

an introduction to

HP DIGITAL MAGNETIC TAPE UNITS

AN INTRODUCTION TO HP DIGITAL MAGNETIC TAPE UNITS



Mountain View Division
690 East Middlefield Road
Mountain View, California 94040

INTRODUCTION

This Digital Magnetic Tape Training Manual is intended to provide a general overview of magnetic tape and tape units as a peripheral device. It should be helpful for those who have not been exposed to magnetic tape units as an initial training text or as a simplified reference for those whose contact with digital tape is infrequent.

Section I covers magnetic tape as a media discussing the tape, recording techniques and data formats.

Section II discusses tape drives outlining designs in current use and providing enough detail for a thorough understanding of the operation of a unit.

Section III provides the general concepts and problems of interfacing tape drives to a data system without getting into the detail of interface design considerations.

Section IV contains a detailed discussion of the Hewlett-Packard 7970 Series Electronics. This is broken down by transport electronics, NRZI data electronics, and PE data electronics.

The Appendix is a glossary which lists the terms commonly used for digital magnetic tapes and drives.

TABLE OF CONTENTS

Section		Page
	INTRODUCTION	ii
I	MAGNETIC TAPE FUNDAMENTALS	
	Storage Device Characteristics	1-1
	Why Magnetic Tape?	1-2
	Recording Media Comparison	1-3
	Product Characteristics	1-4
	The Magnetic Tape Media	1-5
	Magnetic Tape Construction	1-6
	Magnetic Tape Quality	1-7
	Quality Assurance	1-8
	Environmental Limitations	1-9
	Tape Wear	1-10
	Head To Tape Contact	1-11
	Magnetic Tape Life	1-12
	The Best Tape	1-13
	Magnetic Recording Heads	1-14
	The Recording Process	1-15
	Head Construction	1-16
	Head Assembly	1-17
	Head and Tape Problems	1-18
	Gap Scatter	1-19
	Tape Skew	1-20
	Write Time Asymmetry	1-21
	Pulse Crowding	1-22
	Summary of Four Problems	1-23
	Digital Recording Techniques	1-24
	Common Techniques	1-25
	NRZI Versus PE	1-26
	Data Formats	1-27
	Industry Standards	1-28
	Records	1-29
	Nine Track 800 CPI NRZI Format	1-30
	Nine Track 1600 CPI Phase Encoded Format	1-32
	Nine Track Format Comparison	1-33
	Nine Track Track Numbering	1-34
	Nine Track Bit Scrambling Criteria	1-35
	Seven Track NRZI Triple Density Format	1-36
II	TAPE DRIVE FUNDAMENTALS	
	Introduction To Digital Tape Drives	2-1
	Types of Digital Tape Drives	2-2
	Digital Tape Drive Design	2-3
	Basic Elements	2-4

TABLE OF CONTENTS (CONT)

Section	Page
Mechanical Elements	2-5
Reel Drives	2-6
Reel Braking	2-7
Tape Buffering	2-8
Capstan Control	2-10
Head and Guide Assemblies	2-11
Head Types	2-12
Program Restrictions	2-13
Inter-Record Gap	2-14
Electronic Elements	2-15
Block Diagram of Elements	2-16
Reel Servo	2-17
Capstan Servo	2-18
Motion Control	2-19
Write Control	2-20
Write Amplifiers	2-21
Read Control	2-22
Read Amplifiers	2-23
Power Supply	2-25
III INTERFACING FUNDAMENTALS	
Introduction	3-1
Purpose of the Interface	3-2
Interfacing Elements	3-3
Data System	3-5
Commands	3-6
Status	3-7
Data	3-8
Tape Drive Lines	3-9
Interface Operations	3-10
Command Decoding	3-11
Status Encoding	3-12
Data	3-13
Interrupts	3-15
IV THE HP 7970 SERIES ELECTRONICS	
Simplified Block Diagram	4-1
Reel Servo Board	4-2
Capstan Servo	4-4
Power Supply	4-5

TABLE OF CONTENTS (CONT)

Section	Page
Motion Control Logic Functions	4-7
Logic for Load Point and Rewind	4-8
Simplified Load Operation	4-9
Simplified Rewind Operation	4-10
Unit Select Option	4-11
NRZI Data Electronics	4-12
Head Assembly	4-13
Static Skew	4-15
Simplified Read Electronics	4-16
Read Electronics	4-17
Simplified Write Electronics	4-19
Write Electronics	4-20
PE Data Electronics (To Be Supplied)	4-22
Appendix A Glossary	A-1

STORAGE DEVICE CHARACTERISTICS

WHY MAGNETIC TAPE?

ADVANTAGES

- LARGE STORAGE CAPACITY
- LOW COST
- REUSABLE
- RECORD/REPRODUCE SPEED
- STABILITY
- GOOD INTERCHANGEABLE MEDIA

DISADVANTAGES

- SERIAL ACCESS ONLY
- SLOW ACCESS COMPARED TO DISCS

Magnetic tape has become a universal means of storing digital information. The reason for this acceptance as a media will become obvious as we examine the advantages of magnetic tape.

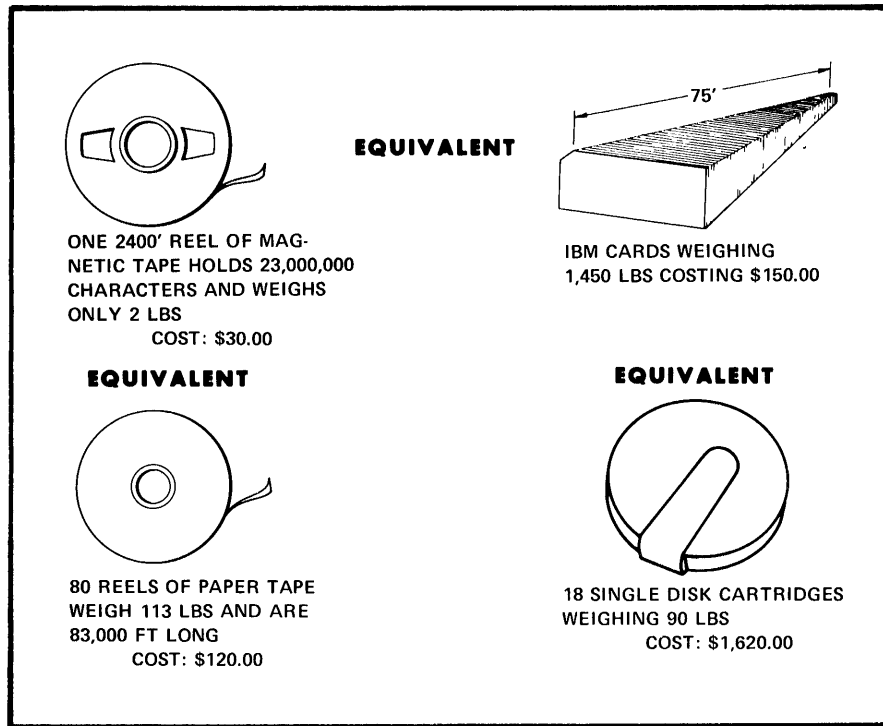
1. **HUGH STORAGE CAPACITY** – One reel of magnetic tape holds 23 million characters. The alternative media required to hold this many characters is shown in the media comparison on the next page.
2. **LOW COST** – The cost per bit of information stored is 1/4 to 1/5 that of cards or paper tape, even if the magnetic tape were not reusable.
3. **REUSABLE** – It can be erased and re-magnetized without degradation, in some cases as many as 10,000 times.
4. **READ/WRITE SPEED** – High compared to punch cards or paper tape. The transfer rate for cards is typically 800 characters per second while the transfer rate for magnetic tape is about 80,000 characters per second.
5. **STABILITY** – Magnetic tape retains its data indefinitely unless exposed to heat or a magnetic field.

Major disadvantages to magnetic tape are:

1. Slow access time when compared with discs, and
2. the fact that they may be accessed serially only.

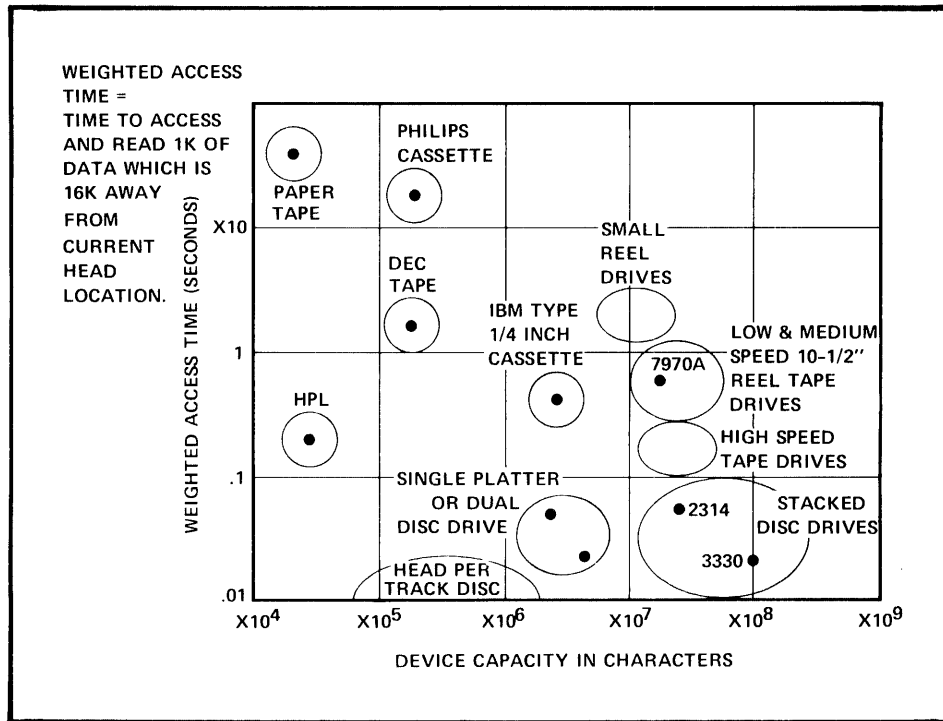
These disadvantages combine to make a magnetic tape difficult to edit or difficult to insert data in the middle of a file.

RECORDING MEDIA COMPARISON



The relative capacity and cost of the different mass storage media are placed in perspective by this drawing. Magnetic tape takes up less space and weighs less than any other media for an equivalent amount of storage. The cost is a fraction of the closest competitive media even on the basis of one time usage. IBM's new 3330 disc pack reduces the cost per bit of this media dramatically but it is still three to four times the cost of a reel of tape for an equivalent amount of storage.

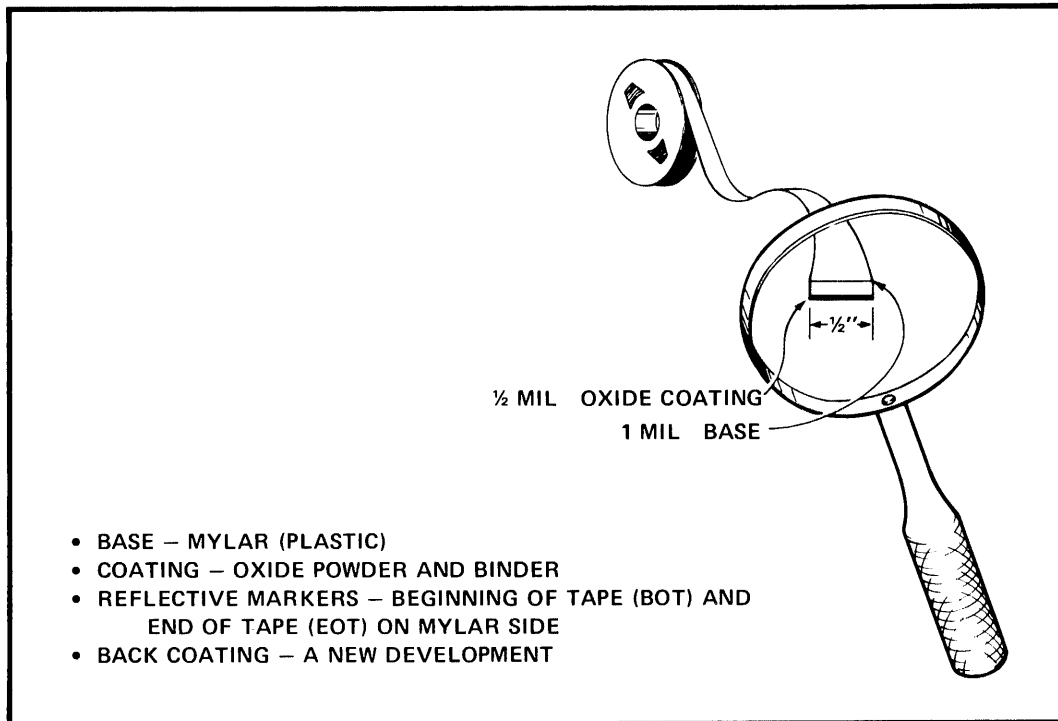
PRODUCT CHARACTERISTICS



The map above shows the alternative products which can be used for mass storage displayed according to their access time versus their capacities. Since the map is on a log scale, each gradation means an order of magnitude difference in either capacity or access time. Of course, as one expects, paper tape is both slow and small in capacity. The better product characteristics, are down and to the right on the map. Note that the only media which has better capacity than magnetic tape is a stacked disc drive, the new IBM 3330 type. Head per track discs by comparison have an order of magnitude less capacity than a magnetic tape albeit two orders of magnitude faster access. Although such a map leaves out factors such as cost, removable media, and random or serial access, it helps to structure the products available in the market place in a way which gives some perspective on the alternative devices.

THE MAGNETIC TAPE MEDIA

MAGNETIC TAPE CONSTRUCTION



The structure and the dimensions of magnetic tape are shown above. The plastic base is one-half inch wide and one mil (1/1000 inch) thick. The base is coated with a Ferro magnetic substance one-half mil thick. The coating is a combination of a magnetic oxide powder and a binding agent specifically formulated to have particular characteristics desirable in a magnetic tape for digital recording. Coatings vary not only in their magnetic properties but also in hardness and durability. There are reflective markers on the back or mylar side of the tape, which are used to signify the beginning of the tape (BOT) and the ending of tape (EOT). These markers are placed on the alternate edges of the tape.

Some newer magnetic tapes have a conductive coating on the back side of the tape. This coating is designed to dissipate the build up of static charges as the tape is handled. This prevents sticking between the layers of tape giving a better tape pack and preventing sticking of the tape on non-moving surfaces.

MAGNETIC TAPE QUALITY

OXIDE/BINDER COATINGS HAVE:

- HIGH PERMEABILITY – EASILY RECORDED
- HIGH RETENTIVITY – RETAINS MAGNETISM
- HIGH COERCIVITY – RESISTS STRAY FIELDS
- UNIFORMITY – STABLE OUTPUTS

PHYSICAL CHARACTERISTICS:

- COATING THICKNESS – UNIFORM
- COATING HARDNESS – TOUGH
- COATING SMOOTHNESS – CRITICAL
- TAPE WIDTH – HIGH TOLERANCE

Some of the parameters measured on magnetic tapes are:

1. PERMEABILITY – The higher the permeability of the tape the easier it is to record.
2. RETENTIVITY – The ability of the tape to retain its magnetism after the magnetizing force has been removed.
3. COERCIVITY – The resistance of the tape from being de-magnetized by stray fields.
4. UNIFORMITY – For a stable output and reliable data.

If one could have all of these measures easily it would be no problem in manufacturing magnetic tape. Unfortunately, there are usually trade-offs between permeability and retentivity. These are influenced not only by the oxide used, but also by the binding agent. The problem is further complicated by the fact that tapes having different characteristics may be better in some applications than in others. For example a tape used for archival records needs high retentivity and coercivity while a daily sales tape would require high permeability.

There are some purely physical aspects that influence the quality of the tape. The smoothness of the oxide surface and the thickness of the oxide on the tape affect the output. Great care must be taken to ensure that these factors are carefully controlled. The final process in the manufacture of tape is the slitting. A web on magnetic tape is cut with knives spaced a half inch apart. If the web wobbles during slitting or the machine becomes misaligned, tape which is practically unusable on any transport is produced.

QUALITY ASSURANCE

TAPES ARE CERTIFIED FOR

- ZERO PERMANENT ERRORS
- SPECIFIED RECORDING DENSITIES
- SELECTIVE PROCESS

CERTIFYING ALSO TESTS

- COATING
- SLITTING

There are so many parameters which can cause tape quality to vary that the manufacturers certify tape. Certified tape means that the tape manufacturer has successfully recorded and reproduced data on the entire length of the tape without finding "any permanent errors" at a specified recording density. The certification process is, however, a selective process. The tapes failing to pass the test at the highest recording densities are retested at lower densities until the tape passes or is finally rejected. In actual operating environments, however, a section of tape which cannot be recorded upon can be skipped over during the write process.

Certifying does not test the specifications of the coating formulation. This is done by sampling the process. Certifying does, however, test the coating and slitting operations and assures the customer that he is buying a useable tape.

ENVIRONMENTAL LIMITATIONS

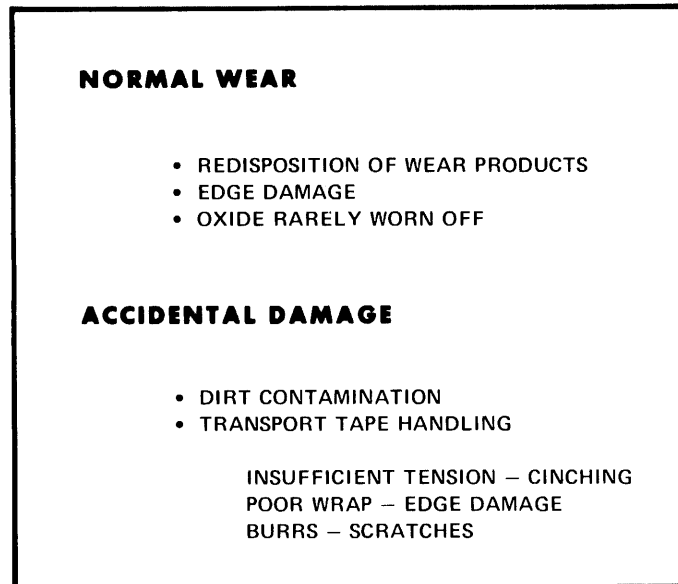
- EASILY CONTAMINATED BY DIRT
- DETERIORATION OF OXIDE, BINDER, OR BASE MATERIAL WHEN EXCEEDING TEMPERATURE AND HUMIDITY RANGES:

TEMPERATURE RANGE	40° TO 90°F
HUMIDITY RANGE	20 TO 80%

Magnetic tape must be used in a clean environment. It can easily be contaminated by all types of dirt. Recommendations of tape manufacturers go to such lengths as recommending no smoking in rooms where magnetic tape is used as well as anti-static drapes and daily moppings of the floor. The point is that an environment cannot be too clean. This is because dirt on the tape will cause drop-outs because of the separation loss. Separation loss is discussed in the section on head to tape contact.

Temperature and humidity ranges are specified because of their effect on the oxide, the binder, or the base material. Outside of the specified ranges the oxide or the binder may decompose or lose adhesion to the base material. Tape manufacturers say that it is impossible to predict the specific effect of any of the factors of temperature, humidity, tape tension, and friction; therefore, the temperature and humidity ranges are ranges where tape performance is relatively well known.

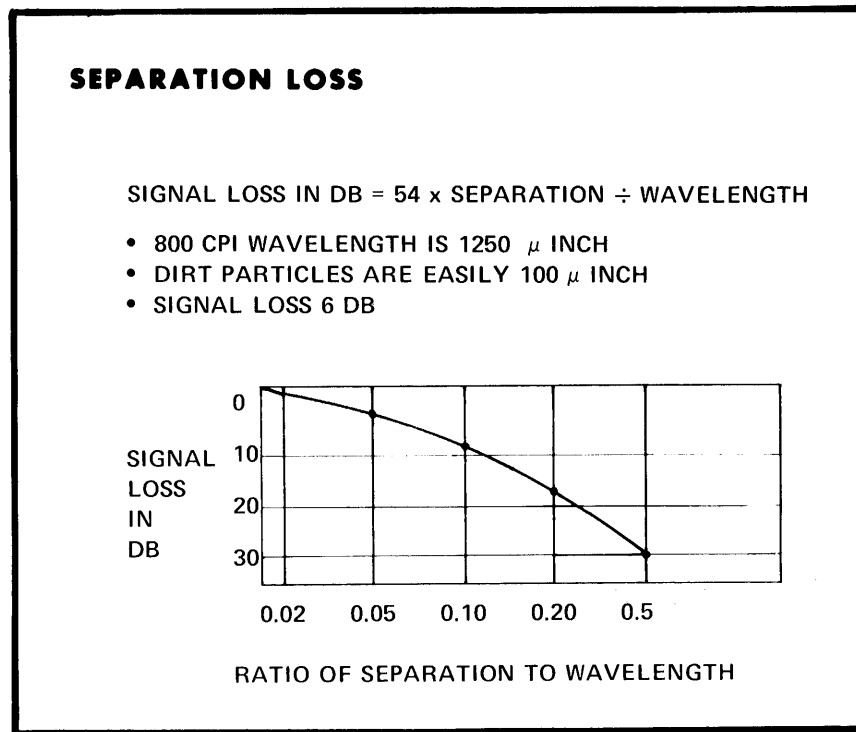
TAPE WEAR



Normal tape wear is primarily due to the redistribution of wear products on the tape. Certain combinations of temperature and pressure cause accumulated material on the head or tape guides to recombine with the surface causing a bump on the tape. These redeposited lumps are often more firmly attached to the tape than the original magnetic coating. The effect of these lumps on signal strength is discussed on the next page. A second cause of wear is edge damage. The action of the tape against the tape guides and other elements in the tape path will sometimes chip oxide from the edges of the tape. This not only reduces signal strength from the outer tracks, but also serves as a ready source of wear products which can be redeposited on the tape. Contrary to what might seem reasonable, the oxide is rarely worn off the tape by action of the heads or guides to such an extent as to cause dropouts.

Tape life, of course, is limited to by accidental damage. Foremost in the realm of accidental damage is contamination by dirt. Tape handling by the transport is also a source of accidental damage to the tape. If the tape tension is insufficient when the tape is wound on the reel, the tape can be damaged by cinching. Cinching is simply the tape being pulled from the reel without any movement of the reel. When this happens the layers of tape toward the center of the reel will buckle causing a permanent crease in the tape. The guiding of the tape on a particular transport may cause a poor wrap, i.e., the layers on the reel shift from side to side. The tape may then be damaged simply by picking up the reel by the flanges and crushing the protruding edges of tape. Microscopic burrs on the heads of the tape drive may also cause tape damage by scratching grooves in the tape. Although a groove may be very slight in depth on one layer of tape, when this is compounded through a whole reel of tape, the outer layers of the tape will become ridged. This ridge can run the entire length of the tape.

HEAD TO TAPE CONTACT

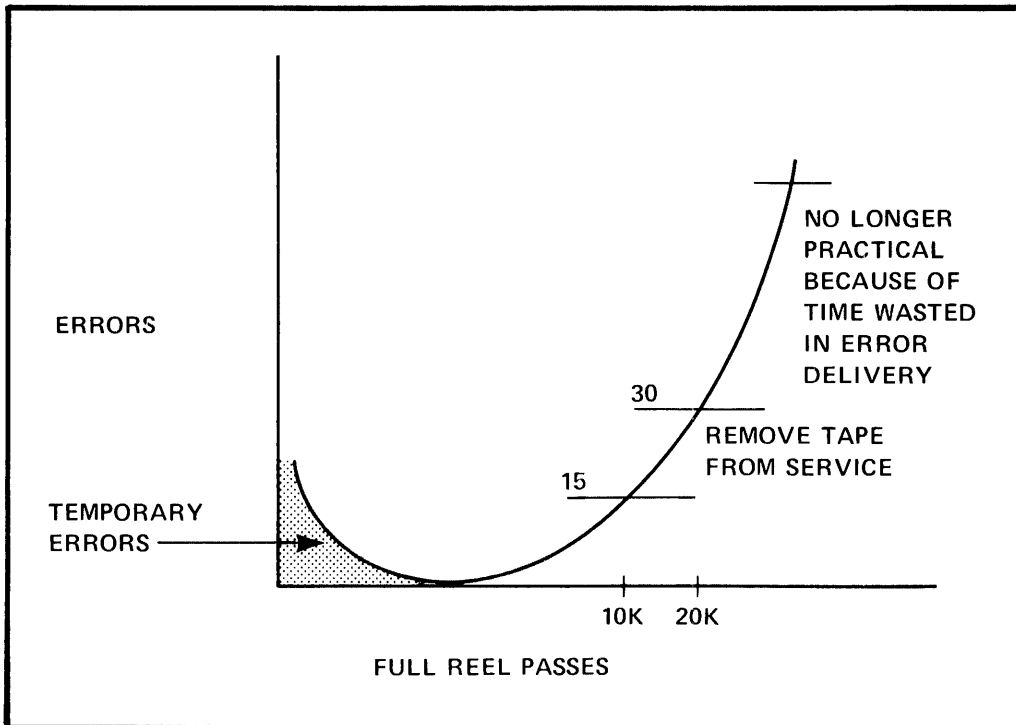


The primary reason for dropouts in magnetic tape is due to “separation loss”. This effect says that the signal strength either going onto tape or coming off of tape is reduced by any separation between the head and the tape. The accompanying chart shows what happens. The formula for signal loss is:

$$\text{dB Signal Loss} = \frac{54 \times d}{\lambda} \cdot \frac{(\text{separation})}{(\text{wavelength})}$$

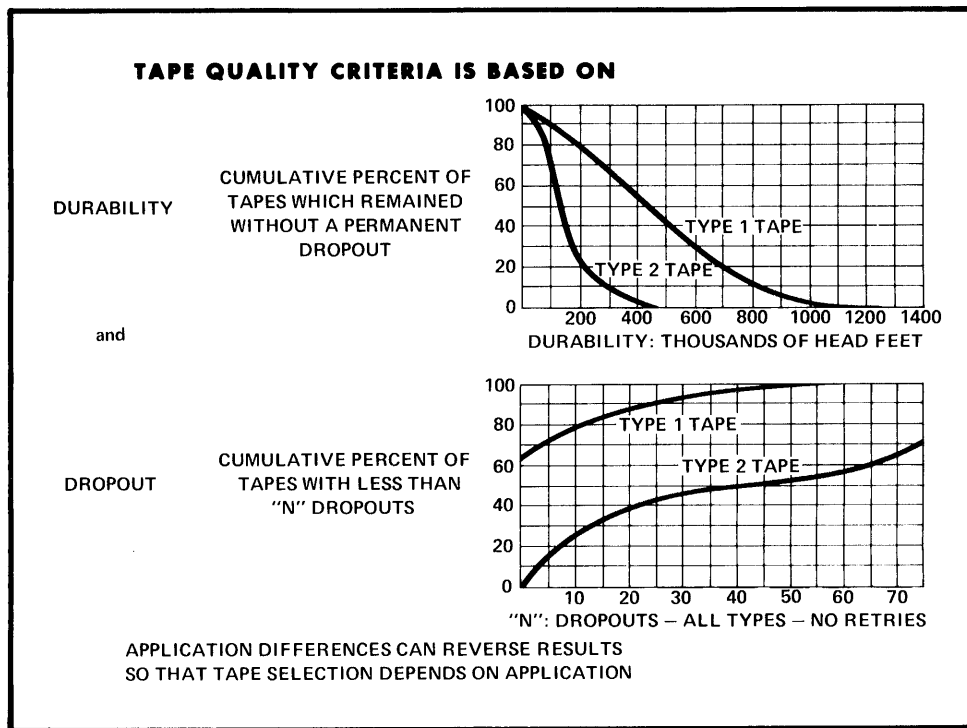
At 800 characters per inch the wavelength is 1250 microinches. A particle of dirt may easily reach 100 microinches. When the dirt particle on tape passes over the head, the result is a 6 dB loss in signal. If this loss occurs both on the record and the reproduce processes the total effect is a 12 dB loss of signal or a reduction of the amplitude of the reproduced signal by 3/4 of what can be obtained with a clean tape.

MAGNETIC TAPE LIFE



The accompanying chart shows the general performance of a magnetic tape over its life. The temporary errors noted on the left are the result of surface irregularities which are smoothed by the movement of the tape over the head and guides. Some manufacturers burnish or polish the tape in an attempt to eliminate these temporary errors. As the tape ages the number of errors will increase as wear or damage to tape increases. Good grades of tape and a tape drive with a good performance characteristic will give tape life on the order of 10,000 passes before a reel of tape needs to be removed from service.

THE BEST TAPE



Tapes can be compared on the basis of their durability and their drop activity. Durability is the number of head feet* traveled before a tape experiences its first permanent dropout. Dropout activity is the number of dropouts for a given amount of head feet of wear. These are statistical measurements and can be interpreted only on the basis of a quantity of tapes.

The chart on durability shows the percentage of tapes which produce no dropouts plotted against a figure of head feet of wear. Six hundred thousand feet of head wear represents two thousand passes, if three hundred feet of tape is used for the test.

The dropout activity shows cumulative percentages with less than N dropouts plotted against the number of dropouts. For 30 dropouts, tape type 1 has 90% of its tapes with less than 30 dropouts while tape type 2 has only 25% of its tapes with less than 30 dropouts.

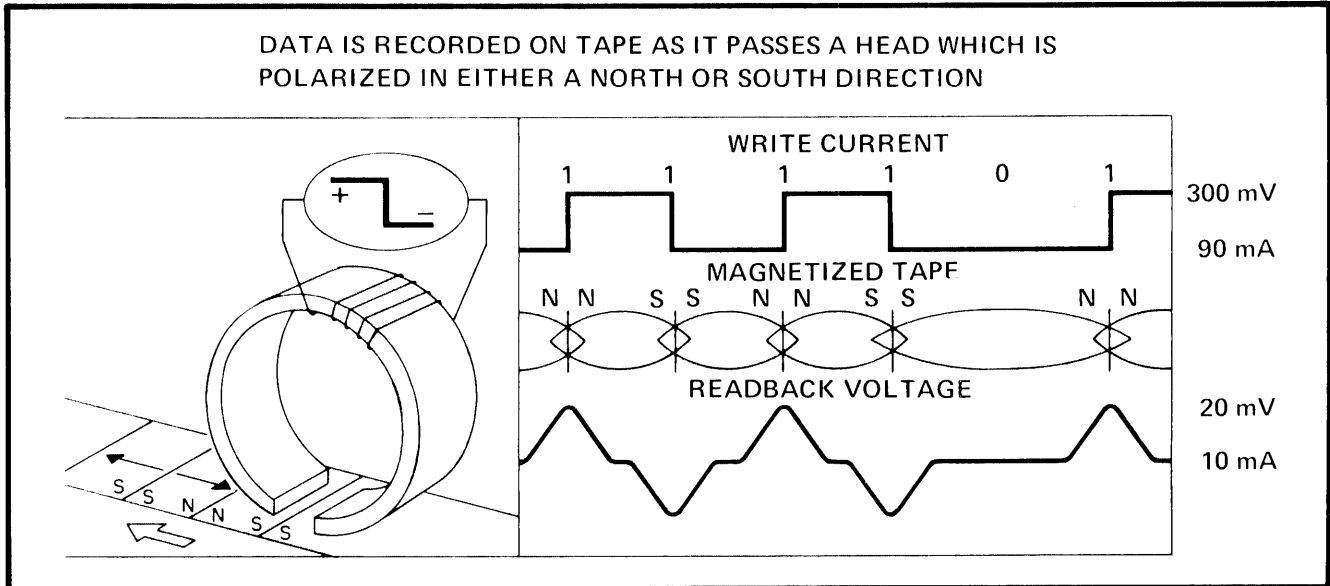
Tape manufacturers are quick to remind users that test conditions may not be similar to their usage and that a given application may materially affect the results. The example of archival records or continuously updated records was given earlier. Tape handling characteristics of a particular tape drive will also influence the results, but tape and application are the dominant factors.

The quality of tapes has been steadily improving over the past few years so that generally any good grade of a recognized band will be adequate. A customer wanting the optimal tape must do his own testing.

*Tests are run using a few hundred feet of tape on a shuttle.

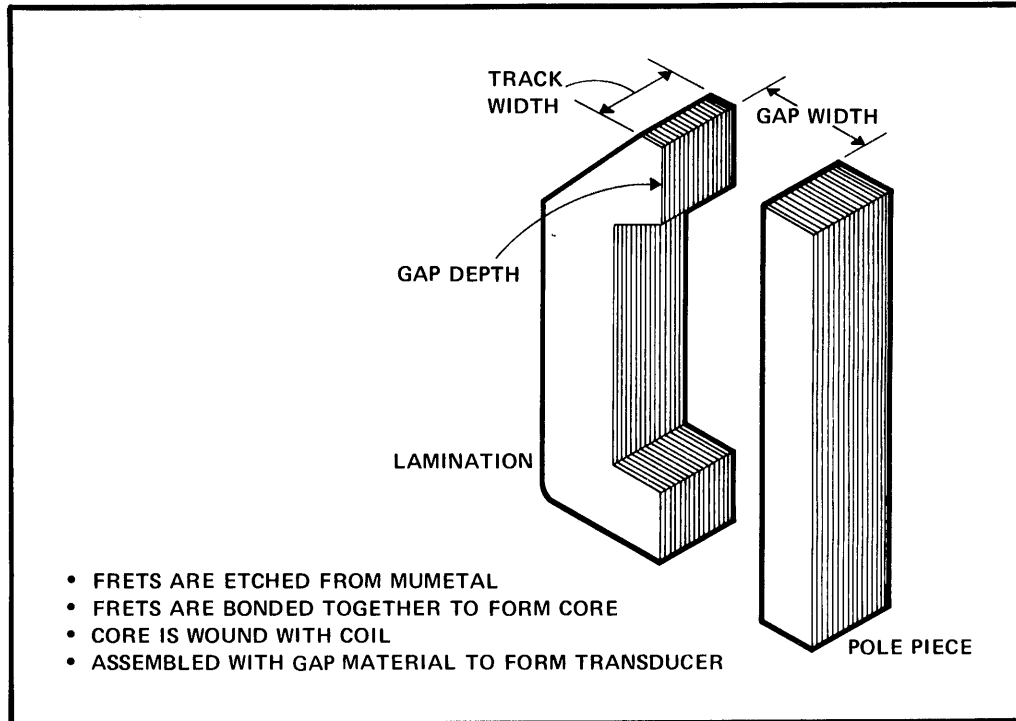
MAGNETIC RECORDING HEADS

THE RECORDING PROCESS



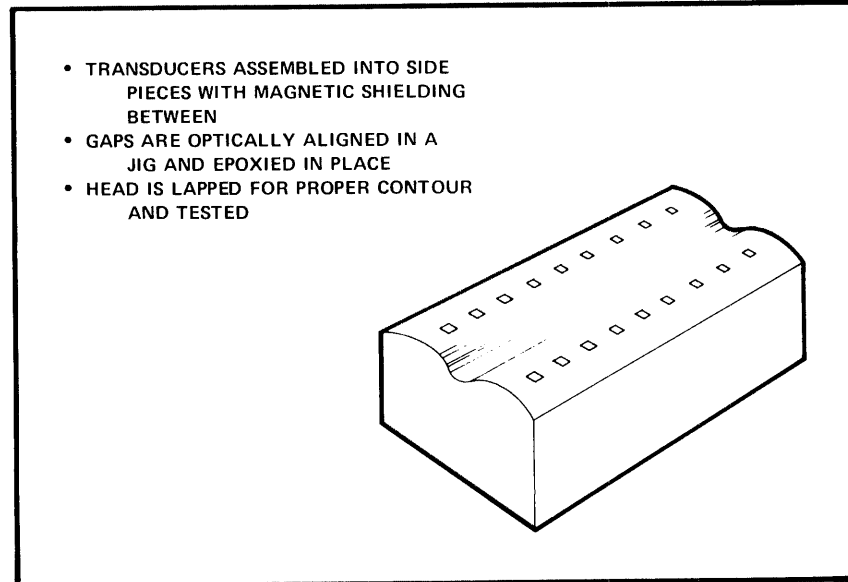
Data is recorded on tape as it passes by a head which is polarized one direction or another. This lays down a series of magnets oriented in first one direction and then the other. The record process is completed as the tape leaves the back edge of the record head. The write current wave form is shown above. For the read process, the changing flux on the tape induces a voltage in the head coil winding as the tape passes. This voltage takes the general form as shown above. This analog voltage must be amplified and reconverted into the digital form from which it originated. Note that the relative amplitudes of the write current and the read back voltage are different by an order of magnitude. Because the head is simply an electro magnet the same head can be used for both reading and writing; however, as is usually the case in physical systems the record process and reproduce processes can be best optimized by using two different heads.

HEAD CONSTRUCTION



A head is essentially a small transformer with only one winding and with the core material divided into two pieces. The core material is a mu metal which is etched from a thin sheet of metal and then bonded together to form a core. The C-shaped laminated core is then wound with a coil. A complete transducer is built by assembling the "C" part of the core and the bar piece of core together with some gap material in between. The gap material provides the separation which forces the lines of magnetic flux to travel into the tape instead of through the material to complete the flux path. Dimensions on the transducer which are important are the track width, the gap width, and the gap depth. The gap width determines the high frequency cut off of the head. The gap depth will determine the life of the head due to wear. The track width is normally that which assures industry compatible tapes.

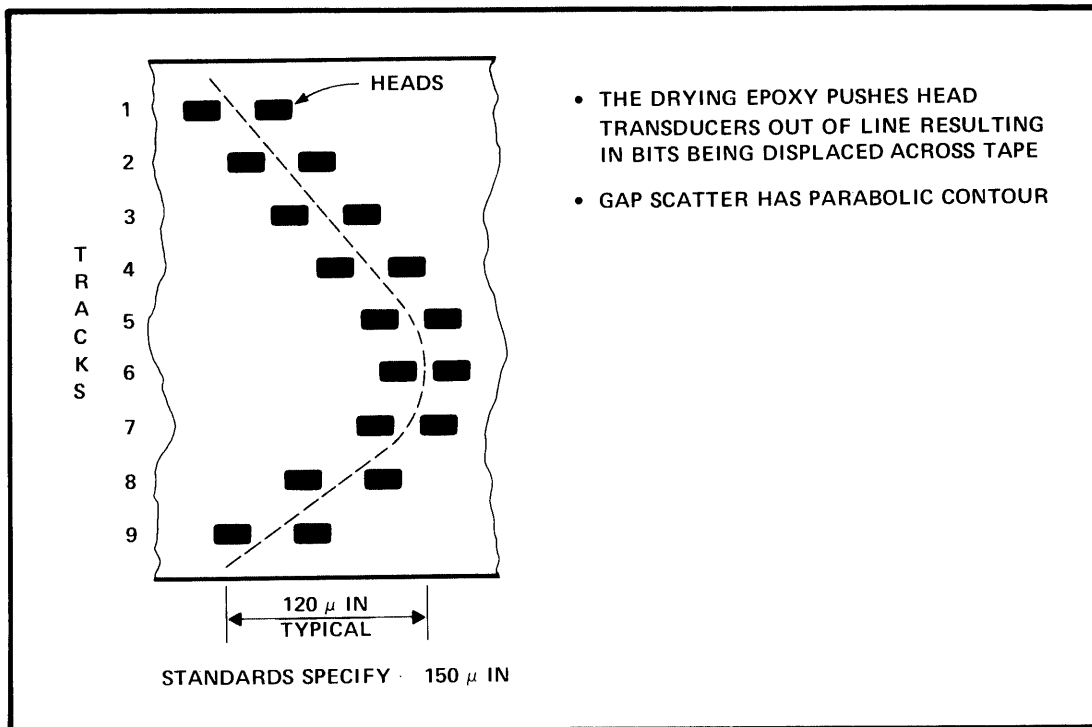
HEAD ASSEMBLY



To build a head the individual transducers are assembled into a jig which allows shielding to be placed between the transducers and side pieces to be added to the whole assembly. The gaps of the individual transducers are optically aligned and then epoxyed in place. The head is then lapped for proper contour, final assembly is made and then the head is tested. This brings us to the four problems which are created by the recording process and the head.

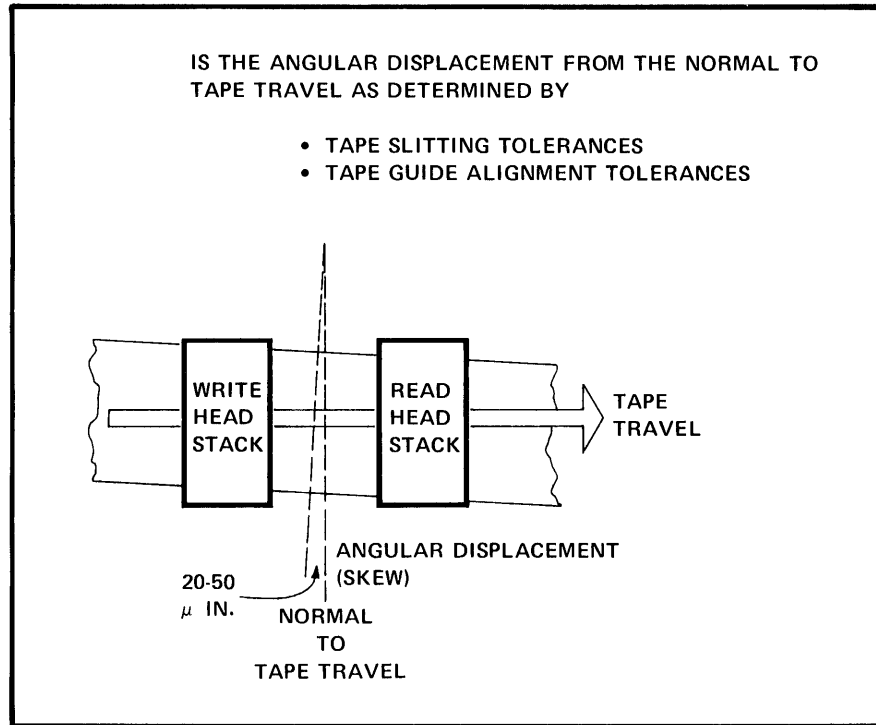
HEAD AND TAPE PROBLEMS

GAP SCATTER



Gap scatter is a measure applied to the tolerances which prevent either 7 or 9 transducers from being perfectly aligned. In spite of the fact that the transducers are optically aligned the drying epoxy pushes the transducers out of line because of its differential drying action. This gap scatter is generally a parabolic contour. Standards in use today specify that gap scatter is less than 120 microinches. Some manufacturers specify gap scatter as low as 80 microinches. Aside from the problem of eliminating gap scatter during the production process, gap scatter produces problems in attempting to record bits of data on tape that are perfectly aligned.

TAPE SKEW



Tape skew is another contributing factor that prevents the individual bits of a character from being perfectly aligned on tape. Tape skew is essentially an azimuth shift in the tape to head contact. This azimuth shift is caused by tolerances in the tape guide alignment, and by slitting tolerances when the tape is manufactured. Typical specifications for tape skew are from 20 to 50 microinches.

SUMMARY OF FOUR PROBLEMS

PROBLEM	TYPICAL ERROR	EFFECTIVE ON		TOTAL * POSSIBLE
		WRITE	READ	
GAP SCATTER	120 μ IN	YES	YES	240 μ IN
TAPE SKEW	50 μ IN	YES	YES	100 μ IN
WRITE TIME ASYMMETRY	75 μ IN	YES	NO	75 μ IN
PULSE CROWDING	50 μ IN	YES	YES	100 μ IN
				515 μ IN**
<p>*THIS MEASURE IS TO BE TAKEN FOR ILLUSTRATION PURPOSES ONLY</p> <p>**APPROXIMATELY 1/3 OF DISTANCE BETWEEN RECORDED BITS</p>				

The effect of the four problems, previously described, on individual bit displacements is shown in the table above. In spite of the fact that initially the theoretical spacing between pulse flux transitions was 1250 microinches, one can see that total displacement may vary on individual tracks up to 1/3 of the total distance. To help compensate for these inherent problems, a number of techniques either mechanical or electrical have been designed to overcome or circumvent the problems. These alternatives are discussed in the section on fundamentals of a tape drive under read and write amplifiers.

DIGITAL RECORDING TECHNIQUES

COMMON TECHNIQUES

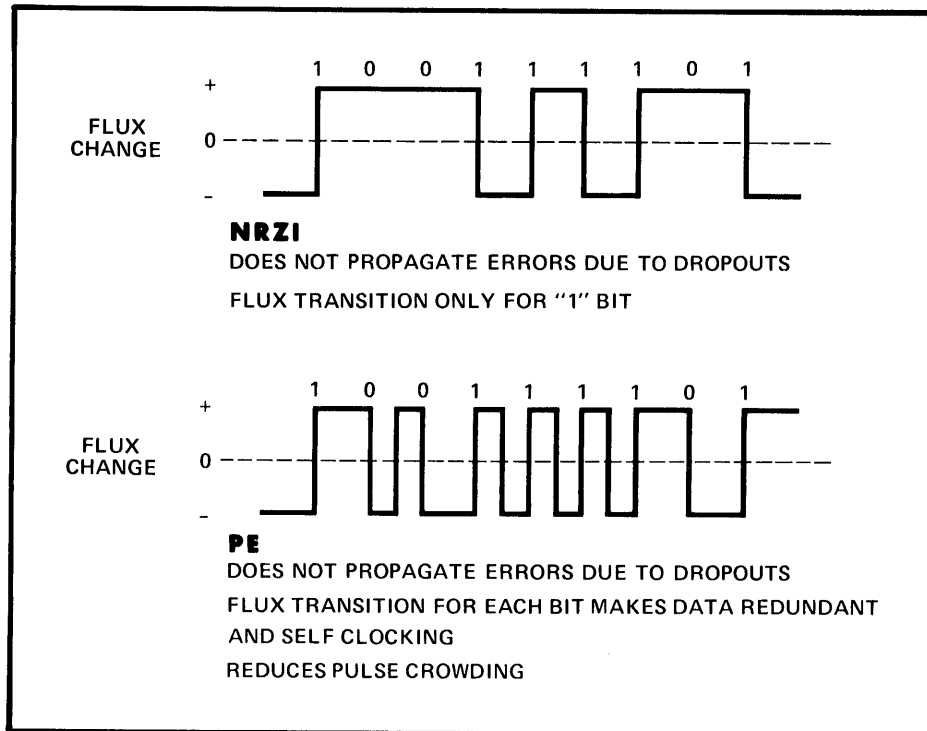
NRZI (NON-RETURN ZERO INVERSION)
PE (PHASE ENCODING)
NRZ (NON-RETURN ZERO)
RZ (RETURN ZERO)
RB (RETURN BIAS)

The standard techniques used in digital recording today are:

1. NRZI or non-return to zero inversion.
2. PE or phase encoding.

OTHER TECHNIQUES have been used, however, none today are widely used for information interchange. These are RZ (Return to Zero), NRZ (Non Return to Zero), and RB (Return to Biase). The return to zero technique attempts to return to zero flux state on the tape using a positive shift for a one and a negative shift for a zero. Although relatively simple in concept the implementation of this technique produces less reliable data than the other techniques. The return to bias techniques is the manner in which most people imagine digital recording takes place. For each "1" bit the flux is changed and returned to the original state. Non Return to Zero technique uses a flux change each time a bit differs from the one before it. This has the unfortunate property of propagating errors because the code counts on obtaining each individual bit in order to be able to interpret the succeeding bit.

NRZI VERSUS PE



The figure shows graphically the differences between the NRZI code and the PE codes. Failure to read one transition in the NRZI code does not cause the succeeding bits to be recognized as something else since zero bits are represented by no transition while one bits are represented by a flux transition.

Phase encoding on the other hand, recognizes a zero bit by a flux transition in one direction while a one bit is recognized by a flux transition in the opposite direction. These flux transitions must take place in the middle of a bit cell. Flux transitions at the end or beginning of the bit cell simply prepare for the proper transition to occur during the bit cell. This requires twice as many flux transitions on tape for an equivalent amount of data than does the NRZI code. It does, however, have two advantages:

1. Pulse crowding is limited because of the presence of two fundamental frequencies.
2. The data is self clocking and fully redundant.

The implications of the first point were covered in the page on pulse crowding. The second point is covered in the comparison of NRZI and PE formats on page 1-32.

DATA FORMATS

INDUSTRY STANDARDS

ORGANIZATIONS

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
FORMERLY USA STANDARDS INSTITUTE (USASI)
STANDARDS LABELED AMERICAN STANDARD CODE FOR
INFORMATION INTERCHANGE (ASCII)
RECORDED STANDARDS PROPOSED TO ANSI BY BUSINESS
EQUIPMENT MANUFACTURERS ASSOCIATION (BEMA)
UNRECORDED STANDARDS PROPOSED TO ANSI BY ELECTRONICS
INSTRUMENT ASSOCIATION (EIA)

STANDARDS

UNRECORDED – TAPE PHYSICAL DIMENSIONS AND PROPERTIES
RECORDED – RECORDING PARAMETERS AND FORMAT

CURRENT STANDARDS

9-TRACK 800 CPI NRZI
9-TRACK 1600 CPI PE
7-TRACK 200, 556, 800 CPI (DE FACTO IBM STANDARD)

There is an organizational structure which has been created to propose and approve standards for information interchange. Standards are now approved by the American National Standards Institute (ANSI) and the standards are called the American Standards Code for Information Interchange (ASCII). The standards which exist today are standards both for unrecorded tape and for recorded tape. The recorded standards consist of recording parameters, such as head current and data formats. These standards have been proposed primarily by the equipment manufacturers. The recorded standards are proposed to ANSI by the Business Equipment Manufacturers Association or BEMA. Attempts are being made to combine the unrecorded and recorded standards into a single standard proposal for future standards such as BEMA's proposed Philips Cassette Standard. The current standards are:

1. 800 CPI NRZI 9 track
2. 1800 CPI PE 9 track (Not yet finally approved, but eminent)

The 7 track 200, 556, and 800 CPI standard is a defacto (IBM) standard. The 7 track data format has never had formal acceptance by a national group.

Additional standards which will be considered in the near future are an 1/8" cassette standard which is single track 800 bits per inch phase encoded standard. The impetus for this standard comes from Philips and is all but accepted by the European Computer Manufacturers Association (ECMA) standards group. IBM has proposed a 4 track 1/4" standard using 1600 BPI phase encoding.

RECORDS



SINGLE RECORDS



BLOCKED RECORDS



VARIABLE LENGTH RECORDS



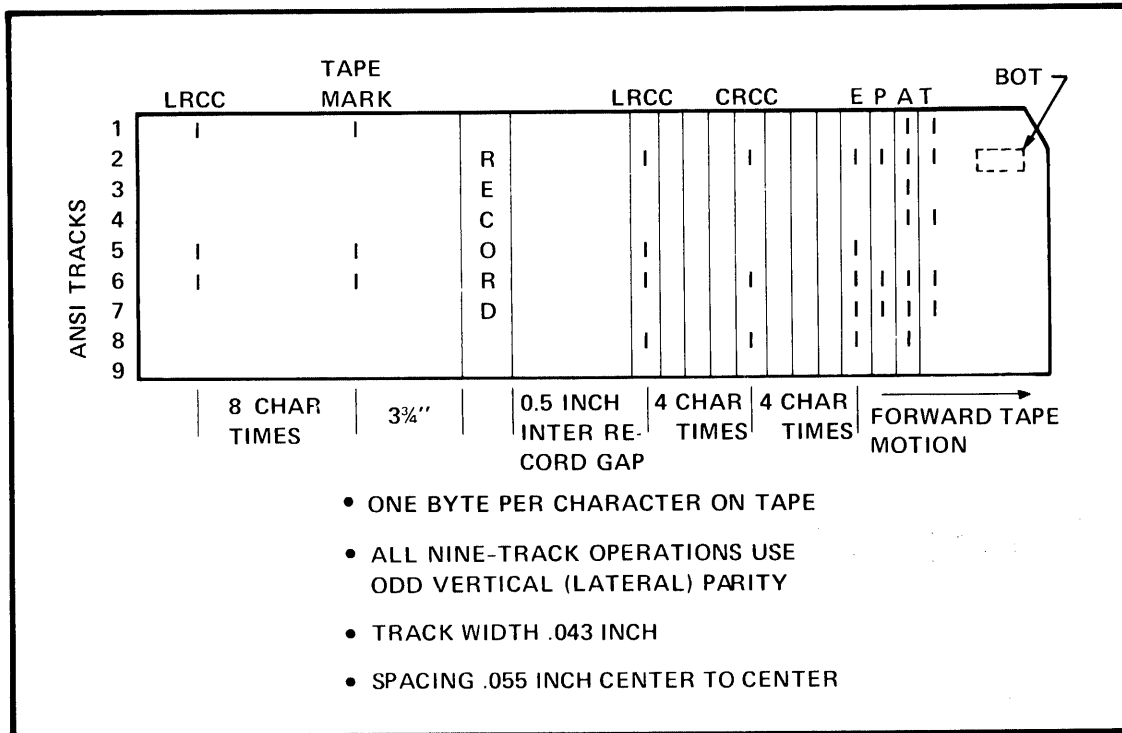
TM
TAPE MARK (FILE MARK)
WITH A FILE GAP

Recording format is defined by the programmer and the capabilities of the computer/controller. The single record format employs one logical record followed by an inter-record gap. These records may be either fixed or variable length.

Blocked records merge two or more logical records into one long block. Each individual record within the block is separated by a unique character.

A tape mark (file mark) is a one character record used by software to indicate the logical end of a file or group of records. Its format consists of a single character followed by a check character called a longitudinal redundancy check character. The tape mark is normally preceded by a 3 to 4 inch gap of erased tape although the gap is not a requirement.

NINE TRACK 800 CPI NRZI FORMAT



This data format was initially introduced by IBM along with their 360 computer series. It is by far the most commonly used format today. The layout of the data on tape is seen represented here. Individual records consist of a number of 8 bit bytes plus a parity bit followed by three character spaces, the cyclical redundancy check character, three character spaces, and finally a longitudinal redundancy check character.

The vertical parity bit is often referred to as a lateral parity bit. It is a bit added to each individual character so that the sum of the bits in the character is odd.

The cyclical redundancy is essentially a diagonal parity check which can be used to locate and correct single track errors. It is developed by adding each individual character in a record to the cumulative sum which has been shifted by one track according to the inverse of the bit assignments. (See page for bit assignments). When the sum is shifted rounding takes place in the center bit assignments if the highest order bit will become 1.

At the end of a record the CRCC will have a predetermined pattern. If it does not, the CRCC is matched against an error pattern register which has been accumulated in the data system. By shifting the CRCC a track at a time and continuing to match against the error pattern register, the track in error can be determined. That track is flagged and the record re-read. When the vertical parity error is detected the bit in the error track is inverted. This means of correcting errors will not work on multiple track errors. Many systems in use do not attempt to use the CRCC. The designers of these

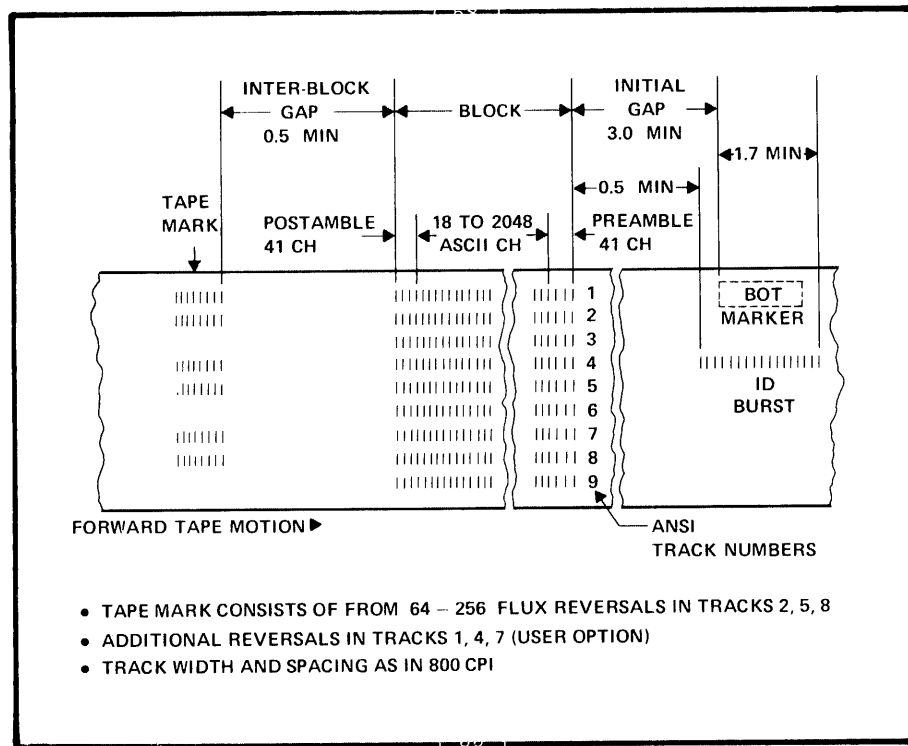
NINE TRACK 800 CPI NRZI FORMAT (CONT)

systems feel that permanent single track errors are uncommon and not worth the effort of implementing the use of the CRCC.

The longitudinal redundancy check character is obtained by adding all of the bits in a track for a record including the CRCC and adding a bit as necessary to make the sum even.

The space between the LRCC of the preceding record and the record following is a minimum of a 1/2" of unrecorded tape. To separate records on tape into files a tape mark is used. The tape mark consists of bits in tracks 2, 3, and 8 followed by the longitudinal redundancy check character 8 character times later. The cyclical redundancy check character or CRCC is not used in the tape mark. The tape mark is preceded by 3-3/4" of blank tape. The numbering of the tracks on tape starts at the top when the beginning of tape mark or BOT is on the right hand side with the oxide surface facing the viewer.

NINE TRACK 1600 CPI PHASE ENCODED FORMAT



- TAPE MARK CONSISTS OF FROM 64 – 256 FLUX REVERSALS IN TRACKS 2, 5, 8
- ADDITIONAL REVERSALS IN TRACKS 1, 4, 7 (USER OPTION)
- TRACK WIDTH AND SPACING AS IN 800 CPI

There is a 1600 CPI identification burst at the beginning of the tape starting slightly before the beginning of tape marker and terminating shortly after the beginning of tape marker. This identification burst is a series of flux reversals (1600 frpi either 01010.... or 101010....) in track 4. (See page 1-26 for the Phase Encoding recording technique). Following the identification burst is a 41 character preamble consisting of 40 zero-bit flux reversals in all 9 tracks followed by a one bit. This preamble is used to synchronize the electronics for reading and writing the 1600 BPI data. The data block will be followed by a 41 character postamble which consists of a one bit character followed by 40 zero-bits in all tracks. The inter-record gap is 1/2 inches. The data block may consist of from 18 to 2048 characters. The tape mark used to separate the tape into files consists of from 64 to 256 flux reversals using 3200 frpi (either ones or zeroes; IBM uses zeroes) tracks 2, 5, and 8. Flux reversals may be added in tracks 1, 4, and 7. These reversals are not used for standard identification but may be used by individual users for special designations. The track numbering system is the same as in the 800 NRZI 9 track format with the tape oriented in a similar manner.

NINE TRACK FORMAT COMPARISON

	800 CPI NRZI	1600 CPI PE
IDENTIFICATION BURST	NO	YES
PREAMBLE	NO	YES
MINIMUM BLOCK LENGTH	18 CHARACTERS	18 CHARACTERS
POSTAMBLE	NO	YES
CRCC	YES	NO
LRCC	YES	NO
TAPE MARK	YES	YES

Obvious differences between formats are the use of an identification burst, pre-amble, and post-amble in the 1600 CPI format. The implication of the pre-amble and post-amble is that the 1600 CPI format is relatively inefficient for small record lengths. The record length must be greater than 82 characters before the 1600 CPI format begins to have any speed or capacity advantages. The use of a tape mark is very similar in both formats, albeit, the tape mark is in a different form. The difference in form is necessary for the synchronization of the 1600 CPI electronics. However, why are the CRCC and LRCC parity check characters missing? As mentioned before, phase encoded data is self clocking and redundant. Every bit cell in any track must have a flux reversal whether it is in one direction or another so that each bit cell provides a timing signal. If a "dropout" occurs while reading one byte the offending track is known immediately and the direction of the flux reversal can be determined by comparing the vertical parity bit with the parity of the character without the bit. As long as the dropout occurs in only one track at a time, this format is completely redundant and no loss of data occurs.

NINE TRACK TRACK NUMBERING

ANSI TRACK NOS.	ASCII BIT DESIGNATIONS	IBM TRACK NOS.
1	b ₃	5
2	b ₁	7
3	b ₅	3
4	P	P
5	b ₆	2
6	b ₇	1
7	Z	0
8	b ₂	6
9	b ₄	4

- NUMBERING BEGINS AT THE TOP OF THE TAPE WITH THE BOT MARKER TO THE RIGHT AND OXIDE SURFACE TOWARD VIEWER
- MOST SIGNIFICANT BITS ARE TOWARD CENTER OF TAPE
- IBM SCHEME HAS TRACK NUMBERING INVERTED TO ASCII BIT SIGNIFICANCE

The track numbers according to the American National Standards Institute, begin at the top of the tape when the oxide surface is toward the viewer and the beginning of tape marker is on his right. The bits, however, are actually scrambled before they are put on tape. These assignments are shown in the table. Also shown in the table is IBM's track numbering scheme. This scheme assigns track 1 to the most significant bit and track 7 to the least significant bit. Since IBM sells systems, the fact that track numbers are not physically sequential is not important internally and it serves to confuse the plug compatible marketing.

NINE TRACK BIT SCRAMBLING CRITERIA

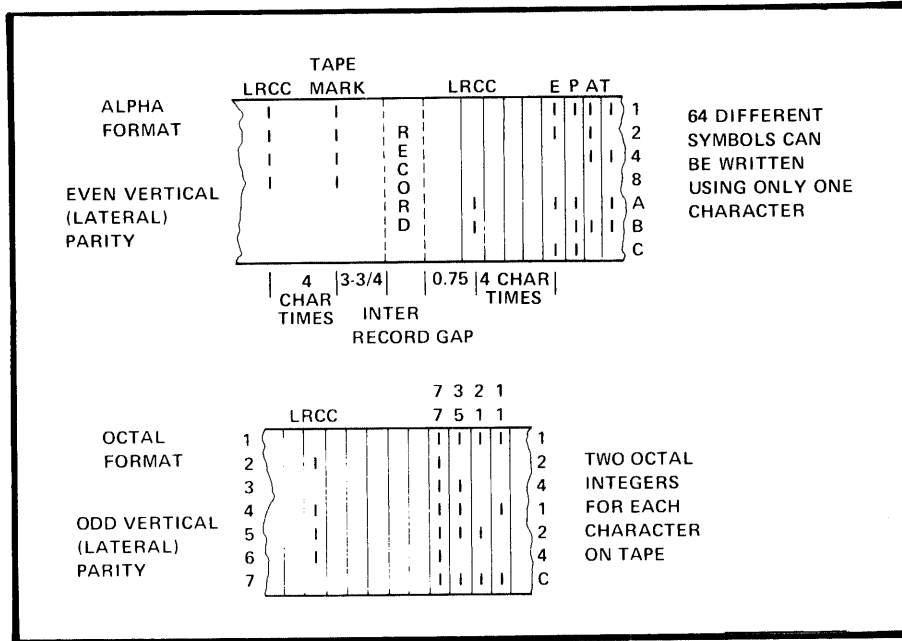
FOR MAXIMUM RELIABILITY AND PERFORMANCE

- MORE PROBABLE THAT A "1" WILL BE INTERPRETED AS A "0" THAN VICE VERSA
- ERRORS ARE MORE LIKELY TO OCCUR ON EDGE RATHER THAN NEAR CENTER OF TAPE
- SOME PORTIONS OF CODE WILL BE USED MORE FREQUENTLY THAN OTHERS

The scrambling of the bits on tape is an effort to ensure maximum reliability and performance of the tape medium. The assumptions which are inherent in this selection are:

1. It is more probable that a one bit will be interpreted as a zero than the converse. This is particularly true in NRZI recording where a one bit is represented by a flux reversal and zero bit by no reversal. The probability that there will be a noise spike on the tape which can be interpreted as a one bit is certainly a great deal less than the probability that head to tape separation will occur and a one bit signal flux reversal will be too low in amplitude to be detected.
2. Errors are more likely to occur at the edge of the tape than near the center. This is true because tape skew problems and edge damage effect the outer tracks to a greater extent than the inner tracks.
3. Portions of the code which will be used more frequently than others have been assigned inner track designations much in the same way that T, H, and Y are assigned central keys on the typewriter.

SEVEN TRACK NRZI TRIPLE DENSITY FORMAT



This is the recording format used prior to IBM's introduction of its 360 line. The densities in this format are 200 BPI, 556 BPI, and 800 BPI. The bits per inch (BPI) designation is used here rather than CPI because a character is generally interpreted to be eight bits even though a character may be represented by a six bit code. These steps in increasing density represent individual milestones in the development of digital tapes and digital tape transports. Individual bytes are represented by a 6 bit character plus a parity bit. The vertical parity in 7 track format may be either odd or even parity. A record is followed by a longitudinal redundancy check character 3 character spaces after the last byte. The inner record gap is a minimum of 3/4 of an inch. The tape mark used to separate the files is preceded by 3-3/4 inch of blank tape and is represented by one bit in tracks 1-4 followed 3 character spaces later by the longitudinal redundancy check character.

Track numbering is consistent with the 9 track scheme, however, there is no scrambling of the significant bits. The least significant bits start at the edge of the tape and move inward to the center as do the zone bit which is the equivalent to a punched card on magnetic tape. An octal format is also seen in 7 track. This format consists of 2 octal characters placed side by side with a parity bit.

INTRODUCTION TO DIGITAL TAPE DRIVES

TYPES OF DIGITAL TAPE DRIVES

CONTINUOUS	INCREMENTAL
<ul style="list-style-type: none">• RECORDS DATA IN BLOCKS AT A CONTINUOUS DATA RATE• CAPSTAN SPEED ACCURATELY CONTROLLED• DATA FORMAT IS COMPUTER-COMPATIBLE• PLAYBACK IN SAME MANNER AS RECORD• VERY RARELY RECORD ONLY BECAUSE OF DIFFICULTY IN INSURING DATA ACCURACY• READ-AFTER-WRITE TYPICAL• READ ONLY AND READ/READ USER OPTIONS	<ul style="list-style-type: none">• USED FOR DATA LOGGING WHERE DATA RATE IS ASYNCHRONOUS• CAPSTAN ESSENTIALLY A STEPPING MOTOR• DO NOT CREATE COMPUTER-COMPATIBLE TAPES UNLESS SPECIFICALLY DESIGNED TO DO SO. THE TIME REQUIRED TO CREATE AN INTER RECORD GAP (IRG) CAN BE A SEVERE LIMITATION• PLAYBACK IS NEARLY ALWAYS IN A CONTINUOUS MODE• ASYNCHRONOUS PLAY BACK A HAIR-RAISING TECHNICAL PROBLEM SO IS RARELY USED• WRITE ONLY MACHINES• INCREMENTAL WRITE AND CONTINUOUS PLAY BACK

Digital tape drives are categorized as either continuous or incremental. Continuous tape drives are the drives used in Data Processing installations and as such are by far the most prominent use of digital tape drives. These tape drives record data in blocks at a continuous data rate. The data format is computer compatible, and the data is played back in the same manner in which it was recorded. To ensure an accurate transfer of data at a continuous rate the capstan speed is very accurately controlled. The typical continuous tape drive is a read-after-write machine so that the accuracy of the data written on tape is ensured. It is very rarely found in a record only version, because of the difficulty of ensuring data accuracy. Payroll or inventory data simply cannot tolerate even a suggestion of error. Read only versions on the other hand are often used for off-line computer output systems.

The incremental tape drive is used almost exclusively for data logging applications where the data rate is asynchronous. Such a tape drive will typically not create computer compatible tapes unless specifically designed to do so. In some applications a great deal of buffering is required to create a computer compatible tape because of the time required to create an inter-record gap. This is caused by the fact that the capstan is essentially a stepping motor which must be commanded to move through the 1/2-inch inter-record gap a step at a time. Conversely the playback of incremental tape is nearly always in a continuous mode of operation. Normally when the data is analyzed or otherwise used, it can be handled at a continuous rate. The fact that asynchronous playback is a hair raising technical problem makes its use rare. Incremental tape drives are often seen in Write only versions, partly because the demand for accuracy in a typical logging situation is not very stringent and partly because of the difficulty of checking data as it is recorded in the asynchronous manner. If playback capability is included on a incremental recorder, it is as mentioned, typically a continuous playback mode. Incremental recorders will not be considered further here.

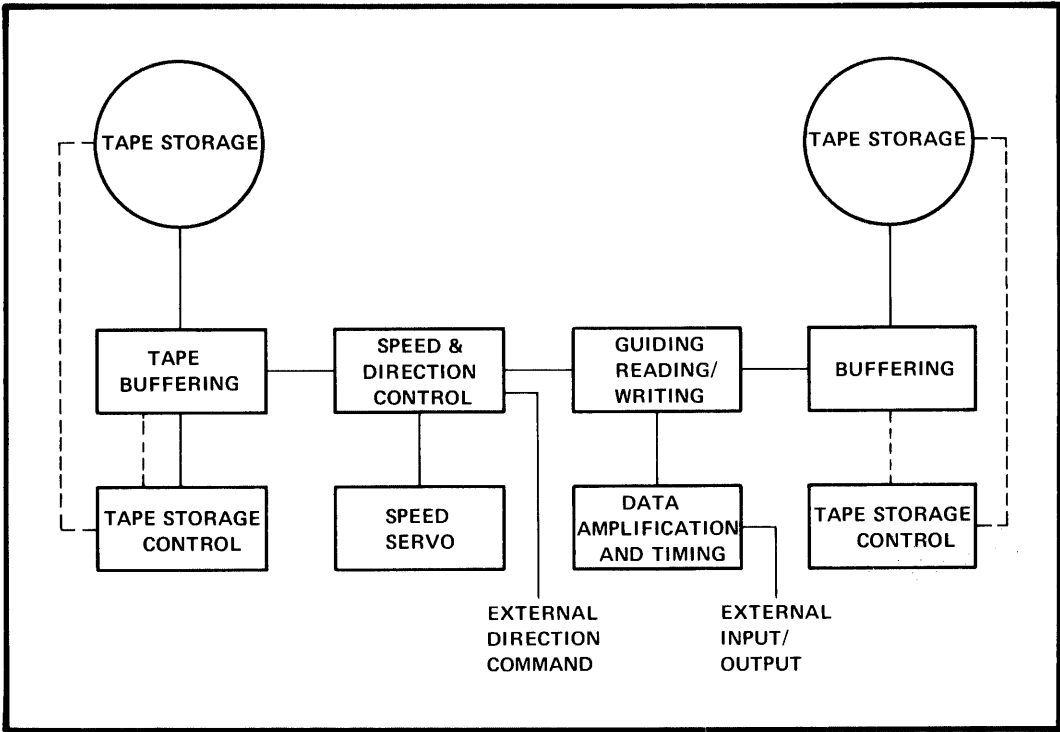
DIGITAL TAPE DRIVE DESIGN

<u>THE JOB</u>	<u>THE PROBLEM</u>
GET THE TAPE UP TO SPEED <u>FAST</u>	OVERCOME INERTIA OF REEL
GET THE DATA ON AND OFF TAPE WITH 100% ACCURACY	DATA MUST BE PERPENDICULAR TO THE LINE OF TAPE TRAVEL. HIGH ACCURATE TAPE GUIDING AND HEAD ALIGNMENT ARE REQUIRED. TAPE SPEED MUST BE CONSTANT.
GET THE TAPE STOPPED <u>FAST</u>	OVERCOME MOMENTUM OF REEL
AVOID WEARING OR DAMAGING THE TAPE IN THE PROCESS	TRANSIENT AND STEADY STATE TAPE TENSION MUST BE KEPT LOW. GUIDING SURFACES MUST NOT WEAR OR DAMAGE EASILY

The design of a digital tape drive might best be summarized as above. The job and the problems are simply stated but the successful implementation of a solution in hardware will take two years of development for a group of mechanical and electrical engineers experienced in digital tape drive design.

Tape path and servo designs belie the amount of work which goes into a successful design because the minute details which make the difference are invisible to the untrained eye.

BASIC ELEMENTS

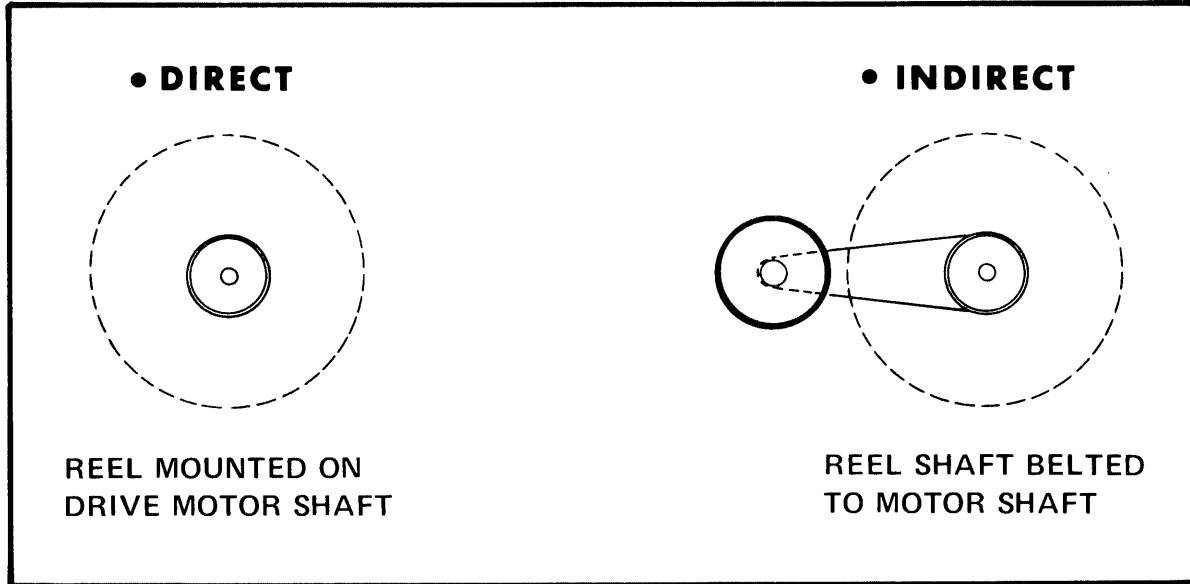


The accompanying figure shows the elements of a tape drive which are used to solve some of the basic design problems in a tape drive. For example:

1. To circumvent the problem of overcoming the inertia or momentum of the reel of tape excess tape is pulled off of the reels and stored in a buffer. The inertia or momentum of the tape is several orders of magnitude lower than the reels so that the tape may be more easily started and stopped.
2. In order to get the data on and off tape accurately high precision guiding elements are used in close proximity to the reading and writing area, tape speed across the head is tightly controlled.

MECHANICAL ELEMENTS

REEL DRIVES



The reels are driven directly or indirectly. A direct reel drive is a drive on which the reel hub is mounted on the motor shaft. Mechanically this is the simplest type of drive to use. The alternative is to use the indirect drive method where the reel hub is mounted on a shaft off-set from the motor shaft with a belt transmitting the driving force from the motor to the reel hub. This, of course, has its disadvantages. Additional moving parts are introduced into the system and the belt, which wears, will require adjustment. The direct reel drive is not subject to the wear problem or adjustment but it is more expensive because of the lack of mechanical advantage requires a heavy duty motor.

REEL BRAKING

- ELECTRODYNAMIC

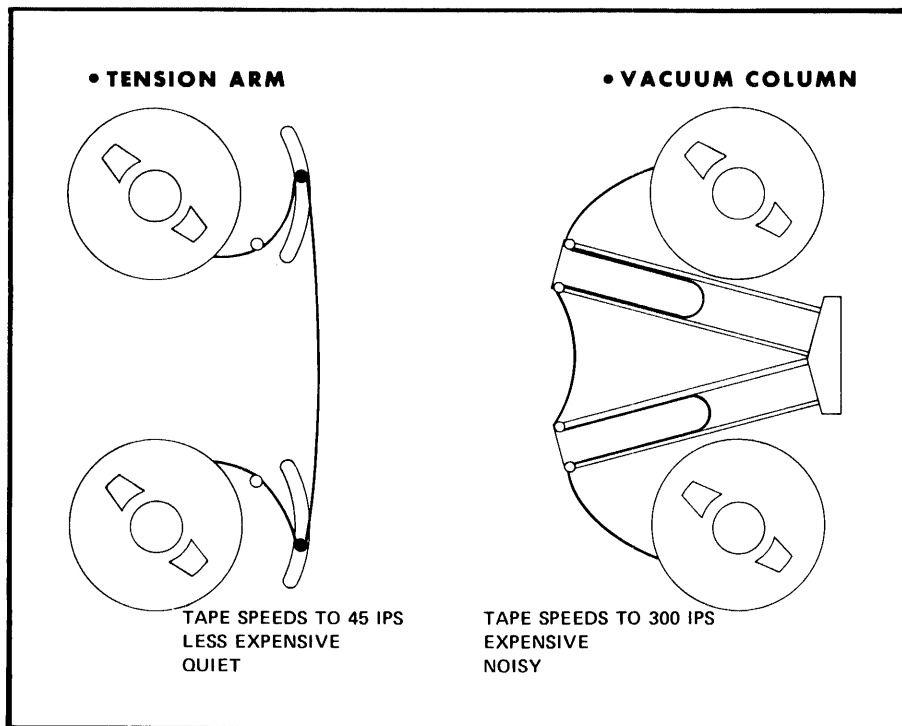
NO ADJUSTMENT
NO NOISE
NO WEAR
ALL NEWER DESIGNS

- MECHANICAL

REQUIRES ADJUSTMENT
MAY BE NOISY
SUBJECT TO WEAR
OLDER DESIGNS

Reel braking is subject to a similar set of design trade-offs. Electro-dynamic braking systems require no adjustment, have no noise, and are not subject to any wear. Almost all of the newer tape drive designs use this type of braking. Mechanical braking systems on the other hand, do require adjustment and may be subject to a great deal of noise. Anyone who has not been in a data processing center which had a tape drive with squeaking brakes will never know how annoying this is to a data system user. The mechanical braking systems are, of course, also subject to wear. The major advantage of a mechanical braking system is its lower cost.

TAPE BUFFERING



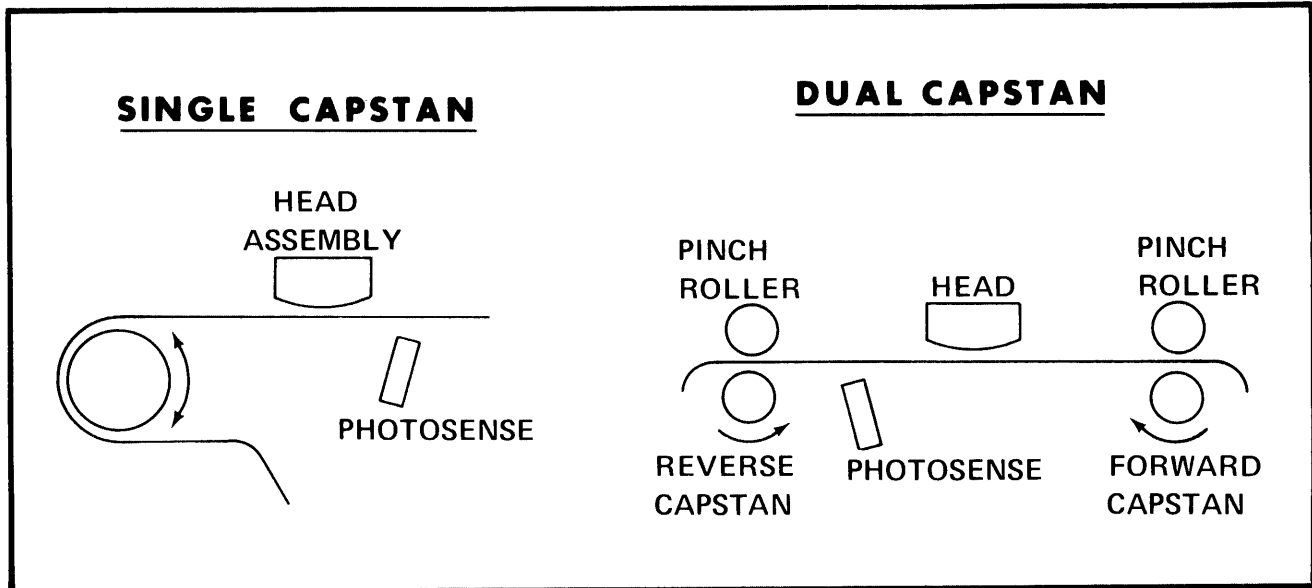
A TENSION ARM tape buffering system is essentially a spring loaded arm which holds a loop of tape in readiness either to be supplied to the reel or to the capstan. The position of the tension arm supplies the feedback to the reel servo control so that the reel either supplies tape or takes up tape in an attempt to maintain the position of the tension arm in the center of its range of travel. This type of tape buffering system is simple in design and therefore, less costly to build. In addition, its operation is very quiet. This design is being used at tape speeds up to 45 ips. At higher tape speeds the inertia of the tension arm itself becomes a problem. In order to provide proper tape handling the tension arms themselves may have to be servoed. When this occurs the tension arm machine loses its inherent simplicity and cost advantage.

A VACUUM COLUMN tape buffering system is very similar in operation to the tension arm system. A vacuum motor sucks air out of a glass column and pulls the tape into the column. The position of the tape in the column is sensed either by vacuum switches or photoelectric cells and this information is fed back to the reel servo which supplies or takes up tape as necessary to keep the tape positioned properly in the column. A vacuum buffering system has the advantage of having only the inertia of the tape and some air pressure to overcome. Vacuum systems are used at all tape speeds. It is more expensive to build than a tension arm system because of higher parts cost and the difficulty of aligning the vacuum columns. A vacuum column machine is also more expensive to repair and more difficult to maintain, particularly in the cleaning of the vacuum columns.

TAPE BUFFERING (CONT)

Many people feel that a vacuum system is better both from the standpoint of handling tape more gently and keeping it cleaner. These feelings are, however, difficult to substantiate. Differences in tape and tape drives from manufacturer to manufacturer not to mention from production run to production run make it almost impossible to evaluate. This indicates that the inherent differences in design are perhaps less important than the actual execution of the design.

CAPSTAN CONTROL



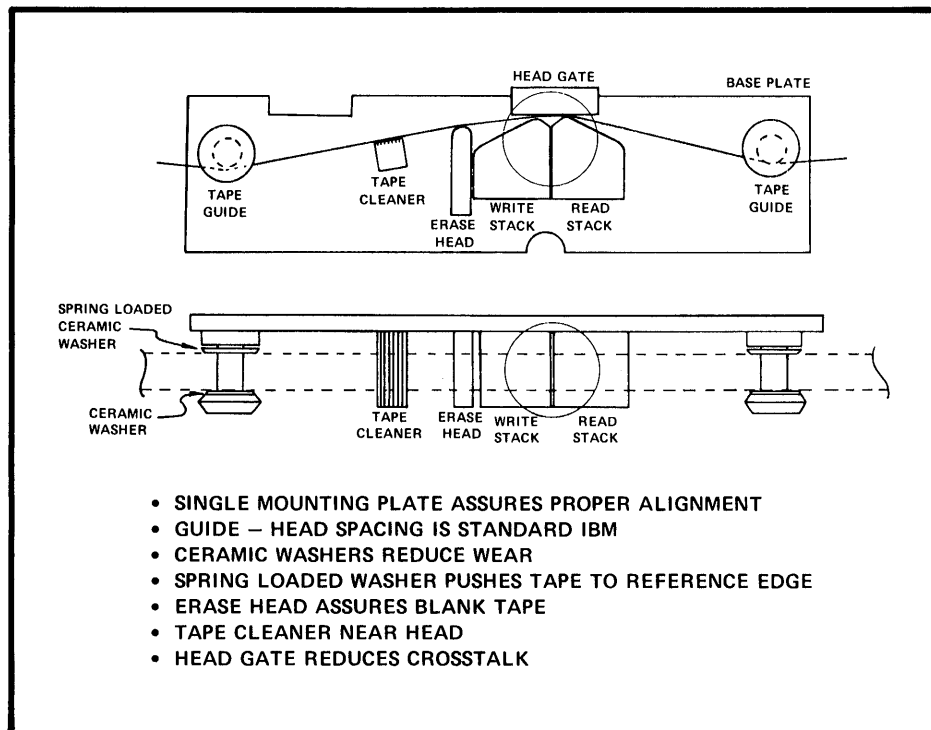
The capstan controls the speed of the tape as it moves past the head. Either single capstan or dual capstan control can be used to provide this bi-directional motion of the tape past the head. A typical single capstan path is shown in the figure here. In a single capstan, the capstan rotates in one direction for forward and in the opposite direction for reverse. The capstan itself must be very low inertia and is normally ramped up and down in speed at a controlled rate. The tape is wrapped 180° around the capstan so that normal tape tension is enough to keep the capstan and the tape in constant contact without any slippage. This type of design has been incorporated in most of the newer tape drive designs.

The typical arrangement of a dual capstan machine is shown in the second half of the figure. One capstan rotating in the direction to pull the tape across the head is placed on either side of the head. Until a tape motion command is given, the mylar side of the tape simply slips on the capstan. When a tape motion command is obtained the appropriate pinchroller on either side of the head is activated pushing the tape against the capstan and moving the tape quickly up to speed. This type of system may use a synchronous motor and a belt and pulley arrangement to drive both of the capstans. For this reason the system is relatively inexpensive to build. This advantage is off-set by the fact that:

1. It has more moving parts.
2. Pinchroller adjustment is critical.
3. Tape may be subject to damage because of pinchroller banging into the oxide surface and the tape being accelerated practically instantaneously up to speed.

Almost all of the latest tape drive designs are of the single capstan type because the cost differential is decreasing and the performance characteristics are somewhat improved.

HEAD AND GUIDE ASSEMBLIES

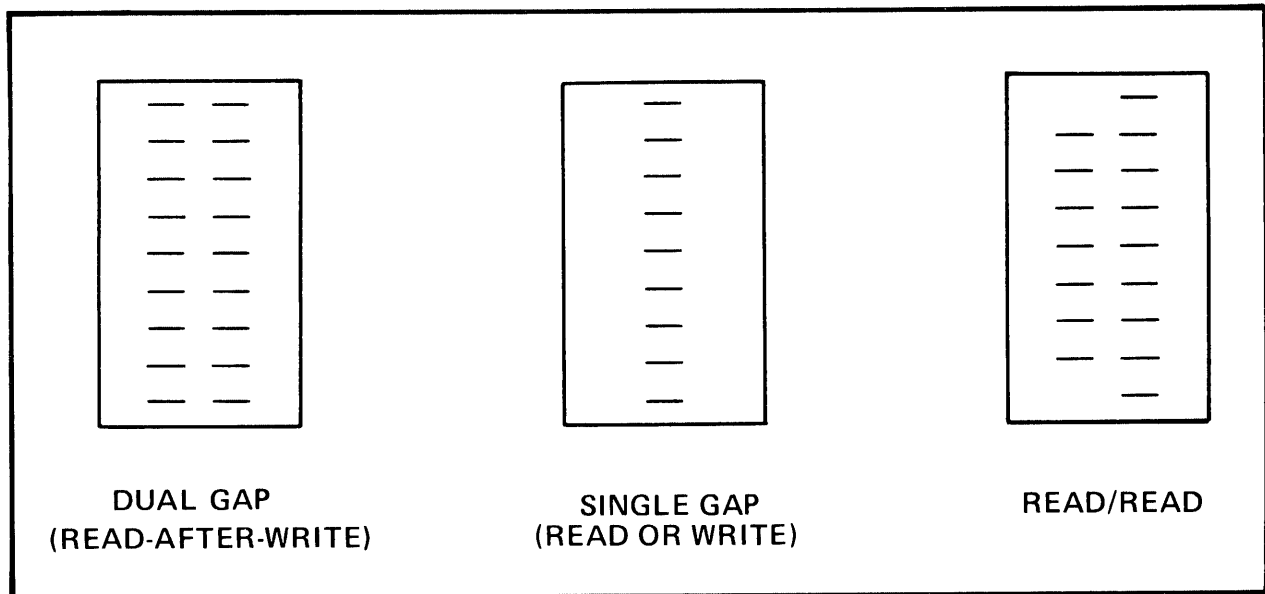


One of the most critical areas of a tape drive is the head and the guidance of the tape past the head. The typical elements of the area are shown in the accompanying figure. The head and tape guides are mounted on a heavy baseplate so that their alignment and dimensional tolerances can be tightly controlled. The spacing between the heads and the guides is ideally the same spacing used by IBM on its tape drives. The guides themselves have ceramic washers for reduced wear, both on the tape and the guide itself. The edge of the tape will scratch and score a metal surface. The roughened surface will in turn chew-up the edge of the tape. One washer is spring-loaded so that the tape is held against one reference edge in spite of the dimensional tolerance of the slitting operation. (Occasionally, trough guiding is used, instead of the edge guiding described here.)

Other elements in the tape path are the erase head which assures a blank tape in the writing process. The use of an erase head is the reason that the write operation is a uni-directional process. A tape cleaner is also included so that any oxide or dirt particles riding on the tape are cleaned off of the tape before it reaches the head area. The head or flux gate reduces crosstalk between the read and the write stacks in the read-after-write mode of operation.

As mentioned this is a typical configuration and variations between manufacturers are considerable. For example, ceramic washers need not be used on the guide even though they are the best material. Head and guides do not need to be mounted on a separate plate or even the same surface although this ensures the most accurate alignment. A tape cleaner can be placed any position in the tape path although the placement shown here is optimal in the sense that should a dropout occur a simple routine to backspace a record will pass the tape over the tape cleaner and enhance the probability that a good record can be either written or read. In fact, some other tape drives may not even provide a tape cleaner.

HEAD TYPES



There are three types of heads which are normally seen on tape drives; read after write, read only, and read/read. By far the most common is the dual gap or read after write head. This is actually two heads manufactured together with a set of write tracks on one side and a set of read tracks on the other. This allows the data to be checked by reading it immediately after it has been written. There are also slight differences in that the read head is optimized for the read operation while the write head is optimized for writing. The dual gap head is manufactured in seven or nine track versions.

A single gap head is a head used for read only or in some cases for both read and write operation. In order to check data written with this head, the entire record must be back spaced and read checking the record written against the one which should have been written. This in effect doubles the time required to write and check a tape. This type of head is also found in seven and nine track versions.

The third type of head is known as a read/read head. It is so called because it is intended for read only applications and consists of two heads, one of which is a seven track read only head while the other is nine track read only. It is intended for applications such as tape to printer or other output functions where the user will be involved in translating data from either a nine track or a seven track tape drive to another media or format.

PROGRAM RESTRICTIONS

ARE RESTRICTIONS ON THE COMMAND RATE TO THE TAPE DRIVE

- **LIMITATIONS ARE CAUSED BY:**

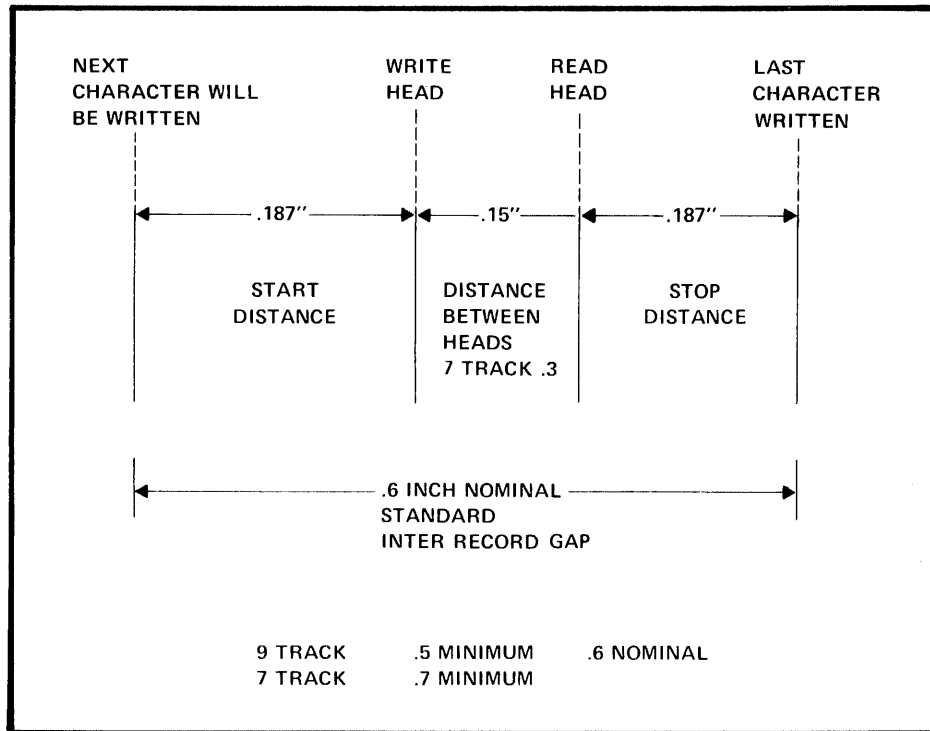
**CAPSTAN INERTIA OR
OVERHEATING OF REEL MOTORS**

- **COMPATIBILITY REQUIRES THAT TAPE TRAVEL DURING START AND STOP TIMES BE LESS THAN THE IRG LENGTH. THIS LIMITATION IS ON READING ONLY SINCE AN IRG CAN BE UP TO 25 FT. ON WRITING (WHICH ALLOWS SPACING OVER BAD SECTIONS OF TAPE)**

As electromechanical devices, tape drives have their limitations. A sign of these limitations are the program restrictions which are sometimes placed on drives. The restrictions are actually on the command rate to the tape drive. For example, a tape drive might have to run under program restrictions at command rates of better than 120 commands per second. This would mean that data conditions requiring command rates higher than this could not be executed or would have to be slowed. For example, start/stop times for a half inch interrecord gap at 45 ips are about 7 ms. The tape drive should not be required to execute another command for 1.3 ms. The limitation is caused by potential overheating of the reel or capstan motors, or the duty cycle exceeding the rating of the power supply.

An example of an application where this might occur is in the write backspace read mode on a tape drive using a single gap head to write data. The "turn-around time" may be limited by the acceptable command rate.

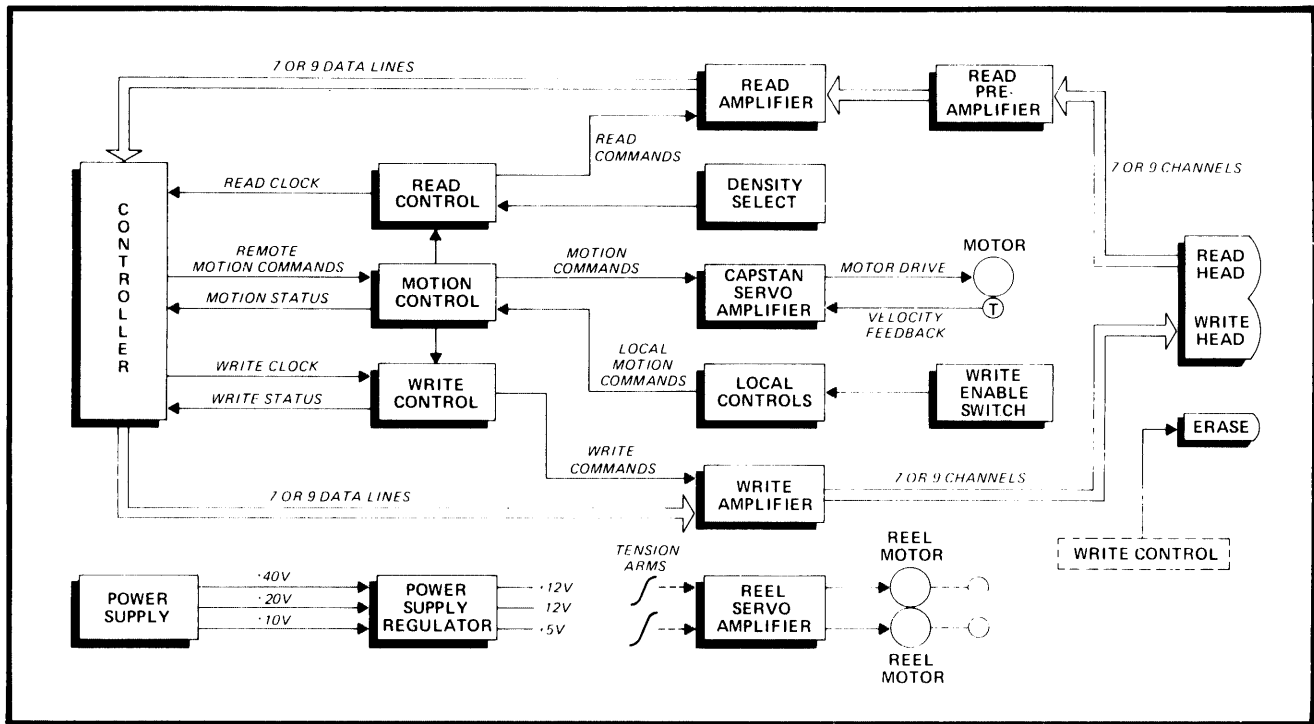
INTER-RECORD GAP



A tape drive may also be restricted in its inability to start and stop in the minimum inter-record gap created on another tape drive. As the tape speed increases the time allowable for the starting and stopping decreases. Therefore, a tape drive being operated just above or close to its design limit may experience difficulty in reading tapes from another tape drive. The same tape drive will have no difficulty in writing tapes because the inter-record gap may be up to twenty-five feet long. This allows for spacing over sections of bad tape. Note, however, that to write a tape with a minimum inter-record gap in the read after write mode requires that the tape drive start and stop with 0.35 inches because of the 0.15 inch spacing between the Write and Read gaps heads. (9 track format)

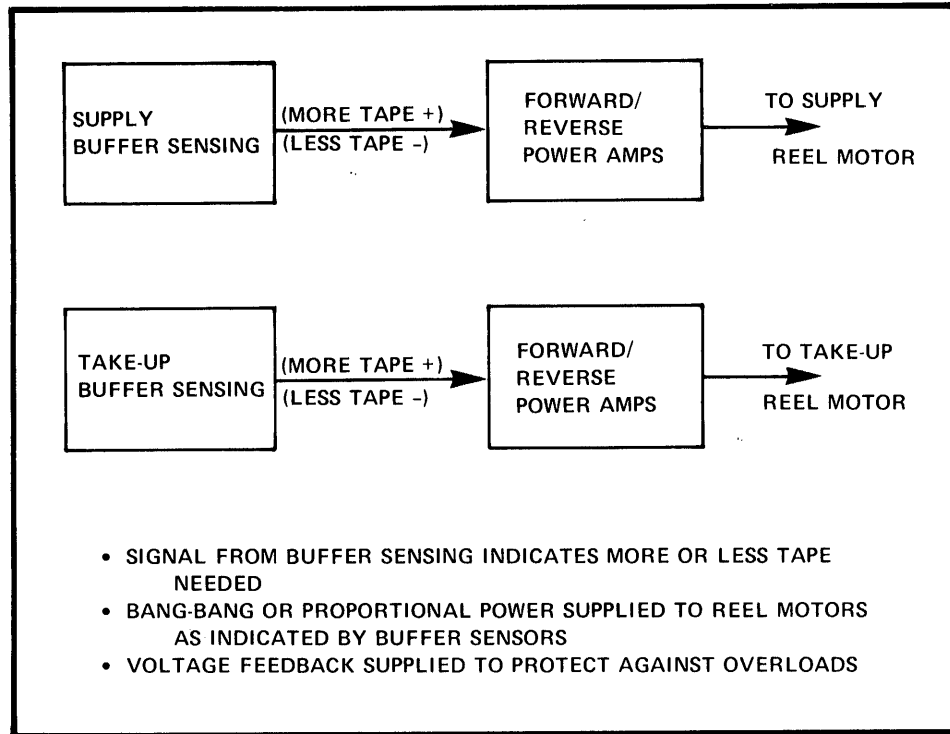
ELECTRONIC ELEMENTS

BLOCK DIAGRAM OF ELEMENTS



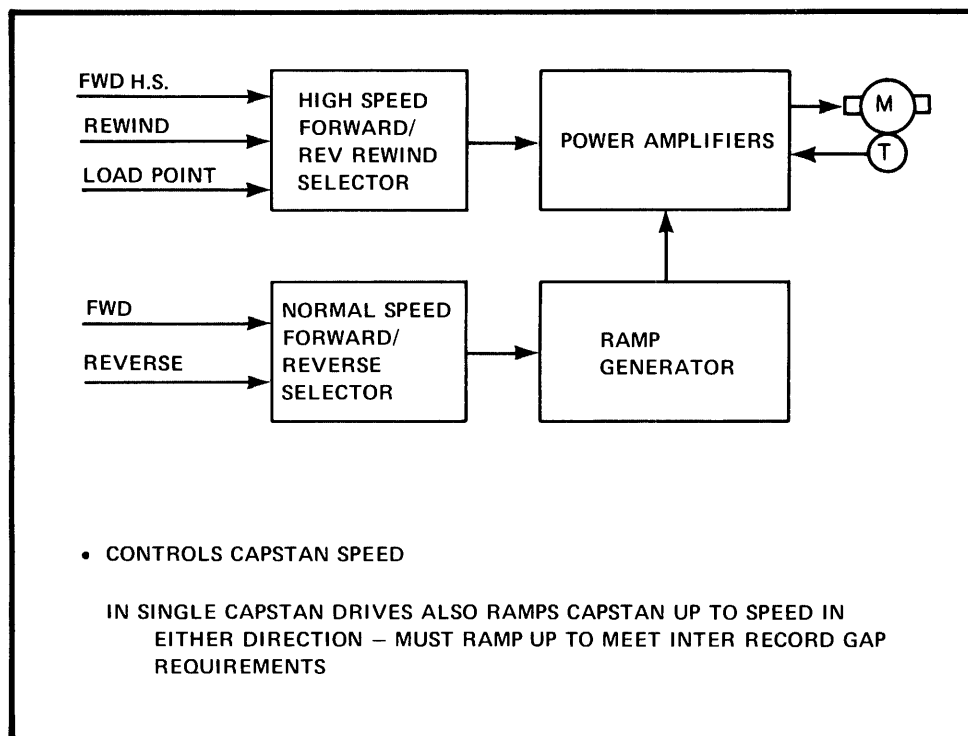
This block diagram shows the relationship of the individual electronic elements to the whole system. It will be worthwhile examining this diagram for a few minutes so that the discussion of the individual elements will make sense. For example, note that the reel servos are isolated from the rest of the system. Motion control may receive local or remote commands to control the capstan. It also generates signals which allow the read or write control units to direct the read or write data amplifiers. In some ways the motion control is the heart of the system. Without it nothing will function.

REEL SERVO



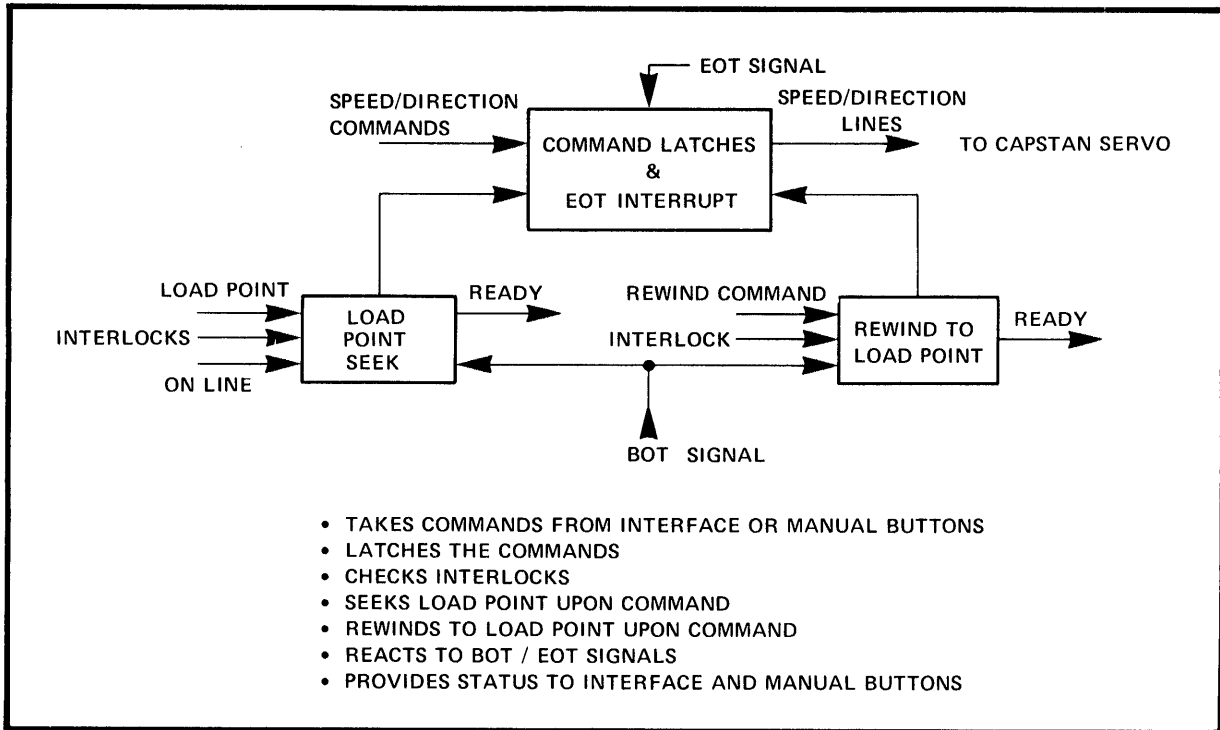
The reel servo is conceptionally a very simple device. The servo receives a signal from the buffering system indicating a need for more or less tape. This causes the reel servo to supply power to drive the reel in the forward or reverse direction. The servo itself may be a bang/bang or a proportional type of servo. There is one servo for the supply reel and a separate servo for the take-up reel. Voltage feedback is often supplied in the servo system to protect against overloads.

CAPSTAN SERVO



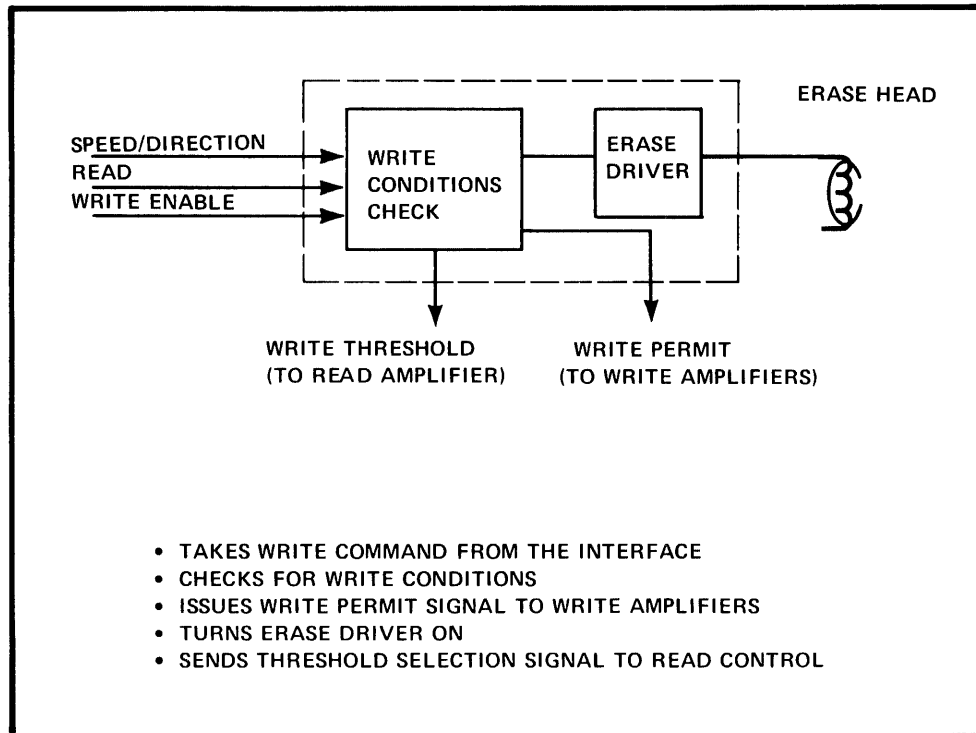
The capstan servo controls the speed of the capstan. The typical block diagram for a single capstan servo is shown above. The servo ramps the capstan up to speed in either direction upon command. The slope of the ramp must be sufficient to meet the inter-record gap requirements for the tape speed being used. To meet information interchange standards, the capstan must be able to ramp up and back down in speed in the minimum inter-record gap which is 1/2 inch for any tape speed being used. To write a tape with the minimum inter-record gap it must start and stop within .35 inches because of the .15 inches between write and read heads. As tape speed increases there is less time to do the ramping and more inertia or momentum to overcome. Methods of controlling the capstan speed vary. Some designs use the back EMF of the motor for speed control. This method is inexpensive but provides precise control as the tape speed drops. More sophisticated systems employ a tachometer feedback voltage in a voltage control system. The phase lock servo control systems typical in analog recorders are not commonly used. In a dual capstan system the speed control may be actually supplied by the line frequency using a synchronous capstan motor.

MOTION CONTROL



Motion control is considered as a separate element here although it could be considered a portion of the capstan servo control system and may indeed be physically located all on the same board and in the same circuitry on many tape drives. The basic layout of the motion control function is shown in the above diagram. The motion control function receives commands from the interface, from manual buttons on the tape drive, or from test accessory cards. These commands are latched until released by another command. For motion control to react to commands the tape drive must be selected and on-line. This means that tape tension has been established and the unit has been selected for operation. The motion control function also includes the logic which causes the tape drive to seek the load point after a new reel of tape has been loaded, the logic which allows the tape drive to rewind to the loadpoint upon command, and, the logic which reacts to the end-of-tape signal. The status of these conditions is also supplied as outputs.

WRITE CONTROL

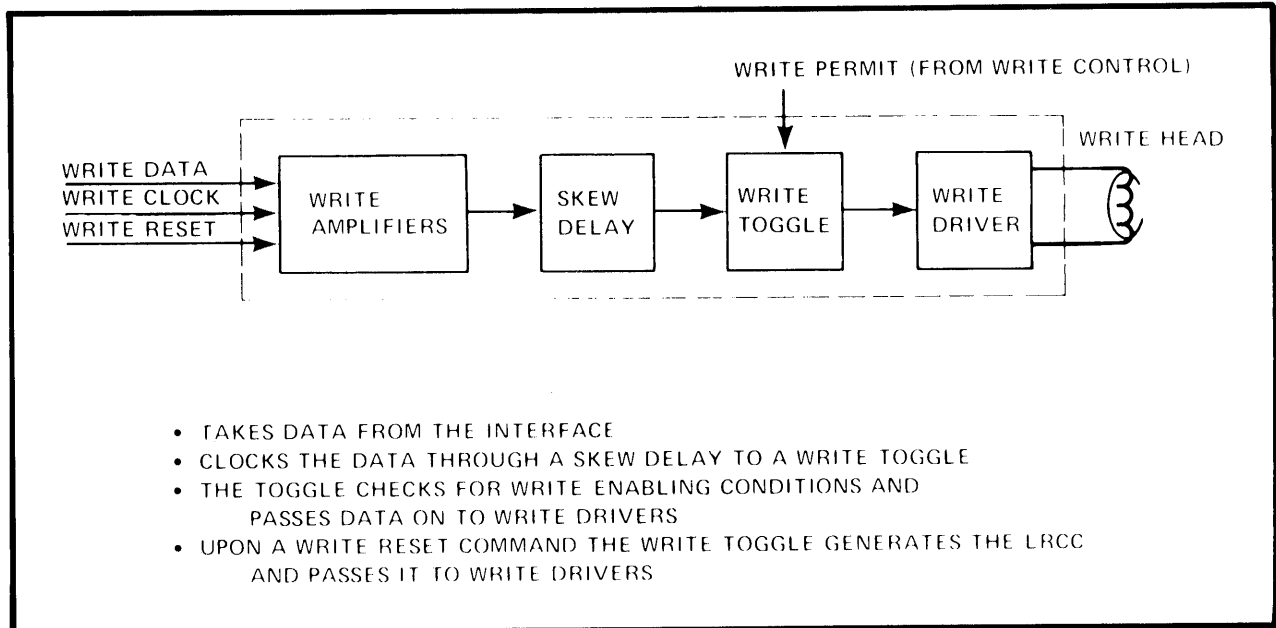


The write control function checks the tape drive for the proper conditions for writing data on tape and then generates the control signals to:

1. Permit data to be written by the write amplifiers.
2. Activate the erase driver to ensure that the tape is clean before the new data is written.
3. Control the threshold level of the read amplifier so that the sensitivity is reduced in the read amplifier for the read after write process.

These signals are sent to all seven or nine of the write and read data amplifiers. All this is done upon a write command from the interface.

WRITE AMPLIFIERS

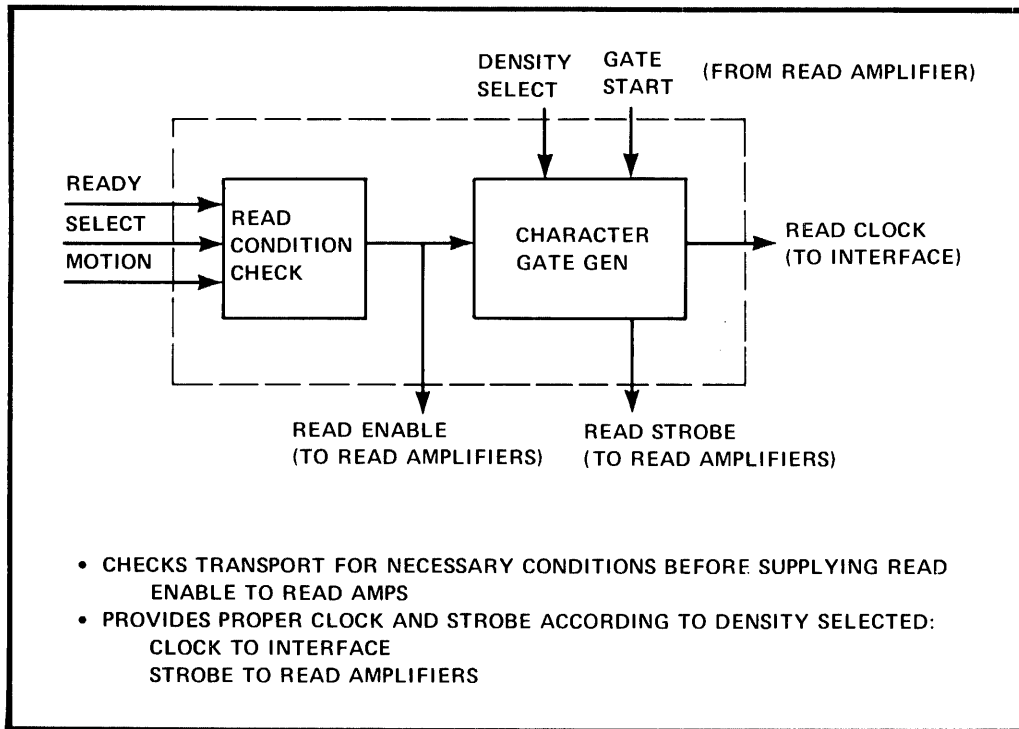


The typical configuration of a write data amplifier is shown above. The first stage is an amplifier stage which accepts data from the interface and clocks the data through to a skew delay. The skew delay compensates for any gap scatter in the head of the transducer for that channel. In some tape drives this "electronic deskewing" stage is omitted. If the per channel deskewing is omitted, then some form of mechanical azimuth adjust will be used on the write head or an electronic averaging scheme which is essentially an electronic azimuth adjust will be employed. Since gap scatter is often a parabolic contour, these techniques may minimize the deviation but not correct it.

The write toggle will pass the data on to the write driver if it is receiving a write permit signal from the write control electronics. The write driver supplies the current which allows the data to be written on the tape. Upon completion of the write operation the write reset signal will reset all write amplifiers and cause the write driver to return to the reset condition unless it is already in the reset condition. This is how the longitudinal redundancy check character is generated on tape.

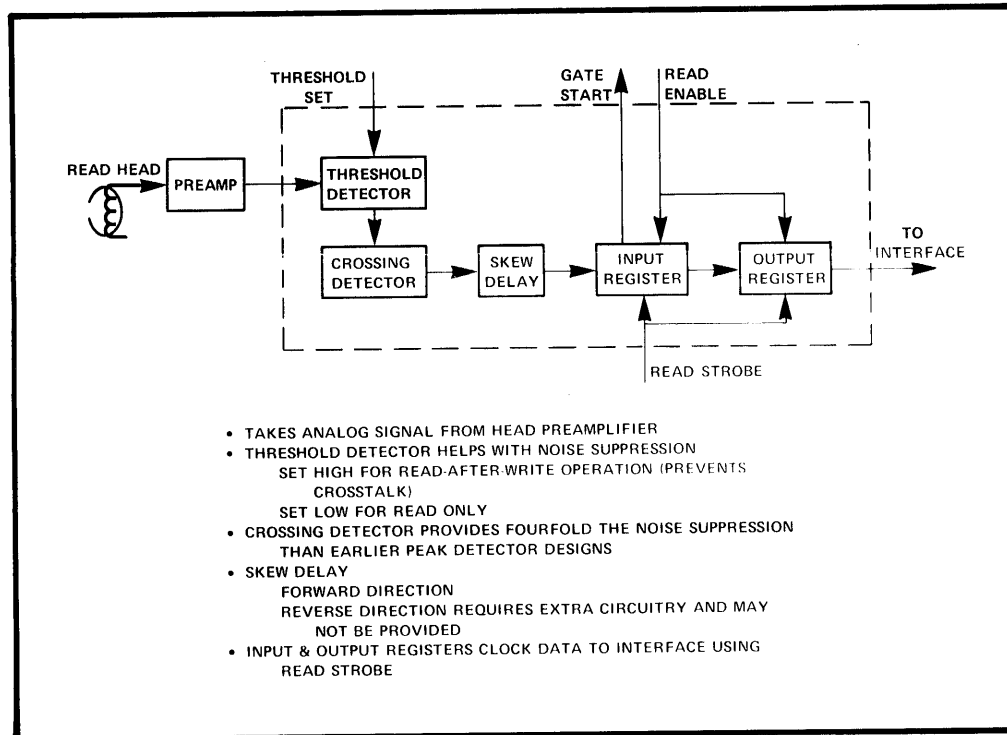
If the data bits are scrambled in the tape drive, the scrambling occurs between the write driver and the head.

READ CONTROL



A typical read control function is shown in the above diagram. The read control unit checks for the appropriate conditions of the tape drive before issuing a read enable command to the read amplifiers. The read enable signal is also sent to a character gate generator. The character gate generator receives a density select signal in seven track multi density machines. The density select signal adjusts the character gate width to correspond to the requirements of that particular density. The gate is started by a signal from the first read amplifier to receive a bit. The read strobe to the read amplifiers and the read clock which is sent to the interface are both generated from the character gate. These signals synchronize the transfer of data.

READ AMPLIFIERS



A typical block diagram of the read amplifiers is shown in this figure. The analog signal from the head goes through a preamplifier and then into the read amplifiers. If the data bits are unscrambled in the tape drive, the scrambling occurs between the preamp and the head.

The first stage is a threshold detector. The threshold detector has high and low settings. The high one is used in the read after write operation to help prevent crosstalk between the read and write heads. It also ensures that a strong signal is written on tape during the write operation. The low setting is used for reading and helps to suppress any noise on the tape. The threshold level set comes from the write control function. A two level threshold scheme is not always provided in a tape drive and in some very inexpensive drives no threshold detection at all may be provided.

The second stage may be either a peak detection or a crossing detection stage. Earlier tape drive designs used peak detection exclusively. Most designs today use crossing detection because it provides a four-fold better noise suppression than the peak detection method.

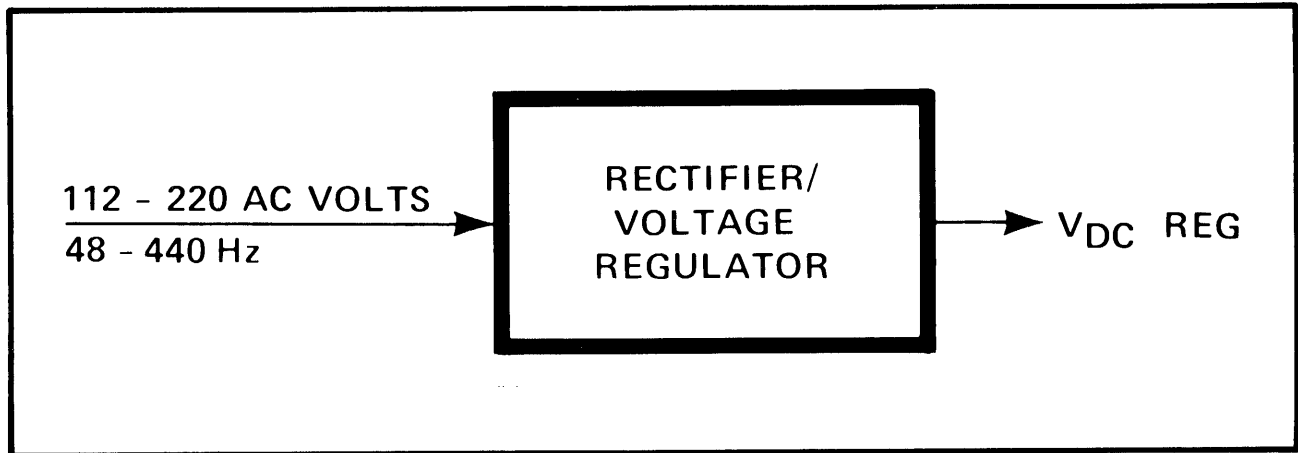
The third stage is a skew delay stage. This is where the signal is delayed to compensate for the gap scatter of the head on the read operation. In the better tape drives skew delay is provided for both forward and reverse direction. If skew delay is provided in only one direction then the gap scatter of the head will be effectively doubled if reading in the reverse direction is attempted. The diagram here is a per channel deskewing scheme.

READ AMPLIFIERS (CONT)

The input register receives the data as it comes through the first three stages of the read amplifier. When it receives a bit it sends a signal to the read control unit which will start the character gate generator if it has not already been started by another read amplifier.

The read strobe resets the input register to be ready for the next bit and at the same time clocks the current data bit from the output register to the interface.

POWER SUPPLY



Yes, every tape drive needs a power supply for its drive motors and electronics. Power consumption is typically from 400 to 1000 watts depending on the size and speed of the tape drive. The better designs are independent of line frequency over a wide range and are easily switched from U. S. to European voltage sources.

INTRODUCTION

PURPOSE OF THE INTERFACE

- **TIMING – MARRIES TWO MUTUALLY ASYNCHRONOUS PROCESSES**
- **FORMATTING – CHANGES STRUCTURE OF DATA AS APPROPRIATE**
- **SIGNAL LEVELS – PROVIDES TRANSITION FROM ONE DEVICE TO ANOTHER**

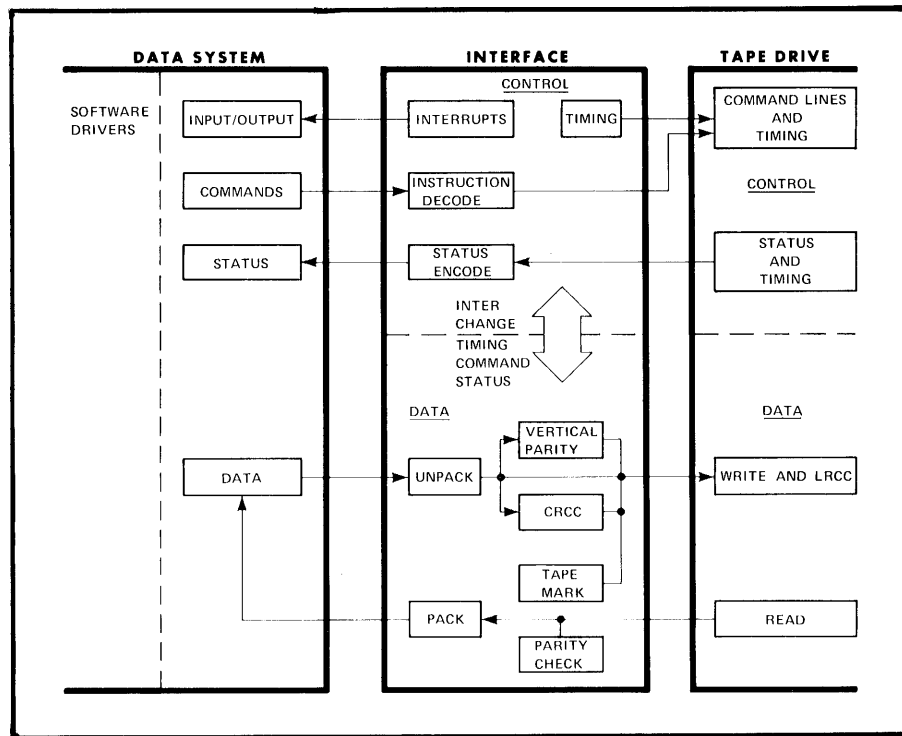
The words interface and controller are used interchangeably. Interfaces solve the three problems inherent in making two pieces of hardware operate together.

Timing requires interfacing because a computer and a tape drive are mutually asynchronous processes. The computer or data systems run on its own internal clock. The tape drive on the other hand runs on a data rate which is dictated by the recording density and the tape speed. These inherent differences are reflected in the hardware by the interrupt circuitry and buffering which are required.

Formatting in the computer or data system is normally in terms of words which consist of 8, 12, or 16 bits. These words are structured for efficient use in the processor. A tape drive on the other hand, has a format of 7 or 9 tracks and is structured for the data reliability and efficient use of the tape drive.

The difference in the signal levels used in the data system and the tape drive are usually a minor problem but does need to be considered.

INTERFACING ELEMENTS



The basic elements of an interface for a tape drive are shown in the above diagram. The interface can be broken into two separate sections; one for control, the other for data. The control portion has the interrupt circuitry to effect transfers of commands, status, and data between the interface and the computer. In addition it generates the timing required to write data and do spacing in the tape drive. The instruction decoding accepts commands from the data system and performs the intent of the instruction by activating the appropriate control lines on the tape drive. Conversely status signals from the tape drive and the controller are changed into words which can be interpreted by the data system in the status encoding portion of the control section. In order to perform its function the control section of the interface must send signals to the computer, to the tape drive, and to the data portion of the interface. The individual elements are discussed in greater detail in the following sections.

The data portion of the interface accepts data from the computer and changes the computer word into the form acceptable for the tape drive. In the process it provides the necessary buffering to help marry the two units. At the same time parity bits and characters are generated to ensure the reliability of the data in its transmission to and from the tape drive. When data is received from the tape drive the process must be reversed with first parity checks and a repacking process to put the character from the tape drive back into a computer compatible word.

It is possible to perform some of the functions shown here by using software in the data system. For most applications, however, this places an unnecessary burden on the data system. Repetitive tasks are performed more efficiently in hardware and have the effect of increasing the usable space

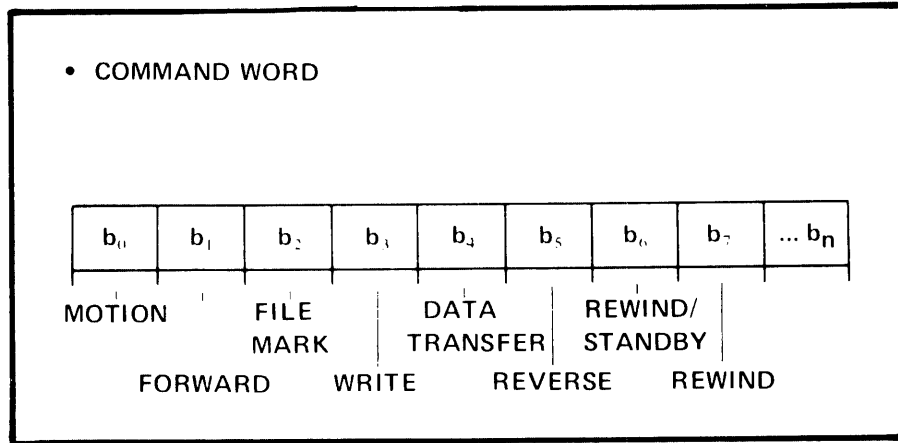
INTERFACING ELEMENTS (CONT)

in the data system. Similarly the tape drive can include its own parity writing and checking capability since these elements are closely related to the tape drive.

Occasionally interfaces are broken into sections called a controller and a formatter. The formatter provides the packing and unpacking of data, the parity, and the timing for the tape drive. The controller will provide the interrupt, instruction decoding, and status recognition functions of the interface. In this area then the controller is not synonymous with a complete interface, however, general usage does not make the distinction sometimes exhibited in the hardware.

DATA SYSTEM

COMMANDS



One of the variables in the interfacing solution is the command word. The command word contains bits which signify operations required by the computer which must be executed by the tape drive. An example of a command word is shown here. The command word is re-defined with the requirements of a particular system. For example, a 7 track read only tape drive used in a off line tape to printer peripheral might have only motion forward, data transfer, density select, and rewind bits defined. These bits may be defined in any sequence, according to the data system used to interface with the tape drive.

• INDIVIDUAL BITS COMPRISE THE ALPHABET TO BUILD COMMANDS

COMMAND DESCRIPTION	SOFTWARE MNEMONIC	BIT COMBINATIONS
WRITE CHARACTERS	WCC	b ₀ , b ₃ , b ₄
WRITE FILE MARK	WFM	b ₀ , b ₂ , b ₃ , b ₄
READ RECORD	RCC	b ₀ , b ₁ , b ₄
FORWARD SPACE RECORD	FSR	b ₀ , b ₁
BACK SPACE RECORD	BSR	b ₀ , b ₅
REWIND	REW	b ₀ , b ₇

SOFTWARE TRANSLATES MNEMONICS INTO BIT REPRESENTATIONS

The bits of the command word are combined to build specific commands. The software drivers in the data system will translate the mnemonic for a particular command into the bit representation of the command word. The table above shows how different commands are built. The mnemonic is the actual character used in the assembly language to initiate the action described.

STATUS

• STATUS WORD

b ₀	b ₁	b ₂	b ₃	b ₄	b ₅	b ₆	b ₇	b ₈ b ₁₅
BUSY	PARITY ERROR	WRITE NOT ENABLED	REJECT	TIMING	EOT	BOT	END OF FILE	LOCAL	

SOFTWARE ROUTINES ARE USED TO SAMPLE STATUS FLAGS AND
PROVIDE APPROPRIATE OUTPUT TO OPERATOR.

The status word is similar to but normally simpler than a command word. Individual bits of the status word indicate particular conditions which arise in operation of the interface and the tape drive. Again these bits may be redefined to suit the particular needs of an application. An example is given in the above chart. Software routines are used to sample the status indication of the interface and provide appropriate response.

The response may be a simple continuation of reading data or a message on the console of "you forgot the write ring again lunkhead".

DATA

• **DATA WORD**

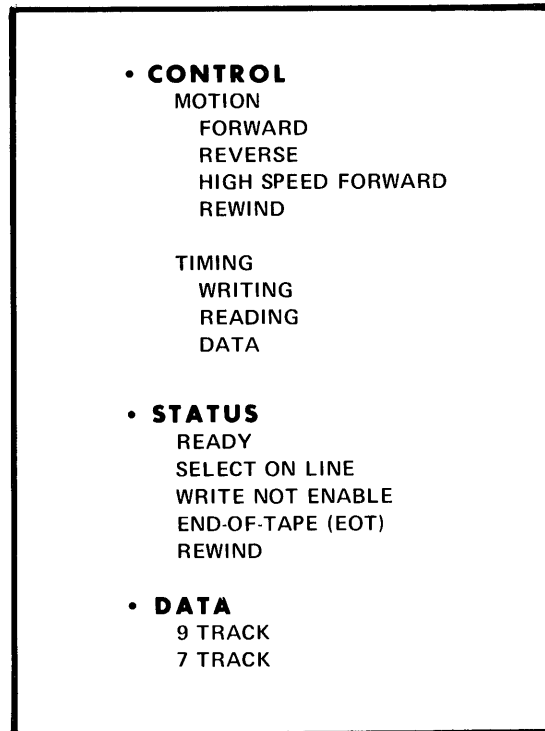
+	2		5			6(8)		
b_{15}	b_{14}	b_{13}	b_{12}	b_{11}	b_{10}	b_9	b_8	b_7
0	1	0	1	0	1	1	1	0

USUALLY 8, 12, OR 16 BITS

READ AS OCTAL (INTEGER) OR BCD (DECIMAL) NUMBERS OR ASCII CHARACTERS

As mentioned previously the data word provided by computer is commonly 8, 12, or 16 bits. The processor itself is designed for efficient utilization of its own particular word size. Note that the computer word is normally represented with the most significant bits on the left which causes the bit numbers to run from right to left.

TAPE DRIVE INPUT / OUTPUT



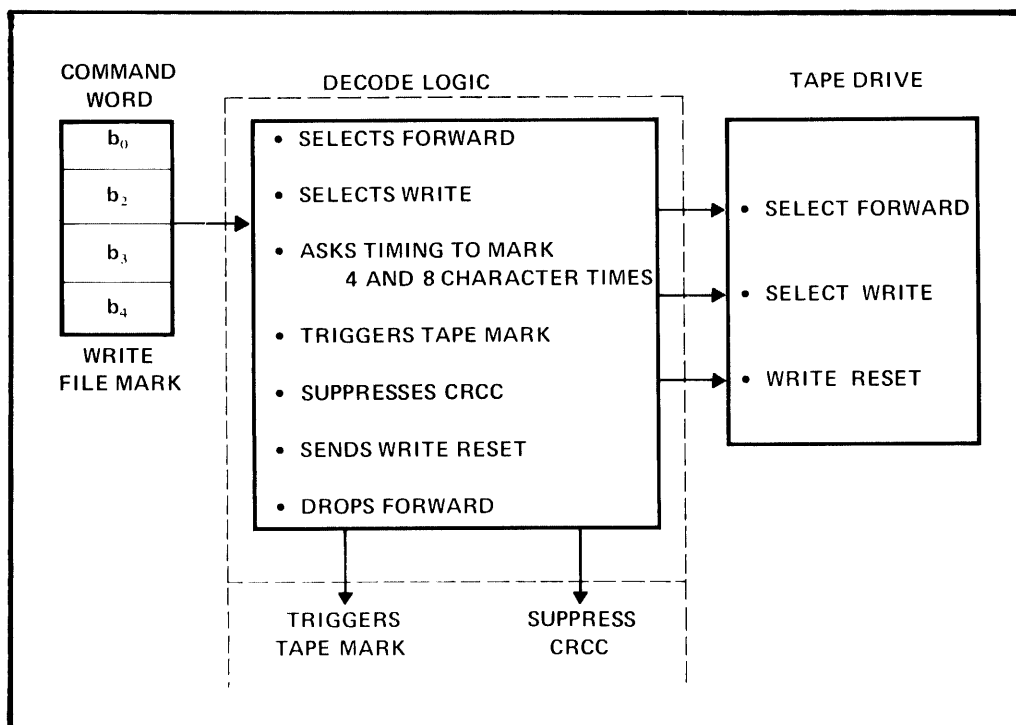
A cursory review of how the tape drive looks to the interface is appropriate at this point. The tape drive controls needed are indications of the speed and the direction of the motion and signals to provide the enabling conditions to read or write data. Timing signals are required for writing data and are provided when reading data.

The status indications provided by the tape drive are the ready condition which means that the tape drive has power applied and is at the beginning of tape. The select and on-line status indicates that the unit has been selected by the data system to receive commands. The additional conditions which provide status indications are the write enabling ring is not installed, the end-of-tape signal when the EOT reflective marked is reached, and the rewind status indicator which indicates the tape drive is rewinding.

The data provided by the tape drive will be nine or seven track including the parity bit.

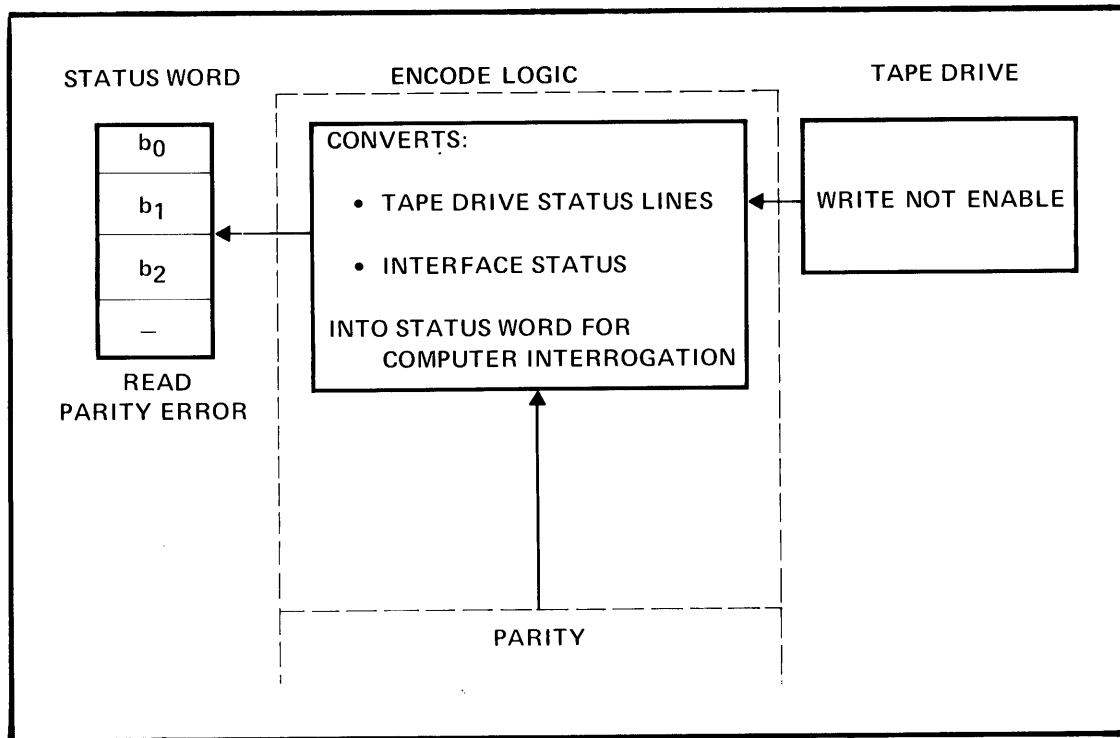
INTERFACE OPERATIONS

COMMAND DECODING



When a command is received by the interface it is held until a control bit from the computer initiates the action. The command will be decoded by the interface and activate the appropriate lines for the tape drive. A sample of this operation is shown here. This command word is for a write file mark (WFM) which was seen in the earlier chart on command words. The decoding section of the interface must select forward motion and the writing process. It must then use the timing clock of the interface to space the appropriate distance before the tape mark may be written. When the distance has been spaced off it must trigger the tape mark generator, space forward eight additional character times while suppressing the CRCC (in 9 track NRZI), send a write reset for the LRCC at the appropriate time, and finally drop the forward motion. Similarly each command word must be translated into a sequence of signals which are meaningful to the tape drive.

STATUS ENCODING



The job of providing status of the tape drive and interface to the computer is not as involved as the problem of translating commands to the tape drive, however, much of the same process is used. Status lines from the tape drive and the data portion of the interface are combined into a status word which may be interrogated by the computer. An example of a read parity error status condition is shown above. The tape drive will be sending a write not enable status and a select and on-line status to the interface. When the parity error occurs the data portion of the controller will send the error indication to the status encoding portion of the interface. When the computer interrogates the status word set up in the controller, a word with bit one and bit two present in the word will be transmitted to the data system. Other conditions must be coded and transmitted to the data system in a similar manner.

DATA

UNPACKING

- BREAKS COMPUTER WORD INTO TAPE COMPATIBLE FORMAT
- DELAYS FIRST BYTE
- FEEDS SECOND BYTE TO TAPE DRIVE
- FEEDS FIRST BYTE TO TAPE DRIVE

PACKING

- ENTERS FIRST BYTE INTO REGISTER
- ENTERS SECOND BYTE INTO REGISTER

PARITY

- WRITE
MONITORS BYTES AND ADDS VERTICAL PARITY BIT
ACCUMMULATES CRCC
- READ
CHECKS VERTICAL PARITY OF INCOMING DATA
CHECKS LONGITUDINAL PARITY OF INCOMING DATA

TAPE MARK GENERATION

- CLOCKS TAPE MARK

The DATA portion of the controller does the packing and unpacking of the data system word to make it compatible with the tape drive. For a 16 bit data system word and a 9-track tape system this will consist of delaying half of the 16 bit word and feeding the other half directly to the tape drive for writing. After this byte is written the delayed half of the word is written. The process for reading is, of course, reversed with one byte delayed to build a 16 bit word. If the data system word were 12 bit or the tape drive 7-track, additional delay and buffering or odd characters must be used. Bit scrambling may be done in the interface or the tape drive.

The PARITY bit or character for the tape drive is provided by the data portion of the interface. During the write process bytes are added to provide the vertical parity bit and at the same time the CRCC is accumulated in a separate register. The CRCC will be released to the tape drive when a trigger is received from the control section of the interface on the end of record sequence. The end of record sequence will also trigger a write reset in the tape drive which will provide the LRCC.

When the data is being read from the tape drive the individual bytes are added and compared with the vertical parity bit to check the validity of the incoming data. At the same time the bits in the individual tracks are added and, finally compared with the longitudinal check character at the end of record. If a mismatch is found in either case a parity error indication is sent to the control portion of the interface. The CRCC check and error correction is often omitted.

DATA (CONT)

TAPE MARK generation is the final function of the data portion of the interface. When the control portion of the interface has spaced the appropriate amount it will send a trigger to the tape mark generator which will put the appropriate bit pattern on the data lines to the tape drive.

The computer data word provided to the interface will commonly be 8, 12 or 16 bits, however, in special applications it could be any number of bits. The data system can be used to pack and unpack its own words for example, it can take a 16 bit word and create two 16 bit words. The first of the two words would contain the first half of the original word and 8 zero bits, while the second word would contain the second half of the original word and 8 zero bits. Software also could provide the additional parity bits required. Normally, this is not done, but it does demonstrate the range of variations that can occur and the flexibility with which systems can be developed to meet applications and cost of development criteria. The cost of developing software would be less than that of developing the hardware simply because the hardware is a translation of the software.

INTERRUPTS

MARRIES THE TIMING OF THE TWO SYSTEMS

- CONTROL BIT NORMALLY MEANS THE COMPUTER IS READY
- FLAG NORMALLY MEANS A PERIPHERAL DEVICE IS READY

ON THE COMMAND CHANNEL:

- A CONTROL BIT INITIATES ACTION
- A FLAG BIT SIGNALS COMPLETED ACTION

ON THE DATA CHANNEL:

- A CONTROL BIT ENABLES READING AND WRITING (SET) OR INITIATES END OF RECORD SEQUENCE (CLEAR)
- A FLAG BIT INDICATES THAT:
 - THE DEVICE HAS DATA FOR READING OR
 - THE DEVICE NEEDS DATA FOR WRITING
- THE TIMING ON INTERRUPTS DEPENDS ON THE SPEED OF THE TAPE DRIVE
AT 37-1/2 IPS FLAGS MUST BE SERVICED WITHIN 33 μ s OR A TIMING ERROR RESULTS

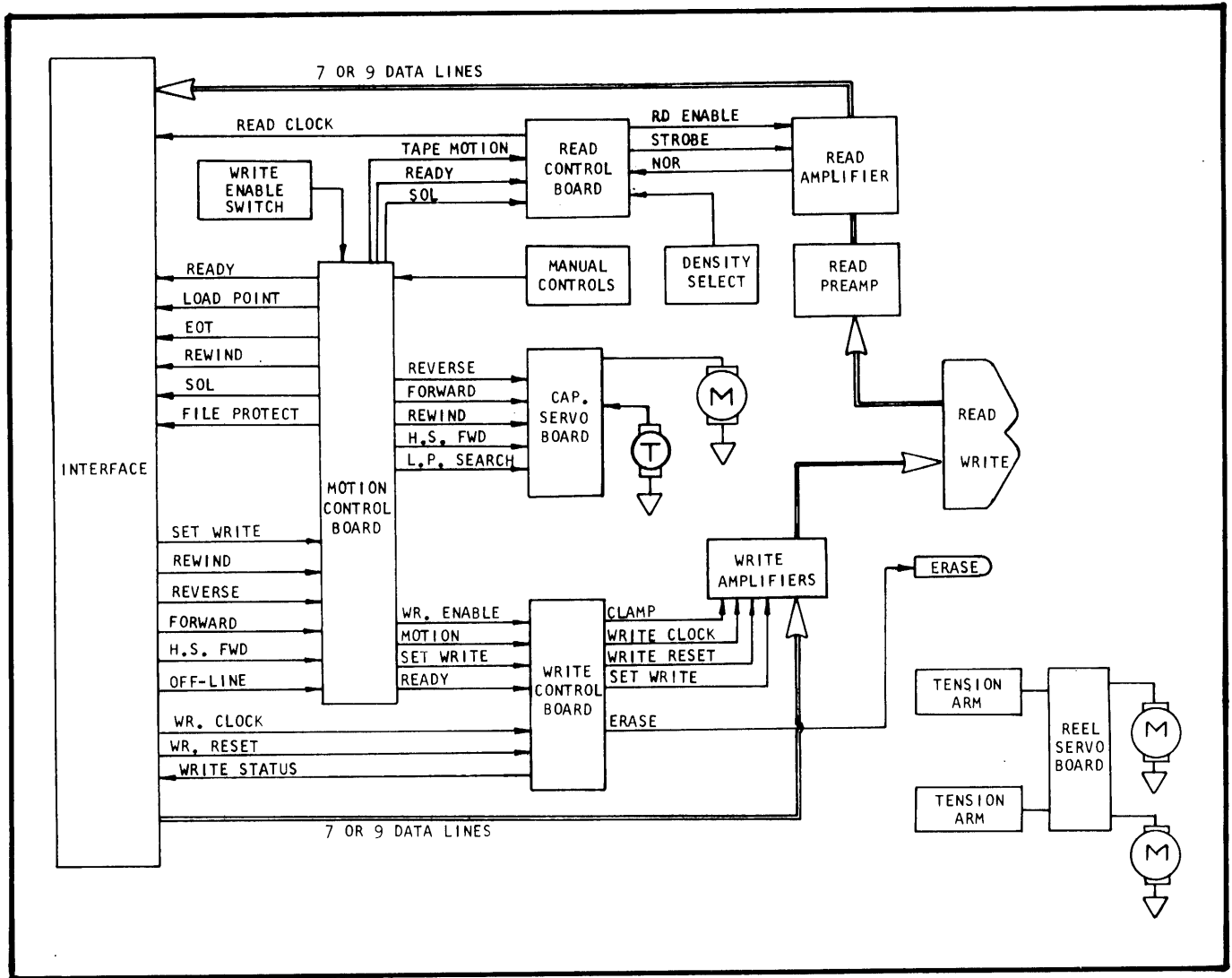
The interrupt portion of the interface marries the timing of the two systems. Interrupt circuitry uses control bits and flags to affect this marriage. Generally speaking, a control bit means that the computer or data system is ready whereas a flag means that a device is ready, the device in this case being a tape drive.

This control bit and flag structure operates as follows:

1. On the command channel a control bit initiates an action while a flag signals that the action has been completed.
2. On the data channel a control bit signals that data has been received and a flag signals that data has been sent.

When the control bit is cleared it will initiate the end of record sequence for the write process. A flag will signal the data system that the tape drive has data when data is being read or that the device needs data when data is being written. Naturally, the timing of these interrupts depends on the internal speed of the data system and on the transfer rate of the tape drive. Using 800 CPI recording density and a tape speed of 37-1/2 ips flags will have to be serviced within something on the order of 33 microseconds or a timing error will result. A timing error means that the tape drive was forced to read or write the next character without having received any data or having sent any data to the data system.

SIMPLIFIED BLOCK DIAGRAM

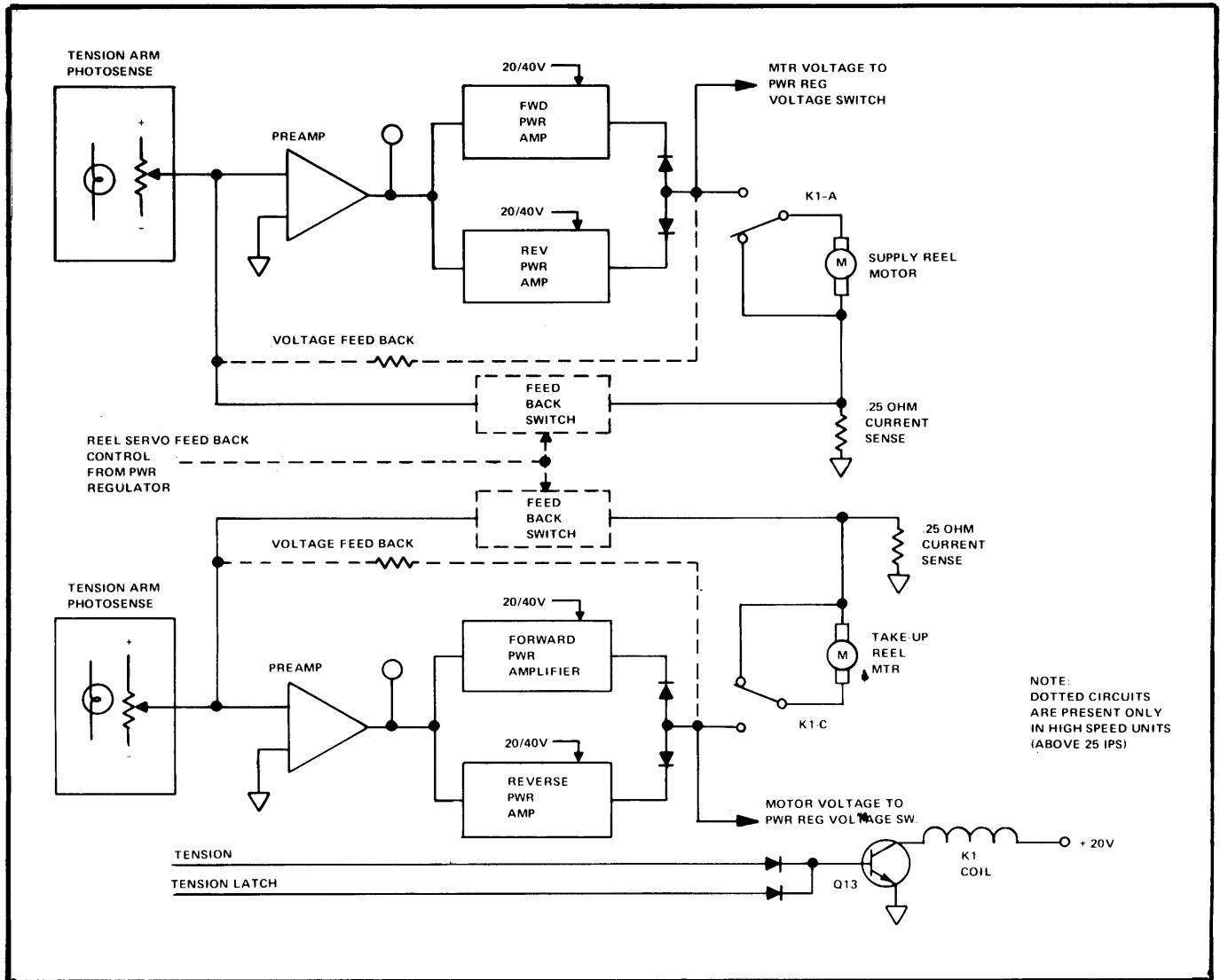


The overall simplified block diagram of the 7970A Tape Unit functionally represents the transport, read electronics, write electronics, and interface or controller.

Note that all motion and status (except write status) lines enter or leave the motion control PC board. This is the heart of the 7970 transport which controls tape motion. All tape motion is provided by the capstan and its associated servo control. Tape storage is provided by the reel servo system. Mass tape storage is handled by the reels and low volume immediate access storage is provided by tension arm assemblies. Reel motion is controlled by photosense assemblies mounted on the tension arms which provide input to the reel servo relative to the position of the tension arms.

The write electronics circuits are controlled by the combined effort of the motion control board and the direct input from the interface. Data is received by the write amplifiers directly from the interface. The read electronics circuits are controlled by the motion control board. During a read operation, data is presented to the interface along with a read clock for interface timing.

REEL SERVO BOARD

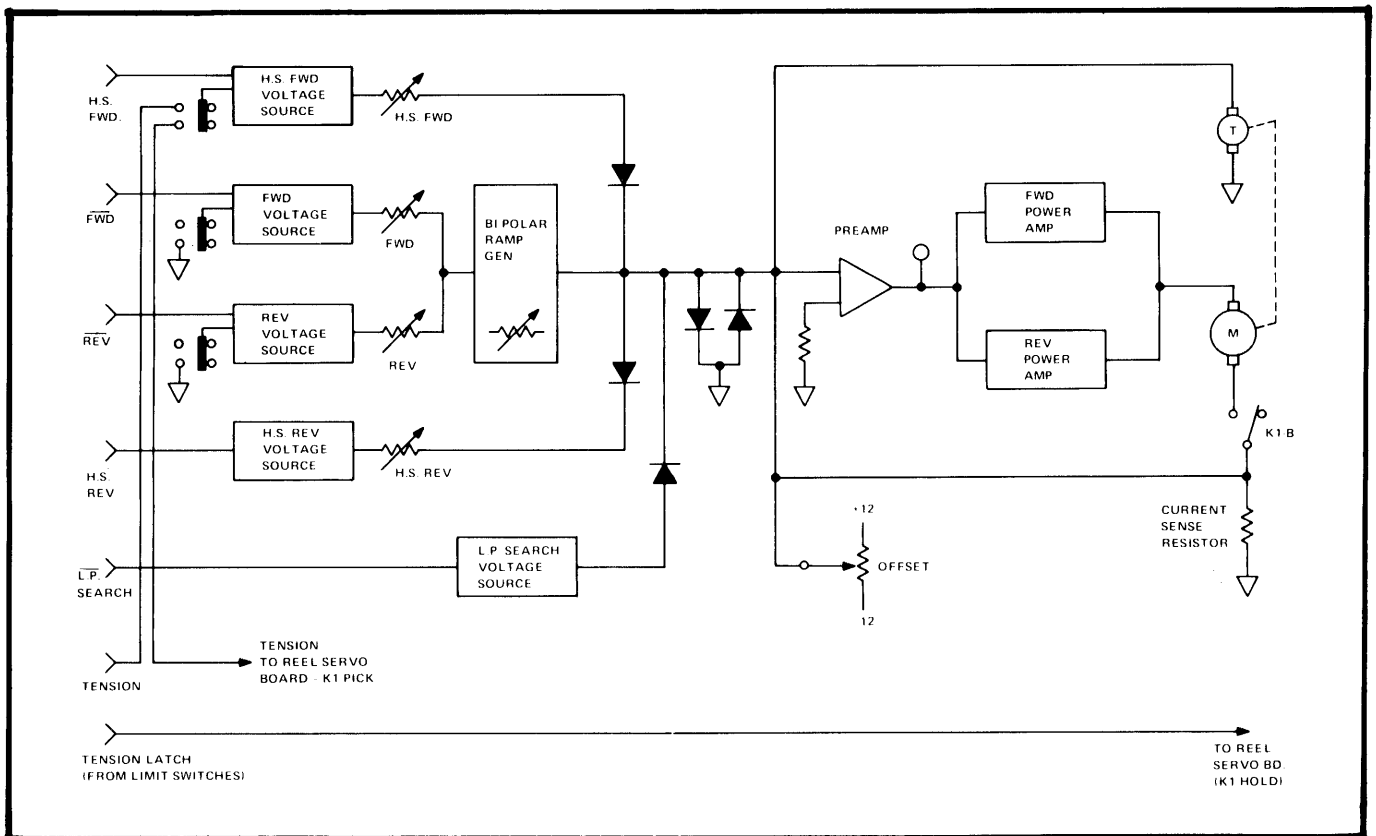


The reel servo board provides drive current for the reel motors relative to the tension arm position. Photosense assemblies on the tension arms provide input to the preamplifier proportional to the amount and direction of tension arm movement. The preamp simultaneously feeds two complementary power amplifiers. The appropriate power amplifier drives the reel motor causing the tension arm to return to its center position. Servo current feedback for low speed units (25 IPS and below) is developed across a 0.25 ohm current sense resistor in series with the reel motor. High speed units (above 25 IPS) normally operate using motor voltage feedback which allows the tension arms more travel and decreases the motor duty cycle. However, when a high speed operation takes place in a high speed unit, the reel servo feedback control line goes negative and current feedback is gated into use. This provides more restrictive feedback and causes the motors to react more per change in tension arm position, thus keeping the tension arm more nearly centered. Supply voltage to the power amplifier is controlled by the voltage switch on the power regulator. The motor voltage is fed to the voltage switch which senses an excess of approximately 11 volts indicating the tension arm is

REEL SERVO BOARD (CONT)

approaching its limits. When this voltage is reached and the unit is in a high speed operation, the appropriate polarity 40 volt supply is gated to the servo amplifier. This allows the reel motors sufficient voltage to maintain the high speed operation.

CAPSTAN SERVO

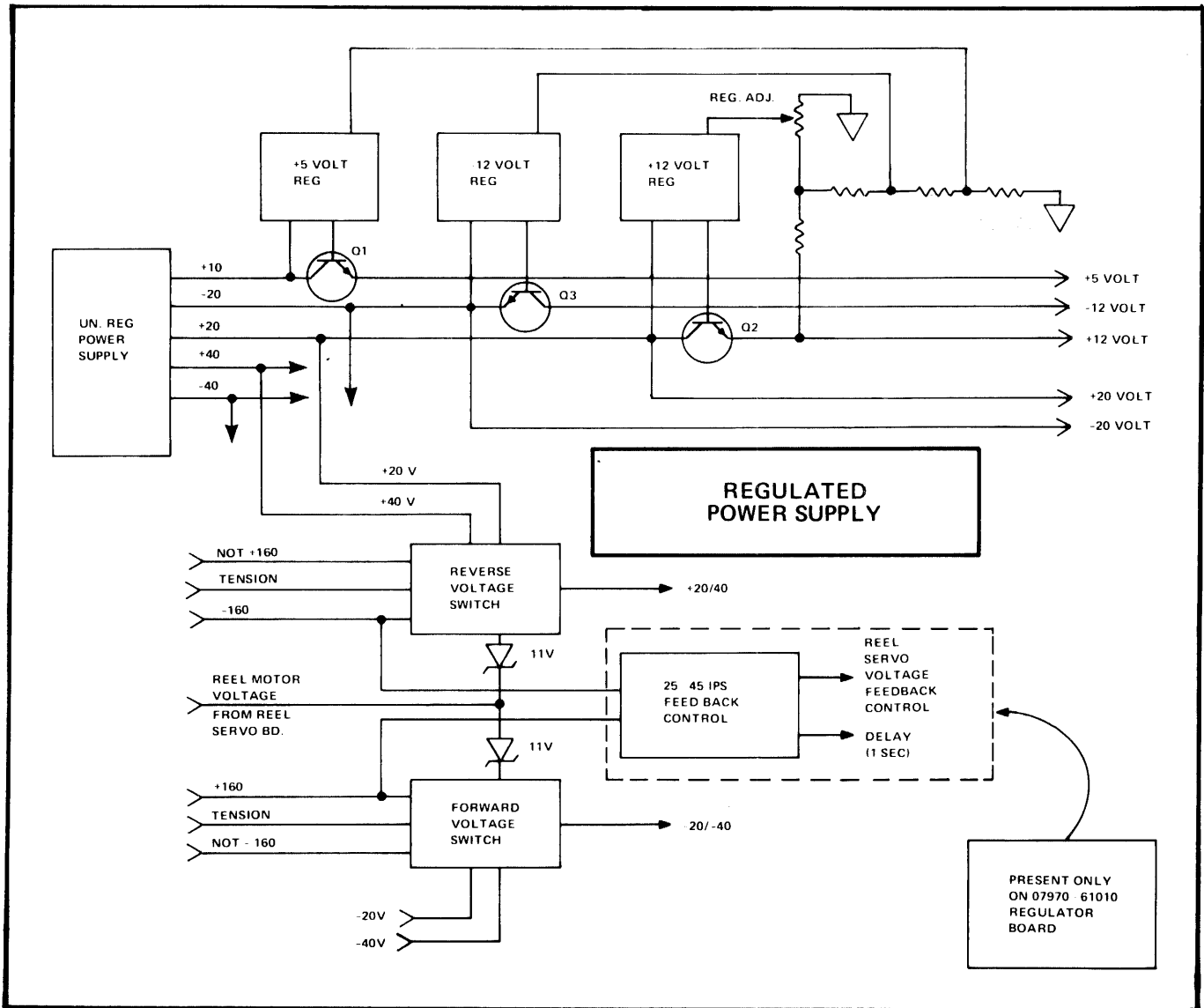


The capstan is the only device on the 7970 transport used for driving tape. Therefore, the capstan drive servo amplifier must be capable of moving tape at 5 different speeds; forward/reverse synchronous, high speed forward/reverse (160 IPS) and load point search speed (20 IPS). Capstan servo command lines enter the servo board from the motion control board and are applied to one of five reference voltage sources. Output from the high speed forward and high speed reverse voltage sources are adjustable and provide an input to a summing junction. Output from the forward and reverse synchronous sources is adjustable and provide input to the bi-polar ramp generator. The slope of the ramp generator output is adjustable to permit changing the start-stop distance; and provides synchronous speed input to the summing junction. The load point search voltage source provides a non-adjustable 20 IPS drive source to the summing junction.

An offset potentiometer is used to compensate for any component leakage and to "zero" the summing junction.

The summing junction provides input to a preamp which simultaneously feeds two complimentary power amplifiers. The appropriate power amplifier drives the capstan motor causing tape motion. Velocity feedback voltage relative to capstan speed is developed by a tachometer and is presented to the summing junction along with motor current feedback which is developed across the current sense resistor. These two feedback voltages oppose the applied drive voltage to maintain a uniform tape speed.

POWER SUPPLY



The power supply voltages can be divided into two major sections: the unregulated, and the regulated voltages. Primary input power must be 115 or 230 volts +10% at 50 to 400 Hz. Maximum power requirement is 400 VA at high line.

Output from 3 diode bridge networks in the unregulated power supply provide +40 volts for the reel servo, +20 volts, and +10 volts. The unregulated +20 volts supplies the +12 volt regulator which employs adjustable feedback for varying the output level. This output goes throughout the transport for utility use as well as to a voltage divider network on the regulator board. Taps from the voltage divider network are fed to the -12 and +5 volt regulator as a reference voltage. Consequently, as the +12 volt output is varied, the -12 and +5 volt outputs also vary.

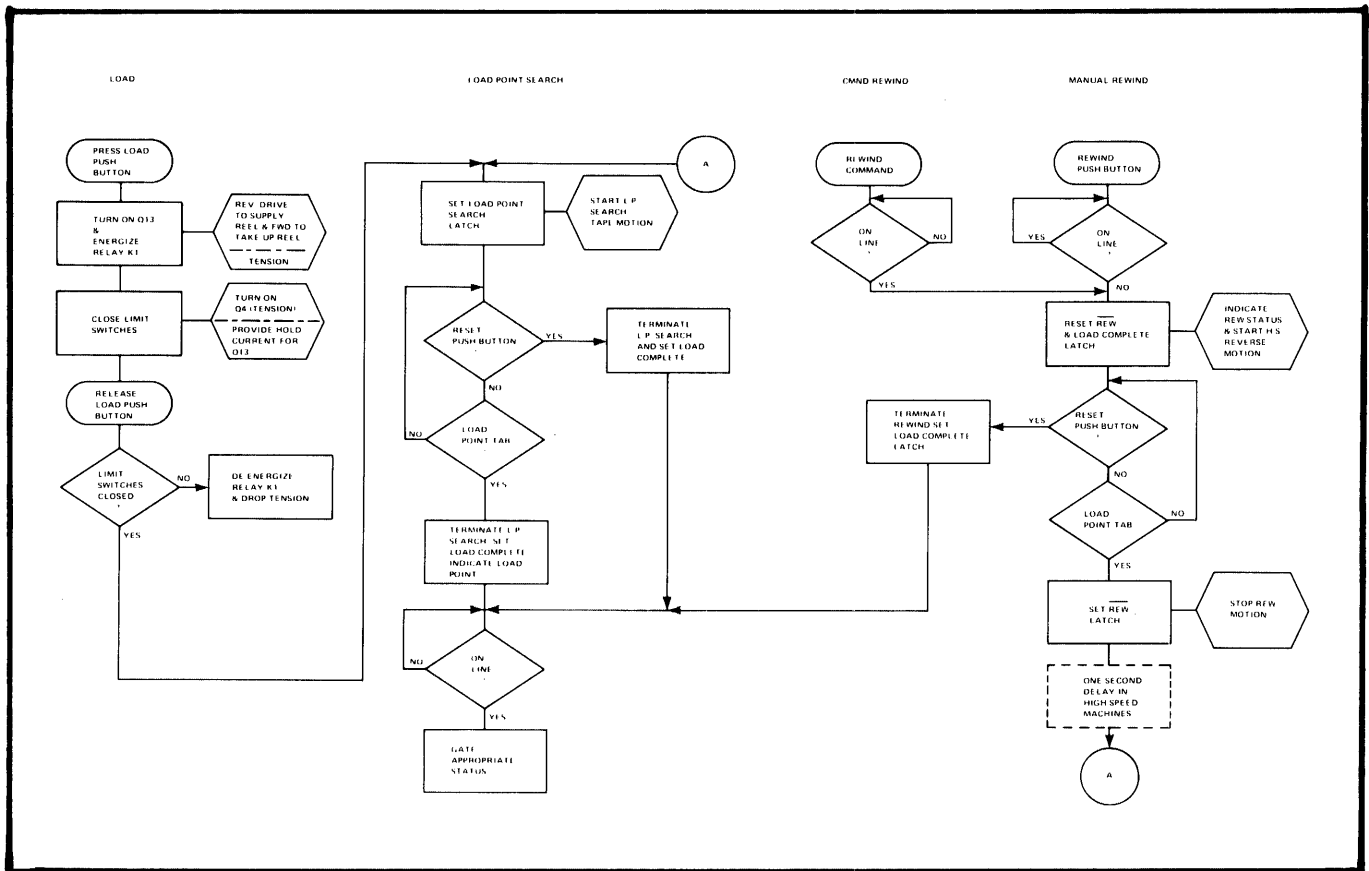
POWER SUPPLY (CONT)

During high speed operations the voltage switch on the regulator monitors the reel servo motor voltage. If the voltage from the servo amplifier exceeds 11 volts (indicating that the tension arm swing is approaching its limits) the voltage switch turns on, supplying 40 volts to the appropriate amplifier. Once the motor voltage returns to less than 11 volts, the voltage switch turns off and removes the 40 volt supply.

For transports operating between 25 and 45 ips, a feedback control circuit is provided. This circuit presents a signal to the reel servo board that causes the reel servos to operate on voltage feedback during normal operations and allows current feedback for high speed operations.

MOTION CONTROL LOGIC FUNCTIONS

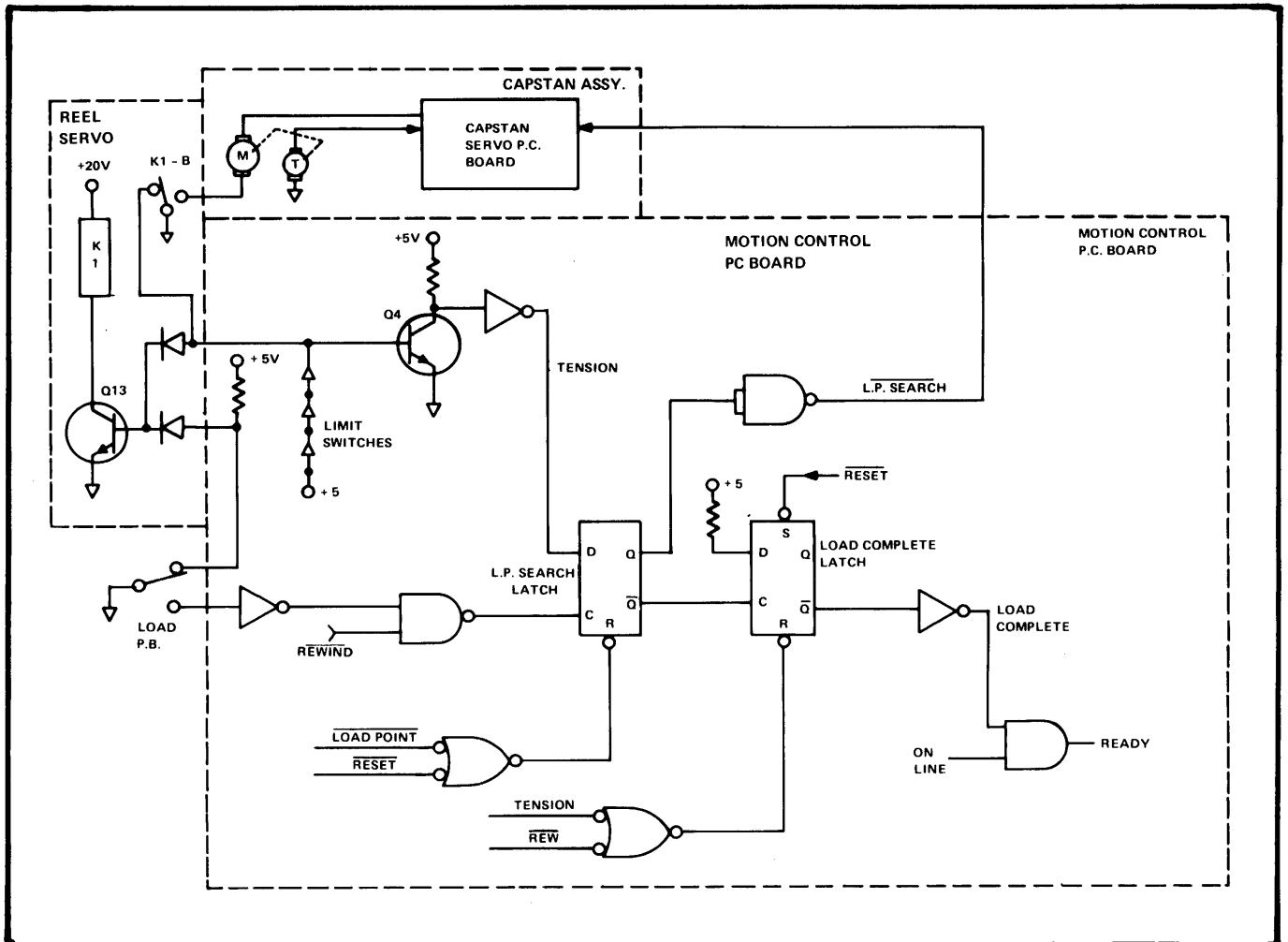
LOGIC FOR LOAD POINT AND REWIND



This flow chart shows the logical steps which are taken to implement to load point and rewind sequences.

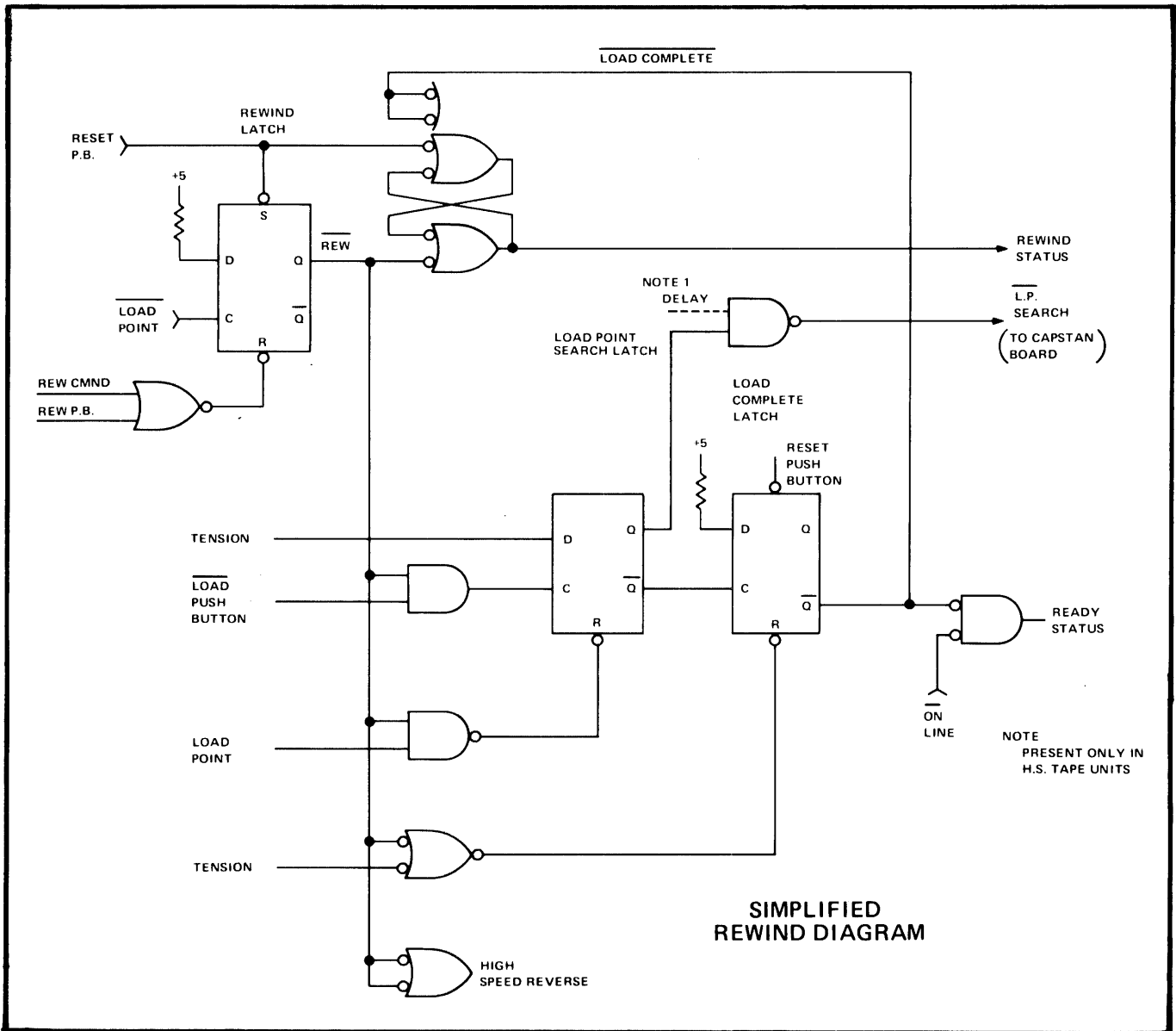
Simplified versions of the circuitry used to obtain this logic is on the following two pages.

SIMPLIFIED LOAD OPERATION



The diagram representing a load operation includes portions of three assemblies: the reel servo, capstan servo, and motion control. Pressing the load pushbutton initiates a load operation by turning on Q13 which in turn energizes relay K1 on the reel servo board. Energizing K1 transfers control of the capstan and reel motors to their respective servo amplifiers. Since, at this time the tension arms are at rest, the supply reel drives reverse and the take-up reel drives forward pulling the tension arms to their center position. This allows the tension arm limit switches to close and provide a holding path for relay drive transistor Q13. Transferring the limit switches also allows transistor Q4 to turn on which provides a "tension" indication to the L.P. search latch. Releasing the load pushbutton "clocks" the L.P. search latch to the set condition, initiating a L.P. search command for the capstan servo. Reaching the L.P. reflector tab or pressing the reset pushbutton generates a direct reset for the L.P. latch dropping the L.P. search command and clocking the load complete latch to the set state. This generates a load complete signal which is anded with ON LINE and sent to the interface as READY status. A second method of generating READY status is providing a rest signal to the direct set input of the load complete latch while tension is true. This directly sets the load complete latch.

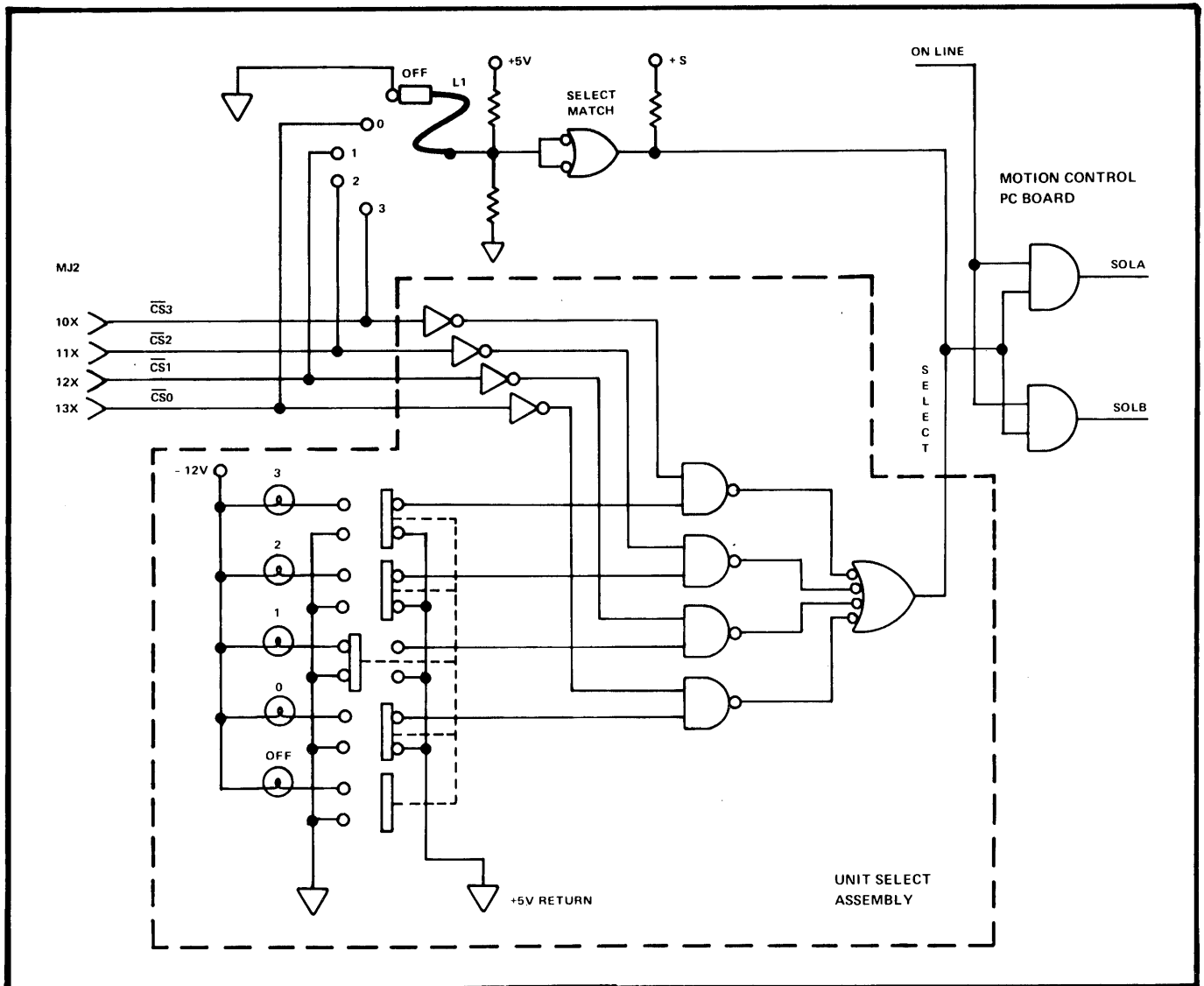
SIMPLIFIED REWIND OPERATION



A rewind operation is initiated by a REWIND command from the interface or by pressing the REWIND PUSHBUTTON. Both methods provide a direct reset to the rewind latch which generates a REW signal. The REW signal initiates a high speed reverse, sends rewind status to the interface, and resets the load complete latch which drops ready status.

With the tape unit rewinding (HS reverse), passing the load point clocks the rewind latch and negates REW command. Dropping the REW command, negates rewind status and clocks the L.P. search latch. Setting the L.P. search latch gates a load point search command to the capstan board if "delay" from the power regulator is positive. This delay is to insure that the rewind command is completely negated prior to starting the L.P. search. Completing the L.P. search (reaching the L.P. tab or pressing reset) sets the load complete latch which gates ready status to the interface.

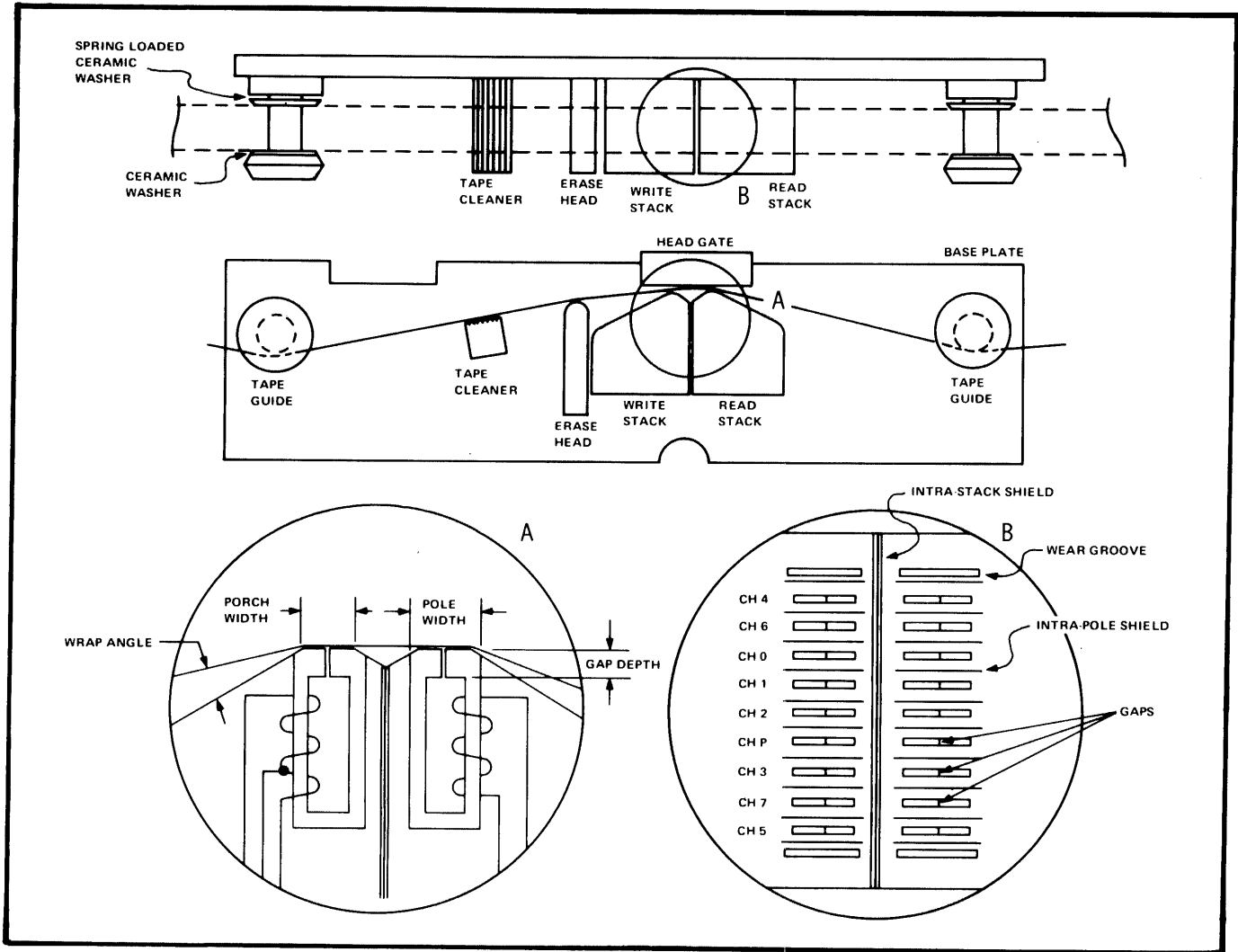
UNIT SELECT OPTION



COMMAND SELECT (CS) signals from the tape unit controller enter the motion control board through connector MJ2. If the unit does not have the Unit Select feature, jumper L1 on the motion control board is connected to the desired unit address pin. This allows unit selection when the C.S. code matches the position of jumper L1. If the tape unit has the Unit Select feature, jumper L1 is placed in the OFF position which disables the SELECT MATCH gate on the control board. When a C.S. signal enters the tape unit, it is anded with the outputs of the Unit Select switches. If the C.S. signal matches the selected switch, SELECT is anded with ON LINE to produce SOL A and SOL B.

NRZI DATA ELECTRONICS

HEAD ASSEMBLY



Since accurate tape guiding over the read/write head is imperative, all components in the head assembly tape path are mounted on a base plate. Tape guiding through the head area is accomplished by two tape guides. The edges of the tape are contacted by two ceramic washers, one fixed position (reference) and one spring loaded to allow for slight variations in tape width. In the forward direction, tape first contacts a slotted tape cleaner which scrapes any foreign particles from the tape prior to its reaching the head stacks. Tape then contacts a full width, high density erase head used to saturate tape in the reset flux state. After contacting the erase head it reaches first the write head stack then the read stack. A head gate near (but not contacting) the tape and over the read/write stack is used to reduce write to read stack crosstalk. A laminated intra-stack shield is placed between the stacks to further reduce the crosstalk. Each track in the head assembly has its own laminated read and write pole, including a coil winding and read/write gap. Separating the tracks are intra-pole shields to eliminate channel to channel crosstalk. As the tape passes over the write head it is magnetically saturated at the write gap. As it passes over the read head, a change in flux polarity induces a current in the read coil which is transmitted to the read electronics.

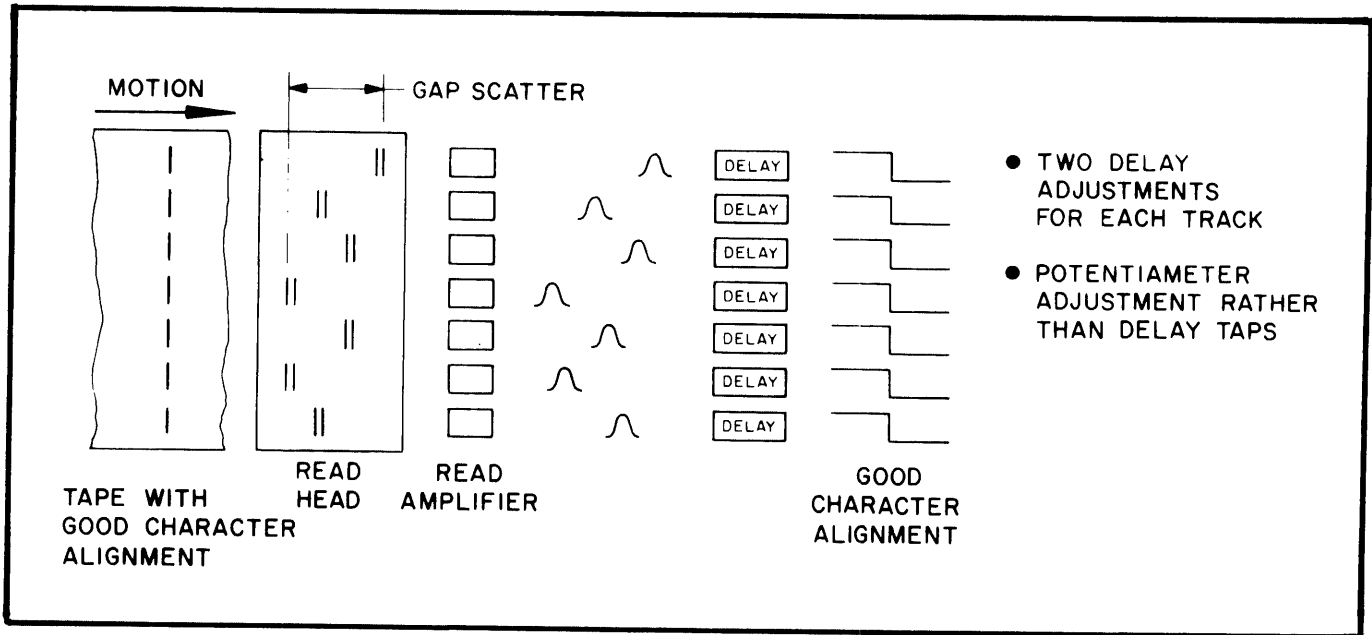
HEAD ASSEMBLY (CONT)

As a head wears, the smooth curve flattens on the top forming a "porch". If the porch reaches the edge of the pole, read or write error may result. At this time the head may be refurbished or re-contoured. This may be accomplished only once since the re-contouring extracts approximately 0.005 inches from the total surface.

Wear grooves are cut into the read/write stacks at the point where the tape edges contact the stack. Their purpose is to decrease tape edge curl due to uneven wear across the head.

The wrap angle around the head stacks, erase head, and tape cleaner is extremely critical. Any alteration of the position of a component may cause characteristic changes in the entire head assembly.

STATIC SKEW

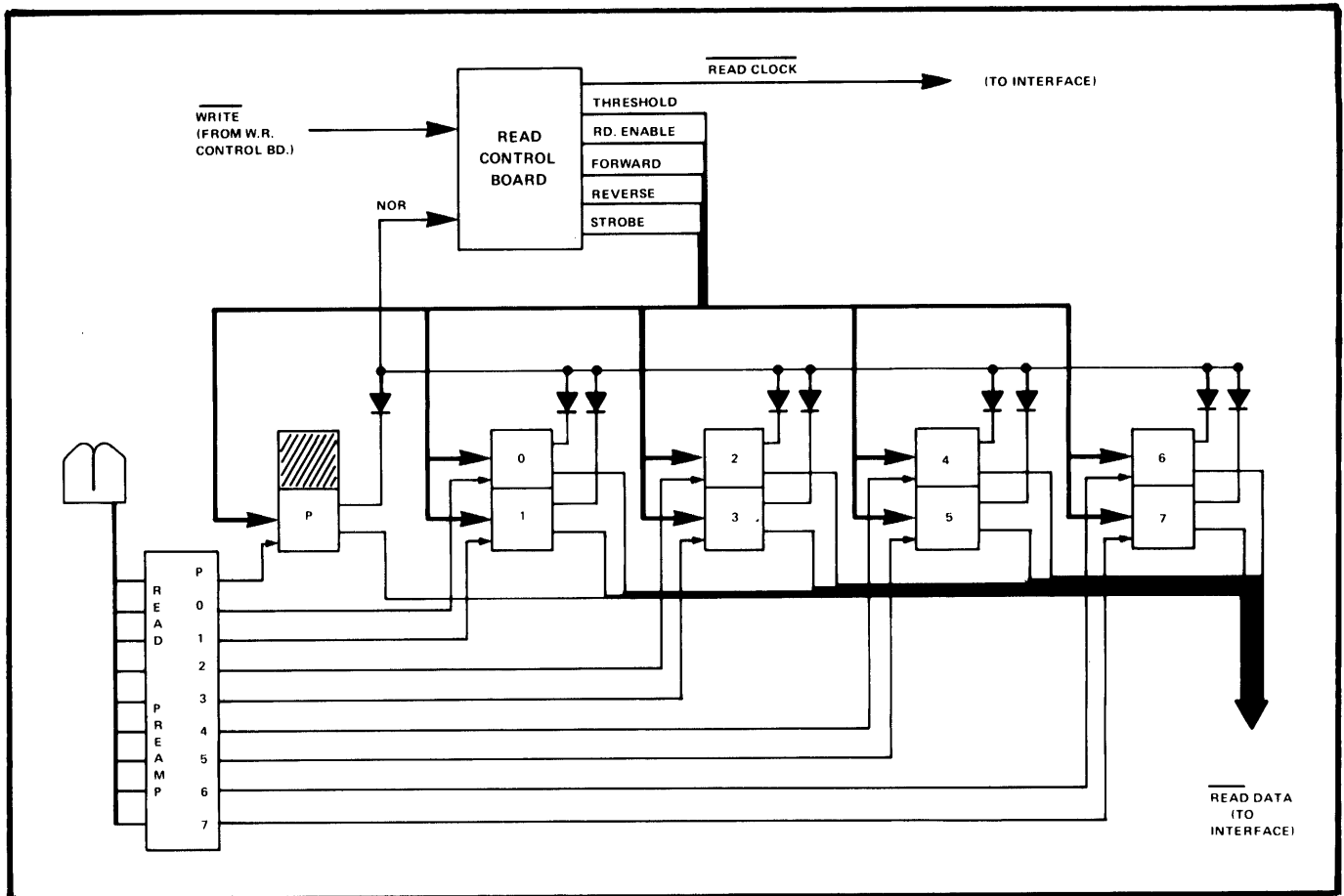


When a digital magnetic tape head stack is constructed, slight variations may occur in gap alignment. Consider the misalignment (called gap scatter) of read gaps. As tape passes over the head the character (assuming good bit alignment) contacts the read gaps at different times depending on gap scatter. This time differential is called static skew.

To compensate for the effects of static skew, the outputs from the read head are presented to skew delay circuits. These delay circuits are adjustable and are used to electrically align all data bits of a character.

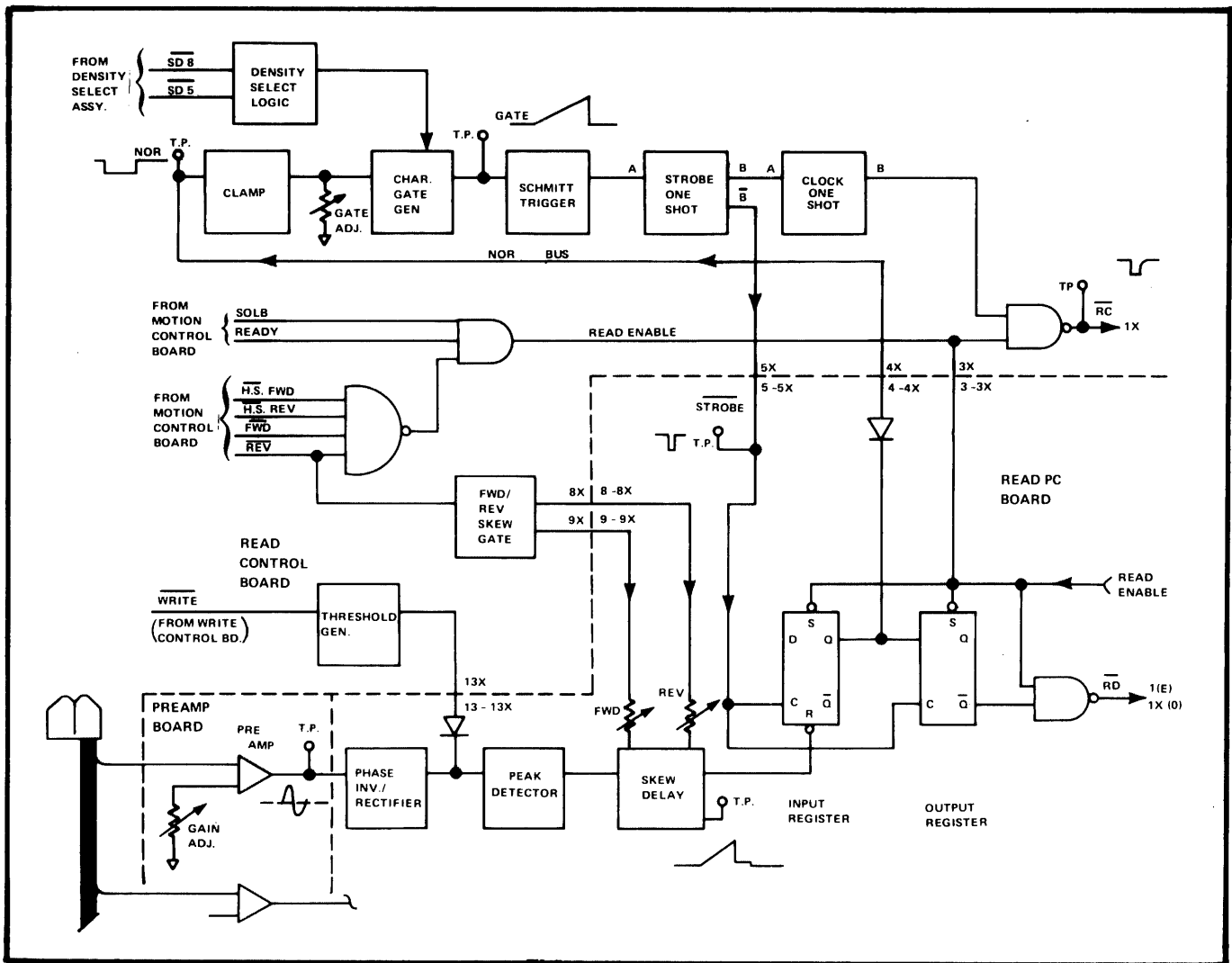
Write static skew effects character alignment when data is written on tape. Data is received from the interface in good electrical alignment. Each channel is then delayed and misaligned to compensate for write gap scatter. This ensures good character alignment on tape.

SIMPLIFIED READ ELECTRONICS



When considering the overall operation of the read data electronics package, we see data is retrieved from tape by the read head and presented to the preamplifier. The read preamplifier amplifies the input from the head assembly and passes it on to the individual read channels. Also presented to the read channels are the bussed control lines from the read control board. **STROBE** is an internally used clock pulse. It is initiated by the **NOR** bus from the read channels and is used to clock data through the read channels. **FORWARD** and **REVERSE** are used to gate the proper skew delay circuits, and **THRESHOLD** signals the read channel when a write operation is in progress. **READ ENABLE** allows read data and read clock to be presented to the interface. **READ CLOCK** is sent to the interface to indicate data true.

READ ELECTRONICS



The function of the read electronics is to receive an analog signal from the head assembly and convert it to a digital output. The associated read electronics block diagram represents the read preamp, the read control, and one channel of a dual-channel read PC board.

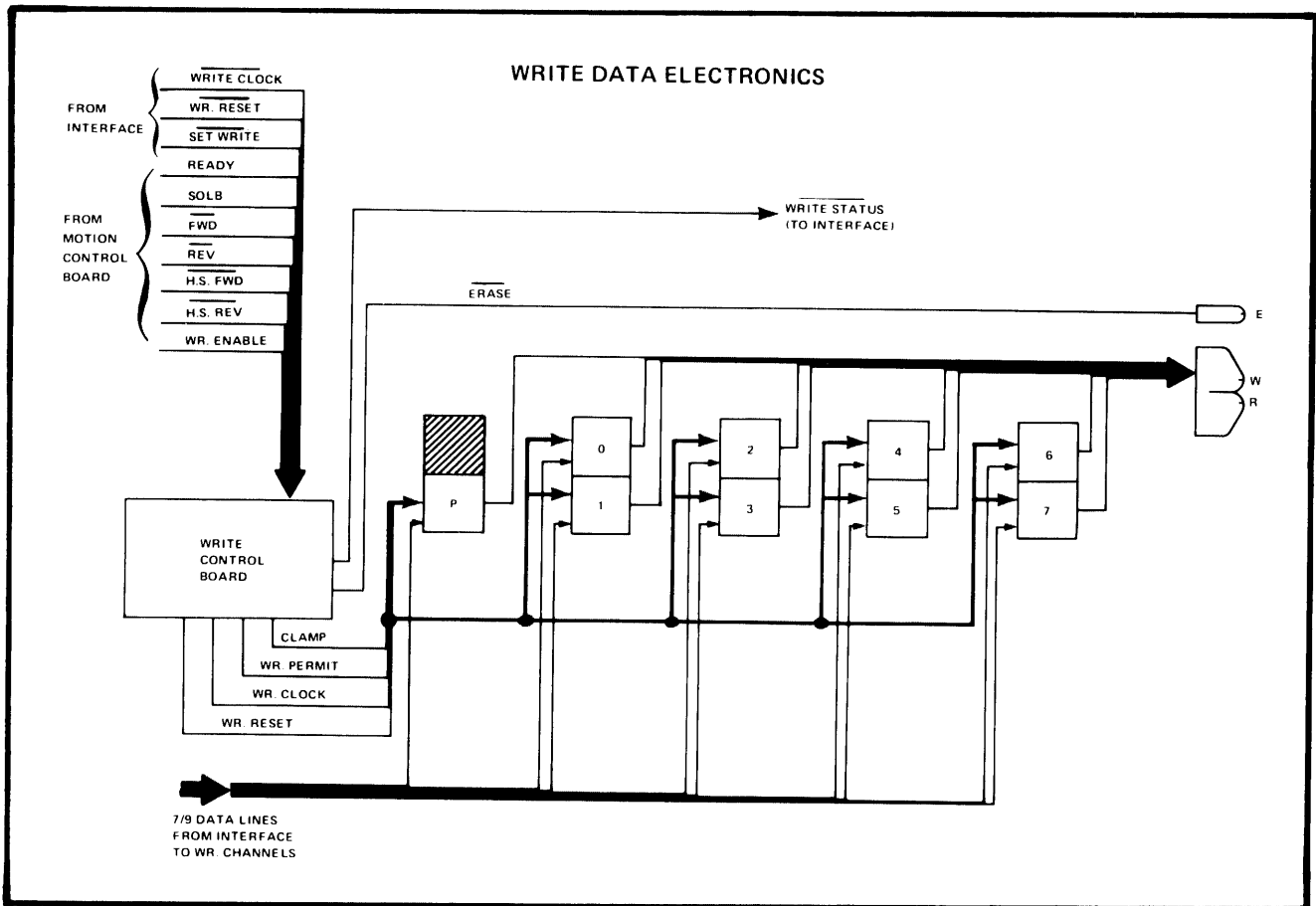
Data from the read head is amplified by an adjustable single stage operational amplifier and sent to the read channel as an analog signal. This analog signal is received by a phase inverter/rectifier which converts it to a full wave rectified signal and feeds a peak detector. The threshold input establishes bias for the threshold detector diode causing approximately 40% base line clipping during write operations and 20% clipping during read operations. This clipping is accomplished to eliminate write to read crosstalk during write operations and provide noise immunity during read operations. The purpose of the peak detector is to represent the peak of the input signal with a sharp positive going edge of a square wave. This edge triggers the skew delay circuit which is used to compensate for static skew. Forward and reverse adjustments are provided for compensating for skew in both directions. When the skew delay ramp times out, a short duration negative going pulse directly resets the

READ ELECTRONICS (CONT)

input register. Resetting the input register puts a "low" on the NOR bus. This "low" triggers the clamp circuit in the read control board, which in turn, starts the character gate time-out. The character gate ramp is coupled to the strobe one-shot through a Schmitt trigger. At the fall of the adjustable character gate ramp, the strobe one shot is fired, which sends a strobe pulse to the input and output registers as a clock. This strobe clocks the input register to its initial set condition and clocks the output register set for a logic zero and reset for a logic one. The trailing edge of the strobe triggers the clock one shot. This output is anded with READ ENABLE and presented to the interface as READ CLOCK. The READ ENABLE signal is used to enable the read clock, input register, output register, and output gate.

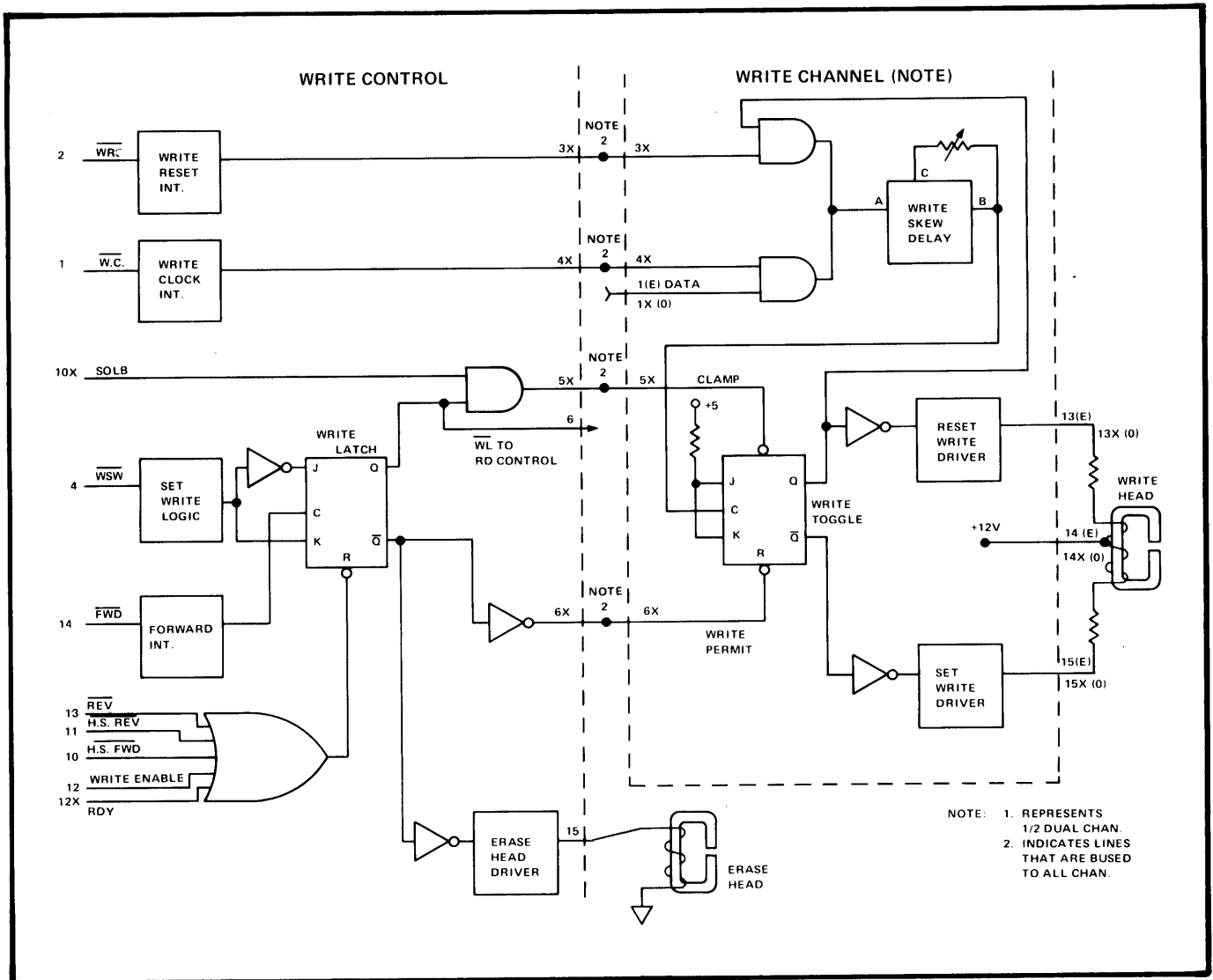
The density select logic input to the character gate generator is used for 7 track tape units when reading tape written at densities other than 800 BPI. This makes it possible to lengthen the character gate for lower densities by selecting a different combination of density control lines.

SIMPLIFIED WRITE ELECTRONICS



In the simplified diagram of the write data electronics, the write control board and 9 data channels are functionally represented. WRITE CLOCK, WRITE RESET (WRS), SET WRITE (WSW) and DATA lines are received directly from the motion control board. The write control board provides CLAMP and WRITE PERMIT control lines, WRITE CLOCK and WRITE RESET to the write channels as well as gating erase current to the erase head and sending write status to the interface. Data lines are received directly from the interface and are controlled internally with WRITE CLOCK. Note that all control lines are bussed to all data channel simultaneously.

WRITE ELECTRONICS



A forward command from the interface is applied to the FORWARD INTEGRATOR on the Write Control Card. The output of the integrator clocks the write latch. If set WRITE is true and direct reset is false (high), the WRITE LATCH is set. This gates erase head current and sends WRITE PERMIT and CLAMP to all write channels. Write clocks (WD) from the interface enters the write clock integrator. The integrator output is "anded" in each channel with data and sent to the write skew delay one shot. A logic one causes the write skew delay to trigger and provides a clock for the write toggle. When both CLAMP and WRITE PERMIT are false, (low) and Q and \overline{Q} outputs of the write toggle are held high which degrades both write drivers. With CLAMP and WRITE PERMIT true (high), the write toggle "flips" with each clock from the write skew delay which alternately causes the reset and set write drivers to conduct.

The quiescent state of the WRITE TOGGLE is reset, causing the reset write driver to drive current thru one half of the center tapped write head. This saturates tape to the same polarity as the erase

WRITE ELECTRONICS (CONT)

head. Each data "one" bit from the interface "flips" the toggle, which reverses the direction of saturation. After all data characters have been written, WRS (write reset) is sent from the interface to the transport write control board. WRS is "anded" with the Q output of the WRITE TOGGLE and generates one more flux reversal if an odd number of bits was written in the channel. All write toggles are therefore left in the reset state. The LRC character is written on the tape as a result of returning all the 7 or 9 write toggles to the reset state.

PE DATA ELECTRONICS
(TO BE SUPPLIED)

GLOSSARY

<u>TERM</u>	<u>MEANING</u>
ADDITIVE	Any material in the coating other than the oxide and the binder resins, for example, plasticizers (materials used to soften an otherwise hard or brittle binder), lubricants (materials used to lower the coefficient of friction of an otherwise high-friction binder), fungicides (materials used to prevent fungus growth), and dyes.
AUTOMATIC	Control of tape motion allowable from remote source. When the tape unit is in this state, it is ready for remote programming (see Local).
BASE FILM	The plastic substrate that supports the coating. The base film of most instrumentation and computer tapes is made of polyester. For less critical uses, cellulose acetate and polyvinyl chloride are employed.
BINDER	The material, usually composed of organic resins, used to bond the oxide particles in the coating.
BIT	Fundamentally, the smallest unit of information. Also used to describe any single logical "one" or "zero", or a representation thereof.
BOT	The beginning of tape as indicated by a reflective marker on the tape.
BUCKLING	Deformation of the circular form of a tape pack which may be caused by a combination of improper winding tension and/or adverse storage conditions.
BYTE	A group of bits operated upon as a unit. A byte may contain one or more characters. This term is widely used for the IBM 360 computers and replaces "character". The byte in a 360 is 8 bits.
CERTIFIED TAPE	Computer tape that is checked on all tracks throughout each and every roll and is certified by the supplier to have less than a certain total number of errors or, more usually, to have zero errors.
CHANNEL	Refers to the circuitry associated with processing and converting data signals from input/output connectors and to and from one track on the magnetic tape.
CHARACTER	A combination of digital bits used to represent a single letter, number, or punctuation mark. In 7 track IBM compatible tape formats six digital data bits plus a parity bit all in parallel form a character. In 9 track formats they are called "Bytes" which consist of 8 digital data bits plus a parity bit.
CHARACTER GATE	A period of time during which bits read from the tape may be "registered" in the read amplifiers for purposes of defining one character or byte.
CINCHING	Longitudinal slippage between the layers of tape in a tape pack when the roll is accelerated or decelerated.
CLOCK	A tape unit input signal or output signal which indicates that during its duration the signals are true, or which initiates a logic sequence. Normally a pulse signal of approximately 10% of the clock rate in duration.

<u>TERM</u>	<u>MEANING</u>
CLOCK RATE	The repetition rate of characters written or read; normally expressed in characters per second.
COATING	The magnetic layer, consisting of oxide particles held in a binder, that is applied to the base film.
CUPPING	Curvature of a tape in the lateral direction. Cupping may occur because of improper drying or cutting of the coating or because of differences between the coefficients of thermal or hygroscopic expansion of coating and base film.
CRCC	Cyclic Redundancy Check Character. A character following the data in a record, but preceding the LRCC, which serves to identify which track was in error in later reading if only one track contained an error. Used in 9 track 800 cpi only.
DATA ELECTRONICS	The circuit board assemblies, write amplifiers, read amplifiers, write control, and read control necessary to convert logic level signals into writing current and/or to convert signals from the read head to logic levels. Contrasted to Transport Control Electronics.
DENSITY	The number of characters written per unit length of magnetic tape. IBM compatible densities are 200, 556, and 800 characters per inch. Commonly expressed as bits per inch, which implies bits per inch per track. Machines set-up to handle multiple densities are commonly referred to dual or triple density units (7-track machines only).
DROPOUT	A temporary reduction in output of more than a certain amount, expressed in terms of the percentage reduction (usually 50%) below the average output of either the roll of tape under test or a reference tape. The duration of the reduction in output may also be specified.
DROPOUT COUNT	The number of dropouts detected in a given length of tape. In digital recording, the length specified is normally that of the complete roll.
DURABILITY INDEX	A measure of the durability of a tape expressed as the number of passes that can be made before a significant degradation of output occurs divided by the corresponding number that can be made using a reference tape. Measurements are usually made by shuttling a given length back and forth over a transport and monitoring the dropout count and/or decrease in output.
END OF FILE GAP	A gap 3.7 inches long preceding the end of a file mark.
END OF FILE MARK	A distinctive character or characters which identifies the end of a file.
EOT	The end of tape as indicated by the reflective marker on the tape hub. This is used as a warning that you are nearly out of tape. It is customary to continue writing past EOT to finish what is in process. You seldom, if ever, stop at the instant EOT is detected because of resultant loss of data.
FALSE LOGIC	Those logic levels wherein a logical "one" is represented by a zero volt logic level and a logical "zero" is either a positive or negative voltage.

<u>TERM</u>	<u>MEANING</u>
FILE	A combination of sequential records forming a specific group.
FORWARD	Tape motion from the supply reel to takeup reel at rated tape speed.
GAP	A magnetized segment of magnetic tape containing no flux changes; normally used to separate records or files. No relation to the head gap.
GAP DEPTH	The dimension of the gap measured in the direction perpendicular to the surface of a head.
GAP LENGTH	The dimension of the gap of a head measured from one pole face to the other.
GAP WIDTH	The dimension of the gap measured in the direction parallel to the head surface and pole faces. The gap width of the record head governs the track width. The gap widths of reproduce heads are sometimes made appreciably less than those of the record heads to minimize tracking errors.
HEAD	The device which contacts the tape and is used for writing and reading.
HEAD-TO-TAPE CONTACT	The degree to which the surface of the magnetic coating approaches the surface of the write or read heads during normal operation of a recorder. Good head-to-tape contact minimize separation loss and is essential in obtaining high resolution.
HIGH DENSITY	The higher density of a multiple Density System. Refers to 556 bits per inch when the 2 densities are 556 and 200, and 800 bits per inch when the 2 densities are 800 and 556.
IBM COMPATIBLE	The ability to write tapes which may be read on IBM 729, 727, or 7330 tape units without error. Also the ability to read IBM written tapes.
INTER-RECORD GAP	A gap which separates written records. One-half inch for 9 track and 3/4 inch for 7 track. A tape drive must start and stop within this gap.
LAYER-TO-LAYER ADHESION	The tendency for adjacent layers of tape in a roll to adhere, particularly after prolonged storage under conditions of high temperature and/or humidity.
LAYER-TO-LAYER SIGNAL TRANSFER (PRINT THROUGH)	The magnetization of a layer of tape in a roll by the field from a nearby recorded layer. The magnitude of the induced signal tends to increase with storage time and temperature, and to decrease after the tape is unwound; these changes being a function of the magnetic instability of the oxide.
LOAD POINT	The position of the tape when the tape is positioned with the beginning of tape marker under the photosense unit.
LOCAL	Control of tape unit from tape unit control panel only. Any malfunction in the tape unit - tape break, loss of vacuum, etc. - will cause the unit to drop into local from automatic.

<u>TERM</u>	<u>MEANING</u>
LOGIC LEVELS	The expression of logical "zero's" and "one's" or true and false states by two voltage levels of which one level is normally zero volts and the other a positive or negative voltage of from 3.5 to 20 volts.
LOGIC POLARITY	The expression of whether the logic level which is other than zero volts shall be a positive or negative potential.
LONGITUDINAL REDUNDANCY CHECK CHARACTER (LRCC)	A character which results from the application of Write Reset Command at the end of a Record. This character is spaced three or seven character spaces from the last character in a record.
LOW DENSITY	Refers to 200 bits per inch in a 556 and 200 bpi system or 556 bits per inch in an 800 and 556 bpi system.
MASTER ALIGNMENT TAPE	A magnetic tape with continuous "ones" written in each track at a specified density. Used to align read amplifier skew compensation circuits.
MASTER OUTPUT TAPE	A magnetic tape of standardized magnetic characteristics. Used to determine efficiency of write circuits and standardize threshold levels in read circuits.
NRZI	The tape magnetization code used for IBM compatibility at all densities except 1600 cpi. Indicates that the tape is constantly magnetized and changes magnetic state to represent a logical "one". A logical "zero" causes no change in magnetic state.
OPERATOR CONTROL PANEL	A panel of lamps, switches, pushbuttons and logical circuitry for the proper control of the Tape Transport in the "Local" state.
OXIDE BUILD-UP	The accumulation of oxide or, more generally, wear products in the form of deposits on the surface of the heads. Oxide build-up causes a loss in output, particularly at short wavelengths, and accelerates tape wear.
OXIDE SHED	The loosening of particles of oxide from the tape coating during use. The term is often used to denote the production of wear products in general.
PHASE ENCODING	The tape magnetization code used for 1600 cpi recording density. A logical zero is a flux change in one direction while logical one is a flux change in the opposite direction.
PULSE LOGIC	That logic wherein a logical "one" is defined as a pulsed transition from the logical zero level to logical one level and return to the logical zero level prior to the next character.
READ	The translation of magnetic information on tape to a useable signal.
RECORD	A combination of sequential characters forming a specific group.
REVERSE	Tape motion from Takeup Reel to Supply Reel at rated tape speed.
REWIND	Tape motion from Takeup Reel to Supply Reel at higher than rated speed (tape speed in this mode is not constant).

<u>TERM</u>	<u>MEANING</u>
SEPARATION LOSS	The loss in output that occurs when the surface of the coating fails to make perfect contact with the surfaces of either the record or reproduce head.
SKEW	<p>Pulses written simultaneously on two or more tracks may be displaced in time when reproduced due to imperfections in the mechanical tape handling system and/or head geometry. This time displacement is termed "Skew", and specified as the worst case time displacement of the reproduced pulse from any track when referenced to the simultaneously reproduced pulse of any other track.</p> <p>"Static Skew" is measured as the observed constant component of the total track-to-track time displacement, and "Dynamic Skew" the varying component.</p>
START DISTANCE	The amount of tape which has been moved during the acceleration interval of Start Time.
START TIME	The elapsed time from application of a Start signal until stable tape motion (within a stated percentage, usually $\pm 5\%$ of normal speed) has been achieved.
STOP DISTANCE	The amount of tape which passes the head during the deceleration interval after removal of a Forward (or Reverse) command.
TAPE	The medium used for the storage of data in Digital Magnetic Tape Units. Consists of gamma ferric oxide particles encompassed in a resin-solvent mixture coated upon a plastic base material, 1/2" wide and up to 2400' long wound on IBM compatible reels. Is available in many grades from many manufacturers.
TAPE PACK	The form taken by the tape wound onto a reel. A good pack is one that has a uniform wind, and is free from spoking, cinching, and layer-to-layer adhesion.
TAPE SPEED	The velocity, expressed in inches per second, at which tape is moved past the head.
TAPE TRANSPORT	The electromechanical mechanism for moving the tape from the file reel past the magnetic heads.
THRESHOLD	A condition set in read amplifiers to discriminate against bits read from the tape of less than a predetermined energy content; expressed as a percentage of normal bit energy or as a percentage of the maximum read head preamplifier output voltage.
TRACK	The longitudinal areas of the tape which contain magnetic information. IBM compatible tapes contain seven or nine such tracks in 1/2" wide tape.
TRACK SPACING	The distance between the center-lines of adjacent tracks.
TRACK WIDTH	The width of the track corresponding to the width of a transducer in the head.

<u>TERM</u>	<u>MEANING</u>
TRUE LOGIC	Those logic levels wherein the logical "zero" is represented by a zero volt logic level.
UNLOAD	Related to the removal of Supply Reels from the tape unit or the removal of the tape unit from remote control.
WEAR PRODUCT	Any material that is detached from the tape during use. The most common wear products are oxide particles or agglomerates, portions of coating, and material detached from the edges of the tape.
WRITE	The magnetization of the tape to correspond with digital data.
WRITE ENABLED	The IBM reel contains a circular slot on the rear surface into which a plastic ring may be inserted. The tape unit detects the presence or absence of the ring and inhibits writing unless the ring is present. When the ring is present the file is "write enabled".
WRITE PERMIT	A tape unit input signal which when true enables the writing circuitry (i.e., there is current in the heads) provided the file ring is "write enabled".
WRITE RESET	Refers to the state of the head current for the generation of gaps or to the tape unit input signal required to place the write amplifiers in the correct state for gap generation.



690 E. Middlefield Rd., Mt. View, California 94040, Tel (415) 968-7291, TWX 910-379-6441
Europe: 1217 Meyrin-Geneva, Switzerland • Cable "HEWPACKSA" Tel (022) 41.54.00