Electrical Adjustable Beds Testing Automation to Identify Mechanical and Electrical Defects

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Abstract— Designing and tuning a system to automate testing and identifying both mechanical and electrical defects appears to be conceptually intuitive, but can be hard in practice, if multiple objectives are to be achieved. This paper addresses the design of a system to detect the main design and industrial problems and to test reliability on an adjustable bed. The test can be processed with different types of data on multiple configurations that will allow tracing backward the exact actions, which the tester performed to the point, where the bug was discovered.

Keywords—adjustable beds testing automation; electrical testing; mecanichal faults detection; Actuator testing.

I. INTRODUCTION

Traditional mechanical and electrical testing methods are performed by utilizing electrical and mechanical measuring devices and require the tester to be physically present to analyze the captured data [1]. Recently some studies especially in bioengineering field are using electrical sensors to build automated systems, these systems are used to increase computational analysis accuracy by processing the medical, biological, chemical, electrical, and materials information with both hardware and software sensory setup for their studies [2, 3] and other studies are using only numerical methods to test and evaluate the mechanical information of an artificial organs and implants with software based on biomechanical theories [4, 5]. Both of these methods can be merged to test and evaluate a realistic product based on electrical and mechanical theories.

The purpose of this study is to reduce the human factor in testing and design a tool to automate testing and to identify mechanical and electrical defects in the adjustable bed by analyzing the recorded data of the motor electrical measurements, where most of other methods are based on semi-automated tool that cannot ignore the human factor.

This tool allows to record and playback manual tests as the playback allows us to reproduce bugs. This test can be run with different types of data on multiple configurations and then we can trace backward the exact actions that the tester performed to the point where the problem was discovered. The tool can record also many test cases separately and rerun them according to the need to regression test a specific part or function of the mechanical system. This system combines software and hardware systems to provide a fully automated test. The testing system includes an automatic wireless control unit, voltage and current measurement for motors in the actuator and video/audio recording. The tool supports care and feeding of regression tests by the ability to automate a test and repeat it indefinitely according to the input change and automatically verify the test results and compare it to the expected results [6].

Test automation guarantees sustainability in the regression testing process which accelerates bugs and error detection. Mechanical problems appear as changes in the actuator motors current, so if we can measure the current passing in the motors with high speed, we can identify the locations of mechanical faults. Mechanical designers are interested in analyzing the dynamics of moving parts during the test and hear the noise coming out of them, which can indicate problems in the product. These operations must be synchronized precisely and do not take much of the computer resources. To automate the whole process, the wireless control unit must be under control of the software. A device was designed to simulate human presses on control unit buttons and that device can be configured through a USB interface and store that configuration during the test to minimize required computer resources. The following sections will give a quick description of the system and its specifications.

An adjustable bed as shown in Fig. 1 refers to the "superstructure" or underlying support base for a sleep surface. The mattress rests on the adjustable bed, just like it would on top of a foundation.

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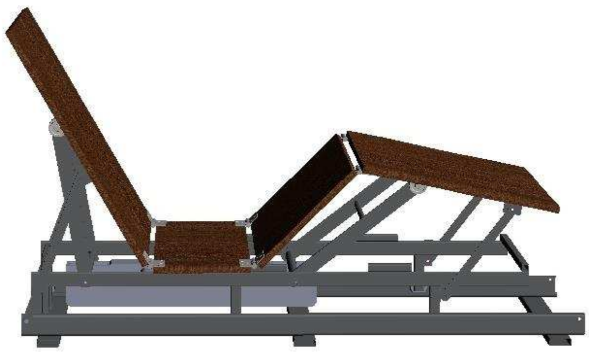

Figure 1. Adjustable Bed

Adjustable beds typically feature a lever system that allows for adjustable movement at the head and foot. The bed is segmented into three portions that move independently to accommodate individual sleeping preferences. The head & foot portions should be able to achieve an incline of 65 degrees to the head section and 45 degrees to the foot section. The Adjustable bed is equipment with a remote control with 6 buttons to adjust the required bed position as shown in the following figures.

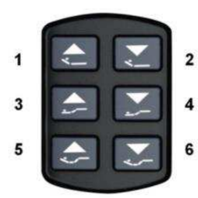

Figure 2. Adjustable Bed Remote Control

Shown below is the mechanical functions related to the numbering of the remote control in Fig. 2.

1: Head Up
2: Head Down
3: Leg Up
4: Leg Down
5: Both Up
6: Both Down

II. MATERIALS AND METHODS

A. SYSTEM HARDWARE

The hardware consists of three modules, first ones is used for activating buttons of the wireless control unit with a pre-defined sequence and uses low current and no mechanical parts. The second is a current sensing circuit that produces a voltage proportional to the current flowing in the actuator. It also includes a voltage divider to enable voltage measuring, and the third module is a multi-channel A/D converter that has a Universal Serial Bus (USB) interface. It can take up to 100 readings per second for both current and voltage and angular position feedback, which is enough to detect any mechanical or electrical errors. All these modules are under control of a Personal Computer (PC) application that configures and stores all that data and synchronizes them with the video and audio recording. The software has functions to display the data and analyze them.

1) First Module: Automatic Remote Control Unit

This device consists of an MCU, which has an embedded USB transceiver, transistor switches to simulate buttons of the control unit and other components required for the circuit operation. It connects to the wireless control unit directly and the user can disconnect it and use the wireless control unit as an ordinary remote control.

The USB transceiver in the MCU is configured to operate at full speed (USB 2.0) and the connection is accomplished using HID USB protocol [7]; it provides easy and fast communication between the MCU and the PC. The software sends orders to the MCU, which always checks the received data while being connected to the PC. The MCU reads the configuration from the software and stores them in its EEPROM to avoid reconfiguration if the device is turned off. The configuration contains a sequence of button functions with different pressing time and delays between them and the number of cycles (number of repetition to that sequence). The MCU stores the number of completed cycles in its EEPROM every 20 cycles to prevent data loss in long tests if the power goes down.

TABLE I. COMMANDS USED TO CONTROL THE MCU OF THE FIRST MODULE

Command	Effect
Start	Starts the test sequence
Stop	Stops the test sequence
Read Sequence	Reads the saved sequence and the current step
Button Pressed Time	Sets the time of pressing a single button in manual control mode
Continue	Resumes the stopped sequence
Restart Current Sequence	Restarts the current sequence. It does not affect the cycle
Disconnect and Save	Disconnects the device from the PC and saves sequence to EEPROM
Set Cycles	Sets the cycles number
Reset All Operations	Restarts the sequence and resets the cycles counter.
Read Saved Cycle Counter	Read the cycles counter saved in the EEPROM
Press a Button	Press one of the six buttons in the remote control unit (manual control)

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To simulate the six buttons on the control unit, we need six transistor switches [8]. The used transistors are MOSFET transistors which are turned on by the MCU. Bipolar transistors can be used, but MOSFET ones almost do not draw current form the MCU, so they save power. The idea is that transistor drain-to-source impedance is low when it is in the on mode and very high in the off mode, so it simulates the buttonsoperation sequence very well.

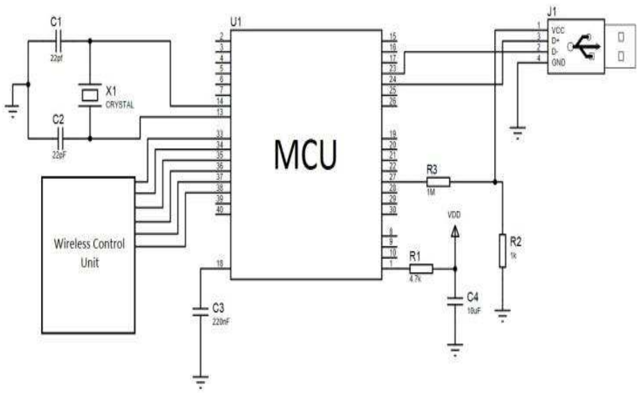

Figure 3. Circuit Diagram for the first module.

2) Second Module: Current and Voltage sensing

The main function of this module is to condition the analog signals to be measured by other digital device, by converting these signals to suitable forms.

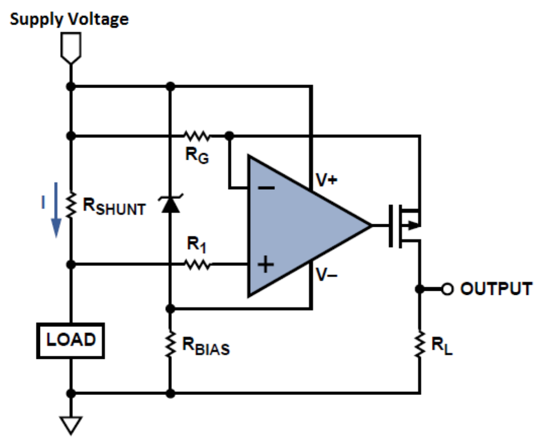

Figure 4. High-current sensing solution using an operational amplifier.

Current sensing circuit is simply a current to voltage converter. As A/D converters accept analog voltage only as an input, we have to convert the current to voltage with proper value.

The circuit topology is easy and familial [9]. The Op-Amp is rail-to-rail input/output type. The values of the resistors are selected to provide an output, which will not exceed 5V for our application that has a maximum continuous current of 3 amperes. This value will enable us to use the embedded A/D converter in the MCU. The Op-Amp is selected to have a fast response to make sure that the output will quickly settle at the right value. The current passes through the transistor and is controlled by the Op-Amp which is converted to a voltage value by a resistor.

Voltage sensing is easier than current sensing in general. In our application, the maximum allowed voltage is 30V, so the values of the voltage divider resistors are selected to provide a maximum of 5V at the output when the input is 30V. The resistors values should be high to minimize power dissipation in the resistors.

3) Third Module: High Speed Multichannel A/D Converter with USB interface

The third device consists of two low-cost MCUs operating at their maximum speed (48MHz). The first MCU is responsible for converting the analog signals to digital ones. For our application, we just need four A/D channels for our application, but there is one additional channel at the circuit for future use. The second MCU is responsible for USB communication. The device uses the USB HID protocol and it is optimized to send short reports at the maximum available speed.

The first two input channels are used for current and voltage sensing. The other two input channels are used for angular position feedback. It is critical to monitor the angular position of head and foot part of the bedduring the test to determine the effect of each test profile on the specified angle. The job is simply done by using two low cost potentiometers fixed on the axes of the moving parts. The outputs of these potentiometers are connected to the channels three and four of the A/D converter.

The communication between the two MCUs is done through a non-standard parallel connection optimized to guarantee maximum data transfer rate.

This configuration allows fast and reliable measuring of the current and voltage values.

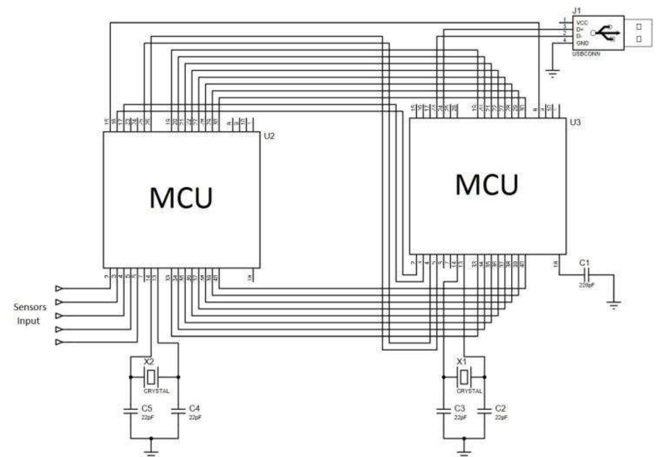

Figure 5. Circuit Diagram for the third module PCB.

B. SYSTEM SOFTWARE

The testing software contains all the features we need for various tests in one package. The program was written using C# programming language.The first section is the automatic remote control with its configuration, controls and readings of the stored data. The table in the middle of the user interface window is used to enter the required sequence of buttons. The same table is used for reading the stored sequence in the device and indicating the current step. The buttons on the left, as shown in Fig. 6, are used to manually press a button on the wireless control unit through the software. There are other fields to configure the button pressing time and the required number of cycles and reading the current number of cycles.

The second section contains the controls of the available tests. The tests are: running the testing sequence only, current and voltage measuring and video and audio recording. The user can choose one or more of these tests and click on the start button and program will send orders to all required devices using USB HID protocol [10] (except the camera and the microphone) and return error message if any device is not connected or has a problem. The other control buttons are stop, resume, restart or reset the test. The outputs of the program are stored into an AVI extension for video and audio and TXT files for current and voltage measurements.

The challenging and most important things in this section are timing, synchronization and computer processor utilization. The application uses the multi-threading concept to provide fast and efficient processor power utilization. The software was carefully designed to make sure that the tests are running simultaneously and their data are recorded with precise timing. Tests data are saved to output files every 10 minutes to allow easy review.

An especial test that will help in the review process is the live measuring test. It gives order to the required button and measures the current in the actuator while graphing the received data on the screen. This can help the testing engineer to see the motion of the tested part and the current of the motor at the same time, so detecting mechanical errors may become easier with this tool.

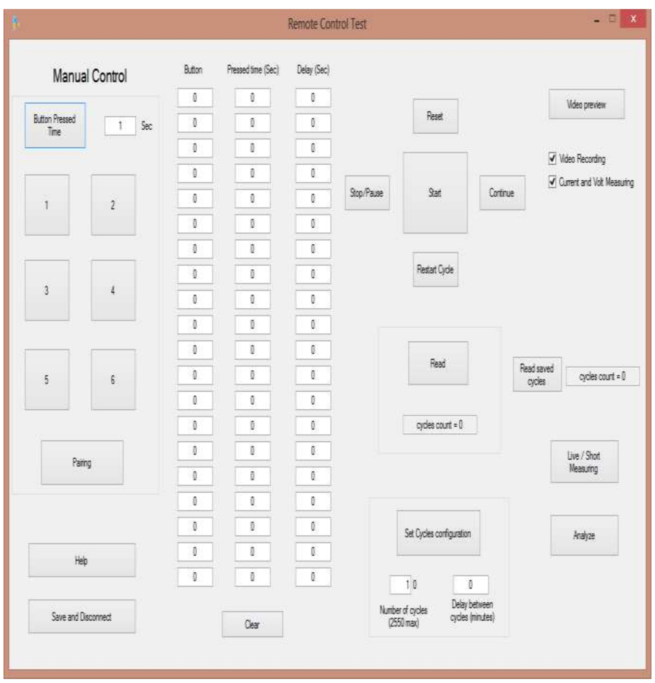

Figure 6. GUI of the computer application.

The program contains a special section for reviewing the tests data. The program reads the output current and voltage value and graphs them with high resolution, which can be adjusted to show more details if required. It detects the beginning and ending of every actuator stroke and calculates the time elapsed during each stroke and shows it in the graph. It can calculate the average of current or voltage values during a specific time.

III. Results

Examples of mechanical and electrical problems that can be detected are:

- Mechanical Misalignment of assembled parts.
- Linear guides Surfaces defects.
- Actuator Gear reduction system mechanical defects.
- Actuator motor Armature-related anomalies which can include commutator bar defects, riser defects and shorted turns or coils in the armature circuit

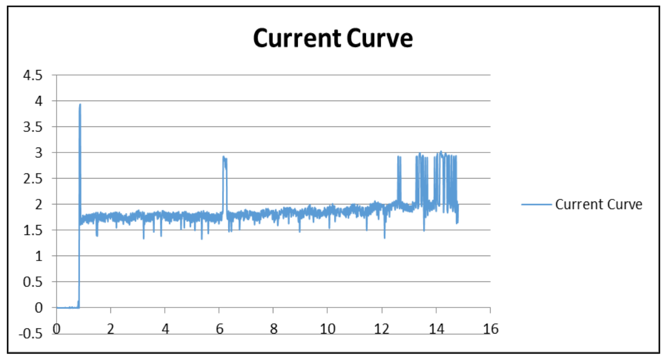

Figure 7. Current Curve Diagram

The above diagram shows the DC Current versus time curve concerning the Actuator motor measurements to the leg movement section of the adjustable bed, the bed leg bend to 45 degrees over an average time of 15 seconds.

By visually analyzing the curve pattern, we can diagnose the mechanical and electrical defects to the adjustable bed shown in Fig. 7 as follows:

a) at t=1 the curve spike to near 4 A which is considered a normal behavior to the peak in rush/peak starting current of a brushless DC motor which typically will be a function of circuit resistance and power resource.

b) The ascending pattern of the curve indicates the load variations with regard to the angular position of the adjustable bed foot section which is also considered a normal behavior.

c) At t=6 there is a sudden spike in the current consumption which is an unusual behavior indicating a mechanical defect. By mechanically analyzing the defect at the given point of time we found that this was caused by a defect in surface geometry in the linear actuator bracket.

d) From t= 12.5 until the end of the cycle there is a disturbed pattern in the curve, we found that there is a problem in the linear guide which gives the bed the wall hugger capability which slides the bed toward the wall, leaving the bed close to nightstand.

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IV. CONCLUSION

The use of data-driven automation approaches and frameworks further increases testing efficiency and can underpin effective configuration testing [11]. This tool is useful in various mechanical systems that uses a DC motor actuator as it support automated testing which serve in estimating product reliability, analyze current and voltage curves to diagnose mechanical and electrical defects, perform aging tests on different operational profiles, perform regression testing by reproducing defects at any given time or mechanical position, perform usability and load testing. Test automation can accelerate the testing cycle and promote product quality. Testing automation gave us a guarantee that each test case is always executed in the same way and in the same environment. When executing a test case manually, some steps could be missed, or intentionally omitted. This can result in not only missing some defects, but also can lead to reporting invalid defect which can result in not only missing some defects, but also can lead to reporting invalid defect.

REFERENCES

[1] N. Petschenik, System Testing with an Attitude, Dorset House, Chapter 2, March 2004, ISBN-13: 978-0932633460.

[2] M. Tayel, S. A. Elaskary, and T. M. Nassef, "A Bio-Sensory System for Increase Implant Longevity for Occlusal Analysis," Proc. Advances in Computational Tools for Engineering Applications (ACTEA 12), IEEE Press, Dec. 2012, pp. 07-10, doi: 10.1109/ICTEA.2012.6462908.

[3] T. M. Nassef, M. B. Tayel, and S. A. Elaskary, "A Proposed Sensory Setup to Increase Computational Analysis Accuracy for Dental Applications," Proc. Computer Medical Applications (ICCMA 13), IEEE Press, Jan. 2013, pp. 01-06, doi: 10.1109/ICCMA.2013.6506145.

[4] L. A. Shinawi, A. Al-Dharrab, T. M. Nassef, and S. B. Tayel, "A novel computational analysis of computer milled zirconium implant abutment head design under reinforced implant supported overdenture," Proc. Computer Medical Applications (ICCMA 13), IEEE Press, Jan. 2013, pp. 01-10, doi: 10.1109/ICCMA.2013.6506144.

[5] Y. M. Alkhiary, T. M. Nassef, I. A. Yassine, S. B. Tayel, and A. E. Kh. Ezzat, "A New Numerical Model to Analyze Stress Distribution of TMJ Disc from 2-D MRI Scans," Advances in Computing, vol. 02, no. 05, Dec. 2012, pp. 66-77, doi: 10.5923/j.ac.20120205.01.

[6] N. Garg, Test Automation using HP Unified Functional Testing, 1st ed., Chapter 4, AdactIn Group Pty Limited, August 2013, ISBN-13: 978-0992293505.

[7] Compaq Computer Corporation, Hewlett-Packard Company, Intel Corporation, Lucent Technologies Inc., Microsoft Corporation, NEC Corporation, and Koninklijke Philips Electronics N.V., Universal Serial Bus Revision 2.0 Specification, April 2000.

[8] A. S. Sedra and K. C. Smith, Microelectronic Circuits, 6th ed., Oxford University Press, 2009, ISBN-13: 978-0195323030.

[9] N. Zhao, W. Liao, and H. Sino, "High-Side Current Sensing: Three Solutions," Analog Dialogue, vol. 44, no. 4, Dec. 2010, pp. 15-19, ISSN: 0161-3626, ©Analog Devices, Inc., 2011.

[10] F. L. Fischer, "Open source HID USB driver for C#," Aug.2007, <http://www.florianleitner.de/index.php/category/csharp/>, retrieved: Jan. 2014.

[11] J. Kent, "Generation of Automated Test Programs Using System Models," Proc. Quality Week, 1999, [7th European conference on Software Testing Analysis & Review took place at the Intercontinental Hotel in Barcelona, Spain, 8-12 November 1999].