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# Conceptual Design of a Testing Jig for Torque Measurements of the SARA

## 1. Introduction

The Sun-Pointing Attitude Regulation Assembly (SARA) is a CubeSat mechanism designed to optimize power intake from solar panels by actively tracking the sun. To ensure its reliability and performance, a testing jig is needed to measure the torque generated by the stepper motor-driven mechanism. This document details the conceptual design of a testing jig based on Advanced Mechanical Design Methods principle.

## 2. Design Requirements & Assumptions

### 2.1 Functional Requirements

- Design a test jig to test the solar tracking performance of SARA and should ensure its modularity to accommodate any type of CubeSat model for testing its tracking performance.
- Measure the torque output of the stepper motor during operation and must cancel any temperature and gravitational interference.
- Ensure accurate data acquisition for performance validation.
- Simulate real-world load conditions encountered in space.
- Provide repeatable and reliable measurements under varying conditions.
- Disruption on advantage and disadvantages.
- Estimation of cost and time needed to implement the jig.

### 2.2 Assumptions

- The test rig is only designed for test purpose not to be included on the CubeSat design structure for launching and the Cube satellite is design on the principles of CubeSat design.
- The stepper motor used in SARA operates at 5V with a holding torque of ~0.2 Nm.
- The CubeSat structure is 97x97x23 mm with an estimated weight of 0.3kg.
- The testing environment is a controlled laboratory setting (20-25°C, minimal vibration).
- The system will be controlled via an Arduino-based data acquisition system [but will be converted to a custom designed PCB if necessary].
- Safety measures such as overload protection and emergency stops are included

## 3. Conceptual Design

### 3.1 Design Overview

The testing jig consists of:

- ✓ Modular Rotational Base: A stable platform to mount the CubeSat mechanism.
- ✓ Torque Sensor (torsional): Captures real-time torque values.
- ✓ Stepper Motor & Driver: Provides controlled movement for testing.
- ✓ Light lamp and Sensors: Simulate real sunlight detection.
- ✓ Arduino board: Collects and processes torque readings.
- ✓ Deferential operational amplifier: to increase the magnitude of measured voltage.
- ✓ Switches to start and stop the operation.
- ✓ Load cell with a Wheatstone bridge configuration: o get the response electrical voltage according to applied torque by the stepper motor.
- ✓ Dc power source 12v.
- ✓ Two voltage activated relays.

### 3.2 Working principle of the design:

The main controlling microcontroller implemented is an Arduino mega. In order to create the artificial positioning of sun under controlled environment, we used two lamps in a controlled chamber with the light sensor mimicking positional sun intensity variation among each end of the satellite.

Therefore, the variable resistor implemented varies the magnitude of the lamp to reduce meaning the sun is in the direction of the higher energy lamp so the steeper motor rotates reading the potential deference created as it goes through the deferential amplifier. So, the as the stepper motor rotates the intensity of light at both light sensors will balance them out (for this case we are balancing manually to see its response time according to our manipulation).

The applied torque is measured on the principle of torsionmeter in which we place 4 strain gauges onto the shaft in helical position as shown below.

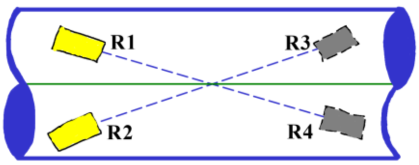


**Figure 1 Strain gauges position on the shaft**

The applied torque will deform the shaft in turn deform the strain gauge. Placing those resistors through the Wheatstone bridge will balance both temperature effect but still will give us the residual reading on terminal T1 and T2 as shown in the schematics and it is feed to a deferential amplifier which gives positive or negative voltage output due to the estimation of the torque applied.

$$E_o = \frac{16(1+v)KE_{in}T}{\pi D^3 E}$$

Were, $E_o$, the output voltage
T, torque applied
D, geometry diameter
E, young's modulus of the shaft material
$E_{in}$, the applied voltage on the Wheatstone bridge.
K, strain gauge constant

So, by calibrating the system we can get an instant reading of the torque as we rotate the stepper motor. And this reading can be given through the serial port of the Arduino in the future I will try to incorporate Processing IDE for designing a visual interface to control and monitor instantaneous results.

The system running Arduino code, the Solidworks model assembly and Proteus circuit model is uploaded in my GitHub repository to access it **click here**.

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### 3.3 Sketch/Diagram

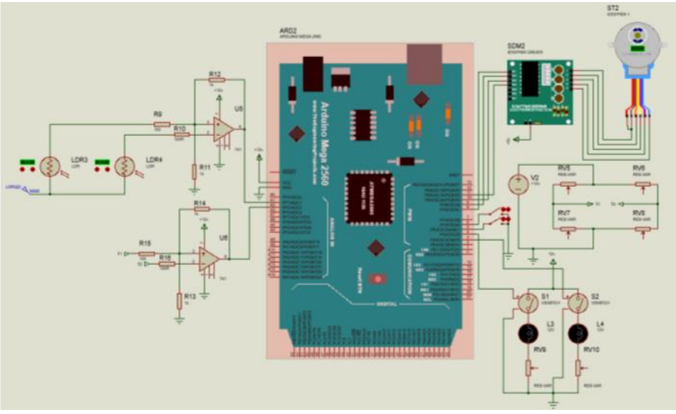

**Figure 2 Schematic diagram of the Jig**

### 3.4 Mechanical Assembly

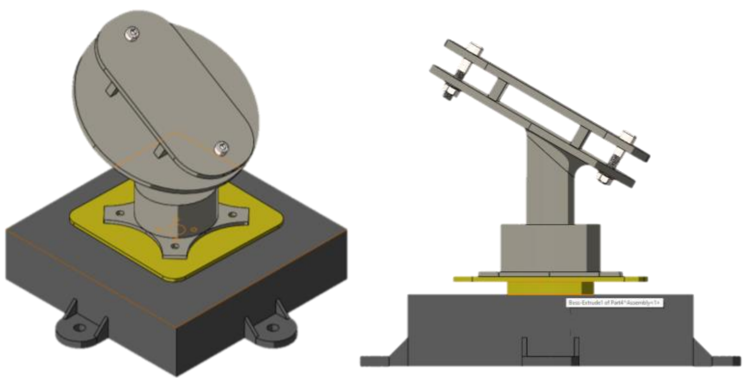

**Figure 3 physical model designed in SolidWorks**

As shown the design is aimed to host the CubeSat SARA and rotate following the intensity difference aimed at each light sensor ends of the satellite. The design is made modular in hopes of incorporating the following specifications of the satellite and make is adjustable for any design changes further on the line.

**Mechanical specs of SARA**
Size: 97X97X23mm
Mass: 0.3kg
Rotation Range: +/ - 180 degrees

**ELECTRICAL SPECS**
Power supply: 12V (unregulated 10-18V)
Power consumption: 5V max
Power transfer type: flex pcb (twist capsule)

**THERMAL SPECS**
Operating temperature range: -40/+60 °

## 4. Manufacturing & Assembly Considerations

- **Material Selection**: Lightweight ABS frame for minimal interference. Produced either by **FDM** or **SLA** additive manufacturing process due to its light weight and rigid mechanical property.
- **Modularity and calibration**: Components should be easily replaceable for testing iterations and easily calibrated in hopes of getting linearity in the torque reading.
- **Precision**: High-resolution torque measurement for accurate data implementing amplification to clearly detect and evaluate its magnitude.

## 5. Testing & Validation Plan

**Step 1:** Assembly and System Calibration (zeroing the sensor readings)
**Step 2:** Controlled torque application with different values of the light sensor readings
**Step 3:** Data acquisition and analysis
**Step 4:** Repeatability and error analysis

## 6. Cost & Time Estimation

### 6.1 Cost Breakdown

| Component | Unit price (€) | Quantity & Unit | | Total |
|---|---|---|---|---|
| **Arduino mega** | 52 | 1 | Pcs | 52 |
| **Stepper motor** – [NEMA – 17] | 12 | 1 | Pcs | 12 |
| **Stepper motor driver -** [L298N] | 7 | 1 | Pcs | 7 |
| **Operational Amplifier** | 10 [4pcs] | 2 | Pcs | 10 |
| **Strain gauge resistors -** [BF350] | 11 [10 pcs] | 4 | Pcs | 11 |
| **Lamp** | 6 [3pcs] | 2 | Pcs | 6 |
| **Light sensor** [light dependent resistors] | 9 | 2 | Pcs | 9 |
| **Normal Resistors** | 7 [100pcs] | 8 | Pcs | 7 |
| **Potentiometer** – [pot] | 2 | 2 | Pcs | 4 |
| **Switches** | 1 | 2 | Pcs | 4 |
| **ABS for 3D printing** | 18 | 1.5 | kg | 27 |
| **Relays** | 8 | 2 | Pcs | 16 |
| **Thrust bearing** | 12 | 1 | Pcs | 15 |
| **Cupper plate and brush** | 10 | 2 | Pcs | 20 |
| **Miscellaneous** | 50 | | | 50 |
| **Total Estimation Cost** | | | | **250** |

### 6.2 Time Estimate

| Inquiry Progress | Time requirement |
|---|---|
| **Concept Development** | 1 week |
| **Procurement, Prototyping and assembly** | 2 weeks |
| **Testing and iteration** | 1 week |
| **Final validation** | 0.5 week |
| **Total** | 4.5 weeks (almost a month) |

## 7. Conclusion

Firstly, I want to give thanks for giving me this opportunity to deliver my skills.

The system is designed and run on Arduino microcontroller to give an instant reply for any change in intensity of light source to get the best to generate power for the satellite. Following the change the motor rotates creating a torque on the shaft which is being read by a strain gauge put in the shaft. This creates a change in voltage across the Wheatstone bridge which then gets amplified and be read.

This reading is posted through the serial port of the Arduino and for further advancement can be done by employing a GUI through processing IDE for better visualization and control.