AUDIO OUT

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Railing against convention – Part 3

MX50 single-rail modification

It may be desirable to convert a dual-rail power amplifier design to single-rail. What better than to use the modified MX50 design described previously in *EPE*, since this is a standard circuit and the following basic modifications are universally applicable. First, an output capacitor will have to be added, the ground and negative rail will have to be joined together, and half-rail bias will have to be applied. The new single-rail power supply voltage will have to be the total of both the original rails. Instead of ±37V, the new single rail will need to be +74V.

Some internal resistors and earthing points may have to be changed. Including the output capacitor in the feedback loop should enable the original dual-rail performance over the normal audio bandwidth to be retained.

A typical value output capacitor for an 8Ω load would be 4700µF 63V, a standard low-cost electrolytic. Negative feedback is taken after the capacitor via a 3.3µF film capacitor. This ensures minimal distortion and bass loss with a –1dB point of 18Hz and a –3dB point of 10.6Hz. The power loss at 20Hz is only 4W relative to 1kHz, dropping from 53W$_{rms}$ to 49W$_{rms}$ into 8Ω. The bias voltage is set by R28 and R33 and this may have to be adjusted (using R32) with a 'scope for symmetrical clipping with different power supplies and load impedances. A capacitance multiplier using a transistor (TR14) and capacitor (C8) is necessary to avoid a big 1000µF decoupling capacitor. This is because the individual current source filter capacitor previously fitted (C5) actually added ripple with single-rail power because the ground reference had changed. A suitable solid polymer capacitor for C8 is a Kemet A759 series from Mouser. The complete circuit is shown in Fig.10.

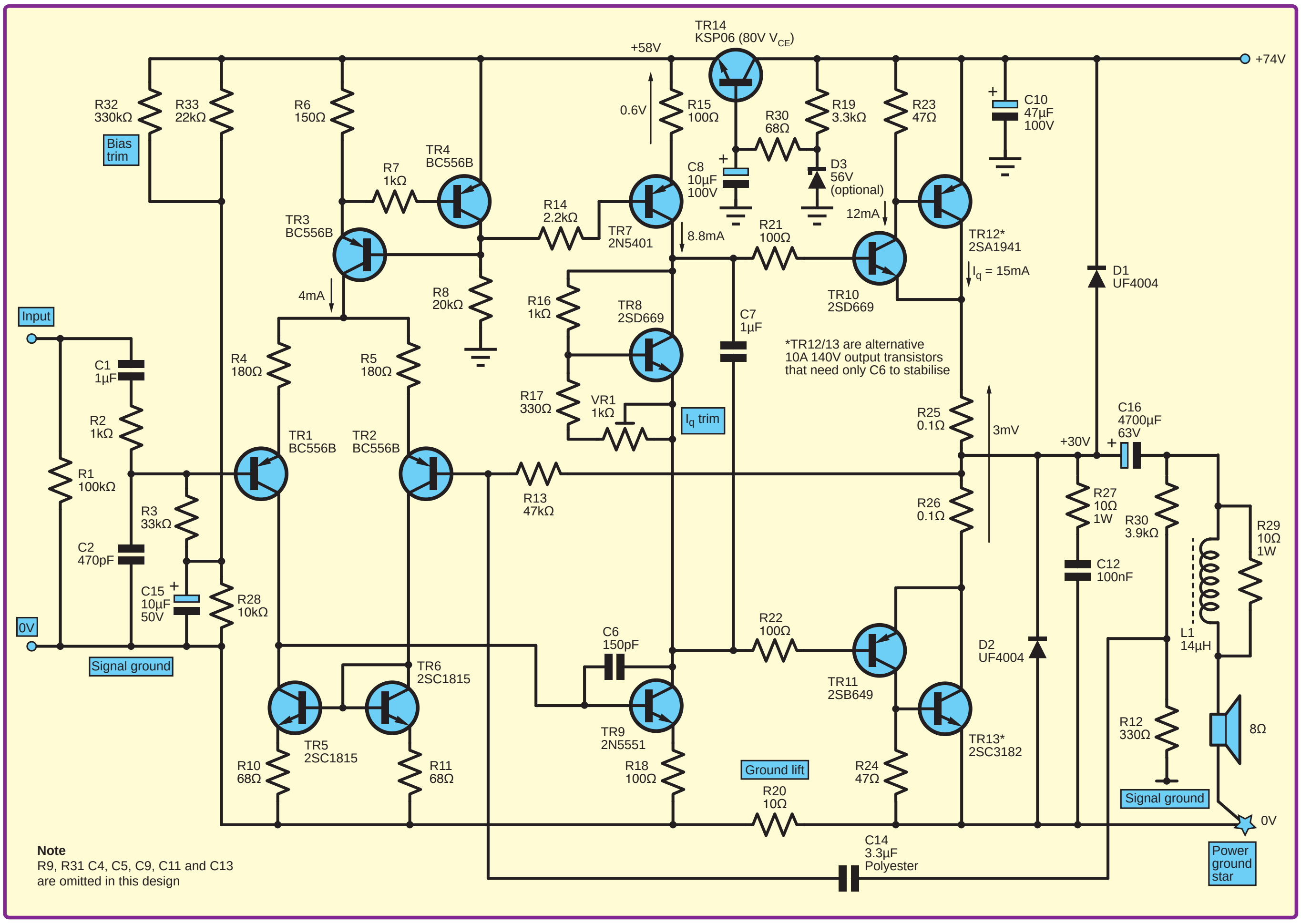

Fig.10. The MX50 amplifier converted to single-rail with negative feedback around the output capacitor. Output was 53W$_{RMS}$ into 8Ω at 1kHz. At 20Hz maximum output is only reduced to 49W. An important warning is merited here: if the output of any single-rail amplifier is shorted to ground before the output capacitor, then the upper output transistor may be destroyed – be careful with those scope probes!

Compared to the dual-rail MX50, the sound is identical until clipping occurs on electronic percussive bass sounds, where a characteristic 'capacitor-induced intermodulation mushy effect' is evident. Acoustic and classical music is unaffected. Recovery from clipping is faster on DC-coupled amplifiers. Also, the beneficial effect of feedback around the output capacitor is lost when the feedback loop is broken at clipping.

Regulation of the low-power stages supply and bias can be done by inserting a 56V Zener diode into the capacitance multiplier across C8. Using simple potential divider bias, rock-solid low-frequency stability is obtained, although output power is reduced from 53W to 46W into 8Ω (at 1kHz). I made the Zener diode switchable for comparison. On listening, I found the reduction in output power outweighed the improvement in stability. The amp remained cleaner to a louder volume without the Zener diode. What looks better on the 'scope does not necessarily sound better. Fig.11 shows the prototype single-rail MX50.

Other amplifiers

Applying output capacitor negative feedback to older amplifiers with a single-transistor input stage (as opposed to a long-tailed pair) is more complicated. A significant current is normally required to pass through the feedback resistor to power the input transistor. This necessitates a low value, typically a few kΩ, which means little capacitor feedback can be applied. The DC feedback resistor can be increased up to 1MΩ by employing an extra transistor as a current booster, thus enabling more AC feedback, as shown in Fig.12. The higher impedance also means the film coupling capacitor value can be minimised. Care has to be taken to reduce the low-frequency open-loop gain elsewhere to avoid low-frequency response humps and consequent 'bouncing' on transients. In this case, there was a peak of 3dB at 8Hz, cancelled out with a smaller input capacitor.

MX50 output capacitor voltage rating

Even though the power supply of the single-rail MX50 is 74V it is possible to get away with 63 or even 50V. This penny-pinching can't be taken too far however. I have seen amplifiers where the output capacitor voltage rating is half the supply voltage, which is dangerous. If the top transistor in a push-pull output stage short circuits and the bottom transistor fails open, then the full rail voltage will be applied to the capacitor. The fuse will blow eventually, but the capacitor may short-circuit, explode and cause speaker burn-out. In practice, however, it does seem to be safe to rate it a bit lower. Hundreds of Leak Delta 70 amplifiers used output capacitors rated at 50V with a 75V rail with no failures in the field. Also, Roberts radios used 6.3V capacitors with 9V supplies. I expect this was because the amplifier's output never quite reached full rail voltage. Possibly, if it did, it only remained high for brief periods, insufficient for the capacitor to fully charge up. Pulses would also have been easily accommodated by the capacitors surge rating, which is generally 20% above the rated voltage.

For the single-rail MX50 I used a 50V (60V surge) output capacitor with an 80V 6800µF smoothing capacitor. In the single-rail MX50 circuit I ended up with only three wet electrolytic capacitors for a stereo amplifier, compared to my absolute minimum of two for the dual-rail version (*EPE*, Dec 2017).

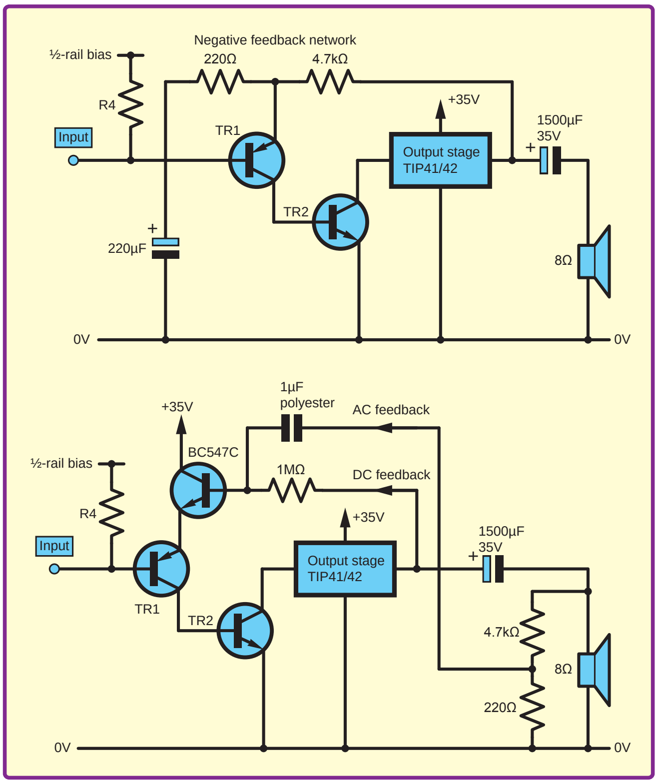

Fig.12. Applying output capacitor negative feedback to a single input transistor amplifier. In this case the Super Simple Retro design (EPE Sept 2016, Fig.23).

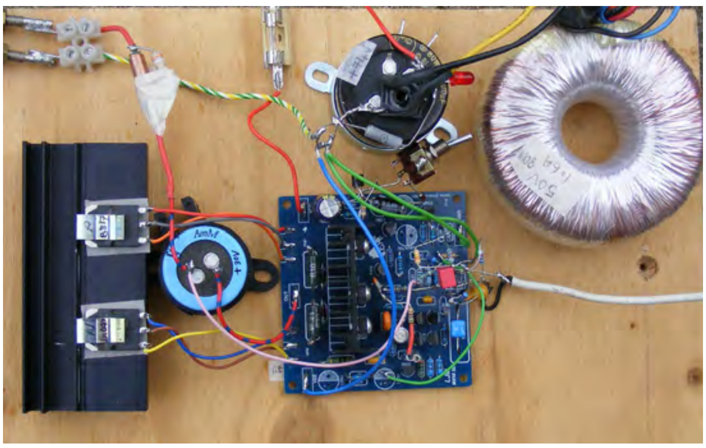

Fig.11. A prototype of the single-rail MX50. Note the blue output capacitor and the single smoothing capacitor. Only one fuse is needed, a bonus of single-rail design since fuses are unreliable.

Note that two 10,000µF 50V capacitors on a dual-rail power supply store the same energy as a single 10,000µF capacitor of 100V rating on a single-rail. Output and smoothing capacitors above the standard 63V rating are required with transformers over 44V (40W into 8Ω) which cost disproportionately more.

Funny noises

On single-rail systems the output capacitor has to charge up to half-rail at turn on. If this is done too quickly, a nasty speaker thump results. This can be mitigated by slowly raising the bias or rail voltage. This also has the advantage of slowly turning the amplifier on. The value of the bias decoupling capacitor C15 in the MX50 has been specially chosen to ramp up smoothly.

A pull-down resistor of around 2.2kΩ is needed after the output capacitor to prevent a loud pop when the speaker is connected.

Summary

A single-rail design with capacitor coupling is best for small power amps. Above 40W, where clipping is likely and for those who love hard punchy electronic bass, the problems associated with output capacitors become more significant. The increased additional cost of DC protection circuitry with relays becomes proportionately less at higher powers.