# RHF1201

## Rad-hard 12-bit 50 Msps A/D converter

## Features

- Qml-V qualified, smd 5962-05217
- Rad hard: 300 kRad(Si) TID
- Failure immune (SEFI) and latchup immune (SEL) up to 120 MeV-cm$^2$/mg at 2.7 V and 125° C
- Hermetic package
- Wide sampling range
- Tested at 50 Msps
- Optimwatt$^{TM}$ adaptive power: 44 mW at 0.5 Msps, 100 mW at 50 Msps
- Optimized for 2 $V_{pp}$ differential input
- SFDR up to 75 dB at $F_S$ = 50 Msps, $F_{in}$ = 15 MHz
- 2.5 V/3.3 V compatible digital I/O
- Built-in reference voltage with external bias capability

## Applications

- Digital communication satellites
- Space data acquisition systems
- Aerospace instrumentation
- Nuclear and high-energy physics

**Ceramic SO-48 package**




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

## Description

The RHF1201 is a 12-bit 50 Msps sampling frequency analog-to-digital converter that uses pure (ELDRS-free) CMOS 0.25 µm technology combining high performance, radiation robustness and very low power consumption. The device is based on a pipeline structure and digital error correction to provide excellent static linearity. Specifically designed to optimize the speed power consumption ratio, the RHF1201 integrates a proprietary track-and-hold structure making it ideal for IF-sampling applications up to 150 MHz. A voltage reference network is integrated in the circuit to simplify the design and minimize external components. A tri-state capability is available on the outputs to allow common bus sharing. Output data can be coded in two different formats. A Data Ready signal, raised when the data is valid on the output, can be used for synchronization purposes.

**Table 1. Device summary**

| Order code [1] | SMD pin | Quality level | Package | Lead finish | Packing | Marking | EPPL |
|---|---|---|---|---|---|---|---|
| RHF1201KSO1 | - | Engineering model | SO-48 | Gold | Strip pack | RHF1201KSO1 | - |
| RHF1201KSO-01V | 5962F0521701VXC | QMLV-Flight | SO-48 | Gold | Strip pack | 5962F0521701VXC | - |

1. Contact your ST sales office for information about the specific conditions for products in die form and for information about SMD packages.

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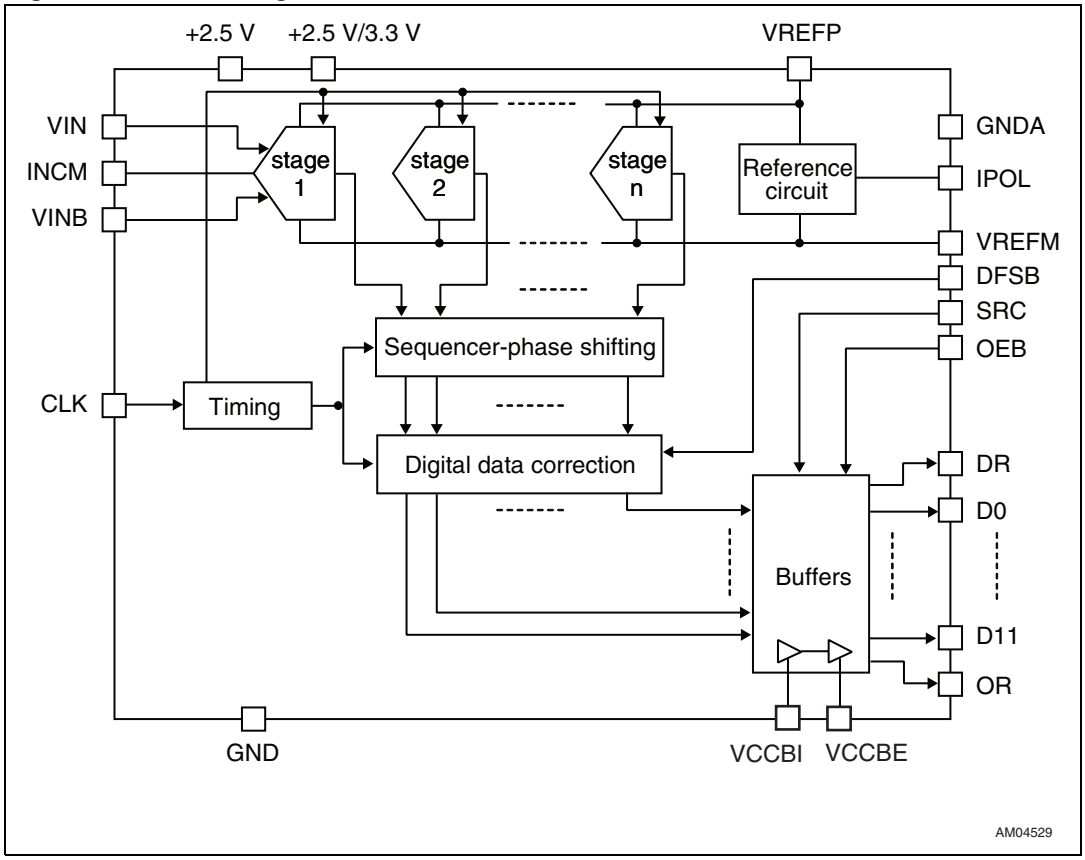
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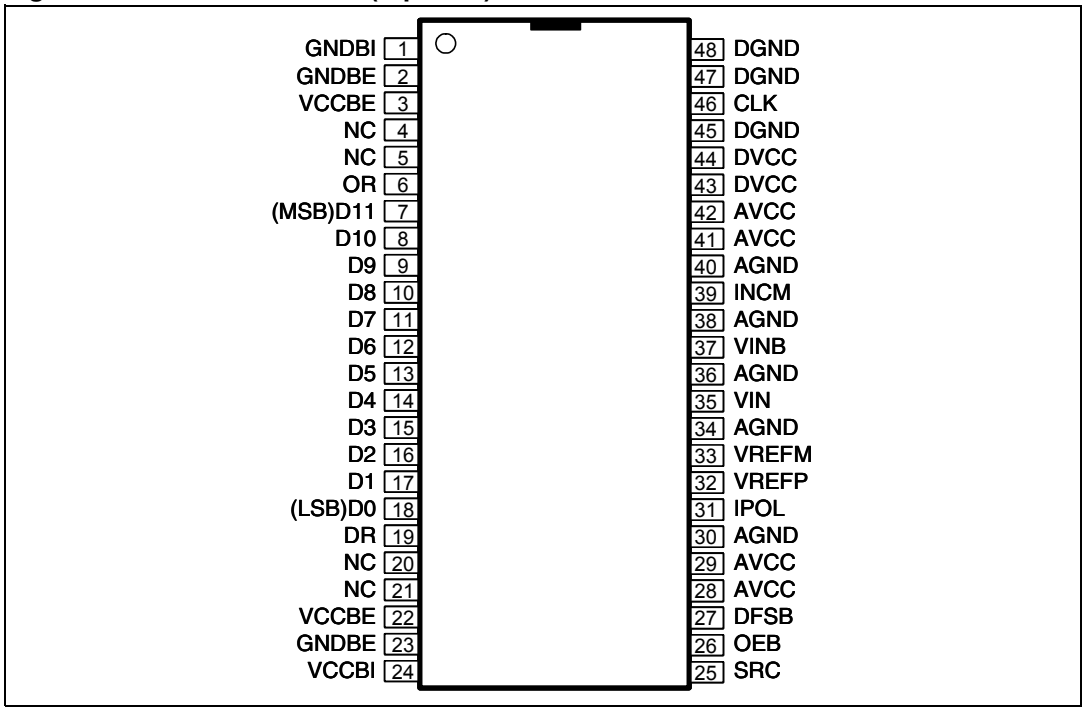
# 1 Block diagram

**Figure 1. Block diagram**



# 2 Pin connections

**Figure 2. Pin connections (top view)**



# 3 Pin descriptions

**Table 2. Pin descriptions**

| Pin | Name | Description | Note |
|---|---|---|---|
| 1 | GNDBI | Digital buffer ground | 0 V |
| 2 | GNDBE | Digital buffer ground | 0 V |
| 3 | VCCBE | Digital buffer power supply | 2.5 V/3.3 V |
| 4 | | NC | Not connected to the dice |
| 5 | | NC | Not connected to the dice |
| 6 | OR | Out-of-range output | CMOS output (2.5 V/3.3 V) |
| 7 | D11(MSB) | Most significant bit output | CMOS output (2.5 V/3.3 V) |
| 8 | D10 | Digital output | CMOS output (2.5 V/3.3 V) |
| 9 | D9 | Digital output | CMOS output (2.5 V/3.3 V) |
| 10 | D8 | Digital output | CMOS output (2.5 V/3.3 V) |
| 11 | D7 | Digital output | CMOS output (2.5 V/3.3 V) |
| 12 | D6 | Digital output | CMOS output (2.5 V/3.3 V) |
| 13 | D5 | Digital output | CMOS output (2.5 V/3.3 V) |
| 14 | D4 | Digital output | CMOS output (2.5 V/3.3 V) |
| 15 | D3 | Digital output | CMOS output (2.5 V/3.3 V) |
| 16 | D2 | Digital output | CMOS output (2.5 V/3.3 V) |
| 17 | D1 | Digital output | CMOS output (2.5 V/3.3 V) |
| 18 | D0(LSB) | Least significant bit output | CMOS output (2.5 V/3.3 V) |
| 19 | DR | Data ready output | CMOS output (2.5 V/3.3 V) |
| 20 | | NC | Not connected to the dice |
| 21 | | NC | Not connected to the dice |
| 22 | VCCBE | Digital buffer power supply | 2.5 V/3.3 V |
| 23 | GNDBE | Digital buffer ground | 0 V |
| 24 | VCCBI | Digital buffer power supply | 2.5 V |
| 25 | SRC | Slew rate control input | 2.5 V/3.3 V CMOS input |
| 26 | OEB | Output Enable input | 2.5 V/3.3 V CMOS input |
| 27 | DFSB | Data Format Select input | 2.5 V/3.3 V CMOS input |
| 28 | AVCC | Analog power supply | 2.5 V |
| 29 | AVCC | Analog power supply | 2.5 V |
| 30 | AGND | Analog ground | 0 V |
| 31 | IPOL | Analog bias current input | |
| 32 | VREFP | Top voltage reference | Can be internal or external |
| 33 | VREFM | Bottom voltage reference | External |
| 34 | AGND | Analog ground | 0 V |
| 35 | VIN | Analog input | Optimized for $1V_{pp}$ |
| 36 | AGND | Analog ground | 0 V |
| 37 | VINB | Inverted analog input | Optimized for $1V_{pp}$ |
| 38 | AGND | Analog ground | 0 V |
| 39 | INCM | Input common mode | Can be internal or external |
| 40 | AGND | Analog ground | 0 V |
| 41 | AVCC | Analog power supply | 2.5 V |
| 42 | AVCC | Analog power supply | 2.5 V |
| 43 | DVCC | Digital power supply | 2.5 V |
| 44 | DVCC | Digital power supply | 2.5 V |
| 45 | DGND | Digital ground | 0 V |
| 46 | CLK | Clock input | 2.5 V compatible CMOS input |
| 47 | DGND | Digital ground | 0 V |
| 48 | DGND | Digital ground | 0 V |

# 4 Equivalent circuits

**Figure 3. Analog inputs**

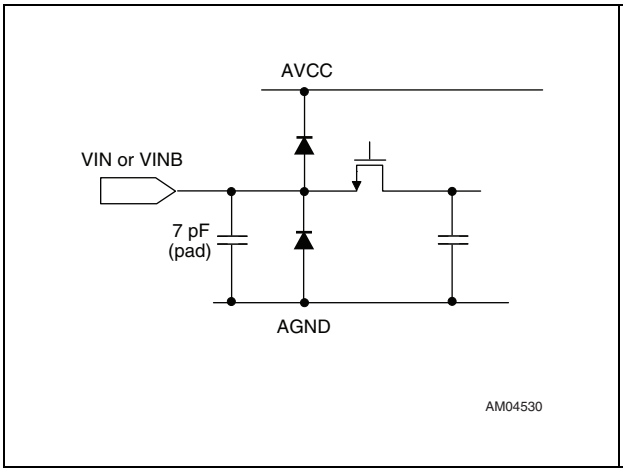



**Figure 4. Output buffers**

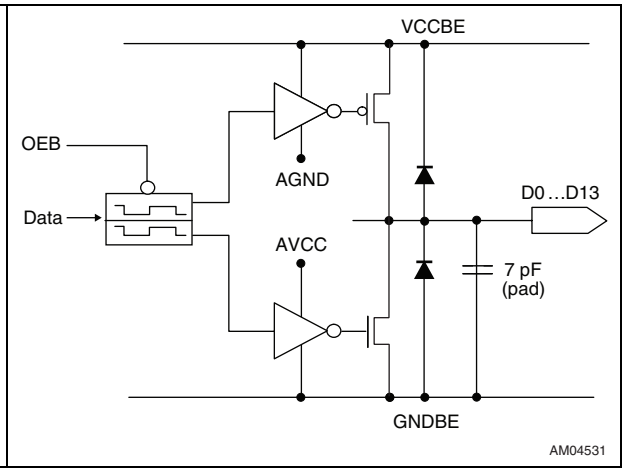



**Figure 5. Clock input**

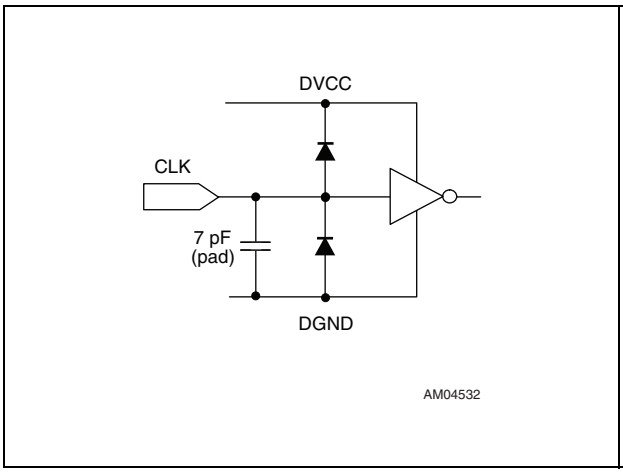



**Figure 6. Data format input**

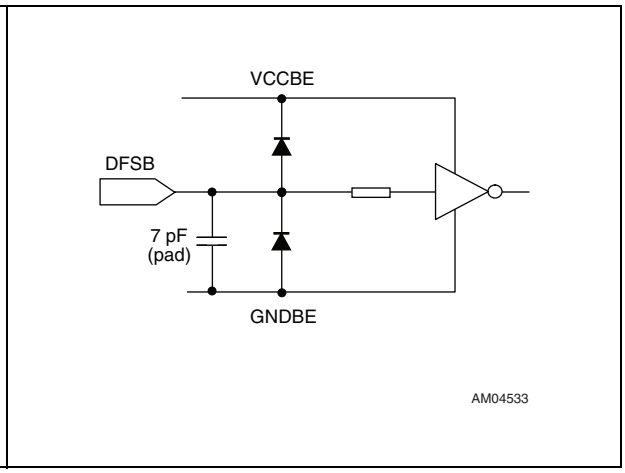



**Figure 7. Slew rate control input**

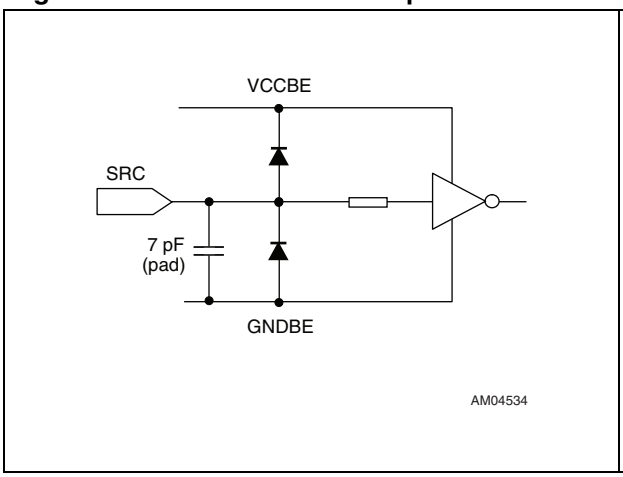



**Figure 8. Output enable input**

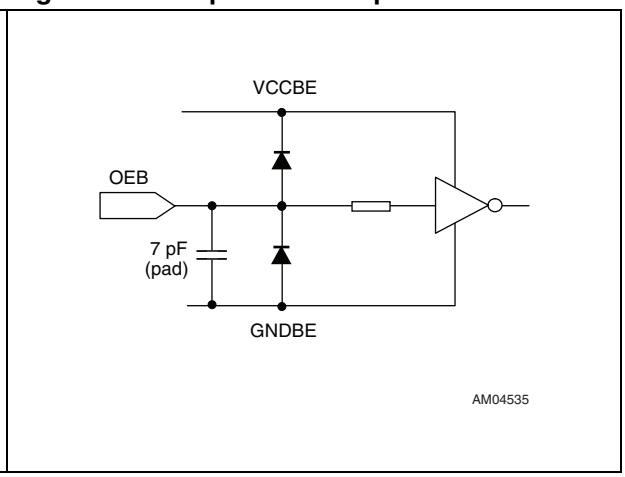


**Figure 9. VREFP and INCM input**

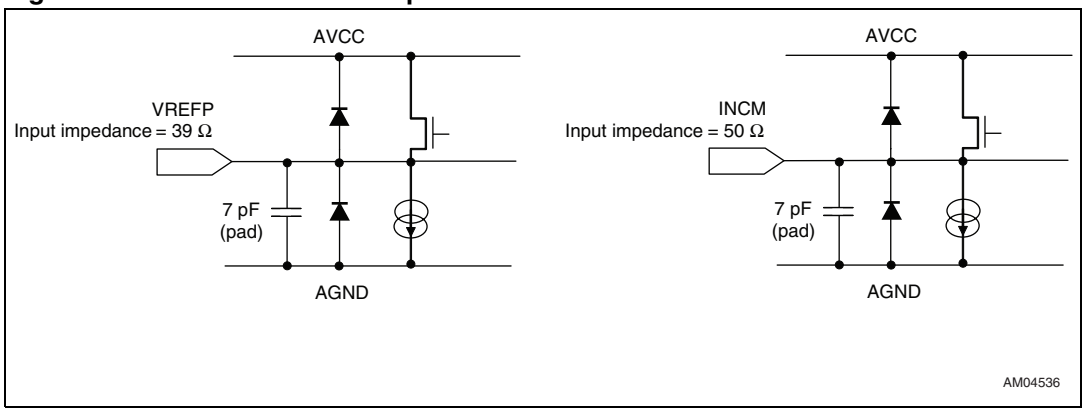
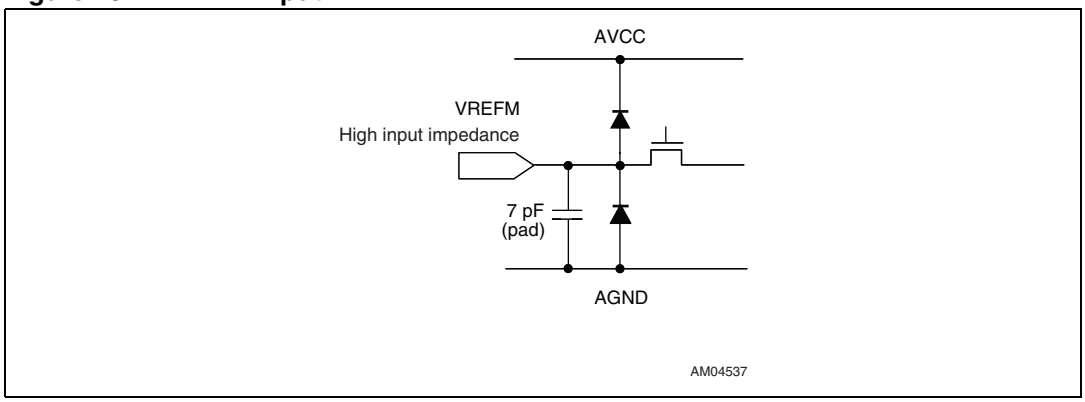



**Figure 10. VREFM input**



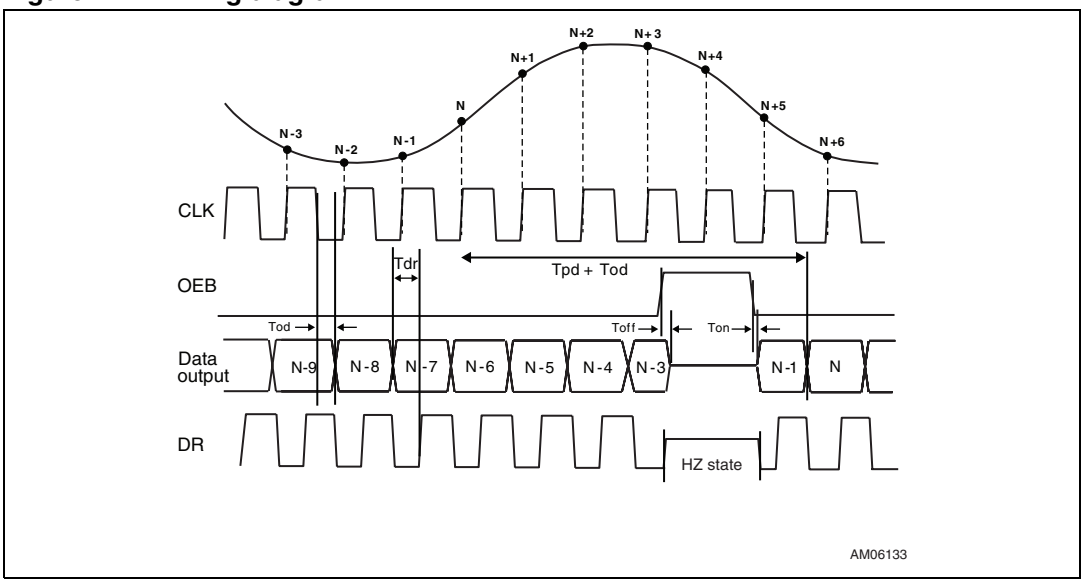
# 5 Timing characteristics

**Table 3. Timing table**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| DC | Clock duty cycle(1) | $F_S$ = 45 Msps | 45 | 50 | 65 | % |
| $T_{od}$ | Data output delay (2) (fall of clock to data valid) | 10 pF load | 4 | 5 | 6 | ns |
| $T_{pd}$ | Data pipeline delay (2) | | 5.5 | 5.5 | 5.5 | cycles |
| $T_{dr}$ | Data ready rising edge delay after data change (3) | Duty cycle = 50% | | 0.5 | | cycles |
| $T_{on}$ | Falling edge of OEB to digital output valid data | | | 1 | 3 | ns |
| $T_{off}$ | Rising edge of OEB to digital output tri-state | | | 1 | 3 | ns |
| $T_{rD}$ | Data rising time(4) | 5 pF load, SRC = 0 | | 2.8 | | ns |
| | | 5 pF load, SRC = 1 | | 5.7 | | ns |
| $T_{fD}$ | Data falling time(4) | 5 pF load, SRC = 0 | | 2 | | ns |
| | | 5 pF load, SRC = 1 | | 4.3 | | ns |

1. See *Figure 34*.
2. Guaranteed by design.
3. Tdr is linked to the duty cycle, conditioned by the duration of the low level of DR signal.
4. See *Figure 35* and *Figure 36*.

**Figure 11. Timing diagram**




The input signal is sampled on the rising edge of the clock while the digital outputs are synchronized on the falling edge of the clock. The duty cycles on DR and CLK are the same.

# 6 Absolute maximum ratings and operating conditions

**Table 4. Absolute maximum ratings**

| Symbol | Parameter | Values | Unit |
|---|---|---|---|
| $AV_{CC}$ | Analog supply voltage | 3.3 | V |
| $DV_{CC}$ | Digital supply voltage | 3.3 | V |
| $V_{CCBI}$ | Digital buffer supply voltage | 3.3 | V |
| $V_{CCBE}$ | Digital buffer supply voltage | 3.6 | V |
| $V_{IN}$ $V_{INB}$ | Analog inputs: bottom limit –> top limit | -0.6 V –> $AV_{CC}$+0.6 V | V |
| $V_{REFP}$ $V_{INCM}$ | External references: bottom limit –> top limit | -0.6 V –> $AV_{CC}$+0.6 V | V |
| $I_{Dout}$ | Digital output current | -100 to 100 | mA |
| $T_{stg}$ | Storage temperature | -65 to +150 | °C |
| $R_{thjc}$ | Thermal resistance junction to case | 22 | °C/W |
| $R_{thja}$ | Thermal resistance junction to ambient | 125 | °C/W |
| ESD | HBM (human body model)(1) | 2 | kV |

1. 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 5. Operating conditions**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $AV_{CC}$ | Analog supply voltage | 2.3 | 2.5 | 2.7 | V |
| $DV_{CC}$ | Digital supply voltage | 2.3 | 2.5 | 2.7 | V |
| $V_{CCBI}$ | Digital internal buffer supply | 2.3 | 2.5 | 2.7 | V |
| $V_{CCBE}$ | Digital output buffer supply | 2.3 | 2.5 | 3.4 | V |
| $V_{REFP}$ | Top external reference voltage | 0.5 | | 1.4 | V |
| $V_{REFM}$ | Bottom external reference voltage | 0 | | 0.5 | V |
| $V_{INCM}$ | Forced common mode voltage | 0.2 | | 1.1 | V |
| $V_{IN}$ | $V_{IN}$ maximum voltage versus GND | | 1.6 | | V |
| | $V_{IN}$ minimum voltage versus GND | | -0.2 | | V |
| $V_{INB}$ | $V_{INB}$ maximum voltage versus GND | | 1.6 | | V |
| | $V_{INB}$ minimum voltage versus GND | | -0.2 | | V |
| DFSB | Digital inputs(1) | GND | | $V_{CCBE}$ | V |
| SRC | | | | | |
| OEB | | | | | |

1. See *Table 9* for thresholds.

# 7 Electrical characteristics (unchanged after 300 kRad)

Unless otherwise specified, the test conditions in the following tables are:
$AV_{CC} = DV_{CC} = V_{CCBI} = V_{CCBE} = 2.5$ V, $F_S = 50$ Msps, differential input configuration, $F_{in} = 15$ MHz, $V_{REFP}$ = internal, $V_{REFM} = 0$ V, $T_{amb} = 25°$ C.

**Table 6. Analog inputs**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{IN}$-$V_{INB}$ | Full-scale input differential voltage(1) (FS)(2) | | | 2 | | $V_{p-p}$ |
| $C_{in}$ | Input capacitance | | | 7.0 | | pF |
| $R_{in}$ | Input resistance | | | 5 | | kΩ |
| ERB | Effective resolution bandwidth(1) | | | 95 | | MHz |

1. See *Chapter 8: Definitions of specified parameters on page 29* for more information.
2. Optimized differential input: 2 Vp-p. The optimized single-ended input is below 1.5 Vp-p.

**Table 7. Internal reference voltage**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{REFP}$ | Top internal reference voltage(1) | $AV_{CC}$ =2.5 V | 0.79 | 0.95 | 1.16 | V |
| $V_{INCM}$ | Input common mode voltage(1) | $AV_{CC}$ =2.5 V | 0.40 | 0.52 | 0.67 | V |
| TempCo | Temperature coefficient of $V_{REFP}$(1) | $T_{min} < T_{amb} < T_{max}$ | | 0.12 | | mV/°C |
| | Temperature coefficient of INCM(1) | $T_{min} < T_{amb} < T_{max}$ | | 0.12 | | mV/°C |

1. Not fully tested over the temperature range. Guaranteed by sampling.

**Table 8. Accuracy at Fs = 50 Msps**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| OE | Offset error | $F_{in}$ = 2 MHz, $V_{IN}$ = 1Vp-p | | +/-0.3 | | LSB |
| DNL | Differential non-linearity(1) | $F_{in}$ = 2 MHz, $V_{IN}$ = 1Vp-p | | +/-0.5 | | LSB |
| INL | Integral non-linearity(1) | $F_{in}$ = 2 MHz, $V_{IN}$ = 1Vp-p | | +/-1.7 | | LSB |
| - | Monotonicity and no missing codes | | Guaranteed | | | |

1. See *Chapter 8* for more information.

**Table 9. Digital inputs and outputs**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Clock input** | | | | | | |
| CT | Clock threshold | $DV_{CC}$ = 2.5 V | | 1.25 | | V |
| CA | Clock amplitude (DC component = 1.25 V) | Square clock $DV_{CC}$ = 2.5 V | 0.8 | | 2.5 | Vp-p |
| **Digital inputs** | | | | | | |
| $V_{IL}$ | Logic "0" voltage | | | 0 | 0.25 x $V_{CCBE}$ | V |
| $V_{IH}$ | Logic "1" voltage | | 0.75 x $V_{CCBE}$ | $V_{CCBE}$ | | V |
| **Digital outputs** | | | | | | |
| $V_{OL}$ | Logic "0" voltage | $I_{OL}$ = -1 mA | | 0 | 0.2 | V |
| $V_{OH}$ | Logic "1" voltage | $I_{OH}$ = 1 mA | $V_{CCBE}$ - 0.2 V | | | V |
| $I_{OZ}$ | High impedance leakage current | OEB set to $V_{IH}$ | -15 | | 15 | µA |

**Table 10. Dynamic characteristics**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| SFDR | Spurious free dynamic range | $F_{in}$ = 15 MHz | | -75 | -63 | dBc |
| | | $F_{in}$ = 95 MHz | | -70 | | |
| | | $F_{in}$ = 145 MHz | | -57 | | dBc |
| SNR | Signal to noise ratio | $F_{in}$ = 15 MHz | 59 | 63 | | dB |
| | | $F_{in}$ = 95 MHz | | 60 | | dB |
| | | $F_{in}$ = 145 MHz | | 59 | | |
| THD | Total harmonics distortion | $F_{in}$ = 15 MHz | | -76 | -64 | dB |
| | | $F_{in}$ = 95 MHz | | -72 | | dB |
| | | $F_{in}$ = 145 MHz | | -58 | | |
| SINAD | Signal to noise and distortion ratio | $F_{in}$ = 15 MHz | 58 | 63 | | dB |
| | | $F_{in}$ = 95 MHz | | 60 | | |
| | | $F_{in}$ = 145 MHz | | 56.5 | | dB |
| ENOB | Effective number of bits | $F_{in}$ = 15 MHz | 9.7 | 10.3 | | bits |
| | | $F_{in}$ = 95 MHz | | 9.5 | | bits |
| | | $F_{in}$ = 145 MHz | | 9.1 | | |
| PSRR | Power supply rejection ratio | F = 260 kHz<br>Fs = 2 MHz<br>$R_{pol}$ = 200 k Ω<br>each power supply at 2.5 V decoupled by 10 µF//470 nF | | 93 | | dB |

**Figure 12. Differential input configuration**

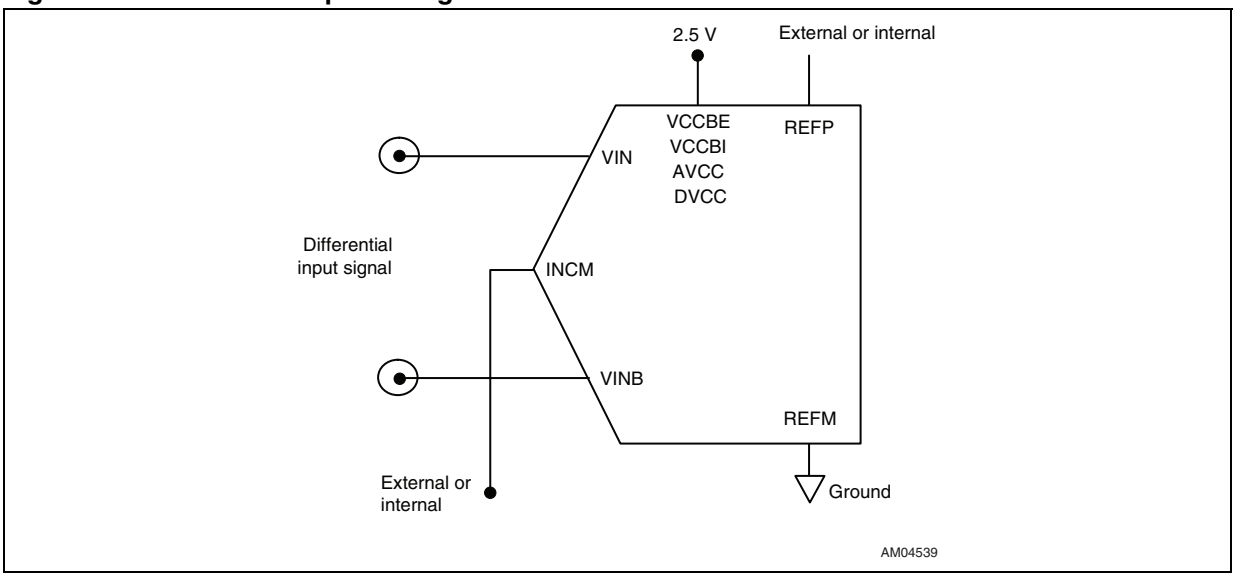



**Figure 13. ENOB vs. diff. input, square clock**

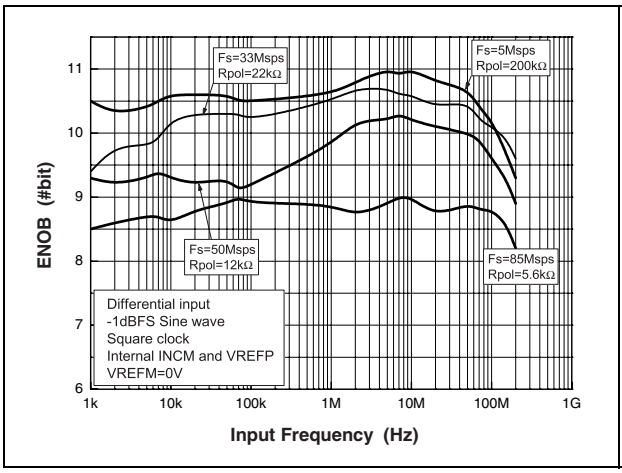



**Figure 14. SINAD vs. diff. input, square clock**

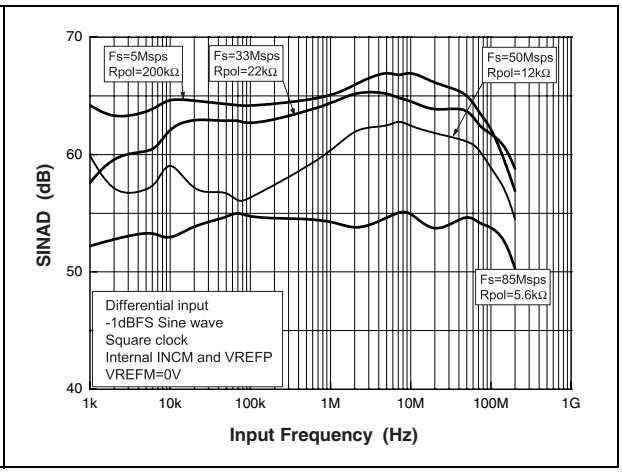



**Figure 15. THD vs. diff. input, square clock**

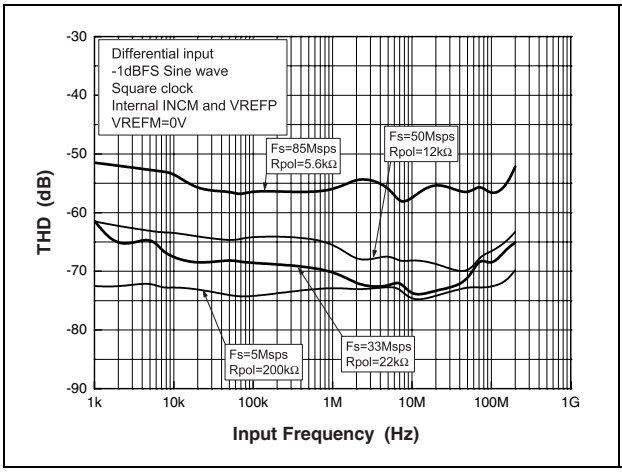



**Figure 16. SNR vs. diff. input, square clock**

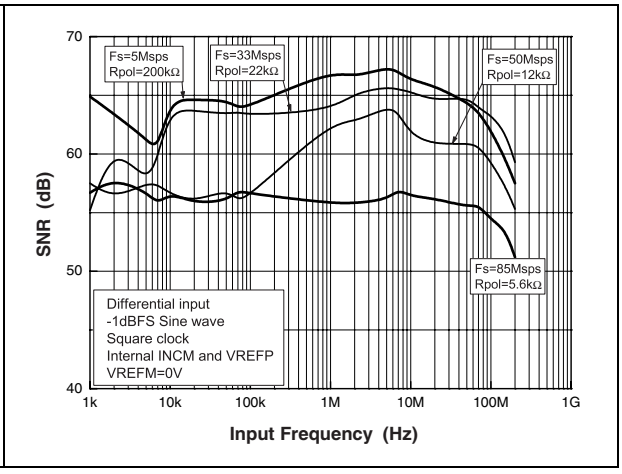


**Figure 17. SFDR vs. diff. input, square clock**

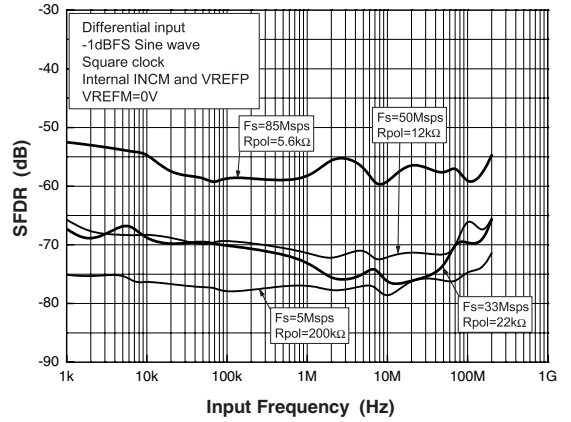



**Figure 18. ENOB vs diff. input, sine clock**

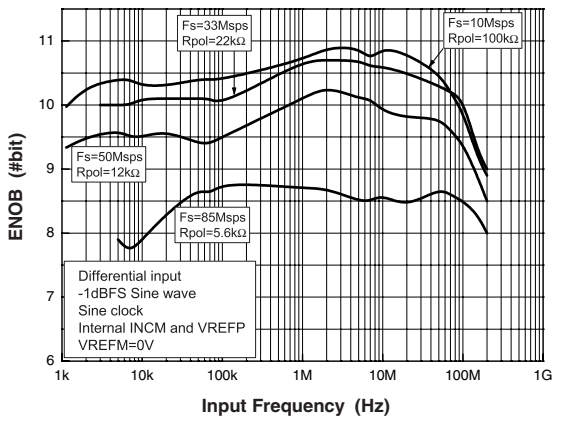



**Figure 19. SINAD vs. diff. input, sine clock**

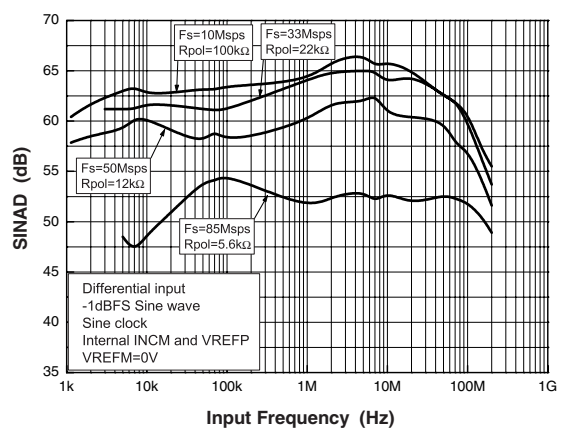



**Figure 20. THD vs. diff. input, sine clock**

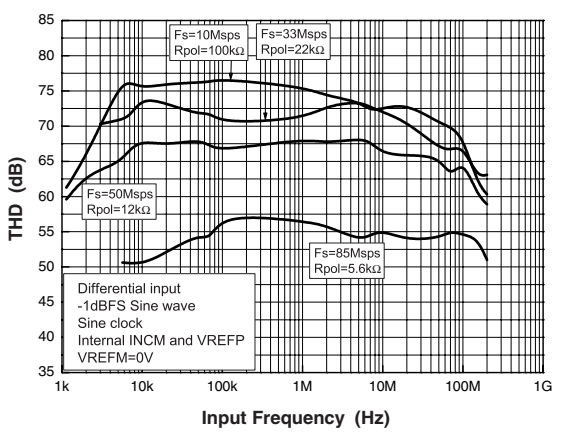



**Figure 21. SNR vs. diff. input, sine clock**

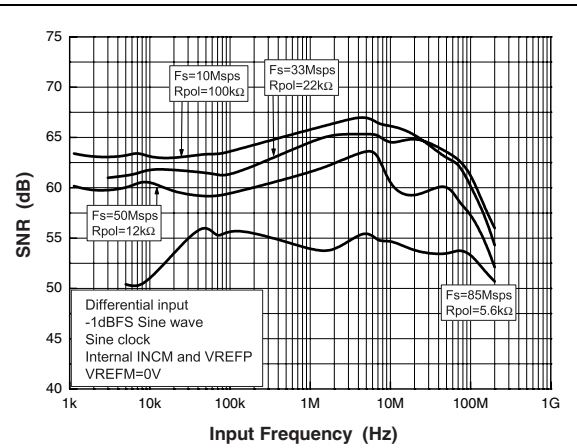



**Figure 22. SFDR vs. diff. input, sine clock**

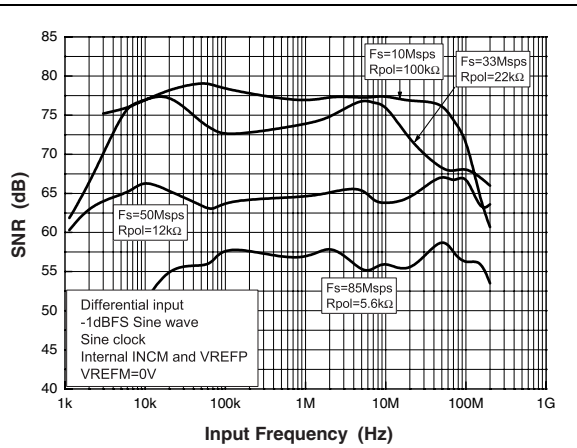


**Figure 23. ENOB vs. square clock, diff. input**

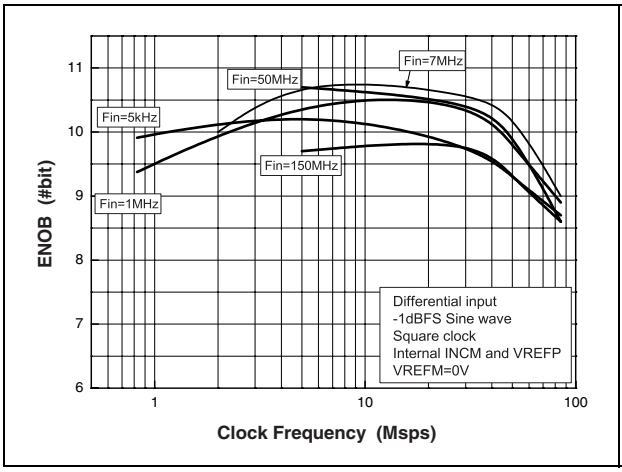



**Figure 24. SINAD vs. square clock, diff. input**

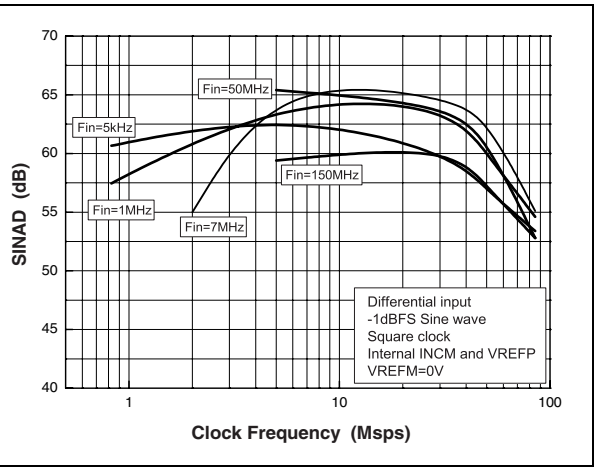



**Figure 25. THD vs. square clock, diff. input**

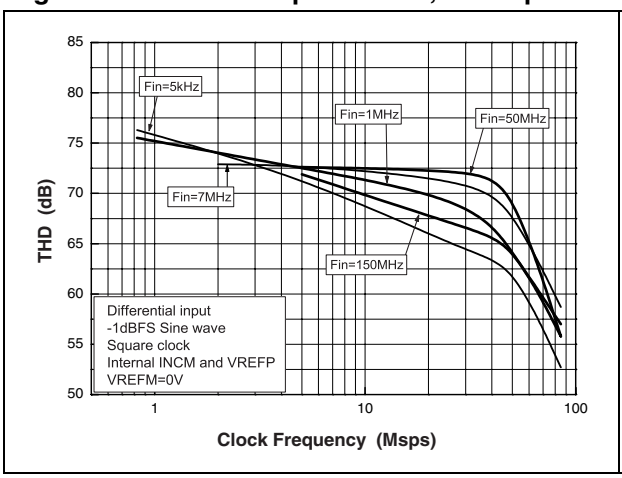



**Figure 26. SNR vs. square clock, diff. input**

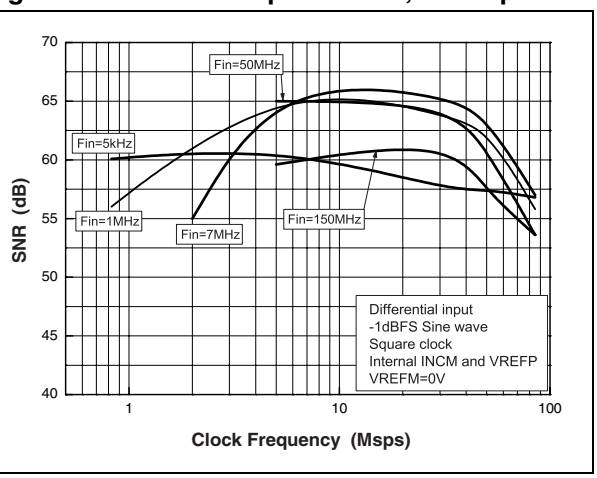



**Figure 27. SFDR vs. square clock, diff. input**

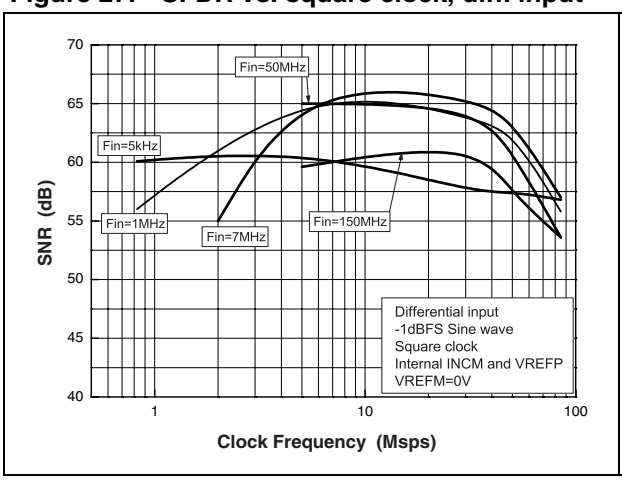



**Figure 28. ENOB vs. sine clock, diff. input**

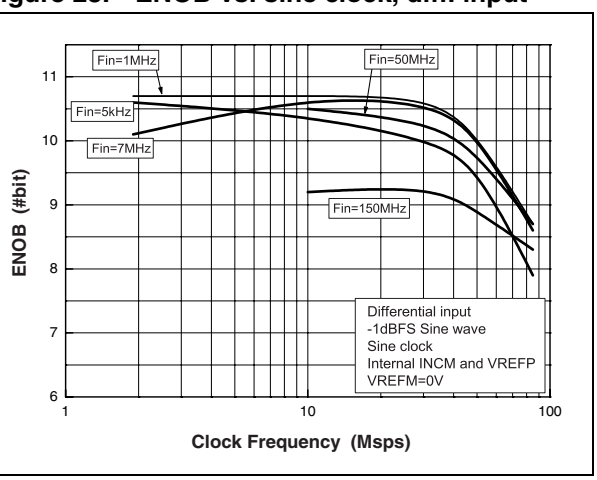


**Figure 29. SINAD vs. sine clock, diff. input**

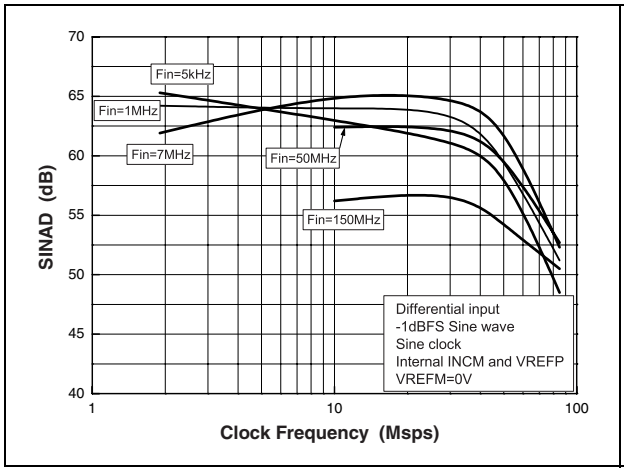



**Figure 30. THD vs. sine clock, diff. input**

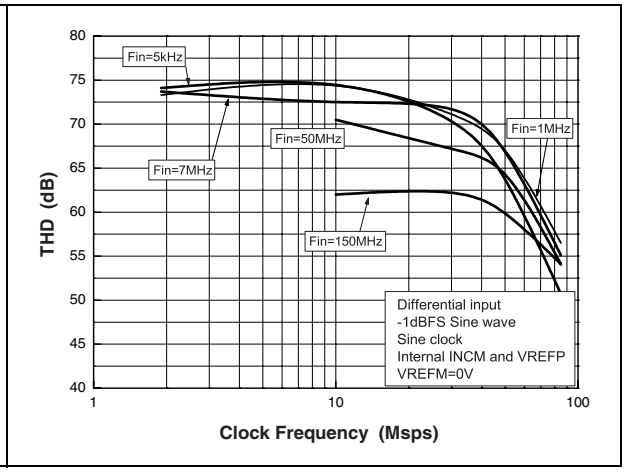



**Figure 31. SNR vs. sine clock, diff. input**

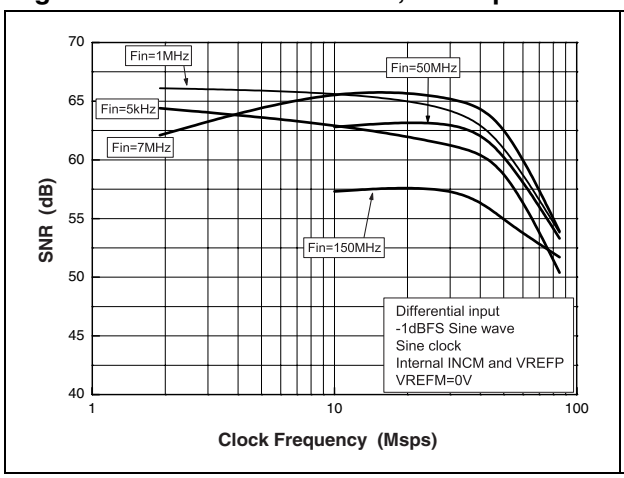



**Figure 32. SFDR vs. sine clock, diff. input**

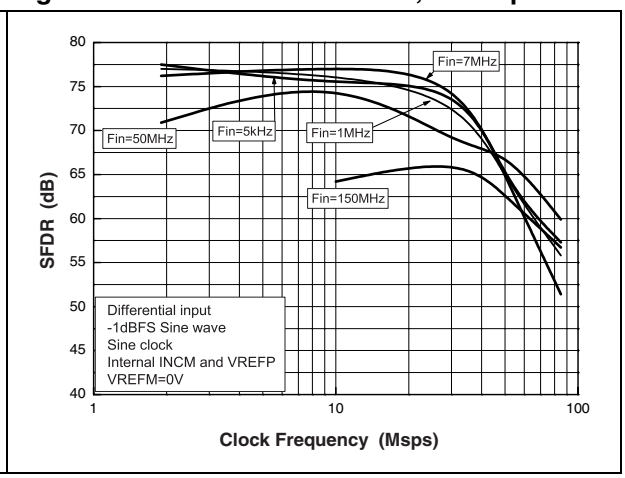



**Figure 33. Clock threshold vs. temperature**

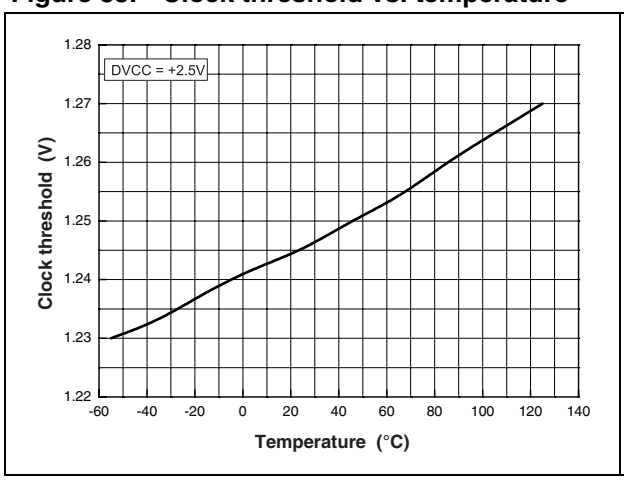



**Figure 34. ENOB vs. clock duty cycle**

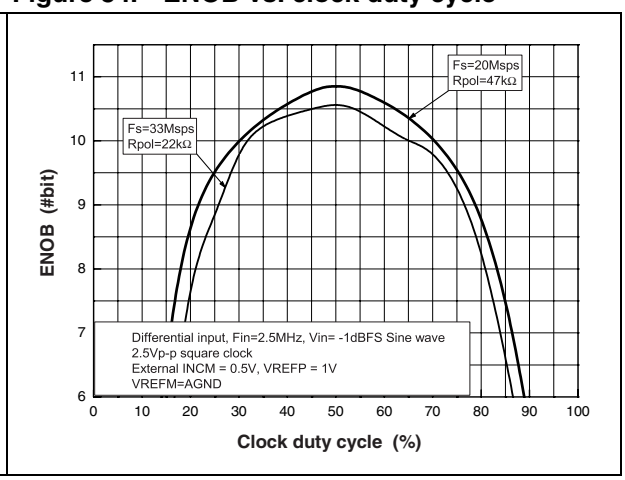


**Figure 35. Output buffer fall time**

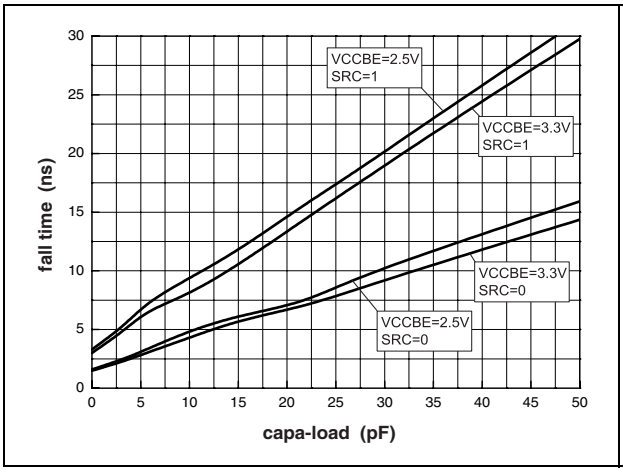



**Figure 36. Output buffer rise time**

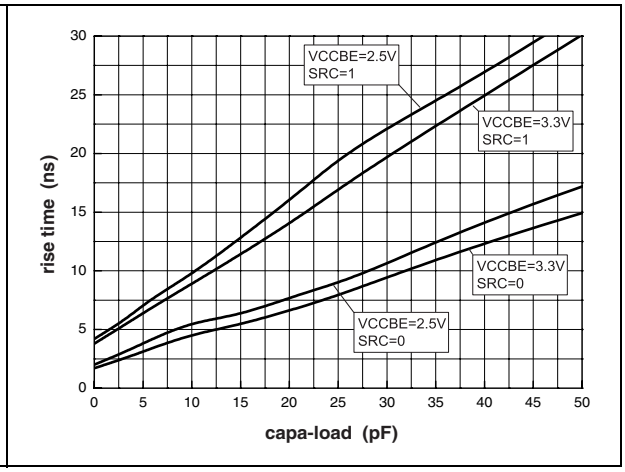


**Figure 37. Single-ended input configuration**

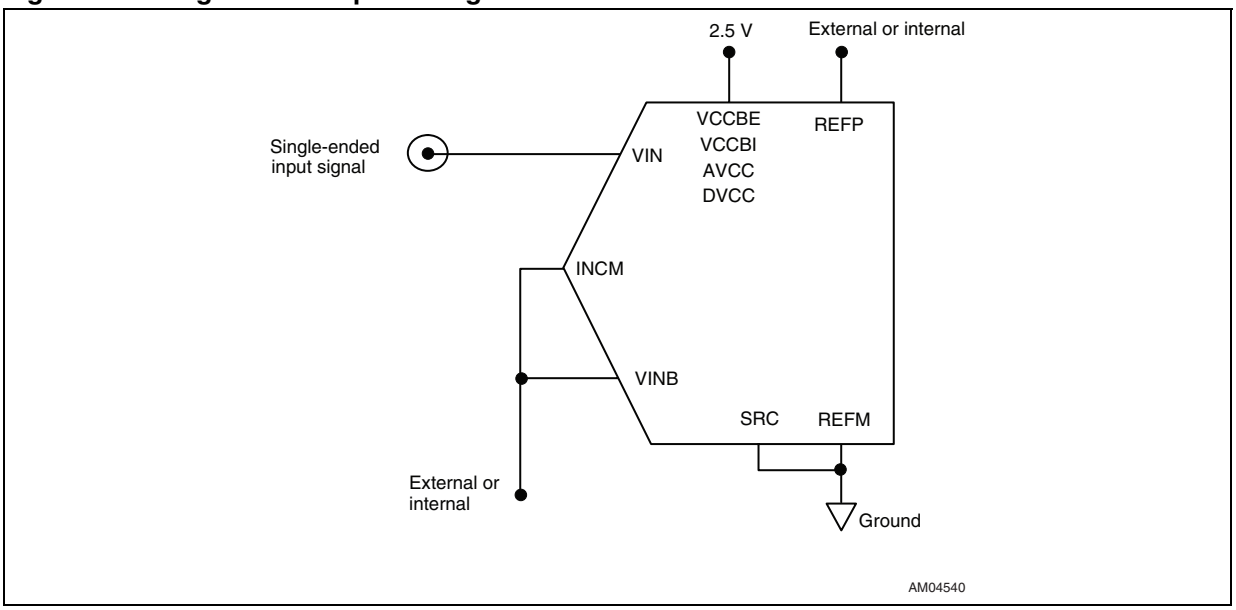



**Figure 38. ENOB vs. Fin, single-ended**

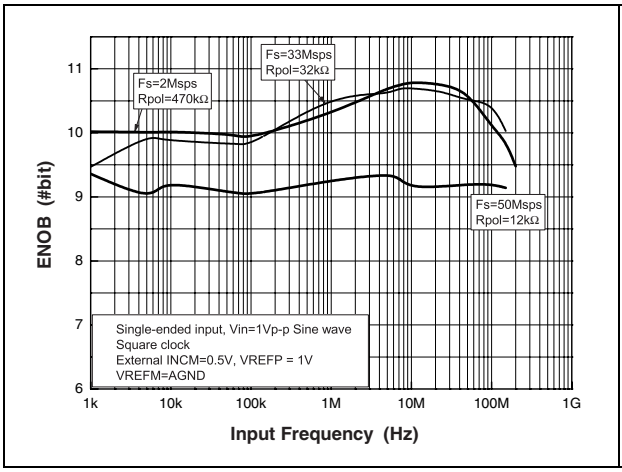



**Figure 39. SINAD vs. Fin, single-ended**

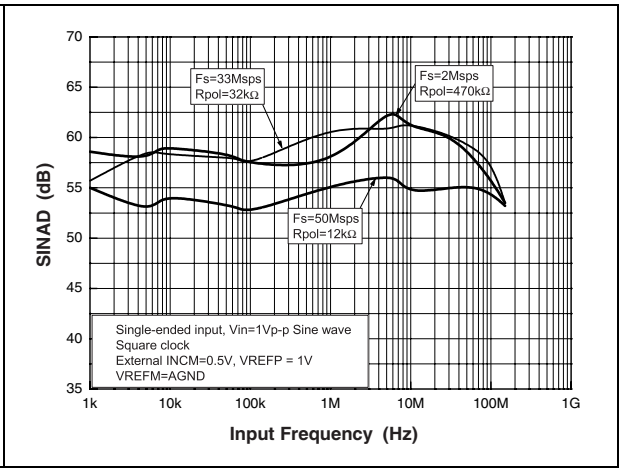



**Figure 40. THD vs. Fin, single-ended**

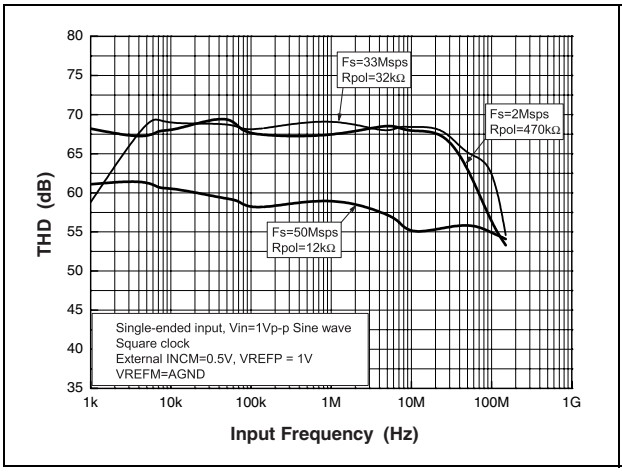



**Figure 41. SNR vs. Fin, single-ended**

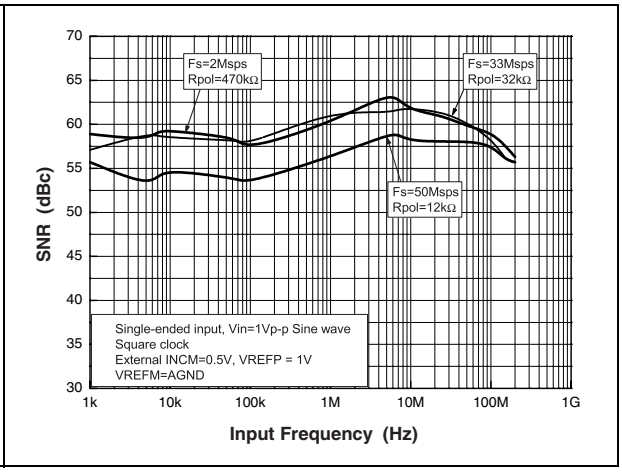


**Figure 42. SFDR vs. Fin, single-ended**

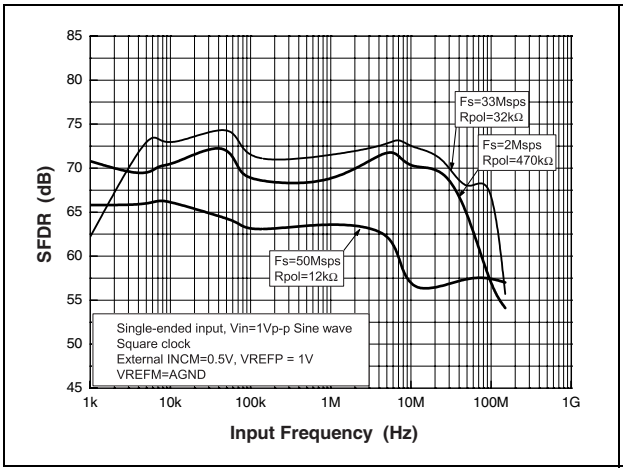



**Figure 43. ENOB vs. Vin, single-ended**

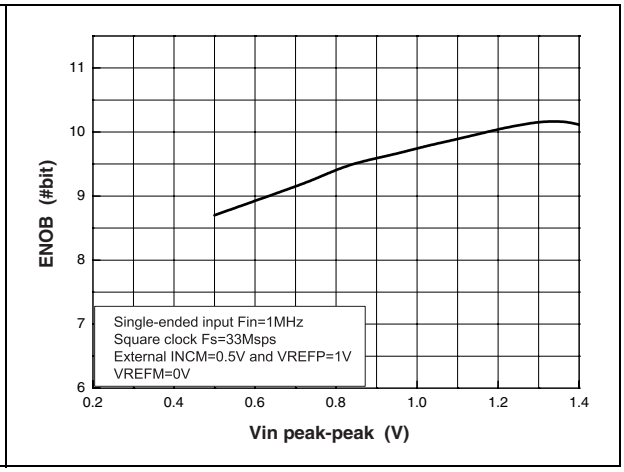



**Figure 44. ENOB vs. INCM, single-ended**

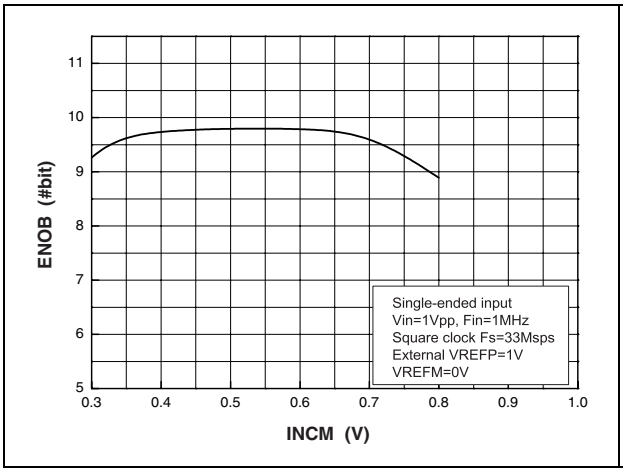
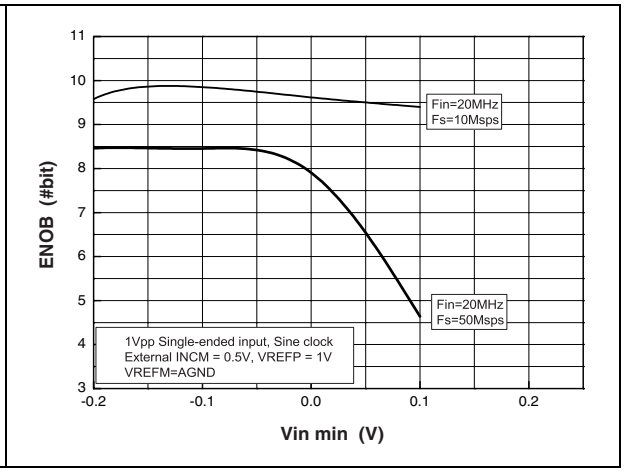



**Figure 45. ENOB vs. Vin min, single-ended**



## 7.1 RHF1201 operating modes

Extra functionalities are provided to simplify the application board as much as possible. The operating modes offered by the RHF1201 are described in *Table 11*.

**Table 11. RHF1201 operating modes**

| Inputs | | | | Outputs | | |
|---|---|---|---|---|---|---|
| **Analog input differential amplitude** | **DFSB** | **OEB** | **SRC** | **OR** | **DR** | **Most significant bit (MSB)** |
| ($V_{IN}$-$V_{INB}$) above maximum range | H | L | X | H | CLK | D11 |
| | L | L | X | H | CLK | D11 complemented |
| ($V_{IN}$-$V_{INB}$) below minimum range | H | L | X | H | CLK | D11 |
| | L | L | X | H | CLK | D11 complemented |
| ($V_{IN}$-$V_{INB}$) within range | H | L | X | L | CLK | D11 |
| | L | L | X | L | CLK | D11 complemented |
| X | X | H | X | High Impedance | | |
| X | X | L | H | X | CLK low slew rate | Low slew rate |
| X | X | L | L | X | CLK high slew rate | High slew rate |

### 7.1.1 Inputs

**Data format select (DFSB):** when set to low level ($V_{IL}$), the digital input DFSB provides a two's complement digital output MSB. This can be of interest when performing some further signal processing. When set to high level ($V_{IH}$), DFSB provides a standard binary output coding.

**Output enable (OEB):** when set to low level ($V_{IL}$), all digital outputs remain active. When set to high level ($V_{IH}$), all digital output buffers are in high impedance state while the converter goes on sampling. When OEB is set to a low level again, the data arrives on the output with a very short $T_{on}$ delay. This feature enables the chip select of the device. *Figure 11 on page 8* summarizes this functionality.

**Slew rate control (SRC):** when set to high level ($V_{IH}$), all digital output currents are limited to a clamp value so that any digital noise power is reduced to the minimum. When set to low level ($V_{IL}$), the output edges are twice as fast.

### 7.1.2 Outputs

**Out-of-range (OR):** this function is implemented at the output stage to automatically detect any digital data that is over the full-scale range. For data within the range, OR remains in a low-level state ($V_{OL}$), but switches to a high-level state ($V_{OH}$) as soon as out-of-range data is detected.

**Data ready (DR):** the data ready output is an image of the clock being synchronized on the output data (D0 to D11). This is a very helpful signal that simplifies the synchronization of the measurement equipment or of the controlling DSP.

As all other digital outputs, DR and OR go into a high impedance state when OEB is set to high level, as shown in *Figure 11 on page 8*.

## 7.2 Driving the analog input

**Figure 46. Equivalent VIN - VINB (differential input)**

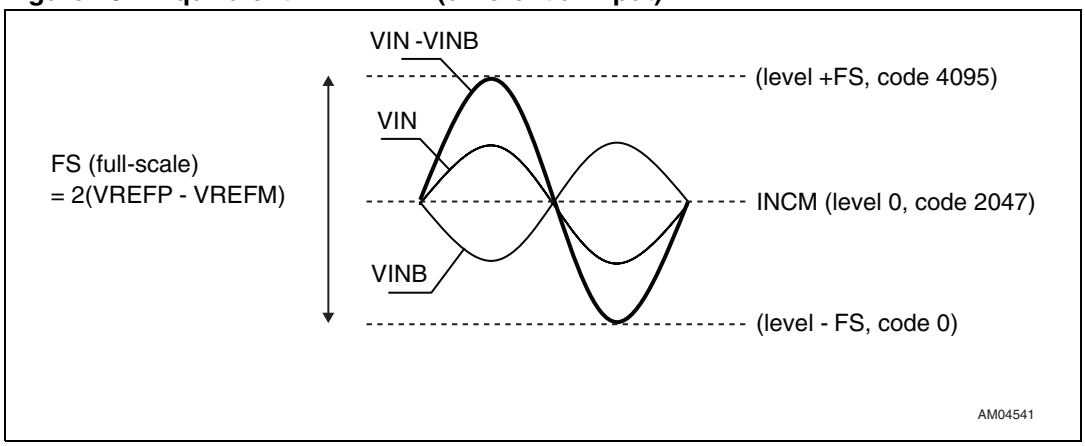



**Figure 47. Maximum input swing on each VIN or VINB input**

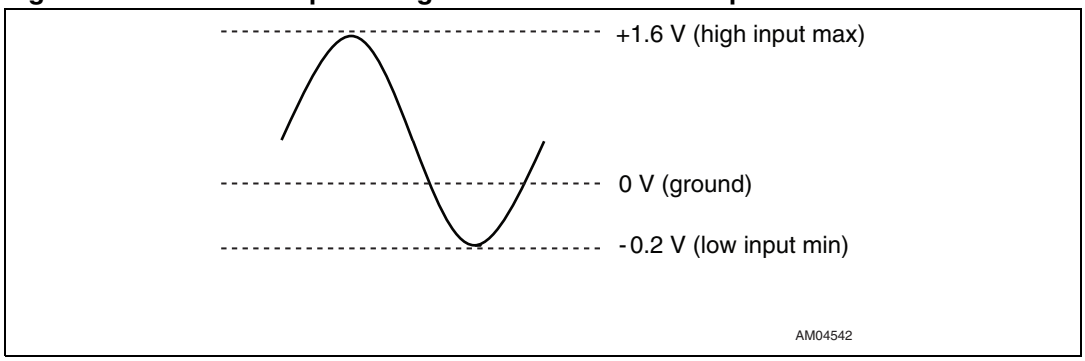
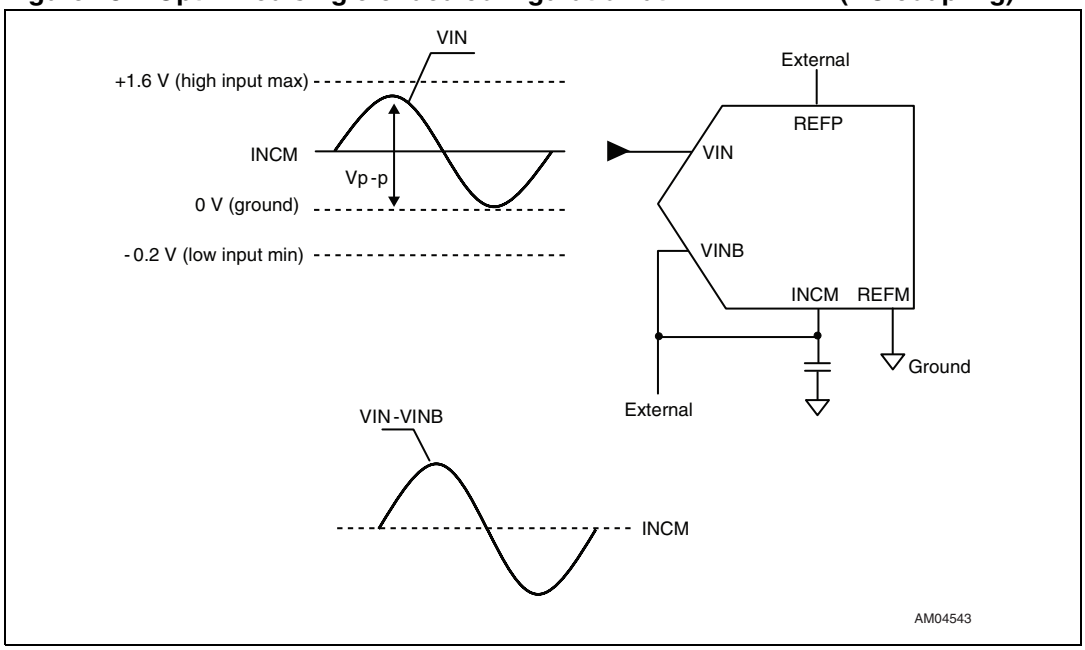
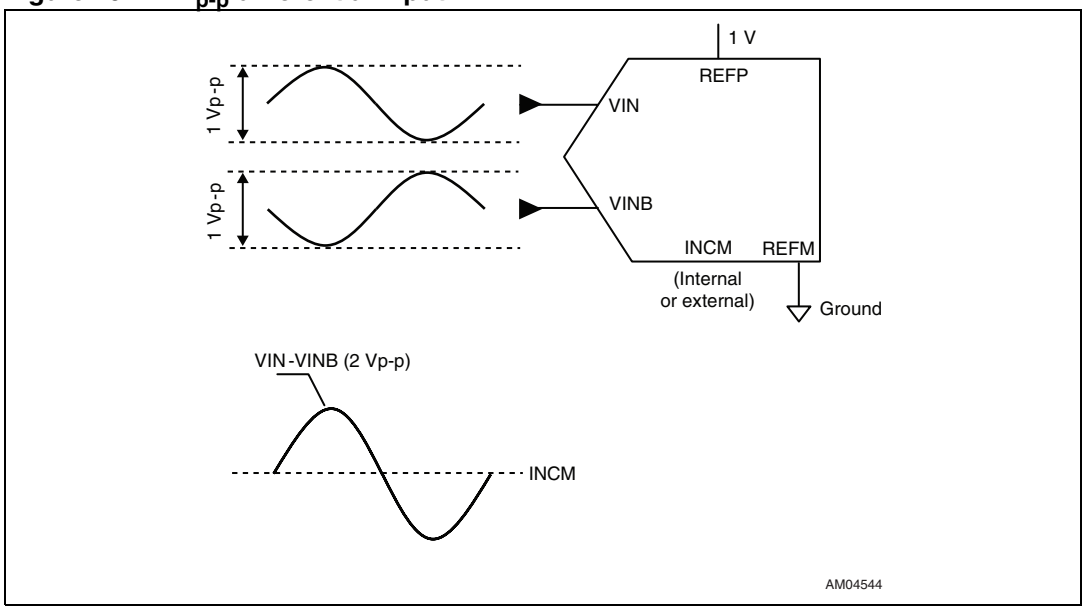



**Figure 48. Optimized single-ended configuration at VREFP = 1 V (DC coupling)**



The RHF1201 is designed for use in a differential input configuration. Nevertheless, it can achieve good performance in a single-ended input configuration. In single-ended, a good-quality conversion can be achieved by using an input amplitude up to 1.4 Vp-p with external references INCM and VREFP (see *Figure 38 on page 17*).

**Figure 49. 2 $V_{p-p}$ differential input**




The RHF1201 is designed to obtain optimum performance when driven on differential inputs with a differential amplitude of 2 V peak-to-peak (2 $V_{p-p}$). This is the result of 1 $V_{p-p}$ on the VIN and VINB inputs in phase opposition.

The RHF1201 is specifically designed to meet sampling requirements for IF, intermediate frequency input signals. In particular, the track-and-hold in the first stage of the pipeline is designed to minimize the linearity limitations as the analog frequency increases. This is achieved by making the input impedance independent of the input frequency.

*Figure 50 on page 23* shows a differential input solution. The input signal is fed to the transformer's primary, while the secondary drives both ADC inputs. The transformer must be 50 Ω matched (for proper matching with a 50 Ω generator), and it must be loaded with 50 Ω on the secondary, as close as the ADC. Tracks between the secondary and VIN and VINB pins must be as short as possible.

The common mode voltage of the ADC (INCM) is connected to the center tap of the transformer's secondary in order to bias the input signal around this common voltage, internally set to 0.52 V (see *Table 7 on page 10*).The INCM is decoupled to maintain a low noise level on this node. Ceramic technology for decoupling provides good capacitor stability across a wide bandwidth.

**Figure 50. Differential implementation using a balun**

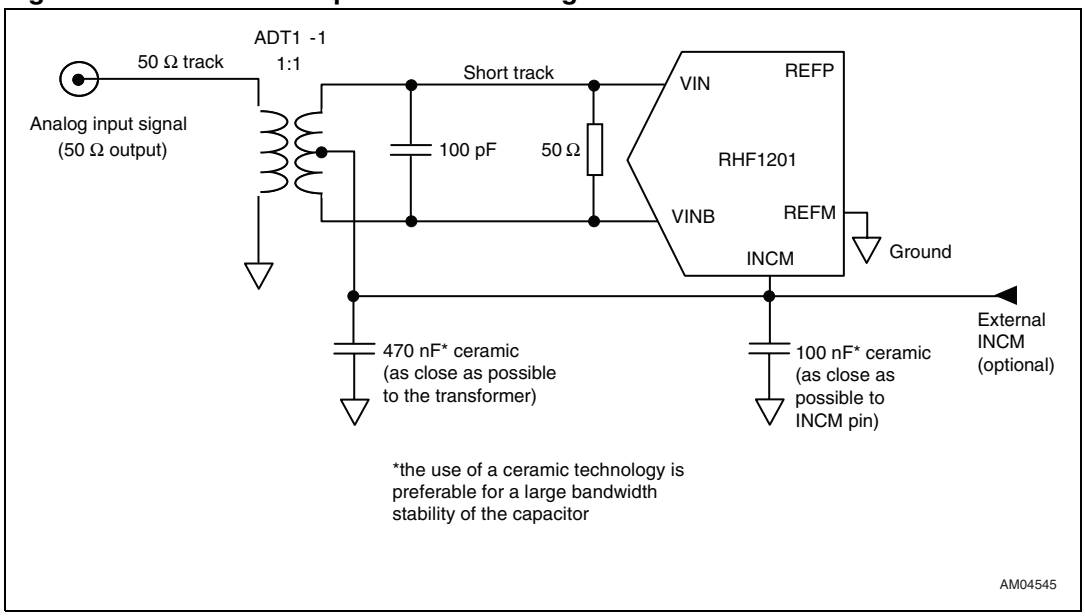
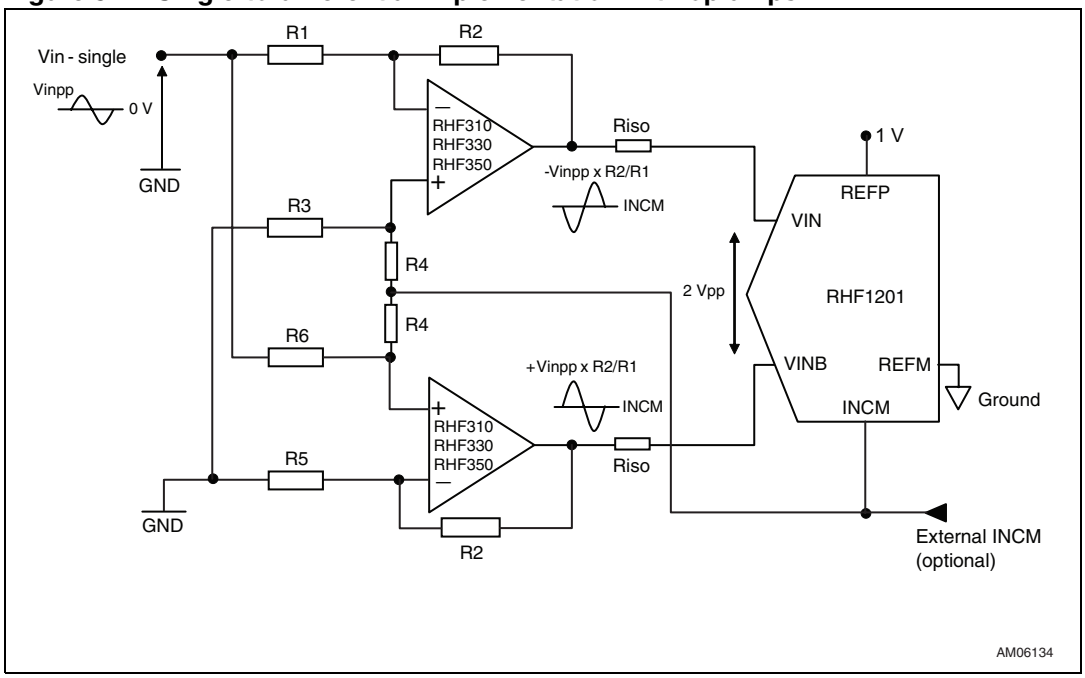



**Figure 51. Single-to-differential implementation with op-amps**




With (Vout-diff) = (2R2/R1) x (Vin-single) and the following conditions on resistors: R1/(R1+R2) = R3/(R3+R4) and R4/(R6+R4) = (R5+R2)/R1 (refer to the RHF310-330-350 datasheet for the choice of R2).

Some applications may require a single-ended input, which can easily be achieved with the configuration shown in *Figure 52*. However, with this type of configuration a degradation in the rated performance of the RHF1201 may occur, compared to a differential configuration. To avoid this, a sufficiently decoupled DC reference should be used to bias the RHF1201 inputs. One may also use an AC-coupled analog input and set the DC analog level with a high value resistor R (10 kΩ to 100 kΩ) connected to a proper DC source.

Cin and R behave like a high-pass filter and are calculated to set the lowest possible cut-off frequency. An example of VINB decoupling to reduce noise is shown in *Figure 52*.

**Figure 52. AC-coupling single-ended input configuration**

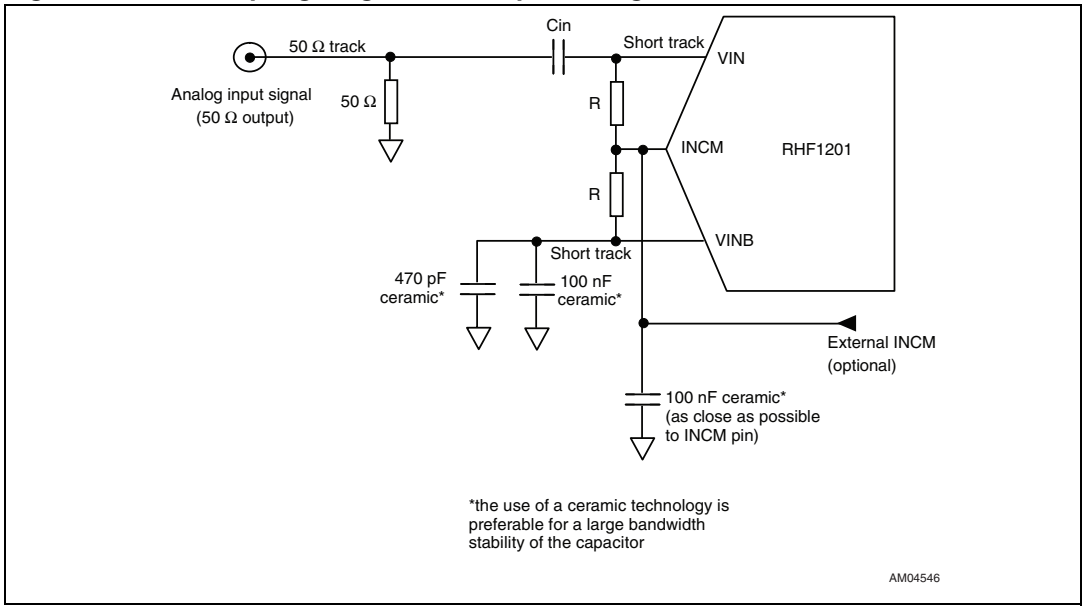
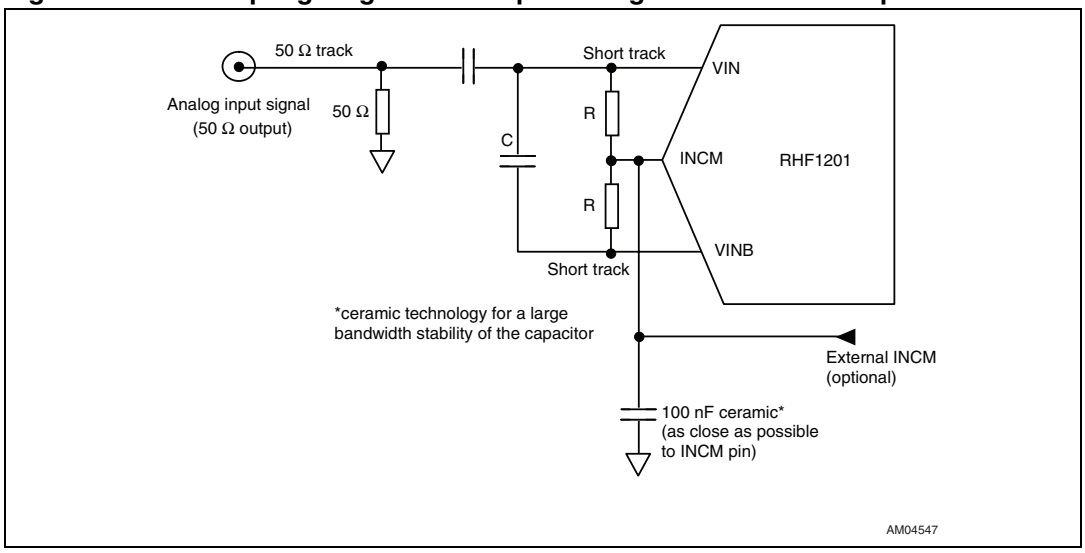



**Figure 53. AC-coupling single-ended input configuration for low frequencies**



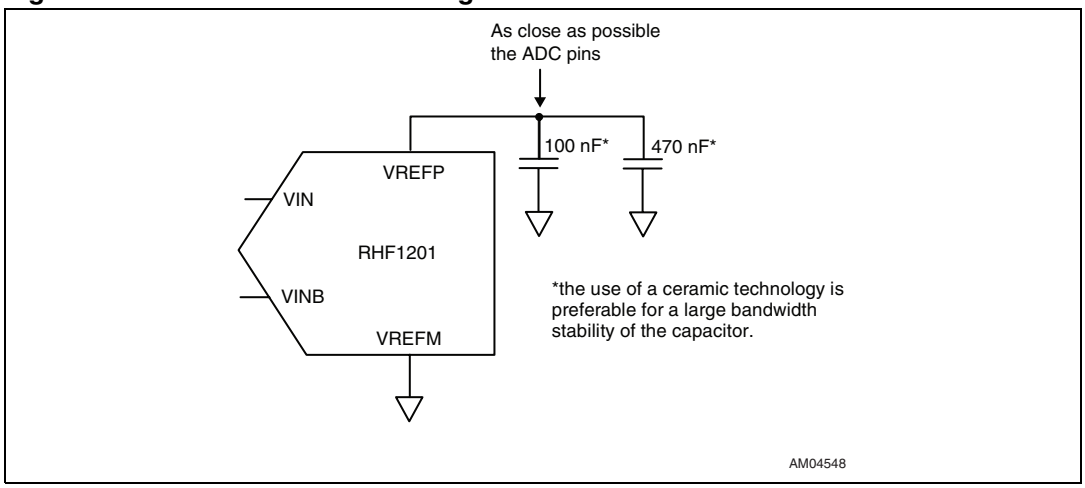

The C capacitor (in the range of 33 pF for example) is dedicated to a low input frequency range. This capacitor is efficient in reducing noise at higher frequencies. When coupled with the resistors, R and C together behave like a high-pass filter. For example, if R = 10 k and C = 33 pF, the cut-off frequency of this filter equals 482 kHz.

## 7.3 Reference connection

### 7.3.1 Internal reference

In the standard configuration, the ADC is biased with the internal reference voltage. The $V_{REFM}$ pin is connected to analog ground while $V_{REFP}$ is internally set to a voltage close to 1.0 V. $V_{REFP}$ should be decoupled so as to minimize low and high frequency noise. *Figure 54* shows the schematics.

**Figure 54. Internal reference setting**




### 7.3.2 External reference

An external reference voltage can be used for specific applications requiring even better linearity or enhanced temperature behavior. In such cases, the amplitude of the external voltage must be at least equal to the internal reference (see *Table 7: Internal reference voltage on page 10*). An external voltage reference with the configuration shown in *Figure 55* and *Figure 56* can be used to obtain optimum performance. Decoupling is achieved by using ceramic capacitors, which provide optimum linearity versus frequency.

**Figure 55. External reference setting**

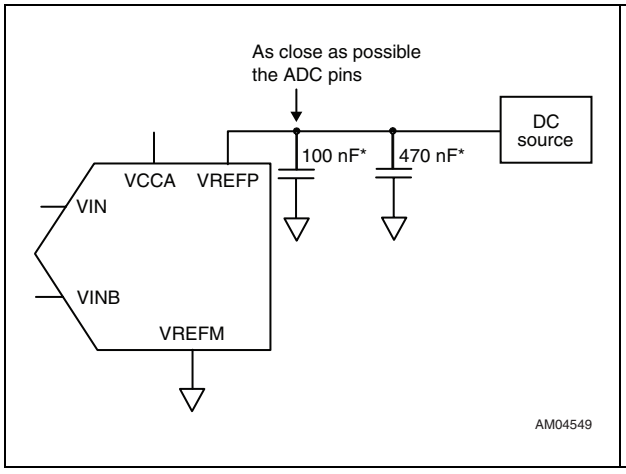
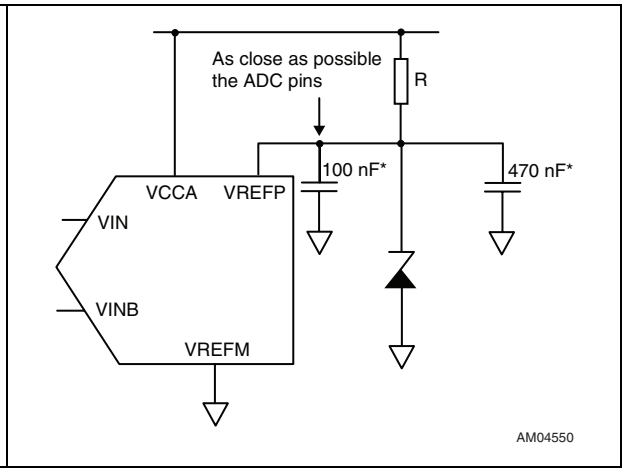



**Figure 56. Example with a zener**




*Note: * The use of ceramic technology is preferable for large bandwidth stability of the capacitor.*

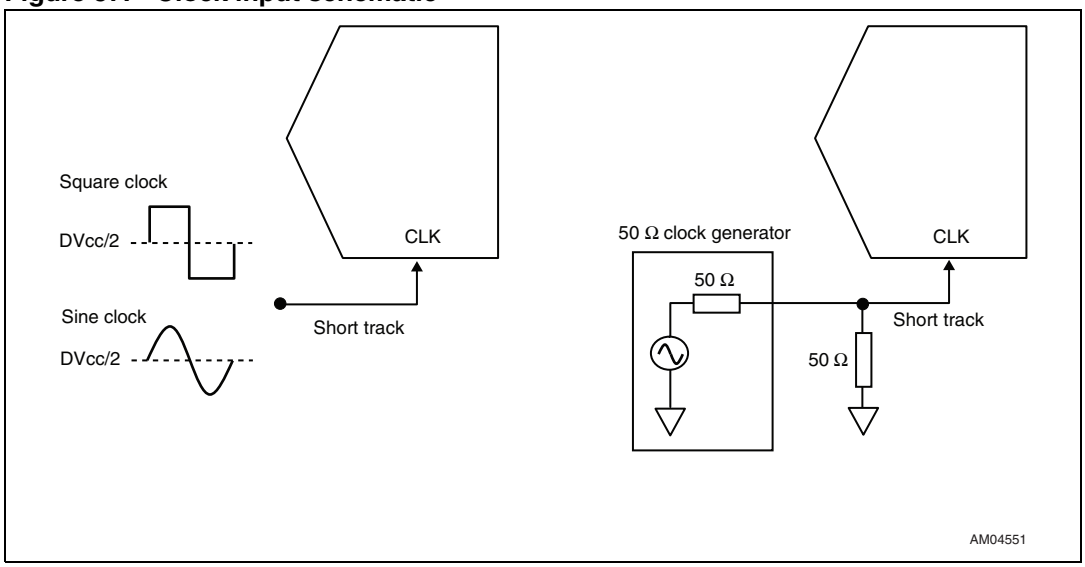
## 7.4 Clock input

The quality of the converter very much depends on the accuracy of the clock input in terms of jitter. The use of a low jitter, crystal-controlled oscillator is recommended.

The following points should also be considered.

- At 45 Msps, the duty cycle must be between 45% and 65%.
- The clock power supplies must be independent of the ADC output supplies to avoid digital noise modulation on the output.
- When powered-on, the circuit needs several clock periods to reach its normal operating conditions.
- The clock input is a MOS input. To bias this input stage properly, a bias current of 10 nA is sufficient.

**Figure 57. Clock input schematic**




The signal applied to the CLK pin is critical to obtain full performance from the RHF1201. We recommend using a 0 to 2.5 V square signal with fast transition times, and to place proper termination resistors as close as possible to the device.

The sampling instant is determined by the rising edge of the clock signal. The jitter associated with this instant must be as low as possible to avoid SNR degradation on fast-moving input signals. To ensure that LSB errors stay below 0.5, the total jitter $T_j$ must satisfy the following condition for a full-scale input signal.

$$T_j < \frac{1}{\pi \cdot F_{in} \cdot 2^{n+1}}$$

n being the number of bits.

In most cases, the clock signal jitter is the major contributor of total noise. Therefore, particular attention should be given to the clock signal when acquiring fast signals with a low-frequency clock.

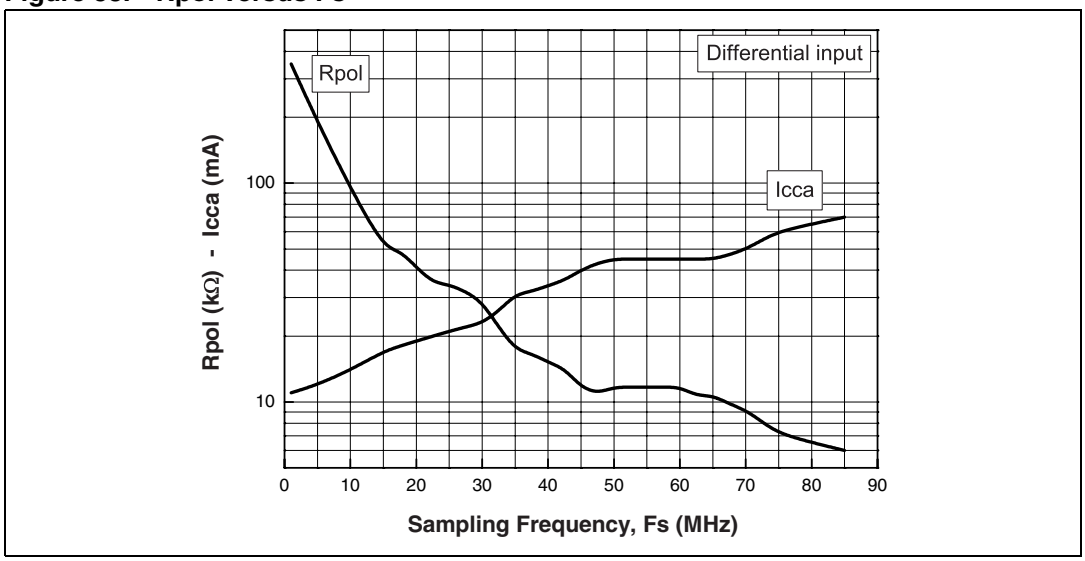
## 7.5 Power consumption optimization

The internal architecture of the RHF1201 makes it possible to optimize the power consumption according to the sampling frequency of the application. For this purpose, an external $R_{pol}$ resistor is placed between the IPOL pin and the analog ground. Therefore, the total dissipation can be adjusted across the entire sampling range from 0.5 Msps to 50 Msps to fulfill the requirements of applications where power saving is critical.

For low sampling frequencies, the resistor value may be adjusted to decrease the analog current without any deterioration of the dynamic performance.

The current consumption Icca, depending on the value of $R_{pol}$, is as shown in *Figure 58*.

**Figure 58. Rpol versus Fs**



## 7.6 Layout precautions

- Use of dedicated analog and digital ground planes on the PCB is recommended for high-speed circuit applications to provide low parasitic inductance and resistance. Ground planes under the digital pins and layers should be avoided to minimize parasitic capacitances.
- The separation of the analog signal from the digital output is mandatory to prevent noise from coupling onto the input signal.
- Power supply bypass capacitors must be placed as close as possible to the IC pins to improve high-frequency bypassing and reduce harmonic distortion.
- All leads must be as short as possible, especially for the analog input, so as to decrease parasitic capacitance and inductance.
- To minimize the transition current when the output changes, the capacitive load at the digital outputs must be reduced as much as possible by using the shortest-possible routing tracks.
- Choose the smallest-possible component sizes (SMD).

# 8 Definitions of specified parameters

## 8.1 Static parameters

### Differential non-linearity (DNL)

The average deviation of any output code width from the ideal code width of 1 LSB.

### Integral non-linearity (INL)

An ideal converter exhibits a transfer function which is a straight line from the starting code to the ending code. The INL is the deviation from this ideal line for each transition.

## 8.2 Dynamic parameters

### Spurious free dynamic range (SFDR)

The ratio between the power of the worst spurious signal (not always a harmonic) and the amplitude of the fundamental tone (signal power) over the full Nyquist band. Expressed in dBc.

### Total harmonic distortion (THD)

The ratio of the rms sum of the first five harmonic distortion components to the rms value of the fundamental line. Expressed in dB.

### Signal to noise ratio (SNR)

The ratio of the rms value of the fundamental component to the rms sum of all other spectral components in the Nyquist band ($f_s/2$) excluding DC, fundamental and the first five harmonics. SNR is reported in dB.

### Signal to noise and distortion ratio (SINAD)

Similar ratio as for SNR but including the harmonic distortion components in the noise figure (not DC signal). Expressed in dB.

The effective number of bits (ENOB) is easily deduced from the SINAD, using the formula:

$$SINAD = 6.02 \times ENOB + 1.76 \text{ dB}$$

When the applied signal is not full-scale (FS) but has an amplitude $A_0$, the SINAD expression becomes:

$$SINAD = 6.02 \times ENOB + 1.76 \text{ dB} + 20 \log (A_0/FS)$$

ENOB is expressed in bits.

### Effective resolution bandwidth

For a given sampling rate and clock jitter, this is the analog input frequency at which the SINAD is reduced by 3 dB, and the ENOB is reduced by 0.5 bits.

### Pipeline delay

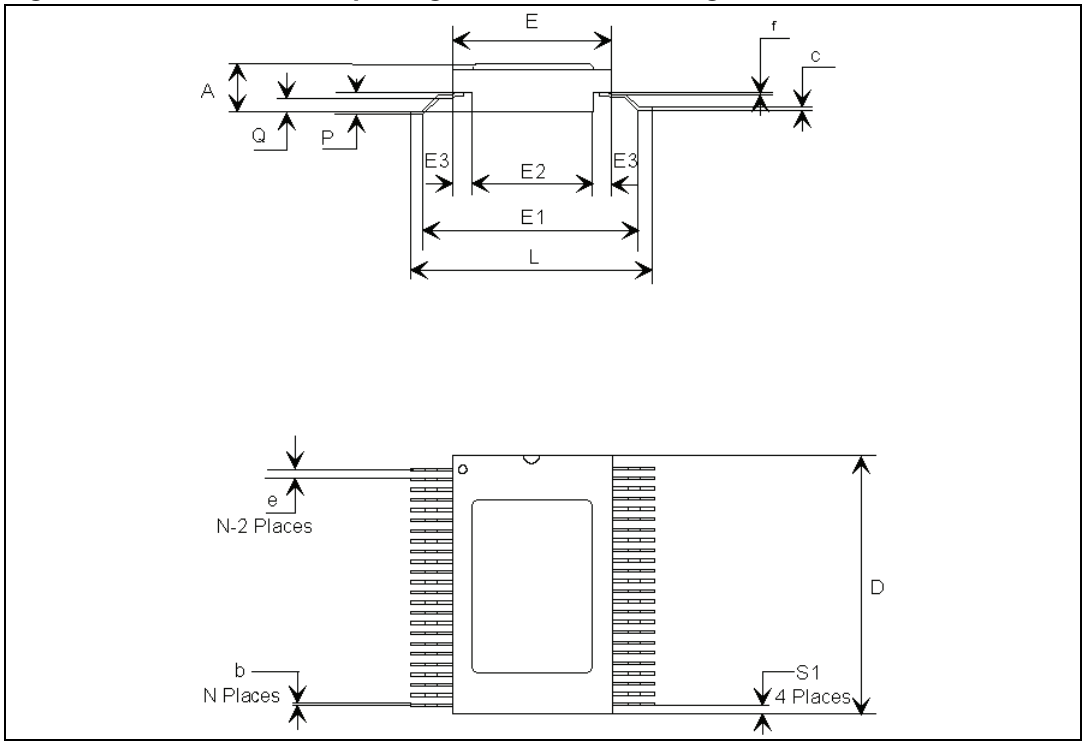
Delay between the initial sample of the analog input and the availability of the corresponding digital data output on the output bus. Also called data latency, it is expressed as a number of clock cycles.

When powering *off* to *on*, there is a delay of several clock cycles before the ADC can achieve a reliable and stable signal conversion. During this delay, some conversion artefacts may appear.

# 9 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.

**Figure 59. Ceramic SO-48 package mechanical drawing**




*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 12. Ceramic SO-48 package mechanical data

| Ref. | Dimensions | | | | | |
|---|---|---|---|---|---|---|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | 2.18 | 2.47 | 2.72 | 0.086 | 0.097 | 0.107 |
| b | 0.20 | 0.254 | 0.30 | 0.008 | 0.010 | 0.012 |
| c | 0.12 | 0.15 | 0.18 | 0.005 | 0.006 | 0.007 |
| D | 15.57 | 15.75 | 15.92 | 0.613 | 0.620 | 0.627 |
| E | 9.52 | 9.65 | 9.78 | 0.375 | 0.380 | 0.385 |
| E1 | | 10.90 | | | 0.429 | |
| E2 | 6.22 | 6.35 | 6.48 | 0.245 | 0.250 | 0.255 |
| E3 | 1.52 | 1.65 | 1.78 | 0.060 | 0.065 | 0.070 |
| e | | 0.635 | | | 0.025 | |
| f | | 0.20 | | | 0.008 | |
| L | 12.28 | 12.58 | 12.88 | 0.483 | 0.495 | 0.507 |
| P | 1.30 | 1.45 | 1.60 | 0.051 | 0.057 | 0.063 |
| Q | 0.66 | 0.79 | 0.92 | 0.026 | 0.031 | 0.036 |
| S1 | 0.25 | 0.43 | 0.61 | 0.010 | 0.017 | 0.024 |

# 10 Revision history

**Table 13. Document revision history**

| Date | Revision | Changes |
|---|---|---|
| 01-Sep-2006 | 1 | Initial release in new format. |
| 29-Jun-2007 | 2 | Updated failure immune and latchup immune value to 120 MeV-$cm^2$/mg.<br>Updated package mechanical data.<br>Removed reference to non rad-hard components from *Section 7.3.2: External reference on page 25*. |
| 10-Oct-2008 | 3 | Changed cover page graphic.<br>Changed *Figure 2*.<br>Added *Chapter 4: Equivalent circuits*.<br>Added *Note 1* under *Table 4*.<br>Expanded *Table 5* with additional parameters.<br>Modified "Test conditions" and Vrefp/Vincm in *Table 7*.<br>Improved readability in *Table 11*.<br>Added *Figure 46* to *Figure 49*.<br>Modified *Figure 50* and *Figure 52*.<br>Added *Figure 53*.<br>Removed *IF sampling* section.<br>Modified *Figure 54* and *Figure 16*. Added *Figure 58*.<br>Added ECOPACK information and updated presentation in *Chapter 9*. |
| 09-Apr-2010 | 4 | Modified description on cover page.<br>Added *Table 1: Device summary on page 1*.<br>Removed RHF1201KSO2 order code from *Table 1*.<br>Removed Fs and Tck values from *Table 3*.<br>Added *Figure 7* and *Figure 8*.<br>Added DFS, OEB and SRC values in *Table 5*.<br>Changed VINCM values in *Table 5*.<br>Removed Fin values from *Table 5*.<br>Removed output capacitive load values from *Table 9*.<br>Changed clock threshold values in *Table 9*.<br>Added PSRR values in *Table 10*.<br>Added *Figure 13 on page 12* to *Figure 45*.<br>Modified *Figure 46*, *Figure 48* and *Figure 49*. |
| 29-Jul-2011 | 5 | Added *Note: on page 31* and in the "Pin connections" diagram on the coverpage. |

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