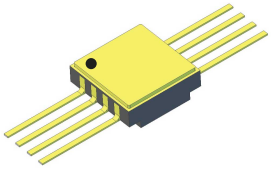
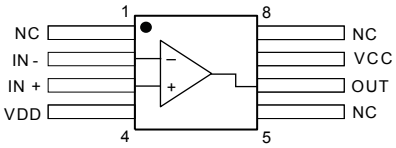
RHF43B

Datasheet

Rad-hard precision bipolar single operational amplifier

Ceramic Flat-8





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

Maturity status link
RHF43B

Features

- Rail-to-rail output
- Bandwidth: 8 MHz gain at 16 V
- Low input offset voltage: 100 µV typ
- Supply current: 2.2 mA typ
- Operating from 3 to 16 V
- Input bias current: 30 nA typ
- ESD internal protection ≥ 2 kV
- Latch-up immunity: 200 mA
- ELDRS free up to 300 krad
- SEL immune at 120 MeV.cm²/mg

Applications

- Space probes and satellites
- Defense systems
- Scientific instrumentation
- Nuclear systems

Description

The RHF43B is a precision, bipolar operational amplifier available in a ceramic Flat-8 package and in die form. In addition to its low offset voltage, rail-to-rail feature, and wide supply voltage, the RHF43B features a good immunity to radiations.

1 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage [1]	18	V
V_{id}	Differential input voltage [2]	±1.2	
V_{in}	Input voltage range [3]	V_{DD} - 0.3 to 16	
I_{in}	Input current	45	mA
T_{stg}	Storage temperature	-65 to 150	°C
T_j	Maximum junction temperature	150	
R_{thja}	Thermal resistance junction to ambient area [4] [5]	125	°C/W
R_{thjc}	Thermal resistance junction to case [4] [5]	40	
ESD	HBM: human body model [6]	2	kV
	Latch-up immunity	200	mA
	Lead temperature (soldering, 10 s)	260	°C

1. *The supply voltage is defined as the difference between the voltages applied on the VCC and VDD pins.*
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 and destructive dissipation.*
5. *R_{th} are typical values.*
6. *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.*

Table 2. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	3 to 16	V
V_{icm}	Common-mode input voltage	V_{DD} to V_{CC}	
T_{oper}	Operating free-air temperature range	-55 to 125	°C

2 Electrical characteristics

Table 3. 16 V supply: V_{CC} = 16 V, V_{DD} = 0 V, load to V_{CC}/2 (unless otherwise specified)

Symbol	Parameter	Test conditions		Min.	Typ.	Max.	Unit
DC performance							
I_{CC}	Supply current	No load	125 °C			2.9	mA
			25 °C		2.5	2.9	
			-55 °C			2.9	
V_{io}	Offset voltage	Vicm = V_{CC}/2	125 °C	-500		500	µV
			25 °C	-300	100	300	
			-55 °C	-500		500	
DV_{io}	Input offset voltage drift				1		µV/°C
I_{ib}	Input bias current	Vicm = V_{CC}/2	125 °C	-100		100	nA
			25 °C	-60	30	60	
			-55 °C	-100		100	
DI_{ib}	Input offset current temperature drift	Vicm = V_{CC}/2			100		pA/°C
I_{io}	Input offset current	Vicm = V_{CC}/2	125 °C	-35		35	nA
			25 °C	-15	1	15	
			-55 °C	-35		35	
R_{in}	Differential input resistance between in+ and in-		25 °C		0.16		MΩ
	Input resistance between in+ (or in-) and GND				2000		
C_{in}	Differential input capacitance between in+ and in-		25°C		8		pF
	Input capacitance between in+ (or in-) and GND				2		
CMR	Common mode rejection ratio	0 < Vicm < 16 V	125 °C	72			dB
			25 °C	72	110		
			-55 °C	72			
SVR	Supply voltage rejection ratio	3 V < V_{CC} < 16 V, Vicm = V_{CC}/2	125 °C	80			
			25 °C	90	120		
			-55 °C	80			
A_{VD}	Large signal voltage gain	Vout = 0.5 V to 15.5 V, R_L = 1 kΩ, 0 < Vicm < 16 V	125 °C	60			
			25 °C	74	85		
			-55 °C	60			
V_{OH}	High level output voltage	R_L = 1 kΩ	125 °C	15.6			V
			25 °C	15.7	15.8		
			-55 °C	15.6			
		R_L = 10 kΩ	125 °C	15.8			
V_{OH}	High level output voltage	R_L = 10 kΩ	25 °C	15.9	15.96		V
			-55 °C	15.8			
V_{OL}	Low level output voltage	R_L = 1 kΩ	125 °C			0.3	

Symbol	Parameter	Test conditions		Min.	Typ.	Max.	Unit
V_{OL}	Low level output voltage	R_L = 1 kΩ	25 °C		0.1	0.2	V
			-55 °C			0.3	
		R_L = 10 kΩ	125 °C			0.1	
			25 °C		0.04	0.06	
			-55 °C			0.1	
I_{out}	Output sink current	Vout = V_{CC}	125 °C	15			mA
			25 °C	20	30		
			-55 °C	15			
	Output source current	Vout = V_{DD}	125 °C	10			
			25 °C	15	25		
			-55 °C	10			
AC performance							
GBP	Gain bandwidth product	f = 100 kHz, R_L = 1 kΩ, C_L = 100 pF	125 °C	3.5			MHz
			25 °C	6	8		
			-55 °C	3.5			
F_u	Unity gain frequency	R_L = 1 kΩ, C_L = 100 pF	25 °C		5		
ϕm	Phase margin	Gain = 5, R_L = 1 kΩ, C_L = 100 pF	25 °C		50		Degrees
SR	Slew rate	R_L = 1 kΩ, C_L = 100 pF	125 °C	1.7			V/µs
			25 °C	2	3		
			-55 °C	1.7			
e_n	Equivalent input noise voltage	f = 1 kHz	25 °C		7.5		nV/√Hz
i_n	Equivalent input noise current	f = 1 kHz	25 °C		1		pA/√Hz
THD+e_n	Total harmonic distortion + noise	Vout = (V_{CC} - 1 V)/5, Gain = -5.1, Vicm = V_{CC}/2	25 °C		0.01		%

Table 4. 3 V supply: V_{CC} = 3 V, V_{DD} = 0 V, load to $V_{CC}/2$ (unless otherwise specified)

Symbol	Parameter	Test conditions		Min.	Typ.	Max.	Unit
DC performance							
I_{CC}	Supply current	No load	125 °C			2.6	mA
			25 °C		2.2	2.6	
			-55 °C			2.6	
V_{io}	Offset voltage	Vicm = $V_{CC}/2$	125 °C	-500		500	µV
			25 °C	-300	100	300	
			-55 °C	-500		500	
DV_{io}	Input offset voltage drift				1		µV/°C
I_{ib}	Input bias current	V_{CC} = 4 V, Vicm = $V_{CC}/2$	125 °C	-100		100	nA
			25 °C	-60	30	60	
			-55 °C	-100		100	
DI_{ib}	Input offset current temperature drift	V_{CC} = 4 V, Vicm = $V_{CC}/2$			100		pA/°C
I_{io}	Input offset current	V_{CC} = 4 V, Vicm = $V_{CC}/2$	125 °C	-35		35	nA
			25 °C	-15	1	15	
			-55 °C	-35		35	
R_{in}	Differential input resistance between in+ and in-		25 °C		0.16		MΩ
	Input resistance between in+ (or in-) and GND				2000		
C_{in}	Differential input capacitance between in+ and in-		25°C		8		pF
	Input capacitance between in+ (or in-) and GND				2		
CMR	Common mode rejection ratio	0 < Vicm < 3 V	125 °C	72			dB
			25 °C	72	90		
			-55 °C	72			
A_{VD}	Large signal voltage gain	Vout = 0.5 V to 2.5 V, R_L = 1 kΩ, 0 < Vicm < 3 V	125 °C	60			
			25 °C	74	85		
			-55 °C	60			
V_{OH}	High level output voltage	R_L = 1 kΩ	125 °C	2.8			V
			25 °C	2.9	2.95		
			-55 °C	2.8			
		R_L = 10 kΩ	125 °C	2.9			
			25 °C	2.94	2.98		
			-55 °C	2.9			
V_{OL}	Low level output voltage	R_L = 1 kΩ	125 °C			0.2	
			25 °C		0.05	0.1	
			-55 °C			0.2	
V_{OL}	Low level output voltage	R_L = 10 kΩ	125 °C			0.1	V
			25 °C		0.02	0.06	
			-55 °C			0.1	

Symbol	Parameter	Test conditions		Min.	Typ.	Max.	Unit
I_{out}	Output sink current	Vout = V_{CC}	125 °C	15			mA
			25 °C	20	30		
			-55 °C	15			
	Output source current	Vout = V_{DD}	125 °C	10			
			25 °C	15	25		
			-55 °C	10			
AC performance							
GBP	Gain bandwidth product	f = 100 kHz, R_L = 1 kΩ, C_L = 100 pF	125 °C	3.5			MHz
			25 °C	6	7.5		
			-55 °C	3.5			
F_u	Unity gain frequency	R_L = 1 kΩ, C_L = 100 pF	25 °C		5		
ϕm	Phase margin	Gain = 5, R_L = 1 kΩ, C_L = 100 pF	25 °C		50		Degrees
SR	Slew rate	R_L = 1 kΩ, C_L = 100 pF	125 °C	1.7			V/µs
			25 °C	2	2.7		
			-55 °C	1.7			
e_n	Equivalent input noise voltage	f = 1 kHz	25 °C		7		nV/√Hz
i_n	Equivalent input noise current	f = 1 kHz	25 °C		0.8		pA/√Hz
THD+e_n	Total harmonic distortion + noise	Vout = (V_{CC} - 1 V)/5, Gain = -5.1, Vicm = V_{CC}/2	25 °C		0.01		%

3 Electrical characteristic curves

Figure 1. Input offset voltage distribution

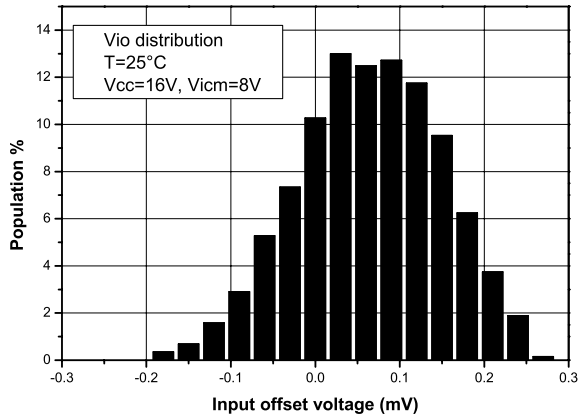


Figure 2. Input bias current vs. supply voltage

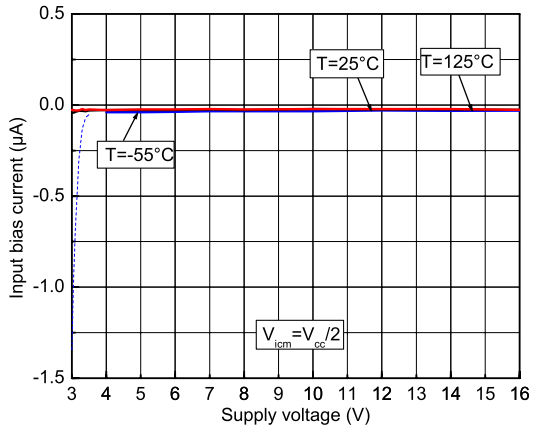


Figure 3. Input bias current vs. Vicm at V_{CC} = 3 V

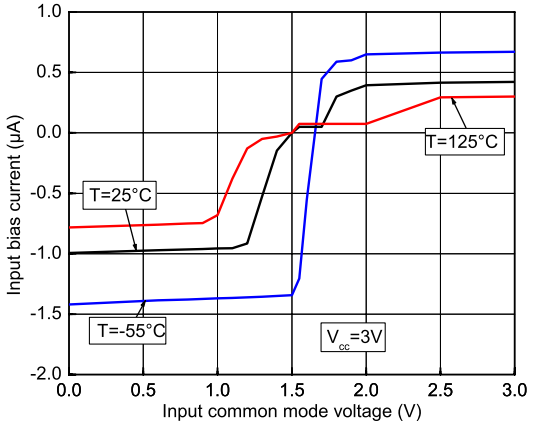


Figure 4. Input bias current vs. Vicm at V_{CC} = 4 V

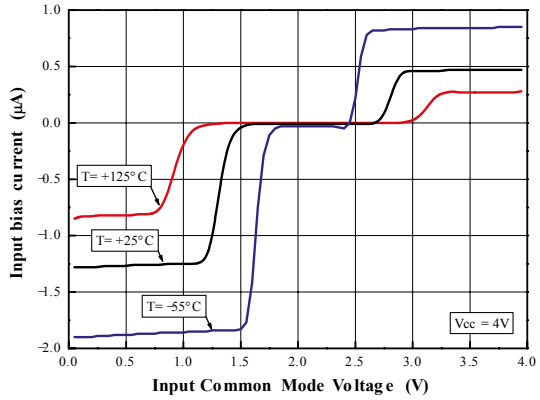


Figure 5. Input bias current vs. Vicm at V_{CC} = 16 V

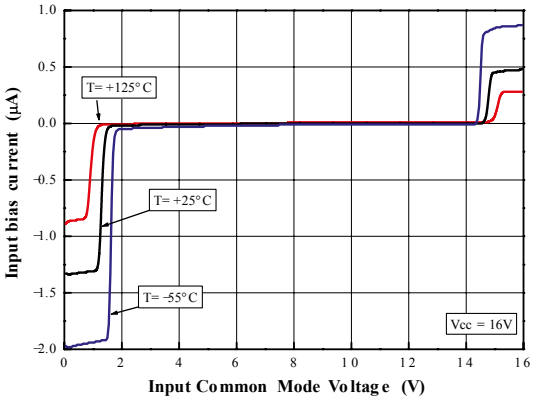


Figure 6. Gain bandwidth product vs. Vicm at V_{CC} = 10 V

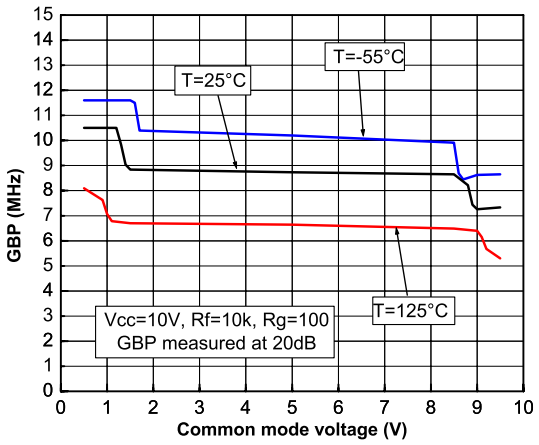


Figure 7. Supply current vs. Vicm in follower configuration at V_{CC} = 3 V

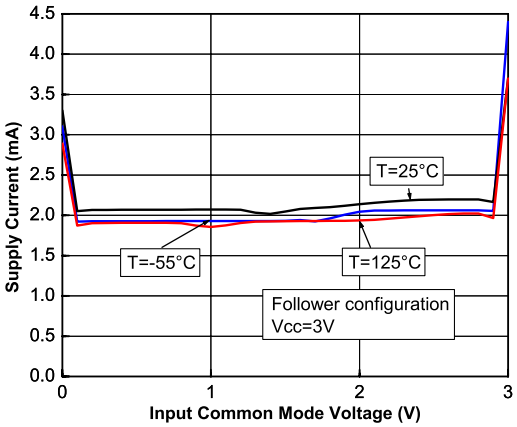


Figure 8. Supply current vs. Vicm in follower configuration at V_{CC} = 16 V

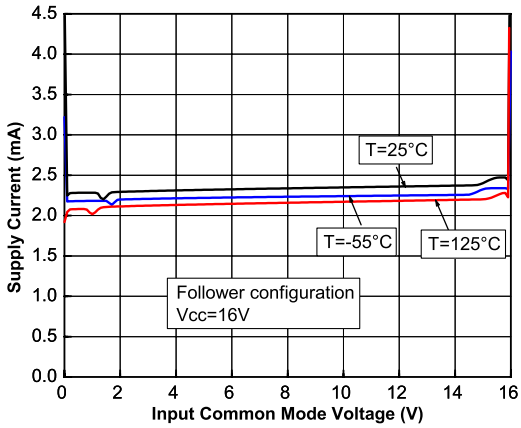


Figure 9. Supply current vs. supply voltage at Vicm = V_{CC}/2

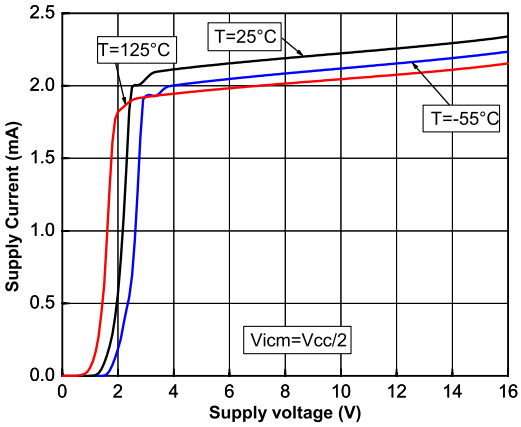


Figure 10. Output current vs. supply voltage at Vicm = V_{CC}/2

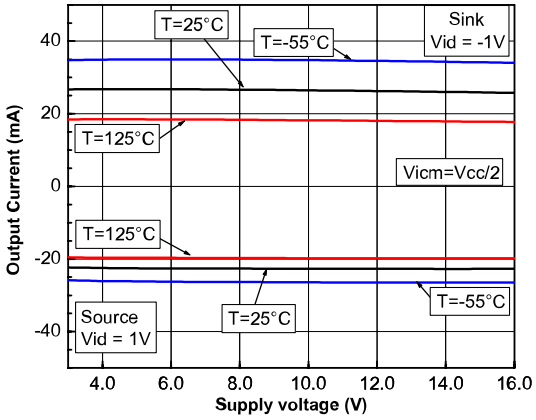


Figure 11. Output current vs. output voltage at V_{CC} = 3 V

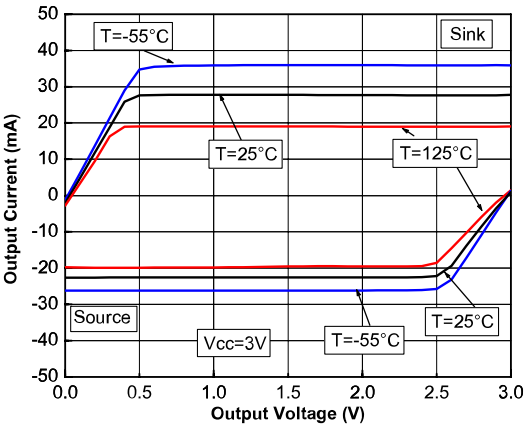


Figure 12. Output current vs. output voltage at V_{CC} = 16 V

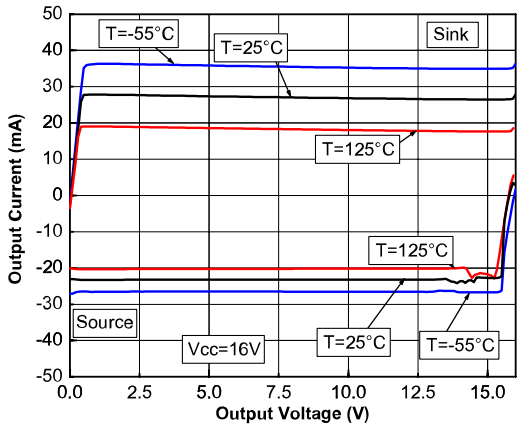


Figure 13. Differential input voltage vs. output voltage at V_{CC} = 3 V

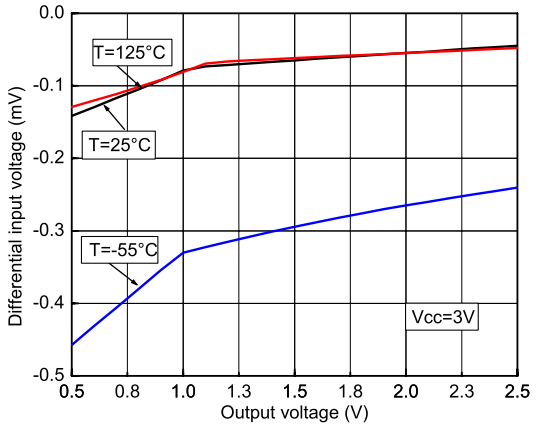


Figure 14. Differential input voltage vs. output voltage at V_{CC} = 16 V

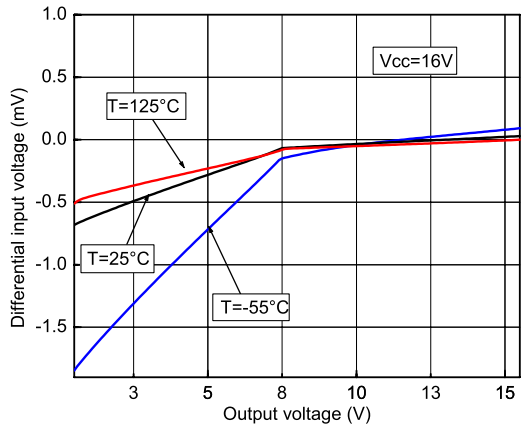


Figure 15. Noise vs. Vicm at V_{CC} = 10 V

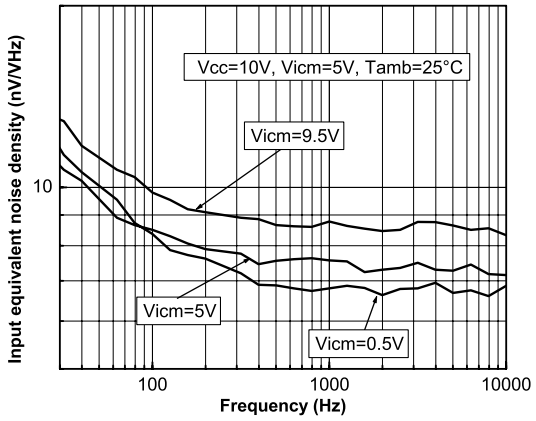


Figure 16. Noise vs. frequency at V_{CC} = 3 V and V_{CC} = 16 V

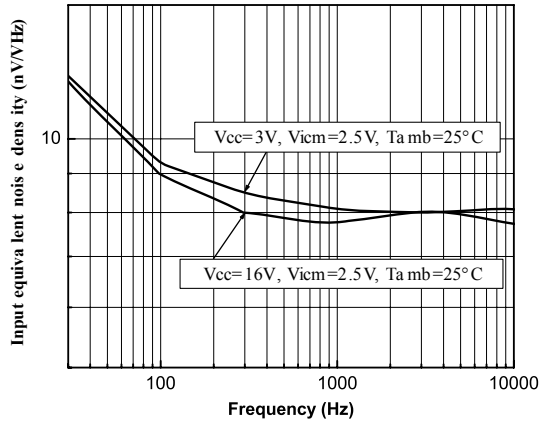


Figure 17. Voltage gain and phase vs. frequency at Vicm = 1.5 V and V_{CC} = 3 V

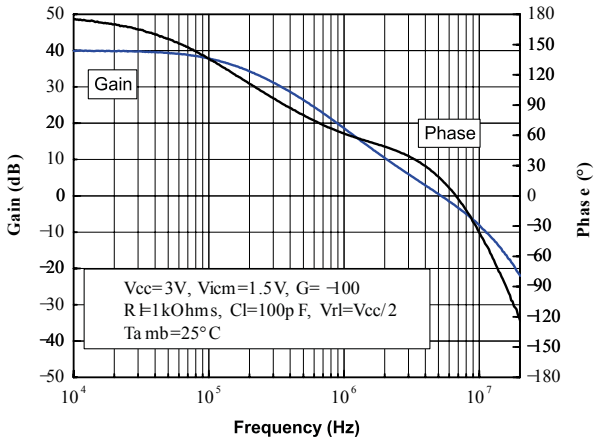


Figure 18. Voltage gain and phase vs. frequency at Vicm = 2.5 V and V_{CC} = 3 V

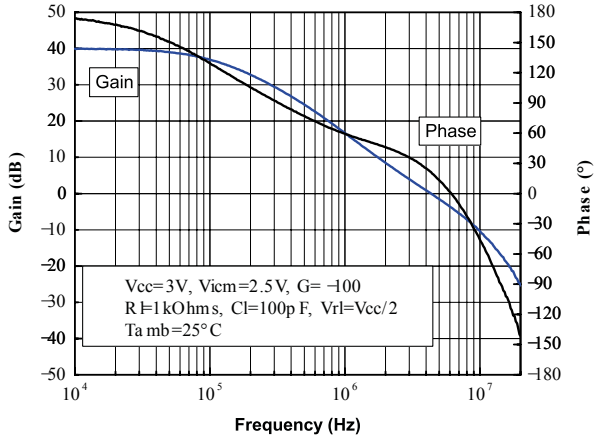


Figure 19. Voltage gain and phase vs. frequency at Vicm = 0.5 V and V_{CC} = 3 V

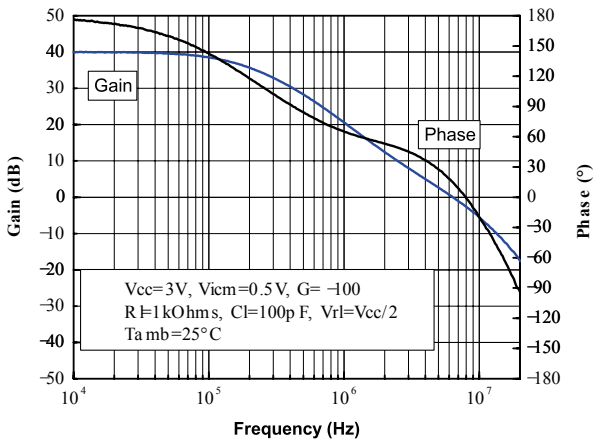


Figure 20. Voltage gain and phase vs. frequency at Vicm = 8 V and V_{CC} = 16 V

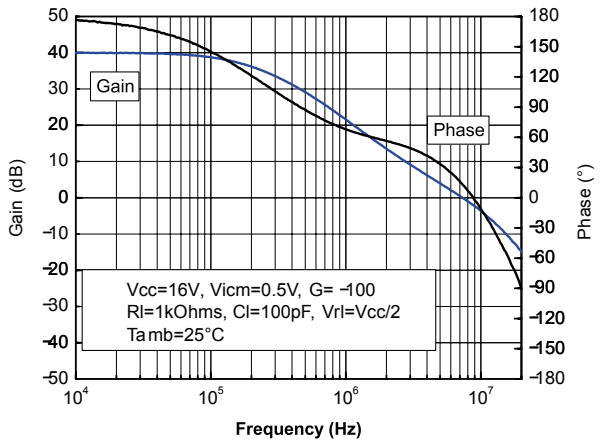


Figure 21. Voltage gain and phase vs. frequency at Vicm = 15.5 V and V_{CC} = 16 V

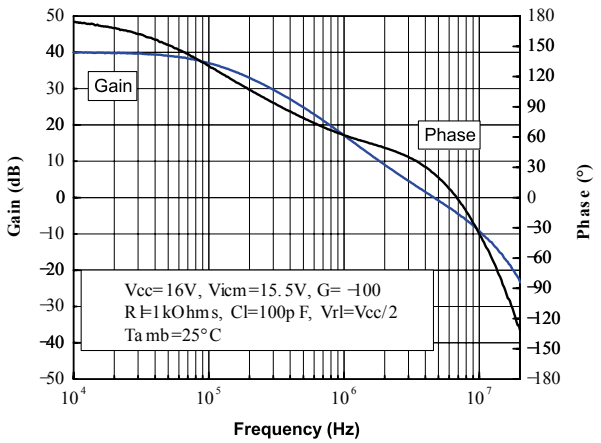


Figure 22. Voltage gain and phase vs. frequency at Vicm = 0.5 V and V_{CC} = 16 V

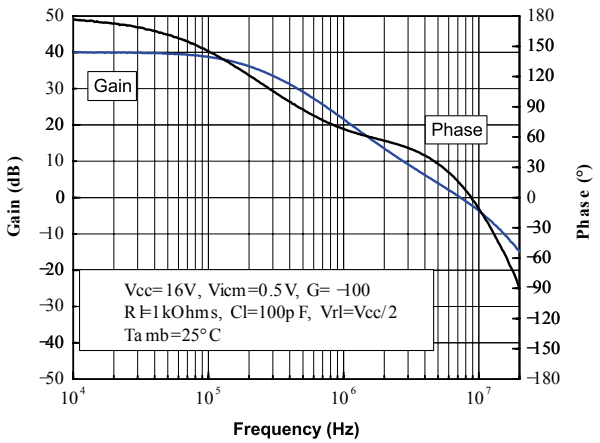


Figure 23. Inverting large signal pulse response at V_{CC} = 3 V, 25°C

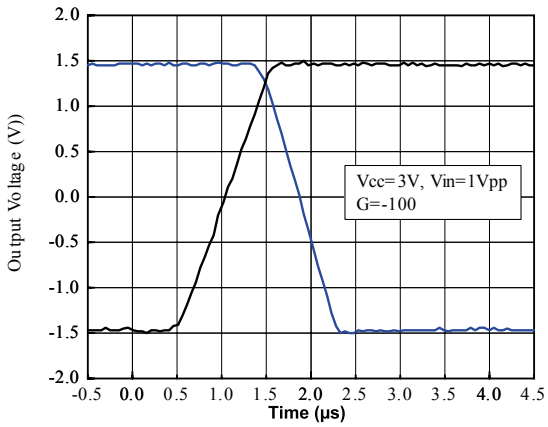
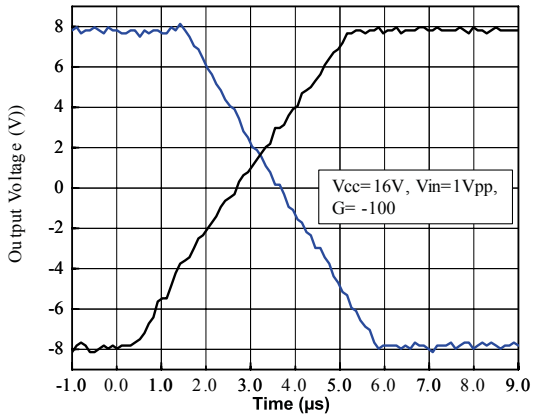


Figure 24. Inverting large signal pulse response at V_{CC} = 16 V, 25°C



4 Radiations

4.1 Introduction

Table 5 summarizes the radiation performance of the RHF43B.

Table 5. Radiations

Type	Features		Value	Unit
TID	High-dose rate		300	krad
	Low-dose rate		300	
	ELDRS		300	
Heavy ions	SEL immunity (at 125 °C) up to:		110	MeV.cm²/mg
	SET characterized	Inverting	LET_{th} = 1	MeV.cm²/mg
			σ = 2.00E-03	cm²/device
		Non-inverting	LET_{th} = 0	MeV.cm²/mg
			σ = 1.00E-03	cm²/device
		Subtracting	LET_{th} = 0	MeV.cm²/mg
			σ = 2.00E-03	cm²/device

4.2 Total ionizing dose (TID)

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

The RHF43B is RHA QML-V qualified, and is tested and characterized in full compliance with the MIL-STD-883 specification. It using 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.

4.3 Heavy ions

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

5 Achieving good stability at low gain

At low frequencies, the RHF43B can be used in a low gain configuration as shown in Figure 25. At lower frequencies, the stability is not affected by the value of the gain, which can be set close to 1 V/V (0 dB), and is reduced to its simplest expression G1 = 1+Rfb/Rg. Therefore, an R-C cell is added in the gain network so that the gain is increased (up to 5) at higher frequencies (where the stability of the amplifier could be affected). At higher frequencies, the gain becomes G2 = 1+Rfb/(Rg//R).

Figure 25. Low gain configuration

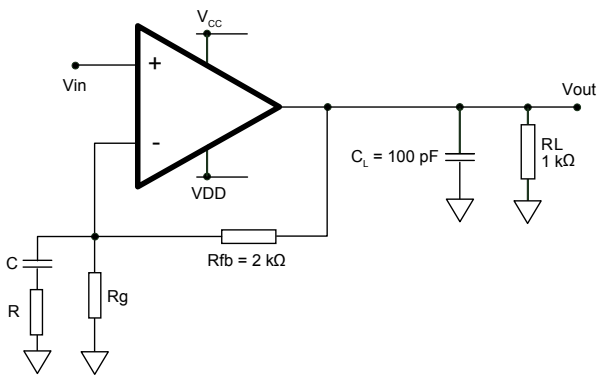
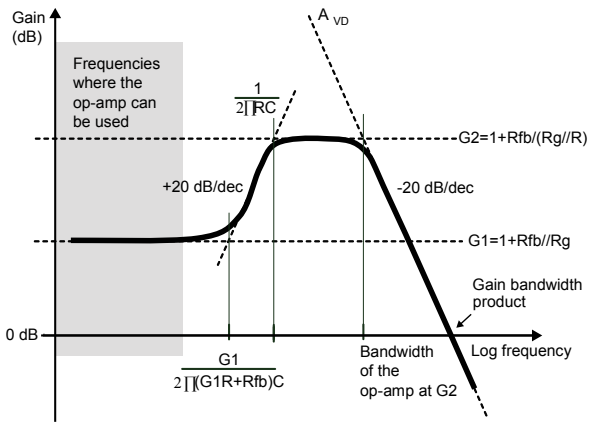


Figure 26. Closed-loop gain



Rg becomes a complex impedance. The closed-loop gain features a variation in frequency and can be expressed as Equation 1.

Equation 1

$$Gain = G1\frac{1 + jC\omega \times \left(\frac{G1R + Rfb}{G1}\right)}{1 + jCR\omega}$$

Where a pole appears at 1/2πRC and a zero at G1/2π(G1R+Rfb)C. The frequency can be plotted as shown in Figure 26.

Table 6. External components versus low-frequency gain

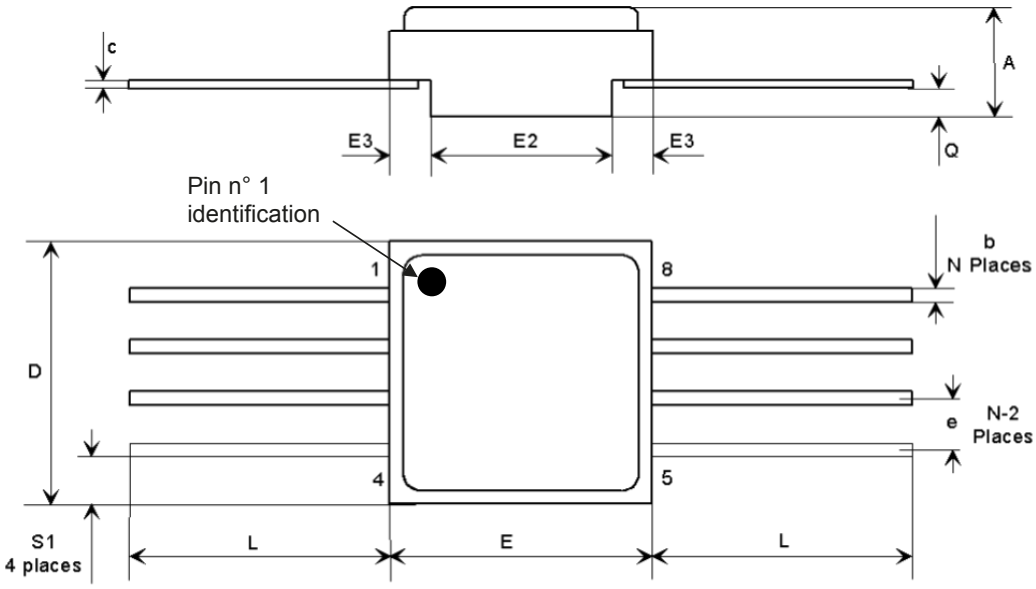
G1 (V/V)	R (Ω)	C (nF)	Rg (Ω)	Rfb (Ω)
1.1	510	1	20 k	2 k
2			2 k	
3			1 k	
4			750	2.4 k
5	Not connected	Not connected	820	3.3 k

6 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.

6.1 Ceramic Flat-8 package information

Figure 27. Ceramic Flat-8 package outline



Note: The upper metallic lid is not electrically connected to any pins, nor to the IC die inside the package. Connecting unused pins or metal lid to ground or to the power supply will not affect the electrical characteristics.

Table 7. Ceramic Flat-8 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		

7 Ordering information

Table 8. Ordering information

Order code	SMD pin	Quality level	Package	Lead finish	Marking [1]	Packing
RHF43BK1	-	Engineering model	Flat-8	Gold	RHF43BK1	Strip pack
RHF43BK-01V	5962F0623701VXC	QML-V flight			5962F0623701VXC	

1. *Specific marking only. Complete marking includes the following: SMD pin (as indicated in above table), 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 engineering model: EM xyywwz

Where:

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

yy = last two digits of the year

ww = week digits

z = lot index of 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 9. 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

Quality level	Item
QML-V Flight	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 10. Document revision history

Date	Revision	Changes
21-May-2007	1	First public release
10-Dec-2007	2	Changed name of pins on pinout diagram on cover page Modified supply current values over temperature range in electrical characteristics. Power dissipation removed from AMR table.
29-Jan-2008	3	Added ELRS-free rad-hard design in description on cover page Modified description of heavy ion latch-up (SEL) immunity parameter in Table 2.
11-May-2009	4	Updated radiation immunity in Features and in Table 2. Updated smb reference in Features.
15-Oct-2009	5	Updated test conditions for Avd vs. Vicm in Table 4 and Table 5. Updated input current and voltage noise in Table 4. Updated order codes in Table 9.
30-Mar-2010	6	Added Figure 4 and Figure 5. Added information for ambient temperature in Table 4 and Table 5. Added Section 4: "Achieving good stability at low gain".
20-Aug-2010	7	Corrected "L" dimension in Table 8.
27-Jul-2011	8	Added note underneath Figure 27 and in the "Pin connections" diagram on the cover page.
08-Nov-2012	9	Features: added silhouette. Added Table 1: Device summary. Table 2: removed ±9 from “Supply voltage”; updated footnote1. Added Figure 6 and Figure 15. Figure 17 through to Figure 22: modified titles. Table 9: Ordering information: updated table and removed order code RHF43BK-01V.
06-Feb-2015	10	Replaced package name with “Flat-8S” instead of “Flat-8” Added marker to show the position of pin 1 on package silhouette, pinout and drawing. Updated Features, Table 1: Device summary and Section 6: Ordering information. Updated note concerning products in die form and QML-Q versions on the cover page. Table 2: Absolute maximum ratings (AMR): transferred radiation information to Table 6: Radiations. Table 8: updated dimension "L". Added Section 3: Radiations and Section 7: "Other information".
24-Mar-2015	11	Replaced Flat-8S silhouette, pinout, and package with Flat-8 silhouette, pinout, and package.
06-Apr-2016	12	Updated document layout. Table 1: "Device summary": updated footnote 1, SMD = standard microcircuit drawing.
05-Dec-2017	13	Updated the description in cover page. Deleted EPPL parameter in the Table 1: "Device summary".
16-Apr-2018	14	Updated figure on the cover page.
23-Feb-2024	15	Updated output source current test condition in Table 3, Table 4, Figure 10, Figure 11 and Figure 12.

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