Emphasis and Deemphasis For Compact Discs

A detailed look at what appears to be an anachronistic adoption of an old technique to state-of-art recordings

By Bob Lochner & Tisi Yamada

Few users are aware that compact digital disc players and recordings frequently utilize emphasis during recording and deemphasis during playback. Although emphasis is an option on the part of the recording companies that make compact discs, the majority of CD players include deemphasizing circuits. For those CD recordings that do employ emphasis (the great majority do, of course), deemphasis is required to assure proper program reproduction.

In this article, we will explore what emphasis and deemphasis are and what this technique contributes to recording and playback of musical programs through the compact disc medium. We will also discuss why some companies elect to forego emphasizing programs. But first a little history to set the stage.

Why Emphasize/ Deemphasize?

To better understand why that might appear to be an unnecessary and outdated technique to state-of-the-art recording equipment, it is necessary to understand why emphasis and deemphasis were used in the first place. The original reason why the recording industry adopted this technique dates back to the early post-War World II days, when high-fidelity recording and reproduction were just beginning to emerge on the scene.

In the early days, reproduction of high frequencies was relatively easy to accomplish. Unfortunately, the ease with which high frequencies could be reproduced resulted in a noise problem as well. Noise resulting from pops, dust, scratches, static discharges on the disc during play and the white noise inherent in the recording and playback electronics was a major problem.

While high frequencies were easy to record and play back, the limitations of the vacuum-tube amplifiers of the time made successful recording and playback of lower-frequency material more difficult to achieve. Because the recording of loud low-frequency passages required considerable stylus excursion, excessive "real estate" was required for each spiral groove on the disc. This resulted in a lower density of grooves cut during recording, seriously limiting the maximum recording time possible on a given disc.

Although amplification of higher frequencies was easier to accomplish, noise of all kinds, naturally rich in high-frequency content, was very noticeable during playback of a disc. What was needed was a way to record a program in such a manner that all of the high-frequency content remained while the noise level was reduced to inaudibility.

Extensive research revealed that rather than recording linearly, emphasizing the amplitude (loudness) of the material being recorded with a rising characteristic as the frequency increased helped significantly in overriding the various forms of noise in the middle- and high-frequency ranges. The higher the frequency, the greater the emphasis.

Of course, on playback, controlled deemphasis with a characteristic that was a mirror image of the emphasis characteristic more or less restored the fidelity of the program while leaving the various noises at a much lower and more tolerable level. Since emphasizing during recording and deemphasizing during playback provided a considerable improvement in the apparent quality of the reproduced program, this technique soon became a standard tool used by all recording companies in combatting noise.

By reducing the white noise that the playback system dealt with, emphasis and deemphasis also reduced the need for wide mechanical excursions of the stylus during the cutting stage. This eventually gave rise to the long-play (LP) disc with which we have all become familiar.

Emphasis and deemphasis may have become a standard tool of the recording industry, but it was (and still is) far from standardized. A number of standards for emphasis/deemphasis were proposed—among them those from CBS, RCA and RIAA—each vying for economic advantage in the marketplace. Though the RIAA standard has since become the virtual *de facto* standard, the tumultuous early days of high fidelity made the common "tone" control a necessity on consumer equipment.

The Current Situation

Recording and playback problems are greatly reduced today in all recording media. However limitations continue to exist in even the latest technologies—including the that of the

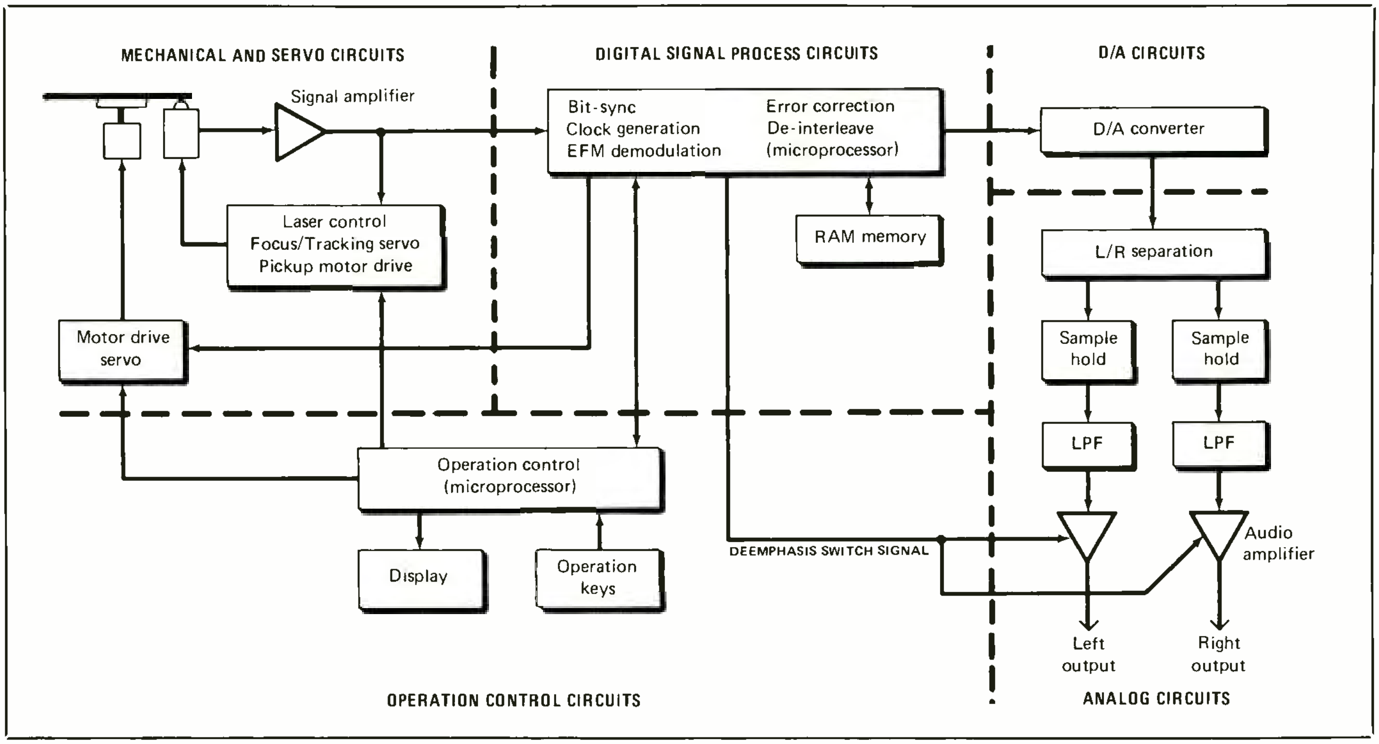

Fig. 1. Block diagram of a Compact Disc player.

Compact Disc. White noise is the one universal bugaboo in all technolgies.

White noise is an inescapable fact of life in any equipment in which amplification is used. By definition, white noise contains all frequencies across the audio spectrum at equal amplitude. But what may appear on an oscilloscope screen as equal amplitudes is not necessarily how the human ear discerns the distribution.

We hear audio frequencies in a more or less natural octave manner; one might say we have a natural logarithmic response. For example, if asked to differentiate between low, medium and high notes in a musical selection, a typical listener might consider the notes from 40 to 300 Hz to be low, from 300 Hz to 2.5 kHz to be medium and from 2.5 to 16 kHz (or the upper range of his hearing) to be high. He is also likely to consider the distribution within each range to be equal.

Simple arithmetic, based on the above example, reveals that the white noise in the "low," "medium" and "high" notes is spread across 260 Hz, 2.2 kHz and perhaps 13.6 kHz, respectively. However, since the white noise is evenly distributed in terms of amplitude, it follows that the combined white-noise energy in the high-note range is on the order of 50 times greater than the combined energy in the low-note range. With this great a variation, white noise in the higher frequencies will always be more noticeable, even in systems that use the latest digital techniques.

White noise also has a major effect on signal-to-noise ratio (S/N) and, hence, dynamic range, both areas in which CD technology has brought significant benefits. The *maximum* dynamic range in decibels (dB) at the output of a Compact Disc player, based on the Sony/Phillips 16-bit CD specification, is determined by the expression: $6A + 1.8$, where A is the number of bits. With the 16-bit spec, maximum dynamic range is $(6 \times 16) + 1.8 = 97.8$ dB for a sine wave.

It is important to understand that the maximum dynamic range spec is met only at the output of the digital-to-analog (D/A) converter and then only when all conditions are ideal. It is not the spec taken at the CD player's audio output jacks. This being the case, dynamic range—and S/N—can only deteriorate as the output from the D/A converter passes through each amplifier stage on its way to the player's output jacks. By the time the signal arrives at the output jacks, it is also to be expected that overally dynamic range will be reduced by a modest factor.

Even the best amplifier stage generates white noise. The white noise component of each successive stage adds to the total and raises the noise floor of the signal, thus reducing dynamic range. Although the D/A converter output in a CD player can, under ideal design conditions, produce a dynamic range of 97.8 dB, a more realistic figure would be more on the order of 90 dB measured at the speaker output. This is still a healthy dynamic range and is virtually unattainable with analog equipment.

Since you will be more aware of white noise at the higher frequencies, due to the ear's combining effect, using emphasis in recording and deemphasis in playback reduces the energy-sum of white noise. In turn, this increases both the S/N and dynamic range of your system's output. And this is the main reason why emphasis and deemphasis is still regarded as a valued ally in modern CD technology.

The Sony/Phillips Spec

The Sony/Phillips design specification for Compact Disc players includes a defined emphasis/deemphasis characteristic. It also includes a provision for encoding discs so that the player can recognize whether or not a specific disc has been emphasized during the recording process.

Not every CD recording is emphasized, and no recording company presently tells the user whether or not a particular disc has been emphasized. Indeed, in many cases, a single company offers titles that are emphasized and others that are not, probably depending on the relative state of the master recording to be reproduced. This was anticipated by the original designers of the CD system. Provision for automatic switching in and out of a deemphasizing circuit was a design element of the CD player right along with the standardization of the emphasis specification. Therefore, virtually all CD players include automatic deemphasis switching.

As shown in Fig. 1, three sections are required in all deemphasis circuits used in CD players. The first is the CPU (central processing unit, commonly called a microprocessor). This device reads the disc's directory and determines from the program information whether or not the recording has been emphasized. If it is, the CPU switches in deemphasis.

The second section is a switching arrangement that switches in and out the deemphasis network upon command from the CPU. There are actually two switches in a CD player, one for each audio output channel. Since switching speeds are not an important consideration in CD players, both FET (field-effect transistor) and relay switches have been noted in representative players we have examined.

FET and relay switches each have their own advantages. FET switches, for example, have no moving parts, isolation is better than 1 megohm in the off mode, and on resistance is on the order of 100 ohms. The last can be partially compensated for by the deemphasis network's circuitry. On the other hand, relay switches offer virtually infinite resistance when off and 8 to 10 milliohms (thousandths of an ohm) when on, which obviates the need for making allowances for switching resistance.

You can easily determine whether or not a recorded program has been emphasized, if this information is not

Emphasized Compact Discs

Manufacturer	Disc. No.	Title
American Gramaphone	AGCD-359	Fresh Aire II
CBS	MK37204	Mendelssohn V-Concerto
	MK37273	Mahler Symphony #1
	CD 36711	Beethoven #5, Schubert #8
Denon	38C37-7069	Concert Royal
	38C37-7062	Tchaikovsky Symphony #6
	38C37-7068	Organ Concert
	38C37-7021	Beethoven Symphony #9
Polydor	3113-6	Screen Music of Love and Prime
Real Time	RT 3009	Darn That Dream
Toshiba-EMI	CC38-3006	The Ring of the Niebelung
	CC38-3022	Ravel Bolero
	CC38-3007	Beethoven V-Concert
	CC35-3015	Vivaldi The Four Seasons

Linear Compact Discs

Manufacturer	Disc. No	Title
American Gramaphone	AGCD-366	Sampler III
Arista	ARCD 8268	Arista's Perfect 10
CBS/Sony	35DP82	Herbie Hancock Future Shock
Delos	CD 3007	Vivaldi The Four Seasons
	CD 3010	F. Handel The Water Music
	CD 3015	Tchaikovsky Symphony #5
Deutch Grammaphon	410 895-2	Berlioz Symphony Fantastique
	410 025-2	Gershwin Rhapsody In Blue
	400 039-2	R. Straus Eine Alpensinfonie
L'Oiseau-Lyre	410 553-2	Pachelbel Canon
London	411 959-2	Luciano Pavarotti Mamma
	410 137-2	Wagner Der Ring Des Niebelungen
	410 552-2	Faure Pavane
	400 047-2	Dvorak Symphony #9
Nonesuch	79033-2	Janacek Idyla/Mladi
Philips	411 420-2	Mozart Raquiem
	411 036-2	Wagner Tristan Und Isolde
Polydor	800 020-2	Vangelis Chariots of Fire
Polygram	816 054-2	Hear the Light I
	814 981-2 M-1	Scorpions Love at First Sting
	816 055-2	Hear the Light II
	814 981-2 M-1	Scorpions Love at First Sting
Toshiba-EMI	CC38-3042	Faure Requiem
	CC38-3030	Wagner Der Ritt Der Walkuren
Warner Brothers	23696-2	Donald Fagen The Nightfly

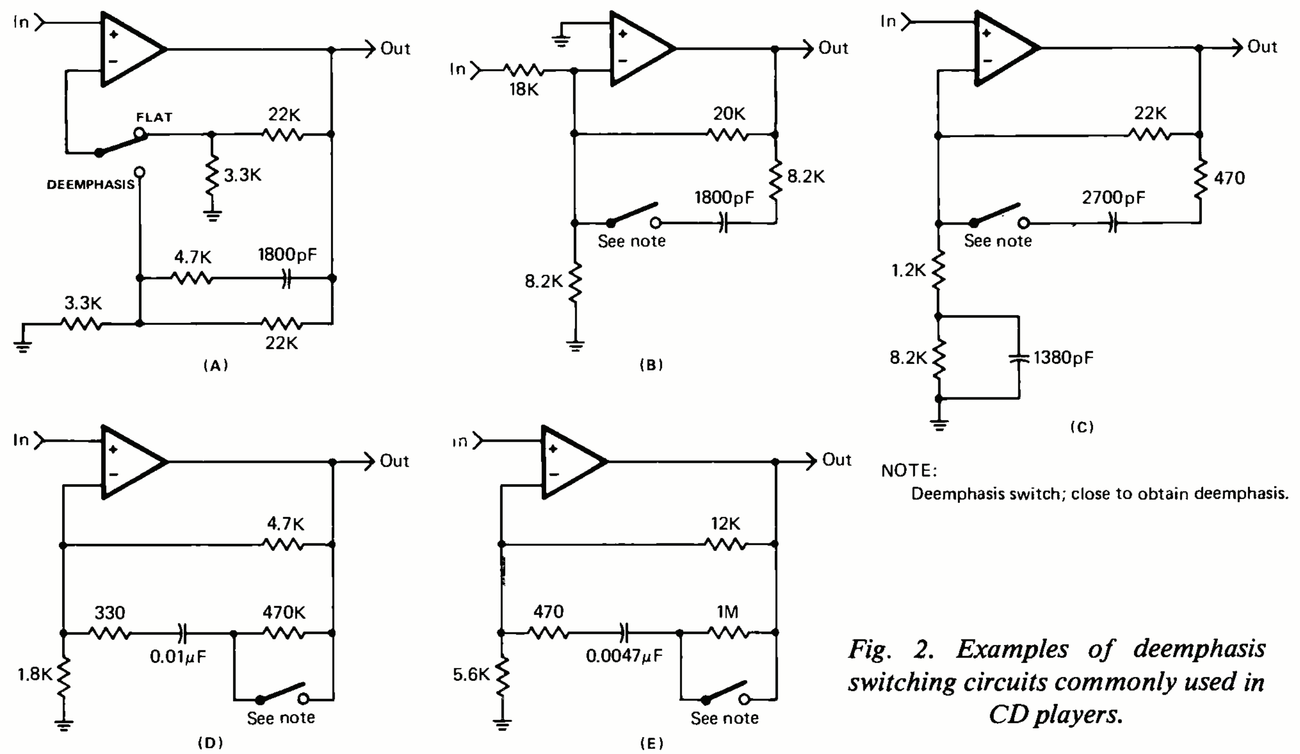

Fig. 2. Examples of deemphasis switching circuits commonly used in CD players.

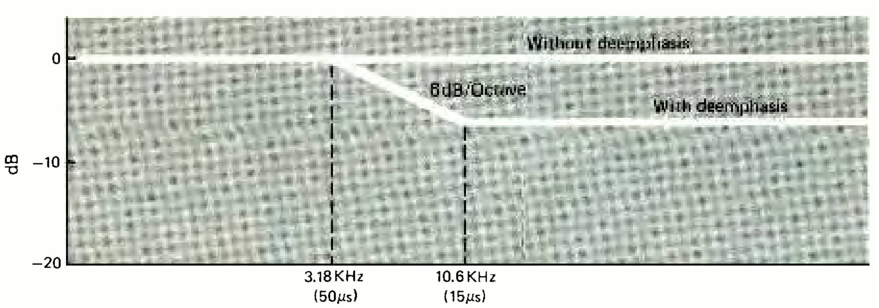

Fig. 3. Ideal deemphasis characteristics for CD players.

given on the disc or the package it came in. Simply monitor the state of the switch used to apply deemphasis.

The third section of the deemphasis circuit is the deemphasis network itself. Different design approaches for this circuit are used by different manufacturers of CD players. Five possible variations are shown schematically in Fig. 2, all of which can be found in current CD players. The circuits shown in Fig. 2 have been simplified for clarity.

Sony/Phillips' licensing agreement specifies a flat deemphasis response to 3.18 kHz, a 6-dB/ocatve rolloff between 3.18 and 10.6 kHz and then a flat response with no further attenuation beyond 10.6 kHz (see Fig. 3). These are ideal figures. In the real world, filter transition points are not sharp, rolloff stages never have straight-line characteristics until at best well past the transition frequency, and the complex reactances of filter components guarantee departures from the ideal.

Although a perfectly responsive deemphasis network to match the Sony/Phillips specification is impossible to build, complex bandpass filter designs are capable of providing a good approximation. However, practical filters will differ from one design to another and even from one set of "identical" components to another in the same design in a production run unless extremely close tolerance, high-quality components are used.

Undoubtedly, one of the major reasons why some CD recordings purposely lack emphasis is the impossibility of designing perfect deemphasis networks. This is especially so when the master recording is already a state-of-the art example made under carefully controlled circumstances, with very low noise and excellent accuracy to begin with. Characteristics of the various deemphasis network designs invariably affect CD program reproduction fidelity in an imperfect way.

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Therefore, to avoid any alterations whatsoever, it is not uncommon for recording engineers to forego adulterating the program material by emphasizing it, assuring the listener of maximum fidelity.

Summing Up

Reduction of noise, which improves the signal-to-noise ratio, is the major benefit derived from the use of emphasis and deemphasis in CD recording and playback. Most major recordings are derived from multiple recorded tracks that are mixed down to the final two to make up the familiar stereo program. At every stage from microphone all the way to digital converter, the analog amplifiers inevitably cause an incremental increase in the noise floor and reduction of dynamic range.

Using enhancement during the recording process both reduces the effect of noise in playback and assists in overcoming the limitations of the playback equipment. Whether improved signal-to-noise ratio or virtually perfect linearity is more desireable is the choice of the producer of a given Compact Disc. The option of using emphasis/deemphasis gives the producer a powerful tool in dealing with noise when it exists to a degree significant enough to have an audible effect on the played back program. ME