Tube Guitar Amplifier
Oscilloscope Diagnosis

OVERVIEW

Caveat

Proceed at your own peril! The methods and procedures I outline in this document have worked well for me. However, they are the results of my personal experiences. I have no doubt a properly trained engineer would have a far different perspective on all this.

Working on tube amplifiers poses extreme risk and potential death. There are voltages close to 800VAC inside an amplifier chassis. Touching these incorrectly can kill you and/or damage your equipment.

If you are unfamiliar with these risks or inexperienced, do not attempt any of the procedures outlined in this document. KEEP THE FILTER CAPS DRAINED!!!

Objective

Outlined in this document are several procedures I used to help diagnose problems and to assist with tuning. These tests are based around the use of an oscilloscope.

A scope is a very flexible device and can be use to perform countless other tests that I am not covering. The procedures outlined in this document are what I use routinely and should address most of the problems normally encountered.

There are other tests that are equally important. However, they are performed with a multi-meter, and are therefore not covered in this document.

There are sections in this document that outline the equipment I use, the types of test I perform, the steps I follow when building an amp, and most importantly a walkthrough of the specific tests I perform.

Author's Note

This document turned out to be far more voluminous than I had anticipated. For that I apologize, but I couldn't condense/distill it any more than I have without loosing valuable content (at least, so I thought). Unfortunately it's a real snooze.

It's not for the faint-of-hart!

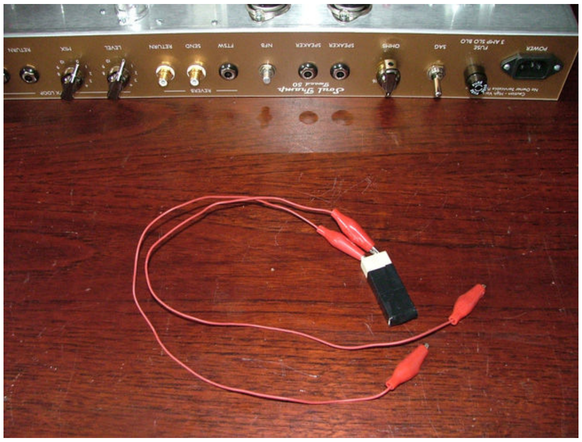
TOOLS

- Oscilloscope – Hantek DSO-2090 USB

- Signal Generator – B&K 3050

- Speaker Dummy Load – Weber Mass 200

- Filter Cap Drain – 200 ohms @ 10 watts (DIY)



PROBLEMS TO TEST FOR

- **Noise –** With the scope you can look at noise in the power supply and in the signal path. As well, you can determine the frequency of the noise. This will help you determine its source.

- **Phase –** This is relevant with push/pull amps. You can test the phase of the NFB loop and both power tubes. You can also test and balance the two sides of the phase inverter

- **Signal Strength & Form –** This is by far the most important area for testing. You can watch the signal as it enters the amplifier at the input jack, and then follow it all the way through to the speaker outputs. You will be able to see how each gain stage, tone stack, sub-circuit, etc, affects the signal.

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SCOPE SETUP

There are countless ways you can set your scope and not be wrong. The settings I use please me. You can use whatever pleases you.

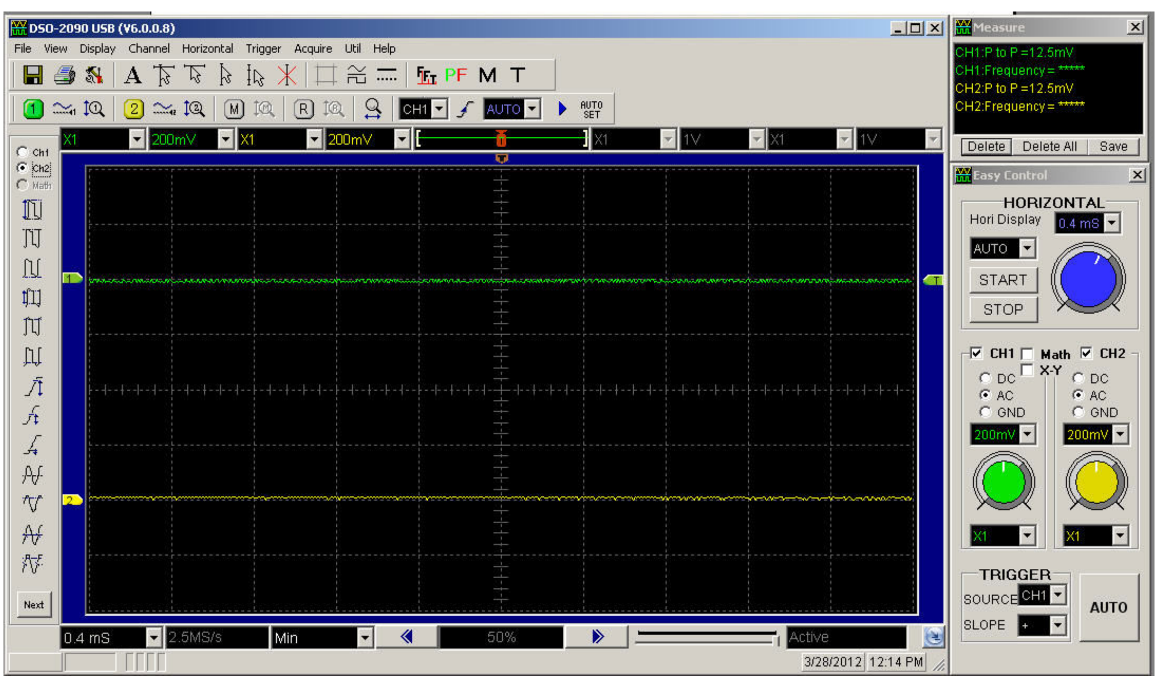
The things we have to be concerned of are the frequencies and voltages we're going to be working with. I set my signal generator at 2.5Khz and at an amplitude that matches the '57 PAF humbucker PUPs in my guitar.

The most important thing to beware of is touching any high voltage with the probe or your body. The first will fry you scope and the second will kill you.

Here are the settings I use:

- Measure AC
- Voltage: 200mv
- Sweep Speed: .4ms
- Measure Voltage Amplitude
- Measure Frequency

Below is what the scope looks like with nothing connected to the probes.



If you are going to test the anything involved with the power supply or tube plates, you have to be sure to adjust the voltage appropriately. And most importantly, DO NOT EXCEED THE VOLTAGE LIMITS OF YOUR SCOPE.

Steps I Follow

When I assemble an amp I always start with the power supply. When it's finished I test all the voltages before proceeding.

Next up is the power amp which includes the output transformer. When finished, I again test all voltages without tubes installed.

Once the power amp looks good I build the tone stack and any front and rear panel do-dads.

With the tone stack completed I move on to the preamp board which includes the phase inverter (if appropriate). When finished apply power and test voltages without tubes installed.

And finally will come any other boards or circuits. Such as an FX loop or reverb.

At this point all of the fabrication and assembly is complete.

Test-1 – With no tubes installed use a multi-meter to test all plates, cathodes, B+ nodes, and –Vbias. Also a good idea to go back and check the secondary side of the power transformer.

Test-2 – Insert the preamp tubes and check voltages with the multi-meter.

Test-3 – Install the power tubes and connect the dummy speaker load. Test all plates, cathodes, B+ nodes, and –Vbias. Be sure you have the bias set at a reasonable point if it's a fixed bias amp.

Test-4 – This is where we use the scope to follow the signal path from input to output transformer. Sometimes I pull the power tubes, other times I don't. All depends on how nervous I am with the build. This test is a composite of the specific test detailed in the next section.

Once I'm happy with all the above tests, I then connect the guitar and speaker for the "real" test.

DIAGNOSTIC TESTS

Plate-To-Grid

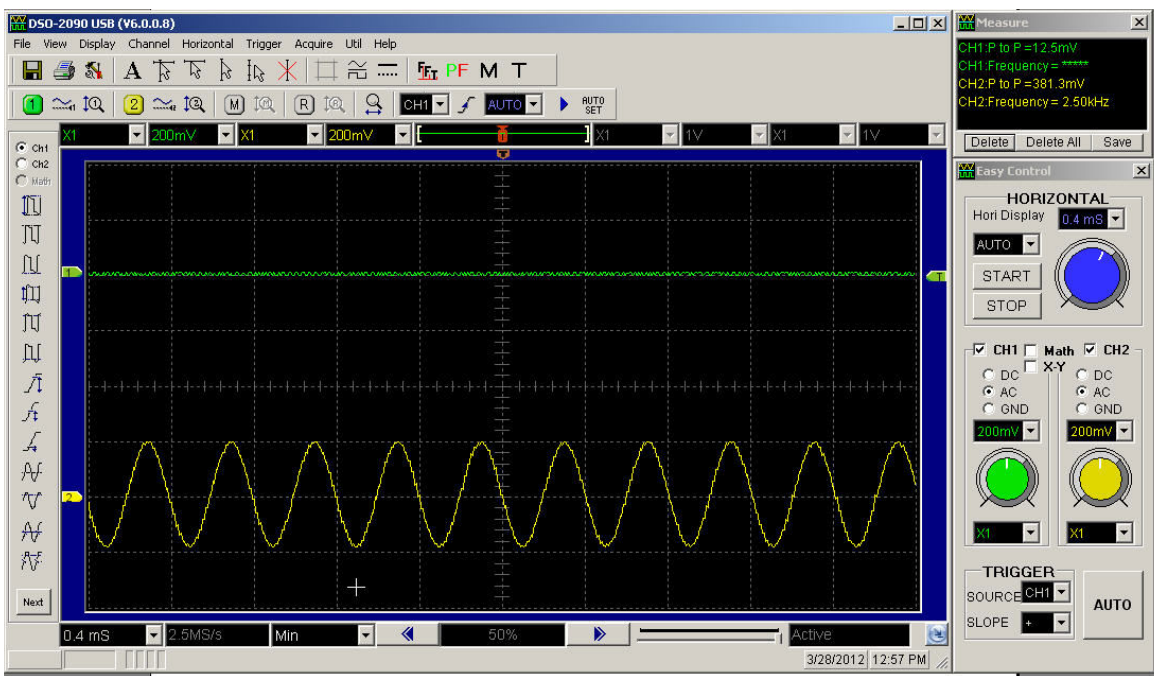
This is the single most useful and important test of them all. This is where you watch the 2.5Khz sine wave (from our signal generator) move from one stage of the amp to the next. You will be able so see if it does in fact move on and whether or not it is in the proper wave form.

For this test I am running dual traces on the scope. The yellow (bottom) trace is taken at the input jack. The green (top) traces is the probe we'll use to look at the waveform as it moves through the amp.

I'm not going to follow the signal all the way through the amp as it would be too repetitive and tiresome.

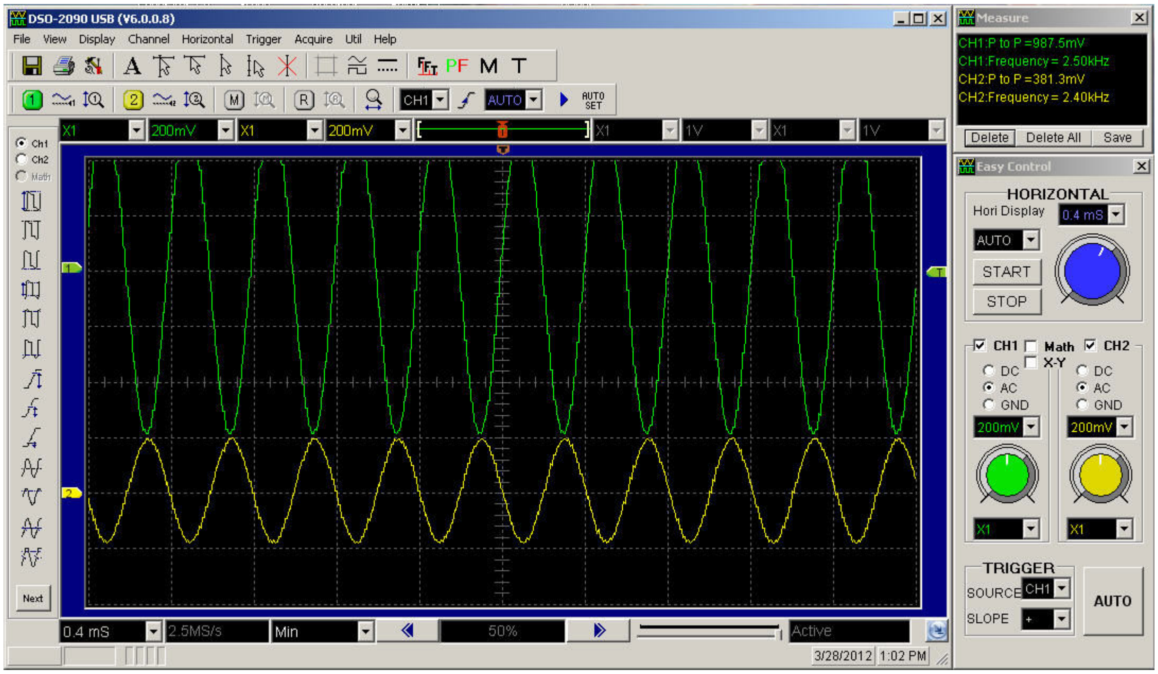
Raw Input Signal

The trace pictured below show the raw 2.5Khz signal at the input jack.



Gain Recovery Stage

Now we attach the green probe to the plate of the first gain stage. Be sure to do so after the coupling cap. Otherwise you be touching the 100VDC – 300VDC B+ rail. What we want to see is the AC signal that comes off the plate.



Notice how the phase has been inverted. Each triode will do this. Generally it isn't a problem. However, if you're working with multiple channels or push/pull amps you have to be careful so as not to mix phases. Keep in mind, a cathode follower does not invert the signal.

You can see how the first gain stage has boosted the amplitude of our signal. This particular amp actually has three different parallel coupling caps that route the plate output to different points in the TMB tone stack. Each coupling cap produces a different gain signal. I'm not going to get into the details here, but this is how you can model the results of different coupling caps.

What we're looking for with this test is a quality signal that has sufficient amplitude and waveform. This test can be repeated by following the signal path through each triode, the tone stack, and any other tone shaping control

Voltage & Gain

The gain of the signal is determined by its voltage. The higher the voltage, the higher the gain. There are many components that will affect this. Coupling cap, pots, grid stoppers (resistors), grid bleeders (resistors), tube type, and how the triode gain is set, for example. Knowing what to use where and why is an entirely different discussion and not part of this document.

I'm assuming you know what you are looking for, and I'm just explaining how to use a scope to measure it.

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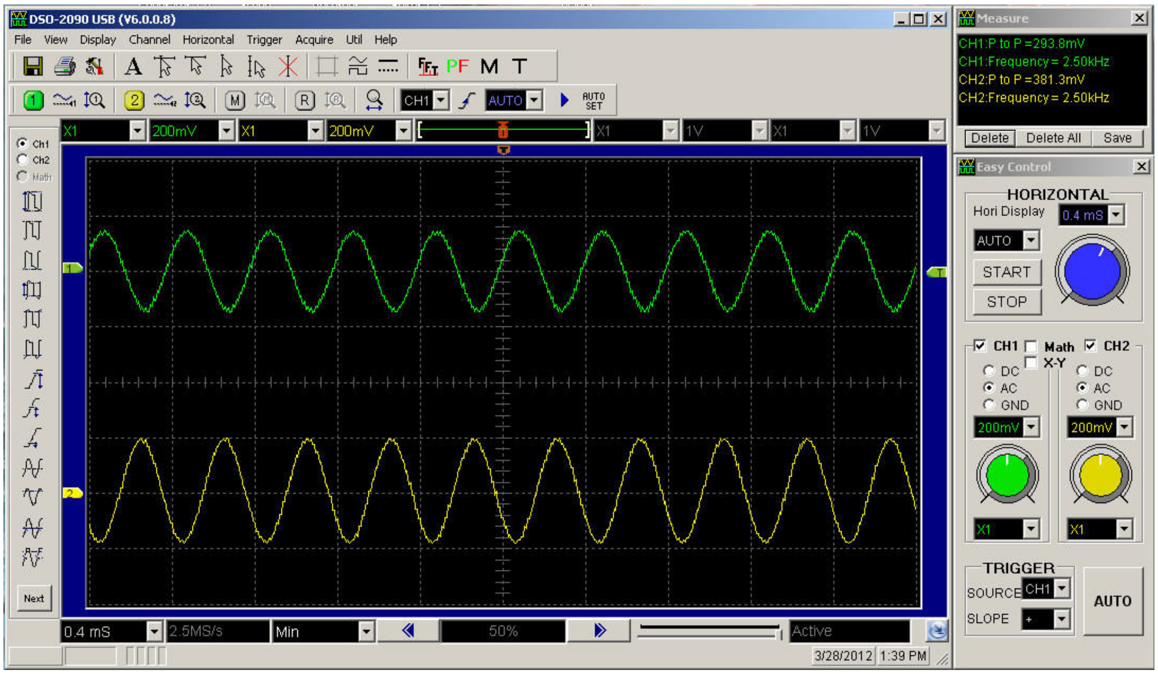
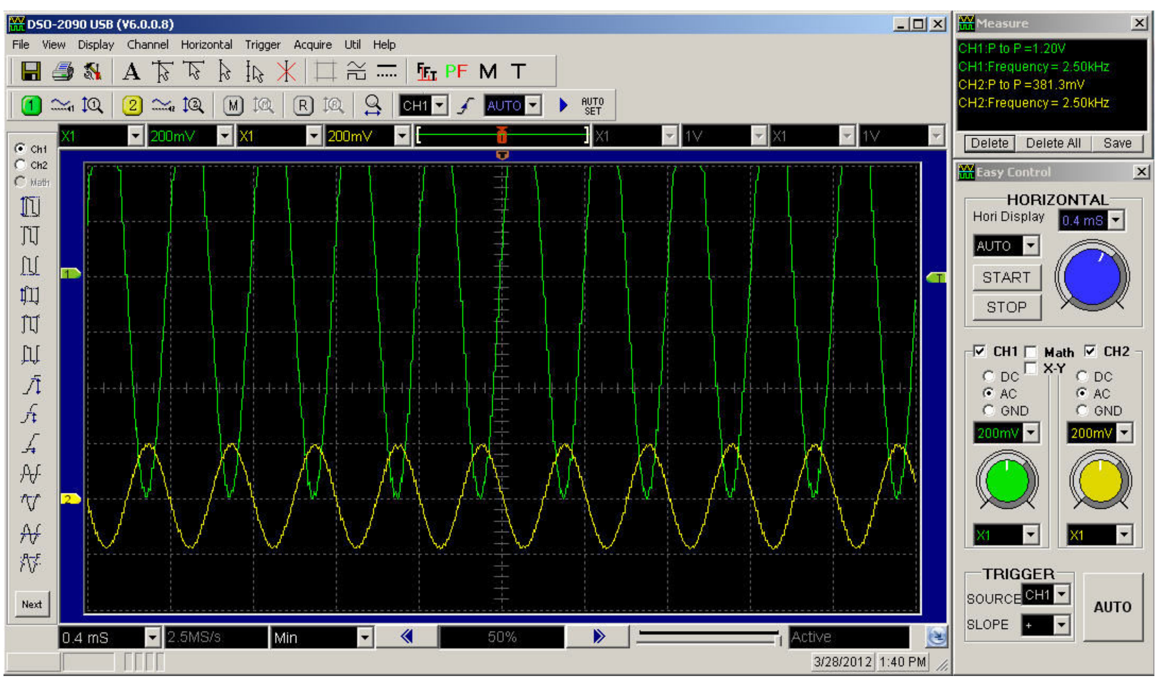
The first screen capture shows how the signal looks coming off the volume control with the volume set at 5 (half).

The second screen capture shows the signal with the volume set at 10 (full).





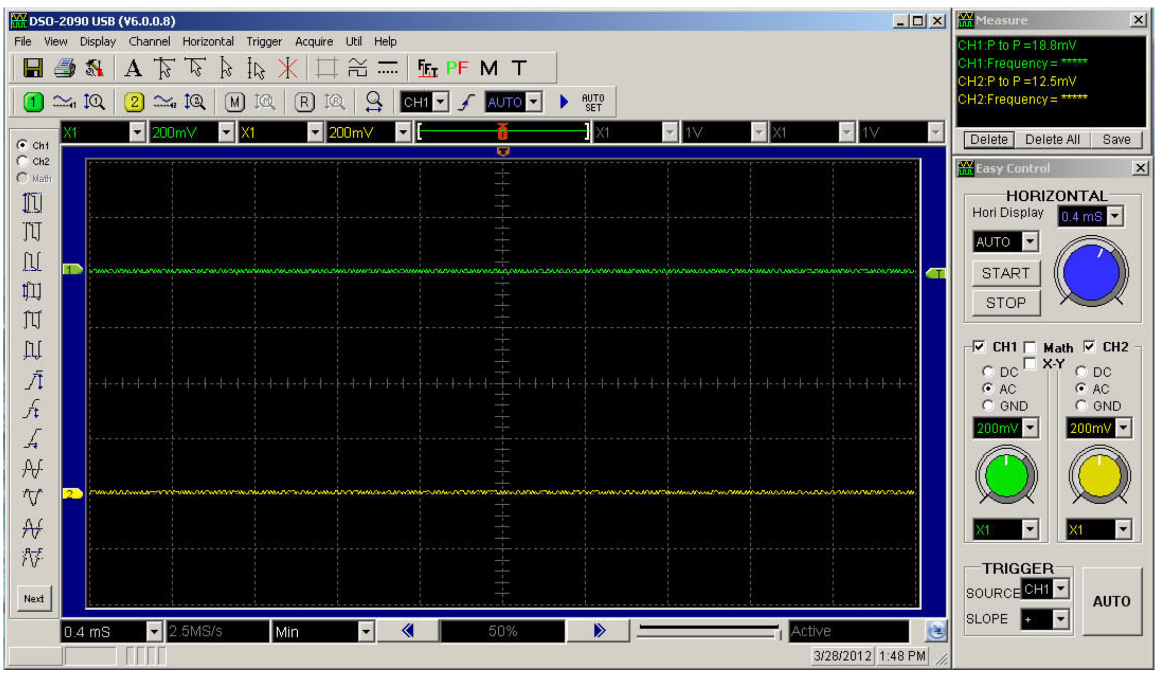
Frequency

It's difficult to see in the screen captures, but the frame in the upper right displays voltage and frequency for each trace (green & yellow). So far all we've looked at has been voltage (gain).

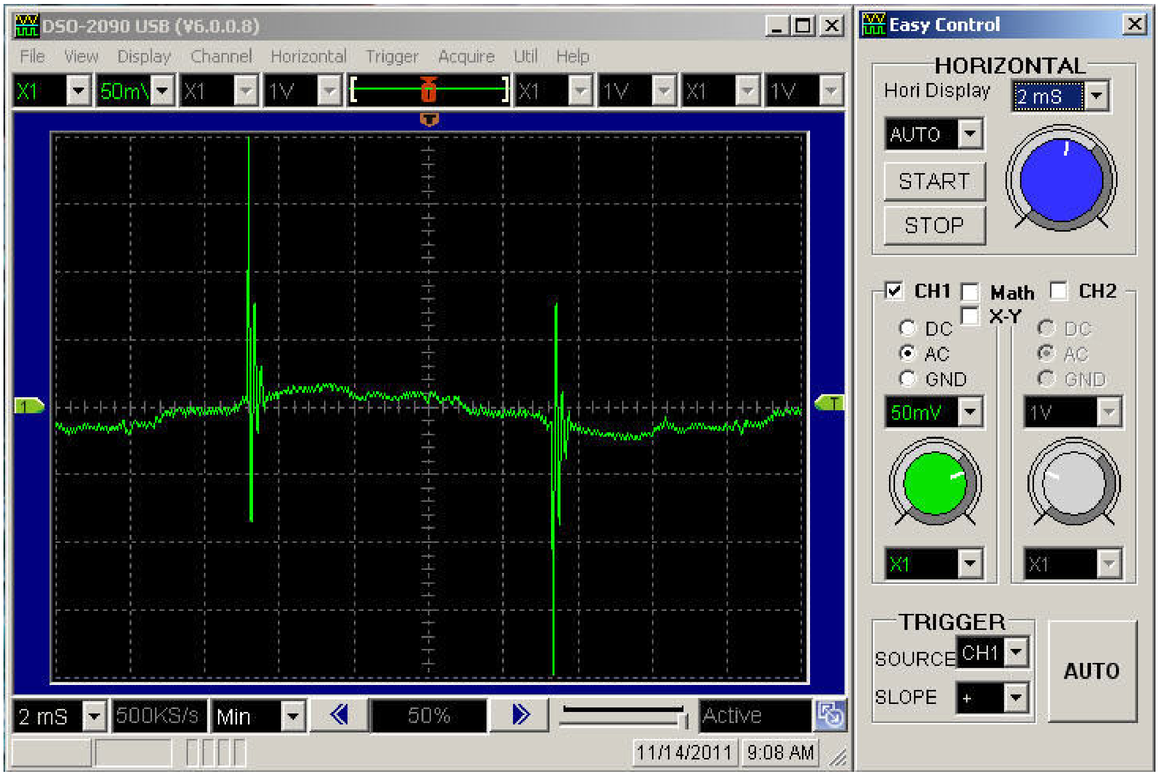
For all of my tests I use a reference frequency of 2.5Khz. I selected this frequency as it falls in the mid-range of what a guitar produces, but it's arbitrary on my part.

You can see from the traces below where I've disconnected the signal generator that the signal gain has dropped to 12mv and zero frequency. This is good.

This is how we test to see if there is unwanted noise. However, there is always ambient noise on the signal path but it is very low gain and/or outside of our bandwidth. If I were to speed up the scope and lower the voltage sensitivity I would see all sorts of noise.



Below you can see the noise created by a dimmer switch. Environmental noise sources are something you have to watch out for. They can enter your circuit through the AC wiring in your house, or as EMF signals in the air.



Tone Stack

There are many different tone stack topologies, and many different ways of doing the same thing. The scope is a great tool for watching how different components and designs affect the outcome.

I'll show a few different traces so you can see what these tone shaping controls look like on a scope.

The trace below shows the signal with both treble and bass set to zero.

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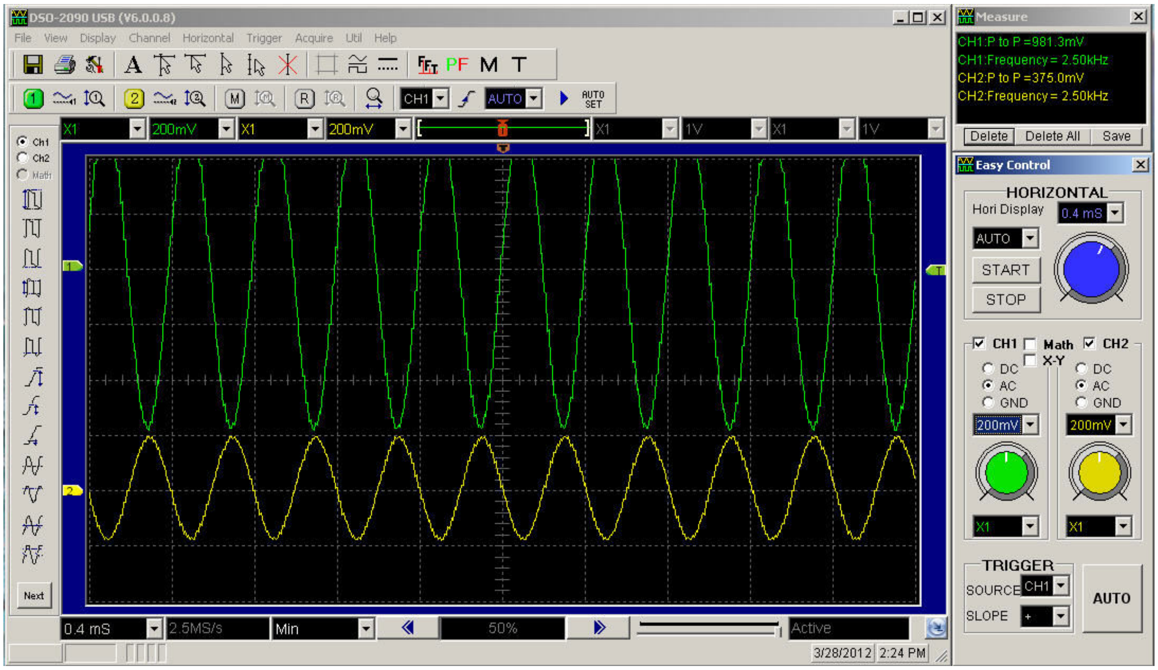
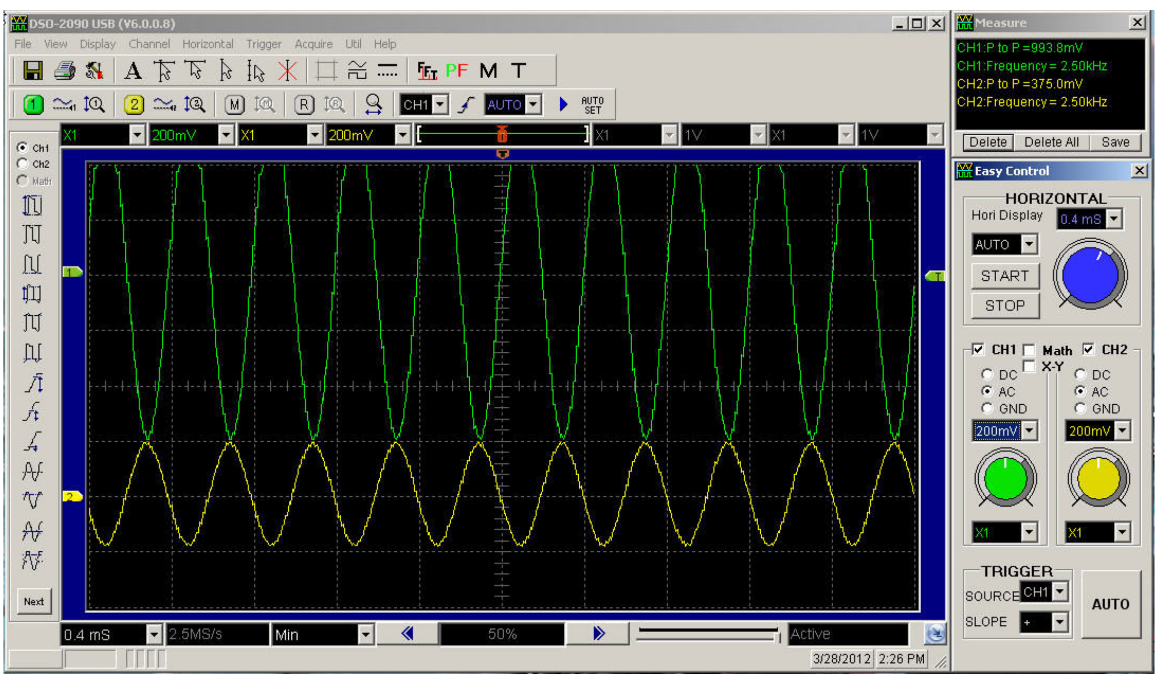
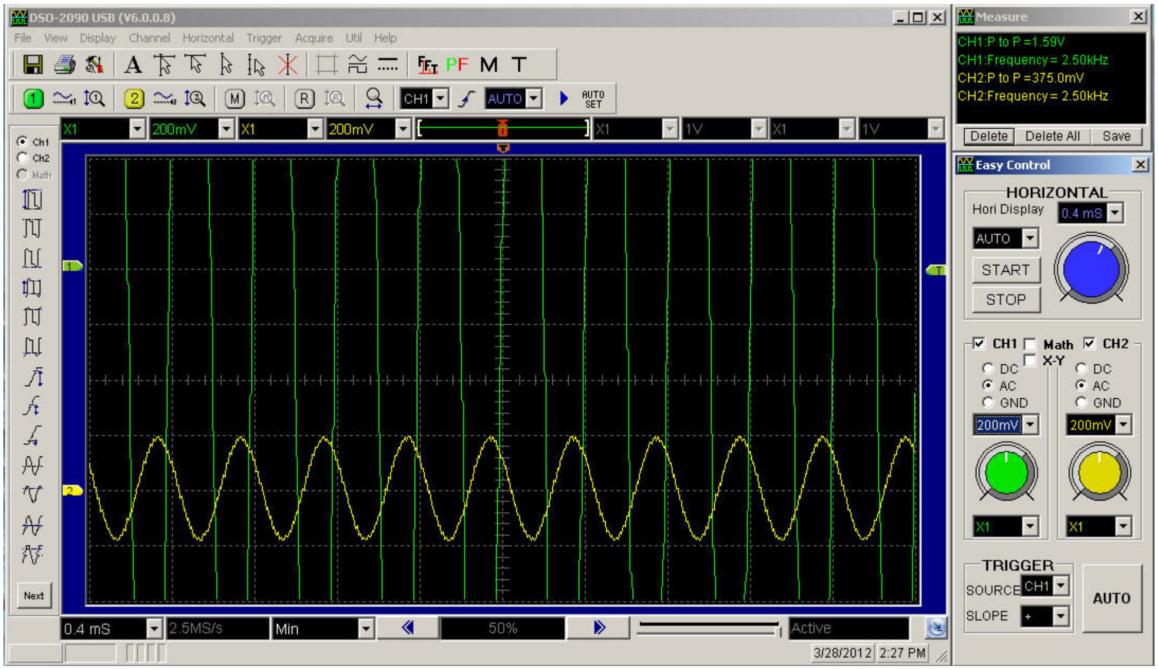


This next trace show the signal with the bass set to 10 and treble set to 0. It's difficult to see the difference. The signal voltage with treble and bass set to 0 equal 981mv. With the bass set to ten the gain is now 1000mv.



Now we see the bass set back to 0, but the treble set to 10. The gain is now 1.59v – a huge increase. This is why amps hiss. We're now able to hear the low lever white noise that was previously hidden below our signal. You can see the green trace is completely off the screen.



In Summary

The temptation when writing a document such as this is to get off on a tangent and succumb to scope creep. It's too easy to keep writing and drift from testing techniques to troubleshooting to designing to brokering world peace to curing cancer.

There's much I've skipped over and left out, but I hope there's enough substance here to help you find solutions to obscure problems. There have been many times when I could not have solved the problem without the use of a scope.