Some thoughts on a VBB seismometer circuit

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In any attempt to modify the circuit, it is vital to assure that the frequency characteristics of the design remain unchanged. The stability of the feedback loop depends entirely on those frequency characteristics and should not be changed. Any modifications aimed at improving loop feedback stability are a separate issue and will not be addressed here.

Looking at a simplified portion of the original output circuit, the P, I and D branch signal currents are summed into the low impedance feedback coil. The component designations are the same as those used in the analysis of the loop, “loop3.pdf”

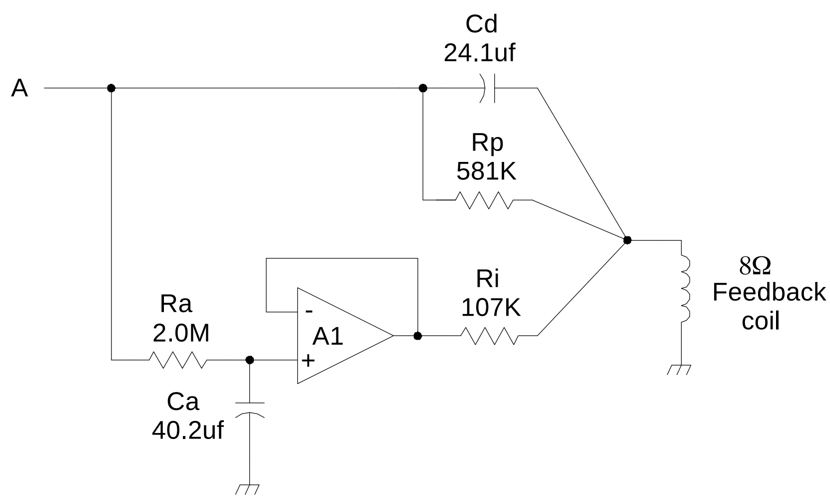

fig.1 - Original Circuit

In order to improve the system performance a modified circuit is being investigated. As indicated above, the components have been carefully selected to duplicate the frequency response of the original circuit. However the new circuit has several characteristics which should be desirable.

The feedback coil is now being driven by a current-amplifier circuit, A3 and A4, having a current gain equal to R2/R1 = 100 The impedance of the feedback coil no longer matters much; in particular, changes of the coil impedance at higher frequencies or due to temperature, will not affect the coil current. Also the three branch currents are now summed at a true virtual-ground point, at the input of A3. The +1 buffer amplifier, A4 is added following A3 so that more current is available for the coil and also so that any minor heating effects will be concentrated in A4, where they won’t introduce temperature related DC errors in A3. Among other things, the x100 current gain allows the value of C2 to be reduced by a factor of 100, to 0.241µf. However, the value of R8 must then similarly go up by 100, to 58.1M.

A2 is a unity-gain inverter, added keep the polarity of the derivative and proportional branches the same as the polarity of the integrator branch.

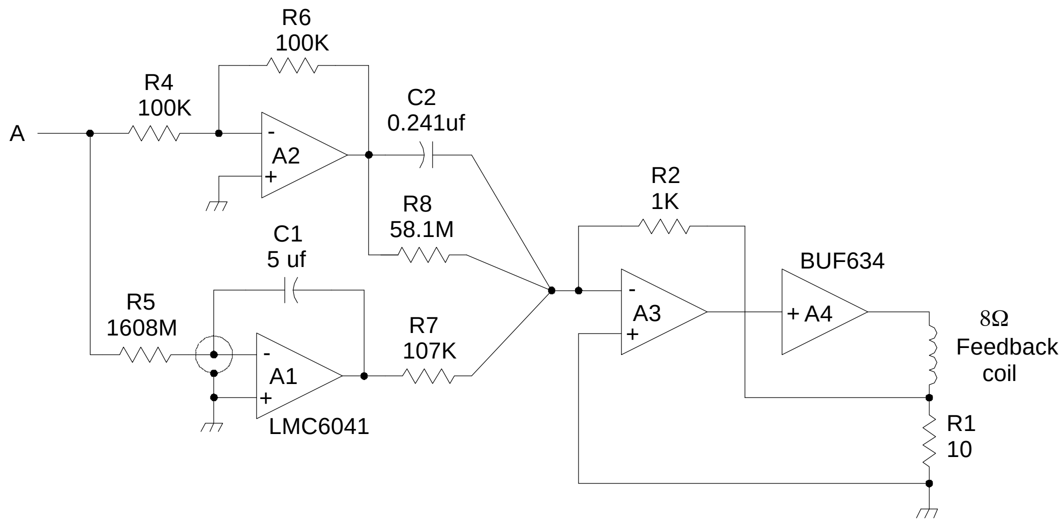

fig.2 - Proposed circuit

The integrator branch is modified the most, using a special low input-current (2fA) op amp to make a feedback integrator. The integrator capacitor is chosen to be 5uf, so the input resistor R5 must therefore be increased to 1608 M. Although the high-value resistors, R5 and R8 will be a little harder to obtain, decent high-value resistors are available. And now C1 and C2 are small enough to be polypropylene capacitors which should perform more predictably. Also some care will be needed to minimize surface leakage on the components and circuit board. A guard ground will likely be helpful, and electrostatic shielding will almost certainly be necessary.

The dynamic range of the integrator branch, has been increased by a factor of 100. Now, very slowly applied forces, if they contain only frequencies which are well below the VBB lower cutoff frequency (.011 Hz), will largely get corrected by the feedback loop and will not greatly alter the mass position. The integrator branch in this design can apply roughly ± 8ma to the coil which permits steady or very slowly varying forces of up to ±0.1 N to be accomodated. The output signals resulting from spring creep, earth tides, and temperature or barometric changes *if they are sufficiently slow*, will be greatly attenuated. It may still be necessary to mechanically re-balance the boom in order to re-zero the loop DC restoring force, but it probably won't have to be done very often, as the mass position should be staying well centered. The main reason for adjustment will be to maintain the dynamic range of A1, keeping its output from getting too close to ±9V (±0.1N unbalance at the mass).

There had been some discussion about whether an integrator could be used which had no low-frequency zero, i.e. no resistor in parallel with C1. As long as the surrounding feedback loop is active and has sufficient DC loop gain, it should work fine. Any integrated errors (say, from leakage currents) will slowly re-position the mass slightly, which will cause the mass position transducer output, returned to point A to change in the exact amount needed to offset the leakage error, via R5. The aim is to make sure that all the DC/low-frequency errors are small enough that they don't require excessive shifts of the equilibrium mass position.

Items remaining to be considered:

1. Power supply requirements. Bypassing. Power bus layout.

2. Stability of A3–A4 loop. Necessary to equalize?

3. Select devices for A2 and A3 (dual op-amp?)

4. Change components to standard values.

5. Confirm sources for high-value resistors.

6. Add any needed DC-zero or gain-trimming networks.

7. Estimate the instrument noise and drift based on device specs.

8. Look at ground layout issues.

9. Find teflon feedthrough/standoff suitable for A1 input guarding.

10. Look into electrostatic shielding.

11. Metering of DC force balance (and of mass position?).

12. Provision to reset and/or reduce the integrator capacitor at start-up.

13. Estimate power-supply sensitivity of integrator.