Customer case of a Gage Measurement System for Communications monitoring

Customer Requirement

The customer requirement is to listen in on communication signals that are then cataloged for future recognition. They require a general-purpose high-speed digitizer to capture a wide range of raw and intermediate communications signals on up to four channels.

The solution to the application must have an input analog bandwidth of 250 MHz and must be able to sample at up to 500 Mega Samples per second. Many applications require the use of an external reference clock with a frequency of up to 500 MHz to directly clock the sampling A/D converter. Since communications signals occur with various durations, they would like to have as much acquisition memory as possible. The minimum requirement is 1 GigaSample for a capture time of 2 seconds at 500 MS/s.

The customer has developed a library of communication signal analysis tools in the MATLAB programming environment on a Windows NT computer. The ideal solution would be capable of controlling the digitizer directly from MATLAB so that the signals could be analyzed on-line, rather than by post-processing stored data files.

The ideal solution must be a rugged, turnkey cost-effective system that can be integrated into a single rack mounted chassis. The system must also be compact, since it will sometimes be deployed in an aircraft.

Gage Solution

For the customer's requirement, Gage Applications Engineers recommended a Gage Measurement System (GMS). The GMS procedure ensures that the customer receives a turnkey system that exactly meets the requirements of their application. Before the order is placed, Gage and the customer agree on an GMS specification document. This document outlines the details of the requirement, the proposed Gage solution, and acceptance testing procedures that are used to verify correct operation of the system. Any custom software or hardware modifications are specified in detail. Once the order is placed, the GMS document becomes the Statement of Work, which is followed to the letter by the Gage Factory when filling the order.

The GMS for this requirement consisted of an Instrument Mainframe 2020E equipped with four CompuScope 8500 A/D cards, each with 2 GigaSamples of on-board acquisition memory. The CS8500 meets all the basic digitizer requirements with its 250 MHz analog input bandwidth and its 500 MS/s maximum sampling rate. Four CS8500s, configured as a multi-card system, allow the customer to capture simultaneously on up to four channels. The 2 GigaSamples of on-board acquisition memory exceeds the requirement and allows the customer to continuously capture up to four seconds at the maximum sampling speed. The four CS8500s were equipped with the External Clock option so that the customer's reference clock can be used to directly clock the CS8500 ADC chips. Photographs of the front and back of the final GMS are shown in Figure 1a and Figure 1b. The CS8500-2G occupies three full-length PCI slots and is shown in Figure 2.

Figure 1a.
Front of GMS

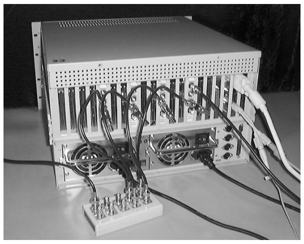

Figure 1b.
Back of GMS showing signal connections

Gage Instrument Mainframe

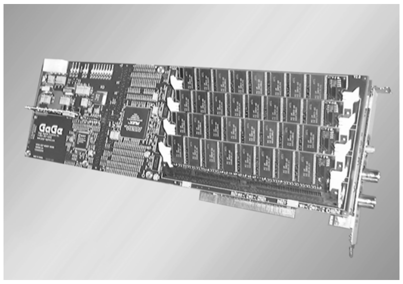

Figure 2.
Photo of CompuScope 8500-2G

Several features of the Instrument Mainframe 2020E were important for the application. Gage provided an add-on card backplane with sixteen contiguous PCI slots. This was necessary since four CS8500-2Gs require twelve contiguous PCI slots. The rugged rackmountable chassis is equipped with forced air ventilation and an ample 600 Watt DC power supply. The system operates under Windows 2000. All Gage software required for correct operation of the CS8500s was installed and configured.

The most unique and important feature of the GMS chassis is its CompuScope card retention mechanisms. Figure 3 shows a photo of the interior of the chassis. CS8500s are equipped with metallic card guides, which ensure that the cards remain securely in their slots. These guides are circled in Figure 3. In addition, a special retaining hold-down bar extends across the chassis interior for added support. With these features the customer can confidently transport the system without fear of damage to the cards or their electrical connectivity.

Multi-Card CS8500 System

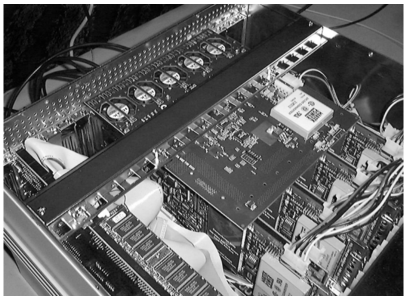

Figure 3.
AMS Interior showing Card Retention Bar and Metallic Card Guides

Design and construction of multi-card high-speed digitizer systems is a non-trivial task. All Gage CompuScope multi-card systems are configured in Master/Slave mode, where a Master CompuScope passes all clocking, triggering and control lines to the remaining Slave CompuScopes through an inter-connecting bridgeboard. Gage uses only rigid bridgeboards in order to ensure non-varying and predictable electrical impedances. All signals are actively buffered and correctly terminated in order to eliminate distorting signal reflections.

At sampling speeds above 100 MS/s, even small signal propagation delays cannot be neglected. Signals propagate in typical circuit traces at about one-half the speed of light or 1/2 foot per nanosecond. Consequently, a clocking signal generated by a Master CompuScope would arrive at a Slave CompuScope that was a foot away a full 2 nanoseconds later. Since 2 ns is the sampling interval at 500 MS/s, this Slave would then sample late by a full clock cycle, which is unacceptable.

In order to compensate for signal propagation delays, higher speed CompuScope multi-card systems employ a Clock Distributor Module. In this scheme, the Master CompuScope passes its clock and trigger signals to the Distributor Module. The Module then distributes these signals back to the Master and to all Slaves along equal signal paths. This timing signal distribution minimizes time skew due to signal propagation delays and maintains the best possible simultaneous sampling.

Special CS8500 Modification for Improved Spectral Response

The customer's application requires the identification of very sharp features in captured signal frequency spectra. As a result, they require that captured frequency spectra are as free as possible from spurious spectral features that may arise due to residual signal distortion or internal cross-talk.

After evaluating a single CS8500 and using their 500 MHz reference external clock, the customer determined that residual spurious frequency components were slightly too high. Accordingly, Gage designed a special shielding modification for the CS8500. This modification was proven to reduce spurious frequency components to an acceptable level and was performed on all four of the customer's CompuScopes. Only the teamwork between Gage's trained Application Engineers and Hardware Design Engineers allowed resolution of this issue.

Controlling Windows Software

Initially, the customer operated the CS8500s using GageScope - the World's Most Powerful Oscilloscope Software. GageScope allows easy acquisition, display and storage of waveforms on all the channels of any CompuScope system in any MS Windows environment. In addition, the Professional Edition of GageScope offers advanced signal analysis tools like Waveform Parameter Analysis, repetitive Signal Averaging and Fourier Transform analysis. Figure 4 shows a screen-grab of GageScope capturing signals on all the customer's CS8500 channels using a 500 MHz external clock and simultaneously displaying their Fourier spectra. Different channels are displayed in different colors and the time-base is 10 ns per division.

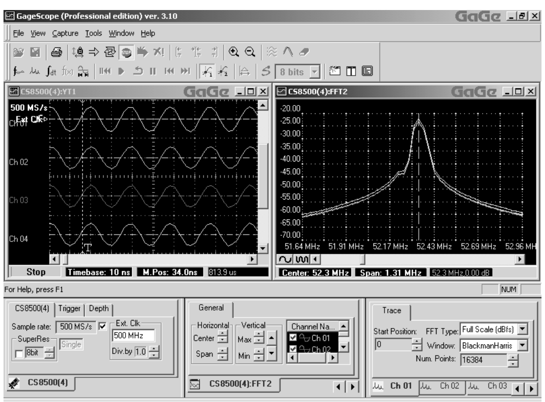

Figure 4.
GageScope - Simultaneous Time and Frequency Domain Displays

Certain obstacles are encountered with respect to the management of CompuScopes with very Deep Memory. Since every sample point consists of one Byte, the total amount of memory on the customer's CompuScopes is 4 x 2 GigaBytes = 8 GigaBytes. A typical Windows computer will only allow the allocation of roughly 100 MB of system RAM to a given software application. Consequently, all the captured data cannot be held by an application like GageScope at one time. This presents no problem for file storage, since data may be moved from the CompuScopes to a hard drive file in small pieces. Problems do arise however, in the display of captured data.

GageScope is equipped with the ability to manage the display of large amounts of data using a technique called *decimation*. In its simple form, decimation reduces a data set by eliminating *n-1* out of *n* data points, where *n* is called the *decimation factor.* For instance, if the decimation factor were 100, then decimation would reduce the size of the data set one-hundred-fold by dropping 99 out of 100 points. More sophisticated decimation techniques include averaging *n* points into a single point and conserving only the minimum and maximum values within a group of *n* points. GageScope supports all these decimation techniques.

In order to thoroughly test the system and to illustrate decimation, Gage engineers simulated a high-speed communications signal. A simple function generator, outputting a 1 MHz sine wave, was connected to the inputs of all four CS8500s. The system was set up to capture for four seconds, filling all on-board acquisition memory. During the acquisition, the function generator was turned off and then briefly reactivated about halfway through the acquisition. The resulting display screen for the whole four-second acquisition is shown in Figure 5. The signal resembles a communication signal in

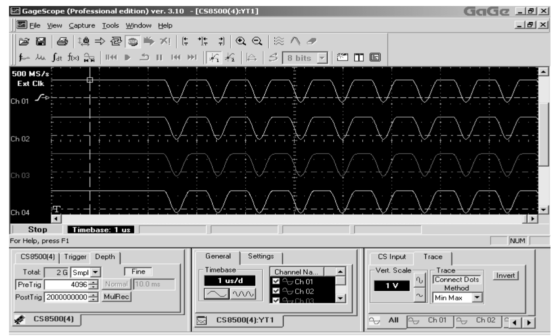

Figure 5. GageScope - Coarse-Grain View of

that it has a high 1 MHz carrier frequency component along with a lower frequency modulation, which results from the switch toggling. The display was made using a decimation factor on the order of 10,000. Notice the erratic appearance of the sine wave that results from the heavy aliasing due to the high decimation factor.

Figure 5 gives a good coarse-grained overview of the entire acquisition. Smaller specific segments of the data set can be viewed with a small decimation factor or even with no decimation at all. To illustrate this, we magnify the brief restart period halfway through the acquisition of Figure 5. Figure 6 shows a 10 microsecond segment of the signal during the restart period and just after the function generator comes out of saturation. No decimation is active in Figure 6 and the 1 MHz sine wave, although clipped on the high side, is clearly visible. Taken together, Figures 5 and 6 illustrate the principle of decimation and the power of GageScope in the flexible viewing of large data sets.

The customer can use GageScope to capture, display and store communications signals to hard drive for later analysis and cataloging. Ultimately, the customer would like to control the AMS from MATLAB, which will allow on-line data manipulation. Accordingly, Gage provided the powerful CompuScope MATLAB Software Development Kit. This kit provides several easy-to-use sample programs illustrating use of CompuScopes in various modes of operation.

The customer's GMS was a project whose assembly required specialized interdisciplinary coordination in the areas of high-speed instrument hardware, Windows-based software and computer assembly. Integration of these elements would have presented a formidable and costly challenge for the customer to overcome unaided. Instead, Gage's GMS Department assembled and integrated Gage instruments into a custom turnkey solution that fitted the exact requirements of the customer's application.

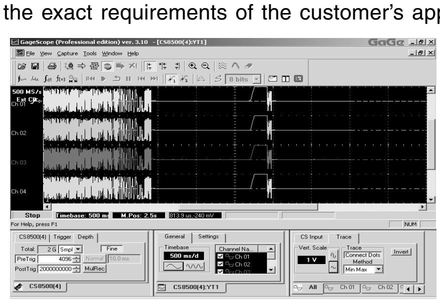

Figure 6. GageScope - Detailed View of Small Segment of Deep Memory Capture