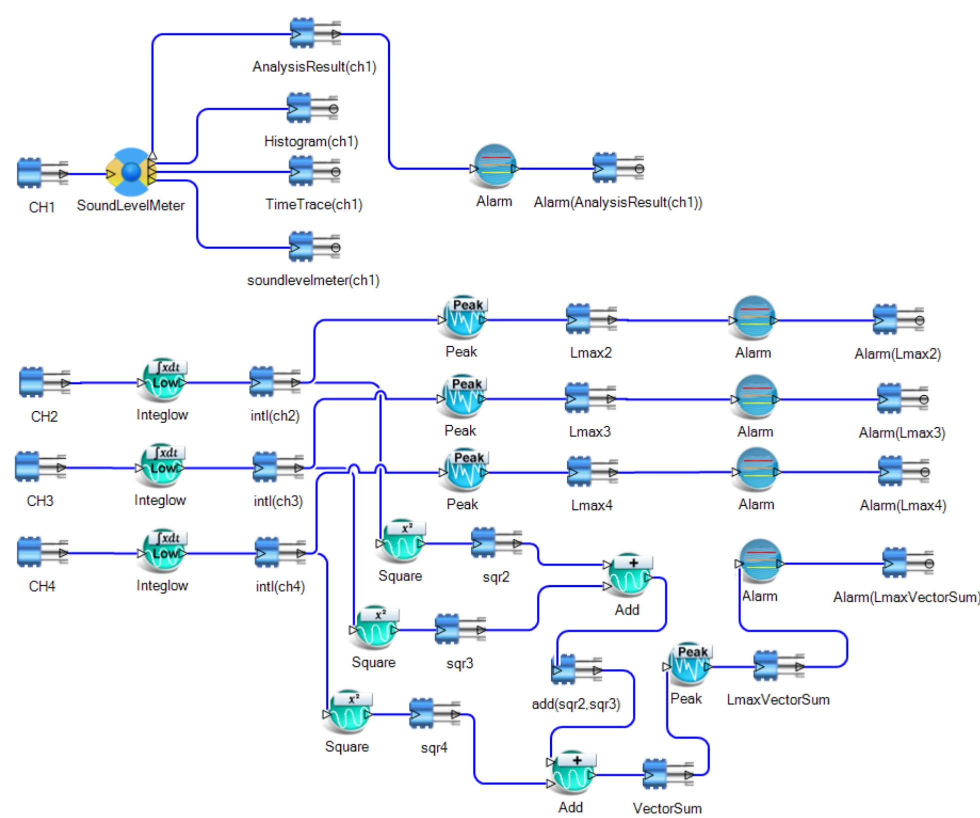
Configurable Signal Analysis

Application Note 018



Contents

Introduction

Configurable Signal Analysis (CSA) is a new concept introduced and adopted by Crystal Instruments in its newest generation of dynamic signal analyzer systems including the CoCo-80. It allows the user to dynamically configure the DSP (Digital Signal Processing) functions so the data processing flow can be customized from application to application. The result is that a portable, hand held signal analyzer can be customized to include specialized, powerful functions while maintaining a very clean and simple user interface for day to day operation. CSA is a unique feature that is currently available only in Crystal Instruments products.

Traditionally, dynamic measurement instruments could only realize fixed data analysis functions. These functions were configured by the manufacturer before the products were shipped to the user. While the user could change some of the parameters in the preset algorithms, they usually had little control over the data processing flow and the sequence of the applied math functions. With such a design philosophy, the user interface of dynamic measurement systems tended to grow more and more complicated as more and more functions were added to meet all the different users specialized needs. Important customers had to wait for the next version for their special request to be adopted by the vendor and small customers had little chance of getting their unique needs met if the function was not widely used.

The new CSA concept completely changes this paradigm. It is designed to keep the user interface very simple while letting each user customize the analysis functions either on their own or with the assistance of Crystal Instruments support.

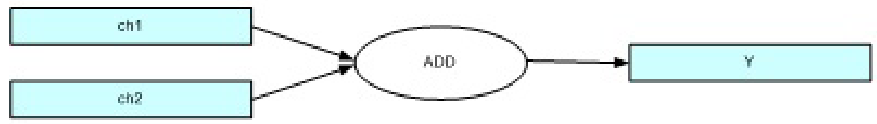


Figure 1.1 Example of math operation with two inputs and one output.

Contrary to the traditional approach, CSA is user customizable. With CSA, the user can flexibly apply various math operations to live data streams without changing the installed program. The processing algorithm is a combination of user customizable math functions. Most of these algorithms are fairly simple, such as add, subtract, multiply and divide operations. Some others are very sophisticated, such as calculating Frequency Response Functions (FRFs), between all the channels. The user can choose and apply the analysis functions that they like, or combine them to meet their particular needs. The user can also cascade these algorithms in sequence combining several functions to generate a very advanced new function. With this approach, the CoCo DSP systems are enabled with "unlimited" application functionality.

1. CSA is implemented by creating a "CSA script" which is like a computer program except that the interface is graphical instead of traditional line code. The graphical interfaced makes developing the CSA script very simple and intuitive. CSA scripts are written in Extended Markup Language (XML). A script body usually consists of version information, parameters used by CSA math modules and several CSA math modules.
2. Many traditional signal analyzers do provide "signal calculators" or "math functions" that the user can define. However, the concept of CSA is much more than this and has several advantages over these traditional signal math calculators, in that:
3. CSA applies not only to the block-based signals, but also to continuous data streams. You can save and analyze the resulting data streams in the same way as to the original input signals.

CSA Implemented at DSP Level

In the past most signal analysis algorithms were based on data block processing. These data blocks were usually described as a matrix or a vector. This model creates a particular challenge when the processing is required to apply to continuous data streams. Complicated control logic such as "while-if-then-loops" had to be used. While manufacturers such as LabView from National Instruments and MatLab from MathWorks offer the capability to do this, it requires advanced programming skills and the code was difficult to read and maintain. In CSA, the concept of data blocks is extended to what is called data streams. The stream describes a data buffer that has its content updated partially at one time. This model provides an easy way of handling the streaming data and enables the engineers, system integrators or the users to apply various mathematical functions to live data efficiently.

A data stream can be represented in a diagram using a square block to represent the stream object such as a real time stream, an oval to represent a math operator and arrows to show the data flow. The figure below shows an example where two streams are the input to a math operator and the output is a single stream. For example, this function could simply add ch1 with ch2 to compute the output. (Figure 1.1)

Math operators can be cascaded. For example, a time stream can first go through a band-pass filter, then an RMS detector to measure the energy over a particular frequency band. (Figure 1.2)

The CSA script controls the math elements and input and output streams that are available. During the run-time, the software interprets the script and translates it into data flow and control logic. While the user need only view the graphical interface that shows the CSA definition, the software automatically interprets the logic and generates the low level code that is implemented on the DSP level.

All this is performed behind the scenes making the implementation very simple for the user. The software also uses the CSA script to handle the stream allocation, de-allocation, math operation, priority, storage and display. (Figure 1.3)

The DSP creates many threads of operation to look at the priority and conditions of each math operator. This is called event-driven operation. A math building block is executed when this math building block is at high priority and its input buffers are full. The execution sequence is managed by a specially developed task manager.

CSA Editor

Customization of a CSA script is done within the CSA Editor which is integrated into the Crystal Instruments EDM software. The CSA Editor uses an intuitive drag and drop graphic language that makes configuring the CSA an easy to learn visual process.

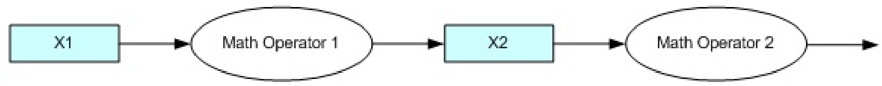


Figure 1.2 Cascaded math operators.

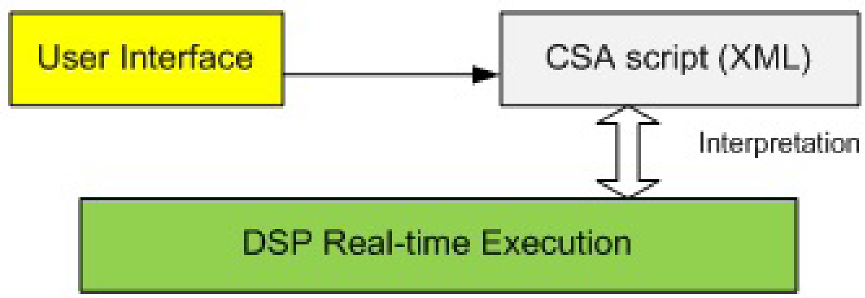


Figure 1.3 The CSA script is automatically interpreted by the software into DSP code.

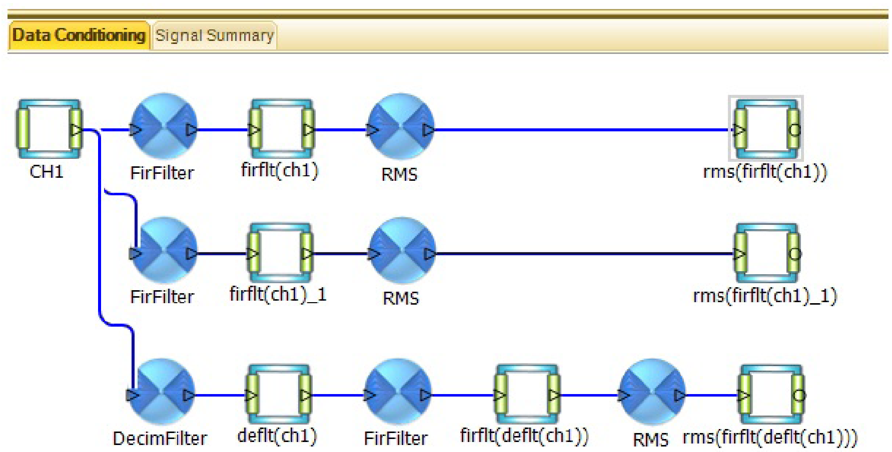


Figure 1.4 Block-Diagram of the CSA of a Multi-Band Filter

In the example below, the user may want to know the energy distributed in different frequency bands. With CSA, the data flow can be structured so that the signal coming from the native channel (CH1) is split into multiple streams. A digital band pass filter is applied to each stream. After the band pass filter, an RMS estimator is applied. The user can then store the time streams coming out of each RMS estimator. The flowchart in the CSA Editor is shown below: (Figure 1.4)

Notice that the last path has a decimation filter (DecimFilter) before the FIR filter. This allows RMS calculation for low frequency data over a long time period.

This example shows that CSA allows the user unprecedented flexibility and an infinite variation of analysis algorithms. Of course, to produce effective analysis and results with CSA, more experienced skills and knowledge of signal processing is required. This can be done by the end user and CI engineers provide paid service to do this task for the customers.

Two applications are described below that show the advantage of the CSA concept combined with the flexibility and portability of the CoCo-80 analyzer.

Application Example 1: MD80 Aircraft Engine Vibration Monitoring

In the following application, an aircraft engine test requires RPM and vibration measurements at different locations on the engine. In addition the test requires a velocity pickup sensor shall be used. The instrument shall convert the signal into displacement, apply a high-pass filter at a cutoff frequency at 40 Hz, and record the peak-peak value time history over a period of time at predefined RPM rates.

This type of test can be easily configured using the CSA technology as shown in the figure below. In the CSA Editor, three math operators are applied to the raw data channel 1: Integration, IIR Filter and Peak-Peak detection. The output is the peak-peak time history. (Figure 1.5)

Figure 1.5 Aircraft engine test setup.

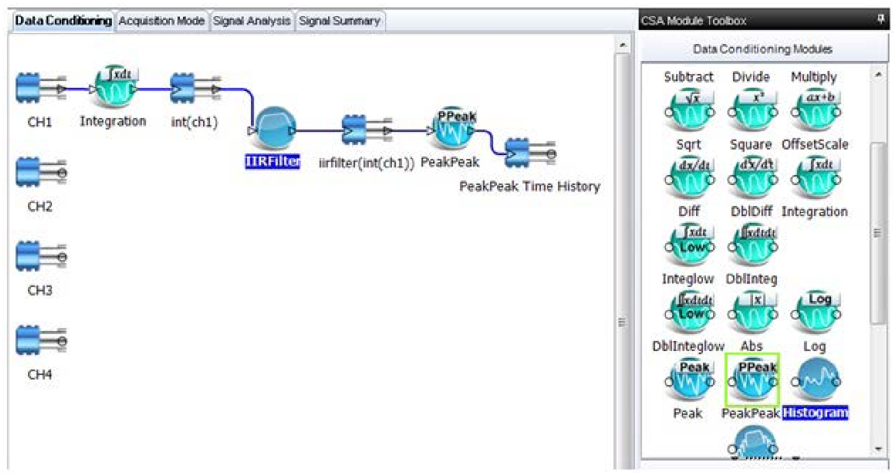


Figure 1.6 CSA Editor with aircraft test including integration, IIR filter and peak-peak detection.

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The math operators can have preset parameters to simplify running the test and keep the operator from accidentally changing the required parameters. Or, the parameters can be set so that they can be modified on the CoCo hardware at run time.

For example, since the high-pass filter will always have a cut-off frequency at 40 Hz, it can be defined as a fixed value in CSA Editor. The filter type, shape, and filter orders can be defined as shown in the following figure. The user can not change this value on the CoCo hardware in the field. (Figure 1.7)

After the CSA is designed, it can be downloaded to the CoCo-80 analyzer, where the user will only see the few parameters required for this specific measurement. This design makes using the hardware in the field very simple even though the analysis that is being performed can be very advanced.

A sample of measurement is shown below: (Figure 1.8)

Application Example 2: Construction Noise and Vibration Monitoring

In this application the CoCo-80 analyzer running a CSA script remotely monitors noise and vibrations at a construction site.

The sensor monitoring and signal processing is very specific for this test and requires customized analysis functions which in the past would require a high end system or customization by the analyzer manufacturer but with CSA can be easily implemented with by the end user.

The hardware setup is described below. When the CoCo is connected with a wireless modem, it communicates with the user through a secure internet connection. This simple integrated solution is far more cost-effective than PC-based solutions. The complete remote monitoring system is illustrated in the figure below. (Figure 1.9)

A remote monitoring system must be designed to accept a remote reset command. Any computerized system can hang up due to unexpected software glitches. Although rarely used, this function is necessary if the operator is a long distance from the monitoring system.

Two software methods are available to monitor the CoCo-80 remotely. One is a dedicated user interface based on the EDM software. The EDM is a Windows application that can be installed and launched on a PC. A special option can be enabled in the software so it can be connected to one or multiple CoCo-80s remotely by using static IP address identification.

The second method goes one step further, using the Internet technology. The EDM software can act as a website portal and post data graphs to a dedicated website address. This method allows the users to view the live data from the CoCo on the Internet anywhere in the world.

The signal analysis and processing for this application is very specific. It includes the following requirements.

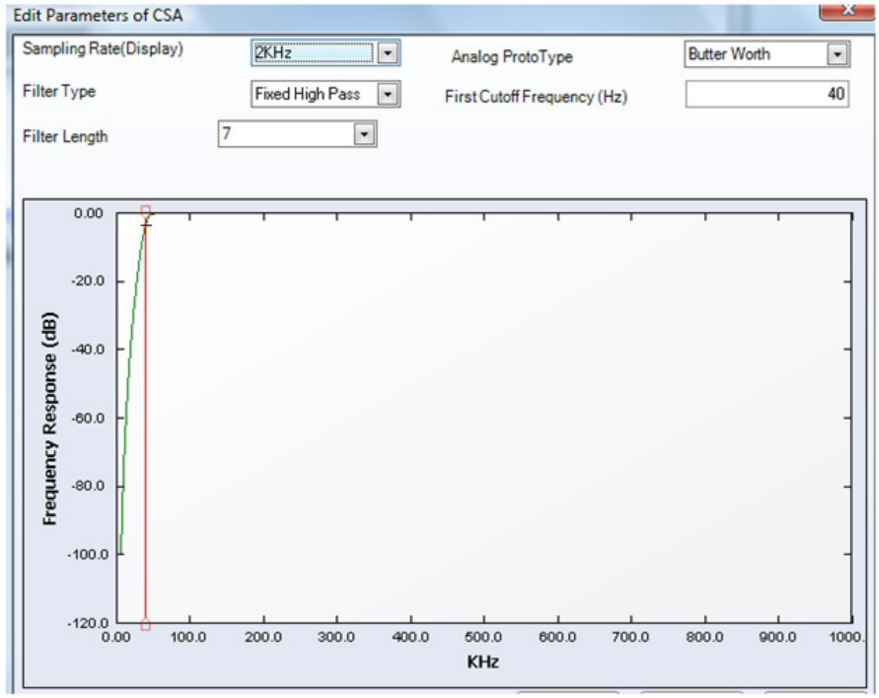

Figure 1.7 Filter parameter interface is configured on a PC as part of the CSA configuration.

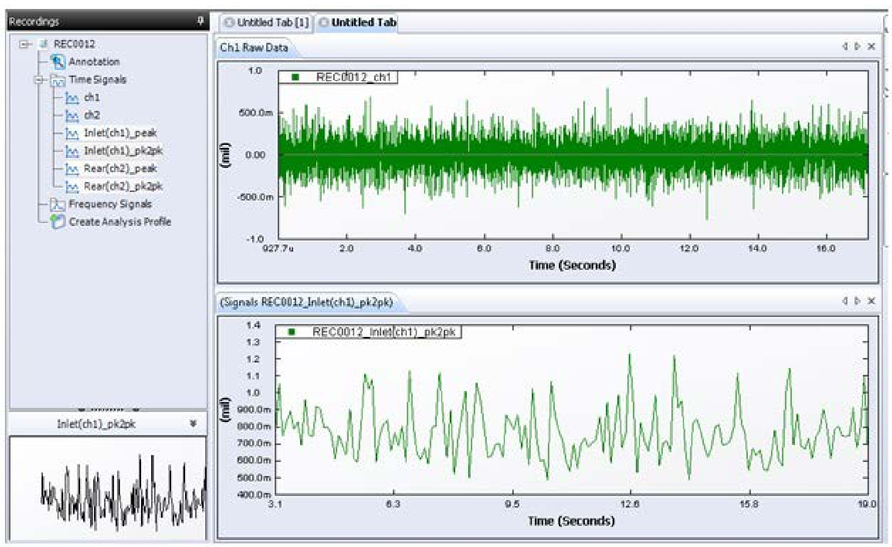

Figure 1.8

1. Microphone Hourly Energy Mean Noise Levels (L_{eq}), Maximum Noise Level (L_{max}) and a histogram
2. Triaxial Accelerometer Peak Particle Velocity (PPV) with L_{max} 1 minute period for X, Y and X and also the vector sum of the three channels.

The general measurement block diagram for this measurement is illustrated in the following figure.

(Figure 1.10)

Although the analysis includes very specific requirements it can easily be implement on the CoCo-80 analyzer using CSA. A CoCo with four channel IEPE inputs will be used for each monitoring device.

Channel 1 on the analyzer is connected to a microphone and the CSA script for this channel is

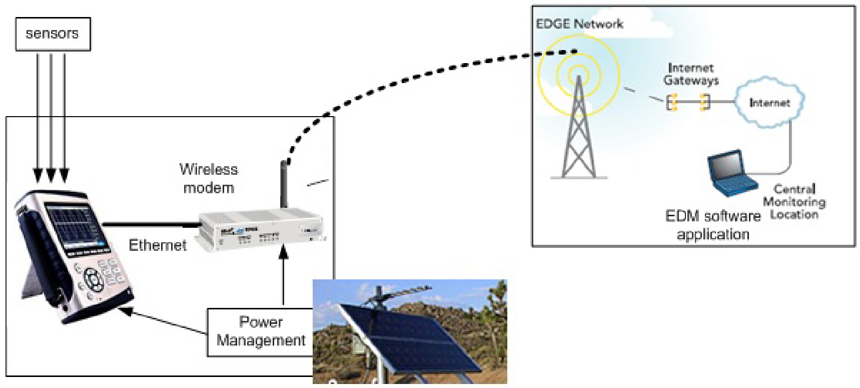

Figure 1.9 Remote construction sound and vibration monitoring setup.

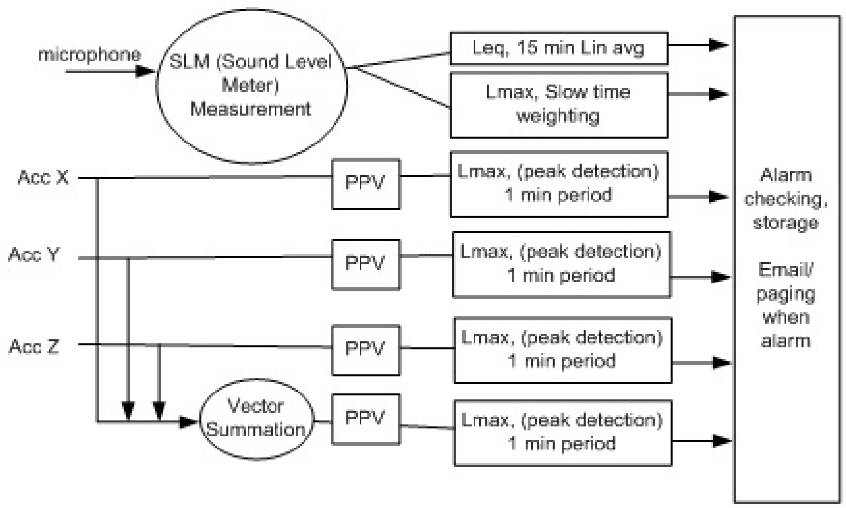

Figure 1.10 Input channel measurement block diagram.

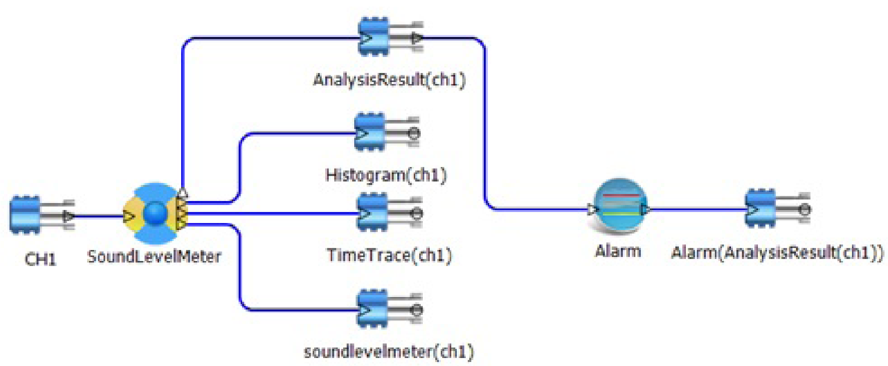

Figure 1.11 Microphone channel CSA script.

shown below. The SoundLevelMeter block includes several calculations including A frequency weighting in the time domain, Leq with 15 min averaging and an Lmax using slow time weighting. These calculations are all performed in the SoundLevelMeter block and the results are included in the AnalysisResult(ch1) signal. This signal is then connected to an Alarm block which is configured to compare the results with a predefined limit and send an email or page a cell phone in the event that the alarm level is exceeded. The other signals: Histogram, TimeTrace and SoundLevelMeter represent live signals that can be viewed on the CoCo or remotely during run time. (Figure 1.11)

Channels 2, 3 and 4 on the analyzer are connected to the X, Y and Z channels of a tri-axis accelerometer. The CSA script for channels 2 through 4 is shown below. First, each signal is integrated to compute velocity from the digitized acceleration signal. Next, the three vibration signals are squared and added to compute a vector sum. Finally peak analysis is applied to all channels. By configuring the time duration of the peak calculation to one minute, a 1 minute Lmax calculation is the result. Finally an Alarm block is added to compare the Lmax to a limit and send an email or page in the event that the signal exceeds the alarm. The same peak and alarm blocks are added to all three channels and the vector sum signal. (Figure 1.12)

Both microphone and accelerometer measurements are processed simultaneously allowing all the test requirements to be met on a single CoCo device. It should be noted that with most traditional signal analyzers, such a customized measurement would require either a very high end, high cost system or custom DSP programming by the manufacturer. Only Crystal Instruments CSA puts this level of customization in the hands of the end user with such a small portable device.

During run time, the status can be viewed remotely on a PC running the EDM software. The figure below shows a screen capture of the EDM PC host software viewed on a remote PC a hundred miles from the test site. (Figure 1,13)

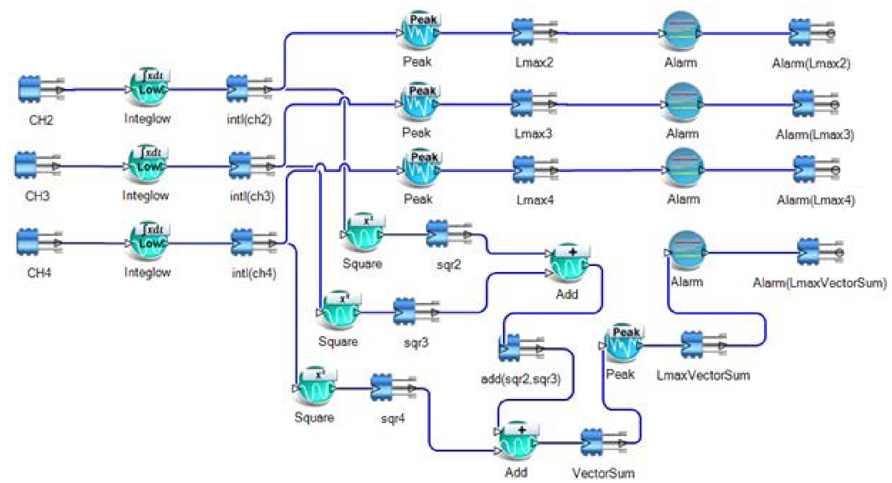

Figure 1.12 CSA script for accelerometer channels.

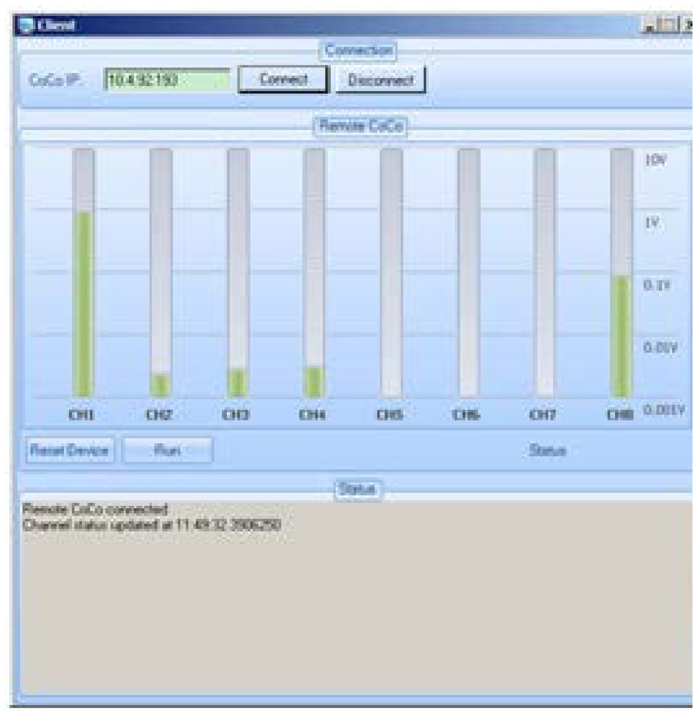

Figure 1.13 Sound level meter display which is viewed remotely on a PC.

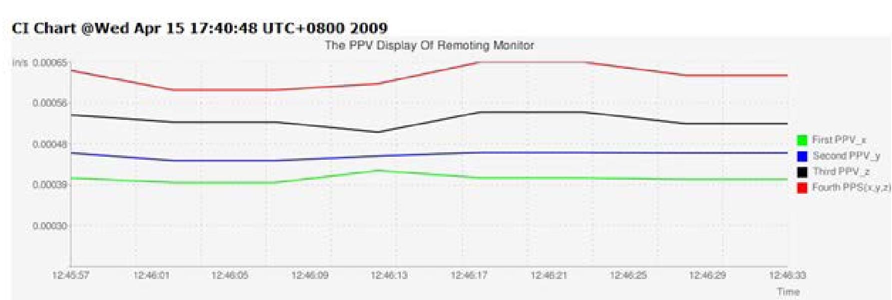

Figure 1.14 Live display of measurements viewed on a web browser.

Alarm limits are set to each of the signals being monitored. When a signal exceeds the alarm, an email is automatically sent to a designated email address.

In addition to viewing the status remotely, data can be automatically posted to a web site directly from the CoCo hardware. The chart below is the live update display shown on the website monitoring the CoCo inputs. (Figure 1.14)

From time to time, the user can download the signal files from the CoCo to the PC. An easy to use interface is developed based on the EDM platform. The user can operate the CoCo unit remotely through the control panel.

Summary

The new CSA technology from Crystal Instruments has the advantage that it provides both simplicity and flexibility to the dynamic analysis system. Traditional analyzers have the disadvantage that with increasing functionality, the complexity of the instrument operation increases. The manufacturers continue to add features and functions to the software over time, and as a result, the product loses its simplicity. In use, specific applications always require specific operations.

These operations are usually repetitive and simple but may not be available on any generic signal analyzer. The concept of CSA allows the user to customize their applications making the parameter setup and the operation tailored to the specific measurement.

Simplicity is very important, especially in a handheld device with limited user interface. Unlike an instrument controlled with a PC interface, a handheld instrument usually is equipped with limited keypad and access space and is designed for field use which requires quick and direct operation. CSA enables multiple functions on the same hardware platform without sacrificing the simplicity of operation.

Another advantage of using CSA technology is that it provides powerful functions for expert users while maintaining a simple interface for use by technicians. This allows the use of the same instruments to conduct simple and also advanced tasks. In a typical working environment, the managers or senior engineers may have the capacity to set up the instrument while the operators are only allowed to conduct routine tasks. CSA makes this possible with one handheld portable device.

CoCo-80/90

CoCo-80/90

CoCo-80/90 is a multi-channel portable data recorder, dynamic signal analyzer and vibration data collector that is ideal for a wide range of industries including machine conditioning monitoring, automotive, aviation, aerospace, electronics and military that demand easy, quick and accurate data recording and real-time processing in the field. CoCo-80 is equipped with 2, 4 or 8 input channels and accurately measures and records both dynamic and static signals on each channel simultaneously. The mass flash memory records 8 channels of streaming signals simultaneously up to 102.4 kHz while simultaneously computing real-time time and frequency-based functions. An embedded signal source channel provides various signal output waveforms that are synchronized with the input sampling rate.

CoCo-90 is equipped with an additional 8 channels for a total of 16 input channels and accurately measures and records both dynamic and static signals. The mass flash memory can record up to 16 channels of streaming signals simultaneously up to 51.2 kHz while simultaneously computing real-time time and frequency based functions.

The CoCo-80/90 system is equipped with two USB ports, 100Base-T Ethernet, SD-card interface, audio input/output, a 5.7 inch color LCD display and a keypad.

24-bit A/D converter, DSP technology and a patented hardware design offers dozens of data processing functions and more than 130 dB dynamic range in measurement, 10 times higher than competitive products. This allows you to capture signals as high as 10 volts and as low as a few micro-volts in the same test without changing any settings. The CoCo-80 software stores and organizes the data in the popular ASAM-ODS standard.

This data standard provides ultimate flexibility and version compatibility. Data may also be exchanged with other data formats such as UFF, BUFF and user-defined ASCII format.

When CoCo is connected to the wireless modem, it becomes a remote monitoring system. With the inclusion of a solar power source, a CoCo monitoring solution can be installed almost anywhere.

The CoCo Vibration Data Collector mode is a specialized user interface designed to be used in the vibration and machine condition monitoring industry. It includes route setup and measurement tools, standard vibration data collection measurements such as rms, true-rms, overall-rms, peak and also waveform, spectrum and demodulation measurements.

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