Precision Controller System for Centrifuge
Centrifuge Controller

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***Abstract*—This study presents a Precision Control System for Centrifuge using Variable Frequency Drive (VFD) and Nuvoton Microcontroller integrated with tacho sensors, a seven-segment display, and five pushbuttons. The system is designed to generate precise centrifugal forces with high accuracy and repeatability, making it suitable for various laboratory and industrial applications. The system uses a closed-loop feedback mechanism with tacho sensors to accurately measure the rotational speed of the centrifuge rotor and adjust the frequency of the VFD to generate the desired centrifugal force. A Nuvoton microcontroller is used to control the operation of the system, with a seven-segment display and five pushbuttons providing a user-friendly interface for controlling and monitoring the system. Experimental results demonstrate that the Precision Control System for Centrifuge using VFD and Nuvoton Microcontroller with tacho sensors, a seven-segment display, and five push buttons can generate precise centrifugal forces with a high degree of accuracy and repeatability. The system has potential for use in various laboratory and industrial applications where precise control of centrifugal forces is required.**

***Index Terms*— Embedded systems, Microcontroller, 8051, AC Motor, Motor Driver, Centrifuge, Sensors.**

I. INTRODUCTION

The Centrifuges are critical laboratory equipment that play an important role in various fields such as medical research, industrial processing, and biochemical analysis. The precise control of centrifugal force is crucial in ensuring the accuracy and reproducibility of experimental results. However, conventional centrifuges often suffer from limitations such as poor speed control, lack of real-time feedback, and limited customization options. To address these issues, we present a novel precision control system for centrifugal force generation using a variable frequency drive (VFD) and Nuvoton microcontroller. The system incorporates tacho sensors, a 7-segment display, and 5 pushbuttons to provide real-time feedback and precise control over the centrifuge's speed and centrifugal force. In this paper, we describe the design and implementation of the precision control system, as well as its performance evaluation and comparison with existing centrifuges. Our results demonstrate that the proposed system offers superior speed control and precision compared to traditional centrifuges, and can be easily customized to meet specific experimental requirements. This research provides a valuable contribution to the development of advanced centrifuge control systems that can benefit various fields of research and industry.

II. PROBLEM DEFINITION

The problem that the "Precision Control System for Centrifuge" using VFD and Nuvoton Microcontroller with tacho sensors, and seven segment display, five pushbuttons aims to address is the lack of an accurate and user-friendly control system for generating precise centrifugal forces in laboratory and industrial settings. Current centrifuge machines often have limited control over the generated forces, resulting in inaccuracies and inconsistencies in experimental results. Additionally, existing control systems may be complicated and difficult to use, limiting their accessibility to users with limited technical knowledge or training. The proposed precision control system aims to solve these issues by providing a user-friendly interface for controlling and monitoring the centrifuge machine, incorporating tacho sensors and seven segment display to provide real-time feedback on the generated forces, and utilizing a Nuvoton microcontroller to accurately control the VFD and generate precise centrifugal forces.

III. LITERATURE REVIEW

Stephen Majekodunmi [1] conducted a study to explore the significance of centrifugation in the pharmaceutical industry, which has received limited attention. Centrifugation is a crucial research technique that is widely used in biochemistry, cellular and molecular biology, as well as in pharmacy and medicine to assess suspensions and emulsions. This review article delves into the fundamental principles of centrifugation, different types of centrifuges and their classifications, the various types of density gradient media, industrial centrifuges, and their applications in the pharmaceutical industry. Centrifugation plays a critical role in the production of bulk drugs and biological products, determination of the molecular weight of colloids, and the evaluation of suspensions and emulsions in the pharmaceutical industry.

In summary, Stephen Majekodunmi's **[1]** review highlights the significance of centrifugation in the pharmaceutical industry, which is widely used in research, biochemistry, cellular and molecular biology, and in evaluating suspensions and emulsions. The article discusses the basics and principles of centrifugation, various types of centrifuges, separations, and density gradient media. It also covers the classification and applications of industrial centrifuges. Centrifugation plays a crucial role in the production of bulk drugs, biological products, determining molecular weight of colloids, and evaluating suspensions and emulsions in the pharmaceutical industry.

J.C. Moore's [2] statement highlights the importance of selecting an appropriately sized motor for a machine to ensure proper functioning. He notes that with the use of computers, it is now possible to accurately predict the brake horsepower requirements of a machine, making it easy to avoid the problem of selecting a motor that is too small. Moore recommends selecting a standard motor rating that matches or exceeds the brake horsepower of the driven machine, resulting in a 0 to 15 percent margin. He also recommends the use of induction motors for drives between 500 and 5000 hp, as they have one insulated stator winding and one uninsulated, shorted rotor winding. No speed increaser is required for 1200-, 1800-, and 3600-rpm compressors, and the 1800-rpm motor is usually the least expensive of the three speeds.

In summary, J. C. Moore emphasized the importance of selecting a motor with a sufficient rating to start the machine it is coupled with. He mentioned that this problem can be easily avoided by using computers to accurately predict the brake horsepower requirements of the compressor and selecting a standard motor rating that matches or exceeds it. He also recommended using induction motors for drives between 500 and 5000 hp, and selecting the least expensive speed (usually 1800-rpm) for higher speeds using step-up gears, without requiring a speed increaser for 1200-, 1800-, and 3600-rpm compressors.

Barry O. Stokes [3] explained the principles of centrifugation, which involve particles of density sedimenting at speed through the fluid medium of density when a centrifugal force is applied to the particle mass. The buoyancy of the medium reduces the effective particle mass, which opposes the forward centrifugal force. The term (dp-dm) accounts for the buoyant action of the medium. Frictional forces, which are a function of the characteristics of both the particle and the medium, also oppose the centrifugal force and are included in the term K.

Tatiya Padang's [4] research focuses on developing a measurement device that can be used for calibration support in medical devices. Specifically, the device is a digital tachometer, which is used to measure the speed of objects that rotate in RPM on a centrifuge. However, some medical devices, such as the ergo cycle and treadmill, are calibrated in km/hour, which requires either the use of two different devices or a conversion from RPM to km/hour. To address this issue, the research aims to design a tachometer that can measure speed in both RPM and km/hour units, allowing for more efficient and accurate calibration of medical devices. The device would essentially serve as a multi-purpose tool for measuring rotational speed, regardless of the unit of measurement required by a particular medical device.

In his research, **Jorge G. Zornberg [5]** aimed to improve the accuracy and number of instruments used in centrifuge testing. According to the author, conventional methods of transmitting data in a moving, high-acceleration environment have limitations in terms of accuracy and the number of instruments that can be used. To address this issue, Zornberg suggests using a wireless ethernet data acquisition system for a centrifuge. This system allows for increased throughput while maintaining control of the centrifuge test from an external computer. By connecting a computer workgroup with wireless ethernet, the system can transmit a large amount of data without noise, which enables the use of a greater number of channels and instruments in a test. The study found that the wireless system consistently outperformed traditional hard-wired serial communication systems in terms of data throughput. However, the system's performance may vary depending on the g-level, transmission direction, and type of wireless card used.

According to **Dawoud Shenouda [6]**, data communication standards consist of two key components: the "protocol" and the "signal/data/port specifications for the devices involved." The protocol refers to the structure of the message and the significance of each component of the message. In order to connect any device to the bus, an external device must be utilized as an interface, which will arrange the message in a manner that satisfies all of the electrical requirements of the port. These electrical requirements are referred to as "standards." The RS-232 is the most widely known serial communication standard. In the realm of IT technology, communication can be either serial or parallel. Serial communication is preferred for data transmission over longer distances because it is less expensive to run a single core cable for serial communication over a long distance than to use multicore cables for parallel communication. Serial communication is a type of communication where data is transmitted one bit at a time over a single channel. In contrast, parallel communication transmits multiple data bits over multiple channels simultaneously.

Umakanta Nanda [7] explained that almost all computers and microcontrollers come with multiple serial data ports that are used to communicate with serial input/output devices, such as keyboards and serial printers. Serial data can be transmitted to and received from a remote location via a telephone line by using a modem that is connected to a serial port. The interface that receives and transmits the serial data is called a UART, which stands for Universal Asynchronous Receiver-Transmitter. The received serial data signal is known as RxD, and the transmitted data signal is known as TxD. A UART is an integrated circuit that is programmed to control a computer's interface to its connected serial devices **[7]**. It provides the system with the RS-232C Data Terminal Equipment (DTE) interface, allowing it to communicate with and exchange data with modems and other serial devices. The UART acts as an intermediary between the computer and the serial devices, handling the transmission and reception of data. The RS-232C standard is a communication protocol used for serial communication between devices. It specifies the electrical characteristics of the communication signals, such as the voltage levels and signal timing. The UART interprets the RS-232C signals and communicates with the attached serial devices accordingly.

In summary, serial communication is a common method for exchanging data between devices, and the UART plays a crucial role in this process by serving as the interface between the computer and its serial devices.

According to **John Buie, a Lab Manager [8]**, the laboratory centrifuge is an efficient method for separating samples with different densities. The original rotors used for centrifugation, developed by Svedberg in the early 1900s, were made of tensile steel. In modern times, materials such as aluminum alloys and titanium are preferred due to their ability to withstand high centrifugal forces. Nowadays, laboratory centrifuges come equipped with standard features such as cooling processes, programming capabilities, automatic imbalance detection, noise reduction systems, and changeable rotor systems. These features enhance the efficiency of the centrifuge and make it easier for researchers to separate samples with precision.

Stephen D. Chastain, Centrifuge Controllers Manual [9] provides specific details regarding the motor and auxiliary circuits of centrifuges designed for oil separation applications. According to Chastain, the motor circuit requires a 240-volt input with a 20-amp capacity, while the auxiliary circuit is designed to operate on 120 volts with a capacity of 15 amps. The cycle time of the centrifuge can be adjusted using the up and down keys, providing greater flexibility in customizing the centrifuge's operation. It is important to note that these specifications are tailored for centrifuges that are specifically designed for oil separation applications.

***The role of Centrifuges in Biotech Research* [10]**

a) Programmable acceleration and deceleration in newer centrifuges have been found to aid in terminating unwanted side reactions and reducing waiting time. This feature also helps to minimize mechanical damage to extracellular vesicles during ultracentrifugation. The inclusion of refrigeration in centrifuges is crucial to minimize sample denaturation, particularly with biomolecules like proteins.

b) Additionally, pre-cooling of centrifuge rotors and minimizing the temperature rise when the rotors are spinning at maximum speed can prevent heat-induced sample damage.

c) With more research institutions striving to adopt eco-friendly practices, centrifuge manufacturers are designing products that are more environmentally sustainable, incorporating features such as lower energy consumption and the use of recyclable materials.

***Lab Manager – Centrifuge Resource guide* [11]**

a) The centrifuge can also monitor other aspects of the rotor during operation. For example, integrated imbalance sensors and system shut down software allow centrifuges to quickly detect and reduce problems caused by improper rotor balancing by shutting down the system before the instrument reaches a critical imbalance condition.

b) When spinning something at high speeds, vibrations become the enemy. Old centrifuges are loud, vibrate when they start, and shake the entire bench, leading to safety issues. New centrifuges fix that problem. For example, they offer shock-absorbing features that limit vibration.

c) Need to balance a centrifuge: Running an unbalanced centrifuge may cause significant damage and injure the operator and other laboratory personnel. The total mass of each tube should be as close as possible- this becomes increasingly important at very high rotor speeds. Balancing masses to the nearest 0.1 gram are advisable, and it is important to balance tubes by mass, not volume. For example, do not balance a sample consisting of liquid with a higher or lower density than water with an equal volume of water.

d) Do not open the lid while the rotor is moving: Many centrifuges have a “safety shutoff”. However, this will only stop power to the rotor, which will still spin due to its own inertia for some time until it is slowed to a stop by friction. If the centrifuge is wobbling or shaking, pull the plug. A little vibration is normal, but excessive amounts can mean danger. First, double check that the tubes are correctly balanced. If this does not resolve the issue, do not operate the centrifuge until it has been serviced by the manufacturer or dealer. Prior to starting the centrifuge, it is necessary to load it correctly. Balancing the centrifuge prevents potential damage to the instrument and is crucial for safe operation.

IV. PROPOSED APPROACH

The architecture used to operate a centrifuge depends on the type and complexity of the centrifuge. There are various types of centrifuges, including manual centrifuges, electrically-powered centrifuges, and digital centrifuges. Each type of centrifuge has a different architecture and control system.

Manual centrifuges typically have a simple mechanical architecture that relies on the manual input from the operator to rotate the rotor at a consistent speed. These centrifuges do not have any complex control systems nor are they equipped with any electronics, and their operation is entirely manual.

Electrically - powered centrifuges have a more complex architecture that includes an electric motor, power supply, and control circuitry. The motor is connected to the rotor through a shaft, and the control circuitry regulates the motor speed to maintain a constant rotational speed. The power supply converts the incoming AC power into the appropriate voltage and current required by the centrifuge.

Digital centrifuges have the most complex architecture and control system. These centrifuges typically include a microcontroller or digital signal processor (DSP) that controls the operation of the centrifuge. The microcontroller or DSP receives input from sensors that detect the rotor position, speed, and other parameters, and uses this data to control the motor speed and other aspects of the centrifugation process. Digital centrifuges also typically include a user interface, such as a touch screen or control panel, that allows the user to set the desired parameters and monitor the progress of the centrifugation process.

This paper is based on digital centrifuge and its design, construction and method of operation. And a digital centrifuge uses various algorithms and features to operate and control its functions. Some of the key algorithms and features used in digital centrifuges are:

1. **Speed control**: Digital centrifuges use sophisticated speed control algorithms to ensure that the rotor is rotating at the desired speed. The speed control algorithm typically uses a feedback loop that measures the actual speed of the rotor and adjusts the motor speed accordingly to maintain a constant rotational speed.
2. **Timer**: Most digital centrifuges include a timer feature that allows the user to set the duration of the centrifugation process. The timer ensures that the centrifugation process is stopped automatically after the set time has elapsed.
3. **Rotor detection**: Digital centrifuges are equipped with sensors that detect the presence and position of the rotor. This feature ensures that the centrifuge does not operate if the rotor is not properly secured in the centrifuge chamber.
4. **Automatic imbalance detection and correction**: Digital centrifuges are equipped with sensors that detect any imbalance in the rotor during operation. The centrifuge will automatically adjust the speed or stop the rotor if an imbalance is detected to prevent damage to the rotor or the centrifuge.
5. **Programmability**: Some digital centrifuges include programmable features that allow the user to set customized centrifugation protocols, including speed, time, and temperature.
6. **User interface**: Digital centrifuges typically feature a user-friendly interface that allows the user to easily set the desired parameters, view real-time status and monitor the progress of the centrifugation process.

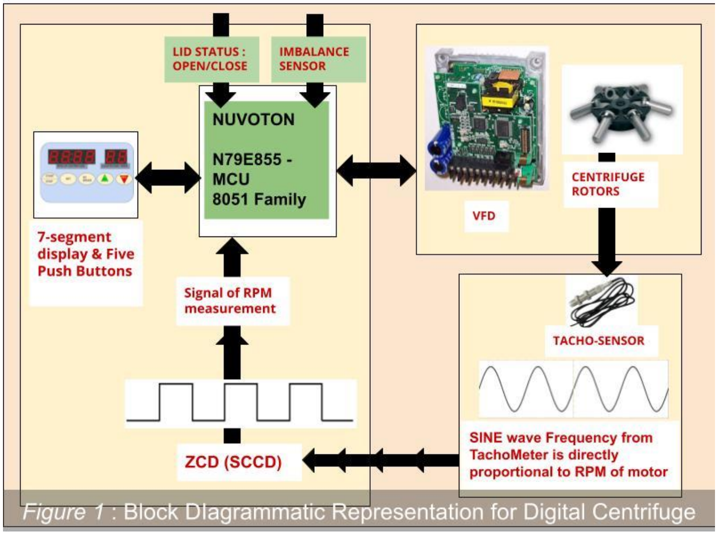


Figure 1 : Block Diagrammatic Representation for Digital Centrifuge

Overall, the algorithms and features used in digital centrifuges enable precise and reliable operation, minimizing the risk of error and improving the accuracy and efficiency of component separation depending on the application.

At any given time, the centrifugal rotors inside the centrifuge are moving at a range of minimum 750 RPM ~ and above 15000 RPM, and with that range of high RPM brings along the high risk of safety concerns. This paper is also focusing on the safety interlocks feature that can be implemented on any centrifugal applications.

Safety interlocks are an important feature of modern digital centrifuges to ensure the safe operation of the device and prevent accidents or damage to the equipment. Magnetic plunger or solenoid lid lock status and imbalance sensors are two such interlocks commonly used in digital centrifuges.

1. The ***magnetic plunger*** or ***solenoid lid lock*** status interlock is designed to prevent the centrifuge from operating when the lid is open. This is important for preventing injury or damage to the equipment due to contact with moving parts during operation. The interlock works by using a magnetic plunger or solenoid to lock the lid in place when it is closed. When the lid is open, the plunger or solenoid disengages, breaking the electrical connection that allows the centrifuge to operate.
2. The ***imbalance sensor interlock*** is designed to detect when the centrifuge is not properly balanced and prevent it from operating. Imbalance can lead to the centrifuge vibrating excessively or even tipping over, which can cause injury or damage to the equipment. The imbalance sensor works by measuring the centrifugal force generated by the rotating mass and comparing it to a reference level. If the measured force exceeds the reference level, the sensor will prevent the centrifuge from operating.

By implementing these interlocks in a digital centrifuge, operators can be confident in the safety and reliability of the equipment. These safety features help to prevent accidents and equipment damage, and ensure that the centrifuge operates as intended, producing accurate and reproducible experimental results.

The safety interlocks mentioned above are pre-installed inside the centrifuge and interfacing such interfaces with the microcontroller *NUVOTON MCU **N79E855** 8051 SERIES* and the user interface has been discussed in this paper.

Using *KEIL4 IDE SOFTWARE* for the Precision Control System for Centrifuge where the user interface is implemented using a tachometer, five push buttons, and a six digit 7-segment LED display. KEIL4 is an integrated development environment (IDE) software that allows users to write, debug and test code for microcontrollers. In the case of the Precision Control System for Centrifuge, KEIL4 is used to program the Nuvoton microcontroller, which is the brain of the centrifuge.

The user interface of the centrifuge is implemented using a tachometer, 5 push buttons, and a 7-segment LED display. The tachometer measures the rotational speed of the rotor and provides real-time feedback to the user. The 5 push buttons are used for various functions such as starting, stopping, increasing or decreasing the speed of the rotor, and selecting different operating modes. The 7-segment LED display shows important information such as the current speed, time remaining, and any error messages.

The implementation of these components in the user interface allows for easy and intuitive control of the centrifuge, providing the user with accurate feedback and control over the centrifugal force generated. The use of *KEIL4 IDE* software allows for efficient programming of the Nuvoton microcontroller, ensuring reliable and precise control of the centrifuge.

Using *ALTIUM 20 SOFTWARE* for the Precision Control System for Centrifuge where it is a software for electronic circuit design and PCB layout, and it can be used to design the circuitry and PCB layout for the Precision Control System for Centrifugal Force Generation.

However, the implementation of the user interface using a tachometer, 5 push buttons, and a 7-segment LED display would require additional programming in a different software, such as a microcontroller IDE like Keil.

Therefore, the Altium 20 software would be used to design the circuitry and layout for the user interface components such as the tachometer, 5 push buttons, and 7-segment LED display on a PCB, while the microcontroller programming would be done in Keil IDE to control the operation of these components.

V. PROJECT IMPLEMENTATION (A) : USER INTERFACE

In this paper about Precision Control System for Centrifuge, *the user interface* is implemented using a tachometer, 5 push buttons, and a 7-segment LED display. The ***tachometer*** measures the rotational speed of the centrifuge rotor and sends feedback to the Nuvoton microcontroller for closed-loop control of the speed. The ***5 push buttons*** allow the user to set and adjust the desired speed and time parameters for the centrifugation process.
The ***7-segment LED display*** provides real-time feedback to the user by displaying the current speed, time remaining, and other relevant information. The display also allows the user to monitor the progress of the centrifugation process and make adjustments as needed.
The implementation of these user interface components provides a user-friendly and precise control system for the centrifuge, allowing for optimal performance and reproducibility of experimental results.

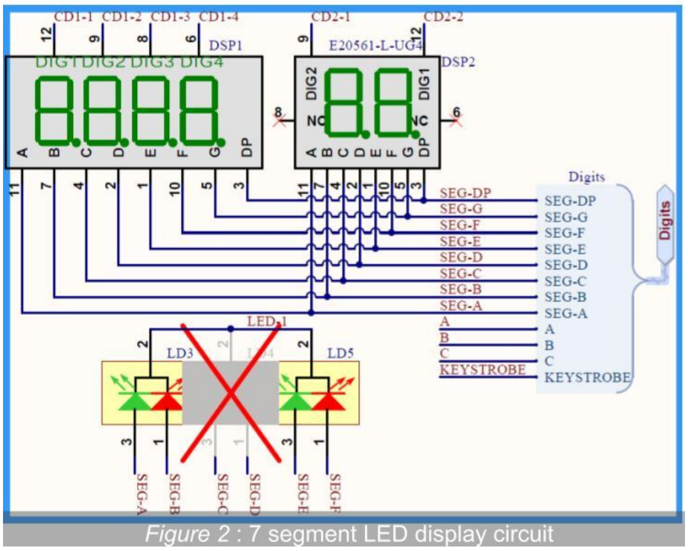


Figure 2 : 7 segment LED display circuit

As shown in Figure 3, 74LS145 is a BCD-to-Decimal Decoder that is used to decode the binary-coded decimal (BCD) signals generated by the microcontroller and display them on the 7-segment LED display. The BCD input is converted to a decimal output and then decoded to display the corresponding digit on the LED display. This IC is commonly used in digital circuits that require decoding BCD signals to drive 7-segment displays. In the Precision Control System for Centrifuge, the 74LS145 is used to decode and display the centrifuge's speed and other relevant information on the user interface. The truth table logic for conversion between BCD and Decimal values is represented in *Figure 4* and the BCD conversion to 7-segment decoder representation is represented below in Figure 5.

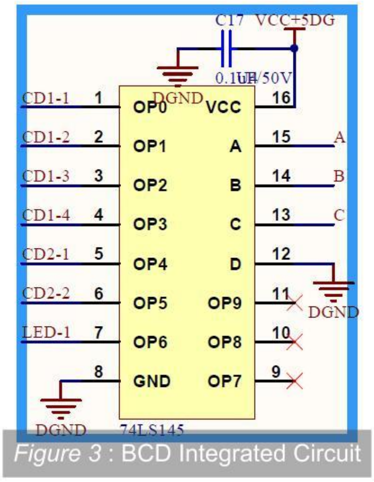
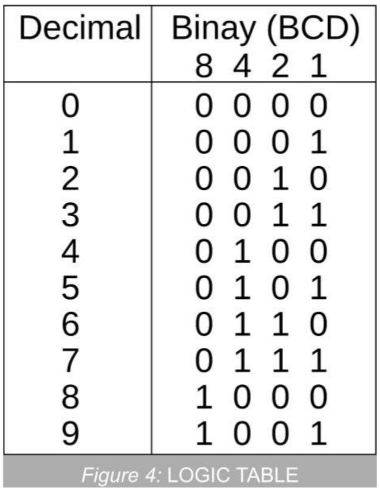


Figure 3 : BCD Integrated Circuit



Decimal	Binay (BCD) 8 4 2 1
0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1

Figure 4: LOGIC TABLE

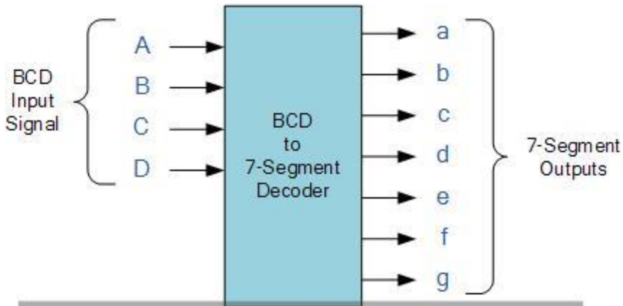


Figure 5 : BCD conversion to 7 segment

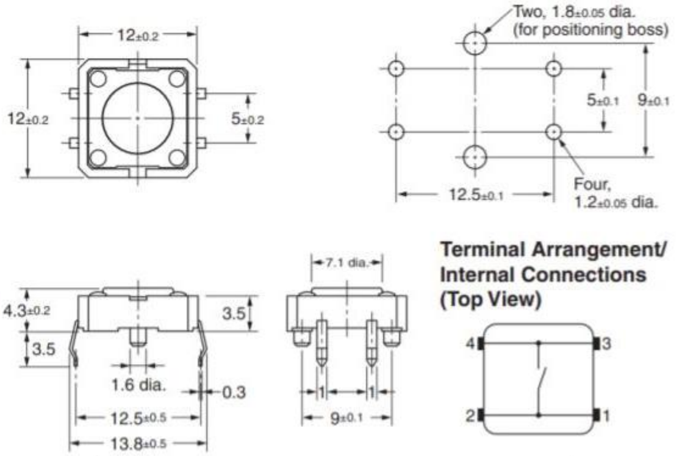


Figure 6(a): Tactile Switches schematics

In this paper, the ***Omron Tactile Switch B3F series*** is the focus of discussion for the push buttons. A 3D view schematic of the push buttons, also known as tactile switches, is shown in Figure 6(a) and Figure 6(b). These push buttons have a height of 4.3mm and dimensions of 12mm x 12mm. The operating force required is 1.27N (130gf) and its durability lasts up to 3,000,000 operations. The operating force required is 2.55N (260gf) and its durability lasts up to 1,000,000 operations.

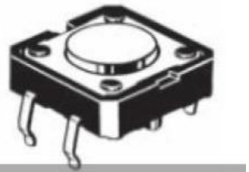


Figure 6(b): Tactile Switch Push Button 3D view

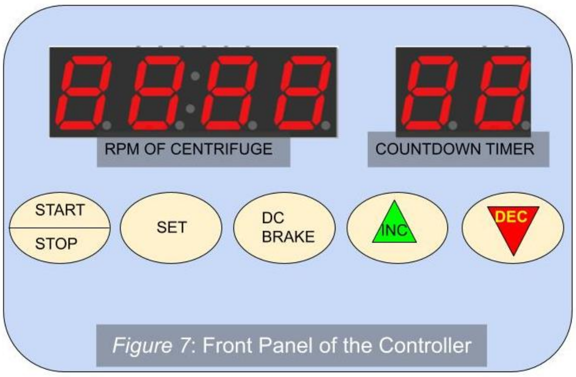


Figure 7: Front Panel of the Controller

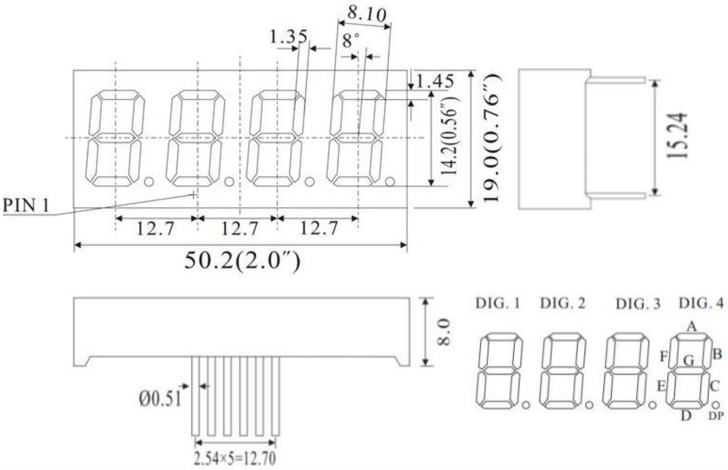


Figure 8: Seven segment LED E40562 schematics

VI. PROJECT IMPLEMENTATION (B): VARIABLE FREQUENCY DRIVE

A Variable Frequency Drive (VFD) is an electronic device that controls the speed of a AC motor. In the case of a Blood Centrifuge Application based machine, the VFD is used to control the rotational speed of the centrifuge rotor, which holds the blood samples. When the VFD receives a signal from the centrifuge controller to start the centrifuge, it sends a variable frequency and voltage to the motor. This allows the motor to start at a low speed and gradually ramp up to the desired speed, which helps prevent damage to the samples.

Once the rotor is spinning at the desired speed, the VFD monitors the speed and adjusts the frequency and voltage to maintain a constant speed. This is important because variations in speed can affect the separation of blood components, leading to inaccurate test results.

In addition to controlling the speed of the motor, the VFD also helps to reduce energy consumption in the centrifuge machine. By controlling the frequency and voltage supplied to the motor, the VFD can adjust the amount of power consumed. This means that when the centrifuge is running at lower speeds or is idle, the VFD can reduce the power supplied to the motor, leading to energy savings. Moreover, the VFD also contributes to the overall reliability and longevity of the centrifuge machine. The ability to start the motor at a low speed and gradually ramp up to the desired speed reduces the mechanical and thermal stresses on the motor and other components. This leads to the less wear and tear, which can extend the machine’s lifespan and reduce the need for costly repairs and maintenance.

Overall, the VFD is an essential component in operating a blood centrifuge machine. Its ability to control the speed of the motor, reduce energy consumption, and increase the reliability and longevity of the machine make it an integral part of the centrifugation process.

VII. PROJECT IMPLEMENTATION (C): FINAL PROCESS METHODOLOGY

Based on the instructions input by the user via the front panel of the controller, the microcontroller will receive the instructions as input. If the instructions were to start running the centrifuge rotor for a given amount of time, the microcontroller will check the digital input signal received from the LID LOCK to verify whether the lid is open/closed. For the motor to run, the lid must be in closed status, and the lid lock is actually a solenoid lock that gets charged when a suitable power source is provided and the lid will remain closed. And in the event of any power failure, the motor will stop running and the solenoid lock is automatically released along with the lid lock status switched to open. And if the imbalance sensor detects any deviations in the rotational balance of the centrifuge rotor. The digital input signal will be received by the microcontroller and the motor will stop running. For compatible communication between the microcontroller (N79E855) and the motor driver (VFD), the hardware module of UART which uses RS232 serial communication protocol. This module is connected to VFD and Nuvoton Microcontroller. Using this communication protocol, the motor's speed can be varied and controlled by varying the frequency sent to the Variable Frequency Drive. The speed of the Centrifuge rotor is measured simultaneously using a Tachometer. The signal from the tachometer is in sine waveform and that signal is later conditioned by the ZCD before sending the input to the microcontroller. Also refer to *Figure 1.*

VIII. FUTURE SCOPE

The Precision Control System for Centrifuge using a Variable Voltage Variable Frequency Drive (VVVFD) and Nuvoton Microcontroller has several potential future applications and scope for improvement. Some of them are:

A. **Automation**: The precision control system can be integrated with automation systems, which would allow for greater control and efficiency in industrial applications.

B. **Remote Monitoring**: Remote monitoring and control of the centrifuge can be implemented using the Internet of Things (IoT) technology, which would allow for real-time monitoring of the centrifuge from a remote location.

C. **Artificial Intelligence (AI) Integration**: Integration of AI algorithms into the control system would enable self-learning and predictive maintenance of the system.

D. **Advanced Control Algorithms**: Implementation of advanced control algorithms, such as model predictive control (MPC), would further enhance the accuracy and efficiency of the system.

E. **High-Speed Centrifuges**: The precision control system can be adapted to control high-speed centrifuges, which would enable the separation of smaller and more delicate biological components with greater accuracy.

Overall, the precision control system for centrifugal force generation using VFD and Nuvoton microcontroller has significant potential for future development and improvement. With advancements in technology and automation, it can be further optimized for various applications in different fields.

IX. CONCLUSION

In this paper, we conclude that in any design of Digital centrifuge the implementation of safety interlocks such as ***solenoid lid lock*** and ***imbalance sensor*** is crucial for ensuring safe and accurate operation of a Precision Control System for Centrifuge. The use of a ***tachometer***, ***5 tactile switch push buttons***, and a ***seven-segment LED display*** as the user interface allows for easy control and monitoring of the system. The use of ***UART RS232*** communication protocol between the ***VFD*** and ***centrifuge rotor***, as well as the signal conditioning with ***ZCD***, enables accurate control of the centrifuge rotor speed. The use of the ***Nuvoton N79E855 microcontroller*** over SiLab-F380 further enhances the system's performance and allows for precise adjustment of voltage and speed control. Overall, these components and techniques combined result in a reliable and efficient Precision Control System for Centrifuge

Figures and Tables

Table 1:List of Components

CATEGORY OF COMPONENTS	**NO.**	**NAME OF COMPONENTS**
HARDWARE	1.	NUVOTON MCU **N79E855** 8051 SERIES
	2.	VFD
	3.	CENTRIFUGE
	4.	FIVE PUSH BUTTONS

	5.	SIX DIGIT - SEVEN - SEGMENT LED DISPLAY **E20561-L-UG4**
	6.	TACHOMETER
SOFTWARE	1.	KEIL 4 IDE
	2.	ALTIUM 20

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X. Acknowledgment

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