MATH'S NOTES

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WHAT'S NEW AND HOW TO USE IT

Transformers or Not Transformers? That is the Question.

Those of us who have built quite a bit in the way of audio circuitry are familiar with balanced and unbalanced inputs. By way of review, the basics of these two coupling approaches are shown in fig. 1.

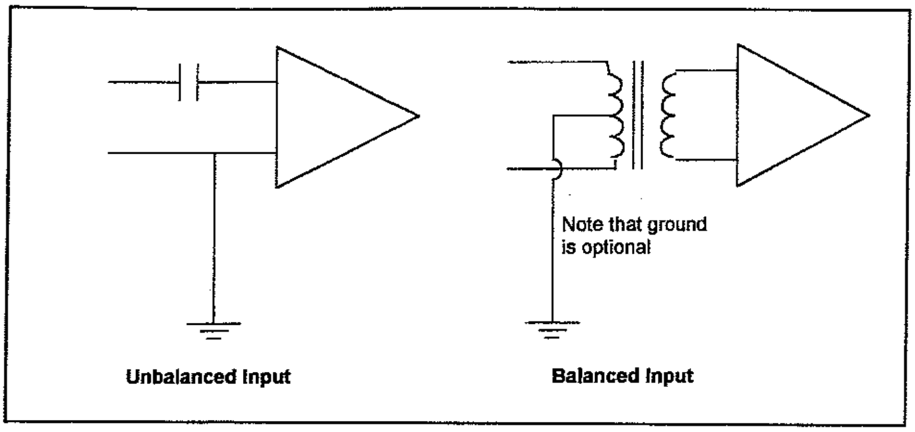

Fig. 1– Unbalanced vs. balanced input configurations.

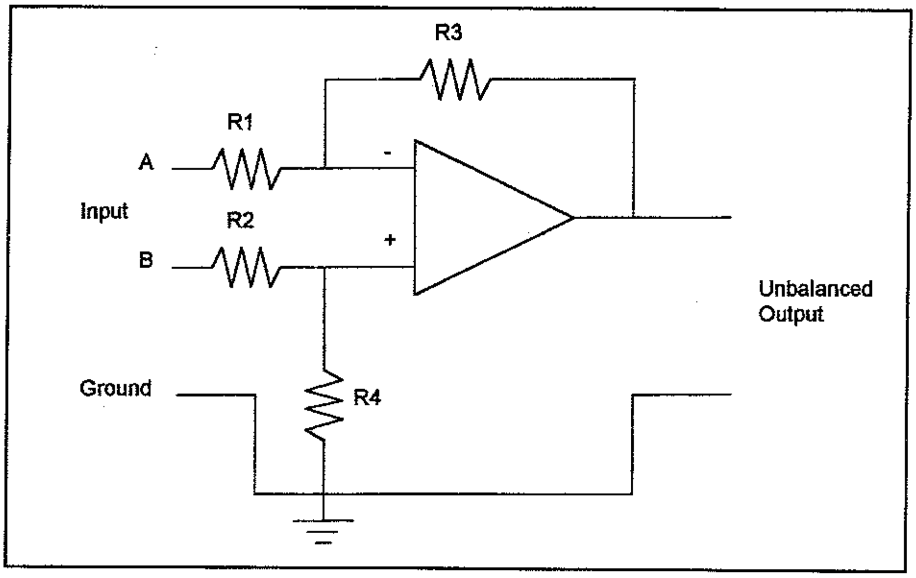

Fig. 2– Balanced/unbalanced op-amp input configuration. Note that all resistors are 10K $^1/_4$ watt @ 1% tolerance.

An unbalanced input is one that is referenced to ground and is the simplest way to interface with common shielded cable (and RCA phono jacks, for example). An unbalanced input often is transformer coupled and interfaced with XLR-type audio connectors. Balanced inputs are normally used to reduce or eliminate unwanted signals such as 60 Hz hum in professional audio installations. A center tap in the transformer winding is also sometimes added for shielding purposes. Incidentally, a balanced transformer input can be converted to an unbalanced input simply by grounding one side of the transformer (and not grounding the center-tap if it is present, obviously). Usually, circuits using balanced inputs tend to be more expensive than unbalanced ones due to the use of the transformer.

There is a practical problem regarding the use of transformers for the experimenter on a budget, however. The low frequency response of any transformer is dictated by the amount of iron in the core, and as the frequency drops to less than 20 Hz or so, all sorts of phase shifts and loss of signal amplitudes soon come into play. Also, at frequencies higher than 15 kHz or so, the efficiency of the iron core begins to suffer and similar problems occur.

Only expensive transformers, specially designed for high-quality audio applications, can usually make the grade. This is true, by the way, for both input as well as line driving output circuitry. So what can one do?

The solution is to use an all-electronic input and/or output circuit. For the input side, fig. 2 shows how an operational amplifier can be used for both the balanced and unbalanced function. In the circuit shown, all resistors are 10 K $^1/_4$ watt 1% devices. A signal applied to the A input appears inverted at the op-amp output, a signal applied to the B input appears non-inverted at the output, and a balanced signal, applied between the A and B inputs, appears single-ended at the output. Unwanted signals applied to both A and B with respect to ground are canceled (the main reason one uses a balanced input).

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In this way, a balanced signal is easily converted to an unbalanced one without the need for a transformer.

The high level of precision of the resistors is necessary to assure that the positive and negative portions of the input signal are equally amplified. Any significant difference in gain between the inverting and non-inverting inputs will result in distortion and poor rejection of common mode (or unwanted) signals.

In commercial equipment these resistors are usually chosen to be as close to a perfect match as possible, and common mode rejection ratios of more than 1000 times are easily achieved.

When an unbalanced input is desired, simple connect the B input to ground and apply the unbalanced signal between the A input and ground. Note, however, that the common mode rejection factor is lost in a single-ended configuration.

The input impedance of this circuit, as shown, is high due to the 10 K resistors. When a lower value is desired, simply connect an appropriate value resistor between the A and B input pins. If you connect a 600 ohm resistor between these points, for example, the circuit will appear as a low-impedance 600 ohm input in either the balanced or the unbalanced configuration.

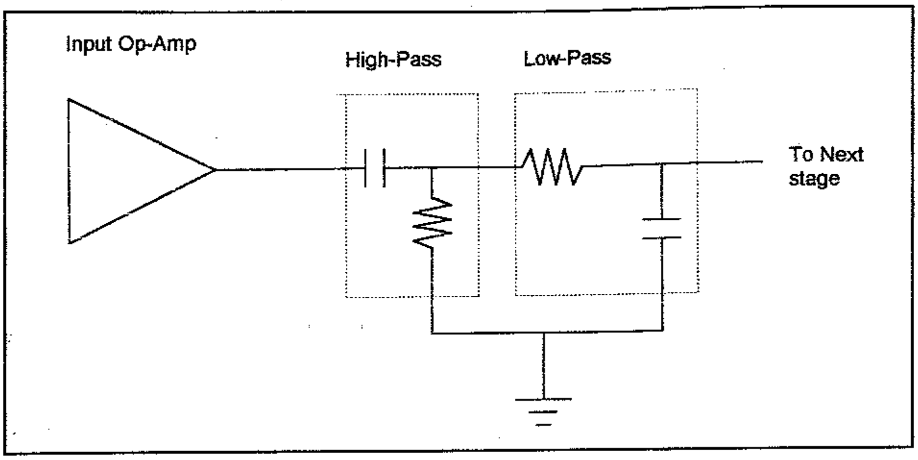

Fig. 3– Input filtering network configuration.

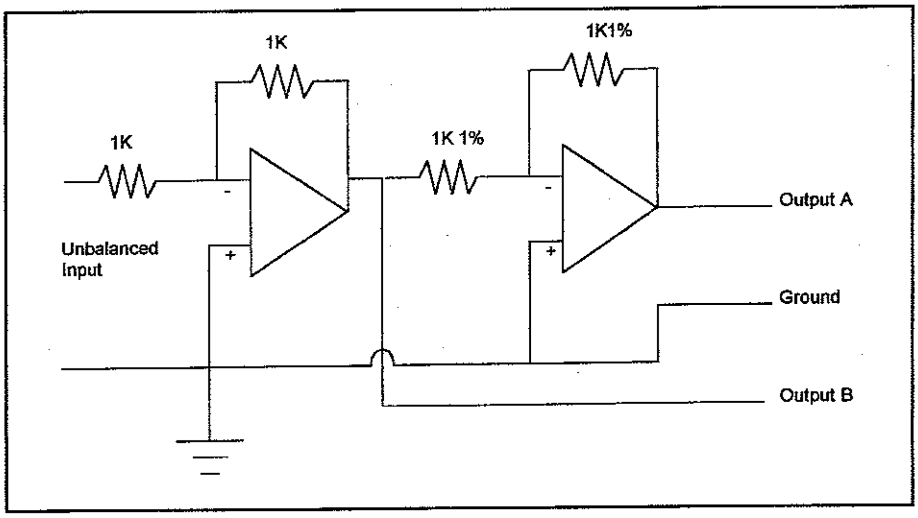

Fig. 4– Balanced/unbalanced output configuration.

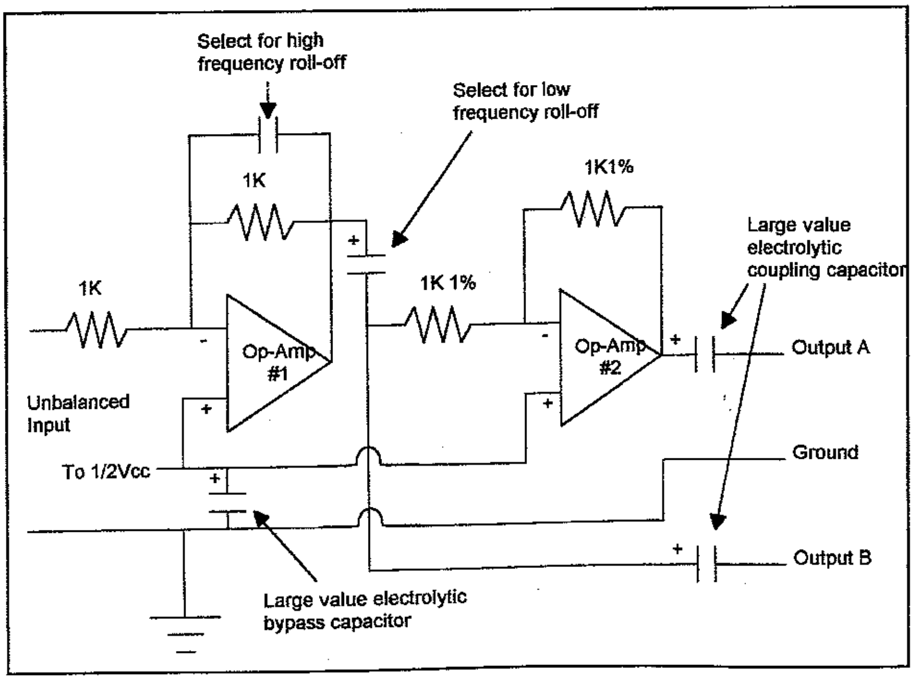

Fig. 5– AC-coupled balanced/unbalanced output configuration.

In addition to the elimination of the transformer, you will also note that this circuit is DC coupled. This means that frequency response will extend from DC to the upper limit of the op-amp. As a result, even with a low-frequency op-amp, response easily will extend well above and below the normal audio range. In fact, the response of such a circuit is so wide that you almost certainly will have to "tailor" it with a filter network of some sort. Fig. 3 shows one way to do this.

The high-pass section of the filter shown is chosen so that the low-frequency roll-off is at the lower limit of the audio pass band desired. For high-fidelity applications this point usually will be around 15 to 20 Hz. For radio communications equipment, 300 to 500 Hz usually will suffice. The low-pass section of the filter is similarly chosen for the high-frequency roll-off desired. Again for high fidelity, this usually will be 20 kHz, while for communications, 5 kHz is adequate. Actual values for these filters can easily be determined experimentally.

Fig. 4 shows how to configure a balanced/unbalanced output circuit. In this circuit both op-amps have been configured to give a gain of one (1), although the op-amp #2 stage is the critical one. Op-amp #2 inverts the output of op-amp #1 as accurately as possible (which is why 1% resistors are used). When a balanced output is desired, it is taken directly between outputs A and B. When an unbalanced output is desired, it is taken from either the A or B output with respect to ground. The only requirement for both of these op-amps is that they have enough oomph to drive the desired load. Most op-amps designed for audio applications usually can drive 600 ohms, so these are not hard to find.

In fig. 4 we have shown the op-amps DC coupled. As in the case of the input circuits, frequency response is quite wide and frequency "shaping" will probably be necessary. To use the DC coupling as shown, by the way, requires that the op-amps be provided with a positive as well as a negative power supply. If this is not critical, single supply op-amps can be used with coupling capacitors between the op-amps and the outputs as shown in fig. 5. If this is done, then the coupling capacitors can be chosen to select the low-frequency roll-off point and the feedback resistor of op-amp #1 shunted with a capacitor to determine the high-frequency limit. This is also shown in fig. 5.

Be careful of the op-amp #2 stage, however. It must be as close to a perfect "inverting mirror" as possible, and the output capacitors must be the same value and capable of passing frequencies at least 10 times lower than the desired lower limit of the equipment. Now you can have your cake and eat it, too! 73 Irwin, WA2NDM