The Process of Writing

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Contents:

1. Introduction.

CD-R recording is a very complicated process. A wide variety of elements and technologies interact with each other when a CD-Writer transfers data contents onto a Compact Disc surface. Ingenious processes, originating from optical, mechanical and chemical sciences, have been shaped and tuned to perform a precise job inside the drive. Disc speed, ambient temperature, dye sensitivity, media reflectivity, laser pick-up lifetime and other properties, contribute to the final result while influencing the processes.

Inside the recorder, every activity is controlled by the core element; the firmware (*). It contains many software routines that instruct and verify the handling of data by the various other key components, like the Encoder/Decoder, Sled- and Spindle Servo and Optical Pick Up.

A certain firmware version of a drive will allow that model to write data (according to the official standards) on a variety of media with a particular quality (ranging from good to excellent) and with a selectable speed. High-Speed recording is not always compatible with High Quality recording. The goal is to find the best compromise between quality and speed.

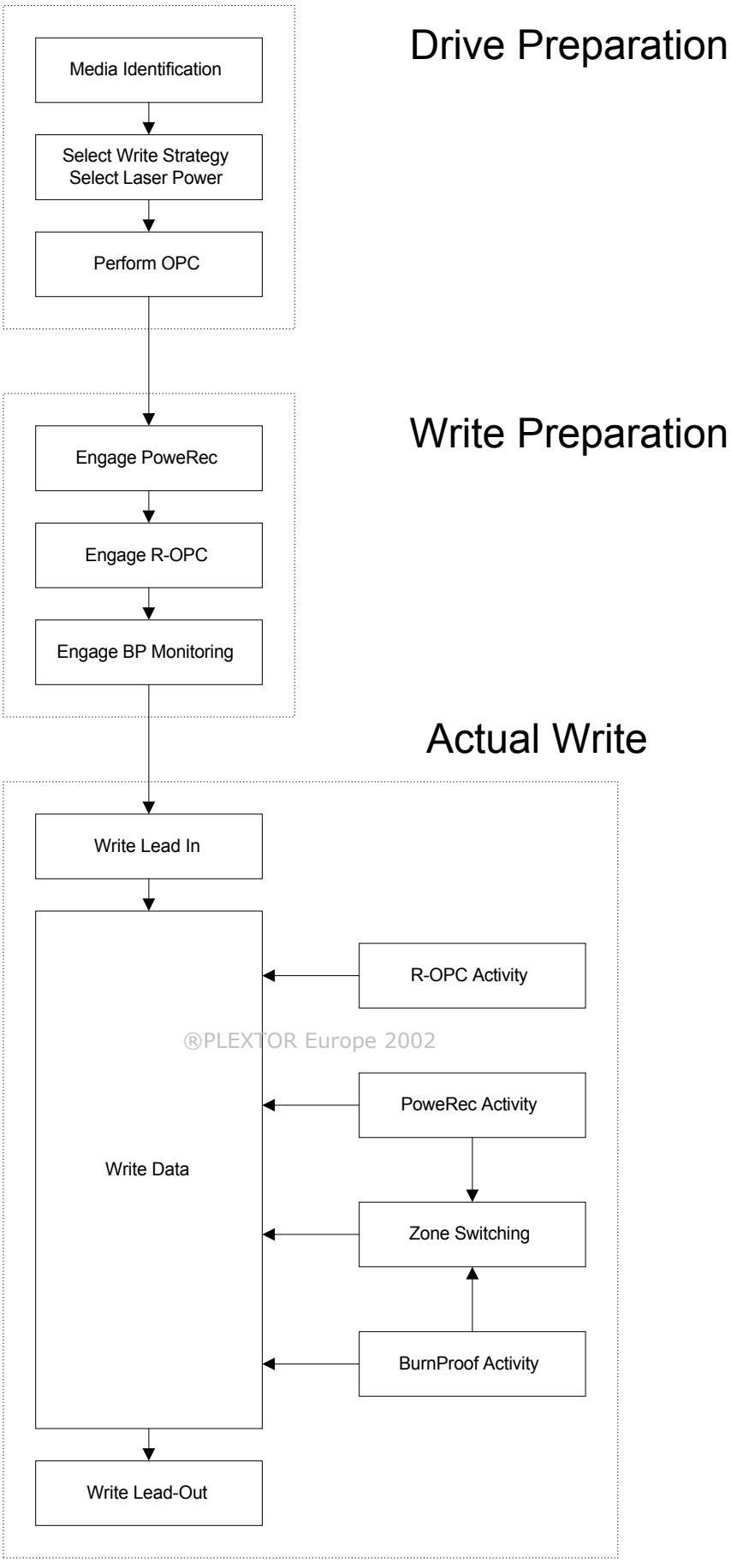
This brief will summarise some of the functions performed by the firmware, and explain some of the latest technologies that are being used in current Plextor CD-Recorders. Moreover, we will indicate for each of them how Plextor addresses the difficulties that arise, which will allow you to recognise the different elements of Plextor's expertise that make the whole of a Plextor product.

(*) Plextor's Expertise :

Plextor is famous for its professionalism and efficiency in firmware design. Software routines are continuously refined and new technologies developed as the hardware components change and improve. Moreover, new firmware is only released into the market when it has passed the high criteria of the Quality Assurance department.

The next graph shows the different steps of the writing process. As a new blank media is inserted and identified, the drive can setup and calculate the parameters that are used in the different processes.

When this preparation is complete, the monitoring processes will be initialised after which the real writing process can start. During writing, constant feedback will make sure the operation proceeds as intended.



2. Media Identification

Definition :

The first thing a recorder will do when a write action is being prepared is to identify the media. This is done by reading the start positions of the Lead-In and Lead-Out areas. Based on this information, the correct write strategy parameters and optimum laser power settings are retrieved from a database in the firmware.

When a certain media's start positions are not present in the firmware database, a general default write strategy is used. The media that is listed in a drive's firmware will give the best quality and speed results since it uses optimised parameters. Because of this, it will be included in the drive's '**list of supported media**'.

This list should not be regarded as the result of a quality qualification. If a certain media is not listed, it could simply mean that it has not (yet) been tested and verified, and the parameters have not been determined. (*)

There could be many reasons not to list a kind of media, even after testing. In the worst case, the media quality could simply be bad. But there is also the possibility that it is too difficult to adjust the drive's parameters, or that the media is not available, and so on.

All media manufacturers have agreed to use different start positions for their media, which allows the possibility of correct identification by means of the unique ID. This agreement has been laid out by the OSJ (Orange Book Study Group of Japan, URL: http://www.orangeforum.or.jp/e/index.htm) and most manufacturers tend to follow this proposal. The agreement applies to CD-R media only.

(*)Plextor's Expertise :

Plextor spends a large amount of engineering time and effort to keep an up-to-date medialist available at all times. As media manufacturers improve their manufacturing processes, we constantly evaluate their latest production in order to improve speed and quality and provide matching parameters.

As a basic rule, every time a new firmware version is released, it contains the latest update of the media parameter database besides the many other improvements. Keeping this policy up, even for older drives, requires a great deal of continuing effort that is rarely seen among other manufacturers.

3. Write Strategy and Laser Power

Definition :

A write strategy is a pre-programmed software routine that determines, together with the laser power, how a recorder writes on a certain media. For this purpose, the firmware contains a large database of parameters. When the parameters are wrong or miscalculated, the resulting write quality will be poor. In this case there is a chance that the write process will complete without an error, but many read errors may occur resulting in possible loss of data.

When a CD-Recorder writes data on a blank disc, its optical laser pick-up will focus a laser beam on the dye in order to create pits and lands. These marks can be recognised during read-back and should result in an identical reproduction of the original source data. If not, the resulting difference will cause increasingly severe side-effects from jitter in the best case, to read errors in the worst. To avoid this, the drives use a write strategy that matches the particular media.

Such write strategies are fixed for writing on a certain media at a certain speed: when the disc is written at a higher speed, the pick-up should start to write a little earlier. Since the reaction time of every unique dye is different the laser power should be increased at higher speeds, which will also affect the timing.

The Importance Of Tuning :

Since every media is different (reflectivity, dye, etc) it is logical to conclude that every media should have its own write strategy. And since the elements that will decide a write strategy will vary at different speeds, it is clear that a different strategy for every possible speed is unavoidable. This is to guarantee writing with as few errors as possible and high playback compatibility.

Plextor's Expertise :

Some manufacturers allow a whole group of similar media to be written by the same write strategy. Plextor's engineers however have spent a great deal of time and effort on testing and fine-tuning of the different parameters that make up a write strategy. New media is continuously investigated, parameters are adjusted and firmware is updated. Plextor's expertise on tuned write strategies will make sure your media is written in the best possible way.

4. PCA, OPC, Disc Manufacturing and R-OPC

The identification of blank media, the selection process of write strategy and laser power, and the fine-tuning of the parameters are all part of Plextor's PoweRec technology. Before we continue to reveal more of the hi-tech used, we should explain some technical terms in order to understand the specific reasons and background of a particular design:

PCA & OPC:

When a blank CD-R disc is inserted in the drive, the media is identified and a matching write strategy and laser power are selected. Then the Optical Pick-Up is directed to a spot on the CD that is known as PCA: **Power Calibration Area**. This is a test area where the optimum laser power can be tested and selected.

This process is called OPC: **Optimum Power Calibration**. The ideal laser power is determined by writing a few sectors with increasing power, and reading them back while carefully monitoring the quality of the signal. Based on the result, the best value for the laser power is selected for this media.

CD-R Manufacturing and R-OPC

A Recordable Compact Disc is manufactured by injecting polycarbonate plastic into a mold on a glass master stamper. This master contains the image of the CD, which in this case is an 'empty' spiral track with timing information.

Next, an organic dye layer is applied by a process called 'spin coating': the dye is added while the disc is spinning. This can cause differences of dye characteristics and layer thickness between inner and outer radius. It is very important that the dye layer is equal over the whole disc surface, but in reality this is difficult to obtain.

During writing to a CD-R, the reflection of the recording laser power is constantly measured. Whenever this value varies from the optimum recording power, the laser power is slightly adjusted. This technology is used to overcome small differences in the dye, which are the result of the way this layer is added during manufacturing of the CD-R. Since this calibration takes place during the writing process, it is called **Running-OPC**.

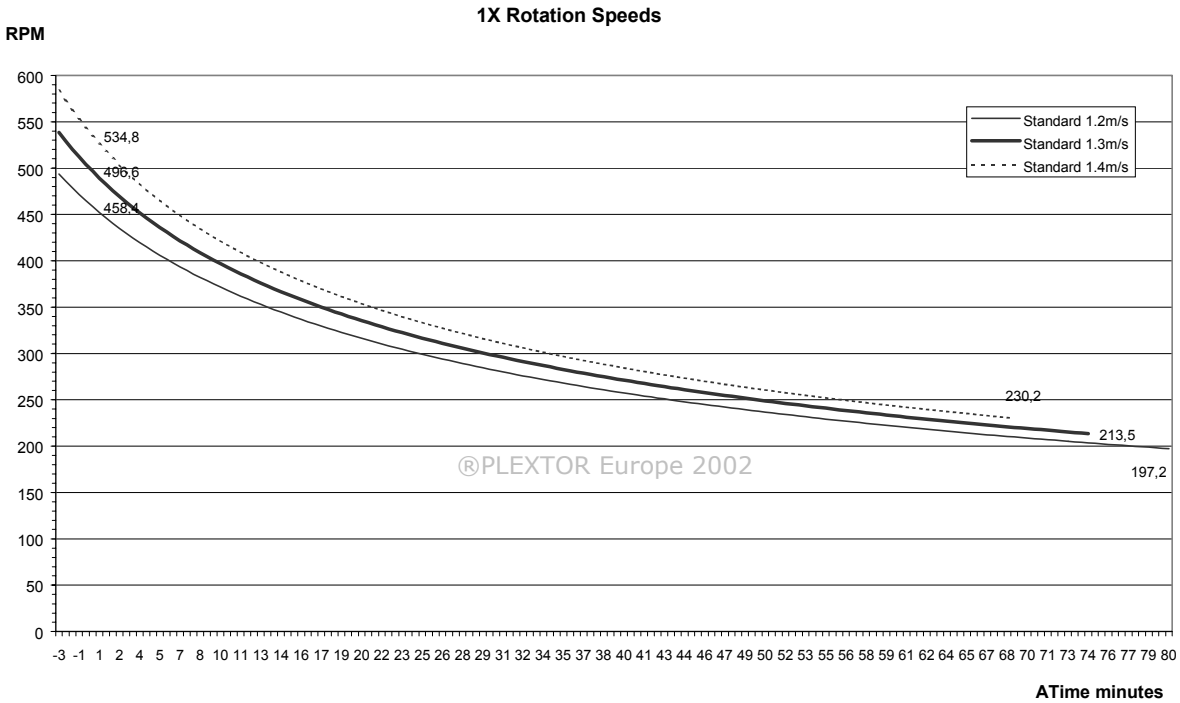
5. Disc Velocity:

Definition :

The CD Standards (Compact Disc Digital Audio and CD-ROM System Description) prescribe a scanning velocity of 1.2 to 1.4 m/Sec. This velocity, together with the track pitch, will decide the length of the spiral track on a CD, and as such the total capacity that is available for recording.

For example, a disk with a velocity of 1.4 m/Sec typical has a capacity of 63 mins. A 74 mins disc usually has a velocity of 1.3 m/Sec. Most current discs have a velocity around 1.2 m/Sec and allow 80 mins recording. Increasing the velocity further and decreasing the track pitch to achieve a higher capacity will put high demands on the recorder's accuracy as well as the drive's playback capabilities.

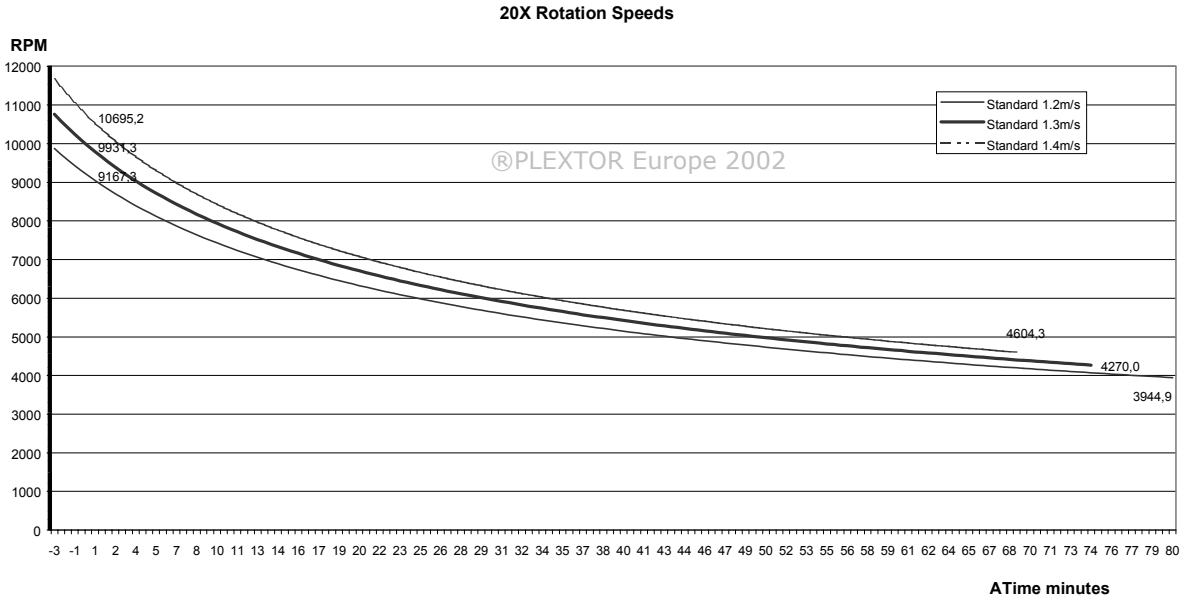
The rotational speed of a disc can be calculated from the Linear Velocity, Track Pitch (Red Book: 1.6 um) and A-Time position on a disc. As you can see from the graph for single speed rotation, there is a big variation in speed at the beginning of a disc (Lead-In), depending on the type of media. Since every CD-R media has its own value of linear velocity and track pitch, this will result in a different rotation speed in each case. For higher speeds, these differences are increased exponentially.



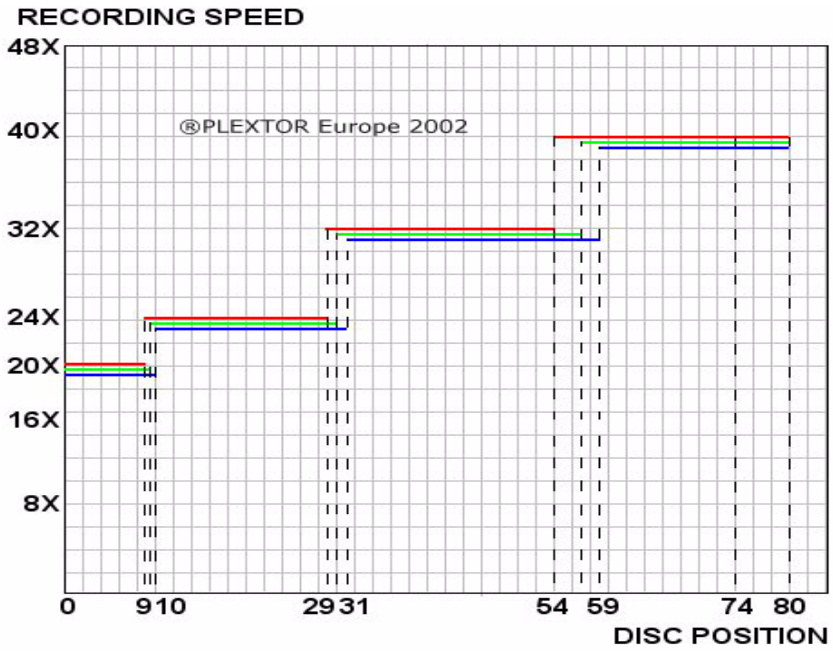
When we want to increase the write speed, we have to take into account the physical limitations of the drive. Depending on the mechanism used in the drive, a limitation of 9200 to 9600 RPM is set. Above this speed, it will become too difficult to control vibration of the disc and establish correct positioning, what may result in write errors or playback problems.

Plextor's Expertise :

In a Plextor drive, every media type is treated according to its specific parameters in order to set the disc velocity. Most manufacturers will treat all media the same, allowing the rotation speed to come dangerously close to the spindle motor's limit. This will be the case in certain areas on the disc, like the Lead-In.



When Z-CLV is used, the switch points to the higher speeds are precisely calculated to allow the speed in the next zone to start at the same RPM again (this is media dependent). Therefore the switching points in Plextor Recorders are not fixed, but greatly dependent on the media that is being used as you can see on the next graph.



6. Disc Rotation Methodology.

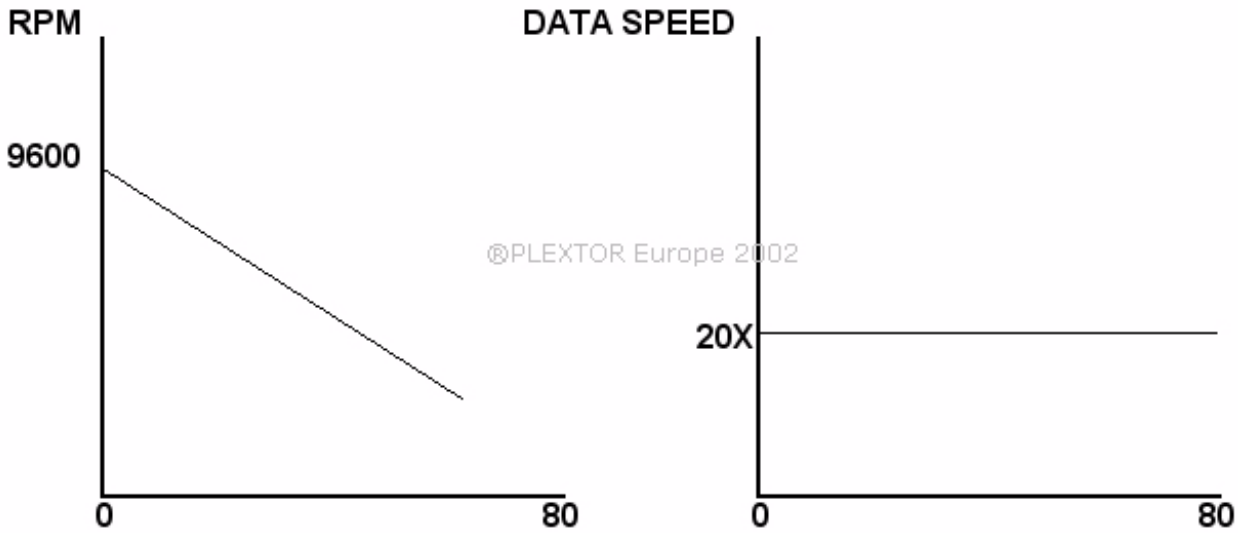
CLV: Constant Linear Velocity

Definition :

CLV was the first technology used for AudioCD Players, CD-ROM drives and CD-Recorders. In order to maintain a constant data transfer speed, the Revolutions Per Minute (RPM) of the spindle motor are gradually reduced as the pick-up is moved towards the outer part of the CD.

In theory this method gives the fastest speed for reading and writing that is possible with a given pickup and chipset. But as every spindle motor has a maximum rotation speed that should not be exceeded, this puts a severe hardware limit on the total system. Current spindle motors allow rotational speeds of up to 9600 RPM, which results in 20X CLV transfer speed (or 20X up to 48X in CAV mode, as you will see later).

Since the writing speed is constant over the whole surface of the disc, the drive needs only a single write strategy and fixed laser power in CLV mode. So this system is quite straightforward, and will result in the best write quality since it is using optimised parameters that do not alter during the whole writing process. This is of course, not taking into account the small adjustment done by the Running OPC process that will overcome small changes in the dye.



Z-CLV

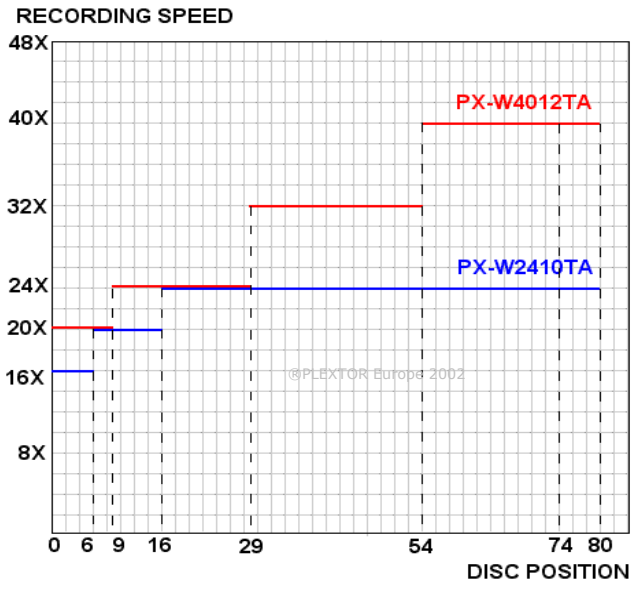
Definition :

Zone CLV technology divides the recordable area of a disc into separate speed zones. In each zone, recording is performed at a Constant Linear Velocity speed with optimized precision. As soon as the spindle motor's maximum RPM limit allows, the drive will switch to the next speed zone by resetting the rotation speed to the beginning speed.

The write strategy and laser power value for each zone are the same as those that are used for normal CLV at the same speed.

How Does Zone CLV Work?

The recording is started at the beginning of the disc at a constant speed in the first zone. After a pre-defined time (when the next zone starts) a switch is made to a higher speed. At the switching point, BURN-Proof technology is used to assure a fast, reliable transition with no loss of data. At the same time, Plextor's unique PoweRec technology will safeguard the write quality.



Plextor's Expertise :

Recording stability is the most important aspect of high-precision recording at high speed. In comparison to P-CAV recording, Zone CLV clearly has the advantage of better recording quality: stable data recording is extremely important and determines the readability of the disc. This is much easier to achieve in Constant Linear Velocity systems, as opposed to CAV (where the write speed is constantly adjusted).

Until recently, Plextor opted for Z-CLV technology as the best compromise of quality over speed. The newest generations of components and technologies allow equal quality and performance to be achieved in CAV systems.

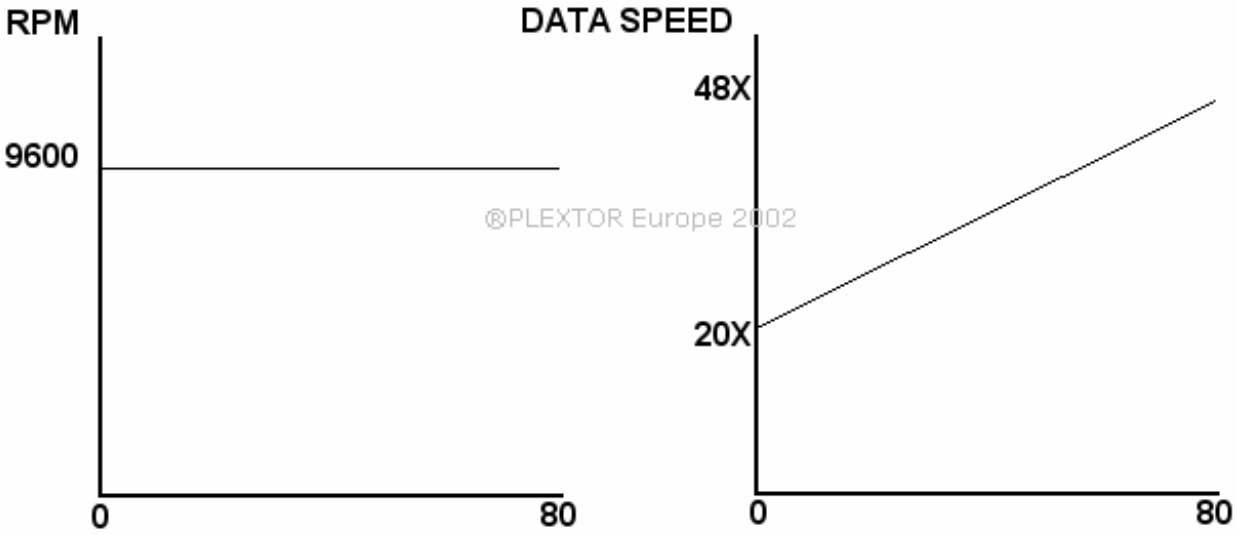
CAV: Constant Angular Velocity

Definition :

CAV is the rotation scheme where the revolutions of the spindle motor (RPM) remain constant, independent of the position on the disc where the data is read. As a result, the data will appear faster at the Optical Pick-Up as the readout position is moved towards the outer radius of the disc.

In reality this mode results in the fastest write speed since the drive's spindle motor is kept at the highest allowed RPM. The big advantage of this system is that the speed can gradually increase to become more than double the initial speed at the outer position of the drive. And as the rotation speed is never changed, this will also have a positive effect on the unit's access time.

The greatest challenge of CAV recording lies in the fact that it is impossible to use a single write strategy and fixed laser power over the whole disc. Since the transfer speed constantly changes, this calls for a constantly changing write strategy and increasing laser power. In theory this would mean thousands of write strategies, which would make the database unrealistically large.



Plextor's Expertise :

In Plextor recorders the database of write strategies for all CLV speeds per unique media has been expanded: every speed in the range from 20X upto 48X is covered in 1X steps and all speeds have been assigned an optimised write strategy.

Additionally the laser power is adjusted on every 1-minute address (position) increment on the disc. As such, the laser power will gradually grow as the rotation speed increases.

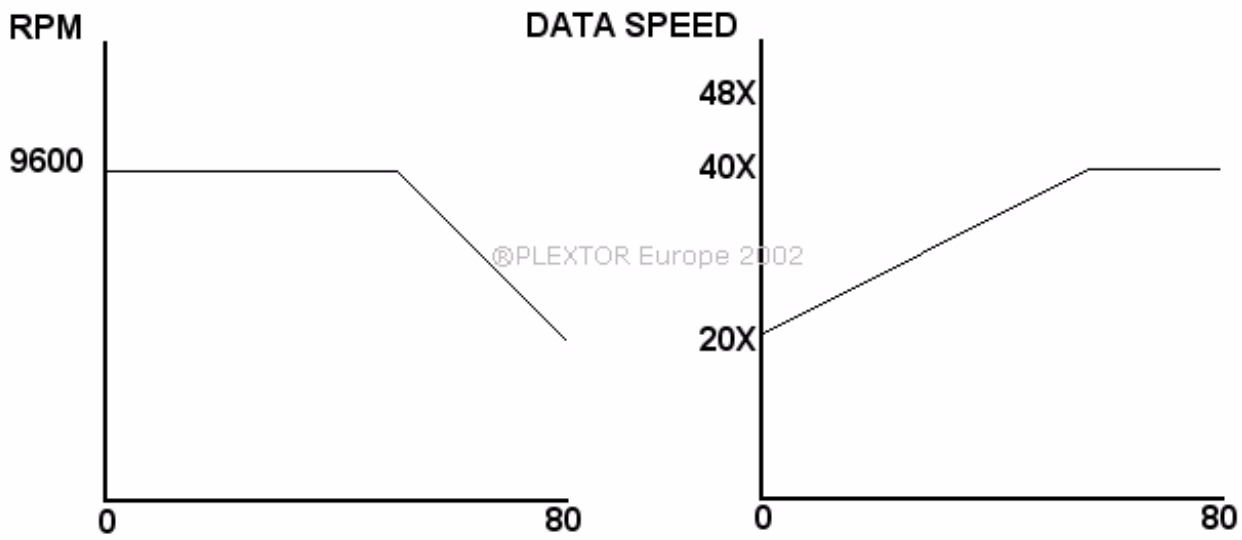
These unique Plextor technologies will assure high-quality in CAV writing.

P-CAV

Definition :

At the outer position of the disc, more hardware limitations may force the drive to switch to a safer CLV mode in order to maintain a stable writing.

Since only the first part of the disc is written in CAV, it is called Partial-CAV mode. It can be seen as a compromise between speed and quality on systems where the hardware limits would normally enforce lower speed recording.



The Difference In Read Speed Versus Write Speed.

Even though it would seem logical to expect the same maximum speed for reading and writing, and if not equal to expect a higher read speed, this is not always the case for Plextor recorders. The reason for this comes from the different characteristics of the media that is typically used in both cases.

Writing is usually performed on brand-new, blank media, with virtually no surface print or labels attached, still free from scratches, probably inserted in a CD drive for the very first time and mastered with very high precision.

In the case of reading, the inserted disc is often a completely different type: there is a good chance that it is a stamped disc, maybe mastered with lower quality, less precision, poorer tolerances and greater eccentricity. It may have heavy or unequal surface printing or attached labels. Maybe it has been used in many drives before what may have introduced fingerprints, scratches or small damage to the inner hub.

Spinning such discs at high speed may introduce vibration, irritating noise, or even read errors that will cause the drive to spin down. Even worse, the micro-cracks caused by certain drives' clamping mechanisms could grow in an avalanche-like way under influence of temperature, pressure and high rotation speed, causing the disc to scatter or 'explode' in many pieces.

Additionally, thorough tests have shown that a large increase of rotational speed will reduce the lifetime of the spindle motor by 25% while at the same time the internal drive temperature will rise, which will affect the stable operation of all components. The effects of a continuous spin at high speed for reading are much worse than the limited time (<3 minutes) it takes to write a disc at this speed.

Plextor's Expertise :

While the spindle motor speed can be set to 9600 RPM (20-48X CAV) for writing, Plextor has kept the read speed below a conservative but safe 9000 RPM in order to avoid the side-effects previously described or CD destruction. This will guarantee reading without errors, silent operation, and avoid exploding discs and resulting damage to drive and disc.

For users that want to experience a higher read speed nonetheless, Plextor has integrated the SpeedRead option that will allow the user to boost the read speed for stamped and recorded data CD's (only).

AudioCD's (including mixed mode) are excluded because they have poorer error correction and will suffer too many read errors. This applies to **CD-RW media** as well because of the different characteristics, like lower reflectivity.

In the case of damaged discs, with heavy surface printing or labels attached, or visual damage, it is recommended to not use this option.

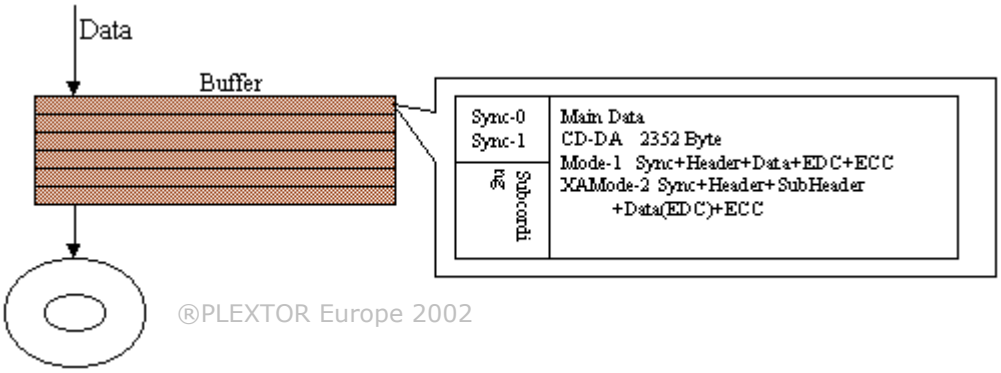
As a final precaution, the tray- and drive bezel have been partially redesigned and reinforced to prevent any particles of an exploding disc escaping from the drive.

7. BURN-Proof

Definition :

One of the biggest problems encountered in recording CD's is when media becomes unusable during recording, due to something referred to as a "buffer underrun". Such Buffer Underruns occur when the PC can't deliver data fast enough while recording.

This can be caused by a PC that is too slow, multitasking, network or interface problems, etc. Therefore, from the start, the CD Recorder must first load a certain quantity of data into the buffer.



This buffer then serves to bridge over minor interruptions in the data stream from the PC. Under normal conditions, the data buffer should always be capable of holding enough data to guarantee smooth recording.

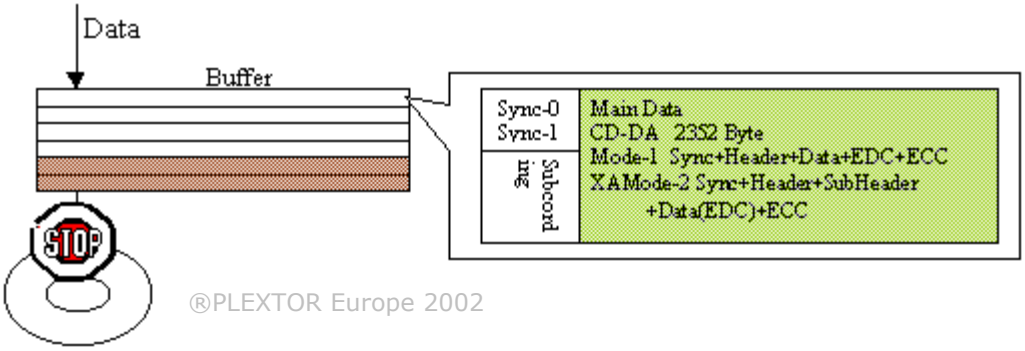
Buffer underruns occur when the content of the data buffer cannot handle the recording demands of the CD Recorder or is smaller than the amount of data demanded by the CD Recorder.

Plextor's Expertise :

Plextor's latest CD Recorders all use the most recent technological developments in order to prevent the above-mentioned "Buffer Underrun" problems. This technology is thus called BURN-Proof (Buffer UnderRuN proof).

How Does BURN-Proof Work?

When the CD Recorder starts recording, the status of the buffer is constantly checked. Shortly before a Buffer Underrun might occur (typically when the buffer falls below 10% of its maximum capacity), the CD Recorder will stop recording at a specific location on the CD. The CD Recorder continues attempting to receive data from the PC and to refill the buffer. In the meantime, the BURN-Proof circuit determines where the last successful sector was written. Using the location of the last successful sector, the BURN-Proof circuit than positions the Optical Pickup. As soon as the buffer has been refilled, the CD Recorder will start recording again.



BURN-Proof is a trademark of ***SANYO*** *Electric Co.,Ltd.*

8. PoweRec

Definition : **PoweRec** = **P**lextor **O**ptimised **W**riting **E**rror **R**eduction **C**ontrol

The most important challenge facing CD-Recorders is to write high-quality discs with perfect readability on all available CD-ROM drives. Plextor recorders have a substantial database of parameters that allow writing to a range of currently available CD-R media. This will assure compatibility with a wide range of media and players.

Plextor's Expertise :

But not every media is suitable for recording at high speeds. For this reason, Plextor has developed a new technology that will guarantee the highest possible recording speed and quality.

How Does PoweRec Work?

PoweRec technology consists out of several unique functions that prevent write errors and as such offer the best quality recording.

- The first function will identify and test the target disc and select an optimised write strategy for this media. Running OPC will overcome the variation in dye characteristics over the disc.

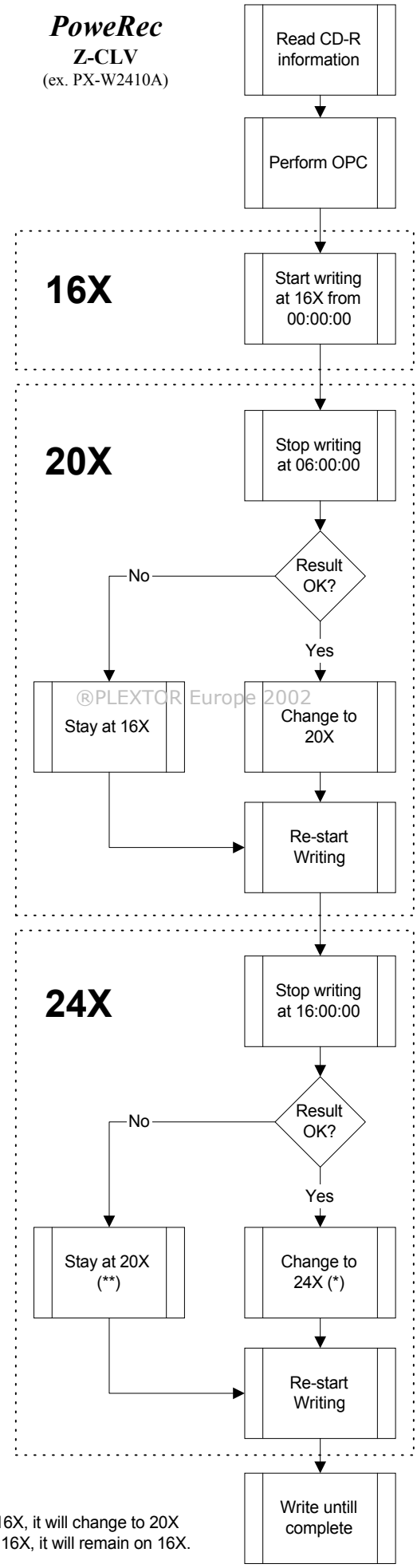
- During writing, real-time write quality monitoring ensures the best write quality for the selected speed. If write errors are likely to occur, the recording speed will be decreased automatically by the drive.

- In addition, PoweRec will act in a similar way for speed- and area switching in Z-CLV recordings. The write quality at the end of a zone will determine the recording speed in the next zone. If reasonable quality cannot be guaranteed, the drive will decide to maintain the current speed.

- For CAV-mode recordings, Plextor developed a unique and fine-tuned mechanism that offers a combination of speed and quality. As explained in the CAV chapter, the write strategy will change every 1X speed step while the laser power is adjusted every 1 minute position change.

  Besides this, PoweRec will also use a double safety system to watch over the CAV writing process:
  - **Continuous monitoring** of the write result will cause the drive to switch to CLV mode if the error signals exceed a certain threshold.
  - Simultaneously a **thermistor-based circuit** will adjust the Laser Power should the drive's internal temperature rise too much.

PoweRec
Z-CLV
(ex. PX-W2410A)



Start of the write process:
Read the information on the blank media.

Perform Optimum Power Calibration in order to optimize the parameters for this media.

Start the write process, and write at 16X during the first 6 minutes of the disc.

When the drive reaches the 6 minutes position, the write process is stopped by means of BURN-Proof technology.

Test if the write quality is good enough to increase the speed.

Change the parameters for 20X writing:
- increase the write speed
- increase the laser power

The write process is started again by means of BURN-Proof technology.

When the drive reaches the 16 minutes position, the write process is stopped by means of BURN-Proof technology.

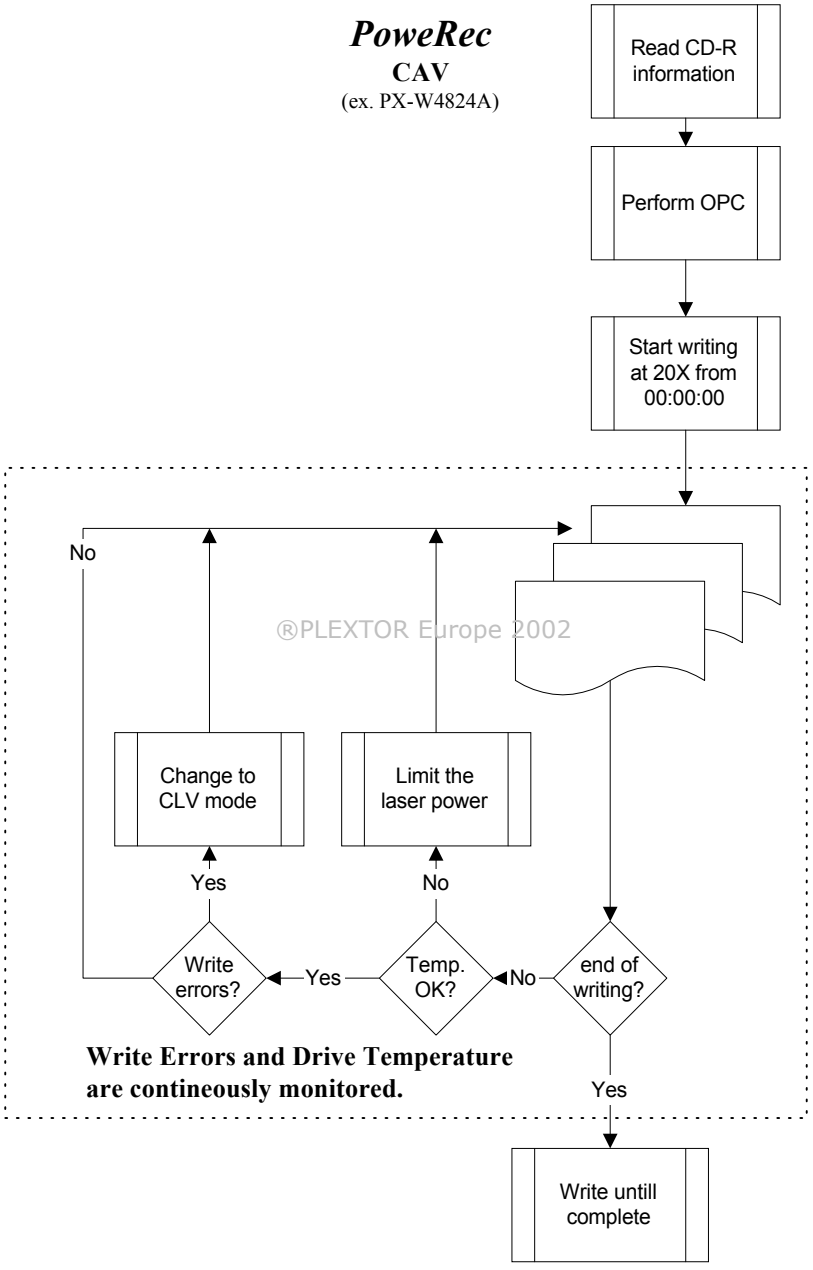
Test if the write quality is good enough to increase the speed.

Change the parameters for 24X writing (*) :
- increase the write speed
- increase the laser power

The write process is started again by means of BURN-Proof technology.

When all data is written, the write process is finished.

Note:
(*) If the write speed was 16X, it will change to 20X
(**) If the write speed was 16X, it will remain on 16X.



Warning:

Disabling the PoweRec function permits to write all media at the highest speed.
In this case, the user should understand that the write quality cannot be guaranteed.

9. VariRec

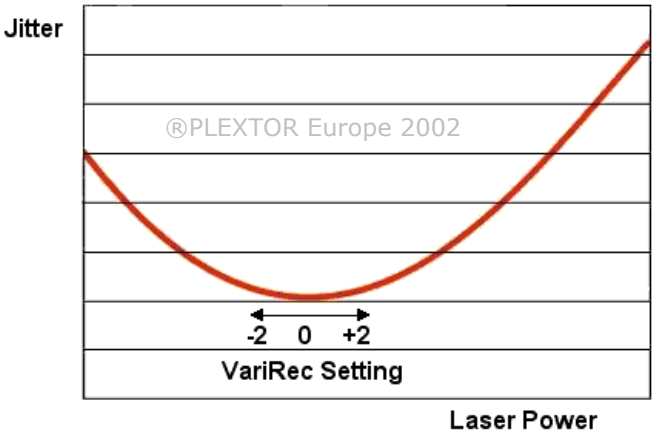
VARIREC
FOR BEST AUDIO RECORDING

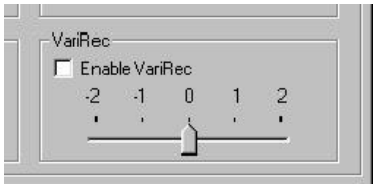
Definition : Plextor's newest feature is VariRec: the **Var**iable **Rec**ording function.

It allows the user to change the laser power when writing CD-DA on CD-R at 4X. The user can make a slight modification to a default setting. This default setting reflects an optimised laser power with lowest jitter. The result will be a change of sound or sound quality and an increase of compatibility with existing players.

Technical Background :

The write strategy of a drive is the list of parameters that are used for writing on CD-R/RW media. For every disc type, and every possible speed, an optimised laser power value is chosen from a database that is the result of thorough tests in the lab. At the start of writing, the OPC (Optical Power Calibration) will retrieve the necessary information from the database and set the parameters. The most optimised write strategy will result in the lowest jitter.





Plextor's Expertise :

VariRec can change the value of the laser power. The resulting effects are:

- change of sound quality of recorded disc (On many CD players there may be a slight change, some kind of effect when VariRec is used on the different settings)
- change of playability or compatibility with Home CD Players or Car CD Players (some players need a slightly higher or lower laser power)
- Most audio professionals have a personal preference for higher/lower laser power (some even say they can hear the difference between a recording at high speed and at 1X)

Warning:

When VariRec is used at the most extreme settings, there is a chance that the playback device will not read the disc properly. In this case, use the default setting or switch VariRec off.

10. About Write Quality

This topic is very complex and many articles can be found explaining it in details. But often it is forgotten that a successful result when writing a disc greatly depends on how CD-Recorder, CD Media and CD Player form a matching combination. Current equipment will rarely pose any problems, though it should be stressed that most errors will only appear during playback.

In order to read the information on a CD, the drive will detect the pits and lands in the spiral track. Timing is very important here and any variations, called jitter, may result in read errors.

All CD's contain errors that can be corrected by the decoder circuit in the player, unless these errors are caused by serious damage like scratches or fingerprints. The CIRC decoder is divided in two stages of error correction: C1 and C2. The number of C1 errors is usually the higher of the two types but they are also easier to correct. It is still advisable to maintain a low number here since these errors can create additional side effects.

While correcting more C1 errors, the decoder circuit may induce spikes on the power line which will travel to the analogue output circuit as well, thus creating a difference in sound. AudioCD Players with separate power supplies for digital and analogue sections will not have any audible differences when playing back CD's with a high or low number of C1 errors. But, in reality, these players are more expensive and therefor not always the popular choice. Mid-range players mostly have a single power supply and could give the most audible distortion.

The Black Tray.

During recording a high-power laser beam is directed to the CD surface. This light is reflected by various objects: the mirror-like metal layer of the disc, but also the shiny metal screw heads, the slider bars, the metal body of the pick-up, the pick-up lens, and so on. This will cause a relative small but existing 'pollution' of reflected light.

When these reflections find their way back into the detection circuit of the pick-up, they can cause distortion of the original signal. Plextor has decided to use a black tray design in order to absorb as much as possible of these reflections. As this decreases the disturbance of the original reflected light, it will result in a better defined signal and less C1 errors. This greatly improves the write quality.

Optimised PCB.

In the process of research and investigation, Plextor has found several ways to improve the overall design of the drive's circuit boards. By means of a careful and balanced selection of components and their values, we were able to reduce power supply induced noise. Special designed circuitry will guarantee host independent and noise-free power supply current. This greatly improves the jitter and deviation levels of the drive that as such produces higher quality writing results.

11. Conclusion.

CD Recording and the process of writing are often discussed in magazines, website forums and the internet discussion groups. Some members often show a certain knowledge about a particular item, others can fill-in the blanks, but the whole picture is not often explained.

Manufacturers are also often reluctant to explain the technologies used in detail, fearing the competitors will learn and copy the result of their hard work, or that weak points may be revealed and emphasised. After all, the recorders are build with key components that are not as perfect as one would wish, and whose tolerances influence the complex tasks that are performed.

Plextor has always encouraged a very open and honest policy: correct information and accurate data in the publications, true test-results and no-nonsense explanations. Our view, in regards to new technologies, is that we want to support as many features as possible, but what we support should work flawlessly. This conservative approach has gained respect from major players in the industry and in the professional field.

Often we get requests from our users to integrate a certain feature. And we when cannot respond positively for a certain reason, there is great disappointment. But our customers can be assured that Plextor always takes their suggestions very seriously and investigates all feedback for feasibility.

New generations of Plextor Recorders are often partially based on existing designs, so proven technology is, in general, carried on to the new drives. Many of our customers appreciate this solid method of development and loyally follow the trend with confidence. It also frequently happens that older drive firmware is updated with the incorporation of new technology, which prolongs the lifetime of the drive and adds to the value of the product.

I hope this technical explanation of technology and background information will allow people to better understand what's going on in their drive, and why Plextor has made a certain decision and selection criteria in order to provide the best CD-Recorder assembly. More information can be found in the datasheets and the technical pages on our website: http://www.plextor.be .

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