Lines and Interconnections

Juan P Bello


Transformers (1)

- Laminated core + primary and secondary windings
- If AC is passed through the primary winding a magnetic flux flows in the core
- Flux changes cause a current to be induced in the secondary winding
- Only AC induces the magnetic flux. A transformer does not pass DC signals
Transformers (2)

- The difference in voltage across the windings is proportional to the ratio of turns between the coils.
- Equal power exists in both coils, thus the current is in inverse proportion to the turns ratio.
- The transformer also works in reverse.

\[
\frac{V_P}{V_S} = \frac{I_S}{I_P} = \frac{N_P}{N_S}
\]
Transformers (3)

- Impedances are proportional to the square of the turns ratio
- E.g. the square of the turns ratio below is 1:16, thus the impedance across the secondary = 1k ohm x 16 = 16k ohms

![Diagram of a transformer with a turns ratio of 1:4, showing a 0.5V input and a 1k ohm resistor on the primary side, and a question mark on the secondary side.]

- The used turns ratio need to be suitable for the task at hand, e.g.:
  - Microphones like to work into impedances 5x or more their own impedance,
  - Electronic inputs (e.g. mixers, pre-amplifiers) need to be driven by low impedances.
Transformers (4)

- An audio transformers should be able to work well on the complete audio range.
- In reality, average transformers introduce more distortion at very low and very high frequencies.
- The frequency response falls away at the extremes (BW = 20kHz)
- Transformers are designed to work within a specific voltage and current range.
- When used outside its intended application, the frequency response and distortion of transformers is likely to be affected.
- They are sensitive to electromagnetic fields, thus they should be protected against interference (e.g. radio frequency, mains hum, etc).
- Therefore their placement and encasing are of great importance.
Unbalanced lines (1)

- They consist of a signal send and a return paths
- The return path is an outer screening braid that encloses the send wire to attenuate the effect of electromagnetic interference.
- Over long distances the cumulative effect of interference may be unacceptable.

Unbalanced lines are common to domestic audio equipment and (to a lesser extent) to professional audio equipment
- Common terminations include the phono and 1/4 inch jack plugs.
Unbalanced lines (2)

- Connecting the screening braid to earth at both ends can result in earth loops (if there is a small differential potential between the earths).
- A better unbalanced connection uses a dedicated return wire and the screening braid connected to earth in only one end.

![Diagram showing signal wire, return wire, and screen (connected at one end)]

- The total (loop) resistance of the cable’s send and return paths should be at least 100 times lower than the input impedance of the equipment is feeding (e.g. for 1K, it should be no more than 10 ohms).
- This is a problem for speaker cables with typical resistances of 0.012 ohms/meter (typical speaker input impedance \( \sim 8 \) ohm).
- It is important to use the shortest possible cable length.
Unbalanced lines (3)

- An unbalanced line acts as a capacitor with the screening braid and the inner conductor as conductive plaques.
- The large conductive area creates some capacitance (~0.0002\(\mu\)F/meter for a typical mic cable) which in turns lower the impedance between the conductors allowing some of the signal to be lost through the screen.
- For a given output impedance \(R\), the capacitance \(C\) (in \(\mu\)F) which will cause a 3dB loss at a certain frequency \(f\) can be calculated as: \(C = \frac{159,155}{Rf}\)
- For a microphone with 200 ohm output impedance, that means that up to 100 meters of mic cable can be safely used without high-freq loss.
Cable effects

- The capacitance of a cable increases with the frequency of a signal thus providing a route for signal info to be lost.
- The result is rise-time distortion (a roll-off of sharp edges).
- For long cables, this affects timing and can make the signal unreadable.

Diagram:
- Source Impedance $R_S$
- Input Impedance $R_t$
- Equivalent circuit with $R_S$ and $R_t$ connected in parallel.
- Graph showing signal distortion.
Balanced lines (1)

- Uses balancing transformers (which isolate the two pieces of equipment). The screen is not part of the audio signal.
- Better at rejecting interference, which is induced equally into the send and return paths and cancelled in the secondary transf.
- This is known as common mode rejection (CMR), which does not affect differential mode signals (the original signal flowing at opposite phases through the cable paths)
- Preferred for professional audio connections
Balanced lines (2)

- Connecting between balanced and unbalanced inputs/outputs.
- Common mode rejection is lost but earth loops are still avoided.
Phantom Power

- In condenser mics, the need to provide power to the electronics within the casing is often addressed using phantom power.
- Phantom power is “invisibly” carried over the audio wires (and does not affect non-powered microphones).

- Microphones are designed to draw currents small enough not to cause a large voltage drop. 48 V is the standard, but microphones exist designed to operate at lower voltage values.
XLR connectors

- The most common balanced connectors in professional audio are the XLR-3 connectors.
- The 3 pins carry, respectively: (1) the screen or external - X -; (2) the send or live - L - signal; and (3) the return - R - signal.
Electronic Balancing

- Sometimes audio equipment includes electronic balancing (using differential amplifiers) instead of transformers
- Differential amplifiers pass differential signals and reject common ones
- Electronically and transformed-balanced equipment can be mixed

- Electronic balancing can be cheaper, smaller and less susceptible to electro-magnetic interference
- Transformer balancing has better CMR, true isolation between devices and less complexity of design.
100-volt lines (1)

- The low input impedance of loudspeakers can result in signal loss over long speaker lines (which are often necessary).
- A solution is to use 100-volt lines.

![Diagram of 100-volt line system](image)

- A transformer is used to increase the effective impedance of the speaker (and thus make the cable impedance negligible).
- This increases the primary winding’s voltage (to 100V).
- To produce this voltage, a step-up transformer is used at the output of the amplifier.
100-volt lines (2)

- Different step-up ratios can be used to match the powers of the amplifier and the loudspeaker.

- Speaker line transformers often have a choice of terminals for primary side wattage settings and secondary side impedance settings.

- This means that a number of speakers (each with a dedicated transformer) can be connected along the line.

- If several speakers are connected along a line, one must be careful that the power amplifier is not overloaded.

- 100 volts lines are not appropriate for domestic settings (where they are potentially dangerous), nor for high-quality reproduction (due to the loss of quality related to adding transformers to the speaker line).
DI boxes (1)

- Direct injection (DI) boxes help interface between non-standard unbalanced outputs (e.g. an electric guitar with 10k ohm output impedance) and balance inputs (e.g. a mixer).
- They convert the output to a low-level, low-impedance balanced signal
DI boxes (2)

- The previous DI box is known as passive, as it requires no power supply.

- Passive DI boxes are also cheap and simple.

- They are entirely dependent on the input/output impedances.

- Active DI boxes replace the transformer with an electronic circuit providing constant high/low impedance to the output/input.

- Other features can be included such as switched attenuation and filters.

- Power comes either from batteries or phantom power on the mic line (preferred).
Splitter boxes (1)

- They allow for the output of mics to feed two or more destinations.
- Useful for recording and/or broadcasting live events.
- They isolate the two destinations (mixers) from each other while maintaining a high enough impedance for the microphones and providing phantom power.
Splitter boxes (2)

- The 1:0.7:0.7 turns ratio implies a 3dB voltage loss on each of the secondary windings.

- This is done to maintain high enough input impedance as seen by the microphone.

- The mixer’s impedances are seen by the microphone as two 2k impedances in parallel, resulting on a total impedance of 1k.

- For passive splitter boxes all is needed is a high-quality transformer and input/output sockets.

- Active boxes are available which can eliminate the voltage loss and provide extra gain.
Patchbays (1)

- Patchbays (aka jackfields) facilitate the non-permanent interconnection of equipment using easy-to-set-up configurations.
- They are connected to mixers using multi-core cables, providing easy-access to mic/line inputs, main/group/aux outputs and inserts and returns for all channels.
- Other equipment (multi-track, outboard processors, connections to other parts of the studio complex) can be connected to adjacent patchbays
Patchbays (2)

- Patch cords are around 1 meter in length and terminate in B-gauge jack plugs (with small tip).
- They provide balanced interconnection: tip is live, ring is return and sleeve is earth.
- Patch cord color code: normal (red), phase-reversed (yellow) and earth unconnected at one end (green).
- “Normaling” routes signals automatically between sockets while allowing to tap into or break the signal path by inserting a plug.
- The most common type is half-normaling which allows listening or breaking the path between output and input.
- Full normaling only allows breaking the path.

In a half-normalled patchbay, inserting a plug into the top socket allows the source signal to be heard without breaking the path to the mixer channel; the direct signal path is only broken by inserting a jack into the lower socket.
Useful References

  – Chapter 12: Cables and Interconnections
  – Appendix 1: Understanding basic equipment specification


• Images from:
  • http://commons.wikimedia.org/wiki/User:Omegatron/Gallery
  • http://en.wikipedia.org/wiki/Transformer