Proton Test Results for a Commercial Fanout Buffer, a Variable Gain Amplifier, and a ±40V Operational Amplifier

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Abstract—We provide proton radiation test results for three commercial analog integrated circuits that have no space-qualified equivalents. Results suggest the components are suitable for some space applications. Additional testing for Enhanced Low Dose Rate Sensitivity and Single Event Latchup is recommended.

Index Terms—Analog Electronics, Commercial Off The Shelf, Proton Testing, Radiation Hardness Assurance.

I. INTRODUCTION

Advanced electronics systems require a wide variety of high-performance analog, mixed signal, and clock distribution microcircuits which aren’t readily available as space-qualified components. In this work, we present proton irradiation data for three such Commercial-Off-The-Shelf (COTS) components: (A) a fanout buffer, (B) a wideband, variable-gain amplifier, and (C) a high-voltage operational amplifier. Test results suggest all three of these components are suitable for some space applications. For additional assurance, we recommend additional testing for ELDRS and Single Event Latchup based on underlying design and process technologies of these devices, in particular the amplifiers.

II. DEVICE DESCRIPTIONS

A. Microchip SY89832U

The Microchip SY89832U is a 1:4, 2.5V, high-speed, 2GHz differential, low-voltage differential swing (LVDS), fanout buffer suitable for very low-skew applications (i.e. applications requiring skew performance of less than 20ps over supply voltage and temperature extremes). The device’s throughput capability ranges from DC to > 2.0GHz with < 570ps propagation delay and < 200ps rise/fall time. This component is typically utilized to provide clock distribution for processor, Synchronous Optical Networking (SONET), fiber channel, and Gigabit Ethernet applications [1]. Fig. 1 shows a block diagram and datasheet performance specifications for the SY89832.

B. Analog Devices ADL5330

The Analog Devices ADL5330 Variable Gain Amplifier (VGA) is a high-performance, voltage-controlled, variable-gain amplifier/attenuator typically employed in RF and IF power control for transmitter and receiver applications ranging in frequencies from 10MHz to 3GHz. Component features include high linearity (i.e. output third-order intercept point (OIP3) ≥31dBm at 900MHz), low noise floor (≤-150dBm/Hz at 900MHz), single or differential-ended operation, wide gain control range (-34dB to +22dB at 900MHz), and operation from a single voltage supply (5±0.25Vdc). The ADL5330 is fabricated on Analog Devices’ high-performance, complementary bipolar process [2]. Fig. 2 shows a block diagram and datasheet performance specifications for the ADL5330.


C. Microsemi SG1536

The Microsemi SG1536 is a complementary bipolar, monolithic operational amplifier (Op Amp) designed for high voltage applications up to ±40V; especially where high common-mode input ranges, high output voltage swings, and low input currents (i.e. less than 35nA) are required [3]. Fig. 3 shows the datasheet schematic of the SG1536.

Fig. 3. Schematic from SG1536 datasheet.

III. PROTON TEST RESULTS

The SY89832U fanout buffer and the ADL5330 variable gain amplifier were exposed to 105 MeV protons at the Triumf radiation testing facility in Vancouver, BC. Both devices were exposed to a fluence of approximately $3.5 \times 10^{11}$ protons/cm$^2$, corresponding to a total ionizing dose of 33 krad(Si). The SG1536 operational amplifier was exposed to 64 MeV protons at the University of California-Davis Crocker Nuclear Laboratory to a fluence of $1.0 \times 10^{12}$ protons/cm$^2$ providing a total ionizing dose of 148 krad(Si). The following sections provide additional test condition details along with the test results for each of the three components.

A. Microchip SY89832U

The schematic for the SY89832U fanout buffer test circuit is depicted in Fig. 4. Using a proven component evaluation circuit board supplied by the manufacturer, the fanout buffer was configured with a supply voltage of 2.625 Vdc. The input signal was a 50MHz, 400 mV peak-to-peak sine wave originated from the auxiliary output of the Tektronix MDO4104C oscilloscope. This single-ended input signal was fed through a balun to produce the differential input required by the device. The differential outputs, Q0 and Q0/, were also fed through a balun for monitoring on the single ended oscilloscope input. Fig. 5 shows the bench setup and Figs. 6 and 7 show the positioning of the test device with a 45° alignment to the beam.

The supply current was logged once per second throughout exposure to the proton beam and remained stable at 69mA (accurate to 1mA). Fig. 8 shows the stability of the supply current during one of the exposures, which is representative for all the exposures. The output signal was continuously monitored on the oscilloscope (in spectrum analyzer mode) and exhibited stable operation at an output level of -26.4dBm with no transients or other anomalies as shown in Fig. 9.

![Fig. 4. Test setup for the Microchip SY89832U; 1:4, 2.5V LVDS, Fanout Buffer/Translator with Internal Termination and Analog Devices ADL5330; Variable Gain Amplifier.](image)

![Fig. 5. Test setup for the Microchip SY89832U; 1:4, 2.5V LVDS, Fanout Buffer/Translator with Internal Termination and Analog Devices ADL5330; Variable Gain Amplifier.](image)
Fig. 6. Positioning the SY89832U in the beamline for 45 degree angle exposure.

Fig. 7. Positioning the SY89832U in the beamline for 45 degree angle exposure.

Fig. 8. Supply current vs. time during an $8.78\times10^{10}$ protons/cm$^2$ exposure.

B. Analog Devices ADL5330

The ADL5330 variable gain amplifier was tested using a manufacturer-supplied evaluation board hosting integral baluns for single-ended to differential signal conversion. The test setup is shown in Figs. 10 and 11 and the part is configured with a supply voltage of 5.25 Vdc, 0.7V peak-to-peak output level, and 560mV peak-to-peak 50MHz sine wave input signal. This configuration produced a -18.9dBm output signal. The supply current was logged once per second throughout exposure to the proton beam and remained stable at 142mA (accurate to 1mA) (Fig. 12). The output signal was continuously monitored on the oscilloscope (in spectrum analyzer mode) and exhibited stable operation at an output level of -18.9dBm with no transients or other anomalies as shown in Fig. 13.

Fig. 9. Output spectrum for SY89832 LVDS fanout buffer during exposure.
C. Microsemi SG1536

The SG1536 high-voltage operational amplifier was tested using a simple in-situ input bias current measurement scheme. The device test circuit board and schematic are provided in Figs. 14 and 15. The device was powered with a supply voltage of ±15 Vdc, which produced an initial supply current of 1.795 mA and input bias current of 1.5 nA. Supply current shifts exhibited during exposure to the proton beam are plotted in Fig. 16. As shown in Fig. 17, the input bias current rose to 7.2 nA at the final fluence of 1.1 x 10^{12} (148 krad(Si)). These minute shifts in supply current, as well as the input bias current, are within the SG1536 specified performance limits.
IV. Conclusion

The results of proton radiation testing for all three COTS, high-performance analog components show promise for space applications. The 105 MeV proton testing of the fanout buffer and variable gain amplifier produced no device performance degradation up to 33 krad(Si) total ionizing dose. The high-voltage operation amplifier, tested with 64 MeV proton radiation, exhibited slight performance degradation; however, operation remained within the device’s specification limits at total ionizing dose up to 148 krad(Si). Additional testing for Enhanced Low Dose Rate Sensitivity (ELDRS) may be warranted for the variable-gain amplifier and the operational amplifier due to their bipolar content.

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REFERENCES