TIME MEASUREMENT TECHNIQUES

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ABSTRACT

This paper will describe the common time measurements as used by the US Air Force Measurements and Standards Laboratory, Aerospace Guidance and Metrology Center (AGMC), Newark Air Force Station, Ohio.

The need for time measurements at several user levels will be discussed. These include comparisons between USNO and AGMC, time measurements in the lab at AGMC, comparisons between AGMC and Air Force precise time activities, and measurements at the activities themselves.

The emphasis will be on electronic counter time interval measurements since this is the most common time comparison measurement in use. The proper use and setting of controls will be covered along with helpful hints and common mistakes to be avoided.

Applications of time measurements will be described. Some of these are timekeeping via Loran-C, TV Line-10, and WWV. Frequency determination using periodic time readings will also be discussed.

This paper will be on a level that can be understood by individuals not previously involved in active day-to-day PTTI measurements. In fact, the purpose of this paper is to acquaint non-PTTI oriented individuals with the intricacies of precise time measurements and to stimulate discussion among others present whose methods may vary from those expressed by the author.

INTRODUCTION

As you may or may not be aware of, time can be measured more precisely than any other basic unit of measurement.

Many precise time measurements are used by the US Air Force Measurements and Standards Laboratory at the Aerospace Guidance and Metrology Center (AGMC), Newark Air Force Station, Ohio. Precise time measurements are also accomplished at various other Air Force activities. This paper describes the techniques normally used by Air Force Laboratories and activities to satisfy precise time measurement requirements.

TIME INTERVAL MEASUREMENTS

The most common precise time measurement is the time interval measurement. In many cases, this measurement is called a delay measurement. An oscilloscope is occasionally used to make time interval measurements but more frequently, a time interval counter is utilized. A time interval reading represents the amount of time that has elapsed between two chosen events. An example of a larger time interval would be the elapsed time between seeing a lightning flash and hearing the thunder. An example of a short time interval would be the time required for the electron beam in a TV picture tube to travel from the gun in the neck to the phosphors on the screen. Naturally, when using a time interval counter, or even an oscilloscope, these events must be defined electrically.

CLOCK COMPARISON

A frequent application of time interval measurement is the comparison or time synchronization of two clocks by determining the amount of time elapsed between the respective 1 pulse-per-second (1 pps) "tick" pulses of the individual clocks. This is accomplished by connecting one clock pulse to the start input and the other clock pulse to the stop input of the time interval counter. In the interest of valid measurements and especially for time interval counters with time base oscillators of questionable accuracy, the external reference frequency standard input can be utilized. The 1 MHz from one of the clocks being measured is most generally used for this purpose. Correct trigger level and slope conditions must be established and will also affect the accuracy of the measurement if not accomplished properly.

A "tick" pulse, or any other pulse, has, along with other shape characteristics, polarity, slope, rise time, pulse length (or duration), and fall time portions. Ideally, before making a time interval measurement, the two clock pulses involved should be observed with the aid of an oscilloscope and the following parameters determined: level (positive or negative), slope (positive or negative) and loading requirements. Next, the point on the pulse that is "on time" must be determined. The time interval counter start and stop trigger level and slope controls can now be set and a reading taken at the rate of once per second. If the time interval counter being used has a storage feature, it can be utilized to hold readings between samples. The algebraic sign given to the time interval reading should be considered next. If the reference clock 1 pulse per second (1 pps) is connected to the start input and the 1 pps of the clock to be measured is connected to the stop input and a reading of less than one-half second results, then the time interval reading is considered to be positive. If a time interval measurement is accomplished and a reading of more than one-half second results, the reading is subtracted from one second and is given a negative sign.

APPLICATIONS

Applications of time interval measurements used by AGMC and other Air Force activities will now be discussed. A time interval measurement is used when comparing the USAF master clocks to the USNO, the USAF master clocks to the AGMC traveling (portable) clocks, and the traveling clocks to the Precise Time Reference Stations (PTRS) at Vandenberg AFB, California, Elmendorf AFB, Alaska, and other Air Force activities who require precise time calibration.

The master clocks at AGMC are steered by daily Loran-C comparisons with USNO. Many other Air Force activities are using the Loran-C comparison method of timekeeping. The reference delay numbers utilized are determined by a time interval measurement. The time interval counter is started with the local clock 1 pps and stopped with the 1 pps from the Loran-C timing receiver.

Another timekeeping technique gaining popularity because of its low cost is the Line-10 TV method. In this instance, the time interval counter is started with the 1 pps from the local clock and stopped with the tenth line odd pulse which occurs once per picture from the Line-10 discriminator. The Air Force is currently using this technique at AGMC, Guam, Colorado, and New Hampshire.

If an activity is keeping time via Loran-C or TV Line-10 and the clock stops, time would have to be known to within a few milliseconds to reestablish precise time. This requirement is usually met by knowing the reference delay number for WWV. An oscilloscope is used for this purpose. It is started (triggered) by the local clock and stopped (position of tick noted on the display) by the detected signal from the HF receiver. So, in essence it is a time interval reading. The measurement represents the time elapsed from the transmission of the tick to the reception of the tick at the timekeeping location.

Another application of time interval measurement is known as "tick to phase" and checks a portion of a clock's digital divider chain. The time interval counter is started with the 1 pps tick pulse and stopped with the 100 kHz from the clock. The trigger level on the stop is adjusted around the zero level until switching the polarity selector from positive to negative yields a 5.0 microsecond difference. The positive polarity reading is then noted and checked from time to time, especially on a clock trip to see if the clock digital divider has jumped.

A characteristic of the 1 pulse per second output from a clock will be discussed next. Here we are concerned with the regularity or repeatability of the 1 pps. The measurement is called tick-to-tick jitter and consists of taking repeated time interval measurements, starting and stopping the time interval counter with successive 1 pps output pulses from the clock being evaluated. A time interval counter with nanosecond or sub-nanosecond resolution and accuracy is a requirement for this measurement. The start trigger is slightly later on the 1 pps pulse than the stop, so the time interval reading is less than one second.

Using successive time interval measurements for determining the frequency offset or frequency drift of a clock will now be described. Basically, this procedure consists of equating the number of microseconds gained or lost in a period of time and computing the offset. A simplified example of this is the timekeeping rule of thumb that approximately one part in ten to the eleventh (1×10^{-11}) frequency offset is the result of gaining or losing one microsecond in one day.

Computing frequency offset after measurement of time gained or lost over a period of days elapsed is routinely used by the Air Force Precise Time Synchronization Teams to determine the frequency offset of various activities site clocks. C-Field adjustment of Cesium clocks are determined using the results of these computations. Actually this is about the only method used at the Air Force Measurement and Standards Laboratory in determining frequency offsets. A variation of this method is sometimes used when time is short and only a few hours or days are available. In this case, a phase comparator/recorder is used. Normally, the 1 MHz signals from a reference and the standard to be measured are compared. This yields a 1 microsecond change each time the indicator travels full scale. Hundredths of microseconds can be read from these recorders and the frequency offset calculations can be accomplished in the normal manner. If greater resolution is desired, a vector voltmeter can be utilized and the degrees phase change measured between the two frequencies being compared is converted to microseconds. One may then use this data to compute frequency offset.

Two other measurements are used by AGMC as confidence checks. First, a good unchanging period count is required of the TV Line-10 pulses prior to obtaining the daily delay numbers. Secondly, although a precise time synchronization team may leave AGMC with sub-microsecond accuracy on their 1 pps of their portable time standard, a check is always made to see that the clock readout indicates the proper hour, minute and second. Credibility is sometimes in doubt when a team claims to be carrying time to better than one microsecond with a clock that indicates a several second or minute error.

SUMMARY

I have attempted to show the need for precise time measurements within the Air Force, how the various measurements are accomplished, and applications of each of the measurements.