Fiber-Optically Isolated Instrumentation for Pulsed Power System Diagnostics

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Abstract
Advances in high sample rate/wide bandwidth analog-to-digital converters have enabled the development of increasingly sophisticated instrumentation which is suited for use in the presence of high electromagnetic fields associated with many pulsed power systems. This article discusses the development of an instrument capability based on the use of a high bandwidth digitizer which is packaged in a compact configuration where the sampled data is transmitted digitally using the TCP/IP network protocol. The system is battery powered and heavily shielded to allow measurements to be made in regions of extremely high field strengths. Connection with external instrumentation and control systems is accomplished by using only fiber optic cabling, providing completely isolated measurements.

I. Introduction
Instrumentation for high voltage pulsed power experiments can be problematic because of the strong electromagnetic (EM) fields present around the measurement location, and the need to maintain isolation through the walls of shielded enclosures. Isolation is important to maintain measurement quality and to ensure personnel safety. Several approaches have been used to build specialized instrumentation to meet these specific requirements. Traditional methods of instrumentation involve placement of an oscilloscope inside a shielded container in close proximity to the measurement point, or the use of analog fiber-optic telemetry systems to route the measurement signal to an external oscilloscope. In general the instrumentation needs to measure the signal in the time-domain, digitize the signal close to the measurement point, offer a wide analog bandwidth, and be as small as possible to minimize field perturbations. In response to these requirements the Compact Remote Digitizer or CRDAQ was developed and tested in comparison to the current pulsed power measurement systems.

II. Compact Remote Digitizer
Analog fiber-optic telemetry systems require regular calibration and careful treatment of fiber-optic cable and terminations. These restrictions can be significantly reduced by digitizing the analog signal at the source and transmitting digital data via fiber. The compact remote digitizer (CRDAQ) seeks to lift these restrictions. This system is a fiber-optically coupled, battery-operated device contained in an EM-hardened case with dimensions of 8 3/8 ″ x 4 3/4 ″ x 5 1/4 ″.

The instrument is based on the 3U CompactPCI (cPCI) standard using commercial-off-the-shelf (COTS) computers and digitizers. For this application the computer was chosen for low power consumption since the need for computing power is minimal. Two digitizers, a 250MHz and 1.5GHz model, have been tested in the system. The 250 MHz PXI digitizer (U1091A) is a current Acqiris product from Agilent while the 1.5 GHz (U1062A) is a PXI product developed through a cooperative effort between NSWC and Agilent.

Agilent U1062A Acqiris High-Speed PXI digitizer

Parameter	U1091A	U1062A
Battery	28.5 V, 5.5 Ahour Lithium-ion	
Power Consumption		
Sampling	30 Watts	45.6 Watts
Standby	3 Watts	3 Watts
RF Bandwidth	DC-250 MHz	DC-1.5 GHz
Resolution	8 bits	10 bits
Sample Rate	100 S/s - 1 GS/s	200 S/s - 4 GS/s
Memory	128 k	256 k/channel
Full Scale Range	50 mV to 70 V (1 W Avg Power)	
Segments	200 max	1800 max
Input Impedance	1 meg, 50 ohms	50 ohms

Table 1. CRDAQ specifications.

Table 1 presents a summary the CRDAQ specifications and Figure 2 shows a block diagram.

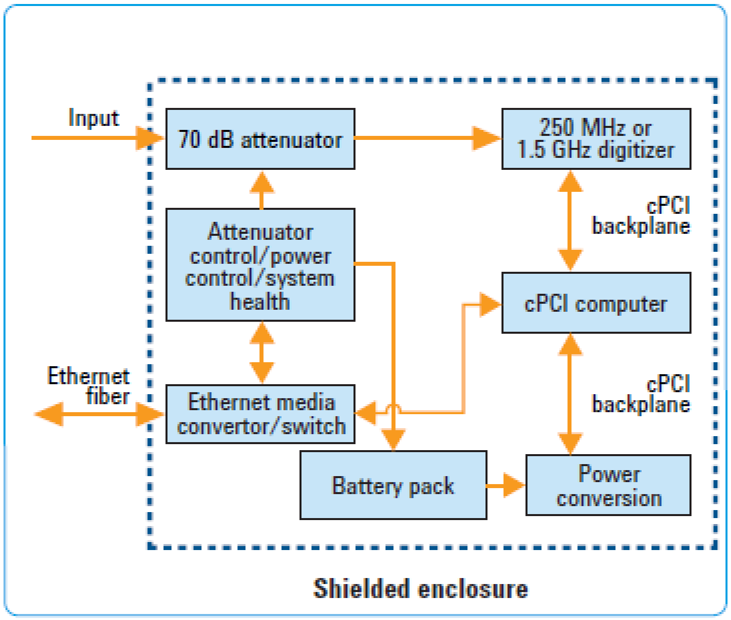

Figure 2. Agilent Acqiris U1062A PXI digitizer card

The CRDAQ consists of the electronic subassembly which contains all of the system components in a single package and an enclosure into which the subassembly is inserted for EM shielding. The electronic subassembly is designed to be removed from the enclosure and remain fully functional while allowing access to the system components for maintenance or repair.

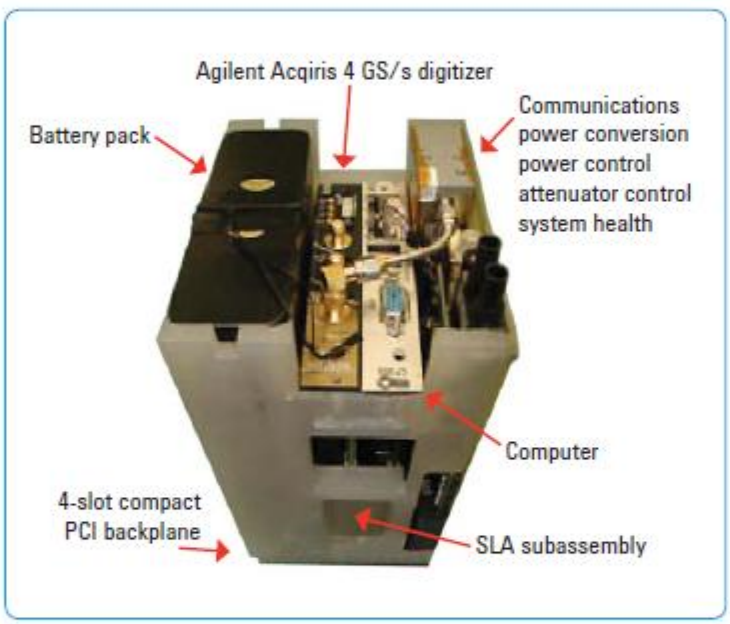

Figure 3. CRDAQ electronic subassembly

Figure 3 shows how the CompactPCI (cPCI) computer, digitizer, battery pack, and controller board (power conversion, communications, power control, and system health) make up a self contained assembly. The hardware to contain the electronic subassembly consists of a custom designed part produced by Stereolithography (SLA) that attaches to the cPCI backplane to make the self contained assembly. This complete assembly is then inserted into the shielded enclosure which has ST connections for fiber Ethernet, a SMA connector for the input signal, an EMI air filter for coo ling, and a separate cover for easy removal of the battery (Figure 4).

Figure 4. CRDAQ assembly process

In order to keep the CRDAQ as efficient and compact as possible the controller board is a simple two layer printed circuit board populated with COTS components. Using COTS components reduces the dependence on extremely specialized circuits thus making maintenance and repair for the end user easier (Figure 5).

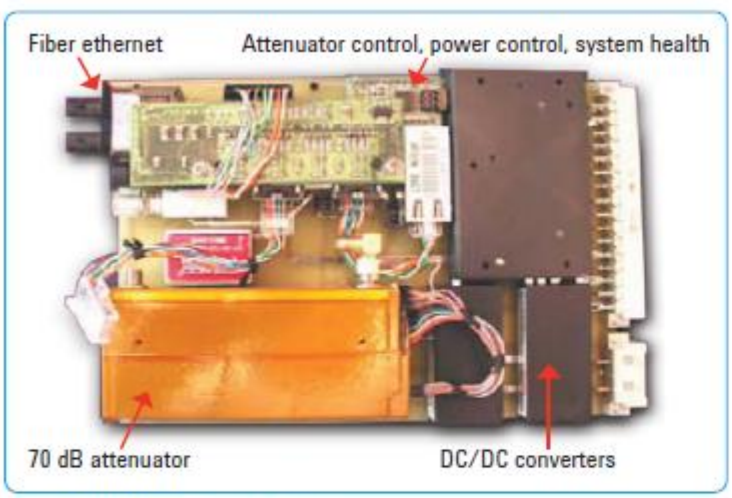

Figure 5. CRDAQ controller board

The same statement is true for the battery pack since it is comprised of 4 Sony Lithium-Ion camcorder batteries connected in series to produce the 28.8V 5.5 amp-hour pack.

Control of the CRDAQ is done using any Windows XP/2000 based computer with Ethernet by two programs; one to control/monitor the CRDAQ system via a microcontroller and one to control and obtain the data from the Agilent Acqiris digitizer. The microcontroller program monitors battery voltage, internal temperature, controls the attenuator setting, and provides for remote startup and shutdown to conserver battery life (Figure 6).

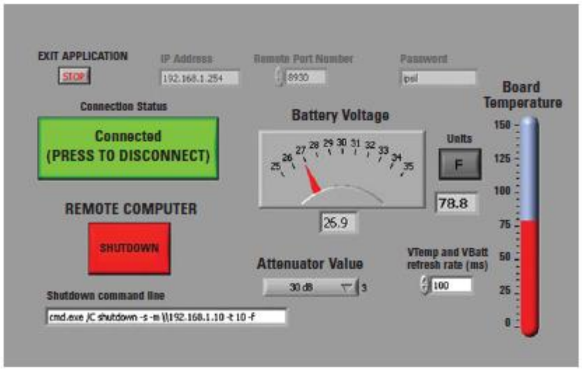

Figure 6. CRDAQ control software

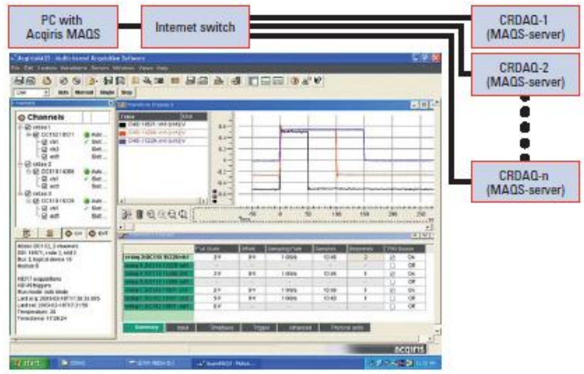

Figure 7. Acqiris MAQS software

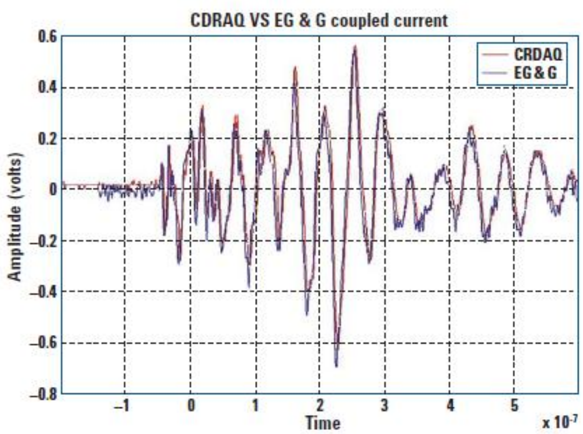

Figure 8. CRDAQ 250MHz Measurement

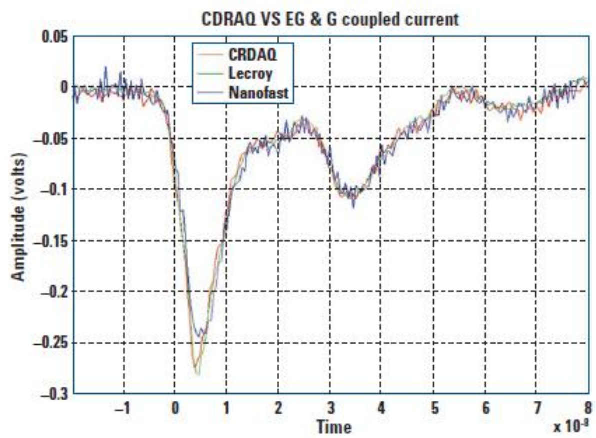

Figure 9. CRDAQ 1.5GHz measurement

The second program developed by Agilent, AcqirisMAQS or Multichannel Acquisition Software, provides a virtual window into the digitizer for configuring the acquisition parameters, arming the unit, and displaying the digitized data which can be saved to a file for further analysis at a later date (Figure 6).

Testing of both the 250MHz and 1.5GHz CRDAQ models has been performed with exceptional correlation with commercial measurement equipment. The U1091A or 250MHz model was used in a recent field test of a pulsed power source at the NSWC Dahlgren MOATS test facility. In this test an Eaton 91550-2 150MHz current clamp was used to measure the coupled current on a power cable with the U1091A CRDAQ and an EG&G ODT-E6 200 MHz analog fiber transmitter. Figure 8 shows how well the CRDAQ signal is correlated with the EG&G signal. One significant observation is that the noise floor of the CRDAQ is less than that of the EG&G.

The U1062A or 1.5GHz CRDAQ verification measurement was made in the laboratory where it was compared with a Nanofast OP300 1GHz analog fiber link and a Lecroy Wavemaster 8300A using a Bournlea pulse generator. The signal from the Bournlea was sent through a 3-way power splitter to all three instruments where a single pulse was sampled and used for comparison. In Figure 8 it can be seen that the CRDAQ measurement is in agreement with the Lecroy oscilloscope, used to directly digitize the signal, as well as exhibiting less noise than the Nanofast measurement system.

III. Acknowledgements

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IV. References

[1] "Technical Product Description, Models U1062A ," Agilent Technologies Inc. USA Mr. Ben Grady received an AASET in 1987, BSEET from ODU in 1993 and a MSEE from Virginia Tech in 2000. From 1986 to 1989 he worked as an Avionics technician, from 1990 to 1994 he worked at NASA Langley Research Center as a Microwave Technolo gist, and as a cellular base station product engineer at Ericsson Telecom from 1995 to 1997. Since 2000 he has been with the NSWC Dahlgren Directed Energy Technology Office investigating the susceptibility of critical infrastructure systems to intentional EMI and developing pulsed power/HMP measurement instrumentation.