# A MULTIPLEXER/RECORDER ARCHITECTURE FOR USE WITH CONVENTIONAL MEDIA TECHNOLOGY

**Albert Berdugo**
**Vice President of Advanced Product Development**
**Teletronics Technology Corporation**
**Newtown, PA USA**

## ABSTRACT

Instrumentation recorders have evolved continuously over the years. Their growth has primarily been driven by technology advancements. The latest recording equipment generally utilizes hard disk, disk array, or solid-state storage technology, which results in greater capacity and performance. Most recorders integrate storage media with multiplexer electronics resulting in a highly efficient yet inflexible and physically large recording system.

This paper describes an instrumentation multiplexer/recorder system using an open architecture between the multiplexer and the storage media that allows insertion of conventional recording technologies. This approach provides a generalized solution with enough flexibility and scalability to address the majority of instrumentation recording needs. This system is based on the latest IRIG-106 chapter 10 standard, thus supporting interoperability throughout the flight test community.

## KEY WORDS

Recorder, Multiplexer, Solid-State, Hard Disk, IRIG-106 Chapter 10

## INTRODUCTION

Historically, instrumentation recorders were based on magnetic tape media with either analog multi-track or digital single-track recording capability. Digital recording has generally required a front end multiplexer for combining multiple data types. Historically, a single-track magnetic tape media digital recorder and a multiplexer were provided as two separate units. However, with advancements in media technology such as hard drive and solid-state drive, many recorder and multiplexer companies have integrated the media and multiplexer into a single enclosure resulting in a highly efficient system. However the inflexibility of such a system to adopt the latest drive technology, and the inability to support flexible system installations have become major concerns for system integrators. At times, a recorder with integrated multiplexer and media is highly desirable, however, a multiplexer with separate media drives communicating over standardized interfaces can prove to be the desired approach in most modern applications.

The architecture described in this paper is based on a stand-alone multiplexer that supports different media types and interfaces for applications ranging from harsh airborne environments to benign lab-based environments. The price range of such a system may also vary drastically

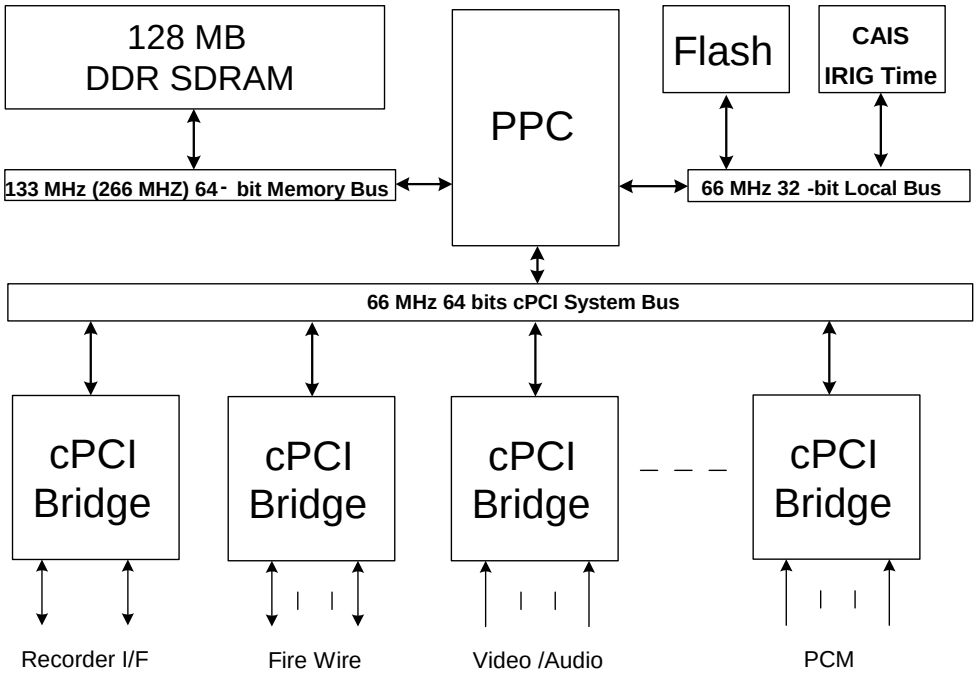
based on the environmental conditions. In a harsh environment where a Solid State recorder is used, the media can be the largest cost item, while in a lab or ground based environment the multiplexer will be the largest cost item when using a an off the shelf, commercial hard drive as the media of choice.

This paper will describe the multiplexer architecture, media types, and media interfaces to provide the user with flexibility and cost advantages. We will also describe how the same architecture will allow for technology insertion when future media and media interface technologies become available.

## MULTIPLEXER / RECORDER ARCHITECTURE

A multiplexer by its nature is an element that acquires multiple input channels with similar or dissimilar data types and combines them into a single data format suitable for transmission and/or recording. In the case of a high speed airborne multiplexer, such a unit must be able to acquire wide varieties of data types ranging from few kilobits per second to gigabits per second (Gbps). The architecture of the multiplexer must be flexible and general enough to accommodate current airborne needs and potential customer-specific needs. For this reason and others, the chosen architecture relies heavily on an internal PCI bus architecture. The types of buses used are PCI-32, PCI-64, and PCI-X. PCI-64 and PCI-X can easily allow for data multiplexing at a sustained rate of 1 Gbps. Figure 1 shows the multiplexer architecture.

**Figure 1. Multiplexer Architecture.**




The multiplexer sustained rate can in many cases be greater than the sustained recording rate of most media types. For this reason the operating system must have the capability to record on multiple medias using media IDs. This can be accomplished using SCSI over Fibre Channel or SCSI over 1394b.

For some applications where data multiplexing is required but the aggregate data is low (less than 20 Mbps), a serial PCM and clock output can be used as the output interface. This allows users to interface with existing PCM solid-state recorders.

As can be seen from the architecture, the PCI bus allows for wide varieties of interfaces to be used. These interfaces enable the use of many commercial, industrial, and ruggedized storage media to be used. The types of interfaces available today in the market place include:

- Electrical or Optical Fibre Channel at 1 or 2 Gbps
- Electrical or Optical Gigabit Ethernet at 1 Gbps
- 1394b (Fire Wire) at 800 or 400 Mbps
- USB 2.0 at 480 Mbps
- Serial ATA at 1.5 Gbps
- Serial Attached SCSI (SAS) at 3 Gbps

The architecture provides flexibility to implement the media interface in such a way that the media can either be internal to the multiplexer chassis, or external to the chassis. An interface to an external media provides the greater flexibility to the user in terms of access to the media and the type of media to use.

## SYSTEM SELECTION PROCESS

Users are faced with a limited selection of data multiplexers for data recording in an airborne application. The prime factor to this is the unique types of data acquired. Such data may include MIL-STD-1553, Weapon Mux Bus, PCM, Video (analog), Video over Fibre Channel, Fibre Channel (electrical and Optical), 1394b FireWire, Ethernet 10/100 BaseT, and other unique buses. The second factor is the environmental conditions, which can vary widely from one application to another. Due to these factors, multiplexer recorder costs are high, particularly when high capacity solid-state media is required. In some applications when environmental conditions are benign, and very large amounts of storage are required, the user can elect to use hard drive based media. The more difficult problem is when large amounts of storage are required for harsh environmental applications. Several key criteria to consider in the media selection process include:

- Capacity - the amount of data storage required
- Performance - throughput requirements
- Scalability - long term data growth
- Environmental – solid state vs. hard drive, and ruggedization
- Budget concerns

The selection process requires an analysis of the key requirements and associated trade offs to arrive at the best solution. All items in the criteria are inter-related, and prioritization in this process means that some compromises may be required.

Media capacity is directly related to the average data record rate and the record time. Generally, both of these factors vary widely on a given program and from mission to mission. Users are faced with the choice of estimating the worst case of these two factors in selecting the desired capacity, which in turn affects the budget concerns.

Media performance is in most cases of an utmost concern. For data acquisition applications where solid state is potentially the media of choice, performance means sustained write rate, and it is more important than the peak burst rate quoted on the supplier's data sheet. Most business applications involve random reads and writes, with more reads than writes, and the peak input / output (I/O) rates quoted by flash manufacturers are likely to be consistent with the performance achieved. To overcome performance limitations of the media, users often cascade multiple media units within an arbitrated loop using fibre channel communications, or consider using a RAID (Redundant Array of Inexpensive or Independent Disks) system when possible.

Scalability provides the user with the flexibility to specify the system based on the current application while still allowing for future growth. Users can choose to start with a single drive configuration that can eventually be adapted to multiple drives, JBODs (Just a Bunch Of Disks), or RAIDs for the future applications.

Environmental conditions are key selection criteria in airborne applications. Rarely will an off the shelf commercial drive be able to be used in such applications without ruggedization. Several companies including TTC (Teletronics Technology Corporation) ruggedize solid state and hard drive media to meet airborne conditions. In most cases this process includes the addition of a 28V DC-to-DC supply and other electronic circuitry. It is not uncommon for customers to attempt to use unruggedized media from commercial sources, only to approach TTC for ruggedized media solution after loosing valuable mission data.

It is expected that budget concerns affect the selection process. A solid-state drive can cost 200 times more than hard drive per gigabyte (GByte). A ruggedized solid-state drive will cost about 1.5 times more than a non-ruggedized one per GByte. A ruggedized hard drive will cost about 10 to 14 times more than a non-ruggedized hard drive per GByte. A ruggedized solid-state drive will cost about 20 to 30 times more than a ruggedized hard drive per GByte. These general cost items do not take into account the additional power supply and circuitry that may be added in the ruggedization process. All these factors must be accounted for when making budget decisions.

## MEDIA and MEDIA INTERFACE TYPES

This section will explore the various avenues available to users in selecting the appropriate media for an airborne recording application based on the desired capacity, recording rate, scalability, environmental conditions, size, and cost. This selection process assumes that the user has chosen a recorder/multiplexer architecture with the ability to select the desired media and media interface, and that the media can either be integral to the multiplexer in minor cases, or external to the multiplexer in the more general cases. Table 1 provides a summary of the information found in this section.

### Fibre Channel Interface

Fibre Channel interface comes in two flavors, namely electrical (wire) and optical fiber, and is available to support either solid state or hard disk media. The electrical interface operates at 1 or 2 Gbps at distances up to 100 feet, and the optical fibre interface operates with even greater distances. SCSI over fibre channel is the protocol used for recording with this interface. Having fibre channel interface port(s) in a multiplexer provides the user with a wide range of choices of media to meet various needs. This is due to the wide acceptance of fibre channel in the storage and archival business area. A second fibre channel interface port on the multiplexer allows the

user to read the recorded media using GSE (Ground Support Equipment). This is particularly useful when access to the media is not possible or is extremely difficult. Some of the media options available when using a Fibre Channel interface are shown below:

- Solid State drives are currently available with capacities ranging to hundreds of GBytes. Multiple drives can be cascaded using an arbitrated loop to increase capacity and throughput. When used in benign environments, these drives require little or no repackaging. However, use in an airborne environment generally requires ruggedization. Solid state drives are also available as a fibre channel RAID system.
- Hard drives are currently available with capacities approaching a half Terra Byte (TByte). Cascading multiple drives can be used to increase the capacity and the data throughput. These drives are available as a single hard drive, JBOD (Just Bunch Of Disks) with up to four drives per unit, and various RAID systems. For a benign environment, many suppliers offer this product off the shelf. Several companies also ruggedize hard drives for airborne applications. Ruggedized airborne drives generally will have some environmental limitations, will be sealed, and may include optional heaters.

**1394b FireWire Bus Interface**

The 1394b FireWire bus and compatible media are becoming available for use on airborne platforms. The 1394b interface operates at 800 megabits per second (Mbps) at distances up to 20 feet. This bus allows the user to cascade multiple drives in order to increase capacity or throughput. SCSI over 1394b bus is the protocol used for recording with this interface. It is common to find multiplexers with integrated drives using the 1394b bus. Having 1394b interface port(s) provides users with some flexibility in the choice of external media, however this flexibility is not as great as that available with the fibre channel interface. This is due to the wider acceptance of fibre channel in the storage and archival business area. Data download of recorded data from an airborne platform using the 1394b from bus is not common (although possible) due to the distance limitations of the bus.

- Solid State drives are currently available with capacities ranging up to several hundred GBytes. Multiple drives can be cascaded to increase capacity and throughput. When used in benign environments, these drives require little or no repackaging. However, use in an airborne environment generally requires ruggedization. There are no known 1394b JBOD or RAID systems available at this time.
- Hard drives are currently available with capacities approaching a half TByte. Cascading multiple drives can be used to increase the capacity and the data throughput. These drives are primarily available as single drives. There are currently no known ruggedized 1394b drives. It is expected that some will be available in the future.

**USB, Serial ATA, and SAS Interface**

These busses are becoming available in the airborne applications. They are primarily found in products where the drive is embedded within the system. The primary limitation of these buses is the inability to communicate as an external drive to a host system due to the restriction in bus length. Generally, the bus length of each of these busses is:

- USB 2.0 – 6 to 10 feet
- Serial ATA – 3 feet
- Serial Attached SCSI – 20 feet

**Multiplexer/Media Configurations**

Table 1 summarizes the various TTC standard commercial recorder products that support multiplexer system with either internal (integral) media or external media. These configurations are all ruggedized for an operating temperature range of -40C to +80C. The hard drive media is ruggedized with internal heaters to allow operation at temperatures lower than 5C. The hard drive enclosure is sealed to allow operation at altitude and prevent moisture ingress.

**Table 1. Multiplexer/Media Configurations.**

| | Standard Commercial Recorder Products | | | | |
|---|---|---|---|---|---|
| | MSR-2002/ MSC-XXXX | RMM-XXXX | XRMM-1XXX | SMS-4000/ 5000 | MSSR/ MMSM |
| Media Configuration | External | Internal | External or Internal | External | External |
| Multiplexer Compatibility | AIM-2000 or MUX-3000 series | AIM-2000R series | Ext: AIM-2000 or MUX-3000 Series<br>Int: MUX-3000R series | MUX-3000 series | MUX-3000 series |
| Interface | Fibre Channel (Electrical) | 1394B | 1394B | USB 2.0 or PCM | PCM |
| Solid State Capacity* | Dual Drive; Up to 147 GByte/Drive | Up to 147 GByte | Up to 74 Gbyte | Up to 74 GByte | Up to 16 GByte |
| Hard Disk Capacity* | Dual Drive; 300 GByte/Drive | N/A | N/A | N/A | N/A |
| Performance | Up to 100 MByte/sec | Up to 50 MByte/sec | Up to 50 MByte/sec | USB: Up to 8 MByte/sec<br>PCM: 2-1/2 MByte/sec | Up to 10 Mbit/sec |
| Scalability | 2 units can be cascaded | N/A | Multiple external units can be cascaded | N/A | N/A |

* The capacity size is only limited to current available drives in the market.

## CONCLUSION

This paper has presented an instrumentation multiplexer/recorder system architecture based on separately housed multiplexer and storage media. This approach provides flexibility and scalability to address the majority of instrumentation recording needs in a cost-effective manner. The process of selecting the best approach for a given application is based on careful analysis of performance, budget and benefit tradeoffs.

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