

OMP glass masters with very low or no Push-Pull signal

1) SCOPE	2
2) CONCLUSION	2
3) READ-OUT PROCESS.....	2
3.1) TRACKING MECHANISM SINGLE-BEAM PICKUP	3
3.2) SIMULATION OF HF AND PUSH-PULL SIGNAL.....	5
4) SINGLE-BEAM PICKUP SYSTEM	6
4.1) CDM4 PICKUP SYSTEM	6
4.2) TRACKING MECHANISM.....	7
4.3) ARCHITECTURE	7
5) TRIPLE-BEAM PICKUP SYSTEM.....	8
5.1) PICKUP SYSTEM.....	8
5.2) TRACKING MECHANISM.....	9
6) MEASUREMENT RESULTS OF SAMPLE GLASS MASTERS WITH VERY LOW OR EVEN NO PUSH-PULL	10
6.1) NON-OPTIMIZED OMP GLASS MASTER:	11
6.2) OPTIMISED OMP GLASS MASTER:	12
7) MEASUREMENT RESULTS OF DATARIUS CALIBRATION DISC 4D.....	13
8) BIBLIOGRAPHY	14

1) Scope

The purpose of this document is to explain the playability of glass masters with a very low or even no Push-Pull signal on single-beam pickup based measurement equipment.

2) Conclusion

Optical CD media, such as glass masters, stampers, and replicas, are basically only measurable on single-beam pickup based systems, if sufficient Push-Pull is available. This is a physical requirement for these optical media.

These optical media are playable and measurable, regardless of the Push-Pull, on triple-beam based systems.

Therefore, optimized OMP glass masters are measurable on triple-beam pickup systems.

This will be explained in more detail in the following chapters.

3) Read-out process

When the laser beam is reflected at the disc surface during playback the varying intensity of returned light is detected by a photo detector (consisting internally of several different photo diodes).

The light striking a pit undergoes a phase change compared with the light reflected from a land.

If the depth of the pit equals $\lambda/4$ there is an optical path difference of $\lambda/2$.

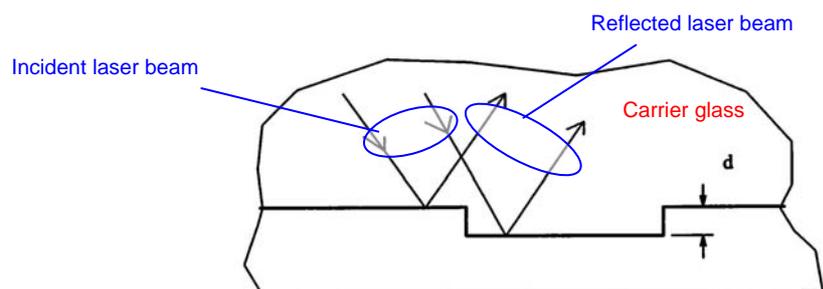


Fig. 1

Optical path difference:

$$OPD = 2 \cdot d$$

Phase difference:

$$\Phi = 2\pi \cdot \frac{OPD}{\lambda} = 4\pi \frac{d}{\lambda}$$

When the light reflected by a pit is in anti-phase with the light reflected by the surrounding area, the overall reflected light is at a minimum.

Another criterion is that the intensity of the light in phase opposition is properly balanced (this will be influenced by the pit geometry).

Thus the light reflected back to the photo detector is modulated according to the profile of the information layer.

The signal level obtained by the reflection of a land area is the 'ITOP'. This is the maximum amount of light captured by the focus lens.

Due to the limited aperture it is possible to collect only the 0 and the two 1st orders of the reflected beam.

Glass Masters are measured through the carrier glass plate.

3.1) Tracking mechanism single-beam pickup

Compared with a gramophone, where the needle of the pickup is guided by means of the track, no such steering mechanism is available in the compact disc system. Therefore the focused spot must be driven by a servo mechanism, so that the track is followed precisely.

We define the tracking error as the difference between the desired position and the actual spot position.

The error signal has to be derived optically, though the HF component is not utilized. The signal from the photo diode is low-pass filtered, so that the high frequency contents are not taken into account. In other words, the individual pits or lands are not taken into account by the servo system. Only an average light level is available for the creation of an error signal.

The optical parameter used for generating the radial tracking error signal in single-beam players is commonly known as 'Push-Pull'.

This is influenced by the pit geometry and therefore also by manufacturing. This parameter is also specified in the RED BOOK.

It is derived as follows:

The light flux through the lens is separated into two parts (see Fig. 3). A split detector is placed in the far field of the reflected beam.

The track structure on the disc represents a diffraction grating and therefore creates diffraction orders in the reflected beam. The interference of those diffraction orders can be seen in the far field. An offset of the optical axis with respect to the track causes relative phase shifts between the diffracted orders.

The value for Push-Pull is specified in the RED BOOK for a radial offset of 100 μ m.

PP is derived as:

$$PP(e) = \sin(\psi_{10}) * \sin\left(\frac{2\pi e}{q}\right)$$

With: q ... track spacing
e ... radial error
Ψ... phase difference between
0 and 1st order

(See [9], Principles of Optical Disc Systems)

There is a relation between the pit depth and the phase difference of the 0th and the 1st order:

$$\psi_{01} = \arctan\left(\frac{-\cot\left(\frac{\Phi}{2}\right)}{1 - 2\left(\frac{w}{q}\right)}\right)$$

With: w ... Pit width
Φ... phase differential error
q ... track spacing

(See [9], Principles of Optical Disc Systems)

The formula above has been derived from a one dimensional grating structure.

With this equation it can be shown that the maximum amplitude will be reached with a pit depth of λ/8.

In other words, if the pits are too deep or too flat, compared to the result of λ/8, Push-Pull will be not maximized (see Fig. 2).

3.2) Simulation of HF and Push-Pull signal

Simulation of HF and Push-Pull signal depending on the pit depth on a compact disc (done by BAYER of Germany):

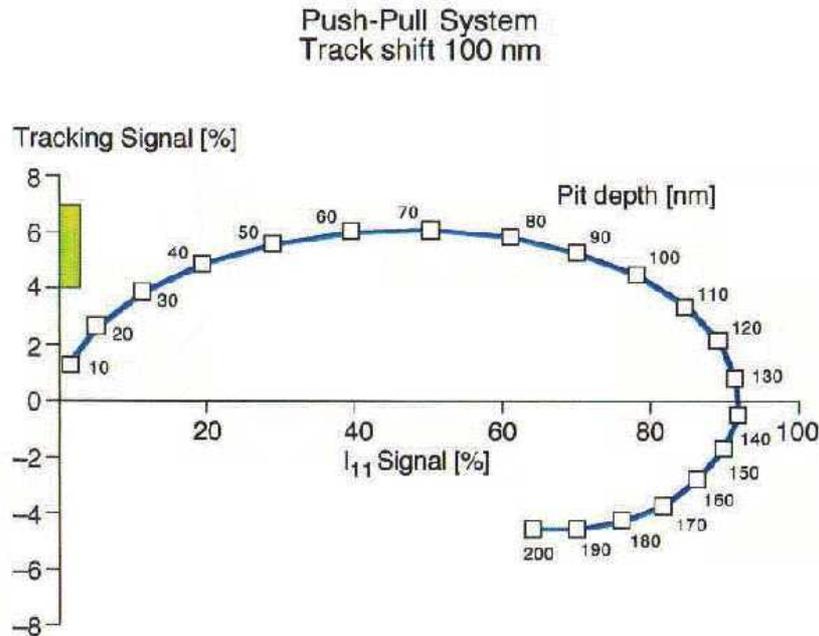


Fig. 2

It shows clearly a maximum HF signal at a pit depth between 130nm and 140nm. Which corresponds with $\lambda/4$:

Laser wavelength $\lambda_{\text{air}} = 780\text{nm}$ ($\lambda_{\text{air}}/4 = 195\text{nm!}$)

Refracting index of polycarbonate: $n = 1.55$ (glass has the same n value)

Laser wavelength in glass $\lambda_{\text{glass}} = 780\text{nm} / 1.55 = 503\text{nm}$

$$\lambda_{\text{glass}}/4 = 126\text{nm}$$

(because, the glass master is read-out through the carrier glass plate)

The maximum Push-Pull signal is achieved at

$$\lambda_{\text{glass}}/8 = 63\text{nm}$$

which corresponds well with the above simulation.

Remark:

The yellow marked range of Fig. 2 above shows the original allowed Push-Pull range according to the original RED BOOK specification (from 4% to 7%). Philips increased the allowed Push-Pull range from 4% up to 9% in further RED BOOK versions.

4) Single-beam Pickup System

4.1) CDM4 pickup system

The first CD players were based on single-beam pickup systems (Fig. 3). The Philips CDM4 pickup is the reference pickup for CD measurement equipment. All DaTARIUS CD Analyzers are based on the CDM4 reference pickup.

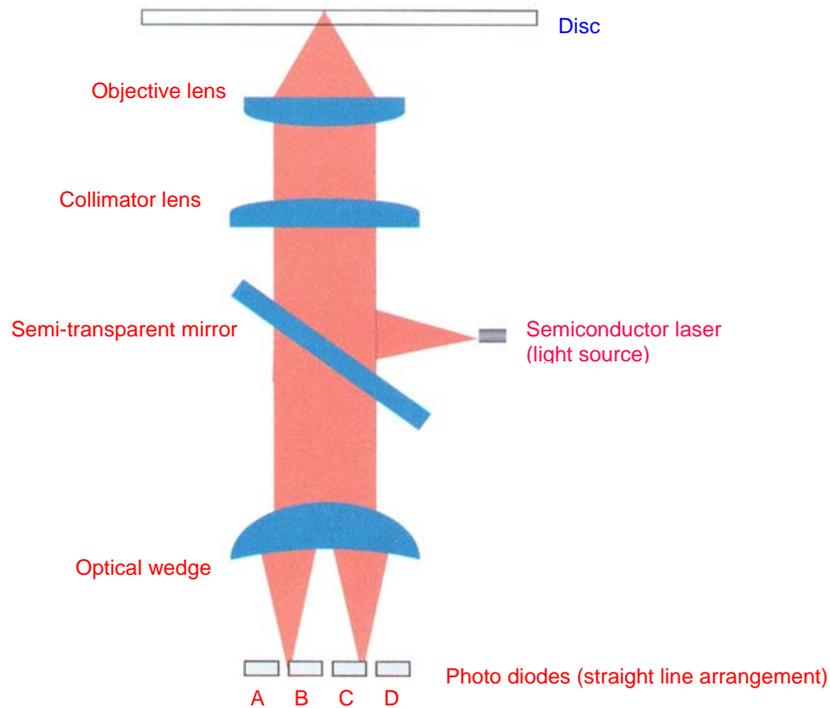


Fig. 3

Data: $A + B + C + D$
 Tracking: $(A + B) - (C + D)$
 Focus: $(A + D) - (B + C)$

RE1 = $A + B$
 RE2 = $C + D$

See chapter 5 and 6 (measurement results).

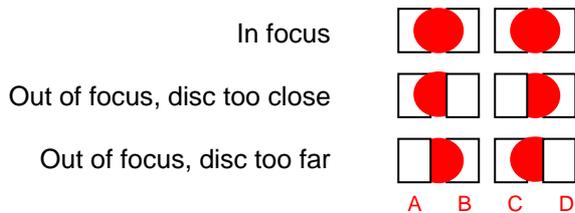
The light is emitted by the semiconductor laser (wavelength 780nm) and strikes a semi-transparent mirror which projects most of the light upwards towards the disc.

The collimator lens makes the laser beam more parallel.

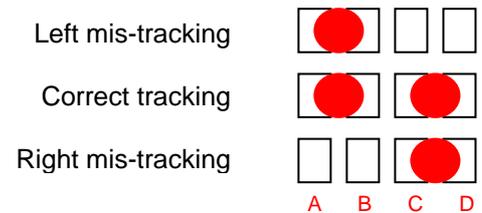
The laser beam is then focused onto the information layer of the disc. Due to interference of the reflected light from land and pit areas of the disc, the light intensity of the reflected beam is modulated according to the information on the disc.

Through the semi-transparent mirror, the light passes through the optical wedge, which basically splits the light into two convergent beams. Those two beams then hit the 4 photo diodes, which are arranged in one straight line (CDM4 pickup design).

Focus system



Tracking system



4.2) Tracking mechanism

For tracking, both error signals RE1 and RE2 are used:

$$RE1 := A + B$$

$$RE2 := C + D$$

The radial tracking error signal is $RE1 - RE2 = (A + B) - (C + D) = \text{Push-Pull}$.

4.3) Architecture

The single-beam pickup system is simpler than a triple-beam pickup system. However, the single-beam pickup system suffers from some limitations against the triple-beam pickup system:

- dust, lodged inside the optical path would create a constant radial displacement of the pickup. This is overcome by injecting a wobble signal (sinusoidal voltage with 650 Hz) into the radial tracking actuator. This causes the actuator to wobble slightly around the track of the disc and hence overcome any constant offset.
- single-beam pickup systems are placed on swing arms, such as the CDM4 from PHILIPS; that means the pickup does not always move perpendicular to the tracks of the disc.

5) Triple-beam Pickup System

5.1) Pickup system

The most common optical pickup system in today's CD players is the triple-beam pickup system (see Fig 4).

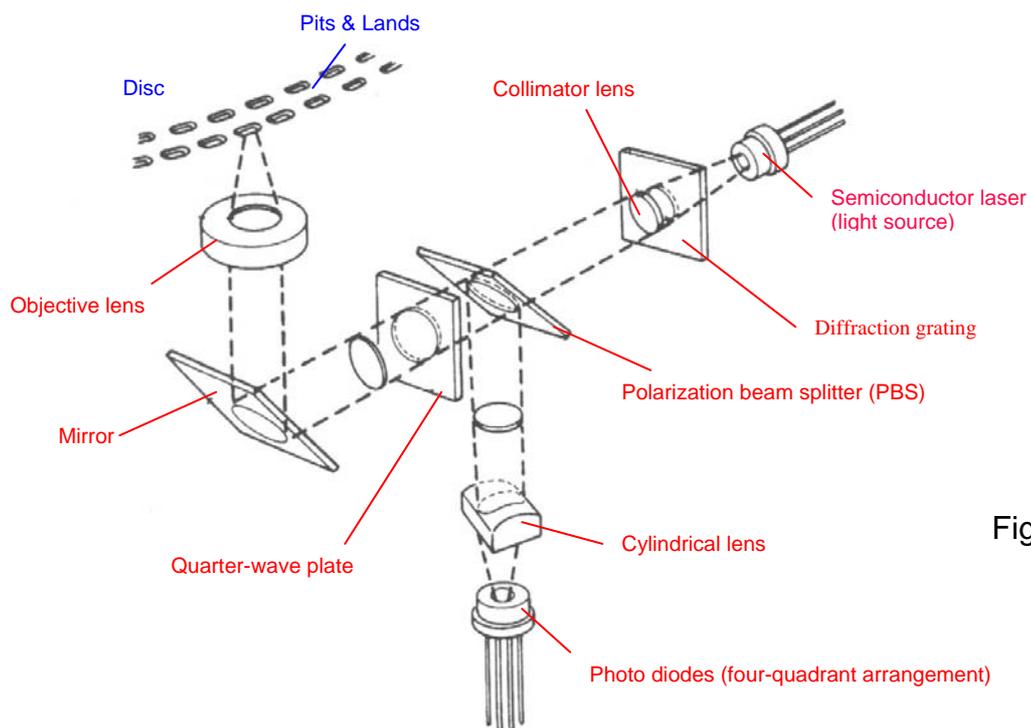


Fig. 4

Data: $A + B + C + D$
 Tracking: $F - E$
 Focus: $(A + C) - (B + D)$

The light is emitted by the semiconductor laser (wavelength 780nm) and enters a diffraction grating. The grating converts the light into a central laser beam and two side beams. The main beam and the two side beams are important for the tracking mechanism of the pickup.

The three beams go through a polarized beam splitter (PBS). This only transmits polarizations parallel to the page. The emerging light (now polarized parallel to the page) is then collimated.

The collimated light passes through a quarter-wave plate. This converts it into circularly polarized light.

The circularly polarized light is then focused onto the information layer of the disc. Due to interference of the reflected light from land and pit areas, the light intensity of the reflected beam is modulated according to the information on the discs.

The reflected light then passes through the quarter-wave plate again. Since it is going in the reverse direction, it will be polarized perpendicular to the original beam (in other words, the light polarization is now vertical with respect to the paper).

When the vertically polarized light hits the polarized beam splitter (PBS) this time, it will be reflected (not transmitted as before). Thus, it will be reflected through the cylindrical lens and be imaged onto the photo diodes. The cylindrical lens is important in the auto-focusing mechanism.

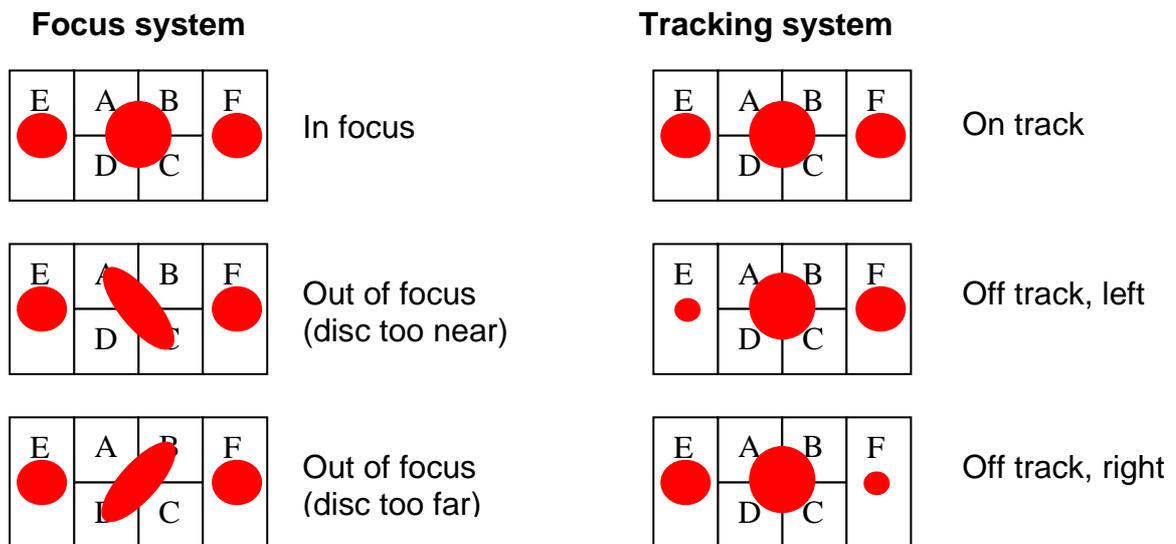


Photo detector: A, B, C, D ... four quadrant diodes
 E and F ... satellite diodes

Focus system: Single Foucault.

5.2) Tracking mechanism

Push-Pull is no longer of interest as the triple-beam tracking system uses the satellite photo diodes E and F only.

Therefore glass masters can be optimized for HF signals, regardless of Push-Pull signal.

6) Measurement results of sample glass masters with very low or even no Push-Pull

OMP glass masters have excellent HF signals but a very poor Push-Pull (PP) signal, due to the optimization of the pit depth for the shortest process cycle times at moulding.

To maximize the HF signals, the optimal pit depth is $\lambda/4$. But the optimal pit depth for Push-Pull is $\lambda/8$ (see chapter 3.2, Fig. 2).

Therefore, a compromise must be found between optimized HF and optimized PP signal for CD manufacturing, according to the RED BOOK specifications.

For DVD, a different tracking mechanism is used, the 'Differential Phase Detection' mechanism. Push-Pull is no longer required. The manufacturing process can be optimized for highest HF signals, regardless of Push-Pull. Typical DVDs, therefore, have a very low Push-Pull.

Stampers, produced from such optimized glass masters, have a PP signal from approx. 4% and higher, because the read-out process by stamper testing takes place in air (see chapter 3.2). In other words, the pit depth at the stamper is equal to the pit depth of the glass master which means the pits are still 'deep'. But the laser wavelength is now 780nm instead of 503nm, and $\lambda/4$ is therefore higher.

Replicas, produced from such stampers, are also fine, due to the moulding.

All the following measurements are performed with the Philips CDM4 single-beam reference pickup system.

6.1) Non-optimized OMP Glass Master:

Radial error signals RE1 and RE2 are showing a sufficient phase shift. The glass master is playable.

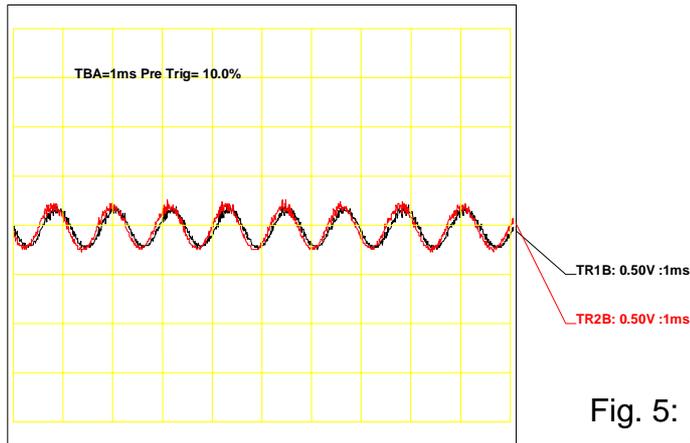


Fig. 5: Radial error signals RE1 and RE2 (see chapter 4)

Sufficient Push-Pull signal (approx. 0.015).
Subtraction of signal done by the oscilloscope.

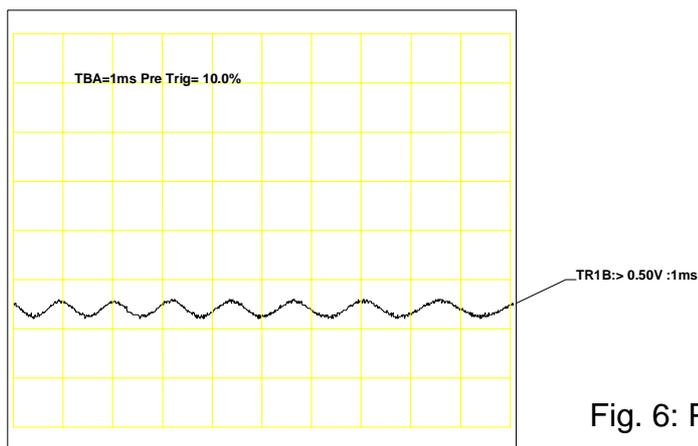


Fig. 6: Push-Pull signal

6.2) Optimised OMP Glass Master:

Radial error signals RE1 and E2 are showing nearly no phase shift. The glass master is not playable.

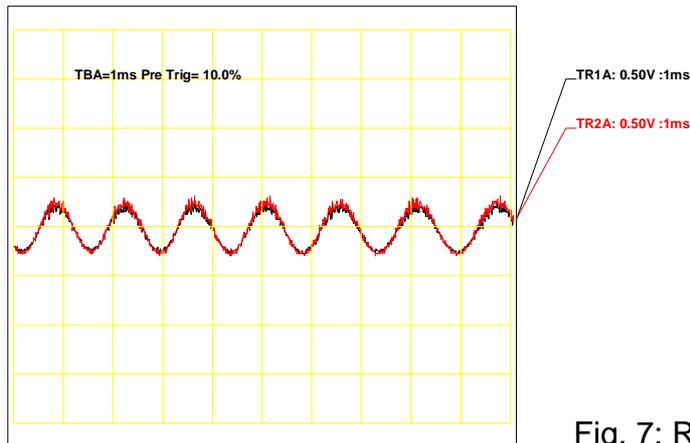


Fig. 7: Radial error signals RE1 and RE2 (see chapter 4)

Very low Push-Pull: $PP = RE1 - RE2$ (approx. 0.005).
Subtraction of signals done by oscilloscope.

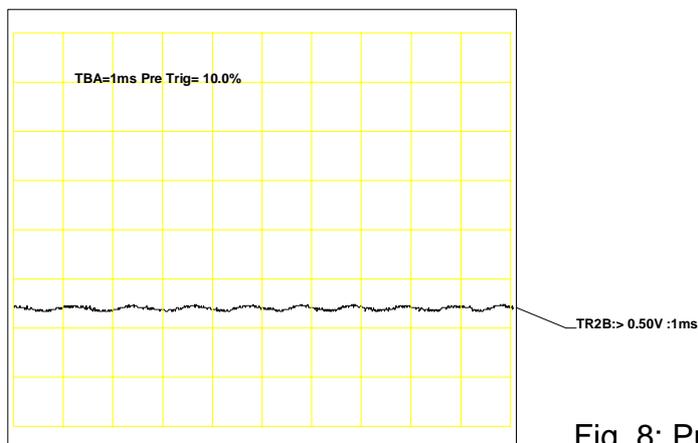


Fig. 8: Push-Pull signal

7) Measurement Results of DaTARIUS Calibration Disc 4D

Graphs from the DaTARIUS Calibration Disc 4D.

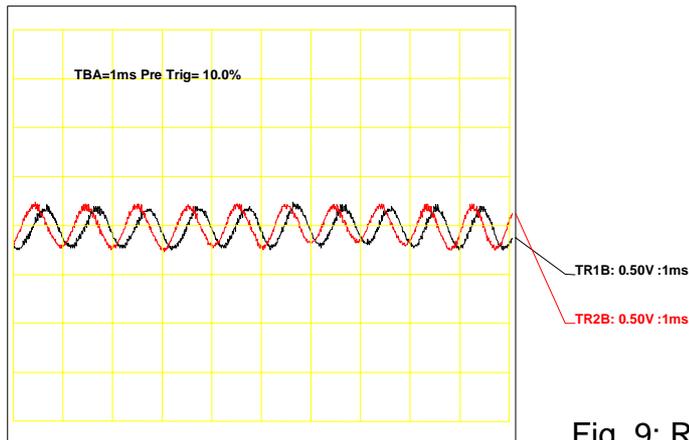


Fig. 9: Radial error signals RE1 and RE2 (see chapter 4)

High Push-Pull: $PP = RE1 - RE2$ (approx. 0.063).
Subtraction of signals done by oscilloscope.

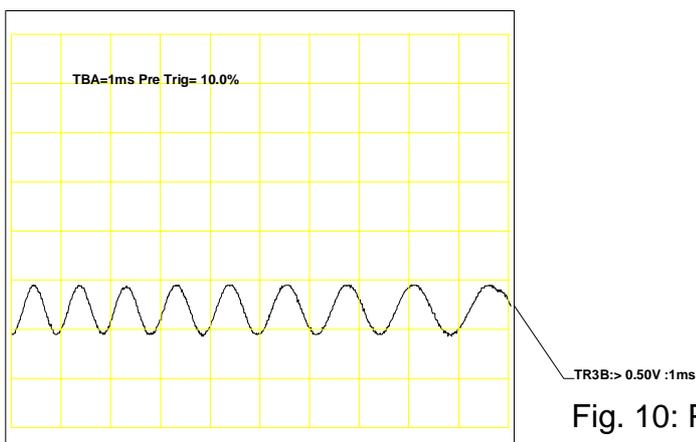


Fig. 10: Push-Pull signal

8) Bibliography

- [1] Compact Disc Read Only Memory System Description
Version: August 1995
Sony/Philips
- [2] Reference Measuring Methods (RMM), Specification Guidelines,
Version 1.0, May 1999
Sony / Philips
- [3] Compact Disc Recordable System Description
Version 3.1, December 1998
Sony/Philips
- [4] CDM-4 Pickup Specification
October 1988
Philips
- [5] Circuit Description
Compact Disc CD2-System
Philips
- [6] The DaTARIUS DVD Signal Guide
DaTARIUS
- [7] E. W. Williams,
The CD-ROM and Optical Disc Recording Systems,
1996, Oxford University Press
- [8] Sorin G. Stan
The CD-ROM Drive, A Brief System Description,
1998, Kluwer Academic Publishers
- [9] G Bouwhuis, J Braat, A Huijser, J Pasman, G van Rosmalen, K Schouhamer
Immink,
Principles of Optical Disc Systems,
1987, Adam Hilger Ltd.