Warning: "Please observe extreme caution after reading the White Paper/the Speculation paper don't play your audio system at low volume, drive an automobile or operate heavy machinery because the papers are going to be submitted to the FDA as a non-addictive treatment for insomnia. But you should feel free to read them when you're having difficulty falling asleep."

REFLECTIONS ON READING, WRITING AND PLAYING OPTICAL DIGITAL DISCS

A Technical White Paper on the Art and Science of Optical Impedance Matching as it Applies to Laser-read Media*

Introduction

UltraBit Platinum™ (UBP™) is a new optical impedance matching (OIM™) treatment and cleaner for optical discs, such as CD, laserdisc, video CD, DVD movie, DVD audio, SACD, DSD, CD-R, CD-RW and all other laser-read media, to enhance playback resolution and fidelity. UBP achieves enhanced playback fidelity and musicality via a one step process. UBP is a unique scientific and aesthetic solution for many of the problems associated with the reading and playback of all laser-read media. UBP is absolutely nonabrasive and cannot harm polycarbonate or Lexan. The treated surface will have increased protection against static build up, atmospheric pollution, and contamination from accidental mishandling, and when treated with care could last for several years.

Surface Contamination

Foreign matter on the transparent polycarbonate protective surface of a disc's encoded reading or burning side may cause distortions/diffractions that scatter the reading laser beam (beams in the case of three beam players) or block its path entirely, causing momentary interruptions of data reading, or mistracking or both. Long before audible mistracking or data loss occurs, excessive error correction/servomotor action may mean increased noise and distortion that decreases clarity, reduces transparency and adds harshness with high frequency glare. And as you may already know, some of the success of separately powered transports, analog amplification stages, and outboard digital-to-analog converters (DACs) has been attributed to the greater isolation of their power supplies from electrical interference caused by overstressed tracking and reading servos. The digital jitter caused by faulty data or clock recovery can also spoil the integration of harmonics to its fundamental and the relationships of the fundamentals to each other. In severe cases all manner of extraneous noises from clicks and pops to actual muting may be heard, and the player may act as if it's stuck in one spot or instead skips forward and backward continuously.

Brand new, fresh out of the package CD's are often coated with mold releasing agents or other substances left over from the manufacturing process. This type of contamination is often invisible. Therefore, if you have any reason to question the cleanliness of a CD's surface you probably should clean it, unless of course, you still resist the idea of cleaning CDs because you haven't discovered yet, that the claim "…CDs represent perfect sound forever, and unlike vinyl records, are practically immune to dust and dirt or damage…" is more mythical than factual.

Shouldn't the playback problems be corrected at the source? Misread music or clock data may mean misplayed music at the player's output. The better and more efficiently a laser tracks and reads the bit stream the better it should sound. Fortunately, although a mistracking laser beam may cause digital glitches and dropouts, it doesn't damage a CD's pits and lands, unlike a mistracking phono cartridge's stylus that damages a vinyl record's grooves.

Surface Scratches

In 1982, when CDs became the new music storage media, the only way to repair scratches was by polishing. While it's true that relatively large scratches or damaged areas may be restored by careful polishing with mild abrasives, you'll invariably end up increasing the number of fine scratches on the disc's playing surface. So although you may reduce or eliminate most of the grossly audible effects of mistracking, you may severely compromise low-level accuracy and musicality. Abrasives in any amount should only be used as a last resort to make an unplayable disc playable, or to eliminate extreme mistracking and or muting. If polishing a disc becomes necessary, we suggest that you don't try to fully correct the damage with one application but rather do a little polishing, a lot of cleaning, and then some listening. If necessary, repeat this process until either the defects have been audibly cured or you cease to hear further improvement. That way you may avoid most of the unpleasant side effects from the damage that occurs when fine scratches mar a previously unblemished portion of the disc's surface.

But, a lot has changed in the eighteen years since the first version of this White Paper was written in 1989 for our first product "Finyl the Digital Solution™"*. Now there's a new method of recovering pristine data that doesn't cause additional harm to the original damaged disc. By using a CD duplicator such as Digital Systems'& Solution's RealityCheckCD Audiophile Grade Duplicator™ (RCCD-AGD™), whose ability to accurately read damaged discs is much more robust than almost any CD or DVD player, a severely damaged disc that's copied to CD-Rs retains all the original data and sounds more musical than the original disc when it was new*, unless the disc is so severely damaged that the duplicator can't read it either. This process is analogous to using a copy machine to make an unwrinkled copy of a wrinkled original. Copying a disc with a stand-alone duplicator produces a first generation CD-R that's polarity inverted relative to the polarity of the copied disc which enables you to correct the polarity of a polarity inverted original. A CD-R copy of the first generation CD-R will make a second generation CD-R that will be in the same polarity as the original disc and will sound at least as good as the first generation polarity inverted CD-R and better than the original. RCCD-AGD copying takes place at four times real time (or faster as set by the user), making it a much quicker process than removing scratches by polishing. If you're interested in the significance of listening in absolute polarity, we can mail or e-mail you a paper titled "A Speculation Regarding Perception of Detail".

We think it's safe to say, there's a general consensus among audiophiles about much of what's been said so far. But from here on differences of opinion may not be so easily resolved. At one extreme the pure subjectivists only trust their ears and have little use for measurements or specifications. At the other extreme, strict objectivists make measurements and study specifications because they don't trust their ears. Then there are the majority of listeners between these two extremes who simply want to enjoy the music for the sheer pleasure, choosing to avoid anything that might otherwise distract. Perhaps what's needed to resolve the differences of opinion, as distasteful and tedious as it sometimes becomes, are double-blind tests to convert some of that intense heat into light.

Does the lack of measurable data explain why UBP is the digital solution engineers hate to love? Without a doubt they love its sound, though when asked to explain why applying UBP to a perfectly clean disc could improve its sound, they express their doubt as follows: since the digital signal can only assume two values, on and off, with nothing in-between (otherwise known "as bits are bits"), once a disc is clean no further treatment should be beneficial. But seldom is anything concerning audio as simple as it first appears or sounds. We think that when you understand more about the way a laser reads a disc you'll appreciate why we call UltraBit Platinum The Digital Solution™. With that in mind we offer the following for your thoughtful consideration.

History of the Problem

We at Digital Systems & Solutions, like many others, felt that CD sound wasn't realizing its full potential. Despite all the improvements in recording and mastering techniques, including oversampling, upsampling, reclocking, playing from a hard drive, or from a memory without any moving parts or vibration, various advanced filtering schemes, the use of vibration dampers and isolation devices with disc stabilizers, the full musical promise of the CD had yet to be fulfilled. Could some heretofore-unknown ingredient be missing from the CD reproduction chain?

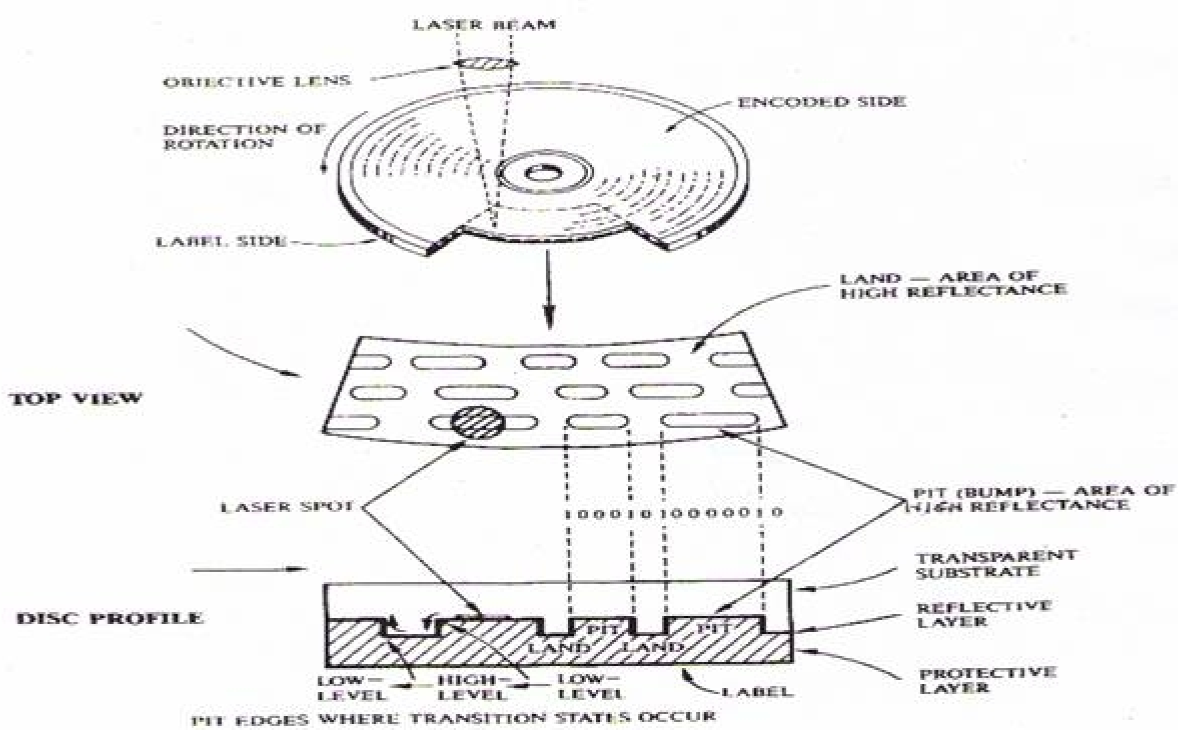
From the outset we decided to limit our search for improvements to those that would be inexpensive, practical and wouldn't void a player's factory warranty. It would also need to be compatible with all players, whether upgraded or not, as well as all laser-read media. UBP isn't only compatible with all factory stock players, it's also synergistic with all modifications and accessories. Not only is UBP inexpensive and practical (two ounces will treat all surfaces and edges of about 500 4-3/4 inch discs), it's a necessity for maximum playback resolution and fidelity of all stamped or burned discs. No player, whether totally upgraded or factory stock, can be guaranteed to achieve its full potential if the data stream it processes has been corrupted by misreading. If you think you like the sound of your player now, imagine just how much better it will sound with lower electrical interference when it receives the bit stream with minimum jitter, music data and clock data intact, with nothing added and nothing taken away. Isn't that what high fidelity is all about?

The Encoding of the Disc

The accompanying illustration should help you understand our written explanation of how optical impedance matching (OIM™) can improve the accuracy of recovered encoded music data's electrical signals produced by the reflected laser beams read by the player's photodiodes.

Notice that although we refer to pits and lands (the lands are flat areas between and around the pits), the laser beam actually reflects off the backsides of the pit bottoms which appear as bumps to the laser beam(s). That's because commercial CDs are stamped from their label side making the pits concave on the label side and convex on the reading side. We will, however, continue to describe the bumps as pits.

Our illustration shows that a continuous pit or land represents an encoded 0 and a pit edge represents an encoded 1. That means steady state reflections represent encoded 0s, and transition states from lands to pits or vice versa represent encoded 1s. This rather clever scheme saves considerable disc space over one that uses each pit or land to represent 0s and 1s directly; it does, however, require two distinct reflectance states to read the data. There's a high-level of almost total reflectance of the beam from lands or pits



and a low-level of reflectance when the beam transits a pit edge and splits into two beams, when their almost simultaneous reflections recombine, because the pit's height is 1/4 of the laser's wavelength. In other words, the split beam's reflection from a land recombines with its reflection from the pit, and the 1/2 wave length difference between pit and land reflections

(1/4 down to land and 1/4 up to pit bottom) tends to make the two beams cancel each other due to the 180 degree phase difference between them attenuating the signal's amplitude at the photodiodes.

The Problem

Any ambiguity or confusion between the high and low reflectance states will probably corrupt the data stream with digital glitches and dropouts. Starting with a clean disc, what factors could impede the reading process? One factor is the partial reflections of the laser beam(s) at the disc's reading surface (which is made of polycarbonate and labeled TRANSPARENT SUBSTRATE in the illustration) which it crosses twice, once on its way to the encoded surface, and then back again on its way to the reading and tracking photodiodes. Another factor is the scattering of the laser beam off the pits (bumps) toward the disc's inner and outer rims (edges) and partial reflections back (because of the .55 difference of the indexes of refraction between the air and disc's rims, explained below) to the reading photodiodes that may interfere with the main reading or tracking beam(s). Measurements at an optical laboratory show that UBP lets more light out at the disc's edge than opaque treatments absorb which makes it more effective than any of the opaque edge treatments we tested, and unlike opaque treatments, you don't need to worry about getting UBP on the reading surface because it's meant to be applied to the entire disc. Misreads may also occur when the laser is defocused and dispersed or diffused due to unwanted refractions by imperfections on the disc's surface. CDs may appear flat and smooth to the naked eye, but under a high magnification with a scanning electron microscope even the best CDs look rough and uneven. A scratch, so tiny that otherwise it might have gone unnoticed, could dominate the view.

Reflection and refraction occur at the interface of the disc's surface with the air because the refractive index of air and polycarbonate are different from each other (approximately 1.00 and 1.55 respectively). The index of refraction of a coating that minimizes the disc's reflectivity is about 1.2455, the geometric mean of 1.00 and 1.55. If the indexes of refraction of air and polycarbonate were equal, then applying UBP to the disc wouldn't be optically impedance matching, as the two mediums would already be perfectly impedance matched. Partial reflection takes place each time the laser beam crosses the disc's surface (air and polycarbonate interface) and disturbs the intensity of the reflected returning beam. In optical physics this is called constructive or destructive interference depending upon whether the relative phase between the reflected beam and returning beam reinforces or cancels respectively the returning beam's amplitude. Refraction and diffusion of the beam by surface defects or imperfections also takes place in both directions causing a defocusing and diffusion of the beam that disturbs the amplitude and integrity of the signal received at the photodiodes. Therefore, although the laser beam starts out tightly focused and nearly 100% coherent, it may end up much less focused or coherent and will be diminished in its overall intensity. The net effect is that a disc treated with UBP improves a beam's reading and tracking by focusing it to a smaller more precise spot at its focal point on the encoded layer. This allows a beam to track and read the data with greater accuracy with quicker more distinct transitions between low and high signal states due to greatly reduced reflection of the laser at the interface of disc and air with less diffraction or diffusion of the beam by surface scratches. UltraBit Platinum applied a CD player's photodiode lens will also improve the optical impedance matching of its interface with air, but it should be applied very carefully to avoid damage.

Erratic shifts of the beam's intensity or amplitude at the photodiodes may cause the bit stream to become so corrupted by errors that even the most advanced error correction algorithms, currently in use, could fail to reconstruct the bit stream sufficiently which causes the audio output to be interpolated or muted. If this occurs, it forces the player's error concealment circuits to take over, which inevitably results in a serious degrading of playback fidelity and musicality. In addition, one shouldn't be surprised when the player or transport tracking servos also misbehave if they are triggered by false signals from their photodiodes. Misread digital words that represent the encoded data may have any number of digital signal glitches and dropouts randomly distributed from the least significant bit to the most significant bit and anywhere in between. If errors go undetected, frequency components of the audio signal will not be harmonically related to the original signal and consequently will not be well masked by the music. Then music that's meant to be enjoyed may turn out less emotionally fulfilling than it is enervating, which is another possible source of digital listening fatigue.

Again, if there's interference with analog circuits or undetected data errors get to the DACs or there's excessive jitter, the random nature of digital glitches dropouts that may occur, means at any particular instant the number of ways the playback sonics are degraded and detract from musicality are not strictly predictable. The following is a list of possible musical and sonic deficiencies that may result:

- Generally increased harshness or roughness that distorts the high frequency harmonics and contributes to an overall loss of smoothness;
- Poor articulation of bass and mid-bass notes;
- Attenuation of dynamics and smearing of transients;
- Increased noise with loss of both inner detail and intertransient silence;
- Reduced mid-range presence that diminishes clarity and transparency;
- Loss of image specificity and focus;
- Reduction of the apparent width and depth of the soundstage, virtually eliminating the possibility of holographic imagery;
- Decreased resolution of the low-level detail that is so necessary to the recovery of hall ambience;
- Altered instrumental and vocal timbres that lack coherence or cohesiveness; and
- A loss of rhythmic drive and pace.

From a musical standpoint the above list barely begins to scratch the surface. Some of the musical values that suffer are listed below, and again the list may not be complete:

- Subtle breath effects on brass or wind instruments become more difficult to discern as are nuances of fingering and bowing on string instruments.
- Vocal texture and expression are obscured.
- Instrumental lines and musical themes are more difficult to sort out.

- Complex rhythms and tempos are less easily followed.
- Above all, it will not be as an emotionally involving and satisfying musical experience than might otherwise have been possible.

Given the above list of possible faults it's no wonder so many music-loving audiophiles are so vocal in their criticism of the sound of laser-read media.

The Search for a Solution

We decided early on that the best place to begin searching for answers was at the beginning, because the first stage in the reproduction chain we could improve was the reading of the disc. The logic of this approach appeared to be self-evident, since the disc is the first element in the reproduction chain the consumer has the option to modify or treat.

In theory, the perfect solution would be to immerse the player's optical system, disc and all, in a liquid with an index of refraction equal to polycarbonate's in order to make the disc's surface optically disappear, scratches and all. By eliminating the air, we also eliminate the .55 difference between its optical impedance (index of refraction) and that of polycarbonate. Although surface reflection and refraction would now be nonexistent, a new problem arises because the .55 difference of the air's refractive index and that of polycarbonate helps to focus the laser on the disc's metallic reflective layer where the encoded data is found. You may want to refer to the illustration of the DISC PROFILE. But even if the index of refraction air and polycarbonate were the same UBP would still be a good disc cleaner and static discharger because it protects the surface from contamination and the disc's tendency to become re-charged. With the immersion approach eliminated from serious consideration, we set out to find a more realistic soluton. The result is UltraBit Platinum the Digital Solution™.

UltraBit Platinum represents our best effort to strike an ideal balance between scientific analysis and aesthetic judgment. As a single layer interface, UBP's formulation had to be tailored with two conflicting requirements in mind. The first is the necessity of minimizing surface reflections, and the second is filling in surface imperfections to eliminate the diffraction and diffusion they cause. The first objective requires an index of refraction equal to the geometric mean of the two different indexes of refraction (air and polycarbonate), whereas the second objective requires the single layer to have the same index of refraction as the polycarbonate substrate. By concentrating on the first objective, to the exclusion of everything else, we were able to cut surface reflections roughly in half. The improvement in the sound and musicality was nothing short of dramatic. However, despite our wonderful first impression, like so many music-loving audiophiles, we soon craved even more improvement. Even though the elusive goal of ultimate playback fidelity had once again escaped our grasp, which probably meant a lot more research and development, we refused to be deterred.

Next we investigated interference coatings that potentially can reduce reflections to almost zero, but it soon became apparent there might be certain insurmountable drawbacks in our specific application. Interference coatings are wavelength specific, whereas lasers used in current CD players may have somewhat different frequencies, at least according to their published specifications, and DVD players have blue lasers of a much shorter wavelength than CD players so an interference coating won't work. We could have made different versions of UBP for the most popular players, but then to play a treated CD on different players you'd need to remove one version before applying another version. And although UBP can easily be cleaned off with our CleanDisc™ disc cleaner, we quickly discarded the idea, because we felt it was too much trouble for the small gains that might be realized. More critical yet, an interference coating is extremely sensitive to the angle of incidence of the light passing through it. Because different angles of incidence represent different film thicknesses to the laser beam, since laser beams consist of both parallel and nonparallel rays, interference coatings wouldn't work all that well anyway.

The Listening Test and Finding the Solution

Now that we had done the science it was time to do the art. If we could optimally combine UBP's Optical Impedance Matching properties with its ability to reduce the degrading effect of surface defects, perhaps we would finally hear a compact disc achieve its full musical potential. Our only goal was the maximum improvement of the sound and musicality so listening tests were absolutely crucial.

To avoid setting our sights too low we wanted to find out what the improvement would sound like if the only objective was enhanced musicality. This would create a reference standard we could use to gauge the success of formulations that might be only slightly less enhancing but much less costly to produce. Next we had to make sure UBP would also satisfy our other requirements. Having made excellent progress, with the release of a finished product appearing imminent, we suddenly realized we overlooked one of the most important requirements of all, that the use of UBP would never harm musical or sonic values. When the tests for possible negative effects failed to produce any usable results, it was abundantly clear we had grossly underestimated the difficulty of the listening task. We decided the best way to beta test UBP was to enlist the aid of a panel of expert listeners dedicated to advancing the state of CD fidelity. All panel members were experienced music loving audiophiles and most had at least some musical training and/or technical degrees. They listened to practically every type of music on a huge variety of systems and players. This included a full spectrum of CD players, DVD players, from inexpensive portables to very elaborate and obscenely high priced two or more piece players as well those with tubes analog sections. Nor did we leave out modified players and accessories such as disc dampers, damping rings, disc edge trimmers, static dischargers, demagnetizers, isolation feet, just to mention a few. Many of the listening sessions were conducted in double-blind fashion to minimize the effect of listener bias. Many other disc optical surface treatments were included to be sure we had a real winner. CDs were compared with their vinyl counterparts whenever possible, but our ultimate reference remained the sound of live unamplified acoustic instruments and voices heard from an aesthetic distance in a natural acoustic environment, which many audiophiles and audio gurus define as the absolute sound (TAS). We needed over one hundred iterations to perfect UBP's unique formulation and sonic properties before it attained the highly refined state it enjoys today.

Last but not least, to solicit opinions from listeners with impartial perspectives, numerous samples were sent out to both prospective customers and potential distributors. Their perceptive and very astute feedback gave us many useful insights and much encouragement. We are especially gratified by their enthusiastic support for the concept behind Utrabit Platinum™. Simply stated, "Maximum playback fidelity begins at the disc surfaces."

Conclusion

When at last the testing was completed and we tabulated the results, the evidence was overwhelming. The listening panel had established a consensus. "If a laser read media disc hasn't been treated with UltraBit Platinum then you haven't really seen or heard it." We carefully analyzed and reanalyzed the test results from every perspective we could think of to see if we could find even the slightest discrepancy, but nothing turned up to change our minds. At last there was positive verification that UltraBit Platinum meets or exceeds all of our original goals! We believe that UltraBit Platinum sets a new reference for disc treatments that enhance fidelity and musicality, and we think you'll agree with us that its price is more than commensurate with its results. We honestly believe that for the fore-listenable and fore-seeable future UltraBit Platinum will remain unequaled in its ability to bring forth music and video images from laser-read media.

We worked long and hard and used all of our technical know-how and listening skills so you could make the UltraBit Platinum listening test. Our ultimate purpose will be fulfilled if UltraBit Platinum enables you to enjoy the greatest possible emotional involvement with the aesthetic values of music. But ultimately for you, it's only your "let the bits fall where they may critique" that matters.

*For an explanation of optical impedance matching see "Optical Physics", Second Edition, Chapter 4 by S. G. Lipson, Ph.D. & H. Lipson, F.R.S., Cambridge University Press. Finyl the Digital Solution™ was one of the first CD surface treatments. This new white paper is an updated version of The Finyl Word, a White Paper on the Art and Science of Optical Impedance Matching as it Applies to Laser-read Media to explain the rational behind Finyl, for its manufacturer Digital Systems & Solutions, authored by George S. Louis, CEO and copyrighted 1989 with all rights reserved.

Finyl the Digital Solution™ won numerous awards including a European Golden Triangle award and was a recommended CD and laser disc accessory by Stereophile and the Perfect Vision magazines. The RealityCheckCD Audiophile Duplicator™ was named 2005 product of the year by EnjoytheMusic.com

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