Subject: Feedback
Posted by Wayne Parham on Wed, 02 Jun 2004 18:35:44 GMT
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I see feedback brought up fairly frequently in tube amp discussions, but not as often in regards to solid state amps. Usually, when I see feedback discussed for a solid state amp, it appears to be used to sort of capture the attention of tube enthusiasts. But in either case, feedback is usually mentioned on a subjective level and rarely in the context of circuit design and the "whys and what fors." So I'd like to see a good technical discussion about feedback here.Very simple circuits with minimal components sometimes have no feedback. The simplest circuits are limited to an active component and practically nothing else. Usually they include biasing and coupling components, but not always. Such simple circuits have fixed gain of hfe or mu and input and output impedance equals the impedance of the active device inputs and outputs.Some biasing components will introduce negative feedback when signal current flows through them causing a voltage drop that biases the active device in a negative direction. This is actually very common. A bypass component has to be added to the circuit to reduce negative feedback. When components are placed around the active device, it chances the circuit's gain, frequency response and input and output impedance. These are usually required and their effects are usually desirable.Negative feedback can be employed on a single stage, as is the case when an emitter or cathode resistor is used without a bypass capacitor. It can also be employed globally, by running an output signal back to the input in reduced amplitude and opposite phase. This is generally done on more complex amplifiers.Negative feedback reduces distortion, but it does so at the expense of reduced gain. That increases the number of gain stages required. Positive feedback increases gain, but it does so at the expense of increased noise, distortion and reduced circuit stability. Excessive positive feedback will cause an amplifier to oscillate. But it was a common technique used in early radios to get enough gain; Global positive feedback was used in old radio circuits called "regenerative" receivers. Hetrodyne and Superhetrodyne circuits made them obsolete.There are pros and cons of each kind of amplifier circuit configuration. I'd like to hear from some of the tube gurus on this one, because I think the topic of feedback is one that's not well understood.

Subject: Re: Feedback
Posted by metasonix on Thu, 03 Jun 2004 03:44:44 GMT
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>Such simple circuits have fixed gain of hfe or muNot in typical RC-coupled circuits. An active plate or collector load or else a coupling transformer or choke is required to get the full device gain as voltage gain.>Some biasing components will introduce negative feedback when >signal current flows through them causing a voltage drop that >biases the active device in a negative directionSometimes called degenerative feedback.>Global positive feedback was used in old radio circuits >called "regenerative" receivers. Hetrodyne and Superhetrodyne >circuits made them obsolete. In most radio receivers, yes. But simpler TRF and regen circuits are still seen today, esp. in specialized applications.Feedback is a well-understood mechanism. If used properly, it is an extremely useful tool. But no tool is perfect. (That's what decent engineering textbooks usually say.)Feedback, not carefully implemented, can cause phase margin errors at

the frequency-response extremes. It can cause the amp to be slightly unstable with some load impedances (esp. certain costly monkey-coffin speakers with complex crossovers).I once saw a Kenwood receiver, brand new out of the box, whose power amp oscillated at ~ 4 MHz--regardless of the load placed on it or the source material. It made a pretty good shortwave jammer, when hooked to a speaker with a long cable. They sold tens of thousands of that model line circa 1990. As a special bonus, each channel oscillated at a slightly different frequency--giving some truly unpleasant IM distortion. Most customers were perfectly happy with them....they were quite unreliable, though, for an obvious reason. So one hopes that line, probably designed by a junior engineer at the factory (typical Japanese practice), is in the landfill. But don't think that'll be the last one!The advantage of tube amplifiers is primarily in two areas:1) low distortion of many triodes (and even some pentodes) allows the design of low feedback circuits;2) tubes do not (usually) have slew-rate issues, and they never have voltage variable device capacitances, which semiconductors often have--in abundance, esp. in cheap devices intended for audio use.And tubes still find a home in audio equipment because:3) feedback has been (and still is) misused in solid-state amps.The problem does not lie in the evil of feedback; the problem is inside the heads of arrogant, self-important design engineers who successfully managed to campaign in the 1960s and 70s that high-feedback transistor amps gave perfect sound. They often did not, and even today mid-fi amplifiers and professional sound reinforcement amps often have horrible feedback implementations.A few names come to mind. Names like Bob Pease....Don Lancaster....If an amp doesn't sound good, I recommend finding the little dweeb who designed it, and kicking his ass. No, wait, better yet, find the bastard who hired him, and kick THAT GUY'S ass. I would be so happy if more audiophiles actually removed their swollen little heads from their buttholes, and started boycotting inferior products. But since most can't seem to agree on what good sound is, I'm not gonna wait around for it. Prefer to talk to the minority who actually listens carefully.(sorry, that probably leaves out most of the SE-triode mafia--they often listen to amps that sound worse then cheap table radios...)

Subject: Re: Feedback
Posted by Wayne Parham on Thu, 03 Jun 2004 06:37:07 GMT
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What amplifier topologies and feedback configurations do you like and which ones do you not like?I often build amps that switch current to a load connected directly in series with the output device. That's a simple and effective configuration, one that is often used in transformer coupled tube stages. Another one I like is to use an unbypassed emitter (cathode) resistor, and sometimes use the voltage swing across it as the in-phase output. It doesn't give the full gain of the device going that way, but it is a simple configuration that is stable and works well. I can't think of any devices that don't work well in these modes, although they are only appropriate in certain situations.What are some of your topological favorites? What are some you steer clear of? And what are those horrible feedback implementations you mentioned? I don't necessarily care to know names, but descriptions of ill-configured circuits would be interesting. Particularly if compared with others that were done right.That may be a bit much for a messageboard post, but it would certainly make a good article. Or maybe a teaser with excerpts on the forum, followed by meat and potatoes in a printed article at a later date. I think everyone would like to know the why's and wherefor's so they'd know what to watch out for in future purchases, kits and homebrew

projects.

Subject: Here's an essay on negative feedback that seemed good
Posted by akhilesh on Thu, 03 Jun 2004 13:11:28 GMT
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http://www.hometheaterhifi.com/volume_5_4/essaynegativefeedbackoctober98.html
thanx
-akhilesh

Subject: And an even more indepth article
Posted by akhilesh on Thu, 03 Jun 2004 13:19:46 GMT
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http://www.normankoren.com/Audio/FeedbackFidelity.html

Subject: Re: And an even more indepth article
Posted by Wayne Parham on Thu, 03 Jun 2004 17:18:39 GMT
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Great articles, thanks. I had previously read Norman Koren's articles, but forgot about this one. He has done a lot of tube amp modeling with Spice, and I came across his articles while modeling Steve Bench's 6DJ8-based active crossover to include response shaping components for compression horns. Norman is very studious and I appreciate your bringing attention to his articles here.I believe these articles address the main issues of bandwidth, gain, distortion and stability. The advantrages of NFB include potentially improved frequency response, reduced harmonic distortion, better gain control, increased input impedance, and decreased output impedance. Those are some of the things that can be gained from a good circuit that incorporates negative feedback.The disadvantages of NFB are that it can cause peaking and other response anomalies bandwidth extremes, sometimes even enough to enter oscillation. It can also increase susceptibility to RF interference and make clipping more abrubt. These disadvantages are usually limited to global feedback implementations, and aren't as likely to occur when feedback is introduced locally, in a gain-stage. But even here, if a device is pushed to its limits, instability can result.So I guess the thing is that each circuit should be taken on a case-by-case basis. There are likely some components that are more susceptible that others to having problems in certain configurations. Each device has its own set of strengths and weaknesses, and the challenge is to find those configurations that work best. It really isn't appropriate to view negative feedback, in and of itself, as a problem. What is best is to examine each circuit to find and address potential liabilities, and to get the most performance afforded by the components used.

Subject: Re: And an even more indepth article
Posted by Manualblock on Thu, 03 Jun 2004 23:05:41 GMT
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As a untutored amatuer may I offer this Quote for comment," when conventional transistor amplifiers enter undefined operating regions the amp clips and feedback loses it's grip on the amp. Conventional designs use feedback to compensate for gain transitions and absorb back EMF from the drivers. Speaker drivers are always creating back-EMF as a result of numerous resonances, many with very high Qs and long time durations. When a conventional amp clips, the source impedance seen by the driver suddenly changes, and the back-EMF is suddenly reflected back to the driver instead of being dynamically absorbed by feedback correction. So although a conventional feedback amp may look benign clipping into a resistive load, things get a lot uglier with real world speakers, and no speaker driver is going to be happy with a power source that has sudden transitions in the driving impedance." Any help with this one?

Subject: Re: And an even more indepth article
Posted by Wayne Parham on Fri, 04 Jun 2004 05:31:37 GMT
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That's a pretty big deal. The issue of back EMF and load impedance is significant.

I think the best way to get a handle on this is to start from a simple perspective and visualize the situation, progressing to more complex attributes in steps.

1. Take a look at a simple voltage divider using two resistors. Use a DC voltage as the source. You'll notice that there is a fixed division of voltage between the resistors.

2. Now use the same voltage divider, but use an AC signal to drive them. You'll see it also has a fixed division of the signal between resistors.

3. Substitute the load resistor with a purely reactive component. Try a capacitor first, then an inductor. You'll find that the capacitor has the highest amount of voltage across it at low frequencies and the lowest at high frequencies. Current through the circuit is highest at high frequencies and lowest at low frequencies. The inductor acts just the opposite.

4. Now make the load a complex impedance having resistance, inductance and capacitance. Try several configurations for the load network. Make some having mostly series inductance and resistance, like a voice coil (sans diaphragm w/mechanical resonance). Make some circuits that are tuned circuits like a radio tuner, notch filter or loudspeaker port. What you'll find now is that the voltage across the load changes in a predictable fashion depending on the frequency.

5. In each of the preceding steps, the source voltage and resistance were held constant. The source voltage frequency was changed, but the amplitude was fixed to a reference value. The source impedance - the series resistance of the voltage divider - was also held constant. But

what if we no make this variable too? That's what happens when amplifier output characteristics change.

A good amplifier acts as a constant voltage source with very low output impedance. But the output impedance is not zero, so it becomes the source impedance. The output circuit, including the speaker wires, is the source impedance and forms a voltage divider with the loudspeaker as the load. So the higher the output impedance, the more fluctuation in signal results from a changing load impedance. And when the amplifier itself fluctuates impedance because of instability or whatever, that adds another level of complexity to the voltage division between these two things, the output source and the load.

Subject: Re: And an even more indepth article
Posted by Manualblock on Fri, 04 Jun 2004 19:07:26 GMT
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Thanks again for the in-depth response; I hope you know these posts are very helpful. In response to the feedback query, if I understand you correctly instability is the factor that most affects the amps ability to reproduce an accurate tracing of the waveform. What would be the requirement for the most stable amp not using global feedback?

Subject: Re: And an even more indepth article
Posted by abajaj11 on Sat, 05 Jun 2004 14:23:31 GMT
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HI Manualblock,My solution is: ensitive speakers that don;t take the amp over 3/4 of the way up...i.e., no clipping. Apprently extends tube life as well. -akhilesh

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Subject: Re: And an even more indepth article
Posted by Manualblock on Sat, 05 Jun 2004 23:41:29 GMT
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I have read that amplifiers clip far more frequently and at lower volumnes than we suspect. Maybe that accounts for why tube amps sound more musical. Something about infrasonic resonances and airborne feedback as well as RFI that reaches the signal regardless of shielding. How's the ASUSA el 84 doin'? Any further observations?

The most experienced engineers I've ever known--guys with experience going back 50 years or more--all seem to say the same thing: the best performance can be had with push-pull low-mu triodes, with about 10 dB of loop negative feedback. This is exactly what you see in early-30s professional PA amplifiers like the Western Electric 86 (300Bs), and most PA amps made by Thordarson/Lafayette/UTC/ etc. (usually had 2A3s or 45s).One occasionally saw 6B5 type class-B amps, but those were in the minority. Class AB low-mu triodes in push-pull were pretty close to being universal.The 6L6 killed all this off pretty quickly in 1936. It came down to a battle of fidelity vs. power/dollar. And the 6L6 won those kinds of battles. It was the Depression. Another thing to disappear in the late '30s was the driver transformer. You want the best possible phase inverter/driver? There is still nothing like a good transformer. Unfortunately, electronic-type phase inverters became the norm--because they were cheaper than a good transformer. Not better. If carefully designed and run from a high plate voltage, a phase inverter is capable of great performance. (Until the tube starts to get weak, that is.)Yet another thing you saw in the best amps (and still do) is fixed grid biasing (negative grid voltage). Cathode bias resistors were cost-cutting measures. They did have one other advantage: they offered better reliability than a negative bias supply (which sometimes fails, usually killing all the output tubes and maybe the transformer). Those old WE theater amps usually had cathode bias for this reason.Look in any old data sheet for an audio output tube--triode or pentode or whatever. The ratings for fixed bias always show lower distortion than similar cathode bias ratings.(Remember, WE didn't sell this stuff, they LEASED it. IBM copied this trick later. You wanna make money producing exotic electronics, you sell it. You REALLY wanna make money, you lease the stuff. Microsoft is such a money-making powerhouse for only one reason: they don't sell outright contracts for ownership of commercial software, they force big businesses to pay big, fat license fees on a yearly basis. They don't actually own the software, they are only allowed to use it on a license-fee basis. That's how to make a lot of money very quickly.)The SE thing is pretty much a freak of the 1990s. Oldtimers look at this trend VERY askance. In the 30s, SE meant simply a low-cost amplifier for low-power applications. The infamous WE 91A was a fluke--it was WE's theater amp for small-town movie houses who didn't make a lot of money. Everything after that you can chalk up to obsessive Japanese guys, who influenced Japanophiles like Arthur Loesch and Joe Roberts. This is very much like the anime world, which is now huge outside Japan because the Japanese anime producers were taking artistic risks in the 1980s, at a time when American animators were producing garbage like "He-Man and the Masters of the Universe". The fact that most anime is also junk doesn't matter. They seized young eyeballs early on, and now they've got those eyeballs for life.With push-pull triode amps, you don't NEED a lot of feedback. So you don't use it. A major problem with a typical feedback loop is that it includes the output transformer--the FB resistor goes from the speaker terminal back to the input stage, usually. This can magnify any tendency the transformer has toward ringing, peaking, phase-margin stability problems etc. So before WWII, one often saw feedback going only from an output tube's plate back to the input. Better output transformer winding techniques solved this.Look at the Harmon-Kardon Citation II. It had a LOT of feedback. All over the place. But it also used a very special transformer, carefully wound to prevent peaking and provide excellent, FLAT high frequency response. A stock Citation can go out to past 100 kHz routinely--this was thought to be impossible in the 30s.The same was true of old Dynaco tube amps. Their transformers weren't quite that good, but they were well-behaved in the audio passband. So 20-25 dB of feedback didn't result in instability. (They needed that

feedback too. 6550s are ok, but EL34s have a LOT of distortion. And those simple 7199 driver circuits are barely adequate for the job. Dynaco amps were masterpieces of minimal design.)The free advice is: 1) push-pull low mu triodes, running near the limit of plate dissipation for lowest distortion. 2) driver transformer, NOT a phase inverter.3) get decent transformers.I'd watch out for some of the crazy, exotic circuits being pushed nowadays. I disagree with many of the hard-ass high-end audio designers, who feel that perfection is only possible with differential amp circuits stolen from old Tektronix oscilloscopes, plus heavy power supply regulation. If you want to see that philosophy in action, go to any high-end salon and look inside the monster push-pull 6550 amps they all sell.

Subject: Re: Feedback
Posted by Wayne Parham on Mon, 07 Jun 2004 04:50:39 GMT
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Great post, Eric, thanks! I feel like I just got an extra page or two in my latest VTV.

Subject: Re: Feedback
Posted by Henry on Mon, 07 Jun 2004 22:19:53 GMT
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I have p-p amps that sound very good, so I understand what you are saying aboutpush-pull low-mu triodes with about 10 dB of loop negative feedback. Same for youridea about coupling transformers, I agree with you.On the other hand, simple amps using single ended triodes are a modern fad,but might they be on to something too? The one thing they aren't good at is powerbut I think some SET amps sound very good at low levels. What do you make of this?What makes a good SET amp? What is the nature of their appeal?

Subject: Re: Feedback
Posted by metasonix on Tue, 08 Jun 2004 08:59:43 GMT
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>but I think some SET amps sound very good at low levels. What do you make of this?It's still an issue of power output. Some (mind you, not all) SE amps have their design just right--by choosing the driver tube and circuit properly, it's possible to get some distortion cancellation. Because this is VERY difficult to design for (computer models and plate curve analyses aren't accurate enough), it's more a matter of finding the right combination. Trial and error.The WE 91A is like that. I suspect that a low-mu triode, combined with a driver tube having very low distortion and a plate characteristic similar to the power tube (310A pentodes of all things), offers the best chance

at effective cancellation.One amp I've seen that does it is the DeHavilland 845 monoblock. Kara did a LOT of trial and error, and came up with something rare. (Please, don't lecture me about whatever the Sound Practices crowd is into this week, or what Bottlehead sells. That stuff is all over the place with regard to cancellation effect.) I feel that SE is popular primarily because it is easy for DIYers to build and mess around with.The safest way is still push-pull. It guarantees cancellation of even harmonics. If you have a lot of patience and really accurate test equipment, you can try for a cancelling SE circuit. Lots of luck.

Subject: Re: Feedback
Posted by Wayne Parham on Wed, 09 Jun 2004 06:45:56 GMT
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I never really thought much about this subject, but I can sure see what you mean. The SE idea is really neat for simplicity - It's usually less than a dozen parts and can be built on an open chassis or breadboard by practically anyone. But with no feedback mechanism, it is particularly sensitive to load impedance fluxuations and without having any complementary components, there's no real way to cancel asymmetries with an "equal and opposite." I suppose you can try to counter the output amp curve with a driver amp curve, but that's not complementary-symmetry, it's more like pseudo-symmetry. So maybe it can be made close, but it's a hack. And the load impedance thing can only be dealt with by brute force, which is kind of an oxymoron when discussing Class A amps.You mentioned the DeHavilland 845. What are some of your other favorites?

Subject: Re: Feedback
Posted by SET lover on Wed, 09 Jun 2004 10:07:27 GMT
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The reason SET is so special is there is no crossover distortion. Crossover distortion makes an unnatural sound and single ended triodes are more musical because of their absense of it. One trades power for presence with a SET amp. They have a magic that no other amp can quite match.

Subject: Re: Feedback
Posted by Manualblock on Wed, 09 Jun 2004 11:13:47 GMT
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What exactly is crossover distortion?

Subject: Re: Feedback
Posted by Wayne Parham on Wed, 09 Jun 2004 23:42:44 GMT
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Certainly, there is merit in what you say. But it isn't like a good Class AB amp has a hard transition between positive and negative cycles. They are made to have a smooth transition where both devices are on through the zero crossing line. So I guess there are probably some amps of both types - Class A and Class AB - that are really good and some that are just mediocre. No feedback Class A (SET) amps will probably tend to have a little more 2nd harmonic distortion and a little less power. Class AB (PP) amps will have greater power and reduced second harmonics but may be susceptible to other artifacts. I can see relevance in both design types.

Subject: Re: Feedback
Posted by Wayne Parham on Wed, 09 Jun 2004 23:48:29 GMT
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On a push-pull amp, you have one component doing the work on positive cycles and another on negative cycles. Class B push-pull amps have a sharp transition at the zero crossing line and are prone to having crossover distortion. Class AB push-pull amps are biased so that both positive and negative driver devices share the load through the crossover region so that the transition is more gradual. Some Class AB amps are made so much this way that both devices are practically run as Class A amps run in parallel. There is a lot of room for performance in Class AB configurations spanning the entire bias range between pure Class A and pure Class B, so the characteristics of a Class AB amplifier are entirely determined by the specific circuit implementation.

Subject: Re: Feedback
Posted by SET lover on Thu, 10 Jun 2004 00:45:34 GMT
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I think we're in agreement but I'd still have to say that SET is my personal preference.

Subject: Re: Feedback
Posted by SET lover on Thu, 10 Jun 2004 00:51:39 GMT
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As Wayne said, with SET amps you have a single driver and with PP amps you have a "push"

side and a "pull" side. That means there can (and must) be some differences in the two sides and you also have the complexity of phase splitting. The input signal must be reversed to send to the "pull" side to make it opposite to the "push". A SET amp is more pure.

Subject: Re: Feedback
Posted by Manualblock on Thu, 10 Jun 2004 03:38:53 GMT
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So if I understand correctly we are back to square one with SET's where the output impedance of the amp is subject to wildly fluctuating load impedances that are frequency derived and reflected back to the plate of the triode tube?

Subject: SET output impedance
Posted by Wayne Parham on Thu, 10 Jun 2004 06:17:03 GMT
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They are sensitive to load impedance, that is true. The parallel feed configuration seems a little less so, perhaps since the transformer is resonated with the parafeed cap down low. Then again, I suppose a big output transformer can be used on a standard configuration to drop output impedance and make the system less sensitive. There have been some pretty substantive discussions about output transformers on this very subject. I guess that's probably the most important thing, maybe even more so than the output tube.

Subject: Re: And an even more indepth article
Posted by akhilesh on Tue, 15 Jun 2004 18:30:21 GMT
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YEah you may be right! About the clippping i mean.The ASUSA is doing really great. I put in an old RCA 12ax7, and a pair of new tesla el84s. After about 20 hours, it rocks. In my opinion it sounds better than the zen by a tad. Better soundstage and imaging. The zen sounds kind of like there is a film on the music.. i suspect becuase the asusa is tweaked wuth high quality coupling caps and a solen cap in the power supply, while the zen is stock (solen coupling caps which are not too bad thuogh). I really like the asusa amp! The one good thing... i no longer think the zen amp is the best amp! MAde me break that slavish mindset!-akhilesh

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Subject: I like SETs too
Posted by akhilesh on Tue, 15 Jun 2004 18:34:06 GMT
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With push pull, the amp sounds better than a SET. With SET, the music sounds better than with a push-pull.Go figure. -akhilesh

Subject: Re: I like SETs too
Posted by Wayne Parham on Wed, 16 Jun 2004 02:38:54 GMT
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