THE LANSCE TIMING SYSTEM UPGRADE*

E.Björklund#, LANL, Los Alamos, NM 87545, U.S.A

Abstract

As part of a planned upgrade project for the Los Alamos Neutron Science Center (LANSCE) accelerator, we are considering replacing our current timing system, which distributes each timing signal on its own dedicated wire, with a more modern event-driven system. This paradigm shift in how timing signals are generated and distributed presents several challenges that must be overcome if we are to preserve our current operational capabilities. This paper will discuss some of the problems and possible solutions involved with migrating to an event system. It will also discuss some recent enhancements to the Micro Research, Finland (MRF) event system that will help us accomplish our goal.

INTRODUCTION

Back in the days when computers were expensive and software was free, the Los Alamos Meson Physics Facility (LAMPF) was designed and built to be one of the first computer controlled linear accelerators in the world. The design of the early LAMPF control system reflected a world in which computers were both expensive, and not very reliable. All of the analog setpoints on the machine were controlled by stepper-motors attached to potentiometers (so that they would survive power failures and computer crashes) and all data acquisition and control was centralized within a single control computer that lived in a climate-controlled room next door to the Central Control Room.

In the late 1980's the Proton Storage Ring was constructed off Beam Line D. As the facility's mission migrated from mesons to neutrons, LAMPF became the Los Alamos Neutron Science Center (LANSCE). Today, more than 30 years since the LAMPF accelerator first achieved 800 MeV, we are planning for a major refurbishment intended to keep the facility running for another couple of decades. Although the control system has become more distributed over the years, both the primary data acquisition and control system (known as "RICE") and the timing system still retain their original centralized design (see Fig. 1). One of the goals of the proposed LANSCE refurbishment is to replace the centralized RICE and timing systems [1][2] with distributed EPICS-based systems.

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#Author's e-mail: bjo@lanl.gov

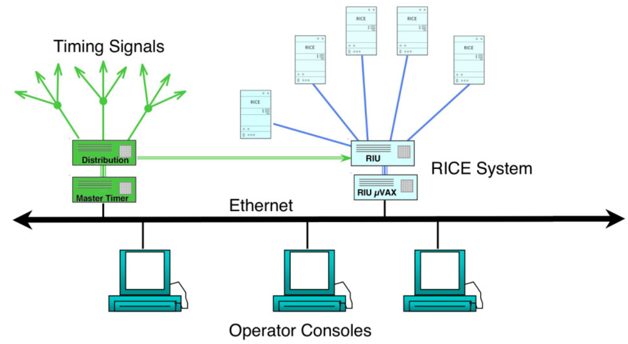

Figure 1:Current System, Showing Centralized Timing and Data Acquisition (RICE)

DISTRIBUTED VS. CENTRALIZED TIMING

The title of this section is a little misleading because timing must always be centralized – at least to the point where there is a common clock source. What we mean in this paper by "distributed timing" is that the timing gates – the actual TTL signals that control the accelerator – are generated locally, and only the machine cycle events – which determine the order and "flavor" of each machine cycle – are generated at a central location.

There are a number of advantages of a distributed event system over a centralized gate generator. These include:

- Reduced cable plant. In a centralized system, a separate cable must be pulled from the master gate generator to each location that gate is required. In a distributed system, only the event link is required to generate as many gates as desired at a given location.
- Increased number of timing gates. The LANSCE master gate generator is limited to a maximum of 96 gates - 87 of which are currently in use. Increasing the number of gates in the current system would require a major redesign. The number of gates generated by an event system, on the other hand, is not even limited by the number of events it can generate (typically around 255). When a specialized gate is needed at an experimental area, it is not necessary to allocate an unused gate generator and run a cable to the desired location. Instead, you need only select an appropriate event to trigger the gate on and set up the appropriate delay and length in the nearest event receiver module.

There are also, however, some advantages of a centralized system over a distributed system, and we would like to preserve these capabilities as much as possible.

- Synchronizing multiple gate instances. When multiple instances are required of a single gate (for example the gate that turns on the RF), it is easy to make sure all instances of that gate have the same parameters (delay, length, etc.) when the gate has a common ancestor at the master gate generator. This is a little harder to guarantee with an event system – particularly if the gate parameters vary on a cycle-to-cycle basis.
- Jostle. This is a "technical" term describing what happens when the event link being a serial line in which no two events can occupy the same time slot. When an event is being moved along the timeline and bumps into another event, either the first event will be "jostled" around the aboriginal event, causing a larger than expected jump in the gates controlled by the event in motion, or the aboriginal event will be "jostled" to another time slot, causing its triggered gates to experience a jump in their delays. Jostle, of course, is not a problem for a centralized gate generator system.

DISTRIBUTED VS. CENTRALIZED DATA ACQUISITION

These days there is very little positive that can be said for a centralized data acquisition system. However, the LANSCE RICE (Remote Instrumentation and Control Equipment) system has some useful features that are essential for LANSCE to serve the diverse needs of its users.

LANSCE can simultaneously accelerate both positive and negative hydrogen ions. In addition, the accelerated beams are multiplexed among several experimental areas, each with its own requirements for intensity, duty factor, and chopping patterns. Roughly speaking, the species and ultimate destination of a particular beam is referred to as its "flavor". It is the responsibility of the master gate generator to schedule which beam flavors will occur within which machine cycles. It does this by creating a map, 120 machine cycles long (one second of wall-clock time), called the "Super Cycle Map". In the LANSCE control system, flavoring is determined by which timing gates are present during a specific machine cycle. Because positive and negative ions can both be accelerated in the same machine cycle, the flavor must also take into account which gates are not desired so that we can see what effect one beam type may be having on another. Consequently, each gate component of a LANSCE flavor has three states – "must be present," "must be absent," and "don't care". All 96 of the master gate generator's gates may be included in a flavor specification, giving us a total number of 3^{96} ($\sim 6.36 \times 10^{45}$) possible flavors. In practice, this is more flavors than we could ever use, but it does allow us to be amazingly flexible in how we configure our machine.

The centralized timing system shares the Super Cycle Map with the centralized data acquisition system. When an application requests a "flavored" read, the data acquisition system schedules that request for the next machine cycle that matches the flavor request.

Because RICE is a centralized system with a "star" configuration (as illustrated in Fig. 1), it also has the ability to acquire longitudinal snapshots of selected data points that are correlated in time. These "vector reads" are important diagnostic tools and we would like to preserve this capability in our new system.

TIMING SYSTEM FEATURES

The project is still in the conceptual design phase, although some prototyping has been done to ensure our concepts are sound. Our initial design is based on the Series 230 event system from Micro Research Finland (MRF) [3]. The MRF event system offers several advantages:

- It is the only commercially available event system that has most of the features we need.
- It is a proven technology currently in use at the Swiss Light Source [4], the Diamond Light Source [5], the Australian Light Source [6], the Linac Coherent Light Source, and the Spallation Neutron Source.
- EPICS support is available.

The design for the new system is shown below in Fig. 2. The goal for the new system is to allow the distributed timing and data acquisition systems to communicate as efficiently and effectively as the current centralized systems do so that none of the flexibility of the current system is lost.

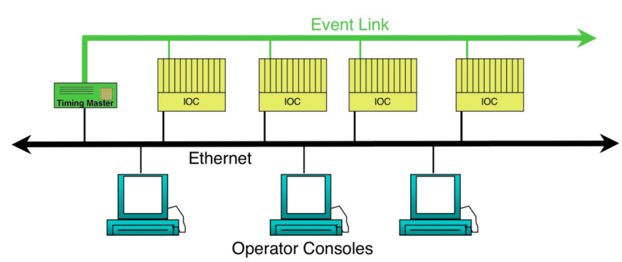

Figure 2: Proposed New System Design With Distributed Timing And Data Acquisition.

In order to accomplish our design goals, we intend to make use of several features of the MRF event system.

Event Clock Synchronization With RF

The event clock can be synchronized with the accelerating RF frequency, which will be important to some of our new diagnostic systems and to some time-of-flight experiments. Our plan is to run the event clock at 100.625 Mhz, which is the first sub-harmonic of the 201.25 RF frequency.

Synchronize Machine Cycle With AC Power

Even after the upgrade, the RF stands and pulse power supplies will still need to by synchronized so that they operate at the peaks of the AC power cycle.

Scripted Event Sequences

Sequence RAMs in the event generator module allow you to store a sequence of up to 2048 events. A timestamp is stored with each event to indicate when that event should fire. The entire sequence may be started by either an internal trigger or by an external trigger – such as AC zero-crossing detection. Each event generator contains two sequence RAMs so that one RAM can be updated while the other RAM is replaying. There are plans for a "Super Sequencer" which will allow us to store and replay an entire "Super Cycle" (120 machine cycles).

Flip-Flop Gates

The event receiver modules can be set up to turn a gate on upon the receipt of one event and turn it off upon the receipt of another event. This feature, along with the event generator sequence RAMs, provides one way to guarantee that those common gates (such as RF gates) which need to be distributed throughout the facility will always reflect the correct width and delay, even if they change on a cycle-to-cycle basis.

Distributed Data Stream

In the MRF event system, each event is 16 bytes long. Eight of those bytes contain the event number and the other eight can be multiplexed between a distributed signal bus and a distributed data stream. This arrangement is shown below in Fig. 3.

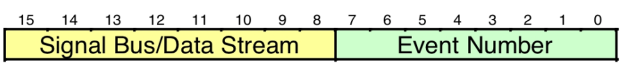

Figure 3: Event Structure

The second half of the event is normally used as a distributed signal bus that can transmit external signals or clocks with the same resolution as the event rate. The signal bus may also be multiplexed with an arbitrary data stream of up to 2048 bytes. When the data stream feature is enabled, the resolution of the signal bus is reduced to half the event clock rate. Figure 4, below, illustrates how the signal bus and data stream are multiplexed when the data stream option is enabled.

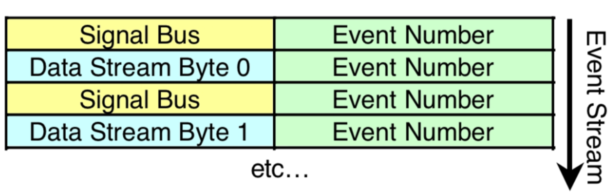

Figure 4: Event Stream Showing Signal Bus and Data Stream Multiplexing.

We plan on using the data stream feature to ensure that all the data acquisition IOCS have a current copy of the Super Cycle Map. We also plan to use it to broadcast the current cycle number within the super cycle. With this information, each data acquisition IOC can make its own decision about when to schedule flavored reads. The mechanism for specifying flavored reads in EPICS is described in another paper in this conference [7].

The Super Cycle Map and current cycle index will also be used by the new low-level RF system to optimize its adaptive feed-forward algorithm for each beam flavor. This information will also be important to the implementation of correlated data.

CONCLUSION

Although there are many details yet to be worked out in the design of the new LANSCE timing system, we are confident that the features described here will allow us to transition from a centralized to a distributed system without losing needed functionality or flexibility.

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