"HIGH SPEED ASYNCHRONOUS DATA MULTIPLEXER/ DEMULTIPLEXER FOR HIGH DENSITY DIGITAL RECORDERS"

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ABSTRACT

Modern High Density Digital Recorders (HDDR) are ideal devices for the storage of large amounts of digital and/or wideband analog data. Ruggedized versions of these recorders are currently available and are supporting many military and commercial flight test applications. However, in certain cases, the storage format becomes very critical, e.g., when a large number of data types are involved, or when channel-to-channel correlation is critical, or when the original data source must be accurately recreated during post mission analysis. A properly designed storage format will not only preserve data quality, but will yield the maximum storage capacity and record time for any given recorder family or data type.

This paper describes a multiplex/demultiplex technique that formats multiple high speed data sources into a single, common format for recording. The method is compatible with many popular commercial recorder standards such as DCRsi, VLDS, and DLT. Types of input data typically include PCM, wideband analog data, video, aircraft data buses, avionics, voice, time code, and many others. The described method preserves tight data correlation with minimal data overhead.

The described technique supports full reconstruction of the original input signals during data playback. Output data correlation across channels is preserved for all types of data inputs. Simultaneous real-time data recording and reconstruction are also supported.

KEY WORDS

Key Words: ARMOR, MiniARMOR, Digital Recorder, Multiplexer/Demultiplexer, Recording Format.

INTRODUCTION

Calculex[1] originally developed the Asynchronous Real-time Multiplexer and Output Reconstructor (ARMOR) for use with a wide variety of digital tape recorders. The ARMOR system has become the de facto industry standard among multiplexer/ reconstructor products. The recording format used in the ARMOR system works well in many conventional instrumentation applications. However, enhancements and improvements were needed in order to keep pace with the latest high-speed recording technology. The system also needed better software and hardware tools to simplify the setup and programming activity, and to enhance the format interchange capabilities among instrumentation users. Also the physical size, power consumption, and manufacturability of the ARMOR needed to be addressed to allow greater efficiencies.

For these reasons, a development program was initiated by Aydin Vector Division and Calculex, Inc. The main goal of the program was to implement the features needed for improvement while maintaining the baseline features of the existing ARMOR format. An overview of the specific development goals are shown below:

- Develop a recording format which can be used to standardize interchange practices for recorded instrumentation.

- Establish a common recording format which works well with different recording equipment and technologies at data rates up to 240 Mbps.

- Establish an efficient recording format which maximizes the available bandwidth depending on the type of recorder being used, and minimizes the associated data overhead penalties.

- Accommodate a wide variety of data types within a single format including the ability to efficiently record low rate data and high rate data during the same recording session.

- Maintain inter-channel time correlation for subsequent replay of multiple, interdependent channels.

- Develop an integrated set of hardware and software support tools.

MiniARMOR MULTIPLEXER/DEMULTIPLEXER[2]

A typical MiniARMOR configuration is comprised of the following card types:

- Multiplexer/Demultiplexer card (MDX-700)
- Controller card (CTL) based on the type of recorder in use
- Input card/s based on the type of signals to be recorded
- Output card/s based on the type of signals to be reconstructed

Every MiniARMOR-700 system uses an MDX-700 card to provide multiplexing and demultiplexing functions. As a multiplexer, this card receives data from all input cards, multiplexes the data into a common recording format, and transfers the formatted data to the recorder via the CTL controller card. As a demultiplexer during tape playback, the MDX-700 receives data from the recorder via the CTL controller, demultiplexes the data, and transfers the data to the various output cards for reconstruction. The MDX-700 card also supports real-time data reconstruction during recording. With a maximum data rate of 240 Mbps, the MDX-700 card is compatible with any type of CTL controller card.

The CTL controller card provides the interface between the MiniARMOR-700 system and the digital recorder. Each MiniARMOR-700 system is configured with one or two CTL cards based on the type and number of recorders in use. In the case of multiple recorders (used for tape duplication and/or extended cascade recording), both recorders are assumed to be of the same type. The CTL card provides the data transfer to/from the recorder, and provides a serial port for communication with a host PC or with an external control panel. In addition, some recorders (such as the DCRsi) also require a serial command port which is also provided by the CTL card.

The MiniARMOR input cards acquire a wide variety of asynchronous digital and analog data types. Multiple cards of the same type can be placed within a single MiniARMOR-700 chassis depending on the number of slots available. Cards are available for the following types of data:

- High speed serial data with synchronous clock (PCM, burst, etc.)
- High speed serial data without clock (Bit Sync option)
- Avionics data buses
- Wideband analog at up to 1 MSPS per channel (provides presample filtering)
- Video Codec for NTSC, PAL, or S-video formats
- Parallel digital data

Channel-to-channel time correlation

Channel-to-channel time correlation is critical in many applications, particularly when several channels are used to monitor a single, physical event. A design goal of inter-channel time correlation of less than 2 bit periods was established. This goal was to be achieved in an efficient manner using the smallest amount of data overhead (only 2 to 4%) resulting in maximal record time. This goal was met through the use of the "MiniARMOR-700 Format" specifically designed for this purpose.

Physical vs. Logical Format

Generally, the MiniARMOR Data Format takes two forms. The <u>physical format</u> describes the information as it is related to a particular type of recording equipment and takes into consideration the media and the recorder's motion control system. This paper does not address the physical format except to say that the MiniARMOR format is compatible with most types of high density digital recorders including DCRsi, VLDS, DLT, and others.

The <u>logical format</u> is only relative to the structure and content of the information stored by the recorder without regard to the physical format in use. This paper addresses the MiniARMOR logical format.

MINIARMOR DATA FORMAT

Format Architecture

Two main divisions exist within the MiniARMOR Data Format; namely, the Recorded Header and the Data Block. The first time a recording session begins, a Recorded Header is recorded followed by a succession of Data Blocks. If the recording session is interrupted (RECORD to STOP to RECORD), a new Recorded Header is recorded. This architecture minimizes the number of Recorded Headers and improves the overall recording efficiency.

RECORDED HEADER FORMAT

Contents of the Recorded Header

The Recorded Header contains all overhead information related to the Data Blocks recorded on tape. See figure 1. These elements are itemized below and discussed in detail in the sections that follow:

- Sync Block information is provided to support high speed data search and retrieval.

- A complete definition of the hardware configuration used to condition and record the data is placed in the Header to support automatic hardware configuration during data playback.

- Individual channel setup parameters are defined including gains, offsets, and other information needed during post-mission analysis.

- The name of the file and the date of the recording is included in the Header for archiving.

- Post-mission data reconstruction is facilitated by the Format Scan List contained in the header.

Figure 1. Recorded Header Structure

Sync Block
General Setup
Controller Setup
Channel 1 Setup
- - - - - - -
Channel n Setup
File Name / Date
Format Scan List
Checksum

Sync Block

For proper configuration of the hardware during playback, one needs to know the recorded configuration which is either stored on a disk or as part of the Recorded Header. To retrieve the configuration from the Recorded Header, a processor must be involved in the loop to interpret the information. However, the location of the Recorded Header should be marked in such a way that it is independent from the physical format. This in turn, requires logical record marking to identify the beginning of each recording session. The approach used here is to mark a Recorded Header with a sync block that a hardware state machine can detect without the need for a general purpose processor. This method speeds up the search of the Recorded Header regardless of the recorder type.

Header Setup

To optimize the recording session, the approach used places all information pertaining to the configuration of the hardware, and its settings, only once per recording session. The rest of the record session is dedicated to actual data. The information in the header file must include detailed configuration of each card and each channel used. This information is used during playback to reconfigure the playback hardware down to the channel level. This file includes serial number of every card used, location of every card in the chassis, configuration of each channel, and the format structure. Using the header, the user can identify the complete configuration of the recording hardware, and the structure of the data blocks.

General/Controller Setup

The Recorded Header contains the general setup used during the recording session associated with the system as a whole. The information in this setup includes software version, clock information, chassis size (-505, -507, ...), time code mode (IRIG A, B, or G), aggregate bit rate of the system, etc.

The header setup also contains the controller setup used to identify the type of tape controller in the MiniARMOR. The controller card provides the interface between the MiniARMOR system and the digital recorder. The MiniARMOR system must be configured with one of several types of controller cards based on the type of recorder used, i.e. AMPEX[3] DCRsi, Metrum[4] VLDS-B, Lockheed Martin[5] VLDS-BR, SCSI, etc. In some cases, in order to extend the recording capacity of the system, two recorders are used. This requires the system to be configured with two controller cards (except for the SCSI controller which can interface with up to 7 recorders).

The controller setup holds the information defining Master vs. Slave, type of recorder/controller used, the compile mode used (enhanced vs. enhanced compatible), communication baud rate, and SCSI drive identifier (primary vs. secondary).

Channel Setup

The Channel Setup is an extensive description of the signal acquisition hardware used to condition each input channel prior to recording. This information includes the channel type, bit rate or sample rate of the channel, samples per frame, filter settings, offset settings, channel number within a card, card location in the chassis, and the card serial number. The information provided for each channel may vary slightly based on the type of channel (analog, digital, communication bus, etc.).

This setup information is used to identify the hardware used during recording, and to automatically setup the playback output channel in order to correctly reproduce the original signal.

Format Scan List/ Data Block

The Format Scan List describes the data format of the data block used during the recording session. This format is sufficiently detailed to identify each channel data block within the overall data block. A simplified view of the format is provided in figure 2. The format is loaded to the controller card (CTL) as part of the header, and is loaded to the Multiplexer/ Demultiplexer (MDX) card for execution of the format during record and playback sessions. The format In the Header is used during playback to reconstruct the recorded data.

The first section of the format contains overhead pertaining to the actual format. This includes synchronization words (32-bit Barker code), frame time words, a CRC word, and fill words when needed to meet system clock requirements. Every word in the format has an associated data source tag (record), data destination tag (playback), and word width (bits per word). The source tag identifies the input channel, and the destination tag identifies the data destination channel. By manipulating the data destination tag, one could map a compatible output channel to an input channel. The synchronization words, frame time words, CRC word, and fill words are considered as overhead and are therefore generated by the MDX formatter.

Figure 2. MiniARMOR Format Structure

Frame Overhead
Ch 1 Overhead
Channel 1
Ch 2 Overhead
Channel 2
•   •   •
Ch n Overhead
Channel n
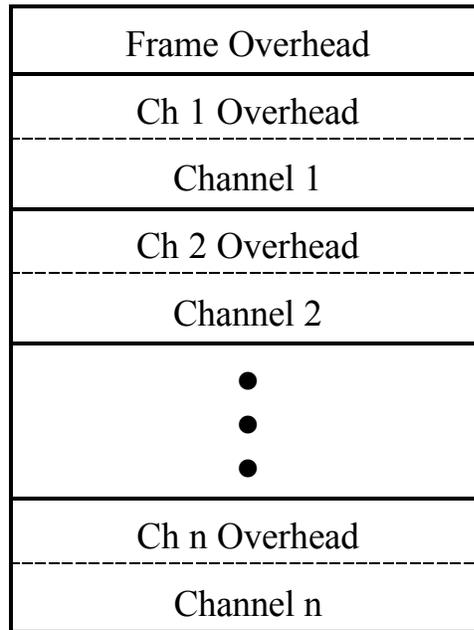
The second section of the format contains channel data block with consecutive samples of that channel. Due to the wide verity of data types (i.e. PCM, Video, Communication Busses, and Analog) it was decided that a channel may have 8, 12, 16, 20, and 24 bits per sample based on the channel type at recording rate of up to 107 Mbps. At recording rate above 107 Mbps samples with resolution of 8 and 12 bits per sample are packed as two samples per word. The advantage of this method is to minimize the word rate in the system bus to 16 Mwps even if the recording rate is 240 Mbps. A channel data block includes both channel overhead and data. The overhead includes sufficient information for the output reconstructor to reliably reconstruct the input data. For example, in the case of a PCM channel data, the overhead of the channel specifies the number of valid data bits to follow in that frame.

SOFTWARE

The MiniARMOR configuration, and Record/Playback format is generated using a PC-based Windows™ software package developed specifically for the MiniARMOR. The software operates in one of two modes; namely the Record mode, and the Play mode. Three complete sets of databases define three possible configurations of the MiniARMOR. One database is used for the Record mode, and two for the Play mode. The existence of these structures is transparent to the user.

In the Record mode, the software supports configuration of the recording hardware and the recorder definition. If real time playback is required while in Record mode, the software allows channel mapping (Input to Output channel). The software compiles all the user data, automatically generates the recording format, and creates the files needed to setup the MiniARMOR. It is not necessary to have the MiniARMOR physically connected to the PC Host computer in order to generate a setup and compile the configuration. The complete Recorded Header is stored in the Record database. The setup is loaded to the MiniARMOR via the serial port of the PC Host computer. Prior to loading the setup, the software automatically scans the MiniARMOR and compares the actual cards in the chassis to the expected cards defined by the user.

In the Play mode, there are two sets of interactive databases. The first database is associated with the recording hardware configuration. In many cases, the hardware configuration used during recording is different from the configuration used in playback. During the Playback mode, the Recorded Header is read by the software either from a disk, or directly from the Recorded Header. The Recorded Header configuration is virtual and can be viewed using the software. Changes to this configuration are not allowed since it reflects the hardware configuration used during recording, and its format. The software allows the user to view this information in detail.

The second database is associated with the hardware playback configuration. For the Playback setup, the output channels are mapped to the input channels used during Record. In this case too, the software scans the MiniARMOR hardware used for playback to insure than any hardware configuration discrepancies are brought to the attention of the user. The output channel configuration assumes the configuration of the input channel mapped to it. The user can determine the input-to-output channel mapping through either a default setting (automatic) or manual setting (override).

CONCLUSION

This paper described a highly efficient recording format which is independent of the recorder type. It accommodates a wide variety of data types during recording and data reconstruction during recording (real time) and playback (post mission).

1. Calculex Inc., Las Cruces, NM, USA.

2. Berdugo, Albert, "Miniature Asynchronous Real Time Multiplexer & Output Reconstructor (MiniARMOR)", European Telemetry Conference 1996, Garmisch-Partenkirchen, Germany, May, 1996.

3. DCRSi and DCRsi are trademarks of AMPEX Data Systems Corporation.

4. Metrum, Inc.

5. Lockheed Martin Data Systems (Loral Data Systems, Inc.).