System Level Block Diagram for Autonomous Vehicle

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The autonomous vehicle uses an EMAC based system that will autonomously navigate the vehicle through the Jobst-Baker quad to the destinations entered by the user. This vehicle operates under the following conditions:

- The sidewalks in the quad are clear of debris.
- The vehicle starts from the same position at the Northeast door of Jobst and is oriented in the same direction pointing South.

The vehicle navigates from point to point using a table of coordinates stored in EMAC memory that maps the quad. This table of coordinates is based on the various sidewalk intersections located in the quad. Large obstacles, such as people, are detected and the vehicle motion is halted until the obstacle is cleared.

This system has three modes of operation and six hardware subsystems. The modes of operation are query mode, maneuver mode, and obstacle mode. The hardware subsystems are the acoustic sidewalk sensors, the acoustic obstacle sensor, the digital compass, the shaft speed encoder, the linear actuator, and the motor. Each subsystem and mode of operation will be discussed in detail below.

Hardware:

Hardware System Level Block Diagram

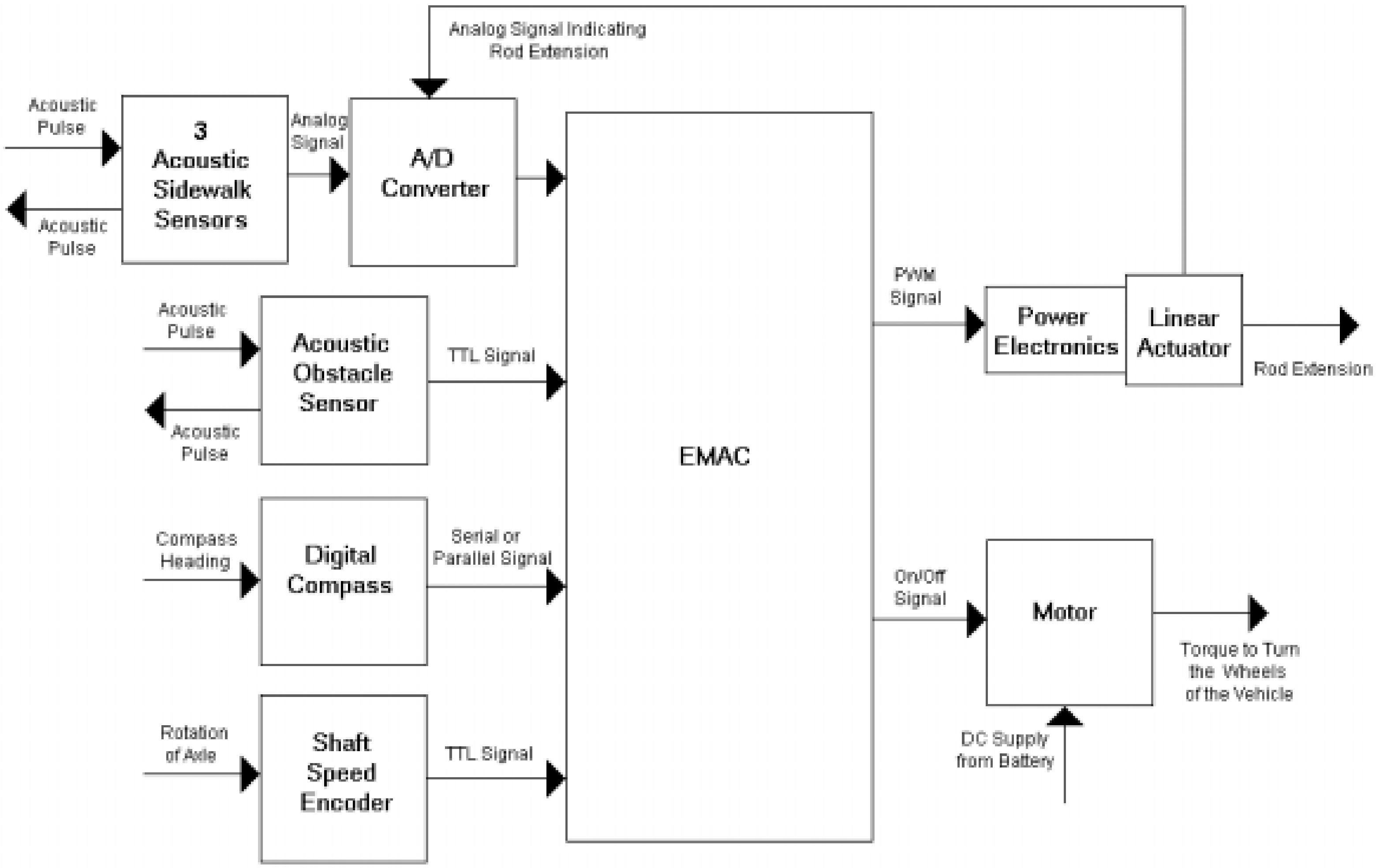


Figure 1 – Hardware System Level Block Diagram

Each hardware subsystem can be seen in the Hardware System Level Block Diagram above in Figure 1. This block diagram shows all of the inputs and outputs of each subsystem and how they relate to the overall system. Each of the subsystems is discussed in more detail below.

Acoustic Sidewalk Sensor Subsystem

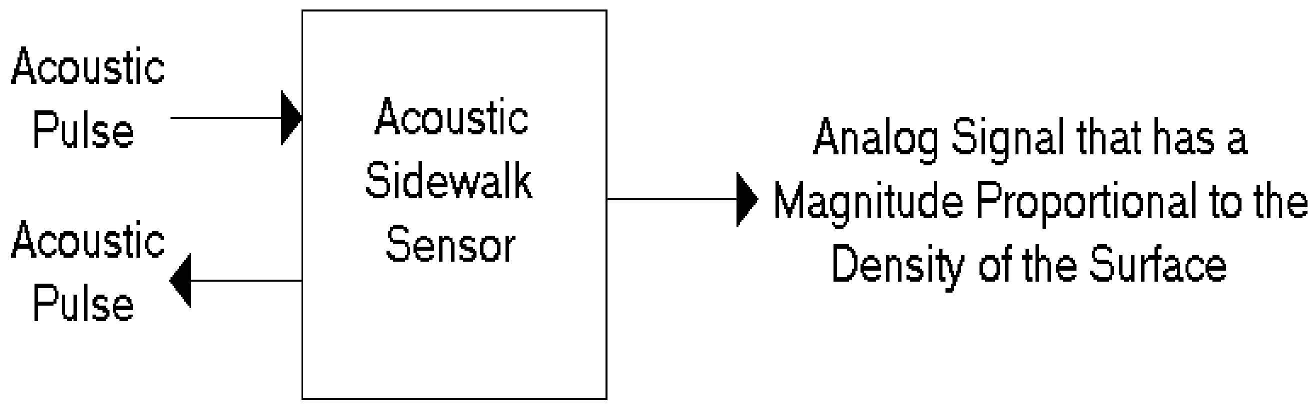


Figure 2 – Acoustic Sidewalk Sensor

Acoustic Pulse Input and Output:
The acoustic sensor transmits an acoustic pulse. If it hits an object, the acoustic pulse reflects off the object, and a portion of the reflected energy propagates back to the sensor where it is detected.

Analog Signal Output:
The acoustic sensor has two outputs: an analog signal output and a digital output. For this application, only the analog signal output is used. The analog output has a magnitude that is dependent on the reflected acoustic energy received by the sensor. This energy depends on the angle of the surface to the sensor bore sight, the distance of the surface to the sensor, the density of the surface, and the texture of the surface. The acoustic sidewalk sensor is mounted on a boom, pointing so that the sensor bore sight is perpendicular to the ground, so the acoustic pulse is normally incident on the surface. Also, the distance of the sensor to the surface is fixed because it is mounted at a certain height. Therefore, when comparing different output analog signals from the acoustic sidewalk sensor, the differences in the magnitude of the analog output signal can be attributed to different surface densities or different surface textures since the distance and angle of incidence is fixed. If there is not a returned acoustic pulse received by the acoustic sensor, then there are no objects within a specified distance, or the object absorbs the incident acoustic energy.

Three acoustic sidewalk sensors are used in this EMAC based system. They are all pointing towards the ground. These sensors are used to differentiate the sidewalk from the grass. The analog signal output is sent to the A/D converter on the EMAC board. This signal provides the appropriate information for determining if the vehicle is on the sidewalk, off of the sidewalk, or on the sidewalk at an intersection. From this information, the EMAC software determines if the vehicle needs to continue in its current mode of operation, or switch to a new mode of operation.

Acoustic Obstacle Sensor Subsystem

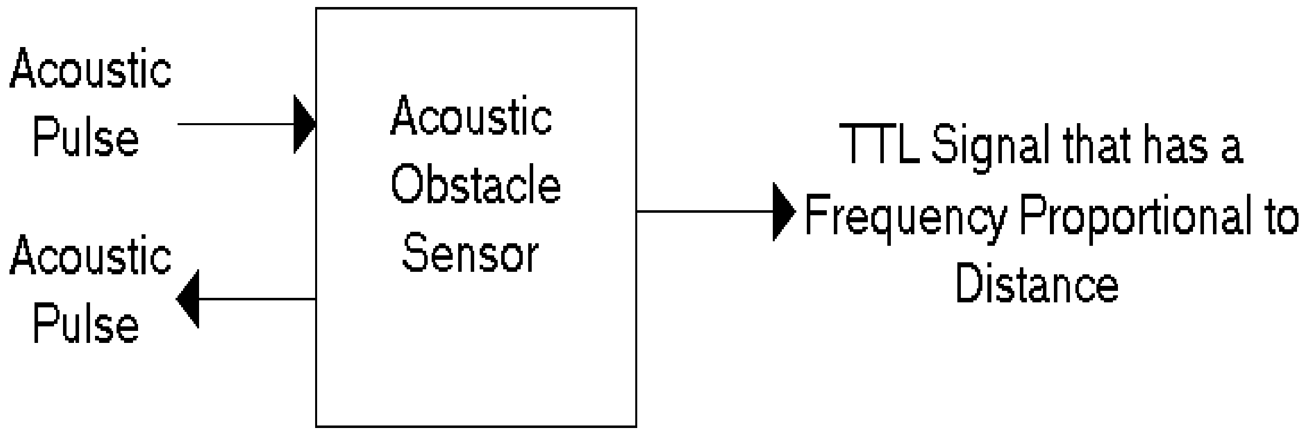


Figure 3 – Acoustic Obstacle Sensor

Acoustic Pulse Input and Output:
The acoustic sensor transmits an acoustic pulse. If it hits an object, the acoustic pulse reflects off the object, and a portion of the reflected energy propagates back to the sensor where it is detected.

TTL Signal Output:
The acoustic sensor has two outputs: an analog signal output and a digital output. For this application, only the digital signal output is used. The digital output is generated if a return pulse is detected. If detected, the time delay of the pulse relative to transmission time is proportional to the distance of the object to the sensor. The detection of the acoustic pulse depends on the angle of the surface to the sensor bore sight, the distance of the surface to the sensor, the density of the surface, and the texture of the surface. Thus, larger objects will return an acoustic pulse at larger distances than smaller objects. Also, objects with a surface normal to the acoustic pulse will return an acoustic pulse at larger distances than objects with a surface not normal to the acoustic pulse.

There is one acoustic obstacle sensor mounted on the top of the vehicle pointing straight forward. Unless there is an obstacle within the specified range, the TTL signal output is zero. If an obstacle is detected, the output goes high with the delay proportional to the distance to the obstacle. Since a pulse train is transmitted, the echo output is periodic and has a higher frequency for closer objects, and a lower frequency for objects farther away. This TTL signal is sent to the EMAC board to determine if there is an obstacle in front of the vehicle. If the TTL signal indicates that an object is within a certain distance, the vehicle will enter obstacle mode and stop. The vehicle will remain stopped until the TTL signal indicates that the obstacle is gone, and then the vehicle will reenter its previous mode of operation.

Digital Compass Subsystem

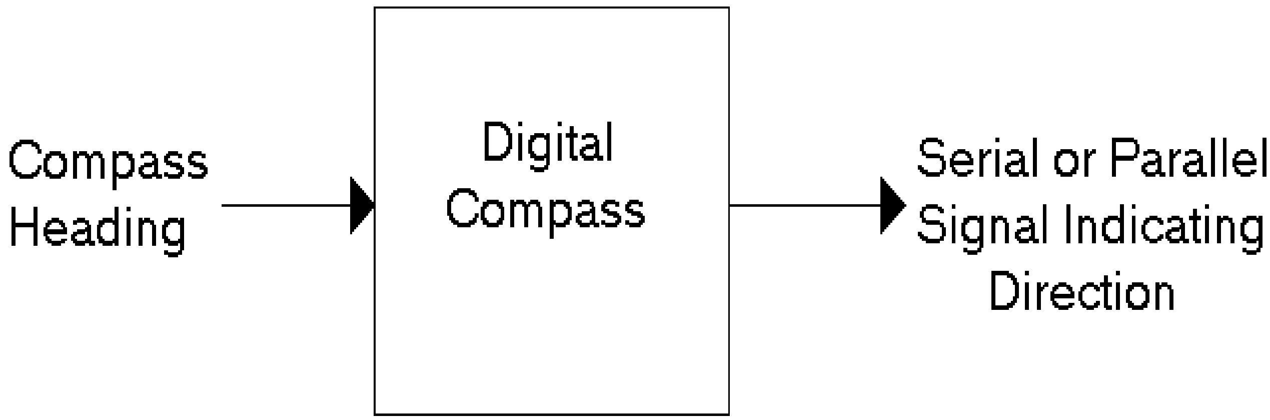


Figure 4 – Digital Compass

Compass Heading Input:
The compass, attached to the vehicle, responds to heading of the vehicle**.**

Serial or Parallel Signal Output:
It is assumed that there is a correlation between the compass' heading (and therefore vehicle heading) to electronic output of the compass. Obviously, more investigation needs to be done to determine the nature of the outputs and compatibility with inputs to the EMAC. This output is sent to the EMAC board where it is interpreted as the direction of the vehicle in degrees relative to North**.** This computed direction of the vehicle is used by the EMAC to aid in determining where the vehicle is heading on the internal map of the Jobst-Baker quad.

Shaft Speed Encoder Subsystem

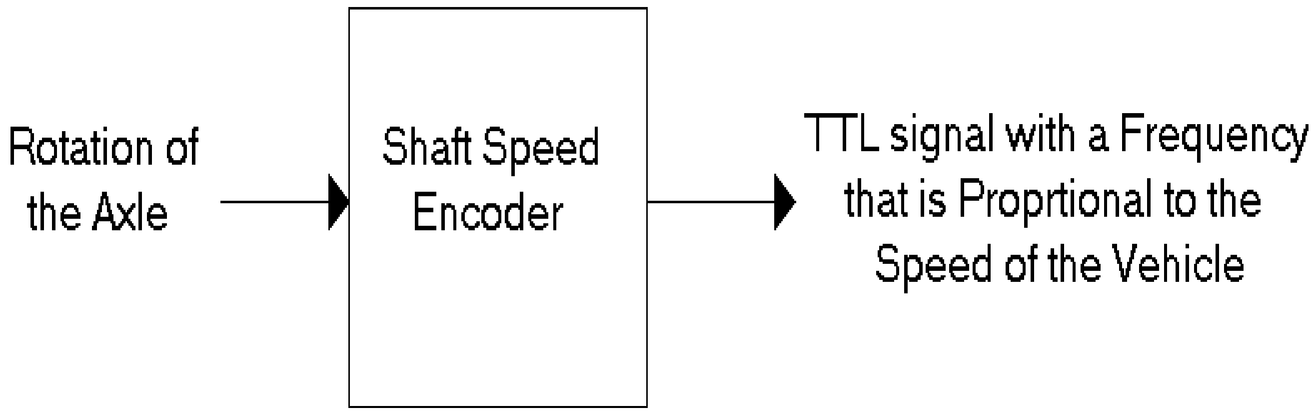


Figure 5 – Shaft Speed Encoder

Rotation of Axle Input:
This input is the rotation of the axle that spins a disk. A clear disk is attached to the axle with opaque markings on it. The rotation of the axle causes the disk to spin.

TTL Signal Output:
The TTL signal output has a frequency that is proportional to the RPM of the shaft. An opto-isolator is used to produce the output signal. Every time an opaque mark reaches a sensor the opto-isolator pulses. More investigation needs to be done to determine the number of opaque markings needed to make an accurate calculation of vehicle speed. If four opaque markings are used, for example, then after every fourth pulse, the axle has made one complete revolution. The output frequency is therefore proportional to the RPM of the shaft. The higher the frequency means the faster the rotation of the axle. The faster the rotation of the axle means the faster the vehicle is traveling.

This TTL signal is sent to the EMAC board. The EMAC software uses the output of this subsystem to determine the speed of the vehicle, which in turn, allows distance traversed to be determined. From the distance the vehicle has traveled, the software is able to determine where the vehicle is on the internal map.

Linear Actuator Subsystem

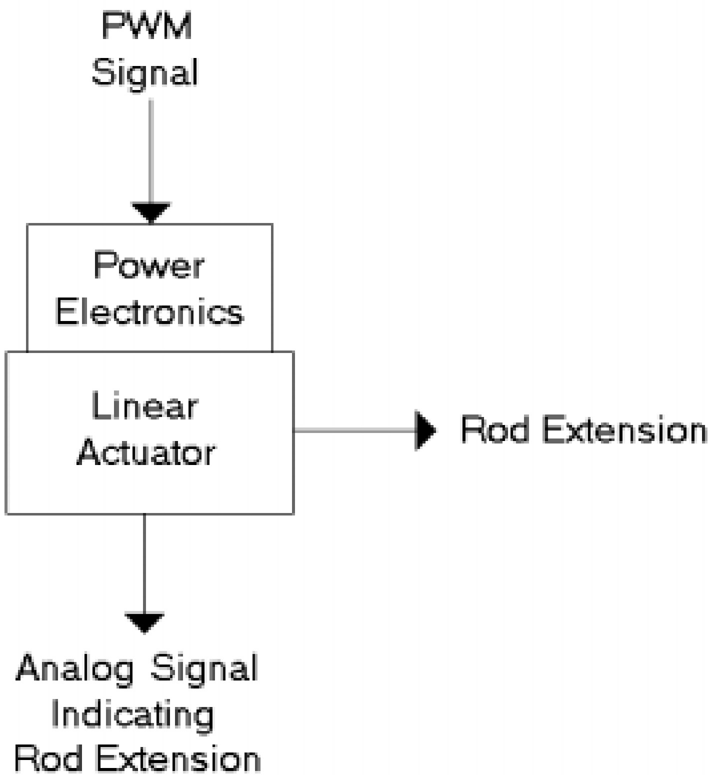


Figure 6 – Linear Actuator

PWM Signal Input:
The PWM signal input is sent to the power electronics from the EMAC board. This signal indicates what the extension of the rod should be.

Rod Extension:
This output is a mechanical output. The power electronics and linear actuator interpret the input PWM signal as the desired rod extension, and the rod extension output is the realization of the desired rod extension.

Analog Signal:
This output signal comes from the potentiometer on the Linear Actuator, and it indicates the current rod extension.

The Power Electronics receives an input PWM signal from the EMAC board indicating the desired rod extension. This information is transferred to the linear actuator, which then produces the mechanical output of rod extension to achieve the desired rod extension. The mechanical output of rod extension is what causes the vehicle to change its wheel angle. The output signal from the potentiometer is sent back through the A/D converter to the EMAC board. The software interprets this analog signal as the current rod extension. The EMAC software uses this information to determine if the vehicle is going straight, turning right, or turning left.

Motor Subsystem

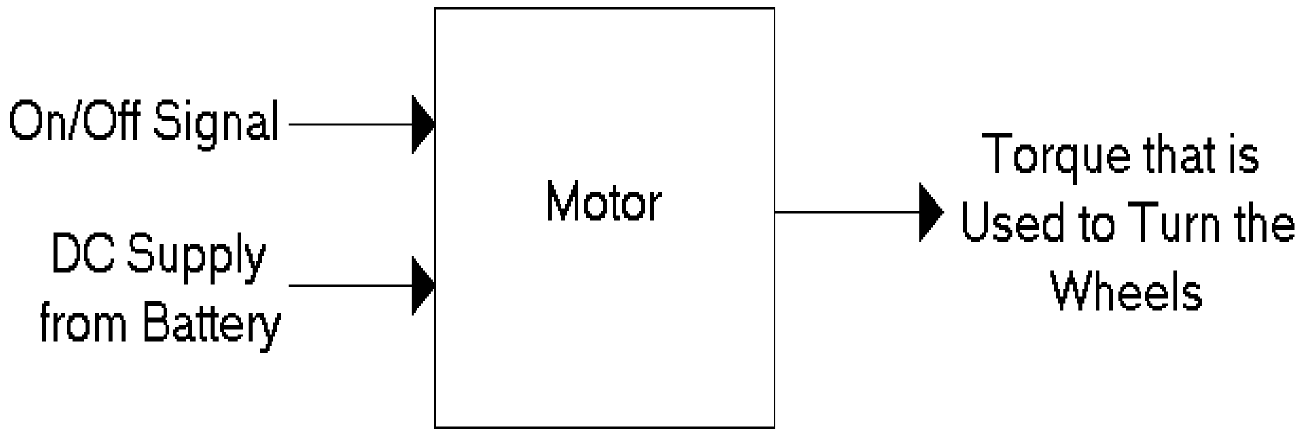


Figure 7 – Motor

On/Off Signal Input:
This input turns the motor on or turns the motor off.

DC Supply Input:
This input comes from the DC battery supply. It provides the motor with the appropriate DC voltage to operate.

Torque Output:
The torque output is a mechanical output produced by the motor.

The EMAC board sends an on/off input signal to the motor. When the motor is on, the motor produces a mechanical output. This mechanical output is torque, and it is applied to the appropriate gearing on the axle to turn the wheels of the vehicle. When the EMAC based system is in query mode or obstacle mode, the EMAC sends a signal to the motor indicating that the motor should be off. When the EMAC based system is in the maneuver mode, it sends a signal to the motor indicating that the motor should be on.

Software:

Query Mode

Before entering query mode, it is assumed that all components are initialized and system is ready for operation.

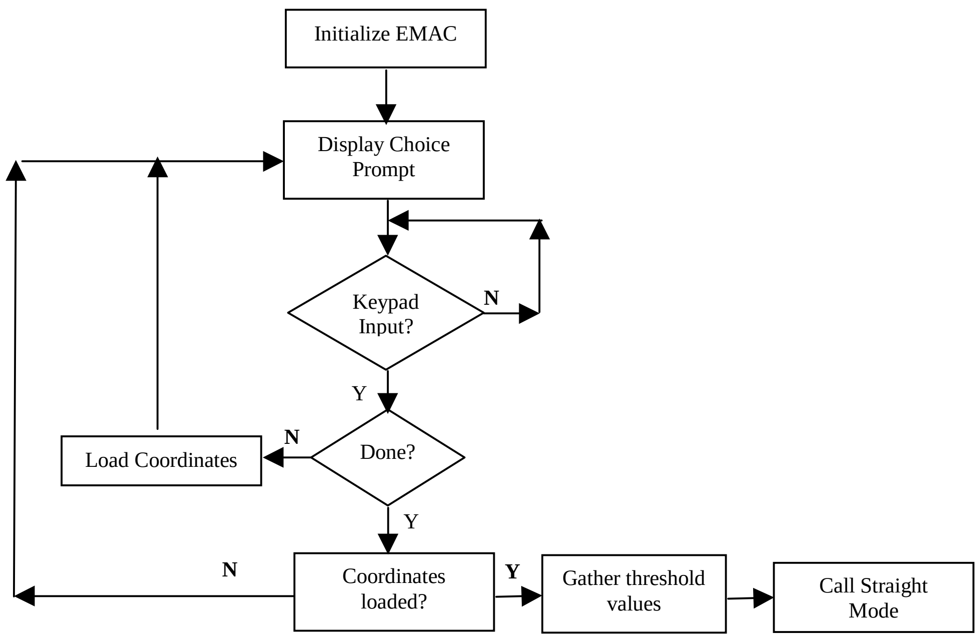


Figure 8 – Query mode flowchart

In Query mode, after the waypoint prompt is displayed, the microprocessor will wait for input from the user. After initial input, the microprocessor will check for a 'Done' input. If no 'Done' is detected, the current waypoint will be stored and a prompt for more points will be displayed on the LCD. Once a 'Done' input has been detected, the microprocessor checks to verify that waypoints were entered. If no points were entered the software will return and prompt the user for a waypoint. Otherwise, the microprocessor will gather a collection of 10 data points from the grass sonar and 10 data points from the concrete sonar to create an average threshold value to compare with future sonar readings. Once the threshold value is computed the **Straight** routine will be called by the microprocessor.

Maneuver Mode

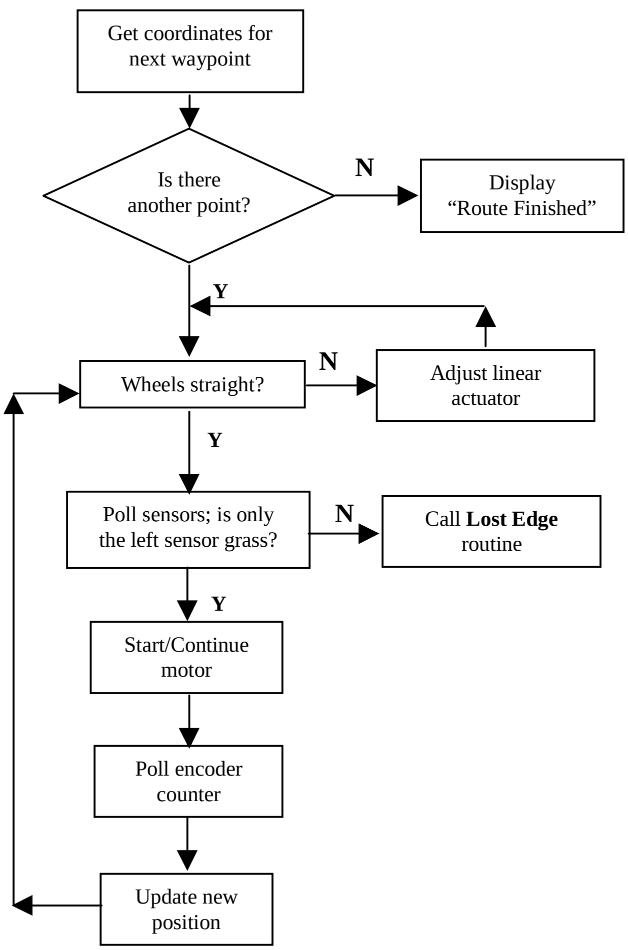


Figure 9 – Straight routine flowchart

In the straight routine the microprocessor is polling the sonar sensors at a minimum 80ms. Currently, this time is derived from the minimum time between sonar transmissions (recycle time). First, the EMAC gets the coordinates of the next waypoint. If there is not another waypoint stored, it is assumed that all user-entered waypoints have been traversed and the cycle is complete. Otherwise, the microprocessor will verify that the wheels are straight and adjust as necessary with the linear actuator. Next, the microprocessor polls the sonar sensors. If only the left sensor has a grass signal, then it is assumed that the vehicle is aligned with the sidewalk therefore power to the motor is started or continued. Otherwise, the microprocessor will call the **Lost Edge** routine. Lastly the microprocessor will poll the wheel encoder count and update its registers with the new position.

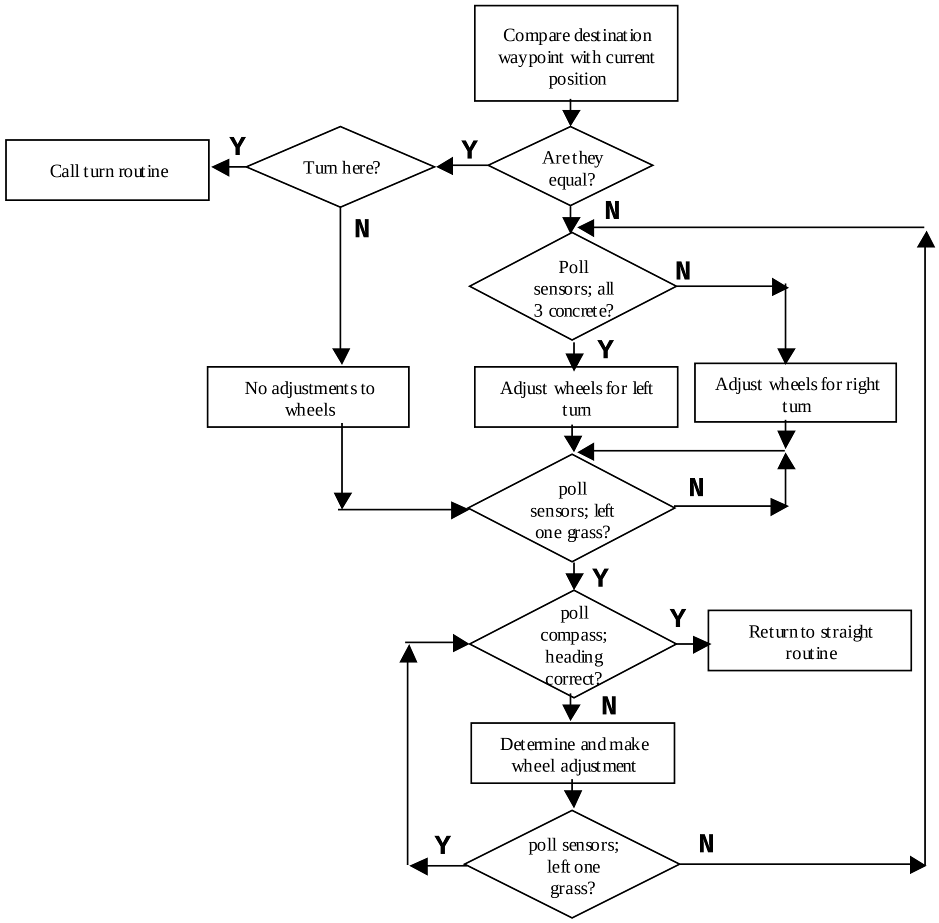
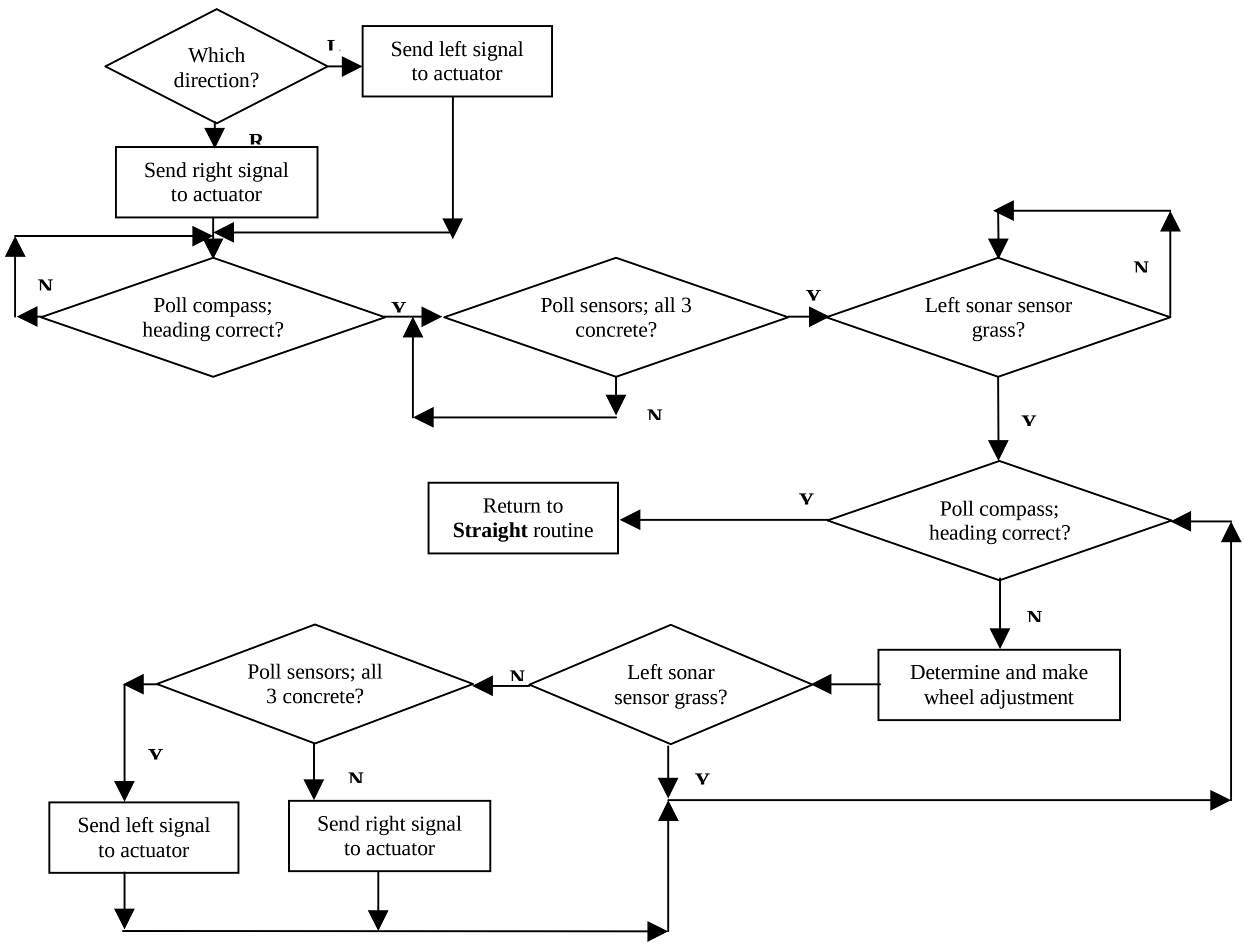


Figure 10 – Lost Edge routine flowchart

In the **Lost Edge** routine will compare the current coordinates of the vehicle with the coordinates the desired waypoint vehicle as entered by the user. If the two sets of coordinates are equal, then the microprocessor will check if a turn is necessary at this way point. If a turn is required at this way point the **Turn** routine will be called (see Figure 11) by the microprocessor. Otherwise, the EMAC will continue moving forward with the wheels straight until grass is detected on the left sonar sensor. If the coordinates are not equal than the vehicle has lost alignment with the sidewalk and needs to be realigned. To correct alignment the microprocessor will poll the sonar sensors and determine if all three sensors are over concrete. If this is true, then the wheels should be adjusted for a left turn and right otherwise. At this point the microprocessor will continue to poll the sonar sensors until a grass signal is detected on the left sensor. Once this occurs, the microprocessor will poll the compass and compare this value with stored heading to verify proper heading of vehicle. If the vehicle has a correct heading, then the microprocessor will return to the **Straight** routine. Otherwise, the necessary heading correction will be determined and the linear actuator adjusted accordingly. The microprocessor will poll the sonar sensors to ensure that the vehicle's left sensor is still on grass. If the left sensor is no longer on grass then the microprocessor returns to the earlier function that acquires the grass edge. Otherwise, the compass will be polled to recheck the vehicle's heading and repeat this process until the heading is correct and the left sensor is on grass. At this point the **Lost Edge** routine returns to the **Straight** routine.



<u>Figure 11</u> – Turn routine

This routine is called by the **Lost Edge** routine. After the desired direction is determined by the microprocessor, it sends the appropriate signal to the actuator. The microprocessor will poll the compass and wait for the a predetermined heading to be reached. Afterwards, the microprocessor will poll the sonar modules and wait for all three to be concrete of signals. Once this set of signals is acquired, the sonar modules will be polled until only the left sonar has a grass signal. Then, the routine will check the heading of the digital compass and compare it to a stored value for this intersection. If the heading is correct, the vehicle is aligned with the sidewalk and is ready to return to the **Straight** routine. Otherwise, a calculated wheel adjustment is made. Then the compass and sonar sensors are polled until the vehicle is aligned.

Obstacle Mode

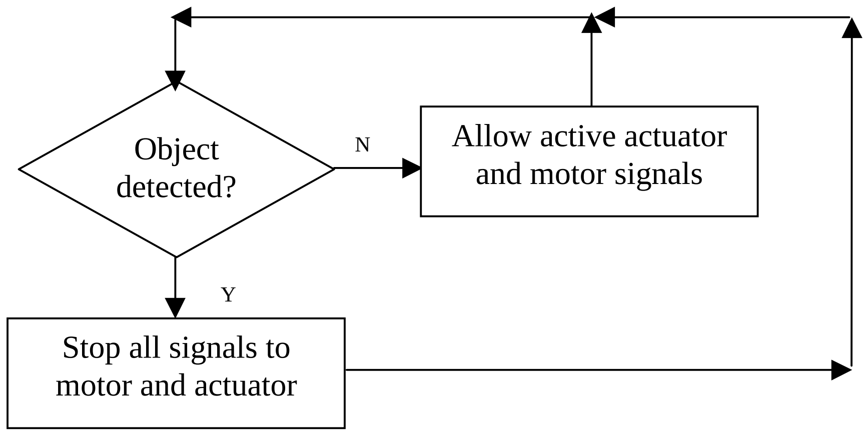


Figure 12 – Obstacle mode flowchart

This mode will be interrupt driven. One sonar module mounted parallel with the ground will determine if there are any objects in the vehicle’s path. If an object is detected, the interrupt routine will be called. This routine will halt any further movement until the object is removed or the vehicle is placed at start and reset.