Radiation Report

LMX2694-SEP Single Event Effects Test Report

ABSTRACT

The LMX2694-SEP 15-GHz RF Synthesizer was tested under heavy ions and monitored for Single-Event Latchup (SEL) and Single-Event Functional Interrupt (SEFI). No incidences of SEL or SEFI were detected at an effective linear energy transfer (LETeff) greater than 43 MeV-cm^2/mg with a fluence of 1 x 10^7 ions/cm^2. SEL testing was performed at maximum operating temperature and voltage.

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Trademarks

All trademarks are the property of their respective owners.

1 Product Description

The LMX2694-SEP is a wideband phase lock loop (PLL) with an integrated voltage controlled oscillator (VCO) (see Figure 1-1). It is part of TI's Space Enhanced Plastic (Space EP) product line for space applications with reduced radiation and reliability requirements[(1)]. The LMX2694-SEP is similar to the Enhanced Product LMX2694-EP[(2)] designed for military and avionics applications, except that the LMX2964-EP does not have the radiation performance or extended reliability qualification of the LMX2694-SEP.

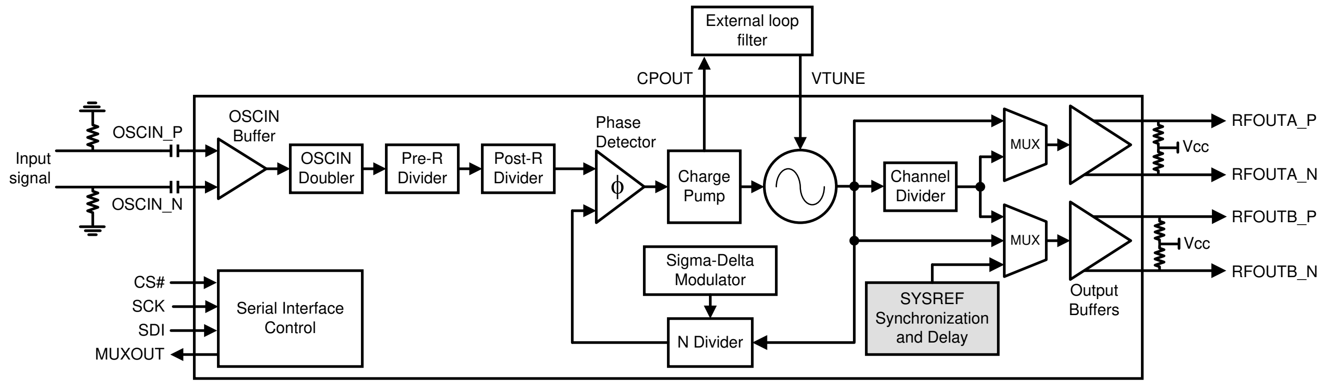

Figure 1-1. LMX2694-SEP block diagram

The VCO operates from 7600 to 15200 MHz and this can be combined with the internal output divider to produce any frequency in the range of 40 MHz to 15.2 GHz. The PLL is fractional-N PLL programmable to better than 1-Hz precision.

The LMX2694-SEP adds support for either generating or repeating SYSREF (compliant to JESD204B standard), and can be used as low-noise clock source for high-speed data converters. JESD204B is a serial interface standard used between data converters and logic devices with serial data rates up to 12.5 Gbps[(3)]. SYSREF is a timing phase reference synchronous with the output signal. The LMX2694-SEP has a dual output where output RFoutB (see Figure 1-1) can be configured as a second output or a SYSREF signal.

The part is configured through a serial peripheral interface (SPI) and the configuration is stored in registers. The state of the registers can be accessed through a register read.

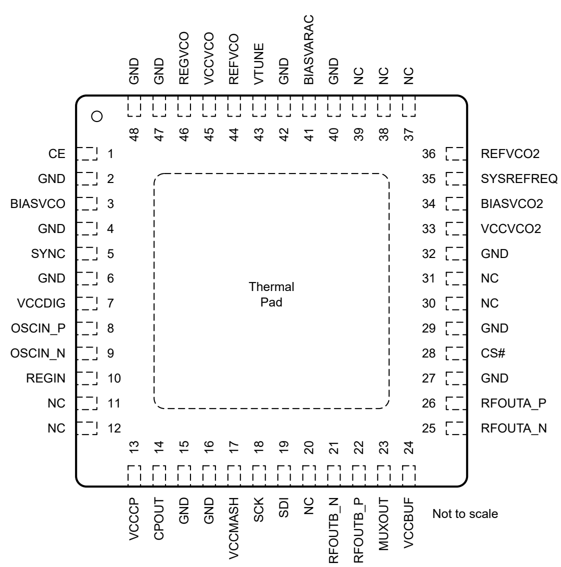

Figure 1-2. LMX2694-SEP Pinout

The process for the LMX2694-SEP is an advanced BiCMOS process with SiGe bipolar transistors.

The LMX2694-SEP was tested under heavy ions for Single-Event Latchup (SEL) and for Single-Event Functional Interrupt (SEFI) to determine if the program registers would be upset under heavy ions.

2 Test Setup

The device under test (DUT) was decapped to expose the surface of the die to the ion beam. The DUT was soldered to an engineering test board similar to the LMX2694EPEVM[4].

Power to the DUT board was supplied by an Agilent 6702 quad supply. The 6702 was controlled and the output current to the DUT board was monitored by an NI-PXIe-8135 controller using a custom Lab View® GUI (PXI Rad Test) developed by Texas Instruments for SEE testing. The voltage was set to 3.45 V as measured at the DUT board. The current limit of the power supply was set to 1 A. The supply current was monitored on every ion run.

The registers were written and read back using Texas Instruments' USB2ANY PC interface and TICS PRO software[4].

An external differential 100-MHz signal was placed on the OSCin inputs.

For SEL testing, the DUT was tested under two different configurations to ensure that all parts of the DUT were powered up for at least one ion run. The configurations were:

- **Configuration 1:**
  - OUTA_MUX = Channel Divider
  - OUTB_MUX = SYSREF
  - SYNC mode VCO PHASE SYNC = 1
  - Integer PLL MASH_ORDER
  - OSC 2X enabled
- **Configuration 2:**
  - OUTA_MUX = Test mode
  - OUTB_MUX = Test mode
  - Fractional PLL: 3rd Order Modulator
  - OSC 2X enabled

During the SEL testing, the DUT was heated using a forced air heat gun and the temperature of the DUT package was monitored with a thermocouple. The heating method was not perfectly stable and the case temperature varied from 117 °C to 132 °C. Typically, the part would start out between 117 °C and 125 °C and drift higher. The actual junction temperature was higher due to power dissipation and self-heating and the actual junction temperature is unknown.

SEFI was tested in two ways:

1. The output of the device was monitored during each ion run. If the function of the DUT changed permanently and the registers had to be rewritten, this would be considered a SEFI.
2. On some ion runs, the registers read before and after the ion run and the results were compared using the Beyond Compare software. If any programmable register bit changed at the end of the ion run, this would also be considered a SEFI.

3 Test Facility

Heavy ion irradiation was done at the Texas A&M University Cyclotron Institute Radiation Effects Facility[5] on June 26, 2020. The linear energy transfer (LET) was greater than 43 MeV-cm^2/mg. Each ion run was to a fluence of 1 X 10^7 ions/cm^2.

4 Results

4.1 SEFI Results

The output of the DUT could have been monetarily upset during an ion run, but the output always returned to the frequency programmed into the DUT. The DUT operated properly after each ion run and the registers did not need to be rewritten.

On some ion runs, the registers were read before and after the ion run. The readings were compared using the Beyond Compare software. No changes were seen in any of the registers. Figure 4-1 shows a screen capture of the Beyond Compare GUI processing data from ion run 34 using register Configuration 1. The “Exact” at the bottom of the screen indicates that the pre and post ion run register readings match exactly.

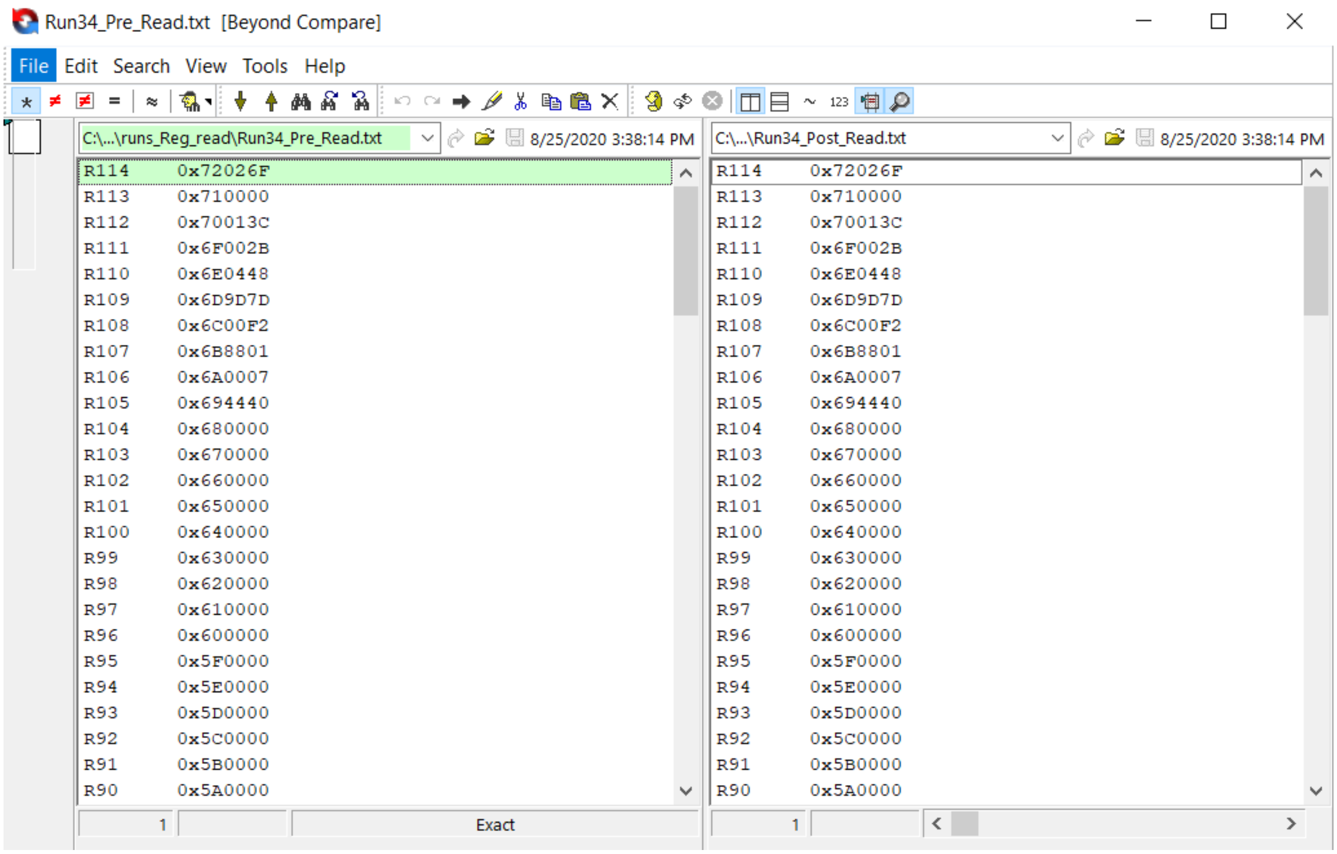

Figure 4-1. Screen capture of Beyond Compare comparing registers pre and post ion run 34.

4.2 SEL Results

Due to slight variations in the DUT case temperature caused by imprecise temperature control of the forced air heat gun, a small amount of drift in the supply current was seen over time. The temperature would fluctuate up and down, but there was a general trend of increasing temperature which resulted in a general rise in supply current.

Figure 4-2 is a plot of the power supply current to the DUT board from ion run 34 with the DUT in Configuration 1. The DUT board current starts at 0.3 A when powered up. The current increases to 0.55 A when the DUT is programmed with Configuration 1.

During an ion run, Single-Event Upsets (SEUs) of the output were detected. With the DUT in Configuration 1, small spikes in supply current were seen during the ion runs as the DUT automatically recalibrated after certain SEUs. The calibration cycle results in a rise in supply current during the calibration. After the calibration was completed, the supply current returned to the nominal value before the ion run was completed. No permanent increase in supply current was seen.

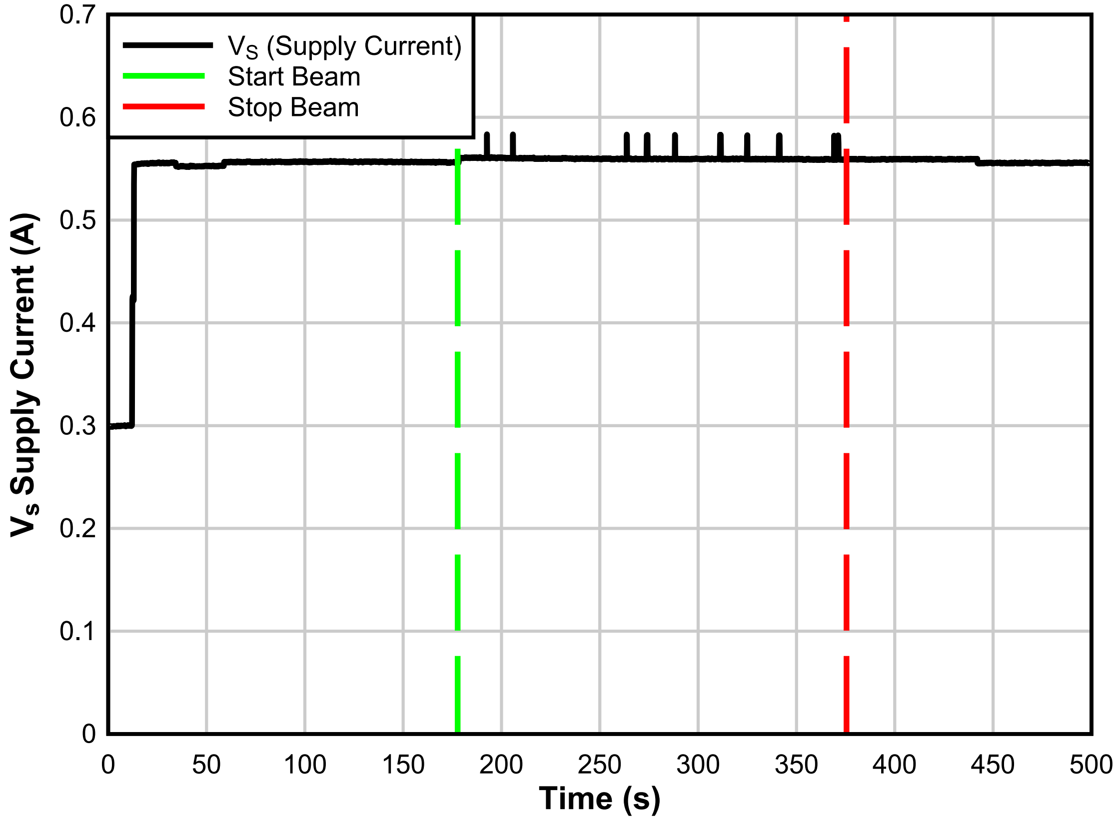

Figure 4-2. Ion Run 34 With DUT in Configuration 1

In the test mode of Configuration 2 with SYSREF disable, the DUT will not self-calibrate. No current spikes were seen during the ion run in this configuration, as shown in Figure 4-3. The supply to the DUT board starts at 0.3 A and then increases after the DUT is configured through the SPI. The downward spike in supply current at close to 50 s occurred when the DUT configuration was changed a second time.

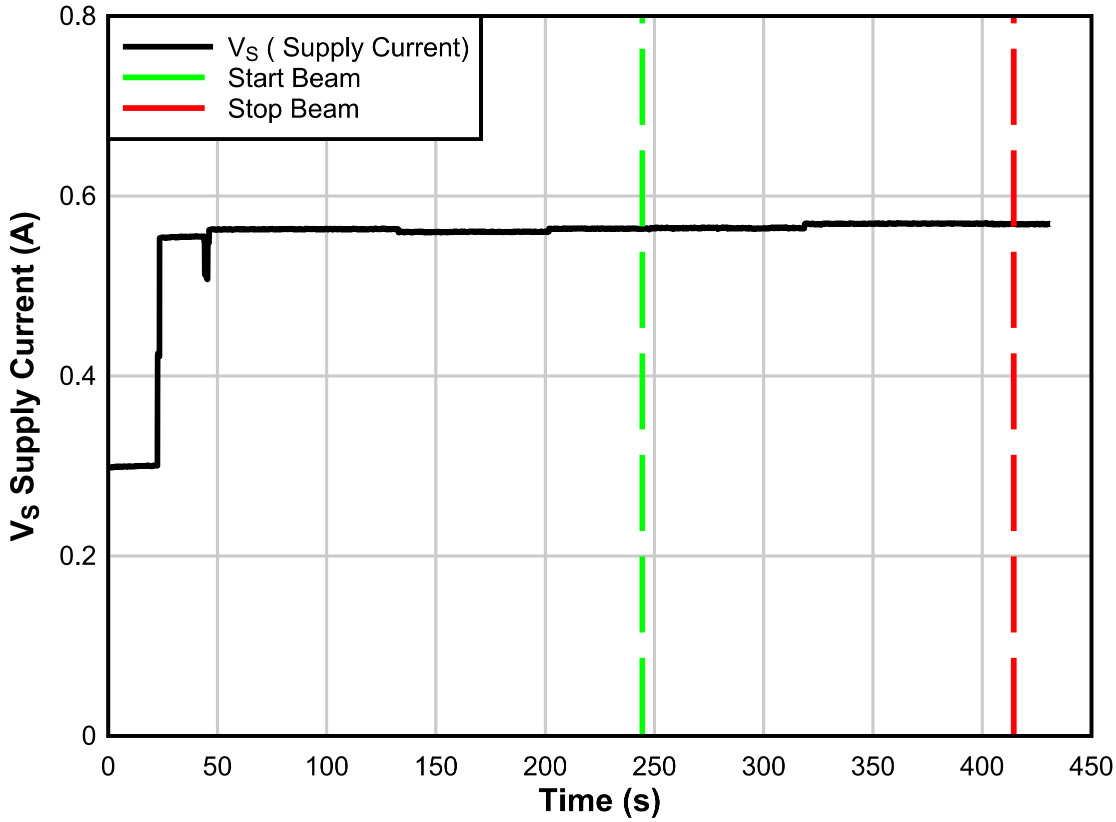

Figure 4-3. Ion Run With DUT in Configuration 2

5 Summary

Under heavy ion testing, the LMX2694-SEP was found to be SEL and SEFI immune up to 43 MeV-cm^2/mg.

6 References

1. Texas Instruments , Dallas, TX, “Reduce the risk in NewSpace with Space Enhanced Plastic products,” Kirby Kuckmeyer, July 2019
2. Texas Instruments , Dallas, TX, “LMX2694-EP 15-GHz Wideband PLLatinum™ RF Synthesizer With Phase Synchronization,” June 2020
3. Texas Instruments , Dallas, TX, “JESD204B Overview,” July 2016,
4. Texas Instruments , Dallas, TX, “LMX2694-EP EVM Evaluation Instructions,” October 2019
5. "Cyclotron Institute, Texas A&M University,"

7 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (September 2020) to Revision A (April 2022)	Page
• Removed the Selective Disclosure statement from the document and set the document for public release.....	1

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