

Figure 8. Shunt compensation network increases phase margin from 28 degrees to 130 degrees.

The ANF Voltage Source

An ANF current source is easily converted into a low-impedance amplified negative feedback voltage source by inserting a suitable voltage reference **D1** between the emitter of transistor **Q1** and resistor **R1** (**fig. 9**). As previously noted the voltage reference can be a series of diodes, an LED or a zener diode. The voltage reference **D1** is supplied with a constant current, which is largely immune to supply rail variations, by resistor **R1**. The voltage output is taken from the emitter of transistor **Q1**. Resistor **R3** increases stability margins of the feedback loop; alternatively, as previously demonstrated, pole-zero shunt compensation from the collector of the control transistor **Q2** may be used to accomplish this objective.

The ANF voltage source possesses the advantage that if the voltage reference **D1** is a zener diode with a positive temperature coefficient of approximately 2.2mv/degree Celsius, then this positive temperature coefficient is compensated for by the negative (~2.2mv/degree Celsius) of the base-emitter voltage of control transistor **Q2**; this gives good stability of output voltage over a wide temperature range.

The variation of the ANF voltage source's output impedance with frequency is shown in **figure 10**. This plot was obtained by connecting a grounded ideal independent current source to the output of the ANF voltage source and running an AC analysis with respect to the ideal current source. The output impedance is then merely the ratio of the output voltage to the current delivered by the ideal current test source. The test source needs to be a current source and not a voltage source because the circuit under test is a nominal voltage source which, therefore, requires a test source with an infinite output impedance to prevent erroneous results being obtained due to the loading of the test source on the circuit under test.

The output impedance of the ANF voltage source is inductive, being of the order of tens of milliohms across the audio band before increasing sharply at ultrasonic frequencies (**fig. 10**). To prevent this rise in output impedance, shunt capacitor **C1** to ground is connected across the ANF voltage source's output (**fig. 9**); capacitor **C1** should be at least 47uF to be effective, as the plot of **figure 10** reveals.

Capacitor **C2** prevents power supply ripple from significantly disrupting the feedback loop; in other words, capacitor **C2** improves the power supply rejection ratio (PSRR) of the ANF voltage source. To obtain the circuit's PSRR with frequency, an ideal AC voltage source was connected in series with the DC voltage source **V1** energising the circuit. The frequency response (effectively the PSRR) with respect to the output of the ANF voltage source was then obtained (**fig. 11**). Capacitor **C2** improves the PSRR of the ANF voltage source by nearly 50 dB (to over 110dB) at the ripple frequency of 100Hz. The decrease in PSRR beyond 1kHz and with **C2** in situ is due to ripple injection through the collector of transistor **Q1**, while the increase in PSRR beyond 80 KHz is due to capacitor **C1** shunting the output.

The ANF voltage source may, for example, be used as a low-impedance voltage source to bias the current sources of the transadmittance stage (TAS) and the transimpedance stage (TIS) in the amplifier of the form shown in **figure 12**. This marginally reduces the component count compared with using two separate ANF current sources, but it compromises performance, at least in principal, because, as previously noted, the output impedance of each of the current sources is now less than one tenth, at 100Hz, of that which would be obtained if wholly independent ANF current sources were used to bias the TAS and the TIS.

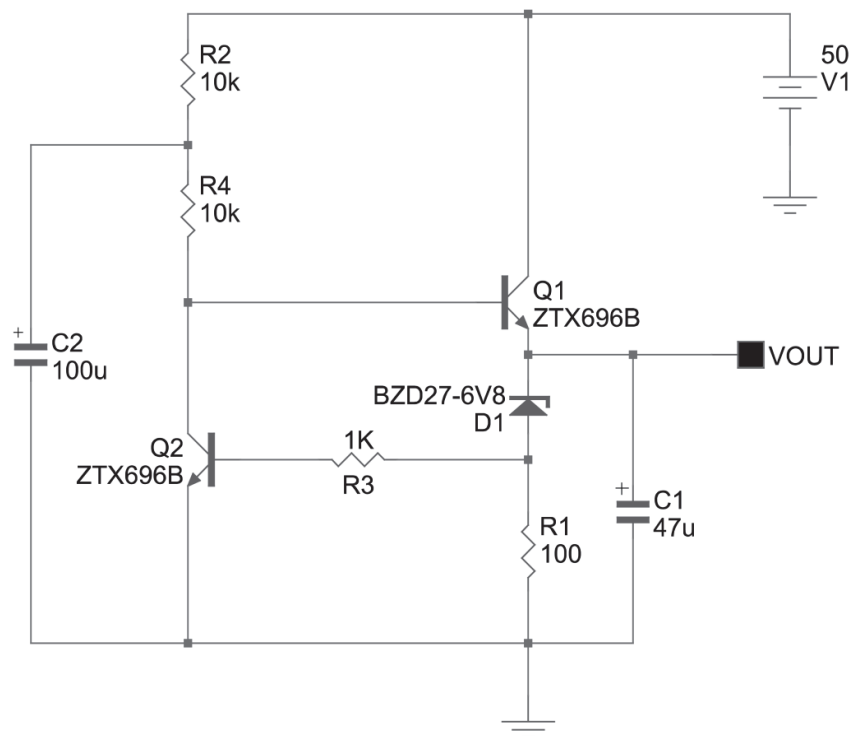


Figure 9. The amplified negative feedback voltage source.

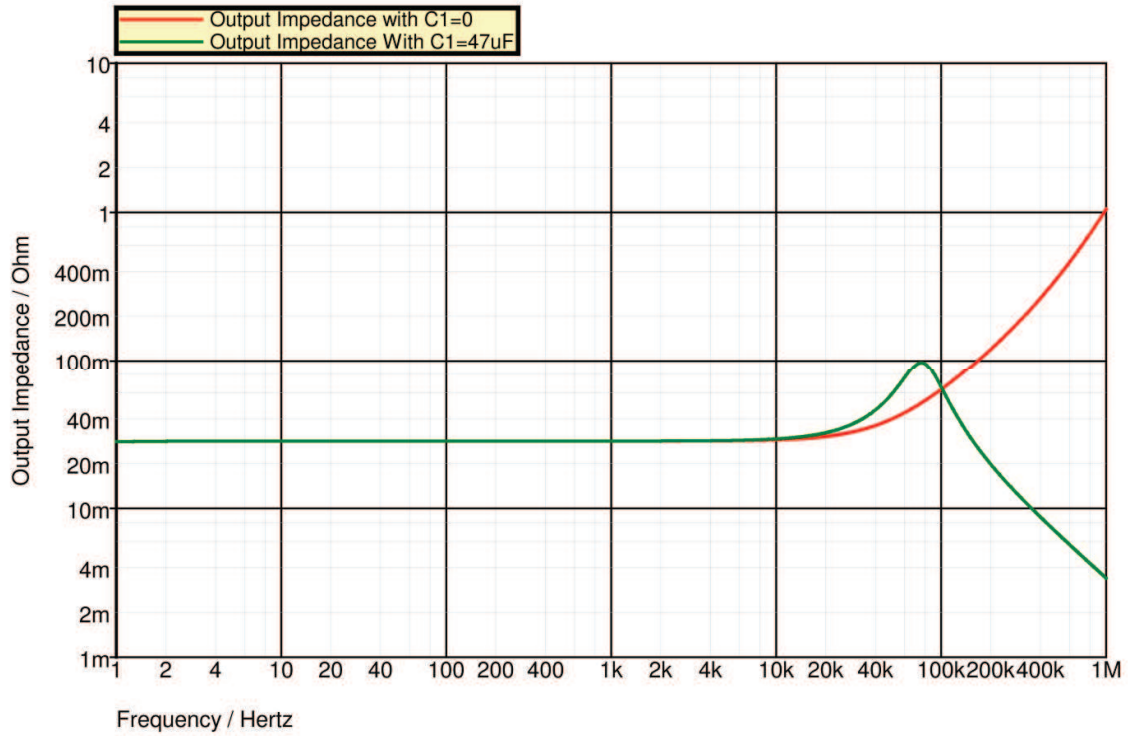


Figure 10. The output impedance of the ANF voltage source is inductive in the absence of output shunt capacitor C1.

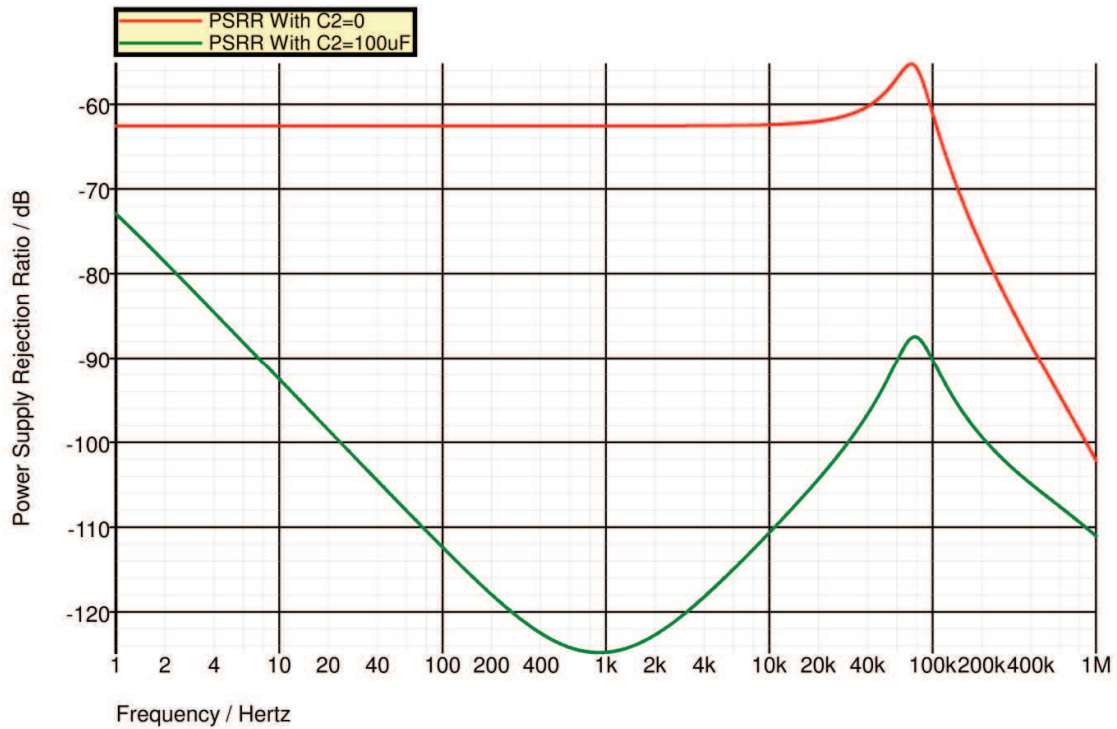


Figure 11. Decoupling capacitor C2 improves PSRR of the ANF voltage source by nearly 50dB (to over 110dB) at the ripple frequency of 100Hz.

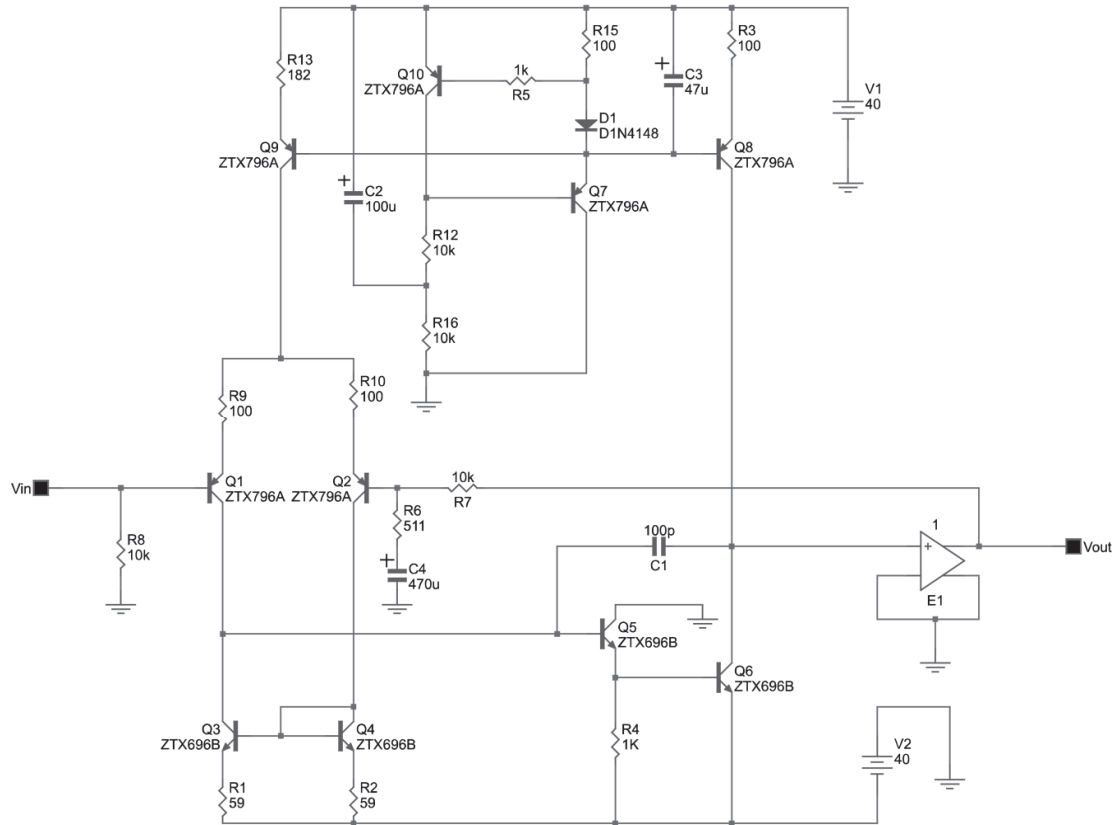


Figure 12. The rudiments of an amplifier of the Thompson topology whose current sources are biased by a single ANF voltage source. The input stage is a transadmittance stage (TAS) while the second stage is a transimpedance stage (TIS); the unity-gain voltage-controlled voltage source E1 represents the output stage of the amplifier.

Conclusion

The ANF current source is a simple and versatile circuit whose output impedance greatly surpasses that of virtually all forms of discrete-transistor voltage-reference-biased current sources across the audio band. In fact, the ANF current source's output impedance is of the same order as that of a cascode current source, with the additional advantage that it functions with a significantly smaller voltage drop across it (the compliance voltage) than the cascode current source; it also possesses a much smaller component count compared with the cascode current source. The versatility of the ANF current source is underscored by the fact that it can be modified to function as a low-impedance voltage source. Given its low cost, it is difficult to conceive of any reason not to use the ANF current source exclusively where a current source is called for in the design of discrete audio frequency amplifiers.

References

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