QML-V flight			5962F1422201VXC	

- Specific marking only. Complete marking includes the following:
  - SMD pin (for QML flight only)
  - ST logo
  - Date code (date the package was sealed) in YYWWA (year, week, and lot index of week)
  - QML logo (Q or V)
  - Country of origin (FR = France)

*Note:* Contact your ST sales office for information regarding the specific conditions for products in die form and QML-Q versions.

### Other information

#### Date code

The date code is structured as shown below:

- Engineering model: EM xyywwz
- QML flight model: FM yywwz

Where:

x (EM only): 3, assembly location Rennes (France)

yy: last two digits 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 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

## 7 Revision history

**Table 9. Document revision history**

Date	Revision	Changes
18-Jun-2014	1	Initial release
08-Jul-2015	2	<p><i>Features</i>: updated Vref. accuracy</p> <p><i>Table 3: Operating conditions</i>: modified <math>V_{KA}</math></p> <p>Corrected <i>Figure 20: Spectral noise density vs. freq. at +25 °C, <math>C_k = 1 \mu F</math></i> and <i>Figure 21: Spectral noise density vs. freq. at -55 °C, <math>C_k = 100 nF</math></i>.</p> <p>Added <i>Figure 23: Low freq. spectral noise density vs. freq. <math>C_k = 100 nF</math> to <math>1 \mu F</math>, <math>I_k = 60 \mu A</math> to <math>10 mA</math></i>.</p> <p>Changed layout of <i>Figure 24: Recommended operating area</i></p>
09-Apr-2018	3	Updated the <i>Description</i> , <i>Table 1: Device summary</i> in cover page, <i>Table 7: Order code</i> and <i>Table 8: Product documentation</i> .

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