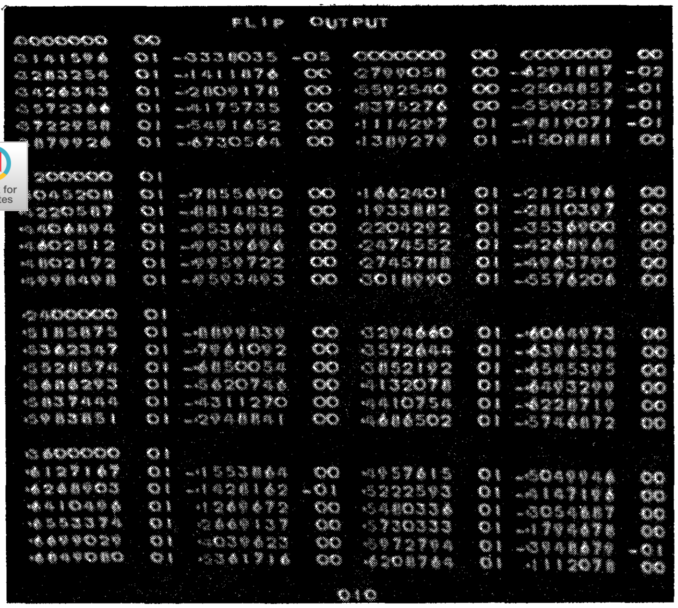


Fig. 9

out of line can be corrected and rerun.

Any of the characters can be used to plot graphs. Multiple graphs can be plotted on the same frame, Fig. 8. The input parameters can also be displayed on the same frame. These graphs represent the solution to two simultaneous differential equations. A table of the values plotted could be separate, Fig. 9.

A question often asked is, "How many characters can be displayed on one horizontal line?" With this installation 50 characters can be displayed horizontally. A Charactron with a 7-inch tube has been built which can display 100 characters per line with very fine definition and sufficient intensity for photographing at a rate better than 20,000 characters per second. It should be noted that the format is not limited with a Charactron. Answers can be printed in vertical columns. Each column, for example, could represent all variables at one time interval of integration.

Early this year, Convair expects to tie together a very large analogue computer with the ERA *1103*. Between the two will be the conversion equipment—analogue to digital and digital to analogue. This setup is for a real time simulation problem. Of course, the output plotters on the analogue will be used, but the output of calculation from the ERA *1103* are also needed. This output must be very fast because of the real time simulation. Since the magnetic tapes have inertia start and stop times which make them too slow, and the drum may not be large enough to store all the answers before the problem is finished, it is felt that the Charactron with its extremely high speed may answer this challenge.

References

1. The Charactron, **Joseph T. McNaney.** *Proceedings*, Institute of Radio Engineers, New York, N. Y. March 1952.

2. The Type C19K Charactron Tube and its Application to Air Surveillance Systems, **Joseph T. McNaney.** *Ibid.*, March 1955.

A New Tape Handler for Computer Applications

ROBERT BRUMBAUGH

THE rapid advances made in digital computer design within the past few years have, unfortunately, not been accompanied by a corresponding advance in the design of input-output equipment of comparable performance. The increasing scope of computer applications has further intensified the limitations imposed by available input-output equipment.

Magnetic recording tape, as a storage medium for digital information, is assuming a role of ever-increasing importance, and is now unsurpassed as an input-output medium for the rapid transfer of information. In addition, magnetic tape equipment has become an important element in automatic data-reduction systems.

Many types of magnetic tape handlers have been designed in the past, the great majority to meet a more or less specific application. As a result, extensive modification has often been necessary to adapt these units for other applications. In recent years, more versatile designs have been evolved to meet the increasingly diversified requirements for digital recording equipment. Although the new equipments represent a step in the right direction, these pioneering efforts were at times overly complex, and consequently caused a sacrifice both of reliability and economy.

For many years Ampex has concurrently pioneered in the recording of analogue signals on magnetic tape. Many of the problems in this field are very similar in nature, if not in degree, to those in the computer field. In addition to their useful analogue function, standard instrumentation recorders have many times been modified for application to computer systems; this approach is obviously not the answer to the increasingly stringent and refined requirements of the computer industry.

Believing that its extensive past experience could be applied to solve many of the increasingly difficult problems in the application of input-output equipment, Ampex Corporation initiated a program to develop a magnetic tape transport for computer use, providing versatility and reliability equal to that of the instrumentation recorder. Briefly, the most desired requirements of a tape transport for computer use are as follows:

Robert Brumbaugh is with the Ampex Corporation, Redwood City, Calif.

1. A wide range of tape speeds, track arrangements, and types of recording/reproducing heads must be possible with little or no change in the basic design.

2. The head assembly and associated tape tracking system must be of a precision and accuracy such that tapes will be completely interchangeable from machine to machine.

3. Reliability and simplicity must be achieved to reduce maintenance and costly "down time."

4. The start-stop time and distance must be kept low, and, perhaps even more important, consistency or start-stop characteristics must be maintained.

5. Price must be low in order to minimize computer accessory cost.

6. Operator skill and training must be minimized; this requires extreme simplicity in tape threading and controls.

7. A high-speed rewind function should be included.

8. A simple, functional appearance is required for integration of the tape handler into existing and future computer systems, many of which are intended for office rather than laboratory use.

A tape transport mechanism incorporating all of these objectives has been developed by the Ampex Corporation, and is shown in Fig. 1.

Fig. 2. Tape feed system

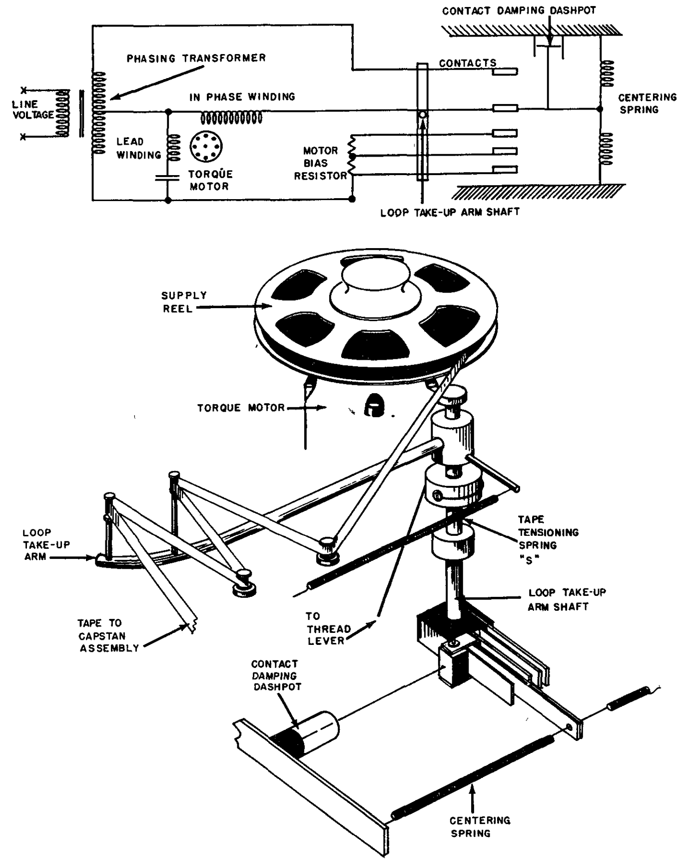


Fig. 1. New Ampex tape handler

Tape Feed System

One of the major problems in accomplishing a rapid start and stop of tape is the development of a reliable, smooth-responding, constant-tension tape feed. The tape feed system isolates the relatively large inertia of the reels from the inertia of the reels from the section of tape to be accelerated and driven past the record or playback head.

Before discussing the details of the system, it is well to review the development. An electronic-controlled servo-system offers the distinct advantage that the response can be controlled and adjusted quite easily. However, such systems are relatively complex and costly; as a result, it was decided to abandon such a system.

A step or "on-off" type of controller offers maximum reliability and simplicity, but for the most part the response leaves much to be desired. The system finally devised combines the best features of both: simplicity, reliability, and smooth response. The performance closely approximates a true proportional system with error-rate damping. A rigorous mathematical analysis of the system (see the appendix) yielded results closely following the actual performance.

Fig. 2 shows the essential details of the servo system. Only the left follower arm is shown for simplicity. The action of the system is as follows.

Quiescent or static tape tension is established by the tensioning spring S. The choice of the spring and the position of the spring lever arm were selected so that the tape tension would be almost constant over the full displacement of the loop take-up arm. Quiescent tape tension (3 ounces) is exactly balanced by a motor torque which is determined by the motor bias resistor R. The actual system has two such bias torque levels, and enough purposely introduced friction to eliminate hunting or contact bounce over the entire range of reel load.

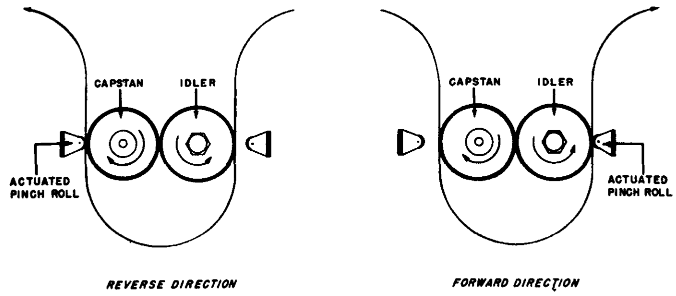
The take-up arm neutral position is established by the control contactor centering springs, and hence the position of the control contactor relative to the take-up arm. An input signal, of either a supply or demand of tape, from the capstan section, displaces the loop take-up arm and contactor. The contactor, in turn, switches the motor in-phase winding to the appropriate side of the servo phasing transformer. Full-power motor torque drives the reel in a direction which restores the loop take-up arm and contactor to its center or neutral position.

This system also offers a very convenient method for accomplishing the high-speed or rewind mode of tape motion. If, for example, we should disable or remove all power from the right hand servo, the right hand take-up arm will drift to the right, coming to rest against its stop. Under this condition the tape on this side is no longer under tension. The differential of tape tension between the two sides facilitates rewind from right to left. Stop, during rewind, is accomplished merely by restoring control to the disabled servo. Total rewind time of a standard 2,400-foot 10-inch reel is somewhat less than 2 minutes.

Table I. Specifications of Ampex Standard 1/2-Inch 7-Channel Digital Record Reproduce Head

Mechanical Specifications	
No. channels	7
Track width	0.032 inch
Track center-to-center distance	0.070 inch
Gap width	0.0005 inch
Gap vertical alignment tolerance	0.0001 inch
Vertical or azimuth tolerance	±1 minute of arc
Electrical Specifications	
Inductance (typical)	Outer tracks, 10 mh Inner tracks, 12 mh
Turns	400/leg, common center taps
Write current (tape saturation)	10 ma (zero to peak)
Read output volts	8 mv (peak-to-peak) at cps, 30 inches per second

Fig. 3. Tape drive



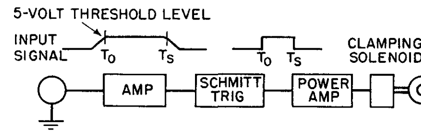


Fig. 4 (right). Control circuit block diagram

Are contacts really reliable and permanent when subjected to many millions of make-break cycles? First, the problems of metal transfer, pitting, and contact sticking are greatly reduced when the circuits are alternating current. Second, and possibly more important, when tape is demanded at rates of from 10–60 bursts per second, the servo integrates this motion into resultant or average tape speed. Under such conditions the contacts may break and make only several times per second. In actual life tests, under full power to an inductive load, the contacts have made upwards of 60 million cycles with more than 50 per cent material remaining for useful service.

Head Assembly and Tape Tracking System

One of the greatest problems facing the user of tape transports is interchangeability of tapes recorded on different machines. The problem basically is one of interchannel timing error, which, in turn, is caused by both static and dynamic factors. The static factors are almost exclusively in the province of head design—lack of consistency in gap alignment and azimuth. Any deviation in these quantities exacts a cost in effective pulse-packing density and interchannel time relationships. The Ampex Corporation has recently introduced a new technique for the manufacture of multichannel head assemblies, a technique which has reduced alignment and azimuth errors to values approaching instrument errors. Table I lists the new head specifications. The close tolerances to which the heads are manufactured eliminate any necessity for azimuth adjustment, and the attendant difficulty of insuring tape interchangeability.

The gap and azimuth tolerances, transformed into time at 30 inches per second between outer channels, would result in a maximum of 30 microseconds error introduced by the gap, and 5 microseconds error introduced by azimuth. The interchannel time displacement error between tape handlers would then be a maximum of 16 microseconds.

The dynamic interchannel time displacement error is also another important factor affecting pulse packing. The tape guides, head mount, and tape drive system exercise the most effect on this parameter. Once again, only design and precision of component manufacture can minimize the error. To take advantage of the excellent head tolerances, the guides and head must be mounted integrally on a plain surface which is held to the same or better dimensional tolerances. The capstan clamping idler must make accurate line-to-line contact with the tape, thus eliminating shear in the plane of the tape. Actual measurements show an outer-channel peak jitter of better than ±3 microseconds.

Tape Drive System

Fast start-stop tape motion is accomplished by clamping the tape to either one of two counter rotating capstans (see Fig. 3). The capstans are covered with 0.062-inch-thick rubber tires. The rubber eliminates tape marking and damage which might otherwise result from impact of the pinch roller. The pinch rollers are driven by two solenoids, which in turn are controlled by two power amplifiers. To eliminate the effect of variations in control signal amplitude and rise time, the solenoid power amplifiers are driven by a Schmitt Trigger circuit. Fig. 4 shows this relationship.

A d-c type of control was selected so that it could be driven directly by a gate or flip-flop.

Conclusion

The myriad applications of digital computation are just beginning. Many steps must be taken before the full

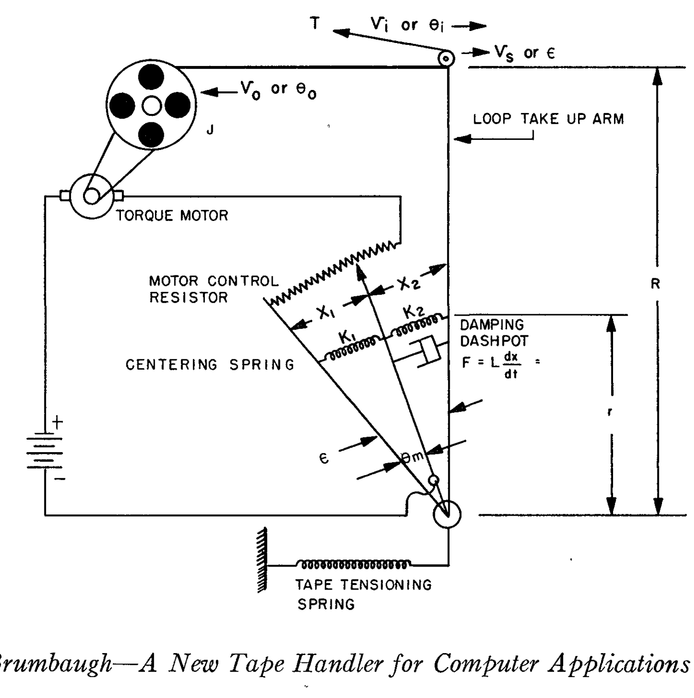


Fig. 5. Unidirectional system

utilization of modern digital computers can be realized. The design of this new tape handler, and future extensions of this design, will materially aid in the attainment of the goal sought.

Appendix

For purposes of analysis a unidirectional system is shown in Fig. 5. The contacts have been replaced by a continuously variable resistor, the static tape tension, friction, and the small component inertias have been neglected.

The following forces are acting on the control resistor slider:

$$K_1X = K_2X_2 + L\frac{dx_2}{dt} \qquad (1)$$

$$\Theta_m = \left(\frac{K_2}{K_1+K_2}\right)\epsilon + \left(\frac{L}{K_1+K_2}\right)\frac{d\epsilon}{dt} \qquad (2)$$

$$\epsilon - Kr(\Theta_1 - \Theta_0) \text{ and } \frac{d\epsilon}{dt} = Kr(W_i - W_0) \qquad (3)$$

Substituting equations 3 into equation 2

$$\Theta_m = K(\Theta_i - \Theta_0) + K(W_i - W_0) \qquad (4)$$

From equation 4, it is apparent that the motor control angle, and hence motor torque is proportional to both input displacement and rate of change of displacement.

Finally, the dynamic forces acting on the motor and tape system are as follows:

$$J_0\frac{d^2\Theta_0}{dt^2} = K\Theta_m = K\left[(\Theta_i - \Theta_0)K_2 + \left(\frac{d\Theta_i}{dt} - \frac{d\Theta_0}{dt}\right)L\right] \qquad (5)$$

From

$$\Theta_0 = \Theta_i - \epsilon$$

$$J_0\frac{d^2\Theta_i}{dt^2} = J_0\frac{d^2\epsilon}{dt^2} + L\frac{d\epsilon}{dt} + K\epsilon \qquad (6)$$

Equation 6 is typical of a "closed loop" system with "error rate" damping only. In terms of the error E, the solution gives:

$$\epsilon = \frac{wi}{\sqrt{\frac{K}{J}}\,\mathrm{SIN}\left(\sqrt{\frac{K}{J_0}}\right)t} \qquad (7)$$

Or in the critically damped case:

$$\epsilon = w_i t e^{-\frac{L}{2J_0}t} \qquad (8)$$

The actual system response may be made to approximate closely either of these cases by adjusting the dashpot damping coefficient L.

Nomenclature

K_1K_2 = centering spring constant
J_0 = Reel and motor inertia
L = Dashpot damping coefficient
$\theta_i\theta_0$ = Input and output tape displacements as referenced to reel radius
ϵ = Take-up arm displacement
θ_m = Motor control resistor angle

Requirements for a Rapid Access Data File

GEORGE EISLER

GENERAL-purpose business-data-processing machines now on the market are limited in their performance mostly by the electronic file systems associated with them. The only file medium that has proved itself acceptable from the standpoint of both cost and speed is magnetic tape. In the quest for better, i.e., faster, cheaper, etc., general-purpose machines, a "random access" file has been held out as perhaps the key to the next step of progress. "Random access," however, is a misleading term if it is used to describe what an ideal file should be, rather than adopted. The considerations which, taken together, point to the requirements for a rapid access data file in a general-purpose data processor will be presented here.

The desirable factors having the greatest influence on system utility are listed as follows:

Speed

High operating speed when large groups of data are to be processed at one time.

Adequate look-up speed when single records are required.

Addressing

Items locatable by the same identifications as in a manual file.

Items locatable by various categories other than normal identifications.

Capacity

Adequate capacity, probably implying both expandability and high utilization of file space.

Interchangeable storage medium.

Nonvolatility

Ability to retain information in the absence of electric power for periods of weeks or months.

Furthermore, these desirable characteristics must be implemented by devices of reasonable cost which, in addition, are within the over-all processor system requirements of reliability, size, weight, and other factors.

The implications of the features listed are considered in detail in the following section; the order, however, in which they are taken up does not necessarily reflect their relative importance since most of them are fairly interrelated.

Speed

One of the most important considerations bearing on the performance of a data-processing system is the speed with which records can be made available by the file for the processing operations.

Data-processing operations calling for some modification of the file can be carried out in two general ways, depending on the particular application. If the time lag is permissible, data for a number of similar operations may be collected and processed at one time as a group; or, if the time lag is not permissible for some reason, individual record modification may be carried out as soon as a new piece of information arrives and the machine is available. The choice of the procedure actually used, however, not only depends on the demands of the processing situation but the characteristics of the file as well.

By way of illustration, the processing of a group of checks which a bank receives from a clearing house may be performed as a single continuous operation at a convenient time in the scheduled daily program. It so happens that with a magnetic tape file in the processor, this is preferable, since it is far faster to process data in a group when both the new and the stored information are in a matched sequence and the tape need be scanned only once. There is no reason, of course, why this operation could not be done by treating the checks separately and in no particular order, if there were a file where any record

GEORGE EISLER is with The National Cash Register Company, Hawthorne, Calif.