AMPEX

MAGNETIC TAPE TRENDS

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RECORDING THEORY AND TECHNIQUES AS APPLIED TO TAPE

PART II - COMPUTER

This issue will discuss the role of magnetic tape in computer applications. The basic recording principles employed here are similar to those found in audio and instrumentation recording, but there are major, distinct differences. All computer recording consists of finite, discrete bits of information recorded on the tape, and instrumentation and audio use analog techniques where long, continuous trains of fluctuating data are recorded. This means a dropout or loss of digital data is intolerable because each bit is independent, and failure to recover even one bit will jeopardize the associated data. Instrumentation dropouts to a certain degree can be tolerated.

This is not the only significant difference. Digital data consists of only two states - it is either there or it is not. At first this appears to be a trite statement, but let's examine it from a tape standpoint. Since the computer can only handle binary format, any pulse over a minimum level will trigger a change of state. So, a bit of information may be recorded to and even beyond saturation. As the tape passes the head, a burst of energy hits the tape and magnetizes one small portion well beyond saturation to record a "one". (Different recording techniques will be discussed later.) In analog recording, every precaution is taken to stay below saturation, but digital recording must go beyond saturation. Distortion does not become a problem in digital work nor does extraneous noise (within reasonable limits). Flutter, skew, and other analog pitfalls are also of lesser importance in digital recording. Before becoming disillusioned with the stringent requirements placed on computer tape, perhaps we should investigate the overall nature of computer tape and pay particular attention to functional aspects such as: How it works, performance and reliability, proper handling and care and storage.

A few detailed facts and impressive dimensions will be presented in the following, but not for the purpose of overwhelming anyone with the precision workings of tape. Computer tape is very fragile, and may become damaged at the slightest provocation, and since many of these damages are not visible or apparent to the naked eye, a discussion of the critical areas of tape will help develop a proper understanding and appreciation for computer tape. It is the intention of this article to point out and explain the idiosyncrasies affecting performance of tape.

The function of computer tape is to store the great volumes of information required by a computer. This must be accomplished in a convenient manner that makes the information readily accessible to the computing electronics. Digital computers are two-state systems, and they can handle basic input data that consist of one state or the other, or combinations of the two. In other words, the computer electronics can perform functions only when a "1" or a "0" is presented, and binary codes are established to express all numbers in combinations of "1" and "0". Alphanumeric codes are used to express symbols, letters, and numbers.

Using a coding system, any number, letter, symbol, or combination thereof may be presented to the computer in the form of various combinations of "1" and "0". Magnetic tape lends itself nicely to this method of input (and output) for the following reason. A small unit of magnetic energy (bit) recorded on the tape may represent a "1" and the absence of a recorded bit may represent an "0". This is the simplest form. Actually, various techniques may be used to express the change of state on magnetic tape, and three of the more popular methods are discussed here.

Return to Bias (RB) It is possible to record bits on magnetic tape by considering magnetic saturation in one direction as zero. Ones are then represented by the opposite saturation as shown in Figure 1. This figure represents a train of bits or pulses for 0 1 1 0 1 1 1. RB must be compared against a clock system to be read properly.

Return to Zero (RZ) This type of recording is illustrated in Fig. 2. With this technique a pulse is recorded for each and every bit, both zeroes and ones. In the illustration, positive pulses represent ones and negative pulses represent zeroes. This form of recording "carries its own clock" since there is a pulse from the head for each and every bit.

Non return to Zero (NRZ) This system also utilizes positive and negative tape saturation, and the interpretation of the magnetic pattern on the tape is different than in RZ or RB recording. Figure 3 shows how 0 1 1 0 1 1 1 would appear using this system. The NRZ system differs from RZ in that a one is represented as a change of magnetic state, and a zero as no change of state.

The main difference between the operation of computer tape and that of instrumentation or audio tape is the actual recording process. Computer tape utilizes digital format where discrete bits of data are recorded to saturation over a minute section of the tape. Instrumentation utilizes analog techniques where a continuous varying signal is recorded below saturation level. If a dropout occurs with instrumentation tape, only a small portion of the wave pattern is lost and the associated adjacent data is not jeopardized. However, if a computer dropout occurs, a finite bit of independent data is lost and the associated record of information is jeopardized. For this reason, computer dropouts cannot be tolerated.

RECORDING PROCESS

A computer transport "writes" on a tape by saturating small, finite areas of the tape. As previously pointed out, in NRZ recording, a flux reversal signifies a "one", and no flux reversal is a "zero". Let's see what actually happens inside the tape during this process.

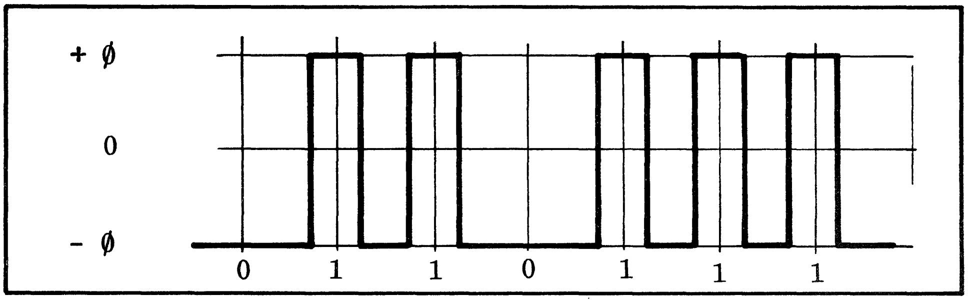


Fig. 1 RB - Return to Bias

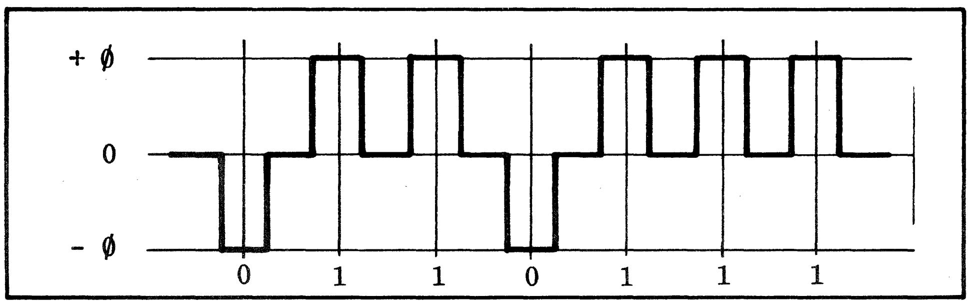


Fig. 2 RZ - Return to Zero

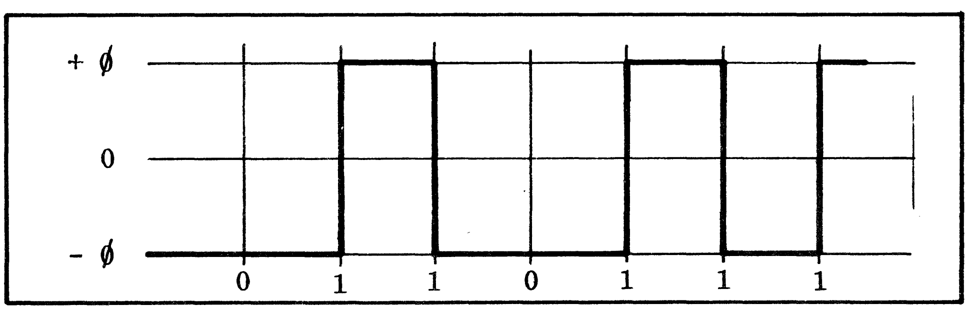


Fig. 3 NRZ - Non-Return to Zero - Mark

Assume that all "ones" are being written. If we are using an 800 BPI system, then 800 "ones" or saturated areas will be written on each track along every inch of the tape. This means that every inch of tape must be capable of supporting 800 separate and distinct bits of information. Quick mental arithmetic reveals that this leaves only a very small physical portion for each individual bit. Also, the tape must accept the individual bursts of energy from the head in a crisp, clean manner. That is to say that the resolution or measure of pulse rise time must be controlled to very tight tolerances. Here is where oxide processing and dispersion become important.

As mentioned many times previously, tape consists of individual oxide particles firmly held in a suitable binder that is coated on flexible base film. The coating thickness generally represents 20-30% of the total tape thickness.

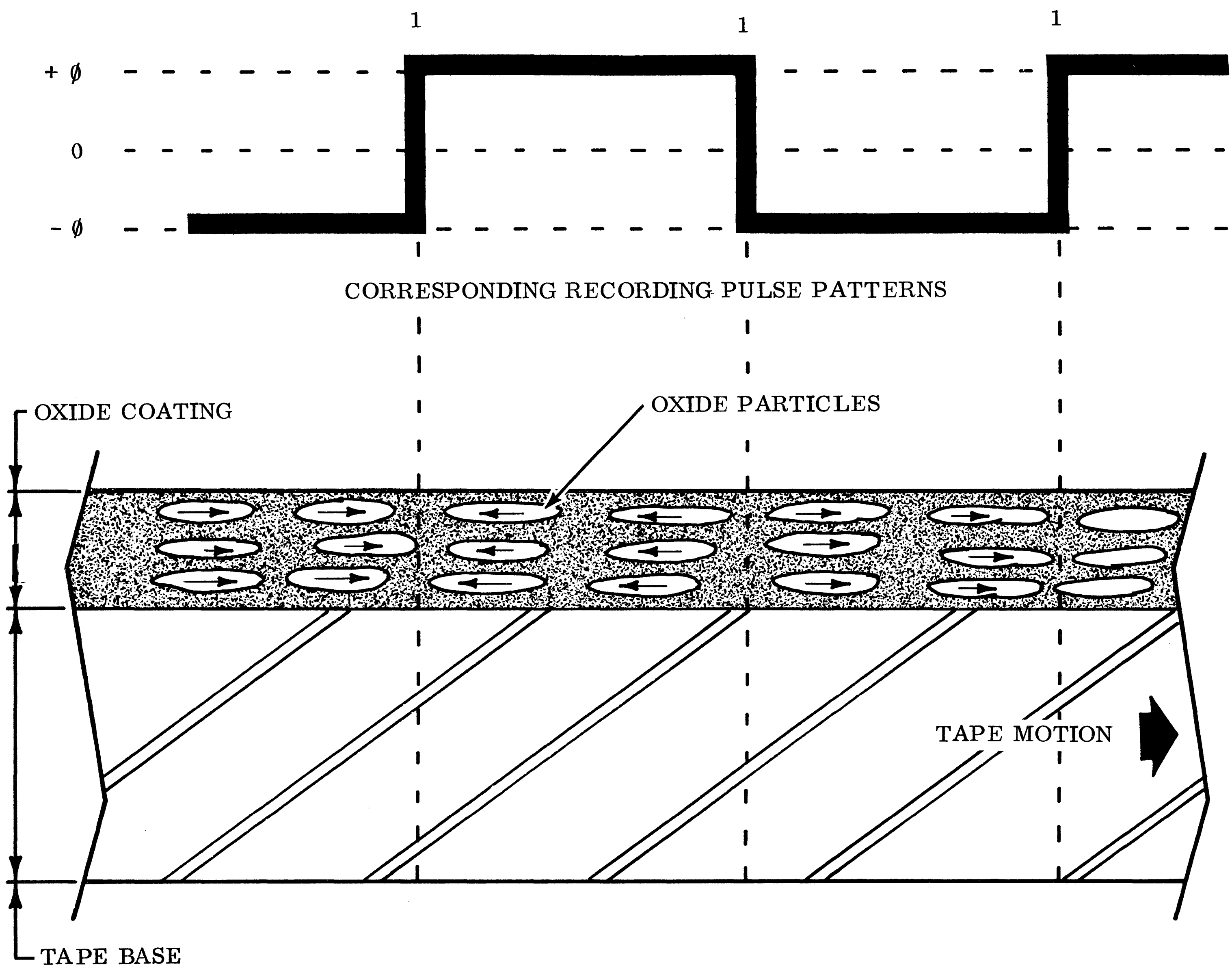
The heart of magnetic tape is the oxide particle itself. In virtually all computer tapes, the oxide used is gamma ferric (Fe_20_3) oxide. These particles are acicular (needle-shaped) in shape, approximately 4 microinches thick and 25 microinches long. They are held in the binder in much the same manner as almonds are held in a chocolate bar.

A computer is able to "write" on a tape because of the nature and characteristics of flux fringing in the vicinity of the recording head gap. The flux in the head is established by, and is proportional to the input signals or current pulses flowing through the head windings. This flux fringing penetrates the magnetic coating and saturates all the oxide particles under the influence of the fringing pattern. In the case of 800 BPI, it is obvious that each bit or saturation pattern must be put down in a crisp, perfect manner because the physical dimension of the recorded bit is extremely small.

In recording pulses a perfect tape would have infinitely small particles that are all magnetically saturated in one direction for each pulse. At the exact point where a "one" is to be recorded, each particle would be saturated in the opposite direction. The transition would be perfect with no interface or boundary effects. Pictorially, this can be generalized by Figure 4.

In this overly simplified diagram a "one" which is signified by a flux reversal, is written perfectly because each particle is saturated in the proper direction. There is no "inertia" in the transition from one state to another which would give a gradual or imperfect pulse rise time. Tapes cannot be manufactured in this simple way. Literally millions of particles must be packed into the coating to deliver the proper output, and practical limitations of dispersion technology make it impossible to achieve the ideal condition.

As the packing density increases, the physical volume (or number) of magnetic particles for each bit decrease which makes it even more important to have perfectly uniform particles that are properly processed and dispersed. To satisfy this requirement, it would be feasible to use smaller and smaller oxide particles, however, resolution is only one factor to consider in the complex equation of a balanced tape design.



LONGITUDINAL CROSS SECTION OF COMPUTER TAPE

FIG. 4

COMPUTER TAPE ERRORS

With the advent of advanced computer techniques providing superior data handling capabilities, computer tape with greater reliability has become an essential requirement. In addition to better reliability, tape bit packing density requirements have increased to the point where conventional quality control procedures are inadequate to insure 100% error free tape. An error free tape checked at 200 BPI or 556 BPI may not be error free at 800 BPI. By errors, we mean permanent dropouts. Much has been written on the nature of permanent dropouts. Simply stated, a permanent dropout is any tape phenomena that produces a reduction or loss in signal below a preset level (usually 50%). A temporary dropout has been defined as a dropout that is removed by normal machine recycling. More persistent temporary dropouts sometimes require brushing to remove. There is a distinct difference between permanent dropouts, permanent dropouts of temporary origin, and temporary dropouts. Let's clarify further by classifying and defining again the three categories.

Type one - permanent dropout. This type of error results from the physical deformation of the tape coating, or an imperfection of the backing material. No amount of machine cycling will remove or alter this dropout. This is the familiar nodule, or impurity that is actually coated into the tape during manufacture. Initial testing and all subsequent tests will indicate this as being a dropout.

Type two - temporary dropout. This is a "here today-gone tomorrow" dropout. It usually is a bit of dust, lint, or foreign matter lightly adhering to the tape coating. Normal machine recycling will completely remove this error. Actually it merely displaces the foreign matter, and it may occur repeatedly in different tape locations. However, this is not a serious problem because the transport is designed to cope with such errors. It simply shuttles the tape back and forth up to a preset maximum number of times to remove the dropout.

Type three. This is a temporary dropout (type two) that has become permanent (type one). This, by far, is the type that creates the biggest problem. A tape can be checked and certified to be free of type one dropouts. There are no two ways about it. The tape does not have a permanent (type one) dropout throughout its length, and it never shall. However, subsequent tests may reveal what appears to be a "permanent" dropout. In reality, this dropout is a small oxide redeposit that entered the tape pack sometime after the certifying test, and became so firmly embedded in the coating that it assumed the shape and appearance of a permanent (type one) dropout. A foreign particle may enter the pack long enough to deform the base film of adjacent layers leaving an impression that will also cause dropouts.

The following analogy clearly points out the precise tolerances required for perfect computer tape.

A 1/2" x 2450' roll of tape with 1 nodule or surface defect that will cause a dropout at 800 BPI is equivalent to a highway 50' wide and 557 miles long with one grapefruit sitting on it.

CARE AND STORAGE OF TAPE

The requirements for meticulous housekeeping and perfect handling techniques are definitely justified for they will prevent real problems. Historically, computer facilities were kept clean and modern because they were new and often used as show places. To a certain extent, this concept prevails today, but is greatly overshadowed by the functional requirement of hospital type cleanliness. Smoking in computer rooms has long been a contested issue. All computer manufacturers and precision tape manufacturers recognize this as a problem, and the universal recommendation is to prohibit smoking in the computer environment for optimum operation, but due to the personal inconvenience involved, the non-smoking rule is enforced in only a small percentage of installations. Strict controls of cleanliness not only improve computer performance, but they promote a higher standard of working conditions. This is without fail reflected as an increase in individual operator's attitude and efficiency. The operator begins to take personal pride in his work, and performance invariably goes up.

Good housekeeping is not only related in a direct manner to the efficiency of a computer operation, but it is an absolute necessity with the high performance 800 BPI computers. An entirely new concept in cleanliness and maintenance must be established, not to mention the increased emphasis on operator techniques. Techniques, procedures, and conditions of cleanliness that were acceptable for 556 BPI operation are not adequate for successful 800 BPI operation. A very loose analogy may be made in considering what happens in flight when the speed is increased from 500 miles per hour to 800 miles per hour. Although the increase in speed was about 60%, the related problems increase considerably more than 60% because the sonic barrier was broken and a new set of conditions become effective. In general, this may be likened to updating a computer operation from 556 BPI to 800 BPI - a new set of operating conditions prevail at the much higher packing density. Many slight problem areas such as minute dimples in the Mylar backing from small dust particles will create a dropout @ 800 BPI and not at 556 BPI. Creases, pinch roller marks, redeposits, and the presence of any foreign particles become critical at 800 BPI.

Proper control of temperature and humidity in a computer environment is vital for reasons other than maintaining the dimensional stability of the tape and machine components. For example, very low humidity will increase the headwear due to change in frictional characteristics. Static buildup on the tape surface increases with low humidity. High humidity affects the pinch roller to tape action, and in prolonged, extreme cases may corrode critical guide surfaces. Effects from fluctuating temperatures during storage and use are less subtle. Changes in temperature are highly detrimental to the tape pack. If a tape is wound at normal ambient conditions and subjected to a higher storage or transient temperature, tremendous pressure will be built up within the tape pack as the base film attempts to expand. After the tape returns to normal, room temperature , the pack will be loose from uneven contraction. When this tape is then placed on a transport, it may "cinch", rendering the entire reel useless.

Computer tape reel design has been an evolution of a functional design to reach its present configuration. Original design concepts were premised on the fact that the flanges must have windage holes to allow the air to flow out of the pack during winding to assure an even pack. It has subsequently been proved that these holes actually "pump" air into the pack instead. The present trend is toward solid flange reels for a very practical reason. Solid flange reels keep fingers away from the tape.

The vast majority of computer tape fails (wears out) due to abuse and mishandling. Accumulated data indicate that less than 20% of computer tape actually wears out from normal machine use. Tape end of life is simple to define - it is that point in tape life where excessive dropouts render the tape useless. This could be after 3 passes or 3000 passes depending upon the origin of the dropouts. For example, if all tapes were loaded on a clean, properly adjusted transport once, and never touched again, the tape would perform perfectly for thousands of passes. Unique, long wearing binders have been developed to resist the normal wear effects of heads and guiding components, but it is impossible to develop a tape that is immune to mishandling. A properly adjusted transport will handle tape effortlessly with no adverse wear on the tape. Premature failure of tape is brought about by abuse, mishandling, and improper storage of tape. For example, the tape pack is seldom perfect due to the normal shuttling, stop and start motion dictated by the program, and if the slightly protruding edges of the tape are squeezed by the fingers in loading or unloading, the tape is slightly creased. This distortion often develops into a dropout. Creases and foreign particles introduced by physical tape handling will also enhance the occurrence of dropouts. Handling tape and touching the surface will deposit a slight, greasy film which will attract and hold minute dust particles. If it is absolutely necessary to handle tape and touch the surface, it must be done very carefully while wearing rubber gloves. This applies to handling tape between the load points, and excludes normal loading operations.

Tape reels should never be squeezed against the tape pack while handling. This action distorts the tape edges. Reels should be supported lightly with the fingers through the ID of the hub and the thumb against the outer edges of the flanges.

Obviously, tape should never touch the floor during loading. Normally, this section of the tape is considered a threading leader and is outside the end of file markers, but if it drags on the floor the chances are excellent that it may pick up foreign particles and deposit them into the tape pack.

With the present day durable binder systems, computer tape rarely "wears out". As previously pointed out, the vast majority of "worn out" tapes are returned due to excessive dropouts resulting from abuse, mishandling, and physical damage. This does not imply that the tapes are mutilated and shredded. These tapes will contain subtle damages such as minute creases, edge damage, scratches on the oxide surface, greasy film, etc. Once again, the efficiency of computer tape performance is directly proportional to the degree of housekeeping and skillful operator handling technique, because it is the only functional computer component that is actually handled by the operators.

TAPE EVALUATION

What makes one tape acceptable and another tape unacceptable? There are numerous parameters that can be compared to answer this question, but they can all be lumped into a simple statement. A computer tape must deliver reliable performance. The only conclusive evaluation for computer tape is to observe its performance over a period of time under normal programming and operating conditions. From the data previously presented, it is obvious that tape efficiency is dependent upon a myriad of variables. An accelerated test, or test performed on a small quantity of tapes will not reflect the true picture of performance in a given installation because it will not subject the tapes to all the influencing factors that have a direct bearing on reliable performance.