Clock Chip and Oscillator Testing Using Carmel's Time Interval Analyzers

A Complete Solution

The time interval analyzers (TIAs) from Carmel Instruments are ultra-fast frequency and time measurement instrument which can be used as the Time Measurement Unit (TMU) of a test system. They are ideally suited for use in semiconductor and other automated test systems because of their high throughput, performance and low cost. You can add the TIAs to a very low cost ATE (Automated Test Equipment) system and turn it into a system with better accuracy and throughput than the most expensive ATE. In clock applications, the TIAs provide the complete solution – the test system is needed only for the power supplies, digital control, handler control, and the like. The benefits of the TIAs for testing clock chips and oscillators in production are outlined below. For complete specifications, see the Datasheets at www.carmelinst.com. The term "clock chips" refers to all parts which are related to clocks and timing, including PLL-based and other synthesizer sources, clock buffers, clock repeaters, and delay lines. "Oscillators" refers to MEMS, quartz, and silicon oscillators.

Total Throughput

The throughput of a test system depends on the total time that is required to perform a test. This is usually composed of the following:

- Measurement Setup Time – The time to set up all the instruments and the DUT (Device Under Test). Since the TIAs are on the PCI or PCI Express bus, the Setup Time is usually 10 to 50 µs, even for the most complex measurements. The complete setup is sent with one driver call. Compare this to the 2 to 10 ms for a typical GPIB instrument!
- Acquisition Time – The time to acquire the measurements by the hardware. For example, the BI201 can make 4 million measurements per second (that's a measurement every 250 ns). That is, you can take 100 pulsewidth measurements in just 25 µs. Also, the time resolution of 3 ps means that the BI201 can make a frequency measurement with 1 ppm resolution in 3 µs, or 0.1 ppm resolution in 30 µs (see the Frequency application below). The BI221 (PXI) can take 1 million measurements per second with 8 ps resolution.
- Read Time – The time to read the results out of the instruments and process the data. Again, the PCI or PCI Express buses mean that it takes under 500 µs to read 100 measurements out.

The above analysis shows how the total time for a test can easily be under 0.1 ms for individual measurements, or under 0.6 ms when collecting statistics on 100 measurements.

Measurement Rate

The BI201 requires a minimum of 250 ns between measurements (1 µs for the BI221). The signal is continuously counted, but the arming of a measurement can occur at this maximum 4 MHz or 1 MHz rate. This is the highest rate of any high resolution time measurement instrument on the market today. This rate is beneficial in providing the high throughput mentioned above, and for the analysis of dynamically changing signals. For example, a clock signal can have 100 kHz FM modulation on it and the BI201 can directly measure the instantaneous frequency (see "Spread Spectrum" below). Another important application for the high measurement rate is in determining the settling time to frequency (see below).

Resolution

The BI201 is has a single-shot time resolution of 3 ps (8 ps for the BI221). That is, each timetag has this resolution without averaging. For example, you can measure the width of a single pulse with a resolution of 3 ps. Averaging improves the resolution. The 3 ps resolution translates into 12 digits per second for frequency measurements (see "Frequency" below).

Cost

The cost for the TIAs is a fraction of the cost of a high performance tester, while they actually provide much better performance. For clock and oscillator applications, the only high precision needed is in the time measurements, so the TIAs allow you to use the lowest cost testers and still achieve the best possible performance.

Size

The BI201 can be plugged into the PCI Express slot of many PC-based testers for a zero footprint, or you may use a bus expansion chassis with one or more PCI Express slots outside the computer. The BI221 is a PXI instrument. PXI chassis are available with up to 18 slots.

Easy Programming

The TIA software includes an interactive front panel which allows you to experiment with the instruments without any programming, and software drivers for Windows NT, 2000/XP/Vista/Win7 and Linux. The driver supports C++, Basic, C# and all the .NET languages, in addition to VBA which is used on some Teradyne testers. It has a high level API for simplicity. If you can use the front panel then you know how to program the instrument.

Application Support

Carmel Instruments prides itself on excellence in engineering and application support. This includes help in integrating the instruments into a tester, loadboard design, and programming. We stand behind the product in every way. If we develop the application, we will guarantee total system performance levels and test result quality.

APPLICATIONS

The application examples below clearly illustrate the superiority of Carme's TIAs and the benefits they deliver in production testing of clocks and oscillators.

Frequency

This is the most basic measurement for a clock chip or an oscillator. For a synthesizer or PLL, you may have to make many frequency measurements to test different settings, and for an oscillator you may need to make many frequency measurements in order to adjust or calibrate it. Either way, the throughput becomes a critical factor. The BI201 can make a six-digit (1 ppm) frequency measurement in just 3 µs, or a 7-digit (0.1 ppm) measurement in 30 µs, and so on, regardless of the actual frequency. For example, you can measure 50 MHz with 50 Hz resolution in 3 µs or 5 Hz resolution in 30 µs. Also, since the instrument is on the PCI Express bus, the total test time remains fast (see “Total Throughput” above).

Spread Spectrum

Some clock chips can frequency-modulate the output clock signal in order to reduce interference. The TIA can measure this modulation directly, since it can make millions of measurements per second. For example, if the modulation frequency is 100 kHz, then you get 40 frequency measurements during each period of the modulating signal with the BI201 (10 measurements with the BI221). Each of these frequency measurements would have a resolution of 12 ppm, or 0.0012%. See the screenshot below for an example of an actual measurement.

Frequency Settling Time

The testing of the settling time of oscillators and PLLs, either after turn on or after setup change, is usually a challenging task. Two aspects of the TIAs make it easy – first, the continuous measurement architecture, which is unique to true Time Interval Analyzers provides the absolute time of each measurement point relative to the start of the block of measurements. Second, the frequency resolution and measurement rate (see above) allow you to get a plot of frequency vs. time with ppm resolution in frequency and sub-µs resolution in time. The instrument driver returns an array of frequency results which can be simply searched for the proper value.

Risetime

The accuracy of risetime measurements is affected by several factors. First and foremost is the bandwidth of the input of the instrument. The BI201 has an analog input bandwidth of 6 GHz, and an input risetime of 50 ps. You can reliably and accurately measure risetimes down to 50 ps. The input risetime affects the results by adding in a root-mean-square fashion to the actual input signal risetime

$$result = \sqrt{inputRisetime^2 + 50^2}$$

For example, if the actual risetime of a signal is 100 ps, then the instrument will report a result of 111 ps. This error can be corrected for specific test cases. For the BI221 the input risetime is 700 ps.

Another factor is the accuracy of the voltage threshold settings. The TIAs are accurate to 6 mV (200 µV resolution).

Jitter

The 3 ps resolution of the BI201 allows you to directly measure jitter sources down to 3 ps. If you need to measure jitter to lower values, then a technique of mixing the signal with a local oscillator is possible which can improve the resolution. It is possible to measure jitter to sub-picosecond resolution with this method. Please contact Carmel Instruments for details. The advantage of using a TIA such as the BI201 for this measurement is the throughput. The alternative methods of oscilloscopes or bit error rate testers (BERT) are much slower and therefore do not apply well to production testing.

For long term jitter which is caused by low frequency sources such as switching power supplies, powerline frequencies (50 or 60 Hz), the TIA is an excellent choice since it can measure the long term drift for as long as you wish without any loss of resolution.

Pulsewidth and Duty Cycle

Duty cycle is the ratio of the pulsewidth and the period so it is done using two separate measurements. For pulsewidth, the accuracy is affected by the analog input bandwidth of the instrument. The 6 GHz input bandwidth of the BI201 means that you get extremely accurate measurements, even with 200 ps wide pulses. The BI201 can also measure pulsewidth of signals at up to 2 GHz or 4 Gb/s. The BI221 has an input bandwidth of 1 GHz and a maximum frequency of 400 MHz for pulsewidth measurements.

Start-Up Time

The time it takes the oscillator or clock chip to start after power-up is usually difficult to measure. It is similar to the frequency settling time measurement described previously, except that the triggering of the block of measurements is done by connecting the power supply of the device to the Ext Arm input of the TIA (on the BI201 this is a 50Ω input so attenuation with a series resistor may be required). The measurement results from the TIA are reported together with the time of occurrence of each of the measurements relative to the arming time. This makes the measurement very convenient and reliable.

Skew

This is the measurement of the time difference between two channels, usually running at the same frequency, although that is not a requirement for the TIA. The 2-Channel Time Interval function would be used and it measures the time from an edge on one channel to the following positive or negative edge on the other channel. The total accuracy of the measurement depends on the accuracy of the TIA plus the mismatch in the test setup including the cables. If the mismatch in the cable is to be calibrated out, it can be measured at test initialization time (usually done only once in the beginning of a batch of parts). There are several techniques for doing this that are beyond the scope of this note. Please contact Carmel Instruments for details, since we have extensive experience in this area. Accuracies down to 10 picoseconds can be readily achieved.

Frequency Drift

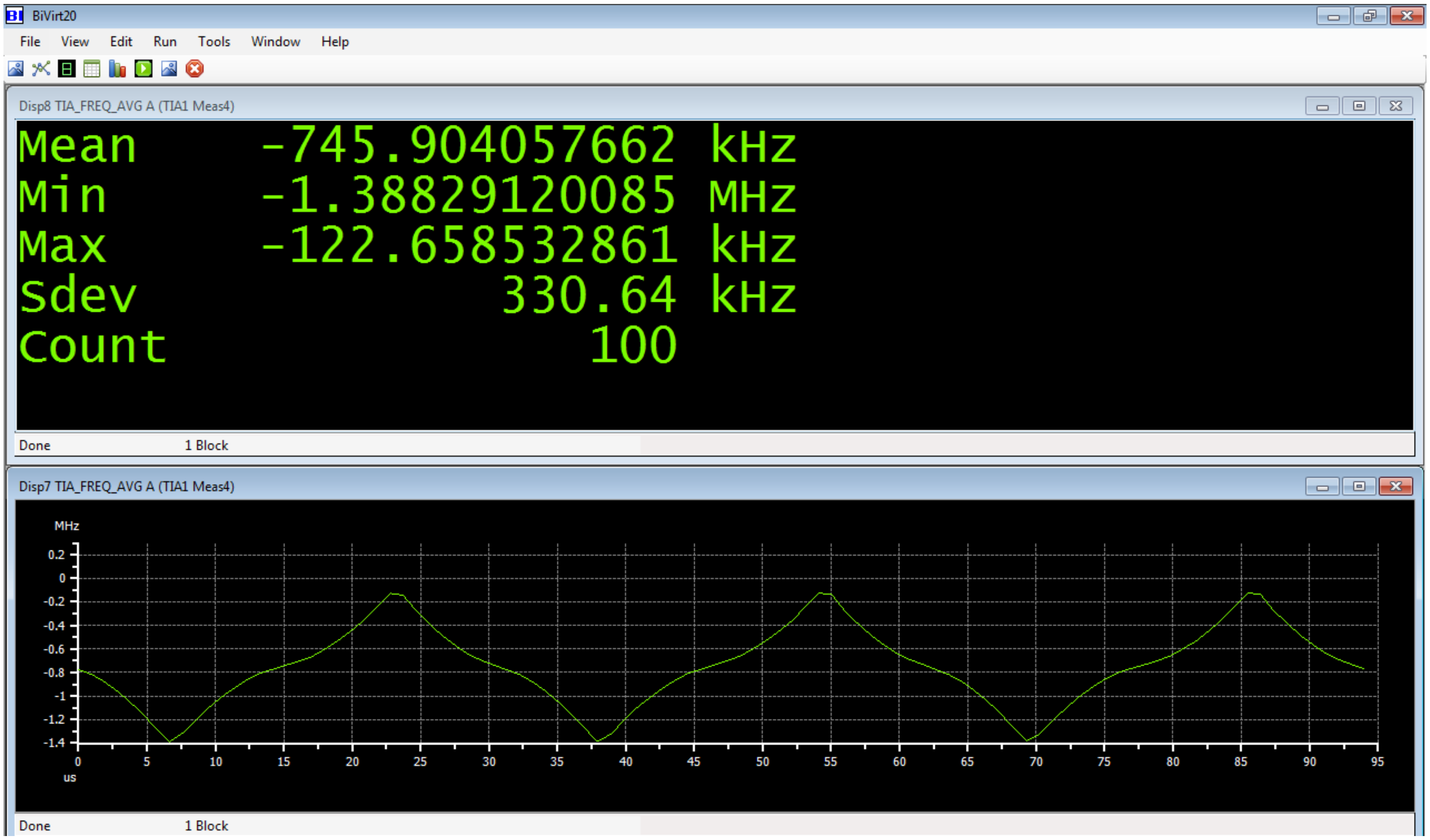
This is a long term and continuous measurement of frequency. Carmel’s TIAs excel in this because you can run measurements continuously and indefinitely. Not one cycle of the signal is missed even if you run the instrument continuously for years. The TIA architecture is therefore great for long term monitoring of oscillators and can detect any abnormal behavior easily.

Multiplexing Multiple Channels

If you have multiple devices or multiple signal sources per device, you can use the BI301 and BI302 Electronic Multiplexers from Carmel Instruments.

System Calibration

Beside the calibration requirements which are outlined in the datasheets, the only requirement at the system level is for skew measurements (see "Skew" above).



Screenshot of Carmel's Virtual Front Panel measuring a spread spectrum clock chip with the BI221 PXI TIA. Shown here are frequency measurements of a 100 MHz clock with 30 kHz modulation. Results are shown as an offset from 100 MHz.