ARTA - APPLICATION NOTE

No 1: The ARTA MeasuringBox

The ARTA MeasuringBox for easy setup of loudspeaker impedance and frequency response measurements.

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

1) High quality soundcard or USB audio device (i.e. Terratec EWX 24/96 or M-Audio USB Transit),
2) Calibrated microphone (i.e. Behringer ECM 8000 or MBC 550),
3) Microphone preamplifier with calibrated gain control (i.e. Monacor MP102),
4) Power amplifier (any audio 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 for connection of a microphone preamplifier,
- Binding posts are for loudspeaker connection,
- Switch SW1 is for switching between impedance measurements and frequency response measurements,
- Switch SW2 is for impedance measurement calibration. Position *Imp Cal*. is for calibration using *Limp*. After calibration the switch SW2 has to be returned to position *measurement*.

On the back side of the MeasuringBox there are two RCA jacks for connection to 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 3 shows the picture of connections inside the ARTA MeasuringBox.

Figure 2. Back view of the MeasuringBox.

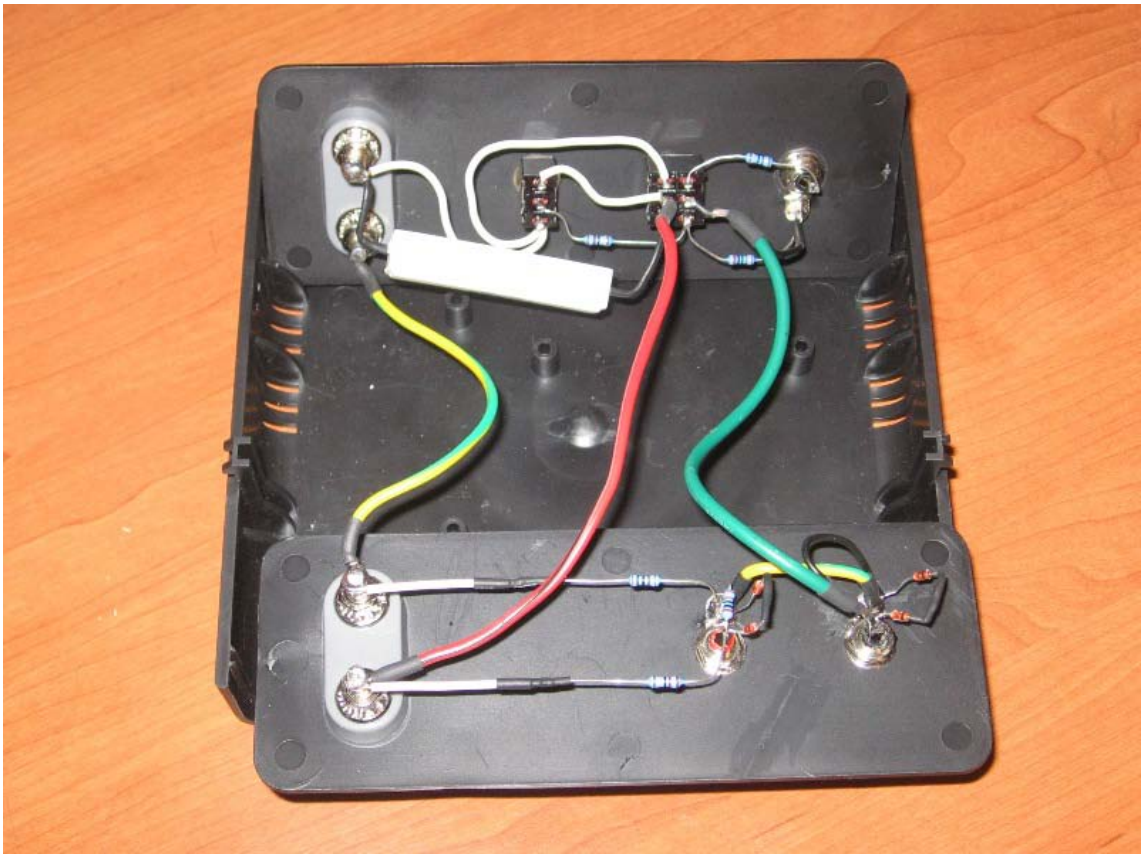
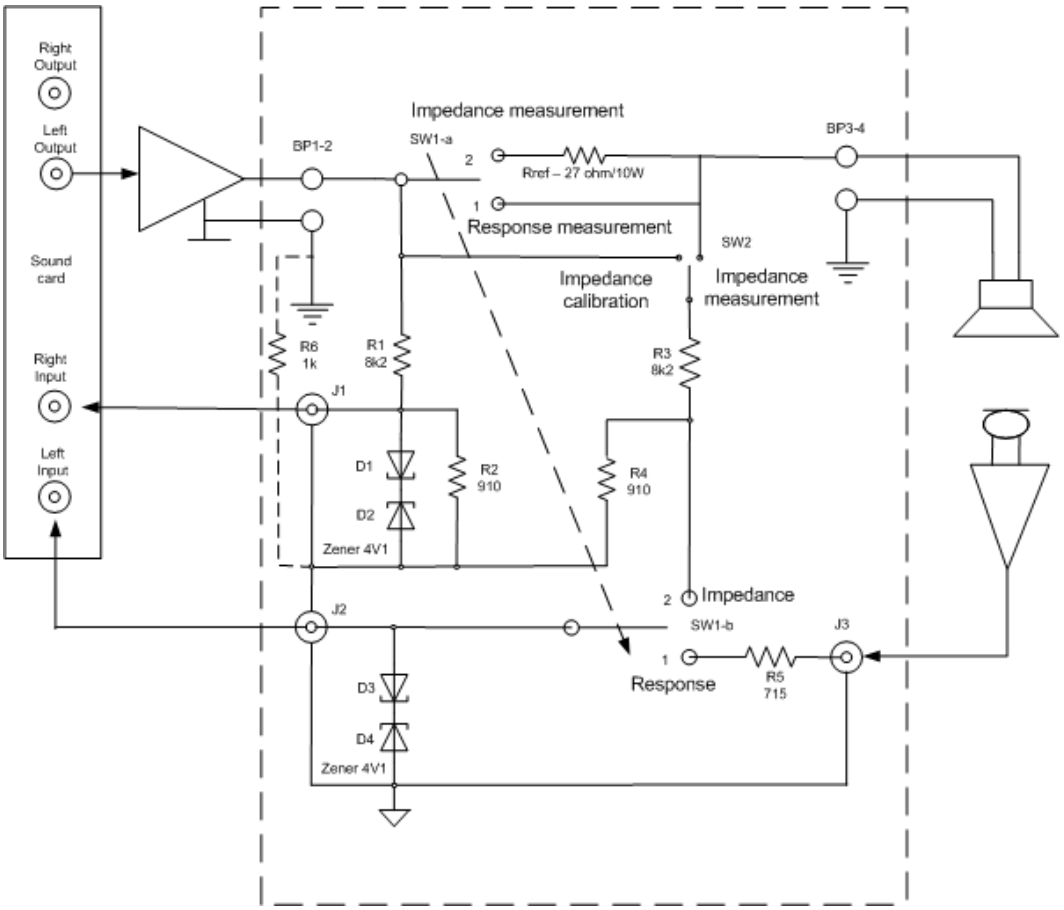


Figure 3. The picture of connections inside the MeasuringBox

Figure 4 shows a schematic diagram of the ARTA MeasuringBox. Table 1 shows the parts list of the ARTA MeasuringBox. Figure 5 shows a connection plan of the 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 4. The schematic diagram of the 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. Elements of the MeasuringBox

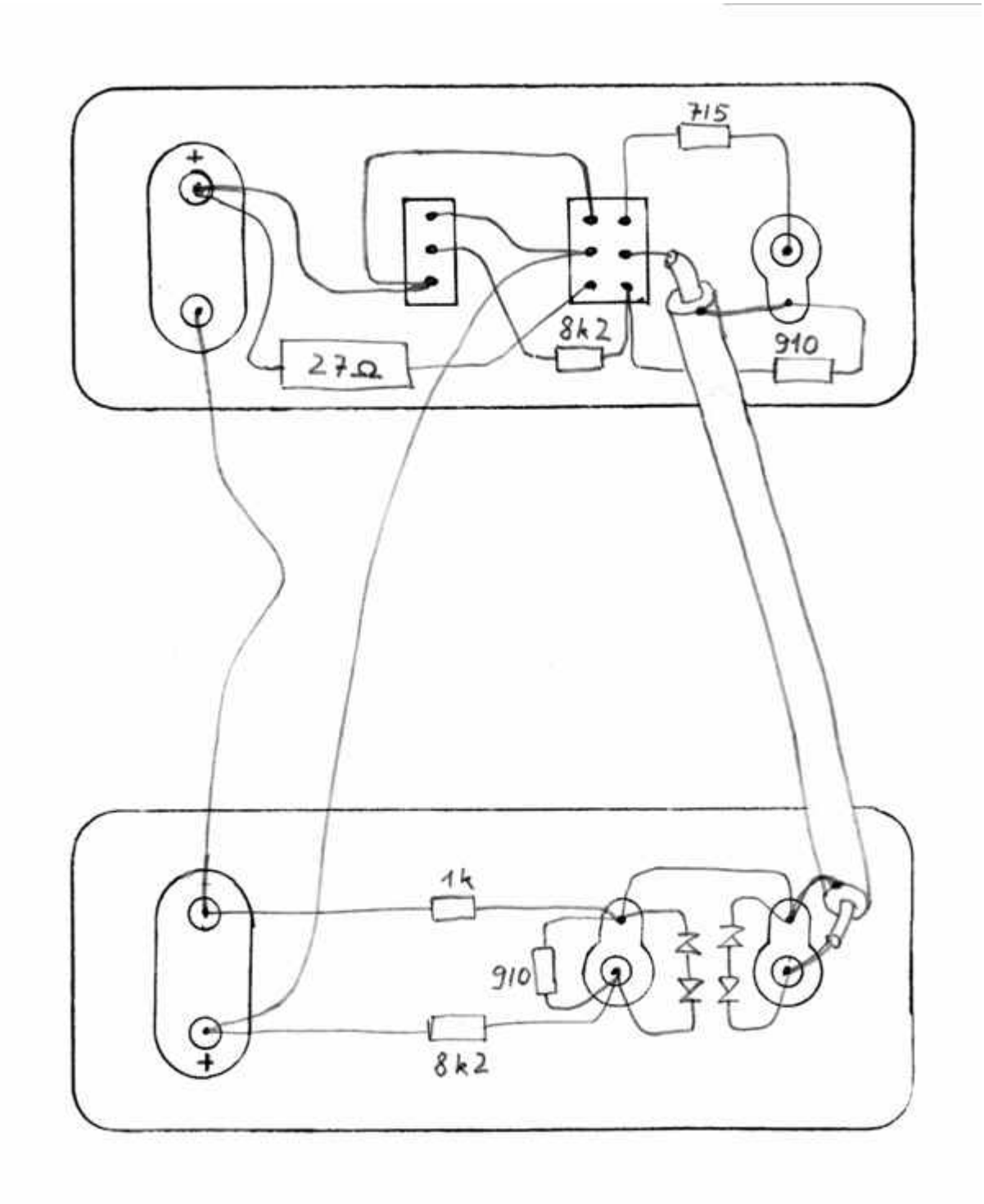


Figure 5. Connection plan for Measuring box

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_voltage_rms_sensitivity* / *k*. Then, *maximal_power* that can be used in measurement is equal to

$$maximal\_power = (voltage\_rms\_sensitivity / k)^2 / nominal\_loudspeaker\_impedance$$

For usual values Z = 10k, R1= 8k2, R2 =910 and voltage sensitivity 1V we get that maximal power is equal to 29W/4ohm or 14.5W/8ohm.

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

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, have to put calibration switch in position 'Imp Cal' and follow usual calibration procedure that is necessary for each impedance measurement. After calibration is done you must put calibration switch in position for 'Impedance measurement'.

In **Dual channel frequency response measurement mode,** in ARTA and STEPS program, we have to enter proper values for left and right preamplifier (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 have to enter voltage probe divider

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

For left preamplifier you have to 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:

$l = 100 * 10000 / 10815 = 92.46$

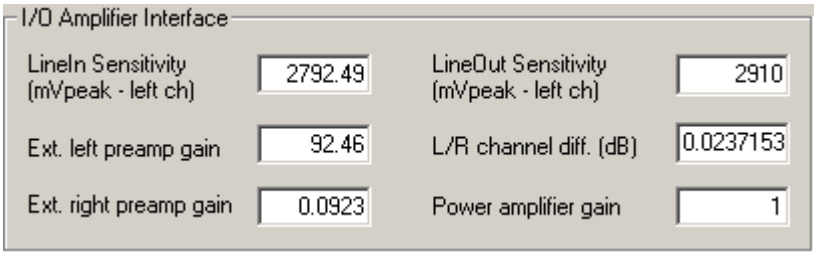


Figure 6. Audio devices setup for ARTA and STEPS program

If we are in single channel mode of ARTA, and want calibrated results, we have to 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 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:

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

Calibration of power amplifier gain is necessary for ARTA single channel FR measurements. 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 and fully calibrated measurements of impedance and frequency response. It assures high safety for a soundcard and other connected devices. There can be other way for the realization of switch box in cases when soundcard has embedded a high quality microphone amplifier (i.e. TASCAM USB-122) or when soundcard has phone output that can drive relatively low impedance. Such cases will be described in other application notes.

Note for owners of prerelease versions of ARTA and STEPS:
There is bug in prerelease version of ARTA and STEPS: setup calibration file (*.cal) confounds left and right preamplifier gain values on loading. To circumvent this you have to enter the calibration value for preamplifier gain on every loading of calibration file.

ARTA MeasuringBox - a PCB Solution

If one is able to produce simple single sided PCB's the following solution of the ARTA-MeasuringBox maybe interesting.

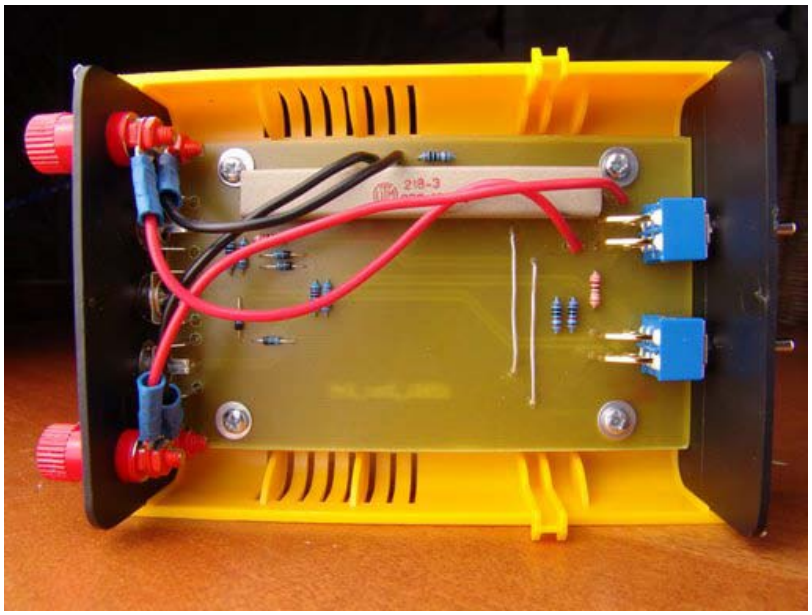


Figure 7. ARTA-MeasuringBox, PCB Solution, top view

Fig. 7 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 ohm and R4 = 910 ohm are not common E24 values the PCB is made to take alternatively two resistors in parallel.

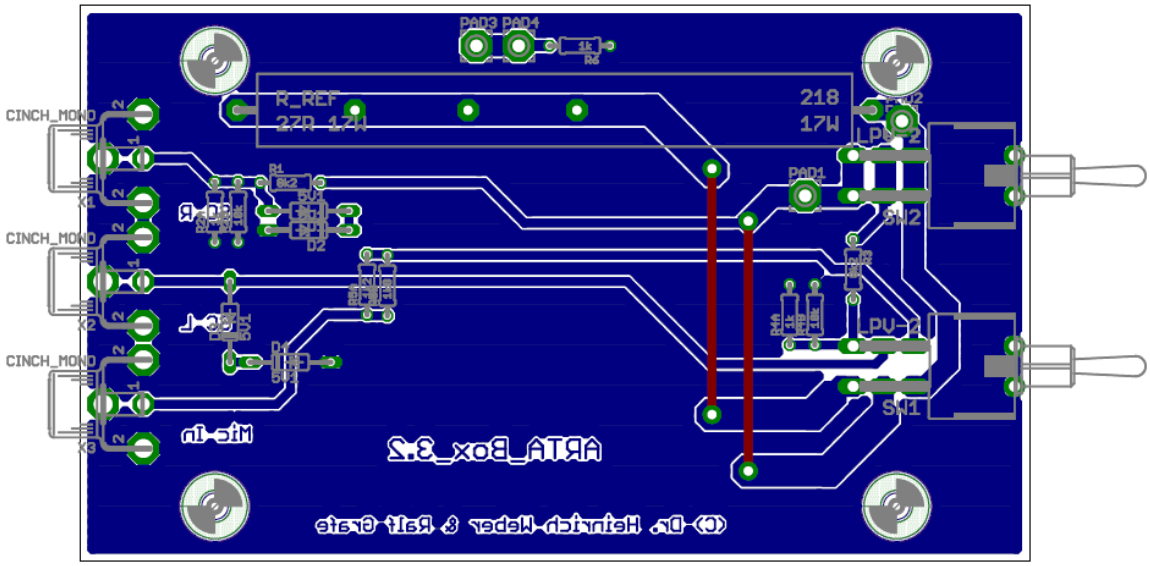


Figure 8. Component side of the PCB for the ARTA-MeasuringBox

Last but not least one can find the location and the value of the components from Fig. 8, the schematic (Fig. 9) and the parts list (Table 2). Fig. 11 shows the layout for the labeling of the MeasuringBox.

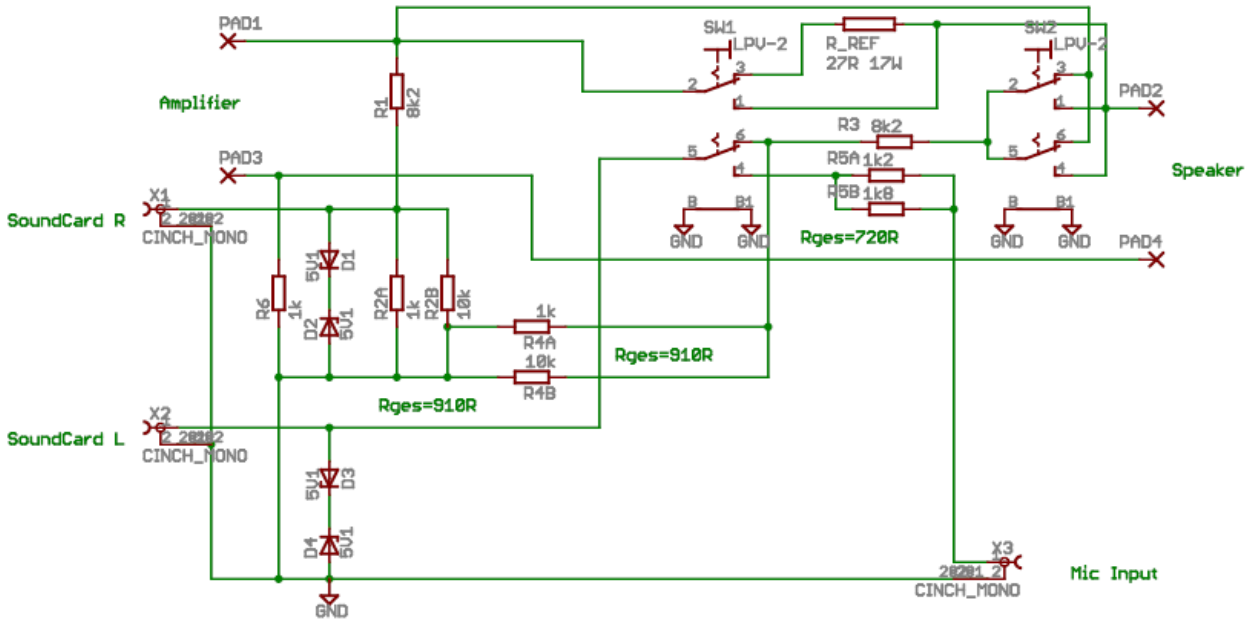


Figure 9. Schematic for the PCB Solution of the ARTA-MeasuringBox

Number	Label	Article
1		PCB
1		Plastik „Euro box“
2	SW1, SW2	Switch
2	PAD3, PAD4	Terminal, black
2	PAD1, PAD2	Terminal, red
3	X1, X2, X3	RCA jack, Print Metall
1	R Ref	Reference resistor 27 ohm/10W
2	R1, R3	8k2 (all resistors are 1%)
3	R2a, R6, R4a	1k
2	R2b, R4b	10k
1	R5b	1k8
4	D1-D4	Zener diode 4,3V / 0.5W

Table 2. Parts list of the ARTA MeasuringBox

Figure 10. The ready made ARTA-MeasuringBox

The layout of the PCB as well as other necessary information one can find here:
http://www.mini-cooper-clubman.de/html/messung.html

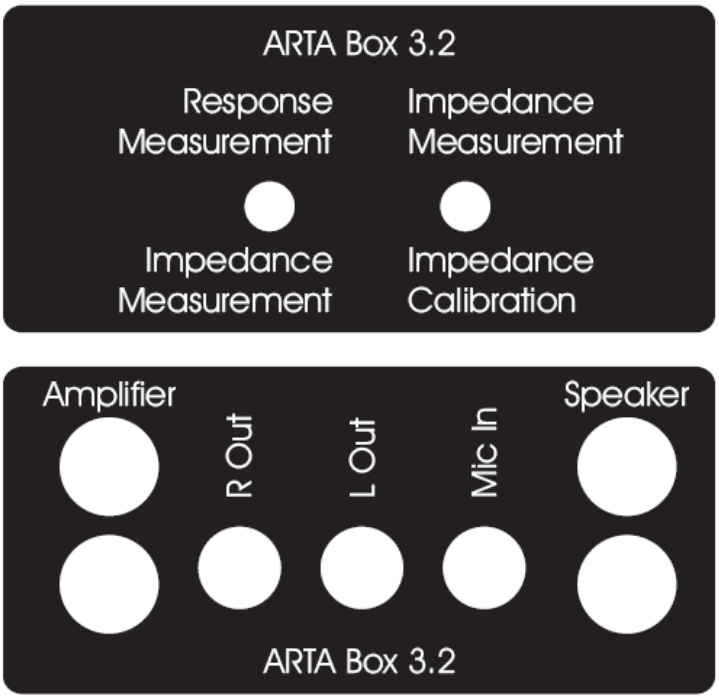


Figure 11. Layout for labeling of the ARTA-MeasuringBox