An overview of the PICO satellite construction for atmospheric monitoring

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Abstract

The purpose of this paper is to engage students with educational activities with hands-on experiences as well as to motivate science, technology and engineering education that can be achieved through classroom learning activities that combine physics, engineering and programming. This system consists of a 9 DOF sensor, a 3-axis accelerometer, a 3-axis gyroscope and a 3-axis magnetometer, a pressure and temperature sensor, and a camera and a transceiver module to communicate with the station. Details of its mechanical and electronic subsystems are presented along with experimental results. The relationship between our Can Sat design and the properties it can measure can be valuable in the field of Stem education. The results of this paper show that the Pico satellite after Launched from an aircraft at an altitude of approximately 1000 meters, it is designed and placed to measure temperature, atmospheric pressure and telemetry data via radio frequency communication. It can be seen that the recorded temperature decreases almost linearly with increasing altitude. This observed phenomenon can be explained according to the inverse temperature gradient law, which can be effective in engaging students with educational activities.

Keywords: Making picosatellite, Arduino microcontroller, Can Sat, Stem education.

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Introduction

In the last decade, there has been an increasing demand for new types of satellites with improved shapes, dimensions and performance characteristics for use in aerospace applications [1,2,3,4,5]. A variety of small satellites capable of transmitting information in the fields of global warming, geosciences, meteorology, atmospheric observation and/or for various space missions have also been proposed [6,7,8,9,10,11]. The Can Sat (can-sized satellite) concept was first introduced in 1998 by Professor Robert Twiggs. Robert Twiggs aimed to motivate children to study science, technology, engineering and mathematics (STEM) [12,13,14,15,16,17].

Can Sat is a simulation of a real satellite, integrated into the volume and shape of a soda can [18,19,20,21,22,23,24]. The challenge is to fit all the subsystems (e. g. sensors, communication systems) into a satellite labeled Can Sat, which is about the size of a 350ml beverage can. The Can Sat is then launched by a rocket launched from a drone, aircraft and/or balloon to an altitude of several hundred meters and begins its mission to collect data, simulating the development of experiments in space during landing. In a relatively short time, the concept of Can Sat and CubeSat nanosatellites became an important educational tool for university and high school students to learn and design such satellites and found wide applications in the field of aerospace education [25,26,27,28].

Can Sat offers a great and unique opportunity for young high school students to get a first-hand experience of a real space project. They are responsible for all aspects from designing and building Can Sat to selecting its mission, integrating all the components of a soda can, testing, preparing for launch, the mission itself and then analyzing the data. In the past years, much attention has been paid to the use of computers [29,30].

tablets or and phone in physics education as supplements or even as substitutes for conventional experimental materials and it was revealed that students can carry outside their own measurements of authentic physical data with their own smart device

To encourage student engagement and motivation, it is recommended to combine methods, procedures and materials by assessing physics and engineering concepts with new technologies. It was demonstrated [31,32,33,34,35,36,37]

that such combination methods and learning activities during the classroom provide how youth can integrate electronics (e. g. sensors, microcontroller) and learn to design a complex programmable circuit with creativity and fun. In this study we report on the design, process of assembling and testing of apico-satellite embedded in the volume and shape of a standard 350 ml soda can. The pico-satellite was designed to measure some physical parameters such as temperature, atmospheric air pressure, magnetic induction of the earth and telemetry data (e. g. data concerning its position, acceleration, taking photos for analyzing the terrain from above) through radio frequency (RF) communication after being launched from a plane at an altitude of approximately 1000 m. The engineering, physical concepts and theory underlying the Can Sat can be explored without having much in-depth knowledge of this subject. [38]

subject:

In this research, we report on the design, assembly process and testing of the A Pico satellite embedded in the volume and shape of a standard 350 ml soft drink can. The picomas satellite is designed to measure some physical parameters such as temperature, atmospheric pressure, Earth's magnetic induction and telemetry data (such as position data, acceleration, taking pictures for aerial analysis of the Earth) via radio frequency (RF). Communication after launching from an aircraft at an altitude of approximately 1000 meters. The engineering, physical concepts and underlying theory of Can Sat can be explored without much in-depth knowledge of the subject.

In the following:

This paper will be as follows: introduction, research, topic of Can Sat system requirements, CanSat system design, system review, system review result, general results of this research.

definitions

Experimental details

Can Sat requirements

It should be noted that according to the researchers, this project was produced under the supervision of Can Sat experts and includes various rounds of Can Sat construction, integration of parts and sensors, software programming, testing of all systems, preparation for campaign launch and finally analysis. and analysis and review. and data analysis has been done [39,40,41,42].

Can Sat Design

The Pico satellite consists of five subsystems, each connected on a printed circuit board (PCB), where all electronic components are assembled and soldered as follows:

(1) Can Sat kit containing an Arduino Pro Micro microcontroller (Fig. 1), RFM69HW 433 MHz transceiver and BMP180 temperature and barometric pressure sensor [43].

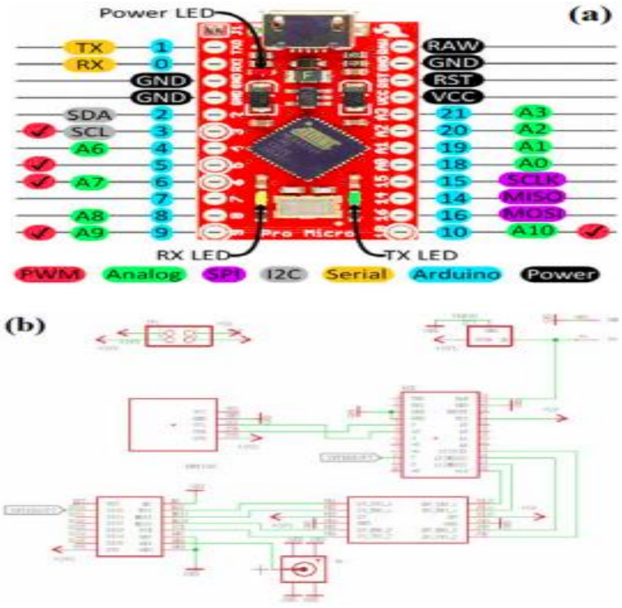


Fig. 1 – (a) Arduino Pro Micro microcontroller used to develop the Can Sat (b)and block diagram of Arduino Pro Micro microcontroller used to develop the Can Sat [39].

Details about the Can Sat kit specifications and sensors employed to develop pour pico-satellite are given in Table 1 and information about operating conditions,

output signal and mechanical characteristics for the BMP180 temperature and pressure sensor are shown in Table 2.

Table 1 Can Sat kit specification [39]

Microcontroller	**Arduino Pro Micro microcontroller** Clock speed: 16MHz 2kb of RAM and 16kb of flash memory I 2 C, SPI and UART serial communication ports; 9 × 10-bit ADC pins RFM69HW 433 MHz transceiver12 × Digital I/Os (5 are PWM capable)

Communica-tion	**RFM69HW 433 MHz transceiver** Frequency: selectable by software over 256 different channels Modulations: FSK, GFSK, MSK, GMSK, OOK 128 bit AES encryption Programmable output power: –18 to +20 dBm in 1 dB steps RF power: 100 mW Sensitivity: –120 dBm at 1.2 kbps SPI Interfaces
Sensors	**BMP180 temperature and barometric pressure** Logic: 3 to 5V compliant Pressure sensing range: 300–1100 h Pa (9000 m to –500 m above sea level) Up to 0.03hPa / 0.25m resolution – 40 to +85°C operational range, +/–2°C temperature accuracy I2C interface

Table 2 Operating conditions, output signal and mechanical characteristics for the BMP180 temperatureand barometric pressure sensor [43].

Parameter	Symbol	Condition	Min	Typ	Max	Units
Operating tempera-ture	T A	operational	-40		+85	°C
		full accuracy	0		+65	
Supply voltage	V DD	ripple max. 50mVpp	1.8	2.5	3.6	V
			1.62	2.5	3.6	
Supply current @ 1 sample/sec 25°C	I DDLOW	ultra low power mode		3		µA
	I DDSTD	standard mode		5		µA
	I DDHR	high resolution mode		7		µA
	I DDUHR	ultra high resolution mode		12		µA

(2) Mission subsystem containing an AltIMU-10 v4 module: LPS25H pressure and temperature sensor, L3GD20H gyroscope, LSM303D accelerometer and LSM303Dmagnetometer. [43].

(3) Power subsystem: 2000 m Ah 18650 lithium-ion battery together with a5V step-up converter was used as a power supply for all the system.

(4) Recovery system & camera: for establishing the position of the pico-satellite during its free fall, but also for recovering it if it will be lost, we shall use the Spark fun Venus GPS module that will give us the longitude and latitude of the satellite; the module has a 20 Hz refresh rate and a 2.5 meters margin of error, making it ideal for our work. Also, TTL Serial JPEG Camera with a resolution of640 × 480 was mounted for taking photos. [43].

(5) Communication subsystem and ground station consists of a radio RFM69transceiver to provide long range communication capabilities. The frequency that we are going to use for data transmission/recep-tion between our Can Sat and the ground station is 434 MHz (license free band in Romania). The Cool Term software was employed to record the serial data sent to the ground station on a text file for later use in our graphing software, it provides a friendly interface without the

problems other serial-recording software seemed to have.

All PCBs are connected and joined each other by means of pin-connectors instead of electrical wires to conform the integration in a 350 ml drink can. The block diagram of the Can Sat is presented in Fig. 2. [43].

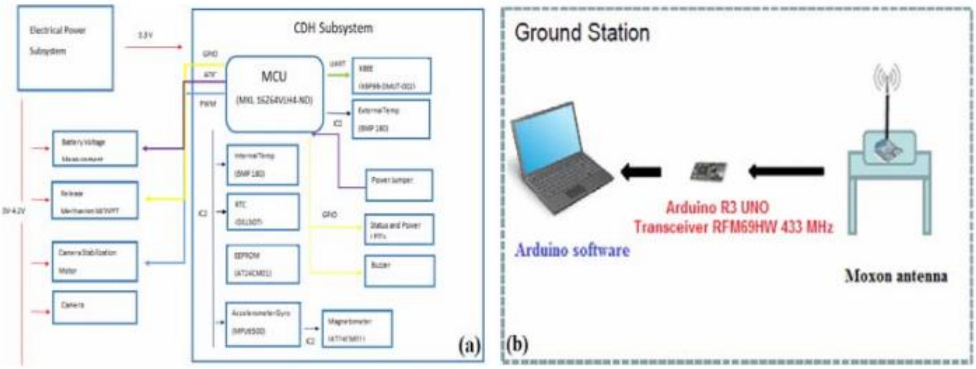


Fig. 2 – The block diagram of the Can Sat (a) and the ground station (b)designed to measure some physics parameters and telemetry data through RF communication.

In order to achieve a slow descent of the pico-satellite a parachute was mounted out-side the soda can (Figs. 3, 4). The parachute was made with a circular geometry (50 cm diameter). In order to provide vertical stability during the descent a 5 cm circular hole was made in the Centre of the parachute. [43].

Fig. 3 – Pico-satellite embedded in the volume and shape of a standard soda can(height: 115 mm, diameter: 66 mm)

Fig. 4 – Pico-satellite embedded in the volume and shape of a standard soda canbefore the launch from the plane (Romanian CanSat competition). [43].

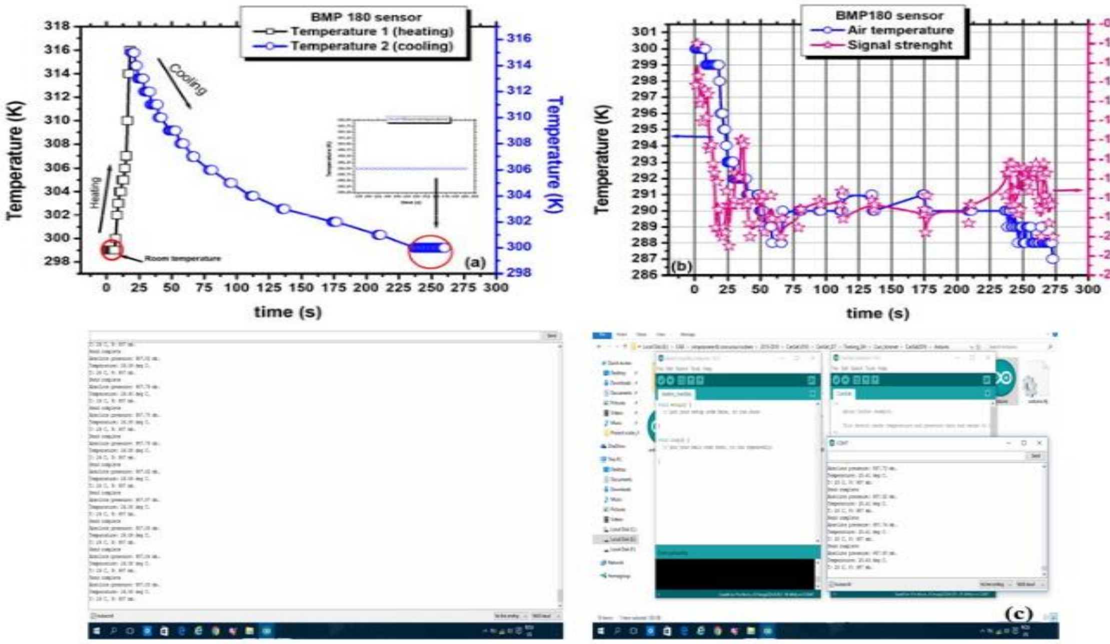
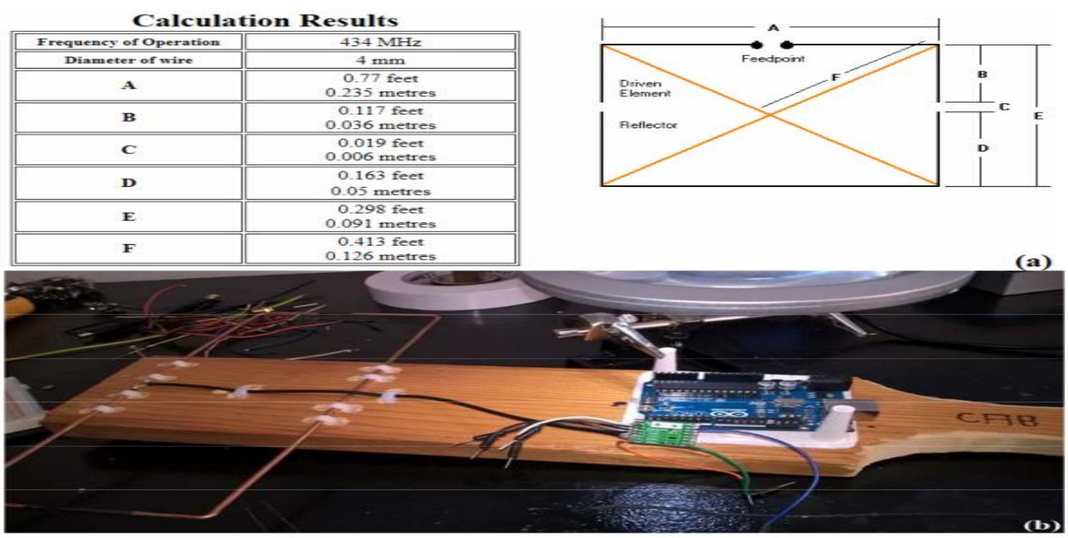


Fig. 5 – Temperature recording with the BMP180 sensor (a), signal strength (b) and screenshot of the Arduino software debug proto-col during laboratory tests (c).

performance review

In order to verify the functionality of the pico-satellite, to confirm the data transmission through RF communication and to verify the deployment of the parachutes a series of tests were made. In Fig. 5 the results obtained during laboratory tests of BMP180 sensor are presented. Communication subsystem and ground station consists of a radio RFM69transceiver to provide long range communication capabil-ities. Using this type of receiver we ensure over 400 meters range when using whip antennas and a several km range when using a Moxon antenna (Fig. 6) on the receiving, while connected to a notebook. In Fig. 7 we present the results during the calibration tests of Moxonantenna. [43].



Calculation Results	
Frequency of Operation	434 MHz
Diameter of wire	4 mm
A	0.77 feet 0.235 metres
B	0.117 feet 0.036 metres
C	0.019 feet 0.006 metres
D	0.163 feet 0.05 metres
E	0.298 feet 0.091 metres
F	0.413 feet 0.126 metres

Fig. 6 – Moxon anten.na design calculator generated with http://w4.vp9kf.com/moxon_calculate.php (a)and Moxona antenna used during measurments (b) [43].

After the laboratory test, the Can Sat was launched from a drone at an altitude of approximately 80 m in order to verify the deployment of the parachute. During the descent the total mass (m = 0.300 kg) of the pico-satellite and the parachute exerted a force (Fig. 8), proportional to the square of velocity. The force and the velocity were calculated using the following equations (1, 2), [25, 40, 41].

$$F_d = \frac{1}{2}\rho . v^2 . c_d . S \qquad (1)$$

$$v = \sqrt{\frac{2.m.g}{\rho.S.C_d}} \qquad (2)$$

where F d is the drag force (the force component in the direction of the flow velocity), ρ is the density of the air, v is the velocity, c d is the drag coefficient (c d = 1,5 for the semi-spherical parachute) S is the surface of the parachute, m is the mass of the pico-satellite and g denotes the gravitational acceleration. [43].

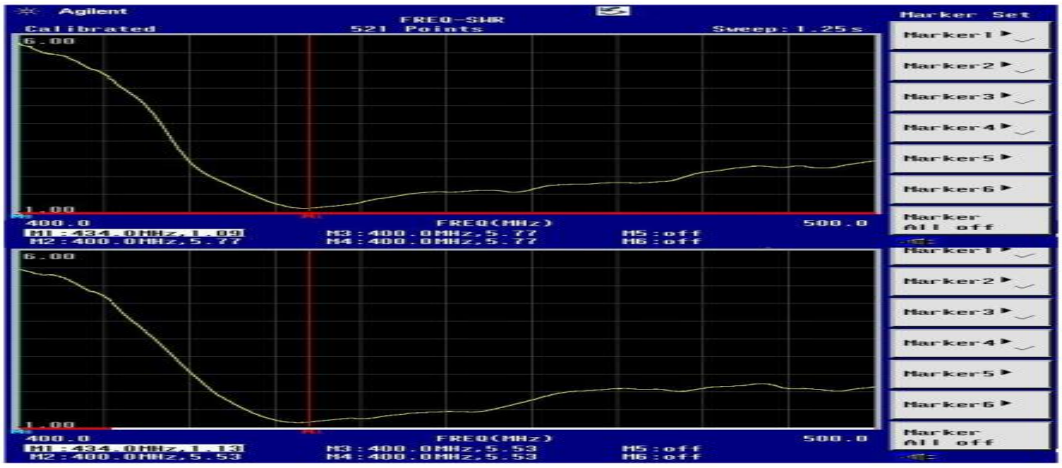


Fig. 7 – Moxon antenna calibration tests.

Fig. 8 – The structure of the CanSat parachute.

During the Can Sat competition the pico-satellite was launched from a plane from an altitude of approximately 1000 m. It then transmits data regarding the temperature and atmospheric air pressure during its free fall, and also telemetry data. During the ascent and descent of the Can Sat, the sensors measured the temperature and pressure every second and the data were transmitted by telemetry to the ground station. The Cool Term software was used to record the serial data sent to the ground station on a text file for later use in our graphing software. The results of the measurements during the ascent and descent of the pico-satellite are presented in Fig. 9. [43].

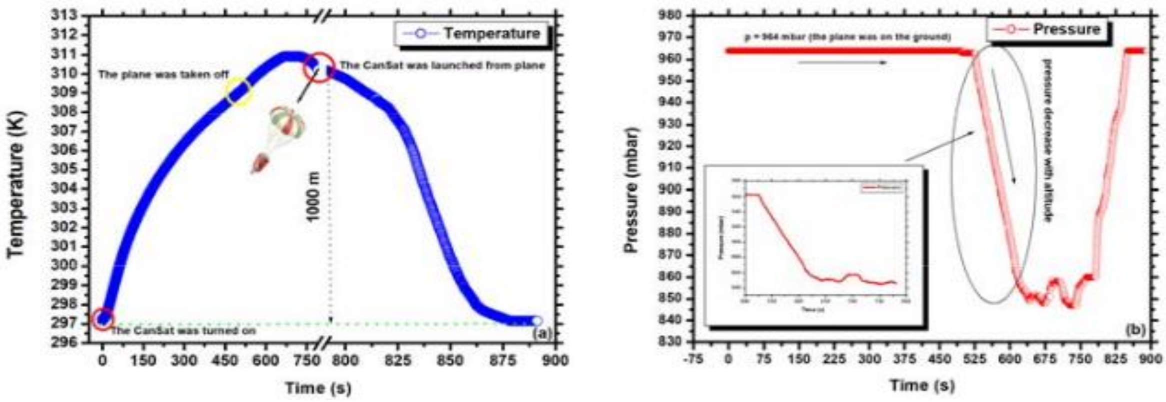


Figure 9 - Temperature and pressure measured during the ascent and descent of the Pico satellite.

The diagram in Fig. 9 presents the temperature and pressure data received from the Can Sat throughout the ascent and descent of the pico-satellite. The temperature diagram is almost linear with altitude and shows that the temperature decreases according to the inversed gradient temperature law [42]. The experimental results obtained by us are in accordance with the theory and with other similar experiments from literature [6, 24, 25, 42]. Also, the measurements from gyroscope are plotted in Fig. 10. [43].

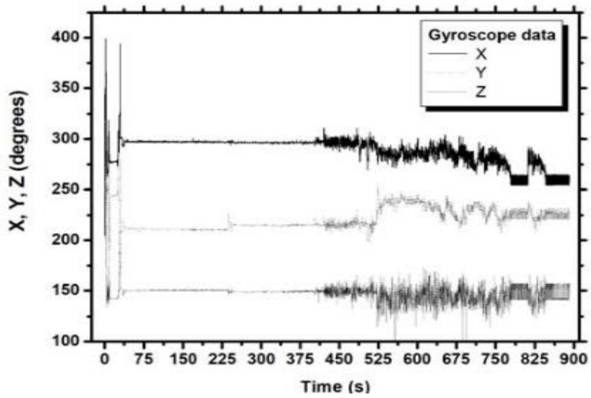


Figure 10 - Gyroscope data recording during ascent and descent of Pico satellite.

During the ascent and descent the movement of the Can Sat is quite stabilized. Yet, just after it was launched from the plane a large rotational movement started during the descent, as expected. Figure 10 shows some changes in the three axes due to the rotational and balancing movements as in [24].

The result of the review

The results of the review are that we present an embedded pico satellite in the size and shape of a standard juice can designed to measure temperature, atmospheric pressure and telemetry data via radio frequency communications after launch from an aircraft. At an altitude of approximately 1000 meters. Recorded temperature decreased almost linearly with altitude. This observed phenomenon can be explained according to the inverse temperature gradient law. The mathematical, engineering, physical and theoretical concepts underlying Can Sat can be explored without deep knowledge of the subject. Ra Can Sat can easily be built by young high school students using information that is available for social media and can definitely be an interesting tutoriaresource for them. The correlation between our Can Sat design and properties the device can measure can be useful in the field of (STEM)[2] education and technologic al applications. [43].

The results

Conclusion and discussion

The results of this article show that the Pico satellite was designed and placed after being launched from an airplane at an altitude of approximately 1000 meters to measure temperature, atmospheric pressure and telemetry data through radio frequency communication. It can be seen that the recorded temperature decreases almost linearly with increasing altitude. This observed phenomenon can be explained according to the inverse temperature gradient law. In this article, the underlying mathematical, engineering, physical and theoretical concepts of Can Sat can be examined without deep knowledge of the subject. Ra Can Sat can be easily built by university students using information available on social media and can definitely be an interesting learning resource for them. The correlation between our Can Sat design and the properties the device can measure can be useful in Stem education and technology programs, and I state that my findings are the same as those in this paper and do not conflict with the findings of the researchers in this paper.

Proposa

The use of this article in the technology education programs of universities and related research institutes to improve the level of students, experimental implementation in scientific centers in an applied manner and conclusions from it.

[2] Stem is a new idea and method of education for elementary ages, which is composed of the integration of important concepts such as Science, Technology, Engineering, and Mathematics. Teaching by stem method has been seriously taught for several years in advanced countries as an important teaching method in schools and preschools.

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