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Design and Development of a Prototype in Digenous Drive System for Azimuth and Elevation Control of Space Observational Equipment

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A R T I C L E I N F O

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A B S T R A C T

Radio and optical telescope are used for studying radiation emitted by extra terrestrial sources. The radio telescope is astronomical equipment consisting of radio receivers and antenna system used to detect radio frequency emission emitted by extraterrestrial sources. The optical telescope is used for studying and analyzing radiation from the visible portion of the electromagnetic spectrum. The performances of space observational equipment's are limited by various factors; 1) The accuracy of the reflecting surface that may depend on the ideal shape because of manufacturing irregularities. 2) The effect of wind load 3) Thermal deformation that causes differential expansion and contraction 4) Deflection due to changes in gravitational forces as the antenna is pointed to different parts of the sky. Human and natural phenomenon like wind load heavy rainfall storm and manual shift (intentional or unintentional) can cause mechanical displacement of the observational equipment thereby causing many receivers move from their designated position. This affects signal reception needed for frontline space research. We propose a dish or telescope positioning control system capable of monitoring and controlling any misalignment of dish orientation through azimuth and elevation. We incorporate motors that can receive command via micro controller connected to the system. This work entails the demonstrative model and the idea is to deliver a system which will control the movement of the observational telescope in all direction in order to overcome the difficulty experienced when adjusting the system manually.

1.Introduction

1.1 Prototype System Description

This project is designed to develop a dish or observational equipment positioning system that can operate using two actuators for azimuth and elevation control. The servo motor used is to change the dish or Equipment position precisely to a specific angle with a high degree of accuracy and precision for receiving Signals used for optical and radio astronomy for frontline space research. The project is also applicable for solar tracking applications. The dish antenna should always point to a satellite in space to receive maximum signal. A slight deviation from the targeted position may reduce the strength of the signal (attenuation).

The antenna position is fixed by forming two angles elevation and azimuth once these values are entered, the dish antenna moves in the vertical and horizontal direction by using 2 DC motors one for each direction (angle). As it moves in either direction, the direction between the fitting and current position gives feedback of error as input. The position is sensed using two Rotary Variable Differential Transformers (RVDT), one for each direction.

Sensors are connected to the shafts of the antenna as changes in the lay of the dish antenna the analog output from the changes in the sensor. Once the sensor position matches the entered position in terms of elevation and azimuth angle both motors stop rotating. Afterward, if there is any direction in the antenna position due to any situation, it impulsively reaches the belonging position using motors. If we want to change the position of the antenna (maybe to track satellites or locate a celestial object), then we change the elevation and azimuth angle, and again the dish or observational equipment moves in a modified direction

1.2Actual System Description

It includes big and heavy motors that can rotate and load the dish antenna. The observational equipment size may vary form from 9-18m depending on our design architecture and specification the rotary differential transformer is chosen or custom-made as per the observational equipment degree of rotation. It gives parallel analog voltage output as per the degree or speed of the equipment change. The complete system is precisely calibrated for Rotary variable differential transformer (RVDT) output as per antenna angle position in both dimensions,

In the course of the prototype model, we use a 5v DC motor. So, for each degree change in angle the output voltage changes by 5/90 -0.055v or 55mv approximately. If this RVDT is used in a system in such a way that the antenna moves from 0-90 it gives the output as 0-5v, then every degree change in equipment/dish position is sensed as a 55mv change in voltage output. The control system generates signals and senses this voltage to drive the motor. In the process or course of our real Model design and development, adequate consideration and specification of our motor, motor driver, and load or application characteristics should be duly observed.

Calculations, Simulations and Modeling should be the basic tools to employ when we intend coming up with the actual model design and development. The necessary software design tool is utilized and necessary specification taken into consideration to come up with an efficient control mechanism that gives us the required output with a high degree of accuracy and precision.

Shown below is a diagrammatic representation of a Radio Telescope System.

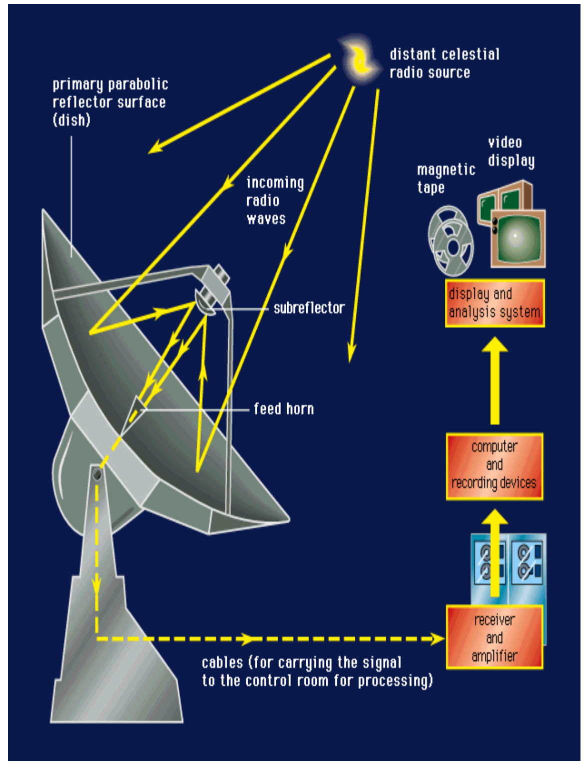

Fig. 1.A Radio Telescope System

2. Literature Review

Richard, V., Editor “motor control electronics headbook” Mc Graw-grant hill, Boston. Chatterjee S., “Industrial Electronics and Control”, New Delhi. Tata Mc Graw-Hill publishing company limited. Using the remote sensing control improves advanced although this is a nice approach to control system robotic the use of dish or equipment positioning via control interface is still very significant in control engineering technology. Emphasis was made on the need to use servo motors to drive heavy load application.

Amritha Mary A.S, Divyasree MV, Jesnapreem, Kavyasree SM, Keesthana Vasu proposed a system “Microcontroller Based Wireless 3D Position Control for Antenna”. This system is based on an android application and Raspberry pi. Raspberry Pi is the major controlling device in this system. Specific or desired angles are keyed in or entered and the antenna rotates to the specified direction or angle entered in the control interface or system.In our work, we incorporated an option interrupter sensor with a servo motor to achieve a very high degree of position accuracy and precision. Interfacing an option interrupter sensor will not only add to accuracy and precision improvement it will also serve as a measure to checkmate the efficacy and functionality of our servo feedback mechanism.

3. Design Methodology

Before we proceed to the design methodology adopted for this valuable project. We need to briefly introduce the term-servo mechanism. This mechanism is employed in this project for precise and accurate dish speed and positioning in azimuth and elevation.

Servo mechanism is a process of generating error output as a difference between control input and output feedback and reduces this error until it becomes zero. That means

- When the system reaches the desired state.
- When the system produces the desired output.

Generally, a servo mechanism is an automatic device that uses error-sensing negative feedback to correct the actions of a mechanism.

Industrial application-widely used defense automation, robotics, power, voltage regulation, satellite monitoring dish positioning, and feedback applications.

Elevation and Azimuth angles are set using input switches, as elaborated in the next section. Once the values are set, the dish antenna automatically moves in horizontal and vertical directions with the help of two DC-geared motors.

Fig. 2 shows the diagram of the antenna system along with the positions of elevation motors (EL axis) and azimuth (AZ axis).

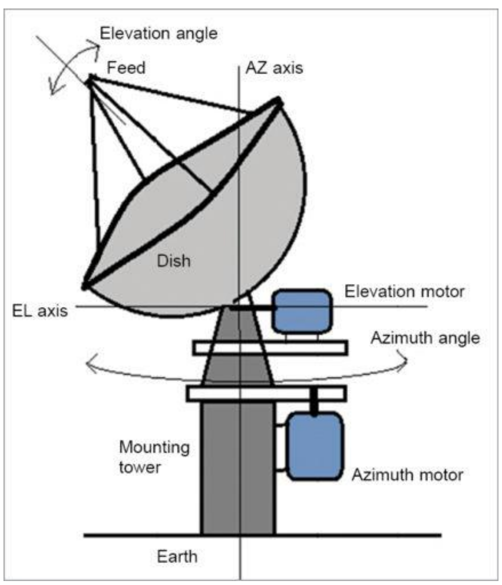

Fig 2: System of a satellite dish antenna

3.1 Circuit and Working

The circuit diagram of the satellite dish antenna angle controller using Arduino is shown in Fig. 2. It is built around Arduino Uno (Board1), two slotted opto-interrupter sensors two5V- 12V DC, MOC7811 (IC1 and IC2), 20×4 liquid crystal display (LCD1), motor driver L293D (IC3), 10rpm motors (M1 and M21) and a few other components. Each sensor circuit is built around MOC7811 having a phototransistor and internal IR LED. Both sensor circuits for azimuth and elevation angles are identical. Internal IR LED is given a 5V supply through 330-ohm current-limiting resistors (R6 & R8), and the photo-transistor is connected to switch configuration using external 1-kilo-ohm resistors (R7 & R9).IR light beams continuously fall on the photo-transistors. Sensor outputs are taken from collectors (pin 2) of the photo-transistors. Both sensor outputs (from IC1 & IC2) are connected to digital I/O pins 2 and 3 of Arduino Uno, respectively. Pins A0 through A4 are connected to 5V through resistors R1 through R5, respectively. Switches S1 through S5 are connected such that when a switch is pressed, logic 0 is given as input to Arduino Uno.

Digital pins 8&9 of Arduino Uno are connected to LCD1 control pins EN and RS, respectively. LCD1 data pins DB4 through DB7 are connected to digital pins 10, 11, 12, and 13 of Arduino Uno. The R/W pin of LCD1 is connected to the ground to enable it to write. Digital pins 4, 5, 6,&7 of Arduino Uno are connected to input pins of L293D (IC3). The motors are connected to the output pins of L293D. Arduino Uno drives the two DC motors (M1 & M2) through L293D.

The whole circuit works on 5V DC supply. Arduino Uno can be given a 5V regulated supply on its 5V pin. A separate 12V supply is given to pin 8 of L293D for the motor supply. Actual controlling of the dish antenna angle controller is done using software (dish_contr.ino) written in Arduino programming language and assembled using Arduino IDE software.

Fig. 3 shows the proposed mechanism for mounting a satellite dish antenna system for a demonstration model. There are two DC geared motors rated at 12V DC with 10rpm speed. The motor that rotates the dish antenna in the horizontal plane is azimuth motor 1 (AZ motor or M1), and the one that rotates it in the vertical plane is elevation motor 2 (EL motor or M2).

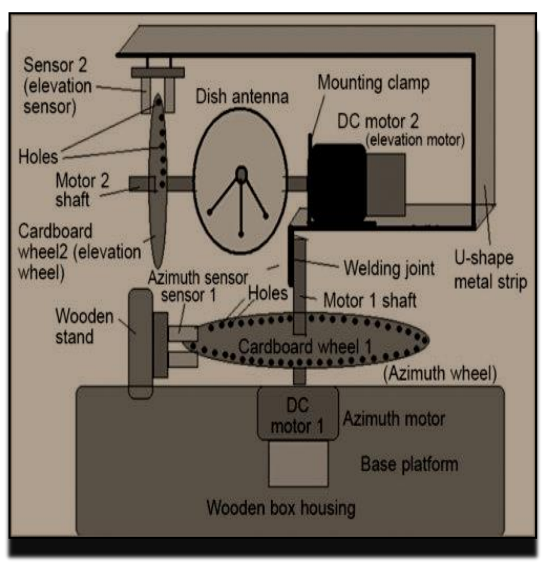

Fig. 3: Proposed mechanism for mounting a satellite dish antenna

Two opto-interrupter sensors (MOC7811) are utilized to give input on the angular locations of motors. Encoding wheels are attached to the shaft of each motor. Each encoding wheel has holes (say, 5mm diameter) at 10°, 20°, &30° and so on, up to 360°. The positioning is done in such a way that, as the motor rotates, the wheel also rotates and its holes pass through the slotted gap of the MOC7811 sensor. Interruption of IR light by each hole generates one pulse per 10° of motor rotation. The proposed ordering of the mechanical assembly is explained step-by-step below.

1. The entire system is set up in a plastic box that houses the circuit and also serves as the base or platform for the demonstration of the model.
2. Azimuth motor (M1) is fixed inside the wooden box using bolts and screws. Encoding cardboard wheel 1 (azimuth) with 35 holes attached to its shaft.
3. Azimuth sensor 1 (IC1) is also mounted vertically using a small wooden stand on the same wooden platform such that holes of azimuth encoding wheel 1 (azimuth) pass through the slotted gap of azimuth sensor 1.
4. A U-shaped metal strip of around 5cm is directly welded to the shaft of the elevation motor (M2). One arm of the U-shaped metal strip is longer than the other arm.
5. Elevation sensor 2 (IC2) is fixed at the end of the longer arm of this metal strip. Elevation motor 2 is mounted on the shorter arm using a mounting clamp and screws.
6. A dish antenna made up of cardboard and aluminum foil is directly fixed on the shaft of elevation motor 2. Encoding wheel 2 (elevation wheel) with seven holes is also attached to the shaft of DC motor 2.
7. This encoding elevation wheel 2 is fixed in such a way those holes of the wheel pass through the slotted gap of elevation sensor 2.

3.2 Periherals/Accessories list

3.2.1 Active Components

- Micro controller Board
- IC1-MOC 7811
- IC2-MOC 7811
- IC3-L293D Motor driver
- LCD-20 *4 LCD Display module (Hitachi HD 44780 driver/controller compatibles)

3.2.2 Passive Components(Current limiting Band Resisitors)

- RI-R5-10 Kilo ohm
- R6,R8-330 Kiloohm
- R7,R9-1 Kiloohm
- R10-220 ohm

3.2.3 Extra Requirements

- M1-5V-12V Motor,10RPM
- M2-5V-12VDC Motor,10 RPM
- Zener diode
- Jumper cables
- Push buttons
- Trim potentiometer-5V,10Kilohm

3.3Working of Demonstration Model

Initially, set the angles of both the motors to 0°. This means the dish antenna has a 0° elevation angle and 0° azimuth angle. Azimuth angle can be set from 0° to 360° in steps of 10° using pushbutton switches S1 &S2.Then, set the elevation angle from 0° to 90° in steps of 10° using S3 & S4.

When both angles are set, pressst art pushbutton S5 to rotate the dish antenna. Automatically, azimuth motor 1 will start rotating to set the dish antenna an azimuth angle. As AZ motor 1 rotates, encoding wheel 1 will also rotate& its holes will pass through the gap of sensor 1.

The sensor generates pulses that give feedback on the motor's angular position. The motor rotates till the set angle is reached. If the set angle is more than the angle of the initial position motor 1, it will rotate in a clockwise direction, and if the set angle is less than the angle the of initial position motor 1, it will rotate ina counter-clockwise direction.

Next, elevation motor 2 will start rotating impulsively. It will rotate the dish antenna as well as elevation encoding wheel 2 till a set angle is reached.

Once sensor outputs match the entered values of elevation and azimuth angles, both motors will stop rotating and the dish antenna will remain in that position. Thus, the dish antenna will accomplish the desired angular position in azimuth and elevation planes.

If you want to change the dish antenna position (like tracking another satellite), change elevation and azimuth angles by entering new values using input changes to move the dish antenna to a new position.

3.4Operation

Initially, when power is switched on, LCD1 will show the AZ angle & set the EL angle as 0°. Set AZ angle by pressing AZ angle Inc or dec buttons using azimuth push buttons, and EL angle by pressing Inc or dec buttons using elevation push buttons. Every time a button is pressed, the angle changes by 10°.

After setting the angles, press S5. Motor 1 will rotate, followed by motor 2. LCD1 will display the values of elevation and azimuth angles. When the dish antenna attains a position, LCD1 will show the set dish position

3.5Hardware Requirement and Specification

3.5.1 Standard tower pro 5G Servo

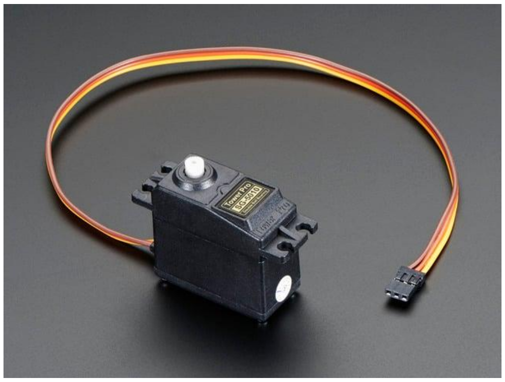

Fig .4.

The above servo is a closed-loop servo mechanism that uses position feedback to control its motion and final position. The input to its control is a signal (either digital or analog) describing the position command to the output shaft. The simplest servo motor uses position-only sensing via a potentiometer. In the process of developing our actual/real model, we employ heavy motors that match our load or application electrical torque and speed characteristics.
Servo motors are generally used as a high-performance alternative to the stepper motor. Stepper motors have some inbuilt ability to control positions as they have built-in output steps. This often allows them to be used as open-loop control systems. They have no feedback mechanism or encoders and their drive signals define the number of steps to rotate. The lack of feedback mechanism or encoders in stepper motors limits their performance so they can only drive loads that is well defined within their capability, otherwise missed steps might result in positioning errors which leads to re-calibration or restart of the process.

The controller and encoder of a servo motor are additional advantages as they optimize the performance of the entire system. (For all accuracy, speed, and power) relative to the power of the basic motor. We incorporate an additional option interrupter sensor or encoder for more precise position and speed monitoring and feedback.

3.5.2Opto Interrupter Sensor

Fig .5.

The MOC7811 optoin terrupter isolator module comes in a plastic mounting that houses an emitter and receiver section. it performs non-contact object sensing.MOC7811 is used in the position of wheel in any motor control system, factory, automation, robots, computers, printers and plotters for position feedback.

Generally, the MOC7811 is an opto isolator module with an IR transmitter and a photodiode mounted on it. The sensor is employed in the project to enhance position and speed feedback precision of our actuator

3.5.3 L293D Motor Shield

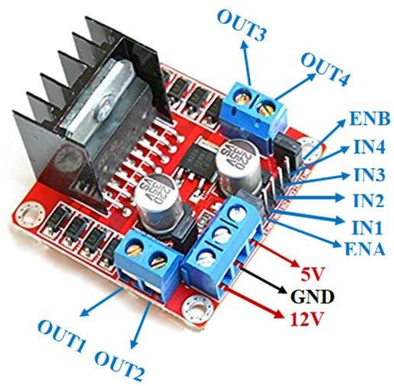

Fig.6.

They are daughter of expansion boards used to drive when interfaced to a micro controller board. Their pin outs are compatible with that of the microcontroller they are interfaced to. The L293D is a universal driver used to drive various categories of motors, steppers and servo motors. The L293D is a high-power driver and consists of a driver IC and a 78mos voltage regulator and it is a dual or h bridge driver with Darlington transistors.

Pin out configuration

- INI AND IN2 motor A input pins
- IN3 AND IN4 motor B input pins
- ENA enable PWM signal to motor A
- ENB enable PWM signal for motor b
- OUTPUT 1 AND OUTPUT 2output pin for motor A
- OUTPUT3 AND OUTPUT 4 output pin for motor b
- 12V input dc power
- 5V logic circuitry power
- GND ground pin

Features and Specifications

- Driver model L293D
- Driver chip-dual h bridge L293D
- Motor supply Voltage (V) - 6v(Max)

- Motor supply current (I) - 2A (Max)
- Logic voltage-5V
- Driver voltsge-5-35V
- Max power (w)-25W
- Driver current-2A
- Logical current-2A
- Heat sink

3.5.4 LCD module (20*4) 7 Segment Display

Fig.7.

The module employed in this work is the Hitachi HD 44780 driver/controller compatibles which is n alpha numeric dot matrix liquid crystal display. They usually have a 16 pin interface the azimuth and elevation speed and position is displayed in the LCD module. The maximum character display is 80 digits.
The Hitachi HD44780 LCD controller is limited to monochrome text display and often used in copiers fax machines test equipment's and networking equipments. Some of these LCD modules come with a back light which may be an LED, fluorescent or electroluniminscent.th e operating voltage of the backlight is 3 to 5v at full brightness

Interface and pin outs
The LCD module has a 16pin interface and mode of communication is parallel-that means the micro controller have to manipulate several pins in order to control the display. The interface can easily be hooked up to the Intelmcs-51x RAM Interface by only using 2 address pins which allow displaying text;
The pin outs are as follows;
Pin

- _VSS-(power ground pin)
- _VCC-(power supply input)
- _Vee-(contrast adjustment)
- _RS-(register select)
- _ R/W-(read/write
- _E-(enable)
- _DBO-(data pin 1)
- _DB1-(data pin 2)
- _DB2-(data pin 3)
- _DB3-(data pin 4)
- _DB4-(data pin 5)
- _DB5-(data pin 6)
- _DB6-(data pin 7)
- _DB7-(data pin 8)
- _A-(LED Power +ve)
- _K-(LED Power-ve)

A trim potentiometer is connected to 5v dc source and to ground with the wiper connected to pin 3(VEE) of the LCD module for contrast or brightness adjustment of our display.

3.5.5Micro Controller: Below is the micro controller unit Atmega 328p and the Program able board.

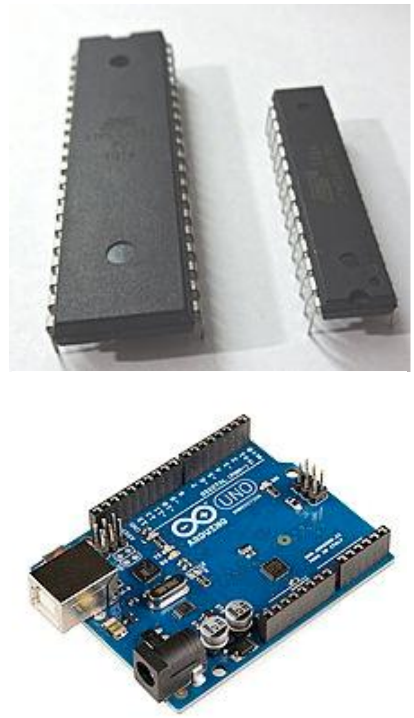

Fig.8.

The Micro controller board used, share the same data sheet with at mega 328p.It is a single micro controller board for designing and developing digital devices.

The Micro controller board is equipped with set of digital and analog input/output pins that can be interfaced to various expansion or daughter boards for prototyping. The board features serial communication interface (USB)which is used for programming, compiling, verifying, and uploading of sketches or program codes to it using a computer via USB. The micro controller can be programmed using c+ and c++ programming language using a standard API which is known as the Arduino programming language.

We used the Arduino programming language to write, debug, verify and upload sketches to micro controller unit. Our Micro controller consists of flash memory, SRAM, EEPROM, ADC, program able Input/output pins, PWM pins, 16 MHzcrystal oscillator and 5v linear regulators.

Pins and Specification

- Version-ATMEGA 328P

- Package-DIL Package
- Nominal Voltage-5V
- ADC Vref-5V
- EEPROM-1KB
- Maximum I/O Pins-23
- I/O Pins-14
- PWM PINS-6
- SRAM-2KB
- ADC Bit-10 BIT
- Maximum no of pins-28
- Maximum operating Frequency-20MHZ
- Analog pins-6
- Programme memory-32KB

3.5.6 Passive electronic component

The component consists of current limiting resistors of different values. The current limiting resistors includes 5(10) kilohms (pull down)connected between 5 switch buttons and analog Pins of the micro controller(pin AO – A4) and 2(1kilohm) resistors for the 2 opto interrupter sensors(encoders) along with a resistor of value 330 ohms.

3.6Software operating condition

A programme for Arduino software can be written in any programming Language with compilers that produce binary machine code for the largest processor. In this work the Arduino integrated development environment (IDE) which is a cross platform application written in java programming language was used for writing debugging, compiling and uploading of codes to drive our hardware interface.

The Arduino IDE includes a code editor which features such as text cutting and pasting, searching and replacing text, automatic indenting and syntax high lighting. It also features a one click mechanism to compile and upload programme to the microcontroller board.

The IDE contains a message area, a text console a tool bar with buttons for a common function and a hierarchy of operation menus. The Arduino IDE supplies a software library for the wiring project which provides several input and output procedures. The motor and LCD library was incorporated in our program codes or sketches.

With painstaking efforts and dedication, our writing, debugging, verification and uploading of our program mecodes achieved desired goals.

4 Model circuit Diagram with pictorial view

The circuit diagram below was designed and developed and we achieved results as signal was sent from the input unit via the microcontroller to the L293D motor shield (expansion or daughter board) and finally to the output (Actuator).

The output (Rotary Actuator) responded accurately by outputting corresponding dish position and speed input signals.

4.1 Model Circuit Diagram

Below is a detailed circuit diagram of the implemented project

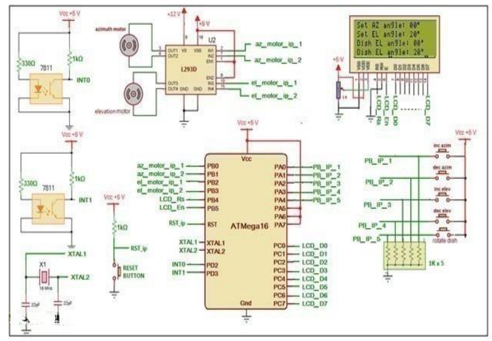

Fig.9.

4.2Model's Pictorial View

Fig.10.

Fig.11.

5 Results and Discussion

The demonstration model was finally designed and developed test runed and worked perfectly. In the course of our real or actual model development we match our micro controller and motor shield electrical characteristics to our output Actuator (motor) characteristics and also match our output motor speed and torque characteristics to our load or application. The project was designed and developed to promote indigenous technology. The current exchange rate in Nigeria is very alarming and this affected significantly the cost of foreign made space observational equipments.

As a result of the above we decided to embark on indigenous technology to save huge cost of equipment acquisition and also limit cumbersome trouble shooting techniques.

6Conclusion

Financial constraints, equipment acquisition cost, frustrating troubleshooting techniques of foreign observational equipments and stressful procurement protocols have facilitated the need for indigenous search, design and development of our own equipments. Adequate Research, Design and Development of indigenous equipments will also foster collaboration and deepen relationship with relevant agencies or institution.

Acknowledgement

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