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From: JaySG

Date: 1/12/2001 12:22 AM

Subject: Tonequest Dr. Z Interview -- Conjunctive Filters

This seems like something to discuss. I'm including some RCA text after the Dr. Z snippet. Please bear with and keep on reading.

Q: What other specific features are unique to your amps?

A: I probably have a couple of original designs that are unique to my amps, and they were all evolved from a circuit that's called a conjunctive filter. It's a filter that goes across the primary side of the output transformer. The Carmen Ghia has a very traditional conjunctive filter, or corrective filter, as it's described in the RCA Receiver's Handbook. It affects the primary impedance of the transformer and allows frequencies to be very flat, or balanced. From say, 100Hz to 3K, the amplitude is the same. So from the high E to low E strings if your pick attack is the same, you'll get the same volume from the notes. The volume of individual notes isn't frequency dependent. So going back to what we were saying earlier about the touch dynamic of our amps, all that is related to the conjunctive filters that we use, and you're really in control because of them.

Q: And this is unique to the Z's?

A: No one else uses it. It's something I found in an old RCA book of my dad's, and again, it's referred to as a corrective filter. It was just a little side note on how to make an amplifier more linear within a certain band of frequencies. When you strum a chord, each note makes it's own contribution to the sound without one note overpowering the other. Jazz players love it when they're playing those big, 6-string chords—it really puts a twinkle their eye when they hear it.

The Prescription is another one in which I went with a different approach with the conjunctive filter. I have Todd Sharp to thank for that. We were in the tuning room for a Rod Stewart show and I'd sent Todd some parts for a Dr. Z Prescription he was using. We started playing around, and before you know it, we had evolved it into a really cool sound with different values of resistors and caps that we used. It's funny how working with artists, you develop things.

From a RCA Receiving Tube Manual:

A corrective filter can be used to improve the frequency characteristic of an output stage using a beam power tube or a pentode when inverse feedback is not applicable. The filter consists of a resistor and a capacitor connection in series across the primary of the output transformer. Connected in this way, the filter is in parallel with the plate load impedance reflected from the voice-coil by the output transformer. The magnitude of this reflected impedance increases with increasing frequency in the middle and upper audio range. The impedance of the filter, however, decreases with increasing frequency. It follows that by use of the proper values for the

resistance and the capacitance in the filter, the effective load impedance on the output tubes can be made practically constant for all frequencies in the middle and upper audio range. The result is an improvement in the frequency characteristic of the output stage.

The resistance to be used in the filter for a push-pull stage is 1.3 times the recommended plate-to-plate load resistance; or, for a single-tube stage, is 1.3 times the recommended plate load resistance. The capacitance in the filter should have a value such that the voltage gain of the output stage at a frequency of 1000 cycles or higher is equal to the voltage gain at 400 cycles. A method of determining the proper value of capacitance for the filter is to make two measurements of the output voltage across the primary of the output transformer: first, when a 400-cycle signal is applied to the input, and second, when a 1000-cycle signal of the same voltage as the 400-cycle signal is applied to the input. The correct value of capacitance is the one which gives equal output voltages for the two signal inputs. In practice, this values is usually found to be in the order of 0.05 microfarad.

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| From: | Jason (jlclal@aol.com) |
| Date: | 1/12/2001 1:17 AM |
| Subject: | Re: Tonequest Dr. Z Interview -- Conjunctive Filters |

Hello Jay,

This is a very cool design choice that I think I would like to try sometime. Thanks for the great info on some great amps(The Dr. Z's are some of the most innovative out there).

Rock On!

Jason C. Arthur

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|-----------------|---|
| From: | anonymous |
| Date: | 1/12/2001 1:34 AM |
| Subject: | Re: Tonequest Dr. Z Interview -- Conjunctive Filters |

When he was first considering using those, he was on a dial-up BBS called Amps n More that I hosted and had members such as Z, Speed Racer, Mark Baier, and about 10 other guys. There are several names for the network. I hadn't ever heard it called a conjunctive filter, but have seen references to Zoebel network, corrective filter, and conjugate load, which is my favorite. Because.. that's what it is. It tries to present the conjugate (opposite sign) load to the tube to smooth out the signal and machinations in the plate circuit of a power amp. It's a great way to clean up an output stage and adjust the frequency response. It can also quench

some of the Ldi/dt and allow the output bottles to run a little riskier.

ted

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From: SpeedRacer
Date: 1/12/2001 2:17 AM
Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters

ah, the good ol' days. 😊

These filters are also a great way to tighten up an amp with a less than stellar OT (like my old Gibson GA20 had..)

No, this is **not** why Z uses them.. !😊 (he designs his own trannies, and does an amazing job of that IMHO)

It's just one more use for them. I was able to tweak the super mushy stage into a pretty good imitation of a good output stage 😊. I think I used a 10K resistor (OT was 8Kp-p) with a .002uF 1kV disc cap across the primary. This would probably work nicely in a Princeton...

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From: anonymous
Date: 1/12/2001 2:38 AM
Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters

is this the same as the resistor cap across the primary of the fender Pro Jr.

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From: SpeedRacer
Date: 1/12/2001 12:15 PM
Subject: Re: Pro Jr

is this the same as the resistor cap across the primary of the fender Pro Jr.

Yes, same basic idea.

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From: DR.Z (drz@drzamps.com)

Date: 1/12/2001 9:49 PM

Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters

Anonymous,
My 18 watt head predates the Pro Jr.
by about 3 years.
But like I stated the idea was sponded
from the RCA manual.

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From: Jason (j1c1a1@aol.com)

Date: 1/12/2001 2:46 AM

Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters

Speedracer,

Seems like you've been around the block a few times. Will this mod affect tone/feel in a negative way? Is this Output topology something used to fix a problem that should have been taken care of elsewhere in the design?

Thanks!

Jason C. Arthur

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From: SpeedRacer

Date: 1/12/2001 12:21 PM

Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters

Seems like you've been around the block a few times.

..it's not the years, it's the miles. 😊

Will this mod affect tone/feel in a negative way?

IME, no. It made my amp a whole lot better actually. It can be argued that it's a band-aid, but that really depends IMHO on how and why it's in use. If it's taking a great amp one level higher, I don't think it's a bad thing. It is also capable of taking a poor amp into good territory.. (if the output stage is a problem, which is often is in cheapo amps)

In the old RCA texts I've read, it seems to be presented as a way to get better response out of

cheap output stages in table radios etc where you might typically have a 6V6 running SE or something. A good OT was expensive even way back when, so if a cheap RC network could kluge you some performance, why not.

Z has taken the idea into some new areas IMHO, which is really cool. It's a fun tweak to play around with, just try lots of different values of caps & resistors and hear the differences.

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| From: JaySG | | | |
| Date: 1/12/2001 9:56 PM | | | |
| Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters | | | |

Speed,

The RCA text I typed in seemed to be saying that it was suitable when no NFB was being used. Is that right?

The Z interview seems to indicate that he's doing more than just a resistor and a cap. Is that consistent with what you're saying? It seems like you could put in some bandpass or bandgap shaping, more than just trying to flatten the response.

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| From: Mike B (mmbb@frontiernet.net) | | | |
| Date: 1/12/2001 2:29 AM | | | |
| Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters | | | |

The following link from Randall's site provides some more info on this circuit:

<http://www.aikenamps.com/zeroz.pdf>

Mike B

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| From: CKP (ckep@aol.com) | | | |
| Date: 1/12/2001 1:48 PM | | | |
| Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters | | | |

I am just wondering. I have seen an RC network on the power section of a leslie cab. This network on the 6550's was designed some reason but not sure. Is this a different filter then what is being talked about ? I have run across several modded amps where someone has been using the same RC network from the leslie power amp design in guitar amps. The results have been

an nice smooth and even response in the tone. Any comments ????

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From: Scott Swartz (nswartz@inlink.com)
Date: 1/12/2001 4:08 PM
Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters

Hifi speakers will often use a Zobel network across the midrange and/or tweeter.

The Zobel could be put across the guitar speaker itself, but the cap value would be correspondingly larger.

There is a design section on this in the Loudspeaker Design Cookbook, for those interested, I'm going to reread it for grins.

Ted Weber, if you're reading this, why don't you just design a constant impedance speaker and we could forget this whole thing 😊.

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From: Ken Gilbert
Date: 1/12/2001 4:15 PM
Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters

ted weber, if you're reading this, why don't you just design a HIGH impedance speaker (say 2k) so we could throw out our OPTs!

kg

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From: Gil Ayan (ayan@earthlink.net)
Date: 1/12/2001 5:20 PM
Subject: Re: Tonequest Dr. Z Interview -- Conjunctive Filters

ted weber, if you're reading this, why don't you just design a HIGH impedance speaker (say 2k) so we could throw out our OPTs!

kg

That would save a little more, no doubt, but I don't believe I'd be comfortable with my speaker

wires at 500V. It would make open back cabinets weapons of mass destruction... 😊

Gil

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From: Max (etorus@infonie.fr)**Date:** 7/5/2002 7:33 PM**Subject:** **Conjunctive filter?Choices?**

Hi everybody!

Could anyone tell me what would be the preferred/best frequency for a conjunctive filter.
And as well do you calculate it with the formula $1/(2*\text{PI}*R*C)$?

Thanks and best regards.

Max.

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From: DR.Z**Date:** 7/5/2002 7:51 PM**Subject:** **Re: Conjunctive filter?Choices?**

Max,

I use 1.3 times the output trannies primary impedance for the resistor, 5 or 7 watt.

And I select the cap by ear, range .001,.002,.0047, or .0068.

I have found that this filter works best with 2 tube outputs, never really liked it on 4 tube outputs.

What I listen for is balanced output from top to bottom string.

DR.Z

Zero-Impedance Output Stage

RAYMOND G. ANTHES*

Excellent transient and low-frequency response and good loudspeaker damping make this amplifier suitable for high-quality, low-power applications.

THE ZERO-IMPEDANCE STAGE to be described was designed for home use, along with its driver, to give good quality performance at moderate cost. A series R-C circuit (R_1 , C_1 in Fig. 1) shunts the primary of the output transformer so that the output tube works into almost unity power factor load. This minimizes harmonic distortion and phase shift. The feedback circuits are direct coupled and the negative voltage feedback is taken from the primary of the output transformer rather than the secondary in order to reduce undesired phase shift to a minimum in this feedback loop.

The low-frequency response is ex-

ceptionally good because the stage is effectively acting as a zero-impedance source feeding the primary of the output transformer. The output transformer used was of good quality and had 1-inch stack. A frequency response taken with the loudspeaker connected, and measuring output voltage across the secondary of the output transformer indicated the 3-db-down point was below 20 cps at the low end, and at 5000 cps at the high end, and only 9 db down at 15,000 cycles per second. At $2\frac{1}{2}$ watts output into a resistance load at 400 cps, the total r.m.s. distortion was under 5 per cent. This is relatively high by most standards, but quite low for a 6V6.

A disadvantage of taking the negative voltage feedback from the primary of the output transformer is that this feedback

cannot correct for the fall-off in high-frequency response in the transformer. The writer prefers to sacrifice some high-frequency response for minimum phase shift in the negative feedback circuit. This assures that the feedback works most effectively, reducing intermodulation distortion to a minimum, giving maximum reduction of harmonic distortion and maintaining a low-impedance source feeding the output transformer, over and beyond the complete audio frequency spectrum. It is possible to compensate for this loss in highs by a fixed equalizer in the preamplifier, but this was not done because the high-frequency loss was not serious. Most preamplifiers incorporate some form of tone control circuit with treble boost which

*Professor of Electrical Engineering, University of Manitoba, Winnipeg, Man.

can be used for this equalization.

The use of the series R-C network across the primary of the output transformer to provide virtually unity power factor load to the tube is not new. The theory of this is well known. If a series R-C circuit and a series R-L circuit are connected in parallel as shown in Fig. 2, where the R's are equal, it can be proved that the impedance of the parallel combination will be a pure resistance equal to R at all frequencies, if $R = \sqrt{L/C}$. At frequencies above the resonant frequency of the loudspeaker, the impedance measured across the primary of the output transformer with the loudspeaker load on the secondary may be roughly approximated by a series R-L circuit. Consequently, within this frequency range, which extends from approximately 125 cps to the highest audio frequencies, the composite load impedance presented to the tube is very nearly pure resistance with small variation in magnitude with frequency.

If values of R_1 and C_1 are chosen to give the optimum composite load impedance, there will be appreciable reduction in available output power at the higher frequencies where the reactance of C_1 becomes small in comparison with the magnitude of R_1 . This is a serious disadvantage. A compromise between these two factors was made in this design.

Adjustment of R and C

The effect of changing R_1 and C_1 can be observed readily on an oscilloscope by the simple circuit of Fig. 3, and the values of R_1 and C_1 were finally selected in this way. The value of R_p used was 47,000 ohms, which approximates the plate resistance of the 6V6. The phase angle of the combination is determined from the ellipse appearing on the screen.

For the tube operating voltages used, the load impedance Z presented to the tube should be from 7000 to 10,000 ohms. The output transformer should match the loudspeaker to this load. A good compromise for R_1 is 2 to 4 times the magnitude of Z and the time constant $R_1 C_1$ should be approximately 150 microseconds.

The value for Z used by the author was low, being around 5,000 ohms; R_1 was 15,000 ohms and C_1 was 0.01 μ f. These values are not critical.

For $R_1 C_1$ time constant of 150 microseconds, the reactance of C_1 is equal to R_1 at approximately 1000 cps. Consequently the power loss in the resistor is low below this frequency. In music, very few fundamental tones occur above this frequency which corresponds to two octaves above middle "C" on the piano. Even though some available power is lost at higher frequencies, it is not a serious matter.

In the usual 6V6 class "A" power amplifier, the average screen current and the average plate current both increase when a signal of sinusoidal or symmetrical waveform is applied. If the signal is keyed on and off and a d.c. milliammeter placed in the plate circuit, the meter fluctuates wildly. If instead of maintaining a constant screen voltage, a particular value of screen dropping resistor R_s is chosen, it is possible to minimize this fluctuation in d.c. plate current provided the screen bypass capacitor is removed. The action is simple. In the presence of signal, screen current increases. The resulting increased voltage drop in R_s causes a reduction in screen voltage just sufficient to provide the required compensation. In order to obtain instant action, the screen-bypass capacitor must be re-

The use of direct-coupled voltage feedback eliminates the need for a large blocking capacitor and ensures proper operation of the feedback circuit at the lowest audio frequencies. The current

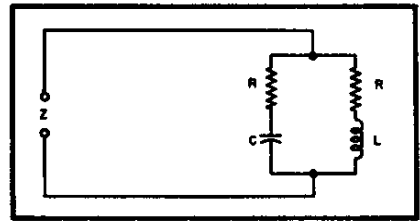


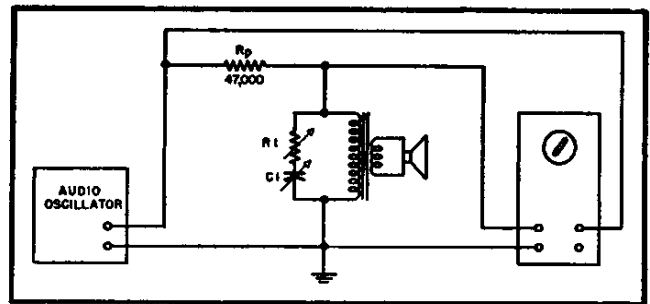
Fig. 2. Series R-C circuit and series R-L circuit in parallel.

through the feedback resistor R_f , must come through the output transformer, which is a disadvantage. Resistors R_f and R_s should preferably be wire wound.

Positive current feedback is obtained from a portion of the cathode bias resistor R_{k1} of the 6V6, as shown in Fig. 1. R_{k1} is a wire wound potentiometer, and serves as a control to adjust the output impedance. This potentiometer may be replaced by a 200-ohm resistor and the current feedback taken across the full 200 ohms.

The positive feedback control is adjusted in the following manner so that the tube presents zero impedance to its plate load. With the loudspeaker connected, an a.c. voltmeter is connected

Fig. 3. Circuit used to determine optimum values of R_1 and C_1 of Fig. 1.



moved. The removal of this capacitor results in about 10 per cent reduction in voltage gain, and a loss in screen filtering.

across the primary of the output transformer with moderate signal applied to the amplifier. A resistor of 5000 to 10,000 ohms (not critical as to value) is then shunted across the transformer primary. The feedback control is adjusted to a point where there is no change in output voltage as this resistor is connected or removed. With full 200 ohms in the feedback control, the output voltage actually increases when the resistor is connected across the transformer, indicating a negative-impedance source. It was found by measurement that the source impedance in the author's amplifier remains zero from 20 to 20,000 cps. It was not checked above this frequency. The drop off below 20 cps is due to the coupling capacitor C_s .

It should be noted that a blocking capacitor cannot be used in series with the negative feedback resistance R_f . If one were used, the negative feedback would become ineffective at some low frequency, yet the positive feedback would still be effective, and low-frequency oscillation or motorboating is likely to occur.

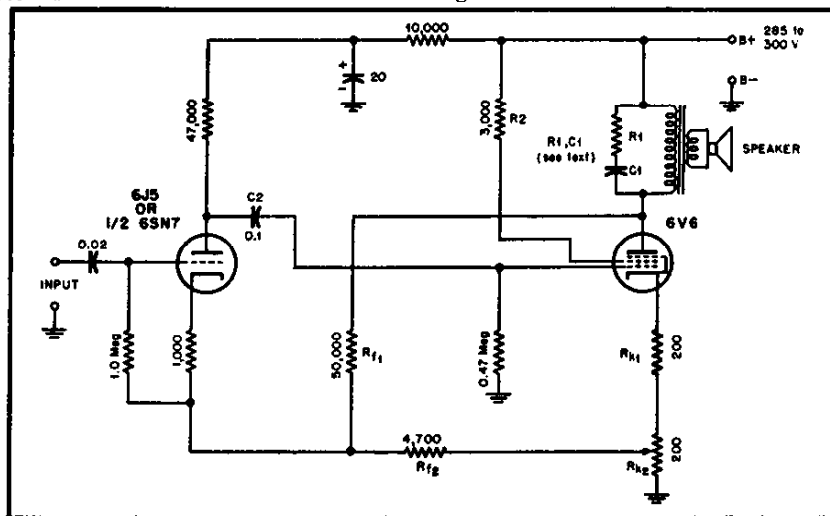


Fig. 1. Schematic of simple two-stage amplifier employing negative voltage feedback and positive current feedback to obtain an output impedance approximating zero.