ROTARY HEAD RECORDERS IN TELEMETRY SYSTEMS

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ABSTRACT

Although magnetic recording devices employing rotary head technology have been around for many years, specific products were not developed with the bit error performance to satisfy the instrumentation recorder needs of the telemetry community. Only recently have a number of new products and new product development programs materialized which offer positive indications that telemetry systems will soon benefit from the higher data rates and storage capacities.

The lack of standards in development of rotary head technology has led to development of a variety of design approaches by various manufacturers and system designers. If this trend continues, the telemetry community will not enjoy the media compatibility which has contributed so much to the success of the IRIG instrumentation recorder. The ability to remove a tape recorded on one vendors recorder and replay the tape on a different ground station containing a second vendors recorder is a capability that should be retained with the advent of the new machines.

Two standards have evolved defining tape characteristics and the format of information on tape for instrumentation rotary head recorders. For the instrumentation tape media to be truly transportable between telemetry ground stations, standard signal and data formal interfaces must also be developed.

INTRODUCTION

Magnetic instrumentation tape recorders have been the standard device for storage of large amonts of unprocessed data in telemetry applications for over three decades. These machines record information longitudinally on 1/2 or 1 inch tape with transfer characteristics such as track spacing & width, head stack geometry and frequency characteristics defined in IRIG document 106[1]. Definition of the transfer characteristics in

IRIG 106 has been an integral part of the success of these instrumentation recorders over the years. The IRIG standard sufficiently defines instrumentation recorder characteristics to allow recorder manufacturers to produce compatible recording equipment. Transfer of recorded instrumentation tapes between ground processing facilities possessing various brands of IRIG recorders is a commonplace event and a capability worth preserving, in any future conversion to new data storage systems.

A new type of magnetic recorder product is now being offered by industry for use in instrumentation data storage applications. These products, based on rotary head recording techniques, achieve much higher data storage capacities than previously possible with longitudinal recorders. Rotary head recording is not a new technology development, as television recording products have been using similar designs for years.

Significant advantages offered by rotary head recorders over longitudinal type machines are:

- Increased data storage - Up to 99,000 MBytes for a D1-L tape cartridge vs. 19,127 MBytes for a 14" longitudinal tape reel with 42 tracks

- Higher Data Rates - Data rates to 240 MBits/sec (Planned growth to 480 MBits/sec) vs. 131 MBits/sec for a 42 track longitudinal configuration

- Longer record time - Approximately 8 times that of a 42 track longitudinal machine for the same recorded bandwidth

- Smaller size and weight vs. longitudinal recorders

- Simplified tape handling due to use of cassettes in most recorders

Use of a rotary head recorder is not without disadvantages, some of which are identified below:

- Single high speed channel .... Multiple data sources must be multiplexed/demultiplexed into the single channel of the recorder

- All digital interface, no provisions for handling analog data other than voice and time code

- Limited industry standardization to date

In spite of the relative immaturity of most vendor rotary head recorder product lines, many telemetry system designers are now beginning to view the rotary head recorder as a realistic solution for their high data rate storage problems. Several new aircraft development programs, both domestic and overseas, are including the rotary head recorder in their instrumentation system designs. With these and other telemetry users already proceeding down the systems design path, increased attention should be given to the problem of integration of rotary head recorders into the typical telemetry acquisition and processing system.

CURRENT ROTARY HEAD RECORDER PRODUCTS

For purposes of discussion, rotary head recorders will be grouped into two general categories; Small Format Recorders (SFR), and 19mm Recorders.

The SFR group includes machines which use commercially available 8mm or Super VHS cassettes. SFR's are generally capable of accepting data rates of between 4 and 5 MBits/sec when 8mm cassettes are used and up 32Mbits/sec on a Super VHS cassette. As of the time of this paper, industry standards have not been adopted to define a common SFR data format. Use of a particular vendors machine for recording will therefore require replay on a compatible machine from the same vendor. SFR recorders are available in laboratory and portable configurations, but a militarized version for airborne applications has not yet been announced. If a militarized machine in this class becomes available, the SFR is expected to offer significant cost/size/performance advantages for telemetry applications where SFR bandwidth is adequate.

Two very similar standards have been written to define the storage media and data format for 19mm recorders. MIL-STD-2179 was sponsored by the Naval Air Development Center (NADC) and Rome Air Force Development Center (RADC) while the ID-1 standard was developed by the American National Standards Institute (ANSI). In order to control cost and guarantee availability of compatible media, both standards use a family of commercially available SMPTE (Society of Motion Picture & Television Engineers) tape cassettes. MIL-STD-2179 and ID-1 are similar standards, but have two important differences which require slightly different hardware designs to implement. MIL-STD-2179 was developed in advance of ID-1 and was designed as a rotary head helical scan with zero azimuth recording. Zero azimuth was selected to be compatible with the existing SMPTE D-1 standard, a general design goal of MIL-STD-2179. ID-1 was later defined by ANSI as an instrumentation version of D-1, also with a rotary head helical scan design. ID-1 however, elected to use +/-15 degree azimuth recording in lieu of zero azimuth. This technique is reported to reduce channel crosstalk, thereby improving bit error rate performance, by offsetting the azimuth of adjacent heads alternately between +/-15 degrees. The ID-1 standard also added a randomizer as insurance that DC frequency components will not appear in the recorded bit stream. At least three vendors; Honeywell, Fairchild Weston Systems, and Datatape are currently developing 19mm products which conform to both standards, although a different model is provided for each standard. Deliveries are expected to begin in 1990 for both militarized and laboratory versions.

Other 19mm machines developed prior to emergence of the MIL-STD-2179 and ID-1 standards have been delivered using unique media and data formats. Examples of these machines include models from Datatape with coaxial reels capable of recording data rates in excess of 100 Mbits/sec and a cassette recorder from Ampex which can also record data at rates in excess of 100 Mbits/sec. Both of these machines are available in airborne as well as laboratory versions.

This paper will deal primarily with 19mm recorder interface considerations in lieu of the SFR. Although SFR's seem to offer tremendous potential for many small telemetry system applications, an airborne qualified unit has yet to appear on the market. At least one model is rumored, however, to be in development.

TELEMETRY SYSTEM TRENDS

Telemetry data rates have continued to escalate in recent years as technology provides faster and more accurate sensors in less space for less cost. As computer controlled devices become more prevalent on test vehicle and other telemetry platforms, the need for storage of inter-computer bus communications and control parameters has added another dimension to the acquisition and storage of telemetry data. Multiple 1 MHz MIL-STD-1553 busses have become commonplace on military aircraft and the development of a new fiber optic bus standard by the SAE Aerospace committee is expected to produce burst data rates up to 50MHz. This general trend toward the need for recording of increased numbers of higher speed digital data sources is providing impetus to the 19mm Recorder development programs. For many applications, the 19mm rotary recorder appears to be the only data storage solution on the horizon which promises the required storage capacities and can operate in severe environments.

However, efficient and cost effective incorporation of a Rotary Head Recorder in a telemetry system design is not a straightforward task for system designers. The single channel nature of the recorder differs widely from the 14, 28 or 42 track longitudinal recorder configurations currently in use. The telemetry systems designer is seldom offered the luxury of designing a totally new telemetry system. More often the new system must take advantage of as much existing system design, hardware and software, as possible.

Data sources to be recorded on an instrumentation recorder are normally quite varied in their form and frequency content. Typical data sources which must be conditioned and/or recorded may include:

- Serial Pulse Code Modulated data streams (20 MBits/sec)
- Parallel digital data sources (20 Mbits/sec)
- Analog Data Sources (20 KHz bandwidth each)
- Frequency Modulated Data Sources (2 MHz)
- MIL-STD-1553 data busses (1.5 MBit/sec)
- ARINC 429 data bus (100 KBits/sec)
- SAE fiber optic data bus (50 MBits/sec)

SYSTEM IMPLEMENTATION

A simplified diagram of a typical flight test system utilizing a 19mm rotary head recorder is depicted in Figure 1. The diagram separates the system into three physical subsystems, the Vehicle Under Test (VUT) subsystem, a Ground CheckOut subsystem and a Ground Telemetry Station (GTS) subsystem. The Vehicle Under Test subsystem must interface and multiplex the various input sources for storage on the single channel airborne rotary head recorder. The Ground Telemetry Station is tasked with playback of the recorded tape and separation of the data sources via a Demultiplexer into the original components for processing and analysis. A Ground CheckOut subsystem allows verification of proper VUT subsystem operation prior to entering the actual test phase. The GTS also may contain a Data Simulation and Multiplexer/Interface function to facilitate self test of the GTS. Not shown for purposes of simplicity are two auxiliary low frequency tape tracks which might be used for time code, voice or other housekeeping information.

The primary data I/O interface to a rotary head recorder is a single channel which is typically an 8 bit wide byte serial interface for 19mm machines. Optional interfaces can generally be provided which offer a single high speed serial bit stream or a 16 bit wide word in lieu of the more common 8 bit byte interface. Obviously when multiple data Sources are to be recorded/replayed as shown in Figure 1, an Interface/Multiplexer/ Demultiplexer system is required to operate in conjunction with the recorders.

The first step toward compatibility between various telemetry system configurations has been achieved with the MIL-STD-2179 and ID-1 standards. In order to provide compatibility at the systems level, it is also necessary to develop standards which define input and output signal characteristics of the Multiplexer/Demultiplexer (Mux/Demux) functions as well as the format of data provided to the rotary head recorder by the Multiplexer.

Three specific Mux/Demux system design concepts will be briefly examined as examples of configurations which are currently being studied and/or implemented.

Example 1

A block diagram of a general Mux/Demux concept currently under development by at least two organizations is shown in Figure 2. This concept is a general purpose high performance approach which represents the most complex and therefore probably most costly implementation of the three examples. It is however, perhaps the most transparent solution for the systems designer as it provides for multiple analog inputs and outputs much like those of existing, longitudinal recorders, except with increased bandwidth.

This design approach generally provides input and output interfaces for up to eight channels per recorder. Each input channel may be an analog or digital input depending on the interface card selected for that channel. Analog inputs are digitized by high speed analog to digital converters integral to the Mux and the digitized outputs are buffered in First In/First Out (FI/FO) memories for merging with other input channels. Overhead in this Mux system is minimized by packetizing the data words into a bit packed format prior to recording. Overheads as low as 5% are possible with these systems and they are planned to support the full recorder bandwidth of 240 MBits/sec.

A significant advantage of this approach is a relatively minor impact to existing system designs. The Mux/Demux would rely on existing external interface techniques for conditioning signals into standard analog or digital formats, as do longitudinal recorder systems. Implementation of this approach is being accomplished for laboratory and airborne versions. The laboratory version is expected to typically occupy 10 to 16 inches of vertical rack space for a minimum 8 channel configuration.

Example 2

The approach described in the second example and shown in Figure 3 utilizes a concept developed for tile EMR 8200 Mux/Demux. The EMR 8200 equipment was developed for transmission of multiple IRIG PCM streams over high speed telephone circuits or commercial microwave links. This Mux system accepts up to 10 standard IRIG PCM streams and automatically buffers, merges and bit packs the data into message packets for transmission (or in this case recording). The Mux adjusts to changes in input channel rate without operator intervention and automatically interleaves input sources into a composite output stream so long as the maximum aggregate output rate is not exceeded.

The companion Demux automatically synchronizes on the Mux composite signal and subsequently reproduces each PCM stream in the same form as originally received by the Mux. Bit packing and packetizing of the data also contains the bandwidth overhead of this approach to less than 5%. Output signals from the Demux are synchronous contiguous PCM signals which may be processed by standard IRIG PCM bit synchronizers.

A significant deviation of this approach from that of Example 1 is the inability to accept analog inputs. This requires the airborne system to perform digitization and other conditioning as required to create standard IRIG PCM data streams prior to presentation to the Mux for recording. This negative attribute may not be as severe as it might at first seem in that most new airborne systems are being designed to convert as much data as possible into digital form as early as possible. In addition, conversion of all data into standard PCM formats will normally simplify the processing task for ground telemetry processing systems and minimize the requirement for new equipment.

The EMR 8200 Mux/Demux is implemented in a laboratory version in two 10 1/2 inch high rack chassis and is capable of an aggregate output rate of 12.9 MBits/sec. Future growth is planned to support rates to 45 MBits/sec which satisfies many rotary head recorder applications.

Example 3

A simplified block diagram of the third example is shown in Figure 4. In this case, bandwidth overhead is headed for simplicity of Mux/Demux implementation. This Mux approach, as in Example 2, requires other systems to provide the Mux with data which has previously been conditioned into standard serial digital data streams. Unlike Example 2, bit or word packing functions, if necessary, must be accomplished by variable word length or compression algorithms prior to presentation at the Mux. The concept is similar to that implemented in the new Chapter 8 IRIG standard for recording of all MIL-STD-1553 bus data, in that input data sources are simply merged into larger word formats with extra bits appended to each digital word to identify the input source.

A typical system based on 16 bit word length would multiplex eight input data sources through FI/FO buffers into 20 bit words for recording. The additional 4 bits in each word would identify the input source and provide a parity bit. Inclusion of the source ID along with each data word greatly simplifies the Demux task. The Demux must simply strip out the source ID and provide the word to the appropriate output along with clock timing.

An important point to recognize with this approach is that the Mux outputs will be data bursts with timing clocks. Serial signals would therefore be connected directly into frame synchronization equipment, bypassing normal PCM bit synchronizers. A by-product of this design is loss of time correlation at the Mux output. As the Mux/Demux/Recording system processes the data through FI/FO buffers, time relationships are distorted and the output data burst at the Demux would not produce a representative Digital to Analog Converter output without further processing. Recreation of the original time relationships may be obtained through further processing in the ground system, provided time channels are merged into the serial PCM streams prior to the MUX. A PCM stream containing MIL-STD-1553 bus data formatted per the Chapter 8 IRIG standard, for example, includes embedded time code words to allow reconstruction of critical time relationships.

Despite the limitations, the simplicity of this approach is expected to promote its popularity. The Mux function can easily be implemented in a compact airborne package significantly smaller and less expensively than either of the two previous examples.

SUMMARY & CONCLUSIONS

As has been shown, a Rotary head recorder can be combined with a Mux/Demux function to provide higher storage capacities in telemetry systems without requiring replacement of the majority of existing designs. Tape media and recorder format are now adequately defined by MIL-STD-2179 and ID-1 for the 19mm size machines and a NADC committee is currently defining a similar standard for the SFR. In order to preserve the ability to interchange recorded tapes, standards are also necessary to define storage formats and signal I/O created by the Mux/Demux function. Some goals for a general purpose Mux/Demux interface definition include:

- “Transparent” transition to rotary head recorder
- Maximum utilization of existing IRIG telemetry processing equipment
- Minimum impact to existing ground processing tasks
- Minimum Mux/Demux setup requirements
- Minimum size for airborne applications
- Low cost mid range performance option when 240MBits/Sec is not required

1 IRIG STANDARD 106-86 are Telemetry Standards published by the Telemetry Group of the Range Commanders Council - last revised September 1988

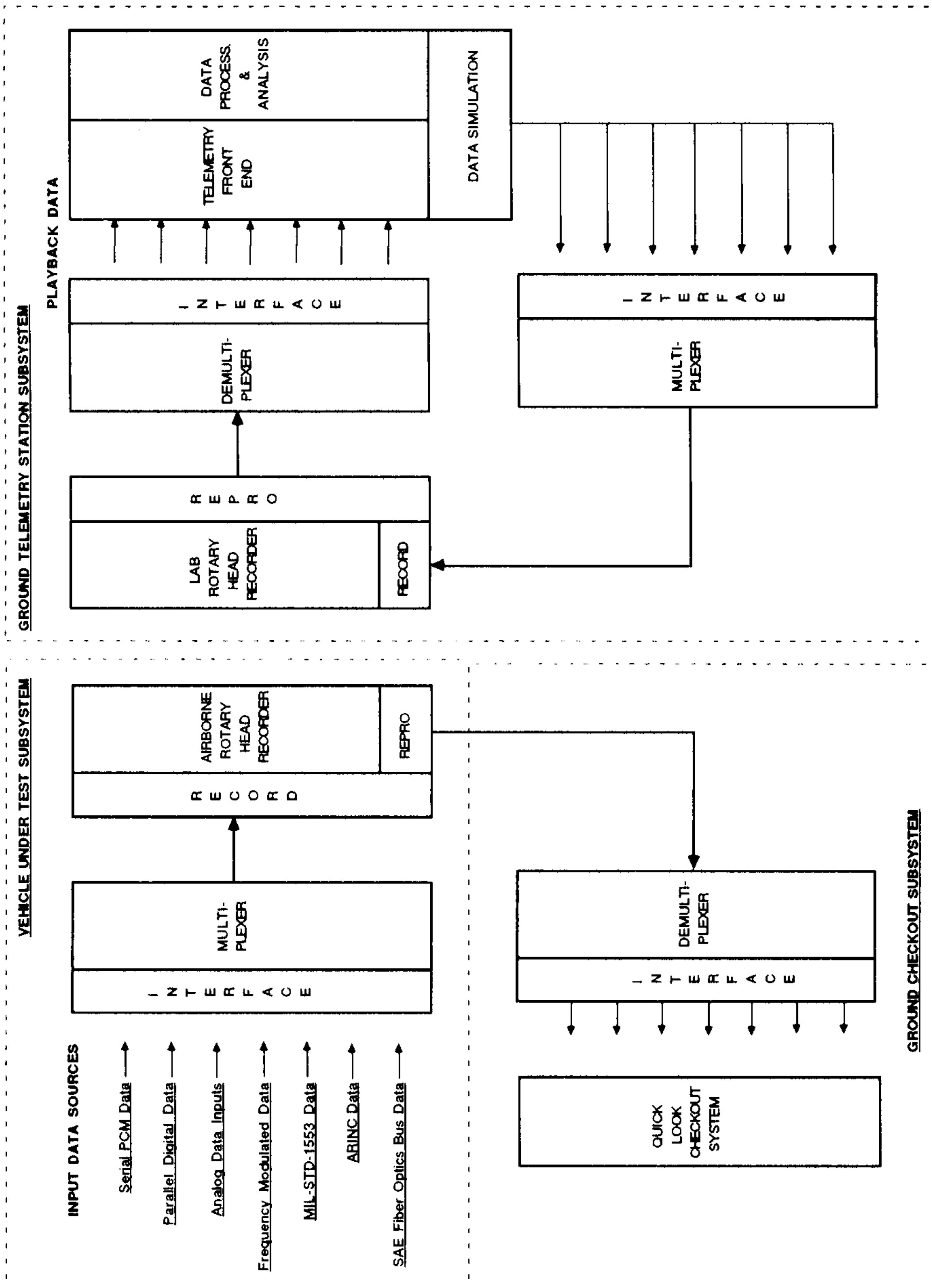

Figure 1. Typical Flight Test System

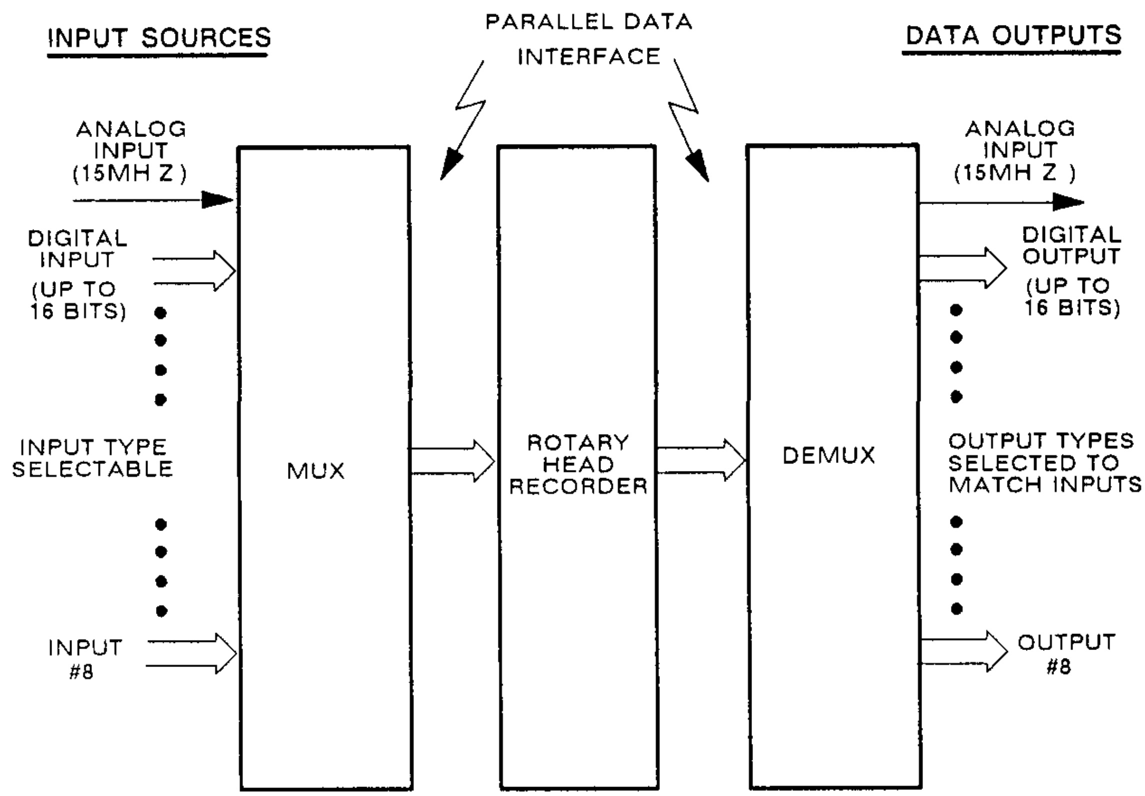

Figure 2. Universal MUX/DEMUX

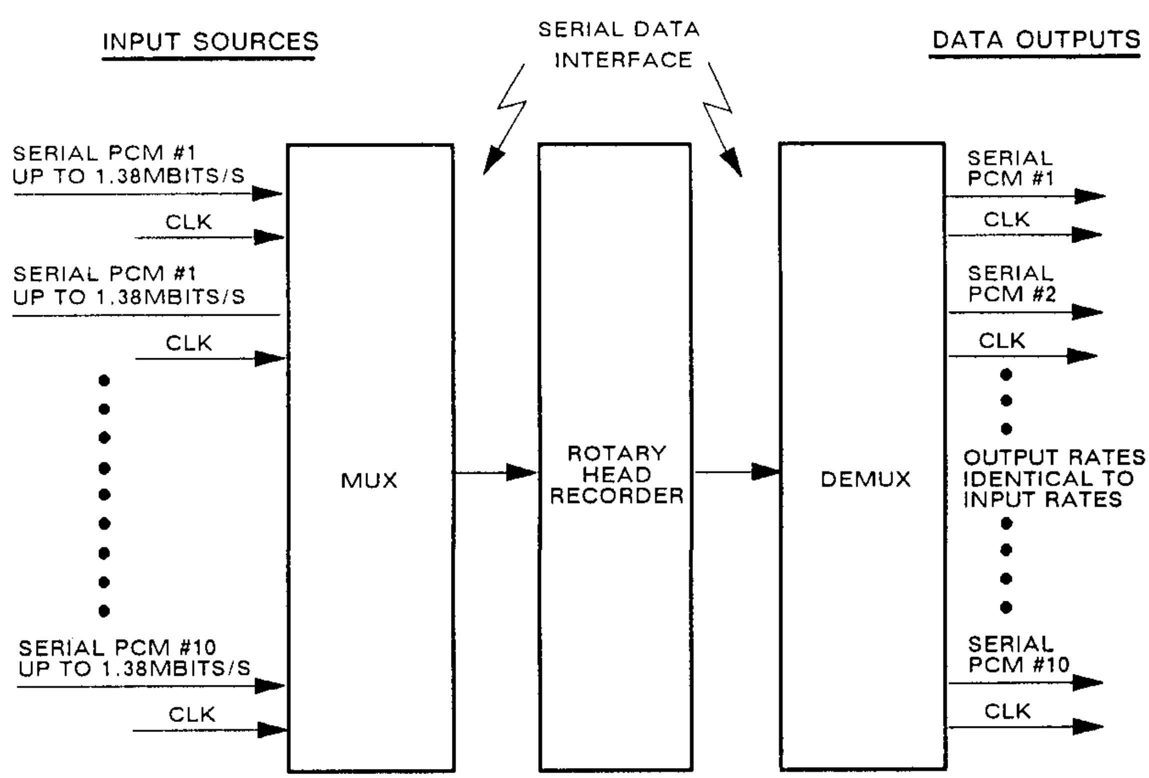

Figure 3. Digital MUX/DEMUX

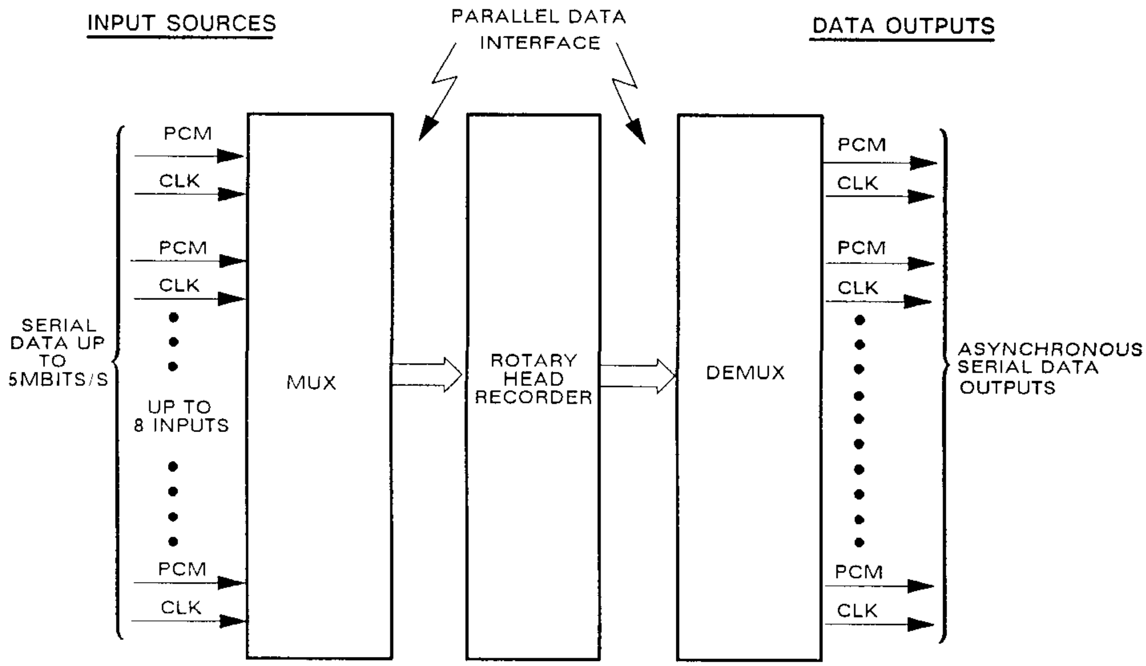

Figure 4. 'Tag Per Word' MUX/DEMUX