"A HIGH-SPEED, RUGGEDIZED, MINIATURE INSTRUMENTATION RECORDER UTILIZING COMMERCIAL TECHNOLOGY"

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ABSTRACT

Due to the vast amount of data required to be collected for design/performance analysis of operational and development systems, there has evolved a real requirement for a high-speed, large capacity, data collection/record system in a small Flight/Ruggedized package. This need is realized by several user communities and factors which include the evolution of small operational vehicles (airborne, land and UAV's), the desire of weapons manufacturers/integrators to be independent from the vehicle during vehicle integration, and a general need for a field/airborne, reliable portable data collection system for intelligence gathering, operational performance verification and on-board data processing.

In the Air Defence community, the need for a ruggedized record system was highlighted after Desert Storm, in which the operational performance of the Patriot Missile was questioned and data collection was not performed to support the performance. The Aydin Vector Division in conjunction with the prime contractor, has come up with a solution to this problem which utilizes a commercially available helical scan 8mm data storage unit. This solution provides a highly reliable record system, ruggedized for airborne and field environments and a low price in comparison with the more traditional approaches currently offered.

This paper will describe the design implementation of this small ruggedized, flight worthy Data collection system deemed the ATD-800[1]. It will also discuss the performance and limitations of implementing such a system, as well as provide several applications and solutions to different operational environments to be encountered. Additionally, the paper will conclude with several product enhancements which may benefit the flight test, operational and intelligence communities in the future.

KEYWORDS

Instrumentation Recorder, Digital Tape Recorder, Error Detection and Correction, 8mm Technology Helical Scan Recorder, Small Computer Systems Interface (SCSI II), MIL-STD-810C, PCM, IRIG-106-86, IRIG-A/B/G Serial Time Code, MIL-STD-1553 Bus Data.

DESIGN IMPLEMENTATION

Traditional recording methods reviewed

The instrumentation recorder has faithfully served the industry for over forty years with the introduction of a true scientific instrumentation recorder in the early 1950's.[2] Today's instrumentation recorders offer a standard of performance which is expected and necessary in many field/aircraft test situations. Greater bandwidth, longer runtime, and enhanced operating features are combined in a package which is thoroughly proofed for use in harsh environments. However, some applications don't require such performance, particularly when considering the real cost of such equipment in terms of weight, size, initial acquisition and maintenance cost. These concerns have led to the development of a new product which will meet the needs of many users in field/aircraft instrumentation applications.

The design implementation process has enabled a commercial product to be adapted for use in a non-traditional role. This is only possible through an intelligent design trade-off study where benefits and liabilities have been carefully managed. The process started with a careful statement of desirable features for the new product, to be discussed in the next section.

Selection criteria for a new method

A digital tape recorder will provide several advantages over their analog counterparts which are important to the overall goals of the development. High record density, extended runtime, the availability of error detection and correction, and the ability to acquire data directly from digital sources are considered extremely important. In addition, the low cost, small size, and their current commercial availability are extremely advantageous. Most commercially available recorders have been designed for the benign laboratory environment, however, the low inertial mass associated with the selected transport and record mechanisms helps to lend this product well to ruggedization and miniaturization techniques.

The popularity and acceptance of the storage media will play an important role in the attractiveness of the approach, as well as providing longevity and universality within the industry. Small size cassettes are simple to use and store when compared to their bulky cousins: tape reels.

With these considerations in mind, a value study was conducted to establish the suitability of various storage technologies. DAT, 4mm, 8mm, and optical solutions were considered. Speed, capacity, reliability, suitability, and many other factors were considered. Since many writers have exhausted this topic, it will not be described herein except for the stating the result.[3] We have selected 8mm technology Helical Scan recorder manufactured by Exabyte Corporation as the data storage unit, model number EXB-8500.

Overview of the EXB-8500, 8mm Technology Data Storage Unit

The EXB-8500 is a high performance, high-capacity 8mm cartridge tape subsystem designed to meet the demands of super-mini, mainframe, and PC computer systems. This unit has been adapted to operate as an instrumentation flight recorder. The recording format is all-digital, achieving storage on magnetic media entirely through discrete flux reversals on tape. Digital storage lends itself well to the recording of computer-based data and information retrieved from computer subsystems typically found in field/aircraft applications. In addition, the direct digital output from PCM Data Acquisition Systems can be acquired for recording with minimal need to reformat the information.

The recording mechanism uses dual read and write head pairs with helical-scan recording technology to achieve a continuous transfer rate of up to 500 KiloBytes Per Second (KBPS). Higher peak transfer rates are met with internal data buffering, thereby achieving peak rates of 4 Million Bytes Per Second (MBPS). The media is standard 8mm cassette (112M) with a typical storage capacity of 5 gigabytes of information. For serial PCM inputs at 16 bits per word, up to 2.7 hours at 4 megabits per second data rate or up to 22.1 hours at 500 kilobits per second data rate are typical run times.

Incremental tape start/stop technology is used allowing the user's input rate to be isolated from the tape transport rate without loss of data flow continuity. This results in maximum utilization of available storage media.

The EXB-8500 uses sophisticated error correction code (ECC) and error recovery procedures to ensure absolute data integrity and fidelity. Data is accessed through a Small Computer Systems Interface (SCSI II) controller and is available in single-ended or differential configurations.

The wide application of the EXB-8500 in commercial applications has led to immediate acceptance of this approach among industrial and military users. Standardization to the SCSI II protocol has eased the task of user-interfacing to the product, as well as enabling the transfer of very high data bandwidths to tape.

Design concerns

Adaptation of the EXB-8500 commercial product to the harsh environments typically found in field/aircraft applications has proven to be straight-forward and easier than anticipated. The success is primarily due to the EXB-8500s ECC circuitry which employs "read-after-write" technique to guarantee 100% data recording under a wide variety of "problem" conditions including environmental extremes and media faults. The unit will faithfully record every bit of information through a combination of Reed-Solomon correction codes, and by physically verifying that every bit was successfully transferred to tape. If a fault condition is found, the unit will automatically rewrite the same data to tape at some location downstream from where the original attempt had failed. This is all done in a real-time background mode, fully independent of normal tape write operations.

The commercial construction and components used in the manufacture of the EXB-8500 were not directly suitable for harsh environments. A "ruggedization process" has been developed using an external chassis with a combination of shock and vibration isolators and the ruggedization/replacement of certain critical support structures. This yields a product suitable for applications in which MIL-STD-810C levels of shock, vibration and temperature are required. "Smart environmental control" has been added to maintain the proper operating temperature and humidity conditions necessary to allow the unit to operate both in the heat of the desert and the cold compartments of aircraft. It is ironic to learn that the primary limitation to operating temperature range is the tape media itself; not the tape drive. A "smart" enclosure fan provides enough positive internal pressure to keep out dust and dirt and to achieve rapid internal temperature stabilization.

System power requirements are 28VDC or 115VAC. Continuous operation between power dropouts and undervoltage, or during short periods when power source transfers occur is provided through an external backup battery provided by the user. This backup battery also allows the removal of tapes should the primary power source be disconnected.

Special Features of the ATD-800

In addition to the ruggedization of the basic EXB-8500 to operate in field/aircraft applications, several functional features are provided by the ATD-800. Figure 1 provides the functional block diagram of the ATD-800 and figure 2 shows a typical system connection.

Although the primary electrical interface to the tape unit is via SCSI II, users may record direct PCM data per IRIG-106-86 at up to 4 megabit per second data rates. Incremental start/stop tape transport and front-end data buffering always yields the maximum data-to-tape capacity regardless of input data rate. Other versions are available which accept IRIG-A/B/G serial time code inputs for time tagging, direct analog voice input encoded and placed on tape, and MIL-STD-1553 Bus data monitored for selected data and stored to tape. A wide variety of additional interfaces are currently in development.

Data Recovery

Once on tape, the data may be recovered by using the ATD-800 in playback mode, or the tape cartridge can be carried to the laboratory for playback and analysis on laboratory-based equipment. The ATD-800 includes EXDATA[4] utility software to facilitate data retrieval with such features as search on embedded time and search on frame number. Once retrieved, the data is placed in standard ASCII format and can then be further analyzed by any number of third party analysis programs such as DADiSP[5], Terametrix System 9000 Software[6], and others.

APPLICATIONS

Operational Performance Verification System

The U.S. Army required a field ruggedized Digital Tape Record System which could record the Weapon System Controller Tracking/Targeting Information for operational analysis and performance verification.

The environment dictated the ATD-800 to survive an 18g shock level and a temperature range of -20 degrees Celsius to +40 degrees Celsius. The unit was reconfigured with shock mounts and a heater/temperature sensor was installed to meet these environments. Additional environmental consideration was needed also for extreme dust particle conditions. The unit would need to survive in a desert environment. A fan/filter combination was included in the ATD-800 with the consideration to provide a positive air flow when the unit was open during tape installation or retraction.

Operationally, the record system was to be a dual configuration such that one unit could be utilized while the other was being read or the tape was being changed. This requirement was met by the ATD-800 by a modification to the standard design. The standard SCSI II bus interface was required to interface with a customer-furnished host bus adaptor, which is specially equipped with a means for addressing several units. The ATD-800s inherent SCSI II Bus structure also provides a means for high data transfer rates (up to 500 KBytes per second sustained; 4.0 MBytes burst).

In addition to the 5.0 gigabytes of storage capacity, the tape deck for this application operates in a "hard disk" type mode where storage of information only occurs when data is transferred to the tape deck; otherwise is remains in an "idle" state to conserve tape.

Re-engine Program

The ATD-800 was selected as the Flight Test Instrumentation Data Recorder for a commercial re-engine program for its capability to record bit rates of 2.0 megabits per second for extended periods of time (greater than 6 hours), its compatibility with existing commercially available PC-based computer analysis systems, and low unit cost. Additional operational criteria included the elimination of pre-programming individual tracksplit information (typically required for analog recording) and the inclusion of a turn-key software playback package which enabled the ability for a "high-speed search on embedded time" capability and interfacing to commercially available graphic analysis packages to allow onboard data analysis when used with the PTU-800[7] playback unit.

Airborne Data Collection System for B-1B/B-52

The Strategic Air Command (SAC) was required to replace obsolete data collection and event acquisition systems supplied with the Test and Evaluation Aircraft from the aircraft manufacturer. The application presented typical flight environmental requirements such as temperature extremes from -35 degrees Celsius to +50 degrees Celsius, vibration, shock and altitude. In addition to these requirements, the collection system was required to operate continuously for an eight (8) to ten (10) hour mission and to time-correlate acquired events to 1 microsecond.

The ATD-800 with a PCM interface was employed with Aydin Vector's MIL-STD-1553 Bus Monitor (ALBUS-1553) to acquire the user-selected 1553 data with embedded time code. The bit rate required for the mission duration was approximately 500 kilobits per second but was also required to vary according to the mission phase (takeoff, cruise, ingress and egress).

The ATD-800 was ideal for this application due to the large 40 gigabit storage capacity and incremental tape start/stop buffer operation which is transparent to the varying bit rate. The miniature size of the tape cartridge and it's commercial availability resulted in significant cost savings in storage and tape cost, and will provide a solution to a long-standing logistics problem to the Air Force.

Weapons Vehicle Integration Test System

Wright Patterson Air Force Base Flight Dynamics Laboratory, as well as many Weapon System manufacturers, required the development of a self-contained, miniature tape recording system capable of recording over two (2) hours of data at a rate of 3.0 to 4.0 MBits per second while installed in a weapon (in this case the Advanced Medium Range Air-to-Air Missile - AMRAAM).[8]

The ATD-800 recorder utilized a synchronized PCM stream interleave interface which allowed WPAFB/FDL to maintain using their Ground Processing System without modification. The ATD-800 is employed with vibration and shock mounts to survive typical Tactical Aircraft Flight environments.

CONCLUSION

The ATD-800 has successfully adapted commercial 8mm recording technology to applications which typically utilize larger and more costly instrumentation recording equipment. This low cost alternative should be evaluated by today's budget-minded instrumentation specialist.

REFERENCES

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5. DADiSP Data Acquisition Software is a product of DSP Development Corporation.

6. System 9000 Software is a product of Terametrix Systems International, Inc.

7. PTU-800 Tape Playback Unit is a product of Aydin Vector Division.

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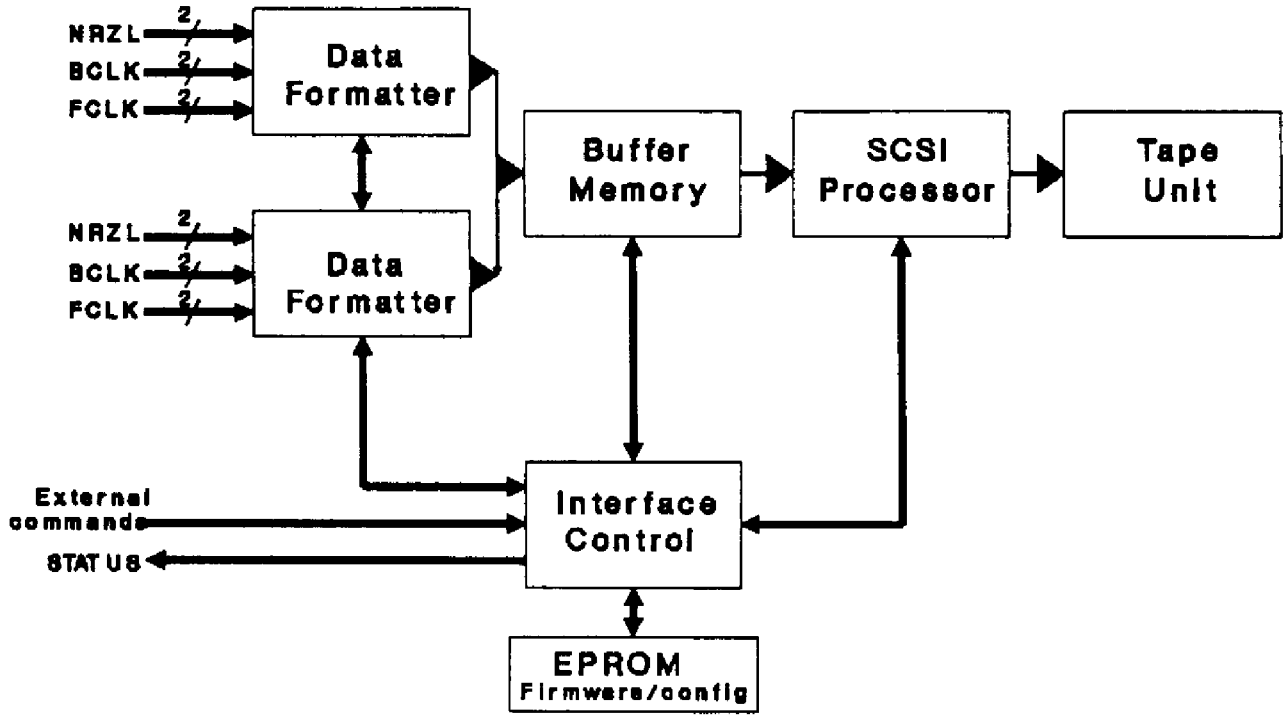

Figure 1. ATD-800 Functional block diagram
PCM Input Version

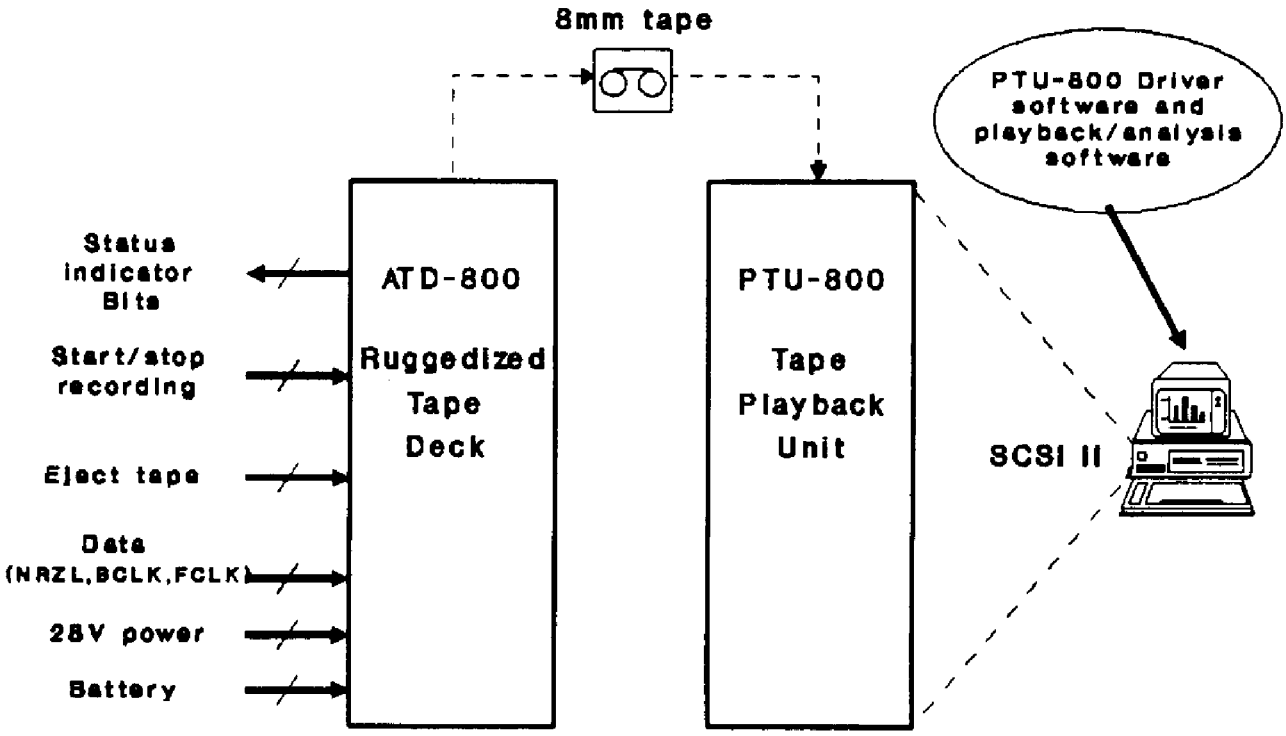

Figure 2. Typical System Application