Using SigLab for Production Line Audio Test

SigLab is ideal for characterizing audio components. Both its input and output subsystems have low noise, low distortion and low cross talk. SigLab's measurement performance exceeds the testing requirements of most any consumer audio device. Its three internal DSP processors and its SCSI interface insures maximum measurement throughput. This note covers the use of SigLab in making several common audio measurements.

Overview

The following are three typical audio measurements on a stereo amplifier that will be discussed.

- channel to channel cross talk
- harmonic distortion
- signal to noise ratio

Other measurements that can be made with SigLab include intermodulation distortion; gain and phase response; and step response.

Measurement Goals

The objective of any automated test is to rapidly determine the quality of a particular product or subassembly. Overtesting as well as undertesting is undesirable. In most cases, test speed is as important a factor as any. The goals of the following test scenario are:

- simple test adapter (no switches/relays)
- all testing completed in under 1 second
- amenable to full automation
- test quality exceeds amplifier requirements

Test Setup

Interfacing the Amplifier to SigLab

The testing of an amplifier requires careful attention to the source and load signal levels and impedance characteristics. In addition the load impedance must be capable of dissipating the power generated by the amplifier.

SigLab's output generators can generate a 20 volt peak-peak signal behind a 50 ohm impedance. If high sensitivity phono inputs are being tested, an attenuator should be used. If a source impedance of greater than 50 ohms is desired, simply add the required resistance in series with the signal conductor from SigLab's output.

SigLab's input subsystem is capable of handling 20 volt peak-peak signals. Therefore, for power amplifiers, a load resistor plus an attenuator is required to bring the maximum signal level within SigLab's input range. To obtain the best measurement dynamic range, the attenuator should bring the maximum expected level down to 5 to 7 volts peak.
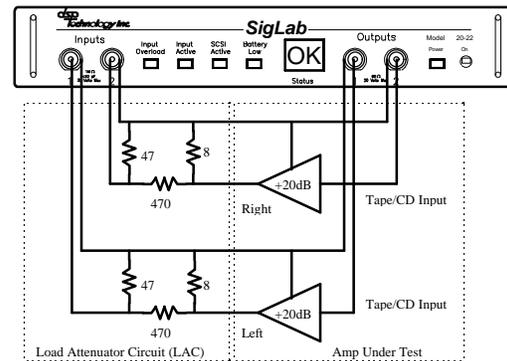

Figure 1 - Amplifier Test Setup

The amplifier under test (enclosed by the broken line) and SigLab are connected by cables, a combination load and an attenuator circuit, the LAC as shown in Figure 1. The input to the amplifier is connected directly to the SigLab output channels providing a 50 ohm source impedance with no attenuation.

The attenuator on the amplifier's output was chosen to be approximately 10:1 or 20 dB. This is actually not optimal since, given the maximum power output of the amplifier under test, a 2:1 ratio would have been more than sufficient to bring the signal levels within SigLab's input range. However, the 10:1 allows an amplifier gain (between CD/Tape input and the output) to be about 20 dB for the testing. The resulting amplifier and LAC then have an overall gain of about 0 dB. This allows the amplifier and LAC to be replaced by two cables to demonstrate the performance of SigLab measuring an "ideal" amplifier with no noise, distortion, or cross talk.

Control Settings

Table 1 summarizes the control settings on the device under test. The actual device was a Radio Shack STA-20 receiver. This note focuses on testing the amplifier portion only.

Control	Setting
Power	On
Tone	Centered
Balance	Centered
Loudness	Off (out)
Volume	+20 dB gain
Input Selector	CD/Tape
Equalization	Off

Table 1 - Control Settings

Baseline Measurements

Before designing the automated measurement system, some measurements were made on the amplifier.

Frequency Response

Frequency response is a typical measurement made on amplifiers. The network analyzer virtual instrument was used to make the measurement shown in Figure 2.
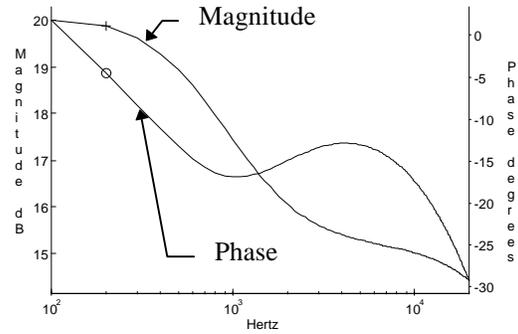

Figure 2 - Frequency Response

It is interesting to note that even with the controls set to the ostensibly flat position, the magnitude and phase response are far from flat. The amplifier gain was set to +20 dB at the low frequency end.

Cross Talk

The network analyzer also was used to measure channel-to-channel cross talk over the 20 kHz range. The excitation was fed to the left channel and the transfer function was measured between the left and right outputs. The transfer function provides an easy and accurate way to get the cross talk as a function of frequency. Figure 3 shows the results of this measurement. At 1000 Hz the left-to-right cross talk is about -54 dB and at 10000 Hz it degrades to -34 dB.

For the crosstalk measurement, the amplifier's right channel must not receive any input. As shown in Figure 1, this is satisfied by driving it with SigLab's channel 2 output set to zero amplitude, since SigLab's output impedance is low (50 ohms).
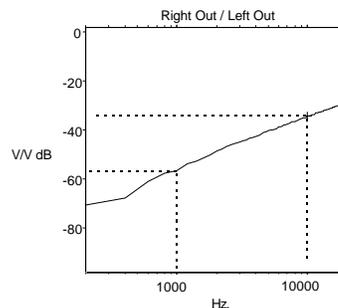
Several methods of implementing this measurement are available. In this example, results are only desired at 1 kHz and 10 kHz. Test time is minimized by setting up an automated test to produce tones and make measurements only at tone frequencies.

Harmonic Distortion

Next, harmonic distortion was measured on the right channel. The function generator virtual instrument was used to provide a 1000 Hz sine wave to the amplifier. The power spectrum (in dB Vrms) of the amplifier output is shown in Figure 4.

Notice, the second harmonic is on the order of 60 dB down from the fundamental. The second harmonic dominates the total harmonic distortion performance measurement.
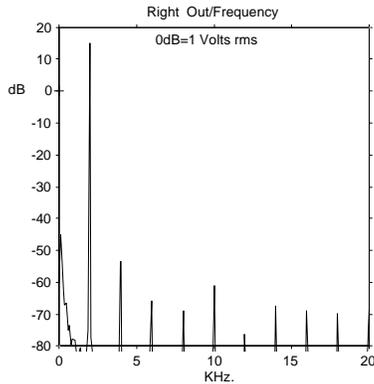
Figure 4 - Harmonic Distortion

Noise

Finally, the noise from the amplifier with no input signal was measured. The results are shown in Figure 5. Typically in most amplifiers, the low frequency spectrum is dominated by 1/f noise. Increased frequency resolution would provide details of the low frequency noise, but this is not really necessary for computing a signal to noise ratio from the data.
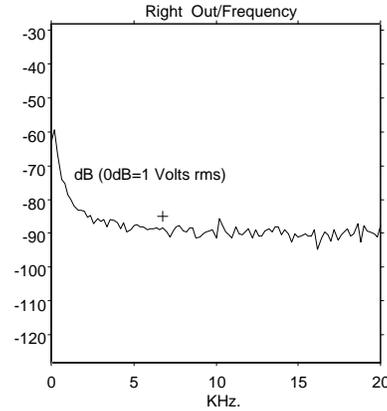

Figure 5 - Amplifier Noise Spectrum

To compute the signal to noise ratio, the power in all the spectral lines, excluding dc, is summed. The ratio of the noise power and the amplifier's maximum rated output power is then computed and transformed to a decibel representation. The computation must also account for the attenuator in the LAC.

Automated Measurements

The SigLab-MATLAB combination is ideal for measurement automation. SigLab has automated versions of its virtual instruments (See the Application Note entitled *Automating Measurements with SigLab*) that take the pain out of measurement automation. When necessary, the measurement conditions can also be controlled from within MATLAB by using calls to *siglab.dll*.

A Simple Amplifier Test GUI

Figure 6 shows a simple application, written in MATLAB, to test crosstalk, total harmonic distortion and signal to noise ratio.
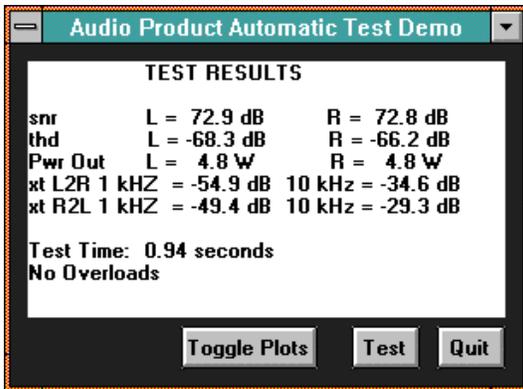
Figure 6 - Simple GUI for Automated Amplifier Test.

The operator interface is simple, containing only three push buttons and a text area to display test results.

The Toggle Plots button turns graphs on for debugging and demonstration; or off for maximum throughput.

The Test Results

The printed results in Figure 6 agree with the previous measurements. The test time report is 0.94 seconds, which satisfies the second goal of completing all tests under 1 second.

The "Golden Amplifier"

As previously mentioned, a 20 dB attenuator makes it simple to analyze a "perfect" amplifier. For this case, the actual amplifier and LAC were removed and the SigLab outputs were simply connected to the SigLab inputs. Nothing else is changed. These cables then became the amplifier under test.
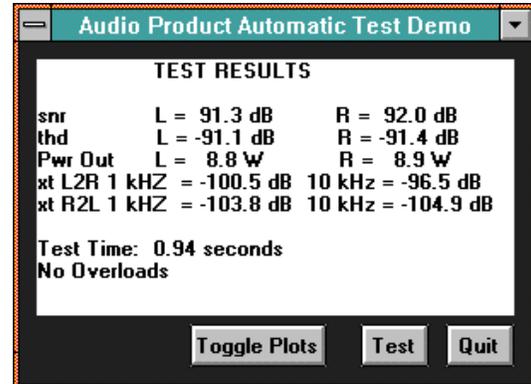
Figure 7 - Measurement Residuals

The results of these measurements are shown in Figure 7. Note, the residual noise and distortion levels due to SigLab are far smaller (about 20 dB) than a typical real audio amplifier.

The Measurement Algorithms.

The following sections provide a description and listings of the measurements and calculations done in MATLAB to implement the three tests. A description of the design process is also provided.

```
% cross talk code fragment from m-file at2.m
    sine_freq = [1000,10000];  % use two tone option ....
    rms_level = 0.6;            % excitation level
    siglab('outlevel',1,1.414*rms_level,'offset',0); % set level, then the function
    siglab('outsine',1,sine_freq(1),sine_freq(2),1); % two tones , same amplitude

    siglab('outlevel',2,0,'offset',0); % shut down other generator
    siglab('outsine',2,10);            % shut down other generator

    % make a spectrum measurement using setup state in file xtlk.vsa
    [AspecDat1,Fvec, WinPwrCor, ChanStat]=vsa_auto('meas2out','xtlk.vsa','new');

    % compute cross talk at the two given frequencies...
    df = Fvec(2)-Fvec(1);
    index_1 = 1+sine_freq(1)/df;
    index_2 = 1+sine_freq(2)/df;
    xtlkl_r = 10*log10(AspecDat1([index_1,index_2],2)./AspecDat1([index_1,index_2],1));

    siglab('outlevel',2,1.414*rms_level,'offset',0);
    siglab('outsine',2,sine_freq(1),sine_freq(2),1); % two tones , same amplitude

    siglab('outlevel',1,0,'offset',0); % shut down other generator
    siglab('outsine',1,10);            % shut down other generator

    % set gains to optimize R to L xtalk
    siglab('inpgain',1,0.078,'ac');
    siglab('inpgain',2,1.2,'ac');

    % using the 'repeat' mode has two effects:
    %               1) it saves some time since setup info is not resent
    %               2) it does not overwrite the gain setting just set
    [AspecDat2,Fvec, WinPwrCor, ChanStat]= vsa_auto('meas2out','xtlk.vsa','repeat');
    xtlkr_l  = 10*log10(AspecDat2([index_1,index_2],1)./AspecDat2([index_1,index_2],2));
```

Listing 1 - Cross Talk Measurement

Cross Talk

Listing 1 shows the details of the cross talk measurement. First, the cross talk between the left-to-the-right channel is measured. The output generator connected to the left channel is set to provide two tones at 1000 and 10000 Hz, while the other generator is turned off. The spectrum of both the amplifier left and right output channels is measured. Ideally, there would be no output on the right channel. The ratio of the left channel to right channel power is computed at the two tone frequencies and converted to dB to produce the cross talk measurement.

Next, SigLab's output channel settings are reversed to measure the right to left amplifier cross talk. A shortcut is utilized to improve the measurement time — rather than reset the entire SigLab front end, calls are made directly to the *siglab.dll* to swap

the input subsystem gain settings. Those are the only input parameters that need to be

changed. The "repeat" feature of the *vsa_auto.m* allows a repetition of the previous measurement without sending new setup information to SigLab.

```
% Harmonic Distortion code fragment from at1.m
    sine_freq = 1000;
    rms_level = 0.707;

    siglab ('outlevel,'1,1.414*rms_level,'offset',0);
    siglab('outsine',1,sine_freq);

    siglab('outlevel',2,0,'offset',0);
    siglab('outsine',2,sine_freq);

    % perform 2 separate measurements for THD since finite amplifier cross talk
    % causes measurement variation which is a function of the relative
    % (and arbitrary) phases of the sine excitations

    [AspecDat1,Fvec,WinPwrCor, ChanStat]=vsa_auto('meas2out','hd12.vsa','new');
                              ovld_1 = ChanStat(1,ovld_i); % log overload info
df=Fvec(2)-Fvec(1);
i_fund   = 1+sine_freq/df;
i_second = 1+2*sine_freq/df;
% for THD, pick out only the harmonics.assume other noise picked up
% in noise measurements, attenuation factor does not matter here.
thd1_db = 10*log10(sum(AspecDat1(i_second:(i_fund-1):length(AspecDat1),1)),...
                                              ./AspecDat1(i_fund,1));
%the ATTEN variable is to the attenuator, use the LAC
pwr1_fund = (AspecDat1(i_fund,1)/Load_res)/(Atten^2);

    siglab('outlevel',2,1.414*rms_level,'offset',0);
    siglab('outlevel',1,0,'offset',0);

    % note: although 2 Aspec measurements are being made, and only one used,
    % it is faster to make the 2 measurements than it is to respec setup of 20-22
    % therefore, the measurement defined by hd12.vsa is 'repeated'.
    [AspecDat2,Fvec, WinPwrCor, ChanStat]=vsa_auto('meas2out','hd12.vsa','repeat');
                          ovld_2 = ChanStat(2,ovld_i); % log overload info

    thd2_db = 10*log10(sum(AspecDat2(i_second:(i_fund-1):length(AspecDat2),2)),...
                                              ./AspecDat2(i_fund,2));
    pwr2_fund = (AspecDat2(i_fund,2)/Load_res)/(Atten^2);
```

Listing 2 - Distortion Measurement

Harmonic Distortion

Due to the existence of amplifier cross talk, the harmonic distortion measurement must also be made separately for each channel. Listing 2 shows the code fragment implementing the distortion measurement. SigLab's output generator produces a single sine wave at 1000 Hz at a specified amplitude. Next, the power spectrum of the amplifier output is measured. To compute the total harmonic distortion, the power at spectral components lying exactly on harmonics is summed and then the ratio of this harmonic power and the fundamental power is taken. The results are expressed in dB. The amplifier output power is also of interest, and is computed from the power in the fundamental tone. The LAC attenuation factor and load resistor must be known to make this calculation.

Again the *vsa_auto.m* repeat function is used to measure the distortion of the right channel to save measurement time. No changes needed for the input setup, just the output generator states are swapped.

```
% Signal to Noise Ration measurement and calculation
% ****************************************************************
    % amplifier and interface parameters
    Pout_max     = 5;  % 5 watts assumed max rms output
    Load_res     = 8;  % load resistance
    Atten        = 47/(510+47); % attenuator after load resistor
    % ****************************************************************

    set(Hat2_([qpb_i,testpb_i]),'enable','off');
    % disable quit,test pbs while test in      progress

    % noise floor measurement
    % set both siglab outputs to 0

    sine_freq = 10;
    rms_level = 0.0;
    for i=1:2
        siglab('outsine',i,sine_freq);
        siglab('outlevel',i,1.414*rms_level,'offset',0);
    end;

    [AspecDat1,Fvec,WinPwrCor, ChanStat]=vsa_auto('meas2out','noise1.vsa','new');

    % sum operator sums elements in columns. 1 column per channel
    % ignore dc bias, remove by starting at element #2

    noise_pwr = sum(AspecDat1(2:length(AspecDat1),:))/Load_res;

    % be sure to include attenuation factor in the calculations
    snr_db = 10*log10(Pout_max*noise_pwr.^(-1))+20*log10(Atten)
```

Listing 3 - Signal to Noise Ratio

Signal to Noise Ratio

First, the noise power output of the amplifier is measured with no input signal. Then the signal to noise ratio is computed by taking the ratio of this power to the maximum the amplifier can produce while staying within its distortion specifications. For this measurement both SigLab outputs are turned off and the left and right channel power spectrums are measured simultaneously. The maximum amplifier output, load resistor value, and attenuation factor of the LAC must be known for this calculation.

Conclusion

SigLab makes quick and accurate automated measurements of key audio amplifier parameters. A simple MATLAB GUI was created to run the tests, display the results, and track the measurement time. The results can easily be compared to test limits for sorting or go/no-go testing.

The SigLab-MATLAB combination is ideal for production-oriented audio testing.

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