WHY DATA VERIFICATION IS NOT ENOUGH!

The concept of disc testing is new to most CD-ROM publishers. Until recently, only disc replication plants tested the discs, and quality control was considered to be their responsibility. Sampling output is an essential part of the replication process, so most CD test equipment is designed for the manufacturing environment. However, in today's market, developers, publishers, and distributors may find that doing their own testing is desirable. And it is now possible to make accurate and consistent quantitative measurements of disc quality using low-cost desktop systems.

Traditionally, CD-ROM publishers have been limited to testing their discs by comparing the data bit for bit with the original source. However, data verification does not reveal anything about the *quality* of the disc unless the disc proves to be unreadable. Because of the superb error correction capability of CD-ROMs, even a very poor disc still can be readable. Data verification does not provide information that indicates whether a disc is about to fail, is likely to have a short life, or can be played on all players. In addition, this test is only possible if the original data is available. Users of desktop testing systems can place discs created by replicators or on CD-Recorders in the unit and run a series of diagnostic tests that provide feedback on disc quality. If the disc is unsatisfactory, the cause can be determined and the problems can then be solved. The desktop testing systems are priced in the $2,500 - $15,000 range, as compared to starting prices around $35,000 for commercial testing systems.

Why Test CD-ROM Discs?

To verify disc quality. Manufacturing CDs is a delicate art, and information about how to make good discs is hard to find. Often, this information has been kept proprietary by companies wanting to maintain a competitive edge. Although most manufacturers produce good quality products, some are better than others. Discs that are made thinner than usual and physical defects such as pit distortion from short manufacturing cycles indicate poor manufacturing techniques and can result in unusable discs. If you are paying for premium discs, you want to be sure the quality measures up. In any case, no quality control program is perfect, and problems can sometimes slip through.

To enhance quality control for CD-Recordable users. CD-R technology has revolutionized many aspects of CD-ROM publishing. The low cost and rapid turnaround time make the technology ideal for small volume publishing. Distribution on CD-Rs is more economical than replication for quantities of less than 2000 pieces. However, with CD-R usage, the publisher becomes responsible for quality control, and CD-Rs are more subject to problems than replicas. The continuous pregroove can sometimes cause tracking problems on some players. Any variations or defects in the dye layer can prevent proper recording. Although CD-R technology has made great strides in the past few years, it is fair to say that CD-Rs have a higher failure rate than replicas.

To provide confidence in product quality. When problems occur, they can be resolved more quickly and easily if publishers know the quality of their discs and have a way to check them. Also, once a product is in the field, fixing a problem is more difficult and expensive. Publishers can avoid returns and maintain a good reputation by tracking the quality of their discs.

To detect media and recorder compatibility problems. Compatibility between media, writer, and software also is necessary to produce good discs. Certain combinations of write strategy, recording speed, and media type can cause poor results. Determining the best media to use with a given recorder (or vice versa) is greatly facilitated by testing disc quality.

To eliminate problems with mastering that result from disc errors. In the majority of glass mastering systems, uncorrectable errors (referred to as E32; see discussion below) automatically abort the mastering session, causing costly delays for both the mastering house and the customer. Most replicators prefer that you be able to demonstrate that your CD-R does not reach this level of error.

To optimize selection of discs for archiving. The initial quality of a disc profoundly affects its potential lifetime. A good disc has greater tolerance for the effects of aging than a poor one. If you are archiving either CD-Recordables or replicas, you will want to select the highest quality discs to archive. This is possible only if you have a way of measuring disc quality.

Measuring Disc Quality

The Red Book specifies more than 50 parameters that are used to define disc characteristics. To be certain of the quality of a disc, tests on all parameters must be run. The easiest way to measure disc quality, however, is to measure error rates. This technique is effective because any serious problems on the disc will affect error rates. A meaningful quantitative measure of disc quality can be obtained using a desktop disc testing system to measure the quantity and severity of errors.

Errors are not necessarily physical features on the disc, but are a measure of how well the total system (disc plus player) works. In fact, all discs generate errors on playback -even the best discs produce thousands of errors. The errors are partly due to the fact that playing a CD is a difficult and complicated process. The width of the pits on a disc is smaller than the wavelength of the light used to detect them, so CD players are operating at the limit of physical laws. Playing a disc is not wholly deterministic, but is rather a statistical process. Therefore, the results will not necessarily be the same each time.

Moreover, the objective (the lens that picks up the laser beam that reads the disc) must stay focused within a range of less than 4 microns while the disc is moving both horizontally and vertically. The pickup must follow the spiral track of pits as it moves to an accuracy of much less than one micron (one millionth of a meter). Several highly tuned and sophisticated servo (control) systems are used to maintain focus, follow the track, control the spindle speed, and handle timing issues related to reading the data. These servos are very sensitive and work only within a certain range. Thus, some of the errors occur as a result of the narrow tolerances within which the equipment must function.

Two primary features of the disc itself that can cause errors are poor pit geometry and physical defects. Pit geometry refers to the depth, width, length, and wall slope of the physical pits created in the disc. Although CD-R discs do not have pits, the recording process produces areas on the disc that function like pits and are subject to imperfections that cause errors. Physical defects include pinholes, black spots, bubbles, and scratches. Poor pit geometry and physical defects can make it difficult or impossible for the servomechanisms to read the data properly.

A determination can often be made as to whether problems are caused by pit geometry or local defects. A burst of large errors confined to a small part of the disc is most likely caused by some kind of local defect. If many large errors are found over the whole disc (or a large part of it), then the problem is most likely poor pit geometry.

It is extremely difficult to measure pit geometry directly. An easier approach is to play a disc and look at the signals produced by the pickup. By observing the pattern (referred to as an “eye pattern”) created by the playback signal, it is possible to measure features such as pit depth and length.

CD-ROM Error Correction

As a way of compensating for the physical limitation of discs and players, as well as for physical flaws in the discs, a variety of error correction schemes are incorporated into each CD-ROM. These schemes are described below.

Cross Interleave Reed-Solomon Code (CIRC)

All CDs incorporate an error detection and correction scheme known as Cross Interleave Reed-Solomon Code (CIRC). It would be impossible to make a usable CD without this error correction, since many errors are generated playing even the best discs under ideal conditions. CIRC is a powerful error detection code that can detect and completely correct all errors on a reasonably good disc. It relies on two principles for its operation. One is redundancy. Extra parity bytes are added to the data stream to facilitate error detection and correction. These extra bytes reduce the available capacity of the CD by about 25%.

The other principle is interleaving. The data is not recorded on the disc in its natural order as it would be on magnetic tape. The data are organized into blocks of 24 bytes (called “symbols” in CIRC terminology.) These are the blocks referred to in the Block Error Rate measure. Eight parity bytes are added to each block of 24 symbols (bytes), making the block 32 bytes long. The data symbols belonging to one block are then distributed over a fairly large area of the disc by “interleaving" them with symbols from other data blocks. The 24 symbols of one data block end up distributed over 109 data blocks. The advantage of this technique is that physical defects on the disc do not eliminate complete data blocks, but instead, small parts of many blocks. These partially bad blocks can then be reconstructed using the parity information.

CIRC error correction is done in two stages referred to as C1 and C2, with deinterleaving of the data taking place between the stages. The C1 stage is used to recover from random errors caused by noise in the signal; the C2 stage is used to recover from larger errors caused by physical defects such as scratches and dirt. The error correction chip typically can correct two bad symbols per block in the first stage and two bad symbols per block in the second stage. Some chips can correct four bad symbols in the second stage in some cases.

Layered Error Detection Code and Error Correction Code

CD-ROMs include an extra layer of error detection and correction, usually called Layered Error Detection Code and Error Correction Code (for brevity's sake, typically referred to as Layered ECC) which works similarly to CIRC by adding parity information to each data sector. The extra error correction capability can correct errors that are not correctable by the CIRC because it adds additional parity bytes and additional scrambling of the data.

Re-try

If a CD-ROM drive encounters an error that is uncorrectable even by the layered ECC, it will try again to read the sector. This is the failure mode most familiar to the CD-ROM user. Obviously, having to re-try slows down access to the data, but sometimes a second try is successful. If the drive cannot recover the data within a certain number of retries, the disc is unusable.

Types of Errors

Disc testing equipment documents the errors that are being detected (and usually corrected) by CIRC. The errors reported during disc testing are classified into a variety of categories. An error of type E11 means that one bad symbol was corrected in the C1 stage of CIRC. E21 means two bad symbols were corrected in the C1 stage; E31 means that three or more errors were found at the C1 stage. If there are more than two errors found at the C1 stage, the block is uncorrectable at the C1 stage, and is passed to the C2 stage. Because of the deinterleaving of the data between the stages, those three (or more) bad symbols are now in separate blocks, and so can be corrected by the C2 stage.

Similarly, E12 means that one bad symbol was corrected in the C2 stage, and E22 means that two bad symbols were corrected in the C2 stage. E32 means that three or more bad symbols were found in one block at the C2 stage, and therefore this error is not correctable.

Block Error Rate (BLER)

Block error Rate (BLER) is defined as the number of data blocks per second that have any bad symbols. BLER is the most general measurement of the quality of a disc. The Red Book specification (IEC 908) calls for a maximum BLER of 220 per second averaged over ten seconds. Discs with higher BLER are likely to produce uncorrectable errors. Presently, the best discs have average BLER below 10. A low BLER shows that the system as a whole is performing well, and that the pit geometry is good.

Relying on the BLER alone is not advisable, however. Although the BLER provides information on the number of bad blocks per second, it does not indicate the severity of the errors. In principle, a disc with an average BLER of five can be unusable, if all those errors are uncorrectable! The error codes described above provide details that indicate the severity of the errors and distinguish between correctable and uncorrectable errors.

Interpretation of Error Data

Small errors (one or two bad symbols per block) are generally considered noise. They have a random characteristic of occurrence, and can be caused by dust, small scratches, etc. Large errors of more than three symbols per block are considered burst errors, and are generally due to some kind of physical defect in the disc.

Testing equipment indicates, either on-screen or via a printed report, the location and type of errors on the disc. The most important aspect of testing is simply determining whether there is a problem. From this starting point, the user then can begin the process of determining the source; e.g., bad media, incompatibility issues, or premastering software.

Standards for CD-ROM Error Rates

All CD-ROMs must meet Philips/Sony Yellow Book specifications. Only two specifications are indicated for error rates: BLER must not exceed 220, and no E22 or E32 errors may be present. Beyond that, it is up to each supplier to decide on disc specifications. CD-ROM users cannot tolerate any corruption of the data, so the CD-ROM community has established some *de facto* standards. Most CD-ROM manufacturers and publishers agree that CD-ROMs should have an average BLER of less than 50, and a peak BLER of less than 100.

Conclusion

The CD-ROM publishing community is changing rapidly because of advances in CD-R technology, and responsibility for testing is now shifting from manufacturers to publishers and duplicators. CD-ROM developers, publishers, and distributors can now monitor the quality of their product using simple, affordable desktop test equipment that provides a quantitative measure of disc quality.

26945 Cabot Road, Suite 114
Laguna Hills, CA 92653
E-mail: info@cloversystems.com

clover systems

Tel: 949.582.8010
Fax: 949.582.1016
URL: http://www.cloversystems.com