LINEA RESEARCH

WHITE PAPER

LINE LEVEL BALANCED OUTPUT CIRCUIT DISCUSSION

As can be appreciated from a casual literature search, the detailed operation of balanced interconnections is deceptively complicated as is their actual performance under adverse conditions. It is also a subject about which diverse opinions are strongly held.

This discussion particularly concerns the various types of 'balanced' output circuit that are used in the professional audio industry, along with some of their major advantages and disadvantages. As can be seen, no topology can be considered best on all counts although when used in harsh real-world situations some can be expected to perform better than others.

WHAT DO WE MEAN BY 'BALANCED' ?

A balanced connection is normally interpreted as implying that the driving device and receiving device are connected together with a screened twisted pair cable. The audio is carried by the twisted pair, one wire (or 'leg') being referred to as 'hot', '+' or 'phase', the other as 'cold', '-' or 'return'. The way that the cable screen should be connected is a controversial subject in itself and is considered in the AES48-2005 standard.

The first thing to appreciate is that the performance of a balanced connection is not dependent on the audio level on each leg of the output. What is important is that the impedance between each leg and ground is the same. This is because a balanced input does not 'know' about leg to ground voltages, it can only 'see' the voltage difference between the legs. Therefore it makes no difference if half the output signal is on each leg or if the entire signal is on one or the other (or in the case of floating transformer outputs, NO signal on either leg to ground!).

A balanced input works by rejecting signals that are of the same level and in-phase on each leg. Interfering noise signals will induce an equal current in both legs of the connection. If the impedances of each leg are the same, these currents will cause equal noise voltages to appear on each leg. As these voltages are in-phase or 'common mode' the balanced input will reject them. From this it follows that it is quite possible to design an output stage that has equal voltages on each leg (and therefore appears to be a good design) but which will not perform well in a noisy environment because insufficient attention has been given to making the impedance of each leg to ground the same. Equally designs that have different voltages on each leg can have excellent performance if correctly designed.

DIFFERENT CONFIGURATIONS

TRANSFORMER OUTPUTS

Considered by many to be the ultimate arrangement, although not without its particular problems.

Transformer outputs meet the requirement that the impedances between each leg and ground are the same by there either being no direct connection between the transformer output and the ground system or the ground being connected to a centre tap. Of course the detail is slightly more complicated because there will always be parasitic capacitances but these should be equal and can therefore be disregarded.

ADVANTAGES:

- Simple
- Excellent impedance balance and hence performance in noisy environments
- Gives the correct audio level if operated unbalanced (one leg connected to GND)
- Provides electrical isolation between the source and destination

DISADVANTAGES:

- Very expensive, especially if good audio quality is required
- Bulky
- Susceptible to magnetic interference unless shielded with expensive 'Mu Metal'
- THD increases with level, especially at LF
- If either leg goes open circuit there will be no audio

SIMPLE BI-PHASE ELECTRONIC

This type consists of one output driving each leg with half of the total output signal level. As these outputs are operated 180 degrees out of phase the full level will be seen between the output legs. If the circuit driving each leg is identical then good impedance balancing will be achieved. Rane amongst some others have used this arrangement.

ADVANTAGES:

- Simple
- Cheap
- Can give good impedance balance if correctly designed
- Gives the *appearance* of good balance because there is the same signal level between each leg and ground

DISADVANTAGES:

- If either leg goes open circuit there will be a 6dB drop in level
- If operated into an unbalanced input there will be a 6dB drop in level and one driving amplifier output will be shorted to ground
- When driving a cable with pin 1 & 3 connected (unfortunately not uncommon), there will be a 6dB drop in level and one driving amplifier output will be shorted to ground

'EBOS' (*E*lectronically *B*alanced *O*utput *S*tage)

Also known as 'electronically floating' and used by BSS and others. It is a deceptively simple circuit, which is quite complex in operation. This is because it relies upon both positive and negative feedback. The intention is, unlike with the 'bi-phase' output described above, to produce the full signal level on one leg when the other is shorted to ground as required when driving an unbalanced input. This was quite important in an era when unbalanced inputs on equipment were more common than they are now. In this respect it behaves just like a transformer. Incidentally, Paul Williams, Linea's R&D director, was instrumental in analyzing and improving this circuit many years ago as R&D manager at BSS audio.

An interesting side effect of this circuit is that if each leg sees the same impedance to ground it will give equal voltages between each leg and ground. It does this ONLY if the impedances to ground on each leg are equal. Indeed to make the circuit work properly it incorporates load resistors to ground on each leg (normally 1k Ohm); this is the only reason why equal levels are measured on a test bench.

Unfortunately this active mechanism has some undesirable side effects. If anything happens that changes the load impedance to ground on one leg, the circuit will modify the signal on the other leg. This is not what a transformer will do and is not desirable.

When operated into a normal balanced input this circuit performs no better than a simpler arrangement, because as we have seen, such an input is only interested in the signal between the legs.

ADVANTAGES:

- Gives the full signal into an unbalanced input.
- Gives the appearance of good balance with the same signal to ground on each leg

DISADVANTAGES:

- Inherently unstable due to positive feedback, this is tamed by tailoring the HF response but makes the performance into unusual loads unpredictable
- Difficult to achieve good balance without manual adjustment
- Susceptible to being put out of balance by varying loads
- Non-optimal output impedance due to dropping resistors which are required to 'measure' the balance. This can be compensated for using negative feedback, but puts a strain on the output amplifier under some load conditions
- The above can cause problems when driving transformers
- Undefined operation when one leg goes open circuit at the end of a long cable because cable capacitance will still provide a load at HF. The circuit will see this capacitance and incorrectly modify the audio on the good leg. Also, cable crosstalk from the good leg to open circuit leg will cause phase and instability issues
- Potential for one-legged problems to be present without them being obvious apart from the audio sounding 'phasey' or just 'wrong'

IMPEDANCE BALANCED

This is the type of output used by Linea Research. It is also used extensively in mixing consoles and is notable for only driving the +leg (XLR pin 2) with audio. When measured on the bench, because of the absence of audio on the –leg (XLR pin 3) this circuit gives the appearance that it is an unbalanced output. In fact it is designed to provide a very good impedance balance, which as we have seen, gives good performance when used with a balanced input.

ADVANTAGES:

- Excellent impedance balance on each leg
- Gives correct level into an unbalanced input without needing special cables or wiring
- Gives correct level when driving a cable with pin 1 & 3 connected (unfortunately not uncommon)
- Cable faults concerning the -leg (XLR pin 3) will not affect the audio level or frequency response
- More tolerant of being incorrectly wired
- Simple

DISADVANTAGES:

- Bench testing gives the impression that it is an unbalanced output
- If the +leg goes open circuit there will be no audio (same as a transformer)