Aleph Current Source Modifications
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The Aleph controlled current source is a simple and effective circuit which provides the active load in the output stage of several Pass designs. The quiescent current in the output stage is set by a single sense resistor and is controlled by a bipolar transistor in a feedback loop. The current can be modulated by feeding an audio signal into the feedback loop. We examine the performance of the circuit at high signal levels; sufficient to cause clipping. It could be argued that the amplifier should not be driven so hard that clipping occurs. However, occasional peak transients may be hard to avoid and the modifications are both simple and effective. The observations have been with reference to Zen V4, but should be applicable to other designs using the Aleph CCS.

The Basic Circuit

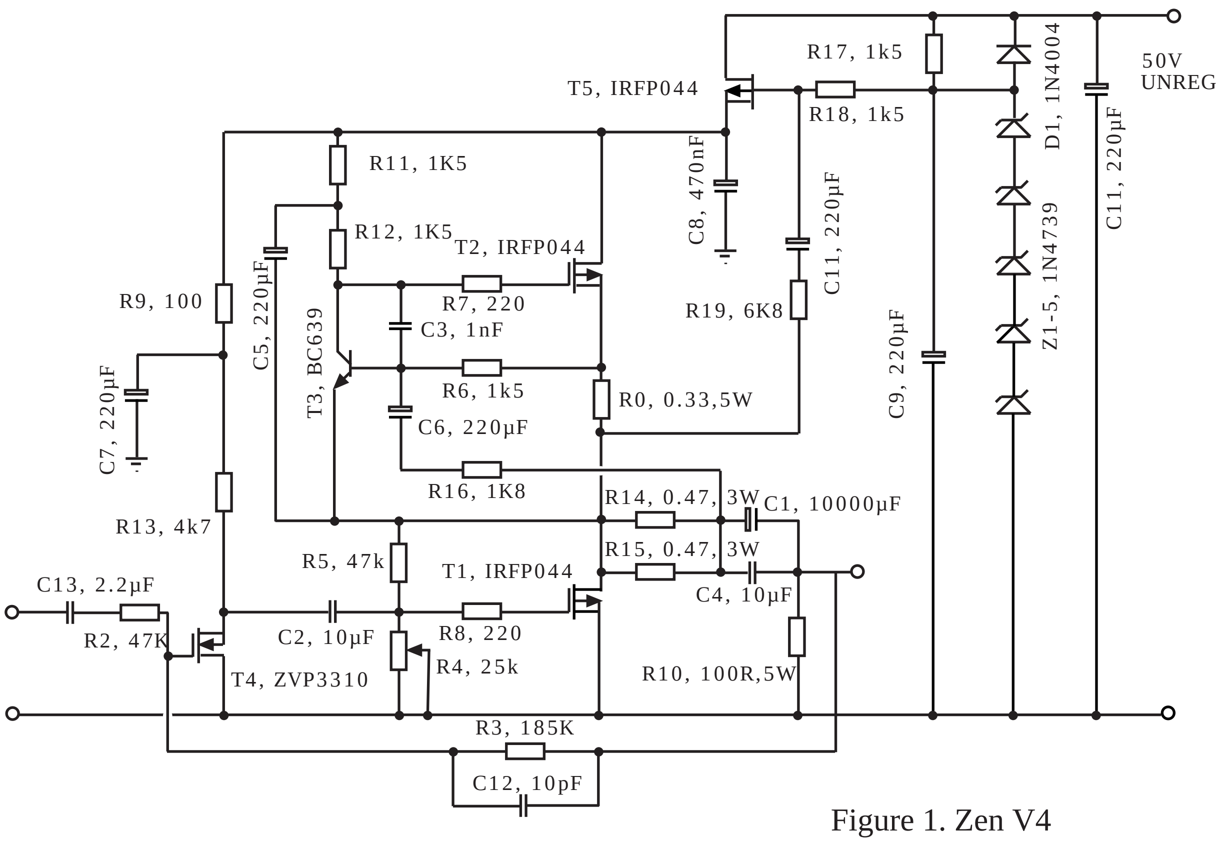

Figure 1. Zen V4

In Zen V4, the potential across R_0 is sensed by transistor T3. A negative feedback loop controls the gate of T2 to maintain a constant drain current of ~ 2 Amps = Vbe/R0. The current is modulated via C6 and R16. A bootstrap capacitor C5 provides a high impedance a/c load for transistor T3 by ensuring the voltage swing across R12 is low.
At low output signal levels, the voltage across transistor T3, Vcss ~ Vgs +V_{R0} ~ 4.7 Volts. Just prior to clipping, the Aleph CSS will be supplying around 2A +/- 1A. The potential dropped across VR0 will swing from 0.3 to 1.0 Volts and Vcss will vary from 4.35 to 5.05 Volts.
If the signal increases still further, clipping will occur and sharp peaks will occur in Vcss as transistor T2 switches hard on. Because of the voltage dropped across R0, the output cannot swing right up to the supply voltage. Given a symmetrical signal, positive clipping occurs before negative clipping. The output voltage starts to clip at 0.8 Volts above the ground rail and 2.0 volts below the positive supply rail. Relative to the 20V mid point, clipping occurs at -19.2 to +18 volts. Figure 2. shows the output and Vcss characteristic at the onset of clipping.

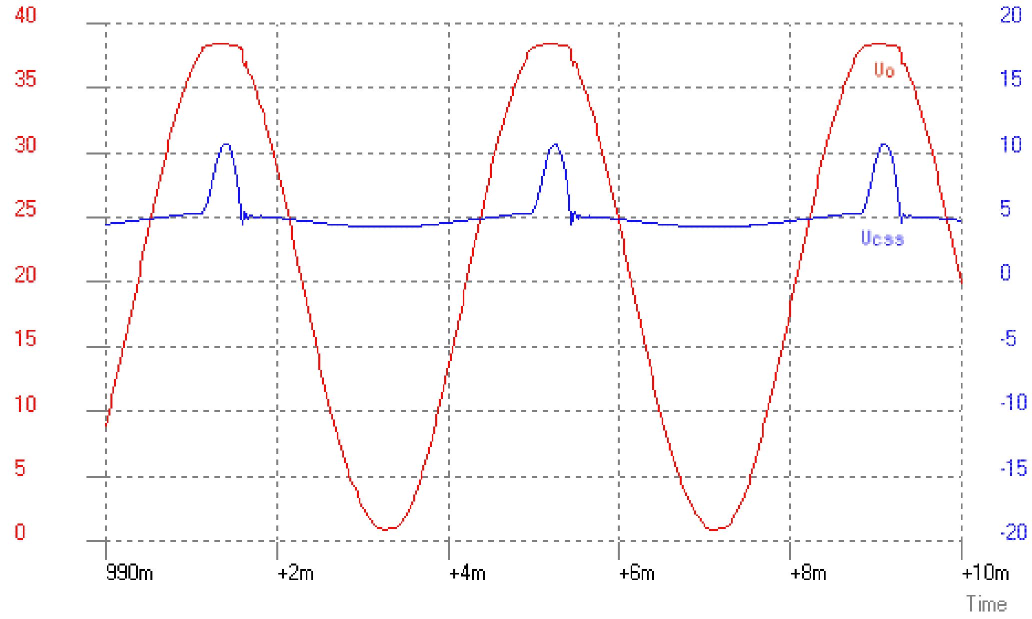

Figure 2. Output and Vcss Characteristic at Clipping

The peaks in gate voltage of T2 exceed 10 volts whilst Vds drops to near zero. During these peaks, the mosfet is well and truly in the linear region and behaves like a resistor of a few milli Ohms. Negative feedback around transistor T3, means that the peaks in transistor T2's drain current have a 'bite taken out'. This can be seen by looking at the voltage dropped across the sense resistor R_0, See Figure 3..

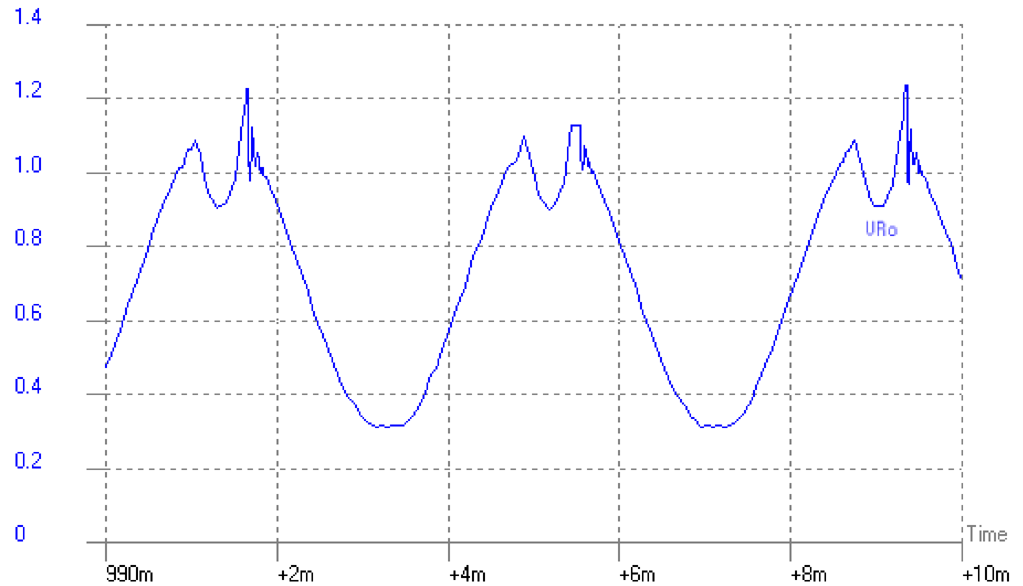

Figure 3. VR_0 Characteristic at Clipping

The peaks in Vcss are rather abrupt and the feedback arrangement, damped by R6 and C3 is a little slow to respond. The result is instability, particularly on the transition from clipping to normal operation. It takes 100 µS or so for the instability to subside. This can be seen on Vcss, VR_0 and the amplifier output V_0. Relative to the 20V mid point, the distortion in the output is noticeable at a positive swing of just 16 volts. See Figure 4.

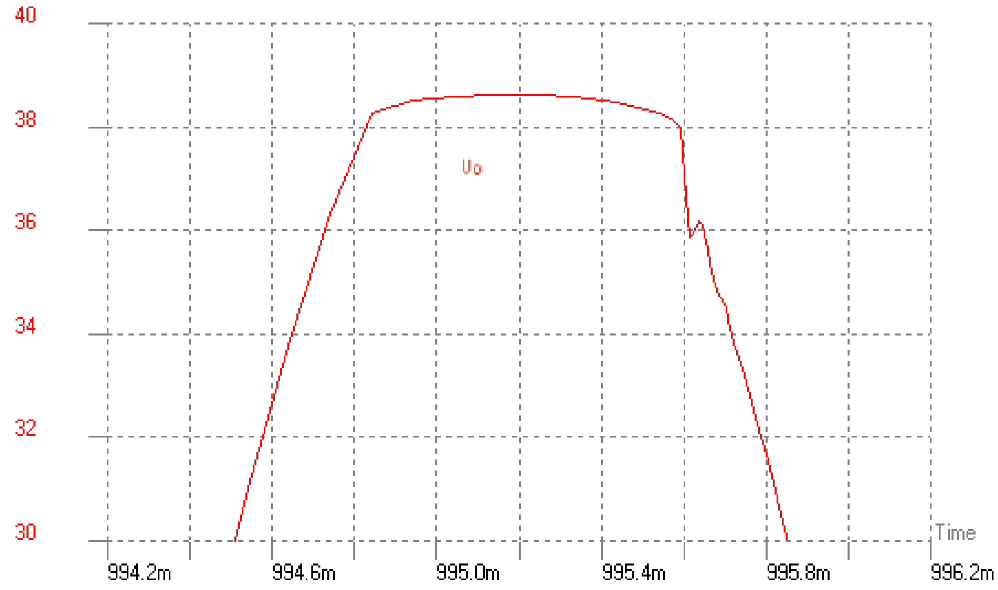

Figure 4. V0 Characteristic at Clipping

Note that the output voltage does not have a flat top. In the positive clipping state, the mosfet Vds is near zero and the rounded top is the mirror of the 'bite taken out' of VR0. The "ringing" can be minimised a little by reducing the value of C3 but doing so risks high frequency instability. The best solution is to limit Vcss.

Aleph CCS with zener clamp

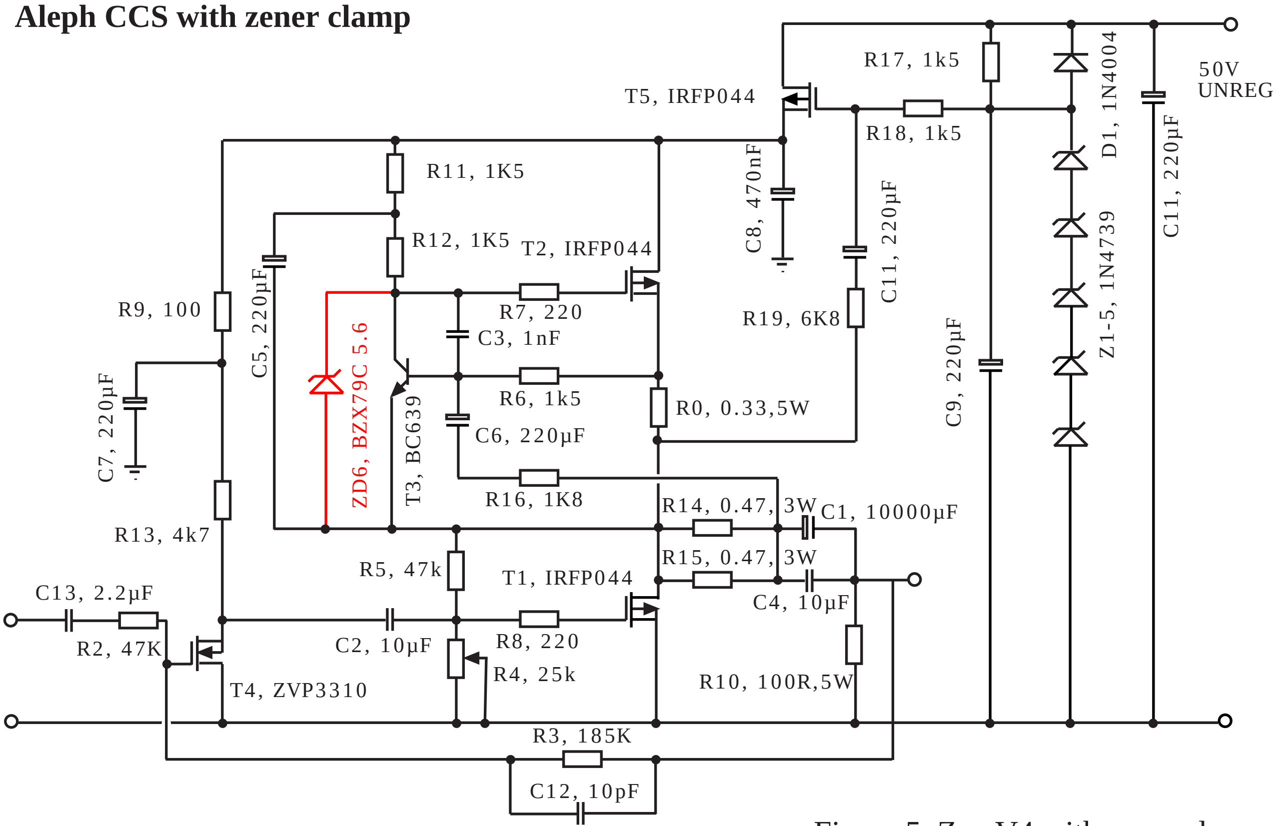

Figure 5. Zen V4 with zener clamp

The basic solution is as simple as it gets. A zener diode prevents Vcss rising above the clamp voltage. which needs to be as close to the maximum normal swing of Vcss. A 5.6 Volt zener should suffice and allows for part to part variation in the threshold voltage of T2.

Aleph CCS with current source and zener clamp

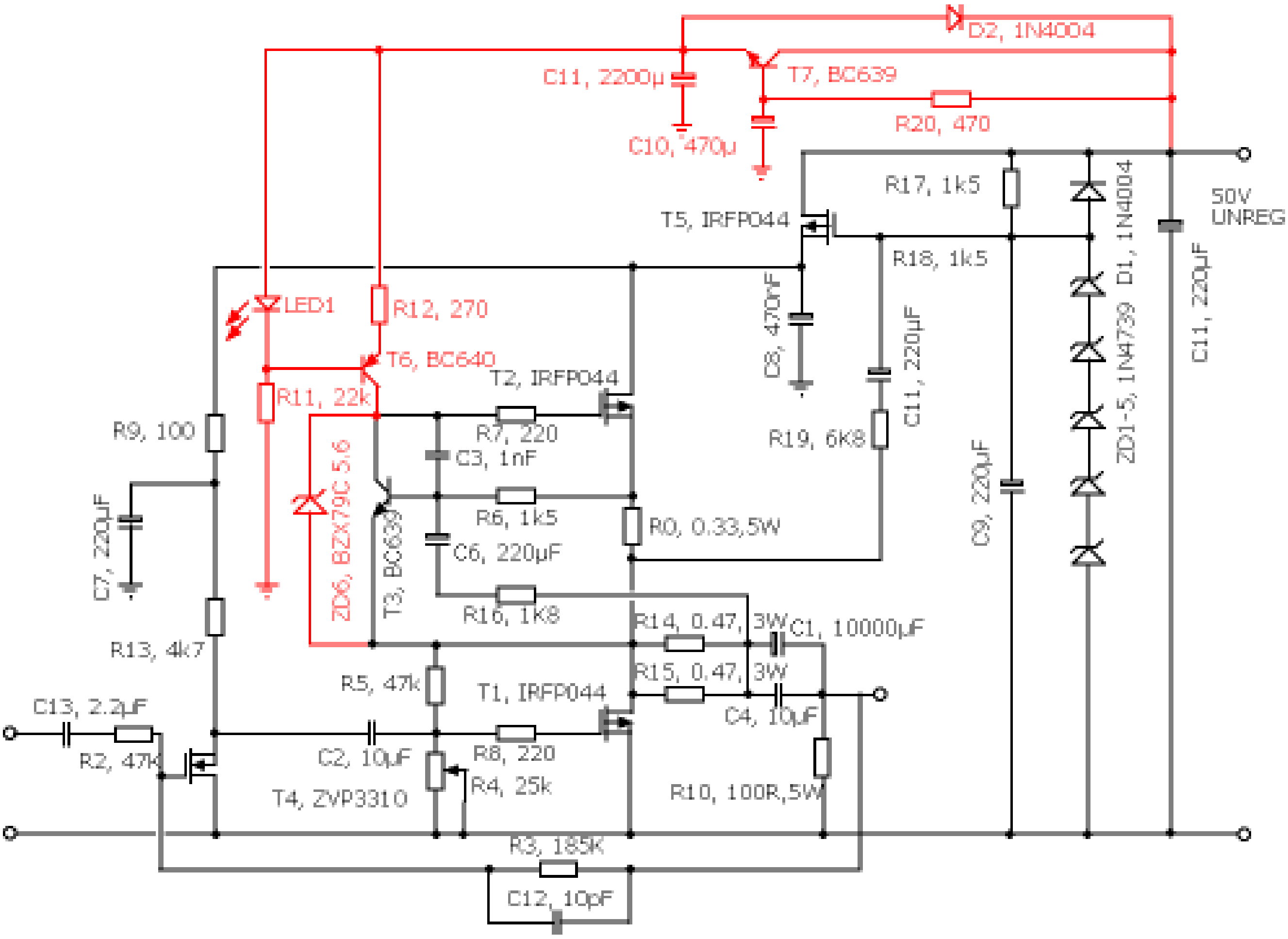

Figure 6. Zen V4 with current source & clamp

The basic circuit uses a bootstrap capacitor to provide a high impedance load for the feedback control transistor T3. For constructors who have built, or are interested in the Aleph CCS variant described in LTPZen, the circuit shown in Figure 6. uses a simple current source instead. The circuit exploits the forward voltage drop of a standard red LED. The current = (Vf-Vbe)/R14 is set at 5 mA but is not critical. The current source requires an elevated supply voltage, provided by transistor T7 configured as a bipolar capacitance multiplier. As with the basic Aleph CSS clamp, the zener diode ZD6, clamps Vcss to a maximum of 5.6 Volts.

Performance

The output characteristic with and without the clamp is shown in Figure 7. The zener clamp completely eliminates the post-clipping instability. As far as clipping is concerned, there is no difference in the performance between the basic circuit shown in Figure 5. and the variant shown in Figure 6.

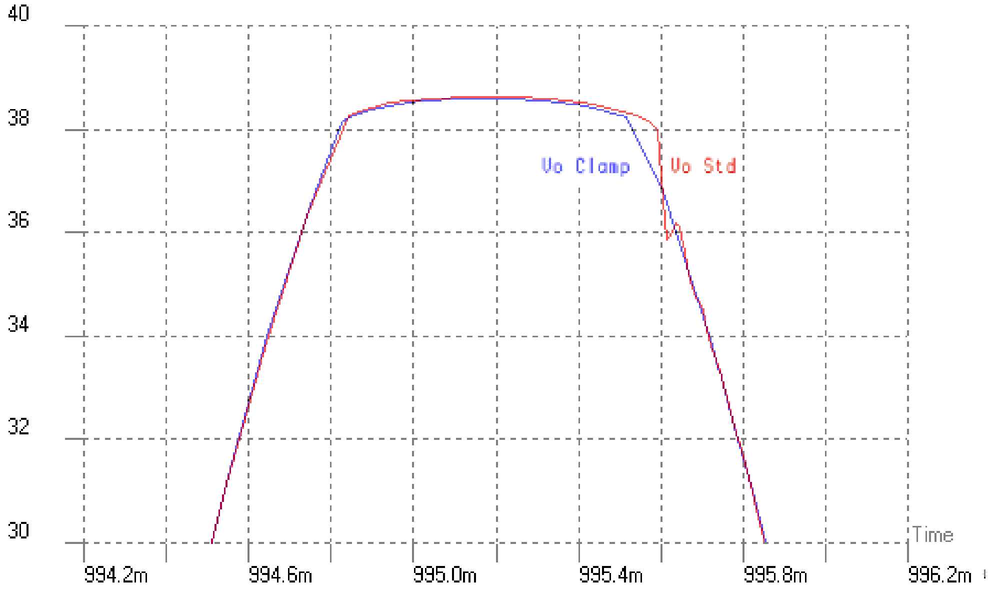

Figure 7. V_0 Characteristic at Clipping; with / without clamp