TECHNICAL NOTE 36

Measurement of oscillator jitter

1. Introduction

The purpose of this note is to summarize the methods that Statek uses to measure oscillator jitter. In brief, we use the jitter measurement capabilities of the LeCroy WavePro 7100A oscilloscope with the JTA2 jitter analysis software package. With this and some signal amplification, jitter as low as about 1.5 ps can be measured.

It is important to keep in mind that the measured jitter is always larger than the true jitter of the oscillator as the measured jitter includes both the jitter of the oscillator and contributions from the oscilloscope. The true jitter of the oscillator may be much lower than that measured. However, while it appears that the oscilloscope's contribution to the jitter is roughly 1-2 ps, we do not attempt to remove this. Instead, we report the measured jitter as the jitter of the oscillator.

In Sec. 2, we describe the basic measurement configuration. While this configuration is often sufficient, it has the disadvantage that much of the measured jitter is dominated by measurement noise. In Sec. 3, we describe the amplified configuration, which reduces the jitter noise floor. Lastly, in Sec. 4, we summarize the details of the oscilloscope setup.

Our conventions and notation follow that of Statek Technical Note 35 [1]. Herein, S refers to samples, so 16 MS is sixteen million samples and 20 GS/s is a sample rate of twenty billion samples per second.

2. Basic measurement configuration

Figure 1 shows the basic configuration used for the measurement of jitter. The oscillator is powered by a dc-power supply set to the nominal voltage for the oscillator (e.g., 3.3 V). As is the normal practice, we add a 0.1 µF bypass capacitor between power and ground near the oscillator.

The output of the oscillator is ac-coupled[1] through a 0.1 µF capacitor to a LeCroy HFP1500 active probe connected to a LeCroy WavePro 7100A oscilloscope. As the probe has a 1.5 GHz bandwidth and the scope has a 1.0 GHz bandwidth, the combination has a roughly 800 MHz bandwidth (440 ps rise time).

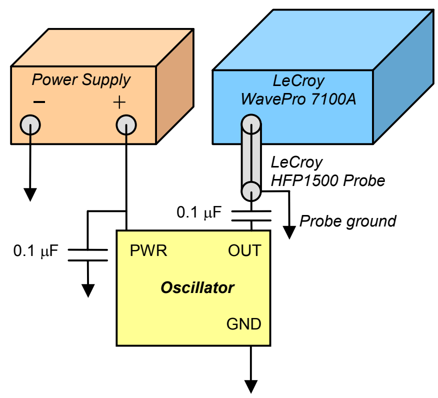

Figure 1—Basic measurement configuration. All downward pointing arrows denote connection to a common ground point (the oscilloscope probe ground).

With the oscilloscope setup as in Sec. 4, we capture 0.8 ms of the oscillator output in real time with a sample rate of 20 GS/s. The JTA2 jitter analysis software creates a histogram of periods as shown in Figure 2. The distribution of periods is normally Gaussian so we characterize its spread by its standard deviation, which is also calculated by the JTA2 software.

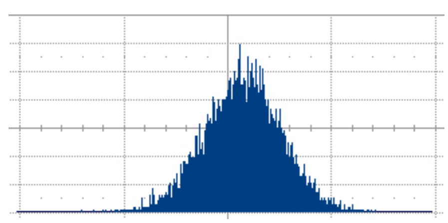

Figure 2—Histogram of the periods of 16,000 cycles of an oscillator produced by the LeCroy WavePro 7100A with JTA2 jitter analysis software. The horizontal scale here is 5 ps/div. The distribution has a Gaussian shape with a standard deviation of 1.75 ps.

[1] The use of the ac-coupling capacitor is not required, but it does have the advantage that it forces the average value of the output signal to zero. With this, we can use zero (ground) as both a trigger voltage and the reference voltage for making jitter measurements.

3. Amplified measurement configuration

One problem with the measurement configuration in Figure 1 is that the lack of perfect voltage measurements of the signal leads to errors in the measured timings, which in turn translates to an increase in the measured jitter. To reduce this effect, we ac-couple[2] the output of the oscillator into the input of an amplifier whose output is ac-coupled[1] into the LeCroy probe and scope as above. Figure 3 shows the amplified measurement configuration.

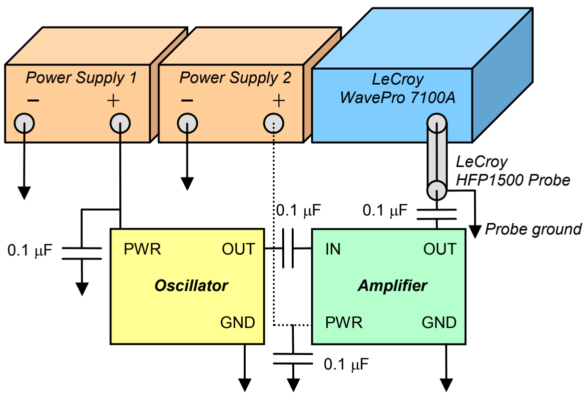

Figure 3—The amplified measurement configuration. Here, the output of the oscillator is amplified with fast rise-time amplifier. All downward pointing arrows denote connection to a common ground point (the oscilloscope probe ground).

For this setup, we choose an amplifier a high slew rate (fast rise time) and operate it on its own power supply at its maximum operational voltage, which further increases the slew rate. The high slew-rate of the amplifier output improves the vertical resolution in our measurements as we now have more voltage change between measurements (which are 50 ps apart in our case).

Again, with the oscilloscope setup as in Sec. 4, we measure the jitter as was done in Sec. 3—the only difference is the amplification of the output of the oscillator.

The amplified measurement configuration is preferred over the basic measurement configuration, especially for lower voltage oscillators (3.3 V and lower).

4. Oscilloscope setup

In both configurations above, we use a LeCroy WavePro 7100A oscilloscope having 16 MS record length and jitter analysis software package JTA2 and a LeCroy HFP1500 active probe. The oscilloscope is setup with the following settings.

Horizontal: We use a real-time sample rate of 20 GS/s, so measurements are made every 50 ps. Further, the record length is set to 16 MS.

Vertical: To maximize the vertical resolution, we set the vertical scale to 20 mV/div.

Trigger: Since the signal is ac-coupled, we trigger on rising edges at zero volts.

Measurements: We set **P1** to measure the period of cycles bound by rising edges through zero volts (**`P1 = per@lvl`**). Further, we set **P2** to measure the period change of neighboring cycles as defined in **P1** (**`P2 = dper@lvl`**).

Math: We set **F1** as the histogram of periods determined by **P1** (**`F1 = hist(P1)`**) and **F2** as the histogram of periods changes determined by **P2** (**`F2 = hist(P2)`**). The histogram in Figure 2 is the histogram given by **F1**.

With these settings, we measure the jitter over a single acquisition, which by the above spans 16 MS × 50 ps = 0.8 ms. Measurement over this short time is appropriate as jitter is defined as a measure of the fast variations in period. We can use many acquisitions to give more data, but care should be taken to ensure that variations in room temperature or other slow factors don't cause the oscillator frequency to wander enough to spread out the period histogram.

References

[1] *An Overview of Oscillator Jitter*, Statek Corporation Technical Note 35, available at www.statek.com.

[2] The ac-coupling capacitor here is required so as not to disturb the dc-bias within the amplifier.