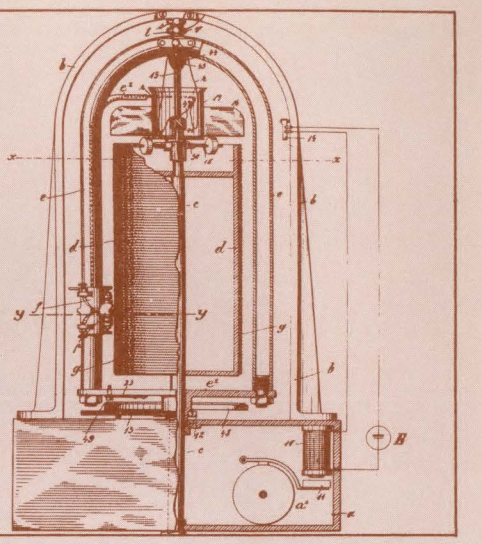
INSTRUMENTATION TECHNICAL INFORMATION NUMBER 2



DISC RECORDING
A Very Versatile Storage Device

BY J. W. Jones

AMPEX

INTRODUCTION

Disc recorders have been used for many years, especially disc packs used for digital data storage in computer systems. The more advanced of these disc machines air-support a flying head a fixed height above an oxide coated disc, thus avoiding damaging contact with the delicate coating.

When the need arose for disc storage of video information, flying head systems were not suitable. The head to disc spacing was too great for the short wavelength, high density recording necessary to achieve reasonable recording times at video bandwidths. To provide video capability, an in-contact head-to-disc system was developed. All metal discs, plated with nickel cobalt to serve as the recording medium, and flash coated with rhodium to give a hard durable surface, made it possible.

Most people have already seen the results of the disc recorder that provides slow and stop motion of sporting events in full color such as the Summer Olympics in Mexico City, or the instant replay of football games. This machine, the HS-100 Slow Motion Disc Recorder was developed by Ampex at the request of the American Broadcasting Corporation. Another increasing use of disc recorders is in the Ampex Videofile* Information Systems that are revolutionizing the storage and retrieval of documents.

The inherent flexibility of the disc recorder offers promise of its ready acceptance for a variety of new applications in the next few years. Before reviewing these, let's take a closer look at disc recorder operation and capability.

HS-100 COLOR SLOW MOTION RECORDER

The HS-100 color slow motion recorder (Figure 1) provides two 16 inch diameter discs mounted on a common shaft and driven at 60 revolutions per second by a servo controlled printed circuit motor. Located in each corner of the top plate, stepping assemblies control the position of the magnetic heads for each of the four disc surfaces. A stepping assembly consists of a digitally controlled stepping motor which is coupled to a sliding carriage by means of a metal belt. The carriage slides along a reference rail so that the head moves along a radius of the associated disc. The stepping distance is 10 mils, and 450 concentric tracks are recorded on each disc surface. Figure 2 illustrates the recording format.

Control of the Machine

It should be recalled that a television picture or frame consists of two vertical fields. Each field is a complete picture in itself but with half the vertical resolution of the interlaced composite.

FIGURE 1: HS-100 Color Slow Motion Recorder

*TM Ampex Corp.

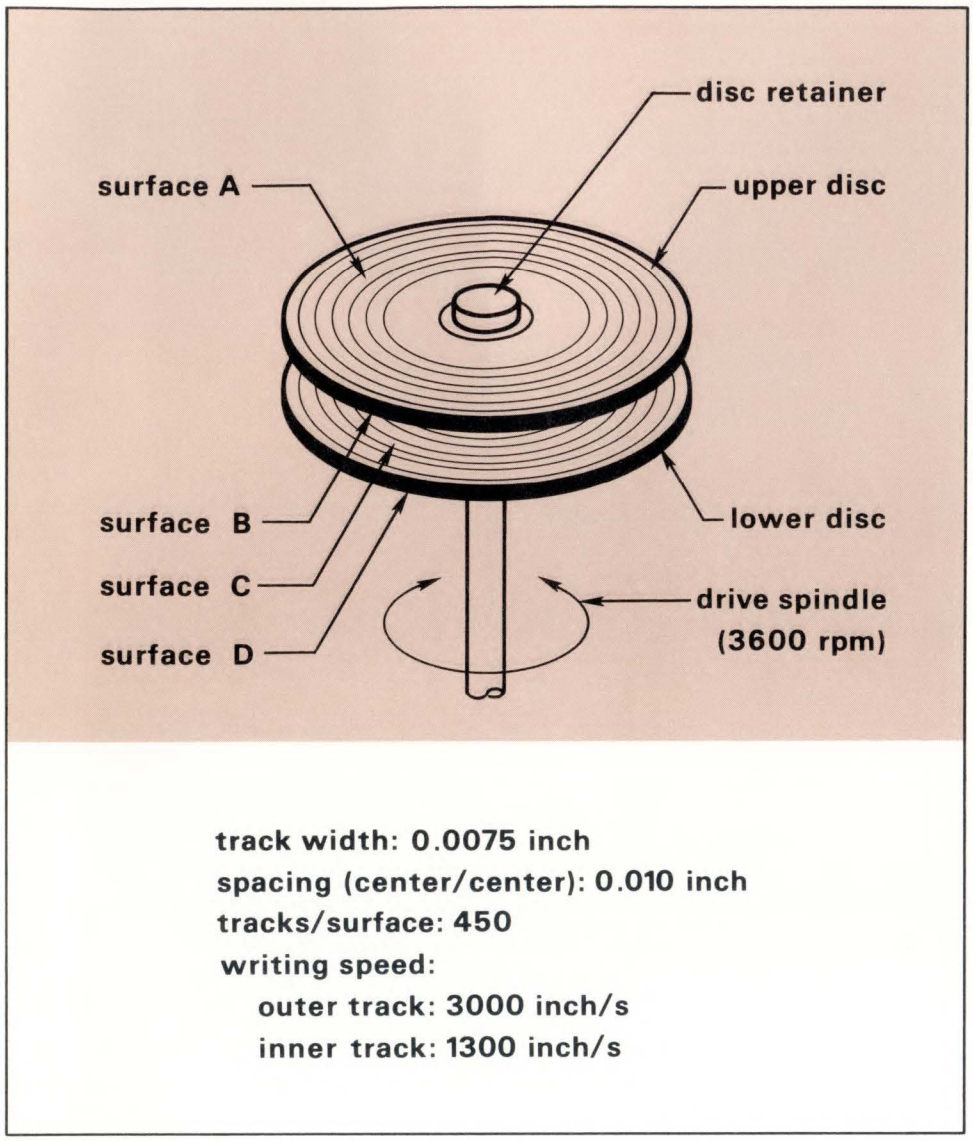


FIGURE 2: Recording Format

By means of a disc drive servo, the rotation of the HS-100 discs is phase locked to a signal derived from the reference vertical sync. During record, consecutive fields are recorded in sequence on surfaces A, B, C, D. (See Figure 2.) Each field occupies one of the concentric disc tracks, and each starts spatially on a common radial line. The head switching format is shown in Figure 3. Each head goes through the cycle erase – record – move – move. Two moves are used so that recording is made on alternate tracks as the head moves towards the center of the disc. At the inner-most track, one move is suppressed, so that during outward stepping, the head records in the space left vacant during inward stepping. A similar single move action occurs at the outer-most track. By this means, the last track in a full recording sequence is adjacent to the first in the sequence and recording can go on indefinitely with continuous update. There is no need for resetting of the machine. With 450 tracks on each of four surfaces, a total of 30 seconds record time is provided. The last 30 seconds of recorded material then is always available during continuous update.

For playback, the heads can be stopped anywhere and the result will be a still picture. If slow motion is required, a slow stepping sequence is selected whereby each picture is repeated a number of times. For normal speed playback, the identical stepping rate as that used during record is selected. By reversing the head stepping sequence, the pictures unfold in the reverse order. Every other field may be recorded to provide fast motion on playback. This has the additional advantage of doubling the record time. For broadcast purposes, it is necessary to modify the reproduced fields so that they are alternately "odd field" and "even field." This is done by switching in a half line delay unit in order to give correct interlacing. For color, the chroma phase also is modified to provide broadcast compatibility.

FIELD	HEADS A	B	C	D
1,5,9, etc.	record	erase	move	move
2,6,10, etc.	move	record	erase	move
3,7,11, etc.	move	move	record	erase
4,8,12, etc.	erase	move	move	record

FIGURE 3: Head Switching Format

CAPABILITIES OF THE HS-100

General capabilities of the Ampex HS-100 provide clues for other applications. Of prime importance, recorded data can be played back millions of times without degradation. Contrast this with 100 passes for broadcast quality videotape recording, or ten thousand times for longitudinal videotape.

Secondly, in the record mode, the machine can be operating in a continuous update mode. In an instrumentation version, recording can begin within a fraction of a microsecond after receipt of a start command. This makes a disc machine ideal for continuous monitoring (perhaps for rare events) and for recording short data sequences. As an example, the videotape recorder and the video disc recorder are natural complements for video program production. The disc is used to gather and arrange short lengths of program material which are then fed into a tape machine. An extension of the HS-100, the HS-200 has been developed for this teleproduction function. The HS-200 promises, among its other applications to revolutionize production of commercials.

The teleproduction use of the machine also illustrates a further quality: versatility of control. Particular data tracks can be addressed and utilized at the touch of a button. The access time on the HS-100 is a maximum of three seconds, but can be reduced to about one second when the need arises. Moving head access mechanisms used in the computer industry offer access times less than 0.1 second and some of these are suitable for application to the type of recorder under discussion.

The qualities of the disc recorder which make it suitable for wideband video service also make it suitable for wideband instrumentation and high data rate digital recording. Just as the HS-100 complements the broadcast video recorder, there are complementary roles to the FR-950 wideband instrumentation recorder. We will discuss these other application areas after a brief note on the techniques of recording and reproducing at these high data rates.

RECORD/REPRODUCE ELECTRONICS

Disc recorders use the same basic recording technique as the broadcast video and wideband

instrumentation machines. For DC to 6 MHz data, an RF carrier in the neighborhood of 9 MHz is frequency modulated by pre-emphasized input data. The frequency modulated signal is saturation recorded on the disc. In the case of the instrumentation application, a 500 kHz pilot signal may be added for later time base correction of reproduced data. The reproduced RF is equalized and demodulated. After de-emphasis and filtering, the original input data is recovered. Both video and instrumentation machines have provision for electronic time base correction to achieve time base errors below 25 nanoseconds peak to peak.

INSTRUMENTATION DISC RECORDER

Because video data is separated into fields, the spacing between fields can be used for switching between tracks without any loss of data. But for general instrumentation applications, some means is required to switch between tracks without loss of data. This is accomplished by recording overlapped tracks as illustrated in Figure 4. Then in playback, during the overlap

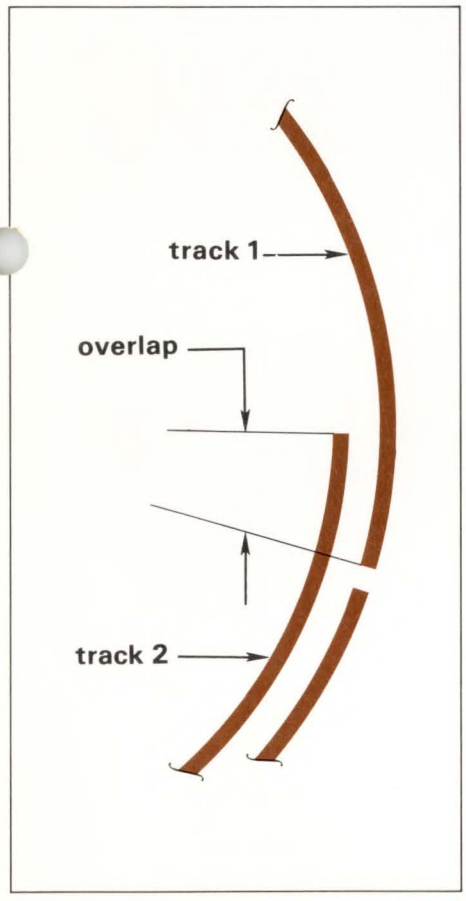


FIGURE 4: Recording Overlapped Tracks

period, the outputs of both tracks carry the same data. Transient-free reproduction is achieved by slow-switching from one track output to the next during this overlap period. The result is continuous uninterrupted data reproduction. (See Figure 5.) For this method to be successful, the time error between the switched data sets should be of the order of one quarter wavelength or less of the reproduced RF signal (about 25 nanoseconds or less relative time error).

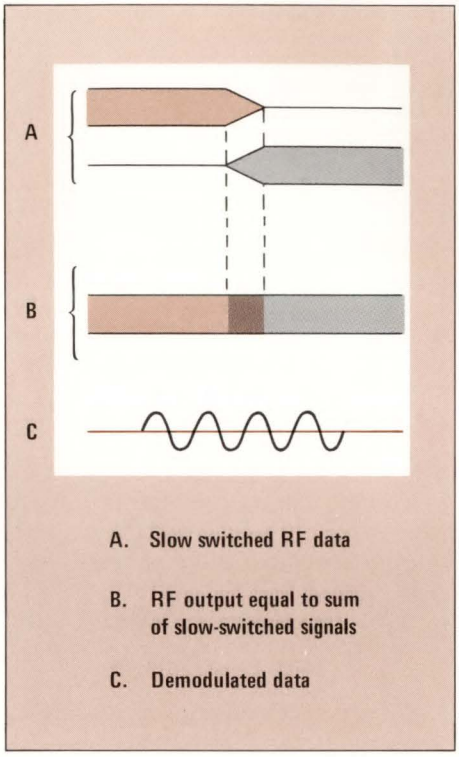


FIGURE 5: Continuous Data Reproduction

An instrumentation machine under development of similar construction to the HS-100 disc recorder has two high-band data channels with data handling capability from D.C. to 6.3 MHz. Two low-band data channels are also provided with bandwidth from D.C. to 100 kHz. Recording time of each channel is 10 seconds.

The machine logic allows for various modes of operation. For example, control inputs X and Z represent the beginning and end track numbers for a record sequence. When the machine is put into the record mode, the steppers position the heads ready to record at track X. Recording begins when a start command is given and ceases when track Z is reached. During the record process, the recording track position is monitored by an output Y. The X, Y, and Z track numbers are all displayed with digital readouts.

The recorded data can be examined in a number of ways. Scanning from X to Z can be done once or repetitively. A second alternative is to move from X to Z but repeat each track a specified number of times. In the case of single track playback, provision can also be made for a progressive sample and hold so that the recorded data can be matched to low bandwidth systems. The disc speed also can be lowered during playback for the same purpose.

DIGITAL RECORDING

The instrumentation machine will also be readily adaptable to digital recording. Figure 6 illustrates recovered digital data using an HS-100 top plate with modified FR-900 electronics. The data rate is 10 megabits per second. Capacity of the two 16" diameter discs using this format is 3×10^8 bits.

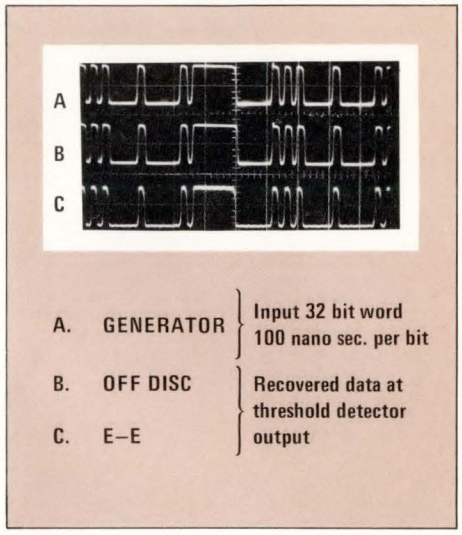


FIGURE 6: Recovered Digital Data

Such a machine, with its capacity divided equally between two channels is suitable for input signal enhancement by repeated addition of 15 second bursts of time multiplexed digital data. Each 15 second burst contains the same data but degraded by random noise. The two memory channels are used alternately to store the results of adding the contents of the other channel to new data entering the machine. The required signal increases in proportion to the number of additions, but the random noise increases only in proportion to the square root. Therefore, the signal-to-noise is enhanced in proportion to the square root of the number of additions. The same additive process can be used with analog techniques, but the results will be limited by analog system parameters.

FIXED HEAD MACHINES

Many potential applications for the disc recorder require very short recording times. Fixed head disc machines provide an efficient solution for these applications. A typical machine might have a head assembly consisting of 25 fixed heads, each capable of recording for one revolution of the disc. The disc rotation period could be 25 milliseconds. For more complex applications, a number of head assemblies may be used.

The heads can time share a record-reproduce system, or have independent record or reproduce systems at the expense of increased complexity. The signal performance of such machines would be similar to those illustrated earlier, but the number of channels would in

general be much higher and time per channel lower.

A SUMMARY OF DISC USES AND POTENTIAL USES

The flexibility of the disc recorder makes it impossible to foresee more than a few of the possible application areas. So far, the largest application area for Ampex has been for television. The HS-100 has been used chiefly for sportscasting. With the HS-200, the disc recorder will enter the teleproduction field in earnest. Another very important use is in the Ampex Videofile system. The Videofile system stores vast quantities of documents as video signals on tape. As part of the system, disc recorders are used as interface buffers to provide soft copy on television monitors, or slowed down to match the speed of a hard copy printer. A recently demonstrated closed circuit recorder, the DR-10, will be suitable for a lower price market than the earlier broadcast machines. It has provisions for both fixed and moving heads. While primarily intended for video use, it is expected the DR-10 will be adapted to instrumentation applications in the future.

Other uses which are currently receiving active consideration include: educational and other closed circuit video, radar recording, transient recording and analysis, and repeaters in disp[illegible] systems. The medical field also holds ma[illegible] applications including, for example, a single frame X-ray recorder to minimize exposure. Most of this technology is suitable for military and airborne applications. Ampex is preparing for a leading role in disc recording expansion through continued development effort, and extension of its manufacturing capabilities in the head and disc areas.

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