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# Growth Factor Inhibiting PKC Sensor in E-coli Environment Using Classification Technique and ANN Method

T. K. Basak, T.Ramanujam, S. Jeybalan, Madhubala Bhatt, Deepali Garg, Richa Garg .....


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## Prototype for Managing the Wheelchair Movements by Accelerometry

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**Abstract:** This article describes the development stages and the obtained results in a design and testing of a wheelchair controlled by bi-axial accelerometers placed at the user head top. This proposed system has the primary goal to facilitate the handicapped persons locomotion who has only the head movement or difficulty moving the hand-arm segment, thus presenting a different control type of most motorized wheelchairs in market. The results showed that low cost acceleration sensors are efficient to assistive technology systems. *Copyright © 2011 IFSA.*

**Keywords:** Accelerometer, Wheelchairs, Assistive technology.

---

### 1. Introduction

Assistive technology is aimed at increasing or restoring human function, providing an independent and productive life for people with a disability. Studies in this area are justified by the fact that approximately 10 % of world population has some type of disability, according to World Health Organization (World Health Organization, 2006). Because of physical disability, a significant portion of society has some personal limitations, therefore also for the professional and social life. The reintegration and promotion of these people are essential to their well being, as well as for the financial and social benefit to the society.

According to Russell *et al.* (1997), the wheelchair usage increased 83 % from 1980 to 1994, totaling 2.2 million (U.S. Census Bureau, 2002). According to Allen *et al.* (2001), the wheelchair represents approximately 10 % of mobility equipment used by adults. Moreover, it is likely to have more people

with mobility disorders due to increase population life expectancy and advances in medicine, favoring the survival after traumas (National Institute on Disability and Rehabilitation Research, 2002; JONEL *et al.*, 1996). So, it is likely to increase the wheelchairs usage for the world's population, as assistive technology device (ALLEN *et al.*, 2006). Watson *et al.* (2005) evaluate the social and technical process of the wheelchair development in society. The wheelchairs development and usage allowed great mobility, independence, and social inclusion for disabled people (WATSON *et al.*, 2005).

Many people have difficulty or impossibility to use a common wheelchair. In these situations, the electric-powered wheelchair is essential to permit functional mobility. According to Jones *et al.* (1996), 200,000 people with severe disabilities in the arms or legs use electric-powered wheelchairs in America. Cooper (1998) reporting about the selection and configuration of the wheelchair, says that electric-powered wheelchair usage is essential for individuals with progressive disease and severe degrees of disability. Dan Ding *et al.* (2005) present a review of the current techniques and future directions for the electric-powered wheelchairs development. According to the authors, the area control concepts and instrumentation has been used in a very few projects about wheelchair. They cite, for example, the possibility of speed control as improving movement precision, the traction control that facilitates the wheelchair usage in adverse environments, and suspension control, improving comfort and safety for users, among others. Many humanitarian agencies report that poor countries have difficulty in providing and to make available assistive technology devices, such as wheelchairs for their population. In very poor countries, it is estimated that only 2 % of people who need a wheelchair have it (Pan American Health Organization, 1994; World Health Organization, 1981).

Considering the previous postings, this work aims to present an automated chair development controlled by signals from a bi-axial capacitive MEMS accelerometer, used as an inclinometer provided at the top of the user head. By measuring the head's bi-dimensional tilt, one of four basic moves previewed for wheelchair will be carried out: rotating clockwise, rotating in a counterclockwise direction, walking forward, and walking back. Systems with this characteristic are justified, once they explore the sensors' usage as assistive devices for wheelchairs automation, allowing users with no or limited control of hand-arm segment to get around independently. This project fits the Assistive Technology definition, because it increases the autonomy of individuals with disabilities or reduced mobility and it serves as a basis for experimental studies of other ways to control a wheelchair.

## **2. Experimental Section**

### **2.1. Block Diagram of the Proposed System**

The block diagram of the proposed experimental system can be seen in Fig. 1. The accelerometer's control circuit picks up the signals from the user head bi-dimensional tilt, featuring the desired movement direction. These signals are provided to a microcontroller that generates the corresponding PWM signal to the driver circuit, controlling the chair speed and direction.

### **2.2. Hardware Platform**

#### **2.2.1. Prototype of the Driver Circuit**

Fig. 2 shows the prototype of the driver circuit.

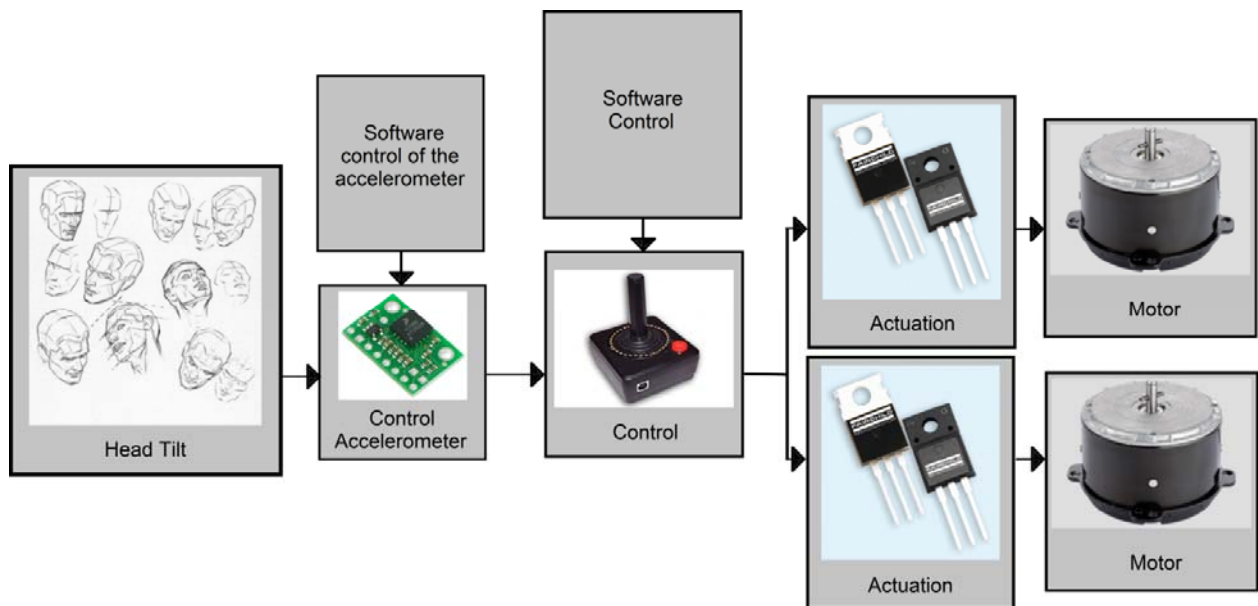


Fig. 1. Block diagram of experimental system.

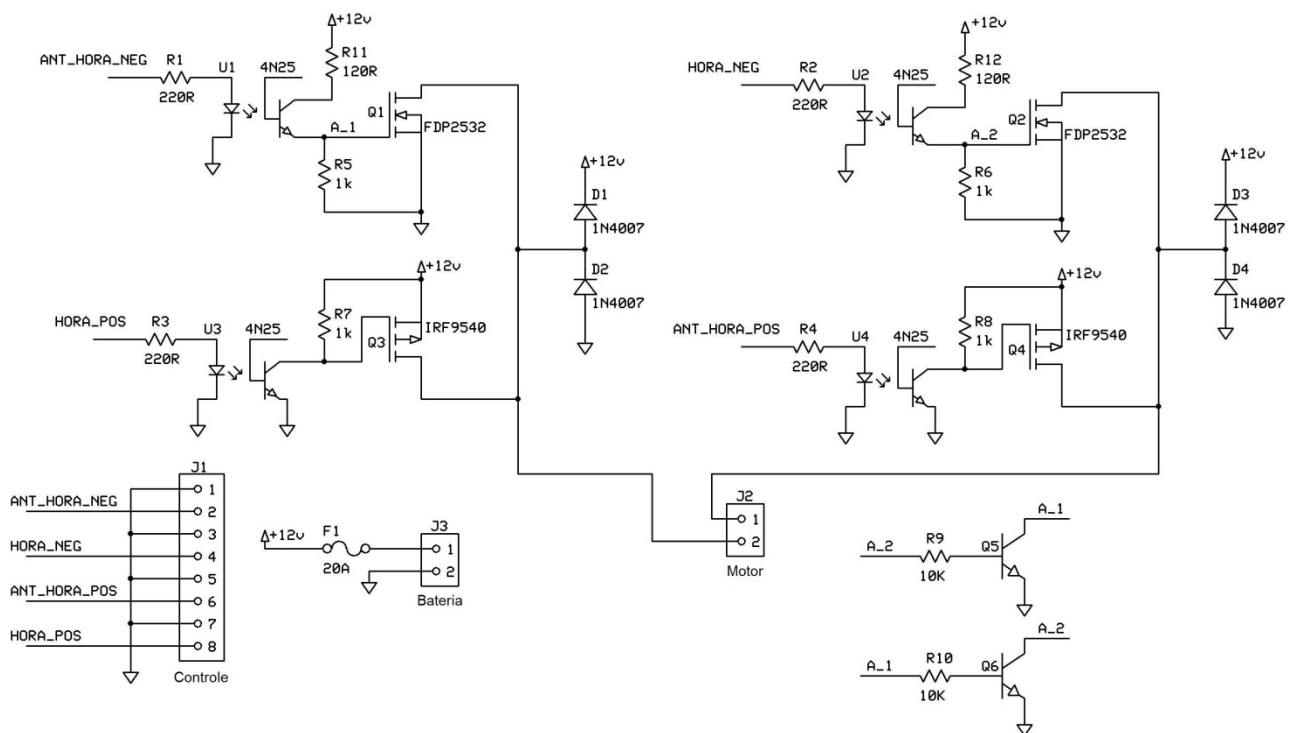


Fig. 2. Designed drive circuit.

The drive circuit receives the PWM signal originated from the microcontroller and uses it to generate *gate* signals in the *MOSFETs*, engaging the engine, so that the speed increases slowly. The applied signal to the engines has equal amplitude to 12 VDC and frequency 5 kHz. This circuit is based on optocouplers to isolate the control signals with TLL level from the signals that are generated within the block, which have voltage level equal to 12 VDC, protecting the control system and the accelerometer. The optocoupler, in addition to insulation, provides adjustment on voltage levels to drive the *MOSFETs*, because they need  $|V_{gs}| = 12\text{ V}$ . A nominal current of 15 A circulates in the motor drive circuit. In addition, it is possible through *MOSFETs* to reverse the engines power supply, thus, to

control the rotation direction. The driving current of the optocouplers is 16 mA with a driving voltage level TTL, i.e., 5 V compatible with the buffers at low cost. The used N-channel *MOSFET* is FDP2532 that has  $R_{on}$  very low, not exceeding 20 m $\Omega$ , so, the dissipated power on it is 4.5 W, considering the current equal to 15 A. The used P-channel *MOSFET* is IRF9540 that has  $R_{on}$  equal to 117 m $\Omega$ , so, the dissipated power on it is 26.5 W, considering the current equal to 15 A.

To prevent that the *software* or some *hardware* failure would cause a short circuit in the power supply due to heating, a circuit was designed that prevents the motor drives to back and forth at the same time. This circuit can be seen in Fig. 2, formed by transistors Q5 and Q6 with their biasing resistors. Whenever one of the N-channel *MOSFET*s is performing, the circuit protection inhibits the *gate* from the other *MOSFET*, forcing to fire only one at a time.

### 2.2.2. Prototype of the Control Circuit

Fig. 3 shows the circuit diagram of the proposed control.

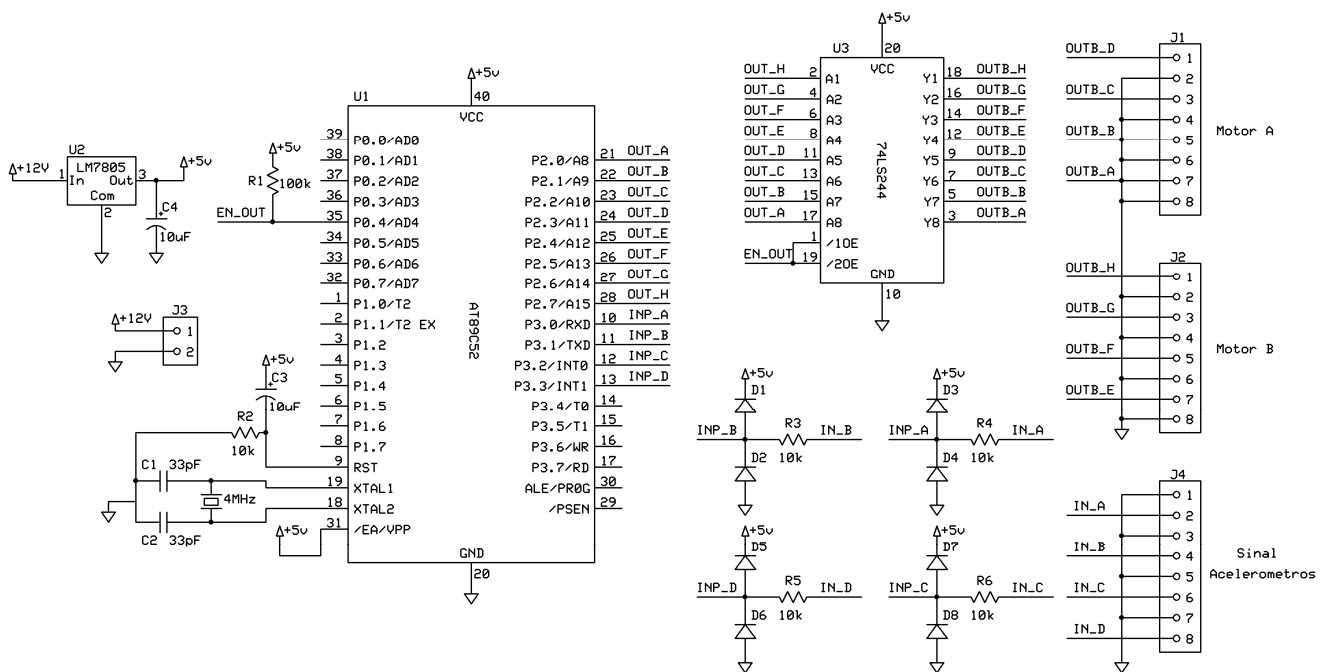
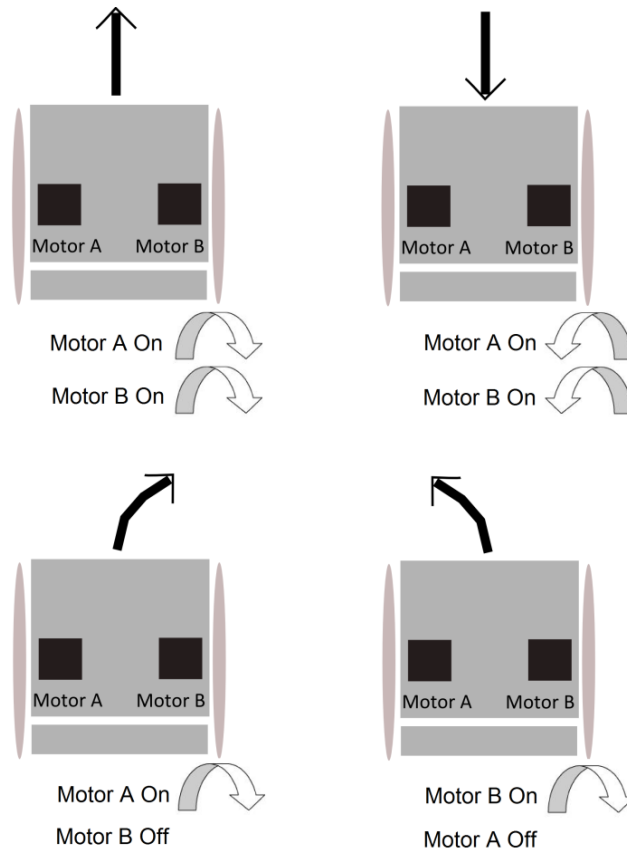


Fig. 3. Control circuit diagram.

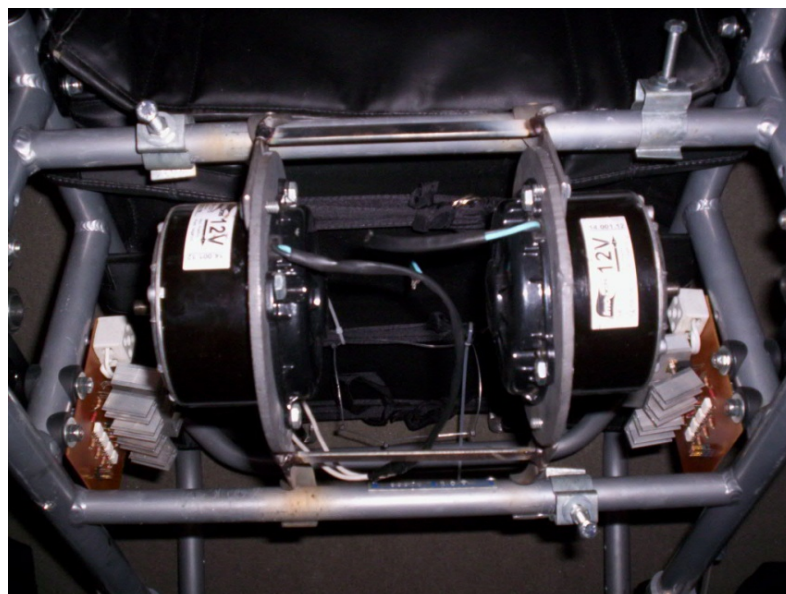
The control circuit is part of the responsible project for generating the PWM to the motors, so, the chair moves according to the signal coming from the accelerometer. The PWM generation is performed by the microcontroller AT89S52. The control circuit has four input signals, one for each wheelchair movement that has 4 outputs to drive each plate, totaling 8 outputs. Each input pin of the control board has diodes to protect against voltages higher than 5 V and lower voltages to 0 V to prevent unacceptable levels of stress from reaching the microcontroller.

After receiving the signal from the accelerometer, indicating to which side the wheelchair should move, the control board initiates the movement, while keeping the PWM with very small duty cycle increasing progressively to provide a slight acceleration without sudden movements. If the desired motion is to move forward, the two motors are triggered with the same duty cycle, spinning both wheels equally. The same action is done to move back, just by reversing the polarity of the applied

voltage to the engines. The motion left or right is performed by activating solely the opposite wheel's motor to the desired side, so the chair rotates around its axis. Fig. 4 shows the wheelchair logical drive (at this time, only the first four motions were designed), due to the two engines' behavior. The chair used is a common wheelchair, not automated, which took the wheel axes modified, providing support to fit the engine (Fig. 5).



**Fig. 4.** Diagram of the wheelchair movements.



**Fig. 5.** The motors fixation in the chair wheels.

### 2.2.3. Prototype of the Accelerometer Circuit

The used accelerometer is a bi-axial capacitive accelerometer MMA7340L, which has 1.65 V voltage for zero acceleration on its output. The typical sensitivity is 440 mV for the measurement scale that was set up to 3g in such accelerometer. Again using an AT89C52 microcontroller and an ADC0838 analog-digital converter (selected according to its very low cost, especially because 8 bits are sufficient for this application) an output voltage of 0V to 3V range appears on the two accelerometer axes, enabling the decision of what should be the chair movement. In comparing the results, a hysteresis will be placed, in order that negligible movements (outside the interest range) have no influence on the desired movement characterization. Ten measures are carried out for every decision and the corresponding average is used to determine the next wheelchair motion. Fig. 6 shows the control circuit diagram of the proposed accelerometer.

Because the ADC0838 operates with maximum *clock* frequency of 400 kHz, it was necessary to create a delay function to divide the micro-controller's working frequency by three. An important feature is the maximum error of the slope measurement. Using 3.3V voltage as reference in the ADC0838 (8 bits), the maximum error is 13 mV, so the maximum error for the slope is 1.7°. The movement characterization is individual for every user and it is calibrated when the system initializes, so the chair movement is performed according the movements possibility of the user head. The values obtained in the calibration are used as decision limits about which motion should be performed.

LCD of 2-lines and 16 characters presents the messages to the user, indicating which movements are necessary to calibrate the system. If the calibration performed is not valid, the software will loop until an acceptable calibration is performed. Any measured value is considered invalid, if the calibration does not have absolute value greater than 3.4° in relation to the rest position, being required a new calibration.

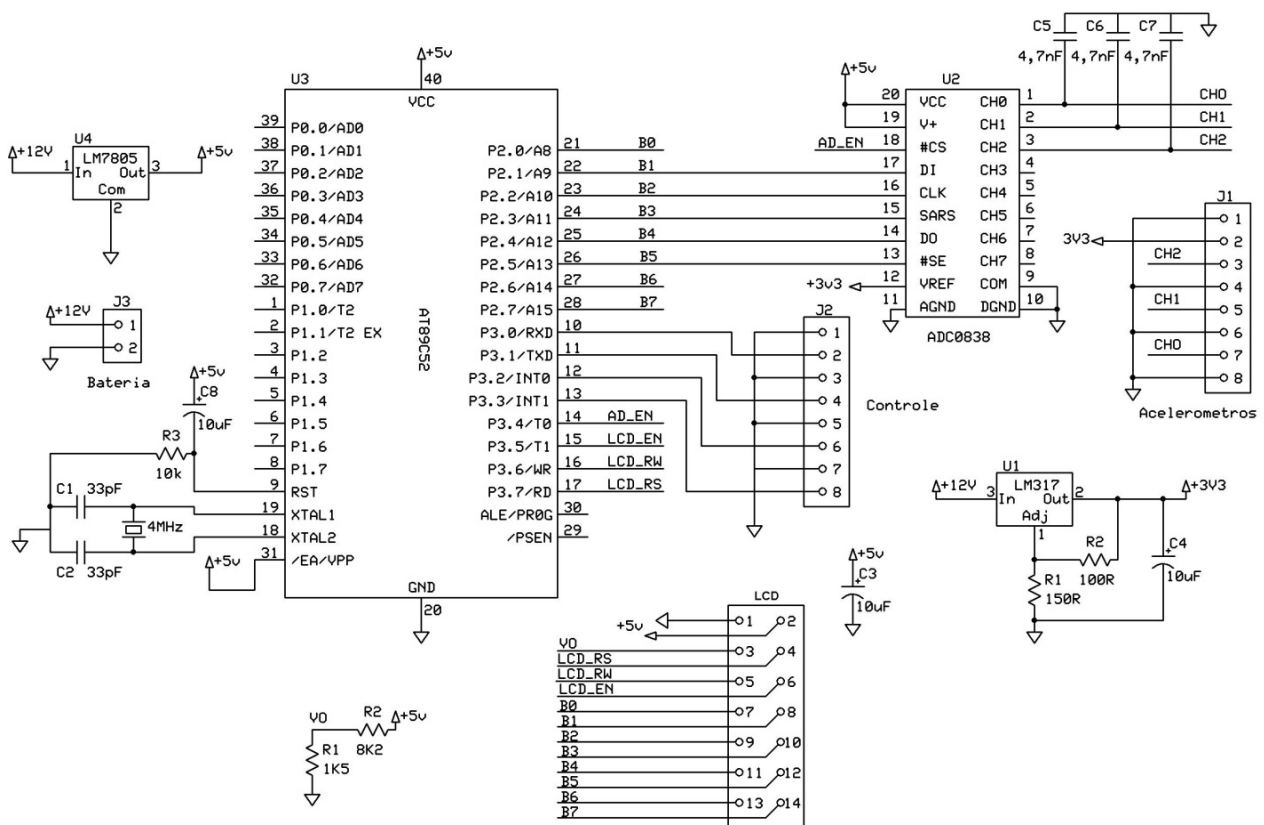


Fig. 6. Control circuit schema of the accelerometer.

## 2.3. Software Platform

### 2.3.1. Software of the Control Circuit

The software generates the PWM signal as the signal coming from the accelerometer. P3 port is configured as the gateway, using only the less significant 4 *bits* to indicate the possible chair movements. A logical "1" in the first 4-bit from the P3 port indicates the desired motion, making the *software* to start the PWM signal generation for moving the *MOSFETs* and to link the engines. The *software* scans from P3.0 to P3.3, respectively, seeking which pin reached logical "1", just starting another scanning cycle after this one coming back to "0". The PWM signal has a fixed period, varying only the active time. This is accomplished, using one of the available timers on AT89S52, summing  $t_{on} + t_{off} = T$ , being  $t_{on}$  the active time of the signal,  $t_{off}$ , idle time, and  $T$ , the PWM signal period, which was chosen as 1/5kHz. Using the engine as low-pass filter, the component of high-frequency signal is filtered, leaving only the zero order component of the signal, i.e., the average signal voltage applied to the motor. We used P2 as output port, driving the *MOSFETs* through the buffer. Each engine requires 4 *MOSFETs*, so four trigger signals, being two signals for each desired rotation direction for which to crank the engine.

As mentioned, the protection circuit against incorrect motor drive operates without SW intervention, even if an error occurs, while initializing the AT89S52 microcontroller or if 74LS244 buffer should fail, then, the protection circuit turns off both. In addition, a fuse was placed to prevent currents above 20 A in the circuit.

After the engines firing, a delay of 100ms was inserted to ensure that the drive *MOSFETs* were totally disconnected, before performing a new movement. This was done, because the capacitance of the *MOSFETs gate* with the bias resistor form a RC circuit, which decreases the *gate* circuit frequency response, beyond the motor reaction's time be relatively large.

### 2.3.2. Software of the Accelerometer Circuit

The *software* of the accelerometer circuit aims to digitize the accelerometer analog output to determine the chair movement, through a decision process. Each decision is based on the average of 10 consecutive measurements of the "X-axis" and "Y" to avoid spurious movements, therefore, characterizing a simple filter. The *software* compares the two measures of X-axis and Y and evaluates which one is farthest from the calibration mean value, thus it makes the decision of the movement. If the measures do not exceed the calibration limits, the system does not perform any movement. The ADC0838 is an analog-digital converter of serial communication that has eight channels with eight-bit resolution and conversion time equal to eight *clock* cycles with maximum *clock* frequency equal to 400 kHz.

The calibration is performed, when the system initializes. A tilt movement of the head forward, to the right, back, and left should be done when the system initializes, according to the LCD messages, so the obtained values are used as boundary for initiating the movement. The system has a calibration validation. Not all values are accepted, for example, no head movement to any side during the calibration. Fig. 7 shows how validation of determined measures is performed in the calibration procedure.

If the calibration is validated by the system, the program prompts the user through the LCD and enters in the main *loop*, reading the accelerometer tilt continuously; seeking what should be the next move. In the main *loop*, every decision made by the circuit of the accelerometer control board is displayed on the LCD.

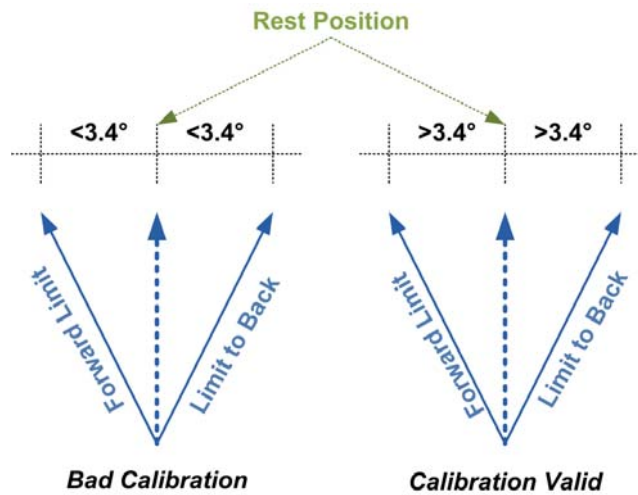


Fig. 7. Calibration validation.

### 3. Results and Discussions

#### 3.1. Verification of the Driving MOSFETs

Fig. 8 presents the signal activation simulation, being the green channel the generator's triangular wave at 4.762 kHz with active period of 145  $\mu$ s and the yellow channel the *MOSFET-P gate* signal. Fig. 9 shows the oscilloscope measure of the *MOSFET-P gate* for comparison.

The same triangular wave of 4.762 kHz with active period of 145  $\mu$ s was simulated and also implemented in the prototype circuit for the *MOSFET-N*. Figs. 10 and 11 show the circuit simulation and the measure with the oscilloscope respectively.

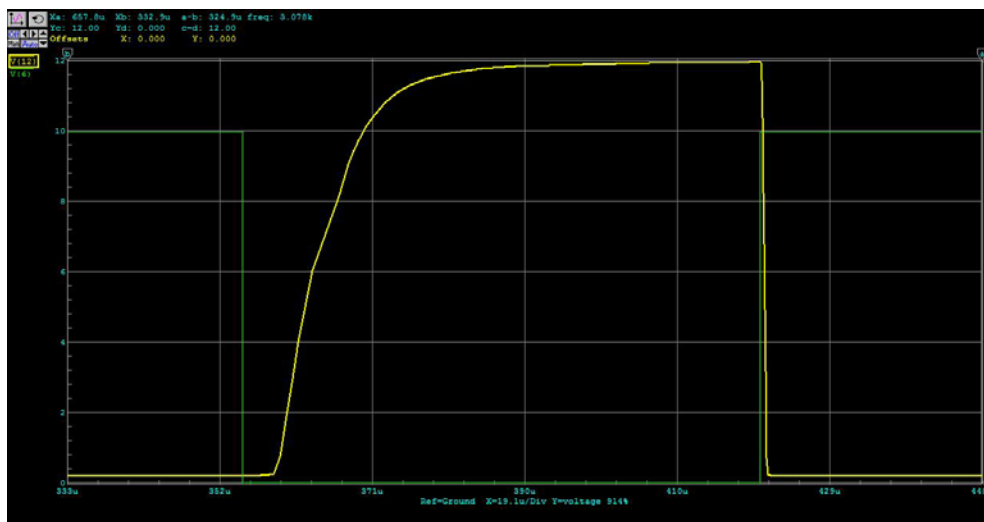


Fig. 8. Simulation of the *MOSFET-P gate*'s waveform.

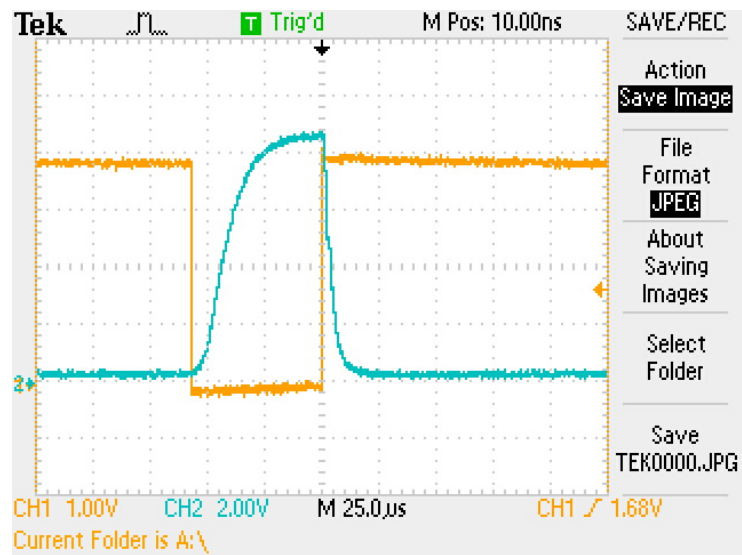


Fig. 9. Measure of the *MOSFET-P gate's* waveform.

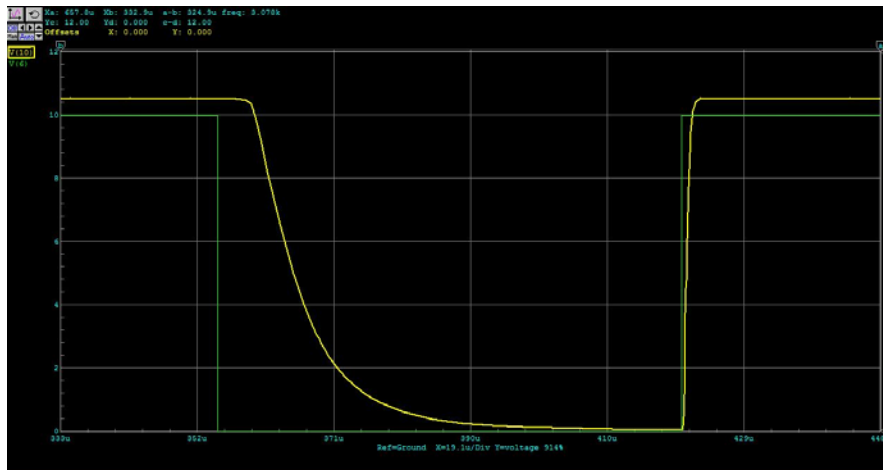


Fig. 10. Simulation of the *MOSFET-P gate's* waveform.

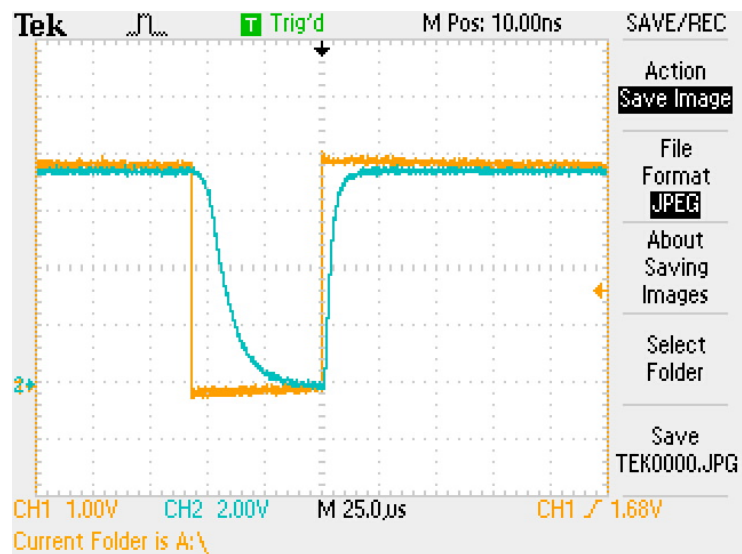


Fig. 11. Measure of the *MOSFET-P gate's* waveform.

The critical period of the driver circuit is during the uprise ramp and d descent of the *MOSFETs gate* signs, P-channel and N-channel, because that is when the *MOSFET* has a resistance between *drain* and *source* greater than the specified resistance in *datasheet*. At that moment, the power dissipation is higher than the calculated one, due to high resistance that *MOSFET* has. So, the *gate* equivalent resistance was designed to be small enough that the RC circuit, which is formed together with the *MOSFET's* intrinsic capacitor, does not leave the signal's uprise ramp and descent very slow. The prototype *MOSFET-P's* uprise ramps and descent are with 15  $\mu$ s and 8  $\mu$ s respectively (Fig. 9). Analyzing the same way the Fig. 11, the *MOSFET-N's* uprise ramps and descent in the prototype are with 8  $\mu$ s and 15  $\mu$ s.

### 3.2. Accelerometer Control Circuit

To check the accelerometer control circuit and also the system's, because the output is measured in relation to entry, a functional test was performed, noting the measured values with the multimeter during the calibration and checking if these values are really used later as limits to characterize the movement. Table 1 shows the observed results that validate the system, because no error exceeded 1.7°, as provided for maximum error.

**Table 1.** The calibrated limits verification.

| Direction | Calibrated value | Value that started the movement | Error |
|-----------|------------------|---------------------------------|-------|
| Front     | 1.850 V          | 1.852 V                         | 0.3°  |
| Right     | 1.293 V          | 1.302 V                         | 1.2°  |
| Back      | 2.220 V          | 2.230 V                         | 1.3°  |
| Left      | 1.705 V          | 1.710 V                         | 0.7°  |

## 4. Conclusions

The designed and produced prototype was able to accomplish what was proposed, i.e., to control a wheelchair movement by measuring the user head inclination. The results showed the control error less than the maximum theoretical error, so the chair motion and calibration is made with a theoretical maximum error of 1.7°, which enables secure, quite accurately, that the calibrated values will be obeyed by the system. For people with limited mobility including the head, the chair allows calibration with small slopes, from 3.4° of inclination in relation to the rest position, ensuring that the slope will not be misunderstood, because at least it sloped the double of the maximum error.

The drive motor through the PWM signal allows the speed control. Circuits based on the *MOSFETs* presented good functioning during the various tests. The optocouplers provided the necessary current for the voltage ramp of the *MOSFETs gate*, and also the *gate* impedance was low enough to ensure a rapid transition between the *MOSFET* "open" and "leading" states, that is the moment of the greatest concern with the heating. It should be noted that several improvements are under development in hardware and in the wheelchair mechanics, as for example:

- Recharging circuit in the drive to ensure the same rotation for both wheels in motion forward or backward, allowing a perfect movement in a straight line;
- Speed control, according to the user head inclination;
- Other sensors usage, allowing the flexibility of a wheelchair usage.

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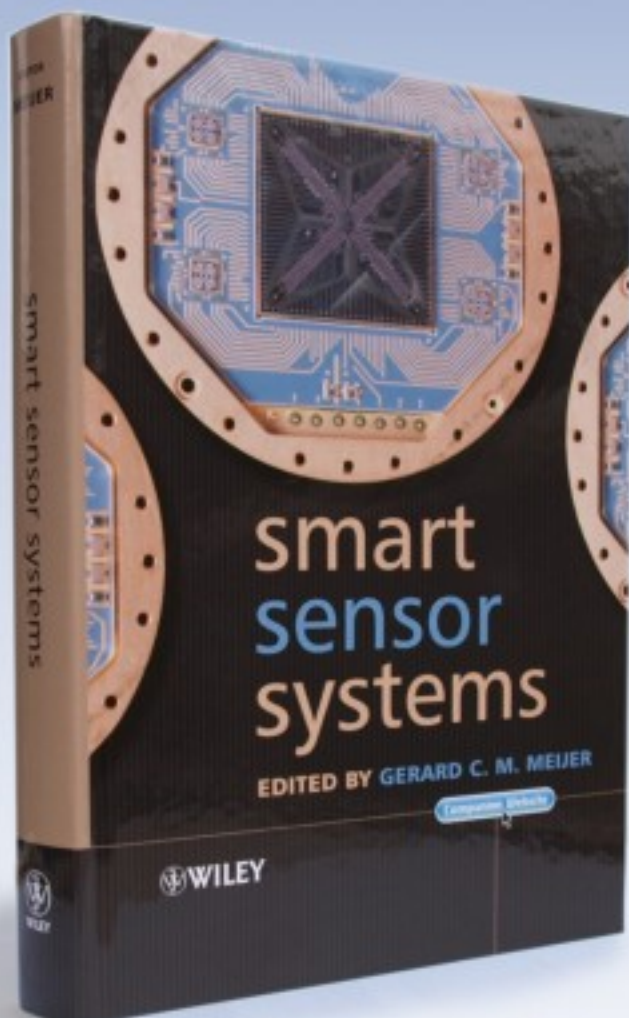
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