Proton Irradiation Test Plan for the LTC6400-20 Differential ADC Driver

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I. Introduction

The purpose of this study is to examine high energy proton-induced single-event-effects (SEEs) of the LTC6400-20 differential amplifier manufactured by Linear Technology.

II. Device Description

The LTC6400-20 is a high-speed differential amplifier designed to drive 12-, 14-, and 16-bit ADCs. The device features a fixed gain of 10 V/V (20 dB), and a -3 dB bandwidth up to 1.8 GHz. The test/part information is listed in Table 1. The device specifications are listed in Table 2.

Table 1. Test and part information

Generic Part Number	LTC6400-20
Package Markings	746 LCCS N112, 705 LCCS N016
Manufacturer	Linear Technology
Lot Date Code (LDC)	0746, 0705
Quantity tested	2
Part Function	Differential amplifier
Part Technology	Silicon-Germanium
Package Style	16-lead QFN
Test Equipment	Power supply, RF generator, high-speed oscilloscope

Table 2. Device specifications

Parameter	**Test Conditions**	**Min**	**Typ**	**Max**	**Unit**
Gain*	V_{IN} = ±100 mV Differential	19.4	20	20.6	dB
Supply Voltage (V_S)		2.85	3	3.5	V
Supply Current (I_S)	$\overline{\text{ENABLE}}$ = 0.8V	75	90	105	mA
Shutdown Supply Current (I_{SHDN})	$\overline{\text{ENABLE}}$ = 2.4V		1	3	mA

* The actual gain measured at the output of the demo board will be ~14 dB.

III. Test Facility

Facility:	Indiana University Cyclotron Test Facility (IUCF)
Beam Energy:	200 MeV/amu and 60 MeV/amu
Flux:	Approximately 4×10^6 to 1×10^8 $cm^{-2} \cdot s^{-2}$
Fluence:	Approximately 1×10^{12} to 5×10^{13} cm^{-2}

IV. Test Method

A block diagram schematic of the test setup is shown in Figure 1. A computer is programmed to observe and capture the SETs. Figure 2 shows the test circuit designed for single-ended input operation. The application circuit uses input and output transformers for single-ended-to-differential conversion and impedance transformation. The -3dB bandwidth is reduced from 1.8 GHz to 1.3 GHz as a result of the transformers.

A high-speed digital oscilloscope will be connected to the output of the board to capture any single-event-transient (SET). The oscilloscope will be placed outside of the irradiation chamber to avoid being damaged from the radiation environment. Therefore a ~50 feet BNC cable will be used to connect to the device output. There will be some signal loss due to the long cable, thus limiting the frequency range.

Previous proton irradiation showed that the part was sensitive to SETs at 200 MHz, with fluence $\geq 1 \times 10^{12}$ cm^{-2}. The SET cross-section increased from the initial run at a fluence of 1×10^{12} cm^{-2} to the final run with a total fluence of 5×10^{12} cm^{-2}. Therefore the SET cross-section increases possibly due to the increase in accumulated TID and/or displacement damage. We examine these effects here, with the following irradiation steps:

(1) Device 1: 200 MeV protons. Fixed incident angle (0^o). Irradiate up to 5×10^{13} cm^{-2}, in incremental fluence steps.
(2) Device 2: 60 MeV protons. Irradiate at 0^o, 60^o, 90^o, and 0^o.

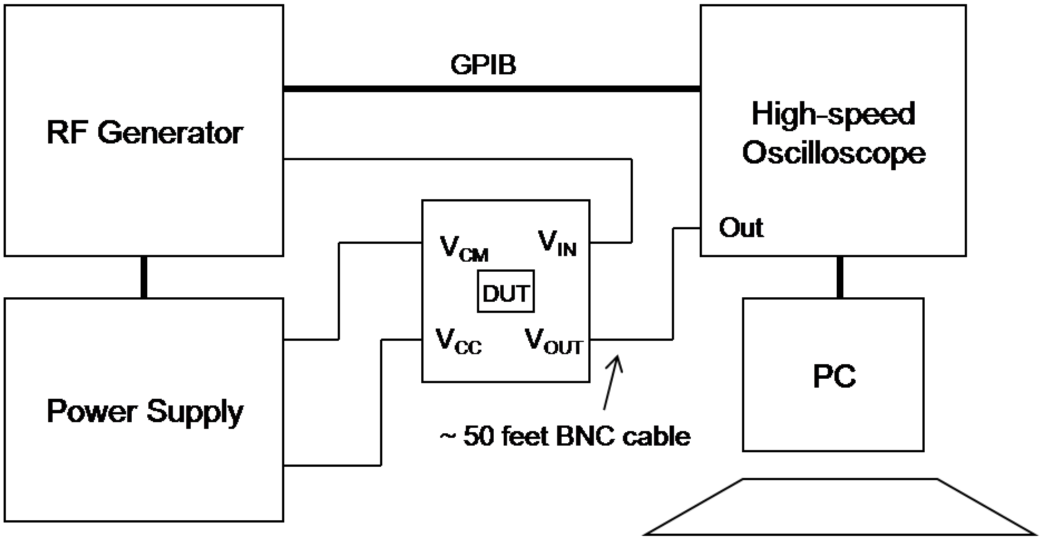
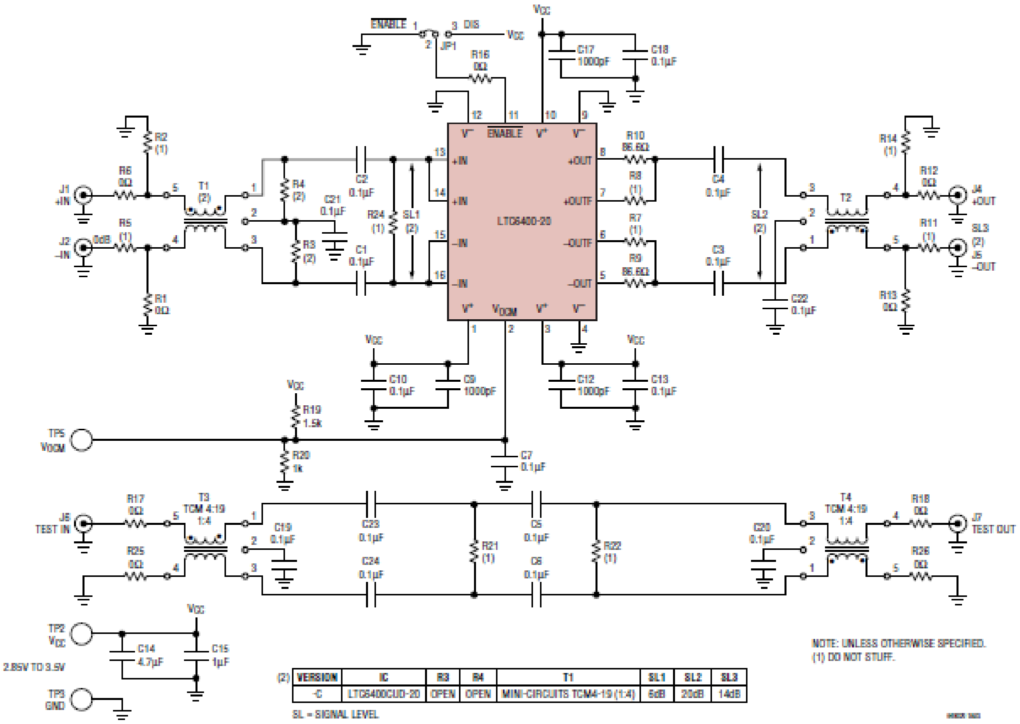


Figure 1. Test setup block diagram.

Demo Circuit 987B Schematic (Test Circuit A)



NOTE: UNLESS OTHERWISE SPECIFIED.
(1) DO NOT STUFF.

(2)

VERSION	IC	R3	R4	T1	SL1	SL2	SL3
-C	LTC6400CUD-20	OPEN	OPEN	MINI-CIRCUITS TCM4-19 (1:4)	6dB	20dB	14dB

SL = SIGNAL LEVEL

Figure 2. Application circuit configuration.

Test Conditions

Test temperature:	Ambient temperature
Angles of incidence:	0^o (normal), 60^o, and 90^o
Operating frequency:	10, 100, and 200 MHz (Since the bandwidth decreases due to increasing frequency, which is also exacerbated by the long cable from the output to the oscilloscope, we will monitor to ensure at least a 3 V/V output to input gain.)
Input supply voltage:	3 V
Common mode voltage:	1.25 V
Input voltage:	100 mV_{pp} sine wave
Parameter:	(1) SETs. The trigger will be set to record deviations in the pulse width of the sine wave signal. SET tests will run until 100 transients are observed and acquired or up to a preset fluence. (2) SELs. The supply current, input currents, and common mode current will be monitored during the irradiation.
Data format:	Data will be reduced to text or Excel format
Beam hours:	8

V. Results

Figure 3 shows the SET error cross-section for a device irradiated at normal incidence up to an accumulated fluence of 2.5 × 10^{13} cm^{-2}. The first data point is based on 1 SET. Therefore the cross-section has a relatively significant error deviation. The dataset may follow a Poisson distribution with allowable standard deviations.

Figure 4 shows the cross-section for the accumulated SETs vs. the accumulated proton fluence. The cross-section increases notably from a proton fluence of approximately 5 × 10^{13} cm^{-2} to 8.2 × 10^{13} cm^{-2}. Then the rate of increase in the cross-section slows after ~ 1 × 10^{13} cm^{-2}. The data points should follow a constant flat distribution, if the SET error rate is independent of proton fluence and/or total dose. The data here show an increase in the error rate with accumulated proton fluence at earlier fluence levels. Figure 5 shows an example of an SET.

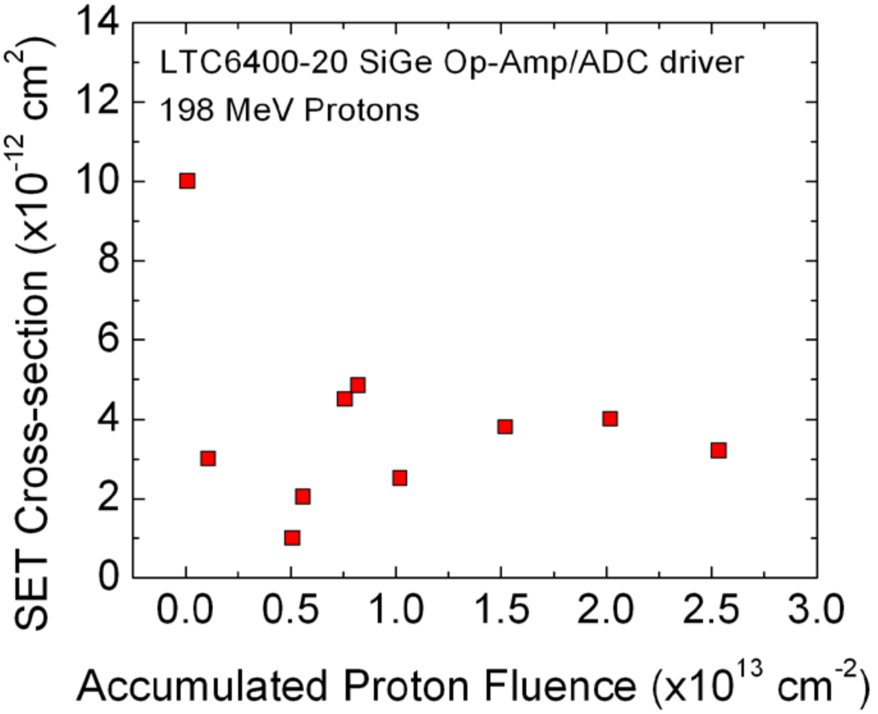


Figure 3. SET cross-section vs. accumulated fluence for the LTC6400 SiGe Op-Amp/ADC driver irradiated with 198 MeV protons.

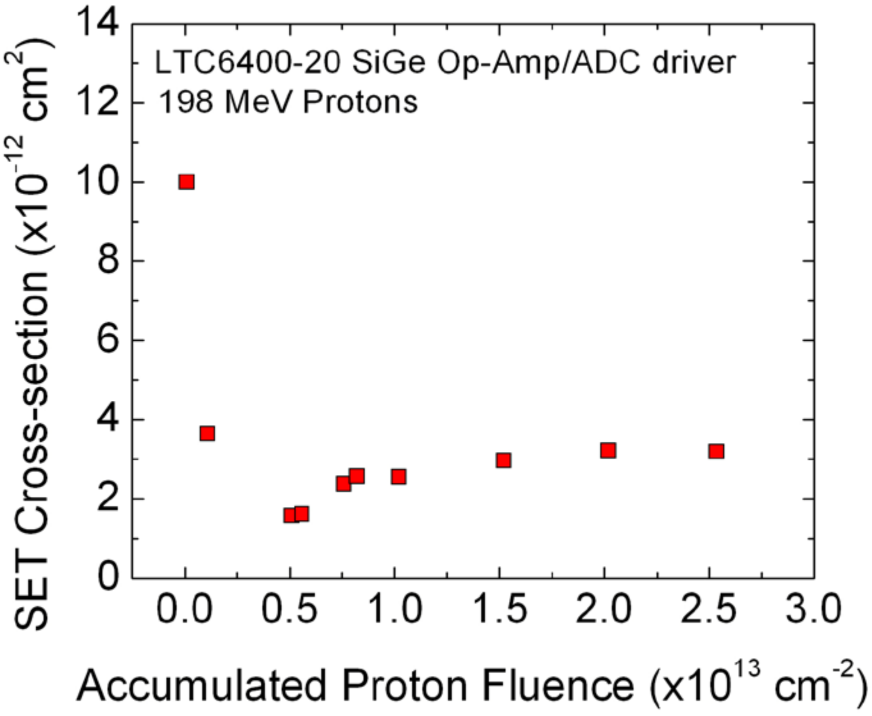


Figure 4. Cross-section from accumulated SETs vs. accumulated fluence for the LTC6400 SiGe Op-Amp/ADC driver irradiated with 198 MeV protons.

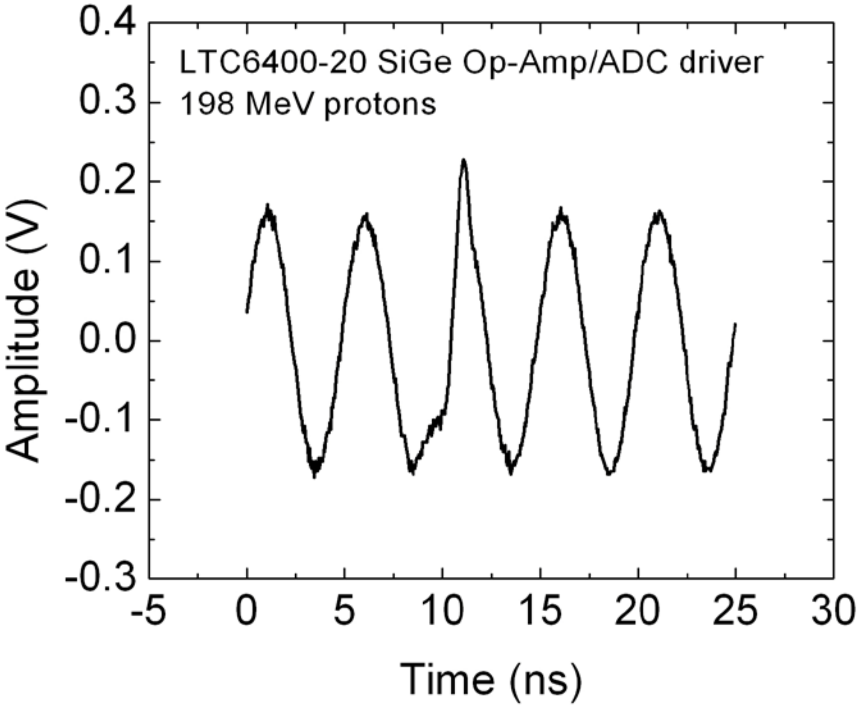


Figure 5. SET from 198 MeV proton irradiation.

We also irradiated a second part with 54 MeV protons at normal, 60^o, and 90^o incident angles. We irradiated the part up to a fluence of 2×10^{12} cm^{-2} for each angle. The irradiation produced 1 SET at normal incidence, 1 SET at 60^o, and 0 SET at 90^o incident angle. We checked the part for consistency with a final irradiation at normal incidence with 198 MeV protons up to 2×10^{12} cm^{-2}, producing 5 SETs and a cross-section of 2.5×10^{-12} cm^2.

VI. Conclusion

The LTC6400 SiGe differential output amplifier/ADC driver exhibits susceptibility to SETs from 198 MeV proton irradiations. Most SETs disrupt one cycle of the signal, with the device operating at 200 MHz.

We suspected an increase in the error-rate with increase in accumulated proton fluence, from a previous proton test. However the devices in this experiment exhibit reduced cross-sections at similar fluence levels. We observed a slight increase in the error rate from accumulated fluence levels of 5×10^{13} cm^{-2} to 8.2×10^{13} cm^{-2}, where the cross-section increased from 1×10^{-12} cm^2 to 4.8×10^{-12} cm^2. However the cross-section is reduced for larger accumulated fluence levels. The results may indicate that the cross-section is independent of accumulated proton dose, if the increase in cross-section at the earlier stages of irradiation can be accounted for by the error deviation of a Poisson distribution. The increase in cross-section may also indicate a dependence on accumulated proton dose, which is consistent with previous results. Part-to-part variation possibly caused the differences in the magnitudes of the cross-sections.