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The Communication System of a Tele-Operated Smart Mobile Robot

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Abstract: In this work, we present the design of the communication system of economical Smart Mobile Robot (SMR). The control of the SMR is achieved using a personal computer interfaced through the parallel port to a wireless communication module whose communication channel is radio frequency. An embedded micro-controller provides the processing capability needed for the control of the Mobile Robot. The robot is controlled remotely from a Personal Computer (PC) interface that was developed using the Visual Basic.net programming language. The design was implemented to achieve forward, backward and differential drives with provision for speed control, as well as the rotation of the SMR's camera. The image captured by the camera is to be transmitted through a wireless channel and displayed on the PC. In addition, we include some level of Artificial Intelligence (AI), in the design through the incorporation of a Proximity Sensor for obstacle detection and avoidance. The detailed implementation of the communication aspects of this project is presented in this paper.

Keywords: Mobile Robot, Tele-operated Robot, Remotely controlled Robot, Robotics

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1.0 Introduction

This work involves the design of a SMR that is capable of moving around, collecting information from its surroundings with the aid of its camera, and transmitting the information through a wireless channel to a PC, remotely [1]. The SMR is controlled from a Graphic User Interface (GUI) on the PC, through the parallel port and over radio frequency. The SMR has a camera mounted on it, which serves as its eye and thus provides the human controller using the GUI, the ability to efficiently control it. So, the system also makes it possible for the information gathered to be transmitted to the computer and displayed on the GUI for the remote human operator. Among other things, the following capabilities were incorporated in the Robot, which earns it the name, SMR:

- A control of the robot's mobility using a pulse width modulation speed control mechanism.
- The ability to detect and avoid obstacles by the use of a proximity sensor.
- A rich GUI with enhanced functionality and user friendliness.

Other mechanical considerations are made to meet certain objectives relating to the weight of the SMR, the reduction of friction within the gear system, achieving a streamlined shape for easy propulsion and so on.

In this paper, however, the objective is to present the implementation of the communication mechanisms involving the different modules of the robotic system. It should be noted that there are different classifications of robots, but in this project, we implement a type of robot in the class of the Mobile robots [2]. Mobile robots are designed to move from one place to another. Wheels, tracks, or legs allow the robot to traverse a terrain. They may also feature an arm-like appendage that allows them to manipulate objects around them [3]. Their ability to move about allows them to interact with their environment while performing a set task. In our case, SMR is designed to move freely in the forward, backward and sideways. It is also capable of detecting and avoiding obstacles through the proximity sensor; and its speed can be regulated. The attached camera makes it possible for the robot to capture the image of its environment and send it to the remote PC. The rest of the paper is organized as follows. Section 2 discusses the communication components used. Section 3 x-rays the implementation, while Section 4 concludes the work.

2.0 Selection of the Communication Components of the Mobile Robot

In designing the Smart Mobile Robot, we adopt the Block Diagram approach, where the various modules are created and integrated. This really proves beneficial as it simplified our analysis and design. The modules are implemented separately and are interfaced. Figure 2.1 below shows the block diagram of the Smart Mobile Robot.

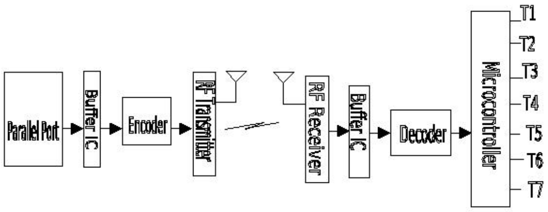


Figure 2.1: Block Diagram adopted for Smart Mobile Robot research

For the analysis and choice of components, we followed the Block Diagram starting from the first module. Since the robot will basically respond to instructions sent through the parallel port by a human controller using the Graphic User Interface (GUI) developed on the PC, the analysis would start from the parallel port.

2.1 Parallel Port

We choose the parallel port over the serial ports Universal Serial Bus (USB) and DB-9 because it is easier to program and also faster. In computers, ports are used mainly for two reasons, namely, device control and communication [4]. Parallel ports were originally meant for connecting the printer to the PC. However, one can program this port for many more applications beyond that, such as the control of a mobile robot, as we have done in this project. Its disadvantage is that it needs more number of transmission lines but this is only significant for long distance communications. Hence, the disadvantage is insignificant for our use.

2.2 IEEE Standard Parallel Ports

The IEEE 1284 standard however specifies three different connectors for use with the Parallel Port.

- The IEEE 1284 Type A is the D-Type 25 pin female connector found on the back of most computers.
- The IEEE 1284 Type B is the 36 pin Centronics connector found on most printers.
- The IEEE 1284 Type C however, is a 36 conductor connector like the Centronics but smaller.

For this project, we make use of the IEEE 1284 Type A since it is adequate for the required task.

The output of the Parallel Port is normally Transistor-Transistor logic level (TTL).

2.3 Buffer

Buffers are used on the transmitting section to isolate the PC's parallel port from the transmitter circuitry to avoid damaging the parallel port, and also on the receiving section to amplify the incoming signal which must have been slightly weakened after going over the radio frequency interface. The 74HCT541 buffer IC was used.

2.4 Encoder

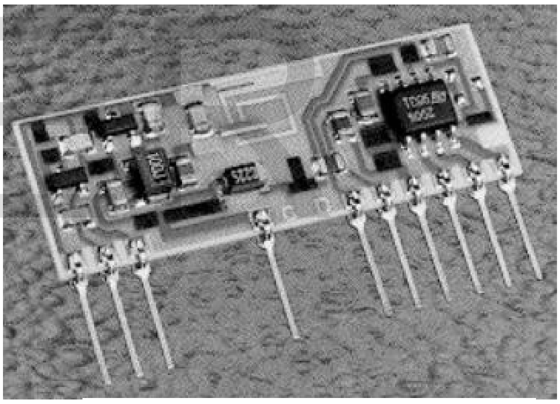
A Radio Frequency (RF) encoder - RF600E was used because of its simplicity. It requires only the addition of input switches and RF circuitry for use. The transmission is automatic without user intervention. The RF600E will wake up upon detecting an input signal and then delay approximately 6.5 milliseconds to ensure that the input stays on, after which it serializes the signal for the RF transmitter. Basically, its aim is to accept at most four input parallel data, serialize and forward the serialized data to the transmitter. Serialization is needed because transmission of data over the radio frequency interface does not occur in parallel, but one after another (serially). This helps preserve data integrity at the receiving section.

The RF600E chip uses a fully balanced Manchester encoded data protocol designed for optimum use of the radio transmission path [5]. Manchester encoding enables the super-heterodyne receiver to maintain efficiency for the duration of the data packet, (unlike many other encoder/decoder systems) which results in reduced bit errors and therefore ensures maximum range.

The encoded data format automatically includes a pre-amble, synchronization header, followed by the encrypted and fixed code data, then a Cyclic Redundancy Check (CRC). The actual packet size is 67 bits. Each transmission is followed by a guard period before another transmission can begin. The data encryption provides up to four billion changing code combinations and includes the function bits along with other data and synchronization information that the decoder uses. The encrypted or hopping code portion of the transmission will change every time an input is received, even if it is the same input.

2.5 Radio Frequency (RF) Transmitter

The RF transmitter we used is produced by RF Solutions Ltd. It is an AM hybrid transmitter module which provides a complete RF transmitter for transmitting data at up to 4 kHz frequency from any standard CMOS/TTL source. Its carrier frequency is 433 MHz. The module is very simple to operate and offers low current consumption (typically 4mA). Figure 2.2 shows the RF transmitter.



FigureF2.2: RF Transmitter by RF Solutions

2.6 Radio Frequency Receiver

The RF receiver used shown in Figure 2.3 is also a product of RF Solutions. The receiver module is a compact hybrid RF receiver with the ability to capture encoded or un-encoded data from any 433MHz AM transmitter, located within a radius of 45 meters. Aside from requiring no radio license for operation, it also has very high frequency stability over a wide operating temperature range; hence even the mechanical vibrations of the DC and Stepper motors which produce electrical fields do not result in interference. Also, it employs a unique laser trimming process which acts as an on board inductor, and therefore there is no need for any adjustable components.

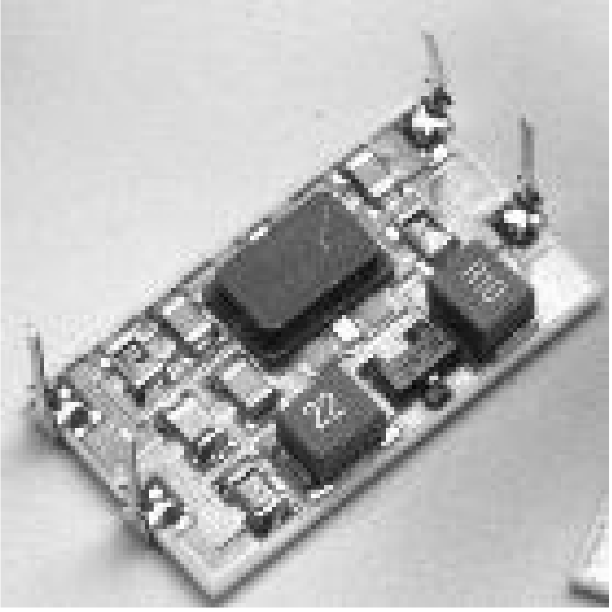


Figure 2.3: RF Receiver by RF Solutions

2.7 Decoder

The RF600D decoder was used to decode the instructions encoded by the RF600E encoder. It has the capability to learn up to 7 unique RF600E encoders. With the addition of an EEPROM memory device, this is increased to 48 RF600E encoders.

2.8 Micro-controller

In designing this Smart Mobile Robot, we needed to make two basic decisions regarding micro-controllers. They are:

- choice of the micro-controller to be used
- choice of the programming language for the micro-controller

Since this paper focuses on the communication aspects of the robotic system, the detailed implementations of the micro-controller will be left for subsequent publications.

2.9 Image Transmission and Reception

Since the robot is to be operated remotely, we decided to use a wireless video camera for visual feedback. The camera is mounted on top of the robot. And as the camera is to be cordless, we only considered the IP camera and the wireless CCTV [6].

IP camera: An Internet Protocol (IP) camera is simply any camera that transmits video utilizing open Internet protocols and standards [7]. IP cameras have several advantages over other kinds of cameras. However, this choice is discarded because of the price of these cameras. An average IP camera cannot be purchased for less than $400.

Wireless CCTV: Closed-circuit television (CCTV) is the use of video cameras to transmit signal to a specific monitor. It may employ a point to point wired or wireless link. CCTV is often used for surveillance. We used the Swann Night Hawk Security Camera that allows the transmission of pictures and sound with ease. It transmits radio waves at a frequency of 2.4GHz, and reception is within a radius of 100 meters in open line of sight. The receiver can be connected to a TV or PC (using a TV to PC adapter). It was chosen because it consumes little power and has night vision [8].

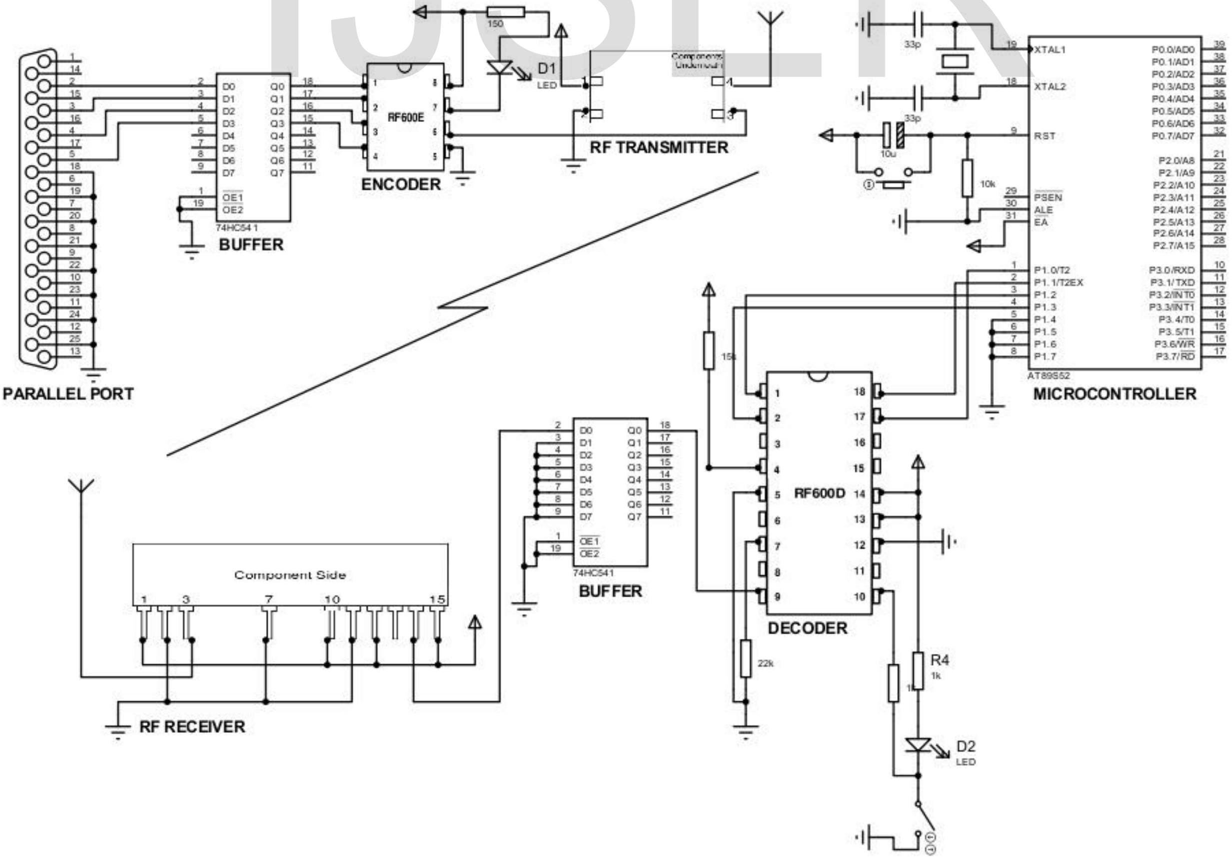


Figure 3.1: Communication Circuit

3.0 Design and Implementation

The communication circuit for the Mobile Robot is a simple but efficient one as shown in Figure 3.1. The parallel port sends the four bit data from the GUI first to the Buffer to prevent sinking current from the computer motherboard, and then to the Encoder to serialize the data in preparation for wireless transmission. With the aid of the RF transmitter module and transmitting antenna, the serialized data is sent over the radio frequency interface and is received by the receiving antenna and the RF receiver module. Next, the Buffer which is employed to boost the received signal sends the serialized data to the Decoder which reconverts the serial data back into parallel data for the micro-controller's use.

However, a learning process must first be carried out in order for the decoder to efficiently interpret the data encoded by the encoder. Thus, the RF600D has the capability to learn up to 7 unique RF600E transmitters, and with the addition of an EEPROM memory device this is increased to 48 RF600E transmitters. The learning process is as follow:

- Press briefly and release the learn switch
- The status LED will illuminate while the switch is pressed and remain on when released.
- Operate the transmitter encoder once, status LED on the decoder will extinguish
- Operate the transmitter encoder a second time, status LED on the decoder will flash
- After the status LED has stopped flashing, the transmitter has been successfully taught to the decoder
- This transmitter will now operate the system

Also, the following process completely erases all transmitter data:

- Press and hold the learn switch on the decoder for 8 seconds
- The status LED will illuminate continuously while the switch is held down and then flash while the decoder erases all memory.
- It may take several seconds until the erase function is complete.

In the course of our implementation and testing, it is observed that even after the learning process, the transmitted data is inverted on the receiver side. For instance, a transmitted four bits data of 1011 will appear as 0100 on the output of the decoder. On further research, we discovered that the RF600E Encoder and RF600D Decoder pair work in that manner, that is, the inversion property of the decoder is intrinsic to their mode of operation. Consequently, we easily handled this development by adjusting our micro-controller codes.

3.1 Implementation of Transmitter Circuit

Considering the need for a dependable circuit, we opted for the use of Printed Circuit Board (PCB) in the circuit implementation. Figure 3.2 below is the PCB layout we designed for the transmitter circuit.

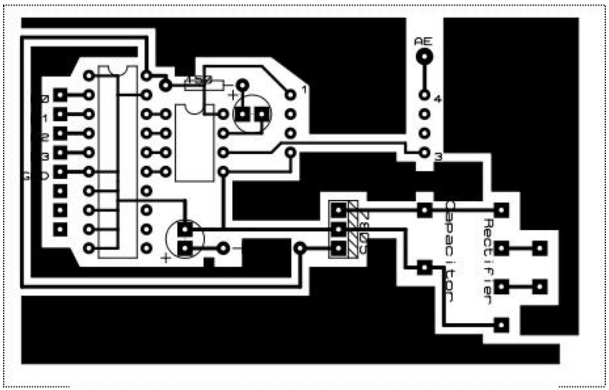


Figure 3.2; PCB Outline for Transmitter Circuit

PCBs are rugged, inexpensive and can be highly reliable. They require much more layout effort and higher initial cost than wire-wrapped or point-to-point constructed circuits. This is not just because of the cost involved in obtaining the PCB software and etching the circuit, but also it takes some patience and effort to obtain the optimal routes in a complex circuit, especially if the routing is done manually. However, the use of PCBs makes for much cheaper and faster high-volume production.

3.3 Implementation of Receiver and Robot Controller Circuit

Figure 3.3 above provides the PCB layout we designed for the receiver and robot controller circuit. Apart from the effort involved in finding the routes for the traces so as to avoid crossing, the outcome was not only a more compact circuit than the wire-wrapped circuit we implemented earlier, but also it resulted in a neat and professional work. The circuit outline was transferred to a copper board using silk screen printing. This technique uses etch-resistant inks (for instance emulsion) to protect the copper foil. Subsequent etching removes the unwanted copper, leaving behind the desired circuit outline.

4.0 Conclusion

In this paper, we have shown how it was possible to realize the communication aspects of our design of the Smart Mobile Robot. The following objectives were seamlessly achieved in our project.

1. A User controls the Mobile Robot with the aid of a Graphic User Interface(GUI)
2. Instructions sent from the GUI pass through the parallel ports of the PC to the Transmitter module
3. A Transmitter sends the instruction to the Mobile Robot over wireless radio frequency
4. A Receiver on the Mobile Robot obtains the instruction sent from the transmitter
5. The images captured on the camera is transmitted back to the remote observer and visualized through the GUI.

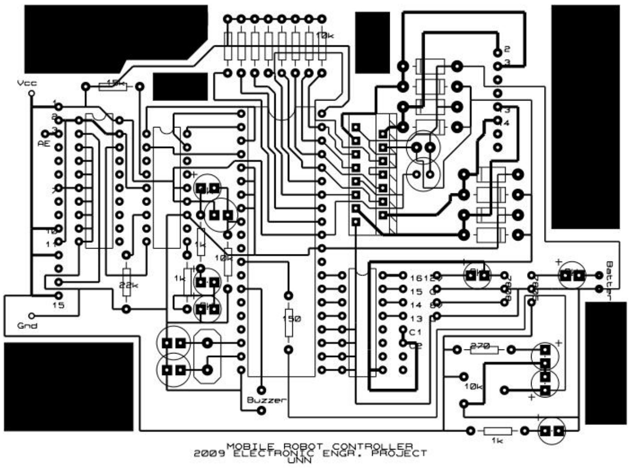


Figure 3.3: PCB Outline for Receiver and Controller Circuit

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