NESCAF vs CALF Smackdown
(Swiched Capacitor vs Active Op Amp Audio Filters)

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OVERVIEW

There are advantages and disadvantages to both switch capacitor and active op amp types filters. In this test we will compare the NESCAF, a switched capacitor filter, to the CALF, an active op amp filter using a piece of software called Room Equalizer Wizard along with audio examples.

Both filter types have their advantages and disadvantages which can be summed up in Table 1:

	Switched Capacitor	**Active Op Amp**
Frequency Adjustment	Variable	Fixed/Limited
Bandwidth Adjustment	Variable	Fixed
Noise	High*	Low
Practical # of chained sections	2**	1-many
Raw Parts Cost	Expensive $3.25 (regulator, clock, pots, etc) +$2.25 / section	Cheap $1.50 (regulator, switches, etc.) + $.50 / section
2 Section Filter	$7.75	$2.50

Table 1 – Basic advantages and disadvantages

* Noise floor rises on narrow bandwidths and lower frequencies.

** Each SCF section requires a resistor or potentiometer for bandwidth per section. Therefore beyond 2 sections additional potentiometers are needed (dual-gang is maximum common obtainable) or a fixed resistor/trimmer is required for each additional stage.

Both filter types may be configured for low pass, high pass, band bass, or notch. Only band pass is observed in this analysis.

CONFIGURATION

To perform some tests the following equipment is needed:

- Computer with sound card - Windows 8 laptop with internal soundcard was used
- WA8LMF audio attenuator for soundcard microphone input
- CALF filter
- NESCAF filter
- Assorted cables and adapters
- Room Equalizer Wizard V5.12 - http://www.roomeqwizard.com/
- Audacity for audio recording/playback - http://web.audacityteam.org/

A few words about the software..... Audacity is a nice piece of freeware for playback, recording, and editing sound files. This was used to record the outputs of NESCAF and CALF which are available later in this document. Another excellent piece of software is Room EQ Wizard (REW). Although it is made for room and speaker analysis, this excellent piece of free software contains various audio/sweep generators, meters, and of course frequency response analysis. Overall a nice piece of software to have in the toolbox. Both pieces of software can run on multiple platforms such as Windows/Linux/Mac. I have no afflilation with either of these sources but if you find it usefull, please consider a donation to encourage the authors to keep it going.

Example of REW settings: Typically when first starting up REW you will want to perform a sound card and SPL calibrations. You can find more details in the on-line help. Additionally you will want to set your audio levels which can be done with the following example:

- Loop back the PC speaker to microphone with an audio attenuator.
- Set the PC Volum1 to 50%
- In REW bring up the audio generate and generate a 700Hz sine wave at -15db.
- Open the REW Levels meter window.
- Open the control panel sound card properties window.
- Using the audio attenuator (optional if it has adjustments) and the sound card properties window adjust the microphone levels for -15db via the REW level meters.
- Turn off the generators, hide the windows, and unplug the loopback.

During testing mode REW measurements are made using the following settings:

- Start Frequency: 200Hz
- End Frequency: 2,000Hz
- Level: -15dB
- Length: 512M
- Sweeps: 4

Hardware configuration:

- Connect the PC audio output jack to NESCAF input
- Connect NESCAF output to CALF input
- Connect the CALF output to the audio attenuator SPKR input
- Connect the audio attenuator MIC output to the PC Mic input.

Note: Both NESCAF and CALF are configured for audio bypass when powered OFF. Therefore a direct loopback also occurs when both devices are off.

TEST #1: NOISE FLOORS

First a comparison of noise floors was observed by muting the PC audio output and monitoring each device in their various modes. Since we are looking at noise, figure 1 looks a little hard to read. By using smoothing techniques we can see a better response in figure 2.

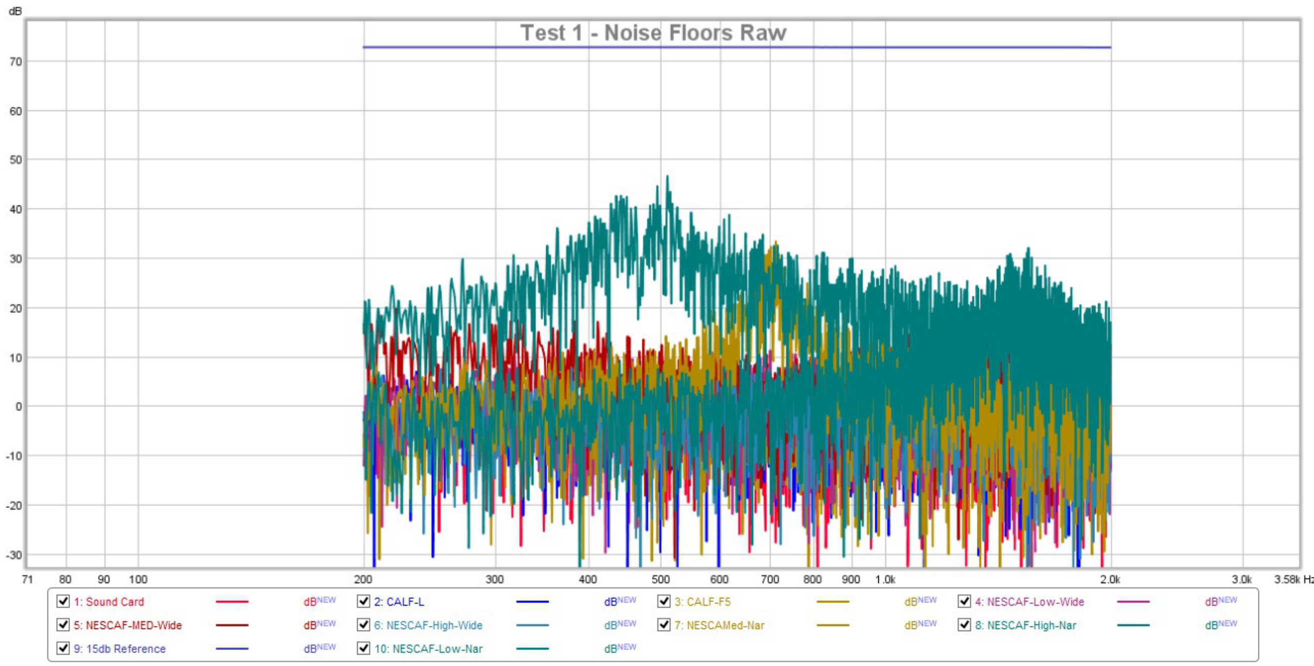

Figure 1 – Noise floors of the PC, CALF, and NESCAF Wide & Narrow modes

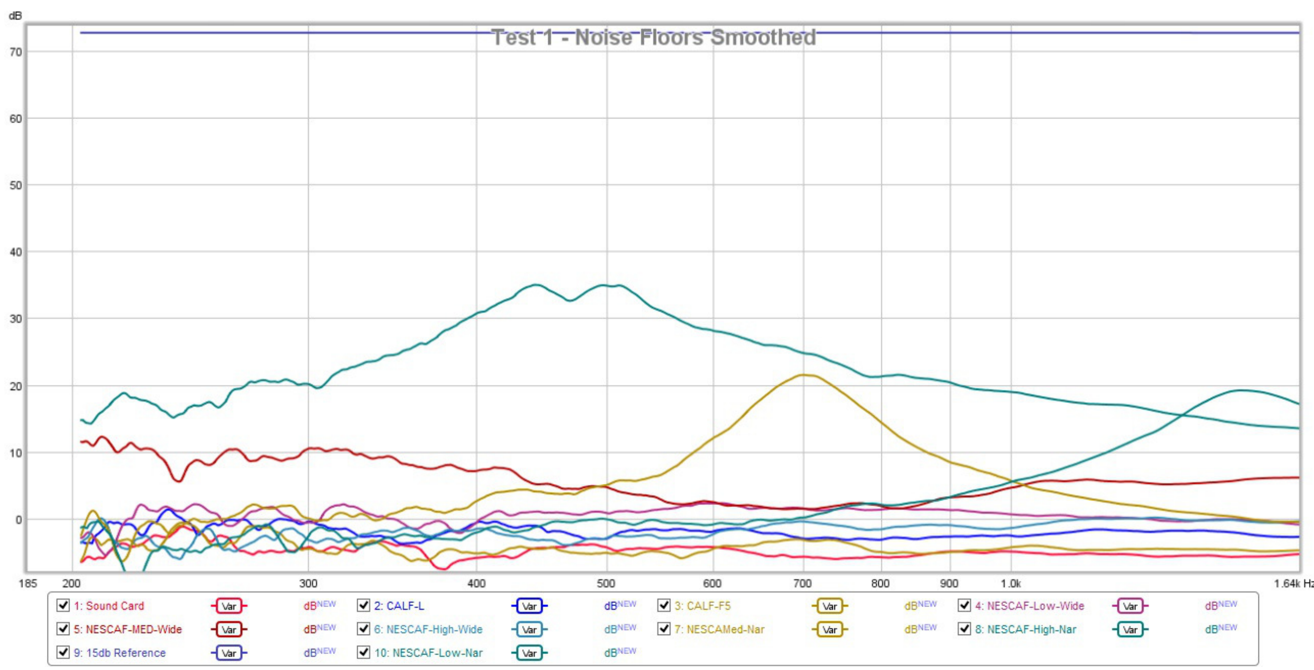

Figure 2 – Smoothed noise floors

Looking closer at the graphs we can see that the sound card noise floor is about 77.7dB below the 15dB reference signal. CALF adds on average about 3-5dB of extra noise as can be shown in Figure 3.

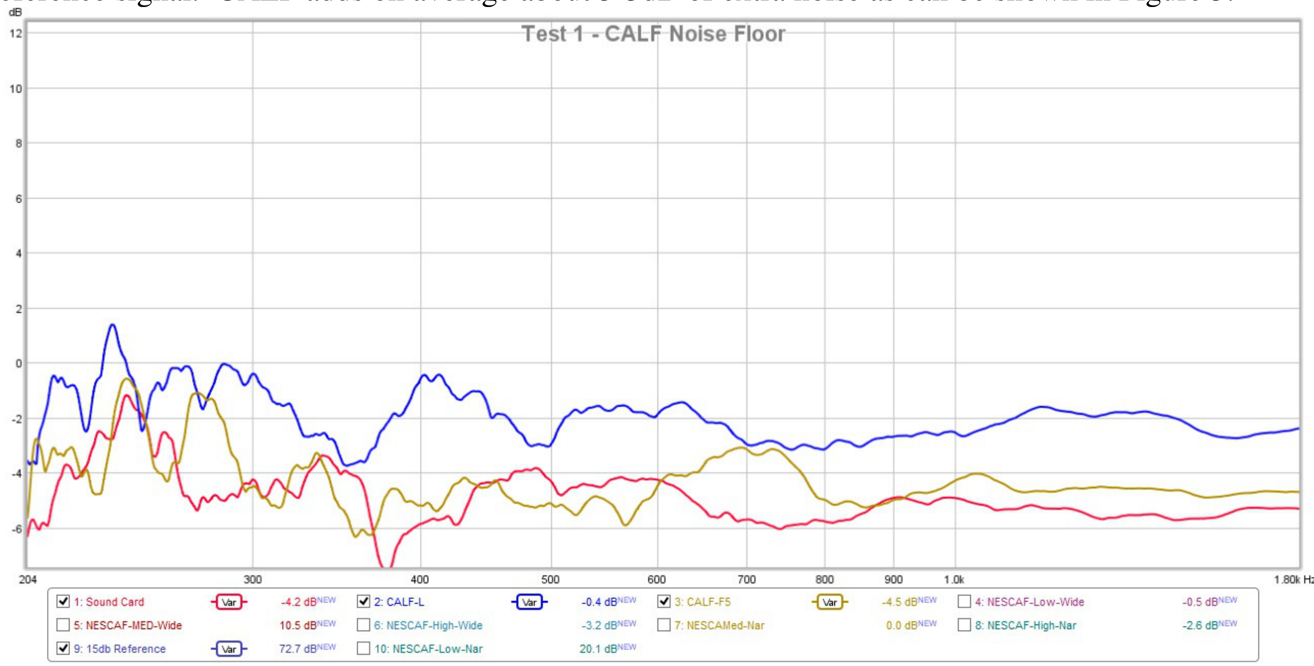

Figure 3 – CALF Noise Floor

The NESCAF noise floor varies as the bandwidth and center frequency changes. This extra noise can be anaverage between 7-13dB in narrow bandwidths to as much as an extra 24-40dB of noise in the narrow bandwidths as show in Figures 4 & 5.

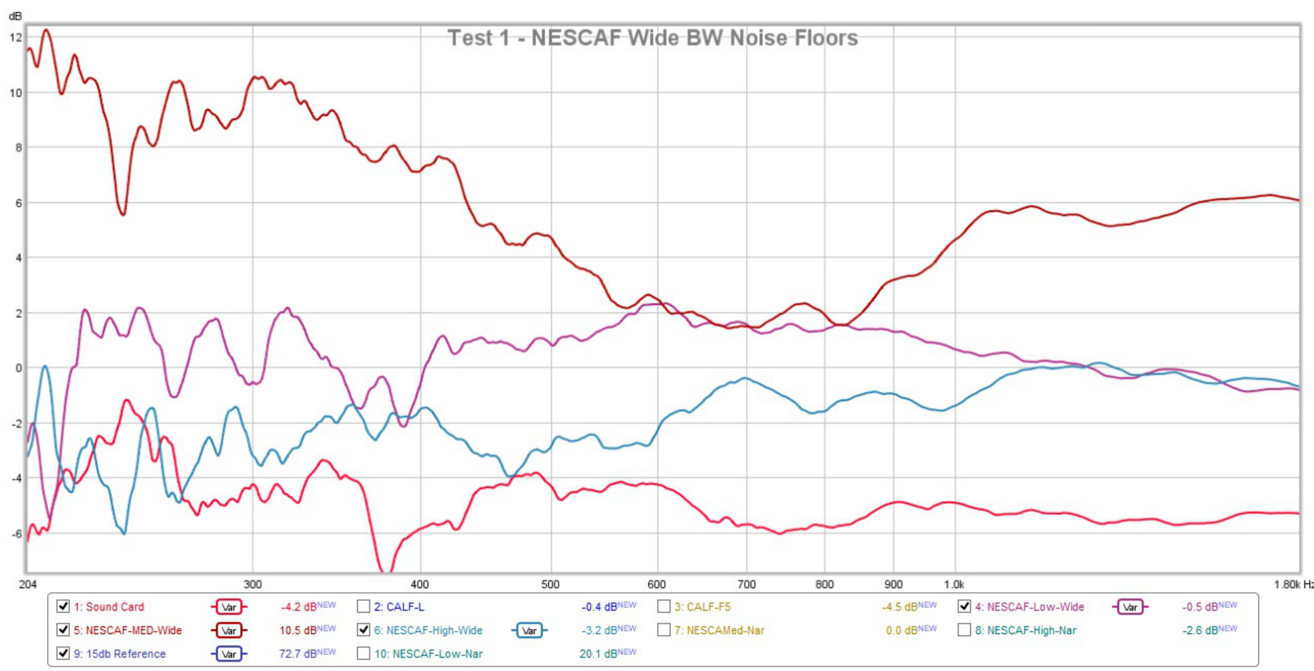

Figure 4 – NESCAF Wide Bandwidth Noise Floor

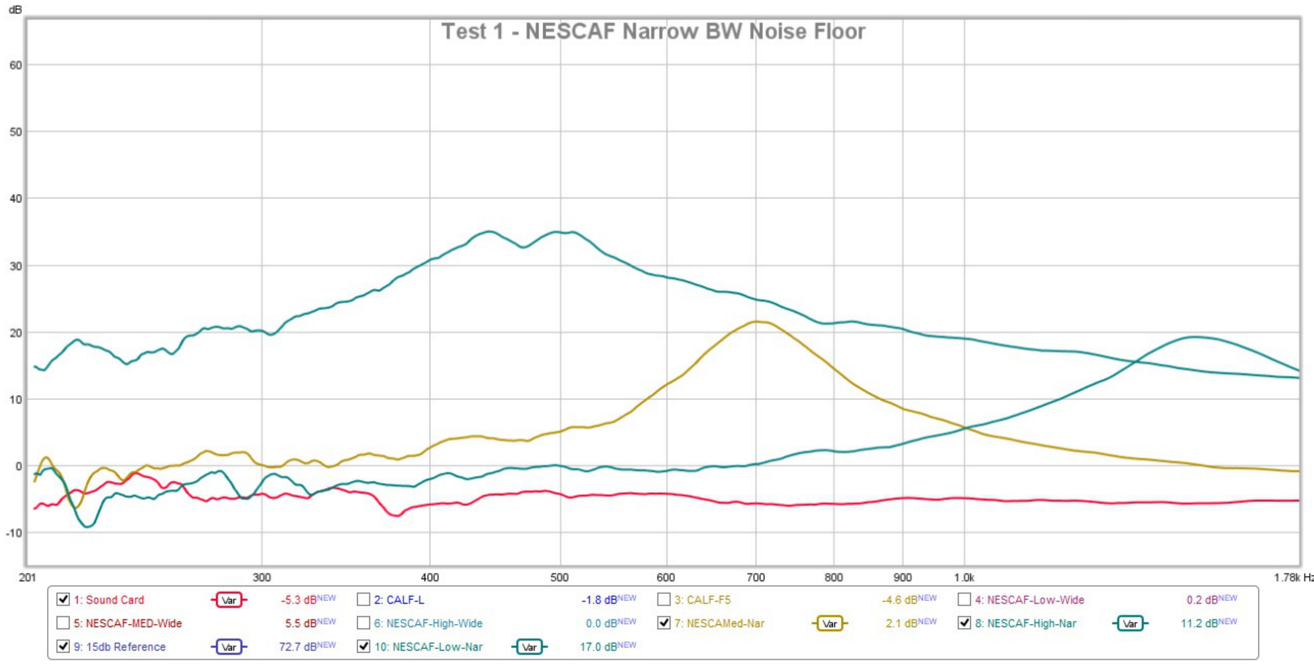

Figure 5 – NESCAF Narrow Bandwidth Noise Floor

When using headphones CALF will generate a slight hiss in extra added background noise. NESCAF creates anything from a pronouncable hiss to an outright rushing sound depending on the frequency and bandwidth settings. A recording of background noise for the PC, CALF, and NESCAF was created with Audacity to hear the differences. Each was sampled for 3 secounds. The recordings were then amplified in order to hear the differences in noise.

TEST #2: CALF RESPONSE CURVES

A signal sweep test was performed on the CALF for each of the filter switch settings with a graphical response in figure 6. CALF contains 6 cascaded filter stages although only 5 switch settings are available. The resulting 3dB bandwidths as well as one octave attenuation can be seen in Table 2. The CALF center frequency is approximately 700Hz.

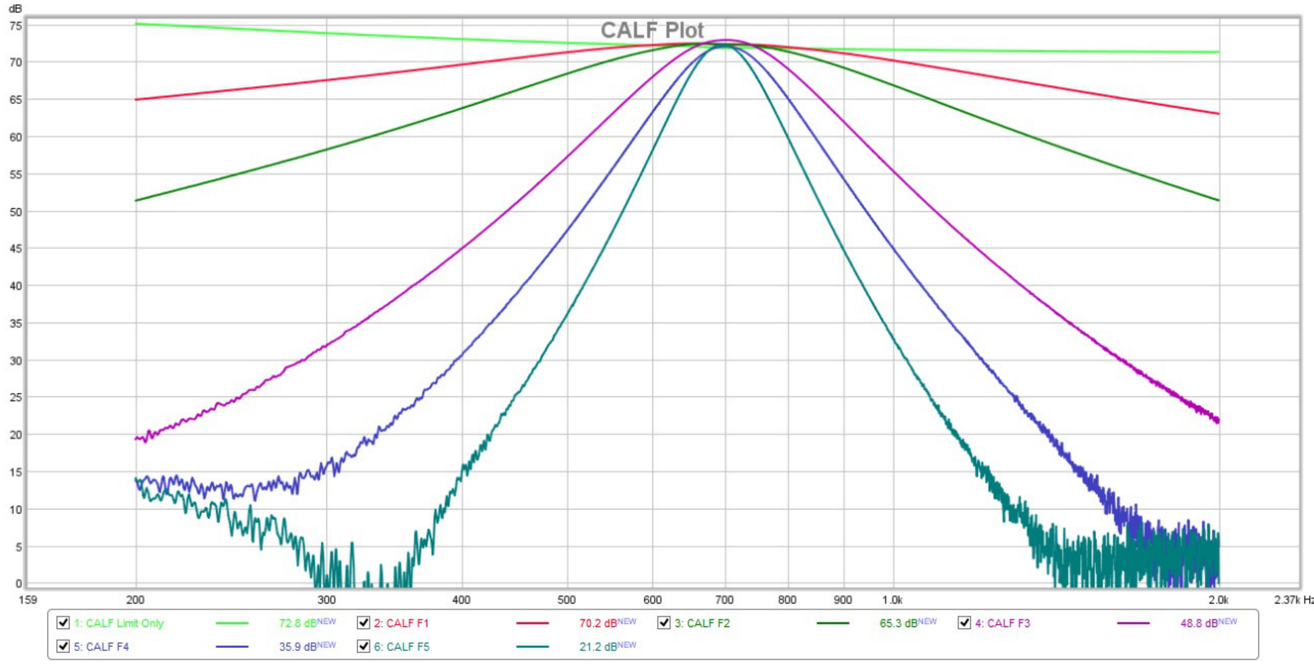

Figure 6 – CALF sweep response

Switch	Stages	3dB Bandwidth	Attenuation @350Hz	Attenuation @1400Hz
F1	1	693Hz	5.7dB	3.7dB
F2	1 & 2	366Hz	11.3dB	13.4dB
F3	1 through 4	165Hz	34dB	36dB
F4	1 through 5	117Hz	49dB	52dB
F5	1 through 6	81Hz	>55dB	>60dB

Table 2 – CALF Bandwidth

TEST #3: NESCAF RESPONSE CURVES

Using a test similar to the above the NESCAF was testing at the center frequency of 700Hz in the narrow and wide settings along with testint at the lowest and highest center frequency settings. The response can be seen in Figure 7 along with a data analysis in Table 3.

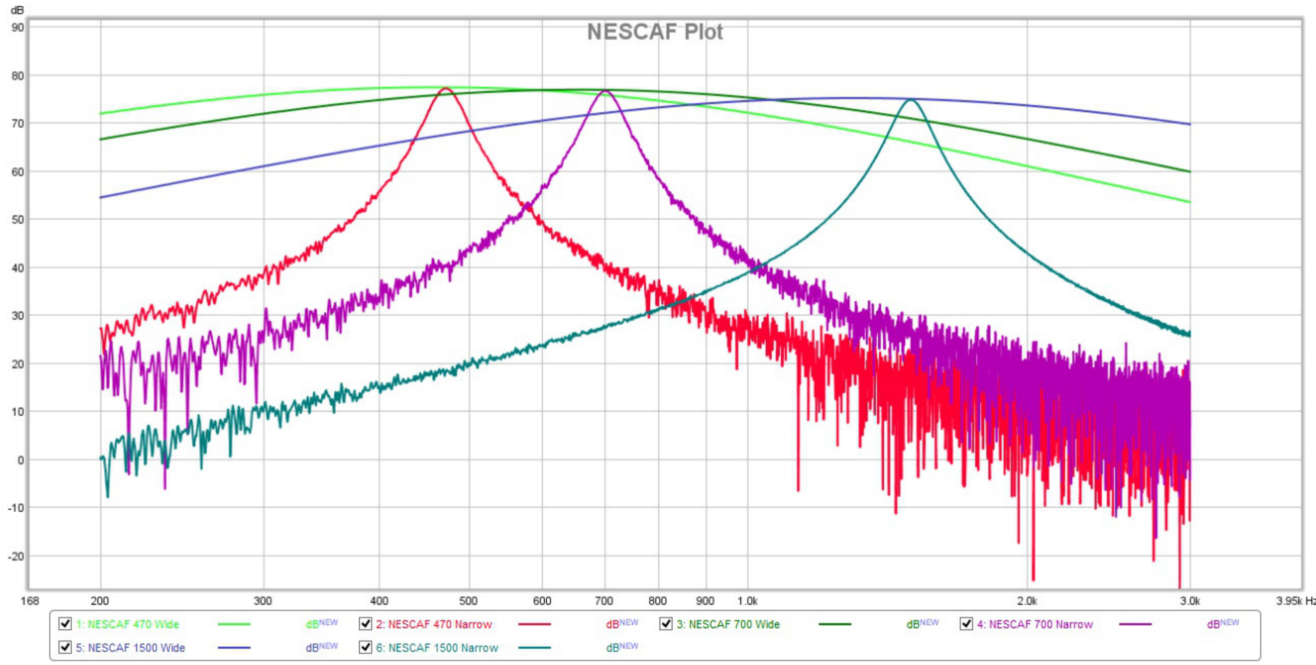

Figure 7 – NESCAF sweep response

Frequency Setting	Bandwidth Setting	3dB Bandwidth	Attenuation 1/2 Octave	Attenuation 2 Octave
470Hz	Wide	557Hz	3.5dB	4.6dB
700Hz	Wide	790Hz	3.4dB	5.2dB
1500Hz	Wide	1663Hz	2.5dB	5.5dB
470Hz	Narrow	30Hz	46dB	49dB
700Hz	Narrow	44Hz	47dB	48dB
1500Hz	Narrow	96Hz	45dB	49dB

Table 3 – NESCAF Bandwidth

One item nocited in the sweep test was the amount of noise generated when the switch capacitor filter is in the narrow mode. In order to determine if this was random noise or a function of switched capacitor filters (replicable pattern) a series of multiple samples were taken and analyzed. A closeup view of one of the slopes is shown in Figure 8.

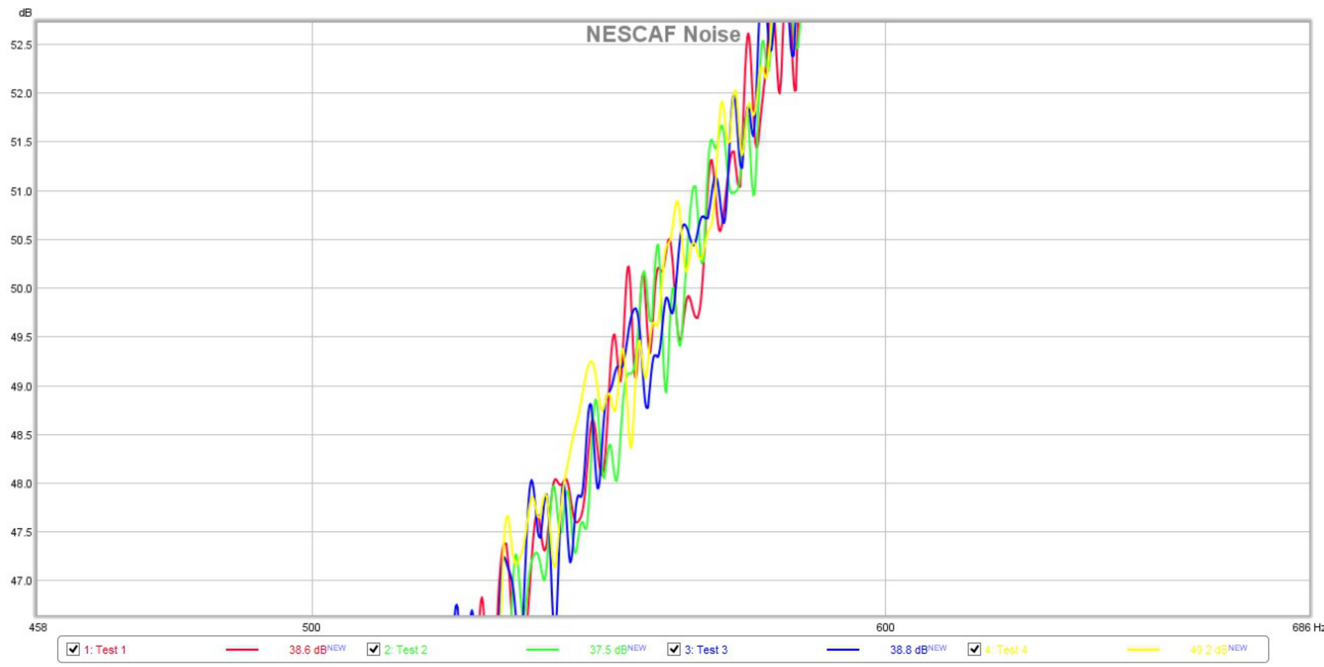

Figure 8 – Multiple sweeps showing the randomness of noise.

TEST 4: Comparing NESCAF to CALF

This test compares NESCAF to CALF by selecting a CALF filter setting then adjusting the NESCAF to match as close as possible. Although data was generated for all 5 CALF filter switch positions, only F1, F3, and F5 are shown in the below Figures 9-11. Even though the F1 test matches pretty close, as additional op amp filters are added the rolloff sharply increases.

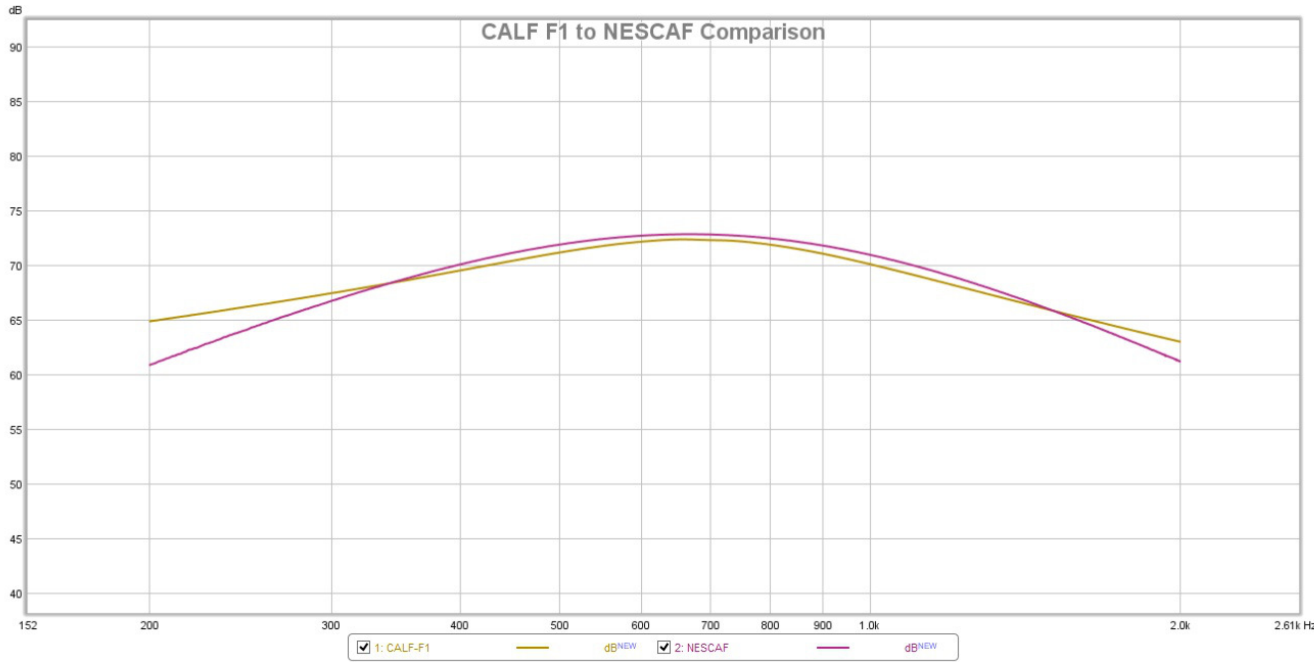

Figure 9 – Comparing NESCAF to CALF in the F1 position

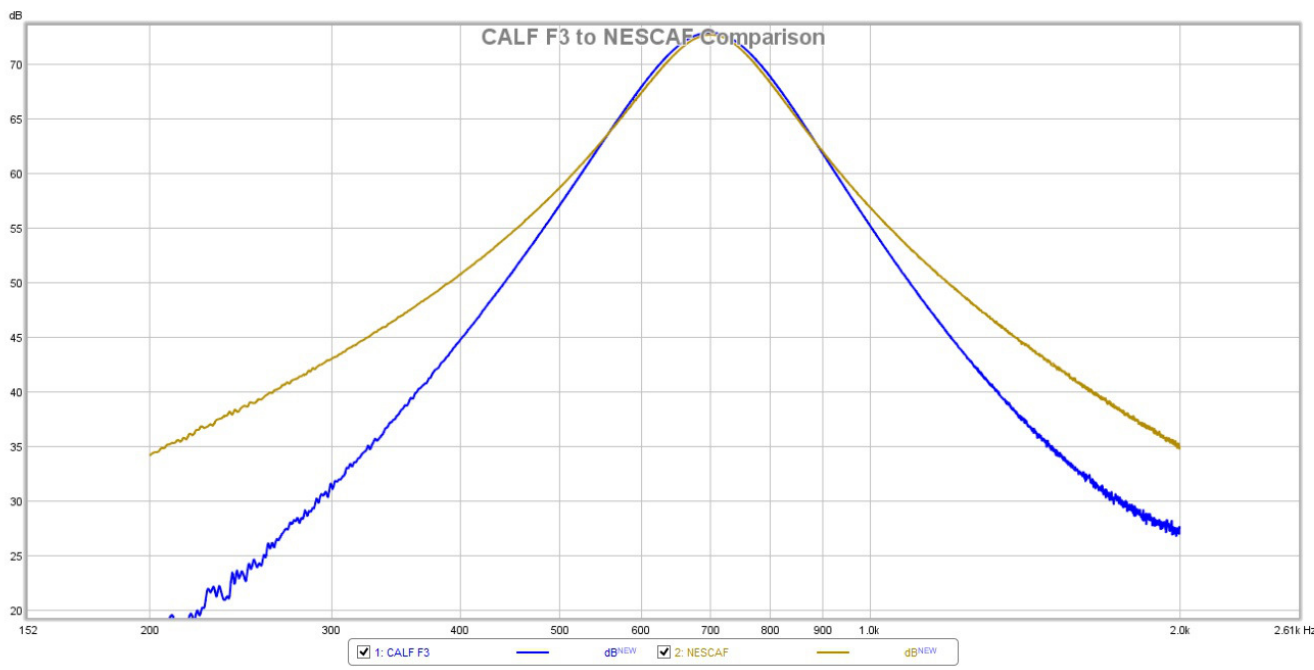

Figure 10 – Comparing NESCAF to CALF in the F3 position.

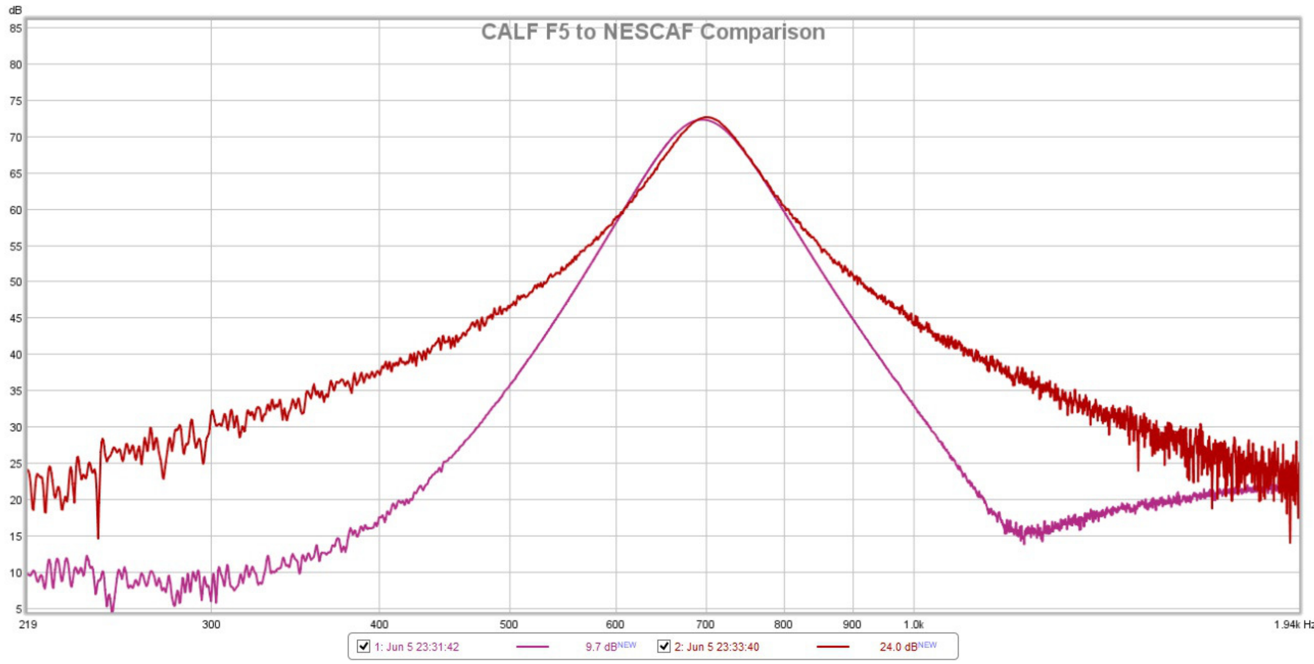

Figure 11 – Comparing NESCAF to CALF in the F5 position.

Test #5: Creating a NESCAF CALF Chain

After hearing the noise within the switched capacitor filter another test was performed using CALF as a post filter in order to see if the noise could be reduced. By using just one or two of the wider op amp filters can greatly reduce the noise. At sweep plot showing the NESCAF followed by CALF in it's various switch settings can be seen in Figure 12. An audio noise floor sample was also recorded using the raw, F1 and F2 filter settings. This recording was further amplified as an aid to hearing the difference.

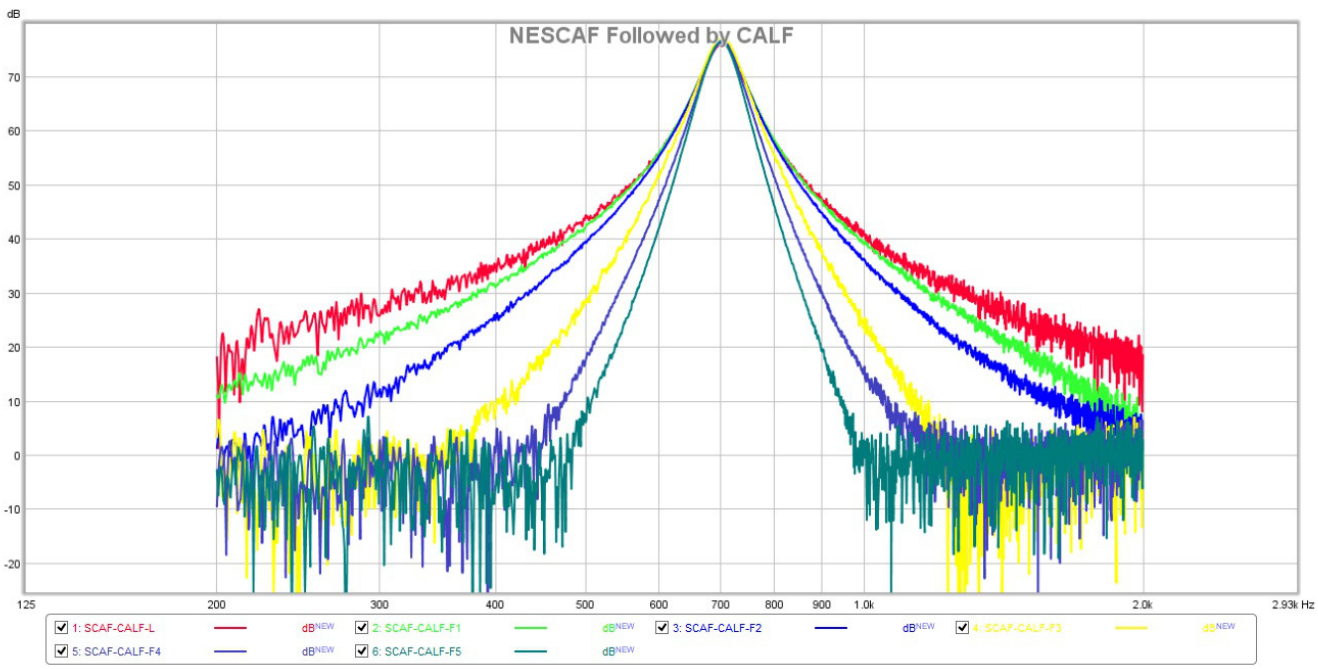

Figure 12 – NESCAF followed by CALF

Test #6: Listening

As a final test several on-air recordings were made and played back with both the NESCAF and CALF and let our ears be the judge. In all recordings about 10 seconds of audio is played several times. The first section is the raw audio as recorded. The second section through NESCAF with a 700Hz center frequency and the narrow setting. The third section is through CALF at the F5 setting with limiting.

Audio Test 1 - QRN with a signal within the noise.
Audio Test 2 – QRM with a strong signal over powering the weaker 700Hz signal.
Audio Test 3 – Both QRM and QRM trying to take over our 700Hz signal.

In the above tests we let the listener be the judge.

OBSERVATIONS

Of course we are not comparing apples to apples in these tests as CALF uses up to 6 filtering stages as opposed to the NESCAF 2. However both filters appear to work well. Each having the advantages and disadvantages as listed in the overview section along with a few other observations noted below:

Tuning the NESCAF center frequency is not smooth and has a "chugging" sound when turning. It was also noted that positioning the potentiometer between the "chugs" can result in greatly attenuated noise. The chugging is also impacted by the bandwidth setting with a narrow bandwith increasing the effect. Tuning for a null in noise can be a challenge and take a steady hand. A sweep plot between tuning for maximum and minimum noise is shown in Figure 13. Additionally an audio recording was created sweeping the frequency potentiometer in both the narrow and wide mode.

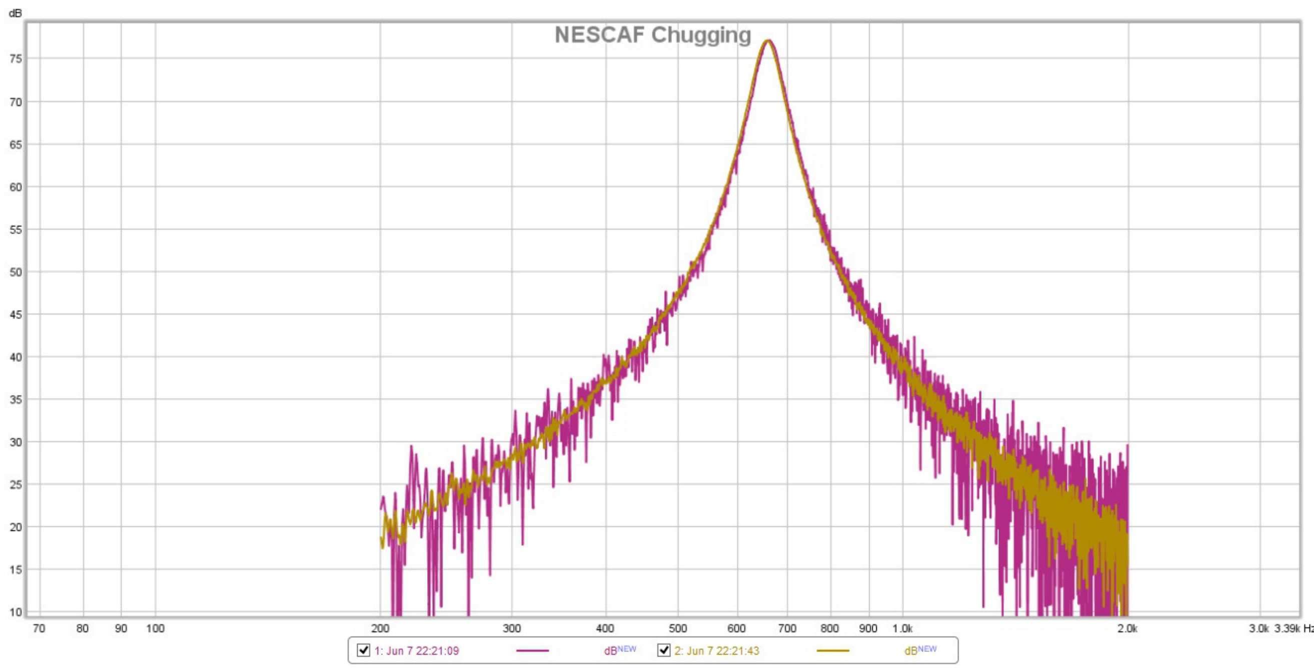

Figure 13 – Chugging while tuning

It was also observed that using an additional op amp filter or two with a wide bandwidth greatly reduces any noise generated by the switched capacitor filter. A best of both worlds scenario would be a hybrid design using front end buffer amplifier/limiter (See the CALF web page for reasons) followed by the 2 switched capacitor filter and then followed up by 2 additional wide op amp filter stages.

A zip file containing this document, audio examples, and REW data files can be found at http://kc9on.com