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Multi-channel wireless signal transmission system for intra-satellite communication

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ABSTRACT

An artificial satellite is a system engineered to transmit different information from space to a ground control station. It is not a single system of communication but is a combination of complex multiple subsystems, which constantly communicate within the satellite with each other. This type of communication is intra-satellite communication. Currently, most of the satellites utilize a wired harness to provide power and signal connections for intra satellite communication, which results in a heavier system integration. This paper takes the approach towards wireless communication within the satellite using Bluetooth module HC-05 between the attitude and orbit control system (AOCS), sensors and actuators. The paper's objective is to reduce the weight of the satellites launched into orbit, in order to provide less thrust requirements. The system is based on Arduino Mega2560 and Lpc2148 which are being considered as two modules for the subsystems of the satellite.

Keywords: *Intra-satellite communication, Lpc2148, Arduino Mega2560, Wireless communication, Attitude and orbit control system (AOCS), Bluetooth module HC-05, sensors, and actuators.*

1. INTRODUCTION

Wireless communication [1] has high prominence in the fields of communication and has been a major game-changer for the human civilization. Bluetooth [1] is one of those remarkable wireless technologies [4] of communication that allows single or multiple systems to communicate with each other using low power. It utilizes a methodology called adaptive frequency hopping (AFH) using an ISM band of 2.4 GHz to 2.483 GHz which is one of its major advantages. There are three classes of Bluetooth with each class pertaining to a different range of applicability. It is for short distance communication purposes, which plays a huge role since the maximum size of the satellite falls between 10 meters to 100 meters which are well within the range of Bluetooth signal transmission and reception. The Bluetooth module HC-05 is an omnidirectional class 2 module with a maximum range of 10 meters.

Artificial satellites are complex systems of human ingenuity that helped in the development of communication systems through the years and will continue to play a deep role in near future. There are many types of satellites, which are all based on the specific purposes such as military, communication, navigational, broadcasting or scientific. Each satellite is a combination of complex and very well designed subsystems which includes telecommands and telemetry systems (TC-TM)[1], attitude and orbit control systems(AOCS)[5], power systems and communication systems if required. It also includes sensors and actuators [5][6], which are core designs for any and all satellites. Proper harness systems are developed to maintain the lifetime of the satellites and provide proper interconnections to all electrical and electronic circuits inside the satellite. There are many signals being sent at a time between the subsystems of the satellite. The sensors which includes sun sensors, power meter and sensor, gyroscope and magnetometer [6] which are constantly taking the readings to maintain the stability of the satellite to stay in the orbit, making sure there is no loss of power due to any wiring problems etc, are constantly being sent and read by the AOCS, which in-turn send signals to the actuator present, to make changes in the orientation if need be. This is the reason the AOCS stabilization systems are one the

important challenges to be dealt with since it plays a major role in the movement of the satellite around its point of reference.

There are many signals transmitted and received continuously which can be power signals, analog signals, and digital signals. Power signals being transmitted wirelessly is infeasible with current technology and if it was adapted, the radiation loss would be too high and could fry the internal structures of the satellite. The analog signals and digital signals are data readings from the sensors, which are currently being sent through the wired harness but if we replace the harness with a Bluetooth module we could eliminate the entirety of using a harness in this particular part of the satellite. The next section of the paper explains the current methodology for data transfer. The third section gives a description of the proposed system. The fourth section is hardware utilized after which the fifth section explains the implementation of the proposed system. Then we give the acknowledgment and the sixth section will be the conclusion of the implementation.

2. CURRENT SYSTEM OF DATA TRANSMISSION

Within a satellite, data is constantly generated by sensors, from TC-TM systems, camera systems, and other subsystems which are either stored in system memory or sent to the ground station. This is all placed and handled by a separate system called Command and Data handling system (CDHS). This system provides these two different ways since satellites at all points of time won't be in the line of sight with respect to the ground control station. However for this to happen, in the first place, the data transfer should occur inside the system. The harness is one such method that is currently in use. In this method, each system is connected via straps of wires through which data transmission occurs. A harness also consists of connectors, terminals, clamps, tubes, and sheaths.

A. Limitations of Harness

• The design of harness mainly depends upon the designer's experience which sometimes becomes an obstacle.

• Due to the above reason, during the integration of subsystems, noise effects occur making the whole system redundant.

• The total harness that is used, is an added weight to the satellite which consumes more fuel and in turn increases the cost of the satellite.

3. PROPOSED SYSTEM FOR WIRELESS COMMUNICATION

To overcome the above-mentioned limitations, one has to come up with a solution which resolves all the issues with using a harness and wireless communication is one of the possible solutions to this problem.

A. Wireless communication system

A wireless communication system consists of mainly 3 blocks, namely Transmitter end, Communication Channel and Receiver end as seen in Fig 1

The transmitter is fed with the message signal which will be in the form of either digital or analog signal. If the signal is in digital form, it will be converted into an analog signal before sending it through Communication Channel.

Communication Channel in this system is a wireless medium which is air. The signal coming from transmitter end passes through this channel and reaches receiver end.

Receiver end takes in the incoming signal and does the required processing to reconstruct the original signal since it may get affected by intermediate noise in the Communication Channel.

The basic block diagram of the communication system is as follows:

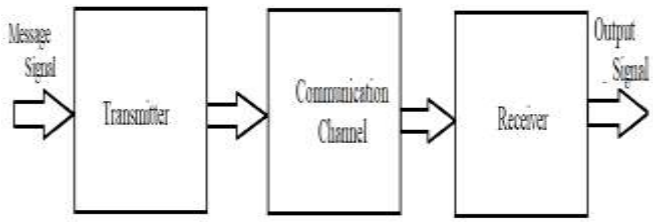

Fig 1 Basic block diagram of Communication System

4. HARDWARE

The choosing of the hardware plays an important role when it comes to developing a brand new system and it must also be feasible to be integrated into the current system within each and every satellite.

A. Arduino Mega 2560

Arduino Mega2560 is a microcontroller based on ATmega2560 as seen in Fig 2. It has 54 digital input/output pins of which 14 can be used as PWM outputs, 16 analog inputs, 4 hardware serial ports(UARTs), a 16 MHz crystal oscillator, a universal serial bus connection(USB), a power jack, an in-circuit serial programming(ICSP) header, and a reset button. It can be simply connected to a computer with a USB cable or powered with a AC to-DC adapter or battery to get started. The pin configuration can be seen in Fig 3[8].

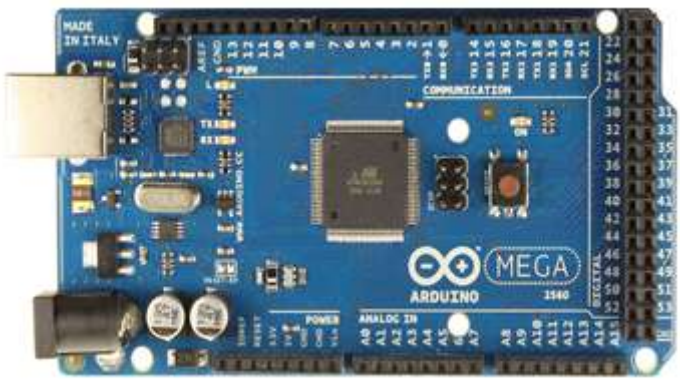

Fig 2 Arduino Mega 2560

Arduino is a powerful microcontroller with many built-in libraries, which are very useful in programming to provide optimal results. Major feature to be highlighted in Arduino Mega is the operational power requirements which is 5v with output current for each pin is 20mA.

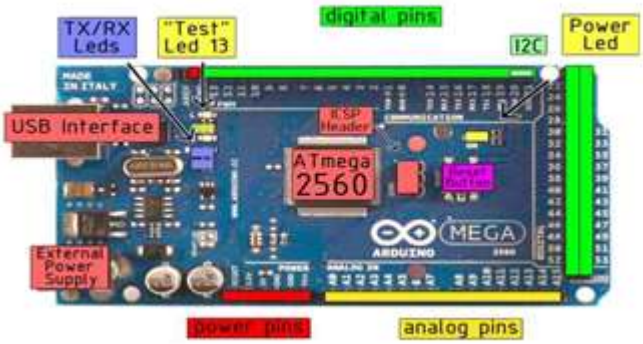

Fig 3 Arduino pin configuration

B. LPC2148

Another board used to design the system is LPC2148 which is seen in Fig 4 which is based on ARM7TDMI-S microprocessor which is seen in Fig 5 which has very high capabilities and can provide high speed flash memory of 512kb. The unique features of this microcontroller is the presence of accelerator architecture, two sets of instruction sets ARM (32-bit execution cycle) and Thumb (16-bit execution cycle), within the same processor, and finally due to its small size and low power consumption, is ideally applicable where miniaturization is required. It is recommended for communication gateways and protocol converters, low end imaging and voice recognition.

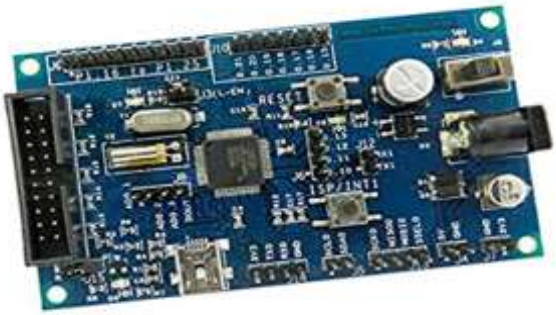

Fig 4 Lpc2148 board

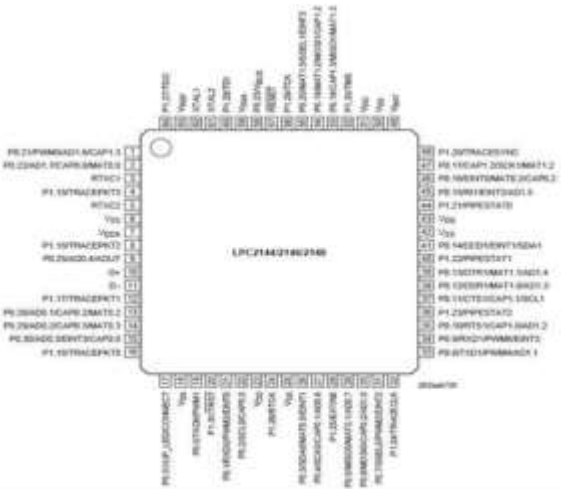

Fig 5 Lpc2148 processor

C. Bluetooth module HC-05

Bluetooth module HC-05[2][3] as seen in Fig 6 .We have used this in order to transmit the data wirelessly. It operates at low a voltage of 3.3v. We can apply 5v and it will be leveled to 3.3v due to the presence of LD1117 level converter within the module itself. The important features of Bluetooth is that its low power and can utilize adaptive frequency hopping(AFH) which is vital for secure transmission of data and to avoid interference with other signals. It implements a hopping sequence to avoid channels used by the same ISM band. Each hopping sequence is unique to the link.

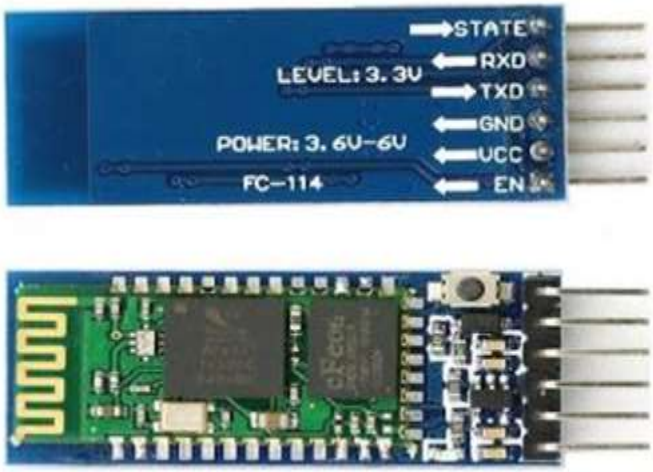

Fig 6 HC-05 Bluetooth module

D. Light-dependent resistor

Light dependent resistor (LDR)[7] is basically a variable resistance. As the intensity of light that falls on the LDR changes the resistance changes which can be seen in Fig 7. Each LDR has a basic structure which can be seen in Fig 8.

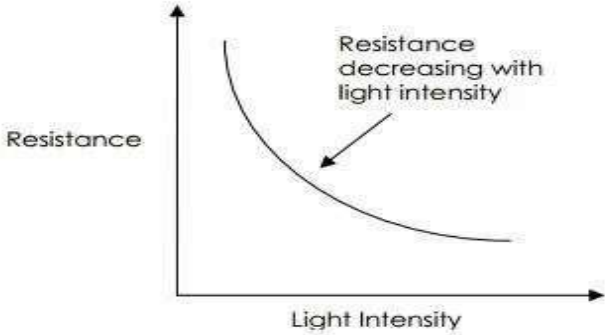

Fig 7 Typical LDR graph

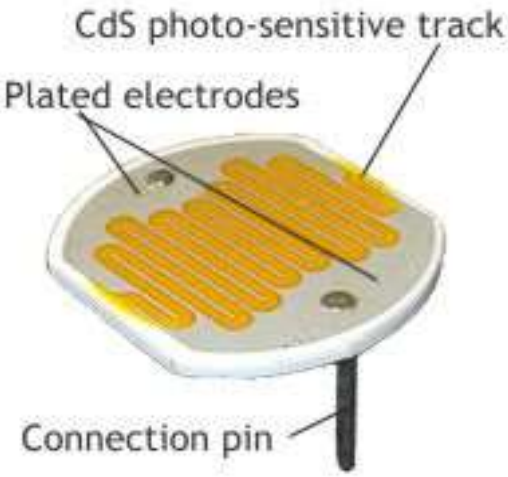

Fig 8 Structure of a typical LDR

5. IMPLEMENTATION

The proposed system is schematically represented in Fig 9, which is a design of using Arduino Mega2560 as a transmitter and LPC2148 as a receiver. Both the boards are 32-bit processors and hence we can use 32-bit ASCII codes in order to produce an operation within the satellite. A designed ASCII code when given as an input to the transmitter is processed and then sent to the Bluetooth module for transmission. The Bluetooth module at the transmitter side can be a master/slave and sends the information to be received at the receiver side which is the LPC2148. The information is then read from the receiver Bluetooth module, which can be master/slave, and processed to compare to a pre-existing ASCII value that is already implemented in the code. If the pre-existing ASCII character when compared to the received ASCII character matches, the board will access its memory and implement a function which is the result of that ASCII character. For the purpose of implementing with the same type signals as in a satellite, we used light emitting diodes (LED's) and LDR. The slave module will then send a feedback to the transmitter in order to make sure that a proper function has been implemented and that there was no error. This is an implementation based for the communication between AOCS, sensors and actuators.

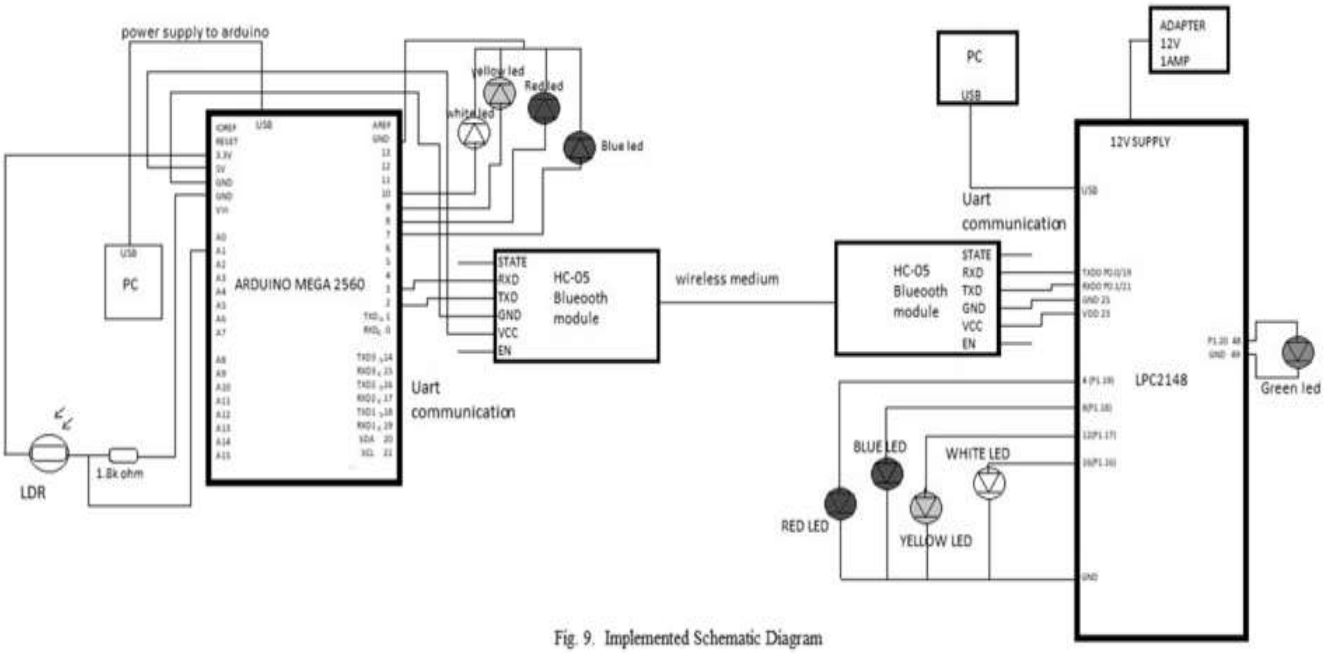

Fig. 9. Implemented Schematic Diagram

6. CONCLUSION

The data is transmitted from Arduino through transmitting HC-05 Bluetooth module to the receiving HC-05 Bluetooth module. The received data is then analyzed by the LPC2148 microcontroller and the respective functionality is performed i.e., controlling of any components by setting up i/o pins high or low. The data can be transmitted up to 10 meters of distance omnidirectionally and the required work will be done even when receiving Bluetooth module is not in the line of sight. Hence we can reduce the weight of the satellites by the use of proposed methodology.

7. ACKNOWLEDGEMENT

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