Abstract — This work deals with the design and development of a time domain reflectometry method based handheld tester for microphone cables. The main aim of the work is to adopt a suitable measuring method for locating faults in microphone cables, develop electrical design and realize its practical implementation. Next, firmware for the microcontroller unit is also created. The measurement is based on a time-to-digital converter integrated circuit used in Light Detection and Ranging (LIDAR) applications. First experimental results confirmed the functionality of the proposed concept.

Keywords — Time-Domain Reflectometry, Microphone Cable, Time-to-Digital Converter

1. INTRODUCTION

During manipulation with hundreds of meters of microphone cables (e.g. a sound system of a concert hall) commonly faults could occur. To find possible faults in long cables is not an easy task. Hence, devices to localize and measure fatal faults in microphone cables are required.

In this work, a handheld device appropriate to measure and particularly localize different faults in microphone cable is introduced. As a measurement method, the impedance mismatch based time-domain reflectometry (TDR) was adopted [1]. The proposed device is developed in cooperation with company OTVP1, which designs, manufactures and installs public address (PA) sound systems.

This short paper is organized as follows. Brief description of the TDR measurement method is presented in Section 2. The concept of the proposed microphone cable tester is described in Section 3. First outputs from the experimental verification of the realized device are discussed in Section 4. Finally, the paper is concluded in Section 5.

2. TDR METHOD

The microphone cable consists of two twisted pairs covered by metal shielding. Its structure is very close to the shielded twisted pair cables employed in Ethernet networks. The microphone cable could be understood as an impedance-matched line with characteristic impedance $Z_0$. When imperfection or fault (e.g. discontinuity, short circuit) occurs in the cable, its impedance locally deviates from the value of $Z_0$.

There exist several methods to localize the faults in a microphone cable. The proposed microphone cable tester adopted the TDR method. It is based on the incurred reflections from impedance discontinuities. In brief, the tester sends a measuring signal into the tested cable and measures the level of reflected power and group delay. The type of fault can be differentiated from the character of the reflected signal [2]. Examples of the reflected signals in the case of open and short circuit line are shown in Fig. 1. The voltage pulse response can be understood as a derivative of the line impedance depending on the distance from the connector. The time is directly proportional to the distance toward fault.

3. MICROPHONE CABLE TESTER

The measurement of the response of measuring signal requires a precision in order of nanoseconds. Every nanosecond, depending on the velocity of signal propagation, could mean approximately 10 cm of inaccuracy. Thereby, an ultra-high speed analog-to-digital converter (ADC) is required, which is not a cheap solution. There are several methods for sensing the response of a signal. In the introduced concept, a technique based on the measuring of time intervals between the transmitted measuring signal

1 https://www.otvp.cz/
and reflection from mismatch is proposed. From this point of view, a time-to-digital converter (TDC) integrated circuit used in LIDAR and ultrasonic sensors applications [3] was chosen. Its IO works as fast stopwatches measuring the time-of-flight (ToF) of measuring signal. TDC is a cheap, affordable and accurate solution for the TDR application.

3.1. Topology

The topology of the developed microphone cable tester is shown in Fig. 2. The principle of the proposed concept can be described as follows. The microcontroller unit (MCU) is used to generate Pulse Width Modulation (PWM) signal with a frequency of 62.5 kHz, filtered by a low pass filter (LPF), that is used as a voltage reference for the comparator. Next, the MCU sends signals (separately or both at the same time) into the buffer and start pin of the TDC. The buffer is employed as an amplifier and the voltage step controlled by MCU goes directly to the measured cable only via resistor trimmer causing impedance cable matching. The typical microphone cable impedance is from 20 to 60 Ω.

Due to impedance discontinuities, reflections occur on the line. These signals with delay are the second input of the comparator. When the voltage level on the measured line is higher than the voltage reference threshold level (taken from the MCU), the comparator flips over and stops TDC. Time accumulated in TDC is directly proportional to time delay of the reflection. The typical value of the measured time delay is from units of nanoseconds to tens of microseconds. The TDC can sense the rising and falling edge of the stop trigger pin, so we are not limited only to positive polarity responses. The MCU and TDC are connected via Serial Peripheral Interface (SPI). The whole device is powered by 5 V power supply (in the future, 18650 battery cell will be used). This voltage level was chosen mainly due to the LCD power supply and as a compromise for the level of measuring signal (to guarantee acceptable signal-to-noise ratio). The TDC circuit is available only in a version of 3.3 V, so the voltage must be converted between the levels of 5 V and 3.3 V. The reference voltage for the comparator can be swept over the entire supply voltage interval.

3.2. Realization

The Atmega328P 8-bit microprocessor (Microchip) and the TDC7002 TDC (Texas Instruments), creating the core of the microphone cable tester, were used at the hardware (HW) realization of the device. They were chosen due to availability, easy of use and low cost. The main time reference is driven by a 16 MHz xtal oscillator. For experimental purposes, a single-side Printed Circuit Board (PCB) was created under home conditions. Minor power consumption is assumed for long battery life time because the device will be realized in a hand-held form. Prototype of the microphone cable tester is shown in Fig. 3.

3.3. User Interface (UI)

The firmware is written in programming language C++. It supports the using of user-interface (UI) created by four buttons (see Fig. 4). The entire UI is arranged in menus and sub-menus and the user can intuitively scroll between them by the using of arrow keys. A 20 × 4 blacklight LCD alphanumeric display is used to visualize information and outputs of the provided tests. The control of device is intuitive and robust (see Fig. 4). Display backlight is also switchable for lowering power consumption.
4. EXPERIMENTAL VERIFICATION

The functionality of the proposed microphone cable tester has been verified in experimental measurements. To obtain results at the measurement of microphone cable in a correct form, it is important to create an appropriate measurement algorithm.

It should identify and measure variations of rising and falling edges at noisy sampled waveform. As a measuring signal, voltage step is used (instead of a pulse) which, unfortunately, results in more difficult
detection of points. As it was mentioned, ADC is not used because causes non-equidistant distribution of the measured points in time domain. The situation is different as in the case of equidistant samples.

The created algorithm consists of these consecutive steps: 1) Measuring of samples for every reference value; 2) Ordering of the measured samples in time domain and filtering by a digital LPF; 3) Providing numerical derivative calculation followed by filtering; 4) Finding minimum and maximum and 5) Calculation of time differentiation of the rising/falling edge.

For the software (SW) debugging, a script enabling calculation and visualization of data was created in program environment MATLAB. The output of the processed data is shown in Fig. 5 (can be compared with Fig. 1). The filtered measured values are highlighted by a blue curve. The resulting point, which is determined by the algorithm as the beginning of reflection, is marked with a black "x". It is visible that the leading edge of the measured signal is not completely rectangular. Hence, it is very important to determine the exact place of the beginning of reflection. Numerical first and second derivatives (red and pink curves) are used for the calculation. The required time delay value defines the first leading edge and the marked point.

5. CONCLUSION

A handheld microphone cable tester, developed and created within the first part of bachelor thesis, was introduced in this short paper. Its topology as well as HW/SW parts were briefly described. Functionality of the proposed concept has been verified by experimental measurements.

Future work plans include the design of a switched-mode power supply for suitable battery supply, SW debugging and the design of professional PCB. After production of the final prototype, it is planned to test the product in real deployment of the company OTVP and its small-scale production.

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REFERENCES

