POWER WHEELCHAIRS

5.1- Introduction

Power wheelchairs provide greater independence to thousands of people with severe mobility impairments. Just as among the ambulatory population, mobility among people with disabilities varies. Mobility is more a functional limitation than a disability-related condition. Powered mobility can have tremendous positive psycho-social effects on an individual.

Power wheelchairs are often used in conjunction with a number of other adaptive devices. For people with severe mobility impairments, power wheelchairs may be used with communication devices, computer access devices, respirators, and reclining seating systems. The integration of the user's multiple needs must also be considered when designing or prescribing a power wheelchair. The power wheelchair itself consists of several subsystems. Power wheelchairs are also designed for different uses.

5.2. Classes of Power Wheelchairs

There are essentially three general categories of power wheelchairs: power bases, power wheelchairs and scooters.

Power bases are self-contained mobile platforms upon which a seating system can be mounted (figure). Power bases are useful where contoured or customized seating systems are required. Power bases can also be used to construct motorized gurneys for individuals who are unable to sit

Figure *Power wheelchair base with linear seating system attached.*

Power wheelchairs contain the seat and the power drive system. Power wheelchairs are used for individuals with moderate trunk balance that only requires moderate seating support (figure). Some seating systems have been developed to provide custom seating in a standard power wheelchair seat.

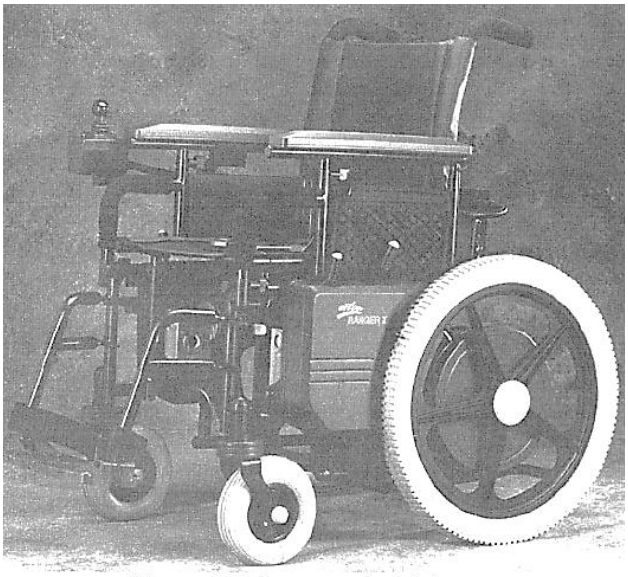
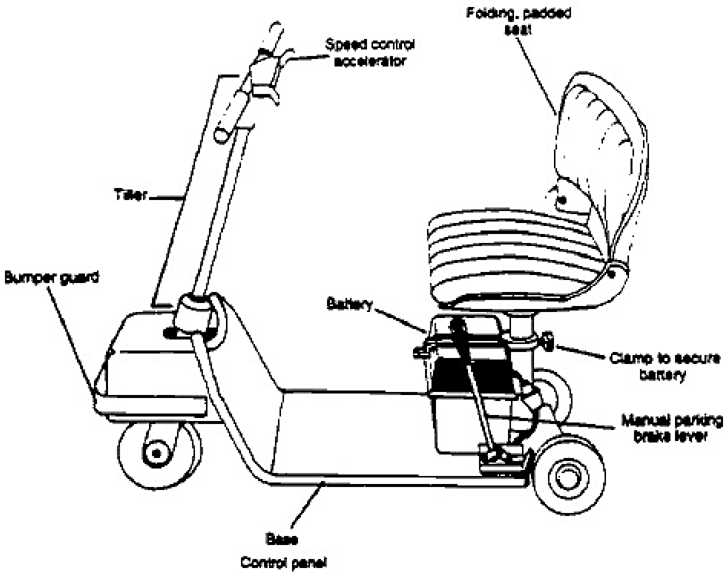


Figure *Full size power wheelchair*

Scooters are powered mobile platforms with a seat, which may swivel, based upon them. Scooters often use a handlebar type steering system (figure). People with limited walking ability may benefit most from scooters.



5.3. Motor Selection

The electric motors are the heart of any power wheelchair system (figure).

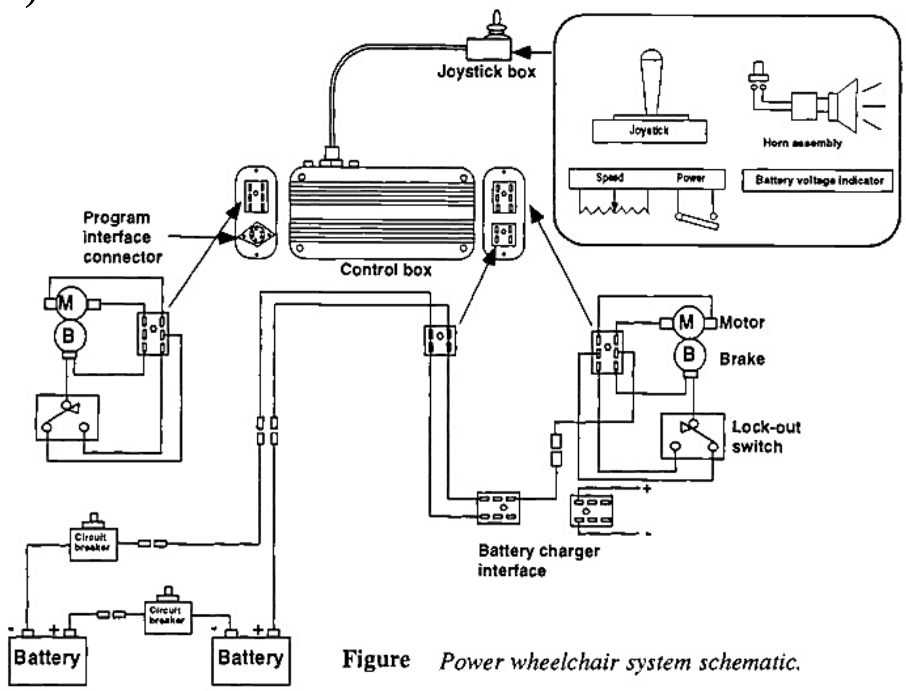


Figure *Power wheelchair system schematic.*

They convert the electrical energy of the batteries to mechanical work. The proper selection can lead to a more durable, functional and efficient power wheelchair system. There are several types of electric motors. Most power wheelchairs use armature controlled, permanent magnet direct current motors. However, other electric motors have been used in prototypes and may eventually become the norm. Proper motor selection depends on translating the demands of the application to the properties of the appropriate motor.

The motor constant, K_m, is an often-used property to describe a parameter which may be likened to the motor's low speed gain, it is a function of torque (T) and power (P)

$$K_m = \frac{T}{\sqrt{P}} \ \mathrm{N\,m\,W^{-1/2}}.$$

The motor constant can be very misleading. It was developed from a class of motors called 'torquers', which are designed for static or low-speed operations, less than 1500 rev min^{-1}. However, motor constants also appear for higher-speed motors.

If the equation for K_m is broken down, this dependence upon the torque constant (K_t)and winding resistance (r) becomes clearer

$$K_m = \frac{K_t}{\sqrt{r}} \, \mathrm{N\,m\,(rev\,min^{-1})^{-1}\,\Omega^{-1/2}}.$$

To get a high motor constant, one has to try and obtain maximum motor torque with minimum resistance, armature, or field.

If the motor is considered to be a black box with wires going into one end and a shaft coming out of the other end, then we can evaluate the motor based upon its ability to transfer electrical power to mechanical power, power rate. The equation describing power rate is given

$$\dot{P}_m = \frac{T^2}{J} \quad \mathrm{W\,s^{-1}}$$

where T is the output torque, and J is the inertia of the motor. Examining the units of power rate leads to understanding of its significance. Ideally, all of the electrical power delivered to the motor would come out the other end as mechanical power. Power rate is a measure of the rate at which electrical power is converted to mechanical power.

5.4. Servo Amplifiers

To implement a motor controller a servo amplifier is required to convert signal level power (volts at milliamps) to motor power (volts at amps). Typically a design requirement for series, shunt, and brushless motor drives is to control torque and speed, and hence power. Voltage control can often be used to control speed for both shunt and series motors. Series motors require feedback to achieve accurate control.

Either a linear servo amplifier or a chopper can be used. Linear servo amplifiers are not generally used with power wheelchairs primarily because of their lower efficiency than chopper circuits. A motor can be thought of as a filter to a chopper circuit, in this case the switching unit can be used as part of a speed and current control loop.

5.5. Microprocessor Control

Power wheelchairs can be controlled with simple analog or with digital microprocessor-based controls. A single microcontroller is used to control the wheelchair and both of its motors. Digital control offers flexible control and accommodation of various input devices (both analog and digital). An internal (resident) program maintains timing, coordination and contains the controls system algorithms. Motor voltage and current are sensed to limit power, to protect circuitry, and to achieve finer control.

Microcontrollers are used to tune the power wheelchair system to the user's individual needs. Many wheelchair controllers permit adjusting maximum speed, yaw velocity and acceleration, acceleration and deceleration rate, input filter parameters, and the input device deadzone. A number of methods have been used to vary controller parameters. An external control unit can be used which interfaces with the wheelchair controller. The wheelchair controller parameters are tuned through a series of switches or key strokes. Another approach is to use the user interface (e.g. joystick, ultrasonic control device) to tune the wheelchair controller.

5.6. Shared Control

The goal of shared control is to enhance the mobility of the users by offloading some wheelchair driving functions to an automatic control system. This approach is sometimes called sensor-based control, because of the array's internal and external sensors used by the automatic control system (see figure).

Some people may have sensory, cognitive and/or physical impairments that limit their ability to control a power wheelchair. A variety of strategies are employed to ameliorate the limitations imposed by physical, sensory, and cognitive impairments. Proper body positioning and support can enhance the driver's ability to maintain control and increase the range of driving tasks that can be performed. The selection of the interface device is also an area of much investigation and has led to expanded ranges of performance for power wheelchair drivers. Once the driver is properly positioned, supported, and has an input device that accommodates the driver's residual abilities, the driver may still be very limited in the activities which can be performed successfully. In this case, the parameters of the microprocessor controller are typically tuned to minimum or near minimum driving parameters (e.g. linear and angular speed, linear and angular acceleration).

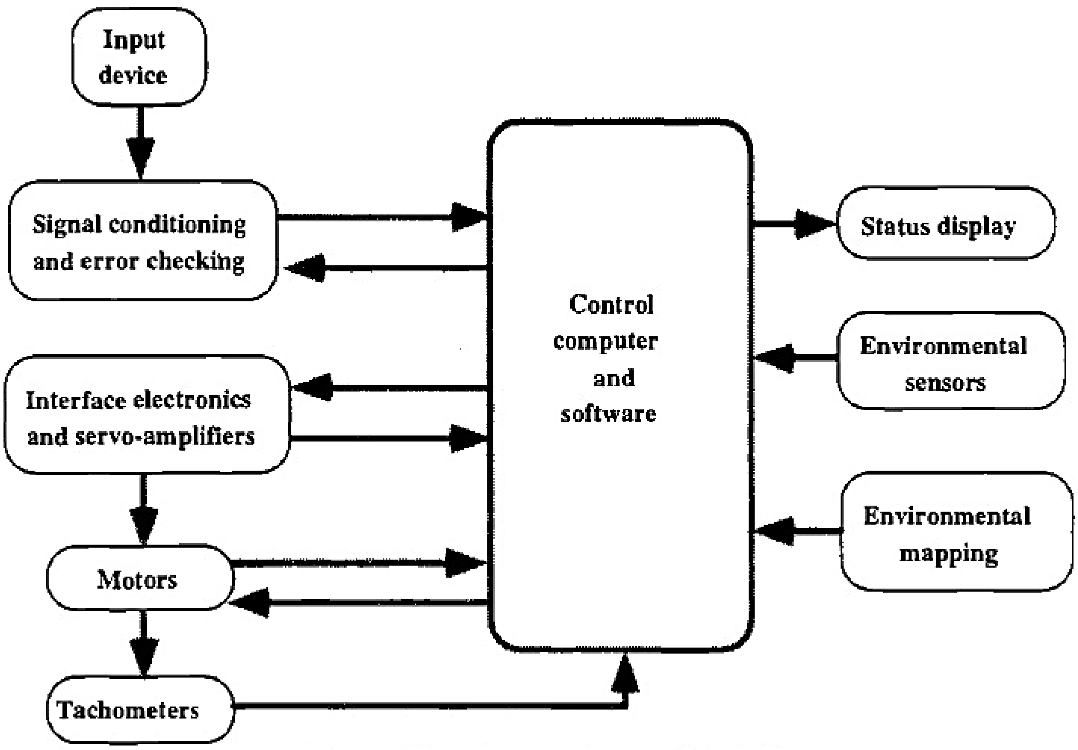


Figure *Shared control system block diagram.*

The controller input filter parameters may also be tuned to remove much of the signal provided by the driver. The result of detuning a classical PI microprocessor control system is a sluggish slow moving wheelchair. Some people attain functional mobility using these methods, however, many do not. Shared control systems are quite successful in many automobile driving applications (e.g. automatic braking systems, adaptive suspension systems, power steering systems, automatic fuel injection). Some of this technology can be applied to power wheelchair driving.

5.7. Integrated Controllers

Many power wheelchair users require multiple assistive devices (e.g. wheelchair, environmental control unit, communication device, computer access device). Integrated controls allow the user to control more than one assistive device through a single input device.

Typically, this is the device chosen to control the power wheelchair. If the power wheelchair is optimized to the driver as described above, then the appropriate hardware and software protocol can be used to interconnect various devices. This would provide the user with effective control of a variety of electronic assistive devices.

Integrated controls are the term used to describe plug-and play for assistive devices. Ideally, all electronic assistive devices would use compatible communication protocols and interconnect hardware. The need for integrated controls is illustrated by the walking-talking problem.

5.8. Batteries

The battery energy storage system is recognized as one of the most significant limiting factors in powered wheelchair performance. Battery life and capacity are important. If battery life can be improved, the powered wheelchair user will have longer reliable performance from his/her battery.

An increase in battery capacity will allow powered wheelchair users to travel greater distances with batteries that weigh and measure the same as existing wheelchair batteries. Most importantly, increases in battery capacity will enable the use of smaller and lighter batteries. Because batteries account for such a large proportion of both the weight and volume of current powered wheelchair systems, wheelchair manufacturers must base much of their design around the battery package.

Power wheelchairs typically incorporate 24 V d.c. energy systems. The energy for the wheelchair is provided by two deep cycle lead-acid batteries connected in series. Either wet cell or gel cell batteries are used. Wet cell batteries may require greater maintenance, but have the ability to store greater energy than gel cells at temperatures from freezing to room temperature.

5.9. Gear Boxes

The efficiency of a power wheelchair is affected by the drive system. An efficient drive system can extend the distance covered on the energy stored in the batteries. Pulse width modulated servo amplifiers can be designed to have high efficiencies, in excess of 80%. The motors of the wheelchair are often connected to the wheels through a gear box or pulley set. The pulley set or gear box decreases the speed of the motor and increases the torque seen at the wheels. This allows the motor to operate about its rated speed, where it is more efficient. However, mechanical losses in the gear boxes or pulley set are also causes of inefficiency.

Three common methods are used to reduce the speed of the motor and to increase the torque at the wheel: a worm gear right angle drive; a spur gear reducer; and a belt-pulley system. The worm gear drive although compact is not very efficient, because the sliding contact between the worm and the worm gear creates high friction forces.

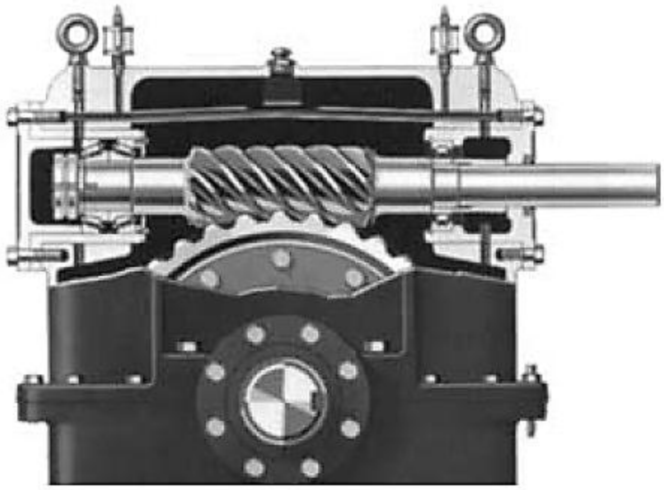
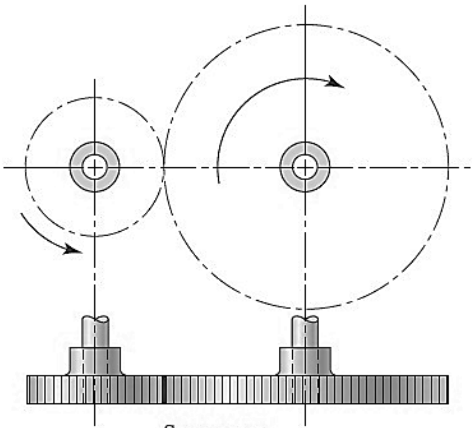


FIGURE worm-gear

A spur gear uses a small pinion, driven by the motor, and a larger gear. Involute cutting of the gear teeth permits the pinion and gear combination to turn with rolling friction, rather than the constant sliding friction of the worm gear.

However, the spur gear arrangement requires the motor to be orthogonal to the gears, which restricts folding the wheelchair frame. Efficiency of a gear train is affected by speed.



Spur gears

The efficiency of a power wheelchair worm gear drive is about 70% compared with 80% for a spur gear drive. Belt drives vary from about 60 to 90%. Helical timing drive (HTD) belt drives though not commonly used on power wheelchairs, have been shown to be about 90% efficient on motorcycles.

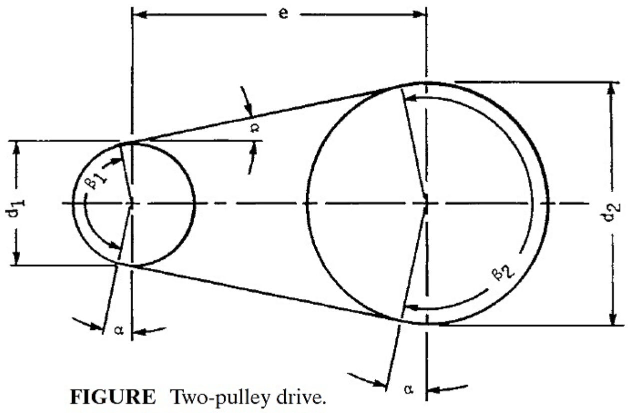


FIGURE Two-pulley drive.

Lubrication is also an important factor to consider when studying gear box efficiency. Many wheelchair gear boxes are designed for other applications, and are filled with high viscosity grease by the factory. This is because the gear drives are often designed for higher speed and load applications. At the relatively low speeds of wheelchair use, this high viscosity grease can cause excess drag

5.10. User Interfaces

Joysticks and switches can be used to effectively control a powered wheelchair or power base **.** The joystick is the most common control interface between the user and the wheelchair. Joysticks produce voltage signals proportional to displacement, force, or switch closures.

Displacement joysticks are most popular. Displacement joysticks may use either potentiometers, variable inductors (coils) or optical sensors to convert displacement to voltage. Inductive joysticks are most common as they wear well, because the stick is not physically in contact with the windings, and they can be made to be quite sensitive. Joysticks can be modified to be used for chin, foot, elbow, tongue, or shoulder control. Typically, short throw joysticks are used for these applications. Force-sensing joysticks use three basic transducers: simple springs and dampers on a displacement joystick, cantilever beams with strain gages, and fluid with pressure sensors.

Force-sensing joysticks which rely on passive dampers or fluid pressure generally require the user to have a range of motion within the normal values for displacement joystick users. Beam-based force-sensing joysticks require negligible motion, and hence may be used for people with limited motion abilities