SAND2020-0100R

Sandia National Laboratories

Icarus Relaxation Oscillator and Time Delay Temperature Testing

Alexis A. Boone

June 2019

U.S. DEPARTMENT OF ENERGY NNSA

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S.Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND No. 20XX-XXXX.

Sandia National Laboratories

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Background

Using the Thermotron S-series environmental chamber and the Sandia National Laboratories' RevD board, four Icarus sensors were characterized from -20 □ to 90 □. The relaxation oscillators and the delay time between the trigger generated by the Stanford Research Systems DG535 delay generator and HST_AW0_EDGE were tested. Icarus sensors IV2-04G04, IV2-09G08, IV2-05-3AG04, and I-11G16 were used. These parts vary in lot number, wafer number, die number, and IV2-09G08 has a copper lid. In Table 1 the specifications of each part are listed.

Part Number	Lot	Wafer	Die
IV2-04G04	140303A	4	4
IV2-09G08	140302A	9	8
IV2-05-3AG04	140303A	5	5
I-11G16	104802A	11	16

Table 1 Sensor Information

Relaxation Oscillator Frequency

To test frequency of the relaxation oscillator, temperature was swept from -20 □ to 90 □ and the oscillator frequency recorded five times every 10 degrees on the Agilent Technologies MSO9104A oscilloscope. Each sensor was tuned to approximately 500 MHz at 30 □ by adjusting the voltage input of HST OSC CTRL to get the frequency as close to 500 MHz as possible. Due to limitations on system accuracy of HST_OSC_CTRL tuning, there is some variation around the 500 MHz nominal frequency. As expected, each sensors frequency varies slightly, but the behavior of their respective plots is similar. The slopes are similar, and all plots show the frequency decrease as temperature increases. The slope is approximately - 0.7 MHz/C. You should expect a decrease of between 5 MHz and 10 MHz for every increase of 10 □ in temperature. Figure 1 shows the relaxation oscillator frequency across the temperature sweep. Figure 2 shows the frequency behavior of the sensors and their relation to each other normalized at 500 MHz for 30 □. To normalize take the difference between 500 MHz and the measurement for 30 □ and subtracted the difference from each measurement for the entire sweep on that sensor, which makes the measurement at 30 □ 500 MHz.

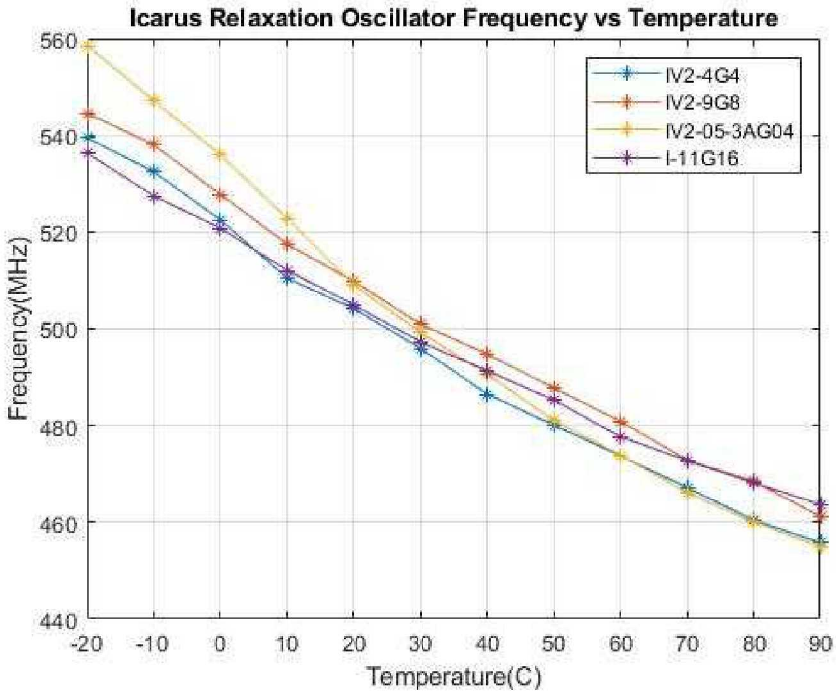

Figure 1 Icarus Relaxation Oscillator Frequency vs Temperature

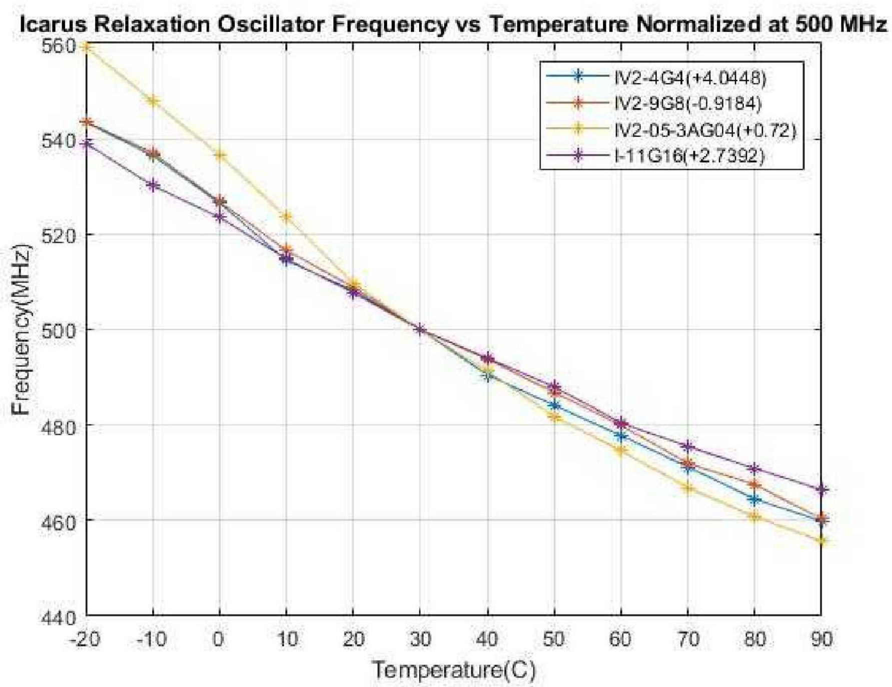

Figure 2 Normalized Oscillator Frequency

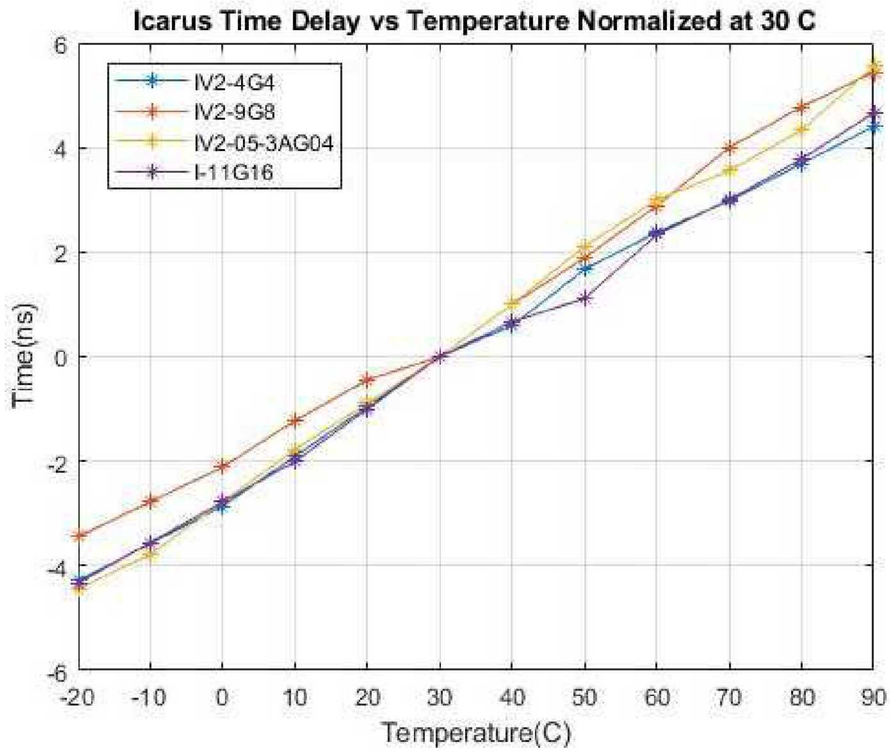

Figure 3 Icarus Time Delay vs Temperature

Trigger to Edge Detect Delay

To test trigger-to-shutter delay over temperature, a temperature sweep from -20 □ to 90 □ was performed, recording the delay between trigger reaching 1.65 V HST_AW0_EDGE reaching 1.65 V every 10 □ was performed. This time delay was recorded on the oscilloscope by setting the trigger and HST_AW0_EDGE on separate channels. The time delay from trigger to HST_AW0_EDGE increases as temperature increases. There is a delay increase between 0.5 ns and 1 ns for every increase of 10 □. Figure 3 shows the delay normalized to a “zero delay” at 30 □ and the comparison of four different sensors. To achieve this normalization, subtract the delay time at 30 □ from each data point leaving the difference between the 30 □ measurement and the other temperature measurements. The raw timing data is shown in Figure 4. As with frequency there are small shifts between the parts, but the overall behavior is similar.

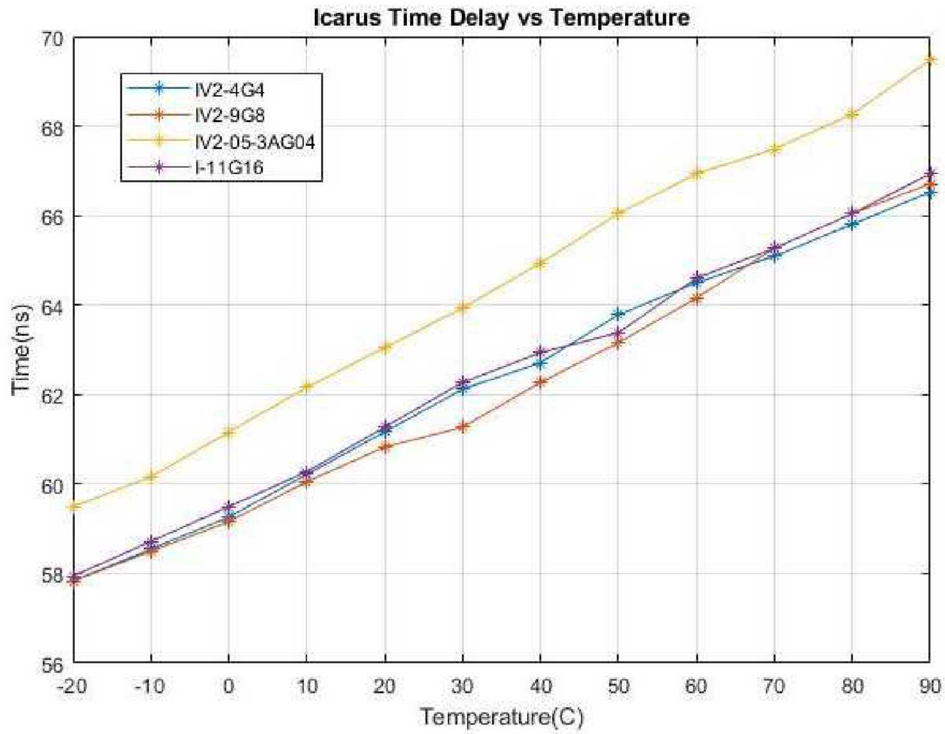

Figure 4 Icarus Time Delay

Standard Deviation of Frequency Test

The standard deviation of the oscillator frequency was also determined during the frequency vs. temperature experiment. In Figure 5, the standard deviation is shown as a percentage of the mean. The standard deviation as a percentage of the mean is under 0.2% for all parts at all temperature points. The original standard deviation as MHz is shown in Figure 6. The standard deviation is between 100 kHz and 700 kHz.

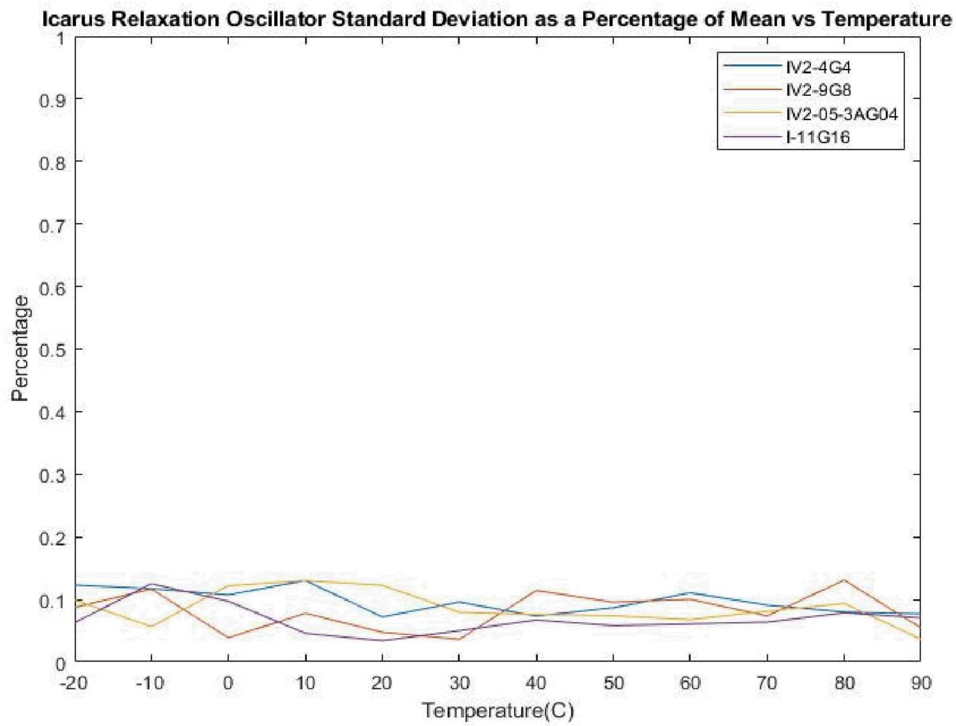

Figure 5 Icarus Standard Deviation as a Percentage of Mean

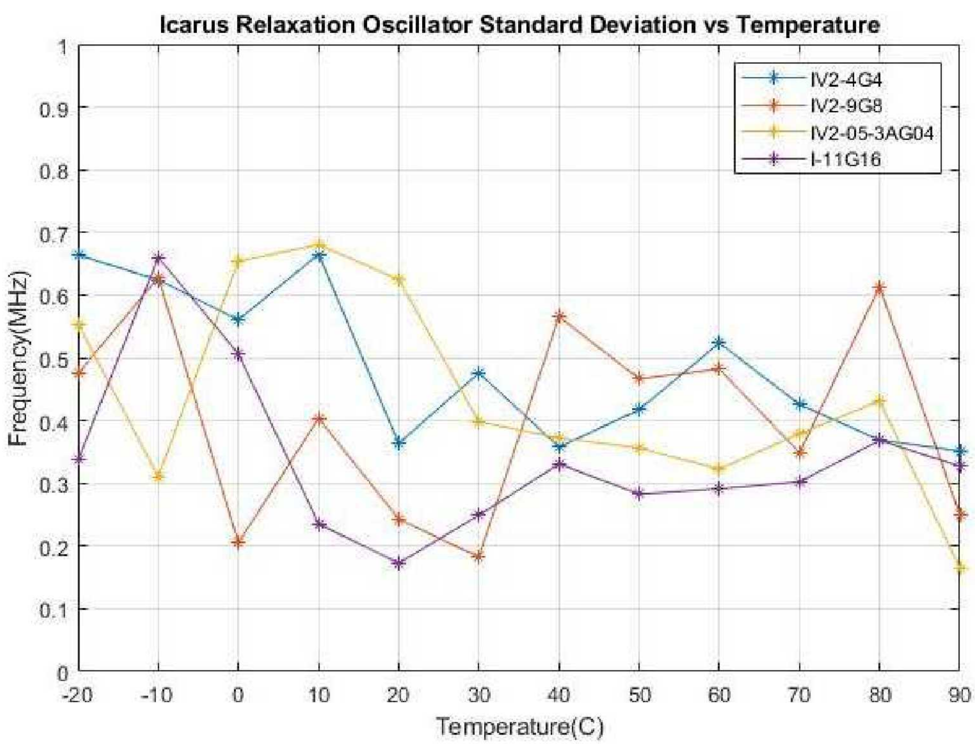

Figure 6 Icarus Relaxation Oscillator Frequency Standard Deviation

Testing Procedure

To find the time delay the oscilloscope was used to mark from when the trigger reached 1.65 V and when HST_AW0_EDGE reached 1.65 V. The trigger is shown on channel 1, in yellow, and HST_AW0_EDGE is shown on channel four, in red, on Figure 5. The measurement markers were used to find the time between, these are the orange markers shown on Figure 5.

Figure 7 Time Delay

To record the frequency of HSTDIVCLKA the frequency measurement on the oscilloscope was used and the frequency was read off the measurement section at the bottom of Figure 6 for channel 2 which is represented as the green waveform in Figure 6. To trigger the oscillations, a delay generator was used and would be executed several times showing different frequencies on the oscilloscope, this was done five times with all five frequencies recorded.

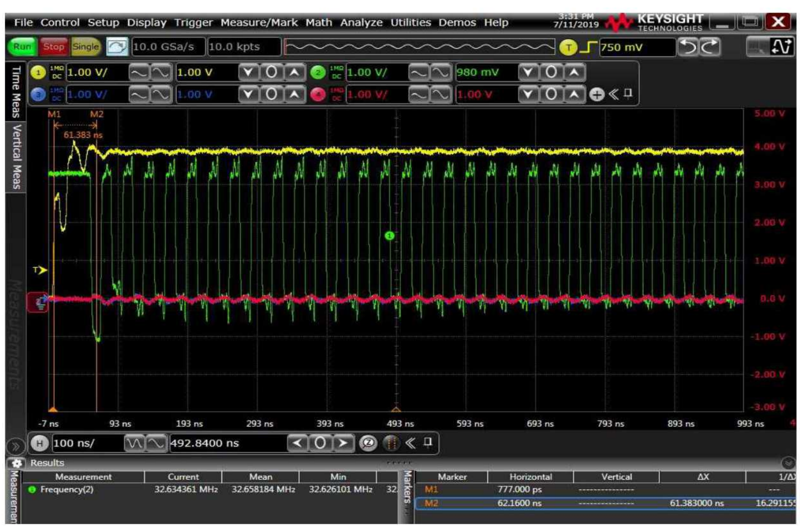

Figure 8 Frequency Measurement

Pigtail Effects

During testing, a pigtail extender was used to connect the sensor and RevD board allowing the sensor to be in the Thermotron without having the RevD board inside the Thermotron. This effected the frequency and time delay. Figure 7 contains the results of the pigtail effects on the testing. All of this was performed at 21.7 □ and used the same test procedure as the previous testing, the only difference was for use without the pigtail the sensor was plugged directly into the RevD board while with the pigtail the sensor was plugged into the pigtail which was then plugged into the RevD board. The delay increased by approximately 5 ns and the frequency decreased by approximately 8 MHz when the pigtail is in use.

Part	Time Delay with Pigtail (ns)	Time Delay without Pigtail (ns)	Frequency with Pigtail (MHz)	Frequency without Pigtail (MHz)
IV2-4G4	62.715	57.498	511.5032	521.522667
IV2-9G8	61.050	56.166	508.7651	516.2608

Table 2 Pigtail Comparison