Testing Evacuation Systems

with the MR-PRO Signal Generator

Examples of 100 V Loudspeakers

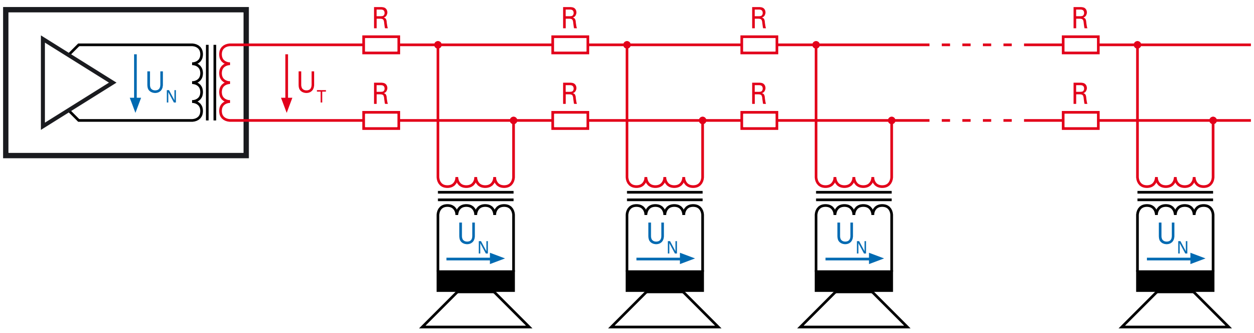
The proper operation of an evacuation system could save lives. Therefore, the correct installation, verification and maintenance of such systems are vital.

The purpose of an evacuation system is to project clear spoken announcements, in case of an emergency, to public areas such as in airports, train stations, cruise ships, conference centers or schools. The correct operation of the whole system and its components must be regularly verified.

Introduction

An evacuation / life safety system is typically composed of a microphone and an amplifier that drives a line of speakers (i.e. several loudspeakers that are connected in parallel). Voltage losses due to the impedance of the connecting wires may compromise the performance of the system, especially over long distances.

Therefore evacuation systems (also called "distributed audio systems") usually include a transformer that converts the amplifier output level U_N to a higher voltage U_T (e.g. 70.7 V, 100 V or 140 V at nominal power), while individual transformers at each of the loudspeakers drops this voltage back to the standard level U_N. Due to the higher voltage U_T, the current that flows through the connecting wires R decreases, thus reducing the power loss $P_V = I^2 * R$ significantly.



Basic structure of an evacuation system

PROs and CONs

The advantages of a distributed audio system are obvious:

✓ Simple parallel operation of many loudspeakers (also in case of different loads)

✓ Low power loss

✓ The system can be operated over long distances

On the other side there are also a few disadvantages:

- Higher costs because of the transformers required
- A higher operating voltage requires precaution during installation and maintenance.

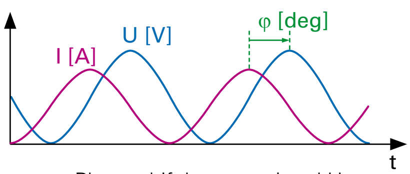
System verification

The complete verification of an evacuation system comprises both electric parameters (e.g. system impedance, power consumption), as well as acoustic characteristics (e.g. sound level, speech intelligibility).

Hint *This application note refers only to the aspects of electric verification of evacuation systems.*

Technical Basics

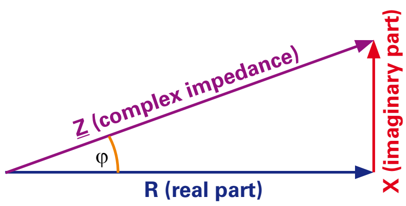
Phase



Phase shift between I and U

In an AC voltage system, the current I is typically shifted by the phase φ towards the voltage V.
This phase shift can be caused, for instance, by the inductivity of a connected loudspeaker, and has an influence both on the measured impedance and the power consumption of the system.

Complex impedance



Complex impedance

The impedance measurement of the whole system or of single loudspeakers is essential for detecting assembly errors or other defects. For this purpose it is required to acquire the complex impedance $\underline{Z}$, which in the *vector representation* is composed of the real part R and the imaginary part X:

$$\underline{Z} = R + jX$$

In practice however, the *polar representation* with the absolute value of the complex impedance |Z| [Ω], the phase φ [deg] and the real part R [Ω] is more common:

$$R = |Z| * \cos(\varphi)$$

Thus, two values are required to determine the complex impedance, the absolute value of the impedance |Z| and the phase φ.

Aside from that, the phase measurement result can be used to identify the type of the load:

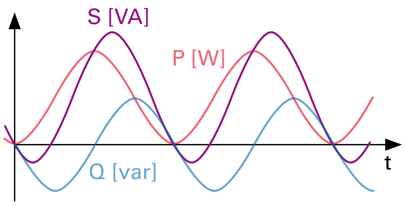
- $\varphi > 0 \rightarrow$ inductive load
- $\varphi < 0 \rightarrow$ capacitive load

Power, power factor

Basically the electrical power is calculated by multiplying the current I [A] with the voltage U [V]. As already mentioned, in all AC systems the phase φ plays a major role.

Thus, in practice, the power is split into three components: the apparent power S [VA], the active power P [W] and the reactive power Q [var]:

$$\mathbf{S = \sqrt{P^2 + Q^2}}$$

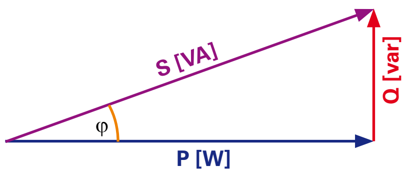


Apparent, active and reactive power

The sketch to the left shows that only the apparent and active power (S and P) have a positive absolute value, whereas the reactive power equals zero (Q = 0).

Similar to the complex impedance we can present the three power components as vectors:

$$\mathbf{S = P + jQ}$$



Vector representation of S

The apparent power S is the most important value, as it defines, inter alia, the required output power of the amplifier. Consequently we have to measure this value in order to get a relevant characteristic of the Device Under Test (DUT).

In practice the power factor λ is frequently provided in addition to the apparent power. This factor defines the relationship between active and apparent power:

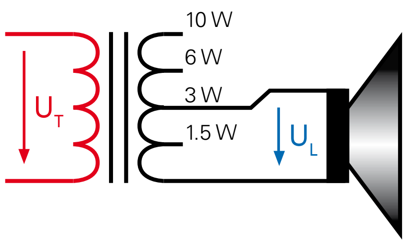
$$\boldsymbol{\lambda} = \mathbf{|P| / S}$$

In case of a sinusoidal test signal, the power factor λ can also be calculated by using the phase φ:

$$\boldsymbol{\lambda} = \mathbf{cos}(\boldsymbol{\varphi})$$

This illustrates that the power factor λ and the phase φ are directly connected to each other.

Volume control

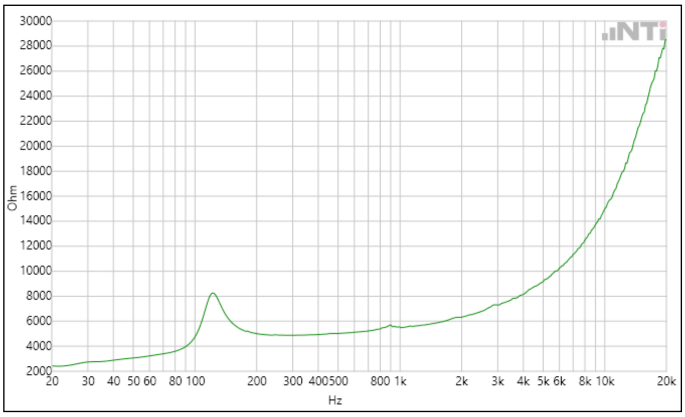


Transformer with taps
for volume control

A special aspect of evacuation systems concerns the loudspeaker volume adjustment. Basically, the amplifier output level applies to the complete line. However, each individual loudspeaker needs also to be adjustable. Consequently, the speaker transformers usually offer several taps, which allow the voltage U_L (and thus the emitted power) to be reduced from the nominal voltage U_N in several steps.

Measurement technology

Frequency dependency



Impedance response of an 100 V loudspeaker

When measuring impedance and power, you have to consider that both parameters depend on the test signal frequency.
The graph to the left illustrates this relationship by showing the impedance response of a 100 V loudspeaker.
This has two consequences for conducting a measurement:

1. You need an AC signal generator and an AC voltmeter.
2. The acquired measurement results must refer to the related frequencies.

Table representation

The three parameters system voltage U, system impedance Z and amplifier output power P are related to each other:

$$U^2 = Z * P$$

This relationship can be represented in a table:

	System voltage			
Power	**25 V**	**70.7 V**	**100 V**	**140 V**
1 W	625 Ω	5 kΩ	10 kΩ	19.6 kΩ
2 W	312.5 Ω	2.5 kΩ	5 kΩ	9.8 kΩ
4 W	156.3 Ω	1.25 kΩ	2.5 kΩ	4.9 kΩ
10 W	62.5 Ω	500 Ω	1 kΩ	2 kΩ
25 W	25 Ω	200 Ω	400 Ω	784 Ω
75 W	8.3 Ω	66.6 Ω	133.3 Ω	261.3 Ω
150 W	4.2 Ω	33.3 Ω	66.7 Ω	130.7 Ω
500 W	1.3 Ω	10 Ω	20 Ω	39.2 Ω

Dependency of the impedance Z [Ω] from P [W] and U [V]

The table can be interpreted in various ways:

a) The system voltage (e.g. 100 V), together with the amplifier output power (e.g. 25 W) give the minimum system impedance (400 Ω).

b) At a given system voltage (e.g. 70.7 V) and system impedance (e.g. 33 Ω) you may calculate the minimum required amplifier output power (150 W).

c) If the system voltage is low (e.g. 25 V), while the amplifier provides a high output power (> 100 W), the system impedance drops. Thus, the contribution of the connecting wires to the system impedance grows, which results in unwanted power loss.

Test Procedures

Applications

The verification of an evacuation system is usually done after it has been installed and put into operation. Afterwards, regular reviews are due, which typically cover the following aspects:

- Conformity of the complete system to the standards.
- Comparison of the system performance before and after specific events or in predefined intervals.
- Individual state of the installed modules & components.

Protective measures

Testing electrical installations that operate with an AC voltage of 50 V or higher, requires adequate protective measures.
This means, in practice:

1. Always disconnect the amplifier first before attempting any measurements on the network.
2. Only use test instruments that have been designed for this purpose.

The Minirator MR-PRO can be protected with an external adapter against excessive voltages and short circuits. This protects both the instrument and the user.

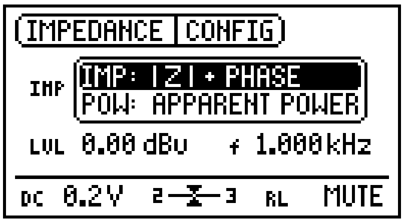
MR-PRO with 70/100 V Protection

Procedure

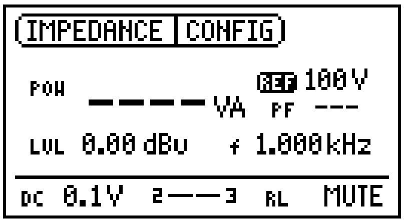
A typical electrical verification of an evacuation system is as follows:

1. Switch OFF the amplifier and disconnect it from the speaker line.
2. Attach the 70/100 V Protection to the MR-PRO and connect it to the loudspeaker line.
3. Turn ON the MR-PRO and select the mode 'IMPEDANCE'.
4. Activate the measurement function 'IMP' or 'POW'; in the latter case, select the actual system voltage.
5. Adjust the test signal level and frequency (*recommended: –20 dBu / 1 kHz*).
6. Press the MUTE button to start the measurement; if required, increase or decrease the MR-PRO signal level.
7. Read the numerical test results as well as the graphical information (→ *see next chapter*)
8. Move the cursor to 'RL' in order to read out the individual impedances of pin2 and pin3.

Hint ***You may document your test results manually or with a screenshot[1].***

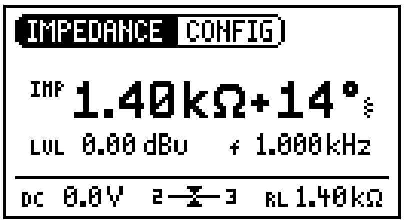


Select the measurement function

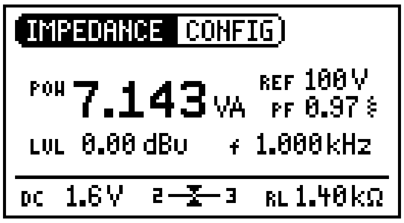


Adjust the system voltage

[1]: Create folder 'screen' in the root directory of the MR-PRO; simultaneously press the ON/OFF & Enter button



MR-PRO display at 'IMP' measurement



MR-PRO display at 'POW' measurement

Measurement result display

The MR-PRO display shows the acquired measurement results as well as further information in numerical and graphical form.

a) Specific results of the 'IMP' measurement
   » Complex impedance [Ω]
   » Phase [deg]

b) Specific results of the 'POW' measurement
   » Apparent power [VA]
   » System voltage [V] (*to be adjusted by the user*)
   » Power factor

c) General information
   » Load type: inductive or capacitive
   » Level of the test signal (*adjustable*)
   » Frequency of the test signal (*adjustable*)
   » Measured DC voltage
   » Signal symmetry
   » Measured impedance of the connected load

Interpretation of the measurement results

The results of an impedance, phase or power measurement can be analyzed qualitatively or quantitatively. The individual interpretation therefore depends on the application.

- *Difference versus the specified nominal value* → is the result within the tolerance?
- *Deviation versus the last test result* → has the device under test changed over time?
- *Load type* → inductive ($\varphi > 0$) or capacitive ($\varphi < 0$)?
- *Power consumption of the system* → compatible with the amplifier?

It is generally recommended to verify the proper operation of the individual components in a 100 V system before its installation.

After the installation, the key characteristics of the whole system should be measured and properly documented[1)] in order to allow for later comparison for verification and/or problem detection.

Application example: power / impedance measurement

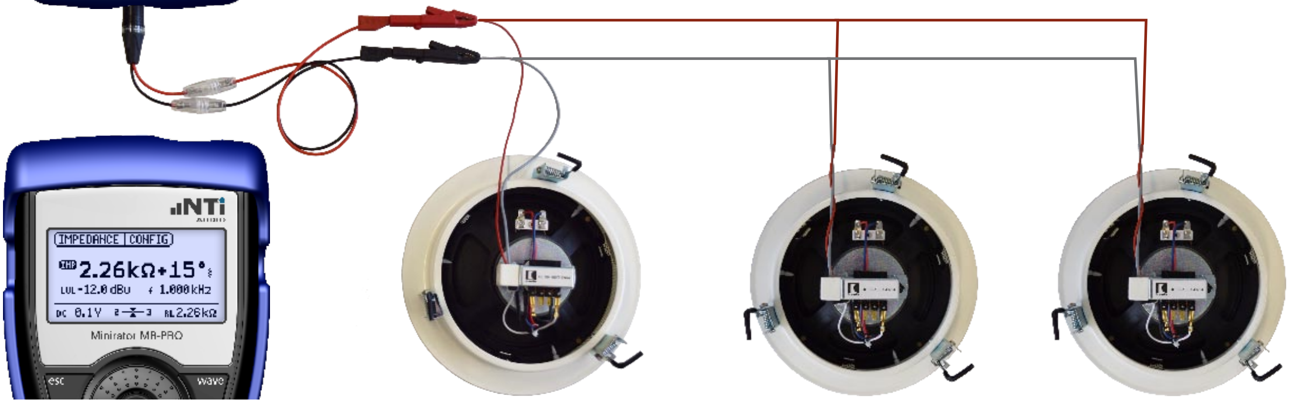
The sketch below shows a typical example of the verification of a loudspeaker line.

- The amplifier is disconnected
- The MR-PRO instrument is connected to the line
- The three loudspeakers have a nominal impedance of 6.8 kΩ and a power of 8 W

In the "Power" measurement mode, the MR-PRO shows a total power of 23.15 VA, which corresponds approximately to the sum of the three loudspeakers.

In the "Impedance" measurement mode, the result is 18.4 Ω, i.e. approximately triple the individual loudspeaker impedance.

We can thus say that the three loudspeakers are operating properly, and the line has been installed correctly.



Example of a power / impedance test with the MR-PRO

Frequently asked questions

Q: Is it possible to record the impedance response of a loudspeaker line?

A: Yes! For instance by using the MR-PRO to measure a row of impedances at different frequencies, writing down the acquired data and displaying them graphically. Or: by measuring the impedance response directly in a sweep with the FX100 Audio Analyzer.

Q: What is the impedance measurement range of the MR-PRO?

A: From 4 Ω to 50 kΩ.

Q: How important is the quality of the installed cables?

A: Better cables and connectors (i.e. with low resistance) result in less power loss.

Q: How can I determine the required area cross-section of the cable for transmitting a specific power?

A: The current as a decisive factor can be calculated from the overall power consumption of the loudspeaker line and the system voltage.

Q: How can I measure the overall power consumption of an evacuation system?

A: Directly with the MR-PRO. Alternatively, supposing that all loudspeakers have the same impedance, you can measure the individual power P_S of a single loudspeaker, and then calculate the overall power P_G of the line: $P_G = P_S$ x number of identical loudspeakers.

Q: How much power is required from the amplifier?

A: It is recommended to use an amplifier with 10..20% higher output power than the calculated minimum requirement of the loudspeaker line, in order to have enough headroom.

Q: How many loudspeakers should be typically installed in an evacuation system?

A: That depends on the area to be covered and the characteristics of the environment (background noise, reflections, etc). The goal is to aim for an equal distribution of sound pressure level across the whole area. This is best achieved with more loudspeakers at lower volumes rather than less loudspeakers at higher volumes.

Q: My loudspeakers have taps at the input of the transformer (primary side) and not at the output from the transformer (secondary side) – does that have special consequences?

A: No, both designs are treated the same.