MICRO-TRACK DIGITAL CASSETTE RECORDING

Edwin Kayes
Penny & Giles Data Systems
The Mill, Wookey Hole,
Somerset, BA5 1BB ENGLAND

KEY WORDS

Data recording, digital cassette recorders

ABSTRACT

The increasing availability of powerful yet relatively inexpensive data acquisition and processing techniques has precipitated a radical reappraisal of the methods used to capture, manipulate and store data of all kinds. Some of the recently introduced recording systems can be used both for fast data capture and for high capacity archival/back-up applications - effectively bridging a long-standing divide between these two formerly diverse aspects of data recording and processing .

This paper offers a brief overview of a new technology known as micro-track recording, and suggests ways in which system designers and integrators may take full advantage of its important new facilities and features.

INTRODUCTION

There was a time when magnetic tape recording products could be discussed in terms of a number of distinct, market-oriented applications - each with its unique technology, language and even culture. For many years, these entities co-existed with little or no interaction. Within the last few years, however , there has been a trend for new techniques, developed to satisfy a user need in one sector, to be adapted and applied to another.

There is now a requirement to take this process one stage further with the introduction of a new class of magnetic tape recorder that combines the attributes of the high speed data recorder with those of the computer peripheral. This need is being driven principally by highly data-intensive applications where the computer derived requirements of data analysis or processing carries equal or greater importance than the traditional approach which has tended to give priority to data capture.

Micro-track recording is a new technology which has been developed specifically to address the problems of bridging the gap between data capture (instrumentation) and computer processing.

DEFINING THE PROBLEM

The basic attributes required of a magnetic tape recorder capable of performing effectively both as a data capture device and a computer input/output peripheral can be summarized as: convenience of media handling; storage capacity per unit of medium; data throughput; continuous; variable and burst data transfer; independent read and write rates; control of data transfer; media/record management; ease of computer interfacing and control.

MICRO-TRACK RECORDING FORMAT

Conventional *continuous* data recorders (both longitudinal and helical) do not lend themselves readily to the fast start/stop procedures fundamental to the efficient operation of any computer input/output device. Yet their media capacities and transfer rates generally exceed those of traditional computer storage devices.

Nevertheless, longitudinal recording, in particular has certain attractions as a starting point for the development of a 'computer-friendly' digital cassette recorder. It is relatively straight-forward to break a multi-track longitudinal recording into blocks, although high density digital recorders using IRIG track-widths and tape speeds have too low a storage capacity (and require too long to start and stop) to be of direct use.

Micro-track recording, as implemented in the new *PEGASUS* recorder manufactured by Penny & Giles Data Systems, is essentially a multi-track longitudinal system in which the track-width is significantly smaller than that of a 28-track IRIG recorder. With *PEGASUS*, the 20-track write heads are interlaced to give forty parallel tracks arranged across a 19 mm wide D-1 tape. Each read head is placed between a pair of similarly-aligned write heads in order to give read-after-write downstream monitoring and bi-directional replay capabilities.

Data is first recorded from one end of the tape to the other, and at the end of the first pass the heads are moved laterally to register with an unrecorded region before recording continues in the opposite direction. The direction reversal is accomplished at an inter-block gap and is transparent to the user.

The micro-track recording process differs radically from continuous longitudinal methods in that writing and reading take place at a single, fixed tape speed and at a constant data packing density.

Data is always buffered, and written (or read) in blocks of fixed length, regardless of input or output conditions. Data is written to, and read from tape incrementally, at a level which ensures that there is sufficient buffer capacity to accept data at the maximum specified rate. The tape drive has a fast start/stop time and uses 'shuffling' for maximum tape utilisation, Fixed heads and a single read/write speed contribute significantly to reliability, and extended life tests have confirmed that the magnetic media exhibits no observable physical degradation or loss of performance - even after several thousand start/stop cycles.

The use of buffered, fixed speed recording means that the system is able to accept write or read clock rates anywhere in the range zero to 120 Mbits/sec (15 MBytes/sec) without adjustment. User data can be written or read at any rate within the range, rather than at a limited number of pre-determined ratios, and can be read in both forward and reverse directions.

An additional advantage of fixed speed recording and reproduction is that the data and control electronics are significantly less complex than i s the case with a system which has to operate over a wide range of tape speeds. Multi-speed equalisation circuits (and their associated calibration procedures) are eliminated and there is no need for a sophisticated capstan servo system.

Burst data transfers (both input and output) are also accommodated. Data is always recorded at a fixed density on tape, regardless of input or output conditions. Furthermore, since the heads do not rotate, and the tape is stationary when there is no data to be recorded, it is acceptable to leave the recorder in a 'stand-by' condition indefinitely, without risk of head or tape wear. The buffer ensures that no data is lost during start-up or direction reversal.

THEORY OF OPERATION

The writing process is initiated by the WRITE command. Data is input to the recorder under the control of the user's clock (UCLK) and is always converted by the Data Interface into a 32-bit parallel format before it is passed to the Data Buffer. The Buffer Controller monitors the state of the Data Buffer and clocks data to the Encoder/Parity/CRC circuits in blocks of fixed length. Control information (including date, time, block address, recorder and cassette ID's, interface type and any user event marking) is also generated. The System Controller initiates the ramp-up procedure and data blocks plus the control tracks are written to tape.

A user clock must also be provided in order to output data. When the READ DATA command is received, the System Controller ramps the transport up to speed and begins to fill the Data Buffer (via the single-speed equalizers, bit synchronizers, decoders and error correction circuits), Once sufficient data is available in the buffer, it can be clocked-out on demand.

This initial description is, in fact, somewhat over-simplified, since it ignores the important hand-shaking routines which should be used to control the flow of data to and from the recorder. This aspect of the system will be addressed in greater detail shortly.

Note that other user inputs and outputs (for example, event marking and annotation) are routed via the control interface, as are all control and status transactions. The recorder also generates other important record management data, including: RECORDER ID - a unique serial number which is automatically logged during recording; CASSETTE ID - automatically assigned to each new or erased tape; RECORDER TIME/DATE - Used with the FIND and READ commands; DATA INTERFACE - ECL serial, ECL parallel, TTL parallel; etc.

PEGASUS OVERVIEW

PEGASUS, the first practical example of a cassette data recorder using micro-track technology, was introduced by Penny & Giles Data Systems in 1993. It is a self-contained recorder/reproducer incorporating data interfaces, input/output buffer and error correction. It has been designed to operate in a range of fixed and mobile environments, including submarines, surface ships and passenger/transport aircraft.

The tape drive handles commercially available D-1 large cassettes in an incremental (fast start/stop) manner. A fixed tape speed is used for writing and reading and precision tape guidance provides the high degree of control needed for reliable and consistent interchange of micro-track recordings.

Initial versions of *PEGASUS* support two-pass operation (one pass of the tape in each direction), although the format allows for additional passes in future models. The two-pass format achieves a data capacity of up to 240 Gigabits (30 GigaBytes) per cassette.

Heads are warranted for 5,000 hours of operation. The mounting arrangements of the heads and other mechanical assemblies are designed to allow field replacement. The inherent simplicity of micro-track recording ensures the highest possible levels of equipment availability combined with low costs of ownership.

PEGASUS is designed to achieve a Mean Time Between Failures (MTBF) of not less than 2000 hours and an average Mean Time to Repair (MTTR) of fifteen minutes.

WRITE HAND-SHAKING

For a new class of recorder to bridge the gap between instrumentation (continuous) and computer (fast start/stop) one critical element is the control of data transfer, as distinct from the traditional tape movement controls of HDDR and most rotary recorders.

Data flow is controlled quite simply, during both writing and reading, using a pair of signal lines (associated with the data interface). These lines are known as DATA READY and USER DATA ENABLE and are used in the following sequence:

1. The user issues the WRITE command to the recorder, via the control interface.

2. The WRITE command will automatically initiate a sequence to position the tape at EOD (end-of-data) unless the tape has previously been positioned using the FIND EOD command.

3. The recorder sends the message READY TO WRITE (at the control interface) and asserts the DATA READY hand-shake line (at the data interface), indicating that it is ready to receive data.

4. When the source device is ready to transfer data, it asserts the USER DATA ENABLE hand-shake line, indicating to the recorder that all subsequent data is valid and should be recorded. The user's clock should be present and stable *before* USER DATA ENABLE is asserted.

5. The user is then able to control the data flow by toggling the USER DATA ENABLE handshake line to input continuous streams or bursts of data as appropriate.

6. The recorder will only negate DATA READY *during* data transfer if one or other of two conditions should occur. First, if the user's average clock rate should exceed the permitted maximum, DATA READY will be negated (inhibiting

further data transfer) until the data buffer has been allowed to return to its normal operating condition. Second, when the EOT (end of tape) point is neared - indicating that further data transfer is not possible.

7. The recorder remains in the WRITE condition until the STOP DATA command is issued.

There is an important distinction to be drawn between a *temporary* interruption of data flow caused by the negation of USER DATA ENABLE, DATA READY or the removal of the user's clock (in which case the recorder is still actually in the WRITE condition), and the negation of the WRITE condition with the STOP DATA command. STOP DATA causes any user data remaining in the buffer to be flushed to tape.

Hand-shaking is always recommended but should certainly be used: whenever the flow of input data is not continuous (commonly referred to as *burst* transfer); when the exact time of arrival of data may not be known (for example, automated recording of satellite data); when the source rate may exceed the system's average input rate.

READ HAND-SHAKING

While the use of hand-shaking to control the input of data is a most valuable feature for certain recording applications, it is on the *replay* side where this technique can often offer the most important advantages. The following sequence is typical:

1. The tape is positioned at the correct starting point either by using an appropriate FIND command or by using the start and finish extensions of the READ FORWARD command.

2. The reading sequence commences with the READ FORWARD (or READ REVERSE) command (with location parameters, if appropriate). Once data is available for output, DATA READY will be asserted (at the data interface).

3. Data is not clocked out of the buffer until USER DATA ENABLE is asserted by the target, indicating that it is ready to accept data.

4. Data transfer can be continuous or in bursts, controlled by the USER DATA ENABLE hand-shake line.

5. Reading continues until one of the following conditions occurs: USER DATA ENABLE is negated (by the user); DATA READY is negated by the recorder (for

example, at EOT); the stop parameter (timecode or event marker) is reached; the STOP DATA command is issued; the user's clock is removed.

The control of data flow to the processing device in this manner is arguably the most important facility offered by the *PEGASUS* micro-track recorder. When transfer is re-started following a pause, the next data bits presented at the output are those immediately following those which were output previous to the pause.

This contrasts markedly with traditional or continuous recorders which require the implementation of tape movement sequences together with some method of identifying the exact place where transfer previously ceased. With *PEGASUS*, the entire process is handled by the recorder, greatly simplifying system integration .

DATA MANAGEMENT AND CONTROL

It may be useful at this point to summarize the range of management and control features available with *PEGASUS*. Much of the operator involvement associated with the use of traditional data recorders has been eliminated. The various functions have been designed to simplify the process of classifying, locating and manipulating records.

During recording: the recorder's input interface can be selected (depending upon the installed interface types); the WRITE sequence eliminates the possibility of over-recording existing data; data is automatically tagged with date and time; event annotation information can be added to assist with subsequent record location; the read-after-write error monitor can be interrogated to verify recorded data quality; the tape can be moved to BOT (beginning-of-tape) and EOD (end-of-data) using simple commands; the recorder's date/time can be set and the amount of tape remaining can be verified.

During analysis: cassettes can be screened for 'housekeeping' information such as the recording data interface, date/time, events, source recorder identity and unique cassette serial number; the read unit can be commanded to locate and read between specified times or events, using simple commands; the cumulative error count can be checked periodically to verify system performance.

All commands and status requests use plain-English syntax for ease of programming and debugging.

A more complete description of the operation and control of *PEGASUS*, together with further applications information, can be found in the engineering handbook

Micro-track Digital Cassette Recording, available on request from Penny & Giles Data Systems.

ADVANCED DATA AND VOLUME MANAGEMENT

At this point it will perhaps be apparent that the ability to automatically tag recordings with additional information has implications far beyond the simple convenience of being able to locate and recognize a certain passage of data within a single cassette. The range of 'housekeeping' data available to the *PEGASUS* user suggests the possibility of implementing data management strategies in advance of anything which may have been practical with previous generations of data recorders.

It will be remembered that each recorded cassette carries the following information: the unique identification number of the recorder on which the data was written; a unique cassette identifier; the date and time at which each block of recorded data was input to the system; the data interface format used for recording, and, optionally, user-generated event and notation data associated with particular records.

Using the example of a data reduction centre which receives large quantities of cassettes from a number of separate recording locations, it is possible to see how the identification and classification of these can be greatly simplified.

In the past, it was generally necessary to make written notes concerning the number and identities of tapes carrying a certain data set, the order in which the tapes had been used, details of the recording parameters, and the position on the tapes of particular test data. Such a process is open to human error, especially in the stressful conditions experienced in many operational situations.

Frequently, before commencing detailed analysis, staff at the data processing centre have no option but to mount and run tapes in order to establish, or at least verify, their contents - a routine often involving a certain amount of ingenious detective work!

The housekeeping data contained within the *PEGASUS* micro-track format permits this tedious process to be virtually eliminated provided that an integrated approach to record management is introduced throughout the data capture and analysis network. A typical record management strategy might include (as a minimum):

At all recording sites: the development of control and status procedures which take full advantage of the functionality of *PEGASUS*; routine reports to the processing centre concerning the identification of all acquisition systems in use at that site; the exclusive use of either new or erased tapes (which become tagged with a unique identifier at the time of use); routine verification of the date and time on all recorders; the development and use of a network-wide system of event marking and annotation (test numbering, start and finish of record marking, etc.).

At the data processing centre: the development of processor-based control and status routines which make the maximum use of inherent *PEGASUS* features; initial screening and computer-based logging of the classification of all in-coming cassettes for: source recorder identification, cassette identification, range of date/time information, events and standard-format annotations, input data interface used for recording. In manual media-handling environments, the development of a system for correlating the physical storage location of all media units with their associated computer-based record management data; the development of procedures for the processing of test or mission data which take maximum advantage of the available data management information.

These thoughts are intended only as an introduction to the subject of how the record management features available in a recorder such as *PEGASUS* might be used to reduce or remove the drudgery associated with handling and managing large and dispersed data sets.

CONCLUSION

It was suggested at the beginning of this discussion of current trends in recording technologies that the opportunity now exists to bridge the long-standing gap between the methods used for high performance data capture on the one hand, and those of data-intensive analysis on the other, with a single multi-purpose product.

In addition, it has been shown that the very same system can effectively address the problem of archiving and retrieving large volumes of scientific and similar data. Never before has it been possible to consider these three facets of data handling in the context of common media, recording formats, record management strategies and controlling software.

As we have now seen, micro-track recording, as typified by the Penny & Giles Data Systems *PEGASUS* recorder, not only makes such concepts a reality in an innovative and useful way, but also offers a range of important new operational features which, when integrated into the user' s total data capture, analysis and archiving strategy, can be of major benefit in terms of: convenience; flexibility; capacity; data throughput; simplified system design and integration; media handling; data management; streamlining of the total data handling process; very long head life; bi-directional data output; minimal maintenance & alignment; low cost of ownership.

To realize the potential benefits which are now made possible by these new technologies, a thoughtful analysis and reassessment of acquisition and processing systems data handling strategy is essential. It is our sincere hope that this short introduction to the subject will both enable and encourage the user to begin this exciting process in the context of the activities of his or her own organisation.