ARTA - APPLICATION NOTE

No 1: The ARTA MeasuringBox – ver. 2

Easy setup of loudspeaker impedance and frequency response measurements with ARTA-MeasuringBox

This application note describes MeasuringBox – ver2, which is slightly different from Measuring Box – ver. 1. Later, we will describe differences.
This box is for soundcards that do not have microphone preamplifier, or have low quality mono microphone preamplifier, but have high quality line inputs and line outputs.

Typical, low cost measurement equipment for loudspeaker measurements with ARTA, STEPS and LIMP should consist of:

1) High quality soundcard that has stereo line inputs and stereo line outputs.
2) Calibrated microphone (i.e. Behringer ECM 8000 or Audix TM1),
3) Microphone preamplifier with calibrated gain control (i.e. Monacor MP102),
4) Power amplifier with volume control and output power 10-50W,
5) A switch box and cables for easy connections of audio devices.

Figure 1 shows a simple switch box - the ARTA MeasuringBox. It is intended for loudspeaker impedance and frequency response measurements.

Figure 1. Front view of the MeasuringBox.

On the front side of the MeasuringBox there are:

- RCA jack (chinch) for connection of a microphone preamplifier,
- Binding posts are for loudspeaker connection,
- Switch SW1 (Impedance - Response) is for switching between impedance measurements and frequency response measurements,
- Switch SW2 (Measurement - Cal/Off) is for switching between measurement or impedance calibration. The SW2 position for calibration also switch off output to

loudspeaker. After calibration the switch SW2 should be returned to position *measurement*.

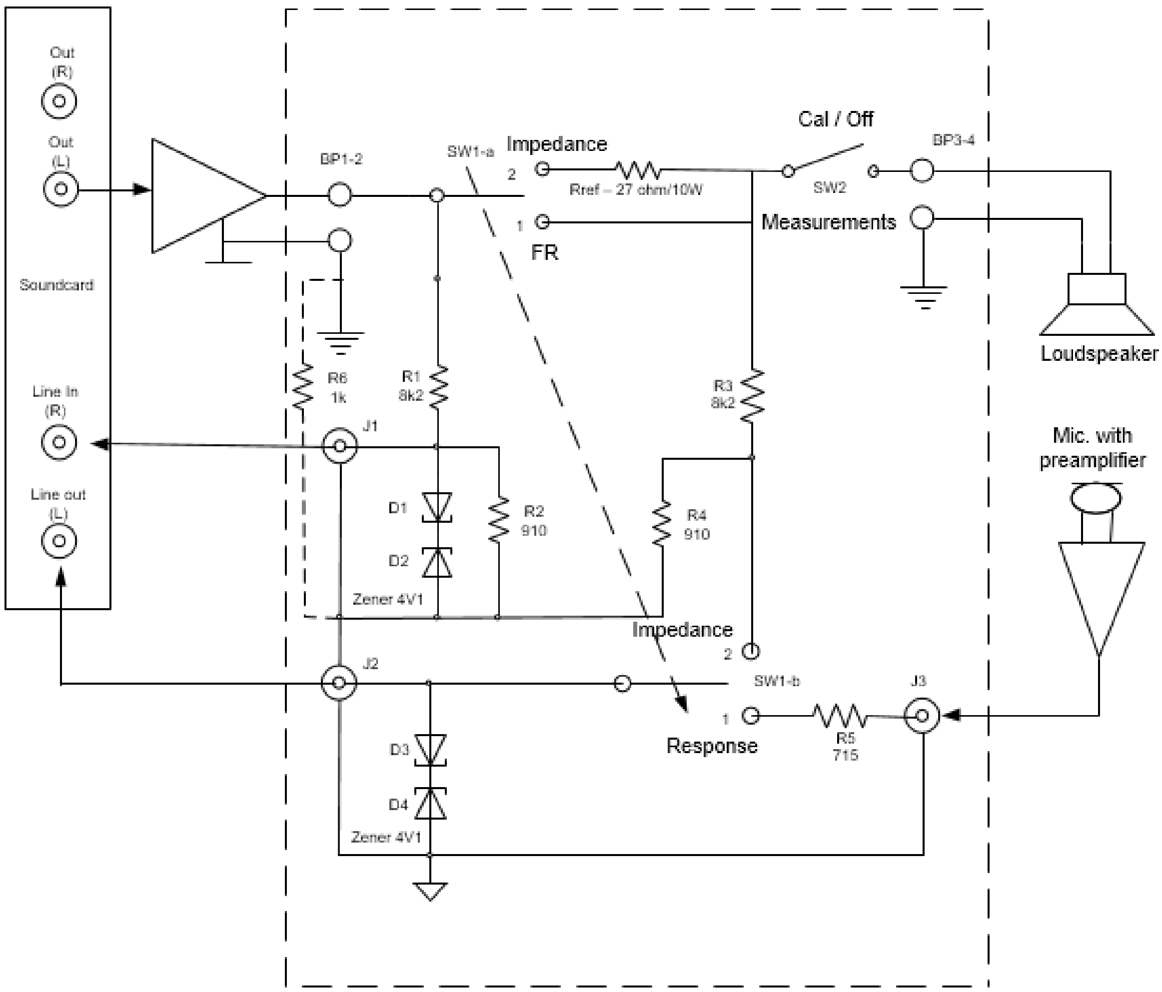
On the back side of the MeasuringBox there are two RCA jacks for connection to the soundcard left and right line input channels, and binding posts to power amplifier output. The red post is signal line and the black post is a ground line.

Figure 2. Back view of the MeasuringBox.

Figure 3 shows a schematic diagram of the ARTA-MeasuringBox. Table 1 shows the parts list of the ARTA-MeasuringBox. Figure 4 shows a connection plan of the ARTA-MeasuringBox.

Element	**Value**
Box	Plastic "Euro box"
Rref	Reference resistor 27 ohm/10W
R1, R3	8k2 (all resistors are 1%)
R2, R4	910
R5	715
R6	1k
D1, D2, D3, D4	Zener diode 4.1V / 0.5W
J1	RCA jack - red.
J2, J3	RCA jack - black
BP1-2, BP3-4	Dual binding posts (red and black)
SW1	DPDT 6A switch
SW2	SPDT switch

Table 1. Electronic elements used in ARTA-MeasuringBox



Note 1 Power amplifier / loudspeaker ground and output low-level grounds are separated by a 1kOhm resistance.

Note 2 Do not use bridged amplifiers with virtual ground!

Safety The soundcard input is protected by Zener diodes. The power amplifier is protected as described in the manufacturer's manual. It means that you have to take care on the nominal loudspeaker impedance.

Figure 3. The schematic diagram of the ARTA-MeasuringBox

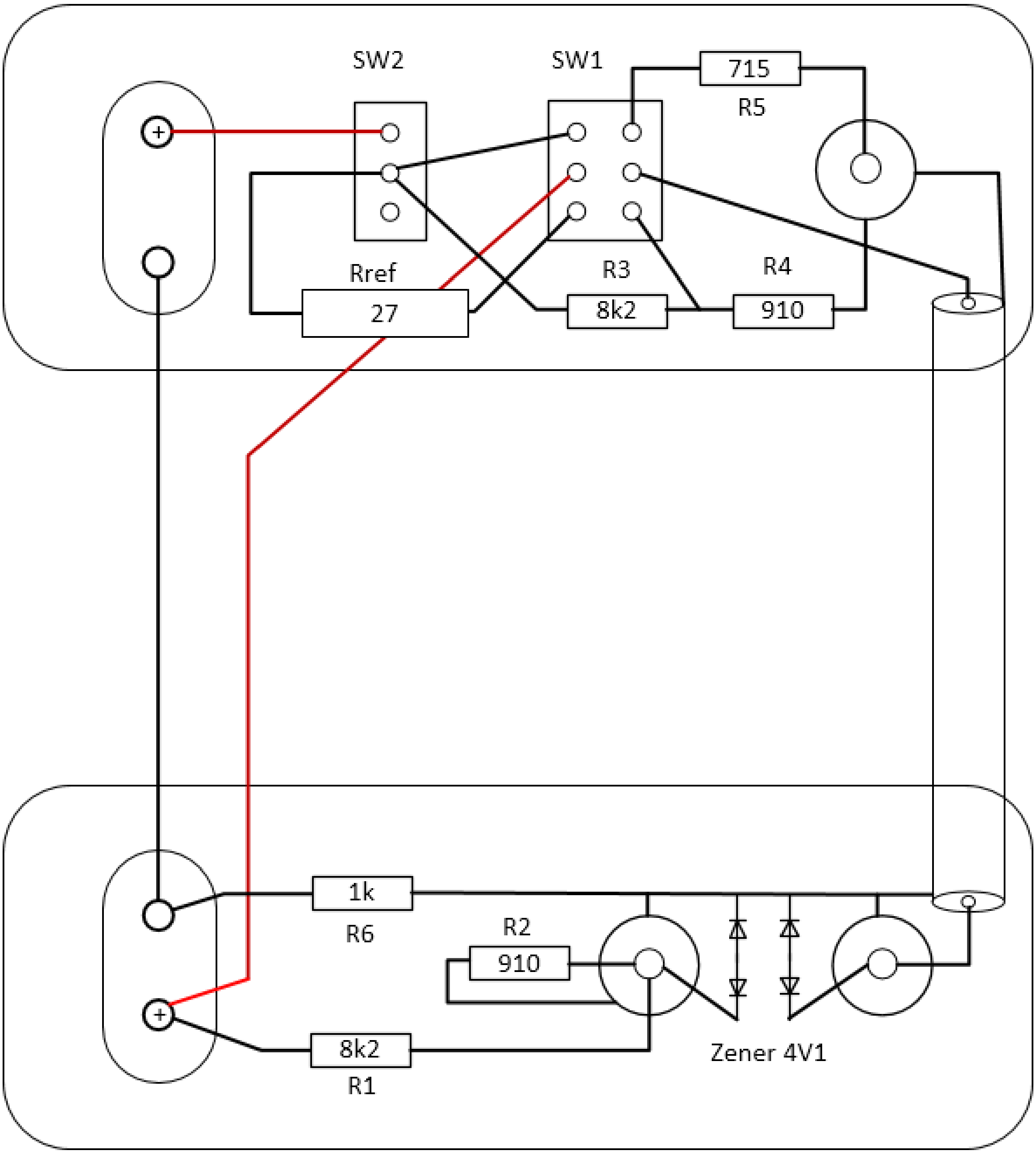


Figure 4. Connection plan for ARTA-Measuring box

A little math for designers or what is necessary to adopt box elements for special needs.

In the default configuration the box has the following operational characteristics. Resistors R1, R2 together with soundcard input impedance Zin, form voltage divider *r* that is equal to

$$r = (R2 \parallel Zin) / (R1 + R2 \parallel Zin)$$

Maximal voltage that can be applied from power amplifier to soundcard line input reference channel is equal to the *soundcard_sensitivity* / *r*. Line input sensitivity is equal to maximum peak voltage that soundcard can record – [ARTA ver. 1.9.2 manual – chapter 1.5]. Then, maximal power *Pmax* that can be used in measurement with MeasuringBox is equal to

$$P_{max} = (sensitivity / r)^2 / (2 * nominal\_loudspeaker\_impedance)$$

Table 2. gives maximal power as function of soundcard line input sensitivity, that can be used with MeasuringBox, for usual values of impedances: Z = 10k, R1= 8k2, R2 =910. If we use larger power than specified, soundcard inputs will be overloaded.

Input Sensitivity (Vpeak-max)	Amplifier output voltage	*Pmax / 8Ω*	*Pmax* / 4 Ω
1 V	7.66 Vrms	7.33 W	14.66 W
1.5V	10.83 Vrms	14.66 W	29.32 W
2 V	15.32 Vrms	29.32 W	58.64 W

Table 2. Power *Pmax* as a function of sensitivity (for Z = 10k, R1= 8k2, R2 =910)

If we have a power amplifier that is not able to deliver this power the voltage divider can be lowered accordingly, alternatively if we want to make testing with higher power we must increase voltage divider.

Note: In loudspeaker system design we rarely need high power for testing frequency response, especially when measuring impedance for loudspeaker parameters testing we need very small power. It is recommended by standard AES2-2012 to use sine voltage about 0.1V. If using multitone or pink PN, rms voltage should be about 0.2V.

Generally, recommendation is to use power amplifier with power less than 20W. If your power amplifier has larger power, excite it with maximum soundcard output level and set its input gain control in position that will give power (or voltage) smaller than values given in Table 2.

The value of resistor R5 has to be determined from the following expression:

$$R5 = R1 \parallel R2 - Zout$$

where Zout is microphone amplifier output impedance.

This equation came from the requirement that both soundcard input channels are driven from generators that have same source impedances. In this configuration we assume Zout=100 ohm (i.e. a value for MP102 preamplifier).

Using the ARTA-MeasuringBox in Calibrated Measurements

For **measurement of impedance** with program LIMP you, must put calibration switch in position 'Cal / Off' and follow usual calibration procedure that is necessary for each impedance measurement. After calibration is done you must put calibration switch in position '*Measurement*'.

In **Dual channel frequency response measurement mode,** in ARTA and STEPS program, we must enter proper values for left and right preamplifier or probe gain. In this mode impedance calibration switch is not used. We assume that right soundcard channel is used as reference channel and left soundcard input channel is used as response channel.

For right preamplifier you must enter voltage probe divider

$$r = (R2 \,||\, Zin) / (R1 + R2 \,||\, Zin) = (910 \,||\, 10000) / (820 + (910 \,||\, 10000)) = 0.0923$$

For left preamplifier you must enter

$$l = mic\_preamp\_gain * Zin / (Zout + R5 + Zin)$$

I.e. for *mic_preamp_gain* = 100 (40dB), Zout =100, R5 = 715, Zin = 10000, we set:

$$l = 100 * 10000 / 10815 = 92.46$$

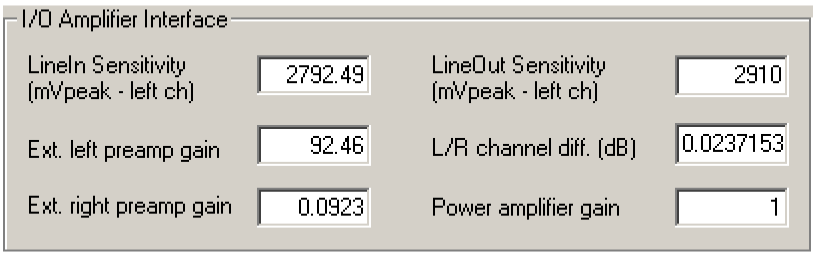


Figure 5. Audio devices setup for ARTA and STEPS program

If we are in single channel mode of ARTA, and want calibrated results, we must enter proper value of Power amplifier gain also.

The easiest way to measure the power amplifier gain is in the two-channel mode Fr2. The procedure is as follows:

1) First connect the left channel input to the soundcard output and the right channel input on voltage divider output that is connected on power amplifier output.
2) Enter the value of the voltage divider *r* in the '**Ext. right preamp gain**' edit box.
3) Set ARTA signal generator to periodic noise (PN pink or PN white) with Multisine generator output volume slightly lowered to -10dB (just to protect soundcard).

4) Start measurement in the $\boxed{\text{Fr2}}$ mode and read the value of the FR magnitude level at 1000Hz.
5) The measured level is equal to the power amplifier gain in dB. To get the absolute value of the power amplifier gain use the following formula:

$$\textit{Power amplifier gain} = 10^{(\text{FR magnitude level at 1kHz}) / 20}$$

Calibration of power amplifier gain is necessary for ARTA single channel FR measurements.

Note: In all measurements we didn't connected soundcard input and output ground. That is way; we get the calibrated system without any ground loop problem.

To conclude:
The MeasuringBox enables an easy control of impedance and frequency response measurements. It assures high safety for a soundcard and other connected devices.

Difference from previous version of MeasuringBox

The role and wiring of switch SW2 make difference from old MeasuringBox. Now switch SW2 serves to disconnect measuring impedance, while in old measuring box it switched connection of both input channels to single point, to allow calibration and compensation of different channel sensitivities. New approach allows additional compensation of current that flow through input channel impedance. That way impedance measurement range is enlarged at least ten times. Please read LIMP user manual (ver 1.9.2 or higher) for description of calibration process.

Users of old MeasuringBox can use new calibration process under two conditions:
1) Switch SW2 should always be in position Measurement (not Cal)
2) During calibration the measured impedance must be disconnected.

Solution for measurement system that uses high quality professional audio soundcard with build in microphone preamplifier.

Professional audio soundcards from most manufactures: RME, M_AUDIO, ROLAND, TASCAM, FOCUSRITE, MOTU, Creative EMU, etc. have similar characteristics:

- dedicated balanced inputs with preamplifiers for phantom powered (48V) microphones,
- unbalanced line or high-impedance instrumentation inputs (usually use TS jack which is build inside XLR balanced connector (named XLR combo jack),
- balanced/unbalanced line outputs with analog volume control,
- headphone stereo outputs, with volume control, that can safely drive impedances with magnitude larger than 40 ohms.
- they are mainly made as external unit with separate power supply and with PC are connected using USB, Firewire or dedicated PCI interface.

For these soundcards, high quality measurements are possible with separate cabling for impedance measurements and separate cabling for frequency response measurements.

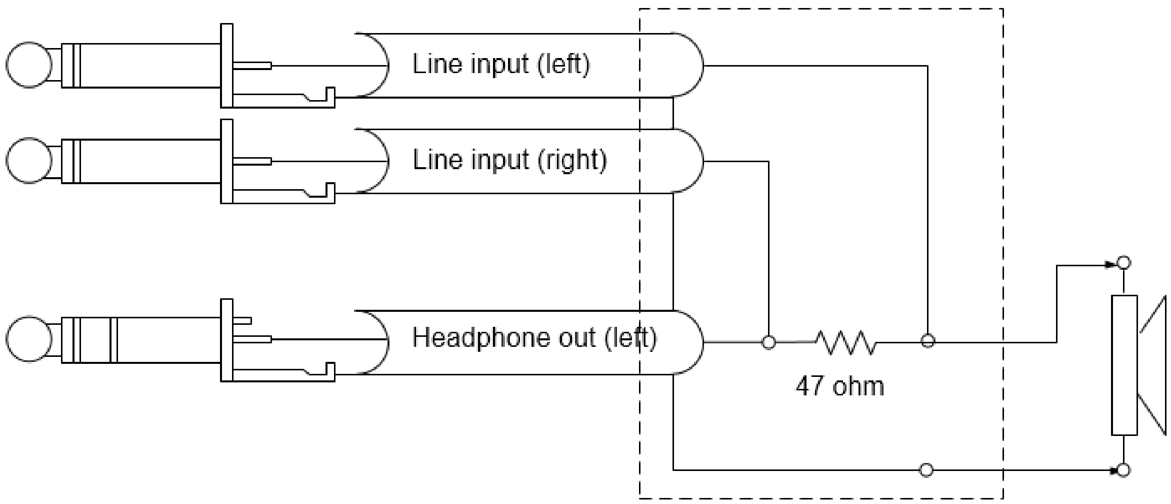


Figure 6. Cabling for impedance measurement using headphone output

Fig. 6 shows cabling for impedance measurement, using stereo TRS jack for headphone output and two unbalanced TS jacks for line (or instrumentation) inputs. Fig. 7 shows cabling for two channel frequency response measurements. Fig. 8 shows cabling for semi 2-channel setup, which is useful for measurement active crossover response. This configuration requires that left and right output channels generate same level and zero phase difference. We check that condition by measuring loopback frequency response in FR2 mode. If this condition is not then we have to make connection from left output to right input.

Bad side of these cabling is that we need to exchange setup if switching from impedance to frequency response measurement (with soundcards that have only two input and two output channels). There are professional soundcards that has several input and output channels (4, 6, 8). In that case, both type of cabling can be permanently used on separate channels and switched using ASIO interface in Audio device setup.

The quality of measurement with this setup can be better than with ARTA-MeasuringBox, especially when measuring of impedance there are no need for voltage dividers, and dynamic range is larger (usual divider reduce input level 20dB).

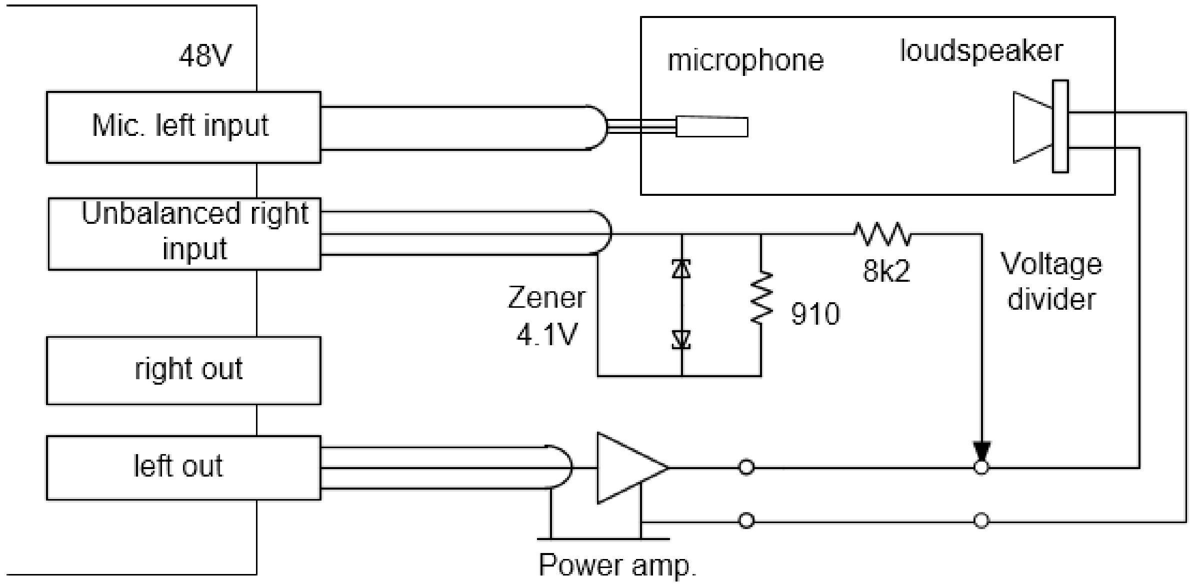


Figure 7. Cabling for two channel frequency response measurements

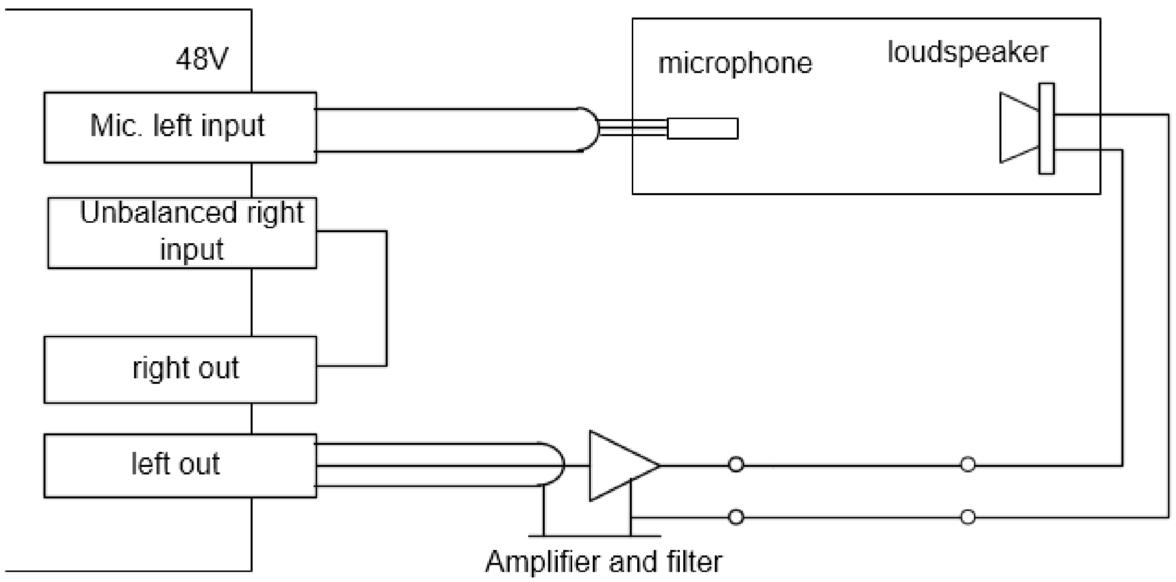


Figure 8. Cabling for crossover response measurements using semi two-channel setup (power amplifier passband gain must be entered in ARTA device setup)