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8th Intelligent Ground Vehicle Competition Design Report

Introduction

In Fall 1998, the Electrical Engineering Technology (ELET) Department at Bluefield State College (BSC) began a long-term Ground Robotic Vehicle (GRV) project. The ELET Department organized and directed an initial group of nine electrical engineering technology students to start the project. The objective of the project group was to design and create a fully autonomous vehicle that will compete in annual Intelligent Ground Vehicle competitions held in Oakland, Michigan. The first competition to be entered is the 8th Annual International Ground Robotics Competition in July 2000. The competition rules outlined the basic design requirements that had to be met to compete. The GRV must traverse a course avoiding obstacles and negotiating "trap" situations over different terrain – all without human intervention. The only human link to the GRV will be a remote motor cut-off in case the vehicle begins to run out-of-control.

The GRV design strategy involved breaking the robotic vehicle into several sub-systems. The subsystems are designed to be easily integrated into the overall design. The sub-systems consisted of the following:

i) Frame and structure

ii) Forward/Reverse Motor and Turning Motor

iii) Obstacle Detection Sensors and Interfaces

iv) Lane Marker Detection Sensors

v) Computer Control System and Software

Frame and Structure

The basic frame for the GRV is from an old riding lawn mower. Extensive changes to the beginning frame left only a small portion of the initial frame intact. A shelf was added above the main frame to allow room for the control computer and electronics. An additional structure was added to provide space for the mounting of electronics with shelter from adverse weather as a consideration. The structure also provided an area to place the needed monitor for software monitoring.

Forward / Reverse Motor and Turning Motor

We chose to use an electric DC motor instead of a combustible-fuel motor or an electric AC motor. A computer can start and control the speed of an electric motor easier than it can a combustible-fuel motor. For example, pulse width modulation (PWM) provides a convenient method of controlling DC motors in many commercial vehicles. With MOSFET transistors, it is straightforward for a computer to operate the PWM device. Another reason to go electric is that we would not have to deal with smelly and harmful emissions with an electric motor as we would with a combustible-fuel motor. DC motors are better than AC motors because of the availability of DC power such as 6-volt and 12-volt car batteries. After having chosen to use a DC motor, we now have to decide on the motor voltage and horsepower required as well as the gear reduction ratio. The motor voltage will depend on how many batteries we can physically carry and on the voltage of each battery. The more horsepower we require, the bigger the motor we would need. Also, at a given horsepower, the lower the voltage we use, the larger the motor, but the less batteries we would need. Gear reduction depends on the speed of the GRV (5 mph maximum in our case), which in turn affects the horsepower required. Given the size of our rear wheels and a motor speed of 3000 rpm, we calculated and fabricated the gear reduction such that the maximum speed of the robot would be 5 mph.

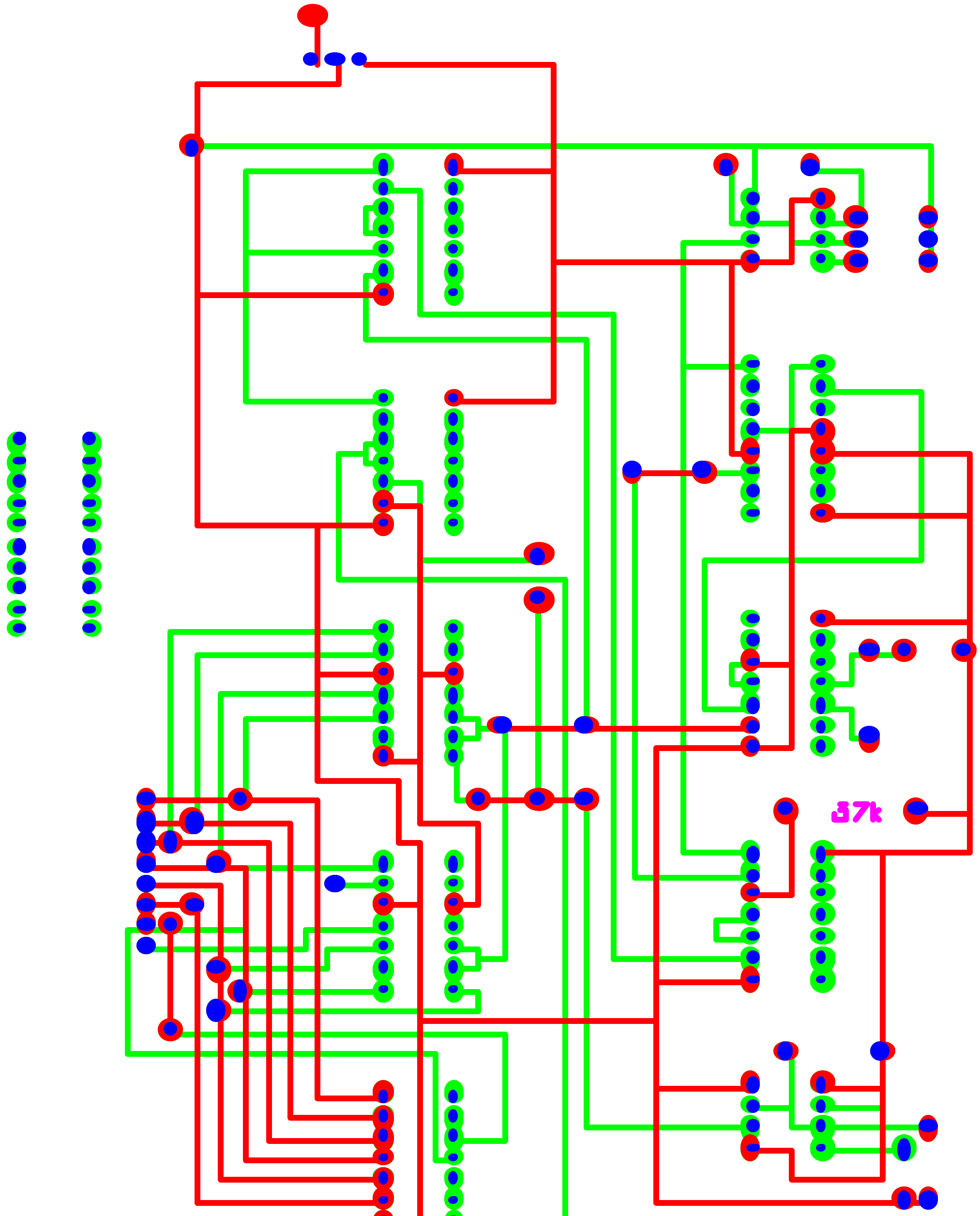
The steering motor is an automobile windshield wiper motor (12VDC permanent magnet motor.) The navigation program turns the GRV by applying a 12-volt pulse to the motor with the width of the pulse proportional to the angle of turn. Turning the opposite direction is accomplished by reversing the polarity to the motor. For future competitions, we may replace this with a stepper motor.

The steering readout consists of transistors, buffers, light emitting diodes (LED's), and transmitter receiver parts. All of which are in groups of three's. The circuit is soldered together on a blank breadboard, which will be mounted on the side of the GRV. There is a metal plate that connects to the shaft on the steering motor. This plate enables transmitter – receiver pairs to "read" exactly where the front wheels are located. When the wheels are at "dead center", all three receivers will be receiving a signal from their prospective transmitters. As the wheels turn left or right, the metal plate will block one of the transmitters off. The top transmitter will count how many "teeth" on the plate that have passed by. Each "tooth" on the metal plate will represent a certain number of degrees of turn. The degrees represented by each one will be determined by the maximum angle (turn radius) of the GRV's front wheels. The way this circuit communicates with the computer is quite simple. Three transmitters will pass through the holes in the metal plate and pick up the receivers. The receivers will in turn feed the signal through three buffers and into a digital Input/Output card in the computer. Three indicator lights will be mounted on the front of the breadboard so that they will be visible to the person advising the GRV. When the wheels are at "dead center", a green light will be illuminated on the breadboard. When the wheels turn left or right, one of the two respective red lights will be illuminated on the board. These lights were added to the circuit just to increase the ability to monitor the GRV in its operation.

Obstacle Detection Sensors and Interfaces

The sonar was made to interact with the onboard computer of the GRV. Five sonar transducers line the front of the GRV to detect objects in front of the GRV. Two Sonar transducers are mounted on the rear of the GRV to ensure that obstacles are not hit if the GRV must move backwards. The sonar transducers will tell the computer how far away an object is from the front of the vehicle. In response to the data given to the computer it will then decide if the GRV should make a left or right turn. The data given to the computer is in the form of binary bits: 1's and 0's. The binary values range from 1 to 128. The distance the GRV is from an obstacle will be calculated by the weights of the binary bits of data received by the computer from the sonar circuit. The distance is calculated by taking the difference in the pulse sent out (initial) and comparing it to the pulse received back from the sonar (echo). The sonar circuit was designed using circuit cam software similar to AutoCad. The circuit had to be small in size because of lack of space. The default size on circuit cam is 9 in. by 11 in., but we were eventually able to decrease it to 4.5 inches by 3.75 inches. This is the size of the circuit, which is now in place on the GRV. Notice the diagram on the following page. The diagram is of the circuit without the buffer chip connected. The buffer is next to the design of the circuit to show the size comparison of the circuit (just to the left of the diagram.) Keep in mind that a chip's pins are about 1/10 of an inch apart. The entire circuit has 7 chips and several resistors, LED's, and capacitors. The green color indicates the bottom layer and the red color the top layer of the printed circuit board. The sonar circuit was designed using

Complementary Metal Oxide Semiconductor (CMOS) technology. This reduced the power consumption of each interface and also provided for lower noise problems compared to TTL circuits.



Lane Marker Detection Sensors

To detect the road edges, we are using diffused visible sensors from Banner Electronics Corporation. These programmable sensors output a bit indicating whether a preset intensity of a certain color is exceeded or not. We are planning to use 2 sensors on each side for the road edges and one in the front for the potholes. The outputs from these sensors tie directly into the digital I/O board on the computer. The GRV will attempt to travel down the center of the road. In the event one of these sensors picks up the stripe on the road edge, then the navigation routine will turn in the appropriate direction to maintain center.

Computer Control System and Software

The GRV will be required to operate autonomously in the competition. This is being accomplished with advanced sensors directly connected to a personal computer. Microsoft Visual Basic software written specifically for the GRV will provide the logic necessary to act upon the various sensors. The personal computer will then provide output to various controls and relays to provide control of the two electric motors tasked with steering control and movement of the GRV. The choice was made to use third party digital Input/Output cards and mechanical relay racks for a more reliable setup and for time constraint considerations.

The digital Input/Output card ordered and installed in the navigation computer is Computer Boards, Inc. CIO-DIO96. The CIO-DIO96 provides 96 TTL Level Input/Output Bits. Four parallel 82C55A integrated chips provide this capability. Each chip consists of three data and one control register in four consecutive I/O locations. Each register contains eight bits, which can constitute a byte of data or 8 individual bit set/read functions. Visual Basic is used to set and read all four registers. Each chip consists of four ports. Port A and B can be programmed as input or output. In mode 0 configuration, the ports configured for output hold the output data written to them and may be read back by the computer software for absolute control. The 8255 can be programmed to operate in three modes. These modes are Input/Output (mode 0), Strobed Input/Ouput (mode 1), and Bi-directional Bus (mode 2). The 8255 is reset on power up. On reset, the 8255 places all 24 input lines in the input mode. The control register configures the 8255 for operation in the mode that the user requires. Under normal operating conditions, the voltages on the 8255 pins range from 0 to .45 volts for the low state to 2.4 to 5.0 volts for the high state. The CIO-DIO96 is being used in the navigation computer to monitor the 64 possible bits of input from the sonar boards. Each sonar utilizes 8 bits of input on the board. This enables the best resolution possible for detecting objects in the path of the GRV. The software converts the 8 bits to a range in feet for the computer to use to react to obstacles in it's path. Three additional input bits are required to accept the data from the steering position sub-system. The three data bits will enable the software to know whether the GRV is turning left, right, or the wheels are centered. The control functions performed by the CIO-DIO96 are performed by 8-bits of output. Bit 8 is used to control the On/Off of the main contactors. Bit 4 is used to control forward/reverse of the movement motor. Bit 6 and Bit 5 control turning of the GRV left and right. Input and output connections to the CIO-DIO96 card is through two 50 pin ribbon cables. The 50-pin ribbon is then connected into a 50-pin header connector on the CIO-Mini50 Terminal boards. The terminal boards provide a convenient screw terminal connection for each bit of the CIO-DIO96 and also brings out +5 V and ground. The terminal boards have a small footprint that was required due to space limitations within the GRV.

Connection to the drive and steering motors required the usage of the CIO-ERBO8 8 channel form relay rack. The relay rack provides eight form C electromechanical relays on one board. The control of the relays is provided from the CIO-DIO96 board. Control signals are routed through the screw terminal board into a ribbon cable with a 37 – pin connector at the relay rack side. Output contact connections are provided for each relay through three screw terminals for each on the relay rack. Relay 8 is used to control the on/off control contactors for the movement motor. Relay 7 is used to control the forward/reverse condition of the movement motor. The normally closed contacts are wired to provide forward. The normally closed contacts provide reverse. These relays are used to control the coil voltage on two Allen Bradley relays with the capability to handle larger currents. A 2.2 Kilo-ohm resistor pulled up to +5V is required to the input of the relay rack for each bit of control data. This is due to the fact that the buffer chips retain the last state and must be forced to toggle to the opposite state.

Conclusion

This report highlighted the major design areas of BSC's GRV. It does not do justice to the amount of work that went into this robot over the past one and a half years. Many paths were tried and many retried, but we are now confident in our final product. We also have many ideas for improving the robot next time around!