The EIA-426-B Loudspeaker Power Rating Compact Disc What's on it? How do I use it?

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EIA STANDARD: EIA-426-B Loudspeakers, Optimum Amplifier Power

- "1.1 This standard was developed by the EIA R-3 Audio Systems Committee working group for study and revision of EIA-426-A, in response to a survey of loudspeaker manufactures which indicated a need to re-examine the current standard in the areas of test signal spectrum, test duration, and the calculation of power. EIA-426-A comprises an "accelerated life" test of full-range systems."

- "1.2 This document extends 426-A to include standards for performance with respect to power compression and distortion at the optimum amplifier power, and provides for a test signal on a compact disc, to improve test reliability and to facilitate and encourage wider use of the standard."

EIA STANDARD: Cont:

- "1.3 Whereas EIA-426-A rated the ability of a loudspeaker to handle power – a concept of little practical use – the revised standard, 426-B, recommends the maximum power rating for an amplifier to be connected to the loudspeaker. This could be considered to be an "optimum" power match, as this is the most power which can be delivered to the speaker while permitting the speaker to operate within acceptable limits of performance as defined by EIA in this standard under the categories of power compression, distortion, and accelerated life testing."

What's on it?

- Test Signals Specified on CD by EIA Standard
  - Amplitude Calibration Tone
  - Accelerated Life-Test Noise
  - Power Compression Test Variable-Rate Sweep
  - Pure Tones for Distortion Tests (20 Hz to 5 kHz)
- Bonus Signals
  - Additional Pure Tones (6.3 kHz to 20 kHz)
  - Shaped Tone Bursts (10 Hz to 20 kHz)

What's on it? Cont.
Bonus Signals

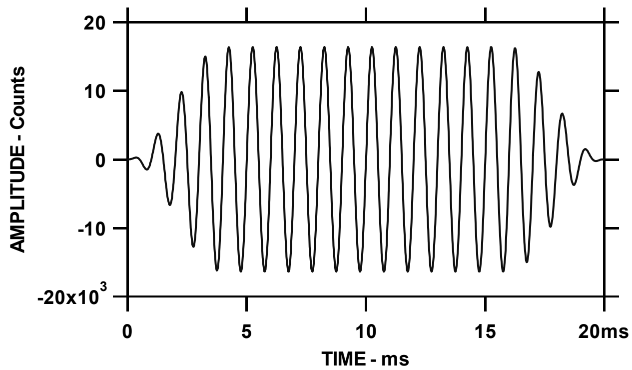
- Shaped tone bursts are provided that are useful for the following measurements:
  - Peak electrical input power and maximum peak SPL of loudspeakers
  - Peak output power of amplifiers
  - Headroom tests of electronic and acoustic systems
  - Frequency response tests of electronic and acoustic systems
  - Energy decay in acoustic spaces
  - Delay and phase/polarity tests of electronic and acoustic systems

What's on it? Cont.
Amplitude Calibration Tone

- Purpose
  - This track contains a 1 kHz pure sine wave signal which is used to calibrate the amplitude of the remaining test signals on the CD.
- Specification
  - 1 kHz sine wave, -9 dBFS rms level (-6 dBFS peak level), one minute length, ramps added to beginning and end to minimize clicks/pops.

Waveform of 1-kHz Amplitude Calibration Tone

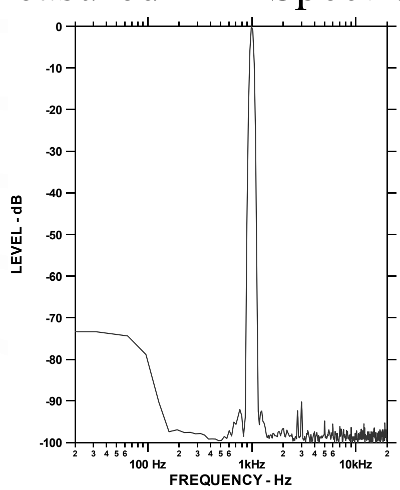
(Shortened to illustrate start and end ramps)



Note: Four-cycle half-Hann ramps added to start and end of tone.

Amplitude Calibration Tone

Measured FFT Spectrum



What's on it? Cont.
Accelerated Life-Test Noise

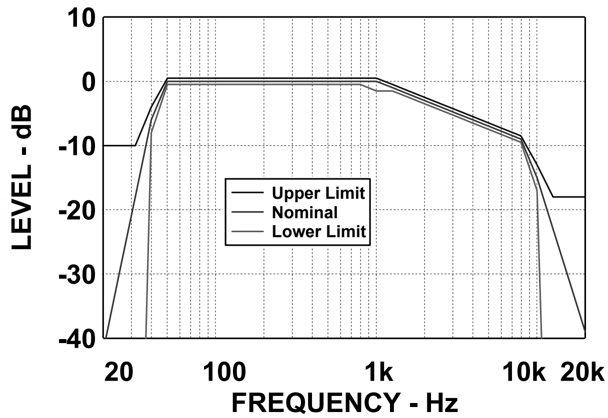
- Purpose
  - The band-limited spectrally-shaped noise signal provides a test stimulus for accelerated life tests of loudspeakers.
  - Quoting the standard: "This procedure simulates the working life of the speaker by testing its ability to withstand a test signal at half the optimum amplifier power for an extended duration without suffering an irreversible and unacceptable change in performance parameters or integrity." …..
  - "The criterion for passing this test is that the speaker not acquire a permanent shift in parameters such as free-air resonance frequency." The standard defines an "extended duration" as eight hours.

What's on it? Cont.
Life-Test Noise: Cont.

- Specification
  - The standard specifies spectral-weighted Gaussian noise, soft clipped to a crest factor of 6 dB and lasting for 30 minutes.
  - The specified weighting (as measured by a constant percentage bandwidth analyzer), band limits the noise to 40 Hz and 10 kHz, is flat between 40 Hz and 1 kHz, and then rolls off at 3 dB/octave (10 dB/decade) between 1 kHz and 10 kHz. The band limiting is accomplished by a 40-Hz high-pass filter of at least 6^{th}-order minimum and a 10-kHz low-pass filter of at least 4^{th}-order minimum, both maximally-flat Butterworth types.

Life-Test Noise: Cont.

Spectrum Specification



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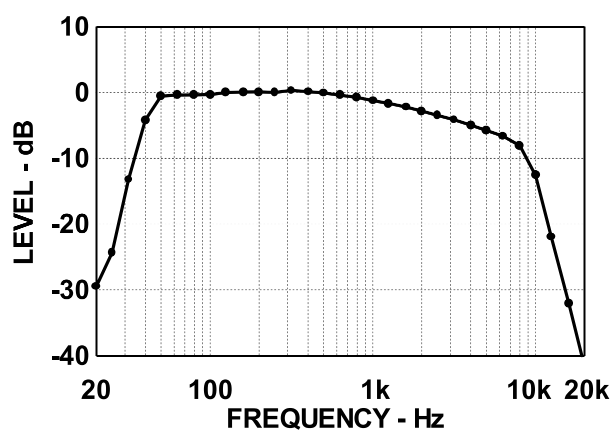
What's on it?, How do I use it?

Life-Test Noise: Cont.

Measured Third-Octave Spectrum



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What's on it?, How do I use it?

Life-Test Noise: Cont.

SOUND DEMO

What's on it? Cont.
Power-Compression Test
Variable-Rate Sweep

- Purpose
  - The variable-rate sinewave sweep test provides a test signal to assess the degree to which the acoustic output of the speaker is compressed as the input level is raised. The low crest factor of the sine sweep maximizes amplifier power.
  - The standard specifies that the speaker passes the power-compression test if it is tested at its rated optimum amplifier power and suffers no more than 6-dB of compression in each one-third-octave band from 40 Hz to 10 kHz or through the bandwidth specified by the manufacturer. The reference for this test is a spectrum gathered when the input to the speaker is 20-dB below the optimum amplifier power.

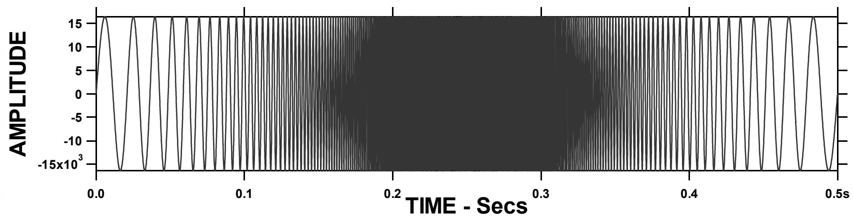
Compression Test Sweep: Cont.

- Specification
  - The standard specifies a variable-rate swept sine wave of constant amplitude with a power spectrum that matches the spectrum of the life test noise on track 2 and lasts for 10 minutes. The signal is composed of a sequence of 0.5-second up-down sweeps whose duration is "chosen to be fast enough not to burn out tweeters, but not so fast as to produce modulation artifacts."
  - A single 0.5-second up-down sweep is to be composed of a 0.25-second 40 Hz to 10 kHz upsweep followed by a 0.25-second 10 kHz to 40 Hz downsweep.

Compression Test Sweep: Cont.

- Errors in Specification
  - Original
    - The standard further specifies that the variable-rate sweep "requires a sweep rate <u>proportional to the square root of frequency from 40 Hz to 1 kHz and directly proportional to frequency from 1 kHz to 10 kHz.</u> The sweep rate function of frequency is continuous at the 1 kHz transition."
  - Corrected!
    - Note: Subsequent investigation revealed that the standard's underlined quote in the previous paragraph is incorrect, and should read: requires a sweep rate *directly proportional to frequency from 40 Hz to 1 kHz and proportional to the square of frequency from 1 kHz to 10 kHz.*

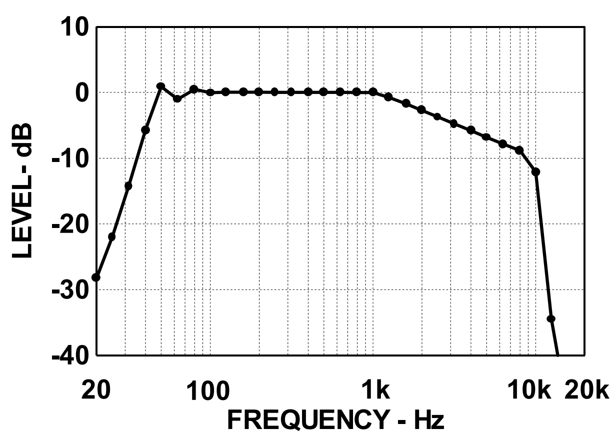
Waveform of Single Up-Down Sweep



- Sweep Composition
  - The first half of the signal is composed of a 40 Hz to 1 kHz log sweep from 0 to 0.1925 seconds, and a 1 kHz to 10.25 kHz square sweep from 0.1925 seconds to 0.25 seconds. The last half is an inverted time-reversed version of the first half.

Compression Test Sweep: Cont.

Measured Third-Octave Spectrum



Compression Test Sweep: Cont.

SOUND DEMO

What's on it? Cont.
Pure Tones for Distortion Tests

- Purpose
  - Quoting from the standard: "This procedure measures harmonic distortion at the optimum amplifier power using sinewave test signals at one-third-octave spaced IEC center frequencies." ….. "Apply the sequence of sine wave test signals to the speaker at the optimum amplifier power. Within its specified bandwidth, the speaker shall generate harmonics whose RMS amplitude is less than that of the fundamental."

Pure Tones for Distortion Tests: Cont.

- Specification
  - A series of sine waves at all the preferred third-octave center frequencies from 20 Hz to 5 kHz. (Four-cycle half-Hann ramps were added to the start and end of track to minimize clicks/pops.)
- Bonus Test Tones
  - Sine waves at 6.3, 8, 10, 12.5, 16, and 20 kHz

Pure Tones for Distortion Tests: Cont.

SOUND DEMO

What's on it? Cont.
Bonus Tone-Burst Tracks

- Purpose
  - These bursts are intended for use as a test stimulus for frequency-dependent short-term peak power assessment and headroom of loudspeakers and electronics, and for testing the frequency response, energy decay and narrow-band phase/polarity of systems.
- Specification
  - A series of 6.5-cycle shaped tone bursts at all the third-octave center frequencies from 10 Hz to 20 kHz. The burst's energy is constrained to a one-third-octave bandwidth. Repeat at rate of one burst per second on left channel and one burst per ten seconds on right channel for 30 seconds.

Tone Burst Equation

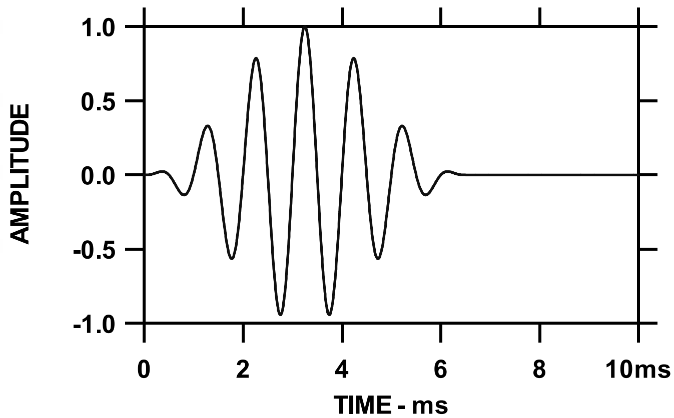
- A 6.5-cycle Hann-windowed tone burst given by the following equation:

$$f(t) = \begin{cases} \left(1 - \cos\frac{2\pi f_0 t}{6.5}\right)\frac{\sin 2\pi f_0 t}{2} & \text{for } 0 \le t \le \frac{6.5}{f_0} \\ 0 & \text{otherwise} \end{cases}$$

Where: $t =$ time, seconds

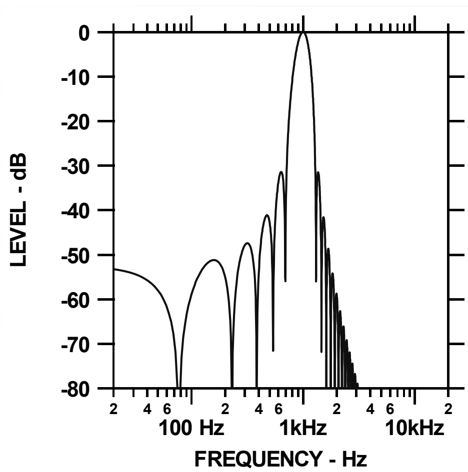
$f_0 =$ burst center frequency, Hz

Waveform of 1-kHz 6.5-Cycle Shaped Tone Burst



Spectrum of Shaped Tone Burst

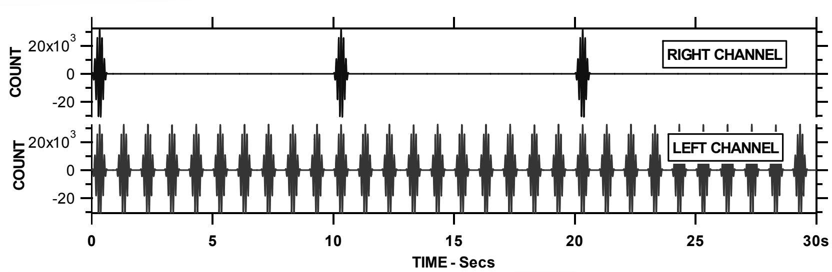
(Exhibits one-third-octave wide spectrum)



Crest Factor of Shaped Tone Burst

- Definition
  - The crest factor is the ratio between the peak level and the rms level of a signal evaluated over a specific time interval.
- Burst Crest Factor
  - If this burst is repeated end-to-end with no space between bursts, the crest factor is approximately 7.3 dB. Repeated at a slower rate the crest factor is appropriately higher. Example: If the 1-kHz burst is repeated at one burst per second, the crest factor is 29.1 dB (42.1 dB for a 20-kHz burst).

Track Layout for 10-Hz Bursts



Left channel crest factor = 9.1 dB

Right channel crest factor = 19.1 dB

Note! 50ms of silence was added to the start of each burst track to insure that the first burst is played back properly on all CD players. The inter-track mute on some CD players mutes part of the data at the start of each track due to slow release of the mute function.

Bonus Tone-Burst Tracks: Cont.

SOUND DEMO

How do I use it? Required Test Gear

- For EIA-426-B Tests
  - EIA-426-B Loudspeaker Power Rating Compact Disc
  - Compact disc player with "Track Repeat" function
  - Power amplifier (minimally rated at the required test power)
  - True RMS voltmeter with ac bandwidth of at least 40 Hz to 10 kHz
  - Audio sine wave generator covering at least 40 Hz to 10 kHz.
  - 1/3rd-octave real-time audio spectrum analyzer using class 2 or 3 filters, capable of displaying "total SPL"
  - Measuring microphone, omnidirectional, flat frequency response from 40 Hz to 10 kHz ±0.5 dB, maximum 140 dB SPL (minimum), and microphone preamplifier.
  - Switched 20-dB attenuator (schematic in standard)
- For Tone Burst Tests
  - All the above
  - Oscilloscope (one of the new digital scopes with waveform measuring capabilities would be great!)
  - Instantaneous-peak reading voltmeter (not very common!) Scope will work here but can use DVM peak voltage measuring adapter (see Keele AES paper).

How do I use it?: Cont. Conditions

- The loudspeaker shall be tested as the manufacturer specifies it to be used.
- Test in a room with ambient temperature 25°C ±5 C and relative humidity 30% to 80%
- CAUTION: Wear Ear Protection!
- Test Sequence:
  - 1. Set level using 1-kHz calibration tone (track 1)
  - 1. Power compression (least stressful) (track 3)
  - 2. Distortion tests (tracks 4 - 28)
  - 3. Accelerated life test (track 2)

How do I use it?: Cont. The 1 kHz Calibration Tone (Track 1)

This signal provides a level-setting signal for all the following tracks. The operator should set the power level when playing this track and then all the following tracks (tracks 2-34) will be at the correct power levels for their respective tests.

- Calculate test voltage: $= \sqrt{\text{OptimumAmplifierPower x RatedImpedance}}$
- Example: assume you want 100 Watts across an eight-ohm load. Calculate: $V = \sqrt{100 \text{ x } 8} = \sqrt{800} \approx 28.3 \text{ V}_{rms}$ While playing track 1, set the power amplifier output voltage to 28.3 Vrms. This will automatically provide a power of 100 Watts for the compression and distortion tests (tracks 3-34) and 50 Watts for the life-test noise (track 2), when these tracks are played.

How do I use it?: Cont. Compression Test (Track 3)

This procedure tests the degree to which the acoustic output of the speaker is compressed at the optimum amplifier power

- Procedure (in brief)
  - 1. Place test microphone in close-mic position (refer to Keele Near-field paper).
  - 2. Apply variable-rate swept sine wave test signal (track 3) at an amplitude 20 dB below optimum amplifier power (1/100th power!).
  - 3. Record reference spectrum of acoustic output with real-time analyzer.
  - 4. Raise level to 6 dB below optimum amplifier power (1/4th power) and listen for distortion and observe spectrum on real-time analyzer. If minimal distortion is heard, proceed to next step, if not stop test and record band of highest distortion.
  - 5. Slowly raise level to optimum amplifier power or until power compression is observed (level drop > than 6 dB compared to ref. spectrum), whichever occurs first.
  - 6. Apply test sweep for one full minute, and then record output spectrum.
  - 7. The speaker will have passed the test if no more than 6 dB reduction is noted in each 1/3rd octave band as compared to the reference spectrum from 40 Hz to 10 kHz or through a bandwidth specified by the manufacturer..

How do I use it?: Cont. Distortion Tests (Tracks 4 - 28)

This procedure measures harmonic distortion at the optimum amplifier power using sine wave test signals at 1/3rd-octave spaced IEC center frequencies.

- Procedure (in brief)
  - 1. Place test microphone in measurement position (close-mic or an on-axis position at some reference distance).
  - 2. Apply the sine wave test signal to speaker at a particular frequency.
  - 3. Slowly raise level to optimum amplifier power.
  - 4. Observe spectrum on real-time analyzer. Caution!: Limit test time to a few seconds when testing tweeters or other HF devices, because they can be burned out quickly with sine waves.
  - 5. Speaker will have passed if within its specified bandwidth, it generated harmonics whose rms sum is less than that of the fundamental. This is judged by observing that the "total SPL" indicator of the real-time analyzer is no more than 3 dB above the level of the fundamental for each frequency tested within its specified bandwidth.

How do I use it?: Cont. Accelerated Life-Test Noise (Track 2)

This procedure simulates the working life of the speaker by testing its ability to withstand a test signal at half the optimum amplifier power for eight hours without suffering an irreversible and unacceptable change in performance parameters or integrity.

- Procedure (in brief)
  - Break-in Pretest (one-fourth power for one hour):
    - 1. Using the 1-kHz calibration tone on track 1, adjust the power amplifier output to a voltage 3 dB below (x 0.707) that calculated for the optimum amplifier power.
    - 2. Play the life-test noise on track 2 of the CD with the player set to repeat the track. This will automatically generate a power level of one-fourth optimum (- 6 dB).
    - 3. Apply the signal to the loudspeaker for an uninterrupted period of one hour.
    - 4. Determine and record as a reference the speaker's fundamental resonance frequency after letting the magnet structure cool to below 35° C.

How do I use it?: Cont. Accelerated Life-Test Noise (Track 2): Cont.

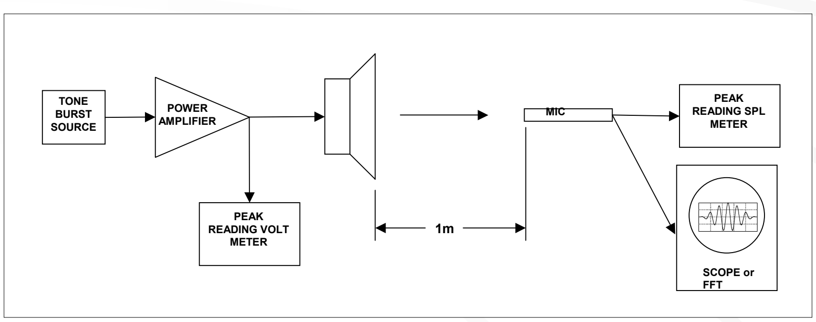
- Actual Test (one-half power for eight hours):
  - 5. Using the 1-kHz calibration tone on track 1, adjust the power amplifier output to that calculated for the optimum amplifier power.
  - 6. Play the life-test noise on track 2 of the CD with the player set to repeat the track.
  - 7. Apply the signal to the loudspeaker for an uninterrupted period of eight hours.
  - 8. After a minimum recovery period of one hour and after the magnet structure has cooled below 35° C, do a sine wave sweep test at one-half test voltage (1/4th power) over the range of 40 Hz to 10 kHz or the manufactures' rated bandwidth.
  - 9. The loudspeaker has passed the accelerated life test if there is no test induced noise or structural damage, and the fundamental resonance frequency has not dropped more than 10% below the recorded reference.

How do I use it? : Cont.
Shaped Tone Bursts

- Procedures:
  - Peak electrical input power and maximum peak SPL of loudspeakers
  - Peak output power of amplifiers
  - Headroom tests of electronic and acoustic systems
  - Frequency response tests of electronic and acoustic systems
  - Energy decay in acoustic spaces
  - Delay and phase/polarity tests of electronic and acoustic systems

Shaped Tone Bursts: Cont.
Peak Input/Output of Loudspeakers
Test Setup

Note: Choose a power amplifier that is more powerful than any speaker that might be tested!



Shaped Tone Bursts: Cont.

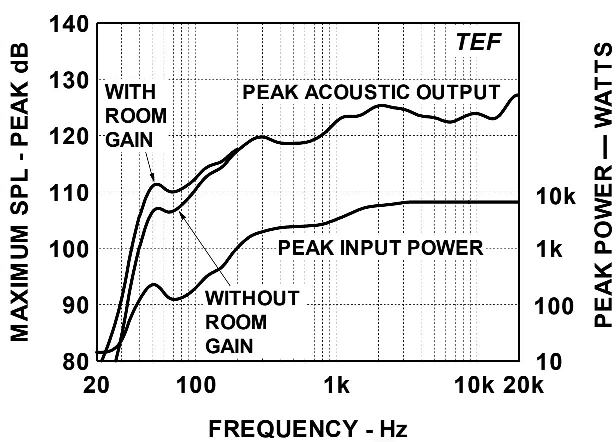
Peak Input/Output of Loudspeakers: Cont.

- Procedure
  - 1. Use suggested test setup.
  - 2. Energize speaker with tone burst at low level.
  - 3. While monitoring the speaker's acoustic output, raise the level gradually until 1) the output sounds objectively distorted or 2) the acoustic output waveform (as observed on the oscilloscope) appears unacceptable distorted, which ever occurs first. Note: Distortion criteria can also be applied.
  - 4. At each burst frequency, record the maximum peak input voltage and the corresponding peak acoustic sound pressure (usually at one meter on axis).
  - 5. Calculate the peak input power by assuming the measured peak voltage is applied to a resistor whose value is the speaker's rated impedance.
  - 6. Plot a graph of the speaker's maximum peak input power and maximum peak SPL versus frequency.

Shaped Tone Bursts: Cont.

Peak Input/Output of Loudspeakers: Cont.

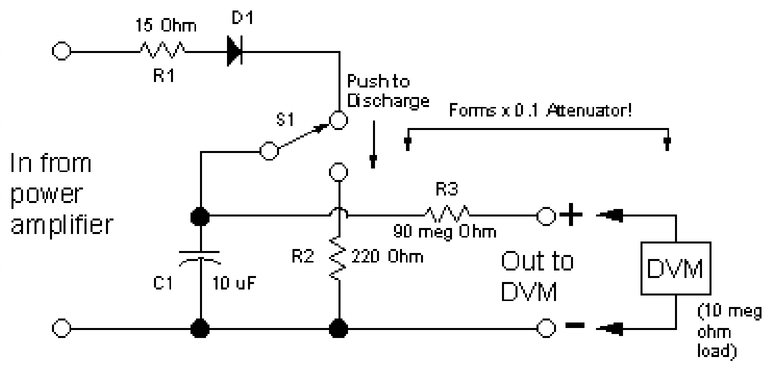
Display of Results



Shaped Tone Bursts: Cont.

DVM Peak Power Adapter Schematic

(Schematic and parts list also in AES paper.)



Shaped Tone Bursts: Cont.

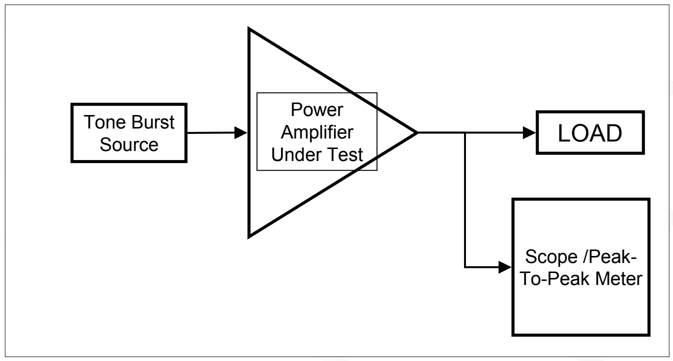
DVM Peak Power Adapter Parts List

(Schematic and parts list also in AES paper.)

- **Parts List**
  - C1: Capacitor, 10 uF, 300 WVDC or higher, ±20% tolerance, low-leakage (Note: oil-bath style AC motor starting caps may work OK.)
  - D1: Diode, high peak reverse voltage (PRV > 500V) (Note: the original version of this adapter used a small-signal 1N645 diode that worked well for many years, although its rated characteristics seemed anemic for this application.)
  - R1: Resistor, 15 Ohm, ½ Watt, 10% tolerance
  - R2: Resistor, 220 Ohm, ½ Watt, 10% tolerance
  - R3: Resistor, 90 meg Ohm, 0.1 Watt, 1% tolerance (Note: nine each 10 meg Ohm, 0.1 Watt, 1% tolerance resistors wired in series may be substituted).
  - S1: Switch, SPDT, push button or momentary toggle

Shaped Tone Bursts: Cont.

Peak Output of Amplifiers
Test Setup



Shaped Tone Bursts: Cont.

Boink Headroom Tests

(Credit to Tom Holman, TMH Corp, and The Hollywood Edge, "Test and Measurement Disk Series")

- Used to detect the peak overload levels at various points in a sound-system signal chain (is frequency dependent!)
- Used to measure peak SPL levels in sound systems versus frequency.

An optimum sound system design matches the measured frequency response of the maximum peak SPL with the expected spectral content of the program material played through that system. This allows the system to play the program material at the loudest level with equal likelihood of overload in each frequency band. In addition, each intermediate stage in a properly designed sound system should reach overload at roughly the same input level to the system.

Shaped Tone Bursts: Cont.

Frequency Response Tests

- As Sigfried Linkwitz points out [*], the shaped tone bursts are excellent for measuring the frequency response of loudspeakers. Armed only with a tone burst source (such as the CD described here), a power amplifier, a calibrated microphone, a microphone preamplifier and an oscilloscope; one can perform free-field measurements in a reflective environment in a manner similar to time delay spectrometry (TDS) or maximal length sequence (MLS) based tests.

*S. Linkwitz, "Shaped Tone-Burst Testing," J. Audio Eng. Soc., vol. 28, no. 4 (1980).

Shaped Tone Bursts: Cont.

Frequency Response Tests: Cont:

- It's only necessary to measure the peak (or peak-to-peak) amplitude of the first received burst (which is presumably the direct sound) on the oscilloscope before the first echo arrives. The distinctive shape of the tone burst makes identifying the echoes relatively easy. As Linkwitz points out, "The low-frequency limit for free-field measurements is reached when the difference in propagation time between the direct and the first reflected signal equals the burst length." This low-frequency limit is the same limit reached by all measurement techniques that attempt to make free-field measurements in reflective environments.

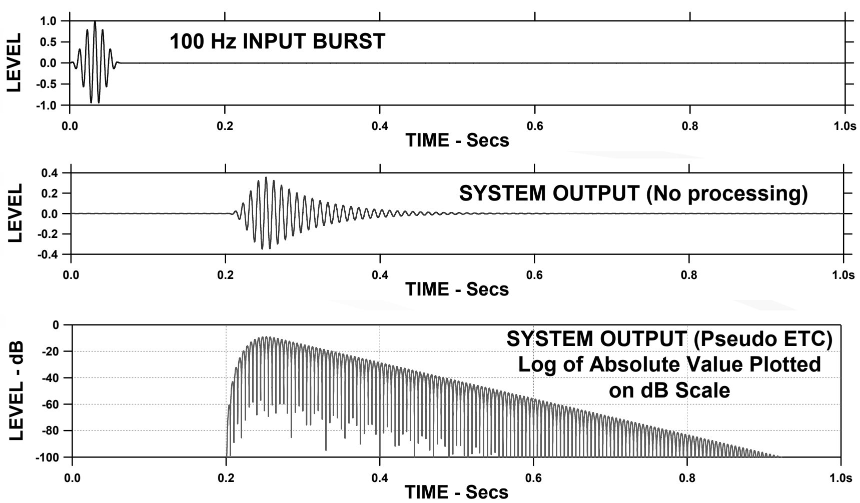
Shaped Tone Bursts: Cont.

Energy Decay Tests

- The burst response shows roughly how the energy decays in a room, the so-called "Energy Time Curve" or ETC. This can be directly seen on the scope screen or computed by taking the absolute value of the response and plotting on a logarithmic vertical scale. The individual decays at each frequency can be combined to form a 3D display of level versus time and frequency.

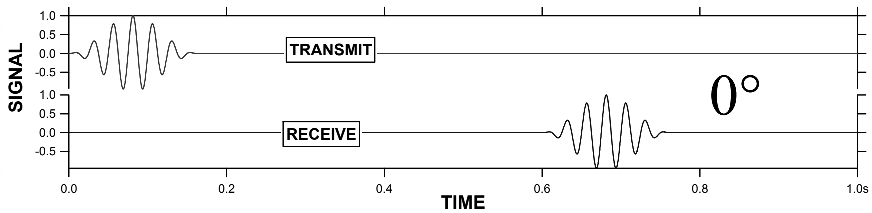
Energy Decay Tests: Cont.

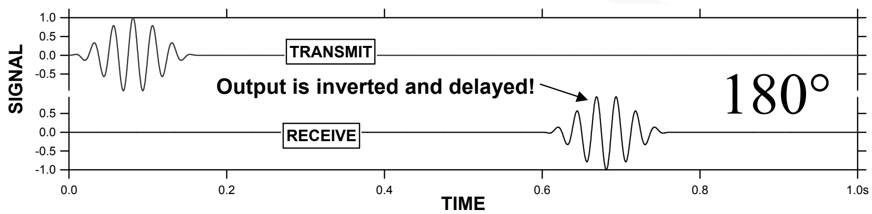
Burst Response of Delayed 100-Hz Second-Order Q=20 Band-pass Filter



Shaped Tone Bursts: Cont.

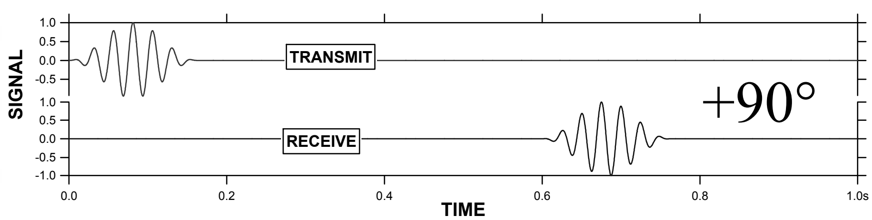
Delay and Phase/Polarity Tests

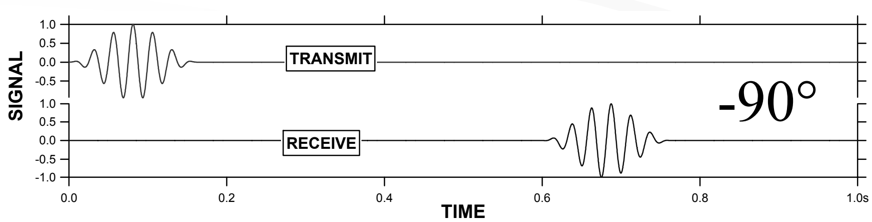




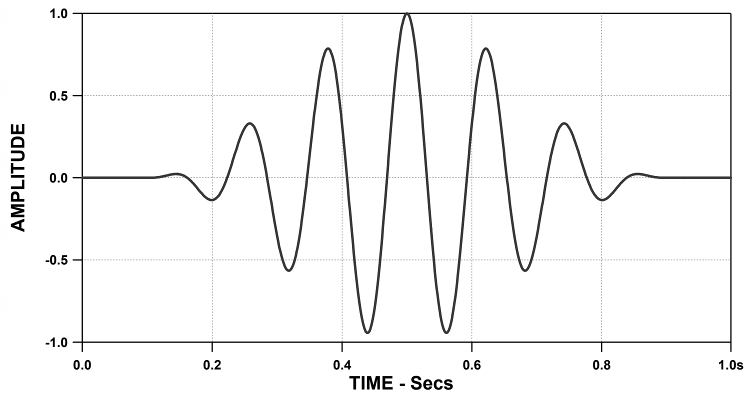
Shaped Tone Bursts: Cont.

Delay and Phase/Polarity Tests: Cont:





Vary Burst Phase
0°



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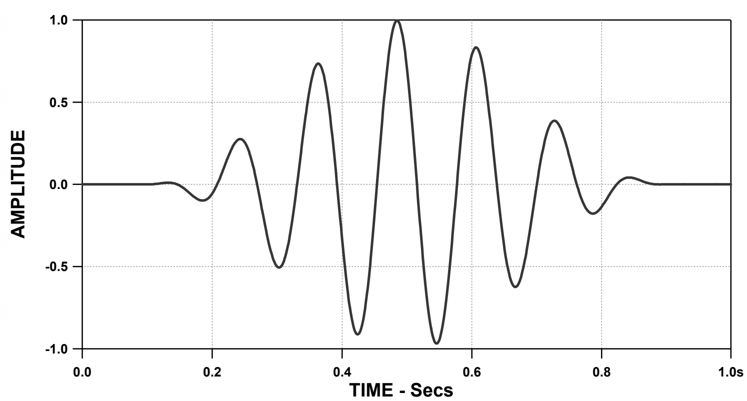
Vary Burst Phase
+45°



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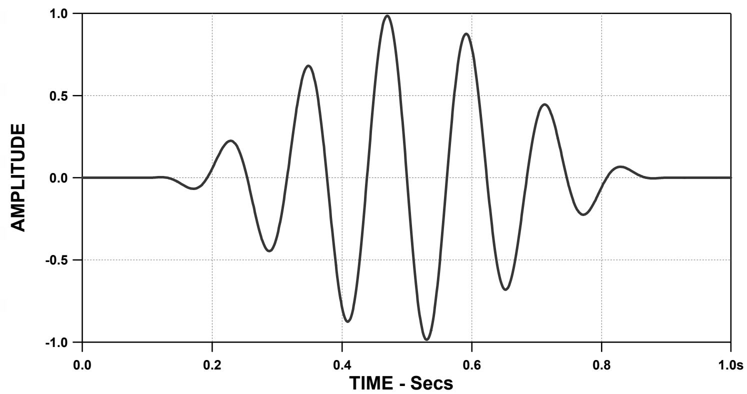
Vary Burst Phase
+90°



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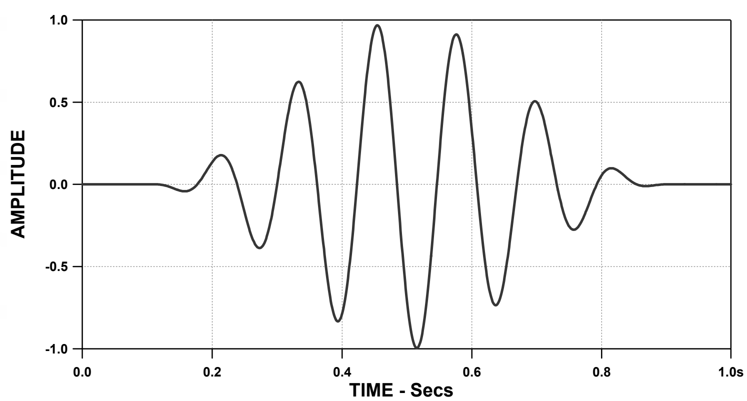
Vary Burst Phase
+135°



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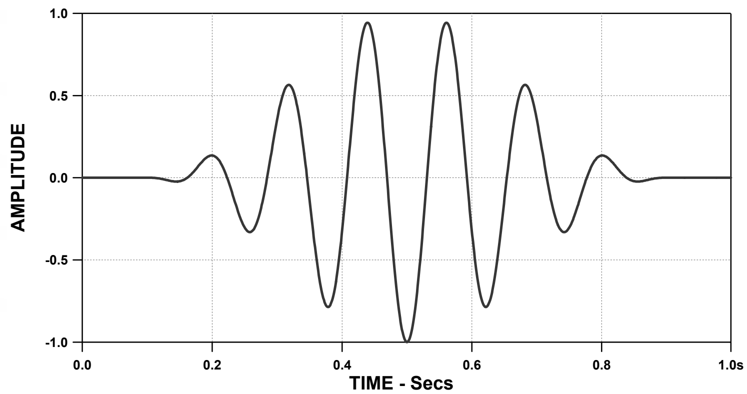
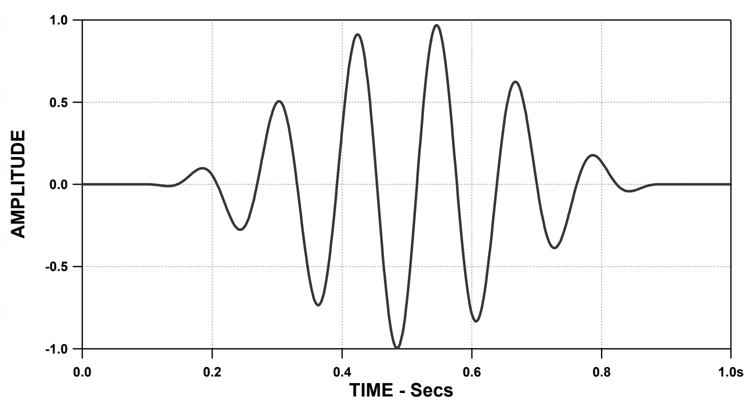
What's on it?, How do I use it?

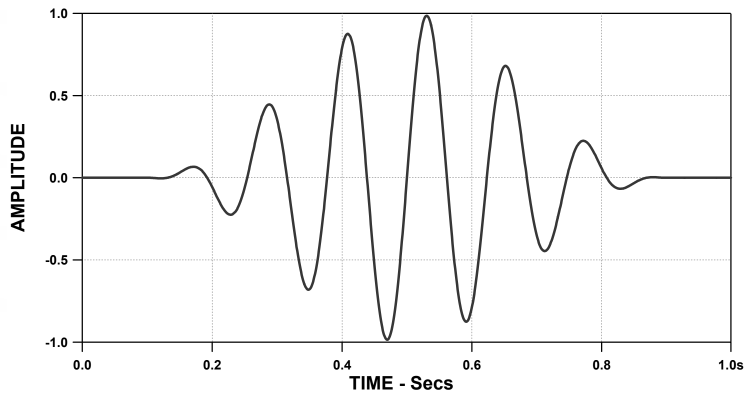
Vary Burst Phase
+180°



Vary Burst Phase
+225°



Vary Burst Phase
+270°



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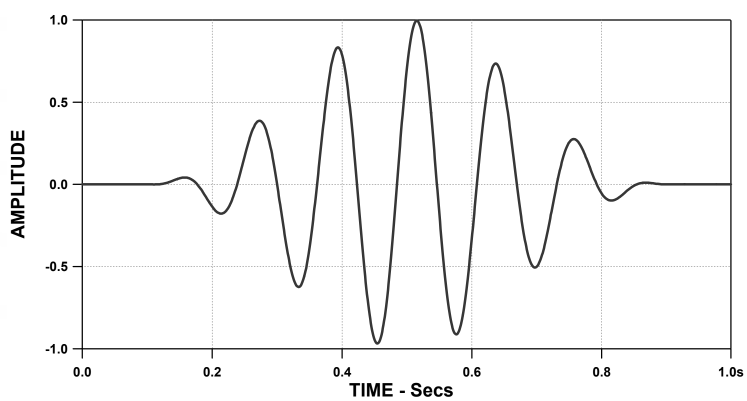
Keele EIA-426-B Loudspeaker Power Rating CD
What's on it?, How do I use it?

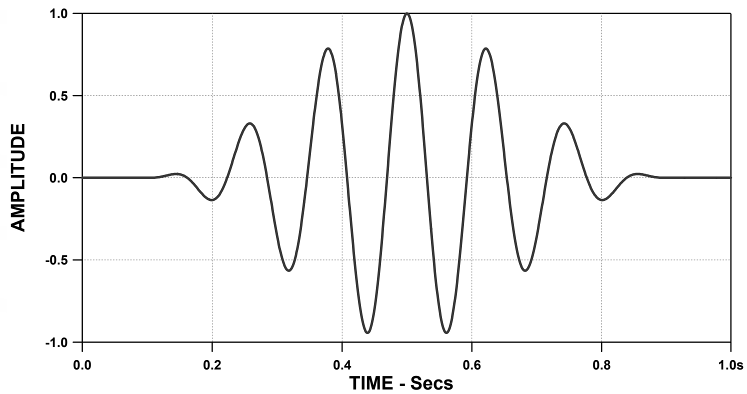
Vary Burst Phase
+315°



July 17, 2001

Keele EIA-426-B Loudspeaker Power Rating CD
What's on it?, How do I use it?

Vary Burst Phase
+360°



The EIA-426-B Loudspeaker Power Rating Compact Disc Conclusions

- The disk provides various test signals to determine the optimum amplifier power to drive a specific loudspeaker or system.
- The optimum amplifier power is determined by performing the following tests:
  - Accelerated life test
  - Power compression test
  - Harmonic distortion tests

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What's on it?, How do I use it?

The EIA-426-B Loudspeaker Power Rating Compact Disc Conclusions: Cont.

- Bonus tone-burst signals are included on the disc that allow various other measurements including:
  – Peak electrical input power and maximum peak SPL of loudspeakers
  – Peak output power of amplifiers
  – Headroom tests of electronic and acoustic systems
  – Frequency response tests of electronic and acoustic systems
  – Energy decay in acoustic spaces
  – Delay and phase/polarity tests of electronic and acoustic systems

The End