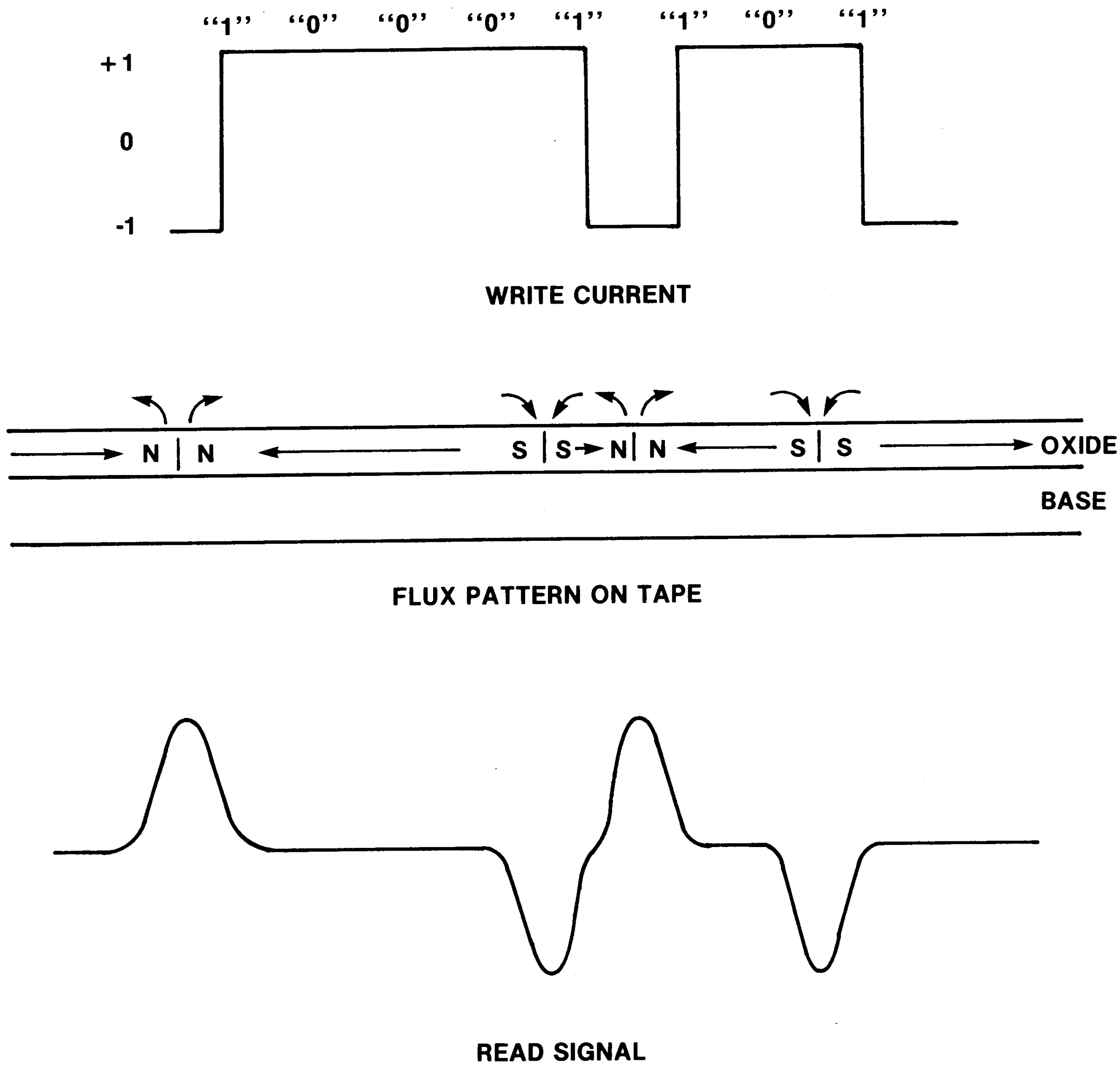


Figure 11.16 Non-Return-To-Zero, Change on Ones

11.5 TAPE PHYSICAL COMPOSITION AND LAYOUT

Digital recording tape is composed of a mylar plastic base which has one side covered with an oxide or ferrous oxide coating of uniform thickness and density.

Tape size is ½ inch wide (0.498 ± 0.002 inches). Tape thickness is 1-½ mil (0.0015 inch). Standard lengths per reel are:

8 inch diameter reel = 1,200 feet of 1-½ mil. tape
10.5 inch diameter reel = 2,400 feet of 1-½ mil. tape

Tape is wound onto the tape reel as shown in Figure 11.17. The hub end is placed next to the core of the reel and wound clockwise around the core. The "reference" edge of a tape is defined as the edge next to the usually clear plastic side of the reel (the front side). The oxide side is wound facing the core of the reel. The job end is not attached to the hub or core of the reel. The rim end is the end left free after winding the tape onto the reel. With oxide side down and rim end to the right, the reference edge will be the edge closest to the observer. The reference edge is used as a starting point for many measurements, such as, track placement and identification, and marker locations.

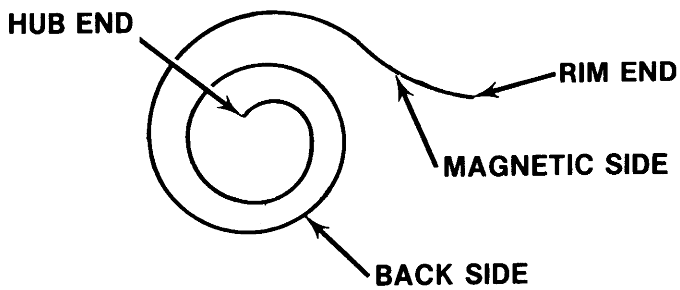


Figure 11.17 How Tape Is Wound On The Tape Reel

The reels have a standard inside hub diameter of 3.690 inches. The inside ‿imension between reel sides is 0.55 inches. This allows a nominal clearance between tape edges and reel sides. Each reel of tape should have two reflective markers; one for beginning of tape (BOT) and one for end of tape (EOT). Locations vary slightly depending upon the recording format to be used. Specifications are shown in Figure 11.18, NRZI Tape Markers; and Figure 11.19, P.E. Tape Markers.

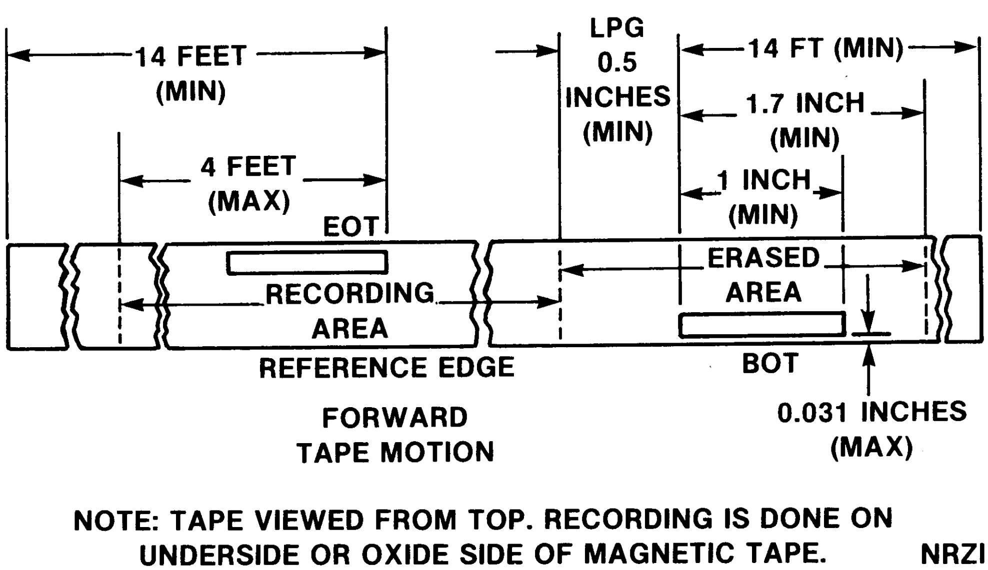
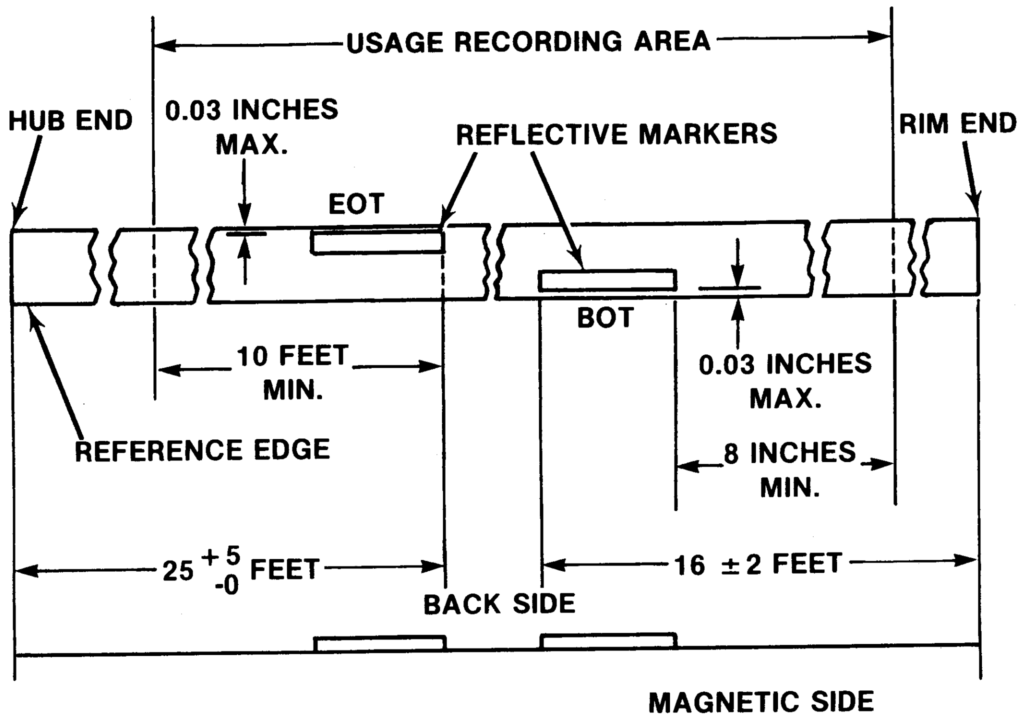


Figure 11.18 NRZI Tape Markers



BOT: BEGINNING-OF-TAPE MARKER
EOT: END-OF-TAPE MARKER

Figure 11.19 P. E. Tape Markers

The markers are silver reflective foil 1.1 inches ±0.2 inches in length and 0.19 ± 0.02 inches in width and 0.0008 inches maximum thickness.

Markers are usually self-adhesive and are applied to the base material side of the tape. They should not protrude beyond the edge of the magnetic tape, nor wrinkle or distort the tape.

The Beginning of Tape (BOT) marker is sensed by tape transports and used to define the "load point" or starting point of recording. The End of Tape (EOT) marker, when sensed, is made available to the tape interface to allow termination of recording within 4 to 10 feet past the EOT. EOT has no function in read modes.

Markers should be replaced whenever they are not reflective. This can be caused by scratches or dulling from wear or abrasion. Care must be taken not to damage the oxide area around the markers as this portion of the tape is considered part of the usable recording area.

11.5.1 TRACK LAYOUT

Digital tapes are recorded and read on a multiple track format - by convention, either 7 or 9 tracks. Each track is produced longitudinally (along the length of the tape) by an individual recording head gap (see Figure 11.20). The multiple gaps are arranged into a single assembly. The standard dimensions for head and track layouts for 7 and 9 track recordings are shown in Figure 11.21. Note that the width of the write gaps or tracks are wider than the read gaps. This allows a margin of tolerance in tape tracking when reading the recorded data.

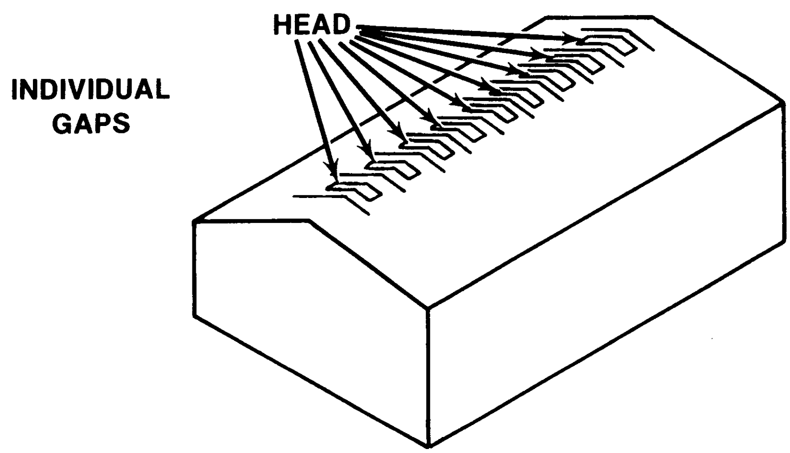


Figure 11.20 Tape Head Construction

In tape head manufacturing, the taps must be placed perpendicular to the reference edge of the tape. Due to manufacturing tolerances, the gap placement cannot, economically, be perfect. In high quality heads, the tolerances are typically a variation in the area of 50 to 75 microinches total between all tracks. This deviation within the vertical column is termed gap scatter (see Figure 11.22).

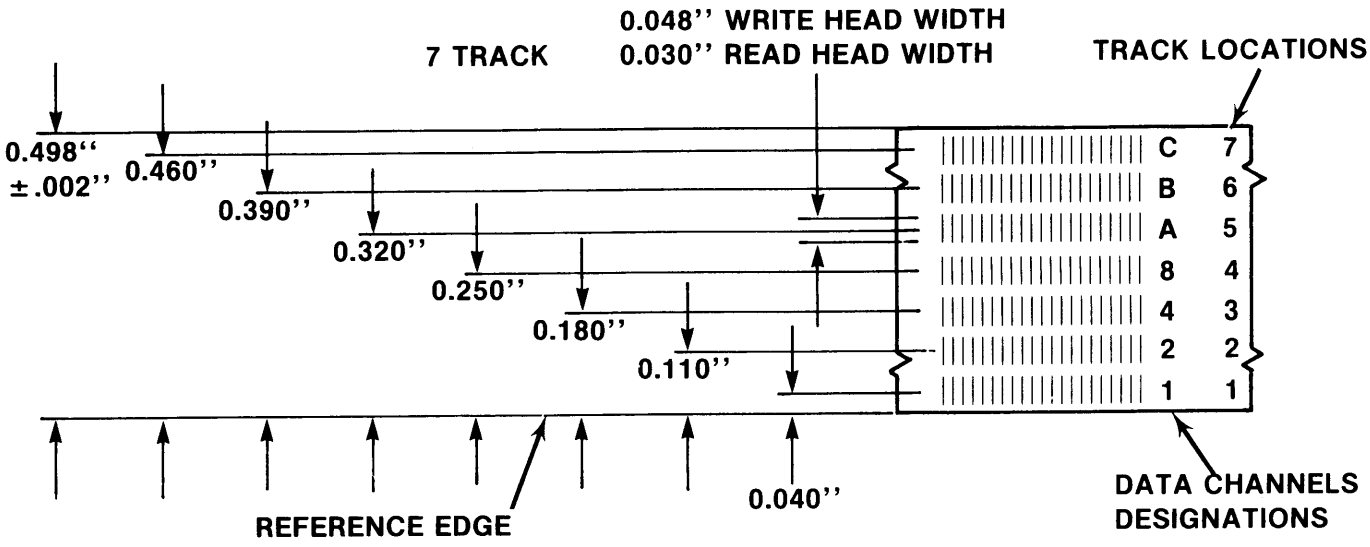
Due to the longitudinal displacement, gap scatter creates a situation wherein tracks will see flux changes on the tape at different times. This phenomena is called skew.

Another source of skew is mechanical alignment of the head relative to the tape path. That is deviation of the effective centerline of the head from true perpendicularity to the tape path as in Figure 11.23. This is usually termed azimuthal skew.

These sources of skew or time displacement between tracks must be compensated for in the read electronics in order to reproduce the data originally recorded simultaneously on the multiple tracks. The skew due to mechanical tolerances in head manufacture and mechanical alignment is called static skew.

In an ideal situation, tape moves across the heads in a smooth, straight and continuous manner. In actual practice, this is not the case and, as tape passes across the heads, some undesired movements take place. The effects due to undesirable tape movement are classed as dynamic skew and may be termed transverse, lateral and longitudinal, which define the axis over which the movement takes place.

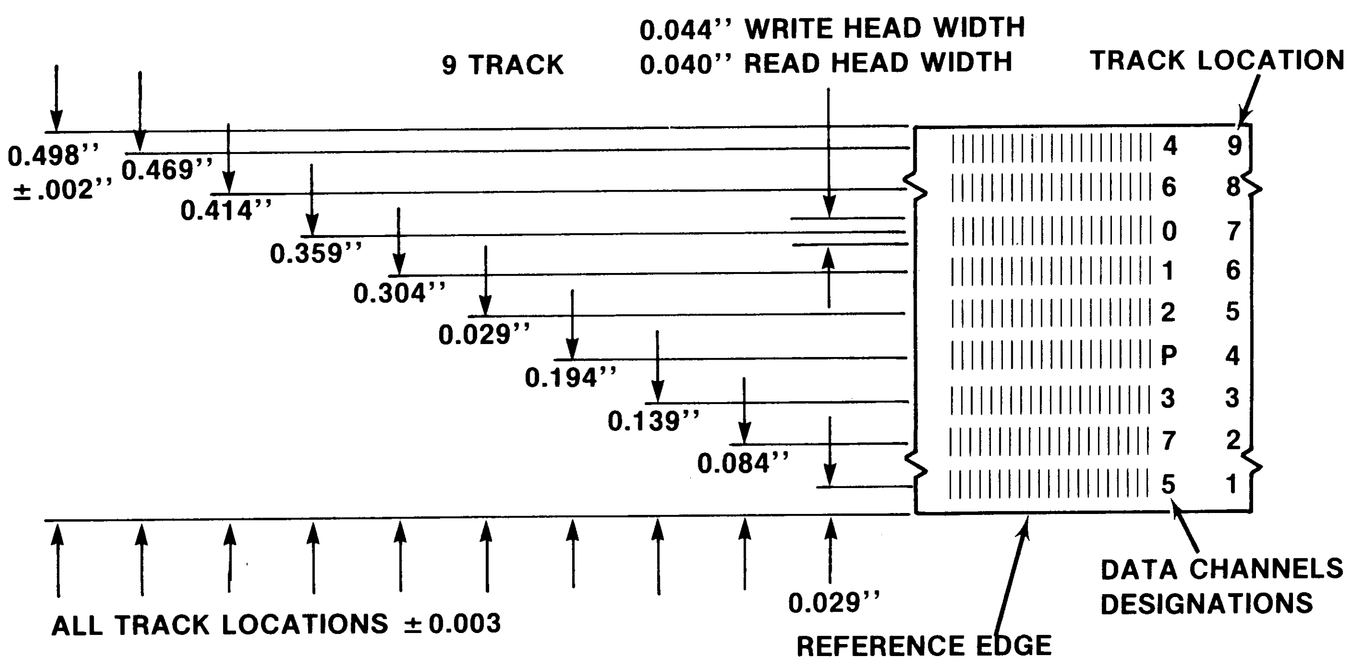
Transverse movement is defined as side to side motion of the tape such that centers of the tracks on tape shift relative to the centers of the head gaps.



TRACK LOCATIONS 2-C: +0.0040"
-0.0035"

TRACK LOCATION 1: ±0.0025"

TRACK LOCATIONS AND SPACING, 7-TRACK SYSTEM



ALL TRACK LOCATIONS ±0.003

TRACK LOCATIONS AND SPACING, 9-TRACK SYSTEM

ACOM/164

Figure 11.21 Track Data

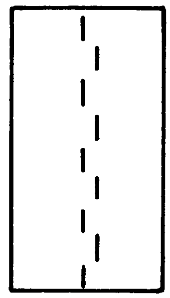


Figure 11.22 Gap Scatter

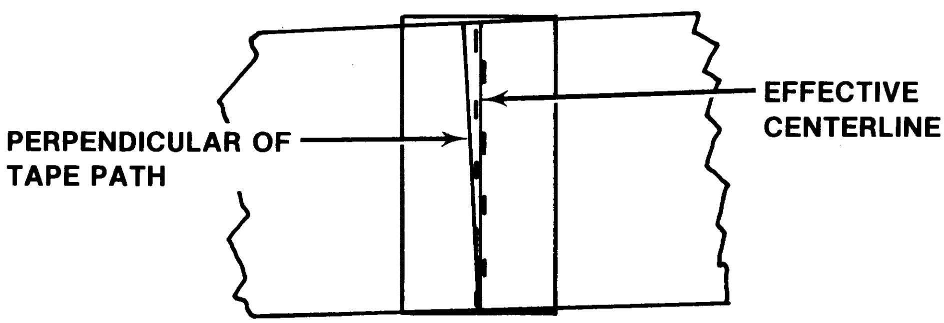


Figure 11.23 Azimuthal Skew

Lateral movement or skewing is characterized by one edge of the tape slightly leading the other in time. This dynamic condition, which is constantly changing due to tape motion, is similar to azimuthal skew.

Longitudinal movement error involves irregular tape speed. In practice, tape speed across the head is irregular due to power variations, eccentric rotary elements and tape friction effects. This causes the time between bits detected to fluctuate.

Lateral, short term longitudinal, and transverse movements are called dynamic skew or jitter (see Figure 11.24). These effects can be minimized by careful and accurate alignment of the entire tape path, from supply reel through all tape guides, buffering, read head, capstan and take-up reel. Long term longitudinal motion (speed) variations are termed flutter and as such, measured and included in the specifications of tape transports.

Verification and adjustment of head alignment is done using a master (skew) alignment tape. A master skew tape is a precisely controlled tape written with a single gap full width head. Skew verification is made by observing the two outside track signals while the transport moves the alignment tape across the head. The two flux transitions displayed must occur simultaneously. If alignment is required to align the gaps, either the tape head or the tape path guides must be repositioned. When both outside tracks are reading the same flux transition at the same time, the gap centerline is perpendicular to tape motion. Tolerance permissible is typically half of the allowable gap scatter, or 25 to 37.5 microinches.

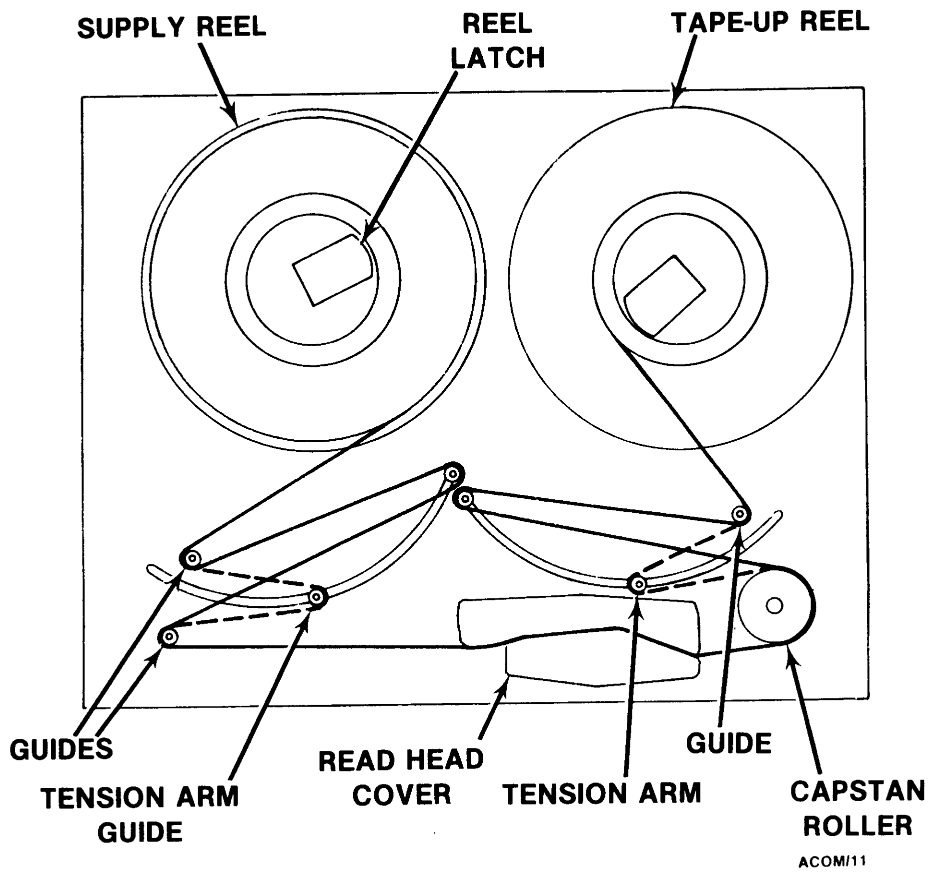


Figure 11.24 Tape Drive Dynamic Skew

Microseconds of error observed can be converted to microinches with the following formula:

Tape speed x microsecond displacement = microinches

Example: Two outside tracks are displaying the same flux transition with a time displacement of 1.0 microsecond. Assuming the tape unit is operating at 75 ips (inches per second), the displacement in microinches can be calculated:

75 ips x 0.000001 sec = 0.000075 inches = 75 microinches

With a tolerance of 25 to 37.5 microinches allowable, this error of 1.0 microsecond would need to be adjusted to 0.5 microsecond or less to fall within acceptable limits (see Figure 11.25).

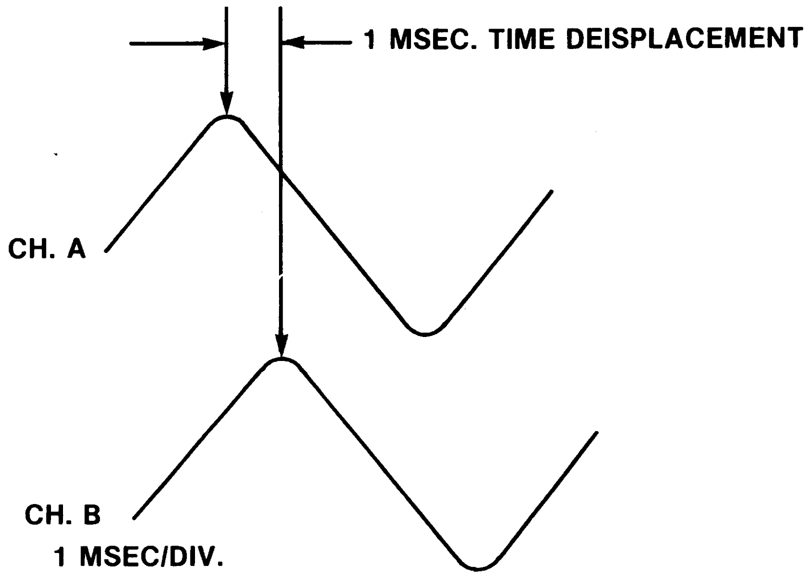


Figure 11.25 Flux Transition Tolerance

11.6 RECORDING METHODS AND FORMATS

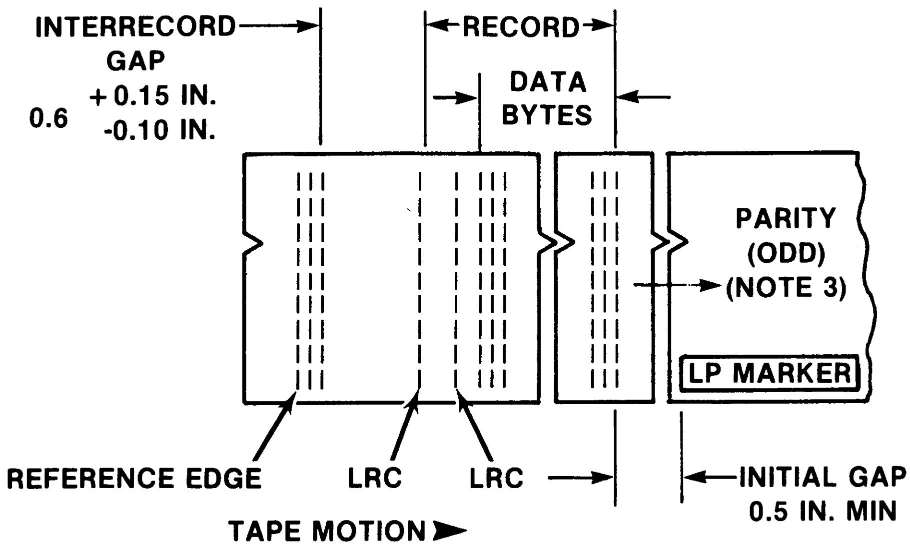
11.6.1 NRZI RECORDING

As discussed in Section 11.4.2, NRZI recording utilizes a change in polarity of the magnetic state on the tape surface to indicate a binary "1" and the absence of flux change to indicate binary "0". Skew compensation for NRZI is accomplished by introducing time delays in playback electronics such that, at the data output, all tracks change simultaneously, even though some tracks gap will "see" the flux change earlier than others. Because of mechanical tolerances in head and tape manufacture and the time delay skew technique, the practical limit for NRZI recording is 800 Flux changes per inch (FCPI). This translates to a data density of 800 BPI (Bits or Bytes per inch). Standards for data recording densities for NRZI are 200, 556 and 800 BPI and 7 or 9 tracks. Specific format information follows.

11.6.2 RECORDING FORMAT FOR NINE TRACK, 800 BPI TAPE

NRZI recording methods one. Bits are produced by each reversal of flux polarity. Tape is magnetically saturated in each direction. Tape is initially DC erased such that the rim end of the tape is a north seeking pole. The initial gap and any interblock areas as shown in Figure 11.26, Nine Track Data Format, are magnetized so that the north magnetic pole will be toward the BOT marker and the south magnetic pole toward the EOT marker.

The initial gap erased area must begin at least 1.7 inches before the end of the BOT marker and extend a minimum of .5 inches past the BOT marker.



NOTE:

1. CRC (CYCLIC REDUNDANCY CHECX CHARACTER). PARITY OF CRC CHARACTERS IS DETERMINED BY THE NUMBER OF DATA CHARACTERS IN RECORD. ODD NUMBER OF DATA CHARACTERS - EVEN CRC CHARACTER, ETC. CRC USED ONLY IN IBM SYSTEM SYSTEM/360, 800BPI - CRC CHARACTER SPACED FOUR BITS FROM DATA CHARACERS.

2. LRC (LONGITUDINAL REDUNDANCY CHARACTER) ALWAYS ODD PARITY. SPACED FOUR BITS FROM CRC.

3. PARITY BIT (A VERTICAL PARITY BIT IS WRITTEN FOR EACH CHARACTER CONTAINING AN EVEN NUMBER OF BITS).

ACOM/165

Figure 11.26 Data Format - Nine Track

A vertical parity 1 bit is written in channel P for any data byte that contains an even number of 1 data bits. Each byte then will contain an odd number of 1s bits or the recording is in "odd" parity.

A CRC character is written 4 bit spaces after the last charcter of each data block. This character, the chclic redundancy check (CRC) character, is used in 9-track 800 NRZI to correct single-track read errors. The CRC character may be either odd or even parity.

An LRC character is written 8 bit spaces after the last data byte of each block. The longitudinal redundancy check (LRC) character makes each tracks' 1 bit count for the entire block (in the longitudinal direction) an even number. The LRC character itself is written in odd parity. It is used to de tect possible data errors not detected by byte parity checks.

Interblock Gaps (IBGs) or Interrecord Gaps (IRGs) are specified as to length, being 0.60 inches +0.15 - 0.10 inches.

11.6.3 SEVEN TRACK RECORDING FORMATS (800, 556, 200 BPI)

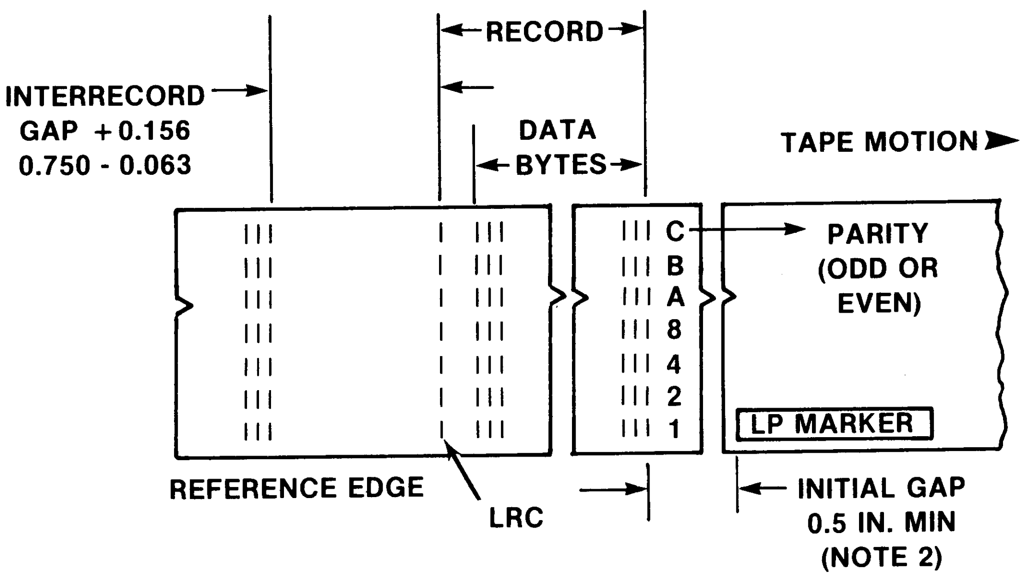
Differences - See Figure 11.27.

Seven track NRZI may be written either odd or even parity.

No CRC Character for 7-track.

LRC character is written 4 bit times after last data byte of block.

IRGs size is specified as 0.750 inches + 0.156 - 0.163 inches.



NOTES:

1. TAPE IS SHOWN WITH OXIDE SIDE DOWN, NRZI RECORDING. BIT PRODUCED BY REVERSAL OF FLUX POLARITY.

2. TAPE TO BE FULLY SATURATED IN THE ERASED DIRECTION IN THE INITIAL GAP AND THE INTERRECORD GAP. ERASURE SUCH THAT A NORTH SEEKING END OF COMPASS WILL POINT TO START OF TAPE.

3. LRC (LONGITUDINAL REDUNDANCY CHECK CHARACTER) ODD OR EVEN-SPACED FOUR BITS FROM DATA CHARACTER.

4. PARITY BIT (A VERTICAL PARITY BIT IS WRITTEN FOR EACH BYTE).

ACOM/166

Figure 11.27 Data Format - Seven Track

11.6.4 FILE MARKS

Following the last data block of a job, or the last block on a tape, a special control block called "File Mark" or Tape Mark is written. See Figure 11.28, 9-Track File Gap Format; and Figure 11.29, 7-Track File Gap Format. The nine track file mark consists of 1 bit for tracks 3, 6, 7 and an identical LRC character 8 bit times later. No CRC character is written.

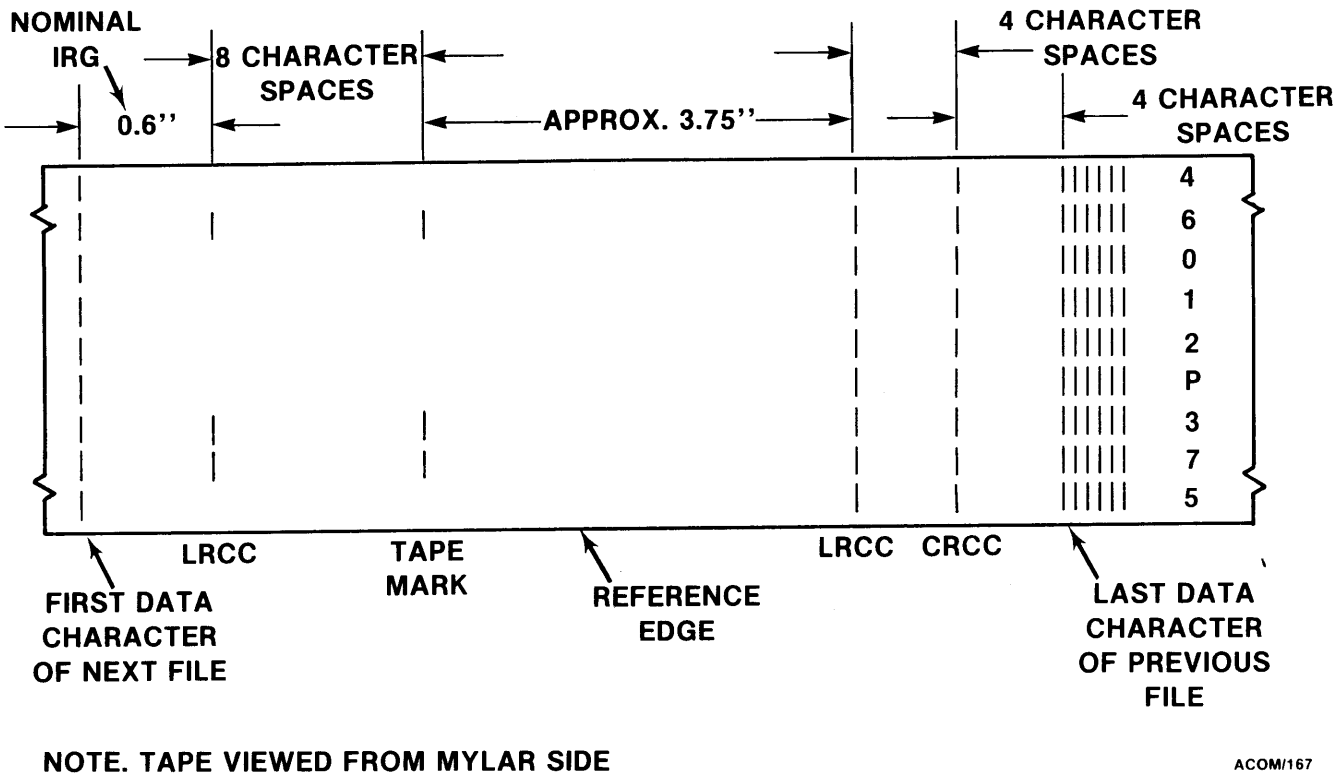


Figure 11.28 9-Track File Gap Format

The seven track filemark consists of 1 bit on tracks 8, 4, 2, and 1 and an identical LRC character 4 bit times later.

11.6.5 P. E. RECORDING

With 800 BPI as the practical upper limit for NRZI recording and the continuing demand for high recording densities, a new recording method was required. Phase Encoding (PE) at 1600 BPI was selected and a tape format was established first by IBM and later adopted by the American National Standards Institute (ANSI) as a proposed standard.

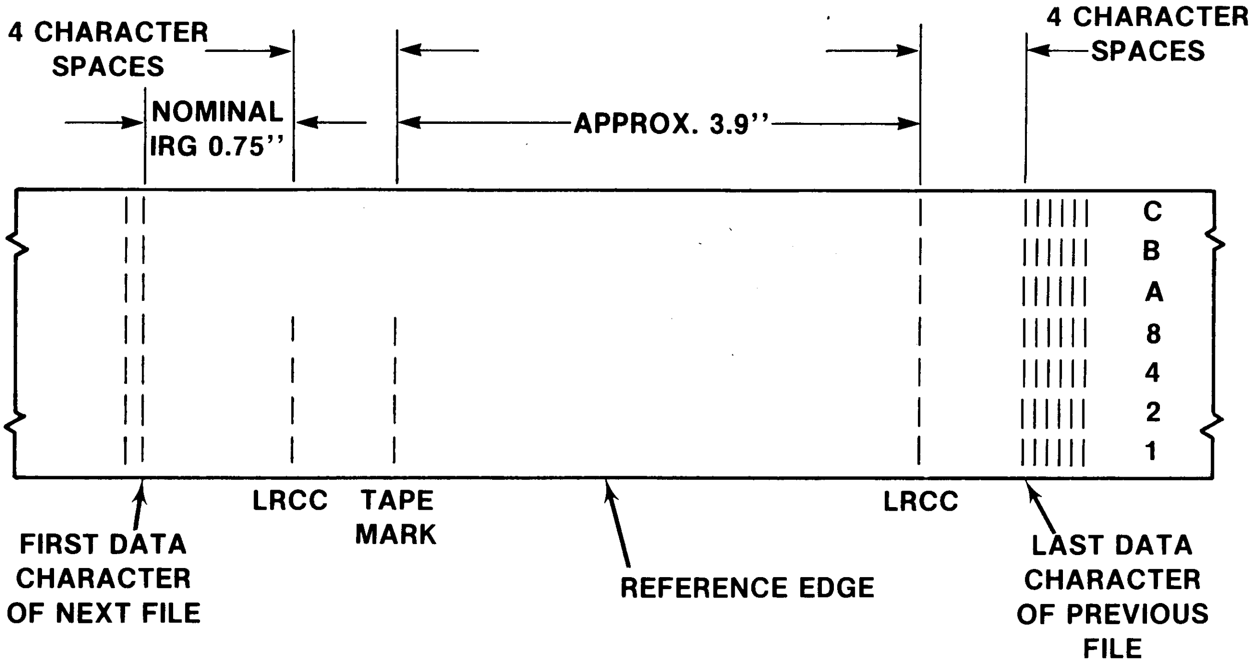


Figure 11.29 7-Track File Gap Format

Tapes are written using magnetic saturation recording. Tape is DC erased with a polarity such that the rim end of the tape is a north seeking pole. A one bit is defined as a flux reversal to reference polarity. A zero bit is defined as a flux reversal toward the opposite polarity. A "phase flux reversal" is written at the nominal midpoint between successive one or zero data bits to establish proper polarity.

The resultant pattern of flux reversals and playback waveforms is shown in Figure 11.30. It can be seen that this method of recording results in two bit densities being recorded, 1600 flux reversals per inch (FRPI) and 3200 FRPI phase shifting of these two frequency components is of the utmost importance to decoding the data on playback.

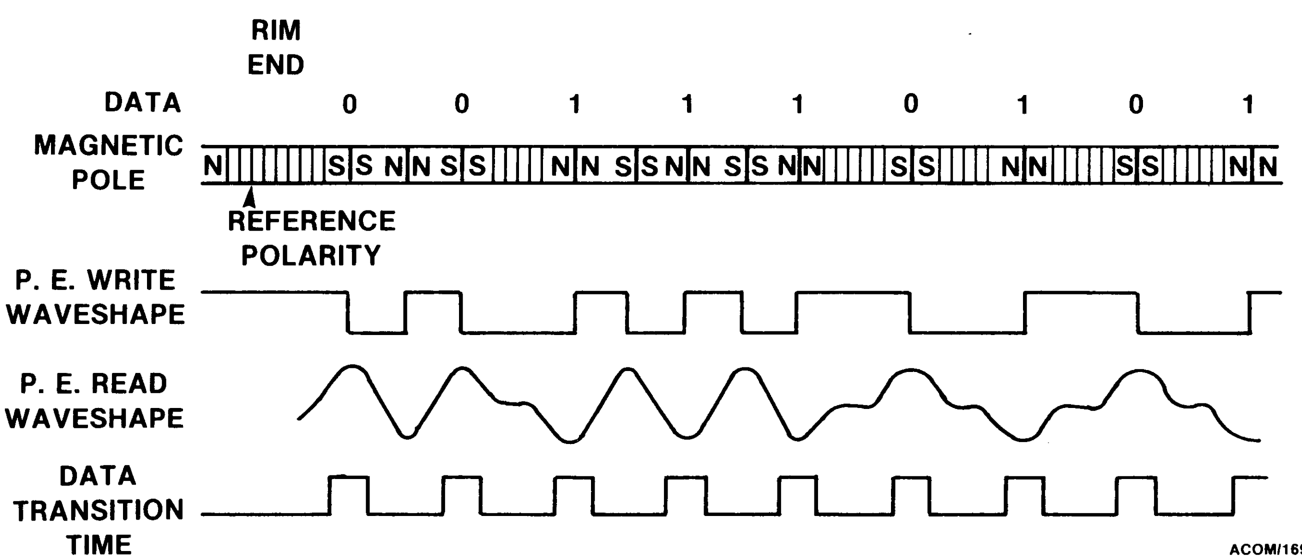


Figure 11.30 P. E. Reversals

11.6.6 PREAMBLE/POSTAMBLE

Reading methods for PE tapes differ from NRZI methods. Following is a general discussion of means employed to extract recorded information in PE. Preambles and postambles are easily identified at the beginning and end of the block (see Figure 11.31). The purpose of the preamble is to allow synchronization of the read electronics with the flux changes before data begins. The preamble is written at 3200 FRPI (all zeros). There are 40 zeros followed by one "all ones" character and following the "all ones character" will be the data.

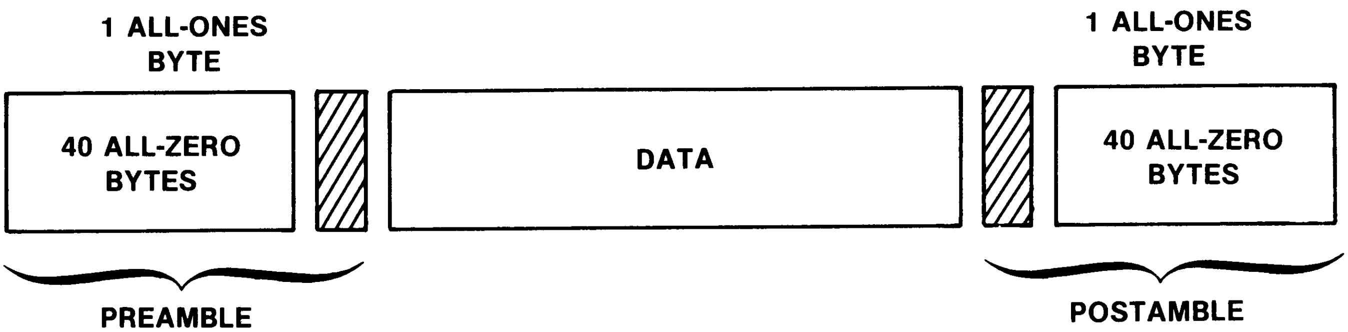


Figure 11.31 Phase-Encoded Tape Block Format

The end of the data is followed by the postamble. This is a mirror image of the preamble. The postamble serves two functions:

1. Indicates the end of data while reading in the forward mode.
2. Serves the same function as the preamble when reading in the reverse mode.

Two conditions should be met before signals are recognized as valid data:

1. Signal must be present in all tracks.
2. A number of zeros must be followed by the "all ones" character of the preamble.

Once detected, the preamble combination of all ones must be treated as a valid character to retain character timing. All zeros is not a valid character unless a single track has been lost. The ones character is not used for data.

The waveform shown as "Data transition time" (see Figure 11.30), is produced by the decoding logic in the PE read electronics. The data transition time signal allows the logic to differentiate between "data bit flux reversals" representing 1s and 0s and any "Phase flux reversals" during the midpoint between data bits. The data transition time signal or "window clock" signal is synchronized to the data on tape during preamble time. Each track synchronizes and detects 1 and 0 bits independently. All

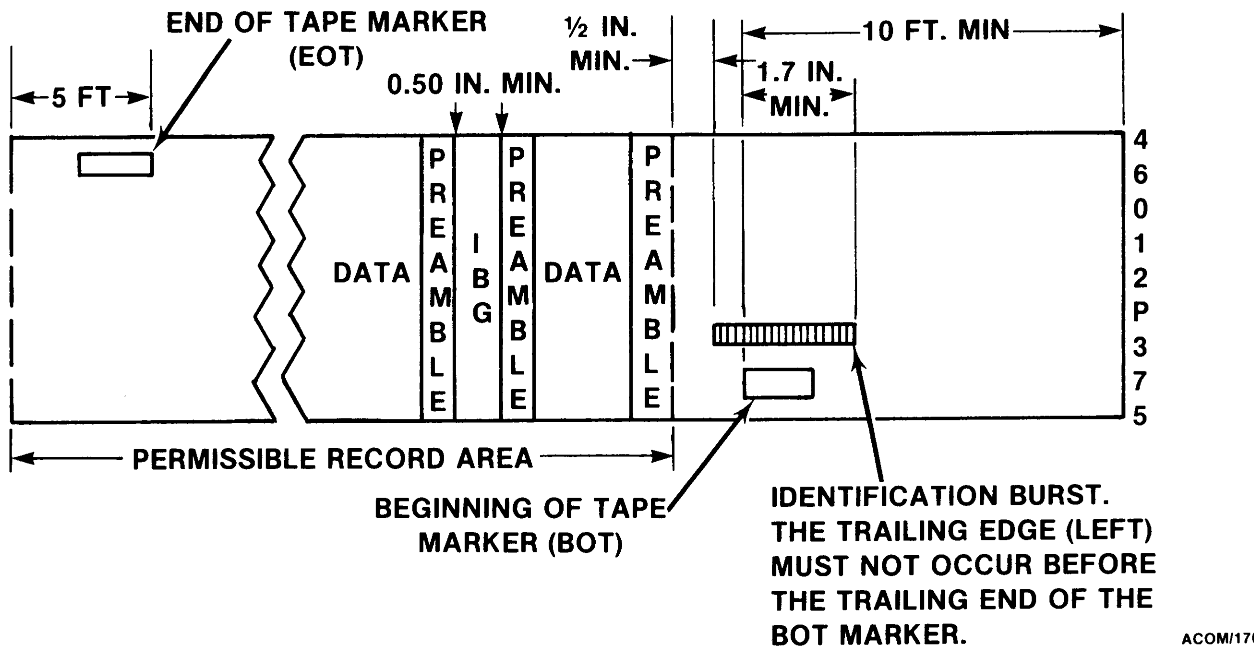


Figure 11.32 P. E. Identification and Gap Format

skew compensation in PE playback is by means of logic rather than time delays and, as such, is not adjustable.

A 1600 BPI P. E. tape is written with an identification burst at load point. This burst consists of 1600 flux reversals per inch in track P, all other tracks erased. The P. E. identification burst must begin at least 1.7 inches before the trailing end of the BOT marker and continue past the BOT marker.

A vertical parity 1 bit is written in track P for all data bytes with an even number of 1s bits. Thus, each byte on tape will be of odd parity.

The data bytes in each block are preceded by a 41 character preamble and the last byte followed by a 41 character postamble. The preamble consists of 40 bytes of zeros in all tracks followed by 1 byte of 1s in all tracks. The postamble is a mirror image, an all 1s byte followed by 40 all 0s bytes.

Interblock Gaps. The size of the Interblock Gap (IBG) is 0.50 inches minimum, 0.60 inches nominal between end of postamble and beginning of following preamble. The first preamble must begin not less than 0.50 inches past the trailing edge of the P.E. identification burst and 0.50 inches from the end of the BOT marker.

P.E. tape mark, or file mark, is any of several combinations of 3200 FRPI on certain channels and DC erasure on others - minimum length is 80 flux reversals in each active track. This is normally preceded by a file gap of 3.75 inches, however, this gap is not specified as part of the standard and may vary. See Figure 11.33.

TRACK	CHANNEL	1	2	3	4	5	6	7·	8
1	5	x	-	x	-	x	-	x	-
2	7	x	x	x	x	x	x	x	x
3	3	-	-	-	-	-	-	-	-
4	P	-	x	x	-	-	x	x	-
5	2	x	x	x	x	x	x	x	x
6	1	-	-	-	-	-	-	-	-
7	0	-	-		x	x	x	x	-
8	6	x	x	x	x	x	x	x	x
9	4	-	-	-	-	-	-	-	-

- dc erased

x recorded at 3200 frpi

* most frequently used combination

Figure 11.33 P. E. Tape Mark Combinations