

Design Consideration of a Low Cost Battery-Operated Wheelchair

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Abstract-In this paper, design considerations and implementation details of a simple, low-cost battery-operated wheelchair are presented. The control of the vehicle is performed by an 8-bit microcontroller. Two dc motors differentially driven by PWM signals provide a motion with easily controllable speed and direction. The user controls the vehicle using a joystick.

Keywords-Battery-Operated, Wheelchair, Wheelchair Circuits, Microcontroller Control

I. INTRODUCTION

Pulse-width modulation (PWM) of a signal or power source involves the modulation of its duty cycle. PWM uses a square wave whose pulse width is modulated resulting in the variation of the average value of the waveform. PWM can be used to reduce the total amount of power delivered to a load without losses normally incurred when a power source is limited by resistive means. PWM is also often used to control the supply of electrical power to another device such as in speed control of electric motors, volume control of audio amplifiers and many other power electronics applications. PWM is applied in a variety of systems. The most common systems are measurement and communication systems, power control systems, energy conversion applications and power delivering systems. As it is known, a PWM-controlled brake can be done by controlling with an analog input signal. In other words, the more voltage or current that's applied to the brake, the more pressure the brake will exert. The output of a PWM controller could be connected to a switch between the supply and the brake.

As is well-known, wheelchairs are divided into battery-powered and manual types. Recently, there have been revolutionary advances in design of battery-operated wheelchairs. Some wheelchairs use voice control [1], [2], [3] and some of electric powered wheelchairs vary forward and backward speed [4], [5], and some wheelchairs use guiding systems (referencing path description) [6], [7] and some of them use assistive navigation system as control mechanisms [8], [9]. All design solutions are aimed to allow performance of daily life of user's activities and to enable user to function more independently. In manual types, the personal assistance to help wheelchair users is the basic mode of coping with limitations in activities of user. Battery-powered wheelchairs are useful in providing mobility especially for those

who have upper limb impairment as well as lower limb impairment. This paper presents design considerations and implementation details of a battery-powered wheelchair prototype. The design

considerations and implementation details of a simple, low-cost battery-operated wheelchair are presented. The control of the vehicle is performed by an 8-bit microcontroller. Two dc motors differentially driven by PWM signals provide a motion with easily controllable speed and direction. The user controls the vehicle using a joystick.

In this study, a PI controlled separately excited direct current (DC) motor speed has been controlled using PIC 16F877 controller. The PIC16F877 Microcontroller includes 8kb of internal flash Program Memory, together with a large RAM area and an internal EEPROM. An 8-channel 10-bit A/D convertor is also included within the microcontroller, making it ideal for real-time systems and monitoring applications. All port connectors are brought out to standard headers for easy connect and disconnect. In the PIC 16F877 programming as a PI controller, the voltage applied to the motor is adjusted by a semiconductor power switch using PWM technique. The new PIC16F877 Controller is the ideal solution for use as a standard controller in many applications.

II. DESIGN CONSIDERATIONS AND IMPLEMENTATION

A battery-operated wheelchair is mainly composed of a joystick, control unit, motor driver unit, motor, and batteries. The block diagram of a simple battery-operated wheelchair is depicted in Figure 1.

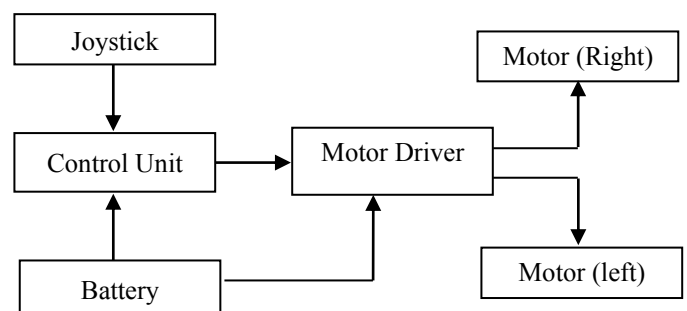


Figure 1 Block diagram of battery-operated wheelchair

A. Control Unit

The advances in semiconductor technology made it possible fast drivers which are able to process faster and relatively smaller than the previous versions using the controllers [10].

There are several alternatives for implementing the control unit of a wheelchair ranging from programmable logic devices to embedded personal computers. Today low-cost microcontrollers are available which have rich sets of on-chip peripherals such as PWM modules, ADC modules and I/O ports with significant current drive capabilities. The presence of these on-chip peripherals reduces the number of integrated circuits and discrete devices in the control unit since many functions are already implemented on the microcontroller chip. The availability of well-established design methodologies and powerful design and test tools reduces the design complexity and engineering effort in a microcontroller-based design. High level programming languages such as C, Basic and Java can be used in development of the microcontroller code. The need for assembly language programming is decreasing as the compilers become more capable of generating efficient code. Today a programmer would typically use assembly language only for some time-critical applications. These considerations make the microcontroller based-implementation a good choice for building the control unit of a wheelchair.

In this application PIC16F877, an 8-bit microcontroller produced by the Microchip Corporation has been used in the implementation of the control unit [11]. In this study, the PIC series 16F877 controller of the microchip is used for the DA motor driver system. With its 20MHz clock, 25mA-rated output pins and its PWM generator, PIC16F877 provided the control facilities required for the system. The control program has been developed using the BASIC language. During the development stage, alterations of the program could be done thanks to the in-circuit serial programming capability of the PIC16F877 microcontroller. The control unit interprets the user inputs and generates the control signals necessary to move the vehicle in the direction and speed desired by the user. The user controls the speed and direction of the travel using a joystick. The position of the joystick lever is converted to a DC signal by the electrical circuit inside the joystick and this signal is fed to the ADC module of the microcontroller. The maximum speed of the wheelchair can be set by the user through a potentiometer. When the vehicle is powered on the position of the joystick lever is checked by the control unit. If the lever is not in the idle position, motion of the vehicle is prevented. This serves to avoid any unintentional movement of the wheelchair at the start-up.

Based on the user input, proper controller signals are generated by the control unit and sent to the motor driver hardware. The speed control of the motors is achieved using Pulse Width Modulation (PWM). A 20 kHz PWM signal is generated by the PWM module on the microcontroller. By changing the duty cycle of the PWM signal the motor speed is adjusted.

A photograph of the control unit circuit board is shown in Figure 2.

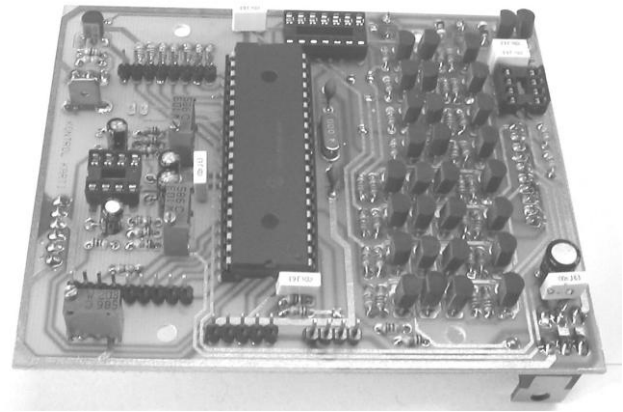


Figure 2 Control unit circuit

B. Batteries

The system is energized by two 12V sealed lead-sulfur batteries each having a charge capacity of 40A. The batteries are connected in series to obtain a 24V supply. Although lead-sulfur batteries have a poor capacity-to-weight ratio, they are preferable to devices based on alternative technologies such as Nickel-Cadmium batteries, due to their much lower cost. The condition of the batteries can be monitored by the user on a panel driven by the control unit. This is especially important to warn the user to utilize the scarce energy efficiently in the case of low batteries. The control unit prevents the start-up of the vehicle when the voltage goes below a certain limit in order to prevent damage to the batteries. During the charging operation all other functions are disabled by the control unit and the vehicle cannot move.

C. Motor Driver

Adjustable, fast motor drivers also played a significant role in the advancement of industrial automation [12]. The 5V square wave produced by PIC is applied to the servo motor. Up to the form of this wave servo motor rotates forward or backward. During the PIC programming process the direction of the impact and for how long it will be sent to the servo motor is the point. PWM produced at PIC and direction control signals are applied to the servo motor through the 4th and 5th pins of the D port. For the 3600 rotation of the motor 5500 pulses, for 10 rotation 15 pulses are required. This way the motor can turn in every angle desired. The speed of the high performance and easily controllable servo motors can be adjusted in wide limits. The outcome, PIC 16F877 controlled servo motor driving circuit, is simple, practical, sensitive, and flexible for various applications [13]. Motor Driver unit provides the interface between the control unit and the motor. An H-Bridge is used to allow the motor rotate in the forward and backward directions. An H-Bridge structure with electromechanical relays is illustrated in Figure 3.

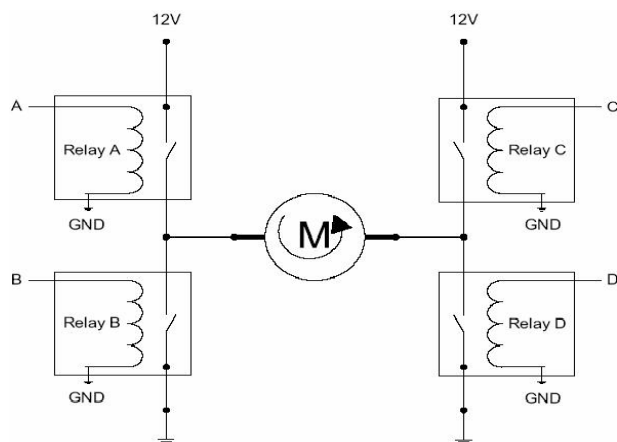
D. Motor

Figure 3 H-Bridge with electromechanical relays

In order to rotate the motor in the forward direction, relays A and D are turned on while relays B and C are turned off. Changing the relay states will make the motor rotate in the reverse direction. During direction changing operation, it is important not to turn on relay B (relay D) before relay A (relay C) turns off, since a heavy current would then flow between the supply and the ground, probably destroying the relays. This requires careful programming in case the relay states are controlled by a microcontroller.

In practice, transistors, rather than relays, are commonly used as control elements in H-bridges. In this application n channel MOSFET devices with 100A current ratings have been used. The direction-control signals generated by the microcontroller are compacted by the PWM signals using four AND gates. This makes it possible to control the speed of the motor as well as its direction of rotation using the same H bridge structure. The control signals pass through several transistor stages for current and voltage amplification before they reach the gates of the high-current MOSFETs. An electro-mechanical relay on the circuit board switches on and off the power of the circuit. The circuit diagram of the motor driver unit is shown in Figure 4.

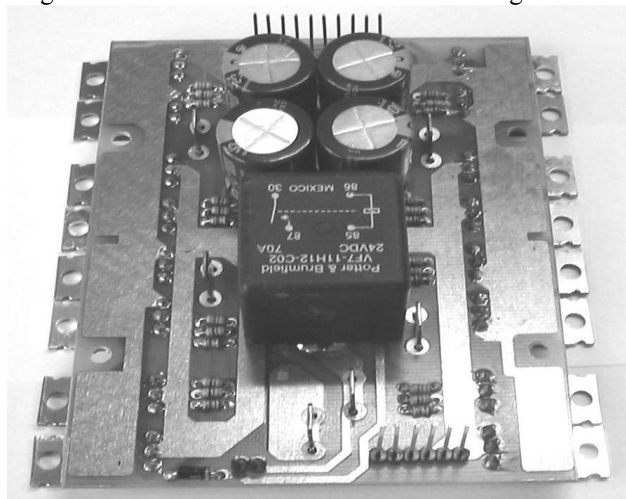


Figure 4 Motor driver unit circuit

The speed adjustment in DA motors was first realized by Ward Leonard in 1891 by means of voltage control. In this method the efficiency of the system was low due to the losses in the resistants. With the usage of thyristors as switching element in power electronics, adjustable voltage sources in speed adjustment of DA motors become more significant. As it is known, semi-conductors such as MOSFET, IGBT, and GTO are used as switching elements. As the switching frequencies of these elements are low in analog circuits, they are much affected by noise. However, with the usage of digital control elements they are less affected by the changing environmental conditions [14].

The wheelchair is powered by two permanent magnet dc motors each having a power rating of 250W and a voltage rating of 24V. A single-stage speed reducing gear is integrated with each motor. Adjustment of the motor speed by electronic means eliminated the need to use a multi-stage mechanical gear and provided an easier control. An electro-mechanical brake with electronic adjustment capability is also incorporated to the system. The motor-gear-brake combination appears as a single unit.

Motor controller is based on PWM system. If the current flowing to the motor has reached a previously determined level, control process is performed to interrupt and restart supply of PWM commands. By interrupting the supply of the PWM commands, the current flowing to the motor is returned from such a level to a normal level. After the motor current is returned to a normal level by the interruption of PWM command supply, PWM command supply is resumed, normal control by PWM command is again performed, and a non-controlling state in the controller is avoided.

Instead of a bipolar transistor, a Metal Oxide Semiconductor Field-Effect Transistor (MOSFET) is used as a switch to obtain high current levels. This transistor can be switched on and off very rapidly for the large currents required for big motors. The motors are driven differentially for direction control. If the user wants to turn right, the speed of the left-motor is increased with respect to the right-motor and vice versa.

III. CONCLUSION

A powerful, easily controllable battery-operated wheelchair was developed using state-of-the-art control and electronic drive technologies. Future improvements to the vehicle may include the addition of regenerative electronic braking capabilities and use of lightweight batteries.

With minor modifications the motor driver and the control software can be used for speed and direction control of medium-power (200-400W) electrical vehicles that may replace small fuel-based vehicles such as scooters, golf carts etc.

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