ELECTROMECHANICAL
COMPONENTS & SYSTEMS DESIGN

REPRINTED FROM NOVEMBER 1964

# DECTAPE TRANSPORT DESIGN

## New mechanisms and some trade-offs between electronic and mechanical constraints in magnetic tape recording techniques

Are you an engineering or scientific user of a computer? Would you like to take your program to the computer, read it more conveniently and rapidly than you could with cards or paper tape, perhaps edit or revise it at a console teleprinter, insert some data to be processed by it and receive your results quickly on a typewriter printout with your revised program recorded on a new magnetic tape? Using conventional tape or perforated paper tape or cards, you'll find your problem-solving use of a computer far less convenient than what we've just outlined.

Thomas Stockebrand, of Digital Equipment Corporation, Maynard, Mass., pointed out that in developing its new tape transports, Digital had to question some basic principles of design embodied in conventional systems. Instead of functioning as a step in the progression of data from computer memory to output device, they wanted their new tape to function in interim steps in processing: for reading a program in, for reading in subroutines while assembling a program, for debugging a program on line, and for recording assembled and revised programs.

Whereas, conventional units often feed a line printer, stopping and reading out a character at a time or a line of printing at a time, operation of the new unit would be continuous while reading in or reading out a sizeable block of data. This suggests a different tape system configuration. Instead of only one or two conventional transports, the computer installation would also have many of the new transports, perhaps enough to allot one to each user. Such a configuration would also offer a multi-bin sorting capability to cut the number of tape passes in search and merge operations.

### SYSTEM REQUIREMENTS

The overriding goals, simplicity and reliability, were considered to have many elements in common. To achieve these goals, Stockebrand said that the designers wanted a system that would function consistently with the fewest possible parts. The minimum system seemed to require places to store the tape, a means of moving it, a guide to position it and a head with which to write on the tape and read from it.

### Tape Storage

Bins and reels were considered for storing the tape. Reels were selected for three reasons: denser packing, hence more efficient use of space; cleaner reel storage and an extremely simple mechanism for pulling tape past the head. For the reels to apply the driving force, the designers considered a tape mechanism as a connector which is elastic between two masses which are in motion, approximating a spring with a weight hanging from each end. Because of the tape's elasticity, it is necessary to limit the amount of force applied to it and to regulate the rate at which this force changes. This general coupling problem was considered to have two parts, dynamic when the tape is changing speed and static when it is coasting or at rest. The dynamic part of the problem encompasses three states of motion: starting, running and stopping. Dynamic control over tape motion must eliminate the slack loops that can form and be taken up if the braking force applied to the trailing hub is not properly matched to the torque and speed of the leading hub. With the tape stopped, the control technique must provide for balanced forces to be applied to the two hubs, keeping the tape from slackening or wandering. Complicating this requirement is the fact that the amount of tape on each reel, hence the diameter and resulting force, can be quite different. The decision was made to have reels made of a plastic composition and to keep the reel diameter ratio small. This would lighten the mass that had to be controlled and reduce the diameter variation between full and empty reels to from 1.3 to 1. With 10″ reels this variation is from 2 to 1.

### Tape Advance

To propel the tape, ac induction motors were chosen because they are reliable, inexpensive, require little maintenance, have favorable torque-speed characteristics and, lacking brushes, run spark-free. To eliminate another prime source of sparking—a significant contributor of error in tape systems—the decision was made to constantly torque both motors in their drive directions thus eliminating: the need for torque reversals; the consequent collapse of motor fields and the resulting rich sparks at switch contacts. The driving motor would run on full line voltage, the trailing motor on partial power to produce the proper torque for maintaining tape tension, and the trailing motor would be switched to full power for braking as the driving motor's power was cut. With both on partial power, the tape would be kept tense while stopped, greatly simplifying the motion control subsystem. Since the ac induction motor does not make a good generator, the net result of running the trailing motor backward would be only a small effect on the power factor. Little heat dissipation was in fact experienced.

The actual field voltage used to achieve the proper torque in the trailing motor is 35 v produced by connecting a resistor in series with the field. This torque results in a tape tension, over the full length of the tape, that remains within 20% of the nominal value. In addition to the full line voltage applied to the fields for driving or braking, a third value, 15 v, is applied to each field, through a second damping resistor, when the tape is to remain stopped. The resistors are shunted in and out simply with relays.

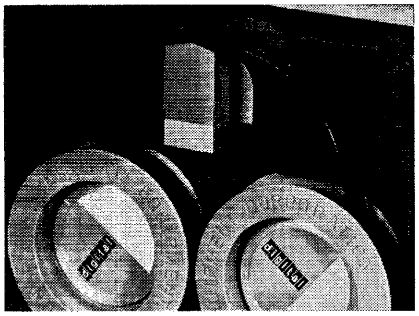
### Tape Guide

The next effort was to find the simplest guide that would position the tape properly as it passed the head. To apply the restraining forces along the edges of the tape seemed desirable, and the simplest edge guide possible, a track formed by a pair of edges paralleling the tape, was selected. It was to function more as a restrainer than a guide in that it would touch the tape only intermittently, only when it was needed to prevent the tape from wandering more than the few thousandths of an inch permitted by the pole piece dimensions. A true guide would constantly hold the tape in the desired position and it would constantly be wearing. Flanged rollers were rejected because they do not guide effectively. Because there is no relative motion of tape and roller, no air cushion forms and the tape is constantly in contact with the roller's surface. The tape then defeats the effort of the flange, crowding up against the pushing side rather than moving in the desired direction. According to Stockebrand, the length of the track would be a function of the degree of skew control required where the tape passed the head. Skew considerations depend on the density of the proposed recording format, that is the nearness of adjacent bits in a track. The resulting guide length was calculated to permit reasonable skew.

To make such a guide function with a minimum of wear—and to be able to edge-guide at all—the force it would have to exert had to be kept to a minimum. With anything but a minimum force, the tape would buckle. If the guide were curved, some resistance to buckling would result, so the amount of guide force needed and the amount of curvature needed to achieve the corresponding resistance were calculated. Air flotation of the tape promised minimum force requirements, but how to achieve air flotation simply and reliably posed design problems. Because air blown in under the tape would bring oil, dust, fragments of coating, and other debris with it, Stockebrand explained that the engineers resorted instead to hydrodynamic lubrication, relying on the viscosity of air to entrain it with the tape and provide the flotation medium. Air is not usually thought of as a viscous fluid; but it is in proportion to its mass.

DECtape overcomes air's low-mass handicap through continuous motion of the tape, eliminating the stop-start operating mode of conventional transports. Boundary layer control is achieved in a tape feed length of from one to two times the guide distance, when maximum flow is reached. Factors affecting this hydrodynamic lubrication are tape tension, instantaneous radius of curvature, relative velocity of tape and guide and viscosity of air. The critical consideration is the thickness of the air cushion, since the aim, in addition to reducing the force needed for guiding, is to float the tape over any roughness and dirt in the guide track and on the head. Increasing the radius of curvature of the guide provides the desired increase in the thickness of the air cushion.

Passing the head, air cushion thickness must be minimum, since separation of the tape from the head by so much as the distance between successive bits (1/375″) attenuates the signal 55 db. Because the tension, air viscosity, and relative velocity over the head are the same as over the guide, the only parameter that can be changed to move the tape closer to the head is the radius of curvature of the head. Again, in choosing to redesign rather than adapt existing heads, the approach taken was reliability through simplicity. It would have been possible to position the tape correctly with pressure pads, as is commonly done, but the pads collect dirt continuously and periodically deposit it on the tape.



**DECtape transport showing the two 3½-inch reels and their relationship to the tape guide and the read-record head assembly.**

DECtape Specifications

**CAPACITY**

$577_{10}$ blocks of $256_{10}$ words (18 bits).
768-6-bit characters per block or $256_{10}$ 18-bit data words. (Any block length possible.)
260 usable feet of ¾″, 1.0-mil Mylar tape on 3½″ reel.
375 (±60) 3-bit characters per inch.

**TRANSFER RATE**

15 kc/s character rate, 6-bit characters.
In reverse, transfer rates vary 20% as reels change diameter.

**ADDRESSING**

Mark and timing rack allow search for particular block and word.
30 sec "Worse Case" access.
Start time is <300 msec, stop time is <150 msec, turn-around time is <300 msec.
Start and stop distances are approx. ≤8″.
When a command to reverse direction is given at a certain tape location, the system is up to speed when that same location passes the head after turn around.

**555 TRANSPORT**

12″ x 19″ for dual transport.
Weight 65 lbs.
Power requirements: 115 v dc, 60 c/s, 1.5 a; idle, 3.2 a.

## ADAPTABILITY

Given this simplified transport, the designers then had to assess its adaptability to conventional recording techniques. Speed control, never a primary design goal, Stockebrand emphasized, demands careful consideration. The emphasis, he said, the designer of the conventional transport must place on speed control is due to the requirements posed by the amplitude-sensing recording technique. A ONE recorded at 80″/s, for example, would not read out as a ONE at slower speeds. To eliminate this speed-accuracy dependency, DECtape designers selected a polarity-sensing technique. In polarity-sensing, the direction of the flux reversal indicates whether the recorded bit is a ZERO or a ONE. Since the amplitude of the recorded signal is not important, low signal-to-noise ratios which would render other techniques useless can easily be used. With this technique, tape speeds from 30 to 600″/s give identical readouts of a given body of data. For writing, because the speed with which the head can switch its polarity is a limiting factor, polarity-sensing gives a speed tolerance of from 60 to 120″/s. Actual design speed is 80″/s, achieved in 6″ of tape travel or less.

As the reel diameter grows on the driving hub, the rpm would increase under constant torque, but the torque-speed curve characteristics of the leading motor are utilized to produce constant tape tension. The constant tension limits tape speed variation to 10% over the entire 260′ length of the tape, well within the limits of error-free operation. Since the speed does vary, programming attention is required to nullify the changing data density when reading in the opposite direction from the writing direction. When reading and recording in the same direction, the user finds no disparity. Data is actually written and read on information derived from a signal given when the prerecorded timing track indicates that a character is in position at the head. The timing track gives every character a specific address, letting the user rewrite a single recorded character or even one bit in it, without affecting adjacent characters. ■