Balanced Line

There seems to be some confusion about balanced line systems. They have been used for ever in professional installations and in radio frequency systems. We shall confine ourselves to the audio side of this discussion.

Note: In the following discussion I only talk about a single channel of the traditional stereo pair. This is for clarity purposes only.

An unbalanced line has only TWO conductors, a hot and a ground. When linking two pieces of equipment with an unbalanced connection, the ground between the two becomes common by virtue of the single ground return circuit. The hots are of course connected together. This system has both advantages and disadvantages. The advantage is it is only a two wire circuit, typically RCA connectors are used and it is less expensive than balanced line circuits. The equipment transmitting the signal needs only a single ended output stage using the hot and ground. The receiving equipment also only needs a single input stage that uses only hot and ground. Disadvantages are that long cable runs cannot be used without high frequency loss UNLESS the transmitting equipment has very low output impedance and can deliver some reasonable current. Never the less it is not advisable in a high quality system to have unbalanced runs of more than 10 metres (30 feet). An unbalanced system is prone to noise pick up unless extreme precautions are taken. Cables should be well shielded (preferably with a second outer braided shield connected to the chassis of the vehicle). Ground loops can be formed unless precautions are taken with grounding techniques.

Note: See the section on ground loops under Techtalk.

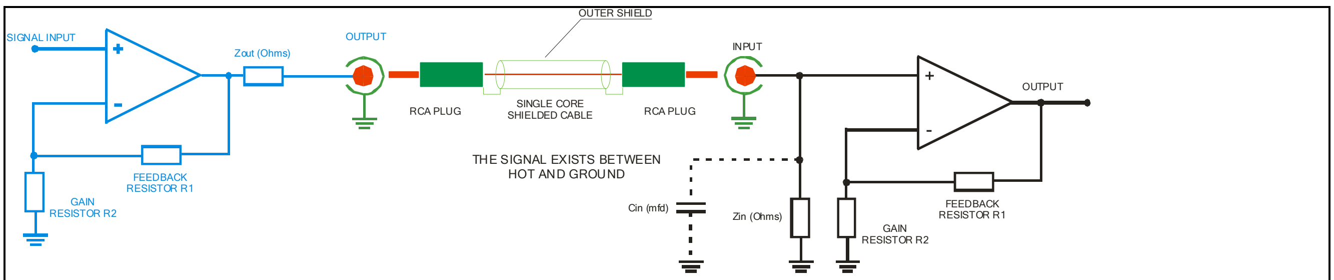
Balanced lines are kind of the opposite of their unbalanced cousins. More expensive due to the 5 wire system and the connectors are more expensive. XLR plugs/sockets are more costly than RCAs (Unless you are stupid enough to spend $3,000.00 on your new 1 metre RCA-RCA “high end” cable). The transmitting equipment must have anti-phase outputs to drive the balanced line hot legs and the receiving equipment must have a differential input circuit. A balanced line circuit with a good CMRR will reject noise if it is picked up on both “hot” legs. Ground loops are easily avoided but still care must be taken with grounding of the various pieces of equipment.

In **Fig 1** showing the unbalanced connections, the signal exists between the HOT and the GROUND leads. As shown the green ground connections MUST be made at each end to complete the circuit. I have shown the two pieces of equipment in a schematic format so one may understand more fully the various impedances involved. The resistor labeled as “Zout” is typically less than 500 ohms from a line level source. The resistor on the receiving equipment labeled as “Zin” is typically many thousands of ohms whether this piece is another line level processor or an amplifier. A simple potential divided is made from Zout and Zin so that the effective voltage which the receiving piece actually gets is Zin/Zin+Zout. A simple example if Zout is 500 ohms and Zin is 10,000 ohms the attenuation caused by Zout is 10,000/10,000+500 = 0.952. So if the output voltage of the sending equipment is 1 volt then the receiving equipment only gets 0.952v (-0.427dB). This fine when there is no capacitance involved, but this is not the rule.

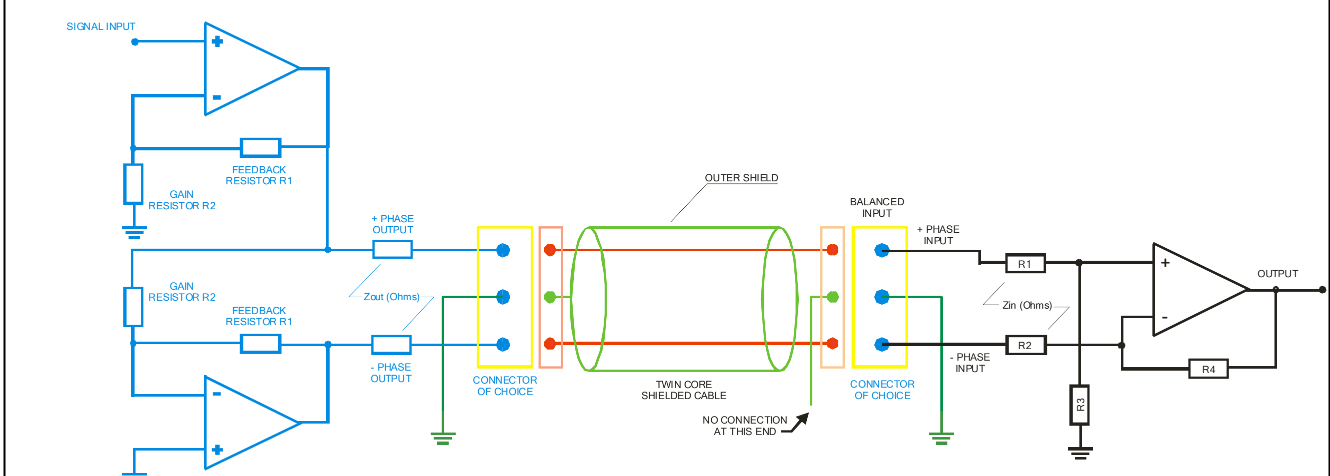
In **Fig 1** I have placed a capacitor in parallel with Zin. This capacitor is made up of the actual capacitor at the input and the lumped capacitance of the shielded cable itself (Normally low). So now Zin is frequency dependent because a capacitor’s reactance varies with frequency.

The capacitive reactance is inversely proportional to frequency. Let us say Cin = 300pF (0.0003 mfd) and Zout and Zin as the example above. So the potential divider made from Zout and Zin has this new component Cin. We have two scenarios here. The total Zin at 20Hz is equal to the value of the resistor labeled “Zin”. Why? Because Cin at 20Hz = 26.5 million ohms – hardly a factor. But at 20KHz the story changes. Cin has a reactance of 26.5K ohm at 20KHz which is in parallel with the resistive part of Zin. So now the calculation for final Zin is done from this formula. 10,000 x 26,500/36,500 = 7,260 ohms. So our input impedance has changed from 10K ohm at 20Hz to 7.26K ohm at 20KHz. What have we now? The signal will be attenuated at 20KHz more than at 20Hz due to this capacitor.

The original formula where the final voltage received was 0.952% of the transmitted voltage NOW VARIES WITH FREQUENCY. At 20Hz it remains 0.952 but at 20KHz it is calculated 7,260/7,260+500 = 0.935 (-0.583dB). So the response is down by 0.156dB at 20KHz with respect to 20Hz. What do we learn from this? If we make Zout as low as we can, it has less effect on the final voltage the receiving gear will receive from 20Hz-20KHz.



TYPICAL UNBALANCED INTERCONNECTION
BETWEEN TWO PIECES OF EQUIPMENT
FIGURE 1



TYPICAL BALANCED INTERCONNECTION
BETWEEN TWO PIECES OF EQUIPMENT
FIGURE 2

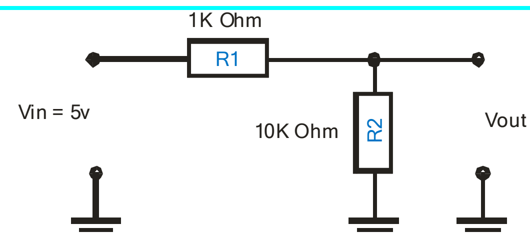
Looking at **Fig 2** above the transmitting gear has anti phased outputs. The bottom opamp is simply a unity gain inverter. Now the signal is ground free and ONLY exists between the + and – phase outputs as shown. The connector is typically a 5 pin for stereo with 4 hots and a shiled ground. (I show only three for one channel). The cable is of course a 4 conductor and an outer shield type (I show again only 2 plus ground for clarity). The outer shield serves only one purpose and that is too shield the inner cores from noise pick up and must only have ground connection at one end. (I show it at the transmitting side) The inner cores should have each pair in a twisted assembly for additional protection against noise pick up. The receiving gear has a balanced input a shown. This is the simplest form of balanced line input (without the use of a balancing transformer). However the input impedance on each leg is different. On the + phase input it is R1+R3 and on the – phase it is R2. So if all four resistors are of equal value (typical if no gain is required) then the input impedance on the + leg is twice that of the bottom leg. What does this do? Well a similar calculation can be done as in the unbalanced system and here is what happens. On the + phase the attenuation is 20,000/20,000+500 = 0.975. (remember the Zout of EACH balanced drive leg is 500 ohms as an assumption). Now on the – phase it differs because the numbers are 10,000/10,000+500 = 0.952. So as we see there is a difference on the two input phase legs of the receiving gear of 0.2dB (A 2% inbalance). This will affect the CMRR (The ability of the balanced line system to reject noise) of the system and there are more complex circuits which allow the input impedances of both phases to be identical.

So what have we learned here? In professional systems where there are many metres of cable and many pieces of equipment the use of balanced line is mandatory. In home and car systems it serves ABSOLUTELY NO PURPOSE if the unbalanced system is correctly designed, the equipment is well designed and the installation is good. Keeping signal cables well away from high current power cables is a must and using double shielded audio line level cable will keep interference out. The line level drive equipment must have low output impedance to keep the hot signal legs at the lowest impedance with respect to ground.

Balanced line in the car is like chicken soup - it cannot hurt. It's major disadvantage is the connectors. Miniature 5 pin DIN plugs and sockets are typically used as they are small. They are difficult to work on and typically do not come with gold plating on either plugs or sockets.

More reading should be done on the link for Ground Loops.

The following circuit is a guide to calculating voltages with a simple two resistor divider which applies to **Figs 1 and 2** above



TO CALCULATE Vout

Using Ohm's Law if Vin=5v the current through
R1 and R2 in series is 5 divided by 11,000 = 0.00045 amps or 0.45mA
So again with Ohm's Law if 0.45mA flows through a
1,000 ohm resistor the volt drop is 0.00045 x 1,000 = .45 volt
So we drop 0.45 volt across R1 and the net across R2 is equal to Vout = 5 minus 0.45 = 4.55v
OR another way is by the ratio of R1 and R2
So R2/R1+R2 x 5 = 10,000/11,000 x 5 = 4.55v