Frequency Measurement Using Compact DAQ Chassis

Georgi Nikolov[1] and Boyanka Nikolova[2]

Abstract – **A CompactDAQ system consists of a chassis, C series DAQ modules, and a Windows host computer connected over USB, Ethernet, or Wi-Fi. CompactDAQ chassis control the timing, synchronization, and data transfer between a host computer and DAQ modules. The core technology in CompactDAQ chassis is known as the third generation of the system timing controller. It is possible to use counters for event counting, quadrature encoder measurement, pulse-width modulation, pulse train generation, or period and frequency measurement. These counters are advanced because they contain an embedded or onboard auxiliary counter. This is not directly accessible by the user, but it can be accessed by the DAQmx driver for some frequency measurements. The present paper is aimed to introduce the basic concepts, techniques and the underlying principles that constitute the realization of virtual universal counter. The introduced virtual device is based on counter module, which is build in the third generation of the system timing controller of CompactDAQ Chassis and graphical application development environment LabVIEW. The various methods of frequency measurement are considered in details, supported with error estimation and comparative analyze.**

Keywords – **Frequency Measurement, Graphical Programming, Reciprocal Technique, Virtual Instrumentation.**

I. INTRODUCTION

An important electrical quantity with no equivalent in direct current circuits is frequency. Frequency measurement is very significant in many applications of alternating current, for data transmission, AC power systems etc. Due to many advantages of frequency as an informative parameter of sensors, many manufactures produce different sensors and transducers with frequency, period, time interval or duty cycle output. This measurement transducer converts an input current, an input voltage or the signal from a sensor (thermocouple, Pt-100, resister, measurement bridge, etc.) into a frequency which is proportional to the magnitude of the input signal. Since the signal is in the form of a frequency, dynamic range is not limited by supply voltage and noise. Sensitivity of the device is maximized by a large detector area and precision input circuitry. Once converted to a frequency, the signal is virtually noise immune and may be transmitted over cables from remote sensors to other parts of system. Isolation is easily accomplished with optical couplers or transformers. The signals of several sensors may be easily multiplexed into one microcontroller or counter using digital logic [1, 2].

Data acquisition (DAQ) technology plays a fundamental role in a lot of virtual measurement solutions. The purpose of such a system is generally the analysis of the measured data and the improvement of the object of measurements. The data acquisition system can be divided in two main parts: hardware and software. The hardware part is made of sensors, cables, data acquisition module and computer. The software part is made of the instrumental drivers and the analysis software.

In present paper a design, development and implementation of frequency measuring system is presented. As measuring hardware a CompactDAQ system is selected. The hardware timebase for CompactDAQ system is located on the backplane of the chassis and is not specific to the DAQ modules themselves [5].

As application development environment for designing and implementing of virtual systems is chosen the LabVIEW [4]. This graphically-based programming language is optimized for test and measurement, automation, instrument control, data acquisition, and data analysis applications. Drivers and abstraction layers for many different types of instruments and buses are included or are available for inclusion in LabVIEW. The abstraction layers offer standard software interfaces to communicate with hardware devices. The provided driver interfaces save program development time and even people with limited coding experience can write programs and deploy test solutions in a reduced time frame when compared to more conventional or competing systems.

II. COMPACT DAQ MODULAR SYSTEM

Though fast, a downside to traditional measurement system is that it is a closed system, typically designed for a specific application. Therefore a new system or large modification is needed to implement a new type of measurement. New concepts in data acquisition technology incorporated into a modular production systems have quickly gained popularity primarily to the flexibility and cost-effectiveness that it brings to the final system.

National Instruments has launched a number of CompactDAQ chassis which can be used with more than fifty DAQ modules [5]. These chassis support wireless, USB and Ethernet buses, giving engineers and scientists the ability of a scalable measurement system for portable and distributed applications. There are more than fifty measurement-specific modules that feature multiple electrical and sensor connectivity options and can be combined with any chassis to create customized measurement systems specific to the needs of various applications. With such number of modules, the CompactDAQ platform eliminates the fixed functionality of traditional sensor measurement systems and gives users the ability to increase productivity while decreasing cost [5]. The metal enclosures make the chassis more resistant to environmental damage as compared to the traditional modular DAQ. An innovative signal streaming technology delivers high-bandwidth capabilities that make it possible to achieve sustained high-speed and bidirectional data streams over serial

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buses. In addition the chassis operate in a wide temperature range and can withstand shock and vibration, making them ideal for demanding measurement applications on the benchtop, on the production line or in the field.

All components of the CompactDAQ platform are supported with DAQmx drivers. With these software drivers, engineers and scientists can log data for simple experiments or develop a complete test system in various software environments. Consistent application programming interface means that an application developed for an wireless chassis will work with an or Ethernet chassis without any modifications to the software

The CompactDAQ (cDAQ) system consists of at least three parts as shown in Figure 1 – Input / Output Module (C Series I/O Module), the module interface, and the system timing controller (STC3). These components digitize signals, perform digital–to-analog conversions to generate analog output signals, measure and control digital input and output signals, and provide signal conditioning [5].

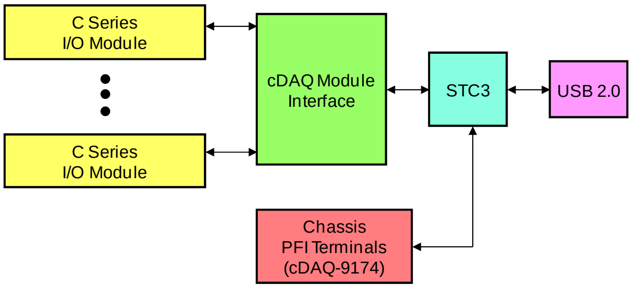


Fig. 1. CompactDAQ-9174/8 Block Diagram.

Input / Output Module (C Series I/O modules) provide built-in signal conditioning and screw terminal, spring terminal, BNC, D-SUB, or RJ-50 connectors. These modules are hot-swappable and automatically detected by the chassis. Bidirectional channels are accessible using the-DAQmx drivers. In most cases, the modules provide isolation from channel-to-earth ground and channel-to-channel.

The CompactDAQ module interface manages data transfers between the STC3 and the I/O modules. The interface also handles autodetection, signal routing, and synchronization.

All multifunction data acquisition hardware requires onboard timing circuitry to control analog, digital, and counter / timer lines. The evolution of timing application-specific integrated circuit technology occurred over decades. The National Instruments System Timing Controller (STC) an custom integrated circuit designed specifically for data acquisition applications. In comparison with the off-the-shelf counter / timer chips generally used on data acquisition devices, the STC stands alone. The third generation timing and synchronization technology STC3 delivers a new level of performance to multifunction data acquisition (DAQ) devices. This technology is the driver behind the advanced digital, timing, triggering, synchronization, counter / timer, and bus-mastering features. STC3 now equips all acquisition and generation tasks with inherent retriggerable capabilities with a single DAQmx property node

With STC3 technology, users can now accomplish more advanced analog, digital, and counter operations. In addition, applications that previously required additional onboard resources or were difficult to program can now execute independently and with less DAQmx code.

Other special functions include buffered pulse-train generation, timing for equivalent time sampling, relative timestamping, and instantaneous changing of sampling rate.

III. METHODS FOR FREQUENCY MEASUREMENT WITH BUILD-IN cDAQ CHASSIS COUNTERS

The CompactDAQ-9174 chassis has four general-purpose 32-bit counter / timers and one frequency generator. The counter / timers can be used for many measurement and pulse generation applications. All four counters on the CompactDAQ chassis are identical. In the Figure 2 the architecture of one of the counters is shown. As can be seen each counter has eight input signals, although in most applications only a few inputs are used [5].

Each counter has a FIFO memory that can be used for buffered acquisition and generation. There are also additional embedded counter. The embedded counters cannot be programmed independent of the main counter and signals from the embedded counters are not routable.

With described functionality of counters build in CompactDAQ Chassis four methods for frequency measurement can be used.

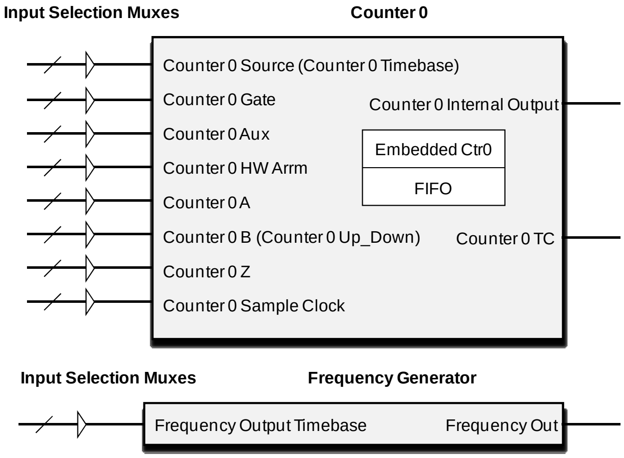


Fig. 2. CompactDAQ-9174 Chassis Counter 0 and Frequency Generator.

A. Period measurement with One Counter

The simplest method is low frequency measurement. This is accomplished by counting the rising or falling edges of a known source frequency f_{ref} between the two consecutive rising or falling edges of the unknown frequency f_X. By taking the frequency of the known source and dividing by the count, it is possible to calculate the period of the unknown signal. Typically one of the internal timebase, 20 MHz or 80 MHz, is used, but external clock source can also be used.

This type of measurement is suitable for low frequency measurement. [7]

B. Frequency Measurement with Two Counters

In this configuration, the counter will count number of unknown high frequency f_X during a period of known signal T_{ref}. The frequency can be calculated by multiplying the count by the frequency of the unknown signal [5].

In this method, a pulse of known duration must be routed to the Gate of a counter. This pulse can be generated by a second counter or can be generated externally and connect it to a PFI terminal. For second approach only one counter is needed.

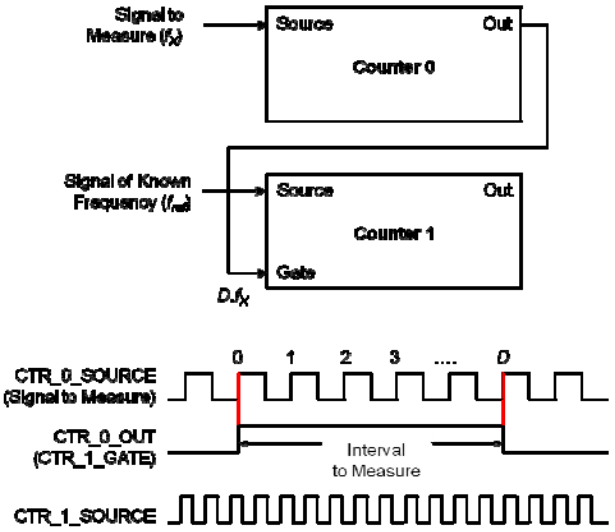


Fig. 3. Large Range of Frequencies with Two Counters.

C. Reciprocal Frequency Measurement with Two Counters

This method is used for measuring a large range of frequencies with two counters. The first counter is used to divide down the frequency of the signal to be measured, and then the second counter is used to measure the period of the divide down frequency. The actual frequency can be calculated by multiplying the resulting frequency measurement by the divide down value D. With this frequency method, the larger the divide down value D, the slower the resulting frequency, and more accurate the measurement result.

The signal to measure is routed to the Source input of Counter 0, as shown in Figure 3. NI-DAQmx automatically configures Counter 0 to generate a single pulse that is the width of D periods of the source input signal. Next, route the Counter 0 Internal Output signal to the Gate input of Counter 1 and configure it to perform a single pulse-width measurement.

D. Sample Clocked Buffered Frequency Measurement

As mentioned buffered counter functionality, using STC3 technology, has improved on its predecessors' capabilities in the areas of buffered period and frequency measurements. The user can now select sample clock as the timing type. When using a sample clock as the timing type, buffered frequency and period measurements are made by counting both an internal timebase (counted by embedded counter) as well as the unknown signal of interest up until the rising edge of the sample clock. However, the sample clock is a signal that must be specified and created by the user. The ideal frequency of the internal timebase is then divided by its count to find the effective frequency up to the next sample clock edge. With sample clocked frequency measurements, care must be taken to ensure that the frequency to measure is twice as fast as the sample clock to prevent a measurement overflow.

E. Choosing a Method for Measuring Frequency

Measurement errors are inherent in frequency measurements, but the effects of this error can be minimized by choosing a frequency measurement method that is most suited for given application [6]. The best method to measure frequency depends on several factors including the expected frequency of the signal to measure, the desired accuracy, how many counters are available, and how long the measurement can take.

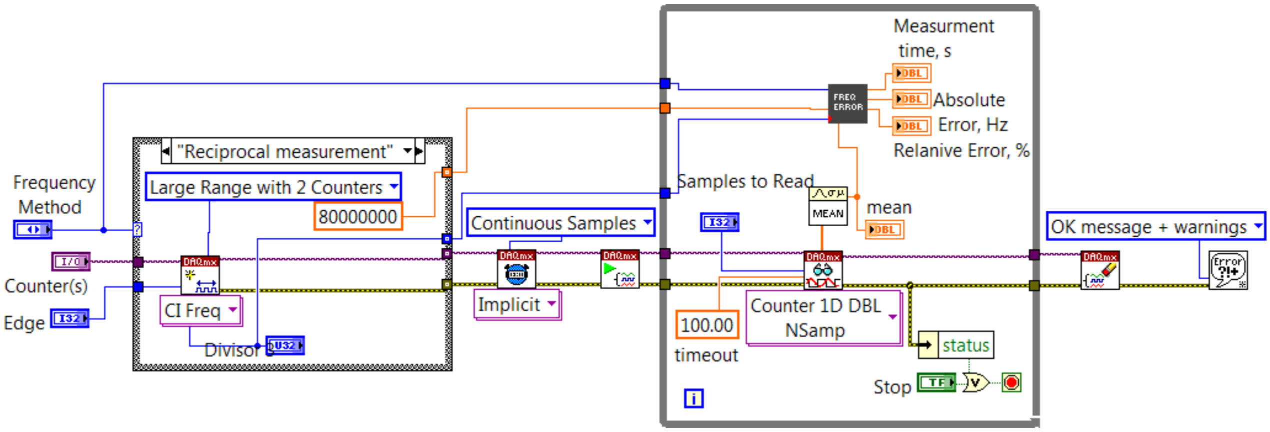


Fig. 4. Block Diagram of Virtual System for Frequency Measurements.

There are two sources of error in frequency measurements: timebase error (errors in the frequency of the crystal oscillator) and resolution error. Resolution may be limited by quantization error and trigger error. Timebase error is the maximum fractional frequency change in the timebase frequency due to all error sources (e.g., aging, temperature, line voltage).

The crystal oscillator used on the CompactDAQ Chasiss is rated at 50 parts per million (ppm) base clock accuracy.

The relative frequency measurement errors and measurement time are summarized in Table 1.

TABLE I
ACCURACY AND MEASUREMENT TIME OF FREQUENCY MEASUREMENT METHODS

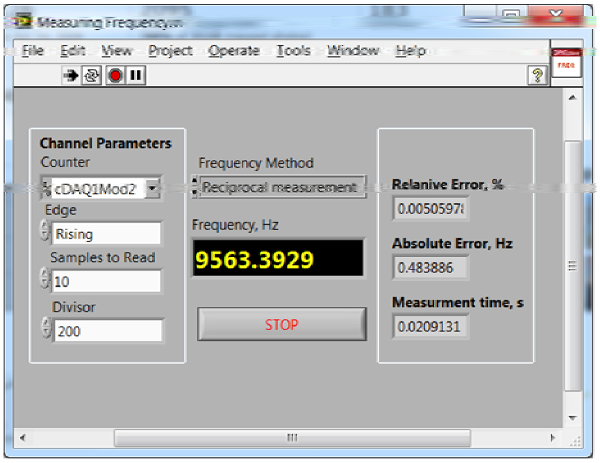
Method	Parameter	
	Measure Time	**Relative Frequency Error**
Sample Clocked	$\frac{1}{f_S}$	$f_{ref}\left[\frac{f_X}{f_S}-1\right]+\frac{\Delta f_{ref}}{f_{ref}}$
Period Measurement	$\frac{1}{f_X}$	$\frac{f_X}{f_{ref}-f_X}+\frac{\Delta f_{ref}}{f_{ref}}$
Frequency Measurement	$\frac{1}{f_{ref}}$	$\frac{f_{ref}}{f_X}+\frac{\Delta f_{ref}}{f_{ref}}$
Reciprocal Method	$\frac{D}{f_X}$	$\frac{f_X}{D.\left(f_{ref}-f_X\right)}+\frac{\Delta f_{ref}}{f_{ref}}$

IV. EXPERIMENTAL RESULTS

With LabVIEW DAQ drivers and other measurement analysis tools it is easy to input real-world, time-domain signals directly from data acquisition hardware and provide results ready for charting, graphing, or further processing. Either traditional NI-DAQ drivers or newer one DAQmx can easy configure counters.

Because this is only a high-level discussion, this paper only touches on significant features of the developed source code. The part of this code or so called block diagram is shown in Figure 4. The “While loop” provides the ability to continuously execute until the conditional operator in low left corner is set to “false”. “Case structure” on the left contains the DAQmx channel configuration for each of measurement methods.

The user interface or so called front panel of the created virtual system is shown in Figure 5. The front panel consists of three main sections. The first one is placed in left and is related to the configuration of channels. The next section is placed in central part of the front panel and consists of menu rings for choose of measurement method. There are and numeric digital indicator that indicated the measured value of current frequency. The last section consists of digital indicators that indicated the relative error, absolute error and measurement time according to selected method of frequency measurement. These values are calculated using equations in Table 1 with additionally developed software code.



Channel Parameters
Counter: cDAQ1Mod2
Edge: Rising
Samples to Read: 10
Divisor: 200
Frequency Method: Reciprocal measurement
Frequency, Hz: 9563.3929
Relanive Error, %: 0.0050597
Absolute Error, Hz: 0.483886
Measurment time, s: 0.0209131

Fig. 5.Front Panel of Developed Virtual System.

V. CONCLUSION

In present paper a design and development of virtual system for frequency measurement is considered. This virtual system consists of CompactDAQ Chassis, Digital I/O C series DAQ, and graphical programming environment. The illustrated approach offers a simple solution for an application that needs the low cost frequency measurement of any sensor with frequency output and DAQs with counter / timers. With software error estimation the system can be used for both designs in the same time: for maximum resolution and accuracy as well as for maximum data acquisition rate.

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