Speed control of stepper motors for use in laboratory animal devices

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Abstract: Stepper motors are the most commonly used motors for all devices that require precise displacement or movement. Among these devices, motorized wheels and treadmills are designed for small laboratory animals and their speed requires adjustment in revolution per minute (RPM) mode. In this study, an Arduino code is introduced to control a stepper motor speed in RPM mode. This software has the ability to set the speed of the motor between 1 and 30 RPM. Additionally, an Android application has been developed for controlling the rotational time of stepper motors. In current study, all codes and Arduino-based circuits were evaluated using a homemade motorized wheel for rat and mice.

Keywords: stepper motor, Arduino, A4988 driver, Speed control.

I. INTRODUCTION

For many biological and medical studies, it is necessary to assess the movements of laboratory animals. As an example, some studies require the animal to run involuntarily on a treadmill or motorized wheel [1-4]. In Alzheimer treatment strategies, exercise plays an important role [5], and forcing a laboratory animal to run involuntarily is imperative. It is also common to assess exercise effects in motor recovery experiments, diseases associated with ischemia, and cognitive disease [6-8]. In these fields, treadmills or motorized wheels could be used to compel animals to exercise. Some small laboratories may not have access to commercial treadmills or motorized wheels. This suggests that an open-source motorized wheel would be beneficial to them. In the development of an open-source treadmill or motorized wheel, the software program and electrical circuit involved in motor speed control are vital. This program and hardware should control motor speed in RPM mode.

The user should also be able to adjust the time the motor runs from several seconds to minutes. Laboratory animal treadmills and wheels use a variety of motor types, including servo, brushless, and stepper motors [9-10]. There appears to be a high price tag associated with servos and brushless motors for do-it-yourself (DIY) projects. On the other hand, stepper motors are much more economical and are capable of producing the appropriate torque for these types of tools. When using such motors, the first and most important thing is to control the precise speed of their rotation in the mode of RPM. Arduino-based sketches exist for controlling stepper motor speed within websites [11-12], however, none of them is capable of controlling the precise speed with a resolution of 1 RPM. Currently, there is only one library with the name stepper.h that can control stepper motor speed in RPM mode [13], but this library does not meet the needs of A4988 drivers. In the field of stepper motors, the A4988 driver is the most commonly used driver. Therefore, it is necessary to develop a code that controls stepper motors' speed with a resolution of 1 RPM using A4988 drivers. This study aims to introduce Arduino-based software and electrical circuits that can control stepper motor speeds with a resolution of 1 RPM for use with an A4988 driver. Moreover, we have designed an open-source Android software application that controls motor running time with a resolution of one second.

II. METHODOLOGY

In the current study, all data and files, including codes, videos and etc. are available in the OSF repository: (https://osf.io/s9gkt/?view_only=4504da2f10254c3cb277378edf58dee7).

A. Arduino based circuit for control of rotational time and speed:

For the control of the stepper motor, there are two electrical circuits. An Arduino, a relay module, a Bluetooth module, and a 7-segment module comprise the first circuit. This circuit receives commands from Android software and displays the time on a 7-segment display. The relay module disconnects the motor power once the time is up, so the wheel stops rotating. figure 1 shows a schematic diagram of the circuit.
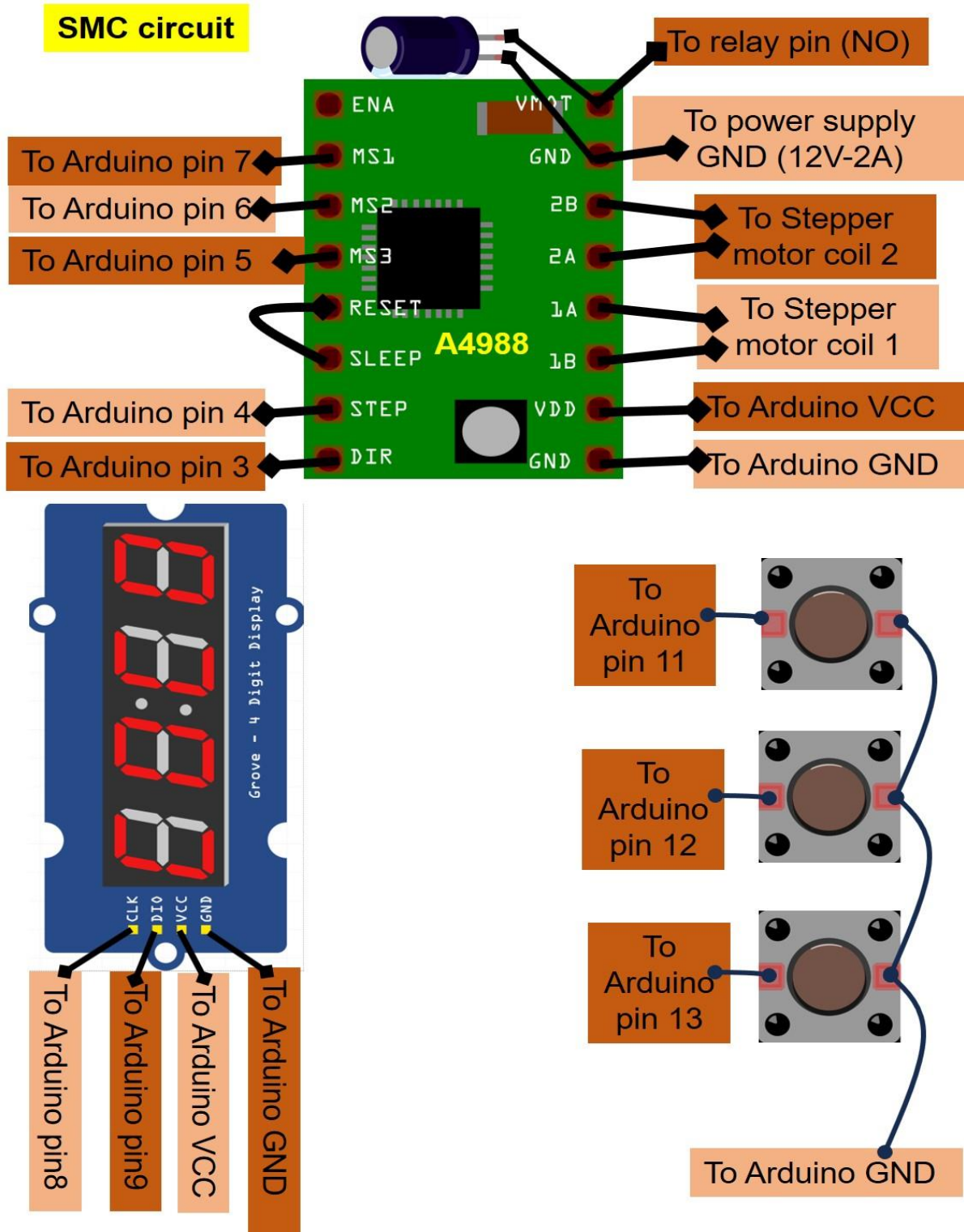

Figure1. Arduino based circuit for control speed

A second electrical circuit controls the speed of the stepper motor. It is composed of an Arduino, tactile switches, a 7-segment module, and an A4988 stepper motor driver. Pressing two tactile buttons determines the stepper motor's RPM. One increases the RPM while the other decreases it. Upon selecting the RPM, a third tactile switch operates the motor. The circuit diagram can be seen in figure 2.
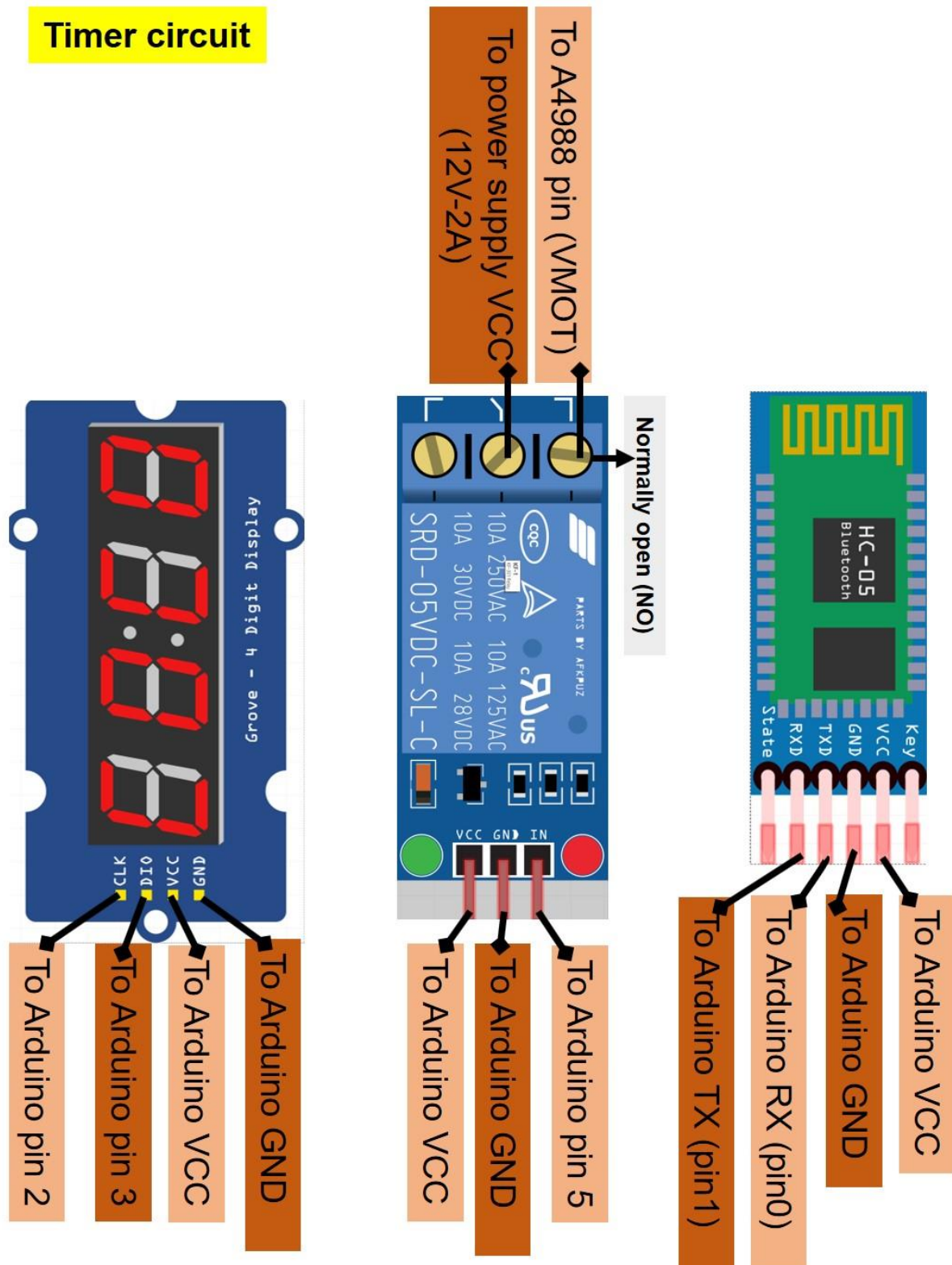

Figure 2. Arduino based circuit for control of rotational time

B. Arduino sketches and codes & Customized Android software:

On the A4988 stepper driver, there is a pin designated "STEP". Motor speed can be altered by changing the frequency of pulses received by this pin. By changing the STEP state from HIGH to LOW and LOW to HIGH, different RPMs are produced. It is possible to alter the frequency of the pulse by changing the delay between two states.

For example, a delay of 508 microseconds is appropriate for 18 RPM, while a delay of 3100 microseconds is appropriate for 3 RPM. the Arduino sketch related to motor speed control could be found in supplementary data (SMC folder).

As a method of controlling motor rotational time, the Arduino receives the time from Android and counts it until the end. After that, the relay disconnects the motor's power supply. The Arduino sketch can be found in the supplementary data folder (timer_control).

Basic for Android (B4A) was used to design the software. The software first communicates with the HC05 Bluetooth module and sends the numbers through serial communication. APK software and B4A codes can be found in the supplementary data.

C. Evaluation of the motor speed and rotational time control software and hardware:

To test all the software and hardware, we first examined the performance of motor speed and rotational time control with a conventional NEMA17 stepper motor (model: KH42JM2). As part of the other experiments, a motorized wheel for laboratory mice and one motorized wheel for laboratory rats were designed and implemented.

This was to test software and hardware in real situations. Details of all instructions needed to implement the motorized wheels for mice and rats can be found in the supplementary material data.

III. RESULTS

On the basis of the results of the first experiment, Android code is capable of adjusting the time of motor rotation and Arduino code is capable of controlling the speed of the motor (at one RPM resolution) (see figure 3 and video 1 in supplementary data).

The second experiment related to motorized wheels for mice or rats showed that the Android and Arduino codes could properly execute user commands and the stepper motor speed could be selected based on user expectations (videos 2 and 3 in supplementary data).
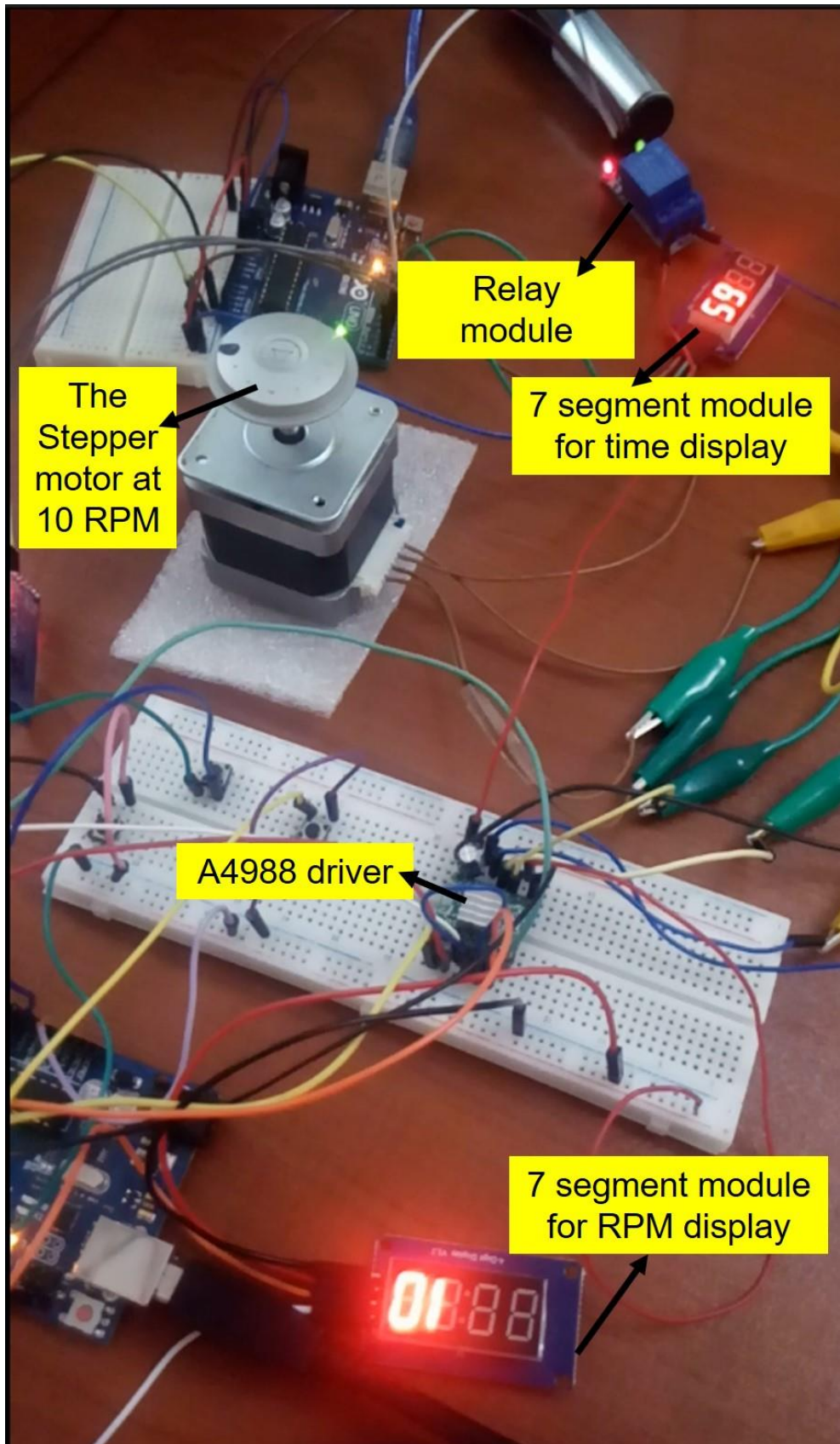
Figure 3. RPM control results

IV. DISCUSSION

Within the web, there are several Arduino codes relating to the control of stepper motor speed [11-12]. In some of them, the motor speed is set by the potentiometer value while others allow the motor to operate in five or six conventional modes (1/32, 1/16, 1/8, 1/4, 1/2, and full steps). Currently, there does not appear to be any specific code that controls the speed of the stepper motor in RPM mode. According to different Arduino libraries for controlling stepper motors, only stepper.h can control speed in RPM mode. This library includes a function called setSpeed that can be used for controlling RPMs. This library is designed for stepper motors. However, the user must run the motor with a Darlington array or SN754410NE H-Bridge to use it [14]. Nevertheless, most DIY projects utilize the A4988 driver because the A4988 can drive all stepper motors with a current consumption of less than 2 amperes.

The A4988 driver is also easy to use, as it is very simple to interface with a microcontroller. The A4988 is also relatively inexpensive, making it a popular choice for DIY projects. For these reasons, the present study attempts to introduce an Arduino code for the production of speed for a stepper motor that has a resolution of 1 RPM. By using our code, the RPM could be adjusted from 1 to 30 and could be easily upgraded to higher RPMs if necessary. On the other hand, we also designed an Android application that controls motor rotation time.

The application can be installed on Android devices running version 4 and higher. As an example, all of these software programs could be used for motor-based devices such as treadmills and motorized wheels designed for rats or mice. It is our opinion that the codes that we have introduced, along with other existing libraries and codes, can improve the control of the speed of stepper motors.

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