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DESIGN OF TILT TABLE FOR ABSOLUTE ACCELEROMETER CALIBRATION

[1]Moh. Mambaul Ulum⊠, [2]Hapsoro Agung Nugroho, [2]Marzuki Sinambela
[1,2]The Indonesia of Meteorology Climatology and Geophysics Agency (BMKG), Jakarta, Indonesia
[2]State Collage of Meteorology Climatology and Geophysics, Tangerang Selatan, Indonesia
Email: moh.ulum@bmkg.go.id

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ABSTRACT

An accelerometer is used in applications that require measurements of absolute or relative acceleration. Tilt table (roll table) is a flat plane whose tilt can be changed. In BMKG (Climatology and Geophysics Meteorological Agency) there are two methods to calibrate accelerometer, namely calibration using relative sine waves and absolute calibration using the media acceleration due to gravity. The tilt table is used as an absolute accelerometer calibration aid. The tilt table uses a DC motor and gear ratio as the actuator to move so that the resolution of the angle changes on the axis of the tilt table will be smaller and smoother. The tilt table is able to assist the technician in calibrating the accelerometer with minimal angle movements so that the inclination settings at the time of calibration are more precise proved by the result of the comparison. The horizontal axis correction is 2,27º and the vertical is 2,31º.

Keywords: Accelerometer, Absolute Calibration, Inclination, Acceleration, Gear Ratio.

INTRODUCTION

Accelerometers are used in applications that require absolute or relative acceleration measurements. The Meteorology Climatology and Geophysics Agency uses two accelerometer calibration methods, namely relative calibration using sine waves and absolute calibration using gravitational acceleration media. The tilt table is used as a tool for absolute accelerometer calibration. In calibration practice, the Earth's gravitational acceleration was often expressed as 9.81 ms^{-2} or '1 g' (Archer, 2017; Pedley, 2015).

The 3-axis accelerometers available on the market have been calibrated with a six-element linear model method consisting of the gain and offset of each axis by the accelerometer vendor (Pedley, 2015).

According to Government Regulation number 46 of 2012 concerning the organization of MKG observations and data processing articles 62-74 (Kominfo, 2002), every piece of equipment operated at an observation station must be fit for operation to ensure the continuity of function and accuracy of observations, including provisions on operational equipment that must be calibrated. BMKG regulation number 23 of 2015 states that calibration is carried out by comparing the indication of a measuring instrument with the value of a standard. To strive for this, a tilt table is designed as a standard medium for absolute accelerometer calibration. It is hoped that the calibration results will improve in terms of quality.

LITERATURE REVIEW

Researches that has been conducted by previous researchers related will be used as a reference and research development, including (Pedley, 2015) from Freescale Semiconductor document number AN4399 entitled High-precision Calibration of a Three-Axis Accelerometers. This document discusses accelerometer calibration methods with absolute and relative methods, also includes calibration calculations that have been carried out at the manufacturer and calibration calculations accompanied by temperature dependence calculations. This research is used as the basis for the absolute calibration method in tool design. (Loka, Sumadja, & Resmi, 2017) from the University of Lampung entitled Prototype door lock using Arduino MEGA 2560-based stepper motor with voice commands on android. This research discusses the design of an automatic door lock system. This research uses the Arduino MEGA micro controller application and stepper motor in the actuation of the lock drive system. This research uses the Arduino MEGA micro controller and NEMA stepper motor as the actuator of the drive system in the research. (Dabet & P, 2021; Lestari, 2019) and (Tarigan, Sinurat, & Sinambela, 2016) which is entitled ARDUINO-Based Electronic Control System Project. This research describes the control system on Arduino. This research applies the PWM (pulse with modulation) control system to the system design. Applied Geomechanics (Dabet & P, 2021; Lestari, 2019; Plant, 2005) Model 791

Calibration Plate for tilt meters and inclinometers. This document contains calibration method of inclinometer and accelerometer using calibration plate and design of calibration plate model 791. This document implements the calibration plate principle in a tilt table for calibrating accelerometers. This research uses the absolute calibration method. The instrument will be designed with each system using 2 stepper motor components and Arduino MEGA as a microcontroller that will be programmed to rotate on 2 table axes. The rotation of the table axis can be controlled through a serial monitor.

SYSTEM DESIGN AND IMPLEMENTATION

This section describes the concept of the proposed system, including the system block diagram, System working principle, and the design.

System Block Diagram

The block diagram of the tilt table system can be seen in Figure 1.

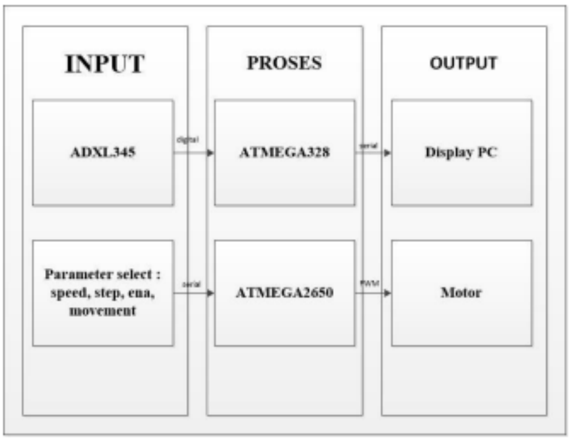

Figure 1. System Block Diagram

The system consists of two components, the orientation sensor and the motion component. The orientation sensor component works in a sequence:

1. The ADXL345 accelerometer reads the acceleration that occurs on each axis.
2. The sensor output in the form of digital data then read by the microcontroller ATMEGA 328.
3. The microcontroller converts the acceleration data readings to the tilt of each axis based on the comparison of the sensor readings with gravitational acceleration.
4. The processed data results are displayed to the PC interface via serial comms.

The motion components work based on the following steps:

1. The user/technician enters the motion parameters of the stepper motor through the pc display. The motion parameters are speed, step, enable, and move.
2. The display pc communicates with the microcontroller using serial.
3. ATMEGA 2650 microcontroller processes the input data to control the stepper motor.
4. The actuator which is a stepper motor will be controlled using PWM (pulse with modulation) frequency through the driver installed on the microcontroller.

System Working Principle

The device consists of a tilt sensor connected to two motion axes. The tilt sensor utilizes an ADXL345 accelerometer to convert acceleration readings into tilt.

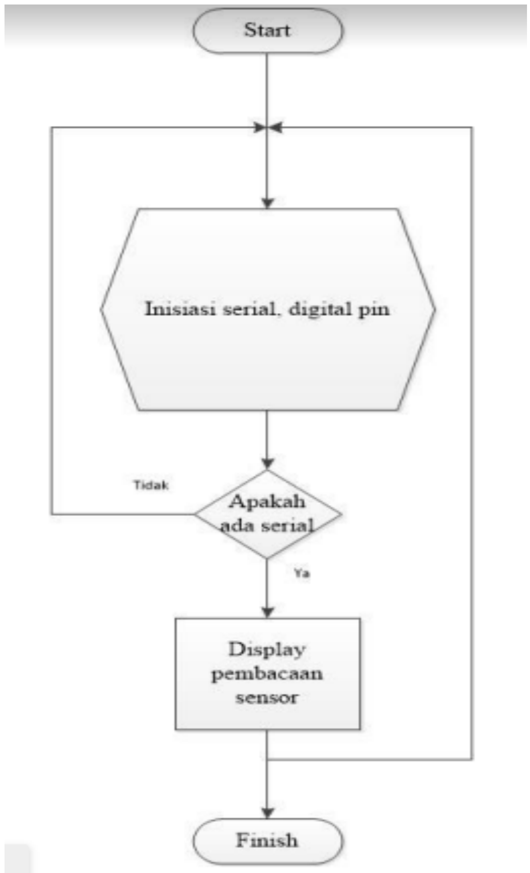

Figure 2. Display workflow

NEMA 23 and NEMA 17 stepper motors have a motion angle of 1.8° per step, to increase the resolution of the motor movement, the mechanical device will be designed by applying the gear mechanism. The horizontal axis has had a 22:80 gear ratio or 0.495° rotary stage angle resolution. The vertical axis has a ratio of 24:80 or 0.52° moment arm resolution.

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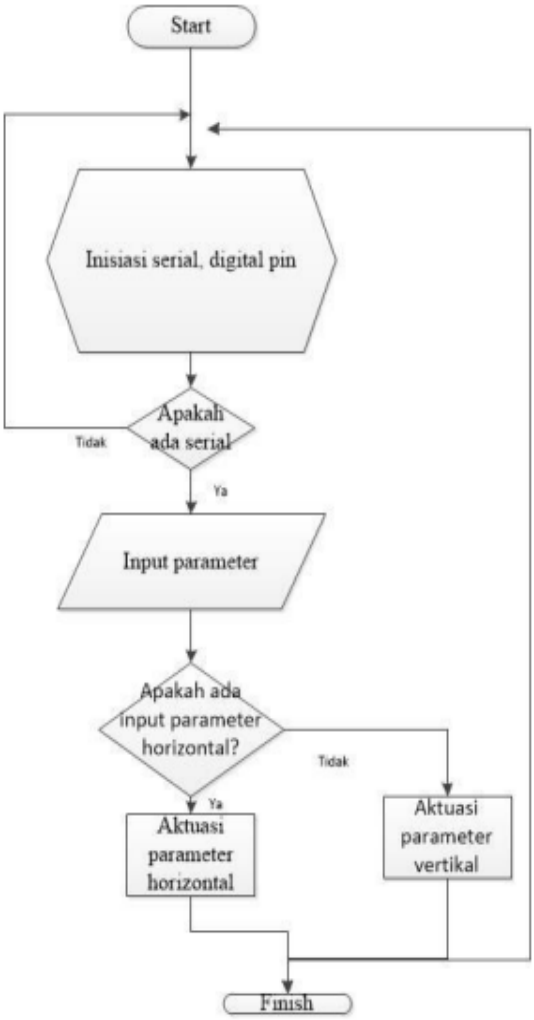

Figure 3. Control flow

System Design

The frame structures are made of aluminum alloy this is intended so that the table structure is sturdy and there is not much shock.

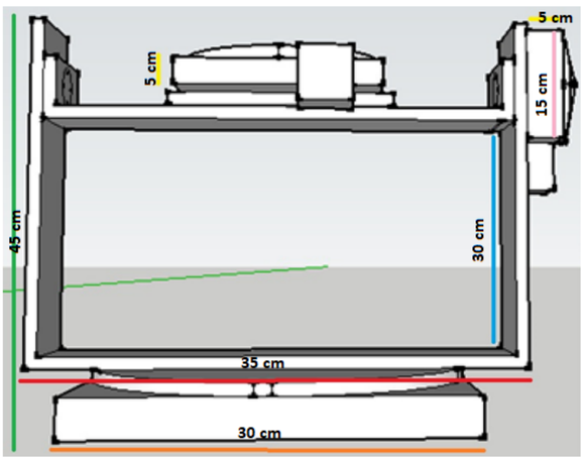

Figure 4. System Frame Design

Rotary stage consists of four components namely moving component, stationary component, bearing, and ratio gear. The rotary stage can also be referred as gearbox because it has a ratio function.

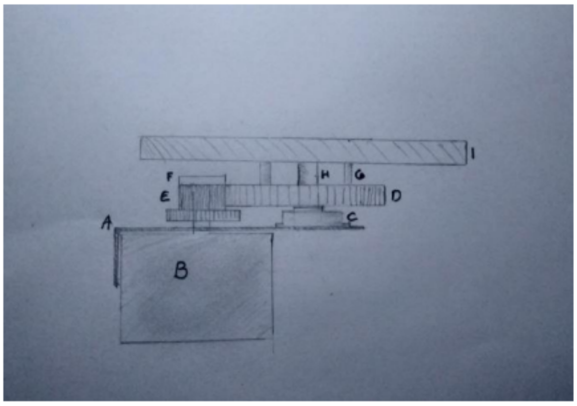

Figure 5. Rotary Stage Design

The calibration plate, apart from being a sensor holder, can also functioned as a calibrator of accelerometer derivative tools such as inclinometers that are based on the model 791 calibration plate as a reference.

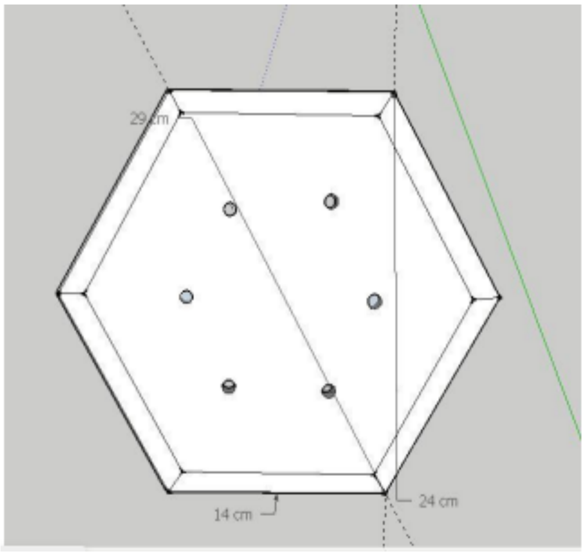

Figure 6. Calibration plate design

TEST AND ANALYSIS

Actuation test

Actuation system testing was conducted to confirm the function of the tilt table motion parameters through the GUI.

Figure 7. Y Initial Position

According to the calculation, pinion gear:spoor gear ratio, 167 motor steps will be required for 90° rotary motion stage.

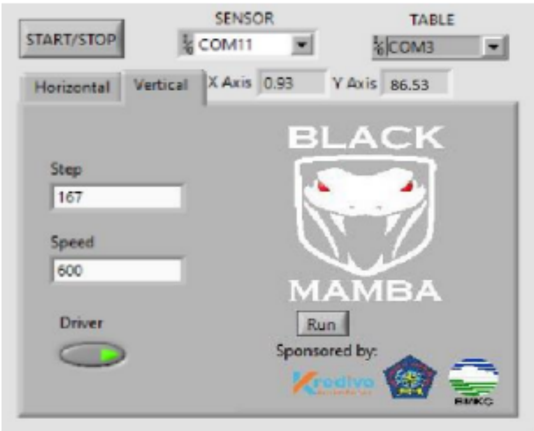

Figure 8. Y final position

The actual movement for 167 motor steps are 95.77° wich is 5.77° error factor or 0.035 ° error offset per step.

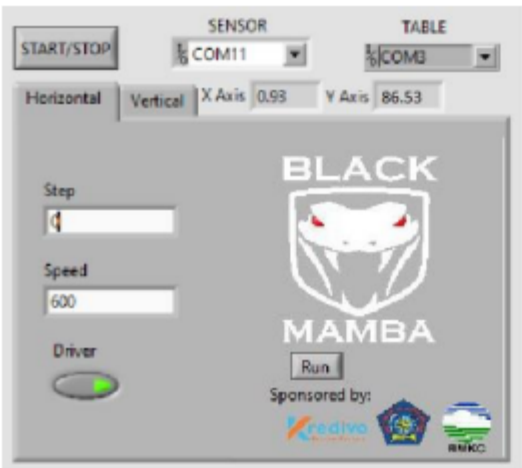

Figure 9. X Initial Position

According to the calculation, pinion gear:spoor gear ratio, 200 motor steps will be required for 90° rotary motion stage.

Figure 10. X Final Position

The actual movement for 200 motor steps are 82.38° wich is 6.72° error factor or 0.033 ° error offset per step. Indicating that greater gear ratio can reduce error offset for the implemented design.

Comparation test

Comparation test are done by comparing the value of the device made with standard measuring instruments. Testing is carried out on 2 (two) axes with 7 (seven) set points, namely 0, 15, 30, 45, 60, 75, and 90 degrees.

. **Table 1.** Vertical Axis Test Result

No	Set Point	Vertical Axis		Comparison
		Standard	UUT	
1	0	0,91	0,8	0,11
2	15	15,87	22,07	6,2
3	30	27,22	32,71	5,49
4	45	43,74	41,84	1,9
5	60	61,05	59,15	1,9
6	75	75,25	74,96	0,29
7	90	88,92	89,2	0,28
Correction				**2,31**

Vertical angle correction obtained from the average difference in readings in the range of 2.31 degrees.

Table 2. Horizontal axis test result

No	Set Point	Horizontal Axis		Comparison
		Standard	UUT	
1	0	0,35	0,5	0,15
2	15	14,72	24,07	6,35
3	30	28,42	29,6	1,21
4	45	43,91	41,57	2,34
5	60	60,36	65,4	5,04
6	75	74,21	73,41	0,8
7	90	86,59	86,61	0,02
Correction				**2,27**

Horizontal angle correction obtained from the average difference in readings in the range of 2.27 degrees.

CONCLUSIONS

Based on the result the 0.035 º vertical error offset are required for each step of vertical axis operation. 0.033 º horizontal error offset are required for each step of horizontal axis operation. The offset may be changed according to the gear ratio. The design implementation of the tilt table has an operational angle correction of the horizontal axis of 2.27 degrees and vertical axis of 2.31 degrees. It is necessary to improve the precision of material measurement, mounting, and mounting mechanics for better performance. Offsetting error can be minimized through increasing gear ratio.

DAFTAR PUSTAKA

Archer, A. (2017). Investigation of Three-Axis Accelerometer Calibration Techniques. *Iowa Researche Online*, (29), 2–4.

Dabet, A., & P, M. I. A. (2021). Pembuatan Sistem Wiper Otomatis pada Kendaraan Menggunakan Aplikasi Arduino Uno. *Malikussaleh Journal of Mechanical Science and Technology Vol.5 No.2 (2021) 17-22*, *5*(2), 17–22.

Kominfo. (2002). POST, Telecommunications, And Broadcasting, (1), 1–41.

Lestari, A. P. (2019). Pemanfaatan Sensor Ultrasonik Berbasis Arduino Uno Sebagai Peringatan Dini Banjir Bengawan Solo Di Kabupaten Tuban, Jawa Timur. *JURNAL GEOGRAFI Geografi Dan Pengajarannya*, *17*(1), 55. https://doi.org/10.26740/jggp.v17n1.p55-62

Loka, W. P., Sumadja, W. A., & Resmi. (2017). Prototipe Kunci Pintu Menggunakan Motor Stepper Berbasis Arduino Mega 2560 Dengan Perintah Suara Pada Android. *Journal of Chemical Information and Modeling*, *21*(2), 1689–1699.

Pedley, M. (2015). High-precision calibration of a three axis accelerometer (AN4399). *Application Note*, *10*, 1–35.

Plant, N. P. (2005). Geotechnical Subsurface Investigation Final Data Report FSAR Appendix 2 . 5-A.

Tarigan, P., Sinurat, S., & Sinambela, M. (2016). Implementation of a Mamdani fuzzy logic controller for building automation using electronic control based on AT89S51. *Proceedings of the 2015 International Conference on Technology, Informatics, Management, Engineering and Environment, TIME-E 2015*, 87–92. https://doi.org/10.1109/TIME-E.2015.7389753