

**A Design for the Integration of Sensors to a Mobile Robot**

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## **Abstract**

The robot “localization” problem is the challenge of accurately tracking robots’ position. When the robot rolls along a surface, wheel slip causes the uncertainty in the robot’s position to increase. The longer the path, the more the errors increase. If several robots cooperate, they may be able to use each other and natural landmarks to measure their position as they move within a region. If they accurately determine their positions as they move, they will be able to create an accurate map of the environment. This research deals with the integration of sensors for a robot exploration team. These sensors recognize natural landmarks and assist in determining the robot positions relative to these landmarks. Four sensors on each robot send out beams in a sequential fashion orchestrated by the range-finding sensor circuit. The time it takes for a beam to leave the sensor and a reflected beam to return from a landmark will provide the robot with the range. This information will be used in providing data necessary for the construction of an accurate aerial map, as well as determining each robot’s position within the region.

## **Background**

The problem of exploring an unknown environment and constructing a map is central to mobile robots, depending on the application. Challenges involved in the exploration of unknown environments include position and orientation errors and inaccurate mapping of the environment. As robot travels along a straight path, due to the limitations in the construction of a robot, wheel slippage occurs. This results in the uncertainty of robot’s position. As the path grows longer, the error increases. If this inaccurate data is used, aerial maps of the explored environment also become inaccurate. These inaccurate aerial maps make it difficult to determine the robot’s general position within the region. Existing approaches that have been proposed for this problem

range from idealized solutions involving perfect virtual robots to practical solutions of indeterminate complexity with real robots [1]. Since designing a perfect and accurate range finder sensor for the sole purpose of robot exploration proves to be a difficult task, researchers have devised a plan that involves two or more robots exploring unknown regions. This team of robots would cooperate with each other to determine their positions within that region. The result is the construction of accurate aerial maps and robot localization [1].

One experiment performed based on this theory involved a team of robots exploring a region independently. As they move, they constructed maps of the areas they explore. When they come into contact with other robots, data is exchanged and an estimate of their relative location is determined. If successful, they combine their data into a shared map and form an exploration cluster [2].

Another experiment involves a team of mobile robots to assist in search and rescue operations. Their tasks included exploring dangerous environments, searching for wounded people in wide areas, providing data for map building, and carrying equipment [3]. This research will expand on the idea of robot exploration teams by integrating sensors capable of recognizing landmarks and measuring each robot's position relative to the landmark. Once the robots are able to determine their position, they can construct accurate aerial maps of an environment. This capability will be useful for a wide range of applications from robots navigating the surface of Mars or the Moon to providing firefighters assistance in searching hazardous areas for disaster victims.

## Methodology

The first thing that had to be done with regard to the sensor integration was to define the design requirements for the robots. These design requirements described the function that the robots were to perform in order to construct accurate aerial maps. The design requirements are

- detect natural landmarks
- detect other robots
- measure distances between multiple landmarks and multiple robots
- image mapping (construct accurate aerial maps), and
- communicate with other robots.

Once these conditions were established, research on various sensors was performed to construct a list of options. Upon completion of the research, a list of sensors was constructed. The sensors included in the list were infrared, sonar, photo resistor, IR range finder, laser, and Bluetooth wireless sensors. All of these sensors met the design requirements in various ways, yet they also carried characteristics that were detrimental to the accuracy of the range readings. These included, but are not limited to, noise interference, small beam distances, and function limitations.

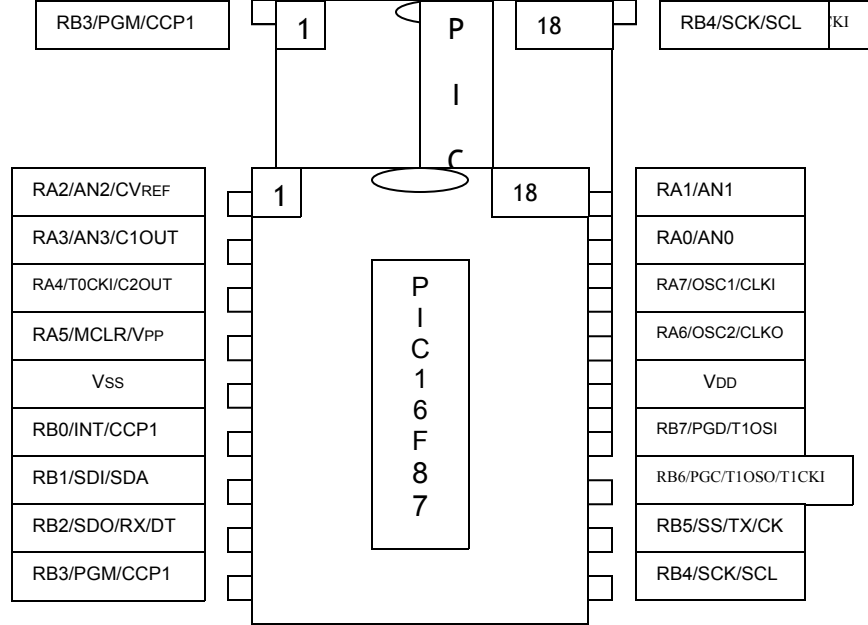
Since we could only use one sensor for communication and one for landmark detection/distance measurement, an additional set of specifications had to be designed for the sensors. These included low power consumption, low cost, high accuracy and resolution, and lightweight packaging. Upon going through the list of available sensors, the choices were narrowed down to two sensors, the IR range finder and sonar. Finally, the LV-MaxSonar-EZ1 sensor as shown in Figure 1 was selected because it meets the specifications perfectly and are

small enough to fit anywhere on the robot. The sonar beams were much stronger and traveled a longer distance than the IR range finder sensor beams.

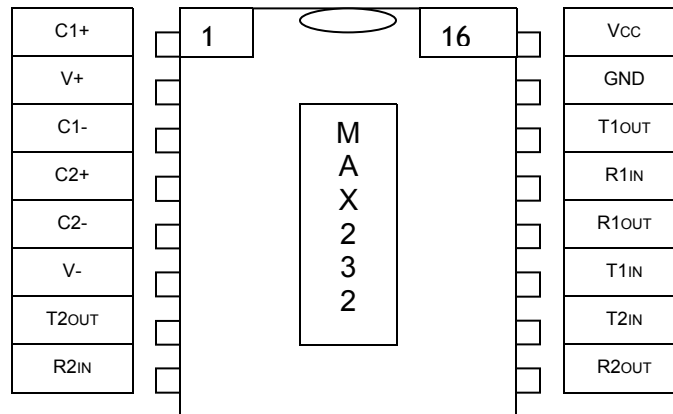


**Figure 1: LV-MaxSonar-EZ1 sensor**  
([www.pololu.com/products/misc/0726/small.jpg](http://www.pololu.com/products/misc/0726/small.jpg))

After the selection of the sensor for the project, a design for the sensor's integration to the mobile robot's platform was created. Experiments were performed on the various ways to wire the sensors to the robots. There are three methods available on the LV-MaxSonar-EZ1 sensor for range detection. These are the pulse width modulation method (outputs a pulse width representation of range), the analog method (output analog voltage with a scaling factor of  $(V_{cc}/512)$  per inch as specified by the LV-MaxSonar-EZ1 datasheet; a supply of 5V yields  $\sim 9.8\text{mV/in.}$  and 3.3V yields  $\sim 6.4\text{mV/in.}$ ), and the serial method (output delivers asynchronous serial with an RS232 format). Two methods for integration were created involving the analog method and the serial method. The analog method involved directly wiring the sensors to the Eports (expansion ports that allow external electronics to be wired to the iRobot Create Programmable Robot) of the robot's command module. The sensors would be placed 90 degrees apart from each other, so the sensor beams would not interfere with the other sensor readings. The sensors' readings would then be accessed directly from the analog port (port on the robot that will input and output continuous variable signals) of the robot's command module. The serial method involved the use of a PIC16F87 microcontroller and a MAX232 RS232/TTL level shifting chip shown in Figure 2 and Figure 3, respectively.



**Figure 2: PIC16F87 Microcontroller Pin Diagram**



**Figure 3: MAX232 Pin Diagram**

In addition, switching diodes, capacitors, resistors and DB9 female serial connectors were used to control the activation of the sensors with them being in close proximity to each other. The PIC16F87 microcontroller has more memory (data and program) with an internal 10-bit analog-to-digital converter (ADC) and an Addressable Universal Synchronous Asynchronous Receiver Transmitter (AUSART). These capabilities were not available with the PIC16F628A, so the 16F87 was selected instead.

The serial method was selected for this project. Using this method, four sensors would be connected to one robot and three robots would be used. The MAX232 chip would receive signals transmitted from a mini-ITX computer connected to the robot. These signals will be entered into the computer in ASCII format. The MAX232 chip will invert the high voltage level provided by the computer into a lower voltage level suitable for the electronic circuit, shown in Figure 4. The information sent to the MAX232 via the R1in pin (pin 13) is sent to the microcontroller's input from the MAX232's R1out pin (pin 12). This will activate a subroutine written in the application program. Once the subroutine is activated, it will initialize the first sensor in the sequence and the sensor will begin to measure distances. An internal timer located in the PIC16F87 microcontroller will keep track of the time it takes for a full reading cycle to be completed on a sensor. After the sensor has completed its measurement cycle, the next sensor in line will be activated. This continues until all four sensors have had a chance to take a range reading. If a change occurs in the readings, a report is sent back to the MAX232 chip via the T1in pin (pin 11) and is then sent to the computer via the T1out pin (pin 14). This process will be continue until power is removed from the circuit (i.e. the robot is powered down). The four 1.0 $\mu$ F capacitors in the circuit are used as "charge pumps" for the RS232. The 0.1 $\mu$ F capacitors and the other two 1.0 $\mu$ F capacitors are used as power filters for the microcontroller and MAX232. The resistors are "pull down" resistors and the diodes are responsible for the fast switching of sensors.

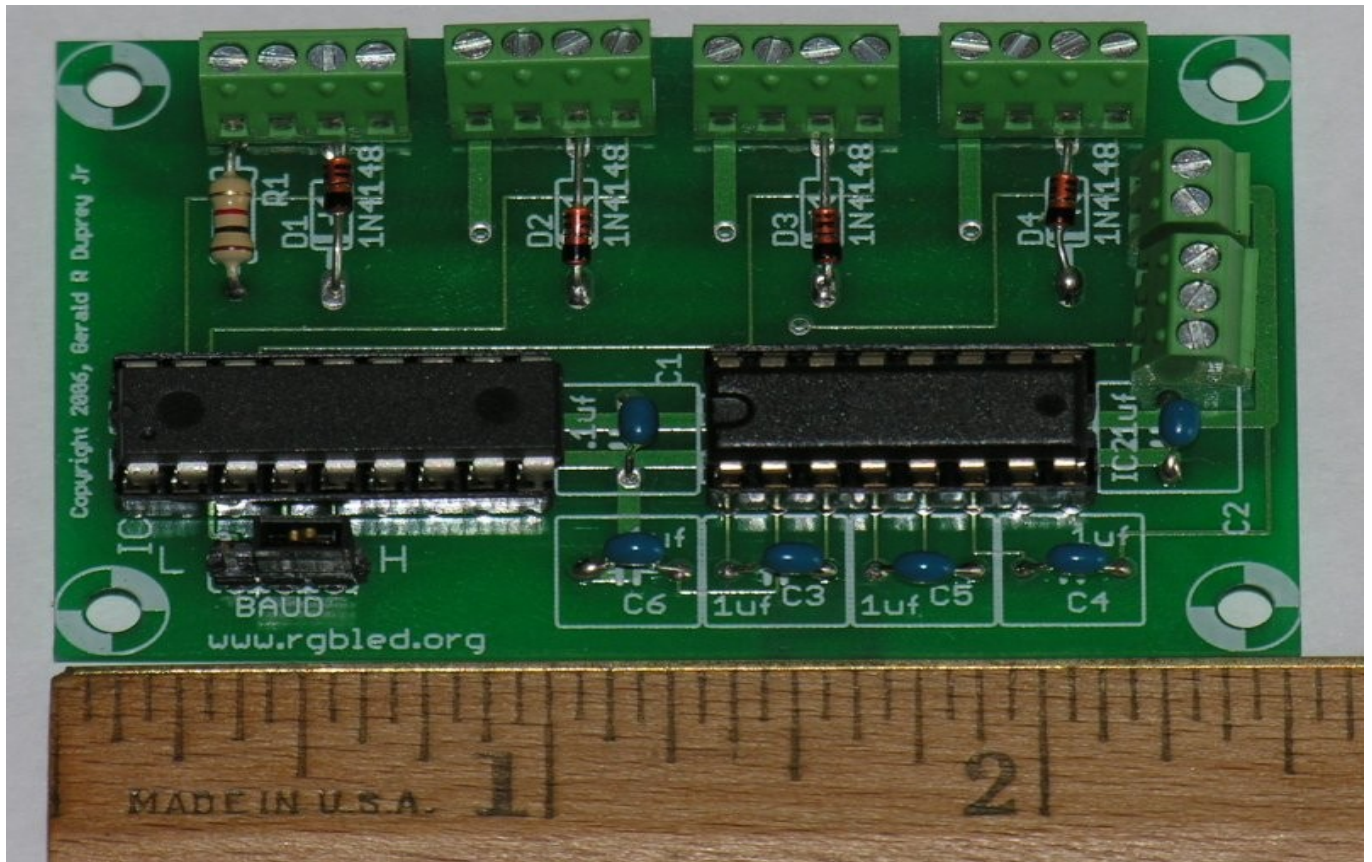


Figure 4: Range Finding Circuit on Printed Circuit Board (PCB)  
([www.rgblead.org/images/small\\_Maxbotix.jpg](http://www.rgblead.org/images/small_Maxbotix.jpg))

## Results

The integration of the LV-MaxSonar-EZ1 sensors to the platform of the mobile robot proved to be successful. The electrical components have been connected onto the breadboard and wired together. The mini-ITX computers that will be connected to the robots have been assembled and are working correctly when power is applied to it. An operating system (Windows Vista) was installed onto the hard drive of the computers since they were delivered without one installed. The electrical components were tested separately to see if each one worked properly before connecting them to the breadboard.

## **Conclusion**

A design for the integration of sensors to a mobile robot exploration team was also created. The design of the circuit (Figure 5) was successfully accomplished using the microcontrollers, level shifting chips, diodes, resistor, capacitors, sonar sensors, and breadboards. This design will make it possible for the sensors to detect natural landmarks, measure the distances between multiple landmarks and robots, and assist in the construction of an accurate aerial map for an explored unknown environment. The circuits, minicomputers, and network adapters will allow for communication amongst multiple robots and the reporting of readings to the main PC. This will result in accurate range readings that will be used in the construction of accurate aerial maps, providing accurate estimates of the robots' location within an unknown region.

## **Further Work**

The purpose of this research was to create a design for the integration of sensors to mobile robots in an exploration team that would control the activation of the sensors, recognize landmarks and other robots, and measure distances between multiple landmarks and robots. The integration would also allow the sensors to assist in the construction of accurate aerial maps. Even though the components of the circuit proved to be in working condition, the circuit has not been wired to the robot to see if it will function properly using the robot's power supply.

Future work to be done on this project would be the testing of the circuit with the actual robots. There are various ways of accomplishing this goal. One such method would be to connect the power supply of the robot to the power terminals of the breadboard and connect the DB9 female serial connector to a personal computer (PC) via an RS232 adapter. Using software

to enter ASCII values to control the circuit, the commands (such as how often to receive a reading report from the controller or how long to activate each sensor for) can be programmed into the chip.

Aside from testing the circuit, further work may have to be performed on the program for the microcontroller. The change could occur due to timing issues of the activation of the sensors. If the activation of the sensors is off, the sensors could interfere with the readings of the other sensors, causing false data to be reported. Altering the code to specify when the sensors should be activated might be necessary to solve this problem. Another reason that the codes might need to be altered is if the reports are being sent to the master PC do not reflect any changes in the readings. The codes would have to be changed to inform the controller that the reports should only be sent when a significant change occurs in the readings.

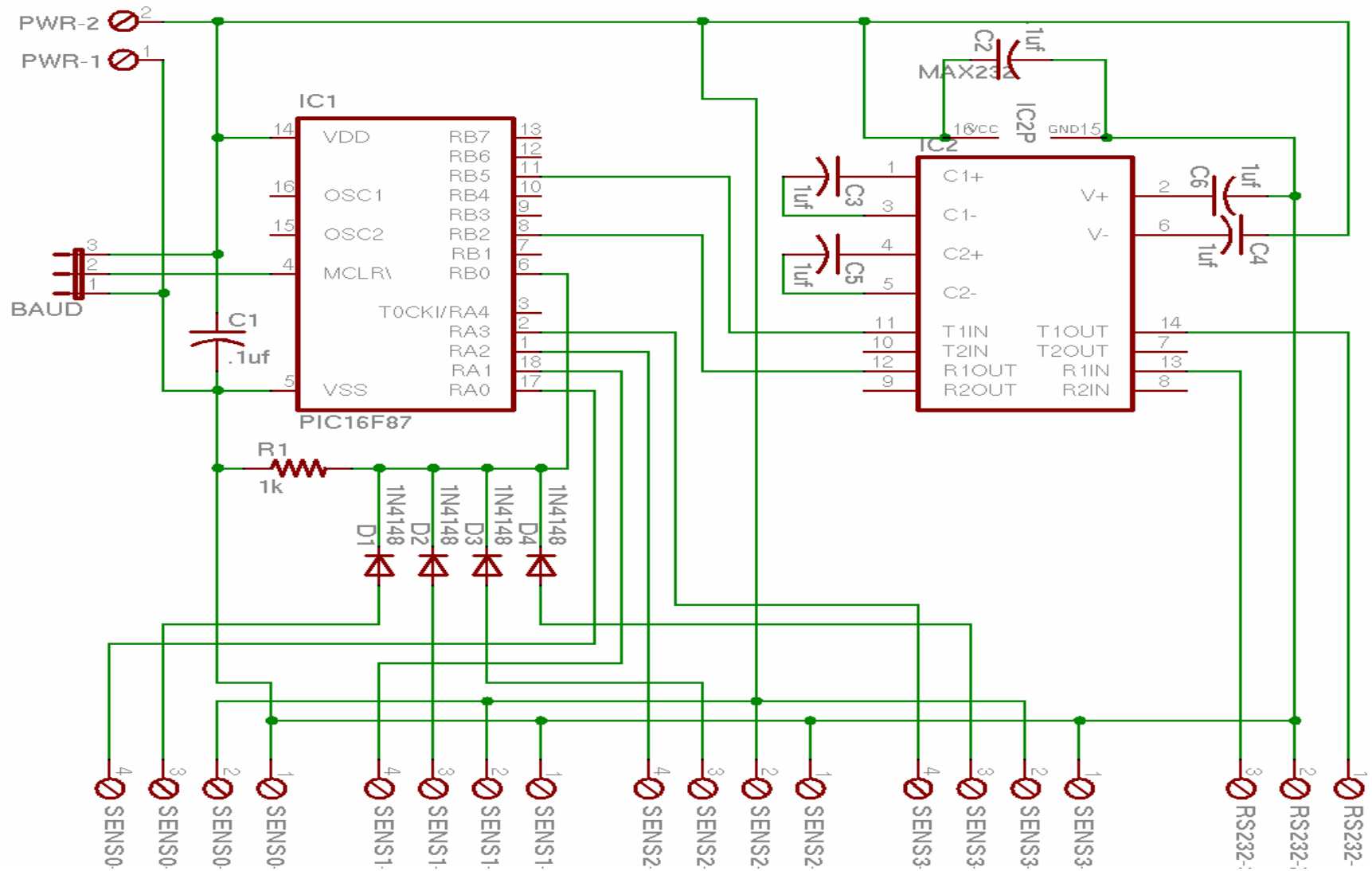


Figure 5: Range Finding Circuit Schematic  
 (rgbled.org/images/small\_Maxbotix.jpg)

## References

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