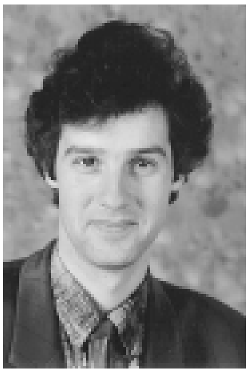
STUDER D731 QC

Quality Inspection of CDs and CD-Rs

by David Roth



David Roth

The compact disc is one of the most reliable media available today. The «red book» (CD) and the «orange book» (CD-R) specify not only the data formats but also the minimum quality criteria for CD players and CDs. The CD technology has become so refined that the manufacturing quality of CDs and CD players now exceeds the «red book» specifications. Playability problems have become rare. This is one of the many reasons why the CD has become so popular.

In order to achieve and maintain this high CD production quality, the minimum quality criteria must be monitored with special quality control CD players. Due to the wear caused by daily use, the quality of a CD can deteriorate to the point where these criteria are no longer met. This eventually results in playability problems which are unacceptable in professional applications, such as radio broadcasting. For this reason quality control CD players are recommended also for these users.

The new Studer D731 QC quality control CD player supersedes the A725 QC which in the meantime has become the de-facto standard QC player and can be found in virtually every CD pressing plant.

In this report I would like to discuss the principal quality measurements conducted with the D731 QC and their significance.

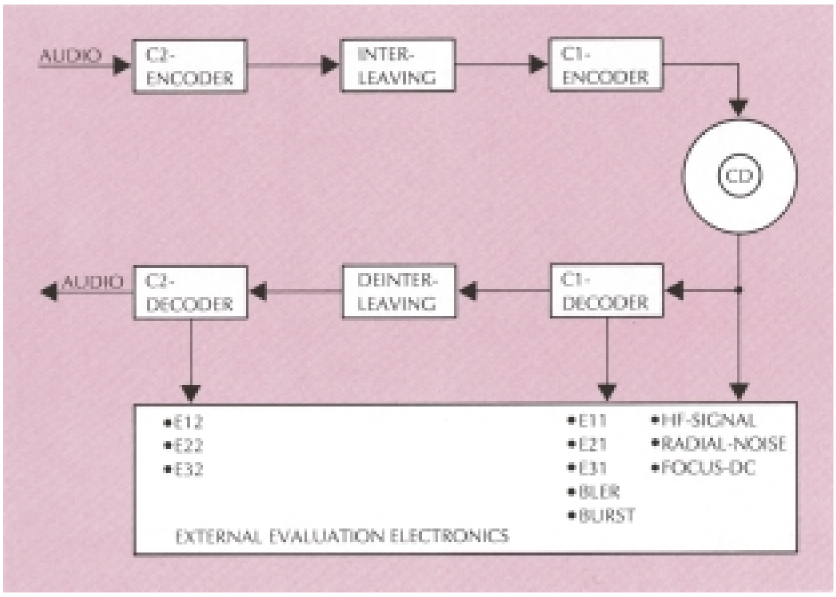


Fig. 1: Two-stage CD encoder and decoder

Digital error flags

The CD decoder works with a two-stage error correction system. The data recorded serially on the CD are taken to the input of the first error correction stage. The data are combined in error correction units, so-called frames. Each second 7,350 frames have to be processed for error correction (digital sampling frequency 44,100 Hz / 6 stereo samples).

In the **first error correction stage**, the so-called C1 decoder, these frames are checked for errors and corrected, if possible. The following digital error flags can be counted:

E11: Total of all frames that contain **one** faulty symbol (byte).

E21: Total of all frames that contain **two** faulty symbols.

E31: Total of all frames that contain **more than two** faulty symbols.

BLER: = E11 + E21 + E31. This is the total of all faulty frames. According to the «red book» no more than 3% of all frames may be faulty, that is, 220 of 7,350 frames.

BURST: This is the maximum number of consecutive frames with E21 and E31 error flags, that is, the number of consecutive frames with more than one faulty symbol.
According to the «red book» no more than 7 consecutive frames may contain multiple errors. On the CD this corresponds to a length of approximately 1 mm.

The **first correction stage (C 1)** of a typical CD decoder is able to correct statistically distributed minor errors (E11 and E21). This is the principal function of the first error correction stage. But if the errors become larger (E31), the CD decoder can no longer correct these errors. These errors are principally caused by local faults such as air bubbles and scratches. In this case the C1 decoder does not perform any correction but flags the frames as C1 uncorrectable.

As can be seen from Fig. 1, the error-free frames, the corrected frames, and the C1 uncorrectable frames are input to the de-interleaving. This reverse interleaving process reassembles the data in the proper sequence. Through this process errors flagged as C1 uncorrectable are «intermixed» with many error-free and corrected frames so that the C2 decoder can still correct them. As a result the decoder «sees» many faulty frames but these contain just a few errors which it can correct.

In the **second error correction stage (C2)** the frames are checked and corrected, if possible. In this process the following digital error flags can be counted:

E12: Total of all frames that contain **one** faulty symbol (byte).

E22: Total of all frames that contain **two** faulty symbols.

E32: Total of all frames that contain **more than two** faulty symbols.

For the second error correction stage there are no direct limits because the E12, E22 and E32 values depend on the performance of the first error correction stage in the CD decoder. Depending on the decoder IC, from one to four symbols per frame can be corrected in the C1 and the C2 decoder. The D731, for example, contains a decoder that can correct the theoretic maximum in both error correction stages. In the CD quality control technology, however, a medium error correction is used that corresponds to the one in most CD players. In the C1 as well as the C2 decoder up to 2 symbols/ frame are corrected. One E22 flag consequently is the limit for this error correction. One E32 flag means that interpolations or even muting can occur. For this reason two decoders are used in the D731QC.

The decoder responsible for processing the digital and analog audio signals is capable of correcting the maximum number of errors, whereas the second decoder employs a medium error correction strategy and supplies the previously mentioned error flags, which are identical to those of the A725 QC player.

Fig. 2 shows the error signals of a test CD containing 3 different errors:
- Information layer interruptions of 0.4 to 1.0 mm
- Black dots on the read-out side: 0.3, 0.5, 0.6, 0.8mm
- Simulated fingerprint

The first 5 diagrams show the pattern of the error flags BLER, E22, E32, BURST and EFAB (system limit of CD error correction, see diagram 5).

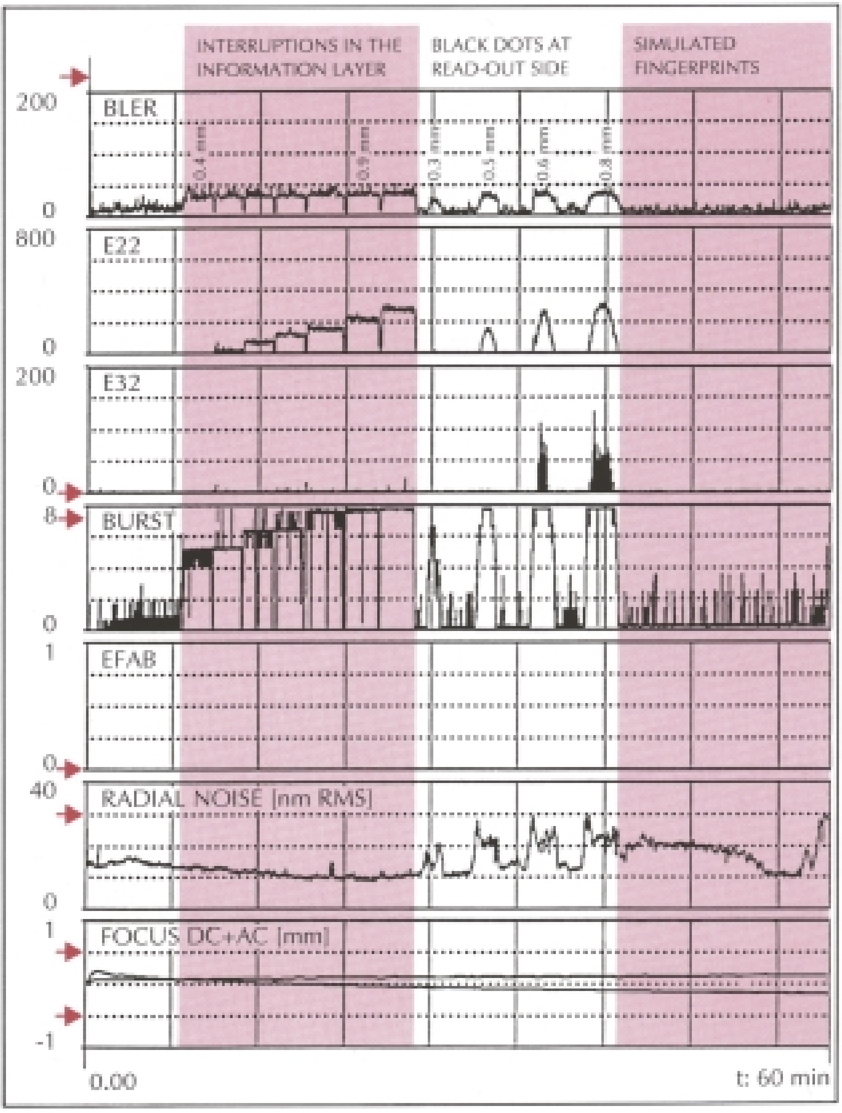


Fig. 2: Typical representation of a playability measurement

- ***Diagram 1***

The **pattern of BLER** shows a base value of approx. 20, a typical value for good CDs. If an interruption in the information layer occurs or if black dots are present on the read-out side, the BLER increases only slightly to a maximum value of approximately 50, that is, it remains well below the limit of 220. Since a small local fault is very small in relation to a complete revolution, the BLER does not increase very much and does not exceed the BLER limit.

The BLER is consequently a measure of the **general pressing quality** of a CD. But it provides no information on local faults!

- ***Diagram 2***

The **pattern of E22** shows that the first error correction stage was able to correct everything. For this reason E22 is 0. Only at the local faults where the information layer is interrupted and black dots occur does the E22 value increase, up to the limit of 300 for a fault with a length of 1 mm. There is no official limit for E22, but an E22 should not exist, otherwise the faults will already become audible on a CD player that employs a very primitive error correction strategy.

The E22 measurement proves a good assessment of **local faults** on a CD.

- Diagram 3

The **pattern of E32** indicates how frequently the capability of a typical error correction strategy has been exceeded. In this example we see that practically all errors were correctable because the base value remains 0. Only for the larger 0.6 and 0.8 mm black dots can significant E32 values of approximately 100 be measured. Normally these produce audible noise in a CD player.

- Diagram 4

The **BURST pattern** is similar to E22. The main reason for measuring BURST is that it is specified in the «red book», which is not the case for E22. The base value of BURST typically less than 2 which is normal for a good CD. As in the case of E22, BURST increases as a function of the error magnitude and exceeds the value of 7 if the information layer interruption is longer than approx. 0.6 mm and black dots on the read-out side are greater than 0.5 mm.

- Diagram 5

The **pattern of EFAB** is normally not measured. EFAB specifies whether or not uncorrectable errors exist after the best error correction (as used in the D730, D731 and D732). Since EFAB in this case remains at 0, there are no interpolations or other audible faults when this test CD is reproduced by our CD players. The pattern of E32 and EFAB clearly shows why our CD players have a significantly better playability than other CD players.

Analog error signals

The best error correction is useless if the laser cannot follow the track. Particularly large local faults make heavy demands on the radial servo. A measure of faults in the radial control circuit is the **RADIAL NOISE**. The«red book» specifies a limit of 30 nm RMS (1 nm = 10^{-3} µm).

- Diagram 6

The **RADIAL NOISE pattern** shows a base value of approx. 10 nm. This is a typical value for good CDs. At the black dots on the read-out side and the fingerprint on the test CD, the RADIAL NOISE increases up to the specified limit. Frequently the maximum value of RADIAL NOISE produced by a local fault does not occur in the middle (where E22 is the highest), but before and after. This behavior is characteristic for air bubbles. Because the laser beam deflection is strongest at the edge of a bubble, the reflected radial error signal is greater than in the middle where the laser beam deflection is not so strong. This example clearly shows that playability problems depend not only on the size but also on the type of the local fault.

- Diagram 7

The **pattern of FOCUS DC** shows the warp and wobble of the CD. The «red book» specifies a limit of ± 0.5 mm peak and 0.4 mm RMS. This means that the test CD is neither concave nor convex. The wobble increases slightly toward the outer side of the disc where it reaches the uncritical value of < 0.15 mm peak.

RF signal from photodetector

Another very important signal is the RF signal produced by the D731QC. This RF signal is still analog and unconditioned as read by the player. This signal provides further indication as to why, for example, the digital error signals show poor measurement results.

The following measurements can, for example, be conducted with the RF signal:

- JITTER:

Jitter is a phenomenon that started to appear with the CD-R. The pits can have only a discrete length of 3, 4, 5...11T (T = 231.38 ns). The «orange book» allows a maximum deviation of 35 ns RMS from the pit length. If this value is exceeded, digital error flags may possibly occure. These problems have particularly been noted with certain makes of CD-Rs that have a recording time of > 74 minutes.

- ASYMMETRY:

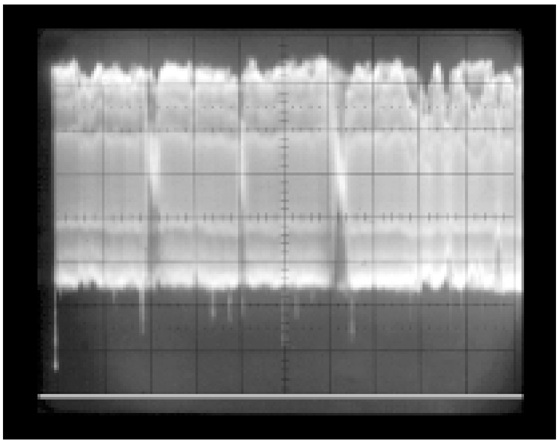


Fig. 3a): RF signal of a severely scratched CD. Time base = 4ms/div.

With a good RF signal the decision threshold should be in the middle of the large amplitude (I_{11}). If this is not the case the pit shape is probably not correct.

- I_{top} :
On the D731QC the maximum reflection (I_{top}) can be measured directly with the oscilloscope. A reading of 1 Volt corresponds to a reflection of 100%. The«red book» limit is 70% and normally does not present any problem.

- I_{11} / I_{top} :
The ratio of the large amplitude (I_{11}) to the total reflection corresponds to the modulation depth. According to the «red book» it must be > 0.6. If this value is too small the pit depth is frequently too small. Since the pit depth is given by the stamper, all CDs of this batch have the same problem.

- I_3 / I_{top} :
The ratio of the small amplitude (I_3) to the total reflection should be > 0.3. If this value is too small, the linear velocity is frequently too low. This also occurs with CDs having a playing time of > 74 minutes.

If only one of the foregoing parameters is outside the tolerance, this normally does not yet result in playability problems, but this will be the case with certain combinations of parameters. In the various CD players available on the market these problems manifest themselves differently, or not at all.

With the CD player STUDER D731QC and appropriate evaluation electronics additional parameters can be measured. The most important ones which are, for example, measured by pressing plants, have been described in this report.

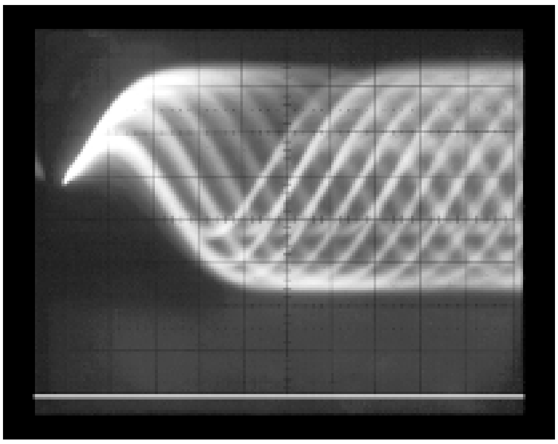


Fig. 3b): RF signal of a severely scratched CD. Time base = 0.4 µs/div.

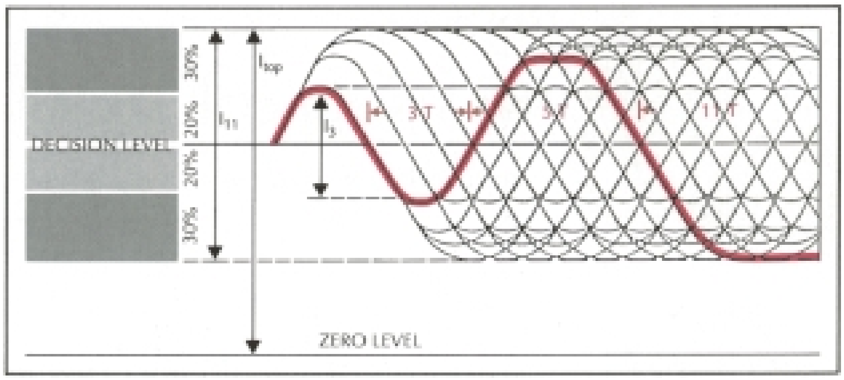


Fig. 4: Ideal RF signal

The D731QC reads and tests all commercially used CD formats
The D731QC can reproduce not only the CD-AUDIO but all commercially used CD formats (CD-ROM, CD-I, VIDEO CD, CD-R...). The digital error flags and the analog error signals are identical for all CD formats and can be measured with the D731QC.

Outstanding playability of STUDER CD player family
Allow me to conclude this report with an answer to question as to why STUDER has developed the D731QC. One of the principal considerations in the development of the new CD player generation D730, D731 and D732 was the playability of poor CDs. The excellent values were only achievable through an in-depth analysis of QC problems. For this purpose we have collected a CD horror set comprising over 100 CDs with different faults for accurate analysis. Numerous tests and experience in radio broadcasting have shown that the effort was worth while. The playability characteristics of the new CD players are without doubt the best that can be achieved today.

The standard broadcast version of the D731 was an excellent base, the step to the D731QC was logical rather than big.

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