UNIVERSAL DEVICE FOR RECOGNIZING PARAMETERS OF PASSIVE AND ACTIVE RADIO-ELECTRONIC ELEMENTS AND AUTOMATIC LOCOMOTIVE CONTINUOUS CODED (ALCS) SIGNALS

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Annotation: *The development of measuring instruments capable of performing multiple functions, handling various tasks simultaneously, and testing elements, devices, and their faulty modules helps reduce valuable repair time, ensures continuity during restrictions, improves energy efficiency in operation, speeds up decision-making, provides readily calculated results, and offers other useful features. The distinguishing characteristic of such devices compared to others is their reprogrammable nature, which allows them to be adapted and enhanced for specific applications and industries. Such universal instruments are widely used in specialized fields of technology. Therefore, this article focuses on the modernization of transistor testers through both software and schematic approaches. The proposed device enables the measurement of the values and pin configurations of active and passive components, measurement of DC voltages, detection of frequencies of simple and pulse-width modulated signals, and transmission of pulse signals. Additionally, it allows for contactless detection of ALS (Automatic Locomotive Signaling) coded signals on railway automatic block sections, thereby determining the operational status of those sections.*

Keywords: *transistor tester, microcontroller, connector, pin, UMD-1 universal measuring device, automatic locomotive signaling, coded signal.*

1. INTRODUCTION

In the design, assembly, and repair of radio-electronic components, various measuring instruments and reference materials (datasheets) are often required. In the past century, specialists in the field of electronics improved measuring instruments to enhance the accuracy of measurements for semiconductor components. For instance, a transistor tester was developed for measuring semiconductor elements.

Up to the present day, transistor testers are not only capable of measuring semiconductor radio-electronic elements but can also recognize and measure passive, active, and various combined components such as sensors and others. Moreover, in practical applications, digital multimeters are widely used to measure constant and alternating voltages and currents, capacitor capacitance, resistor resistance, frequency, and ambient temperature.

When comparing a multimeter to a transistor tester, the multimeter cannot identify the pinout of radio-electronic components, nor can it detect the parameters of certain electronic or complex combined components. Additionally, it may result in measurement losses.

2. RESEARCH OBJECTIVE

At present, the concept and design of the widely used transistor tester based on AVR microcontrollers belong to Markus Frejek and Karl-Heinz Kübbeler, who named it "AVR Transistor Tester with Minimal Additional Components" [3]. The latest versions of transistor testers are built on microcontrollers from the ATmega family, including ATmega8, ATmega168, ATmega328, ATmega644, ATmega1284, ATmega1280, and ATmega2560. These devices are designed to expand measurement capabilities, detect and identify simple and complex radio-electronic components, and implement other useful features [2].

In this regard, the main objective of this research is to improve the transistor tester based on the ATmega328 microcontroller. The enhancement aims to measure the values of active and passive components in measurement units, determine their pin configurations, measure direct current voltage, detect the frequencies of simple and pulse-width modulated signals, transmit pulse signals, and enable contactless detection of ALS coded signals in railway block sections.

3. RESEARCH METHODS

The research results are explained chronologically, from the transistor tester to the level of a universal measuring device. According to the project by Markus Frejek, the circuit was assembled based on the ATmega8 microcontroller. The disadvantages of this circuit include high current consumption, low computational speed for specific tasks, lack of protection against interference from the power source, and no battery charge level indicator (if connected to a battery) (Figure 1).

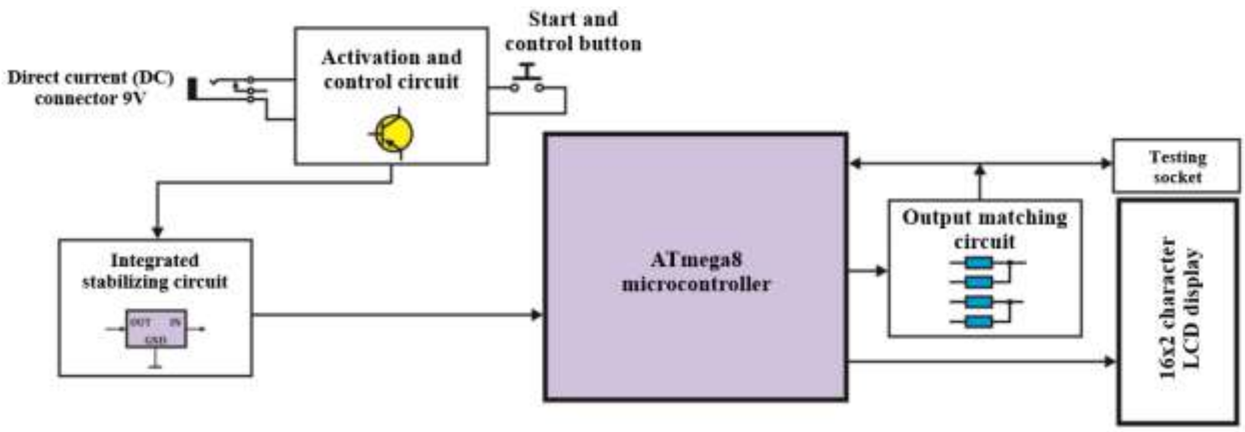

Figure 1. The Structural Diagram of Markus Frejek's Transistor Tester

In the improved transistor tester of the *"LCR-T4 Nostripgrid"* type, the shortcomings mentioned above were addressed through the following electrical circuit solutions: automatic shutdown control, interference-protection RC circuit, "Battery Discharged" indicator, integrated stabilization, a button for startup and control, output matching, increased measurement speed, detection and identification of simple and complex radio-electronic components, and an in-system programming (ISP) port (Figure 2) [2, 3].

During continuous use of the tester, excessive power consumption was observed, especially when the tester was left powered on. This issue was resolved by implementing an automatic standby mode. Additionally, it was found that in standby mode (with the microcontroller in low-power operation), the voltage regulation circuit's integrated stabilization consumed 3 mA of current, which could completely discharge the battery within a week. To eliminate this problem, an automatic shutdown control circuit was connected to the 9V voltage regulation circuit. As a result, the tester's standby current consumption was reduced to approximately 10 nA (0.01 µA or 0.00001 mA). This circuit enables automatic transition to standby mode within 10 seconds. Thus, the issue of excessive power consumption was successfully resolved through a schematic solution [3].

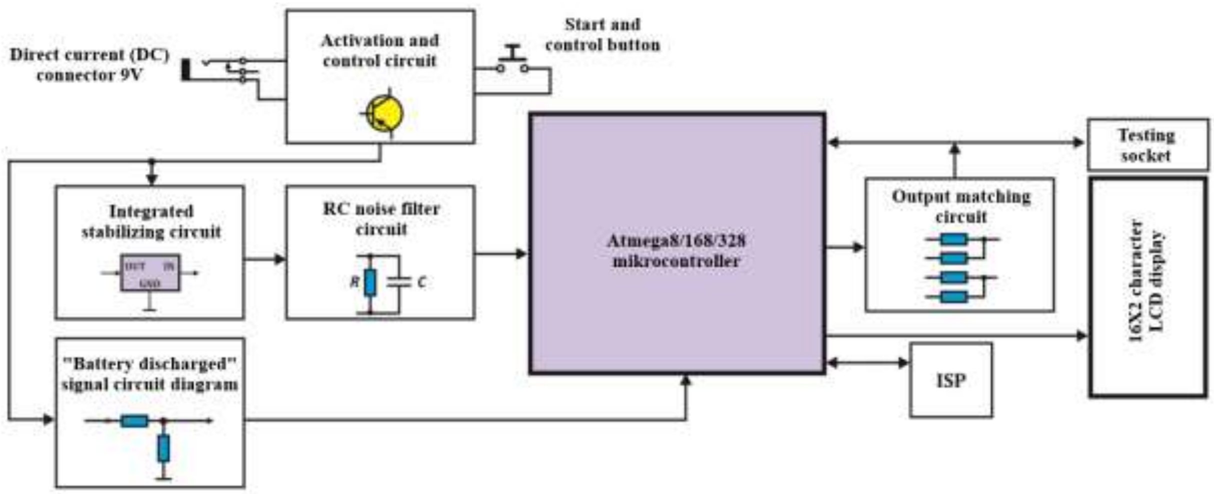

Figure 2. Structural Diagram of the "LCR-T4 Nostripgrid" Type Transistor Tester

The automatic shutdown circuit is sensitive to electromagnetic interference; therefore, to prevent the tester from being accidentally triggered by external disturbances, an interference-protection RC circuit was connected to the system. If the transistor tester is powered by a battery, a power supply control circuit and a voltage monitoring system were integrated to detect when the power supply voltage drops below a permissible level – in such cases, the LCD monitor displays a "Battery Discharged" warning via a signaling circuit. To ensure stabilized power for the device, an integrated voltage regulation circuit was connected for both the microcontroller and the LCD monitor. In the schematic diagram shown in Figure 2, an Atmega328p microcontroller is used, providing high-speed measurement operations and enabling reprogramming via the ISP (In-System Programming) port [3, 4–6].

In order to further expand the functionality of the "LCR-T4 Nostripgrid" type transistor tester, the following schematic solutions were developed (Figure 3):
– A rotary incremental encoder and its control circuit were added for smooth and efficient control of the instrument's menu;

– a DC voltmeter circuit capable of measuring up to 100 V was implemented;

– a frequency meter circuit capable of measuring signals within a 1 Hz ÷ 8 MHz range was added;

– a pulse width modulation (PWM) signal generator was integrated;

– a universal connector was added for connecting various types of radio-electronic components;

– a protection circuit based on the SRV05-4 component was integrated to shield the microcontroller from high currents and voltages;

– a rechargeable battery system equipped with a charging unit was introduced.

This upgraded transistor tester, featuring all of these new functionalities, was named the UMD-1 Universal Measuring Device. The device can now perform not only passive and active radio-electronic component measurements, but also act as a DC voltmeter (up to 100 V), a frequency meter for signals up to 8 MHz, and supports connecting DIP, DPAK, and SMD-sized components via its universal connector.

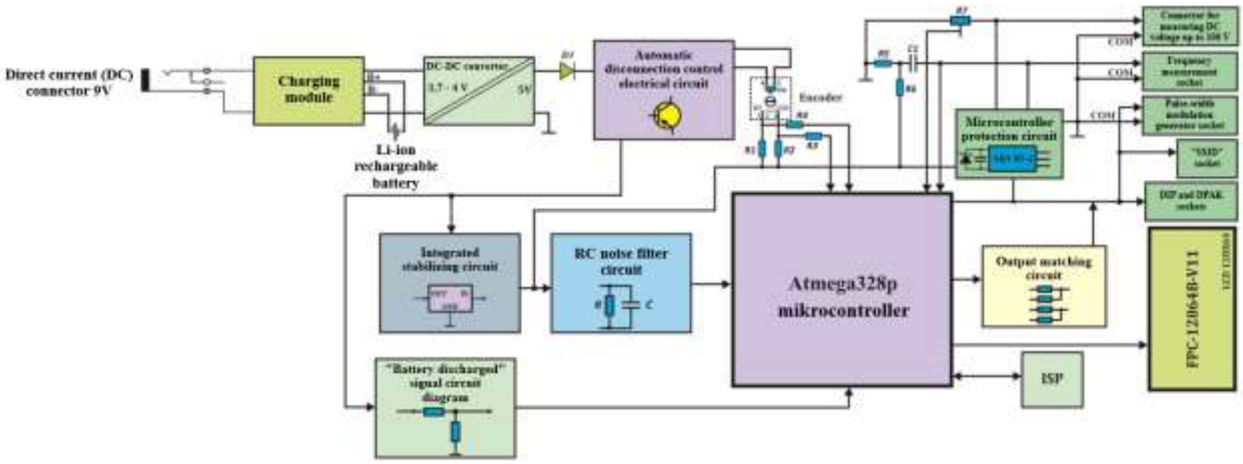

Figure 3. Structural Diagram of the "UMD-1" Type Universal Device

As mentioned above, to solve the issue related to power consumption, a rechargeable battery source and a voltage converter are integrated into the system. It includes a lithium-ion battery with parameters of 3.7 V and 1200 mA, a DC-DC converter that steps up the 3.7 V voltage to a stable 5 V, and a D1 semiconductor diode designed to limit excessive input current and protect against short circuits.

4. RESEARCH RESULTS

Measurement operations in the units mentioned above are performed on devices widely used in most technical control fields. Additionally, in railway transport, these devices are critically important during the installation, testing, and maintenance of automation and telemechanics microelectronic or microprocessor-based control systems.

Let's examine the application of the "UMD-1" type universal device in the railway automatic block signaling (ABS) system. To increase throughput capacity, ensure safety on mainline railway tracks, enhance operational efficiency, and improve working conditions for railway staff, automation and telemechanics equipment is employed. These include integrated train traffic regulation devices, among which the ALS (Automatic Locomotive Signaling) system is particularly significant.

The ALS system comprises trackside transmitting devices, receiving and decoding devices installed on rolling stock, and various interface devices that connect ALS equipment with other signaling, interlocking, indicator, sensor, and executive mechanisms within the train. The ALS system transmits information from the railway track to the locomotive. Depending on the information transmission method, all ALS systems are divided into point-type (**ALPS**) and continuous-type (**ALCS**) automatic locomotive signaling systems. According to their operating principle, ALSN systems can be mechanical, optical, contact-based, or inductive. Inductive systems are further divided into those with a trackside source and those with an onboard source; and trackside source systems are differentiated by whether they operate on direct or alternating current. Continuous ALS systems, on the other hand, can be electro-contact, inductive, radio-relay, or radar-based. **ALPS** systems are also divided by frequency into low- and high-frequency inductive systems [1, 7, 8].

Currently, on Uzbekistan’s railway lines, **ALCS** is used only within station limits, while **ALPS** systems are applied in block section areas. Since the primary part of a railway is composed of block sections, research efforts have been mostly concentrated on these segments.

All devices within the **ALCS** system are categorized as trackside (transmitting) and onboard (receiving) equipment. Trackside devices are located in relay cabinets near track signals and consist of a coded transmitter and a transformer (Figure 5). The transmitter converts the track signal’s light indication into a corresponding coded impulse combination – that is, it periodically sends alternating current electrical signals (codes) with specific numbers of impulses, precise pause durations between impulses, and distinct impulse series within the rail circuit [1, 7, 8].

The signals received by the locomotive’s onboard signal repeater correspond to the following track signal indications as the train approaches:

- Green signal – permission to proceed (the upcoming track signal is illuminated green);
- Yellow signal – permission to proceed (the upcoming track signal shows one or two yellow lights);
- Yellow with Red (or flashing) – permission to proceed but prepare to stop (the next track signal shows a red light) [1, 7, 8].

Three different coded combinations of impulses and intervals are used by the transmitter. Structurally, the transmitter is designed in the form of an electric drive with a shaft carrying three coded disks that sequentially open and close contact circuits in a predetermined code sequence. Based on the track signal indication, a signal relay connects the coded track transmitter to corresponding contacts within the rail circuit. Figure 4 illustrates all three code types produced by the transmitter, along with their impulse sequences and interval timings. The full cycle duration (one complete revolution of the transmitter shaft) is 1.5 seconds.

When the track signal shows a Green indication (Code “G”), the train receives three impulses and three intervals via the locomotive's onboard repeater, followed by a pause with no impulses. At the beginning of the cycle, alternating current impulses arrive for 0.35 seconds, followed by a 0.12-second interval, then another impulse for 0.22 seconds, another interval, and then impulses for another 0.22 seconds, after which there's a 0.57-second interval with no impulses [1, 7, 8].

When the locomotive approaches a Yellow signal (Code "Y"), the repeater receives two consecutive impulses each lasting 0.38 seconds, separated by a 0.12-second interval, followed by a 0.72-second interval.

A Yellow-Red (flashing) signal (Code "Y-R") consists of two impulses, each lasting 0.23 seconds, separated by two intervals each lasting 0.57 seconds [9].

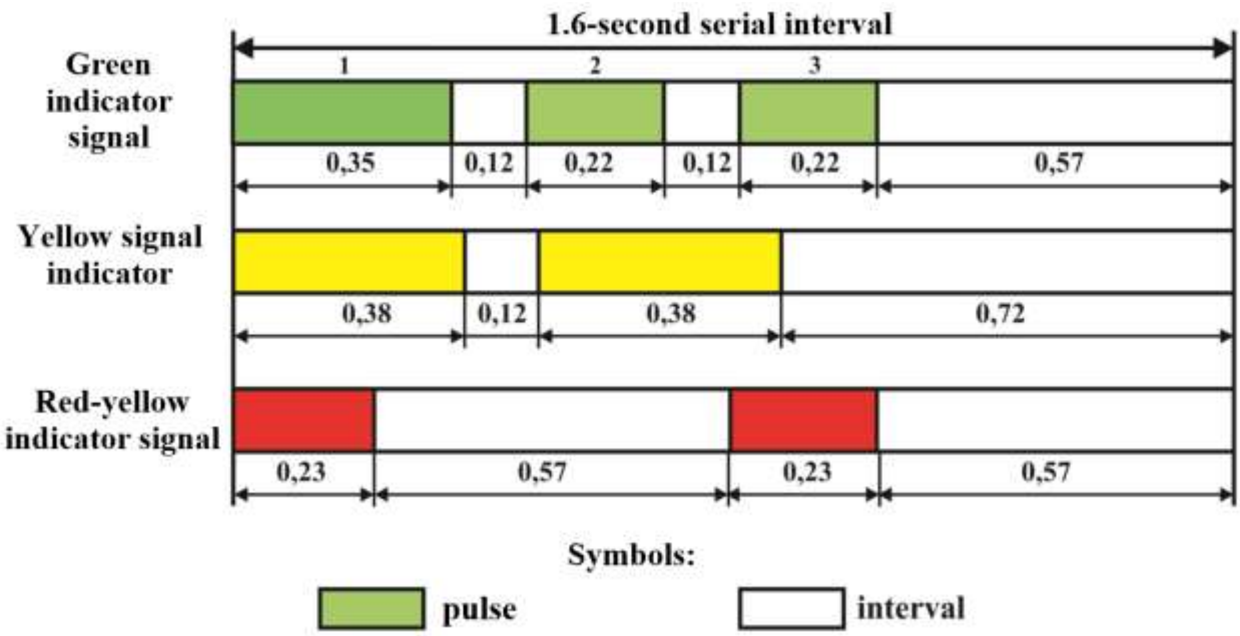

Figure 4. ALCS code diagram [9]

After installing track devices on new railways and on existing devices, including the ALS system, maintenance involves testing the block sections. To date, various measurement methods have been used to identify ALS codes. One method for detecting ALS code signals from the rails is carried out using an analog tester of type Ts-4317. For this, the analog tester is switched to voltmeter mode, and its measuring leads are connected to the rail. The movement of the pointer on the measurement scale is then observed. If the pointer slowly moves toward the maximum limit of the scale and then returns to its original position, the "R-Y" code is considered received; if the pointer quickly moves twice and returns to the starting position, the "Y" code signal is received; similarly, if the pointer moves quickly three times and returns, the "G" code signal is considered received. This behavior corresponds to the **ALCS** signal codes changing according to their intervals, as illustrated in Figure 4.

A drawback of this method is that the analog tester may malfunction (digital multimeters cannot detect coded signals in rail circuits), and in electrified railway sections, interruptions in the choke transformer circuit of the rail circuit can cause incorrect or unclear interval code signals, leading to difficulties when using these measuring instruments.

To overcome these shortcomings, a set of instruments for detecting **ALCS** coded signals has been developed. Figure 5 shows a classic schematic designed to generate **ALCS** codes, which is part of the ALS system. The ALS system mainly consists of the following device sets: choke transformer, coding circuit, coded signal transformer, and transmitter relay T. The instrument set for detecting **ALCS** coded signals includes: a receiving coil, filter, amplifier, and a universal device of type "UMD-1."

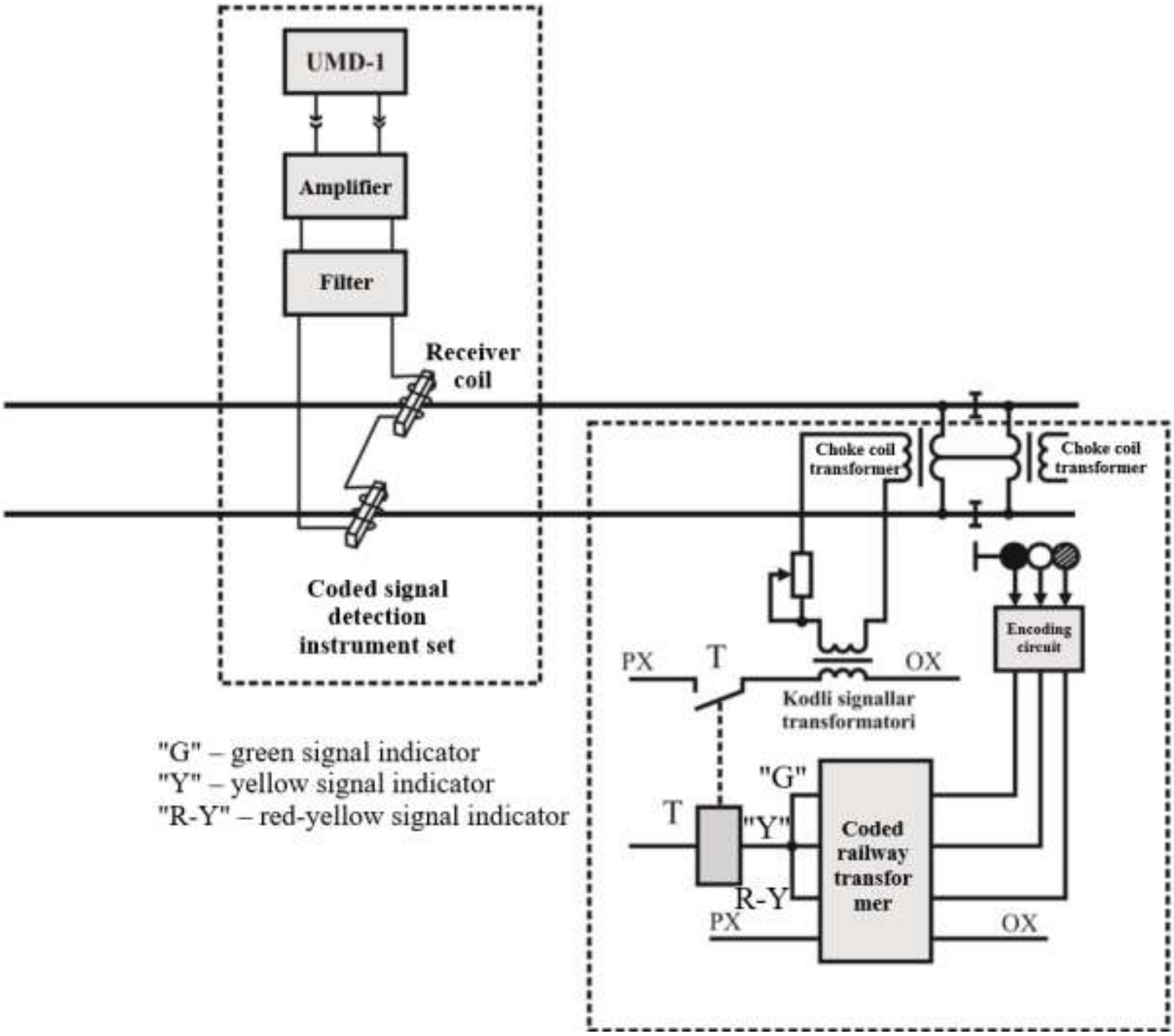

Figure 5. Schematic of the "UMD-1" universal device application with additional equipment for identifying ALCS codes

To test **ALCS** coded signals on new or existing railway sections, an instrument set can be used as an additional or primary device for detecting coded signals. Signal reception from rail circuits is performed through the receiving coil. Coded signals received in the form of electrical impulses are processed by the filter. The filter isolates one of the **ALCS** codes. It is adjusted to extract coded signals from distorted signals. The amplifier amplifies the coded signals and transmits them to the "UMD-1" device via terminals.

The "UMD-1" device receives the signals, counts the **ALCS** coded signal, and displays it on the device monitor. To ensure the reliability of the received coded signal indication, the device checks the signal several times (within 6–8 seconds) and processes it according to a pre-programmed algorithm sequence.

5. CONCLUSIONS

Thus, the modernized transistor tester based on the ATmega328 microcontroller ("UMD-1" universal device) possesses the following capabilities, features, and advantages: an automatic break control circuit, an integrated stabilizer, a signal generator, fast and smooth control through an incremental encoder circuit, frequency measurement from 1 Hz to 8 MHz, protection of the microcontroller from high currents and voltages, a DC voltmeter up to 100 V, measurement and pinout identification of active, passive, and combined electronic components, a charging module and a variable voltage accumulator power source, as well as a universal connector for attaching radioelectronic components in DIP, DPAK, and SMD packages. Based on the research, a set of instruments for contactless detection of **ALCS** coded signals was developed. This device is portable, easy to use, designed for operation inside buildings and in open railway areas, and is securely mounted on a lightweight structure isolated from the rails.

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