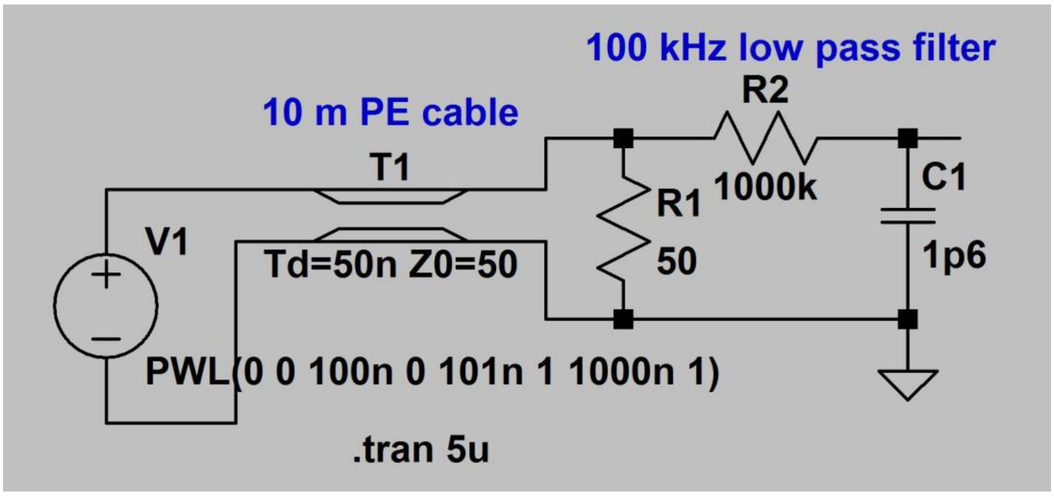
Influence of dynamic loudspeaker impedance on waveform for a given characteristic cable impedance.

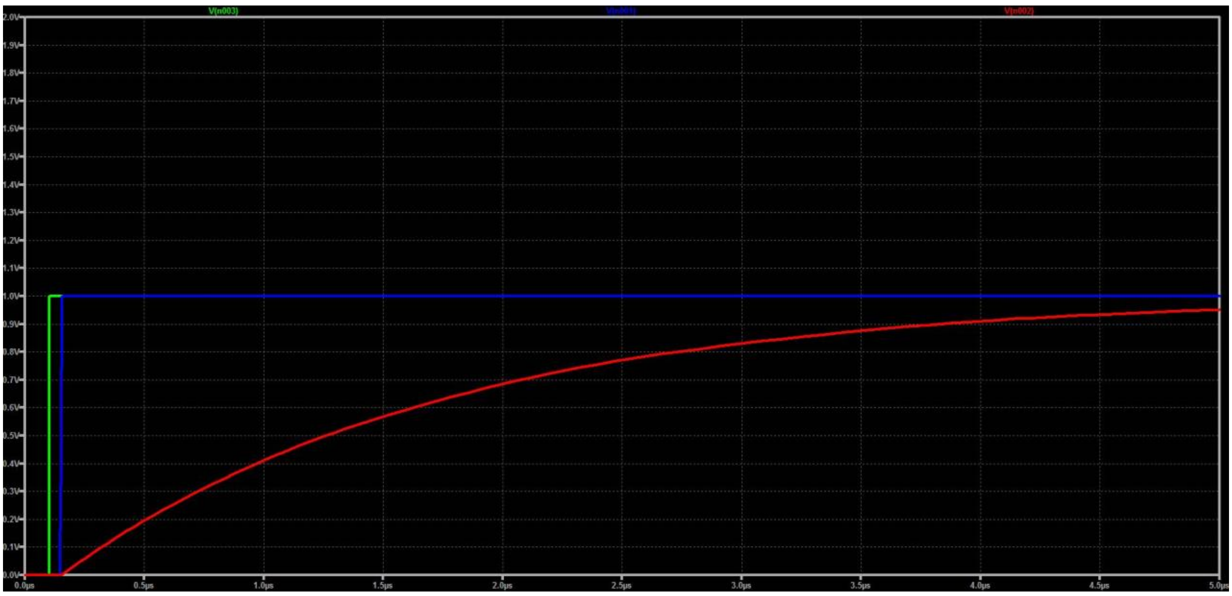
Carsten Kanstrup, August 19th 2020

The following LTSpice simulation was made:



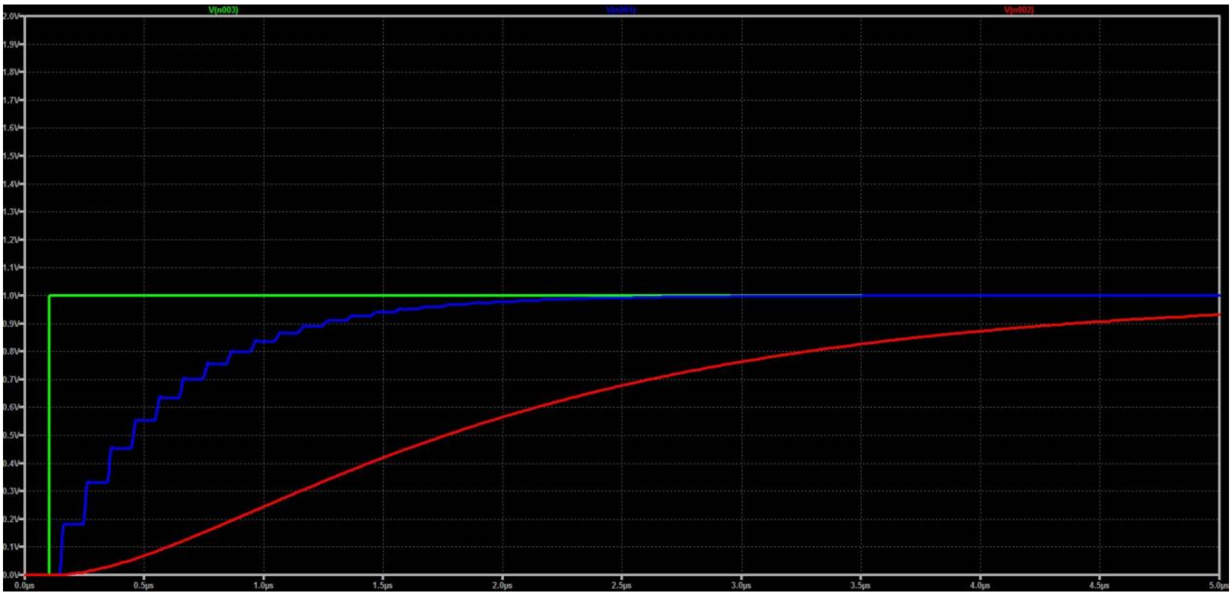
T1 simulates an ideal transmission line without resistance and therefore does not take the skin effect into consideration, but it shows the principle with sufficient accuracy. R1 simulates a pure resistive loudspeaker impedance although it is often more or less reactive i practice. R2 and C1 makes up a 100 kHz low pass filter, which simulates the maximum frequency of the loudspeaker.

If the cable impedance is equal to the loudspeaker impedance = 50 Ω in this case, the signal is only delayed as the blue curve shows (green curve is source signal), but the waveform is (almost) unchanged no matter how long the cable is as shown below:



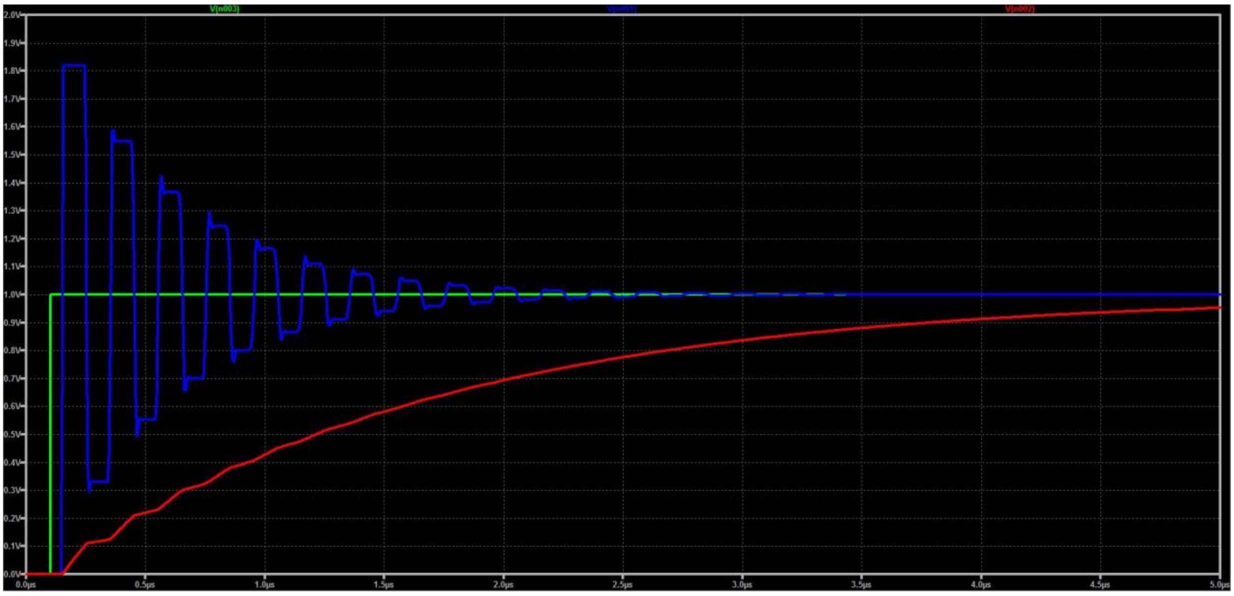
The output signal after low-pass filtering passes 90 % after 3825 ns including the 100 ns delay on the source signal and the 50 ns delay of the cable.

If the loudspeaker impedance is **lower** than the cable impedance – in this case 10 times (5 Ω), several reflections are necessary to build up the signal as shown on the blue curve below:



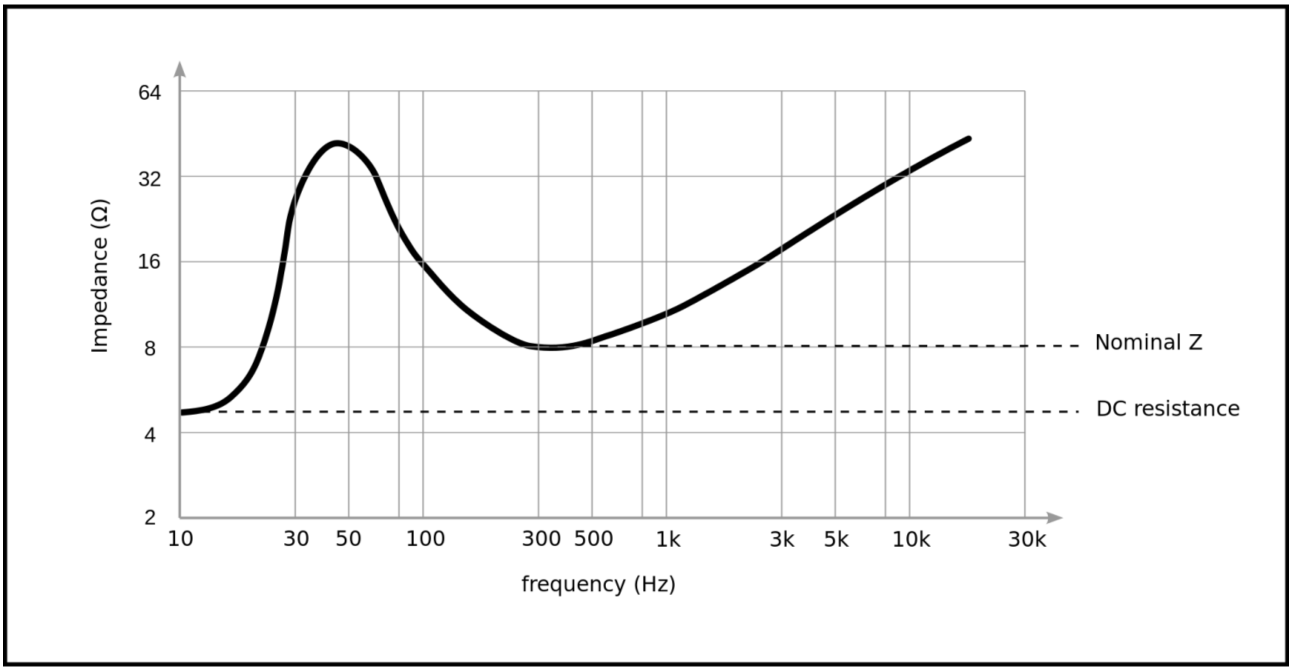
Each step has a length of 100 ns corresponding to two times the propagation delay between the amplifier and the speaker. In this case, the output signal passes 90 % after 4382 ns, which is a delay of **557 ns** compared to the ideal case. **This is likely to be audible!**

If the loudspeaker impedance is **higher** than the cable impedance, a ringing is instead created as shown below for a 10 times higher impedance (500 Ω):



Because the ringing has a very high frequency, it is almost entirely removed by the low pass filtering and in this case, the signal passes 90 % after 3789 ns, which is only a difference of **36 ns** compared to the ideal case!

The conclusion is clear. Since the loudspeaker impedance varies a lot over frequency as shown below and the impedance is also affected by the crossover filter and therefore may be even more complex in practice, the impedance of the cable should be as low as possible since a too low cable impedance has **much** less influence on the signal than a too high impedance. This may be obtained by means of cables, which contains 4 or more wires (2 or more for each conductor), which are intertwined so that the capacitance is increases and the inductance is decreased, which causes a lower characteristic impedance since $Z_0 = \sqrt{L/C}$.



From: https://en.wikipedia.org/wiki/Electrical_characteristics_of_dynamic_loudspeakers#/media/File:Speaker_impedance.svg

A simple and very cheap version of this cable construction is a 4-wire balanced transmission line, which consists of 4 conductors where the two opposite conductors are connected together. This lowers the impedance from approximately 100 Ω for a 2-wire PE insulated cable to approximately 50 Ω, but more conductors can of course lower the impedance even further and create better results. This cable type also has the advantage that the capacitance to other cables is the same no matter how the cable is rotated. If the cable is balanced driven, as it is often the case for DC-coupled loudspeakers, or floating, there will therefore be no mutual coupling to other cables nearby.

Note that a non-polarized insulation material like PE, PEX, polyolefin or Teflon should be used. PVC is **not** recommended due to losses and very high permittivity!

It is also possible to buy extremely expensive high-speed cables with very low propagation delay (3.7 ns/m instead of 5 ns/m for a PE-cable), but this only makes each step shorter, which has **much** less effect.