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19 mm DATA RECORDERS SIMILARITIES AND DIFFERENCES

by

STEVE ATKINSON
AMPEX CORPORATION

19 mm DATA RECORDING FORMATS

Confusion over the use of non-video 19 mm data recorders is becoming more pronounced as we enter the world of high performance computing. What is the difference between ID-1, ID-2, MIL-STD-2179 and DD-2? What is the proper machine for my application? How do I integrate it into my environment? These are all questions the user community needs answered. This paper attempts to address these issues and clear up any misconceptions there might be about 19 mm tape recorders.

HISTORY

The MIL-STD-2179 and ID-1 tape formats are modifications of the D-1 tape format standard used in the television and motion picture industry. The development of D1 based instrumentation standards was driven by the need of military and government users for high speed digital recorders to capture data. The Military Standard 2179 (MIL-STD-2179) was supported by a group of manufacturers and military representatives (primarily the United States Navy) to provide such a recorder. The first prototypes of these recorders are becoming available now for Beta testing in a number of military programs. Loral, Sony, Datatape, Honeywell, and Schlumberger are all working to deliver these machines. An ANSI standard known as ID-1 also exists which is being implemented by same manufacturers. It differs slightly from the 2179 implementation but is not interchangeable due to the use of azimuth recording, which is not used in the D1 TV format or the MIL-STD-2179 format.

Products to support the television D1 format became available in early 1987 and were followed by D2 format products in late 1988. The two TV digital formats differ in that D1 supports component recording while D2 supports composite recording. In laymen's terms, this means that D1 records video as individual data streams and D2 records it as a single stream. The Ampex ID-2 product is based upon the unmodified D2 NTSC video format, but is supplemented with user interfaces specific for instrumentation applications. As such, the Ampex ID-2 products can serve as either a video or instrumentation recorder. D1 recorders are produced for the video industry by Sony and BTS and D2 recorders are manufactured by Ampex with Sony and Hitachi. The D2 recorder is the dominant 19 mm machine in the video industry constituting over 75% of the digital market today and is expected to increase in market share to over 80% by the early 90's.

The need to support high speed data storage and retrieval for the supercomputer industry was identified by Ampex as a major market opportunity as data creation and storage grew exponentially in the 1980's. Hence, the Data D2 (DD-2) development was undertaken as a joint development by Ampex and E-Systems. The basic difference between the DD-2 recorder and instrumentation recorders is that DD-2 is designed as a computer peripheral with computer interfaces and file structures as opposed to an instrumentation recorder which records input as a single uninterrupted stream of data. Each class of machine has its strengths and weaknesses depending on the mission the user wants to accomplish.

COMMON FEATURES

DD-2, MIL-STD-2179, ID-2, and ID-1 physically record data in very similar manners. All implementations use a recording technique know as helical scan. Helical scan recorders lay down data at an angle on tape and provide improved storage density over longitudinal formats and also provide powerful error correction capabilities. Ampex was a pioneer in the helical scan technology used in today's home VCR's.

Each of these scans of recorded data are called tracks. They are grouped together to form track sets, the lowest addressable unit of data from a physical standpoint. The helical scan data tracks are accompanied by three longitudinal tracks. In the video version, these tracks contain control, time code and audio information. The instrumentation and data recorders use these tracks for control, timecode, and for file labels in the case of DD-2.

All four 19 mm formats are implemented in high performance machines with several versions tailored for specific missions. Features commonly supported include high rate data storage and retrieval, robotic compatibility, and positioning to data at speeds of 30 to 60 times playback speed. For DD-2 at 60 times playback speed, this translates to over 800 megabytes per second (MB/s) or the equivalent of four 3480 cartridges every second.

With these similarities in mind, it is easier to discuss how the DD-2 computer storage peripheral and 19 mm instrumentation recorders use the 19 mm platform to accomplish different tasks with different derivations of the same basic technology.

INTERFACES

The applications for instrumentation recorders such as ID-1, and computer peripherals such as DD-2, drive the design of their interfaces. Instrumentation machines are commonly used for data capture which means that data will come in a continuous stream with the recorder turned on when the data starts and off when the data stops. This alleviates the need for any buffering on the recorder since the data should arrive in a continuous mode at a steady rate. The standard implementation is a 16-bit wide data front-end which operates in a synchronous mode. By implication, this means that the recorder operates as the master with the input or output source acting as the slave. This is because the recorder expects to record and retrieve data at a steady, uninterrupted stream. Typically, it handles different data rates by the ability to record/retrieve data at selectable, binary rates of up to approximately 30 MB/s in some implementations. Therefore, it is up to the source to buffer the data for smoothness within a small percentage of the recorder's data rate needs. While this is a good implementation for the field and downlink data recording it was designed for, it poses severe problems in a computer environment.

Most computer operating systems simultaneously execute multiple programs in an interactive, time sharing environment. Input and output to a peripheral is not supported as a steady, uninterrupted stream, but instead is dependent upon the dynamics of system loading, computational rates, and application mix. These operating environments do not include the dedicated data buffering and strict command scheduling required to match rates with a data peripheral. The logic of these operating systems is designed to use compute cycles to serve applications -- not peripherals.

Instrumentation recording on a computing platform requires a dedicated computer, executing only from a predetermined set of controlled applications. Development of instrumentation interfaces, controllers, and special device drivers are required to connect a given peripheral. Memory must be dedicated to support the strict input/output rates of the peripheral.

The DD-2 recorder was designed with these interface shortcomings in mind. The DD-2 recorder from Ampex uses the ANSI standard Intelligent Peripheral Interface Level 3 (IPI-3) interface to send data to and retrieve data from the recorder. This standard computer interface defines command, control, and status for both disk and tape peripherals. The subset of the IPI-3 command set dealing with tape devices is used for the DD-2. A large buffer is included as part of the interface electronics. This buffer performs the rate smoothing to provide a sustained data rate of 15 MB/s with a burst rate of 20 MB/s. Using the IPI-3 command set and the buffering capability allows the host to request data units as small as a single byte so that the host computer does not have to retrieve an entire physical block. The IPI-3 implementation also allows up to 8 recorders to be "daisy-chained" on a single control interface. While one recorder is transferring data, the others can be given positioning commands to minimize the time spent waiting for the subsequent file transfers. Other standard interfaces will be supported in the future. In summary, the DD-2 looks like a standard tape peripheral to the host computer.

DATA FORMAT

As stated earlier, both DD-2 and 19 mm instrumentation recorders physically record data on tape in very much the same way, helical scans grouped as track sets. Once again, the differences lie in the fact that the DD-2 is a computer peripheral recorder. Both machines can retrieve data by track sets if that is the search parameter they are given. The DD-2 also makes use of the longitudinal tracks to implement ANSI 9-track file labeling. Files on the DD-2 can be retrieved by using file labels rather than track set ID's. This allows software already developed on the host computer to manipulate 9-track tape and 3480 cartridges to also make use of DD-2 cassettes. Minimizing the impact of incorporation of DD-2 into existing computer is one of the highest priorities of the DD-2 development.

The traditional concept of tape volumes is incorporated into the DD-2 design while not in 19 mm instrumentation formats. Each DD-2 physical cassette looks like one or more logical volumes to the host computer. These logical volumes can be edited and appended to look like traditional 9-track volumes. Another somewhat related innovation is that the cassettes can be loaded and unloaded without rewinding to beginning of tape or end of tape. This greatly decreases the amount of search time spent positioning to the beginning of a file.

Inter-record gaps are another format difference between 19 mm instrumentation recorders and DD-2. Because most 19 mm instrumentation machines record data at binary rates, the gaps between recorded data are of variable size. This leads to less efficient use of tape as it is indeterminate how much tape is left unrecorded in between data records. The DD-2 uses a consistent gap to further improve upon the substantial data density advantage DD-2 holds over the ID-1/MIL-STD-2179 class of recorder.

ERROR RATE

Image capture and retrieval is one of the most common uses of ID-1 and MIL-STD-2179 recorders. When manipulating images on a host computer, errors on tape can be recovered from by reconstructing the lost part of an image from the remaining parts which surround it. For that reason, the Bit Error Rate (BER) of 10^{-10} specified for MIL-STD-2179 and ANSI ID-1 recorders is sufficient for most of the applications in which it is used but may require tape certification to achieve. This BER is not always adequate for computer applications. DD-2 will deliver an error rate approximately three orders of magnitude better by guaranteeing less than one error event in every 10^{-12} bytes read.

All commercial 19 mm recorders have the capability to read what has been written on tape immediately after it is written. However, the implementation of a data buffer in the DD-2 interface makes verification of the data written on tape possible. When an uncorrectable error is detected by the read-after-write verification function, the data will be rewritten to tape a selectable number of times by the DD-2 controller. When retrieved, invalid data is ignored with only the corrected data returned to the host. This capability is coupled with three levels of powerful Reed-Solomon coding to achieve the improved error rate over 19 mm instrumentation formats. For example, the extended burst correcting capability of DD-2 provides a 50-times improvement over ID-1, minimizing errors due to tape defects.

In addition, the DD-2 will monitor the stress level of the error detection and correction (EDAC) equipment and store the statistics in the recorder. When requested from the host computer, it will be returned as status. In this manner, the host can monitor the "health" of an individual cassette and record the data contained on it to a new cassette when appropriate.

MEDIA

The media used by data storage peripherals and instrumentation recorders is the same as used in the video industry. The cassettes used by all 19 mm recorders contain tape which is 19 millimeters wide (about 3/4 inch). The main difference is that DD-2 and ID-2 use a metal oxide based tape with a total thickness of 13 micrometers, while the ID-1 and MIL-STD-2179 use the older iron oxide formulation with a total thickness of 16 micrometers. 19 mm cassettes are very similar in appearance to home VHS cassettes except that VHS uses 1/2 inch tape. D2 tape is manufactured by Ampex, Sony, Fuji, and Maxell with 3M expected soon to enter the market. D1 tape is available from Ampex, Fuji, and Sony. The important point is that both are supported by more than one source which should result in both a reliable future supply and low user costs.

The storage density of D1 and D2 based recorders is a function of the recorder and tape used. A storage density comparison is contained in this section for simplicity's sake. Both DD-2 and ID-1/MIL-STD-2179 have three sizes of cassettes: small, medium and large. The small D2 cassette contains 25 gigabytes (GB) of user data with a medium containing 75 GB and a large holding 165 GB. This compares to 14 GB, 44 GB, 92 GB for the small, medium, and large D1 cassettes respectively.

A concern has been raised on the shelf life of metal oxide tape due to the high content of iron particles in the tape. Metal particle tape has been in existence over 15 years and has been used in commercial products for over 10 years. All 8 mm Camcorders, as well as other video and data storage products, are based on the metal oxide tape. Ampex has recently completed accelerated life tests which simulate a 14-year archive. No degradation in BER or magnetics was detected with the tape in the cassette. Details were presented by Ampex at the Tape-Head Interface Conference (THIC) proceedings on 9 January 1991. Copies of the presentation are available from Ampex. Tests by other manufacturers also support these results.

SUMMARY

DD-2 and 19 mm instrumentation recorders have missions for which each is well designed. While the differences may appear subtle, understanding the difference between the two is the key to picking the right recorder for your particular application.