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A PAPER TAPE TO MAGNETIC TAPE CONVERTER

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ABSTRACT

The Paper-Tape-to-Magnetic-Tape Converter consists of two racks of electronic equipment whose function is to transcribe seven-channel digital code on punched paper tape to seven-digital code on magnetic tape in a form compatible with the input requirements of the IBM 704 and 709 computers. Recording is accomplished by electronically controlling the "read" and "stop" modes of the paper tape reader while the magnetic tape continuously advances. The converter also checks for certain types of error in the structure of the coded information on the paper tape and indicates their presence. The encoded magnetic tape is used as the information input to a properly programmed IBM computer.

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On development of the Franckensteins (72-inch bubble chamber film-measuring devices) at Lawrence Radiation Laboratory, conditions for data output were:

- (a) Data must be adaptable to the IBM 704 input, as this computer was used to analyze the information;
- (b) Data must be easily accessible for checking and editing;
- (c) Cost of data-handling devices must be in line with over-all cost of the measuring projector.

Paper tape devices meet Requirements (b) and (c) very well, and a paper-tape-to-magnetic-tape converter was developed and built to meet Requirement (a). For magnetic tape to be adaptable to the 704 input, it must have the following format (see Fig. 1):¹

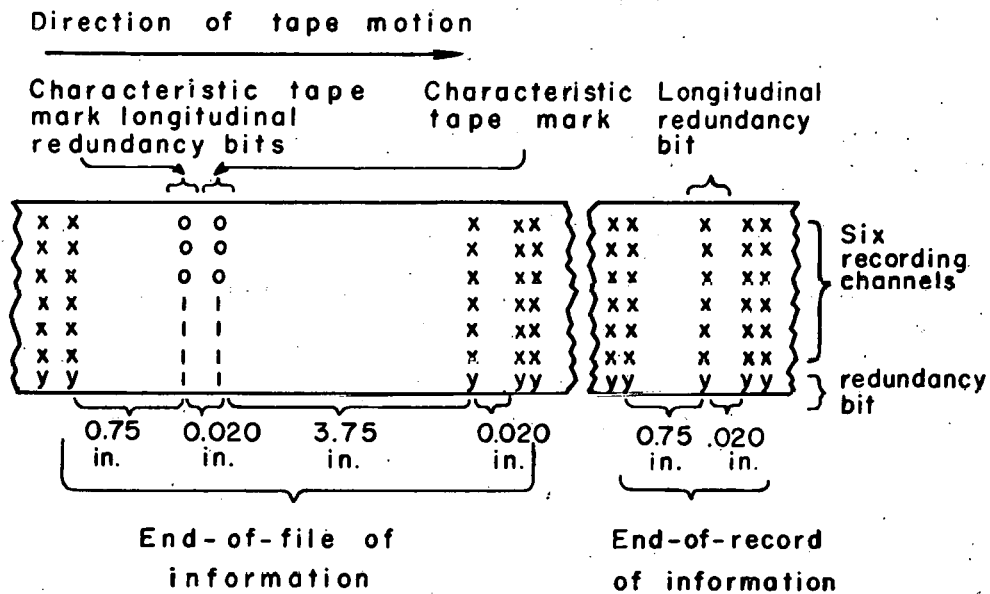
- (a) The longitudinal bit density of the tapes is 200 bits per inch, and each word, the basic unit of information, consists of 36 binary bits.
- (b) Six bits laterally across the tape make up a character and six characters compose a word. In addition, a seventh bit is used to give a lateral redundancy check. This check bit can be used to make the character either odd or even.
- (c) A tape may contain more than one file, and any file may contain any number of records. Each record can contain one or more words.
- (d) At the end of each record written, there must be a longitudinal redundancy check bit in each of the seven channels to cause an even number of binary 1's in each of the seven channels of that particular record. The longitudinal check is always an even check.

Physical arrangement of the information on the magnetic tape is as follows:

- (a) A 0.020-in. blank space, followed by a longitudinal redundancy check and a 0.75-in. blank space that defines an end of record of information.
- (b) A 0.020-in. blank space followed by a longitudinal redundancy check, a 3.75-in. blank space, a characteristic tape mark, a 0.020-in. blank space; a longitudinal redundancy check for the tape mark and a 0.75-in. blank space that defines the end-of-file information. The characteristic tape mark is $(0001111)_2$.

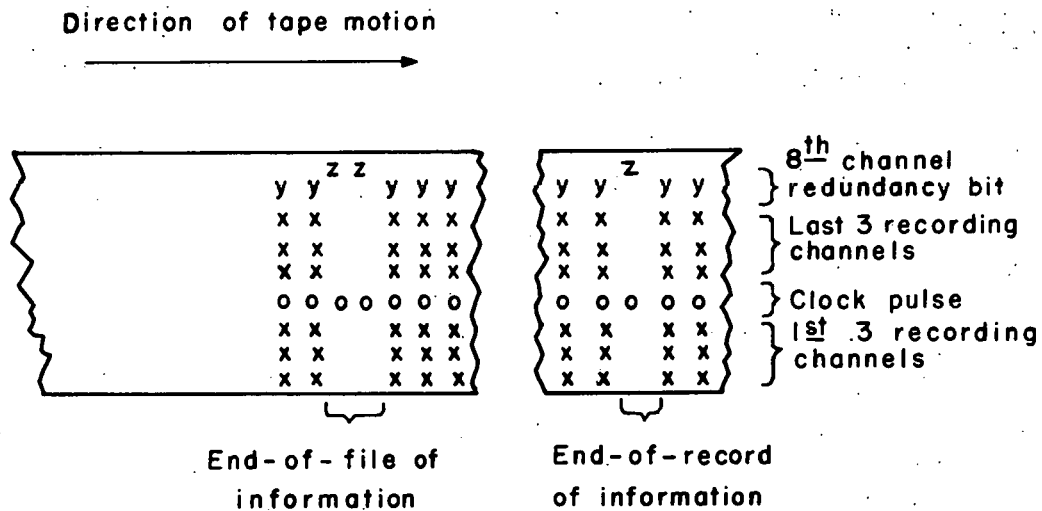
To meet the magnetic tape requirements, the following paper tape format was chosen (see Fig. 2):

- (1) Eight-hole tape was selected as standard.
- (2) The basic unit of information (the word) would be 36 binary bits.
- (3) The first six lateral bits are used for the information, the seventh for a lateral redundancy check.



MU-22543

Fig. 1. Physical arrangement of information on Magnetic tape.



MU-22544

Fig. 2. Physical arrangement of information on paper tape.

(4) The eighth hole controls the end-of-file and end-of-record information. One eighth hole defines end-of-record information. Two succeeding eighth holes define end-of-file information.

(5) A tape may hold more than one file. Any file may contain any number of records. Each record can have one or more words.

The following terminology will be used in referring to the tape converter:

Anycode. Any hole in any one of the seven bits of information (six bits and a redundancy check); or any number of the seven bits of information coupled with a sprocket will produce an Anycode.

Space. Absence of all the seven channels of information but the presence of a sprocket will generate a Space signal.

8. The 8-signal is produced by a hole in the eighth channel and the presence of a sprocket.

Not 8. ($\bar{8}$) is produced by the absence of a hole in the eighth channel but the presence of a sprocket.

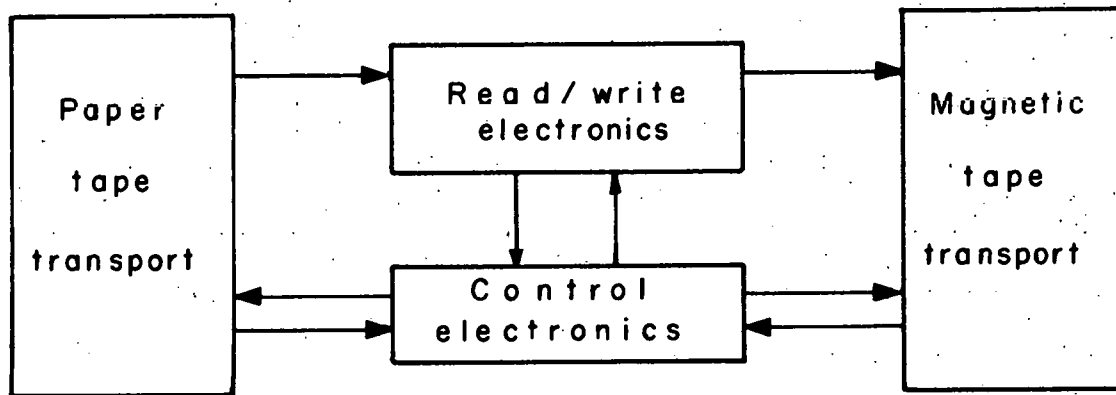
Sprocket. The Sprocket signal is the ninth hole of information on the paper tape. This is a continuous hole on that tape and obviously corresponds to a clock-pulse channel.

It was decided to employ a slow conversion and to forego immediate use of a core storage. Thus continuous motion of magnetic tape is employed and control of paper tape "Stop" "Start" is used in lieu of the core memory. The reading rate of the paper tape then sets the maximum speed at which conversion takes place. A Potter paper tape reader, Model 903, was chosen, with a maximum reading rate of 300 characters per second, and capable of stopping on character upon receipt of the stop signal. This reading rate sets the speed of the magnetic tape at 1.5-in. per sec in order to meet the magnetic tape format. An Ampex 1100 Series magnetic tape transport was chosen. Because the magnetic tape transport employs continuous motion, the stringent requirements of magnetic tape transports "Stop" and "Start" are not required.

The read-write and control electronics are transistorized, and a relay chassis is used to aid control of the transport (see Fig. 3). Included with the read-write control electronics is an electronic system of error checks to aid in checking and editing the paper tape. The read-write electronics reads the information on the paper tape and transfers it to the magnetic tape. Reading is photoelectric and magnetic heads write onto the magnetic tape. The writing employs non-return-to-zero techniques, which reduces the complexity of writing circuitry. A center-tapped magnetic head is employed, driven by a flip-flop that allows us to write a binary 1 by simply flipping the flip-flop.

The end-of-record or end-of-file information is placed on the magnetic tape by simply stopping the paper tape and allowing the magnetic tape to move the proper distances.

There are two modes of operation--check and operate. The conversion occurs during the operate mode. Conversion of information from paper tape



MU-22545

Fig. 3. System block diagram.

to magnetic is a channel-to-channel transfer, i. e., Channel 1 on paper tape to Channel 1 on magnetic tape, Channel 2 on paper tape to Channel 2 on the magnetic tape, Channel 3 on paper tape to Channel 3 on magnetic tape, etc. All end-of-records, end-of-files, characteristic tape marks, and longitudinal redundancy marks originate from the Space signal. The first Space signal simultaneously triggers the paper tape "Stop", stopping the paper tape, and a one-shot whose timing allows the magnetic tape to move 0.02 in. The trailing edge of the one-shot pulse generates the NRZ set and begins the timing cycle that will allow the magnetic tape to move 0.75 in. The NRZ set generates the longitudinal redundancy mark on the magnetic tape. The trailing edge of the 0.75-in. timing cycle sets a memory to remember that an 0.75 has been completed and "Starts" the paper tape. If an Anycode signal follows the Space signal, the 0.75 memory is reset and an end-of-record of information has been placed on the magnetic tape. If, on the other hand, the Space signal is followed by another Space signal, the paper tape is stopped, and the 0.75 memory is sampled to see if this is the second succeeding Space signal. This being the second succeeding Space, a timing cycle is started to allow the magnetic tape to move an additional 3.0 inches, giving a total magnetic tape movement of 3.75 inches. The trailing edge of this timing cycle resets the 0.75 memory, sets a 3.75 memory, generates the characteristic tape mark, and initiates the 0.02-in. one-shot to allow the 0.75 in. timing cycle to begin all over again. As this latter timing cycle times out, the paper tape is started again. If an Anycode follows the second Space signal, all memories are reset and an end-of-file of information has been written. If another Space signal follows, the paper tape is stopped. The 3.75 memory is sampled and the magnetic tape transport is stopped. This is an end-of-conversion as three succeeding Spaces define an end-of conversion.

The .020-in. timing cycle, 0.75-in. timing cycle, and the 3.00-in. timing cycle are of 16 msec, 0.5 sec and 2 sec duration respectively. All these times are simply generated when using vacuum tube circuitry but, except for the 16 msec time, they can be difficult for transistor circuits to generate. This problem was simply solved by constructing a counter for the 60 cps line frequency, which provided a very accurate timing circuit.

The magnetic tape-head write flip-flops are set to the reset position at the beginning of each conversion. The NRZ reset pulse triggers and resets the write flip-flops to the resets position, insuring that the longitudinal redundancy is always an even check. The characteristic tape mark is generated by setting the Nos. 1, 2, 3, and 4 and write flip-flops to the set position.

The paper tape format chosen was easily adapted to a number of checks for editing paper tape errors. The following errors were found to be most probable; (1) The incorrect number of characters to construct an integral number of words between any two succeeding end-of-records, or between an end-of-record and an end-of file marks; (2) an improper end-of-record or end-of-file; and (3) an improper character which can be partially checked by looking and checking the parity on each character.

Although the Space and 8-signals may be the same, for purpose of discussion they are considered as different.

Considering first the six count error: as all records are in multiples of 36 bits (6 characters, one word), a count of characters will suffice to be

sure of the correct number of words between any two end-of-records or between an end-of-record and end-of-file. This is easily done with a counter of six. Any Anycode (character) must be followed by an Anycode or by a Space. The Space is followed by an Anycode. However, the only time that a Space should be followed by another space is to indicate an end-of-file. The counter of six is accompanied by a six count memory, continuously set by the Anycode and reset by the six counter. The six counter counts the Anycode and resets both the memory on the sixth count and itself at the same time. If the six count memory is set when the space pulse is generated, a six count error is indicated. If the six count memory is reset when the Space pulse is generated, then it is obvious that there is a multiple of six characters in the record. The six count error also checks the spacing between sprockets. If two sprockets are too close together, they seem to be only one count instead of two, thus generating a six count error.

An improper end-of-record or an improper end-of-file can be checked by looking at the Space and 8-signals. A proper end-of-record or end-of-file is designated by the presence of both the Space and 8-signals simultaneously. The absence of either is looked for in the following way: two coincidence circuits are developed, one looking for the coincidence of an Anycode and an 8-signal, the other looking for coincidence of a Space and a not-8 ($\bar{8}$) signal. If one of these conditions prevails, then either an improper end-of-record or end-of-file is present on the tape.

Last but not least is the lateral-parity check. This is a character by character check, thus giving a fairly thorough check on the paper tape. The parity of the tape can be either odd or even, and provision is made to check for both depending on which is in use. Although this check only looks for either the odd or even number of bits, correct information is assured by the use of the parity.

The function of the check mode is strictly for editing and checking the paper tape. The paper tape is allowed to run with the magnetic tape off, and the reading circuitry reads and checks for all the previously mentioned errors. If an error is present, the type of error is indicated and the paper tape is forced to stop on the character that has the error. This is conducive to rapid location and correction of all errors on the paper tape.

As the operation of the end-of-file and end-of-record marks stop the paper tape for periods of approximately two seconds and one-half second respectively, these times can certainly add up to loss of machine operating time when checking paper tape rolls of short records and files. For this reason, the check mode allows continuous motion of the paper tape, and the only stops occur when an error is indicated. Thus a 10-in. roll of paper tape can be checked in less than ten minutes regardless of the number of end-of-files and/or end-of-records present on the tape.

Another feature included to add to the reliability of the system was to keep an error check on the lateral-parity of the actual magnetic writing heads. The heads are sampled, and any change of head current in any head is stored. In this manner, checking parity on every character is written onto the magnetic tape. This allows for a complete check on the operation of the converter. Although an error in the recording parity does not stop the conversion process, a written record of errors can be kept to determine if a reconversion is needed.

This machine was developed specifically to obtain information on the magnetic tape in the 704 format described. A general-purpose machine that will handle 5, 6, 7, and 8 channel paper tape into 704, 709, 650, and other computer formats could be easily obtained from this specialized machine by making a few minor changes or additions. The following description is of the changes that can be made.

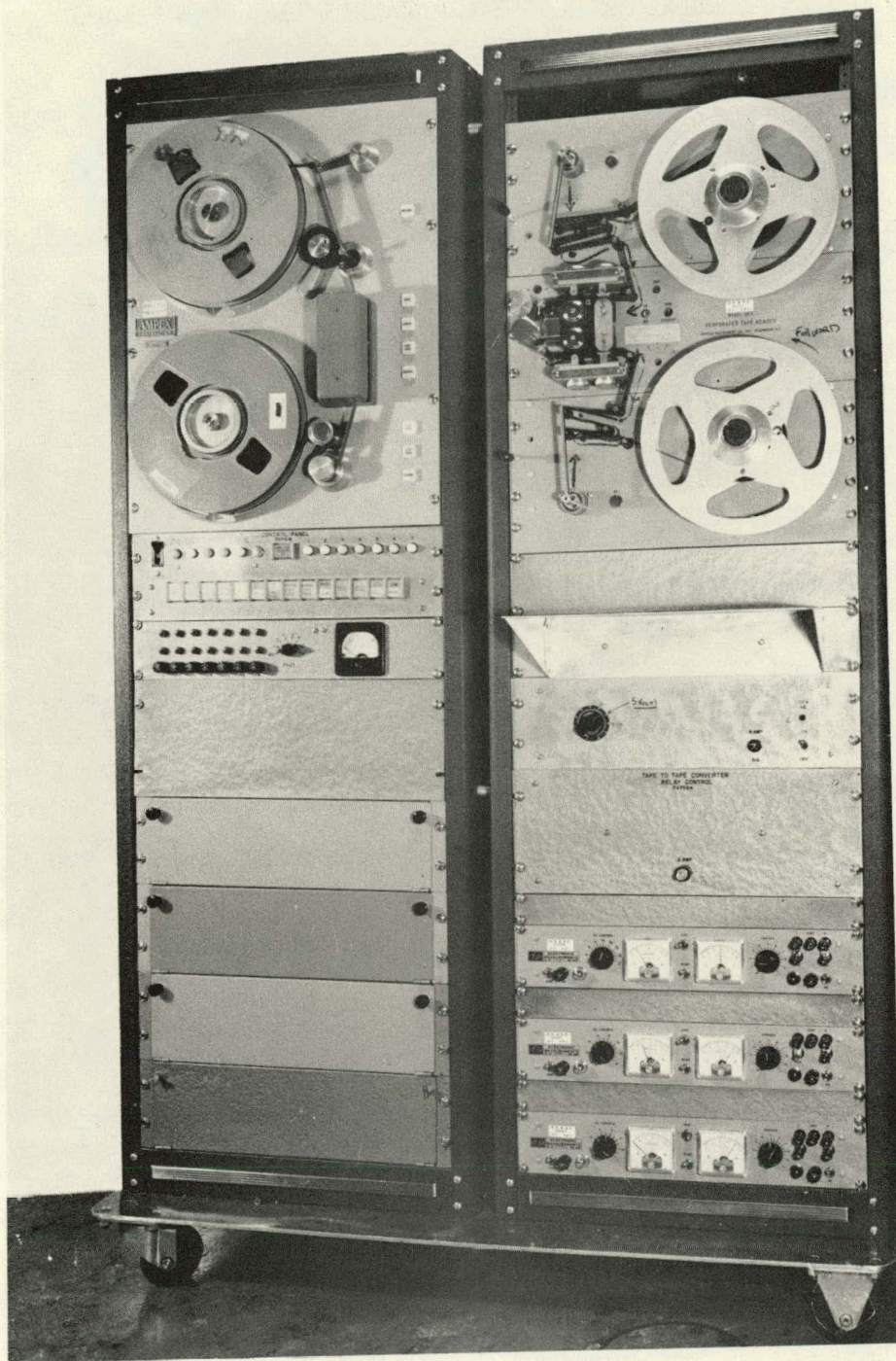
A simple selection system in the paper tape read electronics will enable a choice of either the 5, 6, 7, or 8 channel paper tape. Of course, the definitions of Space, Anycode, and Sprocket, still hold. Error checks can be modified in the following manner. The six count error can be changed to count the number of characters to suit the format at hand, or the six count error can be disabled to allow a random number of characters in any given record. The lateral parity can be left unchanged, since the selection system for the 5, 6, 7, or 8 channel paper tape can also select proper channels for parity check, even or odd. This would also set the parity for the write head check. In the 5 and 6 channel paper tape, parity can be generated in order to allow all 5 or 6 channels to be used for information. The only error check that would have to be completely disabled would be the check for an improper end-of-file or end-of-record marks. In 5, 6, or 7 channel tape the absence of the extra channel does not allow the search for a coincidence of a space and the extra channel.

Addition of a core memory will greatly increase speed of conversion, but will either decrease the maximum number of words in one conversion or will greatly increase the cost of the control electronics. To be more explicit, a large core memory has a capacity of approximately 200,000 bits, and paper tape has a bit density of 54 to 60 bits per inch, allowing each memory to hold only 250 to 350 feet of paper tape. The control electronics will have to be more complicated in order to carry out the conversion. The added conversion speed will have to be weighed against the obvious extra cost, in order to decide on the core memory.

The tape to tape converter consists of two racks of equipment.(Fig. 4). Each rack is a standard 19-in. rack, six feet high. Both racks are mounted on a platform having 4-in. caster wheels, thus giving the converter a high degree of mobility. Power consumption of the converter is 115 v, 60 cps, 1.2 kw input. It has been in operation only six months and therefore reliability figures are still quite sketchy. To date, 108 hours of operation has been the mean time between breakdowns.

Cost for development and fabrication of the converter has been:

Development	\$ 2960.00
Fabrication	<u>17000.00</u>
Total	\$19960.00



ZN-2661

Fig. 4. Tape-to-tape converter rack.

APPENDIX-TAPE TO TAPE CONVERTER PRINT LIST

7V3492	Fuse panel.	
5032	Photocell light power supply.	
6493	4X- 'AND' board Nos. 5, 9, 10, 19, 27, 29, 37, 41, 42, and 58 to 80 inclusive.	
6502	Dual flip-flop board Nos. 7, 8, 12, 13, 14, 15, 17, 18, 23, 24, 25, 26, 28, 43, 44, 45, 46, 54, 55, 56, 57.	
6513	Dual one-shot board Nos. 21, 40, 75.	
6523	Invertor board No. 31.	
6532	Standard 'OR' board Nos. 4, 6, 11, 16, 22, 30, 78.	
6732	Differentiating 'OR' board No. 52.	
6742	Time delay board No. 32, 77.	
7131	Head photocell connections .	} Potter ²
7143	Photo diode difference amplifier.	
7153	Drive amplifier.	
7164	Reel amplifier.	
7182	Magnetic head drivers board Nos. 47, 48, 49, 50.	
7192	Parity generator board No. 33.	
7452	Photocell preamplifier board Nos. 1, 2, 3.	
7462	Brake and clutch amplifier board No. 36.	
7472	Light bank drivers board Nos. 34, 51.	
7482	Counter clock pulser board No. 20.	
7491	Print list.	
7494-1	Bin wiring.	
7494-2	Bin wiring.	
7494-3	Bin wiring.	
7494-4	Bin wiring.	
7514	Control panel.	
7524	Relay control.	
7762	Photo-cell adjusting board No. 39.	
7773	BUD cabinet layout.	
7894	Block diagram	
7964	AMPEX FR11 tape control circuit. ³	
8372	Blocking oscillator transistor board Sch Nos. 35, 36.	
8805	Logig diagrams.	
8782	P.E. Head and test procedure. ²	

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Form A22-6500-3 (February 1960).
2. Potter 903, Perforated Tape Transport Manual, pp. 24-30 (March 1959).
3. "Ampex Series FR 1100 Equipment Operation and Maintenance Manual."

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