A Solid State Transient Test Signal Generator*

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The "Tone Burst" commonly used for transient testing is not necessarily comparable to waveforms actually found in speech and music. A new test instrument is described which generates asymmetric and symmetric pulses as well as damped wave trains. Implications and test results are described for amplifiers, loudspeakers, and acoustic environments.

ALTHOUGH papers on audio transient-response testing techniques began to appear in this country shortly after the end of World War II, enthusiasm for this type of measurement does not appear to be particularly wide spread. Reasons for this might be found in nonstandardized test procedures, difficulty in interpreting test results, and, until recently, the lack of commercially available test equipment. In addition, numerical distortion values are more difficult to arrive at than in the case with the more conventional harmonic and intermodulation distortion measurements.

The most widely used form of transient test signal is the "tone burst" in which a number of cycles are gated from a continuous sine wave of fixed frequency to form an intermittent wave train. Somewhat differing results may be obtained depending upon whether the original continuous wave is interrupted in a synchronous manner, as in the General Radio 1396-A, or asynchronously, in which case turn-on and turn-off deformation of the signal may be produced. In either instance, no naturally occurring sound comes to mind which is comparable in waveform to this type of test signal, and it seems reasonable to explore the use of transients easier to generate and more closely related to those found in nature.

In general it is assumed that a large category of sounds found in speech, music, and noise are a consequence of impulses which are subsequently modified by the acoustic environment to produce sounds of both increased duration and altered spectral content. The variations possible are quite complex, and only a number of simple relationships are explored in the equipment to be described. Figure 1 illustrates a number of artificially generated waveforms. First, pulses, with fast rise and fall times, simulate initial acoustic shock disturbances; secondly, the original pulse shaped by coupling it to a highly damped resonant circuit; and, third, the damped oscillatory pattern of a lightly loaded resonance are shown. The final trace indicates the effect of coupling one resonant circuit to a second identically tuned one. In this instance there is both a gradual rise and decay of the harmonic components, and the trace resembles that of a simple modulated carrier with a fundamental frequency and an upper and lower sideband.

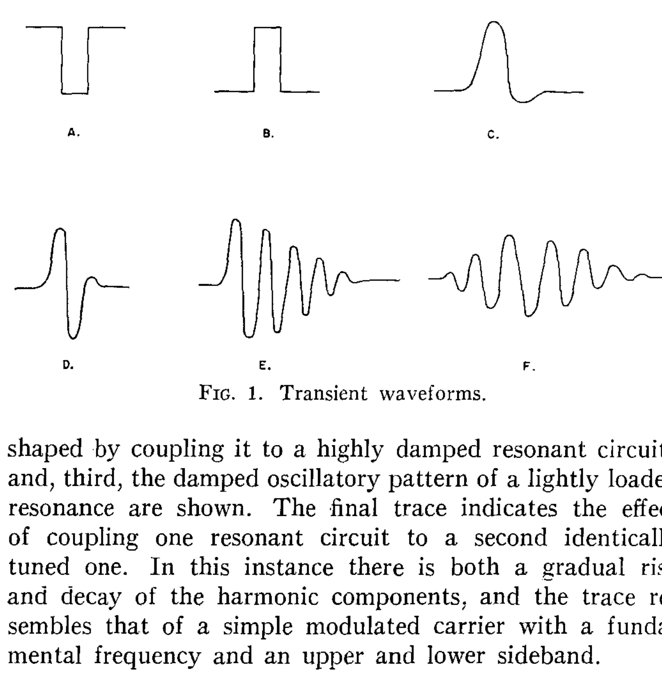

FIG. 1. Transient waveforms.

Means of generating the above waveforms are shown in Fig. 2, the block diagram of the transient test signal generator. A free running multivibrator is used to provide master timing of transient repetition rate, or alternately an external signal source may be employed. In either instance, fast rise time pulses are produced which then trigger a delay multivibrator to create a second chain of pulses with accurately controllable widths. An inverter is incorporated so that pulses of either positive or negative polarity are available at the equipment output.

In the second half of the system, the narrow leading edge of the pulse from the delay multivibrator is used to actuate a transistor switch, shock exciting a resonant element that may be varied in frequency and apparent "Q."

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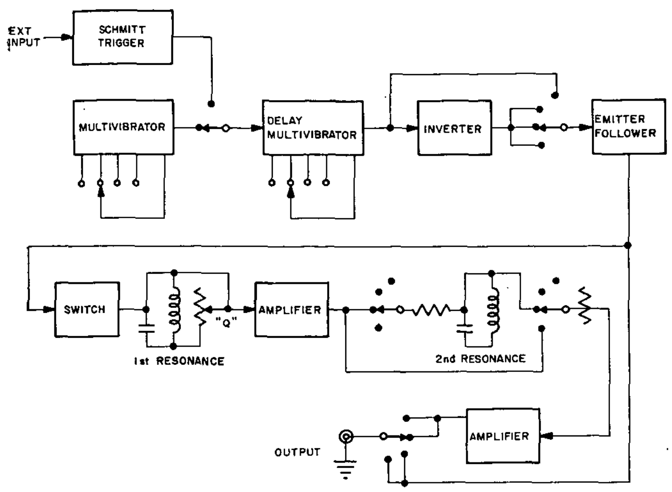


FIG. 2. Transient generator simplified block diagram.

The output of this circuit may be used directly for tests or fed into a second resonant circuit which may be tuned to the same or a different frequency.

Circuitry of the master timing section of the generator is shown in Fig. 3. The master timing multivibrator is tunable in four ranges from approximately one pulse per second to 100 pulses per second, with fine tuning being accomplished by varying the value of the base resistors. Alternate timing from an external source is achieved by using a Schmitt trigger circuit to produce pulses with fast rise and fall times. As only the positive transition in the output is subsequently used, lack of symmetry in either the Schmitt or multivibrator signal is not of consequence.

The master timing transition is coupled to a delay multivibrator in which the output pulse width is controlled by means of various values of capacitance between the collector of the first transistor, and the base of the second. Again, if fine adjustment is required it may be made by altering the value of the resistance in the base of the second transistor. As the output of the delay multivibrator is a negative going pulse, a DC coupled inverter is used for generation of positive pulses, and either may be switched to the input of an emitter follower which provides an AC coupled signal for external use.

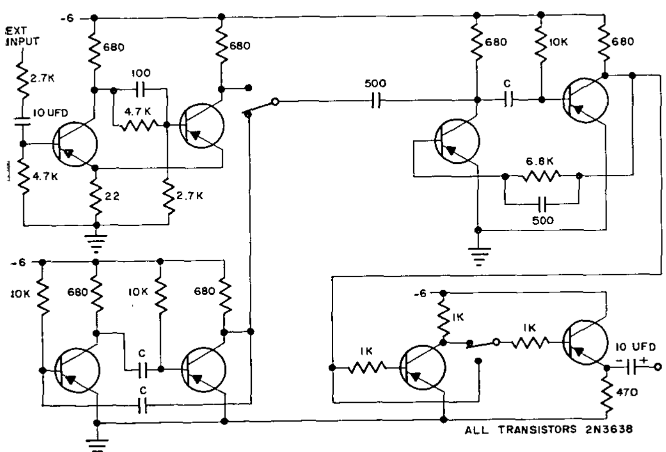


FIG. 3. Timing section of transient generator.

Figure 4 shows the pulse shaping or ringing portion of the generator. The transistor switch connected to the first resonant circuit is normally nonconducting, thus producing zero voltage drop across the RLC elements. Incoming pulses from the timing section are differentiated in the base circuit, and the leading edge of the pulse, being negative going, causes the transistor to conduct heavily with a resultant drop of nearly 6 volts across the RLC configuration. The switching transistor rapidly returns to its nonconducting state and the LC circuit is then free to oscillate at its natural frequency. As "Q" multiplication is not used in this circuit, it is desirable to minimize loading of the resonant elements in order to achieve reasonably long damped wave trains, and, as a consequence, the resonant circuit is "tapped down" by means of the two capacitors, the top one being approximately one fourth the value of the lower one. This signal is then fed into two cascaded emitter followers which serve to provide a relatively high impedance transformation ratio.

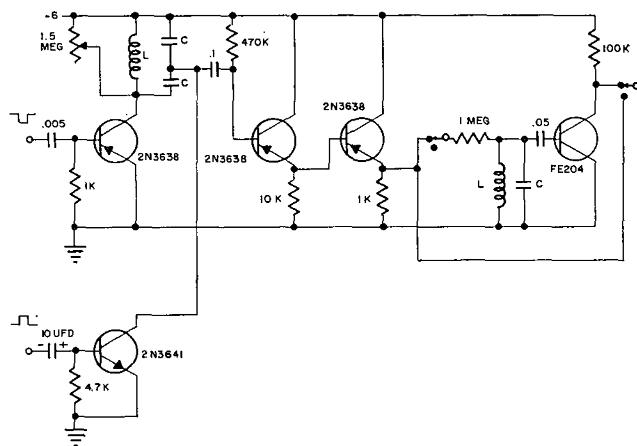


FIG. 4. Transient generator ringing section.

The output of the first ringing circuit may be used directly, or coupled to a second ringing circuit as shown. In this instance a one megohm resistor is used as a coupling device and the resultant low level signal is amplified by means of a field effect transistor which provides minimum circuit loading by virtue of its high input impedance characteristics.

Possibly the most unique portion of the system circuitry is the clamp transistor shown in the lower left hand corner. The reason for this circuit element is the fact that the method of shock exciting the first resonant circuit leads to deformation on the first half cycle of oscillation with a very steep initial wavefront being produced. This sort of effect can also happen in real life, but it was considered desirable to be able to eliminate it at the operator's option in order to prevent possible confusing secondary effects in tests. As the deformed first half cycle is positive going in the circuitry employed, an NPN transistor gate is used to clamp the oscillatory signal to ground for a period determined by the width of the delay multivibrator pulse. The

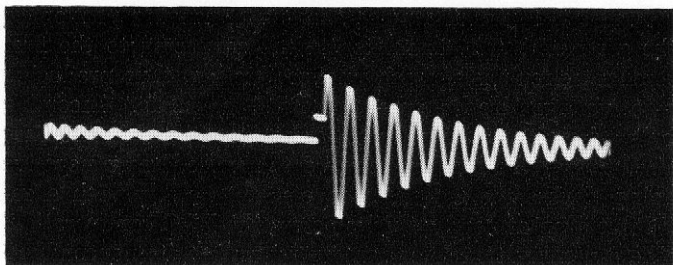


FIG. 5. Secondary deformation.

pulse width must be accurately adjusted to correspond with the oscillatory period of the LC circuit or a secondary deformation will occur as shown in Fig. 5. Proper adjustment of clamp pulse width results in a clean waveform as shown in Fig. 6.

Additional examples of signals produced by the transient pulse generator are the highly damped wavetrain shown in Fig. 7 and the modulated waveforms having moderate rise and decay times which produced the coupling of the two resonant elements as shown in Fig. 8. Figure 9 shows the effect of repeating this setup with the second

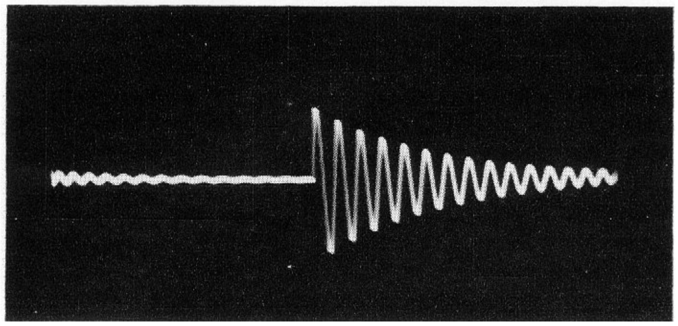


FIG. 6. Clean waveform.

element detuned by approximately 100 Hz with resulting envelope change and introduction of a slight beat.

The uses of the various test signals and the interpretation of results is a fairly complex subject, but a number of applications will be touched upon. First, the asymmetric pulses may be used to determine the effects of instantaneous amplifier overload which may result in the production of a spurious low-frequency waveform directly following the transient. Similarly, combining the pulse with a low-amplitude sine wave will indicate whether a change in amplifier gain occurs after instantaneous overload. Both polarities of pulse should be used in testing.

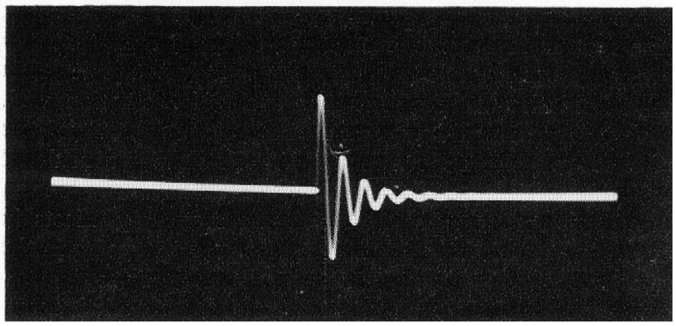


FIG. 7. Highly damped wavetrain.

The damped wavetrain may be used as a reasonably good simulator of voice waveforms for the test and adjustment of speech-amplifying equipment. Typically, the RMS value of these signals will be from 10 to 20 dB lower than a sinusoidal waveform of equivalent peak-to-peak value, and they can be of particular use in the evaluation of limiting or compressing devices.

A quick look at another form of compression or overload may be taken by using a slowly damped wavetrain to

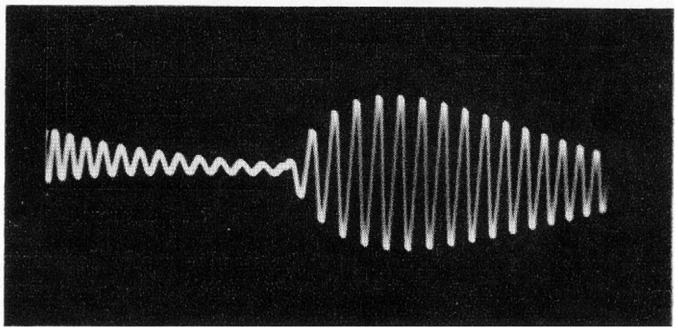


FIG. 8. Moderate rise and decay times—two coupled resonant elements.

examine the performance of tape recorders or electromechanical devices in which gradual nonlinearity, but not abrupt clipping, may occur. The fortunate possessor of such equipment used to be able to make louder TV commercials because of the resultant increase in average energy content of program material.

Both slowly and rapidly damped wavetrains may be used to test loudspeakers or other transducers, and as mentioned earlier, they probably much more closely resemble the signals actually handled than does the conventional tone burst.

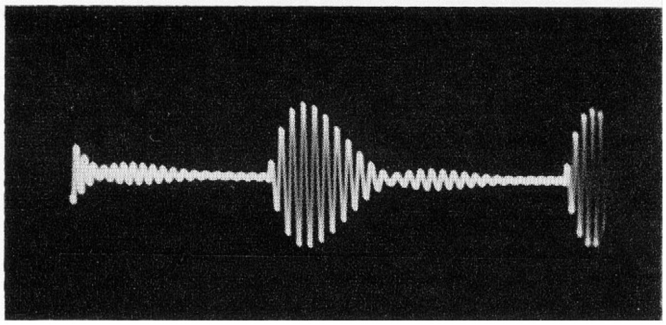


FIG. 9. Waveform when second resonant element is detuned by approximately 100 Hz.

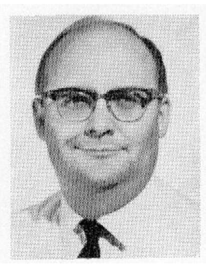
The damped wavetrain and the modulated output of the second resonant circuit may also presumably be used in a variation of difference tone testing through use of a low-pass filter at the output of the equipment under test, and comparison of the amplitude of the original signal to that of low-frequency demodulation products passed by the filter.

A miscellaneous collection of experimental data has been accumulated related to transient reproduction, though results have not extensively verified. First, it might be noted that a number of musical instruments appear to be essentially pulse generators, and some, such as the trombone, seem to produce relatively narrow, asymmetric, pulse waveforms due to the relatively low "Q" of the resonant elements. Reproduction of such instruments is complicated not only by the very poor ratio of peak to average energy, but also by the fact that nearly any reactive element in the audio chain will act to substantially reduce the amplitude of the initial half cycle of the reproduced waveform. Observation of the outputs of probably the most important reactive element in a reproducing system, the loudspeaker, have frequently indicated an initial half cycle amplitude reduction of 6 to 10 dB.

On the other hand, the asymmetric pulse may be strongly influenced by the acoustic environment in which it is propagated, and a series of reflections from differing path lengths may cause pulse "stretching" with the result that a listener, or microphone, located at some distance from the sound, may perceive a deeper and more powerful tone due to acoustic synthesis of fundamental frequencies.

Finally, though it is hoped that the use of damped wave trains of various spectral characteristics will be a useful tool in the examination of architectural acoustics, a test conducted in a medium size living room might be mentioned. In this instance the output of the test loudspeaker was a three thousand Hz sine wave modulated 100 per cent by a 60 Hz envelope. At the far end of the living room, approximately 20 feet from the loudspeaker, wall reflections had caused modulation depth to decrease to approximately 7 per cent. In listening environments such as this, the assessment of the consequences of both transient and intermodulation distortions originating in reproducing equipment becomes somewhat more difficult, and more sophisticated analytic approaches seem desirable.

THE AUTHOR



Glen R. Southworth was born in Moscow, Idaho, in 1925 and received his formal education at the University of Idaho. His professional experience has included extensive independent research, eight years on the Radio-Television staff of Washington State University, and four years as research engineer with Ball Brothers Research Corporation.

Mr. Southworth is currently the president of Colorado Video, Incorporated, which is primarily involved in research, design, and manufacture of laboratory instruments using video techniques. He is a member of the Audio Engineering Society, the Acoustical Society of America, the Institute of Electrical and Electronics Engineers, the Society for Information Display, and the Society of Motion Picture and Television Engineers.