

Hardware Implementation of APRS Based Tracker with Application in Engineering Education

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Abstract – The article presents a hardware implementation of an APRS (Automatic Packet Reporting System) based tracker for determining the location of an object in real time. It was developed and tested in the educational process at the Faculty of Physics and Engineering Technologies of University of Plovdiv "Paisii Hilendarski". Students acquire lasting knowledge and develop skills for working with APRS trackers connected between GPS and radio stations that transmit data in the global APRS network. Combining modern microcontrollers with appropriate software and APRS technology, a device with many current applications is obtained.

Keywords – Automatic Packet Reporting System; trackers.

I. INTRODUCTION

The article offers an APRS-based tracker, hardware-implemented with a family of microcontroller boards manufactured mainly by Smart Projects and vendors using 8-bit (AVR) microcontrollers or 32-bit (ARM) Atmel processors. Groups of digital and analog input / output (I / O) ports are provided, which allow connection to other modules, sensors and circuits.

A team of lecturers and masters trained in Computer and Communication Systems as well as Hardware and Software Systems of the Faculty of Physics of the University of Paisii Hilendarski integrated the Atmega 2560 microcontroller on the printed circuit board for APRS tracker. The choice of the microcontroller was dictated by a number of advantages, superior to the low-power ones and in accordance with the additionally controlled sensors. The choice of APRS network communication is determined by the fact that the network is not loaded with high traffic, is very well developed worldwide and is characterized by flexibility and real-time communication [1].

II. HARDWARE MODULES FOR CONSTRUCTION OF APRS BASED TRACKER

The basic structure of the APRS tracker is illustrated by the generic block diagram presented in Fig. 1.

The Atmega 2560 central microcontroller controls the entire APRS tracker. It contains CPU, SRAM, EEPROM, ROM, ADC, input-output ports and is characterized by the following parameters: CPU – 16MHz, SRAM – 8Kb,

EEPROM – 4Kb, FLASH – 256Kb, digital input-output ports - 54 pcs. and 16 pcs. analog inputs.

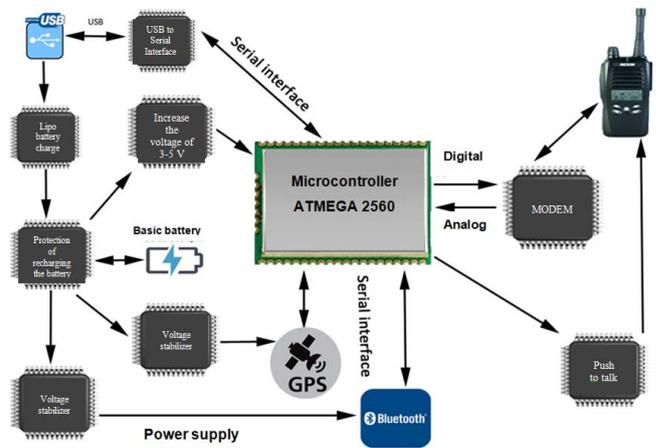


Fig. 1. Block diagram of the basic structure of the APRS Tracker

A. USB to Serial interface

This unit enables the tracker to connect to a computer to perform the following functions: software change, submission of a different set of commands, device monitoring, two-way communication via the APRS network [2].

The schematic diagram of a USB to serial interface converter is given on Fig. 2.

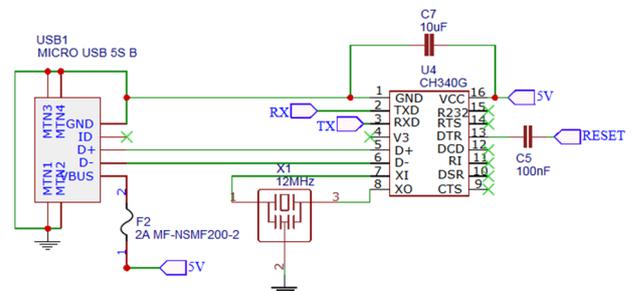


Fig. 2. Circuit of USB converter to serial interface

B. Power supplies

- LIPO Charge Controller TP4056

The module allows the device to independently control the charging of its built-in battery. The TP4056 is an integrated circuit that performs the function of charging a single-cell lithium-ion battery. The SOP housing and the minimum number of external elements allow the circuit to be used in portable devices. It can operate with a 5V supply voltage, which is standard for the USB interface [3]. The output voltage of the circuit is fixed at 4.2V, and the charging current can be controlled by changing the resistance of an external resistor (Table 1). The TP4056 automatically interrupts the charging cycle when the final voltage is reached and the charging current reaches 1/10 of the programmed value. The circuit has outputs for monitoring the charging process - CHGR and STDBY, which are connected to digital inputs PB0 and PB1 of the central microcontroller. This increases the functionality of the end device by allowing it to be upgraded in the future.

TABLE 1. DEPENDENCE OF CHARGE CURRENT ON RESISTOR R8

R8 [kΩ]	4	3	2	1.5	1.2
I [mA]	300	400	580	780	1000

The schematic diagram of the charger is given in Fig. 3.

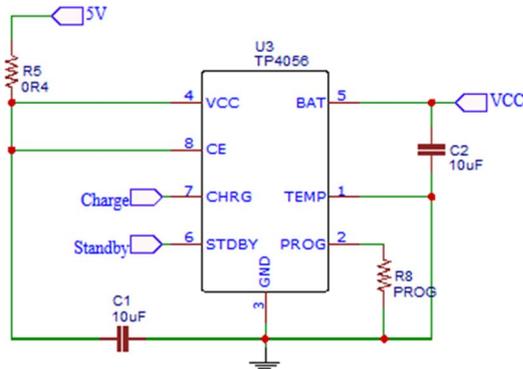


Fig. 3. Schematic diagram of the charger

• *Battery protection IC S-8261*

IC S-8261 protects the battery from excessive discharge, charge and high current. It can operate in the following modes: normal state, high current state (short circuit state), recharge state, discharge state, power supply and step-up DC-DC converter [4].

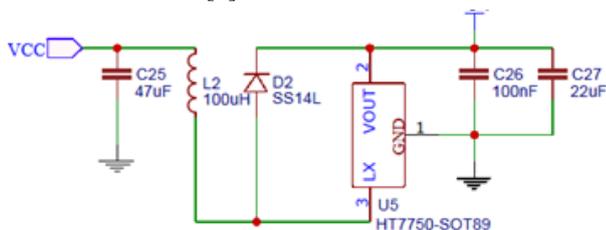


Fig. 4. Schematic diagram of a boosting DC-DC converter

A schematic diagram of a step-up DC-DC converter is shown on Fig. 4. The HT7750 integrated circuit increases

the battery voltage to 5V. The circuit provides a stable 5V power supply for the microcontroller.

• *Voltage regulator - TPS79133DBVR*

The TPS79133DBVR (ultra low noise linear voltage regulator) integrated circuit powers the Bluetooth and GPS modules. The TPS79133DBVR is optimized for battery-powered radio noise-sensitive radio communication devices. The integrated circuit has an option to activate and deactivate via an external input. When the chip is turned off, its consumption is reduced to less than 1µA. shows a schematic diagram of the two power supply circuits on Fig. 5.

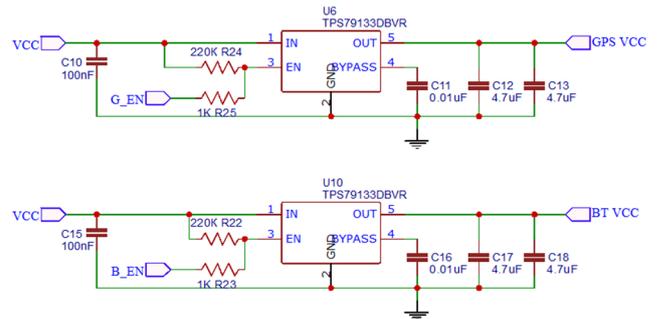


Fig. 5. GPS and Bluetooth power circuits

• *GPS watch power supply*

The scheme shown on FIG. 6 provides charging of the battery to power the built-in GPS receiver while its main power is off.

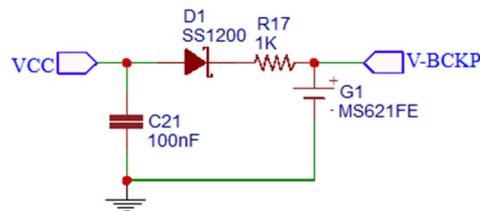


Fig. 6. GPS watch power supply

• *EEPROM*

The EEPROM is used by the NEO-6M GPS module to save settings and data after a restart or loss of power. The integrated circuit 24AA32AT – is 32Kbit EEPROM. It consists of a single 4K X 8bit memory block with an I2C bus. Its design allows it to operate at voltages above 1.7V, consuming 1µA current in standby mode and consuming 1mA current in operating mode, which makes it an ideal choice for integration into an APRS tracker [5, 6]. This integrated circuit allows up to 8 EEPROM devices to be connected on one bus. In such an implementation, the capacity of the equivalent memory can be expanded up to 256Kbit. Terminals A0, A1, A2 are used by 24AA32AT to connect several EEPROM devices. The levels of these pins are compared to the corresponding bits of the child EEPROM devices. The chip is "selected" if the bits match the address of the EEPROM device. In case only one EEPROM integrated circuit is used, pins A0, A1, A2 must be connected to VCC or GND.

- *GPS modul*

The GPS module is used to determine the location of the tracker. It is based on a standalone NEO-6M chip, has a compact architecture, low power consumption and the ability to store its last position in non-volatile memory. The selected GPS receiver uses a 50-channel positioning system to achieve a first connection time of less than 1 second. GPS receivers have three switching methods and they directly affect the positioning time after switching on the receiver. They are: Cold Start, Warm Start and Hot Start. The difference between them is shown in Table 2.

TABLE 2. COMPARISON BETWEEN INCLUSION METHODS OF GPS.

	Hot-Start	Warm-Start	Cold-Start
Last position	Saves	Saves	Deletes
Time	Saves	Saves	Deletes
Almanac	Saves	Saves	Deletes
Ephemeris	Saves	Deletes	Deletes

GPS satellites send mainly 2 data types Almanac and Ephemeris. Almanac data contain data on the course of the satellite's orbit, these data are considered valid for only a few months. Ephemeris data contain data for orbital and time correction, they are considered valid for only 30 minutes. In this case, Hot-Start is used for faster positioning.

The schematic diagram of the GPS module is shown on Fig. 7.

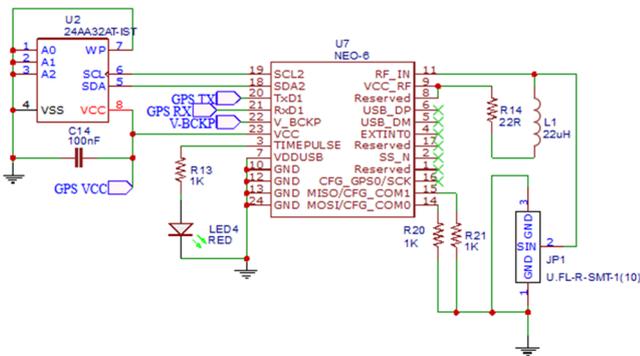


Fig. 7. Schematic diagram of the GPS module

- *Digital thermometer DS18B20.*

The DS18B20 IC can provide nine to twelve bit conversion of temperature readings. With this sensor, the APRS tracker can read ambient temperature data. It has a built-in non-volatile programmable alarm, through which the upper and lower activation limits can be set programmatically. The DS18B20 communicates via a 1-Wire interface, which allows it to transmit data to the central microcontroller via a single wire. Each DS18B20 has a unique 64-bit serial code that allows multiple sensors to be connected to a single bus [7, 8]. Thus, only one microcontroller can process data from many sensors located at a great distance from each other. A schematic diagram of the temperature measuring unit is shown on Fig. 8.

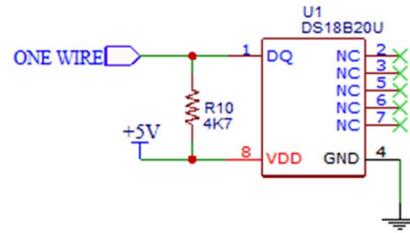


Fig. 8. Schematic diagram of a digital thermometer.

- *Buttons for forced position transfer*

The diagram on Fig. 9 shows a two-button keyboard, the purpose of which is to provide the user with the ability to transmit his position whenever necessary.

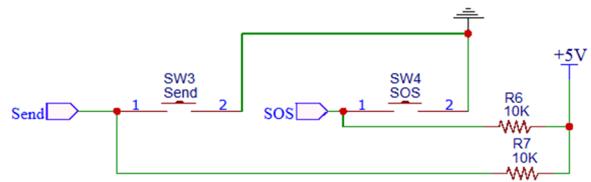


Fig. 9. Schematic diagram of buttons for position transmission

C. Modules for connecting an APRS tracker to a radio station

- *Digital-to-analog converter (DAC)*

The circuit on Fig. 10 is used for digital-to-analog conversion (signal modulation)

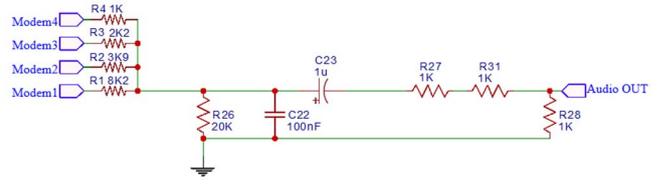


Fig. 10. Digital-to-analog converter

Resistors R1-R4 are a four-bit string resistor. Pulse-width modulated pulses are fed through inputs Modem1 to Modem4, which charge capacitor C22. R26 serves to discharge the capacitor, C23 does not allow direct current to pass from the radio to the rest of the circuit. R27, R31 and R28 form a voltage divider to control the amplitude of the output signal.

- *Analog-to-digital converter (ADC)*

The ADC built into the microcontroller and the voltage divider R36 and R35 with a division factor of 1: 1, which provides 2.5V at the ADC0 input of the microcontroller, are used to demodulate the signal. C24 separates the radio station from the rest of the circuit at direct current. The radio is connected to the Line IN terminal, and the ADC0 terminal of the microcontroller is connected to the Audio IN terminal. A schematic diagram is shown on Fig. 11.

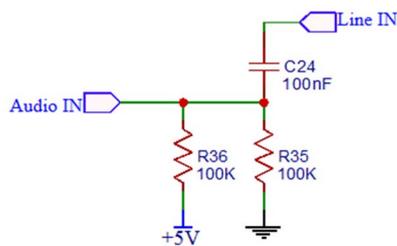


Fig. 11. Voltage divider

- *Electronic switch*

The scheme of FIG. 12 implements an electronic switch that simulates pressing the PTT button of the radio station. Just before the start of the signal transmission it is necessary to press the PTT button, which activates the transmitter of the radio station.

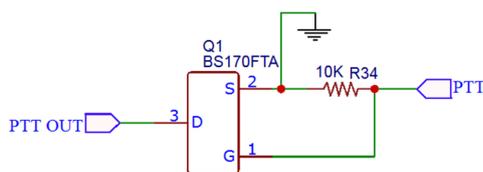


Fig. 12. Electronic switch

- *Wireless communication module*

Bluetooth - HC-06 provides wireless connectivity at short distances between the tracker and mobile phone (tablet / computer). It provides submission of a different set of commands; device monitoring; two-way communication via the APRS network; sending SMS messages without mobile coverage; sending E-Mail without internet.

A schematic diagram of the module is shown on Fig. 13.

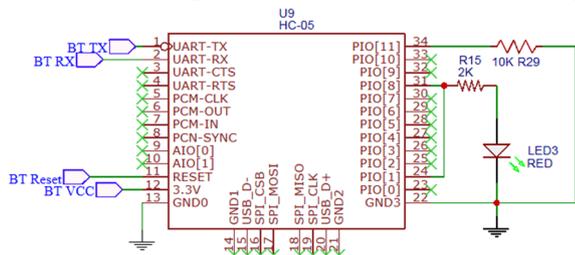


Fig. 13. Bluetooth modul

III. FUNCTIONAL TESTING OF THE DEVICE MODULES

The testing was conducted in two stages - individual testing of the modules and complete testing of the device.

Individual testing of: USB to Serial interface for the communication between it and the microcontroller and for power supply via USB port without battery; Bluetooth module for pairing with another device, for communication between the two devices, for stability of operation (presence of connectivity between the two devices for a long period of time); battery voltage sensor; power supply modules that stabilize the voltage for the GPS module, the Bluetooth module and the central microcontroller; built-in thermometer; GPS module, transmission modem. All tests passed successfully.

For the overall testing of the device, a location on the outskirts of Plovdiv was chosen, as the geographical area allows the transmission of signals over long distances. Successfully passed the tests of: the GPS module of the device, the finding time, connection to the satellites and the APRS functionality.

When analyzing the data from www.aprs.fi. it was determined that the GPS tracker gives greater accuracy in positioning in motion than in tests in stationary position. The deviation is less than 3 meters.

II. CONCLUSION

The developed APRS tracker can be applied to the following spheres: mountain tourism and mountaineering, expedition missions in hard-to-reach areas, forest fires, organizing and managing long-term rescue operations after a natural cataclysm, organizing and maintaining the operation of rescue posts, searching and transporting people in hard-to-reach mountainous terrain at the request of competent authorities.

The implementation of engineering tasks by students in the implementation of the device is reduced to: appropriate choice of hardware components for the development of input-output PCB, testing and reliability of the device. The development of appropriate software for the correct operation of the tracker are presented by the authors in a scientific publication.

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