White Paper No. 4
What is a “balanced input”?

Introduction

The word balanced is also used in everyday language and means equilibrated, symmetrical. Therefore, a “balanced input” is a symmetrical signal input.

The standard IEC60268-2 defines the “balanced input“ to be a connection where both inputs have identical input impedances in relation to one common reference point (e.g. ground).

The symmetrical input (interface) is part of an electrical system for line-conducted, interference-resistant transmission of signals from a sender (e.g. generator) to a receiver (e.g. amplifier) over a long distance.

Possible sources of electrical interferences would be e.g. lamps and lighting control devices; magnetic interference sources are transformers, motors or lines carrying alternating current.

These interference sources emit electrical and magnetic waves that may spread within a cable and thus significantly interfere with the useful signal, depending on their intensity.

Moreover, there may be slight differences between reference potentials (e.g. signal ground) of devices that are more remote from one another due to stray current (e.g. mains filters, parasitic capacities in connection boxes) in the protective ground conductor (PE), which may cause interference and what is referred to as ripple voltage. The voltages and currents from the 50 Hz mains supply reveal a wide range of harmonic outputs which may also be a source of interference.

Transmission of a signal from one device to another is not as simple as it may seem at a first glance.

The following real-world examples are intended to clarify the facts and outline the advantages of balanced signal guidance.

Asymmetrical signal guidance

Example 1

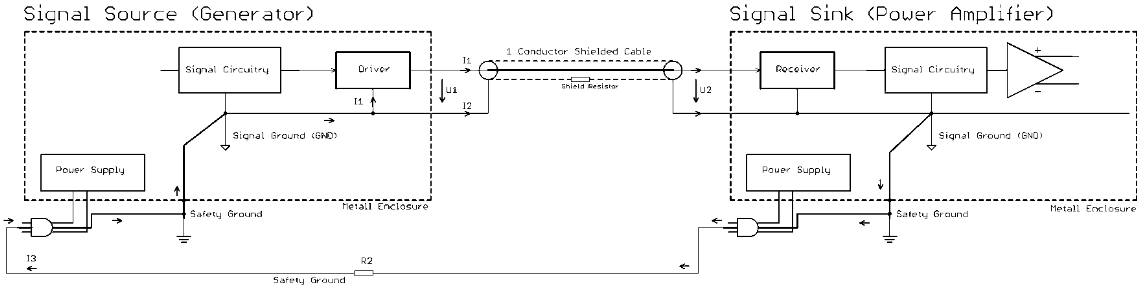

Figure 1: Unbalanced Interconnection

Figure 1 shows an example of an unbalance signal connection of two protection class 1 devices.

The problem: the device grounds are connected via the shield of the signal cable and via the protective ground conductor. Consequently, we obtain what is referred to as ground loop. The current I_2 generates a voltage drop at the resistance of the cable shield and I_3 generates a voltage drop at the resistance of the protective ground conductor. The voltage at the receiver U_2, in relation to its reference point (ground in this case) thus is the sum of signal voltage U_1, the superimposed interference voltage $U_{st} = I_2 * R_{shield} + I_3 * R_2$ and the cable-induced interference voltage. The problem in this scenario is the common conductor (shield) for signal current and induced interference current. The interferences are continued to be processed in the amplifier and thus decrease the quality of its output voltage.

Example 2

Figure 2 illustrates another example. It shows to devices whose reference potential is not connected to the protective ground conductor.

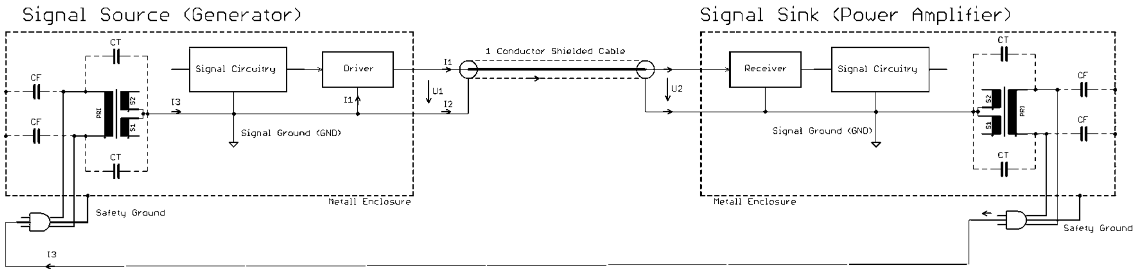

Figure 2: Unbalanced Interconnection

The parasitic capacities C_T in the power supply and in potentially used mains filters C_F close the current circuit for high-frequency stray currents I_3 among the devices.

In this scenario, the signal currents and interference currents are also conducted within the same cable shield. The familiar consequence is: The signal voltage U_2 is superposed by interferences.

Symmetrical signal guidance

For solution of this problem, symmetrical signal guidance is used (has always been used for transmission of telephone calls).

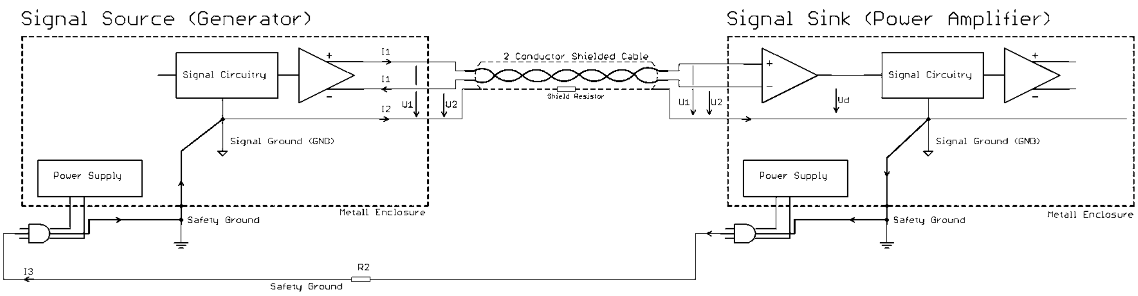

Figure 3: Balanced Interconnection, PE bonded with GND

To this end, the signal is guided through a 2-wire shielded cable. The first wire conducts the useful signal and the second wire conducts the identical signal turned by 180° (also referred to as push-pull operation).

For example (ideal conditions) wire 1 conducts a voltage $U_1 = +0.5$ V and wire 2 the voltage $U_2 = -0.5$ V.

The magnetic waves penetrate the shield and spread in the signal wires, although identical (phase) in both wires, e.g.
$U_{n1} = U_{n2} = 0.1$ V in wire 1 and 2, respectively (common-mode operation).

The sender is equipped with a balanced output and a balanced input is included in the receiver. Behind this is a special amplifier for symmetrical signal guidance, i.e. a differential amplifier. It only amplifies the difference of the signals in the wires.

The consequence for the useful signal is:

$U_d = U_1 - U_2 = (+0.5\ V) - (0.5\ V) = +1\ V$

and for the interference signal:

$U_d = U_{n1} + U_{n2} = (+0.1\ V) - (+0.1\ V) = 0\ V$

Result: The useful signal has doubled its intensity and the interference signal is no longer present.

Another advantage of this signal guidance principle is that interference currents I_2 and I_3 can be kept away from the useful signal I_1 and that the different reference potentials in the respective devices do not interfere with the input voltage U_3.

Pseudo-symmetrical signal guidance

Often, the sources (e.g. industrial function generators) are not equipped with balanced outputs, whereas the receiver is equipped with a symmetrical interface.

Figure 4 illustrates the corresponding set-up.

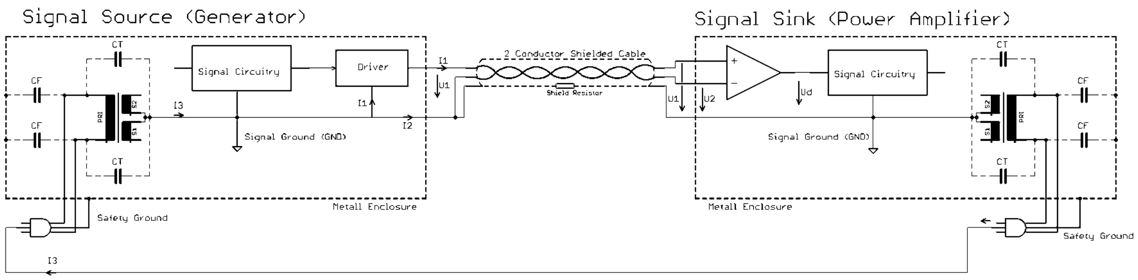

Figure 4: Pseudo Balanced Interconnection

Using the example in section 2, the source supplies U_1= 0.5 V and U_2 = 0 V (signal ground) in this case. The interference induced in the cable is again assumed to be $U_{n1} = U_{n2}$ = 0.1 V.

The output voltage of the differential amplifier in the receiver is:

$$U_d = U_1 - U_2 = (+0.5\ V) - (0\ V) = 0.5\ V$$

and for the interference signal:

$$U_d = U_{n1} + U_{n2} = (+0.1\ V) - (+0.1\ V) = 0\ V$$

In this scenario, the interference voltages have also canceled each other out. However, the results obtained in reality are not as good as those achieved by means of symmetrical signal guidance. The reason for this is the different output impedance values of the sources (line transmitter, ground connection).

An example from a simulation to explain this:

Figure 5 shows the output voltage of the differential amplifier with an input impedance of 1 MOhm in dependence of the source impedances Z_1 and Z_2 with common-mode actuation. With pseudo-symmetrical signal guidance, there is a low ability for common-mode suppression up to 18 dB.

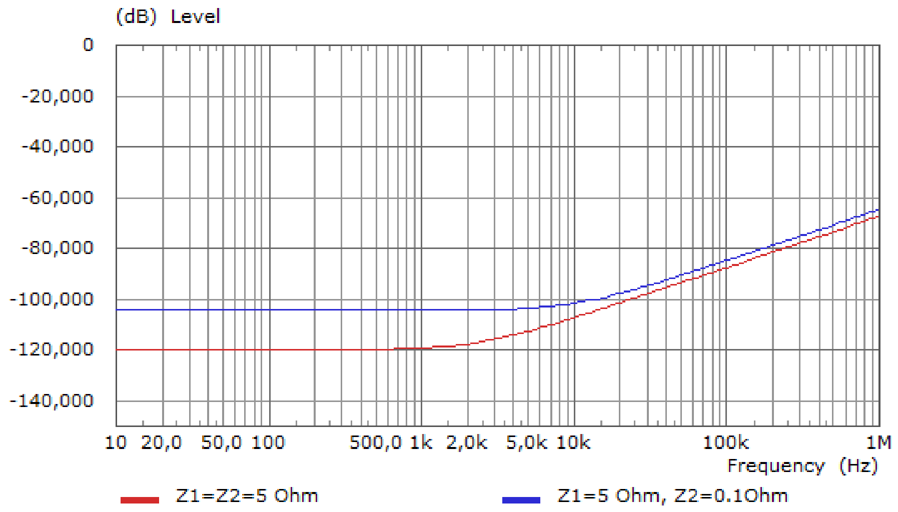

Figure 5: Common Mode Rejection

Balanced input designs

The decisive factor for high quality of balanced signal guidance is for all signal-carrying components to be balanced. The quality of wire 1 and 2 of the cable and the electrical properties (impedances) of the two inputs of the differential amplifier and the two outputs (balanced output) of the senders, respectively, must be equal in all components. A measure for the quality of the balanced input is common-mode suppression (CMR = common-mode rejection).

If galvanic isolation is additionally required, interfaces with transmitters (NF or HF transmission) and optocouplers (DC transmission) are used, e.g. the A1340-C1 isolation amplifier.

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