OMITTED FACTORS IN AUDIO CIRCUIT DESIGN

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Abstract - Traditional measurements of audio amplifiers use test signals that do not represent conditions of actual use. TIM measurement is one factor in improving the correlation between audible and measurable differences in circuitry. Additionally, many circuits incorporate non-linear elements that appear to be distortionless at conventional measurement frequencies, but can be significant sources of distortion when subsonic or supersonic frequencies are included. This paper describes some of these non-linear elements and their effects on actual circuit performance.

I. INTRODUCTION SMPTE intermodulation and harmonic distortion measurements utilizing a 20-20 kHz bandwith, even using commerical test equipment with resolution to .001%, do not fully predict the sonic characteristics of audio amplifiers because of their failure to take into consideration the subsonic and supersonic components of the spectrum usually included with the audible signal.

One major assumption of TIM theory has been the existence of sufficient supersonic information to invoke TIM distortion.(1,2) Critics of the TIM concept usually rely on linear assumptions of what should be possible from conventional sources such as musical instruments, disc cutting systems, and phono cartridges.(3) However, linear assumptions do not fully describe the realistic performance of many cartridges, especially the moving coil type.

II. MEASUREMENTS OF PHONO CARTRIDGES This paper presents the results of measurements of the supersonic component of the spectrum of phono cartridges in order to ascertain the magnitude and subsequent effect on the following stages.(4) For this paper a Tektronix 7L5 spectrum analyzer was used to detect supersonic information to 200 kHz.

Our results showed certain moving coil cartridges to have significant output to 160 kHz. While the absolute level of the individual spectra decreases with frequency, the overall envelope of the spectrum closely simulates the TIM (30,30) waveform. (See Figure 1.)

There are notable deviations from 'worst case' as shown by the spectrums of the moving magnet cartridges such as the Shure M91ED. The low mechanical resonance (20 kHz) with the high series inductance (720 mH) and recommended termination capacitance (400 pf) significantly filter the spectrum above 40 kHz virtual immeasurability. (See Figures 2 and 3.)

This filtering action contrasts with the output of the Denon 103s (Shibata) and the Great American Sound Sleeping Beauty (concial) moving coil cartridges which show significant energy to 160 kHz. (See Figures 4 and 5).

A comparison between square wave rise time and sine wave overload implies that in many cases sine wave overload is a major factor in creating 'worst case' dv/dt. (See Figures 6 and 7).

Virtually all difficult material from records such as cymbal crashes, brass ensembles, and special effects contributes significant output to the supersonic spectrum. Using the TIM (30,30) waveform (See Figure 8.) in a phono preamplifier using a UA741 with a slew rate of 0.6 V/us showed measurable distortion even at moderate levels. Other IC op amps with higher slew rates and greater gain bandwidth showed essentially unmeasurable distortion in the same circuit at moderate output levels. (See Graph 1.)

III. OTHER DISTORTION MECHANISMS

Besides the distortion created by slew rate limiting, non-linear elements such as ceramic capacitors can create distortion if used as low-pass filters or lead networks. In many instances, conventional 20-20 kHz measurements fail to assess the actual distortion because at audio frequencies the capacitors are usually sufficiently decoupled. However, with increased spectral bandwidth, the distortion from these capacitors can dominate an otherwise low distortion design. (See Table 1.)

Another neglected factor is the spurious subsonic information created by record warps and the tonearm/cartridge resonance. This has been well documented by other sources. (5,6)

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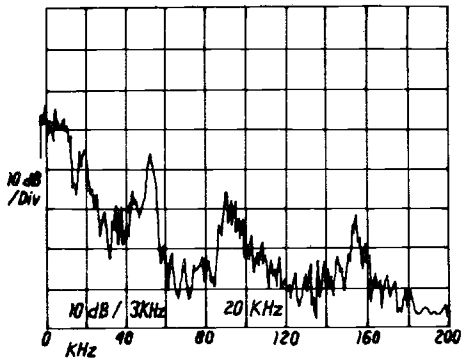


Fig. 5

The spectrum of the GAS moving coil playing a cymbal crash, as in Fig. 1.

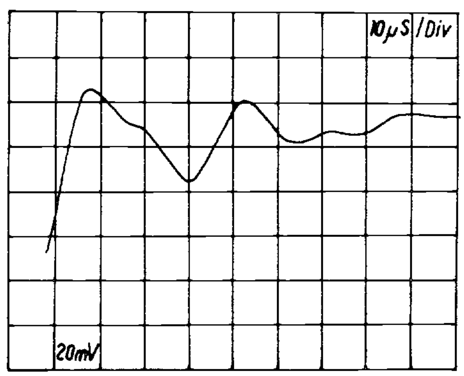


Fig. 6

The rise time of the Ortofon MC20 moving coil cartridge playing the CBS 112 square wave test record.

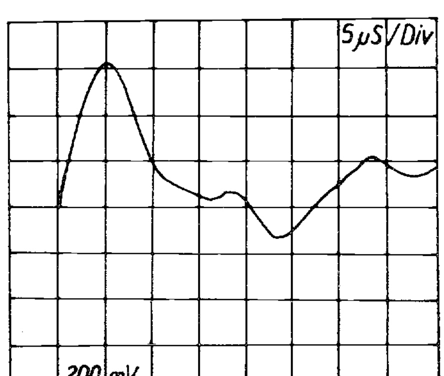


Fig. 7

The rise time of the Ortofon MC20 moving coil mis-tracking a 1 kHz sine wave on the B & K 2010 test record at 24 cm/sec RMS.

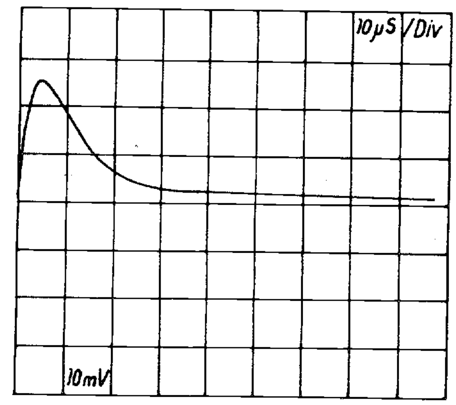
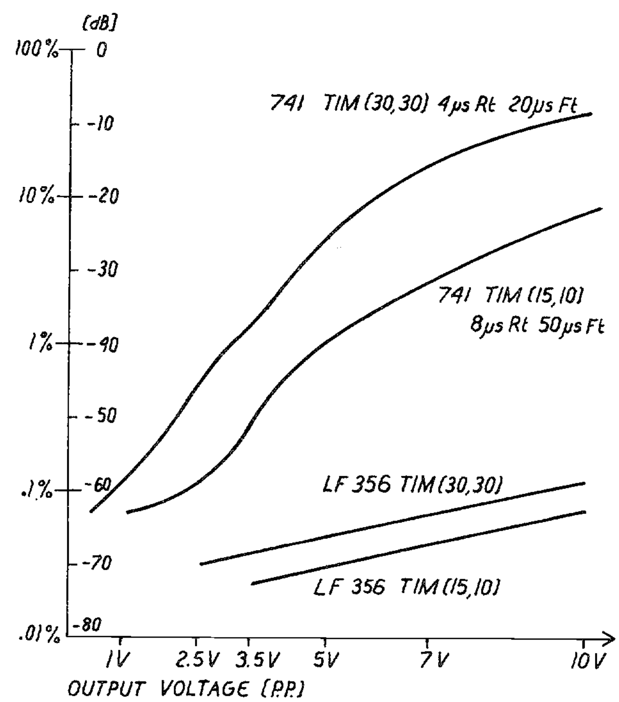


Fig. 8

The TIM (30,30) waveform.



Graph 1

One consequence of the subsonic information is the distortion caused by electrolytic capacitors when coupling between stages with zero D.C. potential across the terminals. Back-to-back coupling or nonpolar tantalums will reduce this distortion, but will not eliminate it completely. One effective compromise is to place two tantalum capacitors side-by-side in reverse phase. This doubles the capacitance while effecting a first order cancellation of the distortion in the capacitors. (See Table 2.)

CONCLUSION

From the preceding data, it can be seen that conventional audio measurement methods do not fully characterize the distortion of a particular audio stage in normal application. Implementation of measurement techniques relevant to the effects of supersonic and subsonic spectra must be considered to describe the actual circuit performance in high fidelity equipment.

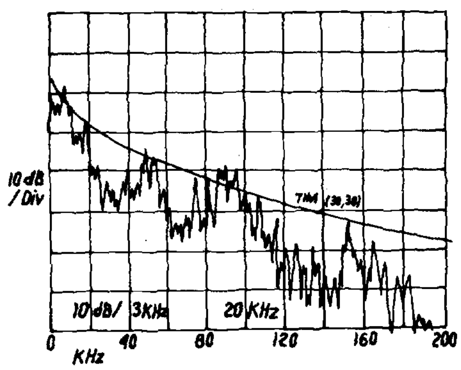


Fig. 1

TIM (30,30) spectrum superimposed on the spectrum of a cymbal crash from the GAS moving coil cartridge playing "The Perfect Song," Sheffield Vol. 3, Lab 1.

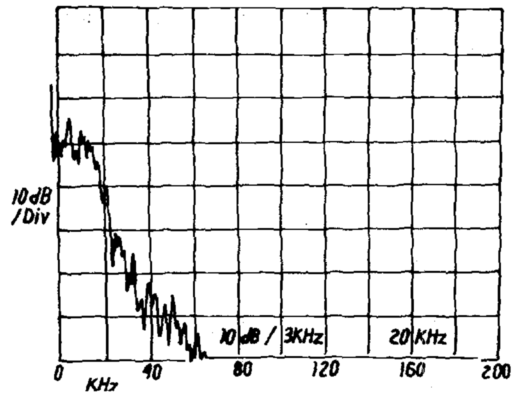


Fig. 2

The spectrum of a Shure M91ED moving magnet cartridge playing a cymbal crash, as in Fig.1.

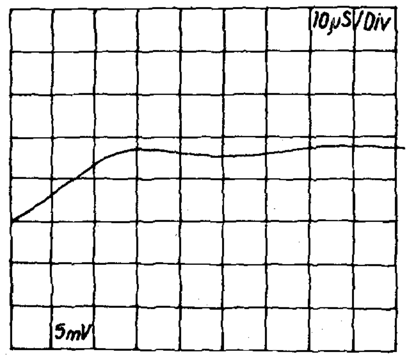


Fig. 3

The rise time of the Shure M91ED playing a 1 kHz square wave from the CBS 112 test record.

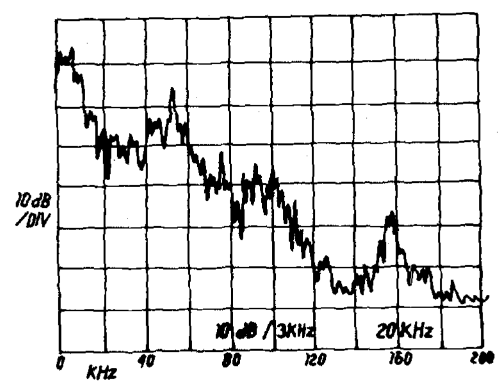
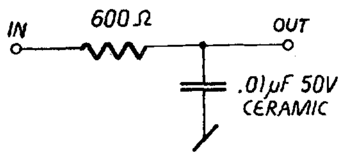


Fig. 4

The spectrum of the Denon 103s moving coil cartridge playing a cymbal crash, as in Fig. 1.

SMPTE IM distortion of a low pass filter using a ceramic capacitor.

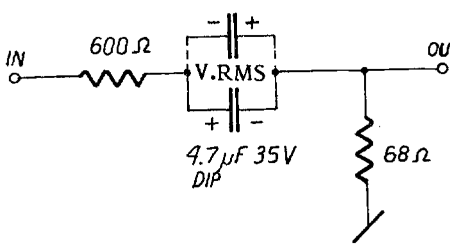


f (-3dB) = 25 kHz

Volts (RMS)	SMPTE IM
15V	.12%
10V	.082%
3V	.028%
1V	.008%
0.5V	.003%
residual	.001%

Table 1

Harmonic distortion of a tantalum capacitor used as a high pass filter.



Single Capacitor			Paralleled Caps.	
Hz.	V.RMS	% Dist.	V.RMS	% Dist.
1000	.155		.08	
50	.31	.0065	.16	
300	.51	.016	.27	
200	.75	.038	.4	.003
100	1.4	.125	.78	.009
50	2.2	.32	1.44	.035
30	2.6	.53	2.0	.06
20	3.0	.7	2.5	.12
10	3.2	1.0	3.0	.26

Table 2

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