

Development of the structural diagram of the device, selection and justification of its primary elements

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Abstract: *The article presents the structural diagram of an automated device designed to protect the window and door openings of buildings of categorized facilities during mass riots, and justifies the selection of its primary elements. The device consists of sensor, control, actuator, data transmission and data display units, as well as a manual control panel. Based on a comparative analysis of the Arduino and Raspberry Pi platforms, the Arduino UNO board based on the ATmega328P microcontroller was selected owing to its real-time operation, low power consumption and simplicity. The technical specifications of the vibration (801S) and infrared (MH-SR602) sensors, gear motors, the LM016L display, the buzzer, the AC-DC power supply unit, the LM2596 voltage regulator, the relay module and the switching elements are presented, and their functions within the device are substantiated. The proposed solution makes it possible to automatically lower armored shutters when an external impact is detected and to alert the operator via a radio channel.*

Keywords: *mass riots, categorized facility, engineering and technical protection, automated device, structural diagram, Arduino UNO, ATmega328P, vibration sensor, infrared sensor, armored shutter*

Introduction

The absence of automated means of protecting the window and door openings of a building during mass riots or other dangerous situations creates serious problems in ensuring security. The lack of means for rapidly increasing the level of protection considerably complicates ensuring the safety of people inside the building, directing them to safe areas and protecting them from threats.

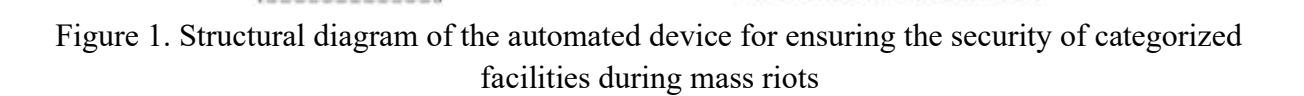
As a solution to this problem, an initial prototype of the “Automated device for ensuring the security of categorized facilities during mass riots” has been developed, which improves the engineering and technical protection systems of categorized facilities and makes it possible to prevent organized threats to buildings. The device operates using the computer program “Device for ensuring the security of buildings of categorized facilities during mass riots” [1]. The purpose of this article is to develop the structural diagram of the device and to justify the selection of its primary elements.

1. Structural diagram of the device

The structural diagram of the device is shown in Figure 1; it consists of five interconnected units and a manual control panel.

The sensor unit consists of infrared and vibration sensors. The sensors are installed at the entrance door or window area; in response to an external impact (movement in front of the building, throwing of various objects) they generate an alarm signal and transmit it to the control unit.

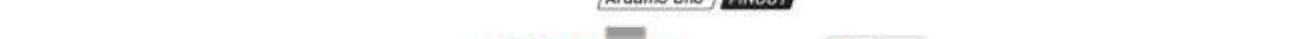
The control unit (ATmega328P microcontroller) processes the data received from the sensors, issues a command to the servo drive of the actuator unit to lower the armored shutter, and sends a message about the external impact to the data transmission unit.



2. Selection of the control platform

At present, the Arduino and Raspberry Pi platforms are widely used to solve automation tasks. The

The main boards of the Arduino family are: UNO (standard size, 20 inputs/outputs), Nano (small



The board is built on the ATmega328P microcontroller (AVR architecture). It is powered via a USB cable, an AC/DC adapter (2.1 mm connector with a positive center pin) or a rechargeable battery (Vin and GND pins). If the voltage is below 7 V, the board may operate unstably; if it exceeds 12 V, the voltage regulator may overheat. The board supports the UART (0 - RX, 1 - TX), I²C (TWI) and SPI interfaces; the on-board ATmega16U2 chip routes UART over USB to a virtual COM port. A fuse protecting the USB port from short circuits breaks the contacts at currents exceeding 500 mA. The main specifications of the platform are given in Table 1 [2, 3].

Table 1

Main technical specifications of the Arduino UNO board

Parameter	Value
Microcontroller / architecture	ATmega328P / 8-bit AVR
Operating voltage	5 V
Input voltage (recommended / limit)	7–12 V / 6–20 V
Digital inputs/outputs	14 (6 of which are PWM)
Analog inputs (ADC)	6 (A0–A5)
Maximum current per input/output	40 mA
Clock frequency	16 MHz
Flash memory / SRAM / EEPROM	32 KB (0.5 KB bootloader) / 2 KB / 1 KB
Interfaces	UART, I ² C (TWI), SPI, USB
Voltage regulator outputs	5 V (1 A), 3.3 V (150 mA)
Board dimensions	68.6 × 53.4 mm

The logic high level of the board's inputs/outputs is 5 V and the logic low level is 0 V; the pull-up resistors connected to the pins are initially disconnected and can be enabled in software. The analog inputs represent an analog voltage in digital form, while the PWM outputs generate an analog voltage from digital values in the form of a PWM signal. The functions of the platform pins are given in Table 2.

Table 2

Functions of the Arduino UNO pins

Pin designation	Function
VIN	Input for connecting an external voltage source in the range of 7-12 V
5V	5 V, 1 A regulator output; powers the microcontroller and peripherals
3V3	3.3 V, 150 mA regulator output
IOREF	Informs expansion boards of the microcontroller's operating voltage
AREF	Connection of an external reference voltage for the ADC in analogReference(EXTERNAL) mode
GND	Ground pin
General-purpose pins (0-19)	Digital inputs/outputs (logic 1 - 5 V, 0 - 0 V)
ADC (A0-A5 / 14-19)	Conversion of analog voltage into digital form
PWM (3, 5, 6, 9, 10, 11)	Output of analog voltage from digital values in the form of a PWM signal
I ² C, SPI, Serial/UART	Communication with expansion boards and sensors via the corresponding interface

3. Elements of the actuator unit

The W2-1 12V gear motor (2 pcs.) was selected to drive the armored shutters, and the 130-3 6V gear motor was selected for the pneumatic device. Gear motors reduce speed and increase torque, which is why they are widely used in robotics and various moving mechanisms. The gear mechanism of both models is made of metal, which increases their reliability, load resistance and service life. The main specifications are given in Table 3.

The main advantages of the 130-3 6V model are its small dimensions, compatibility with low-voltage systems, high energy efficiency and continuous operation. The W2-1 12V gear motor operates in the 6-12 V range and produces sufficient torque to lower and raise the shutter. The motors are controlled via a relay module, and the end positions of the shutter are detected by microswitches.

Table 3

Technical specifications of the gear motors

Parameter	W2-1 12V	130-3 6V
Rated voltage	12 V DC	6 V DC
Operating voltage range	6–12 V	3–6 V
Output speed	110 rpm	110 rpm (at 6 V)
Output torque	~0.8 kg·cm	~0.8 kg·cm (at 6 V)
Current consumption	-	~100 mA (no load), ~500 mA (under load)
Dimensions / weight	-	70×22×18 mm / 30 g

4. Elements of the sensor unit

The 801S vibration sensor is intended for detecting external impacts of a vibrational nature on the facility (blows, thrown objects). The main element of the sensor is a flexible metal spring located inside a plastic tube, which begins to vibrate under any impact. The signal is amplified by an operational amplifier and fed to the analog output. An on-board potentiometer allows the sensitivity and triggering threshold to be adjusted. The sensor has three pins: GND, power supply and the A0 analog signal output.

The MH-SR602 infrared (PIR) sensor detects motion by registering the infrared radiation emitted by the human body. It is distinguished by high sensitivity, low power consumption, compact size and easy connection to Arduino, and is therefore widely used in automatic lighting, alarm, “smart home” and industrial automation systems. Since the sensor has no light sensor, it operates both day and night; it is not recommended to point it directly at sunlight, heat sources or air currents. The specifications of both sensors are given in Table 4.

Table 4

Technical specifications of the sensors

Parameter	801S vibration sensor	MH-SR602 (PIR) sensor
Supply voltage	3–5 V	3.3–15 V (optimal 5 V)
Current consumption	4–5 mA	20 mA
Output	Digital or analog (A0)	High level 3.3 V / low 0 V
Detection range	Contact (vibration)	Max. 5 m (recommended 0–3.5 m)
Signal hold time	–	From 2.5 s to 1 h (factory default: 2.5 s)
Blocking time	–	2 s
Sensitivity adjustment	Via potentiometer	By replacing a chip resistor

5. Elements of the data display unit

The LM016L LCD display is based on the Hitachi HD44780 controller: the controller receives commands and forms the corresponding characters on the screen. Its main specifications are: format - 16×2 characters, dimensions - 80×36 mm, character size - 4.35×2.95 mm, blue backlight with white characters, operating temperature - 0...+50 °C, supply - 5 V. The LiquidCrystal library in the Arduino IDE considerably simplifies working with the display.

The loudspeaker (buzzer) is a piezoelectric sound source housed in an enclosure and used for audible indication. Since it consumes 10-30 mA, it is connected directly to an Arduino digital output through a 100 Ω current-limiting resistor.

6. Power supply elements

A 12 V, 5 A AC-DC power supply unit was selected to provide the device components with stable electrical power. It converts 220 V alternating current into 12 V direct current and protects the device from overload and short circuit by means of a built-in protection circuit. The LM2596 DC-DC step-down (buck) switching regulator is used to obtain the low voltage required for the control and sensor circuits. It operates at a frequency of 150 kHz, which allows the use of small filter components [4]. The regulator has an efficiency of up to 92 % and maintains the output voltage with an accuracy of ±0.5 % even when the load or input voltage changes; at power levels above 10 W an additional heat sink is required. The specifications are given in Table 5.

Table 5

Technical specifications of the power supply elements

Parameter	AC-DC unit (12 V, 5 A)	LM2596 DC-DC regulator
Input voltage	110–240 V AC	3.2–35 V DC
Output voltage	12 V (adjustable)	1.25–35 V (adjustable)
Output current	5 A (max.)	2 A rated, 3 A max.
Power / efficiency	60 W	Efficiency up to 92 %
Output ripple	–	< 30 mV
Protection	Overload, short circuit; IP20	Current limiting
Operating temperature	–	–45...+85 °C
Dimensions	110×78×38 mm	43×21×14 mm

7. Switching elements

The relay module (4 channels, 5 V) enables safe control of high-power electrical devices (gear motors) through a low-voltage control circuit. The control circuit is galvanically isolated by an optocoupler, and the state of each channel is indicated by an LED. The module is compatible with platforms such as Arduino, Raspberry Pi and STM32.

1 kΩ resistors are used in the electrical circuit to limit current, divide voltage and ensure matching between elements; they are the most commonly used passive components in electronic devices.

The KW11-3Z-2 microswitch is a fast-acting, small-sized roller lever switch intended for automatic control of electrical circuits. It is distinguished by high durability and easy installation, and in the device it detects the end positions of the shutter. The rocker switch (REXANT RWB-201, 250 V, 6 A, ON-OFF) has two latching positions and serves to switch the entire device on and off. The specifications of the switching elements are summarized in Table 6.

Table 6

Technical specifications of the switching elements

Element	Main specifications	Function
Relay module (4 channels, 5 V)	5 V DC; ~20 mA per channel; switching 10 A (30 V DC / 220 V AC); optocoupler isolation; COM/NC/NO; 71×53×17 mm	Control of motors and high-power circuits
Resistor 1 k Ω (5 pcs.)	0.25 W; ± 100 ppm/°C; $\varnothing 2.4 \times 6.3$ mm	Current limiting, voltage division
Microswitch KW11-3Z-2	AC 125 V, 5 A; SPDT (1NO, 1NC, 1COM); roller lever; 20×6×10 mm; 2.2 g	Detection of shutter position
Rocker switch REXANT RWB-201 (ON-OFF)	250 V, 6 A; contact resistance ≤ 35 m Ω ; IP30; $-25 \dots +85$ °C; 10,000 cycles	Switching the device on and off

The selected main components of the device are shown in Figure 3.



Figure 3. Main components of the device

Conclusion

A structural diagram of the automated device for ensuring the security of categorized facilities during mass riots has been developed, consisting of sensor, control, actuator, data transmission and data display units. Based on a comparative analysis, the Arduino UNO (ATmega328P) platform, which operates in real time, consumes little power and is easy to program, has been justified as the control unit.

The combined use of vibration and infrared sensors makes it possible to detect external impacts by both contact and remote methods. The selected gear motors, power supply and switching elements provide automatic and manual control of the armored shutters, while the radio channel, display and buzzer ensure prompt notification of the operator. The developed prototype is of practical importance for enhancing the engineering and technical protection of categorized facilities.

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