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ELECTROACOUSTIC SYSTEM IN THE NATIONAL MUSEUM "PANORAMA RACŁAWICKA" IN WROCŁAW

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This paper presents a designed and produced electroacoustic system assisting the tour of an exhibition intended for a great number of visitors. The microprocessor operated electroacoustic system fulfills two functions: transfers the commentary to the exhibition and controls the visitor's traffic.

A sound amplification system, which makes it possible to relay at the same time six language versions of the explanatory commentary to different groups of listeners through loudspeakers and earphones, is presented. Such a system enables simultaneous transmission of two different commentaries to two groups in the same interior.

Fundamental elements of technological designs applied in the electroacoustic system are also discussed here.

W pracy przedstawiono opracowany i wykonany system elektroakustyczny wspomagający zwiedzanie obiektu wystawienniczego przeznaczonego dla dużej liczby zwiedzających. System elektroakustyczny, sterowany mikroprocesorem, spełnia dwie funkcje: przekazywanie komentarza objaśniającego wystawę i sterowanie ruchem zwiedzających.

Przedstawiono realizację naddźwiękowienia umożliwiającą przekazywanie sześciu wersji językowych komentarza objaśniającego jednocześnie dla różnych grup słuchaczy za pomocą głośników i słuchawek. Rozwiązanie systemu naddźwiękowienia głośnikowego umożliwia równoczesny przekaz dwóch różnych komentarzy dla dwóch grup znajdujących się w tym samym wnętrzu.

Omówiono podstawowe elementy rozwiązań technicznych zastosowanych w systemie elektroakustycznym.

1. Introduction

The group of buildings of the "Panorama Racławicka" was created in order to exhibit the famous battle-scene painted by Kossak and Styka. This work of art with great historical value, which rouses enormous interest from the society, required not only an adequate building for exposition but also technical equipment. The "Panorama Racławicka" consists mainly of the painting, but it is only one of the elements of a complex whole.

The "Panorama Racławicka" exhibition consists of the Rotunda with the painting Small Rotunda with the model of the battle and show-cases with iconographic materials, and hall with video systems and film and slide projection screens (Fig. 1). The surface of the scenic platform in the Rotunda is relatively small, because of the geometry and perspective of the painting. Similar limitations concern

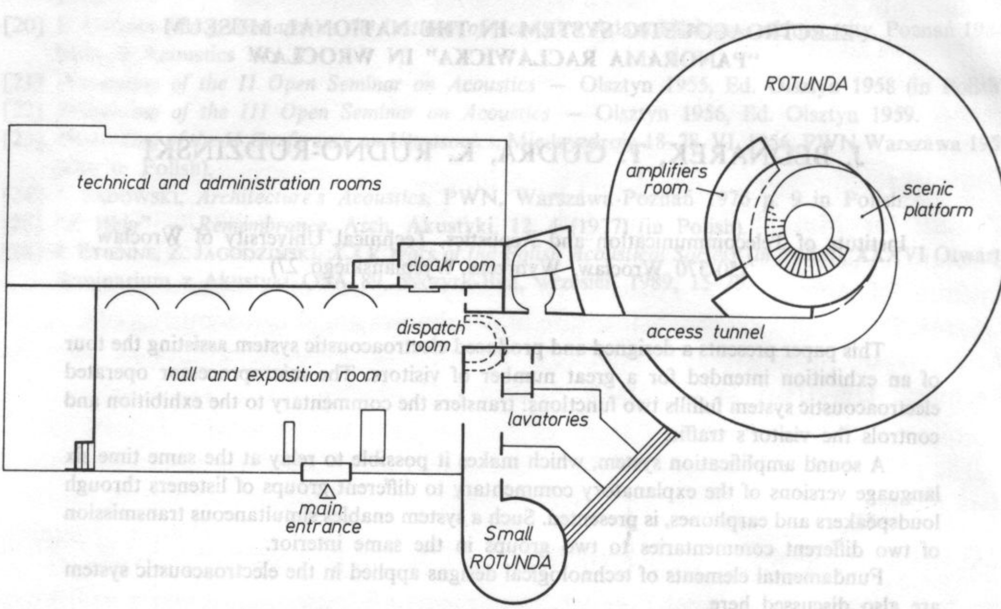

FIG. 1. "Panorama Racławicka" museum — horizontal projection

the Small Rotunda. Therefore, the largest possible capacity of the object with a possible widest commentary on the "Panorama Racławicka" in the conditions of limited space and related safety rules concerning visitors and protection of the painting (e.g stability of climatic conditions inside the building) was the basic problem of the design. Eventually it was accepted that no more than two groups of 40 persons on opposite sides of the platform can be on the scenic platform in the Rotunda at the same time. The touring time of one group was determined at 40 minutes. This time is divided into six intervals corresponding with six sectors the painting is divided into.

On the basis of the nature of the exposition and accepted organization of sightseeing assumptions to the electroacoustic system design were determined. First of all, it has to be made sure that the commentary concerning the painting and the model of the battle is intelligible. It should be possible to transmit the commentary in several languages at the same time. For safety reasons the dispatcher's information had to reach visitors in all possible places. Also, fast communication between the staff of the museum had to be ensured. Furthermore, the whole electroacoustic system should function properly also at different organizations of the visitors'traffic in the hall, Rotunda and Small Rotunda. It should be noted that the sound amplification system was designed when all designs of interiors were confirmed and could not be changed from the point of view of acoustic requirements. All loudspeakers had to be inperceptible, composed with other elements of interior decorations. Mainly stone, metal and glass were used in interiors of the "Panorama Racławicka" object.

In our work on the electroacoustic system we intended to take advantage of experiences from the exhibition of other panoramas of exhibitions with a similar organization of sight-seeing as accepted for the object under consideration. Unfortunately none were found.

2. Idea of the system

The accepted idea of the system was a result of an analysis of requirements of the organization of visitors' traffic on exhibitions and of other assumptions mentioned in the introduction. It was stated that the system has to be automatic and it has to unite two basic functions:

– transmission of the commentary explaining the exhibition,

– control of the visitors' traffic.

Full synchronization of visitors' traffic has to be ensured for this system to function. In this case the staff of the object has different tasks in classical solutions. In normal work conditions the dispatcher of the object has to start the system and chose the sightseeing course (one-group, two-group or single). The choice of languages of the commentary for a given group and a discret supervision of the group are the tasks of guides. Other functions are fulfilled by the electroacoustic system.

Also the replacement of guides by electroacoustic devices is advantageous because of the constancy of the artistic and emotional side of the commentary.

Figure 2 presents a simplified block diagram of the electroacoustic system. It indicates places in rooms of the object in which individual units are situated.

Intensive exploitation of the electroacoustic system and accepted system of earlier ticket reservation imposed high reliability requirements on the devices on one hand and the necessity of quick defect localization and their immediate repair. This problem was solved with reserve systems switched on in a case of a failure (reserve TTL control system, loop tape recorders, power amplifiers). As for the organization of the system, a fault detection system was applied. Fig. 3 present a full block diagram of the electroacoustic system, containing control, diagnostics and sound signal paths.

Two independent subsystems complement the electroacoustic system. The subsystem of the radio relay centre makes it possible to pass dispatcher's informations and instructions to all places in the buildings of the museum, in which people are present. He can use additional loudspeakers in rooms outside the

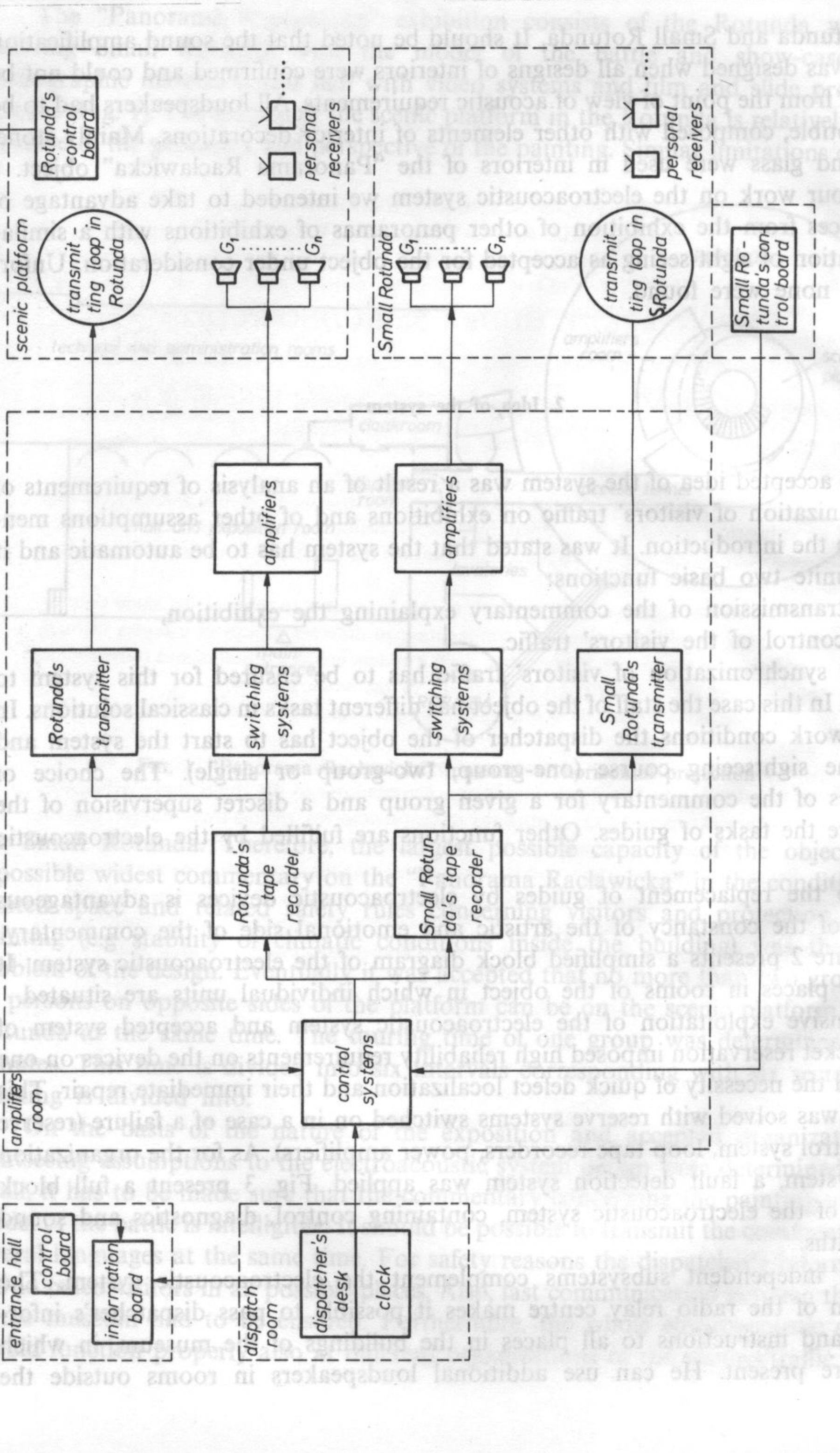

FIG. 2. Simplified block diagram of the electroacoustic system

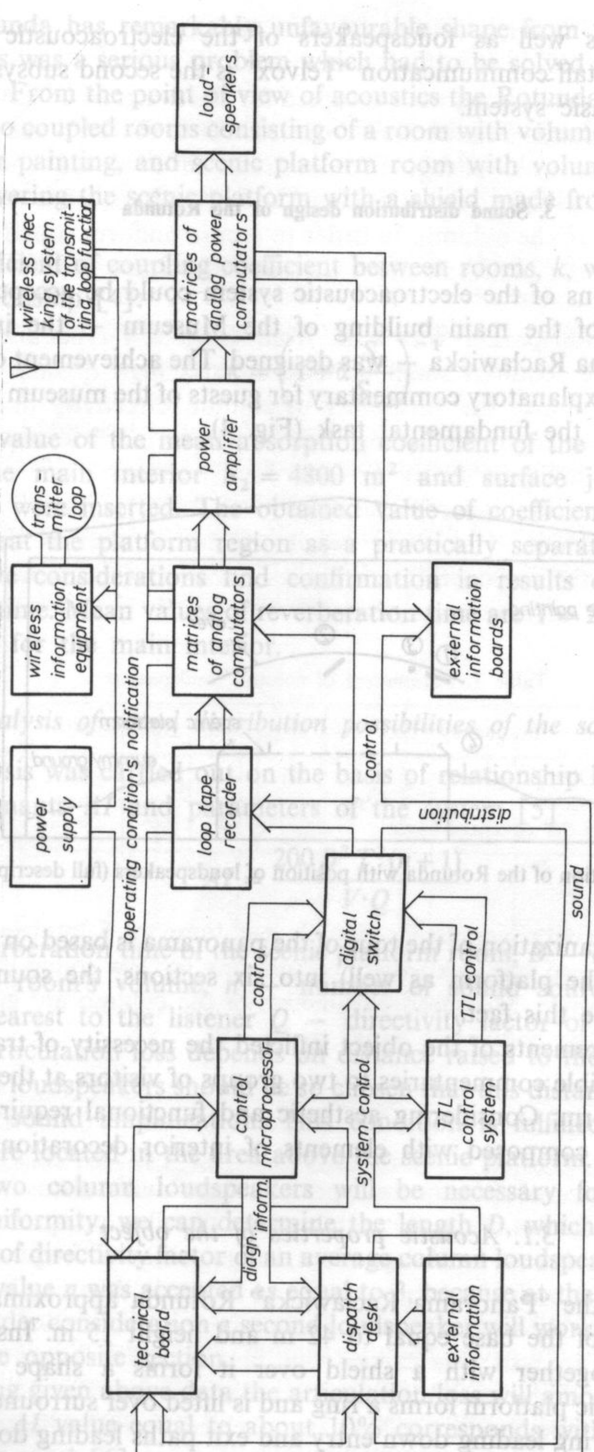

FIG. 3. Block diagram of the electroacoustic system

sightseeing route, as well as loudspeakers of the electroacoustic system. The subsystem of quick staff communication "Telvox" is the second subsystem. It is not connected to the basic system.

3. Sound distribution design of the Rotunda

Detailed solutions of the electroacoustic system could be accepted only when sound distribution of the main building of the Museum – the interior of the Rotunda of Panorama Racławicka – was designed. The achievement of high quality transmission of the explanatory commentary for guests of the museum staying on the scenic platform was the fundamental task (Fig. 4).

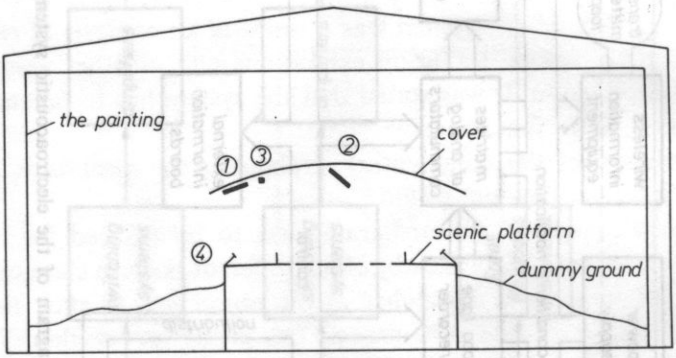

FIG. 4. Diagrammatic section of the Rotunda with position of loudspeakers (full description in the paper)

Because the organization of the tour of the panorama is based on the division of the painting (and the platform as well) into six sections, the sound distribution system must include this fact.

Capacity requirements of the object inflicted the necessity of transmitting two different but intelligible commentaries to two groups of visitors at the opposite sides of the scenic platform. Considering aesthetic and functional requirements, loudspeakers had to be composed with elements of interior decorations.

3.1. Acoustic properties of the object

The shape of the "Panorama Racławicka" Rotunda approximates a cylinder with the diameter of the base equal to 42 m and height 15 m. Inside is a scenic platform, which together with a shield over it forms a shape approximating a cylinder. The scenic platform forms a ring and is lifted over surrounding it artificial ground. Inside the ring leading down entry and exit paths leading down are located (Fig. 1, Fig. 4).

The Rotunda has remarkably unfavourable shape from the point of view of acoustics. This was a serious problem which had to be solved during designing the sound system. From the point of view of acoustics the Rotunda can be described as a system of two coupled rooms consisting of a room with volume of about 20 000 m^3, containing the painting, and scenic platform room with volume of about 800 m^3, formed by covering the scenic platform with a shield made from roll formed sheet aluminium.

The coefficient of coupling coefficient between rooms, k, was estimated on the basis of relationship [4]:

$$k = \left(1 + \bar{\alpha}\frac{S_2}{S_{12}}\right)^{-1}$$

in which the value of the mean absorption coefficient of the main room $\bar{\alpha} = 0.1$. Surface of the main interior $S_2 = 4800$ m^2 and surface joining both rooms $S_{12} = 190$ m^2 were inserted. The obtained value of coefficient $k = 0.28$ makes it possible to treat the platform region as a practically separate room.

The above considerations find confirmation in results of measurements of reverberation time. Mean values of reverberation time are $T = 2.2$ s for the platform and $T = 3.8$ s for the main interior.

3.2. Analysis of sound distribution possibilities of the scenic platform

The analysis was carried out on the basis of relationship between articulation loss for consonants AI and parameters of the system [5]

$$AI = \frac{200\, D^2\, T^2 (n+1)}{V \cdot Q}$$

where T is reverberation time of the scenic platform room, D – loudspeaker-listener distance, V – room's volume, n – number of sound sources apart from the loudspeaker nearest to the listener Q – directivity factor of sound source.

Because articulation loss depends on distance raised to the second power, the arrangement of loudspeakers should be so chosen that this distance is smallest in the entire area of sound amplification. This condition is fulfilled best of all when loudspeakers are located in the area above the scenic platform. Furthermore, if we accept that two column loudspeakers will be necessary for adequate sound distribution uniformity, we can determine the length D, which is equal to 3.5 m.

The value of directivity factor of an average column loudspeaker, equal to 7, was accepted. The value n was accepted as equal to 3, because at the same time with the loudspeaker under consideration a second loudspeaker will work in the same section and two in the opposite section.

Considering given above data the articulation loss will amount to $AI = 10.9\%$. The calculated AI value equal to about 10% corresponds with quality of speech judged as very good [6].

3.3. *Column loudspeaker design*

The following assumptions were accepted for the designed column loudspeaker: frequency response uniform in the band from 200 Hz to 5000 Hz and droping below 200 Hz to limit acoustic energy in the range of low frequencies where the reverberation time assumes highest values and it is impossible to achieve high radiation directivity of the column. In order to secure uniform sound distribution of the entire width of the platform, the 6 dB coverage angle should be equal to 45 degrees.

The column loudspeaker was built from GDS 8/4 type broad-band loudspeakers. They have required small dimensions and high quality.

In order to minimize the variability of column directivity due to frequency, a column with active length decreasing with frequency increase was designed. This was achieved with low-pass filters extreme loudspeakers. Since switching off of extreme loudspeakers at higher frequencies gives lower response of the column, a condenser was connected in series before the transformer at the input of the column to equalize the response. The condenser was also secure adequate load for the power amplifier at low frequencies.

Table 1. Parameters of column loudspeaker

Frequency [Hz]	500	1000	2000	4000
Directivity factor Q	3.1	4.3	6.5	9.0
6–dB coverage angle	130°	69°	59°	45°

Required directivity was achieved with a column of 5 loudspeakers. Further extention of the column was inexpedient considering too low sound uniformity in the required coverage angle. Measured parameters of the column are given in Table 1. The sensitivity of the column is equal to 94 dB.

3.4. *Comparison of various solutions of sound distribution*

When prototypes of column loudspeakers were made, measurements of electroacoustic characteristics of the Rotunda's sound distribution system were performed. The maximal value of local-dependent irregularities of frequency response in a given section in the useful frequency band and crosstalk damping between opposite sections were to be determined from measurements. Pink noise was supplied to loudspeakers. The analysis was carried out in 1/3 octave bands.

The following seven sound distribution systems were tested:

1. 3 units of ZG5c S type loudspeakers located every 20 degrees in the outer railling of the platform (Fig. 4, No. 4),

2. Loudspeakers as above located on the shield above the platform (No. 3).

3. 3 units eight-loudspeaker columns on the shield spaced every 20° over the platform (No. 1).

4. One column as in point 3, installed in an acoustic baffle with dimensions 1 m × 1 m, located in the centre of the shield (No. 2).

5. Single five-loudspeaker column situated in the shield in the centre of the section (No. 1).

6. 3 columns as above spaced every 20° in the shield (No. 1).

7. 2 columns as above spaced every 30° in the shield (No. 1).

Results of measurements of frequency response irregularities measurements indicate two groups of solutions. System 2 and 4 belong to the first group and display much smaller non-uniformity than the rest of the solutions which form the second group. Measured values of crosstalk damping indicate the same repartition of systems; solutions with smallest non-uniformity have smallest crosstalk damping thus worst quality of speech at the same time.

From among other solutions the system with loudspeakers in the railing was rejected as inconvenient from the exploitation point of view and besides sensible to the number of listeners in the section.

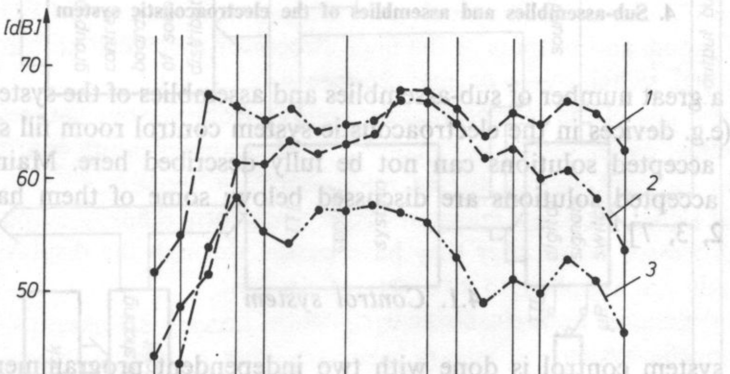

FIG. 5. Level of acoustic pressure under column loudspeaker: 1 — frequency characteristic, 2 — effect of tone quality control, 3 — crosstalk from opposite sector

The chosen previously system with two five-loudspeaker columns reconciles best from among solutions with columns situated above the platform requirements of small non-uniformity high crosstalk damping and minimal number of columns working at the same time. For this system irregularities of frequency response for the entire band is equal to 3 dB, crosstalk damping 9.8 dB (Fig. 5).

3.5. *Speech intelligibility testing*

Measurements of articulation score for logatoms were a final verification of the accepted sound distribution system. Test logatom lists were applied, structurally and phonetically balanced with each other and in relation to adequate Polish language statistics. Simultaneously with logatoms a speech signal similar to the planned manner of reading the commentary was sent from the column in the opposite section. Levels of the test signal and disturbance in their sectors were equalized and equal to 70 dB.

A group of 19 listeners without previous preparation aged from 25 to 50 years participated in measurements. It consisted of 6 women and 13 men — workers of the Technical University of Wrocław, employed as scientific workers, technical workers and workmen.

An analysis of listeners' records noted on forms proved that they had received correctly 88.4% of sent logatoms. This corresponds with articulation loss for consonants not greater than 11.6%, what is a similar value to the given previously estimation, equal to 10.9%. The measured value of articulation store for logatoms corresponds with practically 100-percent intelligibility of phrases.

4. Sub-assemblies and assemblies of the electroacoustic system

Due to a great number of sub-assemblies and assemblies of the system and their complexity (e.g. devices in the electroacoustic system control room fill six CAMAC type racks), accepted solutions can not be fully described here. Main functional elements of accepted solutions are discussed below; some of them have received patents [1, 2, 3, 7].[1]

4.1. *Control system*

Sound system control is done with two independent programmers; a microprocessor system is the superordinated programmer and it is complemented with a TTL control system compatibile with respect to input signals.

There are 3 methods of sound system control:

– with a microprocessor programmer (μP),
– with a TTL programmer,
– with both programmers working simultaneously.

Such a solution increases the reliability of the electroacoustic system and makes it possible to repair one programmer without putting the entire system out of action.

[1] All devices within the electroacoustic system are original designs or adaptations of devices produced in Poland.

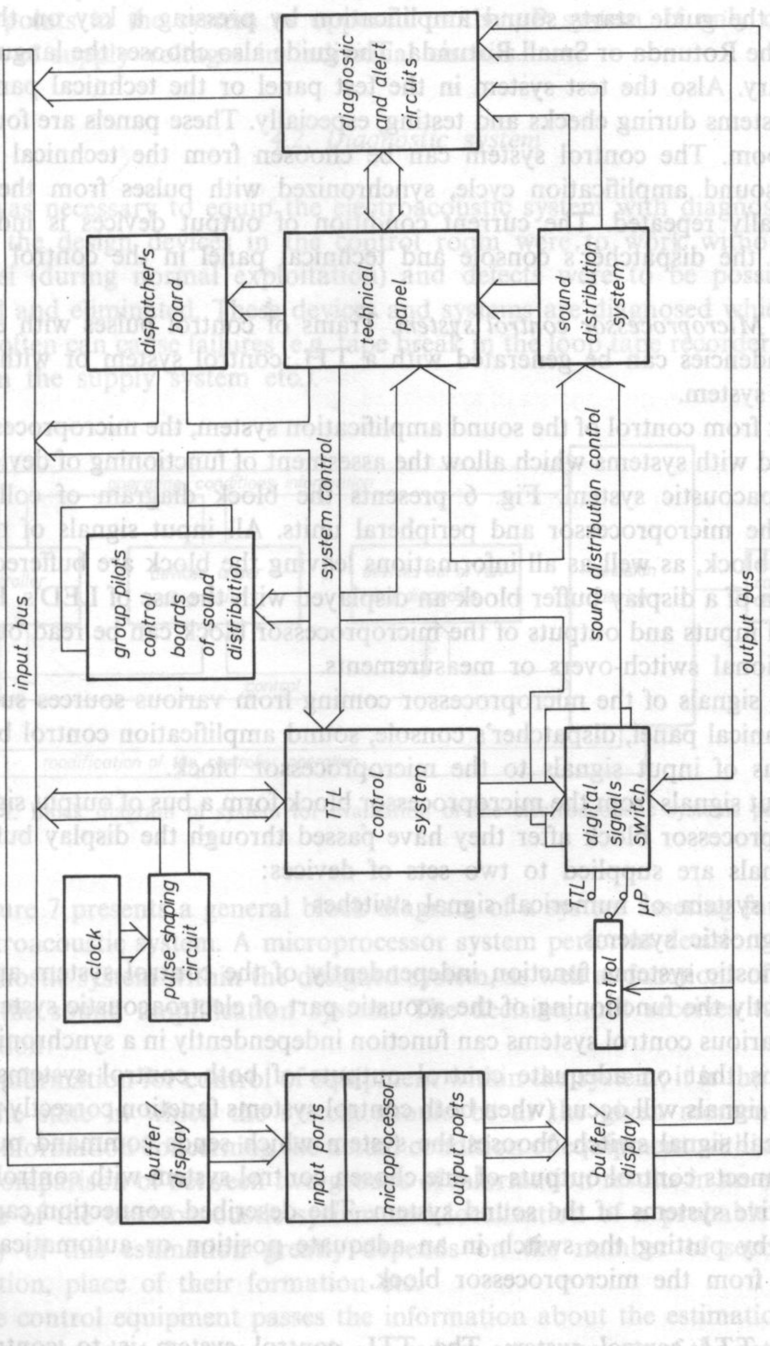

FIG. 6. Block diagram of microprocessor block collaboration with peripheral equipment

Both systems are synchronized with pulses from a clock in the dispatch room. From the console the dispatcher can change the frequency of pulses generated by the clock and allow a single start of sound amplification of the Rotunda or the Small Rotunda; the guide starts sound amplification by pressing a key on the control board in the Rotunda or Small Rotunda. The guide also chooses the language of the commentary. Also the test system in the test panel or the technical panel can be control systems during checks and testing, especially. These panels are found in the control room. The control system can be choosen from the technical panel.

The sound amplification cycle, synchronized with pulses from the clock, is automatically repeated. The current condition of output devices is indicated by LED's on the dispatcher's console and technical panel in the control room.

4.1.1. Microprocessor control system. Trains of control pulses with exact time interdependencies can be generated with a TTL control system or with a microprocessor system.

Apart from control of the sound amplification system, the microprocessor block is equipped with systems which allow the assesment of functioning of devices within the electroacoustic system. Fig. 6 presents the block diagram of collaboration between the microprocessor and peripheral units. All input signals of the microprocessor block, as well as all informations leaving the block are buffered with the application of a display buffer block an displayed with the use of LED's. Hence, the state of all inputs and outputs of the microprocessor block can be read out without any additional switch-overs or measurements.

Input signals of the microprocessor coming from various sources such as the: clock, technical panel, dispatcher's console, sound amplification control boards etc. form a bus of input signals to the microprocessor block.

Output signals from the microprocessor block form a bus of output signals from the microprocessor block after they have passed through the display buffer block. These signals are supplied to two sets of devices:

– to the system of numerical signal switches
– to diagnostic systems.

Diagnostic systems function independently of the control system and do not effect directly the functioning of the acoustic part of electroacoustic system. In this solution various control systems can function independently in a synchronic manner. This means that on adequate control outputs of both control systems identical command signals will occur (when both control systems function correctly of course). A numerical signal switch chooses the system which sends command pulses. This switch connects control outputs of one chosen control system with control inputs of the executive systems of the sound system. The described connection can be done manually by putting the switch in an adequate position or automatically switch operation from the microprocessor block.

4.1.2. TTL control system. The TTL control system is to control sound distribution when the microprocessor system does not function. Output command signals from the TTL system secure functioning of the electroacoustic system identical as signals from the μP system. The TTL control system also allows certain check or test operations; however it does not secure full control and diagnosis of all delicate points in the system as opposed to the μP system. It only controls the presence of supply voltages in individual circuits.

4.2. Diagnostic system

It was necessary to equip the electroacoustic system with diagnostic systems, because the design devices in the control room were to work without servicing personnel (during normal exploitation) and defects were to be possibly quickly localized and eliminated. These devices and systems are diagnosed which probably most of often can cause failures (e.g. tape break in the loop tape recorder, burnout of a fuse in the supply system etc.).

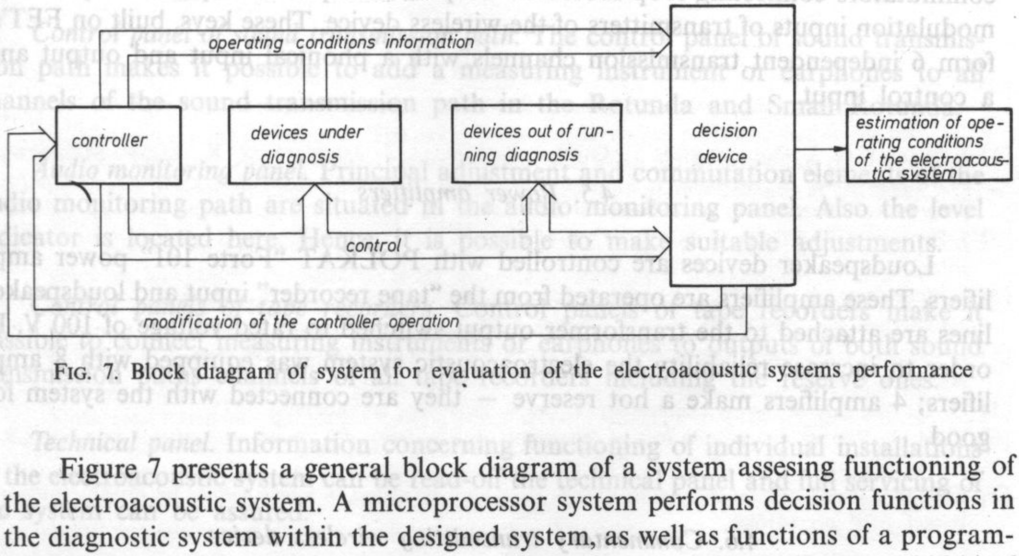

FIG. 7. Block diagram of system for evaluation of the electroacoustic systems performance

Figure 7 presents a general block diagram of a system assesing functioning of the electroacoustic system. A microprocessor system performs decision functions in the diagnostic system within the designed system, as well as functions of a programmer of the sound amplification system. The decision unit receives two kinds of information:

1. information for control of equipment within the system; it is the information about the state in which the system should be at the given moment, and
2. information concerning the actual condition of equipment within the system.

A comparison of between two groups of information results in an estimation of the state of the electroacoustic system and localization of a probable defect. The accuracy of this estimation greatly depends on the number of second kind of information, place of their formation etc.

The control equipment passes the information about the estimation results to the personnel and at the same time it can reduce consequences of the detected failure (e.g. by switching over to a reserve element).

4.3. *Loop tape recorders*

Double track loop tape recorders equipped with special cassettes which make it possible to reproduce the commentary in a continuous manner without rewinding have been used to reproduce the commentary concerning the painting and model of the battle. The tape recorder is operated by the control system. The beginning and end of the commentary is separated with a piece of transparent tape which causes a photooptic sensor to stop the tape recorder. The tape recorder is provided with control systems which through external diagnostic systems continuously control the tape recorder's functioning and signalize its correctness.

4.4. *Switching systems*

Switching systems consists of systems of analogue keys acting as phonical signal commutators connecting loop recorders' outputs with power amplifiers' inputs and modulation inputs of transmitters of the wireless device. These keys, built on FET's, form 6 independent transmission channels with a phonical input and output and a control input.

4.5. *Power amplifiers*

Loudspeaker devices are controlled with POLKAT "Forte 101" power amplifiers. These amplifiers are operated from the "tape recorder" input and loudspeaker lines are attached to the transformer output switched to rated voltage of 100 V. In order to increase reliability the electroacoustic system was equipped with 8 amplifiers; 4 amplifiers make a hot reserve – they are connected with the system for good.

4.6. *Commentary transmitting wireless device*

A method of wireless information transfer was applied to make it possible to listen to the commentary in a language other than that transmitted through loudspeakers. Therefore, the visitor equipped with a special transistor receiver can listen through earphones to any one of five language versions of the commentary concerning the seen part of painting or model of battle.

Two such devices were applied in the "Panorama Racławicka" object; separate ones for the Rotunda and Small Rotunda. Receivers are identical, five-channel and may be used in the Small Rotunda as well as on the scenic platform in the Rotunda. They are switched on and operated in synchronicity with other appliances of the electroacoustic system.

4.7. Monitoring systems

Monitoring systems of the electroacoustic system indicate the functioning of individual elements of the system. They have the form of separate panels placed in stands and have galvanic connections with other elements of the system.

Test panel. The test panel contains a quick-acting test system which starts tape recorders, realizes control connections in phonical channels of the Rotunda and Small Rotunda and also starts reserve tape recorders.

Fast test system's functions are realized in connection with a TTL and microprocessor control system as well as with audio monitoring systems. The fast test system makes it possible (when there is no programme in the phonic channel) to start tape recorders in chosen sector, switch on section keys, switch on zone keys and loudspeaker relays, choice of language for the commentary from loudspeakers. Mentioned functions can be also performed manually or automatically.

Control panel of sound transmission path. The control panel of sound transmission path makes it possible to add a measuring instrument or earphones to all channels of the sound transmission path in the Rotunda and Small Rotunda.

Audio monitoring panel. Principal adjustment and commutation elements of the audio monitoring path are situated in the audio monitoring panel. Also the level indicator is located here. Hence, it is possible to make suitable adjustments.

Control panels of tape recorders. Control panels of tape recorders make it possible to connect measuring instruments or earphones to outputs of both sound transmission paths channels of all tape recorders including the reserve ones.

Technical panel. Information concerning functioning of individual installations of the electroacoustic system can be read-off the technical panel and full servicing of the system can be assured.

Control receivers of the high frequency links. Control receivers constantly check the system for wireless information in the Rotunda and Small Rotunda. They form an unit of five indentical receivers, each tuned in to a different channel and receiving a different language version of the commentary.

Conclusions

The applied system has proved itself functional in practice during over two years of its exploitation. High capacity of the object, amounting to over 0.5 million visitors a year at average time spent inside the museum of about 2 hours, indicates that the right solution was accepted. The electroacoustic system drivers the traffic inside the object. Acoustic control of the traffic allows precise organization and reservation in advance. A tour of the object in a precisely determined period of time is the only possible solution with such a vast interest in the painting. The acoustic system generally was judged by visitors as good. However, there is a certain discomfort when two groups are touring the museum at the same time. Still, the quality of speech of the commentary transfered to two groups of listeners at the same time is very high. It has been confirmed by measurements.

In 1986 the group of engineers was awarded the Prize of the Minister of Science and Higher Education for the development and realization of the system.

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