Characteristics of LIMITER AMPLIFIERS

Maintaining a constant output for great variation in input level is the job of the limiter amplifier. However, some distortion can arise even when the limiter amplifier is functioning correctly.

THE limiter amplifier is a specialized member of the amplifier family. Any amplifier which, without human intervention, acts to change the amplification in a patterned manner is known as an automatic gain control (a.g.c.) amplifier. A.g.c. amplifiers are generally divided into two broad groups: those which act to increase the dynamic range of an audio program and those which act to reduce the dynamic range. The latter are called gain-reduction amplifiers.

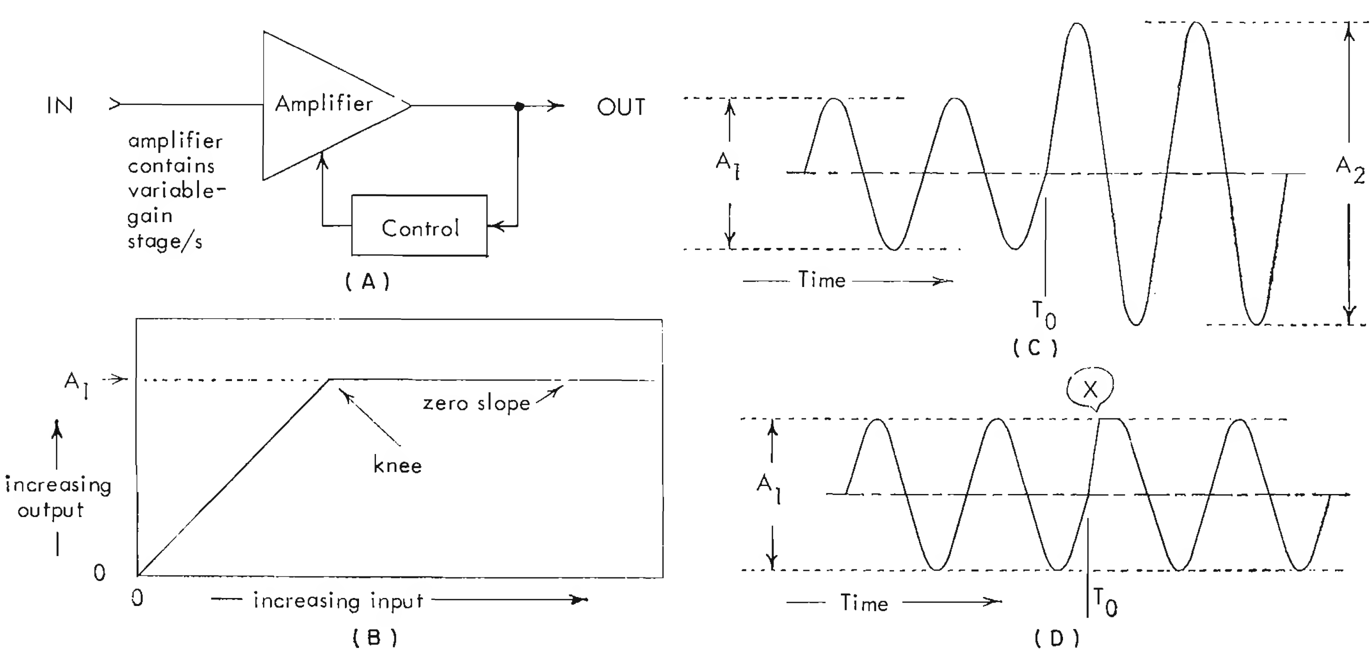
Some gain-reduction amplifiers are designed to compress the over-all amplitude fluctuations of an audio program into a lesser range and are aptly called compressor amplifiers. These usually have a rather slow acting time. But others are meant to act extremely fast and only when the audio signal reaches certain well-defined amplitudes. These last amplifiers are called limiter amplifiers.

The definitions contained in the foregoing two paragraphs are difficult to apply to many commercial units because the ingenuity of design engineers has resulted in "combination" devices. Unfortunately, even a bare listing of the various units which have appeared on the market would require much space.

Limiter amplifiers have been made in forward-acting and reverse-acting versions. The former reduces gain when an input signal reaches a certain amplitude, and the latter acts on the amplitude of the output signal. It is the reverse-acting type that we will discuss.

Fig. 1A depicts the system of the type of limiter under discussion. This is a feedback circuit in that a portion of the output is sampled to correct an "error." The error is defined as the degree to which the output signal amplitude exceeds the set "limit." No feedback system can ever completely

Fig. 1. (A) Block diagram of limiter. (B) Idealized limiting characteristics. (C) Input wavetrain. (D) The output wavetrain.



eliminate error; it can only reduce it. However, because good design can reduce limit overrun to a negligible factor, this property is not to be considered as a defect that is inherent in the system. It is only something to be recognized and minimized. (It is theoretically possible to design a forward-acting unit that has no increase or decrease in output past the limit point, but the problems entailed are formidable.) As a matter of fact, the limiter has only one inherent fault and that is the unavoidable generation of an unwanted transient signal when it "attacks." (It may be argued that the main defect of a limiter is that it does indeed change gain, the very purpose for which it is designed.)

Fig. 1B shows the input/output characteristic of the limiter amplifier shown in Fig. 1A. It is idealized, showing perfect limiting action and a perfectly sharp "knee." The 0 input point may be assumed to be the system background noise (lower limit of the possible dynamic range), and the $A1$ output point is defined as the desired upper amplitude limit to be imposed on system output. Practical units have sharp knees and low slopes; thus the idealized characteristics will suffice as a basis for discussion.

Let us examine what happens when the wavetrain in Fig. 1C is introduced to the input of the limiter. Note that the initial amplitude just reaches the output limit and that at time T_0 it increases from this value ($A1$) to a greater value ($A2$). The amplitude change occurs at the base line of the waves. The two amplitudes are assumed to be of perfect sine function, thus facilitating limiter action analysis. Further assumptions that apply to our "perfect" limiter amplifier are (1) the attack time (time required for the effective reduction of gain), which is zero, and (2) harmonic generation (except that associated with the limiting action itself), which is zero.

Fig. 1D shows the waves after passage. Amplitude $A1$ is unchanged, but $A2$ has been reduced to the level of $A1$, a change in gain having occurred at point X.

Our immediate interest is in the shape of the segment existing from T_0 to a point 90° later. It is evident that a transient signal has been generated and added to the wanted signal.

Bear in mind that this was done by our "perfect" limiter amplifier. The device has done exactly what it was designed for; it held the output to the "limit level." The gain change was not instantaneous; it began gradually at point X and stopped at the crest of the $A2$ input wave. Let us suppose for a moment that the output wave of Fig. 1D was not the result of action by an automatic reduction amplifier but resulted from the action of an incredibly agile human operator who turned down an attenuator control at precisely the right moment and at exactly the correct rate. The same transient would have been generated.

An enlargement of detail from Fig. 1D is shown in Fig. 2B. The rise portion of the wave is sinusoidal, for it is identical to the $A2$ wave in Fig. 1C. The falling portion (after the flat portion) is also sinusoidal. Fig. 2A shows the shape of the generated transient. It is also composed of two sine functions, being computed by subtracting a sine half-cycle from the wave in Fig. 2B. The amplitude A_x may be shown to be $A_x = A1\ [1-(A1/A2)]$. The formula is accurate for gain-reduction conditions: $A2$ must be greater than $A1$.

Overshoot, which is the result of long attack time, is shown in Fig. 2C. This generally occurs at very high audio frequencies in limiter amplifiers. However, long attack time is sometimes designed into compressor amplifiers, and overshoot may occur at frequencies above the mid-range. Overshoot is not particularly objectionable, providing the attack time is at least reasonably short. However, it may cause overmodulation of a radio station or overcutting of a disc recorder. Note also that the gain-change transient (Fig. 2A) is greatly suppressed by the overshoot.

Fig. 2D shows a condition known as thump or pop. It is the result of the gain-control signal getting into the program signal. (This was quite common with electron-tube limiter amplifiers.) Gain-reduction amplifiers which are subject to thump generation are generally equipped with balancing controls so that the user may adjust for the minimum effect.

The thump shown in Fig. 2D is actually quite moderate. Referring back to Fig. 1A, it will be seen that any gain-reduction amplifier which is subject to thump is actually regenerative for control signals and may actually be completely cut off by sharp transients.

Good gain-reduction amplifiers are difficult to design. To this date there has never been a good limiter amplifier on the market (domestic or foreign) that could be called adequate by discriminating audio technicians. This statement is made with full realization of the brilliant and ingenious design work which has resulted in the various highly useful limiter amplifiers in present use.

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Fig. 2. (A) A transient pulse. (B) Detail of Fig. 1D. (C) Example of overshoot. (D) An example of a thump transient.