A Computer Controlled Positioning System for a Turntable

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Abstract— Designing highly accurate control system for a turntable device is a challenging endeavor. This subject paper aims at developing a positioning control system for a turntable unit using LabVIEW application. The general mathematical model of the turntable system is obtained first and then a simulation is carried out in LabVIEW to see how the system behaves with the proposed control system in real-time. A Graphical User Interface (GUI) is developed to set input parameters like angular position in degrees, start and stop control signals; the GUI shows the current position of the turntable device in real time. Output performances are measured on the actual hardware setup. It has been shown that a Proportional Derivative (PD) controller gives promising results in positioning the devise. This system is useful for testing equipment for Electro Magnetic Compatibility (EMC) and Electromagnetic Interference (EMI).

Keywords—Turntable; PD and P Controller; LabVIEW; Turntable control system

I. INTRODUCTION

Since the dawn of the new millennium, men have been able to advance their technological capabilities to great heights, elevating the level of performance, durability and increasing the systematic capabilities of machines. Micro-processing in particular has been one of the ultimate tools of men giving the vast functionality it can offer, not only to people in general but to scientists and engineers. Similarly it has been found that the testing and compliance laboratories are equipped with position setup devices for testing equipment, namely Equipment Under Test (EUT). It is desirable to use an automatic control system for accurate measurement of position and together with time management. In present days, some advanced tools and controller platforms are easily available to develop desired automatic applications. We have used the LabVIEW software and C++ programming in Arduino to control the turntable's speed and position. LabVIEW is mainly an explicitly programmed software tool that many engineers and scientists use in order to improve measurement, test and control systems. The designs in lab-view are generally helpful with in-built graphical icons and wires that resemble a flowchart. Together with the built-in libraries provided in the software itself, it is even easier to interface it with hardware devices and perform advanced analysis and data visualization [2]. The graphical user interface (GUI) is developed to take inputs from the user. It is also highly demanded that real time inputs and outputs are considered to controls of peripheral environment without significant delay. These peripherals are connected to other computer systems with sensors, actuators, and other input-output (I/O) devices [1].

Main feature of LabVIEW software is the data acquisition (DAQ) platforms, in which the signals are captured from different range of instruments. DAQ devices have the ability to generate signals together with collecting them. The signals generated can be used to cooperate with extra operational equipment's/instruments in order to generate events and make things occur [3]. In the next section, we briefly present a literature review.

II. BACKGROUND

Turntables have been vastly used in industrial applications for positioning and automatic production line. By setting the speed, direction, and desired angles, the device operates accordingly. The use of turntables saves a lot of space inside the workshop which also upgrades the production efficiency [4]. Another application of turntables has been found in positioning of antenna [5].

Com-Power Corporation [6] is one of the suppliers of instruments and equipment's for measurement purpose and other applications. The turntable shown is Figure 1 is a low profile wooden turntable, with circular testing platforms. EUT is rotated to identify the position or angle at which the EUT radiates maximum electromagnetic interference. The turntable system is shown in figure that consists of a motor, gear reduction drive and limit switch.

Figure 1: Com-Power Corporation Turntable [6]

The design and implementation of an intelligent Disc Jockey (DJ) system is presented in [9]. The system uses haptic force feedback to expand the expressive abilities of the traditional DJ setup. Detailed description of haptic-design-related problems such as method for accurately calculating low velocities was discussed in this work.

Measurement of radiated emissions of electronic equipment in order to comply with the electromagnetic compatibility (EMC) requirements is discussed in [8]. The maximum radiation from the equipment Under Test (EUT) is captured by using a rotating turntable and by means of a moving the antenna. The developments of the control systems models of a turntable unit and antenna-positioning device were presented in this paper.

A control algorithm for the test turntable system is proposed in [7]. Combination of classical feedback correction and the adaptive feed-forward compensation techniques are used to ensure good performance and stability of the test turntable system. Simulation results also show that the proposed algorithm improves system bandwidth expansion, and system tracking accuracy. In the following section, the positioning control system model.

III. DESIGN AND IMPLEMENTATION

DC motor modelling

DC motors occur in many different models and have various methods for speed control. In this paper, we have used separately excited DC motors for the control of speed. A well-known mathematical model was considered for the presented turntable system. The transfer function approach was used to derive the mathematical model for the turntable system. The input to the system was voltage while the output was represented by the angular position of the rotating plate on the turntable system. To make the modeling simple, factors such as the weight on the rotating plate, effects of the gearbox and support bearing frictional effect have been neglected.

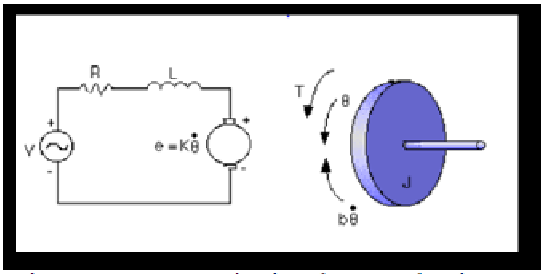

Figure 2: DC Motor Circuit and Free Body Diagram

Figure 2 shows a simple electric circuit [7], which consists of an input voltage (V), resistor (R), inductor (L), motor torque (T), armature constant factor (K), and motor angular position (θ). As the voltage supply is turned ON it will start the motor and keep on rotating until the voltage supply is turned OFF. The following simplified system function was obtained for the turntable system:

θ / V = K / [s ((j s + b) (L s + R) + K2)] (1)

Closed-loop control system for positioning tunrable

A general block diagram of the positioning control system is shown in figure 3. The system was numerically simulated in LabVIEW with PD and P control in order to see its responses.

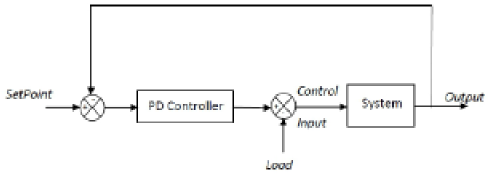

Figure 3 PD controlled closed-loop system

The design of the turntable unit consists of a DC motor, hall-effect shaft encoder, motor controller board, two Arduino mega 2560 boards, support bearings and limit switches. The turntable model was built for a size of 40 cm by 20 cm. The round rotating top plate had a dimension of 20cm in diameter. The load supported by the table is around 500g.

In this work, the LabVIEW software was used to communicate with the Arduino controller. It allows controlling sensors and acquiring data through an Arduino microcontroller by means of the programming environment embedded in LabVIEW. The slave Arduino houses the LabVIEW program and acts as a DAQ device. Master Arduino contains the control algorithm coded in C++. We have used Arduino architecture to control the turntable as a standalone system without LabVIEW computational support. The master Arduino contains a set of codes for standalone operation with external key inputs and LCD display unit. The real-time test results are discussed further in next section.

IV. RESULTS AND DISCUSSION

In order to get the desired response from the designed hardware system, the proper tuning of PD controller has been achieved through simulation of model in software. Upon some successful test results, the optimal values of PD gains, Kp = 0.5 and Kd = 0.01 were obtained. Figure 4 shows the step response obtained in software simulation for the PD controller. Settling time was chosen to be 400 msec for all angle positions to avoid any possible damage to the system. A very fast rotation is not desired as the EUTs are to be placed on the table. A fast response was obtained for only P controller (Kp = 0.5) and result shown in Figure 5.

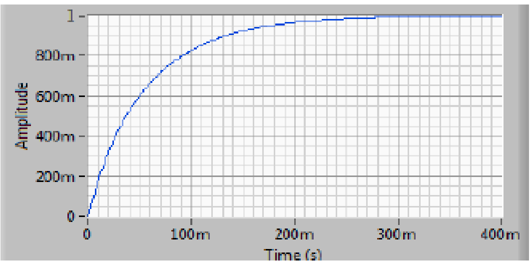

Figure 4 Software simulation step response

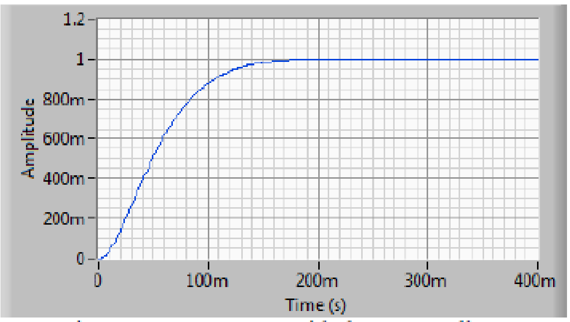

Figure 5 Step response with the P controller

It is to be noted that the LabVIEW code runs on the slave and constantly communicate with the motor control system. The program flowchart is shown in Figure 6. The slave Arduino basically acts as a DAQ device. Once the desired angle has been entered, LabVIEW converts this angle to a Pulse Width Modulation (PWM) signal. PWM signal drives the master Arduino and is converted back to the original set angle. The encoder ISR in figure 6 is able to read 64 counts per revolution of the motor shaft. Adding in the gear ratio of 131:1, total count of one revolution comes to 8400. This is divided by 4 to match the per revolution count of the master Arduino. The actual position of the turntable is calculated by (10) and displayed on the GUI as seen on Figure 7. Arduino contains the PD algorithm (coded in C++ language) and is responsible to control the motor effectively.

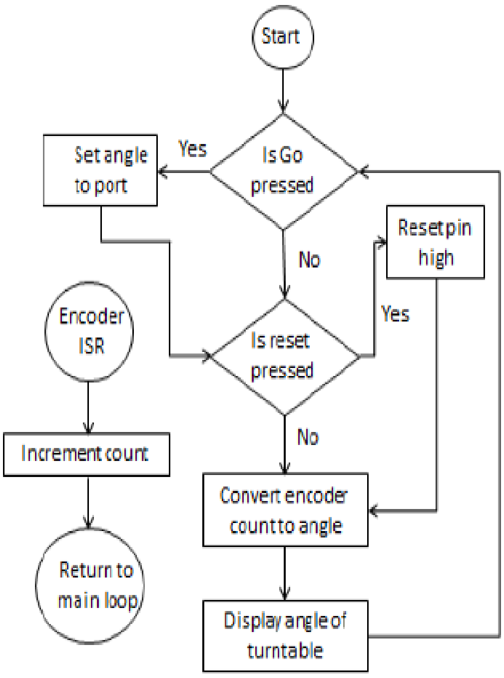

Figure 6 Program flowchart

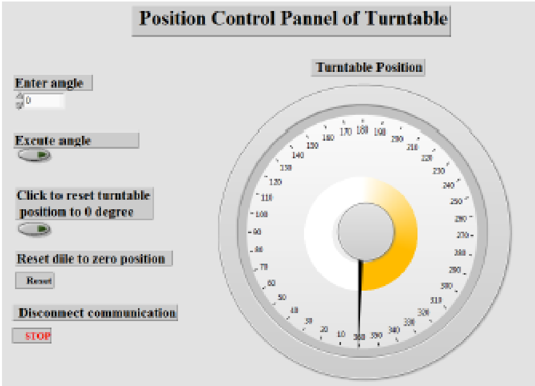

Figure 7 System GUI

The read angle information is taken from the slave. A total of 500 readings are taken and averaged out to eliminate the fluctuations in the reading. Arduino uses 'pulsein' function to determine the time for which the PWM signal is high.

The encoder ISR in master can count only 16 counts per revolution thus 2096 is for 131 turn of the motor shaft that result in 1 rotation of the gearbox shaft. The PD algorithm receives set point as count and the feedback is in terms of counter value obtained from encoding pulse. Encoder read is put in ISR so that none of the information is lost. The 'Go Pressed' condition also takes signal from the slave to determine if the user wants to turn the table.

The output PWM going to the motor controller is limited to between 12 and 20. PWM of below 12 does not rotate the motor and above 20 becomes too fast and leads to overshoot. Due to the limited PWM output both P and PD controller gives similar response as shown in Figure 8. The response of PD was deliberately delayed for comparison purposes.

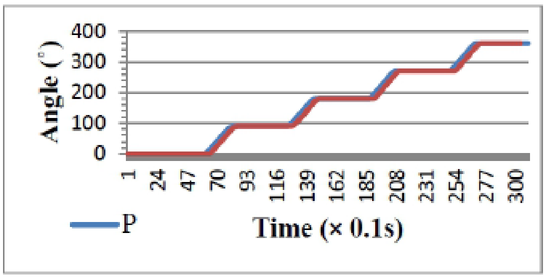

Figure 8 Step response of P and PD controller

The need for averaging the PWM while reading form slave was required because the PWM output for a particular set point varies slightly in every reading. This brought down the error in reading the set point to ±1o. Thus a set point of 90°entered in LabVIEW resulted in a reading of 89°, 90° or 91°. Allocations for the error were made in the C++ code and the error was added or subtracted from the count value of the next setpoint; e.g. if set angle was 90° but the table settled at 91° (due to error in reading set point and not due to control), 1° of counts was subtracted form the next set point that was input by the user. Though the P and PD control showed similar results as seen in Figure 8, PD was selected as the optimal controller as this resulted in better performance when the set point was large e.g. 270°. There are not delay put in place in any of the LabVIEW or the C++ code thus the vision of real time operation becomes evident. Absence of delay makes the control logarithm robust and position of the turntable is immediately reflected on the GUI. The 'pulsein' method used for transferring the set angle form LabVIEW to master may be replace with I2C communication in order to eliminate any possible errors.

V. CONCLUSION

The test of today's complex electronic equipment is around 70% of the product development life cycle. Optimized test techniques are needed to reduce cost, to increase profitability/ credibility, to enhance the testing process, and to meet the market demands on time. The turntable has many applications in the field of EMC/EMI testing, antenna position control and robotics. Developing such system using LabVIEW enables one to build a reliable and user-friendly system. Position control must be achieved with no overshot and steady state error. This has been demonstrated in this work. Real time control was achieved with overall improved performances. An effective computerized control system has been implemented and tested in real-time for accuracy. Numerical simulation results were validated against an actual prototype.

VI. REFERENCES

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