Elliott Sound Products Project 47

Vox AC30 Guitar Amplifier Simulator

Stephan Möller (Edited by Rod Elliott)

Introduction

This project is a little different from most. It was designed in Germany by Stephan Möller, and was quietly residing on his web site until I spotted it. Stephan was very happy to have it reproduced here, as he will get more exposure, and you will get something quite extraordinary. In his own words -

> Dear guitarists who love the VOX AC-30 !
>
> The secret is revealed !
>
> This is my project "AC30SIM", a Vox AC-30 Simulator, based on OP-Amps. I hope you enjoy to read or even test it. I am very happy to publish my page on Rod's page, that's really nice from him, and if you have any questions, I will answer them soon.
>
> Have fun,
>
> Stephan Möller

Stephan has done a lot of work on this, and I only have the essential elements here. Much of the support material is linked back to Stephan's site. These include sound files (MP3 files are local, but the wave files are remote), so you can hear what the simulator and the original Vox AC-30 actually sound like, and some plots from PSpice showing frequency response, circuit simulations, etc.

The material is essentially Stephan's original, reformatted to match the rest of my pages - I have made a couple of comments, and have changed some words - Stephan's English is excellent, but a few words were obviously hard to translate properly.

> Comments I have made are indented, and in this type, so it is really easy to see what I added to the original. If this is not enough, I have also added my "tag". RodE

Vox AC-30 Simulator

Please Note: This is a general description of the circuit AC30SIM, the simulator of the VOX-AC30. Some resistor values are not shown to protect the circuit against commercial use. If you are privately interested to know the values, so that you can build the circuit for your own private use, print, sign and fax me back the non-disclosure agreement

My Fax Number : Germany / Hamburg 0049-40-6688-3388
I will then e-mail you back the values as soon as possible.

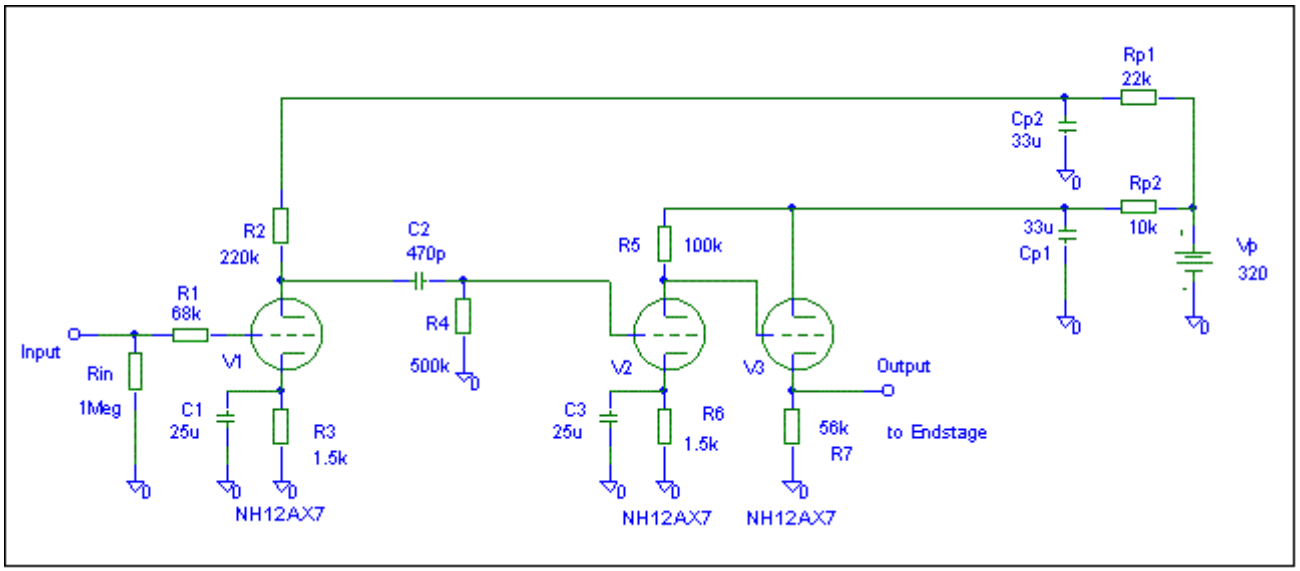

Figure 1 - Simplified Circuit of VOX-AC30 Preamp

The original : The brilliant Input Preamp of the VOX-AC30 Top Boost. The Volume pot is turned to full and therefore replaced with R4. I must say that my PSpice simulations with triodes do not show the behaviour of my VOX-AC30. I don't know why, maybe because of the old tubes in my old VOX (1961) or the PSpice models are not valid enough.

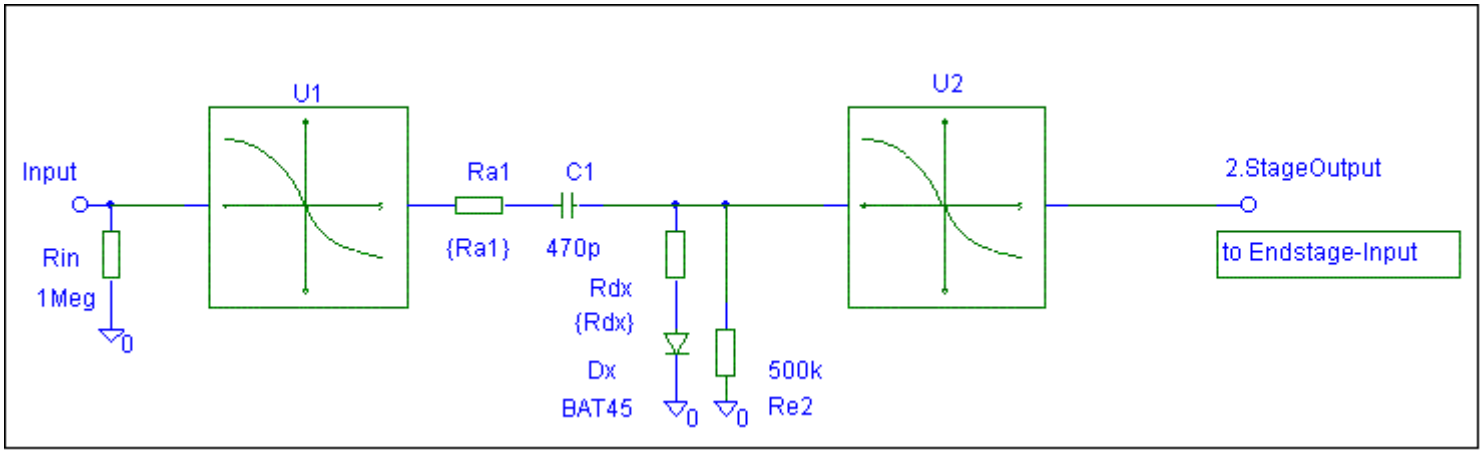

Figure 2 - Block diagram of AC30SIM Preamp

This is a block diagram of the AC30SIM Preamp. U1 simulates the first VOX Valve stage V1 and U2 simulates the second VOX Valve stage V2/V3. U1 and U2 are inverter amplifiers with non-linear transfer functions. Between them is a high pass C1 / Re2. Ra1 simulates the Anode resistor R2, and Rdx / Dx simulates the grid current of V2.

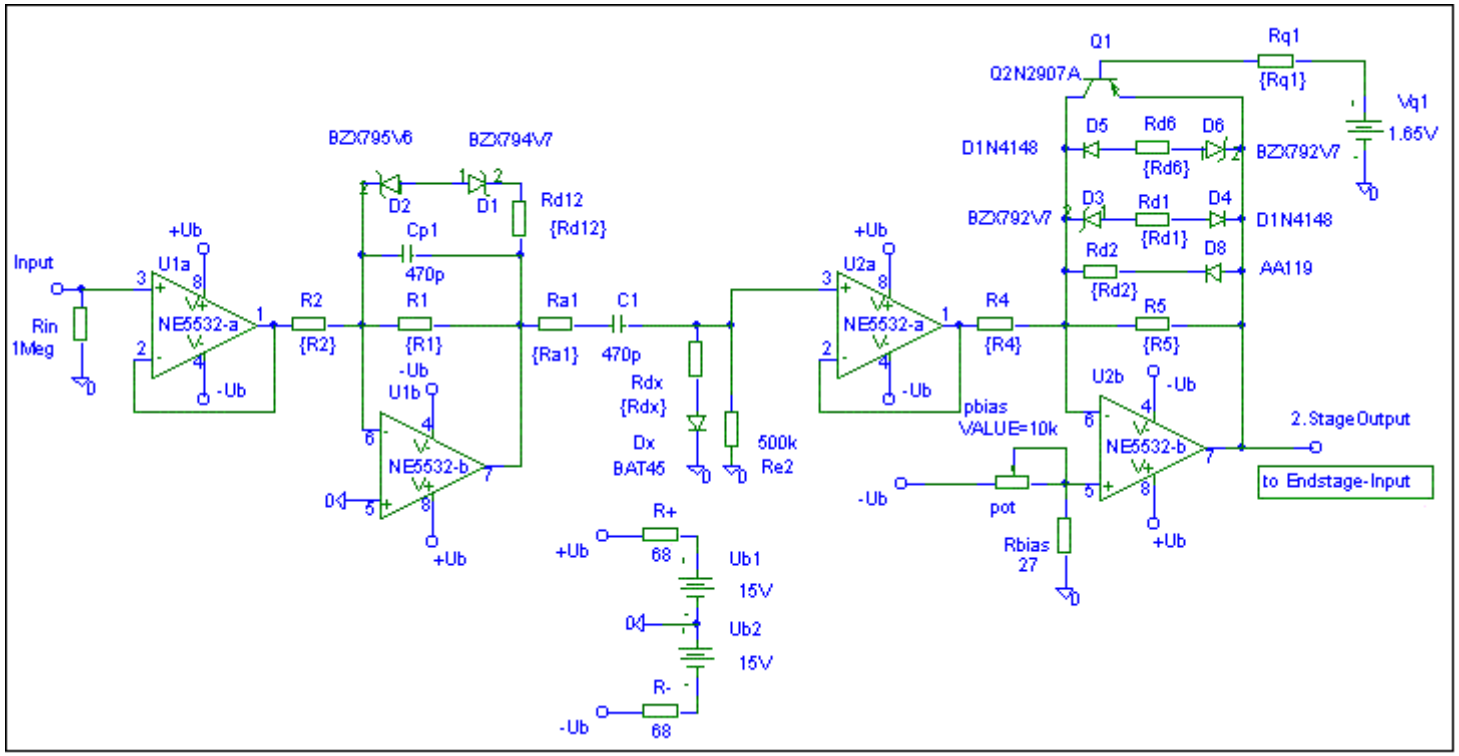

Figure 3 - Circuit of AC30SIM Preamp

My intention was, to develop an opamp circuit which simulates the VOX AC30 Preamp. The main problem was, that the non-linearities of the VOX are hard to determine. For example, it is not possible to measure the DC transfer function of the VOX, because it has capacitors in the signal path. A sine signal is the only signal on which distortions can be identified.

The thing is, that the different input levels of the sine wave will cause different output signals. Like when you play a single guitar tone into an amplifier. At the beginning the tone has full volume and the amplifier has a lot of distortion. Then the tone gets lower and lower, and the distortion gets smaller and smaller. The distortion changes with the input level. So I calculated a sine burst signal with an exponential volume decrease. You can see a comparison of measurements of the preamps (VOX-AC30 and AC30SIM)

If I use a circuit which has exactly the same amount of stages and the same filters between them, it is only necessary to find the non-linearities of each stage to simulate the behaviour of the VOX. It's enough to use an exponential sine stimulus of only one single frequency. Which frequency is not important. I took a 400Hz expontial sine stimulus. That signal I fed into the VOX and began in parallel to compute with PSpice some circuit simulations to find possible solutions to get near to the behaviour of the VOX.

> Some readers might be baffled by Stephan's claim that the frequency is not important, however this is the case provided the chosen test frequency is within the normal bandwidth of the amp - preferably at an approximate centre frequency. For guitar and most music, 400Hz is actually a better test

frequency than 1kHz. Having found the non-linearities and the frequency response, the two combine to provide the overall characteristics of the original.
RodE

When I had a good solution, I took some measurements of my circuit and compared it to the VOX. When the measurements of my circuit where not near enough, I modified the circuit and took some more simulations with PSpice. And so on.

At low input levels it is hard to detect distortions on a sine wave. So the final measurement was to compare the FFTs at low input levels. I took a 400 Hz sine wave which has an exponential volume decrease and measured the FFTs of my circuit and the VOX.

To show the behaviour of the complex non-linearities of the AC30SIM Preamp circuit, I have computed some PSpice Simulations.

The inverter opamp circuit is a good basis to form non-linear transfer functions. Each Opamp inverter is driven by a Opamp buffer to give an independent high input impedance. The complex non-linear network in the feedback loop of U2b is necessary to simulate the unique behaviour of the 2nd stage of the VOX-AC30 preamp. The dual power supply of +/- 15 Volt seems high, but is needed to let the first buffer U1a work without clipping.

Some guitar pickups can produce relatively high output peaks which would easily overdrive the first buffer. The potentiometer at the positive input of U2b is needed for DC offset trimming. Because of the DC coupling between U2a/U2b and the high gain of U2b, a small DC offset of U2a can be significant at the output of U2b and therefore influence the non-linear transfer function very much. The potentiometer is trimmed for 0V DC at the output of U2b.

Instead of the NE5532 any good Fet Input Opamp could be used. The advantage is, that the bias circuit is not needed anymore, because of lower input bias current which causes much lower input offset voltage.

If you would like to see my Pspice simulations for comparison of non-linear Opamp circuit:

- Three basic limiter circuits
- Four inverter / limiters with different non-linear feedback loops

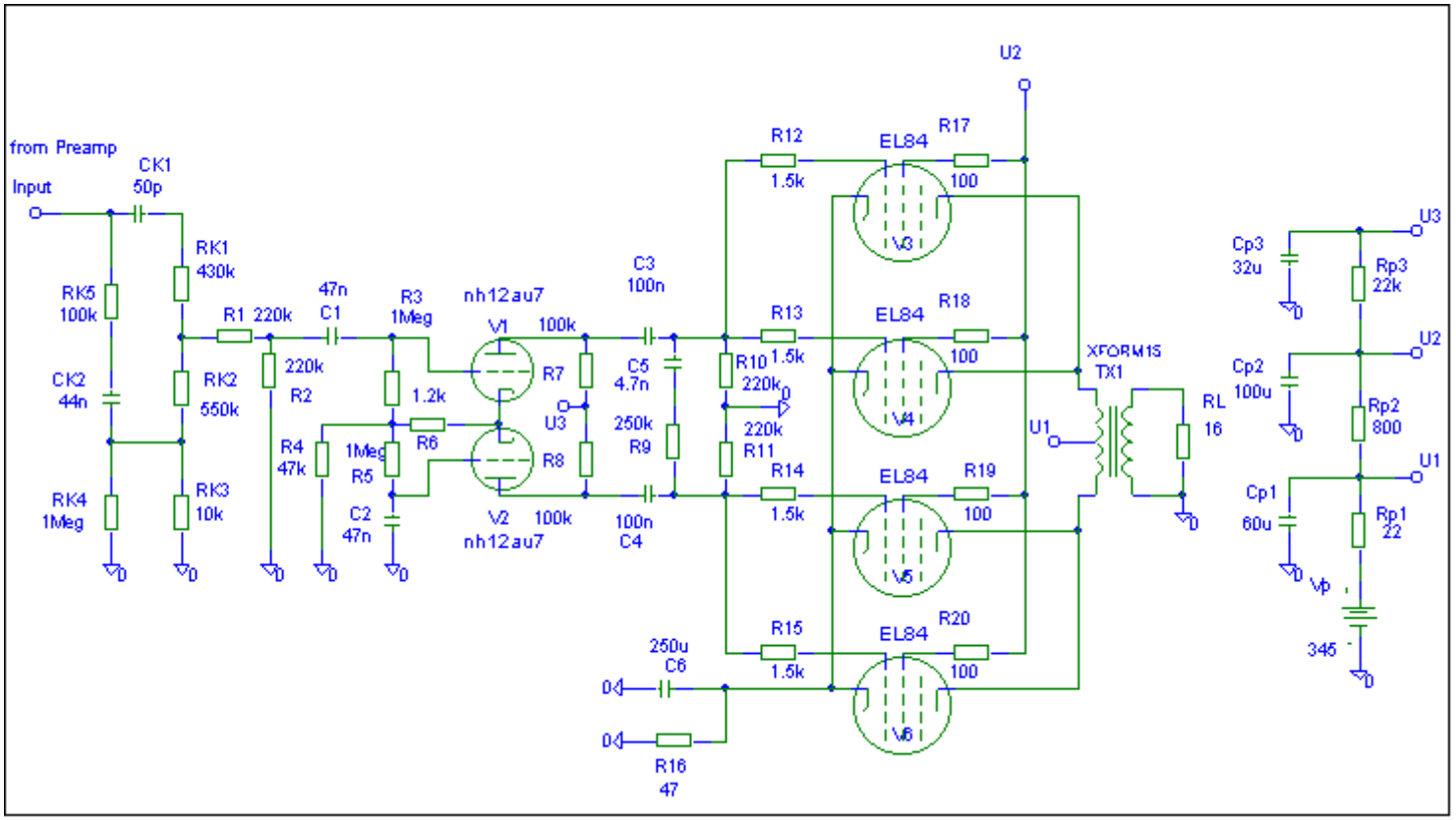

Figure 4 - Circuit of VOX AC30 End stage

This is the simplified circuit of the VOX AC30 Top Boost Power amp. The tone control filter has fixed resistors instead of pots. The treble potentiometer is RK1/RK2 and bass potentiometer is RK4, which stay for my favourite positions.

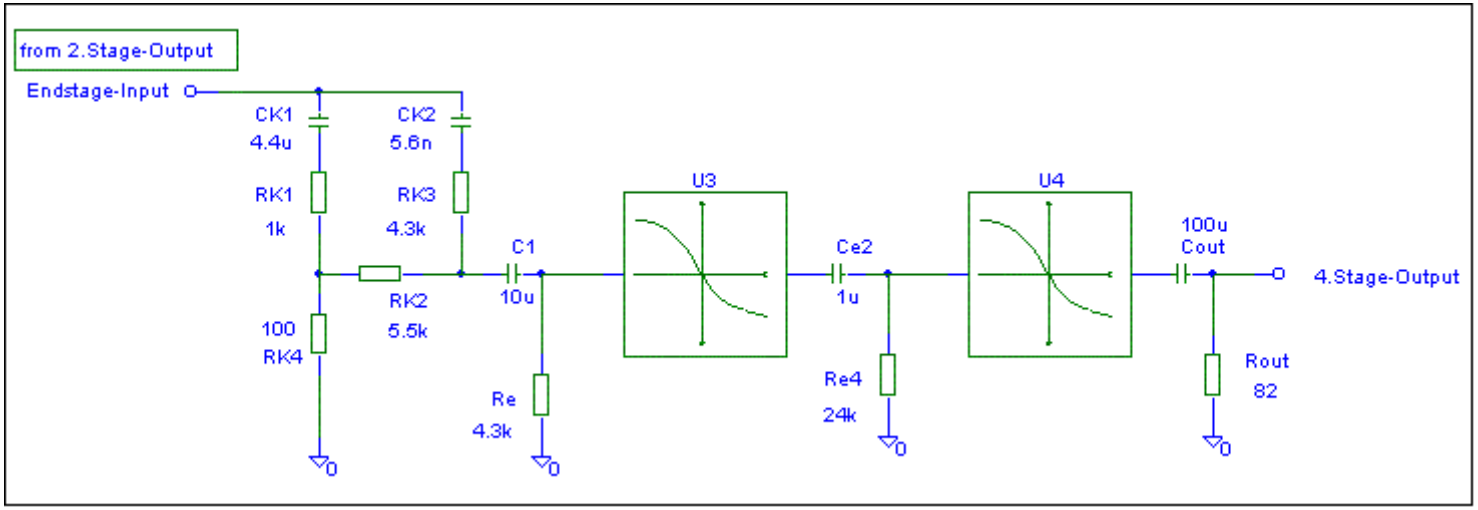

Figure 5 - Block diagram of AC30SIM End stage

Figure 5 is a block diagram of the AC30SIM End stage.

- U3 simulates the VOX Phase splitter V1/V2.
- U4 simulates the VOX End stage V3/V4/V5/V6.
- U3 and U4 are inverter amplifiers with non-linear Transfer functions.

The front end is the tone control filter. Between them is the high pass Ce2 / Re4. The output has a high pass which simulates the transformer of the VOX.

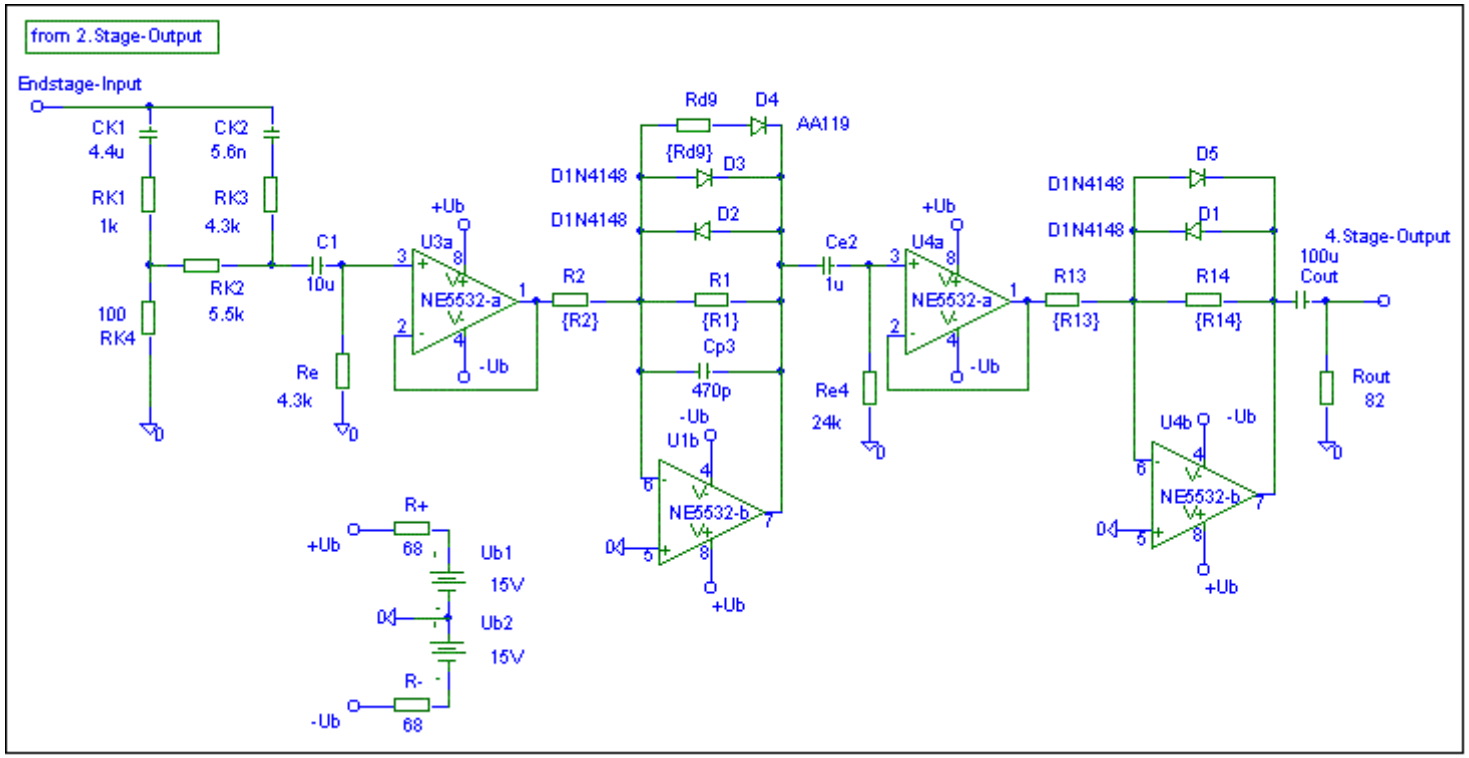

Figure 6 - Circuit of AC30SIM End stage

The circuit is designed to simulate the phase splitter input stage and the output stage of the VOX-AC30 preamp. Each linear network like the tone control filter and the input coupling capacitances of the VOX are transformed to lower impedances but with equal responses to simulate the behaviour of interaction between the non-linear and linear devices of the VOX-AC30.

I simply multiplied / divided the original values of the VOX tone control filter with 100. The only exception is CK1 of VOX-AC30. It is written on the capacitor that its a 50pF. So I took a 5nF capacitor, and I wondered why the transfer curves of both amplifiers had a difference of 3dB in the mid/high range. I measured CK1 of the VOX and it was 56pF. So I took a 5.6nF capacitor.

The non-linear networks of the feedback loops of U3a and U4a are simpler than in the preamp stages. The transfer function of the output stage is symmetrical. Only the phase splitter stage is slightly asymmetrical, which is done by the diode D4. The matching of both gains of U3b and U4b was a bit difficult to find.

Some additional information
A measurement comparison of preamp + end stage from VOX-AC30 and AC30SIM, and a comparison of the 3D Spectrums. A PSpice simulation of the End stage of AC30SIM

I must again say that my PSpice simulations even with pentodes did not show the behaviour of my VOX-AC30.

At least a comparison which might be interesting for those who think that the AC30SIM is not close enough to the VOX. I measured the difference between the AC30SIM and the VOX with ECC83 valves from different manufacturers.

- The result : The difference between Vox with different valve manufacturers is bigger than the difference to the AC30SIM.
- Or in other words : The difference between two Vox amps is bigger than the difference to the AC30SIM.
- Or in more other words: It is useless to develop a circuit which is closer to a VOX than the AC30SIM, because the tolerances of Vox amps are bigger. So if a valve simulator represents say 99% of a real valve amp, it's enough because of the natural tolerance of valve amps.

Valve test

Some Wave files to compare between VOX-AC30 and AC30SIM

I played my guitar direct into my computer sound card, played it back from the sound card and feed the signal to the inputs of the VOX-AC30 and my AC30SIM circuit and recorded both outputs. For not overdriving my sound card input, I reduced the volume of my guitar and increased the output level of the sound card during playback by using the power amp output of the sound card. (Terratec: Maestro 32/96)

With this I have a reproducible guitar signal to feed to the amps, which is equivalent to my original guitar.

Tune 1 & 2	Wave / MP3

VOX-AC30 End stage (Directly measured at the transformer output of the VOX-AC30)

Please Note: All wave and MP3 files will have to be obtained from Stephan's site, as they are causing me grief because of the file sizes and my traffic limits. The above links will take you to the bottom of this page for the link to the original article. RodE

If you don't like my chords, I can do something specially: Play a short phrase on your e-guitar (please < 5 seconds, 16bit, mono, fs = 44,1kHz or 48kHz !!) direct into your sound card and send me your wave file per E-mail.

Use a high input impedance preamp in front of the sound card, because sound cards have an input impedance which might be too low for many pickups (10k - 20k Ohm).

Try to record the highest level as possible without clipping, to get the best signal to noise ratio. I will replay your wave file from my sound card into my AC30SIM, record the output, and send you back the wave file (as soon as possible !). Please write me, if you like to have the direct output or the Speaker simulator output.

Then you can compare that result with the original wave file played back on your amp. Maybe you have to experiment with the input level, because your amp might have a different input sensitivity. But that's always so if you compare different amps. If you think your amp sounds

better, I would like to listen to your wave file.....
(I hope not too many people send me wave files ..ha, ha)

VOX-AC30 with Loudspeaker

A problem is, if you record a guitar amplifier plus guitar speaker with a microphone in a living room and play the recording back on your HiFi System, it will never sound like the original amp. If you put the mic very close to the speaker, you eliminate room resonances but the sound is very coloured in the mid/high range. If you put the mic 1 meter to the speaker, the sound is quite neutral in the mid / high range but very reverberant and boomy in the bass / midrange.

When a mic is placed very close to the speaker, it picks up only a small part of the cone, whereas in free field situation, the microphone has a distance of 1 metre to the speaker, which picks up the complete cone.

To design a speaker simulator, which simulates the sound of the VOX Speaker, you have to know the free field frequency response. I had not the possibility to do that, so I had another idea :

I took 10 white noise records along the radius of the VOX Speaker with a distance of 13 cm and added them with a sample editor. The records have to be correlated, to enable correct operation, which means that the signal starts of all records have to be equivalent (exact triggering !).

The frequency responses of the VOX AC30 Speaker

This response was the target function for the speaker simulator. When you compare to listen to the AC30SIM plus speaker simulator on a HiFi System to the real VOX-AC30 plus speaker, it sounds very close !

The following two sound files are recorded with a microphone (distance = 8cm / 0deg). I must say when you play these on a HiFi System, that they sound absolutely not like a real VOX AC30.

Tunes	Wave / MP3

Microphone - 80mm from cone, on axis

These next sound files are recorded as described in the caption for each group -

Tunes	Wave / MP3

VOX-AC30 End stage (Directly measured at the transformer output of the VOX-AC30)

Tunes	Wave / MP3

AC30SIM End stage - Directly measured at the 4th Stage-output of the AC30SIM

Tunes	Wave / MP3

AC30SIM with Speaker simulator - Directly measured at the speaker simulator output

The best comparison of the sound (despite Stephan's reservations) will be between the microphone recording and the AC30SIM with Speaker Simulator. There will be differences, but listen first for the overload characteristic and second for the general balance, and remember that the mic was 80mm from the speaker for the measurement - this does change the sound. There is also a slight level difference, so don't let this fool your ears into thinking there is a major variation. Tonal changes can be created by tone controls (that's what they are for :-) but the overload characteristic is normally very difficult to duplicate. This is virtually identical.

Comparing the recording from the AC-30 transformer with the output of the 4th stage of the simulator (before the speaker simulator) is also useful - the hard edge is common to all valve or transistor amps before the speaker tones it down again with its (deliberately) restricted frequency response. RodE

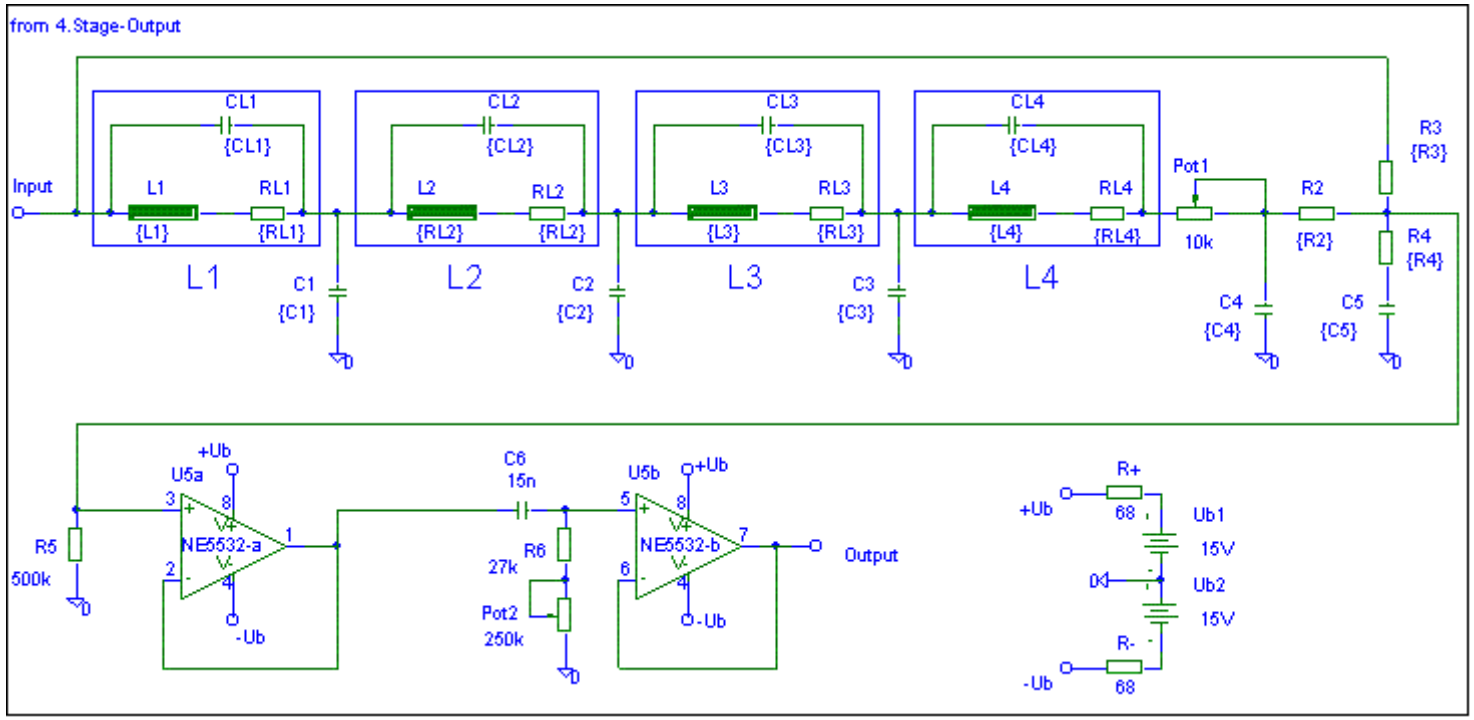

Figure 7- Circuit of Speaker simulator

The speaker simulator is basically a passive L-C-R Filter. You see L1, L2, L3 and L4 which are discreet inductances from a component supplier in Germany : CONRAD-Electronic.

To simulate with PSpice the circuit exactly, the inductances have to be simulated with their series DC resistor "RL" and parallel capacitance "CL". When I put the circuit together on a breadboard, I noticed that the inductors need to have a distance of minimum 10 mm to each other, to eliminate significant cross talk with resulting response distortion.

The OP amp circuit at the end is a simple bass cut filter, which sounds good when the AC30SIM is played on a HiFi system.

Some frequency measurements of the VOX-AC30 and the AC30SIM, a PSpice simulation of the speaker simulator circuit and some photos of the prototype.

That's All Folks

Now, you can visit Stephan's original site, or send him an e-mail, or send me an e-mail (or do something else).

I'm sure that you will agree that this is quite a piece of work. As noted above, you will need to fax Stephan a signed copy of the non-disclosure agreement to get the missing component values. This is outside my normal practice, but quite understandable. I have made no attempt to change this, and will not do so.

Wave and MP3 Files
To download the wave files for any of the sounds, please click here, and you will be transported via the magic of the web to Stephan's site. (These files are quite large, and take up too much space on my server.)

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