ELECTROENCEPHALOGRAPHY AND MEMS BASED HYBRID MOTION CONTROL SYSTEM

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Abstract- The brain has billions of neurons working in unison, all activities of the brain ranging from regular motions and emotions are generated and transmitted as electrical signals (electric discharge), which cannot be measured by the current technology, however when thousands of neurons collectively concentrates on a particular activity these electric discharges cumulate to form waves that can be measured, these waves provide information about the brain state and current level of activity, this paper shall discuss on how these waves can be tapped and used in motion control of a mind controlled robot. There are different means to capture these mind activities, one technique is Electroencephalography (EEG). The EEG sensors are capable of picking up brain activity signals from the scalp and transmit them as understandable signals to any suitable device. The paper also aims to combine the above concept with MEMS (Micro-Electro-Mechanical Systems) accelerometers to attain further ease of control and accuracy. For safety concerns an obstacle avoiding algorithm is also implemented, using ultrasonic sensors to avoid collisions in case of any malfunction of the EEG or MEMS systems.

Keywords- EEG; MEMS; Embedded C; LED; Ultrasonic Sensor; Microcontroller

I. INTRODUCTION

The proposed robot is entitled to record and process the brain activity as well as the position of the MEMS accelerometer and reflect it as per the requirement, the main aim of this project is to create a Low cost yet effective motion assist for the physically disabled individuals, the following design can be implemented on an assistive unit like a wheelchair. This will be most helpful for the individuals suffering from illness like quadriplegia, orAmyotrophic lateral sclerosis (ALS). In few cases there is a need for continuous recording and access of brain activity of the patient, the sensing unit of the project can be effectively put to use under such circumstances. Insomnia or sleep deprivation is one of the most common problems among today's working class, this brain wave monitor can also be used to record the brain activity of such patients and help to suggest a suitable diagnosis. Another area in which the same concept can be implemented to a great extent is road safety, a large deal of highway accidents are due to dozing drivers, this mind sensing device can continuously monitor the brain activity and in case any abnormalities is detected a corrective or protective action shall triggered.

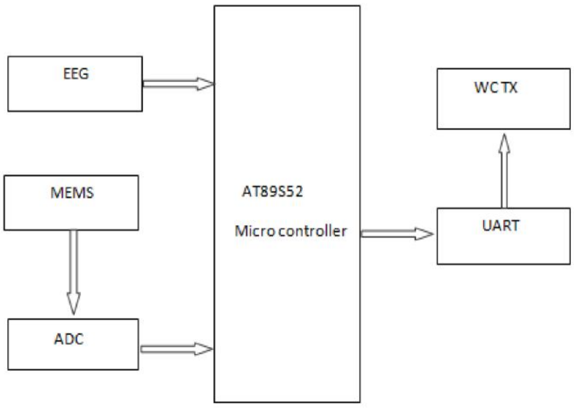
The Mind Control Robot involves obtaining brain electric activity. Research shows that different pattern of neural interactions in brain results in different brain states. These interaction results in different patterns of waves among them following waves are the most important for determining attention and meditation.
1. Theta Waves (frequency 4-7 Hz): These waves are associated with drowsiness.
2. Alpha Waves (frequency 8-13 Hz): These waves are associated with mediation and relaxation and are present during wakeful relaxation.
3. Beta Waves (frequency 14-30 Hz): These waves are associated with active, busy or anxious thinking.

There are different techniques that can be used to obtain these waves. However the Electroencephalography (EEG) technology was used in this project. The EEG provides non-invasive technique of monitoring electric activity in space and time. The signal obtained from EEG sensor is one of the most reliable psychological indicators to measure the level of alertness. The EEG sensor comprises of electrodes which make contact to scalp and forehead. The presence of hair hinders access to large portion of the scalp which results in weak EEGSignal. The quality of EEG signal can be affected by muscle movement and excessive environmental electrostatic noise. The signal obtained from EEG sensor is processed by a microcontroller. The microcontroller makes important decisions in determining the direction of motion of the robot. The motion of robot is supported by 3 wheels. Two of these wheels are driven by DC motors controlled by the microcontroller. The robot avoids obstacles by measuring distance of the nearest object close to robot in real time. It also detects and stops moving on the edge of surface it is moving on.

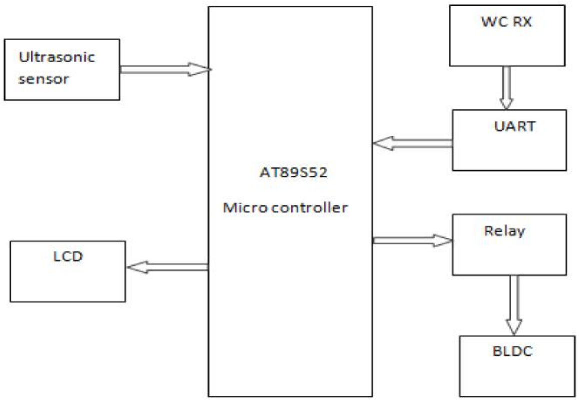
The MEMS accelerometer is a device that can detect the positioning and movement along three dimensions (x,y,z), and these co-ordinates can be recorded and used to fine tune the motion control system along with the EEG unit.

II. DESIGN CONSIDERED

The project comprises of multiple units, the main goal of the project is to implement and showcase the aforementioned capabilities, the entire system is divided into two major units the receiver unit and the transmitter unit. There are many subsystems present in each of these units as shown in figure 1.



Transmitter



Receiver

Fig. 1. Basic Units of the System

On the whole the entire system can be broadly classified into four major parts which are interleaved within the above mentioned transmitter and receiver units,, these four subsystems and their desired functions are as follows (refer Figure 2)

1. Mind Activity Monitoring System: This system records electric activity in the brain using an EEG sensor. The main goal of this system is to perform signal processing on the raw signal obtained. This is achieved by filtering the original signal by passing through multiple band-pass filters. These filters then output Alpha, Beta and Theta waves. These waves are then input to an analog-to-digital converter and are digitized. Further processing is performed on digital Alpha, Beta and Theta waves and the values of attention and meditation levels are extracted. The digitized EEG signal, Alpha, Beta and Theta waves along with attention and meditation level are arranged in discrete data packets. These packets are serially transferred to the Processing System.

2. Processing System: This system acts as the brain of the robot. It communicates with all other subsystems and initializes them. The desired function of this system is to obtain digitized EEG signal including attention and meditation level from Mind Activity Monitoring System and determine the direction and motion of the robot. The motion and direction data is then output to Motion Control System. This system verifies functionality of other systems on reset and notify user if there are any errors. This system is also responsible for detecting any obstacles in the path of motion. It changes the direction of the robot if it detects an edge of surface it is moving on or any obstacle in its path.

3. Motion Control System: This system is responsible to control the motion of the robot. The desired function of this system is to take digital information pertaining to robot motion and direction from the Processing System and move the robot accordingly.

4. User Interface (UI) System: The goal of this system is to provide essential functions to user to control the operation of the Mind Control Robot. It displays mind attention or mediation level on an array of LEDs. User can change the mode of operation using input peripherals of the UI system. This system informs the user when the mode of operation is changed and also alert user if an error has occurred.

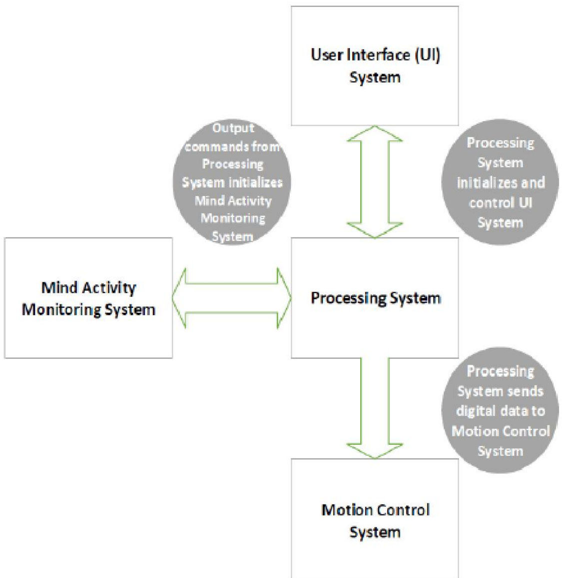


Fig. 2. Interconnected subsystems

Each subsystem is individually designed and tested. A comprehensive part evaluation for each subsystem was performed and suitable components were chosen which are reliable and also cost-effective. The components of each subsystem and their functions are:

A. EEG Sensor

This component is essential part of Mind Activity Monitoring System. Traditional EEG sensors are expensive and their use is only limited to hospitals and laboratories. The electrodes of traditional EEG sensors require using conductive gel to facilitate reading of the signals. For this project portable EEG brainwave headset from NeuroSky was used. NeuroSky, Inc. is a manufacturer of Brain-Computer Interface (BCI) technologies for consumer product applications [4].

Neurosky's Hardware uses a dry active sensor technology to read brain signals. This doesn't require conductive gel on the skin in order to record brain electric activity. For this reasons, headset based on Neurosky technology are cost-effective and easy to handle.

Neurosky offers three headsets for recording brain signals: Mind-set, Mind Wave and Mind Play Band. These three headsets were compared in order to determine suitable headset for this project.

The major difference between these three headsets is that Mind Wave uses RF transmitter and receiver to transmit EEG signal while other two use Bluetooth. The NeuroSky's Mind wave is cost effective and was chosen for Mind Activity Monitor System.

B. Microcontroller

The microcontroller used for this project is an embedded C compatible AT89S52 microcontroller, The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory.

The device is manufactured using Atmel's high-density non-volatile memory technology and is compatible with the Indus-try-standard 80C51 instruction set and pin out.

The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory pro-grammars. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry.

In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM con-tents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

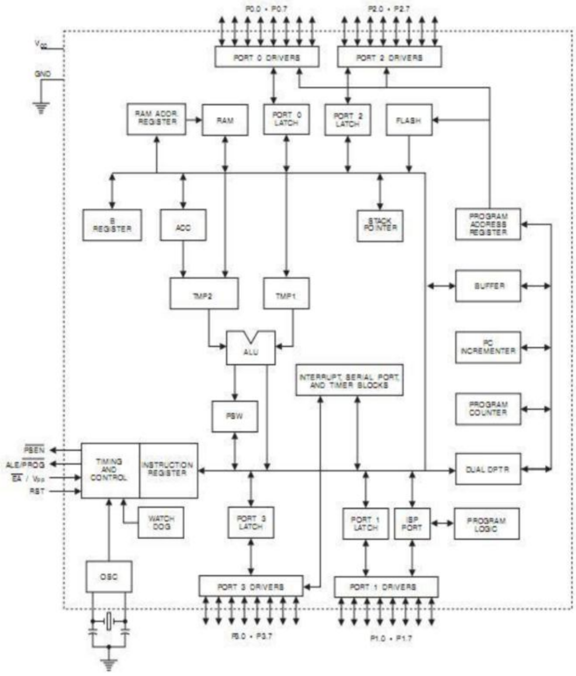


Fig. 3. Architecture of AT89S52

C. UART – Receiver and Transmitter

A universal asynchronous receiver/transmitter is a type of "asynchronous receiver/transmitter", a piece of computer hardware that translates data between parallel and serial forms.

A UART is usually an individual (or part of an) integrated circuit used for serial communications over a computer or peripheral device serial port. UARTs are now commonly included in microcontrollers. A dual UART or DUART combines two UARTs into a single chip. Many modern ICs now come with a UART that can also communicate synchronously; these devices are called USARTs.

The Universal Asynchronous Receiver/Transmitter (UART) controller is the key component of the serial communications subsystem of a computer. The UART takes bytes of data and transmits the individual bits in a sequential fashion.

At the destination, a second UART re-assembles the bits into complete bytes. Serial transmission of digital information (bits) through a single wire or other medium is much more cost effective than parallel transmission through multiple wires.

A UART is used to convert the transmitted information between its sequential and parallel form at each end of the link. Each UART contains a shift register which is the fundamental method of conversion between serial and parallel forms.

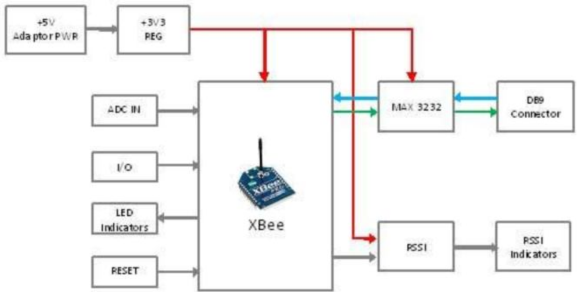


Fig. 4. ZigBee UART Module

D. BLDC

Brushless DC motors are high efficiency motors which are used across a wide variety of applications. These motors require more robust control algorithms then their brushed DC counterpart. BLDC motors are synchronous motors that require a 3-phase AC signal to drive them.

Brushless DC motors are becoming more common in a variety of motor applications such as fans, pumps, appliances, automation, and automotive drive. The reasons for their increased popularity are better speed versus torque characteristics, high efficiency, long operating life, and noiseless operation. In addition to these advantages, the ratio of torque delivered to the size of the motor is higher, making it useful in applications where space and weight are critical factors. The stator of a BLDC motor is similar to that of an induction machine but the windings are distributed quite differently. The stator windings can be seen on the outside ring of figure 1. The two different common distributions of the windings are distributed and sinusoidal. A distributed winding will have a trapezoidal back EMF while a sinusoidal winding will have a sinusoidal back EMF.This application note will focus on BLDC motors with distributed stator windings. The rotor of a brushless DC motor is different in the fact that the rotor contains permanent magnets instead of additional windings. This is represented by the north and south poles.

Unlike a brushed DC motor, the commutation of a BLDC motor in controlled electronically. To rotate the BLDC motor, the stator windings should be energized in a sequence. In order to make sure the motor controller is energizing coils in the correct sequence; Hall Effect sensors must be used to detect the position of the rotor in the motor. When the rotor is spinning inside the motor either a North or South Pole will pass by the Hall Effect sensors which will cause the sensor to output which section of the rotor is passed.

E. Ultrasonic Sensor

The Parallax PING))) ultrasonic distance sensor provides precise, non-contact distance measurements from about 2 cm (0.8 inches) to 3 meters (3.3 yards). It is very easy to connect to BASIC Stamp® or Javelin Stamp microcontrollers, requiring only one I/O pin. The PING))) sensor works by transmitting an ultrasonic (well above human hearing range) burst and Providing an output pulse that corresponds to the time required for the burst echo to return to the sensor. By measuring the echo pulse width the distance to target can easily be calculated.

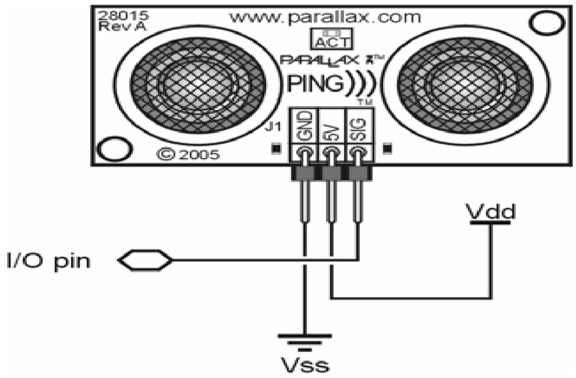


Fig. 5. Ultrasonic sensor

F. MEMS Gyroscopes

A gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. In essence, a mechanical gyroscope is a spinning wheel or disk whose axle is free to take any orientation. Although this orientation does not remain fixed, it changes in response to an external torque much less and in a different direction than it would without the large angular momentum associated with the disk's high rate of spin and moment of inertia. Since external torque is minimized by mounting the device in gimbals, its orientation remains nearly fixed, regardless of any motion of the platform on which it is mounted.

The LPY4150AL is a low-power dual-axis micro machined gyroscope capable of measuring angular rate along pitch and yaw axes. It provides excellent temperature stability and high resolution over an extended operating temperature range (-40 °C to +85 °C). The LPY4150AL has a full scale of ±1500 dps and is capable of detecting rates with a -3 Db bandwidth up to 140 Hz. The device includes a sensing element compose of a single driving mass, kept in continuous oscillation and capable of reacting, based on the Coriolis principle, when an angular rate is applied. A CMOS IC provides the measured angular rate to the external world through an analogy output voltage, allowing high levels of integration and production trimming to better match sensing element characteristics. ST's family of gyroscopes leverages on the mature and robust manufacturing process already used for the production of micro-machined accelerometers. ST is already in the field with several hundred million sensors which have received excellent acceptance from the market in terms of quality, reliability and performance. The LPY4150AL is available in a plastic land grid array (LGA) package, which ST successfully pioneered for accelerometers. Today ST has the widest manufacturing capability and strongest expertise in the world for production of sensors in plastic LGA packages.

G. Software

The code is written using embedded C and compiled using the Kiel compiler, the code takes care of the transmission and receiving modules and sends control signals to the motor drivers, the conditions are specified based on predefined values of EEG and MEMS sensor readings pertaining to brain activity that is to be measured and MEMS co-ordinates, the entire system is operated with a continuous clock cycle that sync the ZigBee modules.

III. FINAL DESIGN

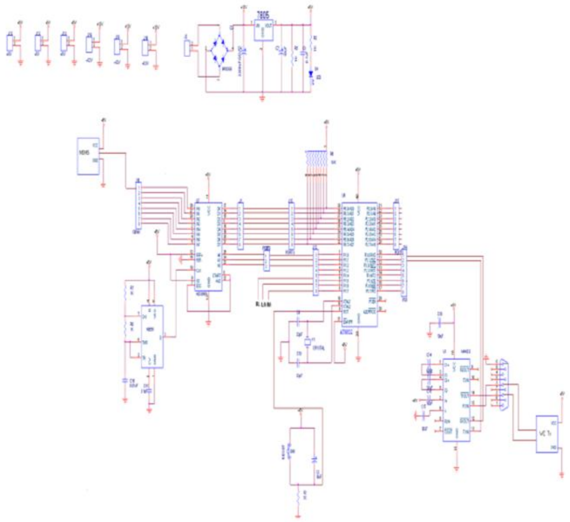


Fig. 6. Final circuit for Transmission module

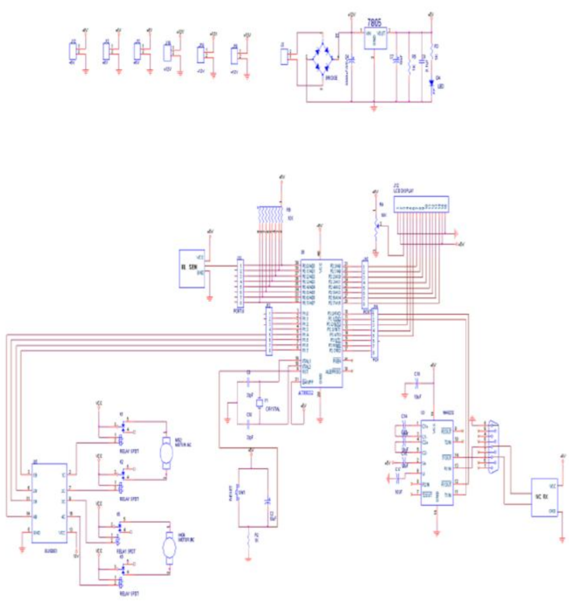


Fig. 7. Final circuit for receiving module

The final design comprises of all the above mentioned devices, each unit is implemented and tested individually, The robot senses the input from EEG, MEMS and Ultrasonic sensor, and the data is interpreted in the appropriate format and processed using the Embedded C code burnt in the microcontroller. The transmission is done using a wireless ZigBee UART transmitter which contains an interfaced RX232 IC. The EEG probes are places on either side of the fore head and on the upper neck which shall act as the reference voltage. The processing unit then communicates with Mind activity monitor system, obtains mind attention and meditation levels and scales them down to accordingly control the robot and display a message on the interfaced LED display.

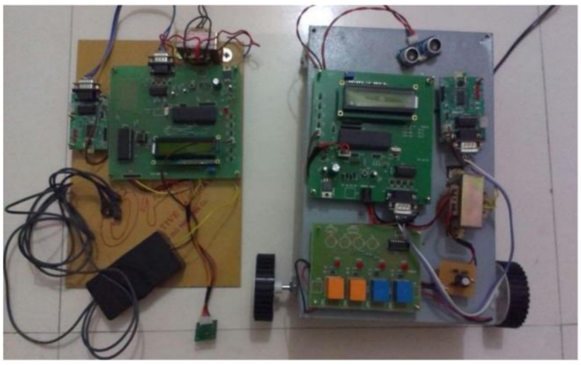


Fig. 8. Final Hardware

CONCLUSION

The design of the overall system for mind control robot is divided into small subsystems that were designed and tested independently using computer models of the other subsystems. The computer model generates stimulus input values to the subsystem under test.

The presented system records electric activity of the brain and the robot moves according to mind attention or mediation level depending on the mode of operation. The motion is also controlled using the MEMS gyroscopes. And a safety feature of obstacle detection and avoidance was also implemented.

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