



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0

**The ARTA MeasuringBox offers accurate and repeatable measurements of loudspeaker impedance and frequency response.**

This Application Note describes the ARTA MeasuringBox version 2.0, which is slightly different from ARTA MeasuringBox version 1. Later in this Application Note, we will describe the differences between the two versions.

This interface box is for soundcards that do not have a microphone preamplifier, or that may have a low-quality mono microphone preamplifier but high quality line inputs and line outputs.

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

- 1) High quality soundcard that has stereo line inputs and outputs.
- 2) Calibrated microphone (i.e. Behringer ECM 8000 or Audix TM1),
- 3) Microphone preamplifier with calibrated gain control (i.e. Monacor MPA-102).
- 4) Power amplifier with volume control and output power between 10-50 W,
- 5) A switch box and cables for easy connections of audio devices.

Figure 1 shows a simple interface 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 for connection of a microphone preamplifier,
- 5-way binding posts for connection to the loudspeaker.
- Switch SW1 (Impedance - Response) is for switching between impedance measurements and frequency response measurements,



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0

- Switch SW2 (Measurement – Cal / Off) is for switching between measurement or impedance calibration. The SW2 position for calibration also disconnects the output to the loudspeaker. After calibration, SW2 should be returned to the Measurement position.

On the back side of the MeasuringBox are two RCA jacks for connection to the soundcard left and right line input channels and a 5-way binding post for connection to the power amplifier output. The red binding post is signal + and the black binding post is -- ground line.



**Figure 2.** Back view of the MeasuringBox.

Figure 3 shows the schematic diagram of the ARTA-MeasuringBox version 2.0. Table 1 shows the parts list of the ARTA-MeasuringBox components. Figure 4 shows a connection plan of the ARTA-MeasuringBox.

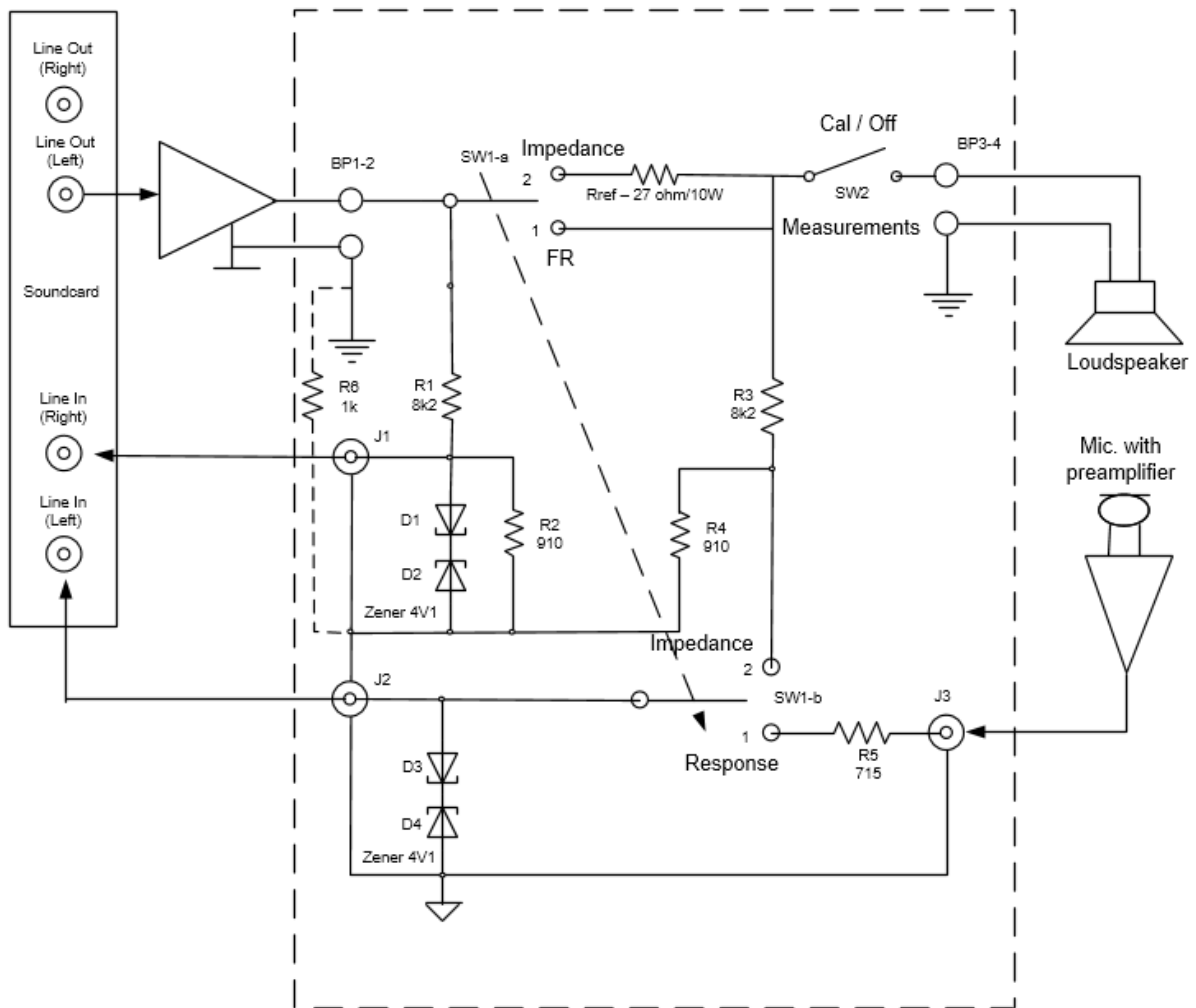
Element	Value
Box	Plastic "Euro box"
Rref	Reference resistor 27 ohm/10W
R1, R3	8k2 (all resistors are 1% ¼ or ½ w)
R2, R4	910
R5	715
R6	1k
D1, D2, D3, D4	Zener diode 4.1V / 0.5W
J1	RCA jack - red.
J2, J3	RCA jack - black
BP1-2, BP3-4	Dual 5-way binding posts (red and black)
SW1	DPDT 6A switch
SW2	SPDT switch

**Table 1.** Components used in ARTA MeasuringBox version 2.0



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0



**Note 1** Power amplifier / loudspeaker ground and output low-level grounds are isolated by a 1 k $\Omega$  resistance.

**Note 2** Do not use bridged amplifiers with virtual ground!

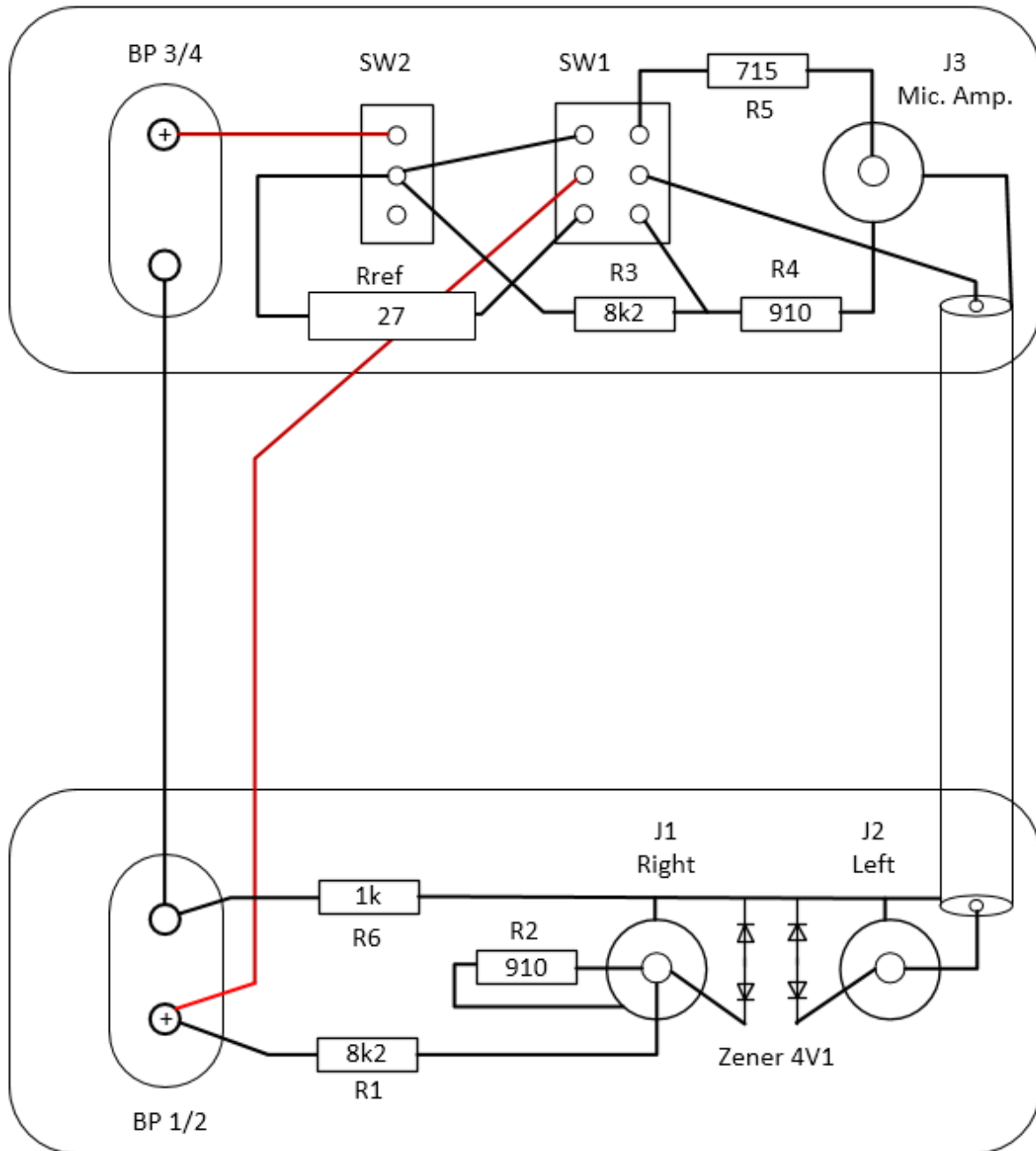
**Safety** The soundcard input is protected by Zener diodes. The power amplifier is protected as described in the respective manufacturer's owner's manual. It means that you have to ensure the amplifier load impedance exceeds to the minimum specification.

**Figure 3.** Schematic diagram of the ARTA MeasuringBox version 2.0



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0



**Figure 4.** Point-to-point connection plan for ARTA-MeasuringBox version 2.0



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0

### A little math for designers or how to adopt ARTA MeasuringBox component values for special requirements.

In the default configuration, the ARTA MeasuringBox has the following characteristics: Resistors R1 and R2 together with the soundcard input impedance  $Z_{in}$ , form a voltage divider  $r$  that is equal to:  $(R2 \parallel Z_{in}) / (R1 + (R2 \parallel Z_{in}))$ . Two lines  $\parallel$  denotes parallel connection.

**Refresher:** To compute the total resistance of two *different* value resistors  $R_A$  and  $R_B$  in parallel, use the following formula:  $R_{TOTAL} = (R_A R_B) / (R_A + R_B)$   
For two parallel resistors of *equal* value, the total resistance is simply 1/2 the value of either resistor.

Solving for  $r$ :  $(R2 \parallel Z_{in}) / (R1 + (R2 \parallel Z_{in})) = (910 \parallel 10k) / (8k2 + (910 \parallel 10k)) = \mathbf{0.0923}$

To prevent overloading your soundcard or external audio device, it is important to know the maximum voltage that can be applied (from the power amplifier) to its line input reference channel (usually the right channel). This voltage is equal to the *soundcard sensitivity* /  $r$ .

The line input sensitivity is equal to the maximum peak voltage that the soundcard can record – [See ARTA version 1.9.2 manual – chapter 1.5]. Therefore, the maximum power,  $P_{max}$  that can be used in measurement with MeasuringBox is equal to:

$$P_{max} = (\text{sensitivity } (V_{pk}) / r)^2 / (2 * \text{nominal loudspeaker impedance})$$

Example: Using the value of 0.0923 for  $r$  (from the solution above) and a  $V_{peak}$  input sensitivity of 1.0 volts;  $P_{max} = (1.0/0.0923)^2 / (2 * 8) = 7.33 \text{ W}$ .

Table 2. lists the maximum power that can be used with the MeasuringBox as a function of the soundcard line input sensitivity and nominal values of loudspeaker impedances. If we use a higher power than specified, the soundcard inputs may be overloaded.

Soundcard Input Sensitivity ( $V_{peak-max}$ )	Maximum Amplifier Output RMS Voltage	$P_{max} / 8 \Omega$	$P_{max} / 4 \Omega$
1 V	7.66 V	7.33 W	14.66 W
1.5V	11.49 V	16.51 W	33.02 W
2 V	15.32 V	29.33 W	58.64 W

**Table 2.** Power  $P_{max}$  as a function of sensitivity (for  $Z = 10 \text{ k}\Omega$ ,  $R1 = 8.2 \text{ k}\Omega$ ,  $R2 = 910 \Omega$ )

If we have a power amplifier that is not able to deliver this power output, the voltage divider resistor values can be altered accordingly. Alternatively, if we want to test with higher power, we must increase the voltage divider attenuation.

**Note:** In loudspeaker system design we rarely need to use high power for testing the frequency response or especially when measuring the impedance for TS loudspeaker



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0

parameters testing. In fact, the AES2-2012 Standard recommends the use of a sine wave voltage of about 0.1V. If using multitone or pink PN, rms voltage should be about 0.2V.

Generally, the recommendation is to use a power amplifier of less than 20 watts. If your power amplifier has a higher output power, drive it with the maximum soundcard output level and set its input gain control so that the output power (or voltage) will be lower than the values given in Table 2.

The value of series resistor R5 can be solved using the following expression:

$R5 = (R1 \parallel R2) - Z_{out}$  where  $Z_{out}$  is the microphone preamplifier output impedance.

Example: Let  $Z_{out} = 100 \Omega$ ;  $R1 = 8k2 \Omega$ ;  $R2 = 910 \Omega$

$$R5 = (R1 \parallel R2) - 100 = \frac{8200 * 910}{8200 + 910} - 100 = \frac{7.462^6}{9.11^3} - 100 = 819 \Omega - 100 \Omega = \mathbf{719 \Omega}$$

This expression arose from the requirement that both soundcard input channels are to be driven from generators that have the same source impedance. In this configuration we assume  $Z_{out} = 100 \text{ ohm}$  (i.e. a value for the MPA-102 preamplifier).

### Using the ARTA MeasuringBox in Calibrated Measurements

For the measurement of impedance with LIMP, follow the calibration procedure in the LIMP User Manual Section 4.7 *Calibrated Measurements*. With the ARTA MeasuringBox version 2.0, you must first put the calibration switch SW2 in the 'Cal / Off' position and follow the calibration procedure that is necessary for each impedance measurement. After calibration is completed, you must return the calibration switch SW2 to 'Measurement'.

Using the **Dual channel frequency response measurement mode** in ARTA and STEPS, we must enter the proper values for left and right preamplifier or probe gain. In this mode, SW2 switch is not used. We assume that the right soundcard channel is used as the reference channel and the left soundcard input channel is used as the response channel.

In ARTA or STEPS, click on **Setup->Audio devices** and using Figure 5., enter the appropriate data.

For the **Ext. right preamp gain**, enter the voltage probe divider value. Using  $Z_{in}$  of  $10 \text{ k}\Omega$  as an example;  $right = (R2 \parallel Z_{in}) / (R1 + (R2 \parallel Z_{in})) = (910 \parallel 10000) / (820 + (910 \parallel 10000)) = \mathbf{0.0923}$ . In decibel notation, that's  $20 * \log 0.0923 = -20.696 \text{ dB}$ .

To calculate the effective **Ext. left preamp gain**, use the formula:  $(\text{Mic preamp gain}) * Z_{in} / (Z_{out} + R5 + Z_{in})$ . e.g. for a mic preamp gain of 100 (40 dB),  $Z_{in} = 10,000 \Omega$ ,  $Z_{out} = 100 \Omega$ ,  $R5 = 715 \Omega$ ,  $left = (100 * 10,000) / 10,815 = \mathbf{92.46}$  or 39.32 dB



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0

I/O Amplifier Interface			
LineIn Sensitivity (mV/peak - left ch)	2792.49	LineOut Sensitivity (mV/peak - left ch)	2910
Ext. left preamp gain	92.46	L/R channel diff. (dB)	0.0237153
Ext. right preamp gain	0.0923	Power amplifier gain	1

**Figure 5.** Audio devices setup for ARTA and STEPS program

The MeasuringBox is constructed for a two-channel measurements of frequency response and impedance, but if we want to measure frequency response in a single channel mode (FR1), with calibrated results, we must enter the proper value in the edit box '**Power amplifier gain**'.

The easiest way to measure the power amplifier gain is to switch in two-channel mode FR2, with connected and calibrated MeasuringBox. Then follow the next seven steps:

- 1) Set switch SW1 to **Response** and switch SW2 to **Off**.
- 2) With additional cable connect soundcard **Line Out (Right)** to **Mic Amp jack** and in the edit box '**Ext. left preamp gain**' enter value 1.
- 3) In the edit box '**Ext. right preamp gain**' enter the value of the voltage divider. This way ARTA measures the proper value of the amplifier output voltage.
- 4) In ARTA open the FR2 Window and set Toolbar combo box **Inp** to **Right/L**. For ARTA software versions older than 1.9.2 in the **Measurement setup** dialog box set the combo box **Preferred input channel** to **Right**.
- 5) Set ARTA signal generator to periodic noise (PN pink or PN white) with generator output volume slightly lowered to -10dB (just to protect soundcard).
- 6) Start measurement in the **Fr2** mode, with smoothing set to 1/6 octave, and read the value of the FR magnitude level at, or near, frequency 1000 Hz.
- 7) 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:

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

### To conclude:

MeasuringBox version 2.0 enables the ARTA, STEPS & LIMP user simple control of complex impedance and frequency response measurements while ensuring safety for the soundcard and other connected devices.

### Difference from previous version of MeasuringBox

The role and wiring of switch SW2 is different than in the original ARTA MeasuringBox. Switch SW2 now serves to disconnect the unknown impedance, while in the old measuring box it switched the connections of both input channels to a single point, to allow calibration and compensation of different channel sensitivities. The current MeasuringBox allows for the additional compensation of current that flow through the input channel impedance. As a result, the impedance measurement range is multiplied at least ten times. Please read LIMP User Manual (version 1.9.2 or higher) for a description of the latest calibration procedures.



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0

Users of the old MeasuringBox can use the new calibration process under two conditions:

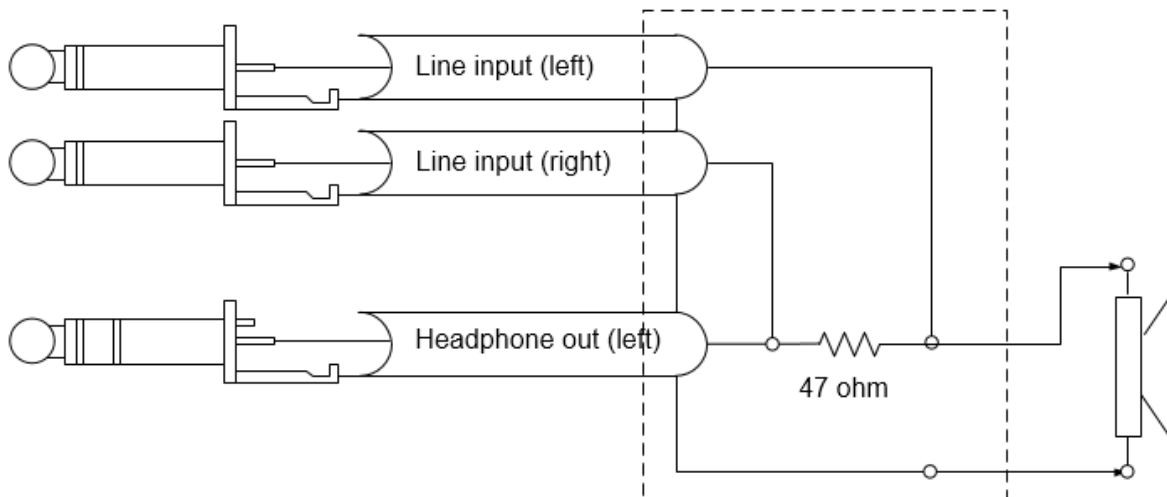
- 1) Switch SW2 should always remain in the Measurement position (not Cal).
- 2) During calibration the measured impedance must be disconnected.

### Solution for a measurement system that uses a high quality professional audio soundcard with built-in microphone preamplifier.

Professional audio soundcards from most manufacturers: RME, M-AUDIO, ROLAND, TASCAM, FOCUSRITE, MOTU, Creative EMU, etc. have similar characteristics:

- dedicated balanced inputs with preamplifiers for phantom powered (24/48V) microphones,
- unbalanced line or high-impedance instrumentation inputs (usually using a combo XLR/1/4" TRS stereo jack.
- balanced/unbalanced line outputs with analog or virtual volume control.
- headphone stereo outputs, with volume control, that can safely drive impedances with magnitude larger than 40 ohms.
- these units have either a separate power supply or are powered by a PC via USB.

For these soundcards, high-quality measurements are possible with separate low loss 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.





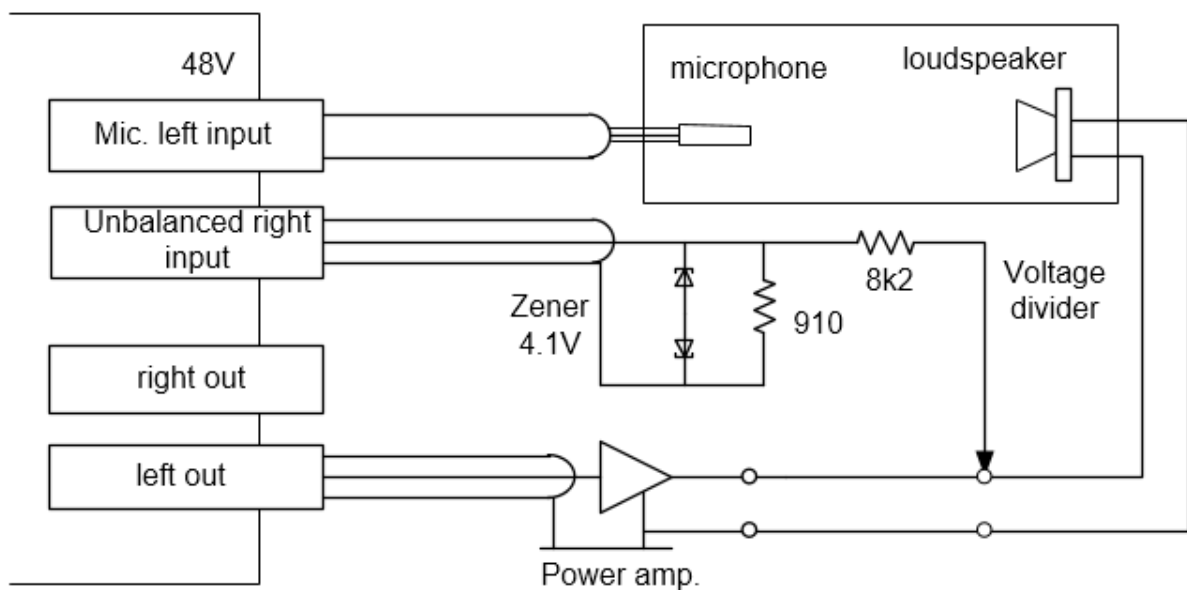
# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0

Fig. 8 shows cabling for semi 2-channel setup, which is useful for active crossover response measurement. This configuration requires that left and right output channels generate the same level with zero phase difference. We can verify that condition by measuring the loopback frequency response in FR2 mode. If the above two conditions are not met, then we have to make connection from left output to right input.

Unless the professional soundcard or standalone device has multiple input/output channels, the user will have to swap cables depending on whether impedance or frequency response is being measured. If the professional soundcard or standalone device has several input and output channels (4, 6, 8), both type of cabling can be permanently used on separate channels and switched using the ASIO interface in **Audio Devices Setup**.

The quality of measurement with this setup can be better than with ARTA MeasuringBox, especially when measuring impedance as there is no need for voltage dividers, and the dynamic range is larger (usually the divider reduces input level 20 dB or more).

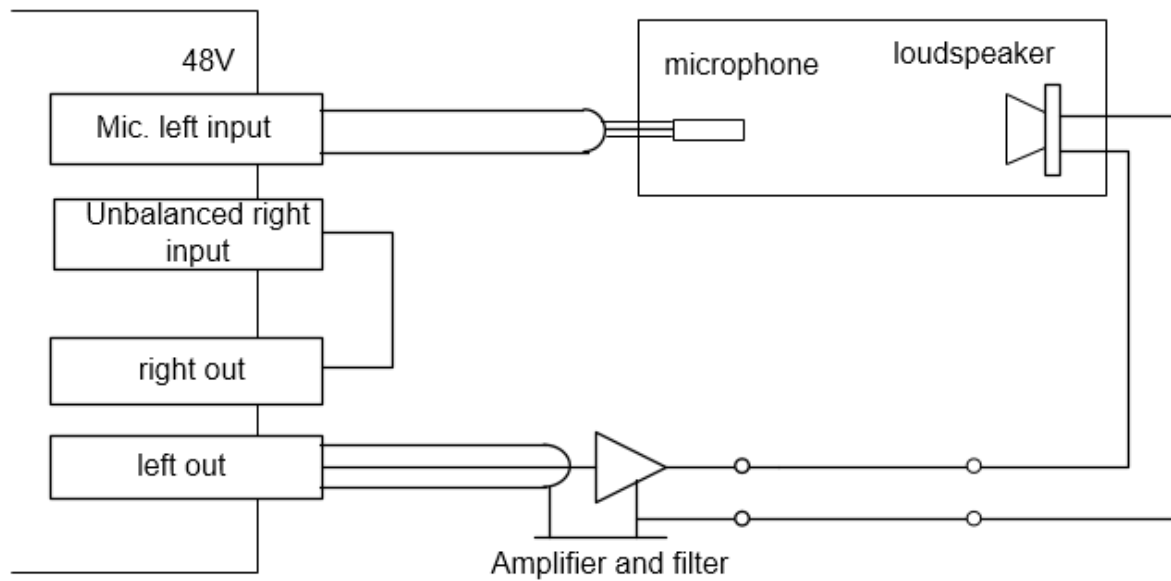


**Figure 7.** Cabling for two channel frequency response measurements



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0



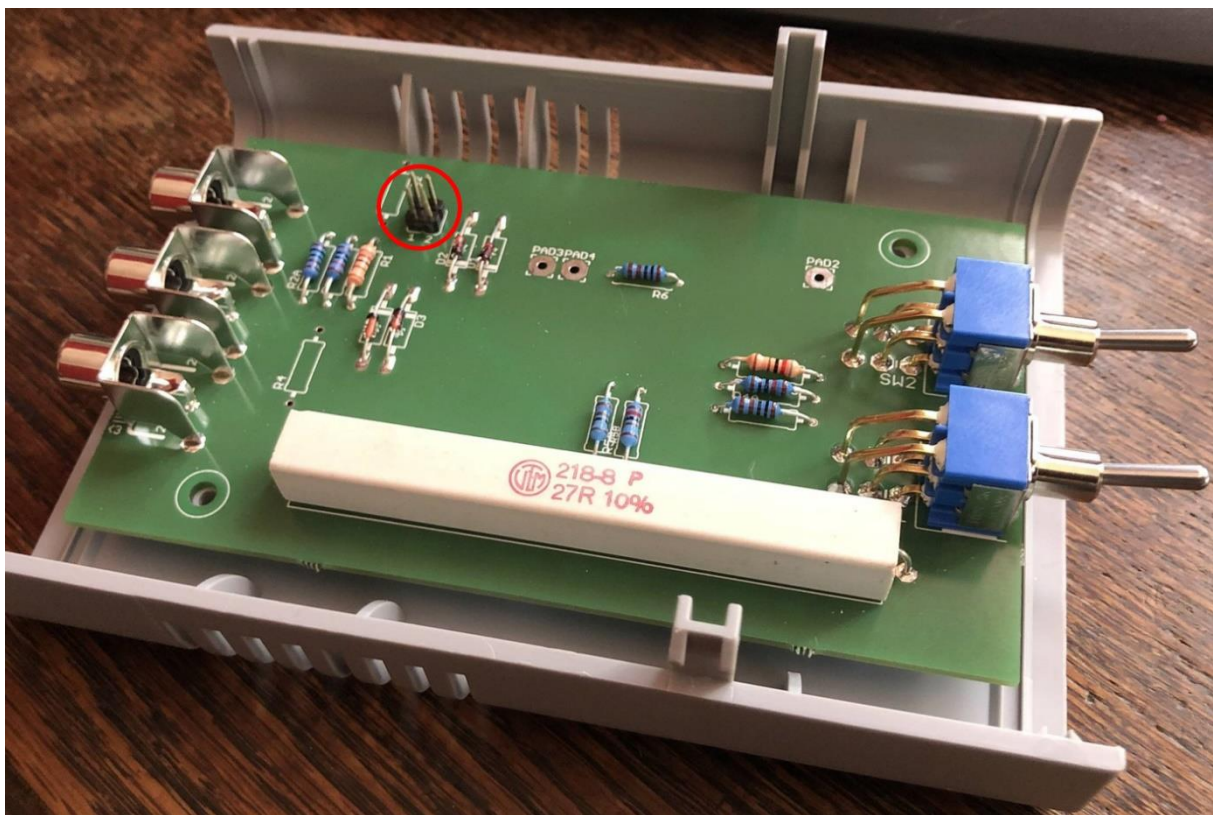
**Figure 8.** Cabling for crossover response measurements using semi two-channel setup (power amplifier passband gain must be entered in ARTA device setup)



### Appendix - ARTA MeasuringBox with a PCB

If one is able to produce simple single sided PCB's the following solution of Ralf Grafe & Heinrich Weber for the ARTA-MeasuringBox may be interesting.

The layout of the PCB as well as other necessary information one can find on Web site <https://www.m1n1.de/shop/>



**Figure 9.** ARTA-MeasuringBox, PCB Solution, top view

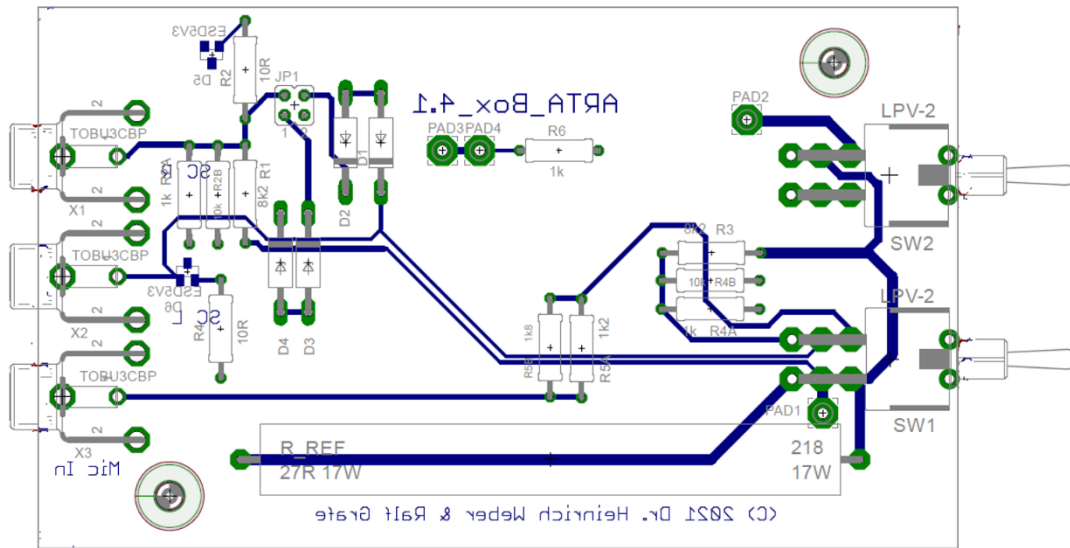
Fig. 9 shows the component side of the assembled MeasuringBox. As one can see, except the loudspeaker connectors all parts are placed directly on the PCB. Because  $R5 = 715 \text{ ohm}$  and  $R4 = 910 \text{ ohm}$  are not common E24 values the PCB is made to take alternatively two resistors in parallel.

Two jumpers are added to schematic. If they are not closed, protective Zener diodes are decoupled from the circuit.



# ARTA - APPLICATION NOTE

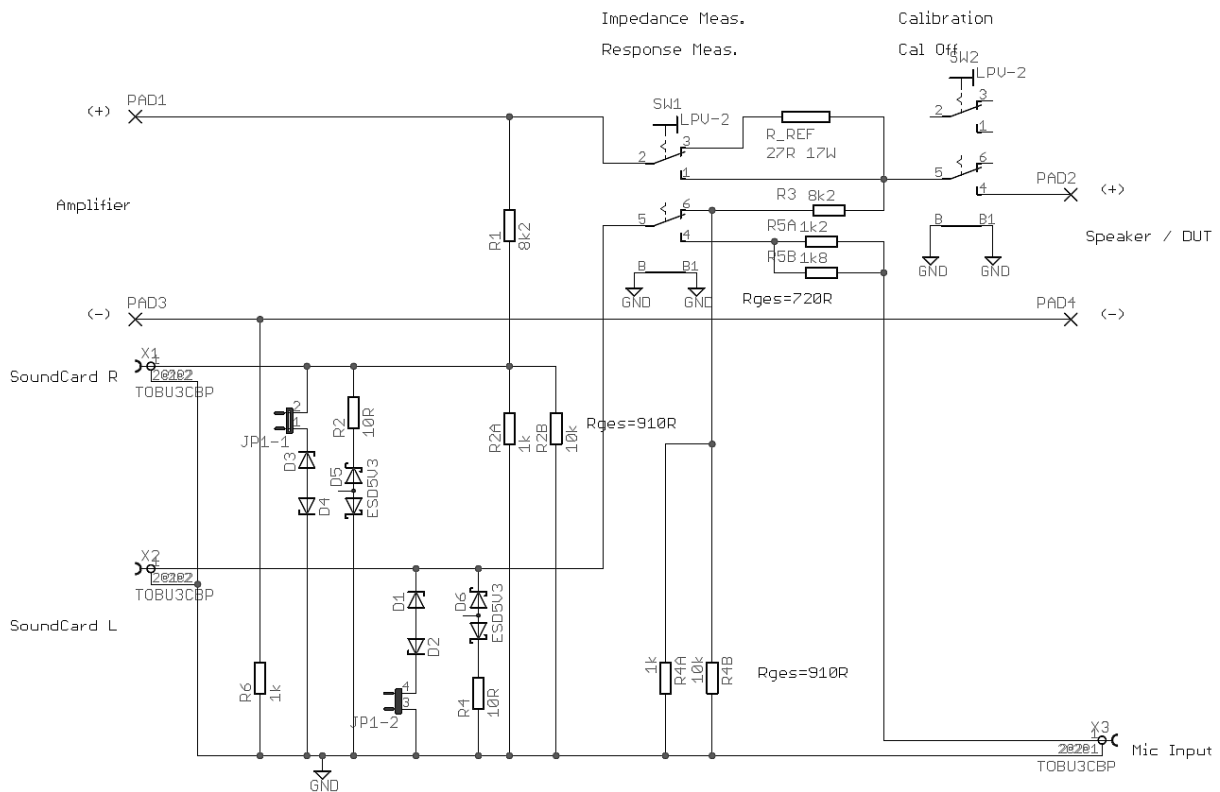
## No 1: The ARTA MeasuringBox version 2.0



**Figure 10.** Component side of the PCB for the ARTA-MeasuringBox

The location and the value of the components from Fig. 10, are shown in the schematic (Fig. 11) and the Parts list (Table 3).

Fig. 13 shows the layout for the labeling of the MeasuringBox.



**Figure 11.** Schematic for the PCB Solution of the ARTA-MeasuringBox



# ARTA - APPLICATION NOTE

No 1: The ARTA MeasuringBox version 2.0



Figure 12. The ready made ARTA-MeasuringBox

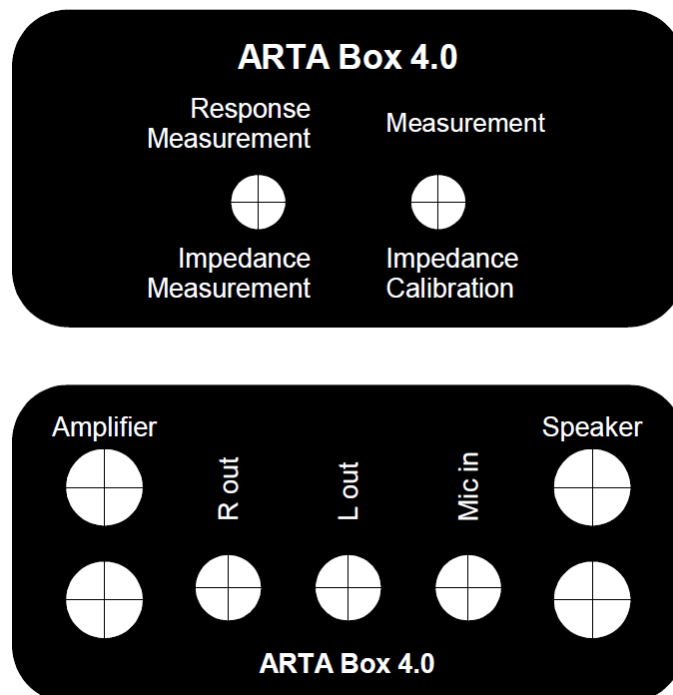


Figure 13. Layout for labelling of the ARTA-MeasuringBox



# ARTA - APPLICATION NOTE

## No 1: The ARTA MeasuringBox version 2.0

Element	Value
PCB	PCB 70x120mm
Box	Eurobox
SW1, SW2	Switch (Reichelt MS 500FVT)
PAD3, PAD4	Terminal, black
PAD1, PAD2	Terminal, red
X1, X2, X3	RCA jack for printed circuit mount
R Ref	Reference resistor 27 ohm/10W
R1, R3	Resistor 8k2
R2a, R6, R4a	Resistor 1k
R2b, R4b	Resistor 10k
R5b	Resistor 1k8
D1-D4	Zener diode 4,3V / 0.5W

**Table 3.** Parts list for the ARTA MeasuringBox – PCB version

Ralf Grafe & Heinrich Weber

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