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Development of a microcontroller and resistive touchscreen-based speed monitoring and control system for DC motor

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ABSTRACT

Speed control is a key requirement in direct current (DC) motor applications where accuracy, reliability, flexibility, and safety are of high importance. In this study, a microcontroller and resistive touchscreen-based DC motor speed monitoring and control system were developed. The core components employed in the development of the system include Arduino ATMega328P microcontroller, thin film technology (TFT) resistive touch screen, L293D motor driver, and infrared (IR) sensor module. ATMega328P microcontroller is the brain of the system around which the overall circuit design was modeled. TFT resistive touch screen displays the motor speed and also, enables the users to set a desired speed. L293D motor driver regulates the voltage and current supplied to the motor, and a feedback loop comprising an IR sensor module ensures the maintenance of the motor speed at the desired level. A performance test was conducted on the developed system to ascertain its correct functionality. The developed speed monitoring and control system operated satisfactorily during testing; achieving a speed control in the range of 800 to 3000 rpm. The developed device is useful and can be scaled up for various domestic and industrial applications.

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1. INTRODUCTION

A direct current (DC) motor is an apparatus that transforms electrical energy into mechanical power. It finds numerous uses in household, robotics, and industrial automation applications [1]–[3]. DC motor is very famous because of its simplicity, growing technologies in its control, and its good performance on implementation [4]–[6]. In most applications, the regulation of DC motor speed is of great significance, particularly in applications that necessitate precise control, dependable protection, and flexible operation [7], [8]. Typical applications of these dynamic speed controls are seen in domestic uses such as automated control of doors and windows, home rotating appliances, and amplifiers [9], [10]. Also, industrial and robotics applications of DC motors with high control requirements are seen in rolling mills, paper mills mine wonders, hoist machine tools, robotic arms and hinges, traction, printing presses, and textiles mill among others [11], [12].

Literature has shown that the majority of DC motor applications benefit from its adaptable speed, effective speed management, frequent starts and stops, as well as the ability to change direction [13], [14]. The DC motor control can be attained via either mechanical or electrical means [15], [16]. In the past, the regulation of DC motor speed was predominantly accomplished through mechanical methods, which necessitated bulky hardware such as step or pulley systems, variable speed friction clutch mechanisms, sets of gears for speed adjustments, and other similar mechanical devices [17], [18]. Electrical speed control methods offer greater engineering benefits and are more cost-effective compared to mechanical speed control [19], [20].

The field of electronics has undergone a complete transformation in the regulation of DC motor speed due to significant advancements. As a result of these advancements, these drives have gained significant relevance [21], [22]. Speed control is the major feature that is sought in domestic, industrial, and robotics applications of DC motors [23]. The pursuit of effective means to enhance the productivity of DC motor applications highlights the necessity for novel techniques to design their control devices [24]–[27]. One of such novel methodologies that are gaining widespread adoption for varieties of user interface and control applications in recent times involves the use of graphic displays which provide an enabling environment for the integration of touch screen technology [28], [29]. The touch screen is a product of robust and advanced technology that can be deployed to suitably implement a user-friendly interface to enhance the effective regulation of DC motor speed via the generation and exchange of signals with a microcontroller that controls the driver circuit of the DC motor.

Therefore, in this study, a system capable of monitoring and controlling DC motor speed using combined actions of a microcontroller and a resistive touch screen was developed. While a microcontroller and infra-red sensor interact to control the speed of the DC motor speed, a thin film technology (TFT) resistive touch screen was integrated to improve the motor speed monitoring and tuning by a user. Hence, the system allows control of the DC motor speed by providing a user-friendly speed-tuning interface through the resistive touch screen. The system simultaneously measures the DC motor speed and displays the information for better monitoring. The remaining sections of this study are Section 2 deals with the review of literature, Section 3 presents the methodology adopted, Section 4 discusses the results, and Section 5 gives the conclusion of the study.

2. LITERATURE REVIEW

Various suitable techniques have been deployed for efficient monitoring and control of DC motor speed. These techniques range from the use of conventional switching methods to the application of microcontrollers, integrated circuits (ICs), and wireless technologies to enhance safety and ease control of DC motors' speed. A brief review of some of these techniques is hereby presented.

Sai *et al.* [7] designed and developed a pulse width modulation (PWM) based speed control system for DC motors comprising electronic components, 555 timer IC, and a potentiometer. Hussain *et al.* [30] developed and experimentally validated a DC motor speed control system for a hybrid vehicle utilizing Arduino and proportional, integral, and derivative (PID) controllers. Megalingam *et al.* [31] utilized Simulink to construct a position and speed-controlled driver system for a brushless direct current motor, incorporating digital sequential blocks and semiconductor switching devices. Hammoodi *et al.* [32] developed and simulated a novel control system that automatically maintains a constant DC motor speed in the face of load variations, utilizing a PID controller.

Maung *et al.* [33] worked on a DC motor speed control, taking into account friction compensation, through the use of a PID controller. The stable performance exhibited by the PID controller in the work is suitable for robotic arm position control systems and other industrial applications. Ismail *et al.* [34] developed a fuzzy logic controller for speed regulation of a series-wound DC motor. The developed controller provided superior performance over an uncontrolled DC motor in terms of rise time, peak time, settling time, and percent overshoot. Chandramma *et al.* [35] implemented a DC motor speed control using Internet of Things (IoT) technology in which an Arduino controller acts as the central processing unit to govern the motor's actions. To enable IoT support, the ESP8266 module was linked with the Arduino, while the Blynk mobile application serves as a platform for remotely controlling connected devices online. Vlad *et al.* [36] worked on brushless DC motor speed regulation utilizing an Arduino-based driver controller.

A critical look into the reviewed literature revealed that a variety of relevant and useful techniques have been deployed in the area of DC motor speed control. However, the utilization of touchscreen technology seems to be an option yet to be explored. Adoption of this technology for DC motor speed monitoring and control is a promising direction to improve safety, enable precise speed control, facilitate real-time monitoring, provide a user-friendly interface, and potentially allow for data logging [28], [29]. Therefore, a control system that incorporates a resistive touch screen technology for easy and suitable speed regulation of DC motor was designed and developed in this study.

3. RESEARCH METHOD

3.1. System overview

An overview of the microcontroller and resistive touchscreen-based speed monitoring and control system developed for DC motors in this study is presented in Figure 1. The speed monitoring and control device comprises both hardware and software segments. The hardware segment consists of an infrared (IR) sensor that measures the motor's analog speed and sends the readings to the Arduino Atmega328p microcontroller, which is the control unit. The microcontroller converts the analog speed to actual motor speed in revolutions per minute (rpm) using the speed and pulseIn equations. The resistive touch screen displays the speed information.

More so, when the resistive touch screen senses touch movement, it processes it as a new speed set and sends the information to the microcontroller which invariably triggers the speed of the DC motor via the L293D motor driver. The microcontroller was programmed using the Arduino programming language developed with C language. The software unit of the system consists mainly of an Arduino integrated development environment (IDE) where the system components are programmed. The environment facilitated the sending and receiving of data from the Arduino board through a serial monitor, simplifying debugging without the need for supplementary software.

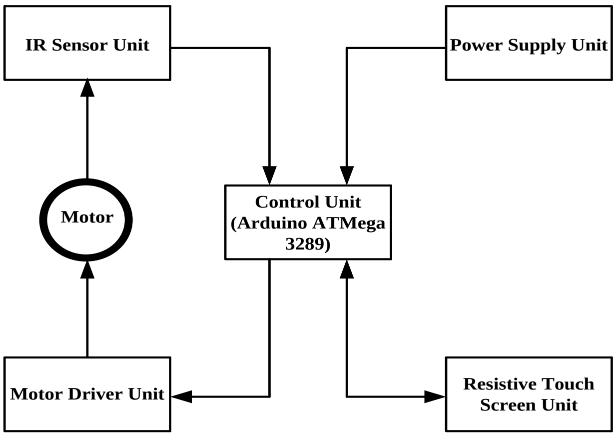

Figure 1. An overview of the developed microcontroller and touchscreen-based DC motor speed monitoring and control device

3.2. Hardware design

3.2.1. Power supply unit

The developed system power supply unit is presented in Figure 2. The input section of the unit transforms the 220 VAC mains supply to 12 VAC output via a 220/12 V transformer. The obtained 12 VAC output was deemed unsuitable because the system utilizes DC power at a lower voltage. To address this, the 12 VAC output was rectified, filtered, and regulated using an LM7805 voltage regulator to the 5 VDC required for the system's operation. To enable the system to function at any time without needing an external source, the power supply unit incorporates a Li–ion battery which stores and supplies the required electrical energy. The charge on the battery is maintained by a TP4056 battery management system.

The filtering capacitance, *C*, for the circuit, was determined from (1) which was modified with the use of (2) and (3) to produce (4) [37]:

$$C = \frac{It}{V} \tag{1}$$

$$t = \frac{1}{4f} \tag{2}$$

$$V = \sqrt{2V_{rms}} - V_d \tag{3}$$

$$C = \frac{I}{4f(\sqrt{2V_{rms}} - V_d)} \tag{4}$$

where I, t, V_{rms}, V_d and f respectively denote the circuit's peak current, period of full rectification, rectified voltage, transformer's output voltage, rectifier's forward voltage, and AC mains supply frequency.

From (4), the substitution of f, I, V_{rms} and V_d as 50 Hz, 500 mA, 12 V, and 1.4 V respectively gave the value of C as 160.56 μF. However, for the filtering process, a 100 μF capacitor is sufficient. Therefore, the choice of 100 μF for the capacitor C_1 in Figure 2. Capacitor C_2 of 100 μF was also deployed to further enhance the filtering of the rectified 12 V output which was regulated to the desired 5 VDC voltage for the system's internal operation by LM7805.

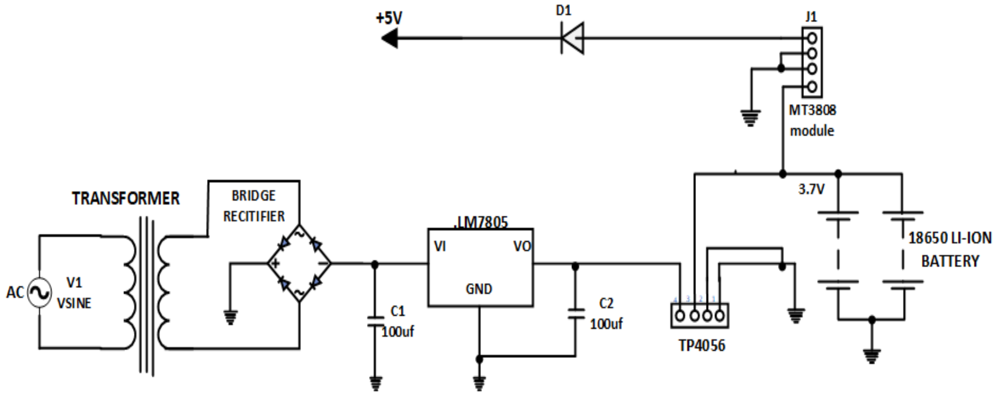

Figure 2. Power supply unit of the microcontroller and resistive touchscreen-based speed monitoring and control system for DC motor

3.2.2. Control unit

The Arduino uno board which uses an ATMega328P microcontroller was a major component of the control unit. The microcontroller acts as the control and processing unit of the system. The Arduino microcontroller was equipped with a power jack, a 16 MHz quartz crystal, a USB connection, an ICSP header, a reset button, six analog inputs, and 14 digital input/output pins. The microcontroller was configured using Arduino programming language derived from the C program. The overall circuit diagram of the developed microcontroller and resistive touchscreen-based speed monitoring and control system for the DC motor is shown in Figure 3.

Directly mounted on top of the microcontroller is the resistive touch screen liquid crystal display (LCD) whose shield was directly connected to the Arduino Atmega328P microcontroller. The resistive touch screen component has three layers; the TFT touch screen for the display of colorful images and interfaces, the shield, and a micro-SD card reader for saving images and other necessary data. The resistive touch screen was also configured using C programming language and implemented with certain libraries to obtain the necessary functionality and interface. The screen serves two purposes displaying the output of the Arduino microcontroller (current motor speed sensed by the IR sensor) and collecting input commands (a new motor speed)

The IR sensor module making up the sensing unit was connected to the Arduino digital pin. It is responsible for sensing the DC motor speed and sending the resulting analog signal to the Arduino microcontroller. The module consists of an infrared transceiver. The transmitter end sends infra-red waves upfront and the photodiode receiver records the observation from the reflected infra-red waves. The sensing unit was positioned in such a way that the rotating blades of the motor were situated in front of it to allow the operation of the module to sense the motor speed efficiently. The motor blade is patterned with a light absorbing and light reflecting part, which when the IR module encounters the reflecting part, interprets it as a rotation, and concerning the distance between the motor and the module, the speed is obtained and the value in rpm calculated. The speed expression coded in the microcontroller to obtain the motor speed S in rpm is given by (5) [38]:

$$S_{rpm} = ((60 * f))/N \tag{5}$$

where N and f respectively represent the number of reflection portions on the rotating object and the number of times the IR sensor detects rotation per second in Hz as expressed in (6).

$$f = pulseIn(ir_{sensorpin}, HIGH) \tag{6}$$

The L293D IC motor driving unit was connected such that all the ground pins were grounded. The 5 V voltage from the power supply unit which enables the IC to operate was connected through input pins 3 and 4. The current supplied to the DC motor was obtained by connecting the output pins 3 and 4 to the two DC motor probes. Thereafter, the enable pins 3 and 4 of the IC were connected to a digital pin on the Arduino; working based on the PWM principle and enabling the output pins of the motor. Figure 4 depicts the flow chart for the operation of the developed system.

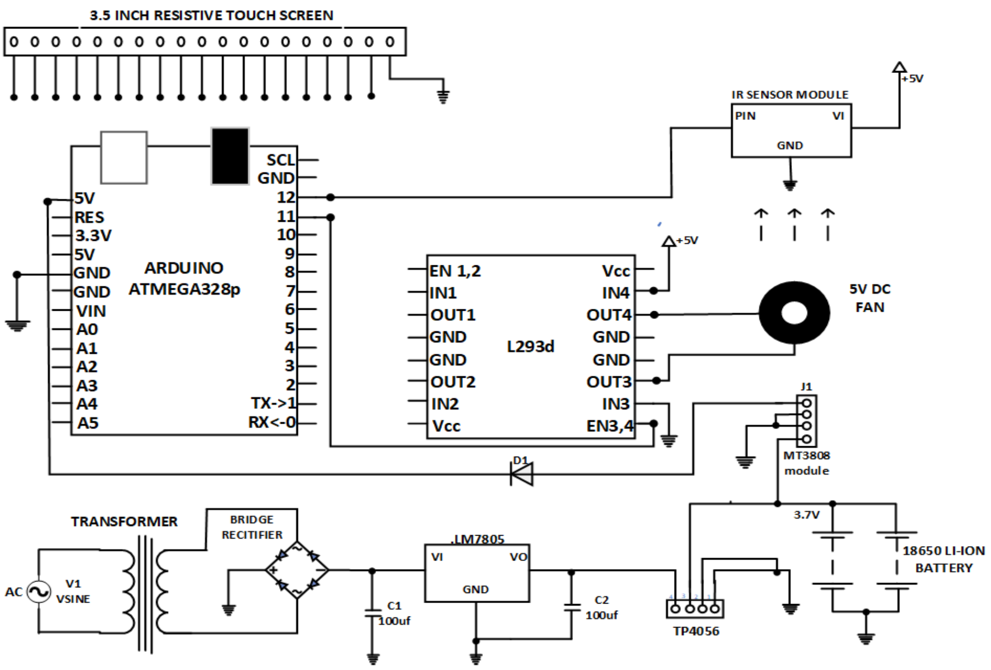

Figure 3. Circuit diagram of the developed microcontroller and resistive touchscreen-based speed monitoring and control system for DC motor

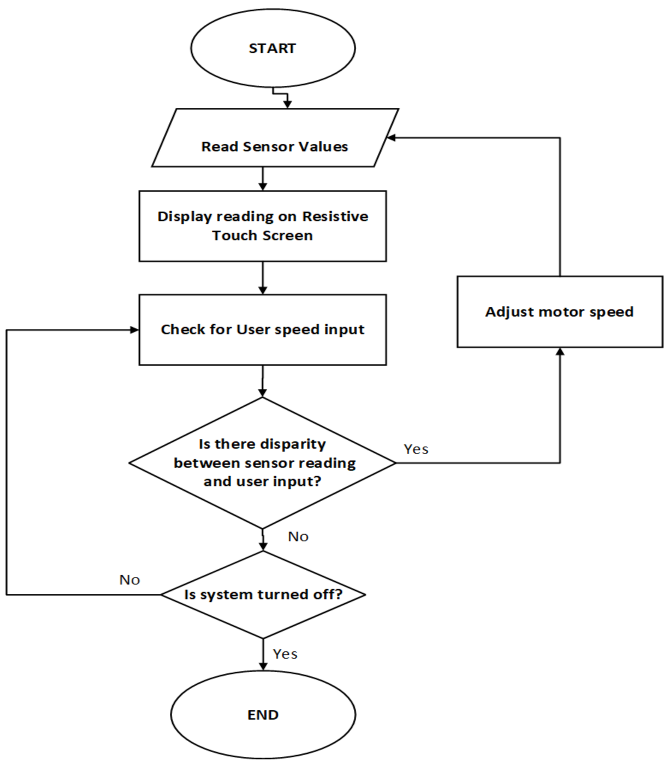

Figure 4. Flow chart for the system operation

3.3. Testing of the developed system

The developed speed monitoring and control system for the DC motor was subjected to a performance test after the final phase of implementation when it had been fully packaged. Each of the major units of the device including the control unit, sensing unit, power supply unit, display unit, and motor driver unit was tested to ascertain their correct functionality and the overall effectiveness of the developed device.

4. RESULTS AND DISCUSSION

4.1. The developed DC motor speed monitoring and control system

Figure 5 presents the fully developed and packaged microcontroller and resistive touchscreen-based speed monitoring and control system for DC motors. The device's external components namely the casing, resistive touch screen unit, system switch, DC motor (fan), battery BMS indicator (located at the side), and external source connector (at the rear) are depicted in Figure 5. Figure 6 shows the internal connection of the system in Figure 5 where components such as the resistive touch screen shield, the Arduino Atmega328p microcontroller, IR sensor, L293D motor driver IC, TP4056 BMS module, li-ion battery, and the voltage transformer make up the developed system are wired to each other.

Figure 5. Developed microcontroller and resistive touchscreen-based speed monitoring and control system for DC motor

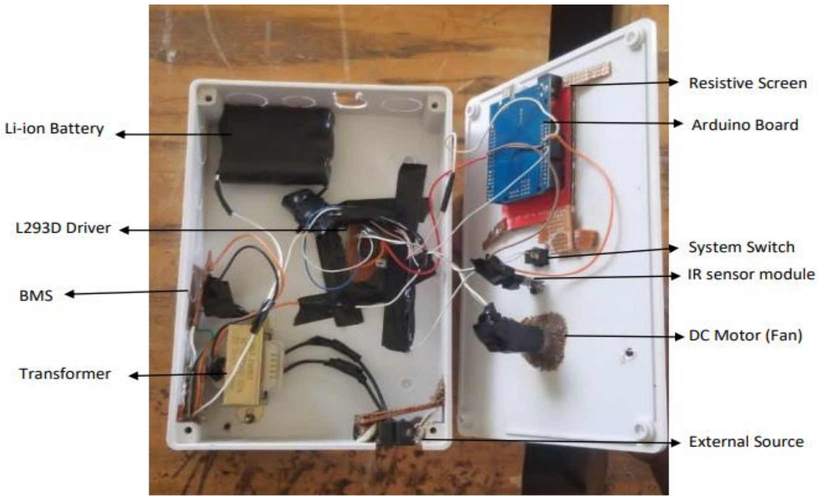

Figure 6. Internal circuitry of the developed microcontroller and resistive touchscreen-based speed monitoring and control system for DC motor

4.2. Performance test results

The voltage needed to power the developed system is 5 V and the power supply unit was confirmed to produce the voltage for the system operation through the use of a digital multimeter. The 1000 mAh Li-ion battery used in the system charges properly when an AC mains supply is plugged in and powers the system when the AC mains supply is unplugged. The TP4056 battery management system which indicates the battery status produced a red light while the system was charging and a blue light when it was fully charged. Figure 7 shows the battery management system was active and therefore, indicates that the power supply unit operates properly during testing.

The resistive touch screen was observed to come on properly when powered with every coordinate on the screen responding to touch as appropriate. The screen displayed the speed information as it changed. Figure 8 shows the performance of the resistive display touch screen on testing.

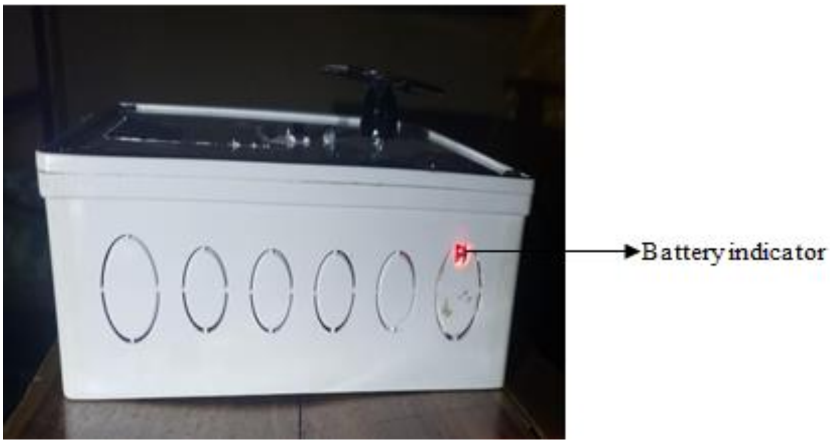

Figure 7. Power supply unit BMS showing the state of the battery (charging)

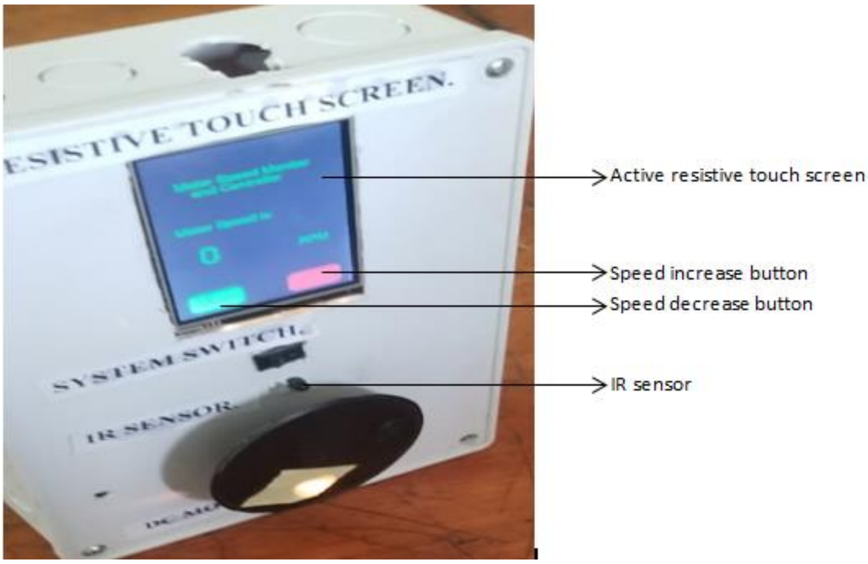

Figure 8. Resistive touch screen unit in operation

The desired speed control during the testing operation was achieved via the speed increase (red) and speed decrease (green) buttons on the touch screen which offer the possibility of minimal contact with the device via a simple tap on either button. The IR sensor operated appropriately on testing, sensing, and transferring analog signals corresponding to the motor speed to the Arduino microcontroller. With the Arduino code deployed, the Arduino microcontroller processes the sensor's analog signals into the actual rpm speed and sends the displayed information to the resistive touch screen and likewise receives input information from it when speed control buttons are pressed. When the user changes the speed level from the screen, the Arduino microcontroller varies the PWM signal going into the enable pin of the L293D motor driver IC which in turn varies the motor speed. Figures 9 to 12 show the speed control at different rpm values.

The main difference between the model of DC motor speed monitoring and control system developed in this study and similar models available in literature employing microcontroller and touch screen technologies is the range of speed that could be controlled. While the model developed in the present study offered speed control in the 800 to 3000 rpm range, two of the models available from the literature offered speed control in the range of 80 to 200 rpm [28] and 190 to 774 rpm [29]. Hence, the developed DC motor speed monitoring and control system could be deployed for speed control for higher speed applications, unlike its counterparts from the literature.

Figure 9. Motor speed controlled at 840 rpm

Figure 10. Motor speed controlled at 1500 rpm

Figure 11. Motor speed controlled at 2040 rpm

Figure 12. Motor speed controlled at 2520 rpm

5. CONCLUSION

A microcontroller and resistive touchscreen-based speed monitoring and control system for DC Motor was designed, implemented, and tested. The Arduino Atmega328p microcontroller was used as the central component around which the functionalities of other components in the system including the IR sensor to the resistive touch screen and L293D motor driver module depend. The implementation of the overall system in this study produced the expected simple and easier speed control performance in the range of 800 to 3000 rpm for the DC motor through the user-friendly interface created by the combined use of Arduino Atmega328p microcontroller and TFT resistive touch screen. This system as a prototype could be adopted and scaled up for speed control for various domestic and industrial applications. In this line, further work is ongoing to develop an improved model of the DC motor speed monitoring and control system that would offer a wider speed control range and four-quadrant operation over the model presented.

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