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THE SYSTEM OF COUNTERACTION TO UNMANNED AERIAL VEHICLES

Nataliia Lishchyna, Valerii Lishchyna, Yuliia Povstiana, Andrii Yashchuk

Lutsk National Technical University, Faculty of Computer Science and Information Technology/Computer Technology and Vocational Education Department, Lutsk, Ukraine

Abstract. In the article, the development of a system of counteraction to unmanned aerial vehicles is considered. A way to counteract unmanned aerial vehicles is described. The analysis of parameters of the system and its constituent parts is carried out. The structural scheme of the system, functional and principle schemes of subsystems on the basis of Arduino are described.

Keywords: unmanned aerial vehicles, control, Arduino, ultrasonic sensor

SYSTEM PRZECIWDZIAŁANIA BEZZAŁOGOWYM STATKOM POWIETRZNYM

Streszczenie. W artykule przedstawiono opracowanie systemu przeciwdziałania bezzałogowym statkom powietrznym. Opisano sposób walki z bezzałogowymi statkami powietrznymi. Przeprowadzono analizę parametrów systemu i jego części składowych. Opisano schemat strukturalny systemu, schematy funkcjonalne i podstawowe podsystemy zrealizowane na bazie platformy Arduino.

Słowa kluczowe: bezzałogowe statki powietrzne, sterowanie, Arduino, czujnik ultradźwiękowy

Introduction

Unmanned aerial vehicles (UAVs) have long been usual all over the planet. They have the ability to deliver goods, perform aerial photography, investigate the composition of the atmosphere and weather conditions, they are used by correspondents, scientists, rescuers, and military personnel to access remote locations, navigate on the ground, etc.

As demand grew, the offer of cheap low-capacity aircraft grew too, they are freely available and their use, as well as security requirements, is almost not regulated. There is no guarantee that no accidental or deliberate injury of people or damage of property may occur during their use. The concern about the use of UAV in terrorist acts has been hanging over special services for several decades. With diminishing dimensions and increased mobility of UAVs, countermeasures must be even more mobile and compact [5].

In this article the result of the research of counteraction to unmanned aerial vehicles by using a sensor trigger control system is submitted. The system should provide sufficient precision with no significant effect on radio frequencies and third-party devices.

The purpose of the work is to describe the set-up and research the system of counteraction to unmanned aerial vehicles.

1. Samples and research methods

The use of unmanned aerial vehicles already has a history of over a hundred years. Civilian unmanned aerial vehicles are not used for so long and their characteristics are more limited. They are categorized according to engine-to-engine diagonal dimensions, without anti-interference systems and not taking into account an altitude. The size usually corresponds to the functionality [1].

For example, in the United States, the Federal Aviation Administration prohibits unmanned aerial vehicles, including unprofessional, flying above 400 feet.

Of course, such strict rules make it impossible to commercially use UAVs, for example, delivery of goods can not be done more than 500 meters from the warehouse. Therefore, the search for alternatives to this conflict of interest has begun. So the British Pilot Association (BALPA) urges that the drone should be programmed to prevent flying into a certain airspace. A series of Phantom drones produced by DJI already has this feature. Unmanned aerial vehicle systems have coordinates of thousands of airports around the world. They can not fly into these zones.

However, there are older models without this function, models that do not use GPS or bypass protection, as well as homemade unmanned aerial vehicles from amateur radio enthusiasts.

The sequence of stages of counteracting the drones is determined: identify, recognize and destroy. To simplify and bring it to automatism, any object that has fallen into the field of view of

the system sensors is considered to be an unmanned aerial vehicle. Therefore, the system for the convenience of development and testing is divided into 2 subsystems, namely, the sensory subsystem that is responsible for locating the UAV and the subsystem responsible for creating interference [3].

The sensor subsystem is most easily built on the basis of Arduino (Fig. 1), a platform that supports most of the principles and approaches of free and open source software (Fig. 2).

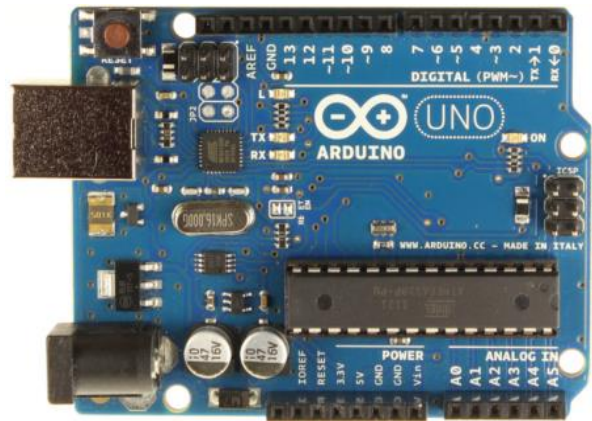


Fig. 1. Arduino Uno R3

The main components are the microcontroller board with I/O elements and the Processing/Wiring development environment with the programming language, which is a simplified subset of C/C++. Arduino can be used both to create stand-alone interactive objects and to connect to software, running on a computer (for example: Processing, Adobe Flash, Max/MSP, Pure Data, SuperCollider).

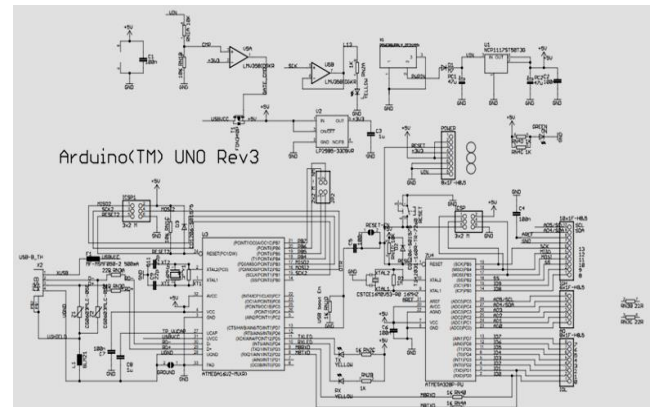


Fig. 2. Arduino uno Rev3 scheme

The platform freely releases its equipment in the form of Eagle CAD design files, licensed under the Creative Commons Attribution Share-Alike license, which allows both personal and commercial derivative works to be used if they are accredited to Arduino and are issuing their projects under the same license. The Arduino software is also open source. The source code for the Java environment is released under the GPL, and the C/C++ microcontroller libraries are under the LGPL created for the rapid and easy development of a variety of electronic devices.

The microcontroller on the board is programmed using the Arduino programming language and the Arduino integrated development environment. Programming does not require a programmer hardware, the program is uploaded through the USB port.

The framework itself is derived from the Wiring-open-source framework that allows you to write cross-platform software for managing devices attached to a wide range of microcontroller boards to create interactive objects. In fact, the language of Arduino is just a set of C/C++ functions that can be called directly from the code, although the sketch undergoes minor changes, and then transmits directly to the C/C++ compiler (avr-g++).

Arduino Uno is a device based on the ATmega328 microcontroller, which is a microcontroller created by Atmel and belongs to the megaAVR family. It has a modified 8-bit processor core in Reduced Instruction Set Computing (RISC). RISC is a processor architecture with limited set of commands, also known as "Load/Store architecture", since the command system of such an architecture does not include arithmetic logic operations with operands in memory. For any data processing, they should first load into the register, perform the necessary operations, and then store back into memory [2].

Using the `pinMode()`, `digitalWrite()` and `digitalRead()` functions, each of the 14 digital outputs can work as an input or output. The voltage level at the terminals is limited to 5V. The maximum current that can give or consume one output is 40 mA.

The Arduino system supports analog signal processing. For input signals, the system has an ADC (analog-to-digital converter), in the case of an output signal the modulation of PWM (pulse-width modulation) is possible.

In Arduino, the core of which is the Atmega microcontroller, there is one 10-bit ADC. This means that the voltage value can be in the range from 0 to 1023. Depending on the reference voltage, 1024 values will be allocated to the appropriate range. As the result, we can obtain different accuracy and different voltage range readable by analog-to-digital converter.

Arduino Uno provides a number of features for communicating with a computer, another Arduino or other microcontrollers. The ATmega328 has a UART receiver that allows serial communication with digital outputs 0 (RX) and 1 (TX). The ATmega16U2 microcontroller on the board provides the connection of this receiver to the computer's USB port, and when connected to the PC, Arduino can be defined as a virtual COM port. The 16U2 chipset uses standard USB-COM drivers, so no external drivers are required. On the Windows platform, only the .inf file is required. The Arduino software package includes a special program that allows you to read and send simple text data to Arduino [2].

The Software Serial Library makes possible the implementation of serial communication on any Arduino Uno digital outputs.

2. Results and discussion

In general, most unmanned aerial vehicles use Wi-Fi frequencies. The Wi-Fi signal is referred to as radio waves, and accordingly, it has the same properties, characteristics, and behavior. Radio waves are subject to practically the same physical laws as light: propagate in space with the same speed, they are subject to diffraction, absorption, attenuation, dispersion, etc [6].

The main characteristics of the radio wave, and hence the Wi-Fi signal, are its length and frequency (frequency range).

Currently Wi-Fi access points and Wi-Fi antennas of 2.4 GHz and 5 GHz are most often used. Unlike 5GHz, at 2.4 GHz, the wavelength is 12.5 cm. Among the advantages there is excellent overcoming of small obstacles, for example, dense forests, due to good penetrating ability and obstruction of obstacles. Among the disadvantages is the additional noise of the ether by other devices operating at the same frequency [4].

The mute of the signal by jammer is not a completely legitimate method of fighting the UAV, but you can use other devices operating at the same frequency. The most compatible in terms of frequency overlays is the use of the generator of high-frequency electromagnetic waves of the microwave range [5].

A magnetron is an electric-vacuum lamp of a special construction in which the electrons move in an additional magnetic field.

The disadvantage of the magnetron is a floating frequency, the advantage is significant power. In radars, for example, the frequency instability is compensated by adjusting the receiver to the frequency of radiation, which is a technically simpler task than maintaining the constant frequency of the transmitter.

By itself, the magnetron is only a part of the system, it requires a transformer, a capacitor, and diodes to provide a voltage.

A transformer is a static electromagnetic device that has two or more inductively coupled windings and is designed to convert one or more alternating current electromagnetic induction into one or more other alternating current voltages without changing the frequency of the alternating current voltage.

The capacitor is a device for collecting charge and energy of the electric field. The capacitor is a passive electronic component. In the simplest version, the design consists of two electrodes in the form of plates (plates) separated by an insulator whose thickness is smaller than the size of the plates. Capacitors for practical use have many layers of dielectric and multilayer electrodes, or alternating dielectrics and electrodes, wrapped in a cylinder or a parallelepiped with four rounded edges. The connection between subsystems is carried out by transmitting a signal on a controlled relay. This relay is powered by a voltage of 5V and is capable of switching to 10A 30V DC and 10A 250V AC.

The relay has two separate chains (Fig. 3.): the control circuit, represented by the pins A1, A2 and the controlled circuit, the pins 1, 2, 3. The chains are not connected in any way.

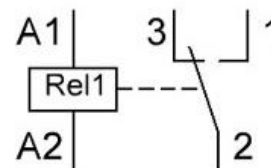


Fig. 3. Scheme of the internal structure of the switch

Between the A1 and A2 pins there is a metal core, when the current flows through it a moving anchor is attracted to it (2). Pins 1 and 3 are fixed.

To control the relay, there are the following components: resistor (R1), p-n-p transistor (VT1), diode (VD1) and the relay (Rel1). Two LEDs are set for display. LED1 is for indication of power supply to the module, LED2 LED indicates relay closing.

When the controller is turned on, the outputs are in high resistance state, the transistor is not open. Since we have a p-n-p type transistor, then in order to open it we need to supply negative current. To do this the function `digitalWrite(pin, LOW)` is used. When the transistor is open the current flows through the control circuit and the relay is triggered. To switch off the relay the transistor need to be closed by supplying positive current to the base with calling the `digitalWrite(pin, HIGH)` function.

The module has 3 outputs (standard 2.54 mm): VCC: "+" power, GND: "-" power, IN: output of the input signal.

The connection of the module is also quite simple: VCC +5 volts on Arduino, GND to any of the GND Arduino pins, IN for any of the Arduino digital inputs/outputs.

As a sensor, a universal sound module is used to detect sound and determine the threshold sound value. The threshold of the operation of the comparator is controlled by a potentiometer.

The process of practical implementation begins with the construction of the principle diagrams of the two subsystems. The design of the sensor subsystem with the switch is made in the Virtual Breadboard environment, represented in Fig. 4.

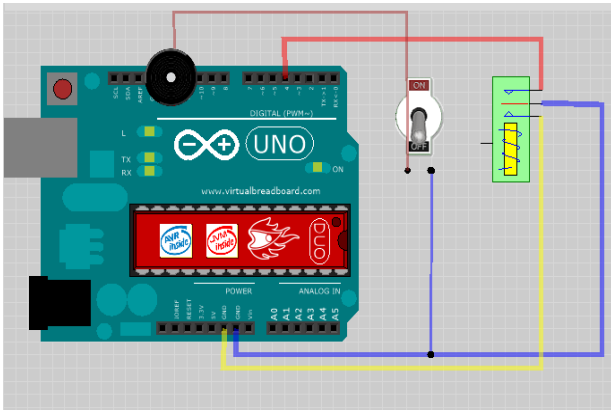


Fig. 4. Circuit diagram of the interconnected subsystems

The next subsystem is a microwave emitter (Fig. 5), which, as already mentioned, should cause interference in connection of an unmanned aerial vehicle with a piloting device.

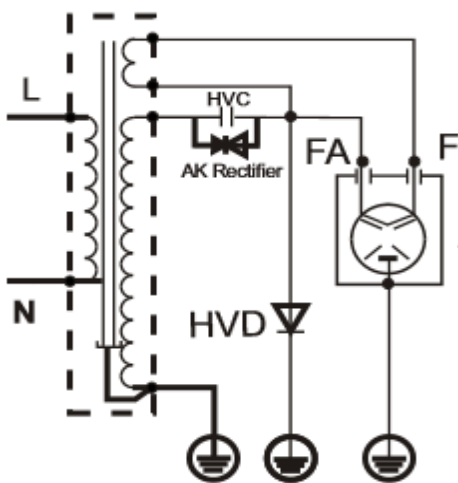


Fig. 5. Schematic of the electric circuit of the second subsystem

As already noted, the subsystem should be made up of a high-voltage transformer, which converts the current, the capacitor that accumulates the charge, and the diode as well as the magnetron, which will cause interference [2].

The subsystem is controlled by a software-controlled relay of the sensor subsystem.

For the practical implementation of the sensor subsystem pin numbers must be selected. So the universal audio module in addition to 5V and GND pins is connected with its digital output to the predetermined and registered pin 7. The connection diagram of the universal audio module is shown in the Fig. 6.

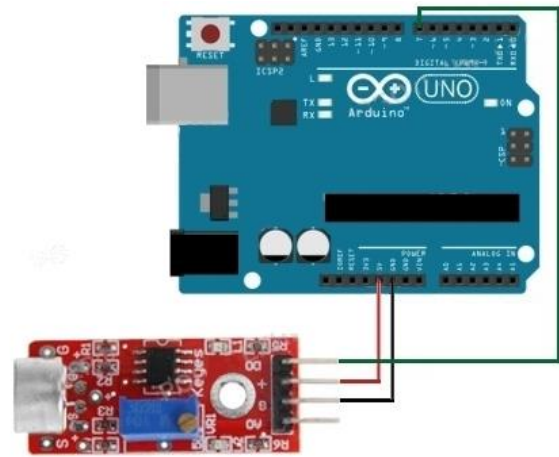


Fig. 6. Schematic of connecting the universal sound module

The piezoelectric element has only 2 pins and does not require extra power. Therefore, it is connected to the pin 8, defined in the program code, and the GND output.

The relay is connected to the 5V, GND pins, and the pin 13, declared in the program code. On the opposite side the so-called wire L and outputs to the transformer are connected to the relay.

The sensory subsystem (intermediate), in addition to the sound sensor and controller, includes a model board, male to female and male-to-male connectors, a USB type/power cable and a power supply. With the preliminary (on the dashboard) serial assembly, the subsystem looks like shown in Fig. 7.

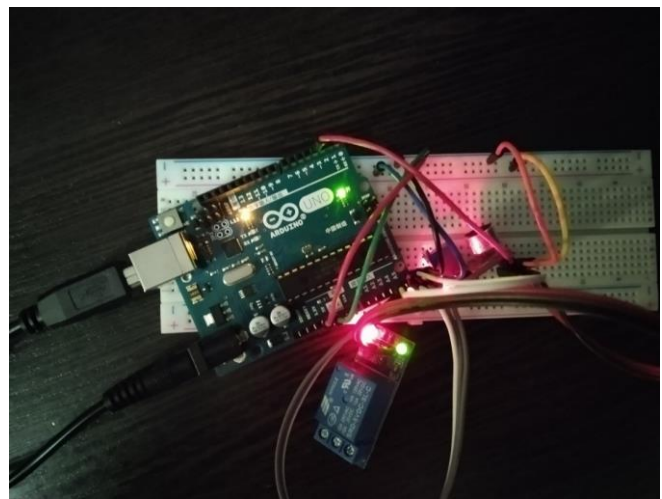


Fig. 7. The sensor (control) subsystem assembled on the breadboard

In the sequential assembling of components, the second subsystem looks like shown in Fig. 8.



Fig. 8. The sequentially assembled second subsystem



Fig. 9. The system of counteraction to UAV, a view from inside

At the very end, the system is powered by a 220V network with a parallel connection of both subsystems. The power supply includes electric plugs with a grounding. It is assumed that the all-electric wires are separated from accessible for touch metal parts by isolation. The metal parts that are accessible to the touch are connected to the clamp or ground connection inside the device. The grounding of metal non-conductive parts is ensured by attaching the plug of the device to a special outlet with a ground connection.

In order to program the board the development environment, drivers of the device, and its connection to a computer are required. The program code may include the additional libraries. When the program code is ready, the name/model of the board and the COM port number from the drop down list in the Tools/Board menu should be selected, and after that, the sketch can be uploaded.

Testing was carried out in order to check the accordance with the parameters of the RAYSUN MD1 system declared by manufacturer. Additionally, debugging testing to check the work of all components was performed, i.e. testing of timing of response and repeated examination of sensors.

Testing and adjusting of the sound sensor occurs in two directions: adjusting the physical resistor to increase/decrease microphone sensitivity and edit timings of pause and recall (in sketches).

As the result of the experimental study of the proposed hypotheses of models and methods is the construction of a system of counteraction to unmanned aerial vehicles. The processed results are listed in Table 1.

Table 1. Comparison of the system of counteraction to UAV efficiency with known analogies

Parameter name	RAYSUN MD1	Investigated sample
Class of protection against electric shock	2	1
Cost of components	-	75 \$
Separate cost of a complete production and testing cycle	-	60 \$
The staff of the developers	-	1
Size [cm]	116 x 33 x 190	56 x 35 x 48
Weight	~6 kg	~10 kg
Voltage of portable power supply	DC 24V	-
Battery capacity	6400 mAh	-
Working temperature	10 – 55 deg	10 – 60 deg
Relative humidity	95%	95%
Class of protection	IP33	IP21
Battery life	60 minutes	-
Battery charge time	4 hours	-
Frequency range	1560 – 1600 GHz 2395 – 2490 GHz 5710 – 5920 GHz	2395 – 2490 GHz
Beam width (range)	15 deg	45 deg
Output power antenna	12 – 15 dBi	-
Effective range	>1100 meters	~3 meters

* “-” – the information is not freely available or components or characteristics are missing

Practical use is limited to the technical characteristics of this system, in particular the serious drawback may be the weight and lack of autonomous power.

3. Conclusions

In this paper the result of the research of counteraction to unmanned aerial vehicles by using a sensor trigger control system is submitted.

In the process of testing, the problem with heat transfer in the subsystem was detected, causing radio interference, therefore it is recommended in the future to solve this problem by installing the ventilation output and the system of heat-shielding. Among other improvements can be the installation of stand-alone batteries (and, accordingly, the development of their service system) to ensure greater mobility. It is also recommended to replace the voltage transformer with a more modern one.

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Ph.D. Nataliia Lishchyna
e-mail: lishchyna@gmail.com

Associate Professor of Computer Technology and Professional Education Department, Lutsk National Technical University, Ph.D. in the specialty "Computer systems and components". Scientific and practical interests are related to such areas as data mining, automated information systems, innovative technologies in education. Author of more than 70 scientific publication.

ORCID ID: 0000-0002-5200-536X



Ph.D. Valerii Lishchyna
e-mail: lishchyna@gmail.com

Associate Professor of Computer Technology and Professional Education Department, Lutsk National Technical University, Ph.D. in the specialty "Mathematical Support and Software of Computing Machines and Systems". Scientific and practical interests are related to such areas as Smart Cities and Modern Mobility, software engineering. Author of more than 70 scientific publication.

ORCID ID: 0000-0002-2371-3850



Ph.D. Yuliia Povstiana
e-mail: yuliapovstiana@ukr.net

Associate Professor of Computer Technology and Professional Education Department, Lutsk National Technical University, Ph.D. in the specialty "Materials Science". Scientific and practical interests are related to such areas as automated information systems, innovative technologies in education. Author of more than 60 scientific publication.

ORCID ID: 0000-0001-5426-4157



Ph.D. Andrii Yashchuk
e-mail: xxxxyandyxxx@gmail.com

Associate Professor of Computer Technology and Professional Education Department, Lutsk National Technical University, Ph.D. in the specialty "Machines and means of mechanization of agricultural production". Scientific and practical interests are related to such areas as software engineering, automated information systems. Author of more than 30 scientific publication.

ORCID ID: 0000-0003-4872-7949

