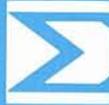


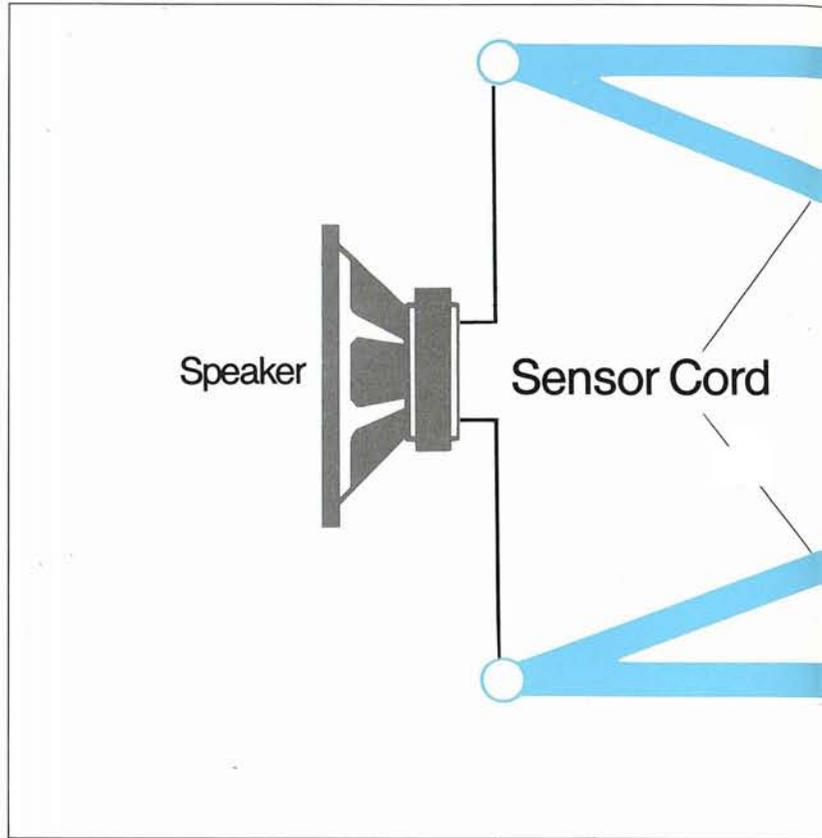
 **KENWOOD**

**TECHNICAL
GUIDE**

 *DRIVE*
SIGMA



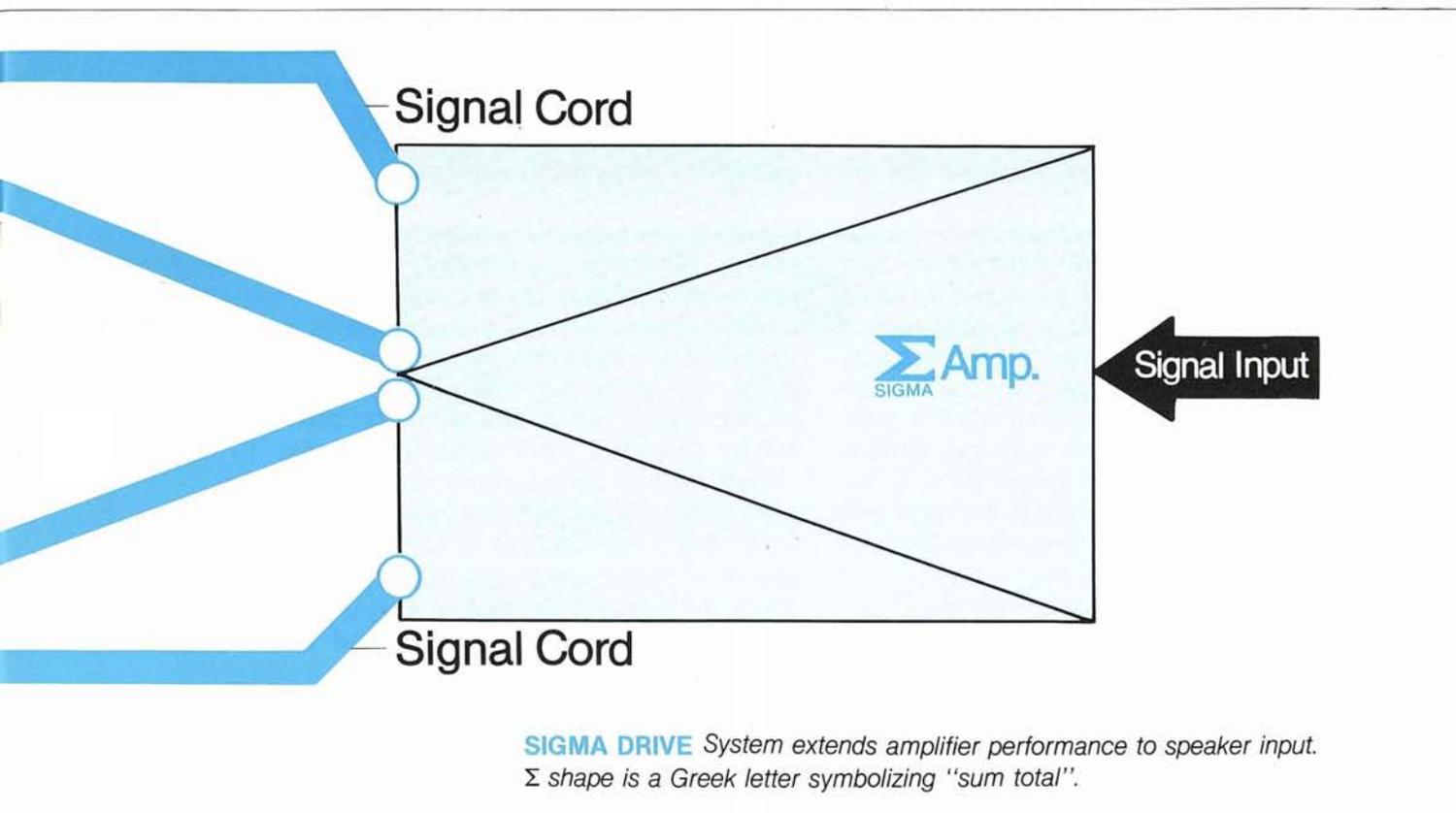
What is Σ Drive? SIGMA



Audio engineers have traditionally tended to regard the amplifier and speakers as separate entities in the hi-fi chain, linked only in the sense that the amplifier is supposed to drive the speaker. Recent research has shown, however, that the amplifier-speaker relationship is much tighter than is conventionally revealed by normal, static performance specifications. In fact, amplifier performance can be radically affected by the behavior of the speakers when high-energy transients in the music signal are being reproduced. Such dynamic considerations are the basis for the new Kenwood technology whose various facets are collectively called the Sigma Drive system.

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Sigma Drive is a method of including speaker behavior within the scope of amplifier performance. It is not simply an improved speaker cord or a better performance specification, but a system that includes many interlocking elements. Now, Damping Factor is not just a vague nominal specification measured at the amplifier output, but a true indication of the amplifier's ability to control the speaker. The Kenwood amplifier Dynamic Damping Factor is actually measured at the speaker input terminals. The merits of the Sigma Drive system can be summarized as follows:

1. Amplifier capability is optimized.
2. The speaker connecting cord is included in the amplifier negative feedback loop.
3. Complete control of speaker counter-electromotive force (back-emf) is achieved.
4. The speaker is forced to reproduce music signals from the amplifier exactly.
5. Constant-voltage drive is obtained.

These factors result in an accurate and authentic reproduction of the music signal by the selected speaker system. Sigma Drive effects such a dramatic increase in sound reproduction quality that it requires a detailed explanation, which appears in the following pages.

Dynamic vs static performance

If you have been keeping track of amplifiers over the years, you know all too well that the amplifier has undergone continuous development. Since the days when solid state devices took over from vacuum tubes as amplifying elements, these design improvements have been accelerating, so much so that the audio world is now constantly confronted by a bewildering array of claims of improved performance. Recently, switching and crossover distortion in Class B amplifier devices have been subjected to close scrutiny, and the new technology to deal with it claimed to achieve a radical reduction in distortion. Yet, looking closely into all this activity, one has the feeling that some so-called improvements are over-rated, if not even superfluous. For example, what is the real point of lowering THD percentages to far below the point where human beings can perceive any difference, especially when other known forms of distortion remain untouched? To many observers, it must look suspiciously like a numbers game.

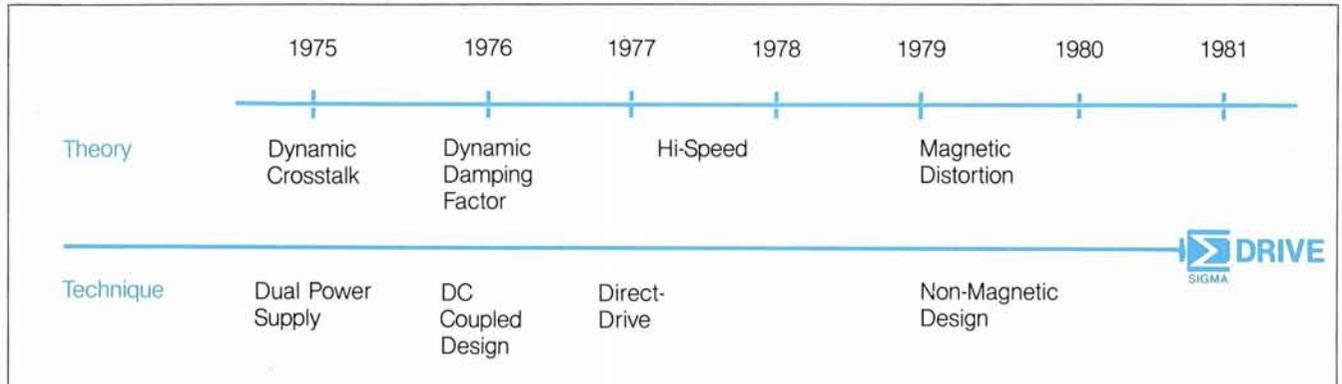
At Kenwood, we march to a different tune. Although the temptation has been great to produce a dazzling display of zero decimal point specifications,

Kenwood engineers have followed a more painstaking path of building on meaningful achievements of the past, so that lines of development flow logically and rationally in a step-by-step progression, each improvement firmly grounded in a former one and each closely interlinked with others.

But what is implied in the word "meaningful"? At Kenwood, there are two platforms on which most research programs rest. One states that mere specifications alone do not necessarily reveal an amplifier's true, dynamic (as opposed to static) performance. The other assumes that the simpler the circuitry, the better the sound will be: adding more electrical elements to deal with a problem can add further problems. Both statements relate to the listener's actual perception of reproduced sound.

By focussing on dynamic reproduction problems rather than mere improvements in conventional performance specs, Kenwood engineers have made major contributions to the field of audio electronics. Let's just stop and review these for a moment, because each one has a prominent part to play in the Sigma Drive system.

A history of technological breakthroughs by Kenwood

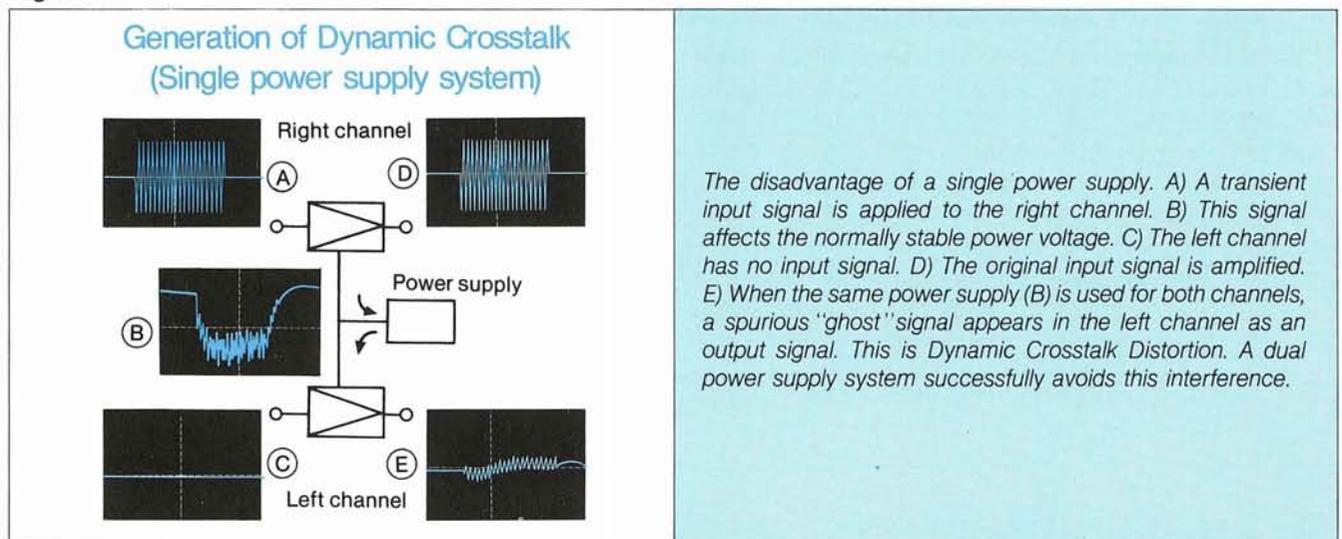


The Dual Power Supply system

In 1975, Kenwood engineers developed a theory around the concept of dynamic crosstalk. It was a theory that departed from conventional amplifier design by dealing with a problem of distortion originating in the power source that was not revealed in static performance measurements. But such distortion was plainly exposed by new dynamic measurement methods used by Kenwood engineers, including pulse signals identical to those in music and square wave testing methods that are now widely used today.

The problem of dynamic crosstalk occurs in amplifiers using a common source of power for the two channels. Ordinary THD measured in one channel may be excellent for test purposes, but the question is, what happens to THD in one channel when the other channel has to reproduce a really heavy signal? Kenwood tests showed that the stronger signal causes a ghost signal to appear in the other channel, resulting in a momentary deterioration in THD. The solution: independent power supplies for each channel. **(Fig. 1)**

Fig. 1

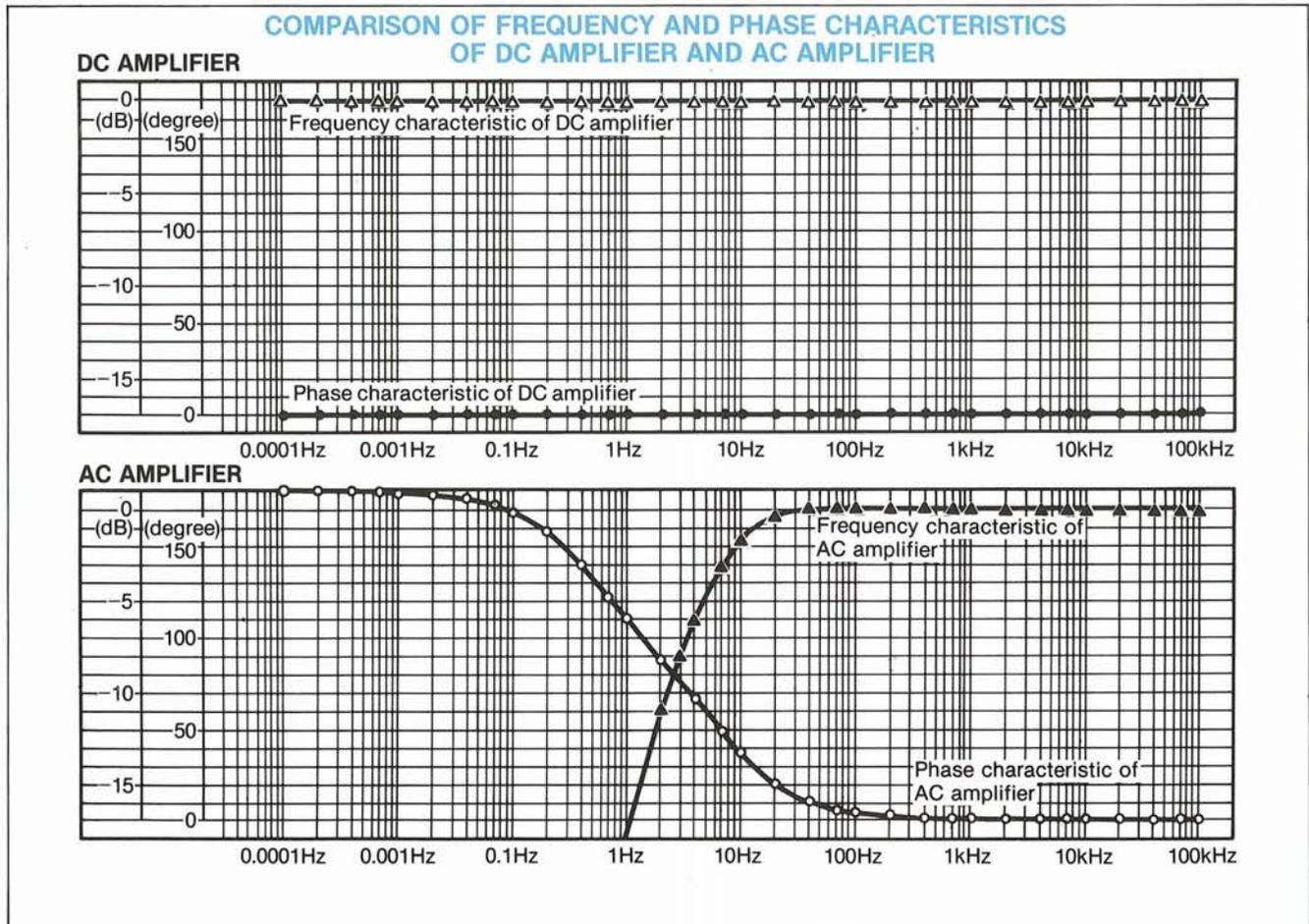


DC-Coupled amplification

Phase-shift distortion is now universally recognized as a defect in conventional AC and even quasi-DC amplifiers (those that do not actually amplify flat down to zero-frequency). Kenwood engineers were among the first to investigate this and their tests proved that phase distortion, even though it is below the audible limit, can be detected by the human ear. It occurs when one frequency of a complex musical signal takes longer to pass through the circuitry than another frequency of the same signal. Kenwood engineers then went on to successfully design a DC am-

plifier that eliminates the low frequency phase shift problem — the energy storage components (capacitors) used in the signal and feedback paths. The secret of their successful DC design was in its stability — through careful design using new measurement techniques. Because of the existence of many partial or quasi-DC (those that retain capacitors in the signal path) amplifier methods, Kenwood engineers term their amplifiers as “DC-Coupled”, or “DC direct-coupled”. (Fig. 2)

Fig. 2

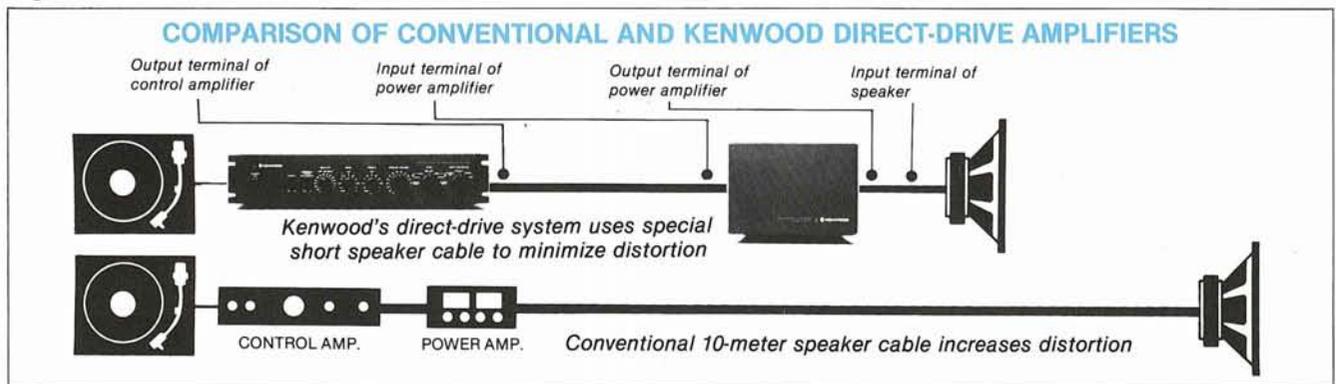


The Direct-Drive amplifier system

The year of 1977 saw the introduction of the Kenwood direct-drive amplifier system (models L-07M and L-05M with L-07C). Basically, this is a system of dual monaural power amplifiers and a stereo control pre-amplifier. It underscores an aspect of amplifiers that is often side-tracked: its purpose is not merely to amplify a signal but to drive a speaker! In other words, the speaker's behavior, like that of the power source, must ultimately come within the scope of the amplifier's capabilities. The L-07/5 Series direct-drive

system is a statement to the effect that the speaker cannot fully respond to the amplifier output unless some part of the output circuitry is in close proximity to the speaker itself. A great deal of research work was conducted on amplifier-speaker relationships, based on the 1976 Kenwood Dynamic Damping Factor theory which many people did not understand too well at the time. This theory, however, laid the groundwork for the Sigma Drive system. **(Fig. 3)**

Fig. 3



High Speed amplification

1977 also saw the introduction of the epoch-making High Speed amplifier. Research on dynamic distortion had uncovered one of the prime causes of TIM distortion, when a loud and complex music passage forces the amplifier to supply very large speaker currents in very short time intervals. The conventional amplifier is a bit like a car with a relatively low top speed trying to join traffic flowing at a much faster speed. By designing an amplifier that could supply the required "top speed" voltage whenever needed, Kenwood engineers eliminated the problem of TIM, itself a result of a limiting of slew rate — its "top speed", or maximum

voltage rate of change. Even though this problem originates far above human audibility, its by-products fall within the range of human hearing. However, it must be pointed out that a fast rise time and high slew rate alone are no guarantee of freedom from TIM; amplifier stability, in other words freedom from oscillation problems, is also important. Only when the oscilloscope shows the complete elimination of output overshoot or ringing (see Fig. 19) can it be said that High Speed works. High Speed has a lot to do with damping factor, too.

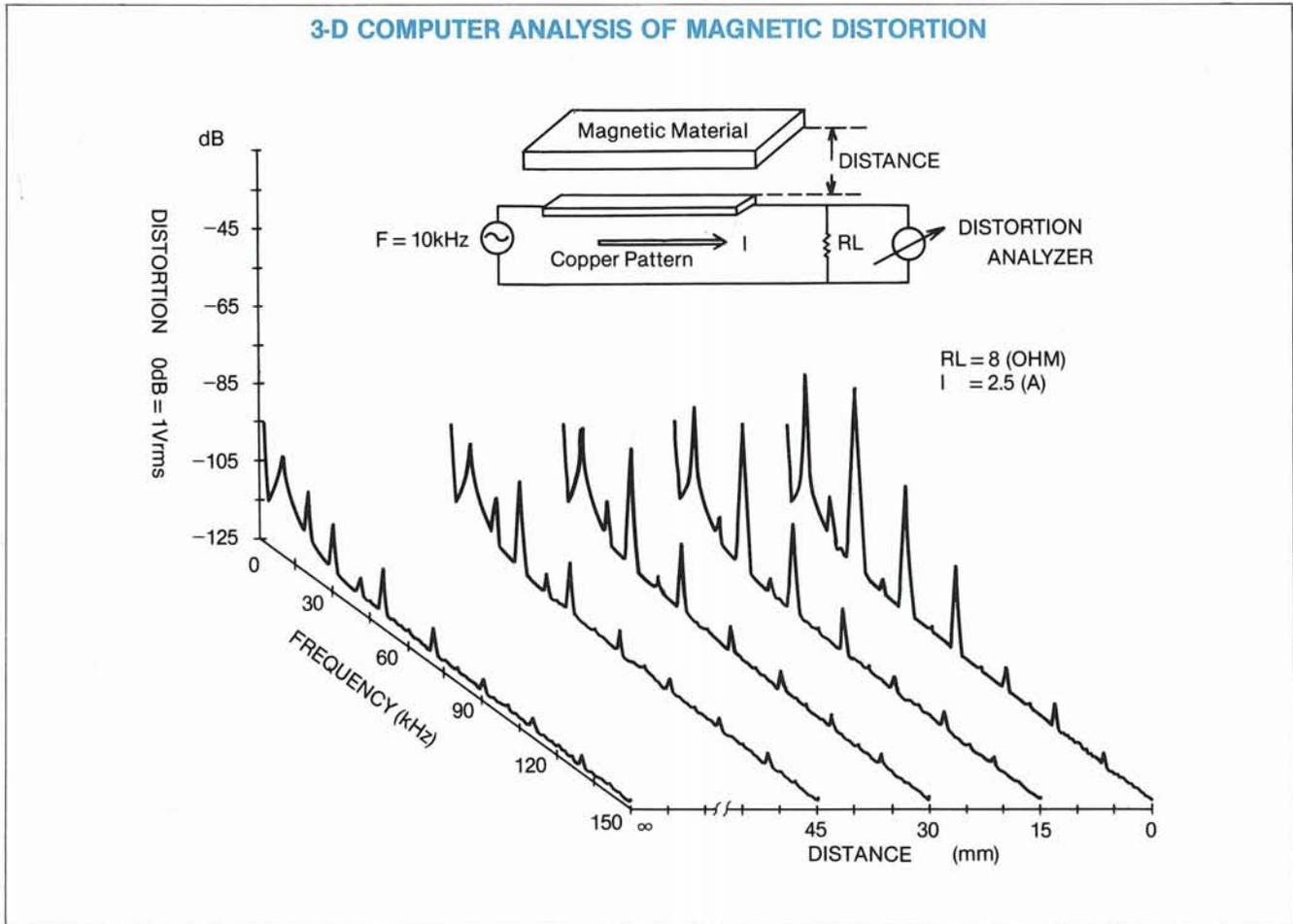
Non-magnetic design

1979 brought another light to bear on amplifier distortion. Kenwood engineers found that magnetic distortion, previously buried among levels of distortion created elsewhere, does far more to degrade the signal than was supposed. The result of their research was a thorough restructuring of the entire amplifier,

including the use of non-magnetic parts throughout the L-01A. This amplifier's power supply is a separate unit external to the amplifier, which provided the opportunity to improve power source stability where relatively higher power is needed.

(Fig. 4)

Fig. 4



Zero-Switching amplifier

The same model incorporates a new Zero-switching design which solves the problem of switching and crossover distortion. From the above it is clear that Kenwood research has followed a rational path, with each innovation based on dynamic, real-world consid-

erations of music reproduction. It is this "wholistic" approach that has directly led to the most outstanding achievement in audio technology to appear in years: Sigma Drive.

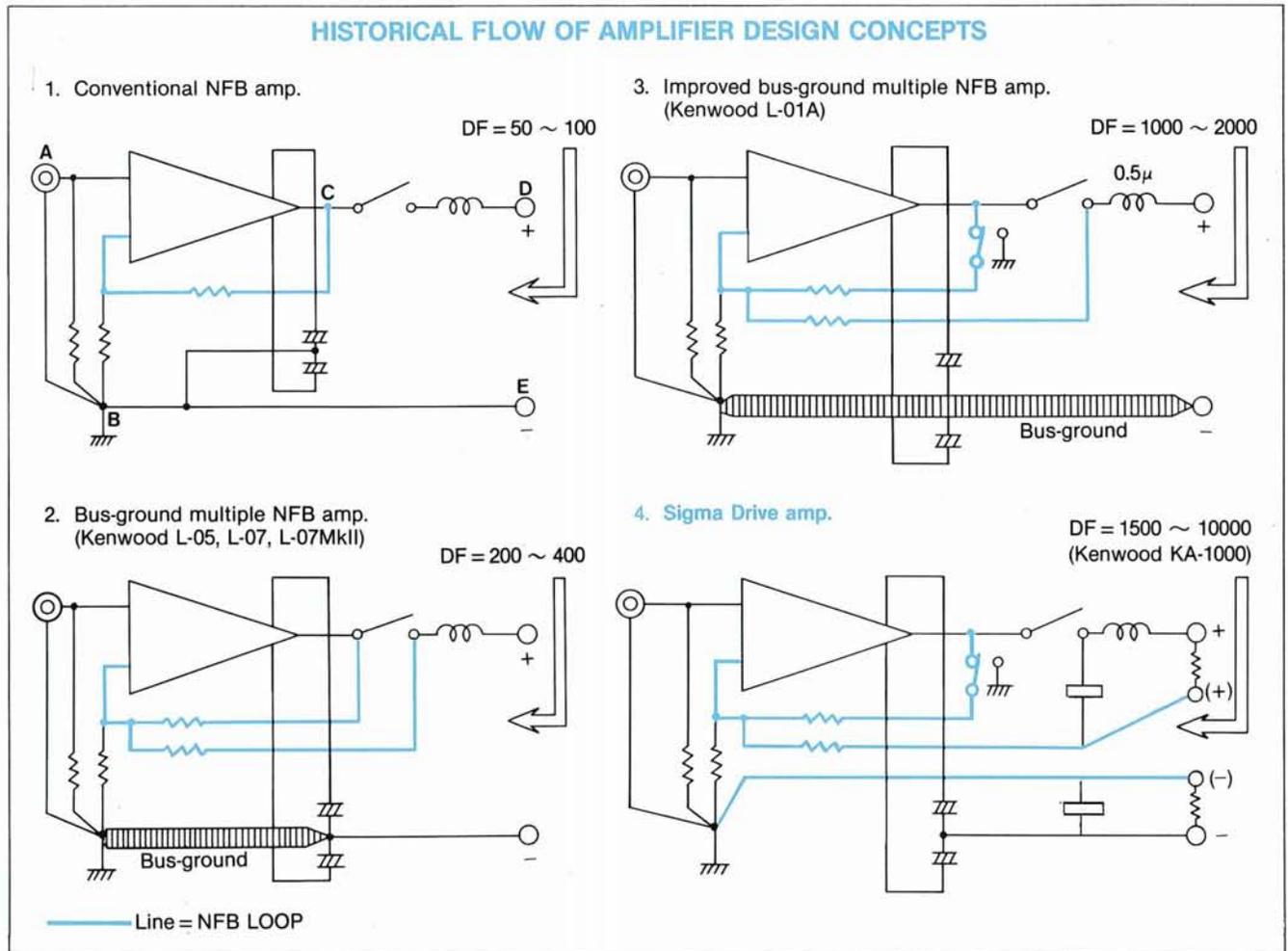
A new departure in negative-feedback technology

One of the cornerstones of the Sigma Drive system is the development of a highly advanced negative feedback circuit. Let's take a closer look at NFB to

see what influence it has on damping factor.

The four block diagrams of Figure 5 illustrate the present situation as regards power amplifiers, power

Fig. 5



sources, grounding procedures and related NFB techniques. All of these ultimately relate to the supplying of signals to the "maverick" load, the speaker. The diagrams show two points of emphasis: the establishment of the reference point for a NFB amplifier with respect to the signal, and the minimization of adverse effects which tend to deteriorate tonal quality and usually arise from the operation of relays, wiring materials, etc. within the NFB loop.

Naturally, there are many approaches to these design problems, based on consideration of A_b (negative feedback amount), output volume, performance, damping factor and so on. One problem is that numbers used conventionally to define damping factor (DF) are only relative and, in fact, are in no way a true indication of the DF of a NFB circuit. DF is simply one of the indices of the efficiency of a NFB amplifier, as, for example, the 1000 DF of the L-01A, which was determined from the bus-to-ground impedance.

In Figure 5-1, the conventional NFB circuit is shown. The signal is input at terminals A and B with the output measured between terminals B and C. The extent of inherent amplifier distortion is accepted as the percentage of distortion measured at this reference point between B and C. However, the actual output at the terminals D and E differs significantly from that applied between B and C. The difference is accounted for by the relays in the NFB circuit between B and C and the high frequency oscillation suppression coil as well as the influence of the impedance in wiring between points A and E. So far as the "hot" side is concerned, the conventional NFB amplifier provides no answers to problems of damping factor, and the ground has no definite reference point.

Figure 5-2 shows how Kenwood engineers originally dealt with the problem: a multiple-NFB configuration that can be seen in previous Kenwood models such as the L-05, L-07 and L-07 MkII. A second NFB loop was introduced between relays using the bus-ground strap between the input ground and the grounded side of the power capacitor. Thus a better reference point was provided.

A second major improvement can be found in the recent model L-01A whose redesigned multiple-NFB circuit is shown in Figure 5-3. Here, NFB is also applied from the same relay on the hot side through a transfer relay, via the bus-ground strap to the ground side of the output terminal. All the components except for the coil are included in the NFB loop. Since the bus-ground point is the ground itself, the reference point is outside the equipment proper and is therefore more meaningful.

The last diagram, Figure 5-4, shows the Sigma Drive layout, in which all components, including the coil, are included in the hot side of the loop. The current flowing has been isolated from the NFB reference point which is now definitely established.

The results of this advanced NFB design show up plainly in the damping factor. Damping factor with the conventional amplifier measures in the region of 50 to 100 while the NFB circuit of Figure 5-2 produces a damping factor of between 200 and 400. In the case of Figure 5-3, DF is over 1000. With the KA-1000, DF measures 1500 at the amplifier output. But theoretically, in "best case" operating conditions, Sigma Drive is capable of achieving an incredibly high DF in excess of 10,000.

Damping factor and the back-emf problem

During the early days of NFB application, it was considered desirable to increase NFB in order to produce theoretically higher damping factors. However, it became apparent to Kenwood engineers that the speaker could no longer be regarded as a simple constant load, but must be accepted as a generative force in its own right. The reason is that speaker drivers generate a counter-electromotive force (or back-emf) that varies according to the signal applied to it from the amplifier output. Tests at Kenwood showed that when a high-energy signal is cut abruptly, the cone tends to continue to vibrate, producing energy. This spurious energy is fed back to the amplifier via the speaker cords in the form of a voltage.

From such observations it is clear that ordinary damping factor gives no indication of an amplifier's ability to control dynamic speaker cone behavior. Moreover, damping factor begins to deteriorate rapidly at the first sign of slew-rate limiting, a major cause of TIM. Slew rate is limited by the phase compensation coil, which serves to raise amplifier output impedance. This is why damping factor is most often specified at a single test frequency (1 kHz) only. The link between damping factor and slew rate limiting is why the High Speed amplifier, with its high slew rate and rise time, is a critical development in the Sigma Drive system.

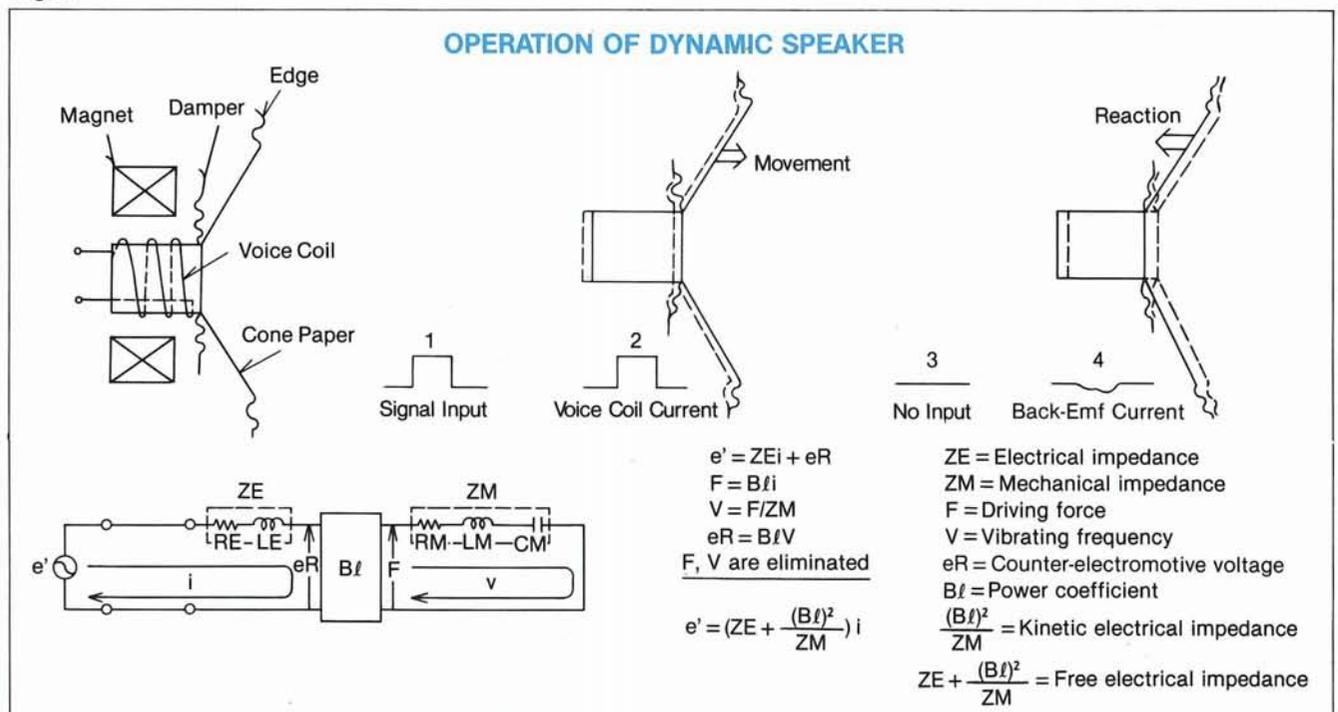
Kenwood engineers have now eliminated back-emf and attendant distortion products entirely from the amplifier-speaker arena. The theory rests on three important assumptions:

1. Speakers always generate back-emf energy values. (Fig. 6)
2. Back-emf appears as both voltage and current fluctuations.
3. Speakers respond to voltage fluctuations.
4. Distortion can be eliminated if the back-emf can be made to appear as only a current variation.

Since the output of the amplifier is a voltage variation across the output impedance of the amplifier, if this can be made to assume a zero value no spurious voltage will be generated. This would therefore effectively eliminate the extra component of the speaker back-emf which appears as distortion.

The idea is similar to reducing amplifier power source impedance in order to present a stable supply of power against fluctuations in impedance created by the speakers during dynamic music passages. This was the approach in the L-05 dynamic power supply system, later developed into the external dynamic power supply unit of the L-01A and KA-1000.

Fig. 6



A damping factor over 10,000?

Damping factor is the quotient of the speaker input impedance divided by the amplifier output impedance. Given the conventional value of 8 ohms for speaker impedance, it follows that the higher the damping factor, the lower must be the output impedance of the amplifier itself, as viewed from the speaker side. For the same reason, the impedance of the speaker cord should also be low. For example, a normal 10-meter low-impedance cord presents an impedance of about 0.24 ohm. Thus, the resultant actual damping factor value in this case, assuming an effective amplifier impedance of zero, becomes a low 33. With an amplifier output impedance of 0.08 ohm, the damping factor may be calculated as follows:

$DF = 8 \text{ ohm (speaker)} / (0.24 + 0.08) = 25$ approx, with a DF of 100 at the amplifier output. If the speaker

cord is 1 meter, not 10, the damping factor improves slightly:

$$DF = 8 / (0.024 + 0.08) = 77.$$

However, if a 1-meter cord is connected to the L-01A which has a DF of 1,000, this figure of merit becomes:

This gives the L-01A an impedance of 0.008 at the output terminal. The actual DF of the KA-1000 Sigma Drive system (including the cable) is:

$$DF = 8 / (0.013) = 600.$$

Thus, if the amplifier output impedance measurement at the end of the speaker cord can be made to be less than 0.0008, DF becomes in excess of 10,000. This shows the importance of DF in helping the Kenwood designer to decide the best method to eliminate speaker back-emf. **(Fig. 7)**

Fig. 7

CALCULATION OF STATIC AND DYNAMIC DAMPING FACTOR

Damping Factor = Speaker Input Impedance divided by Amp. Output Impedance

Theoretical: $\frac{\text{S.P. Imp. (*8}\Omega\text{)}}{\text{Power Amp. Circuit Imp.}}$ *Normal

Actual: $\frac{\text{S.P. Imp (8}\Omega\text{)}}{\text{Power Amp. Circuit Imp. + Relay Imp. + Coil Imp. + Ground Imp. + S P Cord Imp.}}$

Drive: how it works

The Sigma Drive system is something like applying the amplifier's electric tail to the speaker directly. The method is to expand the amplifier's NFB loop to include the speaker input terminals, thus effectively reducing all distortion generated at the output region of the system. Kenwood engineers have achieved this by arranging that the same value of voltage between the amplifier input terminal hot side and ground also applies between a similar configuration at the speaker input. This eliminates speaker input signal distortion, with the result that amplifier impedance is much lower

than usual. Speaker back-emf is eliminated by being converted into current.

Figure 8-1 illustrates the connection of an amplifier to a speaker in the conventional way, and will be used as a basis for comparing this circuitry with that improved by the use of the Sigma Drive amplifier. This diagram shows that NFB is applied on the hot side, at the front end of the relay, which permits the direct input of distortion from the relay, the oscillation suppressor coil and the speaker cord.

Fig. 8-1

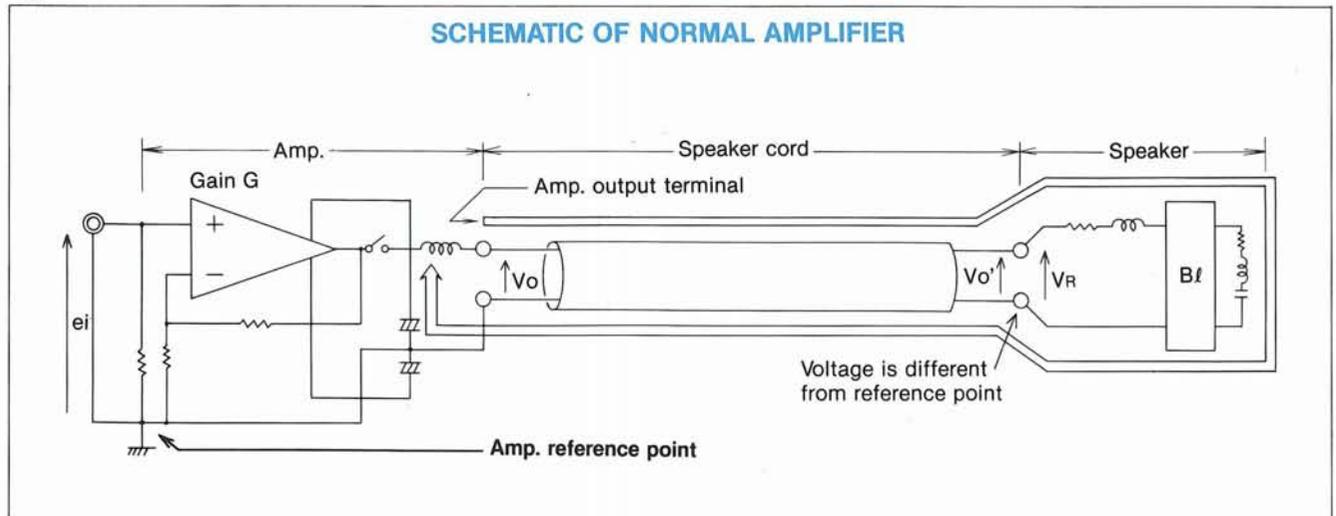


Fig. 8-2

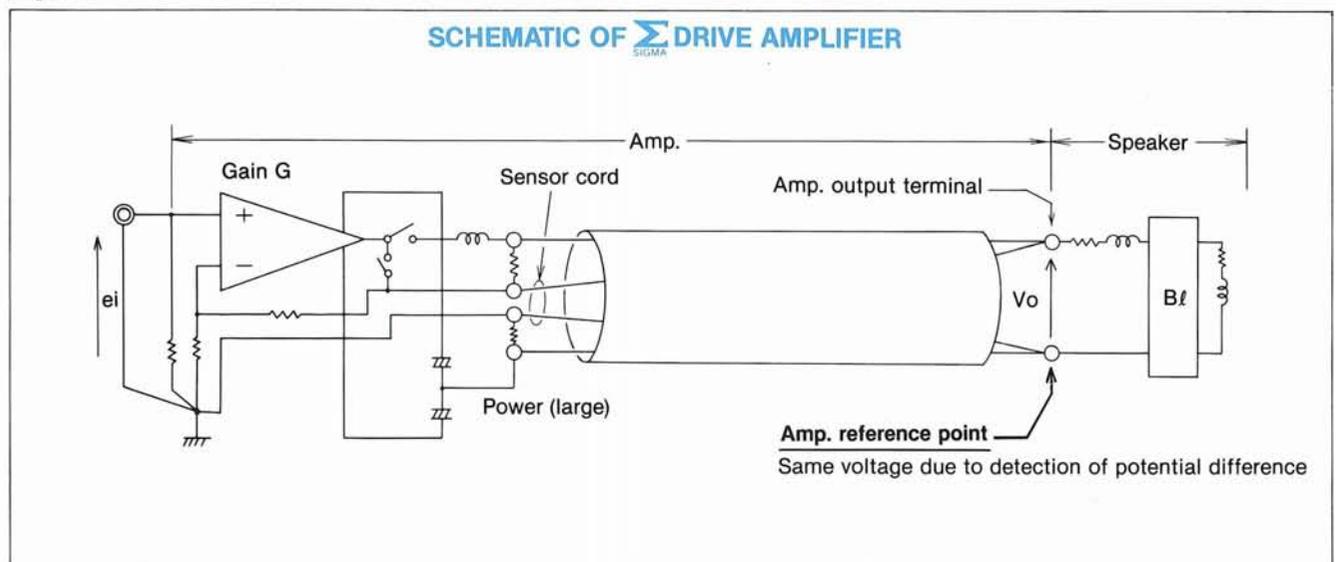


Figure 8-2 shows the Sigma Drive circuitry with the application of NFB to the speaker input terminal. In this way, all previously generated distortion is fed back after being reduced by a factor of $1/Ab$ (Ab signifies NFB amount). In Figure 8-1 the ground side reference point inside the amplifier (voltage reference) is at the input end. Thus, the extension of the bus-ground inside the amplifier and the speaker cord establishes the impedance value, so that the speaker input terminal voltage varies.

Sigma Drive is designed to equalize the voltage above ground at both ends of the system by connecting a voltage-sensing cord between the speaker input terminal and the amplifier input terminal with respect to ground. The impedance of this cord is negligible since the bulk of the current from the speaker to

ground will return to the power source, only voltage therefore being detectable. So if the amplifier impedance, when viewed from the speaker, is effectively reduced to zero, the back-emf of the speaker is converted into a current deviation which is absorbed by the power source.

Although improvements in amplifier performance have continually provided better specifications, the practical implication, from the listener's point of view, is the actual performance of the speaker. Sigma Drive assures that amplifier performance includes all components in the chain from the amplifier input terminal to the speaker input terminal. With Sigma Drive, the physical termination of the amplifier is its output terminal, but the electrical termination is the input terminal of the speaker.

Data speak the truth about Σ Drive

When it comes to data and measurement comparisons of Sigma Drive with conventional amplifier setups, the results are highly revealing. Figure 9 shows the measurement results obtained for Frequency vs Distortion made at the output terminal of an ordinary amplifier with an 8 ohm output impedance and a power output of 10 watts. It can be seen that the best value obtained within the frequency range of 20 Hz to 20 kHz is 0.002%. A speaker connected to it through a 10-meter cord will produce the distortion indicated. At a frequency of 20 kHz, this is 0.03%, while at 20 Hz, it rises to as high as 0.3%. The upper line in Figure 9 indicates use of a normal speaker cord, the lower line represents an improved low-impedance speaker cord. Even with the latter, considerable dis-

tortion is still present.

Figure 9 also shows the case when Sigma Drive is used, where distortion is held to below 0.005% over the entire frequency range from 20 Hz to 20 kHz.

Figure 10 compares frequency characteristics with and without Sigma Drive, measured at the speaker input terminal. The dotted line indicates the performance of an ordinary amplifier. Here, impedance increases 0.4 dB at the low end of the frequency range, and decreases to as much as -0.5 dB at 20 kHz. Looking at this, it is not difficult to understand why, for example, even for sophisticated amplifiers, RIAA equalizer deviation has not improved to better than ± 0.2 dB: there really has not been much point in improving this value.

Fig. 9

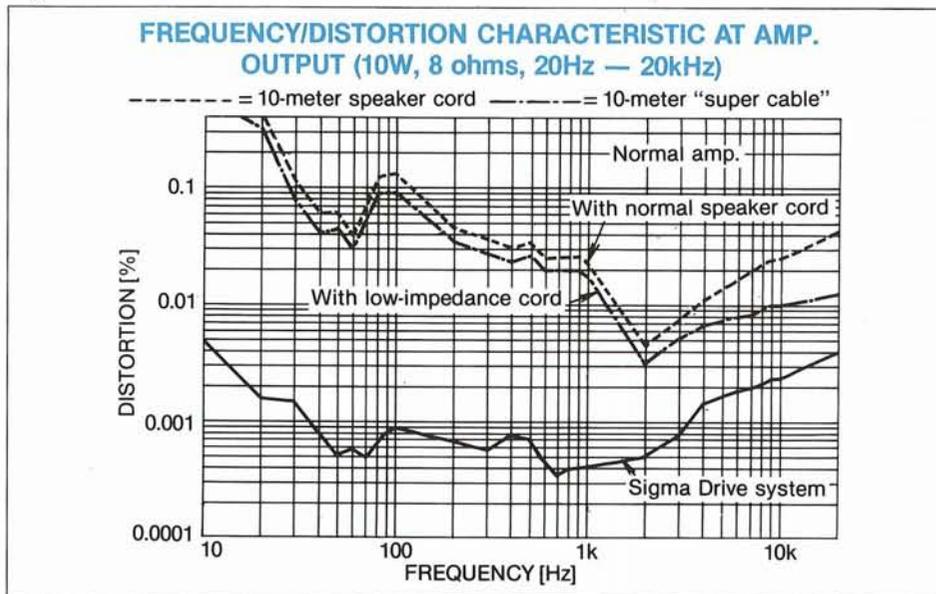
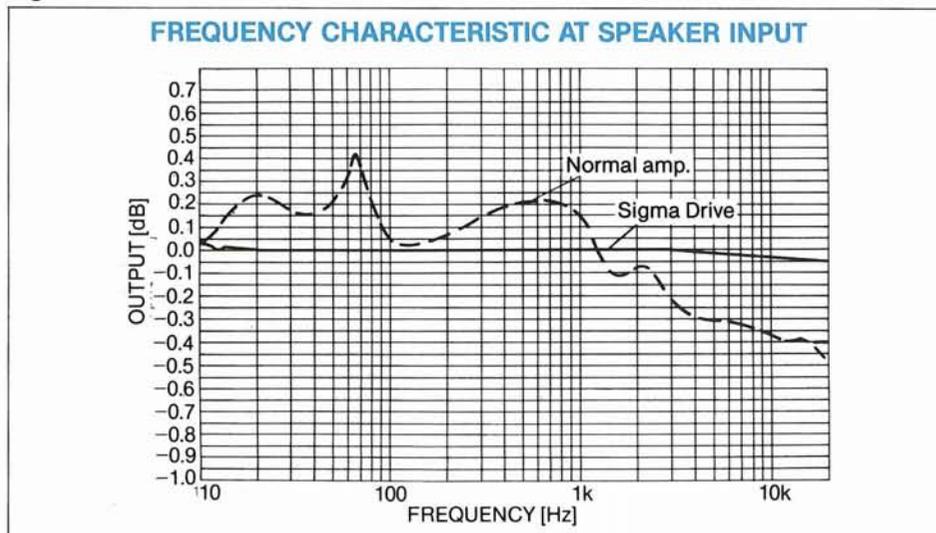


Fig. 10



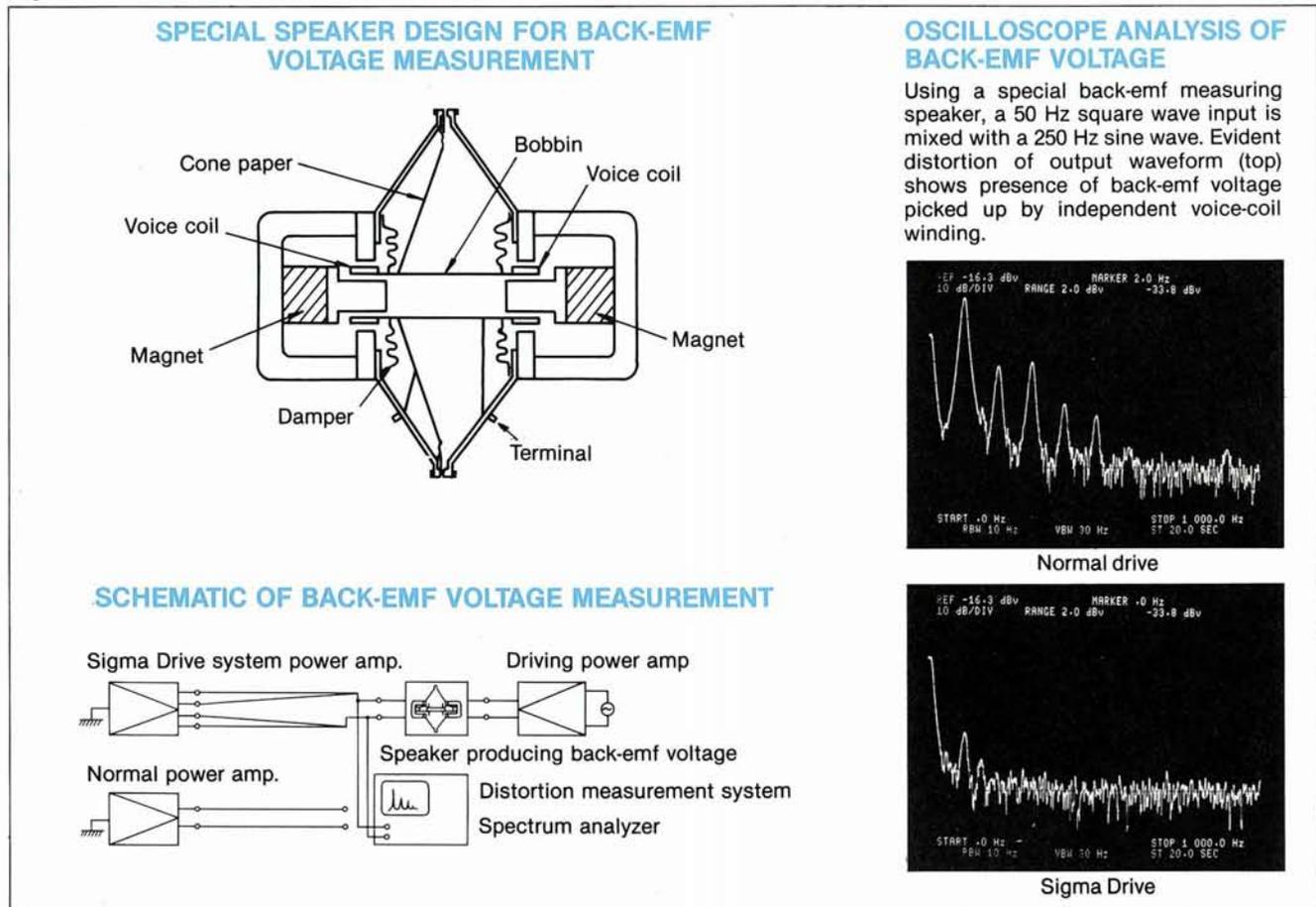
The solid line in Figure 10 represents the use of Sigma Drive. Performance deterioration is a slight 0.05 dB at 20 kHz, and within the frequency range there is no sign of unwarranted peaks and valleys in the response.

Back-emf present in the conventional speaker-amplifier set-up is the cause of variations in the response curves. But, since this back-emf is superimposed on the output wave-form, it is not possible to measure it alone by ordinary methods. However, in order to overcome this obstacle, Kenwood engineers designed a special-purpose speaker, shown in Figure 11, through which it has now become possible to measure back-emf independently of the signal. The schematic shows the

connection of a special driver amplifier to the speaker. When the signal arrives at the speaker, back-emf generated by the speaker is picked up by a special winding on the same coil form as the regular voice coil. When the power amplifier to be measured is connected to this coil winding, since there is no signal being sent from this amplifier, any voltage in the loop made up of the special winding and the output of the amplifier can be considered to be back-emf voltage. Since the speaker is electrically driven, it is possible to measure the degree of distortion by determining to what extent the back-emf has voltage variation associated with it. Results are shown on right.

Figure 12 shows the characteristics detected by a spectrum analyzer from the conventional amplifier;

Fig. 11



the ordinates of the graph depict the voltage as dB, while the abscissa shows the frequency spectrum of the applied signals. When a 20 Hz sine wave is applied at the input, a distinct fundamental wave results, and waves with a high harmonic content indicate that there are back-emf components on the order of -15.6 dB, compared with the reference value of -14.1 dB, almost the same value.

Figure 13 shows the result using Sigma Drive,

except a far lower value of -64.6 dB is obtained. Also, the high harmonic content, following the second trial, is significantly reduced in magnitude, and in fact is less than the critical measurement level (or less than the distortion from the spectrum analyzer).

Figure 14 and those which follow compare the spectral response of the ordinary amplifier and Sigma Drive amplifier, each at 100 Hz and 1 kHz. Clearly, the differences are remarkable.

Fig. 12

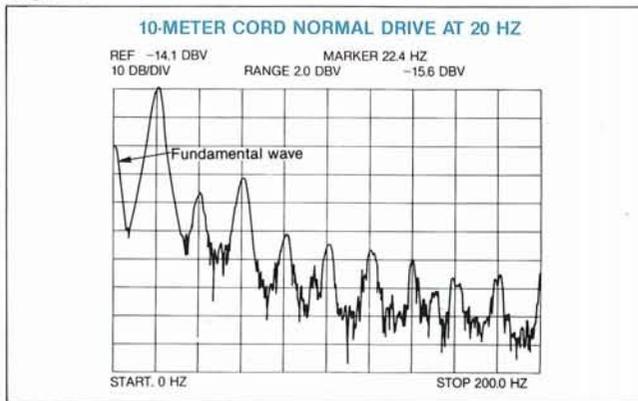


Fig. 13

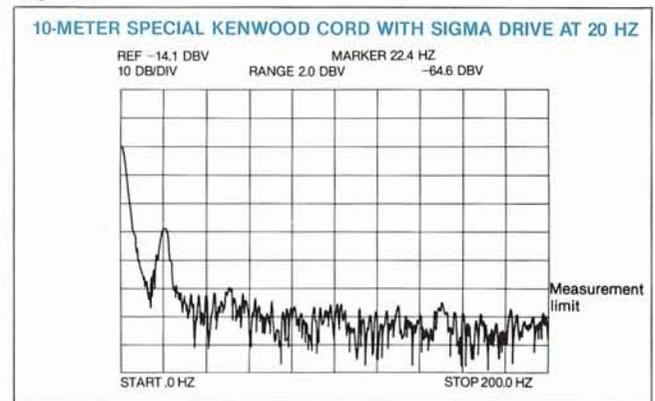


Fig. 14

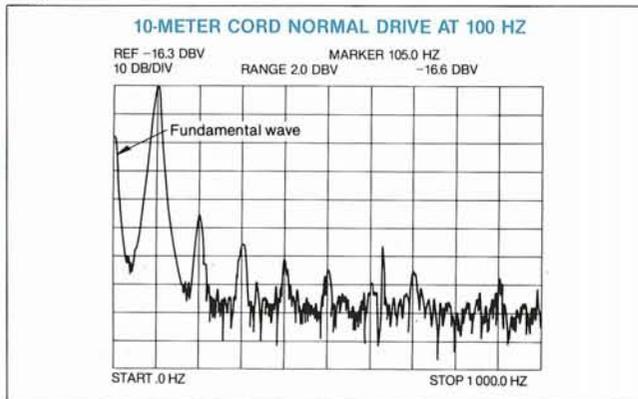


Fig. 15

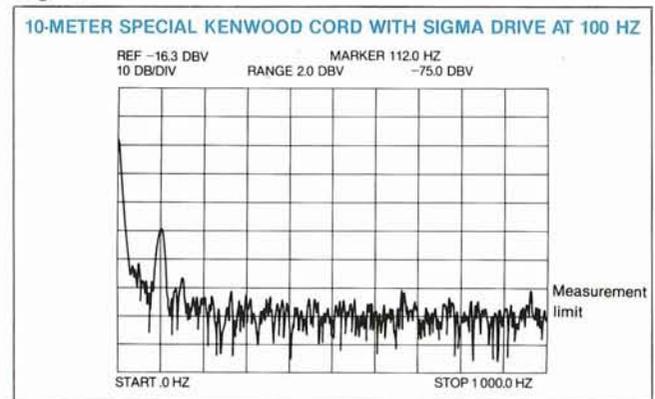


Fig. 16

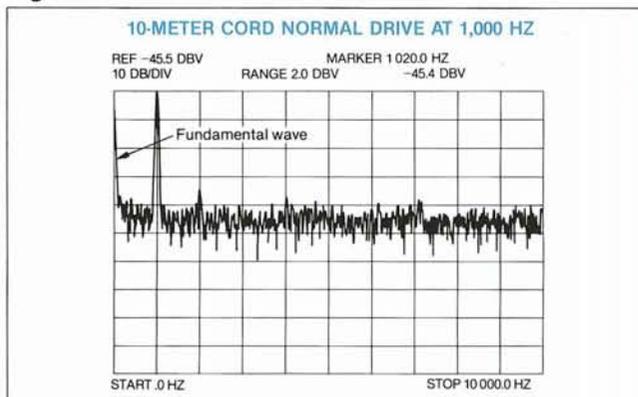
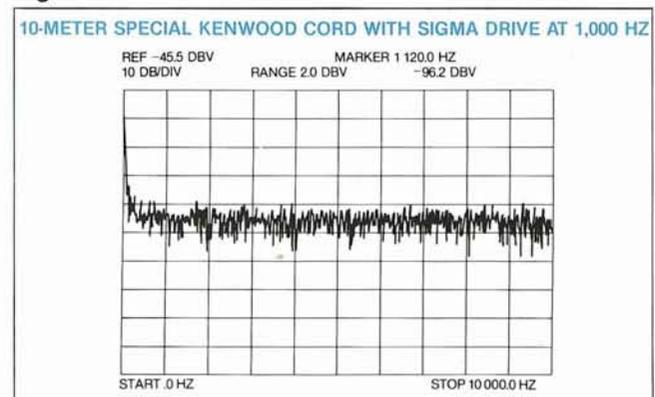


Fig. 17



The simpler the circuitry, the better the sound

The NFB amplifier is extremely difficult to design since it involves the problem of TIM distortion. This problem has been surmounted by reducing NFB time-lag, through the application of advanced High Speed design, in other words, making the device a "high speed" unit. A further problem however is that of NFB oscillation, which makes it virtually impossible to use NFB at high frequencies. For this reason, conventional NFB amplifiers have a reduced open-loop gain ranging from 1 kHz on up into the high frequency region. The difficulty here is that in the region over 1 kHz the amount of NFB is also reduced, resulting in proportionally increased distortion. (Fig. 18-1)

Graphs showing Power vs Distortion curves in various catalogs generally indicate that distortion in the 20 kHz region tends to be greater due to the inability of NFB to work effectively at higher frequencies. It thus becomes impossible to control distortion including the kind recently much discussed, switching and crossover distortion. There are two possible solutions.

One is the method of damping out the distortion usually noticeable to the operator of the equipment in the upper frequencies, by means of an additional circuit. Typical of this added type of circuit is the Variable Bias circuit developed by Threshold, and others such as the New Class A, Super Class A, Non-Switch-

Fig. 18-1

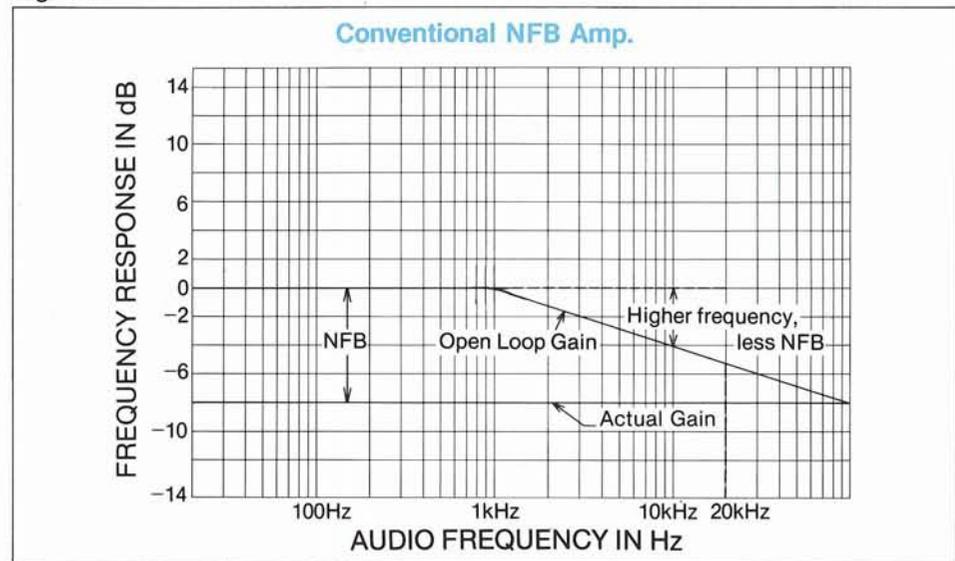
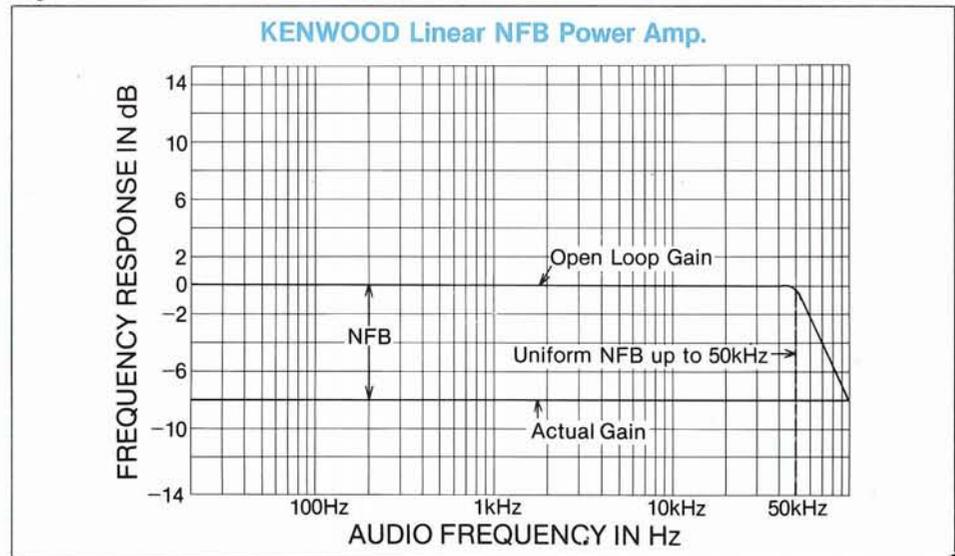


Fig. 18-2



ing, etc., all of which are circuits designed to reduce switching and crossover distortion occurring in Class B amplifier stages. However, Kenwood engineers believe there is a severe demerit in adding circuitry to solve a design problem, since quite often additional distortion problems arise.

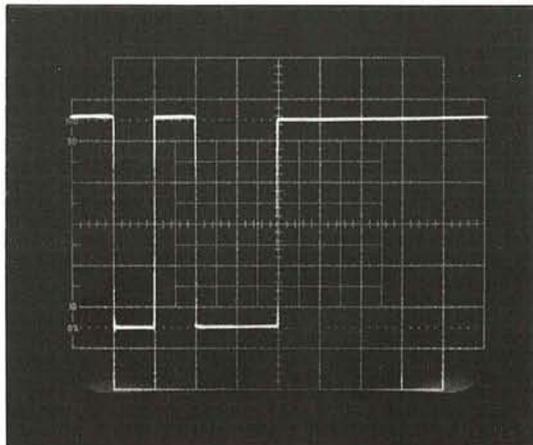
The other method is to try and provide sufficient basic gain at the high frequency end, and apply NFB equally at both ends. This method has, until now, been beyond the ability of most manufacturers who were therefore forced to compromise. Kenwood engineers, however, took up this challenge, having already reached a high level of NFB technology based on work with the High Speed amplifier. **(Fig. 19)**

Another important factor that enters the picture is the use by Kenwood engineers of square-wave testing to reveal dynamic distortion which does not show up in conventional sine-wave tests. In square-wave response tests, conventional amplifiers — even those

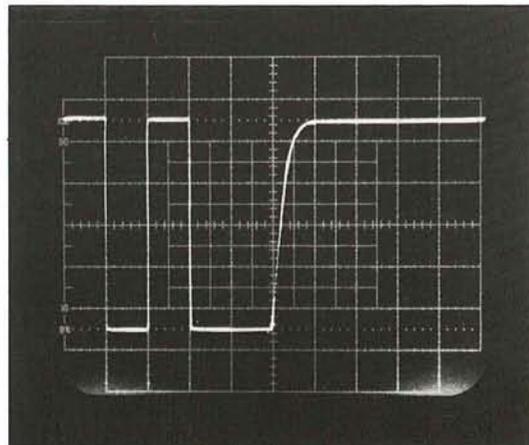
purporting to have high slew rates — can display considerable distortion, including overshoot and ringing effects. This indicates more than simple distortion: it is the condition immediately prior to oscillation. The problems involved in eliminating these effects and achieving circuit stability have for most audio engineers remained largely unsolved, preventing them from attaining any significant design improvements in the high frequency region. On the other hand, the superior high-speed response of the new Kenwood models KA-1000, KA-900, and KA-800 has enabled the achievement of a virtually flat open-loop gain response across the 20 Hz to 20 kHz range, even extending out to 50 kHz, through the application of NFB in a uniform manner throughout this range. This extended response has resulted in a virtually ideal main amplifier, free of distortion in the high frequency region. **(Fig. 18-2)**

Fig. 19

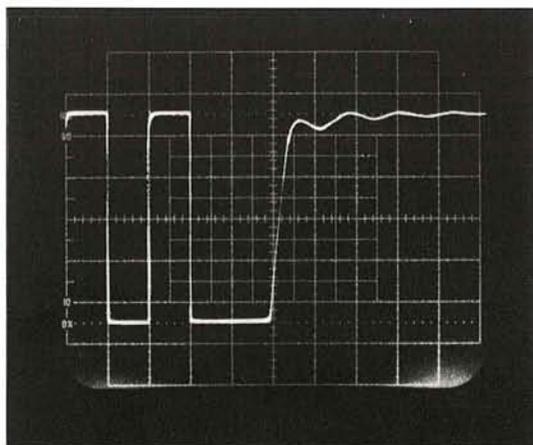
SQUARE WAVE RESPONSE



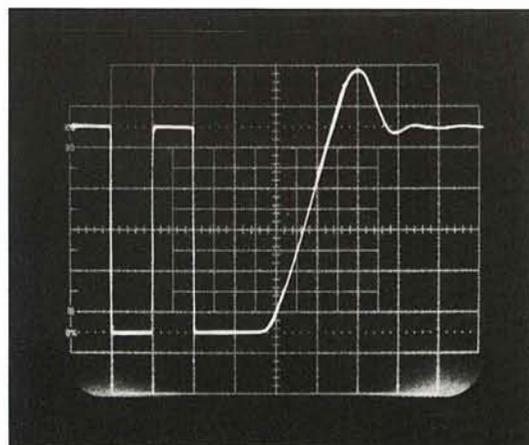
1. Pulse input



2. High-Speed amplifier response



3. An amplifier with ringing



4. An amplifier with overshoot

How the competition stacks up

Other manufacturers have developed other types of circuits but almost exclusively, attention has been directed to amplifier output impedance and ways of reducing it. What are the characteristics of these other amplifiers?

1. RO Control (Yamaha B-4 & A-9, etc.) Fig. 20-1

Impedance between the amplifier and the speaker is cancelled by sensing and feeding back the current through the speaker to the amplifier. This ultimately changes the impedance in the amplifier to a negative value.

Advantages:

— It obviates the need for a sensor cord.

Disadvantages:

- The connection of the speaker cord requires a small control which is practically impossible to supply. (No actual impedance can be detected).
- The added circuit incorporated in the NFB loop actually produces some impedance or even a further distortion.

2. Clean Drive (Aurex) Fig. 20-2

This is a stage of development beyond the RO Control which is intended to eliminate the need for the small control by making use of the speaker cord for this purpose.

Advantages:

— Any speaker cord can be used to cancel the impedance.

Disadvantages:

— As with the RO Control, the incorporation of an extra circuit in the NFB loop creates new distortion.

3. Remote Sensing NFB (Fidelix) Fig. 20-3

This is a BTL combination of two amplifiers, each of which is provided with an NFB circuit on the end of the speaker cord which is connected into the NFB loop.

Advantages:

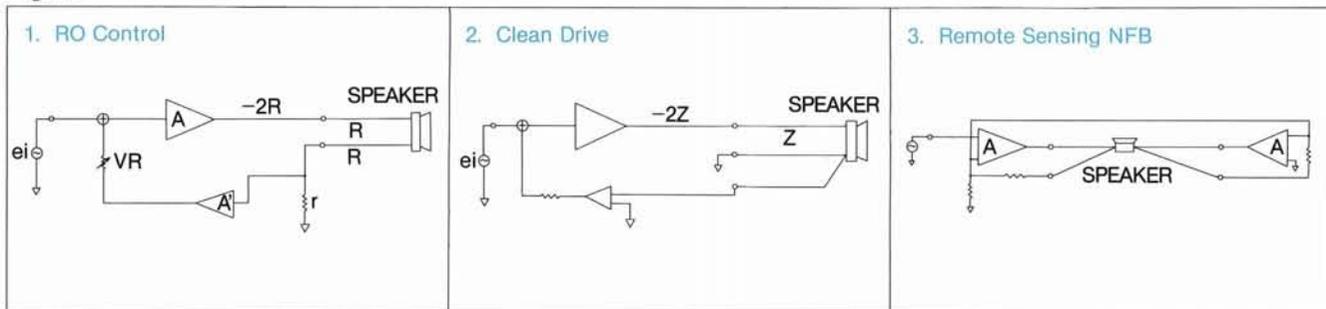
— Unlike the other two designs, it is free from extraneous circuits and therefore from the distortion they might produce.

Disadvantages:

- The BTL connection produces serious distortion during Class B amplification which cannot be improved by using Class A amplification.
- The speaker has a floating ground and cannot be connected to the switch case or selector unit in the audio showroom.

An evaluation of the above designs shows that in Designs 1 and 2 the circuits are designed to reduce distortion by attempting to lower amplifier impedance to zero. If this does not work accurately however, the impedance will drift to become either negative or positive. More importantly, additional circuits tend to complicate things by producing their own distortion. Although the designer has tried hard, he fails to provide something even close to the ideal solution. Design 3, itself like Sigma Drive, strives to minimize impedance by using a reduction method involving the application of NFB through the speaker terminal into the loop. Design 3 is at a disadvantage, however, in that the application of BTL creates distortion of its own, and since it is not possible to connect it to a switch selector unit, the amplifier cannot be demonstrated in the showroom.

Fig. 20



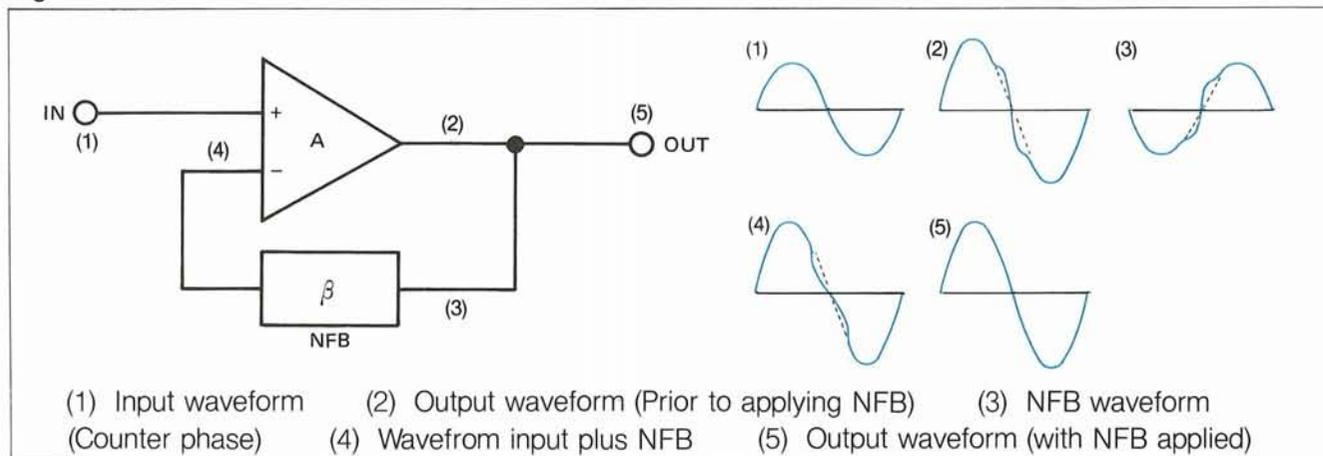
Notes and remarks

Note 1. NFB (Negative Feed-Back)

This is a circuit technology developed for controlling distortion created in amplifiers. Part of the signal

of the amplifier output end is converted to counter phase and feed back to the input side. In practice, the following figures indicate the pattern: **(Fig. 21)**

Fig. 21



Note 2. TIM distortion

The problem of dynamic distortion in NFB amplifiers was first outlined by Dr. Otara in Finland in 1970. NFB amplifiers exhibit a delayed-time characteristic in the feedback loop during sharp transient increases in input signal level. As the result, part of the signal in the high frequency range is lost and TIM distortion results. To solve the problem, Kenwood engineers worked on three possible remedies:

- (1) To increase slew rate to avoid amplifier saturation
- (2) To reduce frequency response at the input in order to avoid sharp transients
- (3) To reduce NFB and increase frequency response in the upper area of the audible range

Among the above possibilities, the narrow band resulting from (2) prohibits its use in hi-fi, while in (3), reduced NFB increases normal distortion and an increase in bare response leads to oscillation. So it is (1), in which a higher slew rate is provided, that offers the most chance of success. However, to ensure that reproduction up to 20 kHz is achieved without TIM, a response extending much higher than 20 kHz is essential. In ordinary frequency response, 20 kHz gain is delayed by -3dB , with phase delayed by more than 40 dB. Therefore, in order to obtain zero gain and zero delay, response must extend out to 200 kHz. Thus it can be seen why a high slew rate is important for NFB.

**Note 3. Threshold circuit
(switching and crossover distortion)**

In most power amplifiers today, the output stage is designed as a Class B amplifier single-ended push-pull (SEPP) configuration. This design employs bipolar transistors, with one amplifying plus potential and the other negative potential. At zero potential neither transistor is operative, but current cannot immediately be cut due to a carrier storage characteristic of transistors. Thus, the cut-off state creates switching distortion. To eliminate this distortion, the Threshold theory says that a small amount of bias current should be applied in order to prevent total cut-off of the transistors. This is basically what the so-called "Super A", "New Class A" and "Non-Switching" circuits are all about.

There is a further complication, however. The various fast-response power transistors that have recently appeared, such as the Ring Emitter Tr (RET) and Emitter Ballast Tr (EBT) to eliminate switching distortion produce another form of distortion, called crossover distortion, when operating at low bias current. In contrast, real Class A amplification applies a large bias current so that neither switching nor crossover distortion occur. Consequently, it is misleading to call fundamentally Class B amplifiers Class A. Quasi-Class A amplifier designs apply a small bias current, and for this reason, crossover distortion is still present. One way out of this is to use a wave-shaping circuit. But the demerits here are that it adds to circuit complexity and is not entirely effective at reducing ordinary THD. Thus, the superior Kenwood NFB design, by inherently eliminating both switching and crossover distortion products without added circuitry, represents the ideal.

Note 4. Feed Forward design

This is a theory, first proposed in 1928, which promises to improve amplifier distortion. In contrast with NFB application that reduces distortion by division, Feed Forward cancels distortion by off-setting it with negative distortion; in other words it is a reduction system. In theory it can obtain zero distortion. Its practical application did not come until the summer of 1980, in a design by Sansui. **(Fig. 22)**

It is a triple-stage design where the (A) Class-A input and (B) Class-B output stages are interposed by another amplifier (C) whose function is to detect and cancel distortion occurring in (B). (B) is a NFB amplifier. The merits and demerits of this design are as follows:

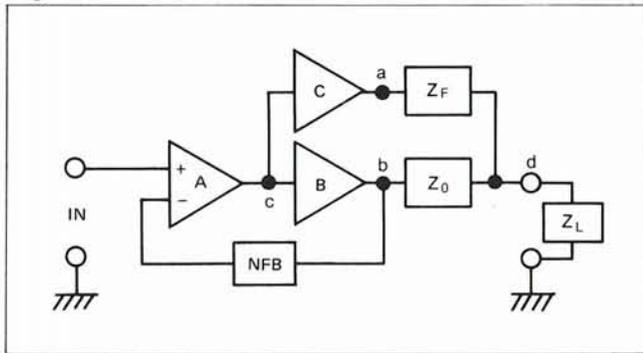
Advantages:

It offers stabilization of the amplifier and a wider frequency response than NFB.

Disadvantages:

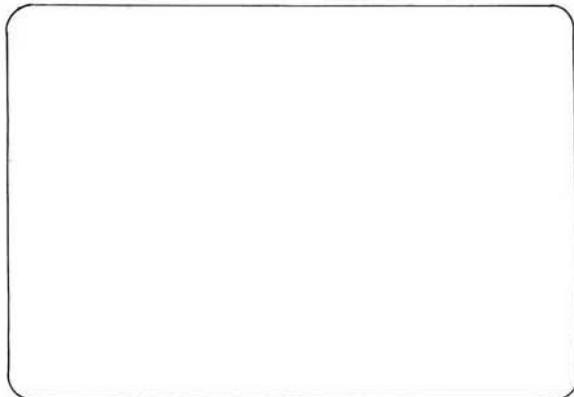
1. It would be good if the combination of NFB and Feed Forward were complementary. In fact, their characteristics contradict and the result is, after all, a compromise. Therefore, no significant improve-

Fig. 22



ment in distortion can be expected. Actually, distortion can only be reduced to the same degree that NFB alone achieves.

2. The distortion detecting amplifier (C) must be at least equal in performance to the other stages. And, since it is an additive circuit, it could easily create its own distortion products.
3. Damping Factor deteriorates.



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