Performance of the THS4302 and the Class V Radiation-Tolerant THS4304-SP Silicon Germanium Wideband Amplifiers at Extreme Temperatures

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Introduction

This report discusses the performance of silicon germanium, wideband gain amplifiers under extreme temperatures. The investigated devices include Texas Instruments THS4304-SP and THS4302 amplifiers. Both chips are manufactured using the BiCom3 process based on silicon germanium technology along with silicon-on-insulator (SOI) buried oxide layers.

The THS4304-SP device was chosen because it is a Class V radiation-tolerant (150 kRad, TID silicon), voltage-feedback operational amplifier designed for use in high-speed analog signal applications and is very desirable for NASA missions. It operates with a single 5 V power supply [1]. It comes in a 10-pin ceramic flatpack package, and it provides balanced inputs, low offset voltage and offset current, and high common mode rejection ratio.

The fixed-gain THS4302 chip, which comes in a 16-pin leadless package, offers high bandwidth, high slew rate, low noise, and low distortion [2]. Such features have made the amplifier useful in a number of applications such as wideband signal processing, wireless transceivers, intermediate frequency (IF) amplifier, analog-to-digital converter (ADC) preamplifier, digital-to-analog converter (DAC) output buffer, measurement instrumentation, and medical and industrial imaging. Specifications of these two amplifiers are shown in Table I [1-2].

Table I. Specifications of the THS4304-SP and THS 4302 amplifiers [1-2].

Parameter	**Symbol**	**THS4304-SP**	**THS4302**
Output Current	I_o	150 mA	200 mA
Supply Voltage	V_s	2.7 to 5 V	3 to 5 V or ±2.5 V
Input Resistance	R_I	100 kΩ	1.6 MΩ
Offset Voltage	V_{os}	+4 to +6 mV	+2 to +5 mV
Slew Rate	SR	675 V/µs	5500 V/µs
Noise Figure	F	15 dB	16 dB
Gain Bandwidth Product	GBP	1 GHz	12 GHz
Common-Mode Rejection Ratio	CMRR	86 dB	60 dB
Operating Temperature	T	-55 °C to +125 °C	-55 °C to +125 °C
Chip Package		10-pin flatpack (U) ceramic	16-pin QFN plastic
Evaluation Board Marking		THS4304-SP Class V	THS4302RGT EVM

Experimental Test Setup

Two evaluation boards, one populated with THS4304-SP chip in an inverting amplification configuration and the other with THS4302 chip, were acquired and evaluated under extreme temperatures. A schematic of the THS4302 evaluation board is shown in Figure 1, and Figure 2 depicts the THS4304-SP evaluation board under test in the environmental chamber. The instrumentation used in the characterization of these circuits is shown in Figure 3. An Agilent Technology Network Analyzer (model E8361A) was used to determine gain characteristics of the amplifier. Each evaluation circuit board was evaluated in the temperature range of +200 °C to -195°C, and its gain was recorded at selected temperatures in the frequency range of 40 MHz to 1.2 GHz. The supply current to each circuit was also recorded as a function of temperature. At each test temperature, the devices were allowed to soak for 15 minutes before any measurements were made.

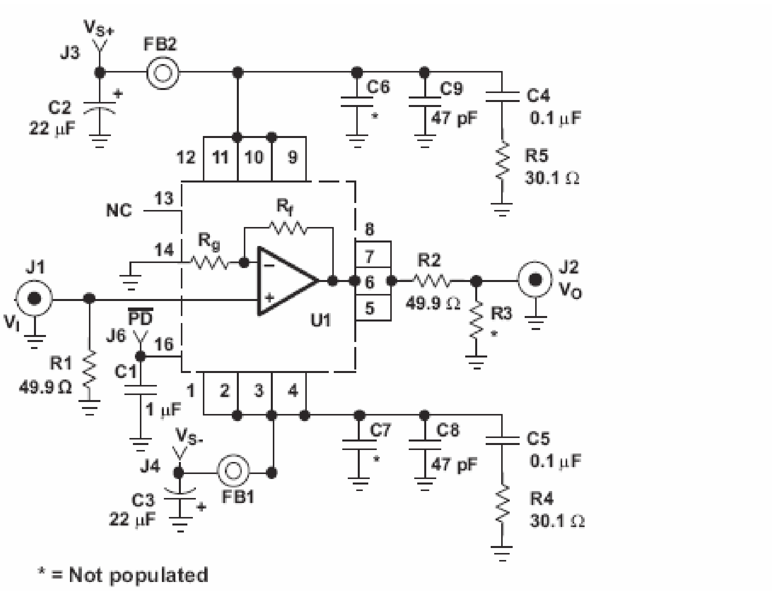

Figure1. Schematic of the THS4302 evaluation board.

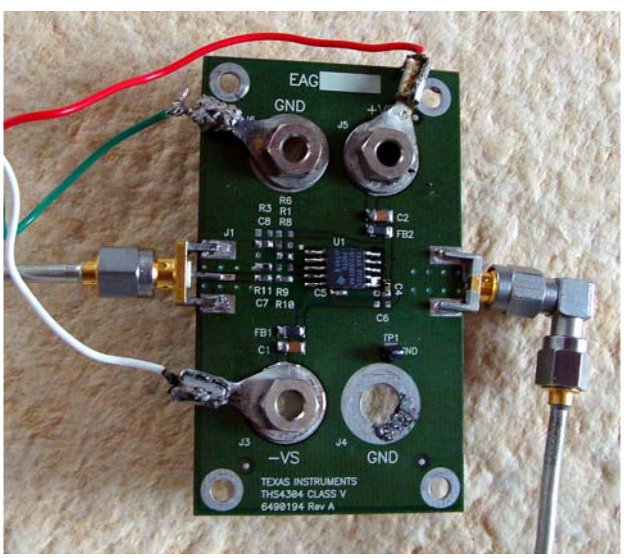

Figure 2. THS4304-SP evaluation board layout and connections.

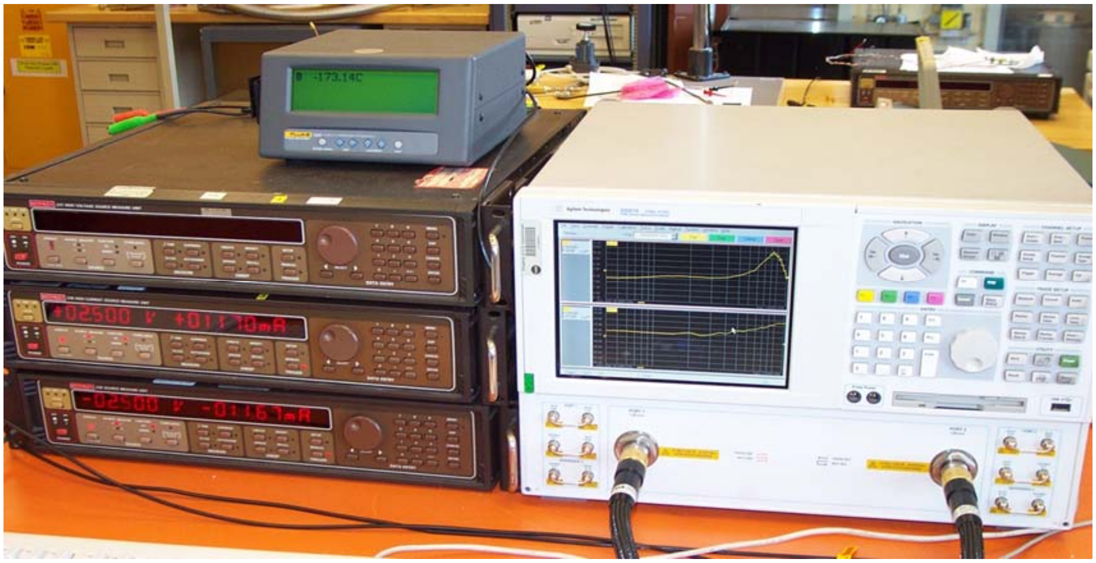

Figure 3. Experimental set up and instrumentation.

Experimental Results and Discussion

The gain of the THS4304-SP evaluation circuit versus frequency at various test temperatures is given in Figure 4. The gain of the circuit was set by the voltage-feedback resistor network. The rf input power was -17 dBm. It can be seen that the gain maintained a value near 6 dB up to 200 MHz at all temperatures. Beyond that frequency, the gain initially began to exhibit an increase in value, reaching a peak that was followed by a decrease as the frequency was increased further. The magnitude of the peak and the frequency at which the peaking occurred depended on the temperature. Figure 4 clearly shows that the amount peaking was relatively small at high temperatures, and peaking increased at low temperatures. While the gain attained a value of 9 dB at 350 MHz at a temperature of +200 ºC, it reached a peak of about 17 dB at 500 MHz at test temperatures in the vicinity of -150 to -195 ºC.

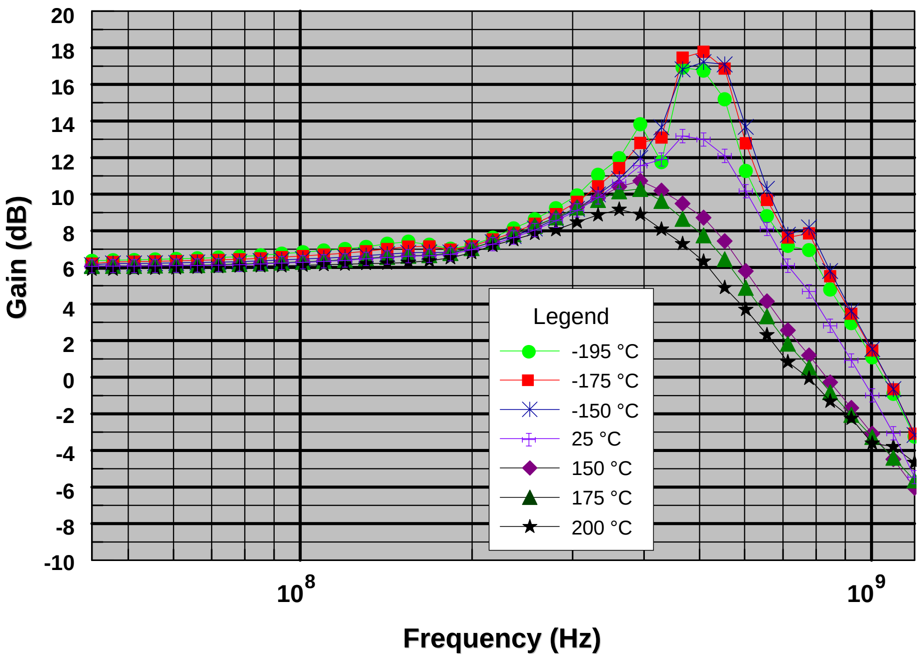

Figure 4. Gain versus frequency at various temperatures for THS4304-SP amplifier.

Figure 5 shows the gain of the THS4302 evaluation circuit versus frequency at various test temperatures. The THS4302 amplifier, that exhibited gain characteristics similar to the THS4304-SP, generally maintained a gain near 8 dB up to a frequency of 200 MHz. Peaking in the gain of this amplifier was more evident at low temperatures. The frequency at which the gain peaked at -195 ºC was lower than that for -175 ºC and -150 ºC. The highest value of gain that was recorded for the THS4302 amplifier was about 10 dB occurring at 670 MHz at -195 ºC.

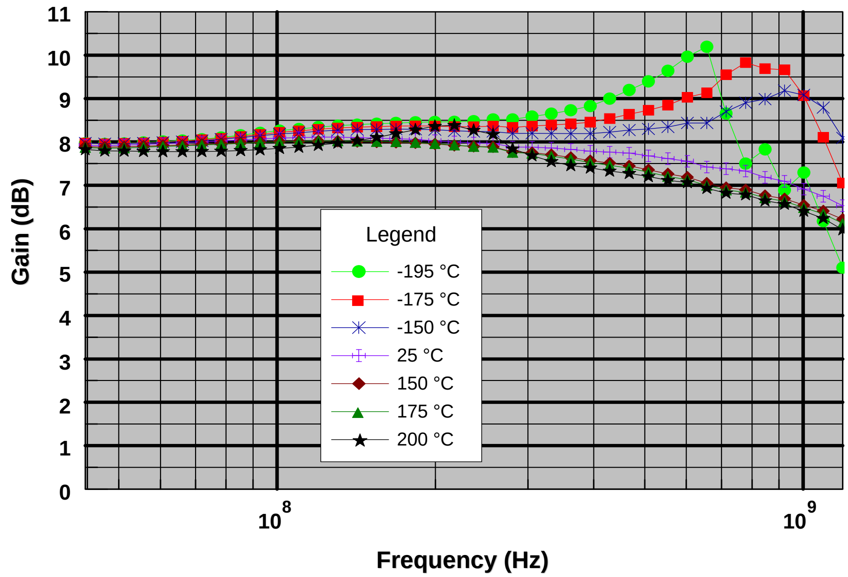

Figure 5. Gain versus frequency at various temperatures for THS4302 amplifier.

The supply currents of both amplifiers are shown in Figure 6. The supply current of the Class V radiation-tolerant THS4304-SP amplifier hovered around 17 mA throughout most of the test temperature range and exhibited a slight increase as temperature increased from -195 °C to +200 °C. The supply current of the THS4302 increased in a linear manner from 9 mA at -195 °C to 52 mA at +200 °C. For the low level input power used, the supply current for each device was not affected by frequency scanning and was within the respective specified range.

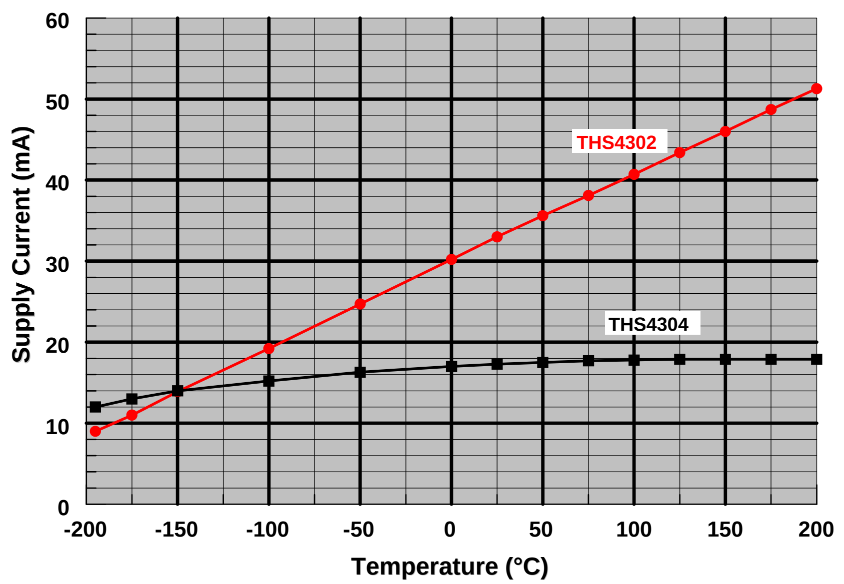

Figure 6. Supply currents as a function of temperature.

Conclusions

Two evaluation circuit boards, one populated with the Class V THS4304-SP radiation-tolerant amplifier and the other with THS4302 wideband amplifier, were evaluated in terms of signal gain at extreme temperatures from -195 ^{o}C to 200 ºC. The frequencies covered were from 40 MHz to 1.2 GHz.

The THS4304-SP operational amplifier circuit maintained a gain value near 6 dB from 40 MHz to 200 MHz at all temperatures from -195 ºC to +200 ºC. Above 200 MHz, the gain began to peak and then drop off. The magnitude of the peak and the frequency at which the peaking occurred depended on the temperature. While the peaking at high temperatures was relatively small as compared to that of room temperature, the peaking increased at low temperatures. For example, the gain attained a value of 9 dB at 350 MHz at a temperature of +200 ºC, and a peak of about 17 dB at 500 MHz at test temperatures in the vicinity of -150 ºC to -195 ºC.

The THS4302 amplifier circuit generally maintained a gain near 8 dB up to a frequency of 200 MHz. Peaking of the gain occurred primarily at cryogenic temperatures. The highest value of gain that was recorded for the THS4302 amplifier was about 10 dB occurring at 670 MHz at the cryogenic temperature of -195 ºC.

This work has shown that both amplifiers exhibited good performance over an extended temperature range that exceeded the manufacturer's specified temperature range. However, further testing and long-term cycling would be needed to fully characterize their performance and to determine their reliability for use in NASA space exploration missions where extreme temperature environments are encountered.

References

1. Texas Instruments, Inc., "THS4304-SP Wideband Operational Amplifier" Data Sheet SLOS436A, July 2004.
2. Texas Instruments, Inc., "THS4302 Wideband Fixed-Gain Amplifier" Data Sheet SLOS403H, August 2006.

Acknowledgments

This work was performed under the NASA Glenn Research Center, GESS-2 Contract # NNC06BA07B. Funding was provided from the NASA Electronic Parts and Packaging (NEPP) Program Task "Reliability of SiGe, SOI, and Advanced Mixed Signal Devices for Cryogenic Power Electronics".