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Electronic Drive System for Four Stepper Motors

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Abstract:
This article describes the progress of an ongoing project to design an electronic drive system for four stepper motors. The product is part of the Maestro Phantom, an electromechanical system replicating the human torso's breathing movements. Four stepper motors are used to track the movement of the model. The main task of this article is to drive a stepper motor using a PIC microcontroller and LabView. This article describes the hardware and software used to drive stepper motors. The stepper motors are driven by a PIC18F4520 microcontroller mounted on a microchip development board. Additionally, the working principle of stepper motors is explained and the advantages and disadvantages of stepper motors are discussed. This article explains how to drive a stepper motor in different directions and speeds and how to count the number of steps and revolutions.

Keywords: Electronic drive system, Four stepper motors, PIC microcontroller, hardware and software, Advantages and disadvantages.

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نظام الدفع الالكتروني لأربعة محركات متدرجة

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الملخص
تعرض هذه المقالة التقدم المحرز في المشروع الجاري بشأن تصميم نظام الدفع الإلكتروني للمحركات السائر الأربعة. هذه المقالة هي جزء من *Maestro Phantom*، وهو نظام كهروميكانيكي يكرر حركة التنفس لجذع الإنسان. يتم استخدام المحركات السائر الأربعة لتتبع الحركة الوهمية. ستكون المهمة الرئيسية لهذه الورقة هي قيادة محرك متدرج باستخدام متحكم *PIC* باستخدام لاب فيو (*LabView*). ستقدم هذه المقالة الأجهزة والبرامج المستخدمة لتشغيل محرك السائر. يتم تشغيل محرك السائر بواسطة متحكم دقيق *PIC18F4520* مثبت على لوحة تطوير الرقائق الدقيقة. بالإضافة إلى ذلك، فهو يشرح كيفية عمل المحركات السائرة بالإضافة إلى مزايا وعيوب المحركات السائرة. تتضمن هذه الورقة كيفية قيادة محركات السائر في اتجاهات وسرعات مختلفة وحساب عدد الخطوات والمنعطفات.

الكلمات المفتاحية: نظام القيادة الإلكتروني، المحركات ذات الأربعة خطوات، المتحكم الدقيق PIC، الأجهزة والبرمجيات، المزايا والعيوب.

Introduction

The stepper motor is increasingly used in various applications, such as in robotics, machine tools, propulsion and automatic door lock systems [1]. The main aim of this paper is to investigate and implement a stepper motor drive via a microcontroller [2]. This article will be integrated into a MAESTRO project (Methods and Advanced Equipment for Simulation and Treatment in Radio Oncology) [3]. The MAESTRO project re-groups into 25 institutions (laboratories, universities, companies) from several European countries with a CTAC (Control Theory and Application Centre). The University Hospital in Coventry is included in this grouping (see reference to the MAESTRO article) [4]. The present MAESTRO article proposes innovative research to develop and validate in clinical conditions the advanced methods and equipment required for cancer treatment of new modalities in high conformal external radiotherapy, employing electrons, photons and protons beams.
In a paper from the European Society of Therapeutic Radiology and Oncology European Institute of Radiotherapy (ESTROIR) an analysis is taken of 3D CT-based in-room image guidance systems. The report is a practical and technical review and guide on 3D CT-based in-room image guidance systems. In the paper, four different solutions for therapeutic radiology are presented. Those four categories are KV CT and KV CBCT, which are also known as cone-beam. The other categories are MVCT and MV CBCT [5]. Also, functionality is listed as a required resource for implementation and the capability of these systems is demonstrated in the article. Moreover, the report is based on generic rather than the manufacturer's instructions [6]. Furthermore, the article is limited to 3D CTIGRT systems which means that only equipment situated within the treatment room is considered [4]. Other situations such as 2-dimensions, orthogonal 2D-2D and planar images were not considered in this article. According to the author the 3DCT-IGRT was chosen because it is one of the most recent additions to the spectrum image guidance solutions available in many clinical locations [4].

The main provided contribution in this study is… while the remaining sections in the article are organized as follows: the main aim and objectives of the study are placed in Section 2. The various applications of the stepper motor are detailed in Section 3. The proposed method and its components are positioned in Section 4. The explanation of the utilized software is presented in Section 5. Section 6 listed the advantages and disadvantages of the stepper motor. The summary of the obtained strategy that is considered as the result of the proposed system is presented in Section 7. Finally, the summary of the conclusion and following the list of references are closing the article.

Aims and Objective

The main aim and objectives of the study are listed below.

1. The main aim of this project is to investigate and implement a stepper motor drive via a microcontroller.
2. Drive the stepper motors in different directions and speeds.
3. Count the number of steps and turn
4. This paper will be integrand into MAESRO project.

Stepper system Applications

It is important to note that although different categories were presented in this article, no comparison was made between the different categories [3]. The operational principles for a 3D CT-based image system can be classified into two different categories, namely beam quality and beam collimation [7]. Beam quality is based on megavolts or kilo volts and beam collimation is based on cone-beam or fan beam solutions. The combinations of these yield four different solutions which are available on the market and are widely used. As demonstrated in Figure 1, commercially available CT-based image guidance systems are as follows:

A. Siemens CT-on-rails.
B. Elekta kV CBCT (Synergy.
C. Varian kV CBCT (OBI).
D. Siemens MV CBCT(Artiste).
E. Tomo-Therapy MV CT.

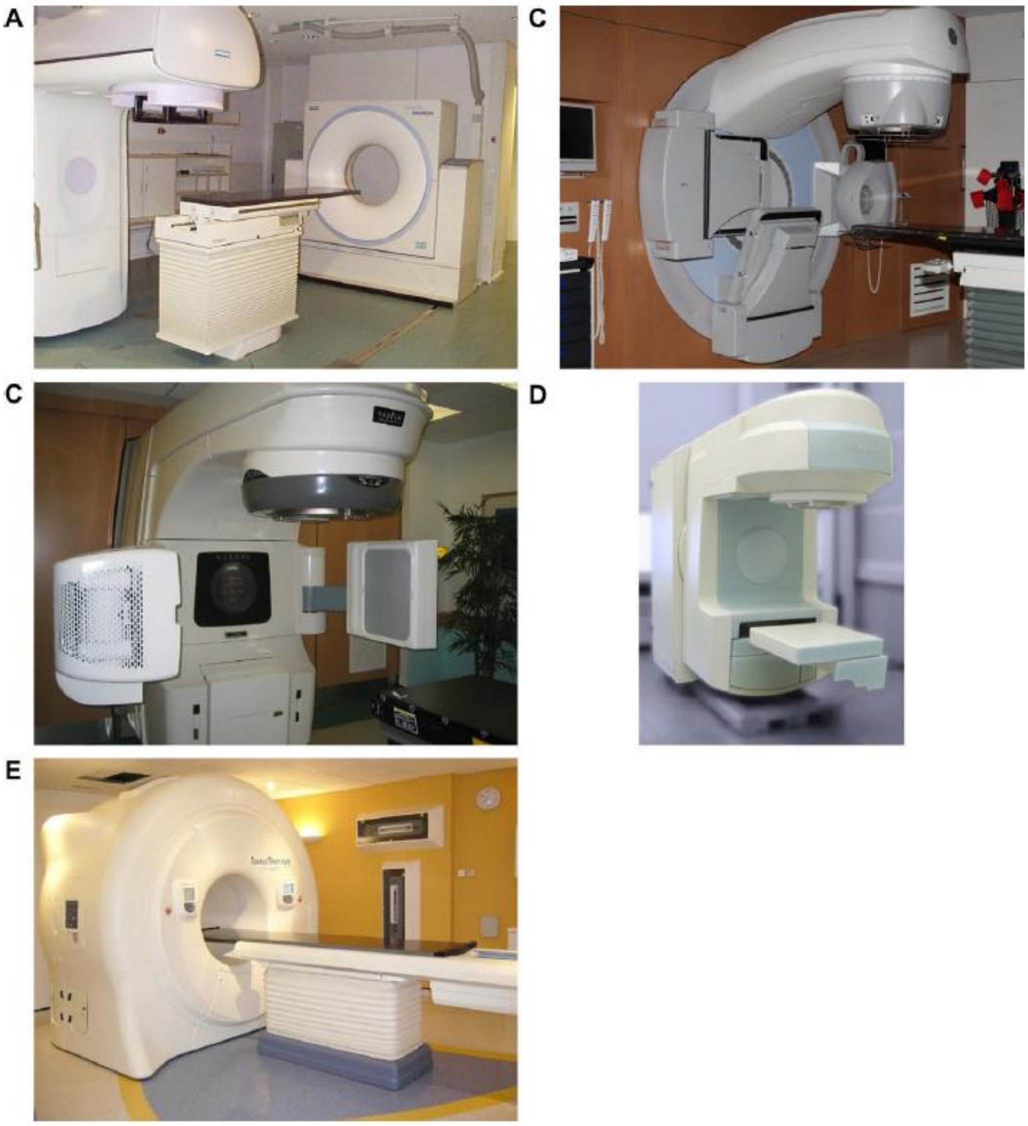

Figure 1: Commercially available CT-based image guidance systems (A) Siemens CT-on-rails; (B) Elekta kV CBCT (Synergy); (C) Varian kV CBCT (OBI); (D) Siemens MV CBCT (Artiste); (E) Tomo-Therapy MV CT.

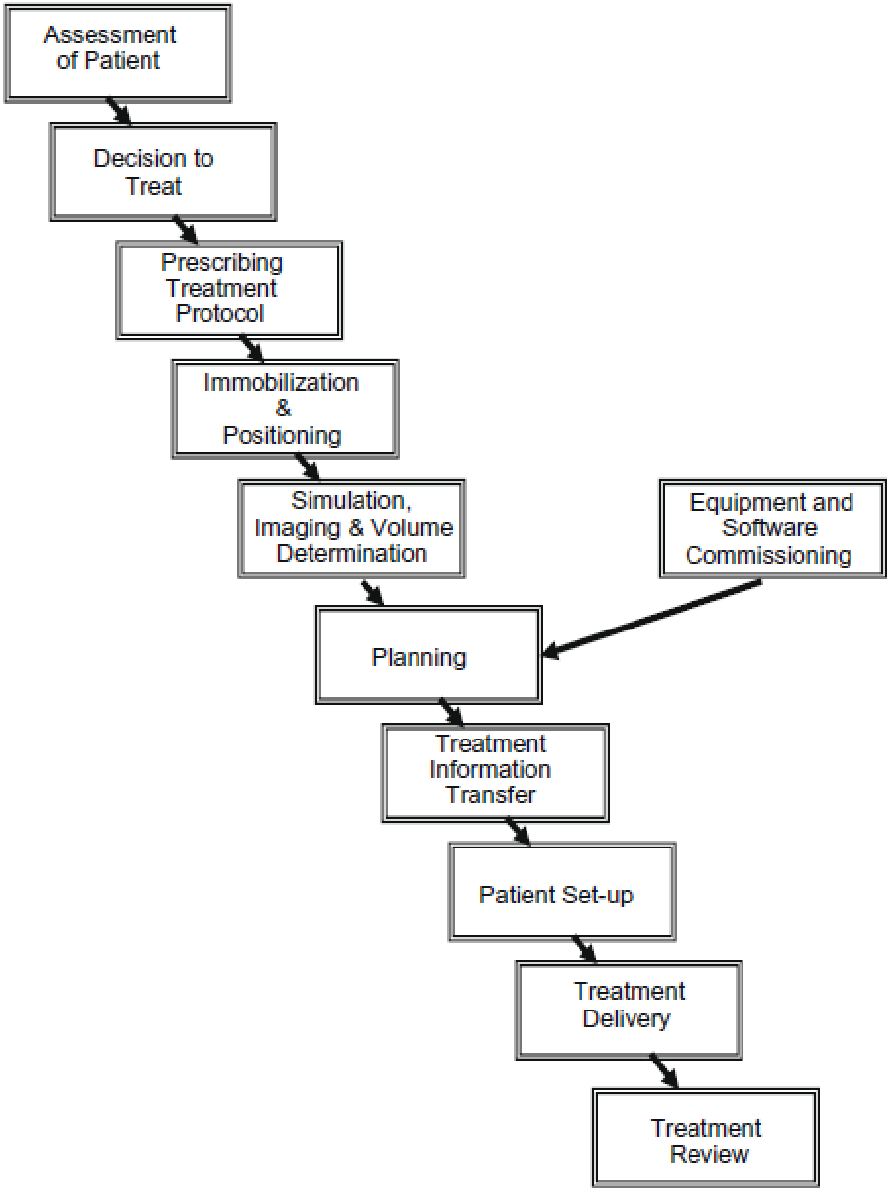

Figure 2: Radiotherapy process of care.

Methods and Materials

This section will introduce the hardware and software used to drive the stepper motor. The stepper motor is driven by a microcontroller PIC18F4520 which is mounted on a microchip development board [8]. The designed hardware comprises the following components as further tabulated in Table 1.

- PC Windows XP with MPLAB 8.50.
- Microchip MPLAB ICD3.
- PIC Development Board 23.
- 5-volt supply.
- Stepper motor outboard.
- Stepper motor controller board.
- Darlington driver.
- I/O board.
- Sensor and timer.
- Connecting leads for PSU, USB and ICD3.

Table 1: Device information [9].

Microcontroller PIC 18F4520		Driver		IC ULN2803APG		Stepper Motor	
Input	Output	Input	Output	Input	Output	Input	Output
ICD 3	Port D		RD3	1	18	4	
			RD2	2	17	3	
			RD1	3	16	2	
			RD0	4	15	1	
		Port C	Counter number of stops				
		Port A	Counter number of runs				

Motor drive

The function and architecture of the stepper motor will be discussed in this part. There will also be an analysis of the benefits and drawbacks of stepper motor use. Thanks to their simplicity and dependability, stepper motors are becoming more and more common in motion control systems. An electric machine without a brush that divides its total action into several stages is known as a stepper motor. Industrial processes requiring high-speed picking and placement equipment are where these motors find the majority of their uses. Furthermore, the precise placement of apparatus like actuators, rotation, and linear stages all depend on them. In addition to those gadgets, stepper motors are utilized in bed scanners, computer printers, packing gear, and many more applications. Stepper motors consist of two main parts: the rotor and the stator. The motor's stationary component is known as the stator, and its moving component is known as the rotor. The rotor and stator are the inner and exterior components of the stepper motor, respectively, as shown in Figure 3. The ends of the wire loops are wrapped around the commutator to enable the rotor to rotate without twisting the wire. Induction happens on a north magnetic and south magnetic because the electric current flowing through the wire energizes each wire and creates magnetic fields across the ferrite material. Stepper motors fall into three major categories:

1. Permanent magnet
2. Variable reluctance
3. Hybrid Synchronous.

When commutators are not included in stepper motors, they become electric motors. This is possible when all the commutation is provided externally by the motor controller. The motor controller circuit is designed for the purpose of holding a motor in a fixed position and rotating in various directions. Some applications may require the choice between stepper motors or servomotors. Although both motors offer similar opportunities in terms of accuracy positioning, they have some differences. The following items summarize the differences between servomotors and stepper motors:

• A servomotor requires a feedback control system while a stepper motor does not require a feedback control loop

• Microprocessors can easily provide controls to the stepper motors, however the drive electronics and logic are more complex

• Stepper motors are brush-less and hence they experience no wear, sparks, or electrical transients in comparison to the brushed servomotors

• When overloaded the stepper motor can easily slip while the servomotor does not

• The repeatability of the positioning carried out by the servomotor depends 27 Literature review on the stability of either the analogue components or potentiometer used in the feedback circuit, while the repeatability of the positioning in the stepper motor depends only on the geometry of the motor.

• While the servomotor is made up of two large stator magnets which are situated on both sides of the rotor, many ferrite poles are placed around a permanently magnetized stator in the stepper motors.

• While the controller of a stepper motor needs to energize the coils at a specific time to turn the permanent-magnet rotor, this is not the case for the servomotor

• A stepper motor has higher torque at low speeds and therefore a driver/- controller is needed to run the motor, while applying the voltage to the two leads is enough to drive a servomotor.

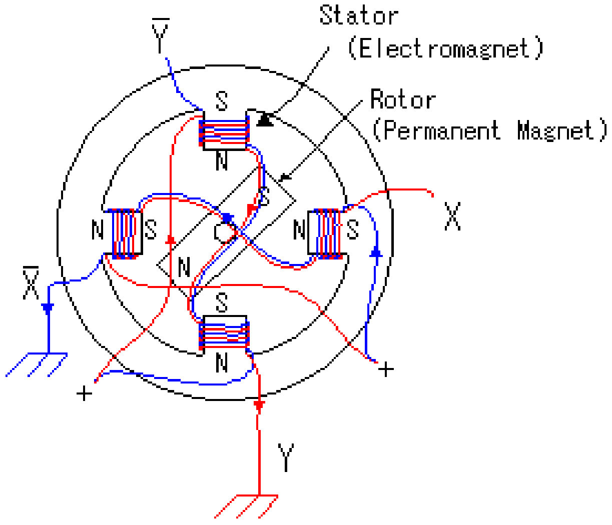

Figure 3: Block diagram for the stepper motor control.

The proposed implementation lab work system is illustrated in Figure 4. Integrating the aforementioned components along with PIC18F4520 as shown in Figure 5 and listing the table details of PIC18F4520 in Table 2.

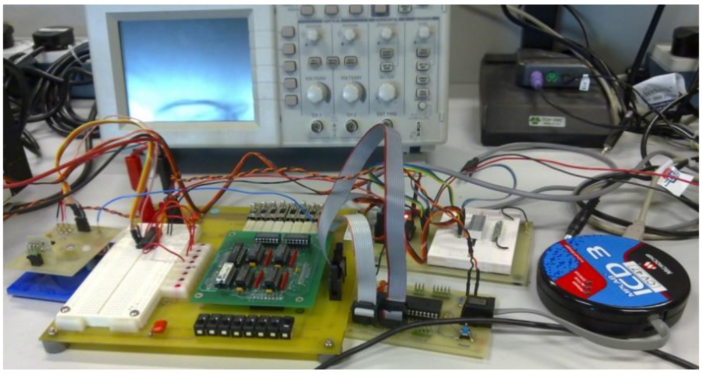

Figure 4: The proposed implementation System

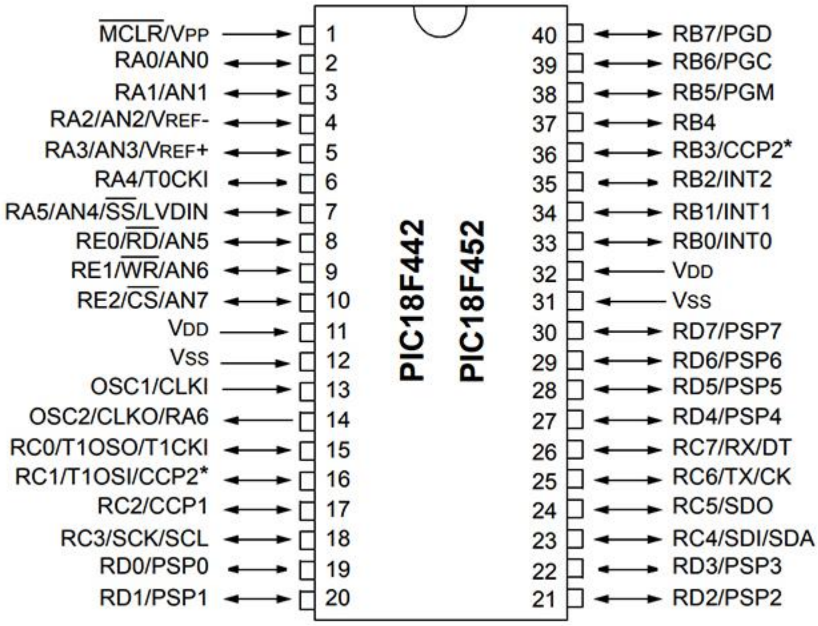

Figure 5: Hardware implementation of PIC18F4520

Table 2: PIC18F4520 features.

Program Memory Type	Flash
Program Memory (KB)	32
CPU Speed (MIPS)	12
RAM Bytes	2,048
Data EEP ROM (bytes)	256
Digital Communication Peripherals	1 – A/E/USART, 1 – MSSP (SP I/I2C)
Capture/Compare/PWM Peripherals	1 CCP, 1 ECCP
Timers	1x8 – bit, 3x16 – bit
ADC	13 ch, 10 – bit
Operating Voltage Range (V)	2 to 5.5

Software

MPLAB IDE

The MPLAB IDE is a free programming environment for microcontrollers. The environment comes with all the tools needed to handle component scheduling, including an editor and a debugger. Assembly language programming is possible, or C programming can be developed with the addition of a cross-compiler. Compilers of several kinds are available, including Hitech PICC, CCS, C18, and others. The CCS compiler is utilized in this piece. CCS is a C compiler designed for the Microchip PIC18 microcontroller.

Module ICD 3

The MPLAB ICD 3 module is a real-time debugger and programmer for PIC microcontrollers using Microchip technology, programs are loaded into the PIC, and then executed in real time and examined in detail using the debugging feature of MPLAB. This feature allows the user to observe the evaluation of variables and registers in the program or scripts in C and the assembler to place breakpoints. MPLAB ICD 3 can also be used as a development tool for PIC microcontrollers.

Rotate the stepper motor clockwise and anticlockwise.

Before programming the microcontroller, it is very important to define an instruction path for the program to follow. This in turn means creating an algorithm which will be a set of instructions either defined as a procedure or a function, whereby they are used to perform a certain task to be executed in a process. Figure 6 demonstrates an algorithm used to run forward and backward directions.

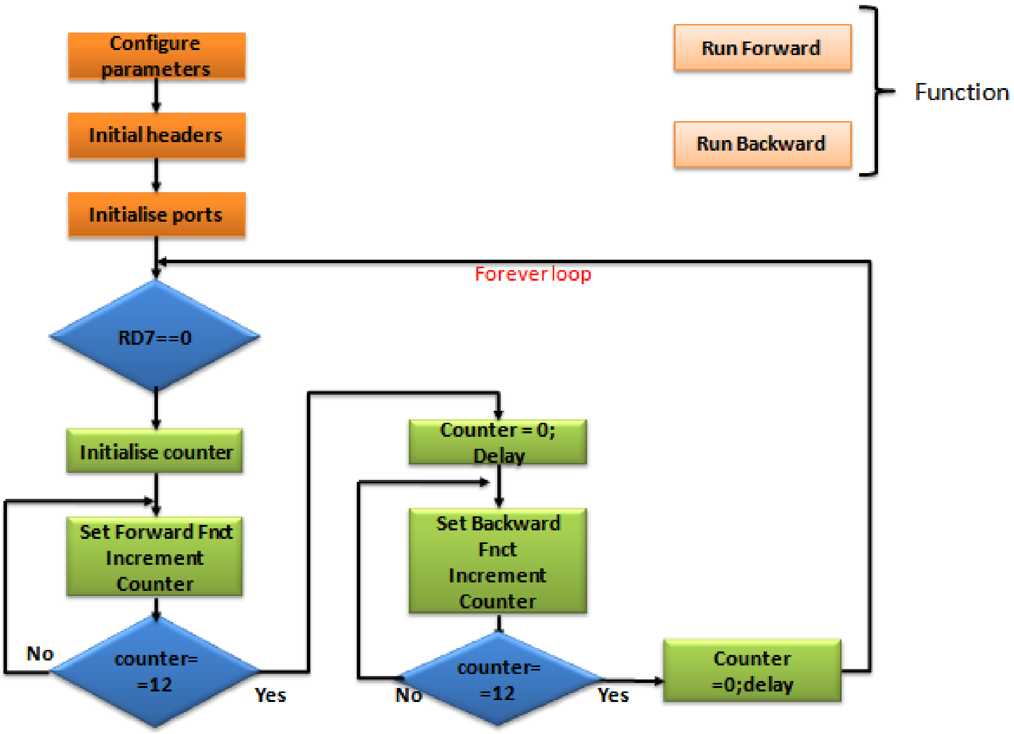

Figure 6: Algorithm of clockwise and anticlockwise stepper motor run.

Two functions have been created to rotate the stepper motor forward, step Motor forward and step Motor backwards where it repeats the step at each time when it calls by the main function.
The main function starts by initializing and configuring Port D and Port C. Then, a forever loop is defined inside the main function which allows the program to turn forever. A condition is used to test the bit D7 of Port D and if this bit is equal to zero, then it will start to rotate the motor in a clockwise direction via a loop which consists of a specific number of turns which should be carried out by the stepper motor.

Advantages and disadvantages of the stepper motors

Stepper motors are widely used in various applications due to their unique characteristics. Here are some advantages and disadvantages of stepper motors as tabulated in Table 3.

Table 3: Advantages and disadvantages of the stepper motors [7].

Advantages	Disadvantages
• It is feasible to get extremely accurate motion control with an open loop system. • Operating in an open loop saves a significant number of sensors. • Because the instruction and motion are incremental, stepper motors can be easily adapted to digital control applications. • It is possible to optimize power needs and torque capacity, and to employ electronic switching to regulate the system's reaction. • There are no significant stability issues even when using open-loop control.	• They have lower torque capacities than servomotors, which makes them less powerful. • Their low torque also limits the pace at which they can operate. • These motors vibrate strongly when in stepwise action. • Significant mistakes and oscillations may arise from an open loop control system that misses a pulse.

Results and Discussion

Based on Figure 4 that counted as the proposed presented work, the strategy is obtained considering LabVIEW system. The hardware implementation operation of the suggested work will be discussed in the next sub-section.

Hardware components and description

In terms of hardware implementation, the proposed system

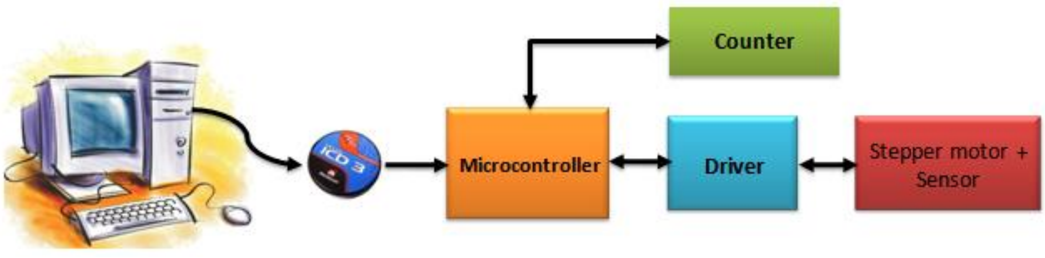

Figure 7 : Hardware implementation

In Figure 8, the front panel is shown. In the figures below the low-level implementation of the VI is shown.

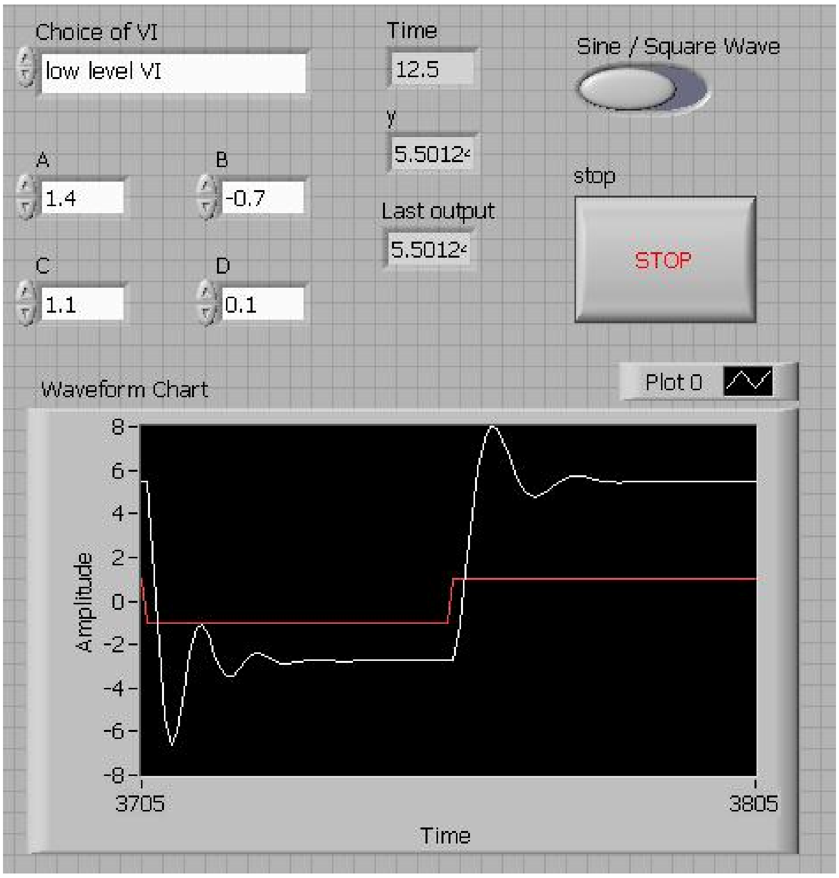

Figure 8: Front panel of LabView

The MATLAB implementation is presented in Figure 10, while the Math script node implementation is illustrated in Figure 9. As is evident, there aren't many differences in this instance. It should be noted that the MATLAB script requires MATLAB to be running in the background, and that the Math script node only occasionally connects to MATLAB. Additionally, the Math script only employs syntax that is comparable to the MATLAB language.

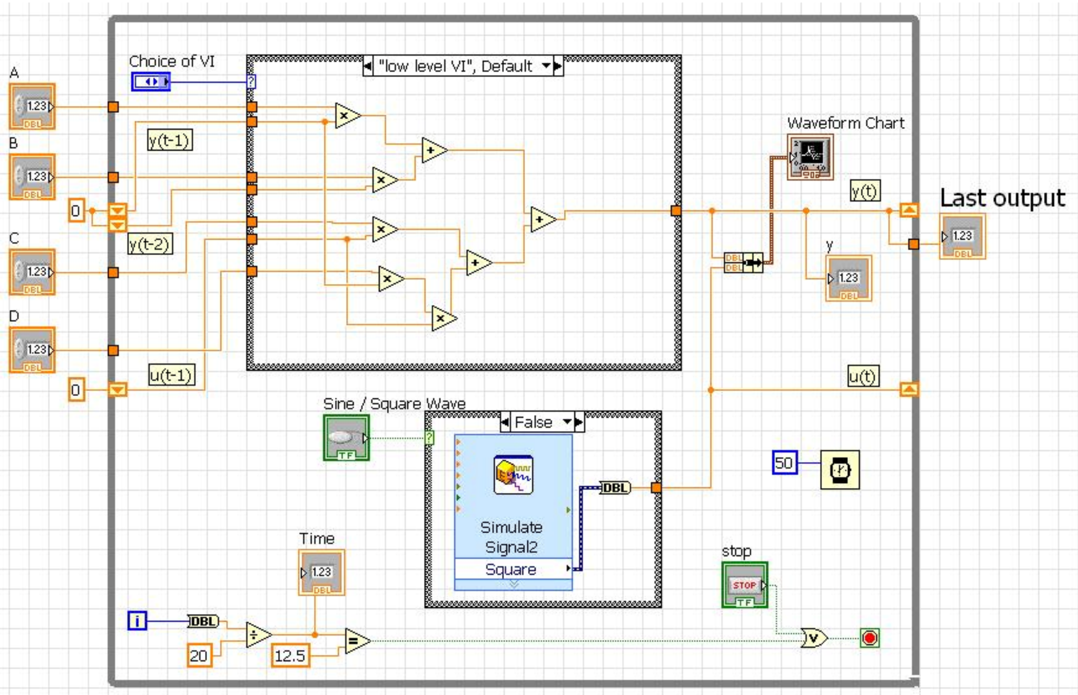

Figure 9 Math script node implementation.

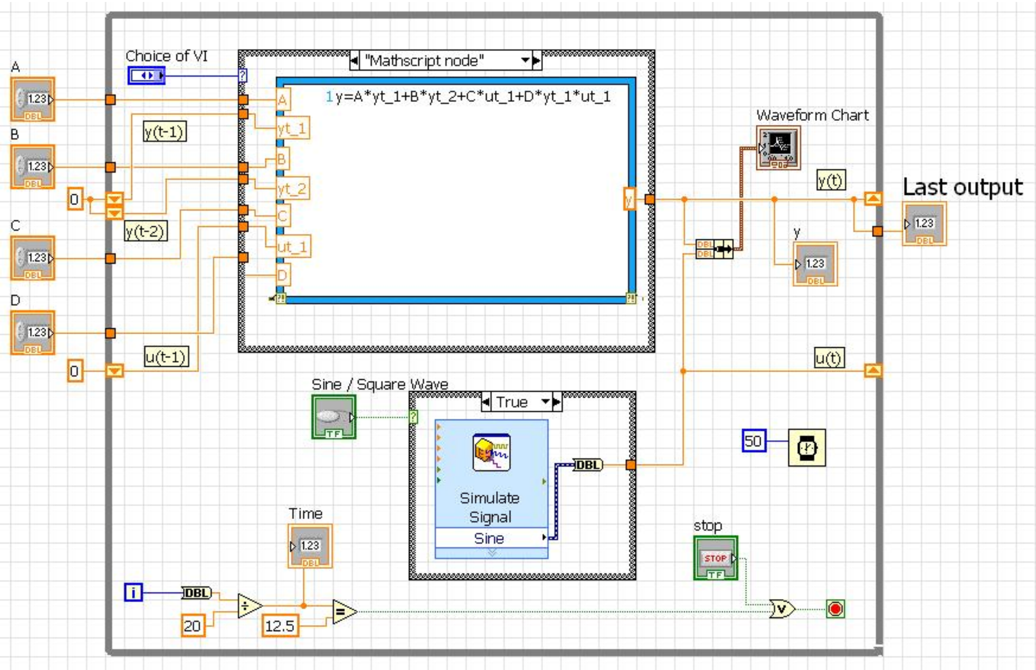

Figure 10: MATLAB implementation.

Figure 11 below depicts the front panel of VI. The appended array shows the last six values of the time obtained and the system output. The program has undergone small modifications. Specifically, as shown in Figure 12 and followed by the MATLAB implementation in Figure 13, the system output along with the appropriate time will be continually saved in an appended array. The user can pause the while loop at any time by pressing the STOP button, even though it is programmed to end after 30 seconds.

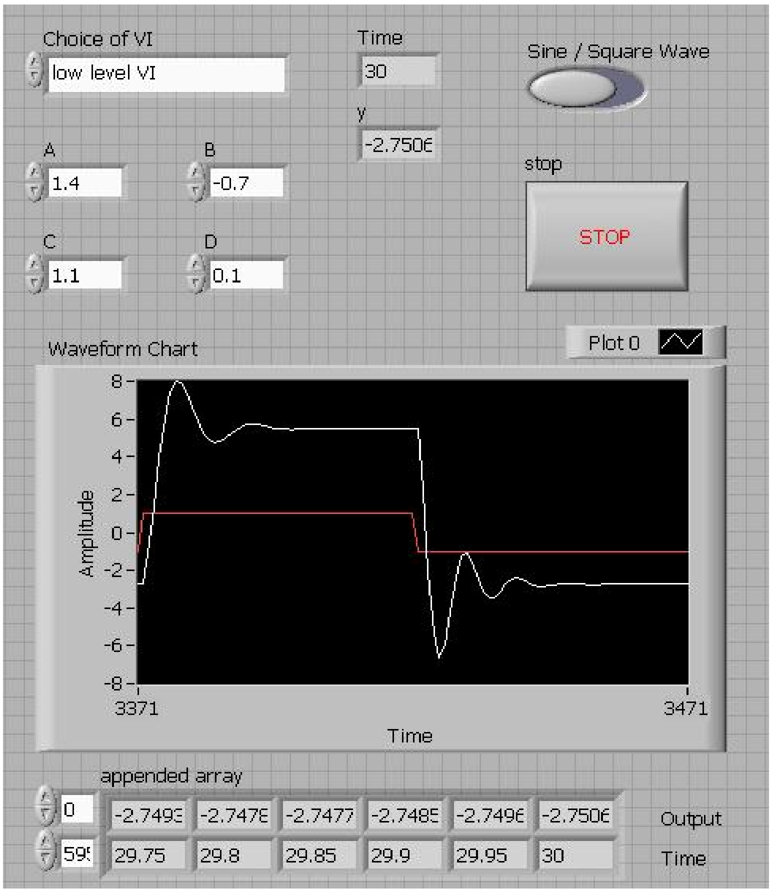

Figure 11: Front panel of LabView.

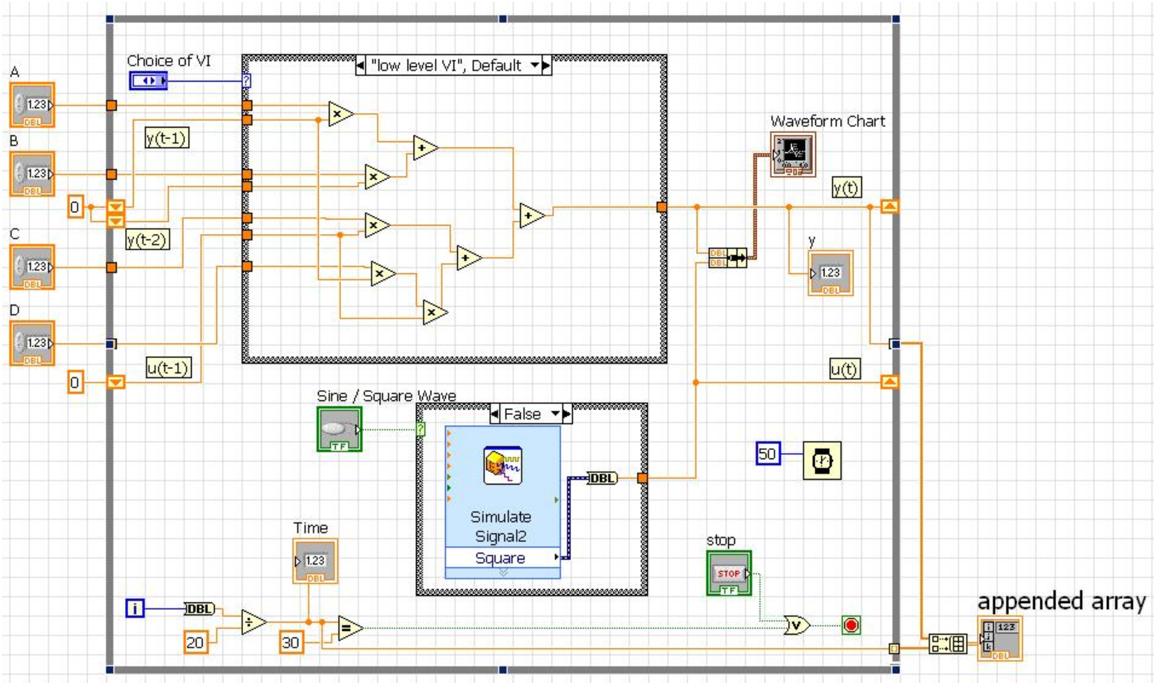

Figure 12: LabVIEW simulation.

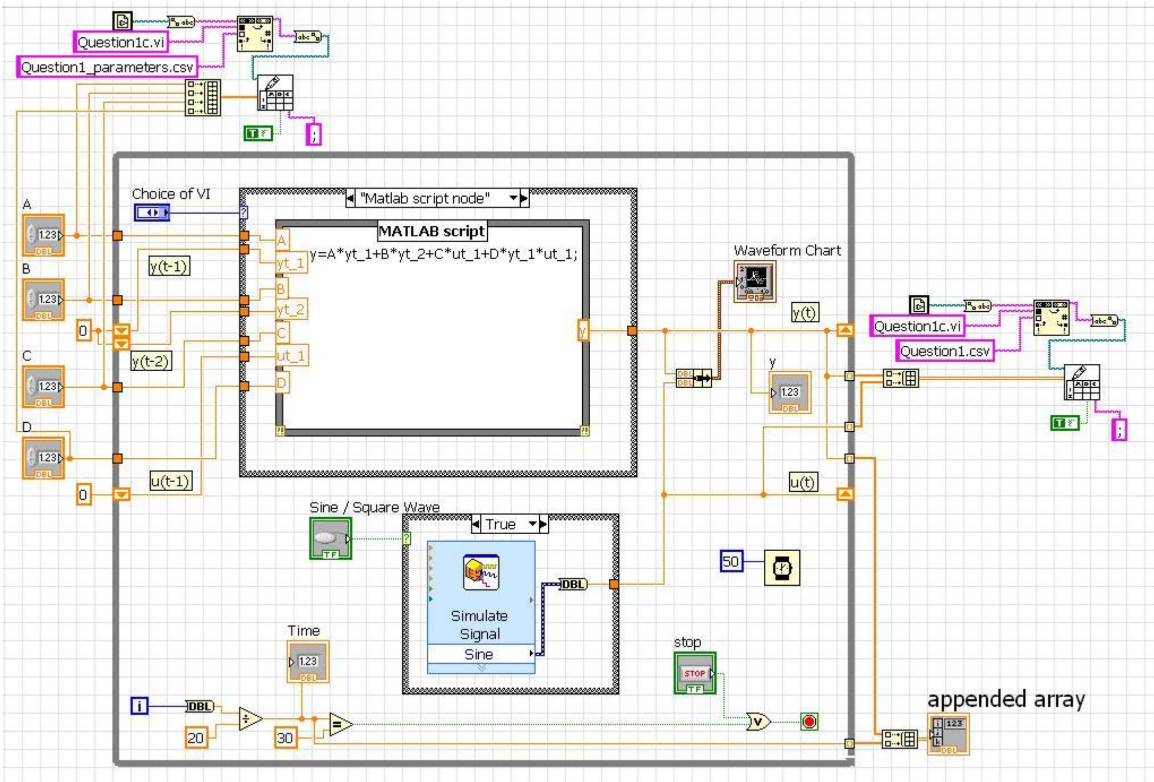

Figure 13: MATLAB implementation.

Conclusion

To sum up, this article reviews the principle of operation, applications, advantages, and disadvantages of stepper motors. The author uses the PIC 18F4520 to implement an algorithm to drive the stepper motor and count the number of steps and turns realized by the motor. The author suggests using a controller such as a PID to track a desired trajectory, for example, the breathing system simulated by the phantom by using a stepper motor to move in three linear directions when the program can be used to control that motion. The author also highlights the importance of planning and improving programming skills. For future direction studies, utilizing a controller, such as a PID, to monitor a desired trajectory for breathing system may be controlled by the program to move a stepper motor in three linear directions.

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