

Re-Interleaving ID1 Error Data

ID1-type tape recorders are widely used in industry today. This type of recorder uses eight helical scanning heads to sequentially read data off magnetic tape. Each head reads a track length of 36,108 user-data bytes (288,864 bits) recorded on the tape at a 5-degree angle.

When data is recorded to an ID1-type tape, it is interleaved according to the ID1 standard. Likewise, data scanned from these tapes is passed through three-dimensional Reed-Solomon Error Correction Coding, which corrects and de-interleaves the data back into user format.

In analysis of ID1 error data, it is most useful to re-interleave the output data back into the tape format for error measurement and analysis purposes. This is easily accomplished through the use of the BitAlyzer ECC option.

The following paragraphs describe hardware interfacing, ID1 interleaving, ID1 de-interleaving, and BitAlyzer re-interleaving. Several analysis examples are included as well.

Hardware Interfacing

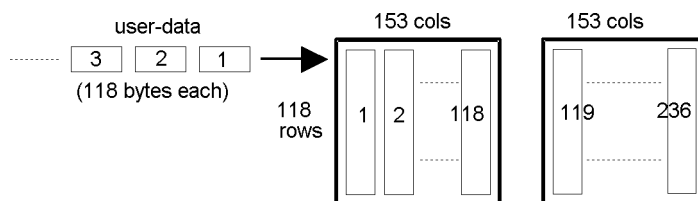
The tape recorder and the BitAlyzer must be connected properly. The “sync” signal must be connected, since it acts as a marker signal for the BitAlyzer. This signal identifies the first byte of each eight-track group.

When performing tests, it is generally beneficial to turn off the recorder’s error correction (C1, C2, and erasure). This will yield data with significant error content, allowing a more in-depth analysis. Analysis of corrected data may also be useful; however this will usually yield error-free playback and the error analysis will necessarily be less interesting.

See the following section, “ID1 Correction Performance,” for more information on analyzing corrected performance from uncorrected error analysis.

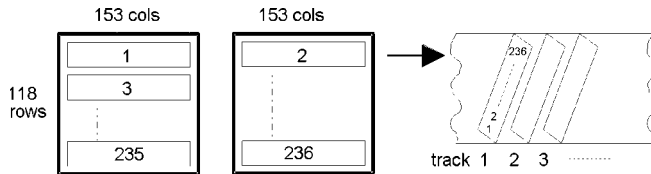
ID1 Interleaving during Record

During record operations, the ID1 recorder interleaves each track’s data using a three-dimensional group size of 153-byte rows x 118-byte columns x 2 tables. The user input data is inserted into the group in a sequential column order (shown below).



Phase 1: User-data fills ECC tables in Column-Major format

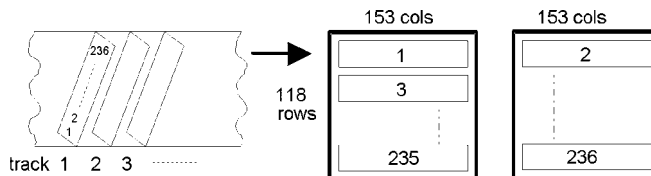
When the group is full, the data is drained in a rows-together order (shown below), after which it is stored on a magnetic tape. This procedure results in separating adjacent user-input bytes by 306 bytes when recorded on tape (this description only pertains to user data; the actual separation is greater considering added bytes of sync and error correction data).



Phase 2: ECC tables drained in Rows-Together format to tape track

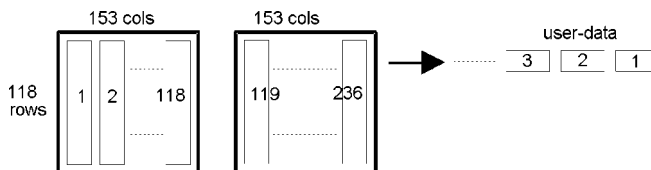
ID1 De-Interleaving during Playback

During playback and read-after-write operations, the ID1 recorder de-interleaves data in a three-dimensional group size of 153-byte rows x 118-byte columns x 2 tables. The raw data from tape is inserted into the group in a rows-together order (shown below).



Phase 1: Tape track data fills ECC tables in Rows-Together format

After error correction, the data is drained from the group in a sequential column order (shown below). This achieves the byte-ordering that is presented to the user as “data-out”, and which is necessarily the same ordering as user data input.



Phase 2: ECC tables drained in Column-Major format to user-data output.

Using the BitAlyzer to Re-Interleave ID1 Data

The BitAlyzer can be used to re-interleave the user data in order to reorganize the error placement

back into the original geometry of the tape. This is a very important step for accurate media scanning, burst length profiling, and other forms of error analysis. By disabling software error correction emulation and setting up an appropriate group size with proper fill and drain characteristics, the BitAlyzer’s ECC scanner can be enabled to only re-interleave the error data and not perform any correction emulation.

To re-interleave ID1 type data on the BitAlyzer, apply the following steps:

1. Open the BitAlyzer ECC panel and then press the ECC **Setup** button.
2. Set rows per table = 118.
3. Set columns per table = 153.
4. Set tables per group = 2.
5. Specify fill tables as **Column Major**.
6. Specify drain tables as **Rows Together**.
7. Make sure C1 correction, erasure mode, and C2 correction are all disabled.


Your settings should be as illustrated:

ECC Setup

Rows Per Table	<input type="text" value="118"/>	Fill Tables	<input type="button" value="Column Major"/>
Columns Per Table	<input type="text" value="153"/>	C1 Correction	<input type="button" value="Rows"/>
Tables Per Group	<input type="text" value="2"/>	Erasure Mode	<input type="button" value="Enabled"/>
C1 Strength	<input type="text" value="3"/>	C2 Correction	<input type="button" value="Columns"/>
C2 Strength	<input type="text" value="3"/>	Drain Tables	<input type="button" value="Rows Together"/>
Erase Strength	<input type="text" value="10"/>	Log File	<input type="text" value="NONE"/>
Groups Per Log	<input type="text" value="0"/>	<input type="button" value="Cancel"/> <input type="button" value="Ok"/>	

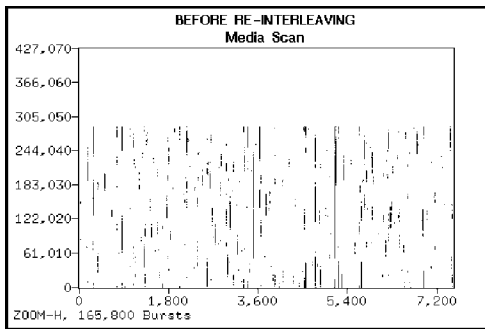
8. Press **Ok** on the ECC Setup panel.
9. Open the Analyzer panel and press the Analyzer **Setup** button. On the Analyzer Setup panel, press **Select Scanners** and make sure the ECC scanner is enabled.

ECC Emulation

10. Press **Ok** on the Analyzer Select Scanners panel.
11. If your error data includes markers, select  **Skip To Mark #2** **Skip to Mark** in the Analyzer Setup panel.
12. Press **Ok** on the Analyzer Setup panel.
13. Make sure the proper interface parameters for the Generator and Detector are selected (Clock Source, Interface, Pattern, etc.).
14. Make the appropriate hardware connections and press **Live, Play**, or **Record** on the Analyzer panel. Your data will first be passed into the ECC scanner where it will be re-interleaved, and then it will be passed on to the other BitAlyzer scanners.

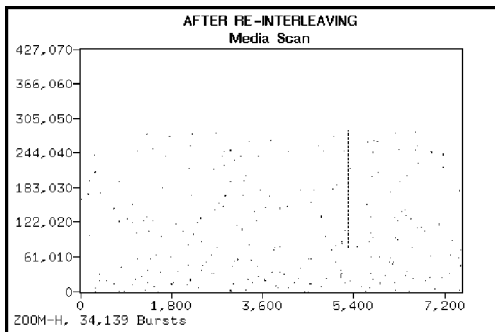
Analysis Examples

This is a media scan of ID1-type data prior to BitAlyzer ECC re-interleaving (user data output from tape re-



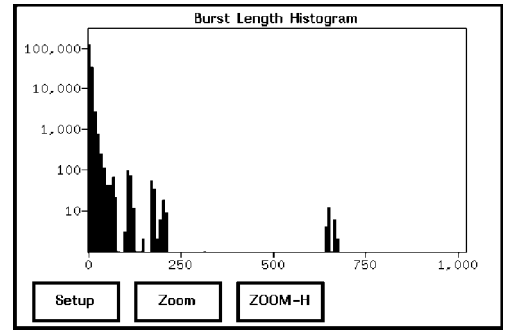
Media Scan (Before Re-Interleaving)

recorder). Notice that the errors are spread out. This is characteristic of the recorder's de-interleaver. Below is the same error information, only re-interleaved by the BitAlyzer. Notice that errors are now placed closer to one another. This media scan illustrates error placement in tape-geometry format.



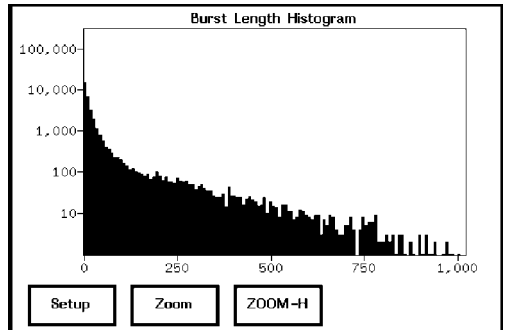
Media Scan (After Re-Interleaving)

The BitAlyzer's burst length profile can also reveal the before-and-after effects of re-interleaving. Before re-interleaving, most of the bursts are smaller (see below). This is expected, since the ID1 recorder's de-interleaver is meant to spread adjacent tape errors apart. After the BitAlyzer re-interleaves the data, we see the bursts as they would appear on the tape. A large number of the error bursts are longer. The following is a modulo-

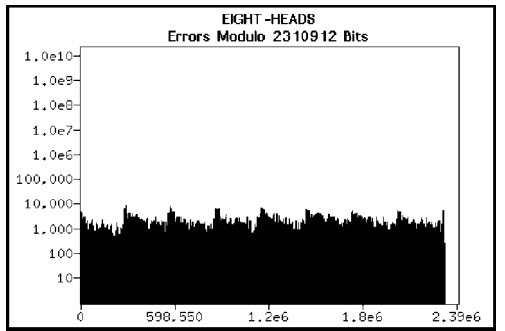


Burst Length Profile (Before Re-Interleaving)

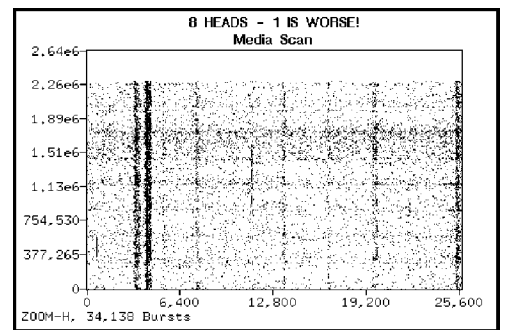
2,310,912-bits analysis (eight tracks of data). The data from each of the eight heads is distinguishable in this analysis. A media scan of all eight heads clearly shows that one head of the eight is much worse than the others.



Burst Length Profile (After Re-Interleaving)



Modulo Eight-Heads Data

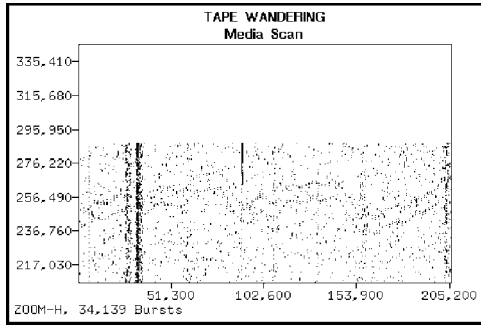


Eight Heads Media Scan

Zooming in on a particular section of the media scan reveals a phenomenon known as “tape wandering”. This is the result of slight imperfections in the tape, created during manufacturing when the tape is pressed flat.

Notice that the imperfection wanders from side to side, perpendicular to the tape length. This is because

the tape maker moves the press rollers during manufacturing in order to minimize adjacent imperfections.

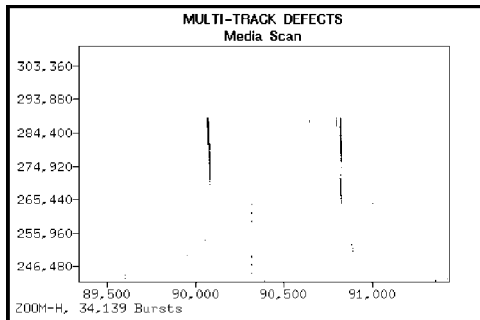


“Web Wandering”

This analysis is often used to determine if system errors are due to poor media or are recorder-related. Media-related problems will shift with the wandering of the web during tape manufacturing; recorder problems will not.

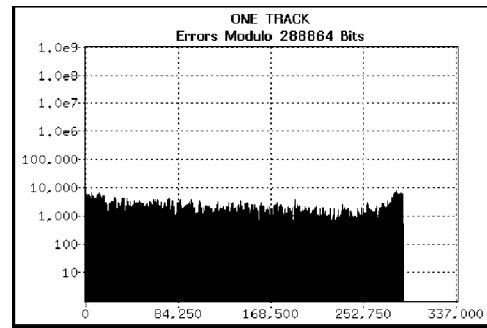
Zooming in even closer on the media scan shows multi-track defects (see below).

These are usually the result of scratches or dimples on the tape that span more than one track.



Multi-Track Defects

Below is shown a modulo-288,864 bits analysis (one track of data). Notice how the errors become worse at the beginning and end of the track. These sections of data are closer to the tape edges. This is consistent with tape recorder issues, such as errors due to difficulty in achieving sync at the beginning of each track, and because of tracking error at the ends of tracks.



Modulo One-Track Data

ID1 ECC Monitoring and Media Verification

If the ID1 recorder has the capability to report error correction statistics while it is running, these statistics can be collected over a specified length of tape and compared with raw error statistics gathered over the same length of tape.

This section describes the capability to accurately estimate the corrected performance of the playback by acquiring the raw errors from an uncorrected playback and calculating error correction statistics from the placement of the errors. These analyses demonstrate media performance in a qualitative way, rather than as a simple go/no-go test.

Real-Time ECC Statistics

Three error correction statistics may be collected during playback while the error correction system is enabled. The three statistics are:

- C1R quantity of symbol errors corrected by C1 error correction processing
- C1B quantity of C1 error correction Blocks that failed error correction
- UCE... quantity of uncorrectable errors (This is actually erred-track-groups)

These statistics report on real-time activity of the Reed-Solomon error correction performance.

BitAlyzer Emulated ECC Statistics

The BitAlyzer’s ECC Scanner produces emulated results for each of the above three statistics. It does this by analyzing the raw errors during tape play-

back, re-creating the processing of the specified Reed-Solomon error correction algorithms, and computing detailed statistics including where errors occur and where correction failures occur.

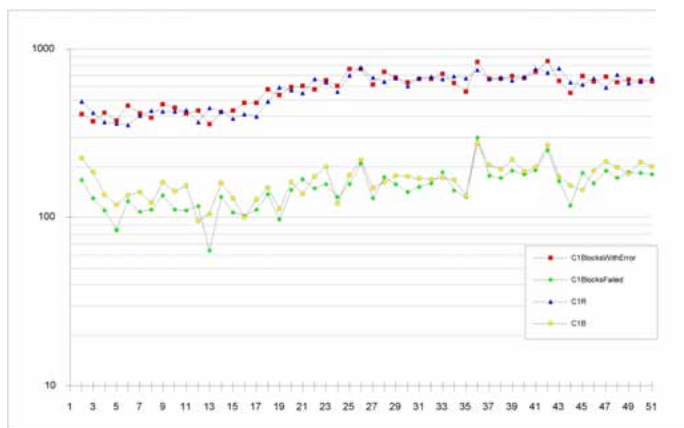
The ECC Scanner computes the following statistics. These statistics are output to a comma-delimited file at specified processing intervals, and can be easily graphed using spreadsheet programs.

C1 Symbol Errors	C2 Symbol Errors
C1 Blocks With Error	C2 Blocks With Error
C1 Symbols Corrected	C2 Symbols Corrected
C1 Blocks Failed	C2 Blocks Failed
Erasures Used	Uncorrectable Symbols
Erasure Symbols Corrected	

These statistics show errors being corrected by certain stages in error correction processing, and can give you a better estimate of how close a particular playback is to being unreadable.

Verifying Emulated -vs.- Real Time Statistics

The following spreadsheet graph shows the high correlation between emulated ECC statistics and actual real-time statistics. The BitAlyzer's "C1SymbolsCorrected" statistic matches the ID1 recorder's "C1R" statistic, and the BitAlyzer's "C1BlocksFailed" statistic matches the recorder's "C1B" statistic.



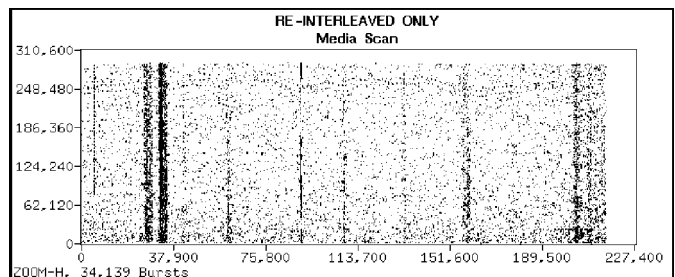
ID1 Recorder Statistics -vs.- BitAlyzer Statistics

The emulated and real-time statistics match well considering sampling differences and the fact that

they are from different playbacks of the same piece of tape. This demonstrates the accuracy of the emulated statistics.

Analyzing Raw Errors

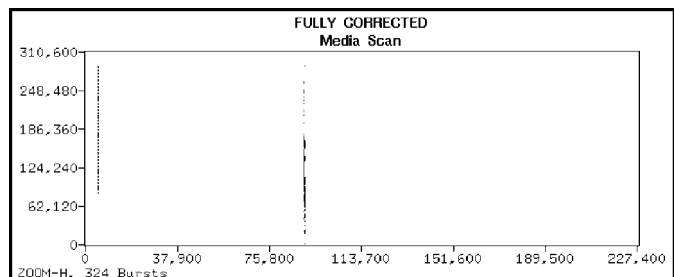
The BitAlyzer can Media Scan the errors encountered during playback. This is done with the ID1 recorder's Error Correction disabled to achieve raw statistics. This information can also be used to determine the size and number of error bursts or error free intervals, along with error rates. Modulo analysis can be used to determine where errors occur on individual tracks by setting the Modulo-N quantity to 288,864, which is the number of bits in one track. Using the BitAlyzer's interleaver and media scanner, the data can be translated into a geometric representation of the error data. The following is a media scanned image of the tape surface with error correction disabled:



Media Scan of Data (Before Correction)

The following image shows the same raw tape errors after the specified ID1 error correction algorithm has been applied by the BitAlyzer. Notice most errors are completely removed. Any error that is not removed is an uncorrectable error.

Notice: The particular recorder used to gather this information only reports the number of ID track-groups containing at least one uncorrectable error. The BitAlyzer's emulated "Uncorrectable Symbols" statistic is symbol-accurate.



Media Scan of Data (After Correction)

Steps in Producing ECC Performance Reports

1. Record a BitAlyzer known pattern on the test tape using the ID1 tape recorder.
2. When ready for playback, disable the recorder's ECC correction feature and make the required hardware connections to the BitAlyzer's detector.
3. Enable the ECC Scanner and the Media Scan Scanner on the BitAlyzer by entering the Analyzer Setup panel, pressing the **Select Scanners** button, and checking the appropriate boxes.
4. Open the ECC Setup Panel and make the following settings for correction emulation reports:

Rows Per Table = 118
 Columns Per Table = 153
 Tables Per Group = 2
 C1 Strength = 3
 C2 Strength = 3
 Erase Strength = 10
 Fill Tables = Column Major
 C1 Correction = Rows
 Erasure Mode = Enabled
 C2 Correction = Columns
 Drain Tables = Rows Together

or these alternative settings for uncorrected (raw) reports:

Rows Per Table = 118
 Columns Per Table = 153
 Tables Per Group = 2
 C1 Strength = 3
 C2 Strength = 3
 Erase Strength = 10
 Fill Tables = Column Major
 C1 Correction = *Disabled*
 Erasure Mode = *Disabled*
 C2 Correction = *Disabled*
 Drain Tables = Rows Together

5. To post ECC statistics to a comma-delimited log file, enter a log-file name and select the number of "Groups Per Log" (e.g., 31,855 groups per log will post statistics after approximately every 15 meters of tape -- you can select statistics reporting one table-group at a time!)
6. Open the Media Scan Setup Panel and make the following setting:

Bits Per Unit = 288864
7. Play the tape using the ID1 recorder. As the tape plays, ECC statistics will be shown on the ECC panel and will be posted to the selected log file.

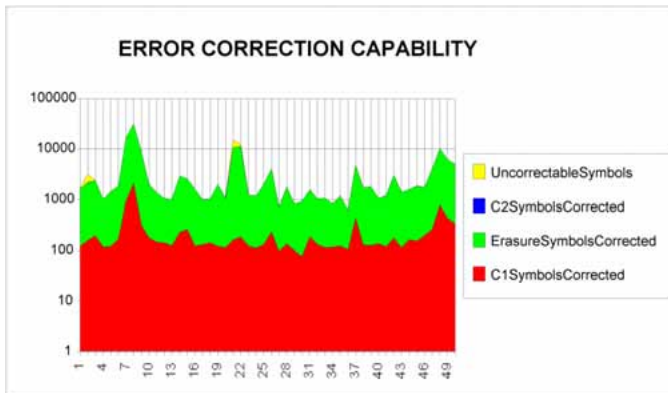
Enhanced Error Correction Statistics

The BitAlyzer's ECC emulation scanner can be used to log error correction performance statistics to a comma-separated format file. These files can be easily imported to a spreadsheet program. The following is an example spreadsheet created by performing ID1 error correction emulation on the same piece of tape shown in the Media Scan screens above.

C1SymbolErr	C1BlocksWit	C1SymbolsC	C1BlocksFail	ErasuresUse	ErasuresSymt	C2SymbolErr
1626	167	123	92	92	1503	0
3192	274	160	181	98	2013	1019
2381	219	199	98	98	2182	0
1006	141	119	67	67	887	0
1445	168	121	88	88	1324	0
1865	197	171	88	88	1694	0
17039	1311	943	749	749	16096	0
31565	2933	2124	1649	1649	29441	0
8794	550	316	355	355	8478	0

Logged BitAlyzer ECC Statistics

Some of the columns from this report were used to create the following spreadsheet graph, which identifies the error correction failures that were seen in the original BitAlyzer Media Scan.



Spreadsheet Graph of BitAlyzer ECC Statistics

In addition to correction failures, this graph shows which errors are corrected during the different phases of error correction: C1, Erasure, C2. Notice that the quantity of C2 corrections is very small. This shows the small number of occurrences when the Erasure Flags are overrun. The symbols corrected in the Erasure phase of processing are actually corrected using the C2 code blocks and check words. They are distinguished from C2 phase corrections, which correct and locate errors.

It is interesting to notice that the very large errors that appeared on the media scan about 15% of the way into the playback were corrected completely.

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