

Design and Simulation of Terminal Node Controller for KufaSat NanoSatellite

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Abstract— This paper presents the design and simulation of communication subsystem of KufaSat Nano-Satellite in general and focuses on the terminal node controller as a key part of the communications subsystem. A transceiver, terminal node controller (TNC), and antenna has been selected as communications subsystem hardware. A terminal node controller consists of a micro control unit, a modem, EPROM and software that implement the AX.25 protocol.

Index Terms— Terminal Node Controller, Communication Subsystem, KufaSat, NanoSatellite.

1. INTRODUCTION

Cubesats is a class of satellites known as Nanosatellites and typically uses commercial off-the-shelf components for its electronics. Dimensions are measured in (cubesat units) called a U. A 1U cubesat is a cube with 10 cm long to each face and weighs less than 1.33 kg. The common cubesat sizes are 1U, 2U, and 3U, where 3U is 10x10x30 cm and weighs less than 4.0 kg. The cubesat standard was developed by researchers at California Polytechnic State University (Cal Poly) and Stanford University to help universities worldwide to perform space science and exploration.

Kufasat is the first Iraqi student satellite project at University of Kufa and has mission to imaging purposes and designed for a low earth orbit (LEO) of about 600km. In accordance with CubeSat specifications, it is 1U Nanosatellite with a total mass of 1kg, and its size is restricted to a cube measuring 10x10x10 cm³. It also contains 1.5 m long gravity gradient boom, which will be used for passive attitude stabilization in addition to three magnetic coils used as active attitude stabilization [1].

2. REQUIREMENTS AND CONSTRAINTS

The cubesat specification sets strict requirements on the mass and the volume to fit properly within, and launch correctly from inside of the Cubesat deployer. The standard cubesat deployer, used successfully in each cubesat mission to date, is the Cal Poly designed Poly Picosatellite Orbital Deployer (P-POD) [2].

One of the main requirements of any satellite is the ability to communicate with the earth reliably by sending and receiving data from the ground station. This data is sensors data which is details of health of satellite, telemetry data which provide the orbital location of the satellite, and commands from ground station to execute a specific program or function.

Communication with the earth can be established using a wide range of radio frequencies, depending on the data rate requirements, earth station equipment costs, and Federal Communications Commission (FCC) licensing restrictions [3].

Amateur frequency bands would be used for uplink and downlink communication in KufaSat. The exact uplink and downlink frequencies will be finalized after coordination with International Amateur Radio Union (IARU). KufaSat will use UHF range for the downlink (status of satellite and beacon) and VHF range for uplink (telecommand and software updates) in addition to use S-band for downlink payload images. Audio Frequency Shift Keying (AFSK) will be used to send commands to KufaSat in at a data rate of 1200bps. The communication system is also capable

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of transmitting a CW beacon periodically carrying telemetry data in Morse code format.

Cubesats are typically launched in what is called a low-earth orbit (LEO). Low earth orbits are characterized by their short range and high orbital velocity. From satellite's orbit we can determine the period, through it the satellite is able to communicate with a fixed ground station this period called the communication window and defined as the amount of time that a fixed ground command station can transmit to and receive signals from a satellite. The duration of this window is determined by the orbital parameters. A communication window for KufaSat of approximately 4-8 minutes, with 3 to 5 passes above the ground station per day

A store-and-forward type of communications architecture is key to the success of the communications subsystem due to the short-duration, multiple pass, and low-altitude characteristics of the orbit and the low-cost requirement of the mission [4].

3. COMMUNICATION SUBSYSTEM ARCHITECTURE

Communication subsystem of Kufasat consists of transceiver including transmitter and receiver, terminal node controller (TNC) including modem, and antenna. Block diagram shown in Fig (1) explain the main parts of communication subsystem of Kufasat.

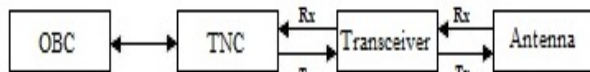


Fig 1. Communication subsystem block diagram

4. TERMINAL NODE CONTROLLER

A terminal node controller (TNC) is a main part of communication subsystem of Nanosatellite. Typical model of a terminal node controller consists of a micro control unit, a modem, EPROM and software that implement the AX.25 protocol.

4.1 Micro control unit

The PIC16F873 was chosen specifically because it support for the Inter-IC Communication (I2C) bus (the protocol used to communicate with the main satellite bus) and its extremely low power consumption and power management abilities [5]. The PIC16F873 is programmed with software TNC that is responsible for both encoding and decoding AX.25 data.

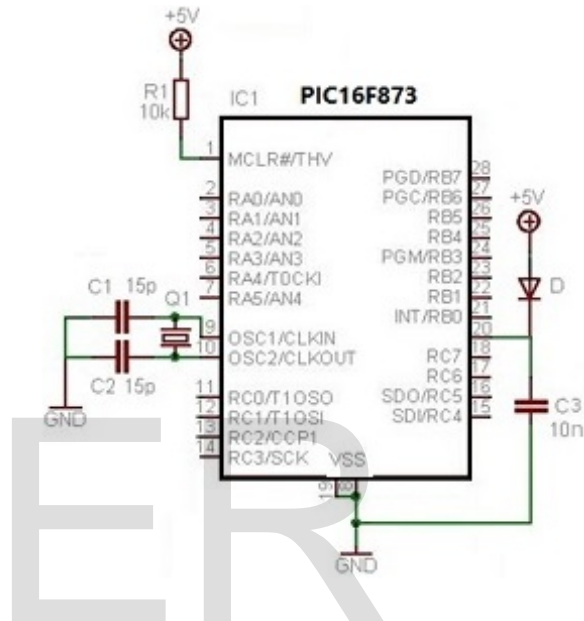


Fig 2. PIC16F873

4.2 Modem

The Modem modulates a 1200 baud AFSK (Audio Frequency Shift Keying) signal. The serial bit stream is provided to the microprocessor which processes the packet radio data. A MX-614 FSK MODEM chip shown in Fig (3) is used for main component for modulation. The MX614 is a low voltage, low power CMOS integrated circuit designed for the reception or transmission of asynchronous 1200bps data. It provides an optional Tx and Rx data retiming function which can eliminate, based on user preference, the need for a UART in the associated μ C when operating at 1200bps[6].

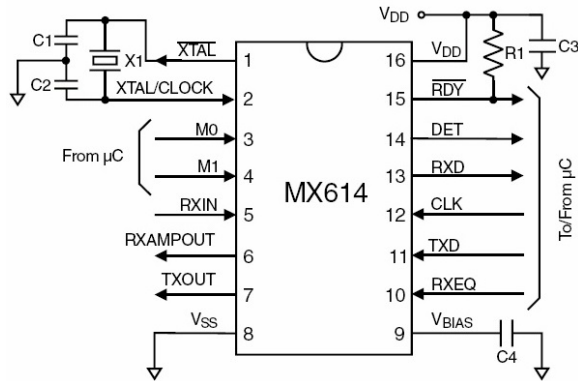


Fig 3. MX614 Modem

4.3 Ax.25

The most commonly used protocol for the data link layer for out of the processor data transmitted is Ax.25 which is designed for use by amateur radio operators. It supports amateur call names, connected links, and half / full duplex. The Ax.25 protocol envelops data into Ax.25 frames to pass over a serial link to a TNC. There are three general types of AX.25 frames: Information frame (I frame), Supervisory frame (S frame), and Unnumbered frame (U frame). Each frame is made up of several smaller groups, called fields. The structure of the three basic types of frames is shown in Fig (4 a), Fig (4, b).

Flag	Address	Control	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	N*8 Bits	16 Bits	01111110

Fig 4a U and S frame construction.

Flag	Address	Control	PID	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	8 Bits	N*8 Bits	16 Bits	01111110

Fig 4b Information frame construction.

The microcontroller will collect the data to be transmitted from the sensors and payload, convert these data into a stream of 8-bit binary numbers. These numerical strings packetize into AX.25 format, and send to modem which modulate it using Audio Frequency Shift Keying (AFSK), then key the transmitter to send the signal to the ground station through the satellite's antenna. Likewise, when receiving commands from the ground station, the TNC will demodulate these commands, unpack and decoding it and then redirect commands to OBC.

5. SCHEMATIC AND PCB LAYOUT

The complete schematics of the engineering model of the TNC card are shown in fig 5. All work with the PCB was done on the computer using Proteus Design Suite V8. The prototype was a two-layer PCB within the physical size of 48x48 mm with 1.25 mm board thickness and 50µm feature thickness. Fig 6 explain artwork PCB layout, (A) Top Copper, (B) Bottom Copper, (C) Two Layer. Fig 7 is 3D view, (A) with components, (B) without components.

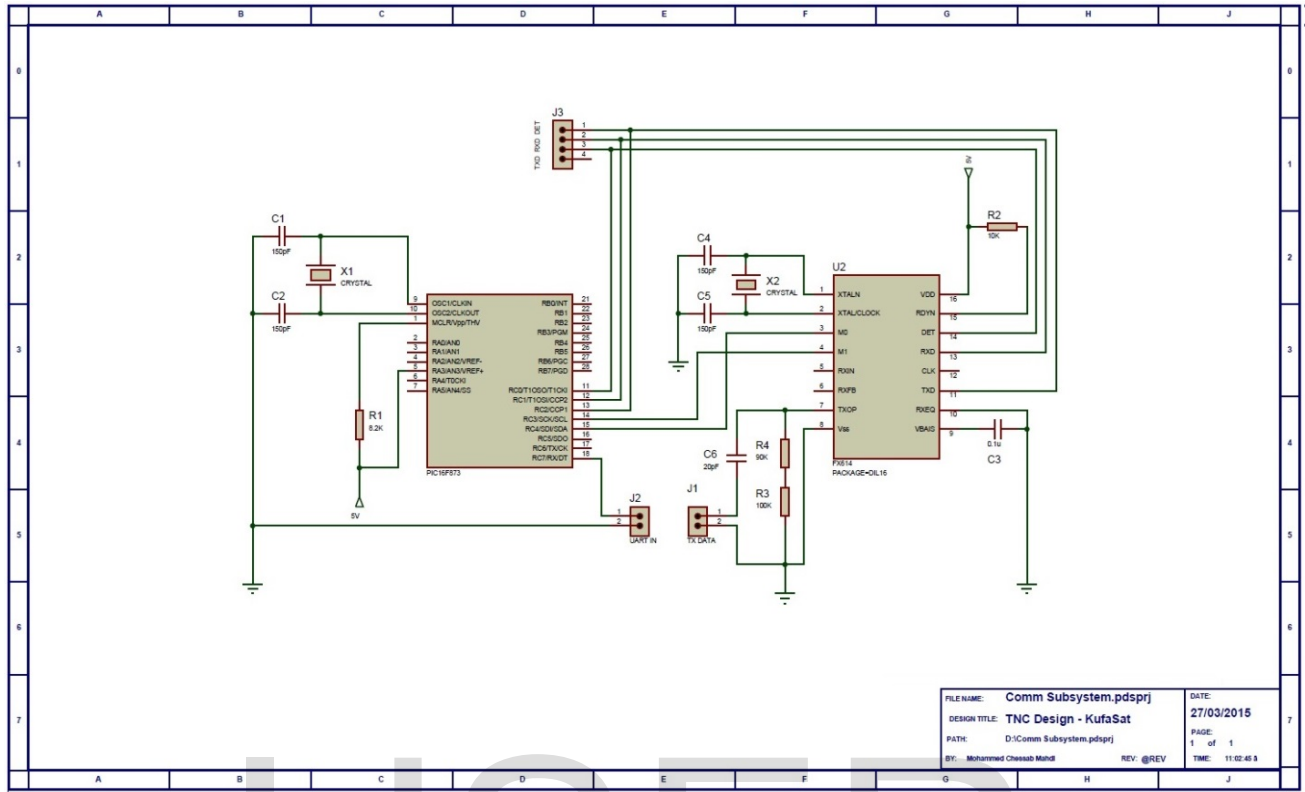


Fig 5. TNC Complete Schematic Diagram

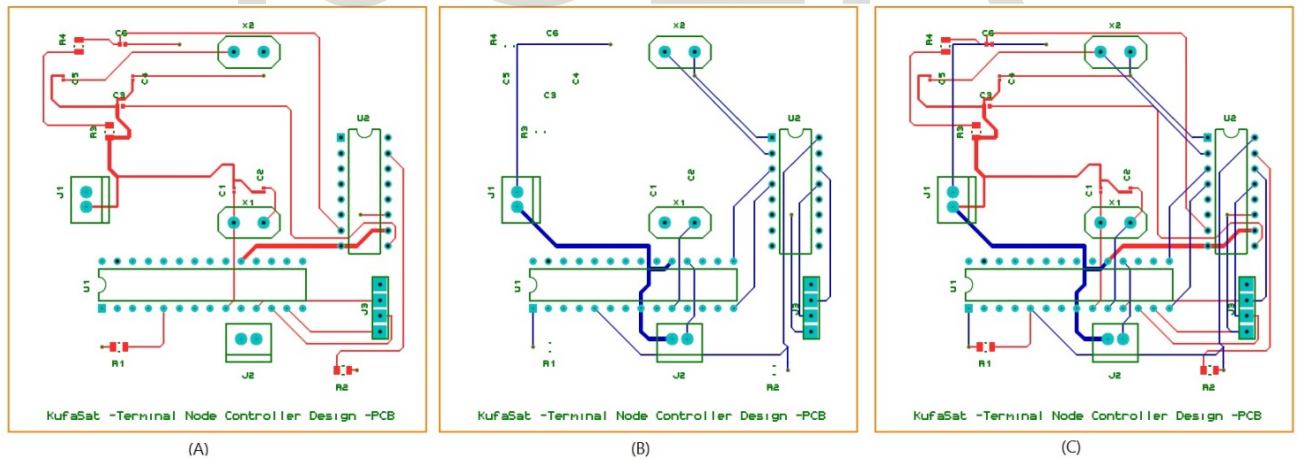


Fig 6. TNC PCB Layout A-Top, B-Bottom, C-Two Layer

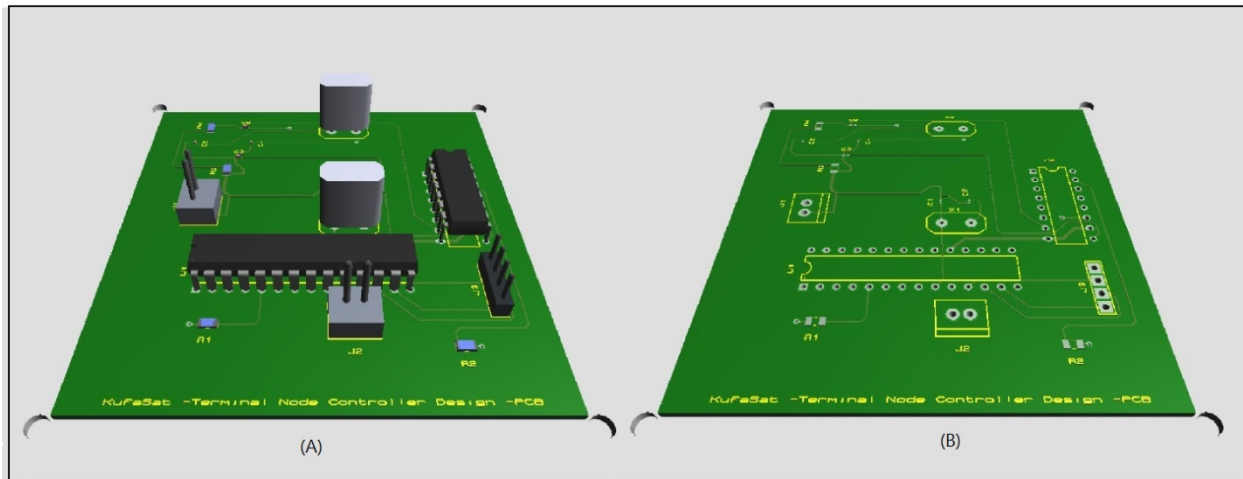


Fig 7. 3D view A- Front view, B- Back view

CONCLUSION

KufaSat mission requirements state that the downlink and uplink communications should be reliable, low power consumption and low cost. The current communications subsystem design meets these requirements through using commercial-off-the-shelf components, which are low cost and low power consumption. The communications subsystem hardware has been selected to work effectively. Further design and implementation is required to ensure functionality in space.

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