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Mechatronics Based Remote Controlled Agricultural Robot

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ABSTRACT
In this project work an engineering solution to the current human health hazards involved in spraying potentially toxic chemicals in the confined space of a hot and steamy glasshouse or agricultural field is achieved by the design and construction of an autonomous mobile robot for use in pest control and disease prevention applications in commercial greenhouses. For this a mechanical robot is designed. The effectiveness of this platform is shown by the platforms ability to successfully navigate itself down rows of a greenhouse, while the pesticide spraying system efficiently covers the plants evenly with spray in the set dosages.

. A robot which could spray chemicals under grapevine trellis was developed and experimented. From the experimental results, it was observed that the robot system made precise spraying operation and its precise operation record possible. Based on the precise operations and records, an optimum management of chemicals could be expected, that is, necessary amount of chemicals would be sprayed only at necessary considered that this robot would be able to contribute the minimum input maximum output production system by establishment of trace ability system in grape production.

In this regard here is a demo model of such equipment, which performs the operation very effectively. Such types of robots, which are used in the agricultural fields, are called as Agrobots. Here in this module we have designed a robot, which can be controlled by using a remote for spraying the pesticides in the field or greenhouse. By the development of these agrobots lot of manual labor will also be decreased. Here in this project a remote is designed with the help of RF transmitter, which encodes the data to the robot for controlling the movement as well as spraying the pesticide. The robot is equipped with RF receiver, which decodes and controls it. The transmitting and receiving modules are constructed using micro-controllers.

Key Words: Microcontroller, Robot, Agriculture, etc.

1. INTRODUCTION

This project work described here is quite useful in the agricultural fields. The project aims on the design, development and fabrication of the demonstration unit of the project "Remote Controlled Agricultural Robot for Spraying Liquid Type Pesticides."

More than 42% of the total population in the world has chosen agriculture as their primary occupation. In recent years, the development of autonomous vehicles in agriculture has experienced increased interest. This development has led many researchers to start developing more rational and adaptable vehicles. In the field of agricultural autonomous vehicles, a concept is being developed to investigate if multiple small autonomous machines would be more efficient than traditional large tractors and human force. These vehicles should be capable of working 24 hours a day all year round, in most weather conditions and have the intelligence embedded within them to behave sensibly in a semi-natural environment over long periods of time, unattended, while carrying out a useful task.

Moreover, such a system may have less environmental impact if it can reduce over application of chemicals and high usage of energy, such as diesel and fertilizer, by control that is better matched to stochastic requirements. There are a number of field operations that can be executed by autonomous vehicles, giving more benefits than conventional machines.

This project is divided into two modules. One is the transmitting module i.e., the remote and the other is the receiving module i.e., the robot for spraying. The transmitter is built by the controller 89C2051. The data is modulated and transmitted by the RF transmitter. The receiver module is equipped with RF receiver, which will demodulate the received data and feed it to the controller 89C51. The agrobot is quite capable of performing several operations like application of fertilizers and chemicals, harvesting, cultivating, seeding, etc.

In this project work, micro-controller chip is playing a major role, the controller used in this project is ATMEL 89C51, and this is 40pin IC having 32 I/O lines. Nowadays with the advancement of technology in the field of micro-controllers, all the activities in our day-to-day living have become part and parcel of information technology and we find micro-controllers in each and every application. Thus, the trend is directing towards controller based project works. Moreover, for the movement the agrobot, it is designed by using DC motors, which will be driven by the H-bridge IC, depending on the instructions of the micro-controller. As this is a proto type module the distance between the transmitter and the receiver, (i.e., remote and agrobot) which have been connected to each other by RF communication link, the range is restricted (approximately 10-15 feet). While operating for real applications huge power radiating transmitter should be used for longer distances. The required power supply for the module is derived from the battery that is equipped with the agrobot. Here DC motors are preferred as the current consumption will be lesser compared to any other type of motors. The operation and the function of the module are explained in the later chapters.

2. GENERAL DESCRIPTION ABOUT AUTOMATED PESTICIDE VEHICLES

Successful development of multiple small autonomous vehicles calls for a software framework that can handle the complex, dynamic and semi-natural environment specific to agricultural fields. A context for investigating and developing such novel software architecture are set-up. The challenge involves establishing the basis for understanding of desirable agent behaviors; this is done by analyzing and defining

operational tasks to be performed by such a vehicle. The project has:

- Described a framework for formalizing component-based systems in general as illustrated by an agricultural robot.

- A software packages has been extended and tested to embrace the complete analysis of all possible faults in a safety driven design of a robot

Uses for Agricultural Robots

The number or agricultural robots, agrobots, is increasing each year. The jobs they can do are also increasing with new technology in hardware and software. Robots are milking cows, shearing sheep, picking fruit, weeding, spraying, and cultivating, they use GPS and sensors for navigation. The new robots are getting smaller and smarter.

Fungicides: Robots can be used to combat plant diseases that cause a lot of damage to crops. Fungi are the most common causes of crop loss in the entire world. To kill a fungal disease you need a fungicide, a kind of pesticide. Fungal diseases interfere with the growth and development of a crop. They attack the leaves which are needed for photosynthesis and decrease the productivity of the crop and cause blemishes on the crops which makes them worth less on the market. After the crops are harvested fungi can grow and spoil the fruits, vegetables, or seeds. Robots can treat plants that have been infected or destroy them if necessary. They could treat just the plants that need it, instead of covering the entire crop with fungicide.]

Herbicide: Another use for robots is in weeding. Robots can pull weeds from around the plants or just cut the tops off. All of the material can be collected by a robot and brought to a composting site limiting the need for herbicides, chemicals that destroy or inhibit the growth of plants. Herbicides are intended to kill weeds but many times also damage the crops.

Pesticide: Pesticides are used to control insects that can be harmful to crops. They are effective but have many side effects for the environment. Insects also adapt to the toxin in a pesticide and the survivors breed and pass the resistant trait on to the next generation making stronger insects that are harder to kill. Robots could solve this by removing pests from the crops without using chemicals. They might suck them up with a vacuum. A bellow base air system makes a vacuum that doesn't require the large amount of power of regular vacuum systems. There are ways to kill the insects without chemicals. The robot could submerge them in a container with water or into one closed up to produce extreme heat in the sun. Microbial fuel cells could be used to reduce the insects to electrical power with bacteria. Pesticides kill everything. Robots could be programmed to rid particular pests and not harm anything else.

3.BLOCK DIAGRAM AND ITS DESCRIPTION

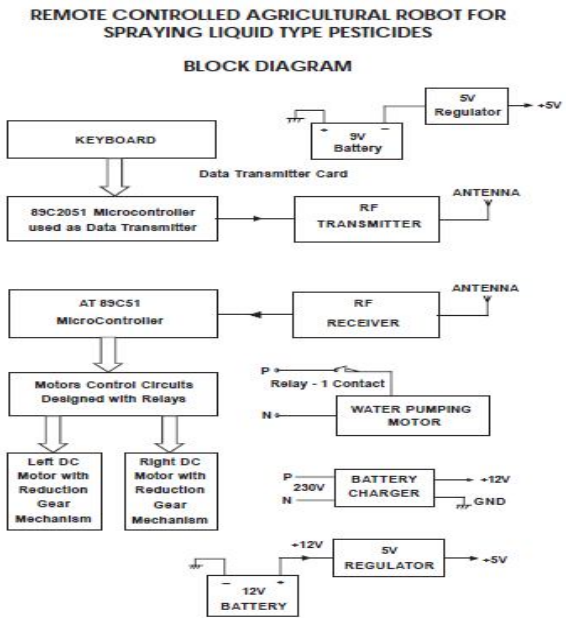

Figure.1

The block diagram and its description of the project work "Remote Controlled Agricultural Robot for spraying Liquid type Pesticides" is explained. The complete block diagram shown at the end of this chapter is divided into various blocks and each block explanation is provided in this chapter. The description is as follows.
The project is divided into 2 modules. They are:

1) Remote. (Transmitter)
2) Agrobot. (Receiver)

The transmitter i.e., remote is built by using Key-board, which is interfaced with the controller 89c2051. The RF transmitter will transmit the data that is given by the controller.

The receiver i.e., agrobot is designed by DC motors for the movement of the robot, RF receiver in order to receive the data, Controller to decode it, H-bridge to run the DC motors and relay to operate the motor for spraying the pesticide.

3.1 KEY BOARD

There are 6 keys in the remote for controlling the agrobot. This is interfaced to the controller. The operation of the keys is:

1) Forward
2) Reverse
3) Left turn
4) Right turn
5) Spraying
6) Stop.

3.2 MICRO CONTROLLER

Depending on the key pressed the controller will be transmitting the data. Here in this project we are using two micro controllers. One is 89C2051 used in the transmitter and the second one is 89C51 used in the receiver. The controllers play a major role in the project, there by the following description mainly focuses about Micro controller and its architecture, because it is treated as heart of the project work. Today, there is no such instrument that can function without Micro controller. Micro controllers have become an integral part of all instruments. Many tedious from simple to dedicated tasks are left over to the controller for solutions. The Micro controller used in this project work is ATMEL 89C51, basically this IC belongs to 8051 family. In1981, Intel Corporation introduced an 8- bit Micro controller, which is named as 8051. This controller is having 128 bytes of RAM, 4K bytes of ROM, two timers, one serial port, and four ports. This IC is called as 8- bit Processor, means that the CPU can work on only 8-bits of data at a time. The 8051 is having four ports and each port contain 8 input / output lines. This IC became very popular after Intel allowed other manufacturers to make and market any flavors of the 8051 they please with the condition that they remain code compatible with the 8051. This has led to many versions of the 8051 with different speeds and amounts of on-chip ROM marketed by many manufacturers. ATMEL is one of the major manufacturers of these devices and are compatible with the original 8051 as far as the instructions are concerned. The original 8051 of Intel are having a maximum of 64K bytes of on-chip ROM, whereas the ATMEL 89C2051 is having only 2K bytes on the chip. ATMEL 89C51 is designed with 4K memory, like wise up to 20K bites on the chips are available from ATMEL Company. The Atmel Corporation has a wide selection of 8051 chips and out of, the AT 89C51 is a popular and inexpensive chip used for many applications. It has 4K bytes of flash ROM; 'C' stands for 'CMOS', which has low power consumption.

The ATMEL AT89C51 is a low power, higher performance CMOS 8-bit

microcomputer with 4K bytes of flash programmable and erasable read only memory (PEROM). Its high-density non-volatile memory compatible with standard MCS-51 instruction set makes it a powerful controller that provides highly flexible and cost effective solution to control applications.

Micro-controller works according to the program written in it. Most microcontrollers today are based on the Harvard architecture, which clearly defined the four basic components required for an embedded system. These include a CPU core, memory for the program (ROM or Flash memory), memory for data (RAM), one or more timers (customizable ones and watchdog timers), as well as I/O lines to communicate with external peripherals and complementary resources all this in a single integrated circuit. A microcontroller differs from a general-purpose CPU chip in that the former generally is quite easy to make into a working computer, with a minimum of external support chips. The idea is that the microcontroller will be placed in the device to control, hooked up to power and any information it needs, and that's that.

A traditional microprocessor won't allow you to do this. It requires all of these tasks to be handled by other chips. For example, some number of RAM memory chips must be added. The amount of memory provided is more flexible in the traditional approach, but at least a few external memory chips must be provided, and additionally requires that many connections must be made to pass the data back and forth to them.

For instance, a typical microcontroller will have a built in clock generator and a small amount of RAM and ROM (or EPROM or EEPROM), meaning that to make it work, all that is needed is some control software and a timing crystal (though some even have internal RC clocks). Microcontrollers will also usually have a variety of input/output devices, such as analog-to-digital converters, timers, UARTs or specialized serial communications interfaces like I²C, Serial Peripheral Interface and Controller Area Network. Often these integrated devices can be controlled by specialized processor instructions.

Originally, microcontrollers were only programmed in assembly language, or later in C code. Recent microcontrollers integrated with on-chip debug circuit accessed by In-circuit emulator via JTAG (Joint Text Action Group) enables a programmer to debug the software of an embedded system with a debugger.

3.3 RF TRANSMITTER

The encoded data from the controller is fed to the RF transmitter in order to transmit. The purpose of a transmitter is to modulate the data. To establish a communication link between the remote and the agrobot RF is used. We are having different types of communication links like IR, FM, etc. The IR (Infra-Red) is restricted to shorter distance only and more over both the transmitter and the receiver should be in the "Line of Sight." That is the transmitter and the receiver both should be facing each other. And FM is preferred for transmitting audio signals. As the range of FM is low (88 MHz-108MHz) lot of noise signals are present.

3.4 Need for Modulation:

Modulation is nothing but generating of carrier signal and superimposing that with the data signal (or) changing the characteristics of the data signal with respect the carrier signal. Direct data can also be transmitted. But as that is transmitted in the free space and covering distance, the signal will become week. And in the space we will have lot of frequency signals. Now whenever the data signal becomes week

external frequency signals may be added with the data signals. By that we may not receive exact data in the receiver or some of the data may be lost. To prevent that we go for modulation techniques in which the carrier signal will be generated and will be acting like a protective layer to the data signal. Generally the carrier signal will be enormously very much greater than the data signal.

3.5 DC MOTORS

The DC motors to be operating they require 12v dc. So we cannot operate them directly from the micro controller why because the maximum voltage that we give to the controller is +5v. For that reason the DC motors will be operated by using H-bridge IC, which will be controlled by the micro controller.

3.6 RELAY

A relay is nothing but automatic electronic switch. It does the operation just like a switch, but will be done automatically depending on theinstructions of the controller. Here the relay is used to operate the AC motor that is used to spray the pesticide. And more over we have different types of relays i.e., SPDT (Single Pole Double Throw), DPDT (Double Pole Double Throw), etc.. Here in this module we are using SPDT.

3.7 POWER SUPPLY

This is an important block why because all the components require power supply to be operating. Micro controller requires +5v, relay and DC motors require +12v. In the transmitter a 9v battery is used and a voltage regulator in order to derive the required power supply for the micro controller i.e., 5v. And in the receiver as we require a maximum of 12v we are using a 12v battery to operate the relay and the DC motors. Again voltage regulator is used to derive 5v DC.

4. CIRCUIT DIAGRAM AND ITS DESCRIPTION

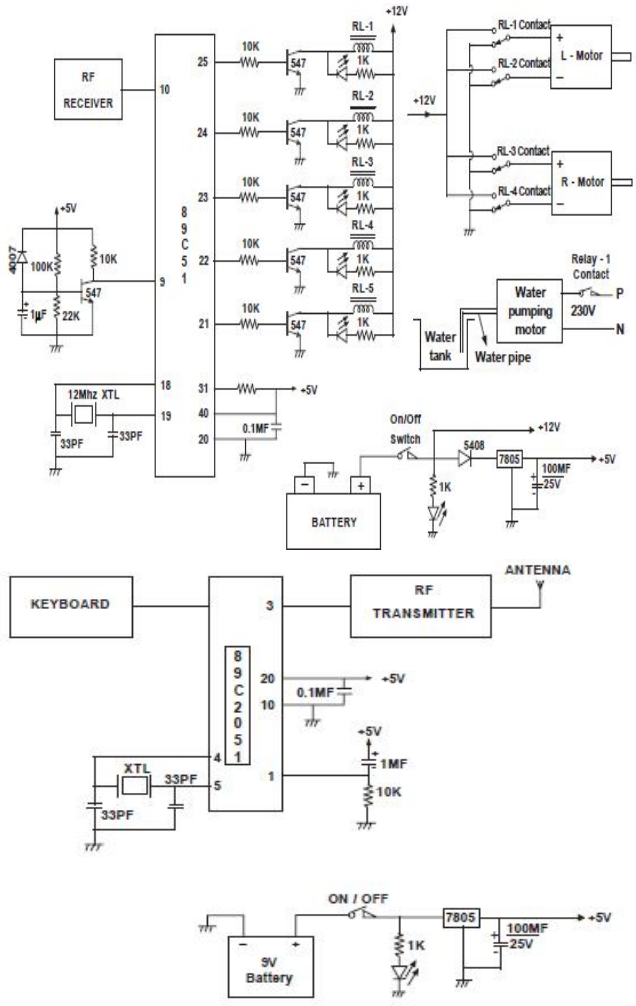

Figure 2

The complete circuit diagram shown at the end of this chapter is to be referred always to understand the following description. As explained in the block diagram this project is divided into two modules i.e., the transmitter and the receiver (agrobot). The transmitter i.e., the remote has been equipped with Keyboard and RF transmitter, which have been interfaced using micro-controller 89C2051. There are 6 keys for controlling the robot. 4 keys are used for the direction control i.e., moving forward, backward, right turn and left turn. And the rest of the 2 keys are used to stop the agrobot and to spray the pesticide.

When a key is pressed in the keyboard, the controller receives a signal. By that the controller encodes the data to the RF transmitter, which will be transmitted from the antenna in the form of electro-magnetic waves in all the directions. The controller that we are using here in the transmitter is Atmel 89C2051 which 20 pin IC. And is having 2kb of flash memory. In this we are having 2 I/O ports (Input/Output). Each port is having 8 pins. The pin description and the configuration of the chip is explained in the hardware details.

4.1 RF TRANSMITTER

Depending on the key pressed the controller encodes the data to the RF transmitter where the data will be modulated and transmitted. The RF transmitter is a three-pin module in which first is the input that is connected to the micro controller and the next two pins are Vcc and ground respectively. This is an in-built module, which is available in the market. The specifications of the module are as follows:

1) Working Voltage : 3 – 12 V
2) Dimension : 22mm x 23mm
3) Working Current : 10 – 15 mA
4) Working Mode : AM
5) Transmitting Speed : 4 KB / Sec
6) Transmitting Frequency : 315 / 433 MHz
7) Transmitting Power : 10mW
8) External Antenna : 315 MHz

And coming to the receiving end i.e., the agrobot that is equipped with RF receiver, which will be demodulating and the data will be given to micro controller for decoding. The controller used here is 89C51, which is having 4KB flash memory. This is a 40 pin IC having 4 I/O ports. The controller will be decoding the received data from the RF receiver. Depending on the data received, the controller will be operating the DC motors with the help of H-bridge IC. By using a single H-bridge IC we can drive two DC motors. We can drive the Dc motors by using the relays and transistors. But the complexity of the circuitry will be increased. For that reason we prefer H-bridge IC here in our module.

4.2 L293D “H” BRIDGE

The motor driver package L293D is interfaced with 89C51 microcontroller through IN1 to IN4 of H Bridge (L293D). Both the enable pins (EN1 and EN2) of motor driver L293D is combined together and fed to controller to access the command signals. Depending up on the command signals issued by the controller, the enable pins are activated to control all the four internal drivers of L293D respectively to drive two geared DC motors. Hear H Bridge is required, because the microcontroller output is not sufficient to drive the DC motors, so current drivers are required for motor rotation.

The L293D is a quad, high current, half-H driver designed to provide bidirectional drive currents of up to 600mA at voltages from 4.5V to 36V. It makes it easier to drive the DC motors. The L293D consists of four drivers. Pins IN1 through IN4 and OUT1 through OUT4 are input and output pins, respectively, of driver 1 through driver 4. Drivers 1 and 2, and drivers 3 and 4 are enabled by enable pin 1 (EN1) and pin 9 (EN2), respectively. When enable input EN1 (Pin1) is high, drivers 1 and 2 are enabled and the outputs corresponding to their inputs are active. Similarly, enable input EN2 (Pin9) enables drivers 3 and 4.

The DC motors that we are using here require a power supply of 12v and a current of approximately 150milli-amps for one Dc motor. That is derived from the battery. The detailed description about the DC motors is explained in the later chapters.

4.3 RF RECEIVER

As explained in the block diagram the RF receiver will be demodulating the received signal. The demodulated output will be the actual data signal i.e., original signal that is transmitted from the transmitter. The RF receiver consists of 3 pins. First is ground, second is the output, which is connected to the micro controller and the third, is the Vcc. The specifications of the RF receiver are as follows:

1) Receive Sensitivity : -95 dbm
2) Working Voltage : 5v
3) Dimension : 37mm x 16 mm
4) Receive Frequency : 315 / 433MHz
5) External Antenna : 18 – 25 cm
6) Receive Speed : 4 KB / Sec
7) Working Temperature : -10 to +70 degrees
8) Working Current: 0.5 – 0.8 mA.

4.4 RELAY

In this project the relay is used to operate the AC motor for spraying of the pesticide. The relay will have the following terminals:

1) Coil
2) Pole
3) Normally Closed Contact (N/C)
4) Normally Open Contact (N/O)

Pole is the input terminal and N/C, N/O are the output terminals. As mentioned in the block diagram it's an automatic electronic switch. Means a switch is either used to make a circuit or break a circuit. But the relay is doing the same operation automatically, depending on the controller instructions. The figure of the relay is shown below.

5.DC MOTORS – AN OVER VIEW

Permanent magnet DC motor responds to both voltage and current. The steady state voltage across a motor determines the motor's running speed, and the current through its armature windings determines the torque. Apply a voltage and the motor will start running in one direction; reverse the polarity and the direction will be reversed. If you apply a load to the motor shaft, it will draw more current, if the power supply does not able to provide enough current, the voltage will drop and the speed of the motor will be reduced. However, if the power supply can maintain voltage while supplying the current, the motor will run at the same speed. In general, you can control the speed by applying the appropriate voltage, while torque is controlled by current. In most cases, DC motors are powered up by using fixed DC power supply, therefore; it is more efficient to use a chopping circuit.

Principles of operation

In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. As you are well aware of from playing with magnets as a kid, opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion.Let's start by looking at a simple 2-pole DC electric motor (here dark black represents a magnet or winding with a "North" polarization, while light colour

represents a magnet or winding with a "South" polarization).

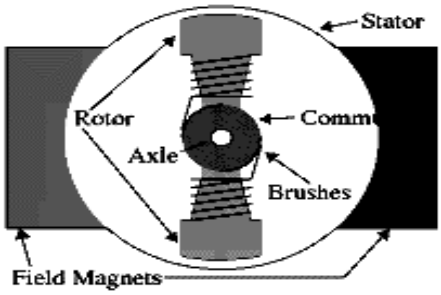

Figure.3

Every DC motor has six basic parts axle, rotor (a.k.a., armature), stator, commutator, field magnet's, and brushes. In most common DC motors, the external magnetic field is produced by high-strength permanent magnets. The stator is the stationary part of the motor -- this includes the motor casing, as well as two or more permanent magnet pole pieces. The rotor (together with the axle and attached commutator) rotates with respect to the stator. The rotor consists of windings (generally on a core), the windings being electrically connected to the commutator. The above diagram shows a common motor layout -- with the rotor inside the stator (field) magnets.In real life, though, DC motors will always have more than two poles. In particular, this avoids "dead spots" in the commutator. You can imagine how with our example two-pole motor, if the rotor is exactly at the middle of its rotation (perfectly aligned with the field magnets), it will get "stuck" there. Meanwhile, with a two-pole motor, there is a moment where the commutator shorts out the power supply (i.e., both brushes touch both commutator contacts simultaneously). This would be bad for the power supply, waste energy, and damage motor components as well. Yet another disadvantage of such a simple motor is that it would exhibit a high amount of torque "ripple" (the amount of torque it could produce is cyclic with the position of the rotor).

6. DETAILED DESCRIPTION ABOUT 89C51

Intel Corporation introduces 89c51; it is an 8-bit micro controller. This micro controller has 128 bytes of RAM, 4K of on-chip ROM, two timers, one serial port, and four ports of 8-bits each all on a single chip. 89c51 is basically Flash ROM version of 8051 families. 89c51 is basically a 40 pin Dual-in-package. Block diagram of 89c51 is as shown in chapter-10, i.e., hardware details. The main features of 89c51 Hardware can be labeled as below:

1. It has 8-bit CPU with registers A (the accumulator) and B.
2. Sixteen-bit program counter (PC) and data pointer (DPTR).
3. Eight-bit program status word (PSW).
4. Eight-bit stack pointer (SP).
5. Internal ROM of 0 to 4K.
6. Internal RAM of 128 bytes.
7. 32 I/0 pins arranged as four 8-bit ports: P0-P3
8. Two 16-bit Timer/Counters: T0 and T1
9. Full duplex serial data receiver/transmitter: SBUF
10. Control registers: TCON, TMOD, SCON, PCON, IP, and IE.
11. Two external and three internal interrupt sources.
12. Oscillator and Clock circuits.

6.1 DETAILED DESCRIPTION OF 'H' BRIDGE

Basic Theory

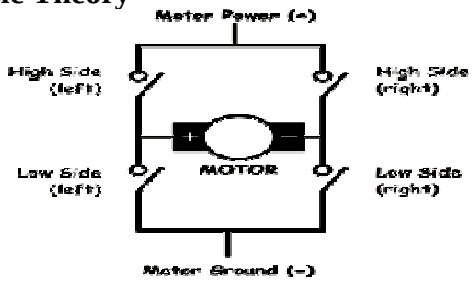

Figure.4

Let's start with the name, H-bridge. Sometimes called a "full bridge" the H-bridge is so named because it has four switching elements at the "corners" of the H and the motor forms the cross bar. The basic bridge is shown in the figure above. The key fact to note is that there are, in theory, four switching elements within the bridge. These four elements are often called, high side left, high side right, low side right, and low side left (when traversing in clockwise order).

The switches are turned on in pairs, either high left and lower right, or lower left and high right, but never both switches on the same "side" of the bridge. If both switches on one side of a bridge are turned on it creates a short circuit between the battery plus and battery minus terminals. If the bridge is sufficiently powerful it will absorb that load and your batteries will simply drain quickly. Usually however the switches in question melt.

High Side Left	High Side Right	Low Side Left	Low Side Right	Quadrant Description
On	Off	Off	On	Forward Running
Off	On	On	Off	Backward Running
On	On	Off	Off	Braking
Off	Off	On	On	Braking

In the above table the last two rows describes condition about short circuit the motor which causes the motors generator effect to work against itself. The turning motor generates a voltage which tries to force the motor to turn the opposite direction. This causes the motor to rapidly stop spinning and is called "braking" on a lot of H-bridge designs. Of course there is also the state where all the transistors are turned off. In this case the motor coasts freely if it was spinning and does nothing if it was doing nothing.

1. Using Relays: A simple implementation of a H Bridge using four SPST relays is shown. Terminal A is High Side Left, Terminal B is High Side Right, Terminal C is Low Side Left and Terminal D is Low Side Right. The logic followed is according to the table above.

2. Using Transistors: We can better control our motor by using transistors or Field Effect Transistors (FET's). Most of what we have discussed about the relays H-Bridge is true of these circuits. See the diagram showing how they are connected. We should add diodes across the transistors to catch the back voltage that is generated by the motor's coil when the power is switched on and off. This fly back voltage can be many times higher than the supply voltage.Don't turn on A and C or B and D at the same time.

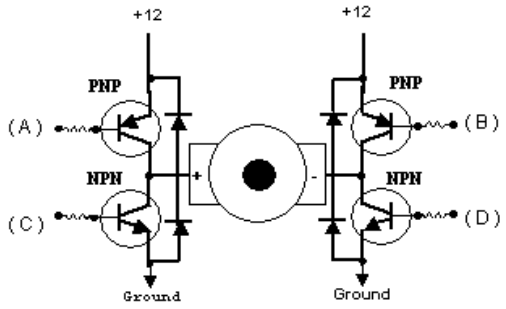

Figure.5

Transistors, being a semiconductor device, will have some resistance, which causes them to get hot when conducting much current. This is called not being able to sink or source very much power, i.e.: Not able to provide much current from ground or from plus voltage.Mosfet's are much more efficient, they can provide much more current and not get as hot.

To use Mosfet's in an H-Bridge, we need P-Channel Mosfet's on top because they can "source" power and N-Channel Mosfet's on the bottom because they can "sink" power. It is important that the four quadrants of the H-Bridge circuits be turned on and off properly. When there is a path between the positive and ground side of the H-Bridge, other than through the motor, a condition exists called "shoot through". This is basically a direct short of the power supply and can cause semiconductors to become ballistic, in circuits with large currents flowing. There are H-bridge chips available that are much easier, and safer, to use than designing our own H-Bridge circuit.

7. ADVANTAGES

- Avoid the former being exposed to toxic pesticide vapours produced during spraying.
- Reduce the workload on the farmer and as it is easier to operate.
- The former need not spry in the hot sun, he can operate the device while standing in a cooler place.
- By the development of these agroboats lot of manual labor will also be decreased and the farmer life will save from chemicals.

Figure 6: Experimental setup of Agro boat

8. CONCLUSION

- The robot for agricultural purpose an Agrobot is a concept for the near the performance and cost of the product once optimized, will prove to be work through in the agricultural spraying operations.
- We have been successful in developing a robot whose construction is enough to withstand the challenges of the field.
- We are sure that once this concept is presented in a manner suitable to Indian market, it will diffenetaly help in bringing down the 15% molality rate found in the Indian formers associated with the agricultural spraying operation

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