Q U E S T   F O R   Q U A L I T Y

A practical guide to increasing quality in diskette duplication.

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Trace.

About Trace

Trace is the worldwide leader in diskette duplication and certification systems. Founded in 1981, Trace's success has mirrored the remarkable growth of the international software industry. Following successive years of double-digit growth, annual revenues exceed $50 million.

The Trace customer list includes virtually every major software and hardware company in the personal computer industry and almost every major duplication service company.

The company's products include: high-speed industrial duplication systems, low-cost desktop duplicators, media certifiers, write-once CD-ROM systems, and a host of peripheral products such as autoloaders, diskette labelers, and printers.

Based in San Jose, California, the company employs more than 275 people worldwide. Trace maintains an extensive sales and support network with 16 offices throughout the world.

International sales represent more than 40 percent of company revenues. This effort is driven by eight wholly-owned subsidiaries in Belgium, France, Germany, Hong Kong, Ireland, Japan, Singapore, and the United Kingdom.

For more than a decade Trace has been the leading force in duplication technology. The company employs more than 60 people in its engineering groups, investing more than 8% of sales in research and development.

The company also invests significant resources in customer support. More than 70 professionals throughout the world provide hot-line phone support, on-site repair, warranty service, end-user training, electronic bulletin boards, media analysis, drive refurbishment, expedited spare parts delivery, and extended support programs.

The fine art of balancing productivity and product quality.

The industrial duplication industry faces a never-ending challenge—more productivity (additional diskettes per hour) while improving product quality (fewer failures in the field). ▪ Over the past decade, productivity has doubled and doubled again. Impressive quality improvements have also been posted—but such achievements require a strategy, process controls, exacting technologies, and a strong commitment. ▪ Whether you duplicate diskettes within your company or employ a professional duplication service, the same quality issues quickly surface. Every diskette failure costs customer goodwill and money—lots of money. A 1% failure rate can cost the industry millions of dollars per year. ▪ *Quest for Quality* documents the significant issues and solutions which impact product quality. Each section begins with a broad summary and is followed by a more technical discussion. Industry-specific terminology is referenced in the glossary. ▪ At Trace, our Quest for Quality began more than a decade ago and, as the following articles indicate, the quest continues. . . .

When a copy is better than the original.

You've spent months, perhaps years, writing and testing that new piece of software and, at last, the "golden master" diskette is ready for duplication. Now you are ready to generate thousands and thousands of exact duplicates of your master diskette. Right? Wrong!

Believe it or not, you've already created a quality problem. The problem is staring you in the face—the PC or workstation that produced the final code. It may be a great development tool, but as a final recording device, it's heavily flawed. Before duplication can proceed, the golden master has to be audited, checked, and "cleaned up."

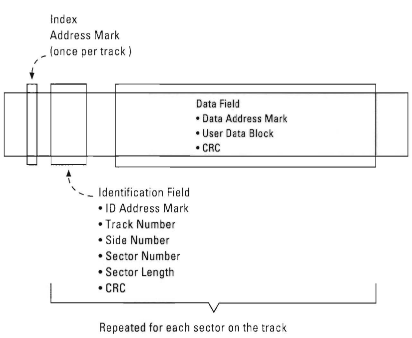
The fastest and most reliable way to clean up your master is with Trace Series 2000/3000 Systems. When you employ the Trace read-in process, several techniques are employed to ensure that your master image is virtually flawless. Ironically, once this master image has been cleaned up, it produces copies that are higher in quality and easier to read than the original golden master.

Trace systems provide Master Cleanup, Assured Image Integrity™ checksums, copy protection, serialization, and "load and go" software to expedite system operation for standard diskette formats. Unlike other systems, Trace Series 2000/3000 systems read and analyze each element of the track—not just the data field. Write splices are removed, clocking violations are repaired, gap lengths are restored to specification, and Assured Image Integrity checksums are performed to ensure data integrity.

How do Trace industrial systems accomplish all this? Start by reading in the original master diskette. During read-in, the system automatically reads more than it requires on each track to ensure that all data is available in the master file (created by the system). During analysis, the track length is adjusted to eliminate extraneous data. The system reads the data with 100% windows (refer to "Windows and Verification") to ensure maximum readability of even the most poorly written masters.

After read-in, analysis begins. During the analysis process, each track is brought into memory bit by bit and compared against the appropriate format file which is stored in the system. This ensures the format on the diskette matches industry specifications. System software is loaded with manufacturer-defined formats, and additional formats can be added by deleting or reorganizing the format information as needed (usually in order to create copy protections). Sync fields and gaps between ID fields and data fields are set to proper values, address marks are checked, and cyclic redundancy checks (CRCs), are calculated to ensure that the data is correct. Figure 1 shows a typical arrangement of information on a track.

FIGURE 1



If all tracks are analyzed correctly (no bad CRCs, missing or extraneous data), the image file is converted to a product file. This file will be slightly smaller than the image file, since the system removes the excess data from the end of the track. The system then calculates the Assured Image Integrity™ (AII) checksums. Each track has its own write and verify checksums, and there is a global "checksum of checksums." These checksums are used to guarantee that the same data which is on the master is present on the copy.

All of this analysis is done in the background. After the golden master is read in, the autoloader can begin duplication of another job. With the system's multitasking abilities, you can perform other functions while the analysis continues.

Trace Series 2000/3000 systems actually have two methods of performing read-ins. The original method, FreeForm™, allows for the precise duplication of any diskette, whether or not the format has been modified, and regardless of pre-compensation or copy protection schemes. The second method is called HyperTrace, and it allows extremely fast read-in for users who use standard formats without modification or copy protection.

The two read-in methods have slightly different ways of creating an image file. In both methods, the master diskette is completely cleaned up—there are no write splices adjacent to data fields which could detract from a target system's (end user's PC) ability to read a duplicated diskette. There is only one write splice per track. The data and format are written in the same pass and data bits and clock bits are placed for optimum read performance. In other words, this ensures maximum readability of your diskettes on most target machines.

HyperTrace is a faster and easier method when used with these standard formats which are based on rigid industry specifications:

- 3.5" High Density (HD)
- 3.5" Low Density (LD)
- 3.5" Extended Density
- 5.25" LD
- 5.25" 96 TPI HD
- 5.25" 96 TPI LD
- Amiga 3.5"
- Macintosh Double-Sided (800K)
- Macintosh Single-Sided (400K)
- Macintosh High Density
- Apple II Standard Density
- Commodore 1571
- Commodore 1541

Since HyperTrace concentrates on these formats, it can analyze faster. It takes the first track from the first master, and brings it into memory. As soon as the track is there, a second program begins analysis of that track against the format specification. If the track passes, it becomes part of a master file built directly in memory. The faster the drive, the faster read-in and analysis can occur. In low density formats, the system analyzes tracks as fast as the drive can bring them into memory.

Keep in mind that although HyperTrace is faster than FreeForm for standard format, quality is not sacrificed. HyperTrace reads and analyzes each entire track—not just the data field. Write splices and gap lengths are cleaned up, and Absolute Image Integrity checksums are created to ensure data integrity. These checksums can even be generated for older image files created by HyperTrace or FreeForm. So the Series 2000/3000 systems not only take care of your current files, they can also reach back into your archives and apply state-of-the-art checks.

Making sure what you have is what you get, every time.

During high-speed duplication, data moves at lightning speeds from your master image through the Trace system and then over to the QualiCopy™ Drive which records the magnetic pulses onto the new diskette. A small power surge or a slightly worn component can interrupt the flow of data onto your diskette. Sometimes these problems only surface intermittently, others periodically repeat themselves.

Since the loss of just one bit of information can make the final product unusable, a constant audit process must occur. To eliminate such potential problems, Series 2000/3000 systems run a number of checksums which audit the transfer process, step by step, track by track. This series of checksums is called Assured Image Integrity™ (AII). In total, AII runs 642 separate checksums on every diskette before it is accepted and keeps a running log of every checksum failure so you can precisely chart reject statistics. Trace's AII checksums are a key method of achieving maximum quality of your duplicated images.

The term "checksum" is mentioned frequently in discussions of data integrity, but is open to interpretation. A checksum is a general term for an error detection test which verifies whether two strings of data match. A simplified example of a checksum is shown in Figure 2. Any system can create checksums—but Trace checksums are precisely tuned to guarantee product file quality.

FIGURE 2

Byte A	Byte B	Byte C	Byte D	Byte E	Byte F	Byte G	Byte H	
0	1	0	1	1	1	0	1	
1	1	1	1	1	1	0	0	
1	0	1	1	0	1	0	1	
0	1	0	1	0	1	0	0	Even (0) or odd (1) sum for each bit
0	0	1	0	1	1	0	0	
1	1	1	0	0	1	0	1	
1	0	1	1	1	1	0	0	
1	0	0	0	0	1	1	0	
1 +	0 +	1 +	1 +	0 +	0 +	1 +	1	= Checksum

While an image is being read in, the AII checksums are created and stored as part of the product file. When any part of a file is transferred from one part of the system to another, the checksums are recalculated and compared to the original. If the checksums match, that portion of the file or data transfer operation then passes the checksum test. If the numbers do not match, a checksum error is generated. When a checksum error occurs, the system displays a message which uniquely identifies the specific operation that failed.

AII is unique because it is so thorough. While conventional controllers only check the ID and data area CRCs, AII monitors every data transfer during the duplication process. Every time a portion of the product file is moved from one part of the system to another, Absolute Image Integrity makes sure that the copy matches the master image.

Assume you are duplicating (using write/verify) a product file stored on your system hard disk. The duplication process always begins with an image file, which consists of the image table and all the data and clock bits which comprise the format and user information. The entire file is first transferred to system memory, where checksums calculated during the transfer are compared to the checksum in the file. This is the most critical of the checksums, since any intermittent hardware or software errors, caused by a power surge, for example, might cause the file in memory to be different from the original. If this checksum indicates that the two files do not match, duplication will stop or retry until the files match.

As outlined in the previous article, the read-in process by HyperTrace and FreeForm not only reads the data from the master, but also performs stringent analysis of the data to clean up write splices between data sectors and ensure that the finished product will match format specifications. All product files stored as hard disk images (image files) on the Series 2000/3000 have been subjected to these exacting tests which adds to the overall quality of your diskettes.

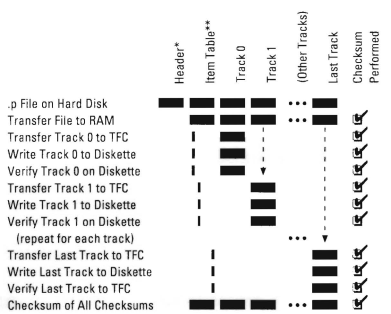
Masters can also be created on an independent host computer system or with PC Trace and transferred via the TraceNet™ network as Trace Mini Format (TMF) files, which include AII-style checksums. Once they are read in to a Series 2000/3000 systems, these files are expanded to full product files with complete AII checksums.

Once the file is in memory, the system checks the item table to determine the contents of the file and how it is to be written. The system then transfers the first track to the proper controller (having independent memory on each controller allows multiple controllers to duplicate different images simultaneously or the same image independently). Checksums occur as the track information and the corresponding part of the item table are transferred.

Next, the track is written to the target diskette, and the write checksum ensures that the information written matches that stored in the controller's track buffer. The verify function ensures that all the bits that should have been written to the diskette were written, and the verify checksum ensures that all bits are in place.

This process is repeated for every track. The system keeps a running tally of the checksums. As soon as the last checksum is transferred to the controller and the track is written and verified on the target diskette, the system computes an overall checksum of all the checksums. This is the final insurance that all of the tracks which were supposed to be duplicated have been duplicated. (See summary in Figure 3.) There is an impressive number of checksums being performed: one checksum at the initial memory transfer, one as the item table entry for each track and side is checked, and one as each side of the track is transferred to the controller. A checksum is performed as each track and side is written to the diskette, and as each track and side is verified. Then there is the final checksum of all the checksums. An 80-track master image, for example, has 642 separate checksums performed before the system passes each duplicated diskette. No other duplication system goes to such lengths to ensure that the duplicated product mirrors the master file.

FIGURE 3



* Header contains information only necessary for product file and is not part of final duplicated product.

** During each track transfer, the corresponding portion of the item table is also transferred.

Making sure an imperfect diskette still does the job.

Without question, most duplication quality problems are caused by contaminated, damaged, or imperfect diskette media. This isn't surprising given the fact that electronic pulses are compressed onto a flexible coating which is thinner than a human fingerprint. And to heighten the challenge, these pulses are applied as the diskette "cookie" spins at 600 revolutions per minute!

When media imperfections and debris reduce or block a recorded signal, it's commonly referred to as a missing pulse or dropout. In many cases, this generates a fatal flaw on the diskette. To combat such media deficiencies, additional duplication process quality checks are required. The Trace solution is the individual bit Missing Pulse Circuit (MPC), a technology that is built into QualiCopy electronics which constantly monitors distinct media problem areas.

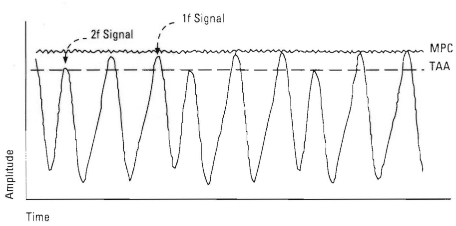
Although missing pulse testing occurs in both certification and duplication, there are differences in the methods and results. Certification is designed to test media for manufacturer process defects, while the MPC circuit tests the actual recording quality. Missing pulse testing is essential to ensuring that each diskette captures the wide range of signal patterns inherent in duplication, and that each bit will subsequently be readable.

In order to maximize capacity, bits are placed so closely together they may influence each other. To ensure that the media you are using will be as readable as possible, there are several ways to detect media defects during two important stages of media life, certification and duplication. One of the ways to ensure readability is through dropout or missing pulse detection. Both terms refer to the same issue, the reduction or loss of a recorded signal due to a defect in the magnetic surface. Ultimately, this can cause the loss of one or more bits in the data stream, which can make the diskette unreadable.

The first line of attack against media defects is certification, which typically occurs during the media manufacturing process. Essentially, certification validates that diskettes are physically and magnetically suitable to store magnetic transitions. Certification is also used by many software manufacturers to ensure that the media they receive meets their quality parameters.

In certification, each bit is compared to the Track Average Amplitude (TAA), which represents the average of a full track of bits. Every track is written with a single frequency pattern, and TAAs vary no more than 2% from track to track. But in duplicated media, the TAA can vary widely from track to track because no two tracks contain the same patterns, so the previous track's average is irrelevant. If any bit has an amplitude below a defined percentage of the TAA, a dropout or missing pulse has occurred.

FIGURE 4



Therefore, the amplitude reference for duplication must be dynamic. Because of this, Trace's SDS QualiCopy Drives incorporate a circuit that quickly establishes a reference level for each track based upon the peaks detected. Since the reference level is a function of the bit pattern, it is dynamically adjusted. Figure 4 shows the QualiCopy MPC reference level, created from the bit pattern below it. Each bit on the track is compared to the current reference value, and if any bit fails to fall within the acceptable percentage of signal remaining, an MPC error occurs (the default percentage is 30%, but it is user-definable).

Compare this level to that of a certification TAA, also shown in Figure 4, which represents the level of the previous track's 2f pattern only. As you can see, the TAA reference level is somewhat less discerning than that of the MPC which takes 1f patterns into account. A bit failing to reach the MPC threshold might still pass on the TAA reference.

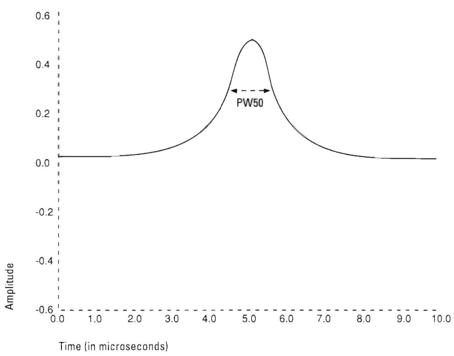
When an MPC error has occurred, QualiCopy electronics shut off the read data signal to the controller, causing a verify error. The track is usually reread, then rewritten, and then reread several times. If the error persists, the system assumes there is a media defect and the diskette is rejected. Standard diskette drives do not have this capability for detecting MPC errors. Only Trace QualiCopy electronics offer individual bit MPC.

MPC testing exceeds standard media certification in another important quality control capability. The MPC can detect a phenomenon called "embedded resolution," in which 2f pulses surrounded by 1f pulses create pulse amplitudes lower than normal 2f patterns. Additionally, write precompensation can create the effect of lower-than-normal 2f amplitudes. These conditions produce lower pulse levels than are encountered during certifier tests at a single frequency. The media could pass certification, but have unacceptably low pulse amplitudes during duplication. These types of patterns only occur during duplication, so media which might be acceptable to a certifier might not be adequate for recording signals which are less readable than the 2f pattern.

To further understand the importance of MPC vs. Certification testing, a clearer understanding of the nature of recorded media is needed.

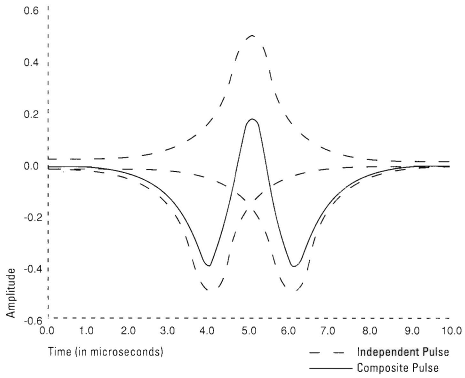
Both certification dropout detection and MPC detection rely on the measurement of pulse amplitudes. Pulse amplitude depends on physical characteristics of the media, such as strength of magnetization and coating thickness. In addition, pulse amplitude is affected by the presence of nearby pulses in the recording. This latter effect can be predicted from the individual pulse shape and the spacing of nearby pulses, and depends greatly on the pulse resolution (pulse width) and how close the pulses are to each other (pulse crowding).

FIGURE 5



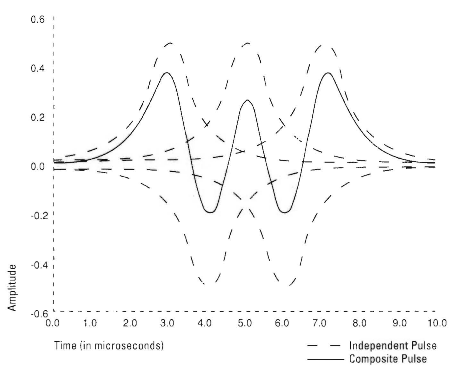
Resolution refers to the narrowness of the pulse generated by a single isolated transition. (Refer to Figure 5.) A common measurement of pulse resolution is PW50 (the time-width of the pulse at the point where the pulse amplitude is 50% of its peak value). Here, the peak value is 0.5 amplitude units. The width of the pulse at the .25-unit level is 1.2 time units. PW50 varies from track to track because of media velocity and write current/filter bandwidth switching.

FIGURE 6



To show how the pulse width (resolution) affects peak amplitude, we will build up a 2f pulse train by adding adjacent pulses to the typical pulse. Figure 6 shows the addition of adjacent pulses at 2f spacing, one on either side of the original pulse. When pulses overlap, the net amplitude at any point is the sum of all the amplitudes appearing at that point. The two adjacent pulses have "tails" that overlap the central pulse. When

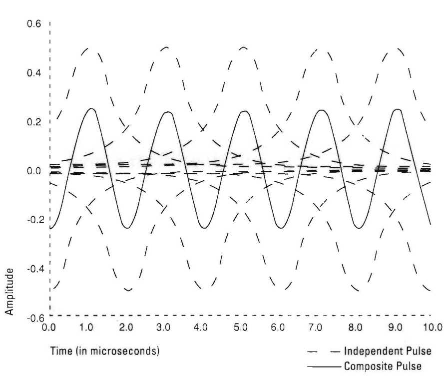
FIGURE 7



pulses are close enough to affect each other, pulse crowding effects are observed. In this example, the effect of the adjacent pulses, since they are of opposite polarity, is to reduce the peak amplitude of the central pulse.

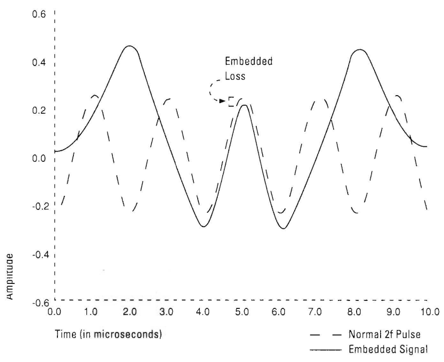
In Figure 7, we have added two more pulses on our way to forming a long 2f pulse sequence. Note that these new pulses have the same polarity as the original pulse, and that their tails increase the peak amplitude of the central pulse. Because these pulses are further away than the immediate neighbors of reversed polarity, they do not fully restore the amplitude lost.

FIGURE 8



Each successive addition of pulses to the train in turn reduces, then increases, the amplitude of the central pulse, but in each case, the effect gets smaller and smaller until adding more pulses has no noticeable effect. Figure 8 shows the result of adding a long string of 2f pulses and the resulting peak amplitude, which in this example is .25 amplitude units. This is the 2f signal used to measure dropouts during certification

FIGURE 9

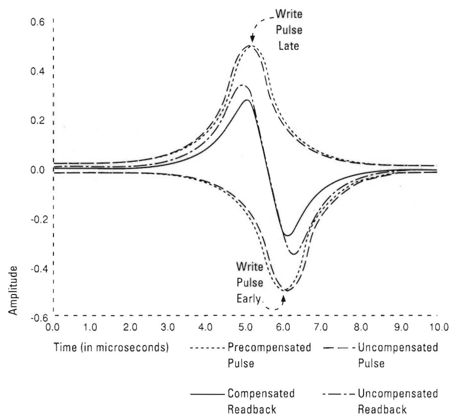


(and the signal that sets the TAA). The clipping level referred to in certification is the lowest level of peak amplitude permitted during a dropout, measured as a percent of the TAA.

The 2f pulse train derived in Figure 8 does not represent the weakest signal that can be recorded on a diskette. If we look back at Figure 6, an intermediate step in the construction of the 2f signal, we find a pulse that is of much lower amplitude than the continuous 2f signal. The isolated pattern of this figure cannot occur on a normally recorded diskette due to clocking rules. A similar effect occurs, however, if the "next adjacent" pulses added to this figure were not at 2f, but at 1f. The greater distance of the 1f pulses reduces the restoring effects of the pulse tails. In Figure 9, the embedded pulse is shown compared to the previously derived 2f pulse train. Note the reduced amplitude of the embedded pulse. This is what we refer to as embedded resolution.

Another effect of pulse superposition is peak shift. In Figure 10, the dotted-dashed line (uncompensated readback) represents two adjacent 2f pulses which have been superposed. Not only is amplitude reduced, but also notice that the composite peaks of the pulses are not lined up with the peaks of the original pulses (dashed lines). This is peak shift. Peak shift is compensated for during recording by changing the timing of the recorded pulses. The dotted lines (precompensated pulse) are recorded by writing the first pulse late and the second pulse early. This is called write precompensation. The result (compensated readback, the solid line) shows that the peak locations are now exactly right. However, the pulse amplitudes of the precompensated pulses are significantly lower than before. Thus the addition of precompensation is another source of pulse amplitude reduction.

FIGURE 10



The isolated pulse pair shown in Figure 10 cannot occur on a normal recording—a more typical precompensation condition occurs during a transition from a 2f pulse sequence to a 1f pulse sequence, or in an embedded 2f pulse, which further aggravates the embedded resolution effect. Referring to Figure 9, note that the peaks on either side of the central pulse are shifted. Precompensation will be used to correct the peak shift, resulting in further reduction in amplitude to 75% of the original 2f signal.

If this same amplitude reduction is applied during a dropout which measures 45% signal remaining during certification, it would now produce a pulse amplitude of 34% signal remaining for this pattern (based on the same TAA). In actuality, the situation is much worse. Dropouts do not merely reduce the amplitude of a signal, they also have a significant effect on pulse resolution.

A typical dropout is produced by a media defect or surface contaminant that lifts the media from the head. It is this head-to-media separation that reduces signal amplitude during a dropout. The separation also causes an apparent widening of the recorded pulses, severely reducing resolution. Thus, all of the pulse crowding effects described above are made worse during a spacing induced dropout. An embedded pattern that produces a pulse of 75% of 2f under normal conditions would produce an even lower percentage in the middle of a dropout.

In addition, the TAA measured on a typical recording will be a mixture of 1f and 2f amplitudes, rather than the uniform 2f pulse used in certification. Duplication MPC circuits in fact produce a TAA closer to the 1f amplitude. So a 45% certifier dropout appears as a 21% dropout if it occurs during a precompensated embedded pulse. But if the dropout occurs in a less sensitive area (during a 1f pulse train, for example), the dropout actually measures a higher remaining signal than reported by the certifier—as much as 67% of 1f TAA signal remaining. So we see the extreme variability of dropout amplitudes as a function of data patterns.

Distributing magnetic pulses so they don't interact.

As previously discussed, diskettes use magnetic pulses to store data. Since the pulses must be placed closely together, they have to be carefully laid out to minimize the effects of adjacent magnetic fields. It's somewhat similar to lining up magnets. Careful spacing is required so one magnetic field does not impact its neighbor.

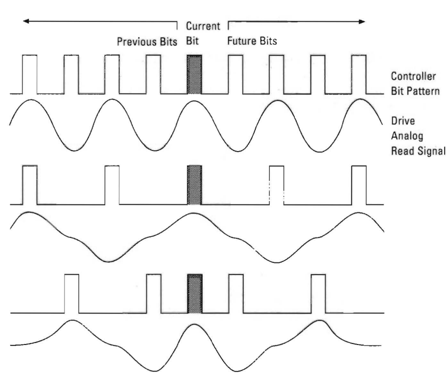
One feature of Trace duplication systems that is entirely transparent to most users is precompensation. You don't have to know about precompensation to benefit from it because it enhances the quality and reliability of duplicated product. Precompensation is another way to increase the likelihood that diskettes can be read on target machines.

Write precompensation is used to correct predictable, pattern-sensitive peak shift; the amount of this peak shift, and thus the amount of precompensation, depends solely upon the pattern of preceding and succeeding transitions surrounding the bit, and the resolution of a transition as it is read.

The pattern of transitions surrounding a given bit is predetermined by the data and encoding of the bitstream and is known at the time the bitstream is written. However, the resolution depends on many factors, only some of which are known or are controllable.

One of the important factors determining peak shift is the sensitivity of the bit pattern to resolution. The degree of peak shift depends on the symmetry in the placement of bits surrounding an individual bit. If a bit pattern is symmetrical around a bit, that bit will experience no predictable peak shift, regardless of the resolution. But the greater the asymmetry of the bit pattern, the greater the opportunity for peak shift, and the larger the amount of precompensation needed.

FIGURE 11



Refer to the symmetrical bit patterns shown in Figure 11 (Patterns shown are for example only, and may not represent actual format patterns). In each case, the shaded bit's position is not affected

FIGURE 12

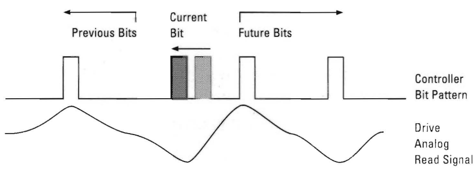
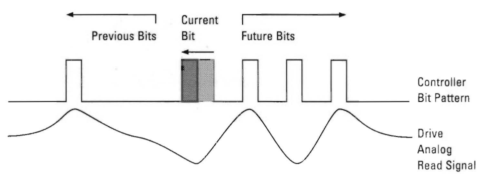


FIGURE 13



by the surrounding bits. But if the pattern is asymmetric (as in Figure 12), the bit will shift in the direction shown.

Figure 13 shows a third pattern in which one more bit is added to the right side of the pattern shown in Figure 12. This increases the apparent asymmetry surrounding the shaded bit. However, the peak shift resulting from the pattern here is actually less than that in Figure 12. This is because the polarity of surrounding transitions, not just location, determines peak shift effects. The newly added transition is of the same polarity as the indicated transition (transition polarities reverse at each successive bit in magnetic recording). The effect is to add amplitude to the current bit, reducing the amount of bit shift. Although it is impossible to provide total precompensation for every asymmetric pattern (in fact, many commercial controllers use only one increment of precompensation), Trace's Series 2000/3000 systems support up to four different increments of precompensation classifying all potential asymmetric patterns into one of four groups. When precompensation is applied, group one (those patterns exhibiting the smallest peak shift), receive a smaller amount of precompensation than group two; group two patterns get less than group three; and so on. This permits more accurate bit placements, since a greater range of displacements can be corrected than if a single amount of precompensation is used for all corrected patterns. In Trace systems, the level and direction of precompensation applied is based on the four bits preceding and the four bits succeeding a given bit.

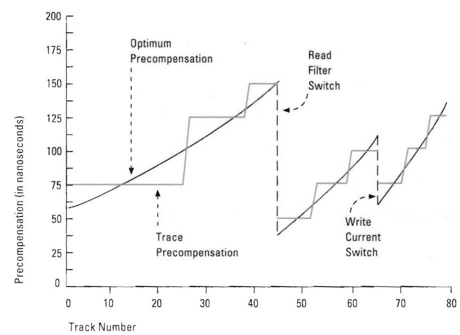
Even though precompensation is applied in relation to the overall bit pattern, the actual amounts will vary. Considerations include system resolution, which is determined by bit rate, track location, and drive rotational speed; drive parameters, such as head-to-media interface, head geometry, write current level, and read channel bandwidth; and media parameters such as coating thickness, coercivity, and coercivity distribution. This is why precompensation amounts must be determined empirically using measurements involving actual drives and media. It should be reemphasized that these resolutions are system values, representing the combined resolution of the writing drive, the media, and the reading drive. The duplicator has some control or knowledge over the first two, but little or no control over the quality of the reading drive.

A major problem faced when trying to establish actual precompensation amounts is the fact that both media and drives vary widely in resolution, making it impossible to pick a single number that works equally well under all conditions. Even when a box of new media from a single manufacturer is tested for peak shift on the same drive, there is significant variation of resolution from diskette to diskette within the same box of one brand, not just from brand to brand.

While duplicators can exert some control over the media used in duplication, PC drives come from a variety of manufacturers and have widely varying characteristics. A test of brand-new, currently available drives using identical media would show that resolution varies widely among drives. When it comes to media consistency, unfortunately, the duplicator has little control.

In establishing the precompensation values for Trace systems, nominal drives and media are used to empirically determine values that produce the best margins as read on a target drive. Once the reference drive and media are selected, actual values are determined by plotting a curve of "ideal" precompensation values versus track number. Such a curve (for only one pattern level) is shown in the black line in Figure 14. Two characteristics should be noticed: the function of precompensation value versus track is not linear (the lines are curved and become steeper toward the inner tracks); also, the curve is not smooth—there are two distinct breaks in the progression from outer to inner tracks.

FIGURE 14



The first discontinuity in the curve occurs at track 43. This is a result of filter switching in the target drive that lowers the read resolution at the outer tracks. In the case of the outer tracks of high density drives, the peak shift observed is almost entirely due to the reduced bandwidth imposed by the read electronics, not from head-to-media characteristics. This imposed low resolution results in a peak shift at track 43 which is actually worse than that at the innermost track. The excess filtering is removed at track 44.

The next break in the curve of Figure 14 occurs at track 65. High density drives write with a higher write current on the outer tracks in order to oversaturate the media and ensure adequate overwrite performance. This oversaturation reduces the written resolution, and is undesirable at the inner tracks, where resolution loss is significant and overwrite is not as much of a problem. Therefore, the write current is dropped for inner track recording. Since the change in write current results in a change in resolution, precompensation amounts are adjusted accordingly.

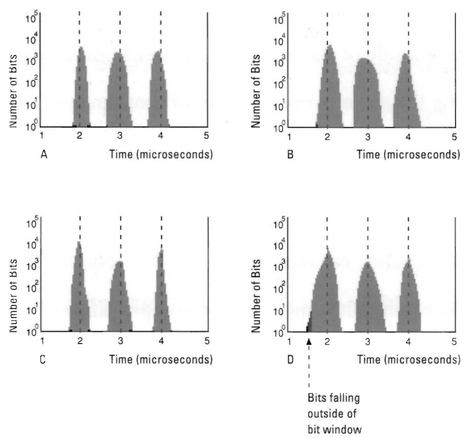
Trace precompensation bands and values are selected to provide a best fit for the plotted curves. This is done for each pattern class and separately for side 0 and side 1 heads, and is how the precompensation files for the various drives and encoding formats are derived for Series 2000/3000 systems.

There is increasing interest and discussion about improving duplication quality by fine-tuning precompensation values to the media used. If a duplicator can depend on a consistent media supply, precompensation values may be adjusted for the resolution characteristics of the media in use, and some degree of margin improvement can be achieved. However, media variation encompasses a smaller peak shift range relative to drive resolution, which varies over a 100 nanosecond range.

Fine tuning for the media can therefore take care of only a small portion of the resolution variability problem. While this can be of benefit, it must be kept in proper perspective, since obtaining a 10 to 20 nanosecond improvement in peak positioning may not produce noticeable performance improvement in the field, where drive variations probably exceed 100 nanoseconds.

There is a potential danger involved in tuning precompensation to compensate for media of very low resolution. While it may be possible to apply enough precompensation to make the resulting product appear to have high margins and low peak shift, excessive precompensation reduces the amplitude of the read signal, making it more susceptible to noise. This can actually increase the field failure rate, even though the product looks good on test equipment.

FIGURE 15



An extreme example of this type of failure occurred with a host system drive operating in a very noisy environment. Figure 15 shows several Time Interval Analysis (TIA) histograms showing the number of bits which occur at a given time interval. Perfect bit placement would show very high and narrow bars at each format-specified interval.

Diskettes recorded with very low precompensation levels have significant peak shift and loss of margin (Figure 15-A, as read on a clean drive). Under the noisy conditions, the signal is severely degraded (Figure 15-B), but the recording is still readable, though with minimal margin. If the write precompensation is adjusted to provide an ideal TIA (Figure 15-C), the margin as read on the normal drive is definitely improved; however, when this recording is read on the noisy drive, the spread of the short-period 2f intervals is increased (Figure 15-D), with several bits falling outside the permissible read window. The addition of precompensation has reduced the peak amplitude of the short interval transitions, reducing the signal-to-noise ratio for those pulses.

In summary, tuning up precompensation for known media characteristics can improve product quality, but any adjustment that requires increasing the amount of precompensation should be approached with caution. If at all possible, for MFM-encoded formats, select media with a higher resolution and reduce the precompensation levels.

Trace Series 2000/3000 systems provide you with default precompensation values which are based on average media and drive characteristics. Although custom precompensation values can be created, in most cases, default values do not require modification.

Ensuring that every bit knows its place.

WHEN PRODUCING COPIES OF DISKETTES, YOU HOPE TO MAKE THEM UNIVERSALLY READABLE BY AS MANY PCS AS POSSIBLE. THIS IS NOT AS SIMPLE AS ONE MIGHT THINK. THE COMPUTERS THE DISKETTES ARE INTENDED TO WORK ON—THE TARGET MACHINES—VARY CONSIDERABLY FROM THE IDEAL IN TERMS OF DRIVE ALIGNMENT, DRIVE SPEED, ELECTRONICS, AND "NOISE LEVEL." TO COMPENSATE FOR THIS VARIABILITY, SOPHISTICATED DISKETTE DUPLICATION SYSTEMS LIKE THE SERIES 2000/3000 USE VARIOUS TECHNIQUES TO ASSURE READABILITY.

ONE OF THE MOST IMPORTANT TECHNIQUES IS THE WINDOW TEST. WITH WINDOWS, YOU CAN SET BIT PLACEMENT THRESHOLDS LOOSELY (AT 90%, FOR EXAMPLE) OR STRICTLY (60%). WHEN THE WINDOW IS TIGHTENED, MORE DISKETTES ARE REJECTED, BUT THE LIKELIHOOD OF SUCCESSFUL READABILITY SOARS. TRADITIONAL METHODS OF DETERMINING WINDOW LOCATION ADJUST TO THE RATE OF THE BIT STREAM TO COMPENSATE FOR VIOLATIONS IN HOW THE DISKETTE WAS WRITTEN AND HOW IT IS BEING READ. THIS TECHNIQUE FAVORS DATA RECOVERY AT THE EXPENSE OF BIT LOCATION STRINGENCY. TRACE FLOPPY CONTROLLERS (TFCS) AND TRACE TURBO CONTROLLERS (TTCS) MEASURE THE ACTUAL TIME BETWEEN BITS WITH A PRECISION TIMING CIRCUIT TO PROVIDE THE MOST STRINGENT BIT LOCATION TEST AVAILABLE.

Format rules are set up to help create a standard method of reading and writing diskettes. Among these rules are specifications regarding bit placement. A 360K IBM®-type format, for instance, specifies that bits can be written at 4, 6, and 8 µs intervals. The minimum resolution, or time period that distinguishes a unique bit is 2 µs. Therefore, when an IBM-compatible computer reads such a diskette, it requires that bits occur in 2 µs windows of time. In other words, a bit has a 2 µs interval during which it can occur. If it occurs earlier or later, the bit means something completely different and the diskette will likely fail. For this reason, proper bit placement is crucial.

A number of factors can prevent precise bit readback when the diskette is written (media characteristics, bit shift, and other factors). This poses a challenge for a target machine trying to read a diskette. The real problem arises when the target machine has problems which adversely affect the way the diskette is read. Such problems (rotational inconsistency, instantaneous speed variations, data separator circuitry deficiencies, and media modulation) are not uncommon. These problems can affect already mediocre bit placement to the point where the diskette fails on the target machine. The diskette can be written correctly, that is, with bits in the proper windows, and still fail when it is read on a target system. The best place to put bits is in the exact center of the bit window. Since most target (end-user) machines have some minor imperfections, placing the bit in the exact center of the window ensures that your diskettes can be read on most target machines (See Figure 16).

FIGURE 16

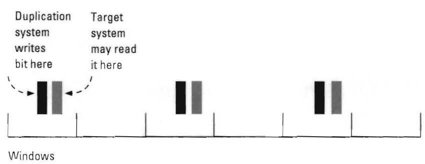
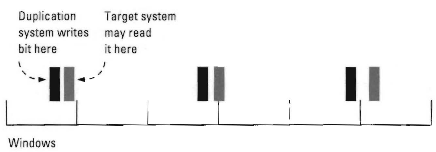


FIGURE 17



If bits are not written in the center of the window, target machines may be unable to read the diskette (See Figure 17).

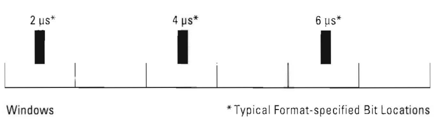
To ensure that the diskettes are as readable as possible, verification is performed. The best verification would be to test diskettes on a large sample of target machines. But since it is impossible to test every target machine that exists, Trace systems perform a test on each track being verified. Part of the purpose of this verification is to check that data has been placed in the most universally readable locations. This test is called the window test. If a diskette can be read using stricter bit placement criteria than normal, then it is more likely to be read successfully by target machines. In a sense, the Series 2000/3000 system is simulating the reading behavior of a flawed target machine—one that demands that the data be more precisely located on the diskette. If the duplicated diskettes are read by this demanding machine, then the diskettes will be readable by the vast majority of PCs.

Windows are simply percentages of the format-specified bit window. For example, a 100% window means the entire format-specified interval is available. Using the example of the 360K IBM-type format, a 100% interval is 2 µs. A 75% window limits the bit to the center three-quarters of this interval. The window opens at .25 microsecond and closes at 1.75 microseconds. Figure 18 illustrates this concept. We can widen or narrow the window depending on the desired quality levels. However, setting the window too tightly may be counterproductive, as this may fail diskettes that are perfectly adequate for the vast majority of target machines.

FIGURE 18

Generally, only larger duplication systems incorporate window measurement. In most of these systems, a Phase Lock Loop (PLL) is used to generate the timing of the windows. Basically, the PLL circuit examines bit placement intervals, calculates a running average, and predicts each successive window based on this average. Phase Lock Loops can be quite sophisticated in making corrections based on "bit history." Such historical averages, however, can be corrupted by a stream of bad data. In other words, future data placement will be incurred. This running average is referred to as a "rubber ruler." The Trace alternative is called Absolute Window Measurement™ (AWM).

FIGURE 19



AWM is a critical evaluation of the placement of bits on the diskette anticipating potential problems which would occur on the target machine. Rather than using the "rubber ruler," AWM uses the format specifications as a "steel ruler" to measure each bit independently using a precision timing circuit as a constant, absolute reference (See Figure 19). In generating each window, AWM calls on a chip in the Trace controller which performs the function of a TIA, precisely measuring each bit's location down to billionths of a second. When AWM generates windows, it does so with the precision needed to most critically test optimal bit placement.

A final test to ensure drive mechanics are perfect.

ONE OF THE MORE VEXING, INVISIBLE PROBLEMS AFFECTING DUPLICATION QUALITY IS DISKETTE MISCHUCKING, WHERE A 3.5" DISKETTE BECOMES MISALIGNED DURING THE EARLY STAGES OF DUPLICATION. UNTIL RECENTLY, IT WAS IMPOSSIBLE TO DETECT THIS PROBLEM DURING THE DUPLICATION PROCESS.

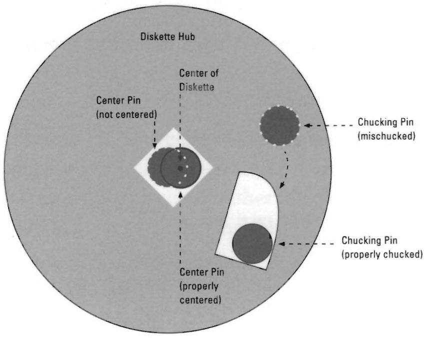
REPEATED DISKETTE INSERTIONS CAUSE WEAR AND TEAR ON THE DRIVE PINS. EVENTUALLY THIS WEAR MAY CAUSE DISKETTES TO BE IMPROPERLY CENTERED IN THE DRIVE. AS A RESULT, THE FIRST FEW TRACKS WRITTEN ON THE DISKETTE ARE PLACED INCORRECTLY. THIS SITUATION IS CALLED MISCHUCKING.

AN EXCLUSIVE NEW INNOVATION CREATED BY TRACE ADDS AN ADDITIONAL AUDIT FUNCTION THAT DETECTS AND INTERCEPTS MISCHUCKED DISKETTES DURING THE WRITE/VERIFY PROCESS. AS PART OF NORMAL DUPLICATION, THE SERIES 2000/3000 WRITES DATA FROM TRACK 0 INWARD TO TRACK 79. IT THEN RETURNS TO TRACK 0 AND ENSURES THAT THE FIRST TRACK IS THE PROPER NUMBER OF STEPS FROM THE LAST TRACK. WHEN THE SYSTEM RETURNS TO TRACK 0, IN-PROCESS CHUCKING DETECTION™ (ICD) VERIFIES THAT THE TIME FROM INDEX SIGNAL TO A SPECIFIED FORMAT MARK IS CORRECT RELATIVE TO WHERE IT WAS WRITTEN. ANY DISKETTE THAT FAILS THE TEST IS IMMEDIATELY REJECTED.

One of the areas in which it is critical to ensure track and bit location occurs just as a 3.5" diskette is loaded into the drive. There are two pins on the drive which hold the diskette in place as it spins and has data written to and verified from it. The first pin, the center pin, is inserted into the square hole at the center of the diskette and acts as the spindle as the diskette spins. The second pin is the chucking pin, which inserts into the off-center hole in the diskette and is responsible for forcing the diskette against the centering pin and driving the diskette revolution. After loading thousands of diskettes, the two drive pins and the springs which keep pressure on them may begin to show signs of wear and tear. As a result, the diskette does not "seat properly," and as data is written, the diskette spins eccentrically (illustrated in Figure 20). This mischucking means there is a high probability that many target systems won't be able to read the diskette. Mischucking can also be caused by media with excessive or insufficient torque.

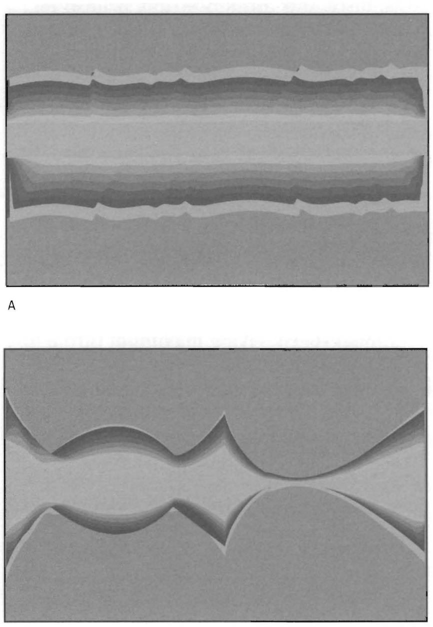
Mischucking often only occurs randomly, meaning that random cross-verification sampling may not catch the problem—in fact, since the modulated signal may have sufficient amplitude, even 100% reverification may not detect a problem.

FIGURE 20



In Figure 21, graph A shows a normal track on a diskette, with the signal even and strong across the track. Graph B shows a track written with a mischucked drive as read by a properly chucked drive. Because the track was written off-center, the signal shows peaks and valleys as the drive looks for normally aligned tracks. The most effective way to detect chucking is before it

FIGURE 21



A

B

leaves the write/verify cycle. ICD is based on a very sensitive measurement which is similar to the technique used to adjust the drive's index timing with an analog alignment diskette with ICD, the Series 2000/3000 measures the time from the drive's index signal to a specific pattern which is part of the format. ICD knows when this pattern should occur, and if it is not read within a specified tolerance, it means that the diskette has moved relative to the the spindle since the initial track was written.

A diskette's data is written from the outermost track, track 0, inward to track 79. As part of the normal Series 2000/3000 duplication cycle, the drive head then steps back 79 steps to ensure that the track 0 signal will occur at the proper step. With ICD, when the drive head reaches track 0, instead of ejecting the diskette immediately, the controller verifies that the index-to-mark timing on track 0 meets requirements. If the ICD test detects a discrepancy, the diskette is rejected. Best of all, ICD adds less than two-tenths of a second to the duplication cycle.

ICD can also be used during cross-verification, allowing you to specify a drive-to-drive tolerance for index-to-mark. Although Trace's other data placement features (AWM and AII) help ensure that the sectors end up according to format specifications. drives and media vary enough that some percentage of cross-verification or duplication drive monitoring is always a good idea. So when you cross-verify diskettes produced on one drive or another, you can set the index-to-mark timing in increments of 6 μs and reject any diskette which falls outside your preset tolerance.

Series 2000/3000 Systems

Trace's premier high volume diskette duplication systems have become the de facto standard for virtually every large hardware, software, and duplication service company in the world.

The 2000/3000 delivers unparalleled throughput, quality control, and flexibility. They can control from 8 to 20 autoloaders simultaneously via Trace's proprietary UNIX® operating system. These systems also employ Tracer autoloaders and QualiCopy Drive technology.

DiskTracer II™

Designed for small-to-mid-range copying requirements, the DiskTracer II is a dedicated standalone diskette copier. Roughly the size of a photocopier, this desktop unit has been well-received by small software developers and companies that wish to distribute data, templates or software on diskettes.

PC Trace™

PC Trace turns your personal computer into a low-volume diskette copier. Utilizing proprietary hardware and software, PC Trace interfaces with a Tracer autoloader to significantly automate the duplication process. PC Trace can manage a variety of MS-DOS® formats and diskette sizes.

DL Series Diskette Labelers

These industrial-strength labelers have been enthusiastically embraced by professional duplication and software companies throughout the world. The hallmark of the DL series is significant throughput (it can keep up with 20 Tracer autoloaders), ease of use, quick set up, simple maintenance, and unparalleled durability. Some units have labeled more than five million diskettes without a service call.

Trace 5300 In-Line Printer

This modular bubblejet printer fits onto the end of a Tracer autoloader. As the diskette moves from the Tracer autoloader, the In-Line Printer generates a high-definition label which can print a variety of fonts, unique serials numbers, and bar codes. The TIP5300 works in conjunction with any Series 2000/3000 system.

LH-2600 CD-ROM Duplicator

Offering double-speed recording, the LH-2600 can generate a unique write-once CD-ROM disc at twice the speed of previous generations of hardware. Able to simultaneous write up to 16 CD-ROM discs, this turnkey system is ideal for low volume, fast turn CD-ROM replications.

Galaxy Microdisk Certifier

Specifically designed to perform high-speed, unattended certification, the Galaxy Certifier can certify 1MB or 2MB diskettes at double the normal rotational speed, giving maximum throughput while simultaneously testing both sides. The Galaxy can run standalone, or networked to other systems via Galaxy Network Software.

1F FREQUENCY The lower operating frequency of a diskette. In a single density format, it corresponds to all clock and no data bits.

2F FREQUENCY The higher operating frequency of a diskette. In a single density format, it corresponds to all clock and data bits in each bit cell.

ABSOLUTE WINDOW MEASUREMENT (AWM) A window test which evaluates bit location relative to a precision timing circuit rather than a phase lock, data following recovery circuit.

AMPLITUDE The voltage level, or strength, of an electrical signal.

ASSURED IMAGE INTEGRITY (AII) A series of checksums which audit the image transfer process, step by step, from the image source through verification of each written track.

ASYMMETRY An undesirable condition that displaces recorded bits from their ideal location. It can result from improper drive electronics adjustment, defective read/write heads, or media that has not been properly A.C. degaussed.

BANDWIDTH The amount of information that can pass through a system per unit time.

BIT SHIFT Also called peak shift. A shift in the detected signal peak caused by the influence of a neighboring flux transition or transitions.

CERTIFICATION The process of verifying the magnetic properties of the media coating.

CHECKSUM A general term for an error detection test which verifies whether two strings of data match.

CLIPPING LEVEL Also called missing bit level. In certification, the lowest peak amplitude permitted, measured as a percent of the Track Average Amplitude (TAA).

CLOCK BIT A transition that is recorded to maintain synchronism between the data stream and the data separator.

COERCIVITY A measure of the strength of a magnetic material. High coercivity coatings are more difficult to write, but provide stronger read signal.

CONTROLLER A device that interfaces one or more diskette drives to a computer system. The controller provides features such as data separation, CRC generation and checking, write clock, and drive select.

CYCLIC REDUNDANCY CHECK (CRC) An error checking scheme used in the diskette format to detect errors in the ID and data areas of the recording.

DATA BIT A transition recorded to represent one bit of information.

DATA FIELD The portion of a diskette format that contains the user-defined data. It also contains sync bytes, and CRC bytes.

DATA SEPARATOR Also called Phase Lock Loop. A circuit built into diskette drive controllers systems which determines bit windows based on analysis of where previous bits have been read.

DROPOUT Also called missing pulse. A readback pulse that is below a prescribed threshold.

DRIVE The mechanics that rotates the media, positions the read-write head, drives the write and erase elements, and amplifies the read signal. Drives do not usually include controllers.

DUPLICATION The production of diskettes that are identical to a master diskette or master image.

FREEFORM A programming language developed by Trace which allows users to create custom duplication formats. In Trace documentation, FreeForm also refers to the versatile duplication program which uses the formats generated in FreeForm.

GAP, FORMAT In a diskette format, a gap is a region between ID fields and data fields that allows for errors in rotational speed and signal frequency.

GAP, READ / WRITE HEAD The read/write head gap is the non-magnetic zone which allows flux to enter and exit the core.

GOLDEN MASTER The original diskette that contains the information to be duplicated Although referred to as "Golden", in almost all cases it is not as good as the diskette that a Trace system duplicates.

HEAD The transducer element that writes to and reads from the media.

HYPERTRACE A Trace analysis program designed to expedite the duplication process. HyperTrace supports all of the most commonly used formats.

ID FIELD / IDENTIFICATION FIELD That part of a soft sector format that precedes the data field and identifies the track, side, sector, and record size.

IMAGE FILE Also called product file. A Trace defined file which contains the master diskette data, format information, and Assured Image Integrity.

INDEX TO DATA Usually made with an analog alignment diskette which is used to locate the start of each track relative to a signal generated by the drive.

INDEX TO MARK A test performed by Trace systems to ensure that a 3.5" diskette is properly chucked.

MASTER DISKETTE The original diskette whose contents are to be read in to the duplication system.

MEDIA Also called diskettes. The storage element of a rotating magnetic memory device.

Mischucking A condition where a 3.5" diskette is not properly centered and located prior to duplication.

Missing Pulse Also called dropout. A readback pulse that is below a prescribed threshold on a track written with a specific frequency pattern.

Missing Pulse Circuits (MPC) A technology that is built in to Trace QualiCopy electronics which constantly monitors distinct media problem areas.

Modulation Readback signal amplitude distortion.

Peak Shift Also called bit shift. A shift in the location of the readback peak due to the influence of adjacent transitions.

Peak The highest amplitude portion of a waveform.

Phase Lock Loop (PLL) A circuit built into drive controllers which determines bit windows based on analysis of previously read bits.

Precompensation A method of reducing the effects of peak shift, at the expense of amplitude, by changing the transition locations in the write data stream (writing them closer together than normal).

Product File Also called image file. A Trace file which contains the master diskette data, format information, and Assured Image Integrity.

Pulse Crowding How close the pulses are to each other in the recording.

PW50 The time-width of a pulse at the point where the pulse amplitude is 50% of its peak value.

QualiCopy drive A drive modified by Trace to be more durable than standard drives and which contains special circuits to provide assurance of duplication quality.

Quality Products in conformance to specified requirements.

Read-In A process which uses a master diskette to create a product image that conforms perfectly to format specifications.

Resolution The ratio of 2f amplitude to 1f amplitude on a given track. Resolution is a measurement of overall performance.

Simultaneous Double-Sided (SDS) A specially designed drive and mode of duplication which allows both sides of a double-sided product to be written and verified at the same time. Normal operation would have to write and verify side 0 before side 1, using up additional time.

Series 2000 An industrial diskette duplication system which can control up to 4 SDS autoloaders, each performing independently.

Series 3000 An industrial diskette duplication system which can control up to 10 SDS autoloaders, each performing independently.

Sync Bytes A series of bytes located before identification fields or data fields to allow the data separator to synchronize with the data stream. Each time a sector is updated, a write splice is created at the beginning and end of the update. The write splice can throw the data separator out of synchronization. The sync bytes allow the data separator to recover.

Trace Floppy Controller (TFC) An advanced-design controller card which is installed in Series 2000/3000 systems and performs high-speed duplication of diskettes.

Trace Mini Format (tmf) Trace defined format files created on a host computer system, or with PC Trace, and are transferred to the Series 2000/3000 system over the TraceNet network. As they are read in, these files are expanded to full Series 2000/3000 files. TMF is the basic file structure of PC Trace.

Trace Turbo Controller (ttc) The Trace Turbo Controller (TTC) enhances the duplication performance of Series 2000/3000 systems. The TTC enables Series 2000/3000 systems to duplicate MFM-format (high density Macintosh and IBM-compatible high/low density diskettes) up to 25% faster than competitive controllers.

Track Average Amplitude (taa) In certification, each bit is compared to the TAA, which represents the average of a full track of bits of a single frequency pattern.

Track Concentric ring that contains the data on rotating memory devices, such as diskettes.

Transition The area on the media coating where the direction of domain magnetization reverses. This transition is the recorded bit.

Verify An operation that compares the written diskette with the data held in memory to ensure that the write operation was successful and completed with acceptable quality.

Window Test A technique for estimating the error rate performance of a system, without transferring the specified number of bits. The window is reduced until a predetermined error criteria is encountered. The window test indicates the potential performance of the device being tested.

Windows The time interval during which a valid data or clock pulse is expected.

Write An operation that places the data on a diskette.

Write Splice The discontinuity that results when a write operation is started or stopped, especially over a formatted track. Each update write will result in a write splice in the format gaps.

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