

Balanced Transmitter and Receiver II

Rod Elliott (ESP) / [Uwe Beis](#) *

[Updated 01 April 2002](#)

Introduction

This is essentially an update to the original article on the subject, and includes some ideas to stimulate further thought on the subject. This is especially true of the last section ([Hey! That's Cheating](#)) - everyone wants balanced outputs free, well you can have them free (well, near enough anyway).

The balanced transmitter and receiver described in [Project 51](#) work very well, but both are less than optimum under difficult conditions. Uwe has written an article (published on The Audio Pages) describing an active balanced transmitter that has performance almost equivalent to a transformer. There are ICs available that (almost) manage the same thing, and the principle uses feedback to equalise the levels from each transmitter opamp.

While Uwe has gone to a great deal of trouble to get his circuit to match a transformer as well as possible, this is not an easy circuit to get working well, and it requires 0.1% tolerance resistors and wide bandwidth opamps.

Enter ESP and the "simplification methodology" that I tend to use wherever I can. The result is a transmitter (in particular) that is extremely good, and matches the performance of a transformer to a quite acceptable degree. It's not perfect, but it is very stable, and requires no adjustments or close tolerance parts (1% resistors will provide a maximum error of 1/100, or 40dB common mode rejection and balance).

Use of closer tolerance resistors - and good or premium opamps - will give a circuit with excellent performance, and it will come very close to that of a transformer balanced circuit with none of the associated cost. Response is flat to at least 50kHz, with a low frequency limit of DC (as shown). Capacitors can be used to limit the low frequency limit if desired.

Mk II Receiver

The receiver is shown in Figure 1, and as shown does not have any RF protection. This configuration is somewhat better behaved than that shown in the original article, and presents exactly the same impedance to each of the balanced lines in the cable. This is also the case with the original version shown, but *only* if the source is balanced.

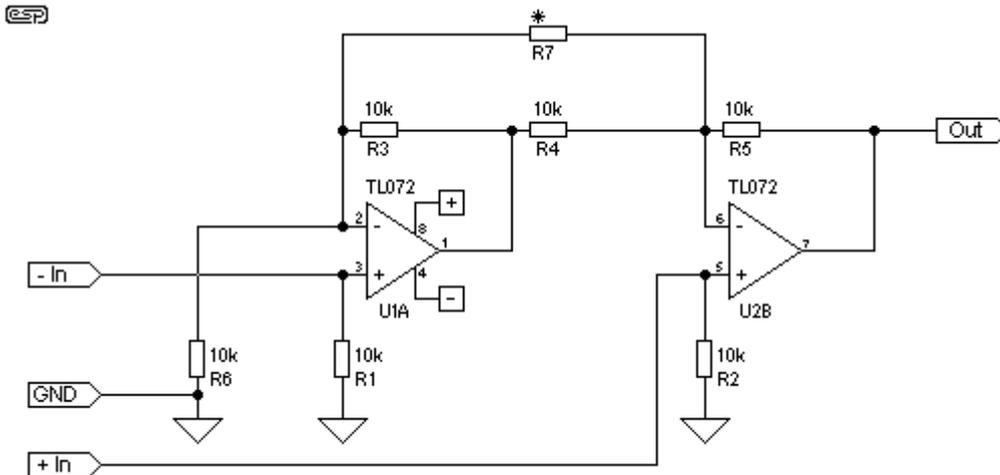
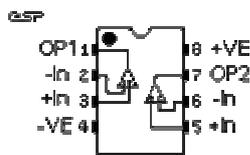


Figure 1 - Active Balanced Receiver

The resistor marked * (R7) may be left out, and the circuit will have a gain of 2. Installing this resistor will increase gain, but will have no effect on the input impedances or balance performance. The minimum gain for this circuit is 1.5 (if R6 and R7 are omitted), and this increases to 2 with R6 installed. The gain setting resistor R7 still works if R6 is omitted, with a value of 10k providing a gain of 3.5, and 1k giving a gain of 21 (26dB).



The standard pinouts for a dual opamp are shown (top view of device). It is suggested that a bypass capacitor (typically a 100nF ceramic or polyester) be connected between pins 4 and 8, as close to each opamp package as possible. Even with "slow" opamps, it is always a good idea to use a bypass cap to prevent possible instability at high frequencies.

The exact same scheme as shown in the original project could be used for the inputs on this version. One possible connection is shown in Figure 2. This is virtually identical to the configuration shown in Project 51, and will provide a very high noise rejection.

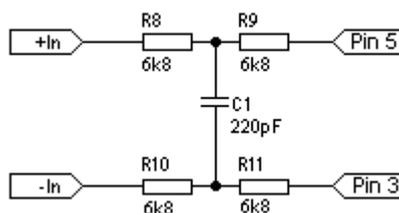


Figure 2 - Input Circuit for Receiver

The 10k resistors (R1 and R2) to ground are still needed, and this arrangement will reduce the gain by a little over 7db. Use lower value resistors for less attenuation, but remember that as the attenuation is reduced, so is noise immunity. 1k resistors would be the lowest value I'd recommend, and will cause minimum attenuation

times the "correct" value), the overall stability and frequency response is much less dependent on the component values and opamp quality. I was able to verify that even using 741 type opamps, frequency response is less than 1dB down at 75kHz.

Somewhat surprisingly, output impedance is 100 ohms, and not the 200 ohms one would expect - there are 100 ohm resistors in series with each output after all. The crossed feedback paths make the difference here, and both simulation and measurement confirm that this is the case.

Construction Hints

Both the transmitter and receiver circuits require at least 1% tolerance resistors, or common mode rejection will be unacceptable. Even with 1% tolerance, the worst case rejection is only 40dB, and if you can use your multimeter to match the resistors to closer tolerance this will improve the performance.

Although the transmitter and receiver are shown with (mainly) 33k and 10k resistors respectively, these may be changed if desired. Any value between 10k and 100k could be used, but remember that higher value resistors create more thermal noise. R5 and R9 in the transmitter are approximately 1.2 times the other resistors - the next E12 value up. For example, if you elected to use 22k resistors throughout, then R5 and R9 would be 27k. Also remember that for the transmitter's input, the impedance is 1/3 of the resistor value used - 10k resistors would therefore give an input impedance of about 3k.

Both circuits require a balanced +/-12V or +/-15V supply ([Project 05](#) or similar power supply), and it must be free of noise. Make sure that 100nF ceramic caps are placed between the supplies as close as possible to the supply pins of the opamps. This is especially important if you use high speed opamps.

Hey! That's Cheating

Finally, for those who want a balanced output that is really simple, try the circuit shown in Figure 4. Now look at it again - it's not balanced at all ... or is it?

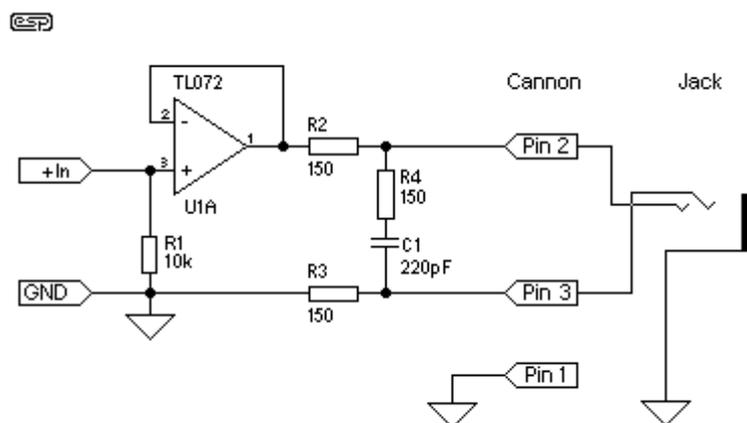


Figure 4 - Simplest Possible Balanced Output

Now, before you get all horrified, let's have a proper look at what is happening. The main trick with a balanced circuit is that the receiver should "see" the same impedance on each input. It doesn't actually care that much if there is signal on either or both wires (indeed, that is merely an *expectation* on our part), but even if the wanted signal is only on one wire, any induced noise will still be common mode, and will still be in phase across both wires. The noise gets cancelled either way, and the signal gets amplified, which is just what we want.

Yes, it's cheating - but it works. Apparently, this trick is used on some of the popular stage mixers, as well as some very well regarded phantom feed microphones (although as far as I know they don't use the Zobel network - this is optional BTW). There is less signal than one would expect (most balanced transmitter circuits have an effective gain of 6dB), but this is generally not an issue. In the case of a microphone, the signal is the same as it would normally be anyway, and with a line output, 6dB of additional gain is usually not a problem to achieve. The amplifier as shown in Figure 4 only needs 2 x 10k resistors in the feedback path to achieve this (10k from output to -ve input, and 10k from -ve input to ground).

In most cases, this will work *just as well* as a true balanced output circuit. From the perspective of the balanced input circuit (the receiver), this arrangement provides exactly the same signal as if the circuit were fully balanced. Although 150 ohm resistors are shown for the balancing network, these can be changed if desired. Normally, I would expect that the values shown will be fine for almost all applications (effective output impedance is 300 ohms).

Somewhat predictably, the signal is only on one lead, so the cables had better be wired correctly if it is feeding an unbalanced input (but this is something that should be regarded as essential for all stage and studio work anyway).

Caveats - the output impedance of the opamp should be flat to a suitable high frequency, and this will not often be the case. Although I have shown a TL072 (or half thereof), I suggest that a better opamp should be used. A very high speed opamp (Such as the Texas Instruments THS6012 - See [The Need For Speed](#)) will help enormously here, but at considerable cost and inconvenience - unfortunately. In general, the output opamp should be as good as you can afford. A cheap opamp will give a cheap result. The optional zobel network will help ensure that the line appears properly balanced at all frequencies including RF, but cannot guarantee perfect results with any opamp. Resistor tolerances are just as important here as with any of the more complex versions - 1% is the minimum acceptable tolerance.

Inspiration

This new project article was inspired by Uwe Beis, and his article on the (almost) perfect [balanced transmitter](#) is published on these pages. Although the material here is somewhat "off topic" from his approach, the inspiration to experiment and try the various techniques came from his submission. I recommend that you read the full article, as it explains the operation of the balanced transmitter shown in Figure 3 very well, and will give you an idea of the dedication of some people (Uwe in this case) to the advancement of their understanding of analogue electronics.