Op-Amps in Audio Circuits – A Quick 10 Point Check List

Many audio DIYers like to experiment with op-amps, often swapping out devices in an existing design in order to 'improve the sound'. There is a lot of commentary on the internet about *the sound of opamps*. Listed below are 10 simple guidelines to make sure the change in sound you are hearing isn't because of oscillation, ringing, TID or any other problems. These 10 points are not an exhaustive list, but paying attention to them will solve most problems when you find things don't quite sound the way you'd hoped.

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1. Never try to run a non-unity gain stable opamp (also referred to as a 'de-compensated' opamp)at unity gain, or at a gain that is less than the minimum specified in the data sheet.. If you do, the circuit will ring, or oscillate. Check out the op-amp data sheet and make sure you comply with this important boundary condition.

2. Don't run an uncompensated opamp without a comp cap, or too small a comp cap. Uncompensated op-amps do not fit the miller integration cap around the VAS stage on the chip – this has to be added externally (see point 3 below). If a compensation cap is not fitted, you are likely to get oscillation or ringing.

3. Make sure you fit the comp cap across the correct pins in an uncompensated op-amp (i.e. pins 1-5 instead of pins 1-8 and vice-a-versa). For this reason, in circuits where a comp cap is fitted, just swapping the op-amp out without checking this point, can lead to changes in audible performance.

4. Always fit an isolation resistor (47 or 50 Ohms) in series with the output when driving a real world load - like a cable for example, or a capacitive load. Locate this resistor as close as possible to the output pin, just after the feedback resistor or network.

5. Ensure that the junction of the feedback network is located physically very close to the op-amp feedback input pin (usually the inverting input). Any noise voltage appearing between the junction of the feedback resistor network (i.e. the upper and lower legs) and the inverting input on the op-amp, will be amplified by the full loop gain of the op-amp. On a high performance op-amp like an LM4562, with an OLG (open loop gain) of 140dB, this would easily give 1V (yes, 1V) of output noise for a 1uV noise signal. To reiterate: keep the junction of the feedback resistors and the inverting input on the opamp as physically compact as possible.

6. Locate any input filter as physically close as possible to the op-amp input (usually the non-inverting input). In this scenario, any noise signal induced on the connection between the non-inverting input and the filter will be amplified by the closed loop gain of the amplifier. So, while not as critical as in the inverting input pin case above, it is still important to consider.

7. Decouple the supply rails adequately and close to the op-amp supply pins. Typically, 0.1uF to 1uF ceramic from the supply pins to ground will prevent any oscillation or instability. And, no, using ceramic caps to decouple the supply pins will not ruin the sound. Also, make sure you do NOT use the signal ground for the decoupling capacitor ground return – you should use a separate power supply ground return for this purpose.

8. Never use an opamp not characterized for audio usage. Typical examples are uA741 (an early 1970's relic), TL072 (ok for DC work, but not high quality audio), LF355,356, 357 - also relics from the late 1970's. Low supply rail, low power op-amps are also generally not good for audio. Look for devices with the following general characteristics:-
    - Slew rate of at least 10V/us
    - Full Power bandwidth of 50KHz
    - Low frequency PSRR of >70dB (modern op-amps do >100dB) on both +ve and –ve rails; HF PSRR should be better than 70dB
    - 600 Ohm drive capability
    - 600 Ohm 1KHz 10Vpk output distortion of 20ppm or better (modern devices will achieve low single digit ppm figures at 20KHz and sub 1ppm at 1KHz

9. Scope your physical design out . . . it's always possible, despite your best efforts, to have your op-amp design or swap out, oscillating at some high frequency. HF oscillation or ringing will definitely affect a circuits sound for the worse.

10. Make sure you understand how the opamp behaves under input and output overload conditions.. You'd be surprised how otherwise reasonably specified devices misbehave under these conditions. Some op-amps suffer output phase reversal if the input signal goes within a volt or two of the supply rails for example. Look out for rail sticking when the output clips, and slewing when driving a large square wave signal (a problem with the LF355 family for example).