Implementation of Stepper Motor Control using ARM Cortex M7 Microcontroller

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CERTIFICATE

This is to certify that the project report submitted along with the project entitled Internship /Project **Implementation of Stepper Motor Control using ARM Cortex M7 Microcontroller** has been carried out by Mr. **Daksh Kakadia** under my guidance in partial fulfilment for the degree of Bachelor of Engineering in **Electronics and Communication Engineering**, 7^{th} Semester of Gujarat Technological University, Ahmedabad during the academic year 2023-24.

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DECLARATION

We hereby declare that the Internship / Project report submitted along with the Internship / Project entitled **Implementation of Stepper Motor Control using ARM Cortex M7 Microcontroller** submitted in partial fulfillment for the degree of Bachelor of Engineering in Electronics and Communication Engineering to Gujarat Technological University, Ahmedabad, is a bonafide record of original project work carried out by me at Space Application Center (SAC), ISRO under the supervision **of Shri. Mohammad Waris** and that no part of this report has been directly copied from any students' reports or taken from any other source, without providing due reference.

Daksh Kakadia

ACKNOWLEDGMENT

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ABSTRACT

This report presents the design, implementation, and evaluation of full stepping and half-stepping control techniques for a stepper motor using a 32-bit Cortex-M7 microcontroller. Stepper motors are widely used in various applications that require precise motion control. Full stepping and half-stepping are two fundamental methods for controlling stepper motors, each offering distinct advantages and trade-offs in terms of accuracy, torque, and power consumption.

This study begin by providing an overview of the stepper motor principles and the theoretical underpinnings of full stepping and half-stepping. Then detail the hardware setup, including the choice of stepper motor, motor driver, and ARM Cortex-M7 microcontroller. The control algorithms for both full stepping and half-stepping modes are developed and implemented in embedded C.

This project provides valuable insights into the practical implementation of stepper motor control using a microcontroller and demonstrates the advantages and limitations of full stepping and half-stepping techniques in real-world scenarios. The findings of this study can guide engineers and researchers as a base to control the speed of Stepper motor and implement more complex control algorithm in future.

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Chapter 1 : Organization Profile

1.1. Indian Space Research Organization (ISRO):

ISRO, established in 1969, stands as India's principal space agency. Over the years, it has played a pivotal role in advancing the nation's space capabilities. ISRO's responsibilities encompass a range of space-related endeavours, including the creation, development, and launch of satellites, space exploration missions, and the nurturing of indigenous space technology.

Figure 1 ISRO Logo

ISRO's accomplishments have garnered significant recognition. Notably, the Chandrayaan-1 mission of 2008 marked India's maiden lunar exploration. This mission achieved unprecedented success, notably by the discovery of water molecules on the Moon's surface. In 2013, ISRO made history again with the successful launch of Mangalyaan, India's inaugural Mars mission. In addition to these missions, ISRO has launched numerous satellites for purposes spanning communication, remote sensing, and navigation.

The organization boasts a substantial workforce consisting of scientists, engineers, and professionals from diverse backgrounds. Complementing this are interns, typically students pursuing undergraduate and postgraduate degrees in fields such as engineering, science, and management. Both employees and interns actively engage in various projects within the realm of space research, which encompass satellite development and the orchestration of space missions.

The roles of ISRO's employees vary according to their areas of expertise. Scientists and engineers contribute to the conception and execution of space-based systems, including satellites, launch vehicles, and ground systems. They oversee rigorous testing and evaluation processes to ensure the reliability and effectiveness of these systems. Additionally, ISRO employees are instrumental in devising mission blueprints, payload selection, and mission management.

Interns at ISRO actively participate in diverse projects associated with space research. This includes involvement in the design and development of satellite components, software creation, and data analysis. Under the guidance of seasoned professionals, interns gain hands-on experience working on live projects, which offers invaluable exposure to the intricacies of the space industry. They also benefit from attending workshops and training programs aimed at honing their knowledge and skills.

Figure 2 ISRO’s successfully launches Chandrayan 3 in its LVM3-M4 rocket

Figure 1.2 ISRO’s successfully launches Chandrayan 3 in its LVM3-M4 rocket

ISRO's employees and interns collectively pursue a common objective: advancing India's space technology capabilities. Their contributions have been instrumental in nurturing indigenous space technology, driving progress in fields such as communication, navigation, and remote sensing. ISRO's ongoing commitment to advancing space technology assures further breakthroughs in the future, underscoring India's dedication to harnessing space technology for the nation's socio-economic development.

1.2. Space Application Center (SAC):

The Space Application Center (SAC) is an integral part of the Indian Space Research Organization (ISRO) that holds a central role in India's space endeavours. Located in Ahmedabad, Gujarat, SAC was established in 1972 under the Space Commission's purview. Its primary mission revolves around harnessing space technology to drive various applications aimed at advancing India's socio-economic development.

SAC shoulders the responsibility of conceiving, crafting, and operating space-based systems tailored for tasks like remote sensing, communication, meteorology, and navigation. Additionally, the center engages in research and development activities that underpin space applications, yielding noteworthy advancements in multiple spheres of space technology.

Figure 3 SAC Logo

One significant arena in which SAC has excelled is remote sensing. This discipline involves scrutinizing the Earth's surface from space via satellites. SAC has taken the lead in designing and constructing an array of remote sensing satellites, exemplified by the Indian Remote Sensing (IRS) series. These satellites have been pivotal in diverse applications, encompassing the prudent management of natural resources, effective disaster response, and precise weather forecasting. Concurrently, SAC has engineered sophisticated ground-based systems for receiving and processing data beamed down by these satellites.

Furthermore, SAC has left an indelible mark in the realm of communication satellites. These satellites, pivotal in activities like television broadcasting, telecommunication, and internet services, have been masterfully designed and developed by SAC. The Indian National Satellite (INSAT) series, in particular, stands out, serving as the backbone for nationwide telecommunication and television services.

Meteorological satellites have also been a forte for SAC, contributing significantly to weather forecasting and monitoring endeavours. The METSAT series, among others, has been instrumental in applications such as cyclone tracking, flood prediction, and drought assessment.

In addition to these accomplishments, SAC has spearheaded the development of navigation systems. Among its notable achievements is the Indian Regional Navigation Satellite System (IRNSS), a regional navigation system delivering precise positioning and timing services to users in India and its adjoining regions.

Internationally, SAC actively engages in collaborations with esteemed space agencies, including NASA, ESA, and JAXA, fostering joint space missions and research initiatives. Notable projects include the Global Monitoring for Environment and Security (GMES) initiative, a partnership between the European Commission and ESA.

Chapter 2 : Literature Review

2.1. Hardware Components:

1) **Microcontroller:** Microchip's ARM Cortex-M7 Microcontroller
2) **Motor Driver:** Microsemi Motor Controller
3) **Motor:** Stepper Motor

2.1.1. Microchip's ARM Cortex-M7 Microcontroller-EK Board:

This evaluation kit is supported by Microchip's MPLAB® X Integrated Development Environment (IDE) and provides easy access to the device features. It supports stand-alone debuggers and includes an on-board embedded debugger

2.1.1.1. Features of Microchip's ARM Cortex M7 Microcontroller-EK Board:

- **On-Board Memories**
  - 512 Kbytes (8-bit wide) Flash
  - 512 Kbits (8-bit wide) SRAM
  - 64 Mbit SPI Flash
- **On-Board Clock Management**
  - 32.768 kHz crystal
  - 10 MHz oscillator
- **Communication Interfaces**
  - UART emulation through USB interface
  - Two CAN ports supporting ATA6563 transceivers
  - Two SpaceWire connectors
  - Two MIL-1553 connectors
- **Analog Function Interfaces**
  - DAC outputs: Buzzer / SMB connector
  - ADC inputs: Potentiometer / SMB connector
- **Embedded Debug Access**
  - On-Board Embedded Debugger (PKOB4)
  - JTAG Debug connector
  - TRACE connector
- **Extension Capability**
  - Three headers compatible with Xplained mezzanine board
  - Four connectors with direct access to the microcontroller pins
- **On-Board End User Interface**
  - One mechanical Reset button
  - Four mechanical user push buttons
  - Six user LEDs
  - One pin for NMIC
- **5V Power Supply**

- USB-C port
- Power status LED

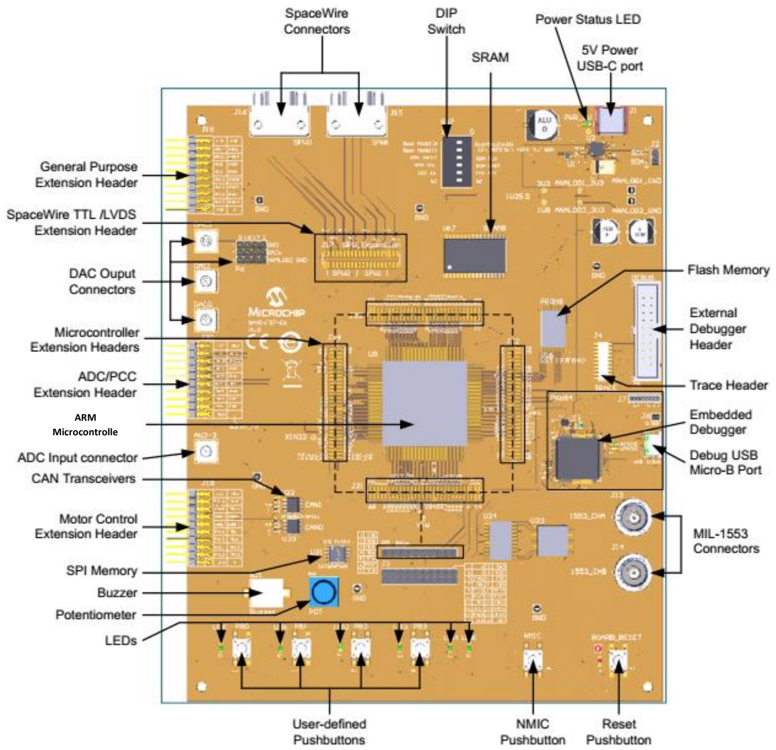

Figure 4 ARM Cortex-M7 Microcontroller

2.1.2. Microsemi Power Driver:

The features a wide input voltage range, up to 50V, and can drive a variety of motor types, including 3-phase brushless DC (BLDC) motors, stepper motors, and DC brushed motors. The controller offers high-resolution sensorless motor control and supports a range of advanced control algorithms.

2.1.2.1. Features of Motor Controller:

- Four half-bridge N-channel MOSFET drivers
- Four floating differential current sensors
- Pulse modulated resolver/LVDT transformer driver
- Three differential resolver/LVDT sense inputs.
- Fault detection
- Low power consumption

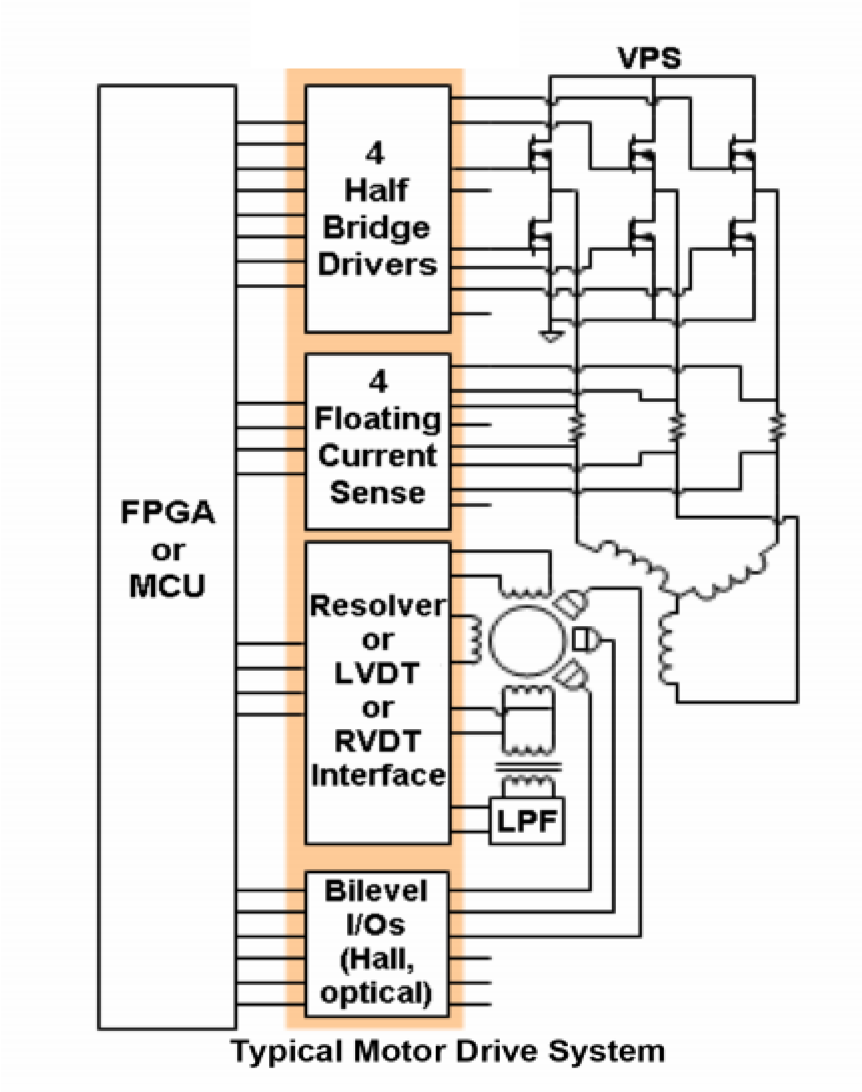

Figure 5 Motor driver block diagram

The Microsemi motor driver is reliable motor driver IC, it offers a range of applications for motor control. These control features and monitoring capabilities allows it to have huge range of applications like motor driver servo control, Linear actuator servo control, Stepper, BLDC, PMSM motor driver and Robotics.

2.2. Software Used:

• For Practical Implementation:

1) **MPLAB® X Integrated Development Environment (IDE)**
2) **MPLAB® XC32 Compiler**
3) **MPLAB® Harmony v3**

2.2.1. MPLAB® X IDE and MPLAB®XC32 Compiler:

Microchip's MPLAB X IDE, alongside the XC32 Compiler, constitutes a robust software package for creating embedded applications designed for Microchip's 32-bit microcontroller family. MPLAB X IDE serves as a user-friendly and potent platform that offers an integrated development environment. It enables developers to craft, troubleshoot, and program applications tailored to Microchip's microcontrollers. The IDE boasts advanced capabilities like code profiling, code coverage, and built-in version control, all of which contribute to enhancing the quality of code and developers' overall efficiency.

Figure 6 MPLAB X IDE Logo

Figure 7 MPLAB XC32 Logo

The XC32 Compiler, on the other hand, is a high-powered optimizing C/C++ compiler specifically designed to generate streamlined and highly efficient code for Microchip's 32-bit microcontrollers. This compiler is equipped with advanced functionalities like inter-procedural optimization, loop optimization, and register allocation, which empower developers to create code that runs efficiently within their applications. Notably, the XC32 Compiler also supports the integration of inline assembly code, simplifying the inclusion of low-level code components into C/C++ projects.

2.2.2. MPLAB® Harmony v3:

Figure 8 MPLAB Harmony Logo

MPLAB Harmony v3, a software development platform by Microchip, provides a comprehensive environment for creating embedded programs. It offers libraries, drivers, middleware, and tools to build reliable and high-quality programs for Microchip's microcontrollers. The platform includes a user-friendly Configurator tool that simplifies customization of framework components.

Developers can select and configure libraries, drivers, and middleware for their applications using an intuitive graphical interface. Additionally, it offers editable templates to meet specific project needs.

MPLAB Harmony v3 Configurator supports various programming languages, including C and C++, and is compatible with a wide range of Microchip microcontrollers, such as PIC32, AVR, and SAM families like SAMRH71 and SAMRH707. The integrated code generation in the Configurator makes designing, debugging, and deploying applications a seamless process within the MPLAB X IDE.

In summary, MPLAB Harmony v3 Framework and Configurator provide embedded application developers with a versatile solution that accelerates time-to-market, improves code quality and efficiency, and simplifies the development process.

Chapter 3 : Introduction to Motors

3.1. Motors:

Motors are devices that convert electrical, mechanical, or other forms of energy into mechanical motion. They are essential components in a wide range of machines and systems, serving various applications across different industries. Motors can be categorized into several types, each designed for specific tasks.

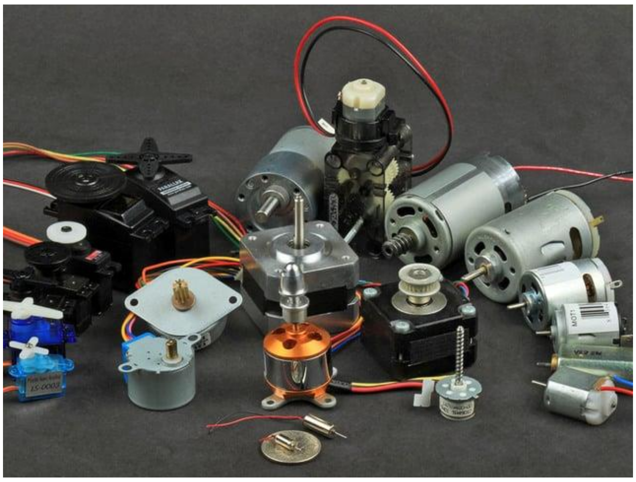

Figure 9 Different types of motors

Motors play a fundamental role in modern technology and automation, enabling the movement of machinery, vehicles, and equipment. The choice of motor type depends on the specific requirements of the application, such as the desired speed, torque, precision, and power source, among other factors

3.2. Types of motor:

There are mainly two types of Motors which are DC(Direct Current) motors and AC(Alternating Current) motors.

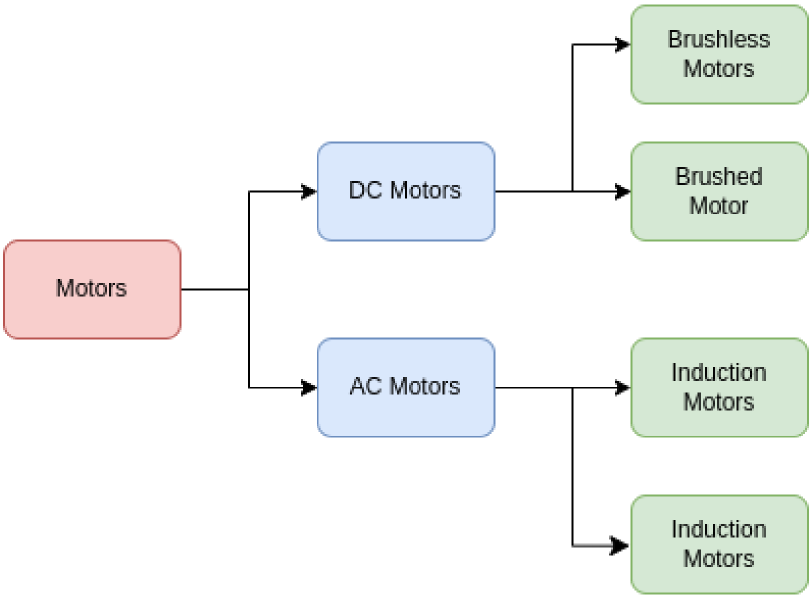

Figure 10 Main Categories of Motors

DC Motors or Direct Current motors are a type of electrical motor that operates using direct current electrical power. These motors are widely used in various applications due to their simplicity, controllability, and reliability. DC motors can be classified as

1. Brushed DC Motors: These motors use physical brushes and a rotating switch to create motion. They are found in simple, low-power devices like toys and household tools.

2. Brushless DC Motors (BLDC): These motors use electronic switches to control movement. They are more efficient and dependable than brushed DC motors and are used in high-power applications such as electric vehicles and drones.

3. Stepper Motors: These motors move in precise, tiny steps, making them great for exact positioning. They're commonly seen in robots and machines that need accurate control like CNC machines.

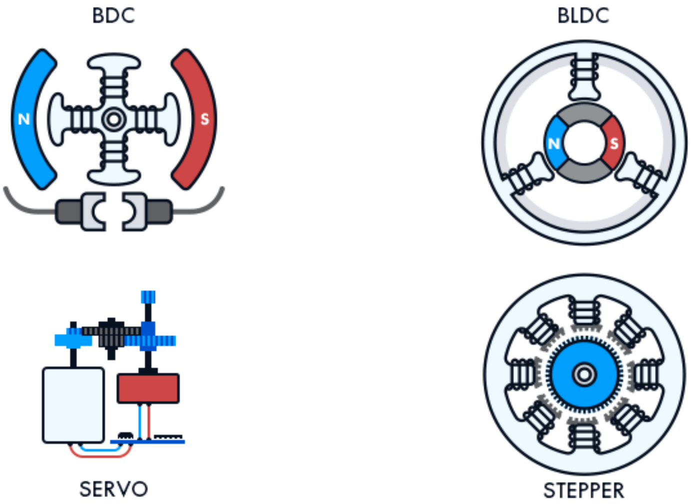

Figure 11 Types of DC Motors

AC Motor run on electrical power that frequently changes direction, and they find use in a broad array of applications that demand strong rotational force at slow speeds. These motors come in various categories:

1. Induction Motors: These are the most commonly used AC motors. They work by creating a rotating magnetic field through electromagnetic induction, resulting in reliable and low-maintenance operation, making them well-suited for industrial use.

2. Synchronous Motors: Synchronous motors run at a fixed speed synchronized with the AC power source frequency. They're precise and often used in applications where exact timing or control is essential, like electric clocks and precision machinery.

3. Brushless AC Motors: These motors use electronic switches to manage speed and power. They're highly efficient and dependable, finding use in high-power applications such as industrial pumps and fans.

3.3. Stepper Motors:

A stepper motor is an electrical motor known for moving its shaft in precise, fixed-angle increments, or steps. This unique attribute is achieved through the motor's internal design, eliminating the need for external sensors to determine its exact position. This step-wise motion capability makes stepper motors versatile and suitable for a broad array of applications.

Like other electric motors, stepper motors consist of two main components: a stationary part known as the stator and a mobile part called the rotor. The stator features teeth around which coils are wound, while the rotor can be either a permanent magnet or a variable reluctance iron core. We will explore the various rotor configurations in more detail later. In Figure 3.4, you can observe an illustration depicting a cross-section of the motor, where the rotor is depicted as a variable-reluctance iron core.

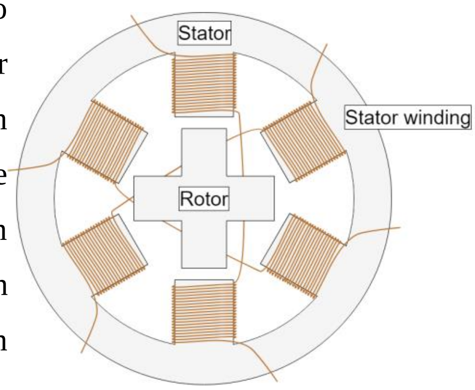

Figure 12 Structure of Stepper Motor[1]

The fundamental operational principle of a stepper motor operates as follows: When one or more of the stator phases are supplied with electrical current, it creates a magnetic field, and the rotor aligns itself with this magnetic field. By successively energizing different phases in a specific sequence, the rotor undergoes rotational movement by a precise angle, eventually reaching the desired final position. Figure 2 illustrates this working principle. Initially, coil A receives power, causing the rotor to align with the magnetic field it generates. Upon energizing coil B, the rotor rotates clockwise by 60 degrees to align with the new magnetic field, and a similar rotation occurs when coil A is powered again. The colours on the stator teeth in the illustrations represent the direction of the magnetic field produced by the stator windings.

Unlike brushed DC motors, Stepper motors do not have a mechanical commutator. Instead, they use electronic commutation to control the current flow to the armature winding, producing rotational motion. This is done by controlling the flow of current to the armature winding. The electronic commutation is typically achieved using a control circuit that converts the incoming DC voltage into a series of pulses of varying widths.

3.3.1. Types of Stepper Motor:

1) Permanent magnet rotor, the rotor itself is a permanent magnet that naturally aligns with the magnetic field produced by the stator circuit. This configuration ensures a robust torque and provides detent torque, meaning the motor offers some resistance to position changes, even when no coils are energized. However, this design has some limitations, such as lower speed and reduced precision compared to other motor types.

2) Variable Reluctance Rotor: the rotor is crafted from an iron core and designed with a specific shape enabling it to align with the magnetic field . While this configuration allows for higher speed and precision, it often delivers lower torque and lacks detent torque.

3) Hybrid Rotor: The hybrid rotor is a unique blend of the permanent magnet and variable reluctance designs. It features a rotor with two caps, each having alternating teeth and being magnetized axially. This design combines the strengths of both permanent magnet and variable reluctance versions, offering high resolution, speed, and torque. However, achieving these enhanced performance characteristics necessitates a more intricate construction and consequently results in a higher cost. Figure 3 provides a simplified depiction of this motor's structure. When coil A is powered, one tooth of the N-magnetized cap aligns with the S-

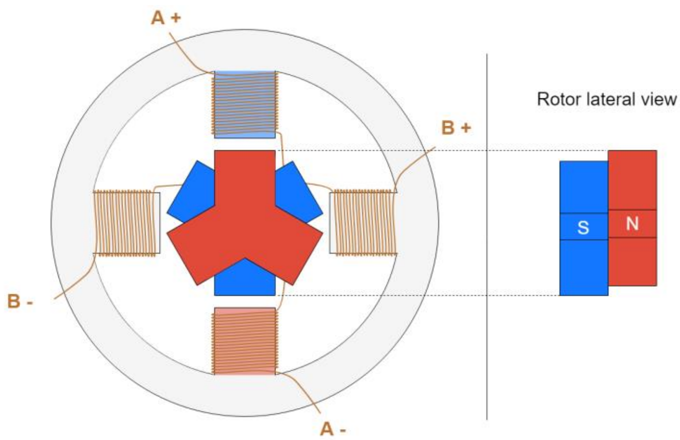

Figure 13 Structure of Hybrid Motor[1]

magnetized tooth of the stator. Simultaneously, due to the rotor's structure, the S-magnetized tooth lines up with the N-magnetized tooth of the stator. In real motors, the structure is more complex, featuring a greater number of teeth than shown in the illustration. Nevertheless, the fundamental working principle of the stepper motor remains the same. The increased number of teeth enables the motor to achieve smaller step sizes, down to 0.9 degrees.

3.3.2. Advantages of Stepper Motor over other motors:

There are several advantages of Stepper motors over other types of motors including:

1) Precise Positioning
2) Open-Loop Control
3) No Drift
4) Simple Control
5) Low Maintenance
6) Low Maintenance

7) Position Hold Capability
8) High Resolution
9) Cost-Effective
10) Ease of Integration

Chapter 4: Introduction to Stepper motor Control

4.1. Block Diagram of Stepper motor control:

Block diagram for stepper motor control is as shown below, it contains Timer counter and motor driver provides PWM peripherals, which are provided by ARM microcontroller and H-Bridge which is provided by Motor driver.

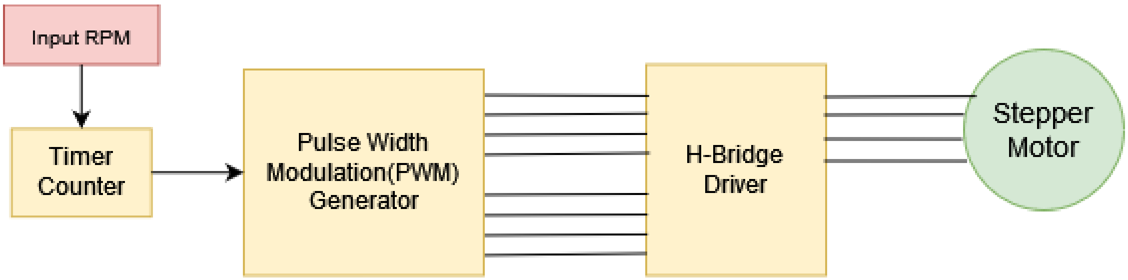

Figure 14 Block Diagram of Stepper Motor control circuit

The timer unit is used to put delay between PWM signals, the timer period is set according to the speed required. The PWM time period is set according to the specification of motor and the output will be obtained form eight different channels/

Stepper motor can be controlled with the help of motor driver, which simultaneously switch voltage with the help of H-bridge and PWM. Pulse Width modulation (PWM) is provided by microcontroller. Stepper motor consists of two windings A and B. To achieve switching Eight PWM signals are required to control Two H- Bridge drivers.

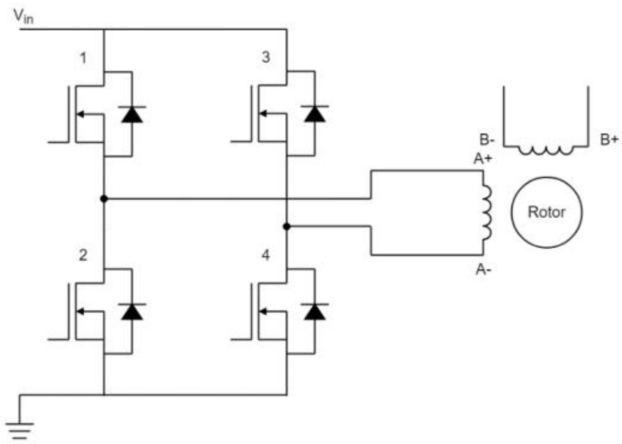

Figure 15 H - Bridge Structure

As shown in figure MOSFET 1, 2, 3, 4 are connected with PWM0_H0, PWM0_L0, PWM0_H1, PWM0_L1, Similarly For winding B MOSFET 5, 6, 7, 8 are connected with PWM0_H2, PWM0_L2, PWM0_H3, PWM0_L3.

4.2. Introduction to Full-Stepping:

In full-step mode, two phases of the stepper motor are continuously energized simultaneously. This driving mode is illustrated in the figure, which showcases the distinct steps in this operation. These steps bear a resemblance to those observed in the wave mode; however, the significant distinction lies in the motor's ability to generate higher torque. This increase in

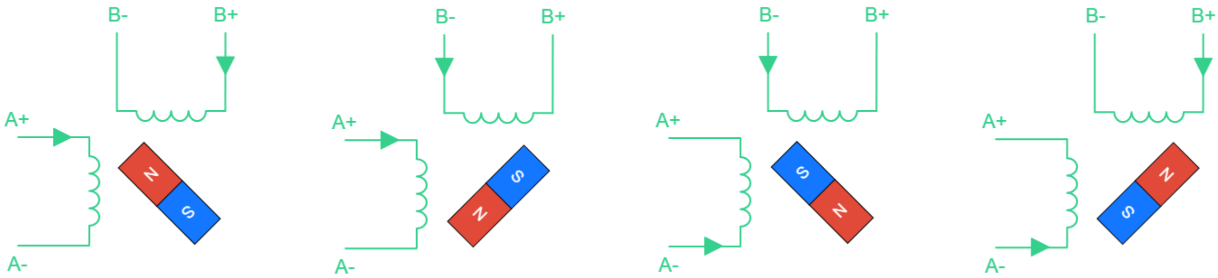

Figure 16 Full stepping Switching Sequence

torque is attributable to the fact that more current flows through the motor, leading to the creation of a more robust magnetic field. As a result, the motor can exert greater force during its rotation. This mode is advantageous in applications where enhanced torque is necessary for effective performance.

4.2.1. Flow Chart of Full-Stepping:

Full stepping can be implemented by following flow chart. In full stepping Timer units period is set according to the RPM of motor as needed. Timer interrupt is triggered every time when period value is reached and ISR of timer is called. It contains call back function which bin turn increases the step count according to the stepping method used. For full stepping step count is four.

Timer period is calculated as below given formula:

$$period = \left(\frac{60}{RPM * N * 50}\right) * clk\ freq$$

Where, N = number of step (4)

$clk\ freq$ = frequency of clock(10MHz)

RPM = required Rpm of motor

For current setup the Rpm is set to 100 and clock frequency to 10MHz and as per above formulae the value of period will be 30000 i.e. timer will count 30000 and interrupt will be generated at every 3 micro seconds (µs).

The flow chart shows the flow of code to implement full stepping.

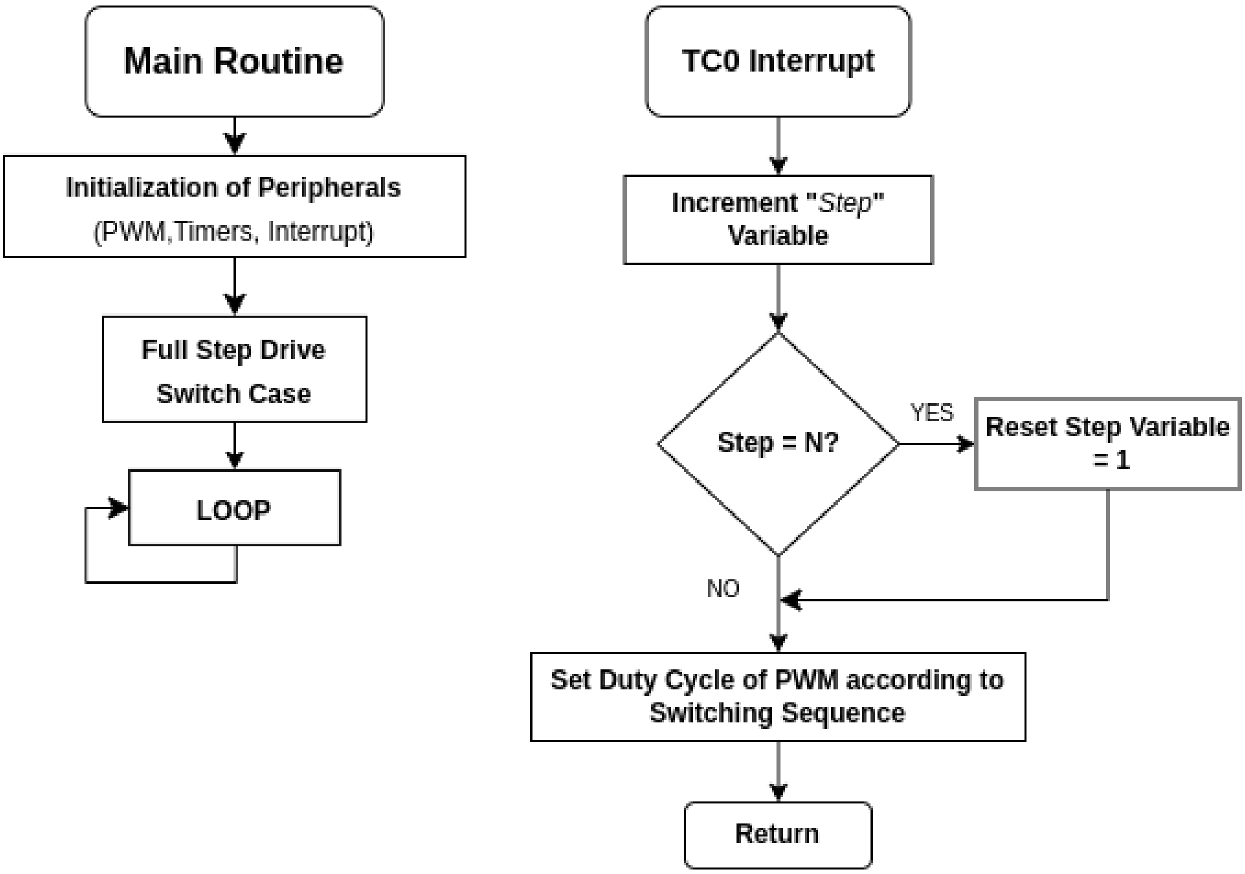

Figure 17 Full stepping Flow chart

4.2.2. Stepping Sequence of Full-Stepping:

In Full stepping method both coil are energized at same time and polarity across the winding is observed as below

Winding A	+	-	-	+
Winding B	+	+	-	-

Now according to above switching sequence we get following waveform for voltage across Winding A and Winding B, this electrical cycle is repeated after every four steps.

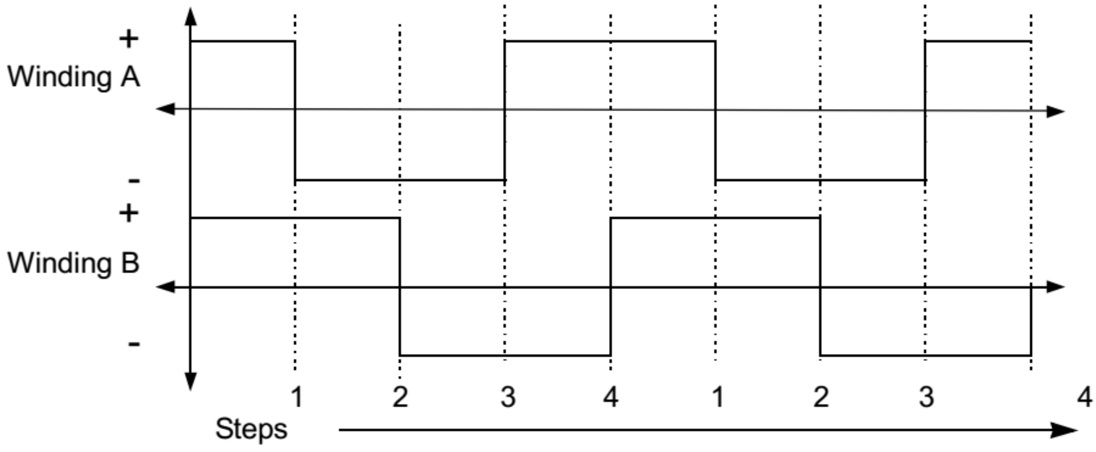

Figure 18 Voltage waveforms of Full stepping[3]

4.2.3. Practical Implementation of Full-Stepping:

Physical connections of microcontroller, motor driver and stepper motor are important and crucial part of this project. The microcontroller is powered with Type-C cable from computer and motor driver is connected with four different power supply, which are +12.7V for VGS, +5V for VMPS, +3.3V for VDD and +5V for VCC.

For Full stepping the PWM output is as shown in figure with each cycle taking 12ms. This waveforms are for eight different MOSFET of H-bridge. Yellow

Figure 19 PWM Output for Bridge A [Scale:3V/div]

Figure 20 PWM Output for Bridge A [Scale:3V/div]

Voltage output waveform of motor phases is as shown in figure below as seen here the yellow and green signals are voltage across winding 1 while blue and red are voltage across winding 2. Both Windings have waveforms at **phase shift of 90°**.

Figure 21 Output Voltage waveforms of motor driver [5V/div]

Current waveform for Full stepping are shown below in figure, it can be observed that waveform switches polarity and direction of current changes, both current waveforms are at phase difference of 90°.

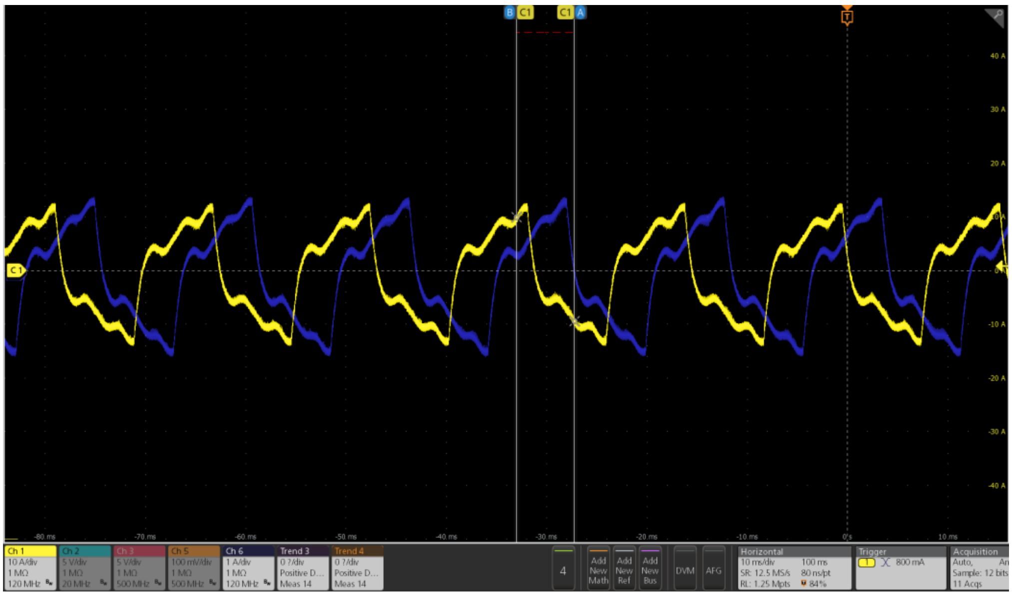

Figure 22 Output Current through Motor Windings [10A/div]

Figure shows zoomed image and it can be observed that PWM switching results in rising and falling of current within the windings.

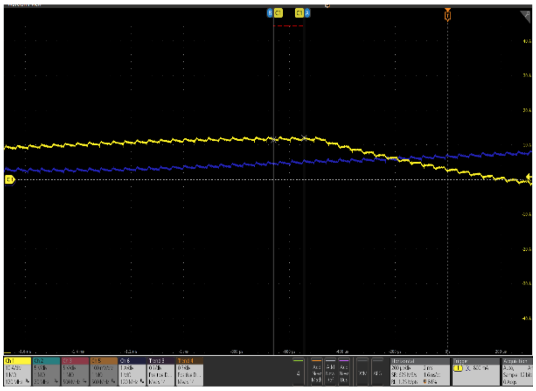

Figure 23 Zoomed in Waveforms of current

4.3. Introduction to Half-Stepping:

Half-step mode represents an intermediate stepping mode, combining features from both the wave and full-step modes, as depicted in Figure .

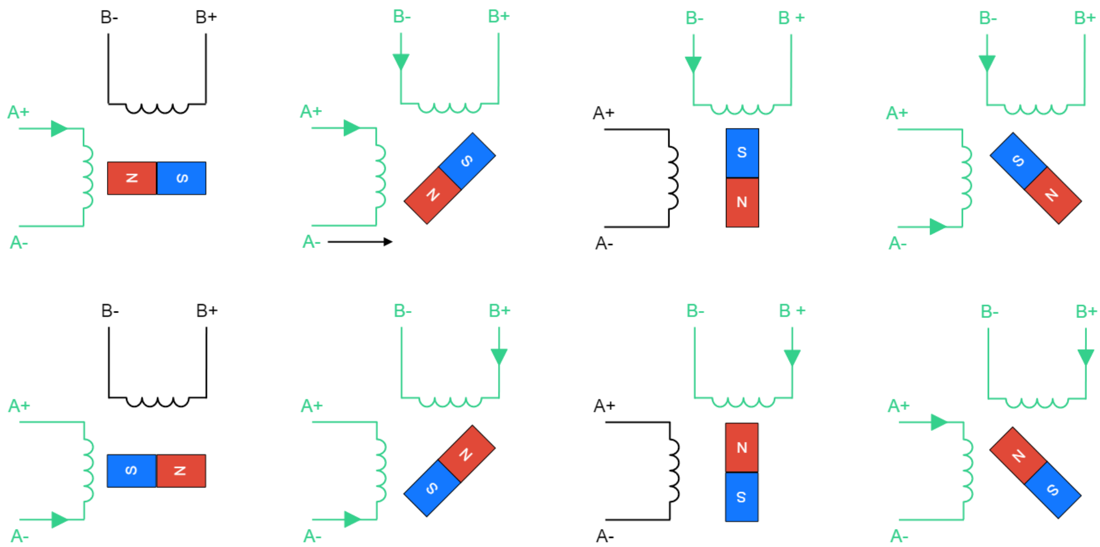

Figure 24 Half Stepping switching Sequence [2]

This unique combination reduces the step size by half, resulting in a 45° rotation instead of the usual 90° in full-step mode. However, one noteworthy consideration is that the torque generated by the motor is not constant in this mode. It is at its maximum when both phases are energized, creating a stronger magnetic field and thus higher torque. Conversely, when only one phase is energized, the torque weakens. This variation in torque is a characteristic of half-stepping and is important to consider when choosing a stepping mode for a specific application.

In half stepping flow is same as full stepping, only difference is in number of steps here total number steps in one electric cycle is Eight so the time between individual step is halved as compared to Full stepping.

4.3.1. Stepping Sequence of Half-Stepping:

In Full stepping method both coil are energized at same time and polarity across the winding is observed as below

Winding A	+	0	-	-	-	0	+	+
Winding B	+	+	+	0	-	-	-	0

Here 0 represents the state where no input is given to the winding of the motor and total number of steps is Eight.

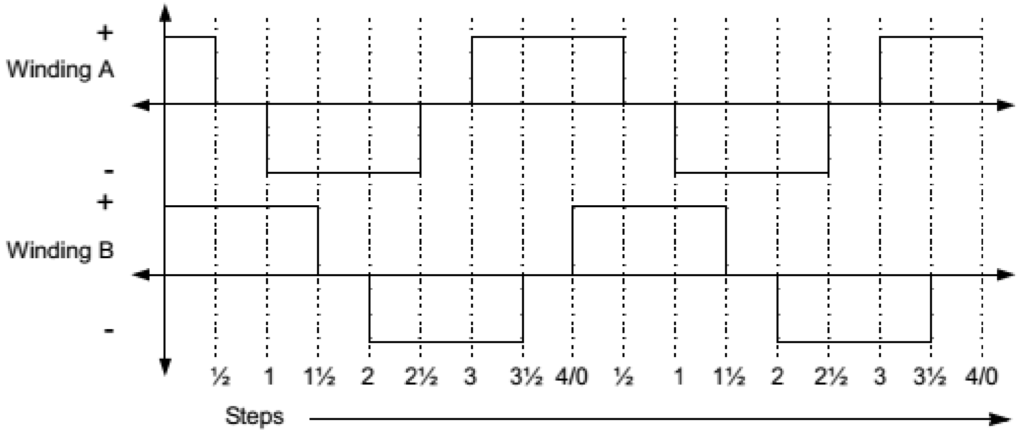

Figure 25 Voltage waveforms of half stepping

4.3.2. Practical Implementation of Half-Stepping:

In half stepping the only change is stepping sequence where there is a zero state in between when no input is given. The PWM output of Microcontroller is as shown below.

Figure 26 PWM output for H-Bridge A [5V/div]

Figure 27 PWM output for H-Bridge A [5V/div]

Voltage output waveform of motor phases is as shown in figure below as seen here the yellow and green signals are voltage across winding 1 while blue and red are voltage across winding 2. Both Windings have waveforms at phase shift of 90°. Additionally there is a zero state between voltage signals.

Figure 28 Output Voltage Waveform from motor driver [10V/div]

4.4. Chopper Control:

Chopper control is a way to limit the current in the winding of a stepping motor when using a high voltage supply (a voltage higher than a motors rated voltage). The basic idea behind chopper control is to use a high voltage source to bring the current in the winding of a stepping motor up to IMAX very quickly. When IMAX is reached the voltage is chopped or switched off. A pulse-width modulated waveform is used to create an average voltage and an average current equal to the nominal voltage and current for the winding. The duty cycle of this PWM waveform is shown in the following relation:

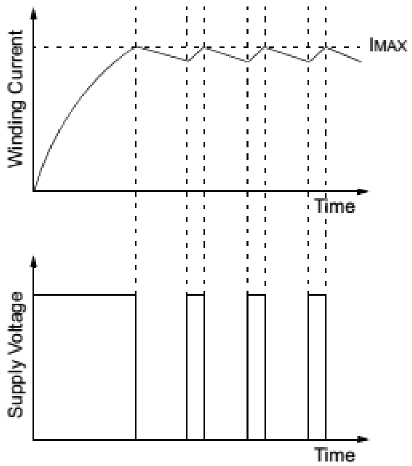

Figure 29 Chopping method with PWM[4]

4.4. Decay Modes:

When a motor winding is switched off by the PWM, the current in that winding begins to decay until it reaches zero or until the winding is energized again. The rate at which the current decays depends on the configuration of the H-bridge at that specific moment. The different current decay methods of which slow decay is discussed here.

4.4.1.Slow Decay:

Slow decay is entered by shorting the motor winding when it is not driven by the supply voltage. This is obtained by keeping one of the drive MOSFETs open at all times. If two MOSFETs are on the diodes are shorted, allowing less power dissipation and less current drop during slow decay.

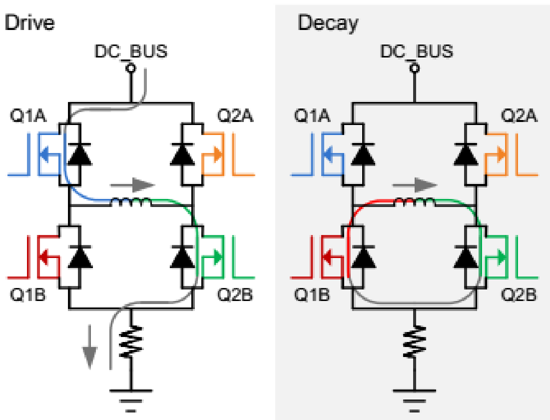

Figure 30 Slow decay implementation [1]

For implementing slow decay figure 4-15 shows when PWMH1 is pulled Low at the same time PWM for lower MOSFETS (PWM1L1 and PWM1L2) are high and current dissipation will take place.

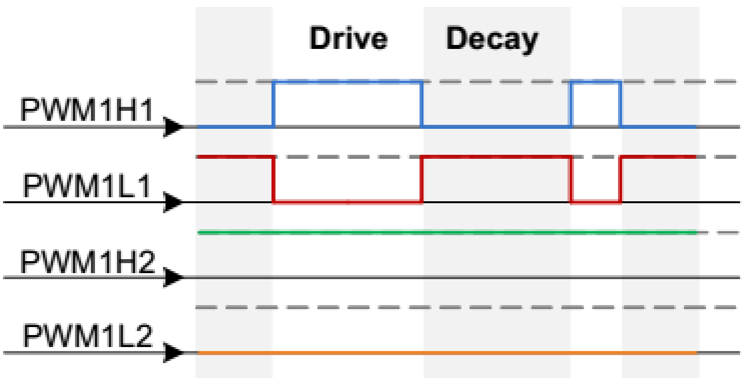

Figure 31 PWM Waveforms for Slow Decay[1]

After implementing slow decay we can see in current waveforms we do not get sharp switching and obtain dip in the waveform, other methods like fast decay or combined decay method can improve waveforms certainly. Motor control methods with feedback loop can also be implemented to improve accuracy.

Chapter 5 : Conclusion and Future Scope

5.1. Conclusion of the project:

In conclusion, this project aimed to design and implement a motor control system for a Stepper motor using ARM Cortex-M7 microcontroller and Microsemi motor controller. The system was designed to control the speed of the motor, and was implemented with Full Stepping and Half Stepping control algorithm.

The project successfully achieved its goals, demonstrating the ability to control the motor's speed. The system was able to generate appropriate control signals for the motor driver based on the desired speed of the motor.

The results gained through this projects shows that a 90-degree phase shift in both phases of motor was obtained. This phase shift results in continuous motion of motor and stepper motor was functioning properly. This was supported by observation of readings through Mixed signal oscilloscope showing the 2 current waveforms using current probes.

There were some limitations and areas of improvement that were identified during the project. One limitation was the current waveform obtained was not sharp and contained a dip in magnitude. This could be improved further by configuring the time period and duty cycle of Pulse Width Modulation (PWM), and timer unit of Microcontroller.

Despite these limitations, the project has demonstrated the potential of the designed system for a range of applications, including in robotics, automation, and space applications. The system could be integrated into robotic systems to provide precise control of motors for movement and manipulation tasks. It could also be used in automation systems to control the speed of motors in manufacturing and industrial processes. Additionally, the system could be used in space applications where precise control of motors is required for spacecraft propulsion and other tasks.

Overall, this project has successfully designed and implemented a motor control system for a Stepper motor using ARM Cortex-M7 microcontroller and Microsemi Motor Controller. Further research and development could be undertaken to improve the accuracy and functionality of the system by implementing Micro stepping and other close loop control algorithms, opening up opportunities for wider applications in the future.

5.2. Application of the project:

Due to their properties, stepper motors are used in many applications where a simple position control and the ability to hold a position are needed, including

1. **Robotic Arms:** The motor control system can be integrated into robotic arms to provide precise control of the arm's movement and manipulation tasks. The system's ability to accurately control the position, speed, and torque of the motor can ensure the robotic arms' smooth and precise movement.
2. **Humanoid Robots:** The motor control system can be integrated into humanoid robots to provide precise control of the motor for smooth and natural movements. The system's ability to control the motor's position, speed, and torque can ensure that the movements of the humanoid robot are precise and natural.
3. **Gyroscopic camera (Avionics application)**: Unmanned planes, also known as drones, need cameras with high stability and image precision. Hence, the integration of stepper motors in such systems to control either the zoom /focus of the image or the pan/tilt of camera.
4. **Space Application:** Satellite antennas require precise positioning to ensure accurate communication with the ground station. The motor control system developed in this project can be used as a base to developed highly accurate system, solar arrays, reaction wheels are few area where this project have its base.

5.3. Future of the project:

Micro stepping can be seen as a further enhancement of this project, because it allows to reduce even further the step size and to have a constant torque output. This is achieved by controlling the intensity of the current flowing in each phase Using this mode requires a more complex motor driver compared to the previous solutions. This provides the ability to reduce by half the size of the step, compared to the half-step mode; but it is possible to go even further. Using micro stepping helps reaching very high position resolution, but this advantage comes at the cost of a more complex device to control the motor, and a smaller torque generated with each step. Indeed, the torque is proportional to the sine of the anglebetween the stator magnetic field and the rotor magnetic field; therefore, when the steps are smaller, the torque is smaller. This may lead to missing some steps, meaning the rotor position does not change even if the current in the stator winding has.

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6) Anuraag Pal ‘ Implementation of Motor Control using ARM Cortex-M7 Microcontroller‘.