X-Stream Technology Adds Turbocharger to Oscilloscopes

The WaveMaster series from LeCroy are the first digital oscilloscopes to incorporate X-Stream technology. This technology provides a high integrity signal acquisition path and a streaming mode of data handling (see Figure 1) that surpasses the performance of all previous oscilloscopes in capturing and processing the types of long data records which are required for precise measurement of complex signals.

Many high speed signals are brought into test instruments using low loss cables from the signal source. For testing of data that comes via probing of a circuit, the signal path for the WaveMaster series starts with an (optional) ultra low capacitance (0.18pf) probe with 7.5 GHz bandwidth. Whether the signal arrives via cable or probe, the signal enters the WaveMaster through a front panel connector whose core conductor is rated at 18 GHz. A block diagram of the front end is shown in Figure 2. The next circuit element in the signal path is a relay which switches a x1 or x10 attenuator into the signal path. When oscilloscope power is off, this relay provides 50 ohm termination to any signal connected to the scope. When power is on, this 12 GHz bandwidth relay provides the first element of signal conditioning, just prior to the SiGe amplifier/attenuator. This high speed chip (> 6 GHz bandwidth) is a LeCroy design which is manufactured using an IBM process. It has three outputs. One goes to the analog to digital converter (ADC) assigned to its channel, the second goes to the ADC of another channel (allowing interleaving of two ADC's to attain twice the sampling rate when only two input channels are in use) and the third output of the amplifier/attenuator goes to the trigger chip. The same IBM foundry which produces the amplifier/attenuator also produces the LeCroy designed SiGe ADC chips (with >6GHz bandwidth it is the world's fastest 8 bit ADC) and trigger chip (with >5 GHz bandwidth it is the world's fastest real time trigger in a digital scope) used in the WaveMaster series. This trio of SiGe chips is unmatched by any other digital oscilloscope.

After the signal conditioning elements, the incoming signal passes through a differential point-to-point connection to the ADC. Since normal PC board material has less than 5 GHz bandwidth, signals in the WaveMaster are carried on a special Rogers 4003 low dielectric constant material. These traces have 0.18 dB loss per inch at 10 GHz. The ADC is a single chip (on each input channel) running on a 10 GHz sampling clock which converts the incoming analog signal into eight bit data with one measurement occurring each 100 picoseconds. If the user is only capturing two signals, the unused ADC's of the four channel scope are applied to the two active channels, providing a sampling rate of 20 GS/s (50 psec per sample). The data bits from each ADC are sent via six data ports (grouped in pairs) to three LeCroy designed high speed embedded DRAM ASICs (Application Specific ICs). Each chip accepts data at an aggregate rate of 3.3333 gigabytes per second. Since each data sample is a byte, the combination of the three memory chips can absorb the 10 Gbyte/sec data rate produced by each channel's ADC.

The high speed embedded DRAM ASIC is one of the key X-Stream technologies. In addition to storing the 10 Gbyte/sec data stream from each of the four ADC's in real time, these chips, built on a high speed CMOS process, perform several other crucial operations. Prior to storage in the embedded DRAM this ASIC provides several full speed processing functions including decimation (used for very low sample rates). This ASIC also provides a very short intersegment deadtime (approximately 5 usec) by managing the memory structure in a configurable manner onchip. This allows a user to achieve a very fast acquisition rate when acquiring a series of signals and storing them in memory in a fashion that allows measurements and analysis. For readout, the DRAM ASIC includes a high speed gigabit (physical layer) link which provides a very efficient method of piping data to an FPGA situated on the processor's PCI bus. Much of the support for gigabit including the 8b10b encoding is implemented on the ASIC. One gigabit link is dedicated for each pair of channels (note the ASICs support chaining of the gigabit link as shown in Figure 3) to provide an unprecedented readout speed for this type of instrument. The gigabit encoding standard serves two purposes. It provides enough zero crossings for clock encoding and it also provides better noise immunity by eliminating the possibility of the bits changing from all zeros to all ones. When a user sets the scope for long timebases---longer than can be supported at the maximum sampling rate, the ASIC performs the decimation function to remove unneeded samples. For example, the WaveMaster 8500 with 24 Mbytes of acquisition memory per channel can acquire data at 10 GS/s for 2.4 milliseconds (or on two channels at 20 GS/s into 48 Mbytes of acquisition memory for 2.4 msec). On a longer timebase, the sampling rate is decreased so that the available memory can cover a longer period of time. In many previous scope designs, the sampling rate of the ADC was changed by changing the frequency of the sample clock. This has many disadvantages related to the dependency of ADC performance and sampling rate. But since the embedded DRAM ASIC of the WaveMaster can perform on-the-fly data decimation, the sampling clock can always run at a constant optimum frequency. Building a fixed frequency, 10 GHz sampling clock, rather than a variable frequency sampler allows the WaveMaster to have an extremely stable timebase. The jitter of the sampling clock is less than 150 femtoseconds.

After arriving at the FPGA via dual gigabit Ethernet links, the data is routed via PCI bus. At the current state of technology, this bus is the limiting factor in the data transfer rate of the X-Stream (as shown in Figure 4). Its data handling capability is 125 Mbytes/sec under optimal conditions. Though this data handling capability is far faster than previous generations of oscilloscopes, it is the slowest element of the X-Stream technology. Fortunately, there is much work being done to design a faster replacement for this bus. When the new technology is available the scaleable nature of the gigabit readout system, will enable even faster versions of X-Stream.

From the PCI bus, the data is routed to the microprocessor. LeCroy has completely rewritten all the software code used in the WaveMaster series as a library of more than 300 com objects optimized for high speed handling/processing of data packets. This modular software architecture allows the Windows 2000 operating system to be completely integrated with the oscilloscope data handling, measurement calculations, analysis routines, display algorithms and I/O functions. The architecture also allows the user to create customized signal parameters or waveform math functions and embed them in the processing stream (rather than exporting data to a third party program). This level of integration also allows the X-Stream technology to utilize the powerful DSP capabilities of the CPU. Older technology scopes use Windows 95/98/ME systems and an Intel processor to handle the user interface, but data handling in those scopes is done with a slower embedded processor. In the WaveMaster, LeCroy has crafted the data handling code to optimize the transfer of processing routines and data packets into cache memory. With previous oscilloscope technology, even the fairly commonplace task of calculating a few pulse parameters used up large amounts of processing resources, slowing down acquisition rate and causing a substantial increase in deadtime between triggers. In contrast, the WaveMaster can quickly calculate eight simultaneous histogram icons—"histicons" showing parameter distributions.

Often a user of a high performance scope needs to perform waveform math on more than one trace. For example, if a scope user wants to subtract channel 1 from channel 2 and then perform an integration of the resulting waveform, the WaveMaster is designed to have a data packet from each channel plus the instructions for subtraction and integration all resident simultaneously in cache. This enables processing to occur at rates 10 to 100 times faster than scopes using other data handling/processing methods. The result is not so noticeable if the user wants to simply display a waveform, but the advantage of optimizing the use of cache memory become very apparent when a user wants to measure and analyze data. The cost penalty for analysis functions is much lower using the packetized/streaming/cachable X-Stream technology.

The invention of X-Stream technology is particularly crucial for use in oscilloscopes with high speed ADCs. At 20 GS/s, a scope builds a data record that is 20 times the size as for a 1 GS/s scope capturing the same interval of time. A data record that was 50 kbytes with one sample per nanosecond becomes 1 Mbyte with 20 samples per nsec. Scope users who in the past did not have to worry about slow calculations on long data arrays will now have to wait while a scope makes computations on very long record lengths. Or even worse, if they get a scope with high bandwidth, fast sampling and short memory they will have to worry about aliasing. For example, a 6 GHz scope sampling at 10 GS/s has a Nyquist frequency of 5 GHz. Frequency components of the input signal between 5 and 6 GHz are passed through the amplifier and aliased by the ADC. And this problem becomes much worse if the scope cannot maintain the 10 GS/s sampling rate due to short memory. With X-Stream technology, the fast sampling rate of the ADC is supported by high speed embedded DRAM ASIC with up to 24 Mbytes of memory per channel (longest in the industry) and the pipeline that handles the data from the embedded DRAM ASIC all the way to the microprocessor is optimized for making calculations on long data arrays.

As signals becomes faster and more complex in shape, and as the need for higher precision measurements becomes more crucial, X-Stream technology provides a new method to handle the challenges of current and future generations of product design. More types of measurements can be made, the calculations can be performed faster and the deadtime between triggers when making measurements/analysis is much shorter In the end, the engineer gets more precise measurements and a higher level of confidence. The ability to get work done faster, to make sure that crucial features on signals are not missed and to perform new types of analysis that cannot be supported by older technologies allows the engineer to reach highest productivity.

Figure 1 Conceptual View of X-Stream technology. Data flows in real time at 10 gigabytes per second from the ADC to custom designed high speed acquisition memory then in packets through multiple gigabit Ethernet links and eventually into cache memory. Processing of signals is 10 to 100 times faster than previous oscilloscope technologies.

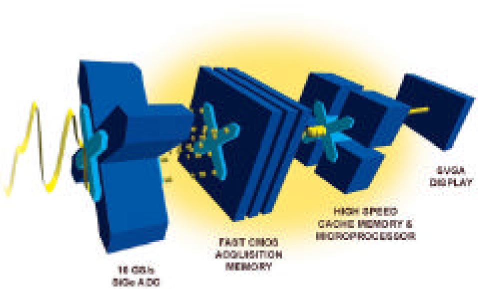
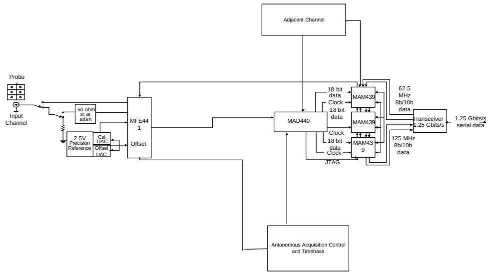


Figure 2 Block diagram of the front end of the WaveMaster. The MFE (Monolithic Front End) and MAD (Monolithic Analog to Digital converter) each have >6 GHz bandwidth. The data stream moves from the ADC to the MAM (Monolithic Acquisition Memory) and then via multiple gigabit Ethernet links to the FPGA and then the CPU as shown in Figure 4.



·e 3. Each WaveMaster ADC has inputs from two amplifiers (to allow interleaving) and a third input which is used only ·ervice diagnostics. Data from the ADC is routed in real time via six LVDS (low voltage differential signal) byte wide (grouped in pairs) to three custom DRAM ASIC MAM's (monolithic acquisition memory) and then to the next step of ·-Stream via gigabit Ethernet

Signal Flow Block Diagram

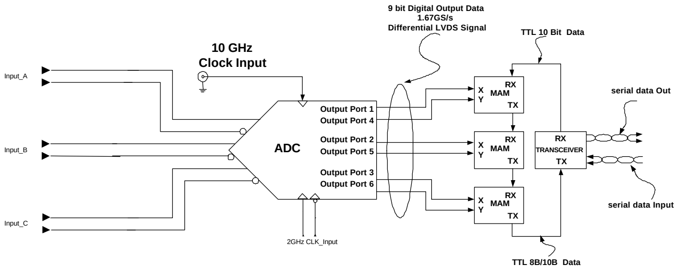


Figure 4 A block diagram showing the path from acquisition memory through dual gigabit ethernet links to the FPGA and then to the PCI interface and CPU. Data handling is done via packets with optimized algoritms to enhance the use of cache memory.