CALIBRATION of Test Equipment

by DaTARIUS Technologies GmbH

What is calibration?

Calibration is a method of adjusting any measuring device so that it measures a parameter according to set standards. Many different devices are calibrated that are in common use today, for example a set of scales at the supermarket are regularly tested and adjusted so that customers are not under or over paying for their goods.

Calibration of CD and DVD testers is also necessary to ensure the following:

That you are measuring according to known standards, for example to the DVD forum and Philips Red Book. This is normally referred to as **accuracy**.

That you get the same results when retesting a disc with the same tester. This is normally referred to as **repeatability**.

That when you retest across different testers, you attain the same results. This is normally referred to as **comparability**.

With knowing the results of a given disc, and that these results are within a given acceptable range as set forth in the standards, this allows the disc to be ***playable*** in all different types of players in the market. This is the ultimate advantage of good calibration and the aim of all manufacturers worldwide.

Why calibrate test equipment?

Testers need to be regularly calibrated to allow accurate results. Tester results can change over time, for example, due to:

Laser Diode aging and deteriorates in signal strength

Optic Pickup head can distort over time, effecting the spot size and shape

Contaminations build up on pickup and other components

Mechanic parts such as swing arm or sled wearing

Offset and gain filters can change with temperature and aging

Electronics and servos can drift over time

And many more...

How do you measure accuracy, repeatability & comparability?

When you purchase any device where tolerances are mentioned, to what level do you expect these tolerances to be met – 100% of the time? If this were the case, for example, purchasing a television with 110V input, would not work with 111V input. Therefore tolerances are allowed within a “normal working environment”, thus allowing for inputs of between 100V to 120V. This is normal as house hold power supply fluctuates up and down depending on consumption, wiring, time of day or year, etc.

The same goes for with technical measuring equipment. Oscilloscopes measure to a certain accuracy and repeatability given the different signals. The higher the accuracy and repeatability the higher the price of the equipment. This is due to the components and technology used. The variations, can be measured in many different ways, but are typically set to defined limits, using approximately 99.7% of all results (sigma 3). In this way, the vast majority of measurements fall within the stated accuracy, even though there are times when accuracy falls outside this limit, these are the exceptions. Another consideration has to be the measurement range. Parameters falling outside the normal range of measurement have a lower accuracy compared to that in the middle of the measurement range. Therefore accuracy is normally measured at both an upper and lower limit of the parameter range to give a fair accuracy statement. Other factors have also to be considered, as depending on what you are measuring, both temperature and humidity can make different effects and result in higher variations. This needs to be considered when making measurements with any device and parameter.

Methods of calibration

There are many different methods (and combinations) of calibration, some with good features; others leave something to be desired. Here is a definition of some different methods, used in combination, that are necessary for accurate calibration of optical media.

Single Point Calibration

On Chart A, we first have to look at the measurement repeatability. If, for example, the measurement repeatability for this given signal is plus or minus 10%, we need to find the middle or average position. The final result is a raw measurement. On Chart A the raw measurement is 1.2. At the same position, we know that the actual value is 1.0 and therefore an adjustment has to be performed so that the tester reads 1.0. This is done through a factor calibration, which is explained later in this document.

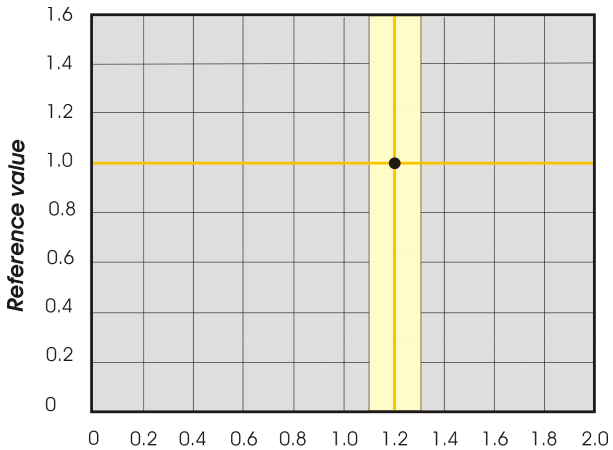

Chart A

Multi Point Calibration

The main issue with single point calibration is that with only one point being measured, the calibration line may not follow the reference value at different positions. On Chart B, the ***reference value*** for calibration is in red, however, with only one point measured, the response from the tester may be the yellow line. Although the reference point of the single point calibration has been met, the further away from that one point the accuracy decreases dramatically.

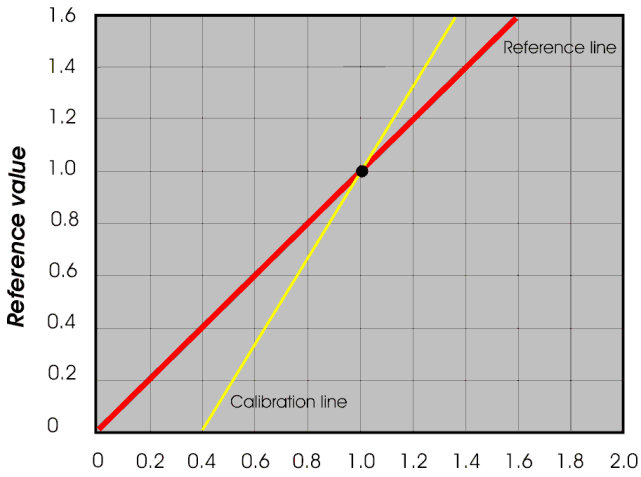

Chart B

As an example, an accuracy at the single point of calibration may be within plus or minus one percent, where the accuracy at the upper and lower limits may be plus or minus ten percent. The solution is to take **two or more calibration points**, so that both the calibrated and reference values are the same across the entire frequency. Normally this is done within the specified limits of the standards such as Red Book or DVD Standards. The calibration points are normally at the

high end and the lower end of the limits, so that the most accurate calibration can be done.

Indeed many signals are showing different variations on different drives. Therefore multiple points need to be calibrated to position the calibration line within the known reference values to give a good "average". More signals are influenced by other signals depending on the replication process and the testing drive.

Factor Calibration

Factor calibration is the ability to bring both the reference line and the calibration line to be **parallel to each other**. This is done by calculating the variation of the raw value and the reference value at each calibration point. Then the software calculates using algorithms the correct position so that the measurements are uniform across the entire measurement range.

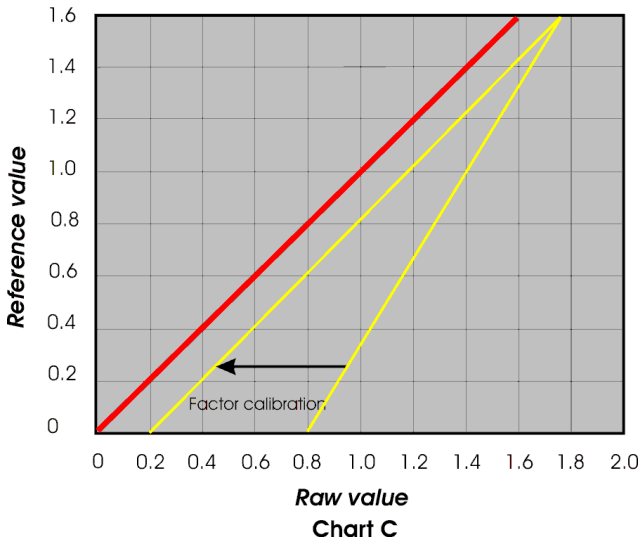

Chart C

Offset Calibration

Offset calibration then brings both parallel lines **together**, so that the calibrated values are the same as the reference values. If the lines were not parallel before the offset calibration, then errors occur in the offset that gives inaccurate results.

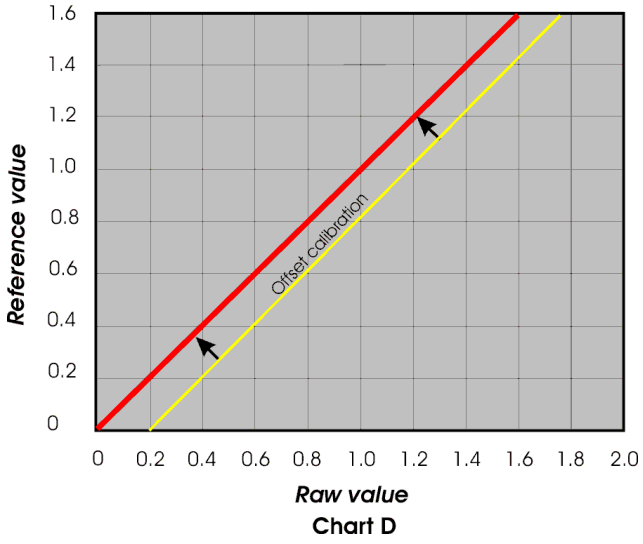

Chart D

Multi Disc Calibration

Multi disc calibration is also required, because many different aspects have to be combined:

- ✓Highest flexibility
- ✓Upper and lower limit signals
- ✓Signals' radius dependency
- ✓Wide range of effects on different discs
- ✓Use of additional discs (Philips reference disc, customer developed disc) in combination with DaTARIUS calibration set.

Therefore the software must have the ability to calibrate using multiple discs, with different parameters and signals to allow unlimited calibration procedures.

More info in § Calibration media

Radius Dependent Calibration

Experience at DaTARIUS has shown that signals can vary across the radius of the disc. These variations can be caused by several different effects, such as the wear on mechanical parts close to the start of a disc versus the wear at the very end of discs, just to name one example. To overcome this, a radius dependent calibration feature has been added to our software that enables multi point calibration at various points on the disc. These typically are the inner, centre and outer areas, and the results are then adjusted to give a very high accuracy across the whole surface of the disc.

Calibration Features

With any good calibration, there must be some **safeguards** and **checks** to ensure that nothing has gone wrong – or indeed that the calibration is successful. Also, other features are required to ensure that the calibration is done accurately. Here are some of the Calibration Features that DaTARIUS employs within their test system software.

Calibration Accuracy Check

During the calibration cycle, and after the adjustments, the tester will use the calibration file to measure different areas of the disc with known reference values. This is a double check that the calibration has been done successfully and no other problems exist that would affect the results. As an example, a simple calibration would be to measure two points on the disc, one at the higher signal level and one at the lower signal level. The software creates the calibration for this signal, and then goes to a third area on the disc to measure a known point and compare the results.

Note: It would be easier to check the position used for calibration but this **does not** reflect the calibration's quality.

Player Check

From time to time you may feel that it is necessary to check the tester to see if it needs calibration. With ISO and other standards, it is necessary to perform a regular check to ensure measurement accuracy. DaTARIUS has a "player check" function, where a calibration or other special disc can be tested at reference points and results compared to known standards. This is a quick and simple method of checking any tester at any time. The standard reference file, which are used for calibration can also be used a "player check".

Un Calibrated Message

A most important feature of DaTARIUS test equipment is the ***"UNCALIBRATED"*** message. If a tester is not calibrated for any reason, then this message appears on the screen and also on any test reports printed. This ensures that the tester does not produce "wrong" test results due to the fact that it is not calibrated. This is a must for test equipment.

Calibration Files by Tester

Another obvious feature of the DaTARIUS software is that the serial numbers of the tester and boards are listed, together with the calibration file. In this way you can change the order of the players in the rack, and the software can easily recognize this and apply the correct calibration file. If you change testers, the software detects this and asks for the player to be calibrated. There is no way to trick the software of accepting a bad calibration reference file, thus ensuring correct results all the time.

Multiple Paths for Multiple Speeds

With tests performed at different speeds, it is necessary to electronically have separate paths to allow for different calibration. DaTARIUS has these different paths so that each speed can be calibrated independently, allowing for accurate results at the reference speed. It is relatively simple to build a tester that runs at a higher speed, however, many differences occur with the behaviour for example of the digital decoder, thus causing differing results to that of the reference speed. By having different paths, each path can be optimised for that given speed, for example 2x speed. This optimisation allows for the most accurate high speed testing available on the market today.

Printout of Calibration Reports

Another critical factor is a traceability of the calibration. To ensure accurate results, we print out each calibration report for the customer to examine and file. Here all the signals are listed, together with the offset, factor, reference and raw values. From this report it is easy to read the variations from raw to calibrated signals, which have taken place, together with the changes from one calibration to another. When the calibration on the player has finished, you will see the screen as yellow for a pass of calibration or red for a failure. The printed report allows you to check for errors during calibration, and to see the status of the player being calibrated.

Calibration Media

DaTARIUS designs and replicates its own calibration media for its test equipment. We do this so that we can get a high and low signal, within the specifications at the limits, or within practical production limits. For example, there is an upper limit to jitter, however, there is no lower limit. In real production environments, it is impossible to get a disc with zero jitter. We produce discs with jitter values around the limit and calibrate to be the most accurate at this signal level. The signals also must be constant for periods of or longer than one minute, as calibration may take into account a large amount of data, and then the result is averaged to give a consistent and accurate result. If the signals are either varying or measured over short periods of time, it can make it difficult or even impossible to measure accurately and thus the calibration is not as effective. Many thousands of hours go into producing these discs, and to have the discs results qualified by various sources. For example, our discs are measured by Philips Test Laboratories, Pulstec in Japan and on our own laboratory test equipment purchased from vendors such as Philips for jitter measurements and Pulstec for the DDU1000. We also work very closely with other companies such as Sonopress, Warner, Technicolor and Universal to compare the accuracy and repeatability of the test results – thus giving results valid for a wide range of discs coming from different replication and mastering process.

CD Calibration Discs

The CD calibration discs are a set of two discs, specifically designed for CD replica and stamper calibration. There is also another separate calibration for master testing even with high or low reflectivity of the master. These discs were tested by Philips so that there is an ability to trace back to known standards. They come with each set of equipment sold by DaTARIUS.

DVD Calibration Discs

Here we have a set of two specifically designed discs, one for DVD-5 and one for DVD-9 replica and stamper, including masters. These discs were tested by the DVD Forum – Pulstec and Philips once again to provide an ability to trace back to known standards.

Philips Reference Discs

Why Philips reference discs? Well the answer is simple:

Philips 5B3

is a reference disc that can be used by manufacturers of drives to test their ability to play a “normal” standard disc. The disc is a good average disc from production with little to no variations in most signals. This disc can also be used to check test equipment to ensure it is measuring accurately and according to Philips. They are however, not good for calibration, as the discs can only be used for single point calibration and can only provide accuracy at that given signal value. The more a signal being measured moves away from

normal production, the higher the number of variations that occur which means a less accurate measurement and could lead to false conclusions with your production line.

DVD-5 and DVD-9

are also reference discs, although sometimes they are called *calibration disc*. It is true that these discs do contain variations in signals, however the current measured signals are only six in total. Already DaTARIUS calibrates more than 14 different signals, and need variations in all of these to be able to measure accurately. Philips released these discs primarily to allow companies with large laboratory test equipment such as the DDU1000 from Pulstec, to be checked against a known reference and adjust the numbers accordingly. The reason why this disc is called a calibration disc is that it is the first known standard in the industry (there has not been one up to now and we are pleased that Philips took this responsibility) and people can check their laboratory test equipment with this disc.

Other Reference Media

There is also many other sources and types of reference media that can be used for different purposes. These are commonly used for player manufacturers to determine the performance characteristics of players in the market. Some of these discs are also used by DaTARIUS to do factory calibration and checks before shipment to customers.

How Often to Calibrate?

For both CD and DVD this is quite a common question with not a quite clear answer. The answer depends on many factors, such as temperature, stability of temperature, dust, humidity and contamination, usage, etc. Typically calibration can occur between once per week up to once per three months. Heavy usage, more contamination and higher temperatures result in more frequent calibration. As a good general rule, each drive should be calibrated once per month for an average site. Heavy usage sites should look towards twice per month or more. By monitoring your tester with the player check function, you can fast and easily define the periodicity of calibration.

Why Automatic Calibration?

In the early days calibration was done by measuring a series of discs and taking the measurement results and then manually entering these into a special file, usually edited in DOS. Then the calibration was finished. This manual system could cause numerous problems: the manual entering of numbers in a DOS file lead to mistyping and again large variations in results. Now, automatic calibration takes care of all of these tasks quickly and easily, which leads to a simple and easy procedure

What Does Good Calibration Mean For You?

Good calibration

- ✓Enables traceability to known standards
- ✓Ensures the high quality of the product, end-consumer satisfaction and notoriety
- ✓Ensures playability of the replicas
- ✓Is an efficiency tool to increase yields
- ✓Assists in reduction of waste
- ✓Improves overall process resulting in higher profits.

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