A Portable Epilepsy System with Android Alert

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Abstract: **-Epilepsy is a neurological disorder characterized predominantly by an enduring predisposition to generate epileptic seizures. The apprehension about injury, or even death, resulting from a seizure often overshadows the lives of those unable to achieve complete seizure control. Moreover, the risk of sudden death in people with epilepsy is 24 times higher compared to the general population and the pathophysiology of sudden unexpected death in epilepsy (SUDEP) remains unclear. This thesis describes the development of a wearable electro dermal activity (EDA) and accelerometer Epilepsy is a neurological disorder characterized predominantly by an enduring predisposition to generate epileptic seizures. We present the design of sensor nodes for humanposture tracking purposes. Each sensor node is equipped with amicrocontroller, an RF transceiver chip and two sensors: a 3Daccelerometer and a 3D magnetometer. Based on the signals ofthese sensors, the orientation of a sensor node can be estimated.Combining several of these nodes into a sensor network, allowsfor complete human posture tracking, as the human body canbe approximated as a rigid body consisting of 15 links. We present a novel method for monitoring sympathetic nervous system activity during ep A). ileptic seizures using a wearable sensor measuring electro dermal activity (EDThe wearable sensor enables long-term, continuous EDA recordings from patients.**

1. INTRODUCTION

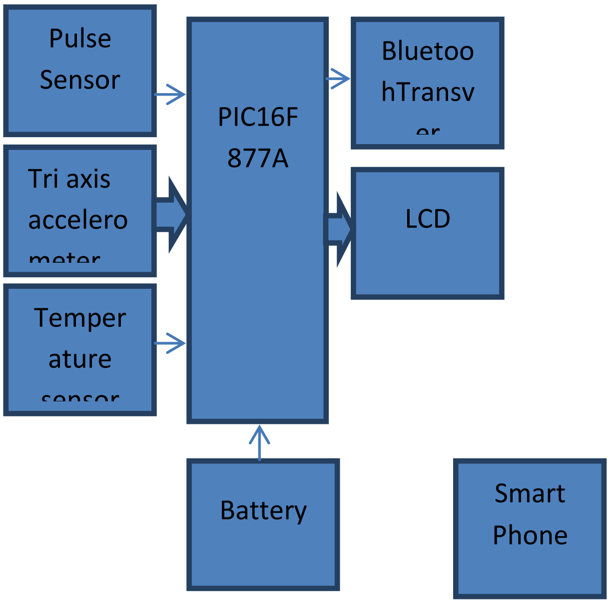
EPILEPSY is a common neurological disorder that involves repeated and spontaneous seizures. These seizures are the manifestation of abnormal, excessive or synchronous neuronal activity in the brain.Epileptic seizures are often associated with significant changes in autonomic nervous system (ANS) functioning. Autonomic signatures such as flushing, sweating and piloerection often accompany partial seizures and auras. In contrast, generalized tonic-clonic seizures (GTCS) are associated with severe increases in blood pressure and changes in heart rate and cardiac conduction. Seizure-induced autonomic dysfunction can have serious clinical consequencesand potentially fatal effects when the cardiovascular or respiratory systems are involved. There are distinct differences between the sympathetic and parasympathetic divisions of the ANS. While parasympathetic discharges produce responses to promote restoration and conservation of energy, the sympathetic nervous system increases metabolic output to adjust to external challenges. So far, autonomic alterations in epilepsy have mostly been studied using indirect parameters such as heart rate, respiratory rate and blood pressure changes that are dually modulated by both divisions of the ANS. Spectral analysis of heart rate variability (HRV) can provide a sensitive index of cardiac parasympathetic control via the vagus nerve, but its utility for un coupling sympathetic activity remains controversial. To this end, we designed a wearable EDA sensor suitable for long-term monitoring.The Seizure Monitor Device does not have a particular client. However, the group has been interviewing extensively various doctors along with people who suffer seizures to get a better idea as to how do go about creating the Seizure Monitor Device. The group felt it was important to both cater the project to the needs of patients who suffer from seizures and also to get the input of experts. Creating a project with advice from these individuals will hopefully lead to a better device for potential clients.

2. SYSTEM DESCRIPTION

The purpose of the Seizure Monitor Device is to create a watch that will be able to detect a seizure and notify a caretaker. The device will be worn by patients suffering from epilepsy to monitor seizures. Seizures which go unnoticed while a patient's asleep can be extremely detrimental to one's health, resulting in loss of consciousness, exhaustion, nausea, vomiting, and inadvertent injury1. In the event of a seizure, the device will transmit a warning to signify to the caregiver that a seizure is in progress. The ideal product will be a small, wristwatch-like accessory which can and should be worn 24 hours a day. The monitor will catalog the time, duration, and severity of the seizure for evaluation by one's doctor. The monitor will have Bluetooth communication for a close proximity auditory and visual warning system. This would allow the caregiver to recognize an onset of a patient's seizure. Real time information will be transferred to the doctor or caregiver's handheld accompanying device. The seizure monitor will function on rechargeable batteries to reduce waste. The size and wireless capacity of the device is unusual and differs significantly from current seizure monitors which lie under the patient's mattress. The seizure monitor will also display the time and date to a screen on the front of the monitor.

A commercially available ArduIMU module (SparkFunElectronics) provides 3- axis accelerometer and 3-axis gyroscope data for motion and orientation, respectively, for all three axes. The module provides digital outputs for both sensors and samples the raw data at a rate of 70 Hz. In order to compensate for drift with the accelerometer and gyroscope,a magnetometer, also embedded on the ArduIMU, is used for drift correction. Figure 2, left, shows raw data from the 3- axis accelerometer that indicates a free fall with a spike in the zdirection. The ECG sensor is implemented using a 3-lead system: electrodes are placed on the left and right inside elbows, using the chin as a reference. An instrument amplifier and discrete filter amplifies the differential ECG signal and removes noise and power-line interference, respectively, before outputting the signal to the sensor board for analogtodigital conversion. An example of the processed ECG sensor acquisition data is shown in Figure 2, middle. The GSR sensor consists of a voltage divider and captures voltage differences between two electrodes placed on the fingertips. Its continuous voltage level outputs also feed into an analogto-digital converter on the sensor board.

3. BLOCK DIAGRAM



BLOCK DESCRIPTION

An accelerometer programmed to detect shaking characteristic of tonic-clonic seizures can generate a record of seizures in an online electronic diary, without need for patient cooperation beyond wearing the watch and recharging the battery (current battery life extends to 5 days when fully charged). Patients need not be literate, technologically sophisticated or even aware of their tonic-clonic seizures. With information uploaded to a web-based diary, accuracy and adherence also becomes less problematic. Selection bias against people with limited literacy, ability to write in a diary or use technology is reduced. Sensitivity of the watch for detection of GTCS and automatically logging to a diary was 100% provided that the watch was on, the watch battery charged and the relevant limb not restrained. In the inpatient setting, care was taken to ensure that the battery was charged and the watch was on, but such supervision will not necessarily be available in the outpatient setting. In two cases, the data uploaded to the online diary on the bedside tablet, however, it did not upload to the online portal, possibly due to interference with the Bluetooth/WiFi signal when the patients were being held or turned. The absence of any logged GTCS or epileptic seizures by a paper diary was surprising. Prior studies have suggested that from 23 to 60% of seizures in an epilepsy monitoring unit go unrecognized by the patient [6,12] For the patient swith captured GTC Sonv EE Gand by watch, the number of seizures captured approximated the verbally reported seizure frequencies on admission though the increase in frequency of seizures during monitoring is mostly explained by withdrawal of anti-seizure medications (Table1). But even in the EMU setting with specific instructions to log seizures, none of the epileptic seizures, including the GTCS, were recorded inthe paper diaries. False-positive detections are a concern for logs documenting benefits of therapies and for clinical trials. One study utilizing ambulatory 16-channel EEG in 502 patients found 87% of log entries to lack concurrent EEG changes [7]. How many of these were false-positive detections versus deep focal seizures not transmitted to scalp EEG are unknown. With an accelerometer watch analertpatient can cancel false detections, but our study still registered a 48% false positive detection rate for non-seizure events that the patients did not cancel. However, all but one false positive in our study occurred during wakefulness. Additionally, there were 34/39 uncancelled false positives that had audio recordings with background noise but none had sounds concerning for ictalactivity. In 11/12 GTCS, the audio recordings provided sounds consistent with epileptic seizures so we confirmed the observation that a retrospective review of audio recordings during the events can help distinguish true from false-positive seizure detections [5,13]. Accelerometers are useful for detecting shaking [14–17,20], but not activities associated with most tonic, absence, myoclonic or focal seizures without evolution to convulsive generalized tonicclonic movements. Other detection methods employing electrodermal responses [18], EEG [19] or seizure-associated sounds [5,13] are under investigation to improve the specificity and allow automatic detection of a broad range of seizure types. Seizures that are localized to a body part not wearing the watch will not be detected. Important behavioral components of seizures, including non-motor components and post- ictal phenomena, will not be recorded by an accelerometer; whereby, the true duration of a seizure may be longer than the period of rhythmic shaking, as was seen in our study. Although automatic detection of GTCS underestimated the seizure durations detected on v EEG, it was superior to paper logs and verbal reports by patients and caregivers. In addition to raw seizure counts, an accelerometer can provide information not easily obtainable with paper or electronic diaries, namely, precise time of day, duration, shake frequency, shake amplitude and accompanying audio. Further study could explore whether this additional information is useful for manage mentor in clinical trials. For example, if the total number of seizures in a patient with medically refractory epilepsy does not decrease but the duration and intensity of events have decreased by 50% with use of a certain medication or device, this could be considered a beneficial change. The quantitative data provided by the accelerometer might

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allow trials to be designed around continuous numerical data, which could increase the power of a study, reduce required sample size and allow for previously UN measurable outcome variables, such as seizure severity.

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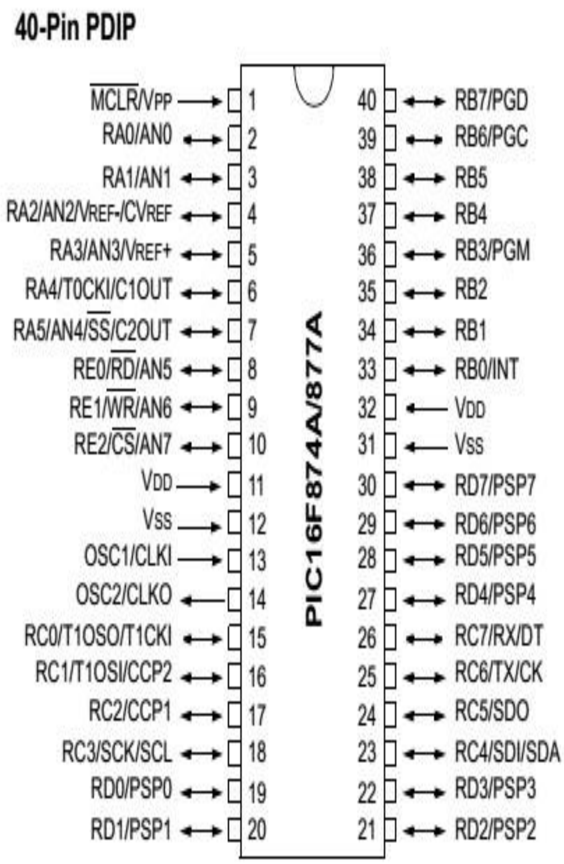
CORE ARCHITECTURE:

The PIC architecture is characterized by its multiple attributes:

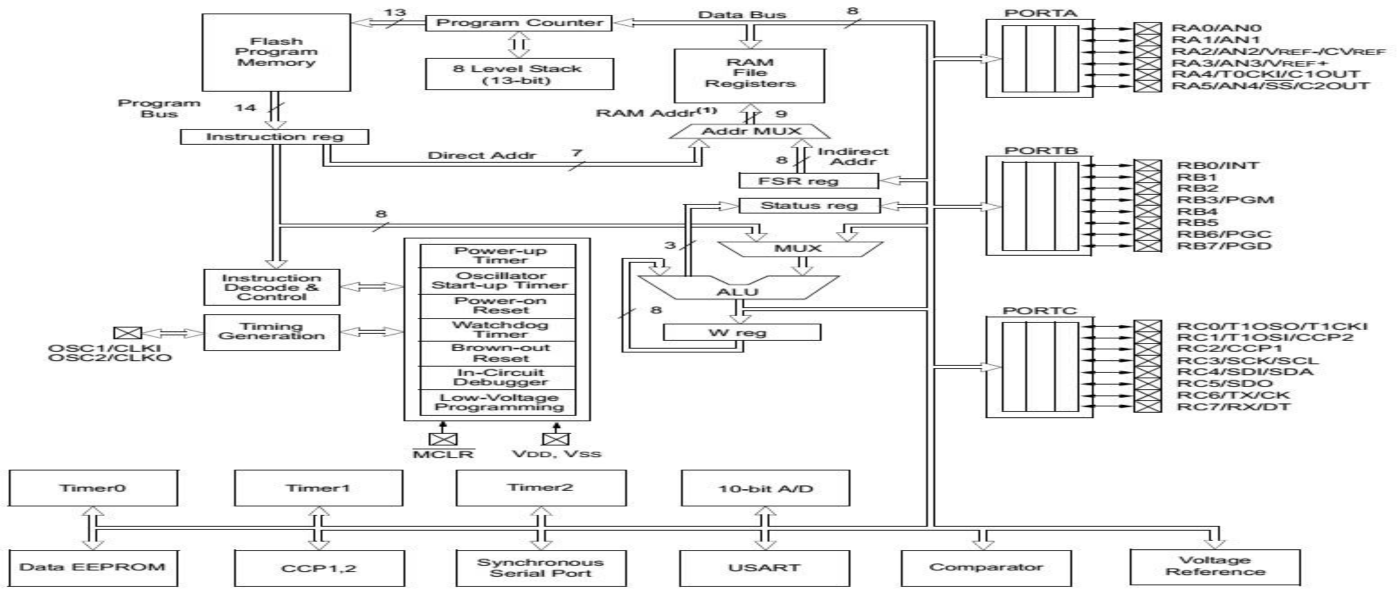
- Separate code and data spaces (Harvard architecture) for devices other than PIC32, which has Von-Neumann architecture.
- A small number of fixed length instructions
- Most instructions are single cycle execution (2 clock cycles, or 4 clock cycles in 8-bit models), with one delay cycle on branches and skips
- One accumulator (W0), the use of which (as source operand) is implied (i.e. is not encoded in the OPCOD
- All RAM locations function as registers as both source and/or destination of math and other functions.
- A hardware stack for storing return addresses
- A fairly small amount of addressable data space (typically 256 bytes), extended through banking
- Data space mapped CPU, port, and peripheral registers
- The program counter is also mapped into the data space and writable (this is used to implement indirect jumps).

PIN DIAGRAM



Pin Name	PDIP, SOIC, SSOP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI	9	6		ST/CMOS(3)	Oscillator crystal or external clock input.
OSC1			I		Oscillator crystal input or external clock source input. ST buffer when configured in RC mode; otherwise CMOS.
CLKI			I		External clock source input. Always associated with pin function OSC1 (see OSC1/CLKI, OSC2/CLKO pins).
OSC2/CLKO	10	7		—	Oscillator crystal or clock output.
OSC2			O		Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO			O		In RC mode, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
MCLR/VPP	1	26		ST	Master Clear (input) or programming voltage (output).
MCLR			I		Master Clear (Reset) input. This pin is an active low Reset to the device.
VPP			P		Programming voltage input.
					PORTA is a bidirectional I/O port.
RA0/AN0	2	27		TTL	
RA0			I/O		Digital I/O.
AN0			I		Analog input 0.
RA1/AN1	3	28		TTL	
RA1			I/O		Digital I/O.
AN1			I		Analog input 1.
RA2/AN2/VREF-/CVREF	4	1		TTL	
RA2			I/O		Digital I/O.
AN2			I		Analog input 2.
VREF-			I		A/D reference voltage (Low) input.
CVREF			O		Comparator VREF output.
RA3/AN3/VREF+	5	2		TTL	
RA3			I/O		Digital I/O.
AN3			I		Analog input 3.
VREF+			I		A/D reference voltage (High) input.
RA4/T0CKI/C1OUT	6	3		ST	
RA4			I/O		Digital I/O – Open-drain when configured as output.
T0CKI			I		Timer0 external clock input.
C1OUT			O		Comparator 1 output.
RA5/AN4/SS/C2OUT	7	4		TTL	
RA5			I/O		Digital I/O.
AN4			I		Analog input 4.
SS			I		SPI slave select input.
C2OUT			O		Comparator 2 output.

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTC is a bidirectional I/O port.
RC0/T1OSO/T1CKI	15	16	32	34		ST	
RC0					I/O		Digital I/O.
T1OSO					O		Timer1 oscillator output.
T1CKI					I		Timer1 external clock input.
RC1/T1OSI/CCP2	16	18	35	35		ST	
RC1					I/O		Digital I/O.
T1OSI					I		Timer1 oscillator input.
CCP2					I/O		Capture2 input, Compare2 output, PWM2 output.
RC2/CCP1	17	19	36	36		ST	
RC2					I/O		Digital I/O.
CCP1					I/O		Capture1 input, Compare1 output, PWM1 output.
RC3/SCK/SCL	18	20	37	37		ST	
RC3					I/O		Digital I/O.
SCK					I/O		Synchronous serial clock input/output for SPI mode.
SCL					I/O		Synchronous serial clock input/output for I^2C mode.
RC4/SDI/SDA	23	25	42	42		ST	
RC4					I/O		Digital I/O.
SDI					I		SPI data in.
SDA					I/O		I^2C data I/O.
RC5/SDO	24	26	43	43		ST	
RC5					I/O		Digital I/O.
SDO					O		SPI data out.
RC6/TX/CK	25	27	44	44		ST	
RC6					I/O		Digital I/O.
TX					O		USART asynchronous transmit.
CK					I/O		USART1 synchronous clock.
RC7/RX/DT	26	29	1	1		ST	
RC7					I/O		Digital I/O.
RX					I		USART asynchronous receive.
DT					I/O		USART synchronous data.

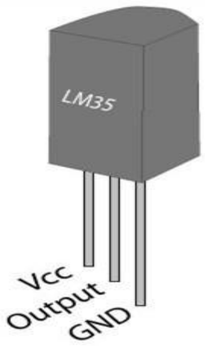


Device	Program Flash	Data Memory	Data EEPROM
PIC16F873A	4K words	192 Bytes	128 Bytes
PIC16F876A	8K words	368 Bytes	256 Bytes

TEMPERATURE SENSOR

LM35 is a IC **temperature sensor** with its output proportional to the temperature (in ^{o}C). The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With **LM35**, temperature can be measured more accurately than with a thermistor. It also possess low self heating and does not cause more than 0.1^{o}C temperature rise in precision still air. The operating temperature range is from -55°C to 150°C. The output voltage varies by 10mV in response to every ^{o}C rise/fall in ambient temperature, *i.e.*, its scale factor is 0.01V/^{o}C.

Pin Diagram:



PIN DESCRIPTION:

Pin No	Function	Name
1	Supply voltage; 5V (+35V to -2V)	Vcc
2	Output voltage (+6V to -1V)	Output
3	Ground (0V)	Ground

FEATURES

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated for Full −55°C to 150°C Range
- Suitable for Remote Applications
- Low-Cost Due to Wafer-Level Trimming
- Operates from 4 V to 30 V
- Less than 60-µA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Non-Linearity Only ±¼°C Typical
- Low-Impedance Output, 0.1 Ω for 1- mA Load

BLUETOOTH - HCO5

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04-External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping

Feature). It has the footprint as small as 12.7mmx27mm. Hope it will simplify your overall design/development cycle.

4. SPECIFICATIONS

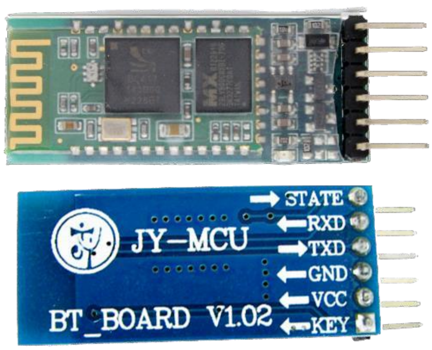
Hardware features

- Typical -80dBm sensitivity.
- Up to +4dBm RF transmits power.
- Low Power 1.8VOperation, 3.3 to 5 V I/O.
- PIO control.
- UART interface with programmable baud rate.
- With integrated antenna.
- With edge connector.

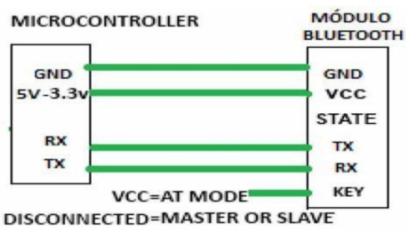
Software features

- Slave default Baud rate: 9600, Data bits:8, Stop bit:1,Parity:No parity.
- PIO9 and PIO8 can be connected to red and blue led separately. When master and slave are paired, red and blue led blinks 1time/2s in interval, while disconnected only blue led blinks 2times/s.
- Auto-connect to the last device on power as default.
- Permit pairing device to connect as default.
- Auto-pairing PINCODE:"1234" as default.
- Auto-reconnect in 30 min when disconnected as a result of beyond the range of connection.

PIN OUT CONFIGURATION



5. TYPICAL APPLICATION CIRCUIT

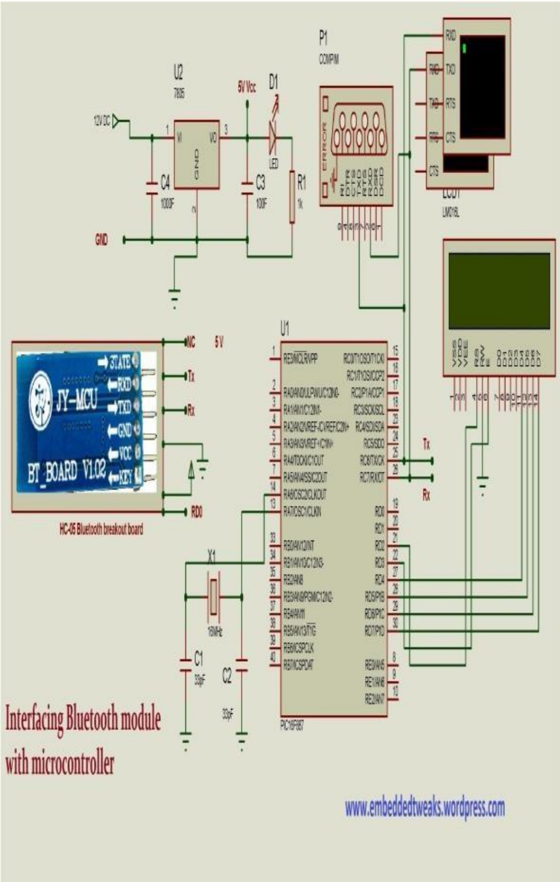


The Module has two modes of operation namely,

- AT command mode
- Connection mode

6. MICROCONTROLLER SECTION

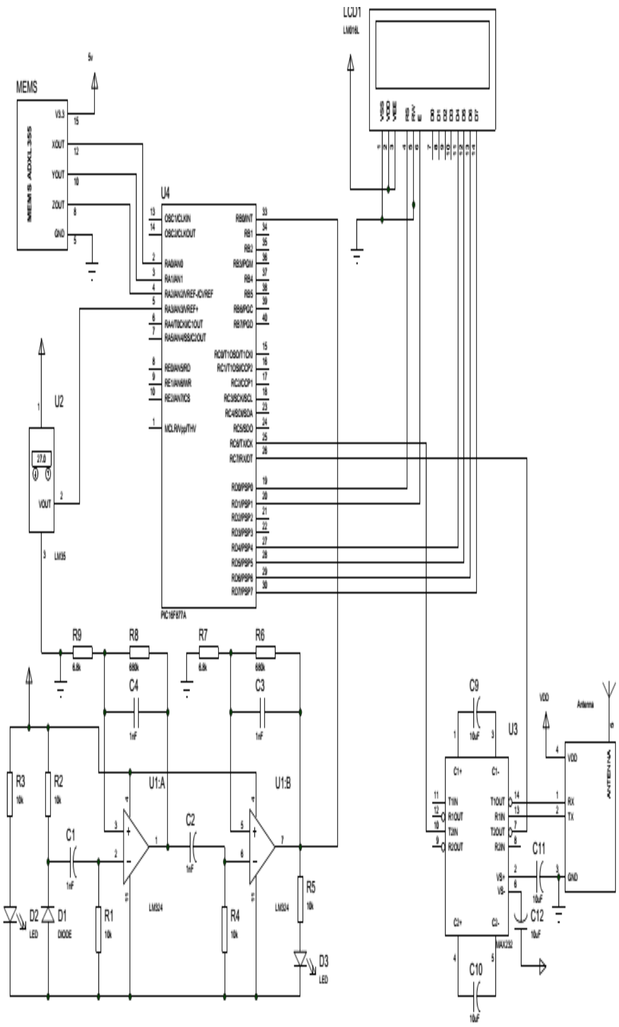
A Bluetooth module is widely used with Microcontroller to enable Bluetooth communication. The Bluetooth is interfaced with PIC microcontroller, which contains atleast one serial port. This module can be interfaced using the UART in PIC microcontroller where the data are transmitted in the form of packets. The pins TX and RX pin of the HC 05 form the path for data transmission and reception. These TX pin of HC05 must be connected to the RX pin of PIC Microcontroller and vice versa. Whereas the key pin of the module is used to set the password for pairing the module with our devices.



7. TRIAXIS ACCELEROMETER

An **accelerometer** is a device that measures the galaxy proper acceleration; proper acceleration is not the same as coordinate acceleration (rate of change of velocity). For example, an accelerometer at rest on the surface of the Earth will measure an acceleration due to Earth's gravity, straight upwards (by definition) of $g \approx 9.81\ m/s^2$. By contrast, accelerometers in free fall (falling toward the center of the Earth at a rate of about $9.81\ m/s^2$) will measurezero. Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. Accelerometers are used to detect and monitor vibration in rotating machinery. Accelerometers are used in tablet computers and digital cameras so that images on screens are always displayed upright. Accelerometers are used in drones for flight stabilisation. Coordinated accelerometers can be used to measure differences in proper acceleration, particularly gravity, over their separation in space; i.e., gradient of the gravitational field. This gravity gradiometry is useful because absolute gravity is a weak effect and depends on local density of the Earth which is quite variable.Single- and multi-axis models of accelerometer are available to detect magnitude and direction of the proper acceleration, as a vector quantity, and can be used to sense orientation (because direction of weight changes), coordinate acceleration, vibration, shock, and falling in a resistive medium (a case where the proper acceleration changes, since it starts at zero, thenincreases). Micro machined accelerometers are increasingly present in portable electronic devices and video game controllers, to detect the position of the device or provide for game input.

8. CIRCUITDIAGRAM



CIRCUIT DESCRIPTION

When AC is applied to the primary winding of the power transformer it can either be stepped down or up depending on the value of DC needed. In our circuit the transformer of 230v/15v is used to perform the step down operation where a 230V AC appears as 15V AC across the secondary winding. In the power supply unit, rectification is normally achieved using a solid-state diode. Diode has the property that will let the electron flow easily in one direction at proper biasing condition. As AC is applied to the diode, electrons only flow when the anode and cathode is negative. Reversing the polarity of voltage will not permit electron flow. A commonly used circuit for supplying large amounts of DC power is the bridge rectifier. A bridge rectifier of four diodes (4*IN4007) is used to achieve full wave rectification. Two diodes will conduct during the negative cycle and the other two will conduct during the positive half cycle. The DC voltage appearing across the output terminals of the bridge rectifier will be somewhat less than 90% of the applied RMS value. Filter circuits, which usually capacitor is acting as a surge arrester always follow the rectifier unit. This capacitor is also called as a decoupling capacitor or a bypassing capacitor, is used not only to ‘short’ the ripple with frequency of 120Hz to ground but also to leave the frequency of the DC to appear at the output. The voltage regulators play an important role in any power supply unit. The primary purpose of a regulator is to aid the rectifier and filter circuit in providing a constant DC voltage to the device. Power supplies without regulators have an inherent problem of changing DC voltage values due to variations in the load or due to fluctuations in the AC liner voltage. With a regulator connected to the DC output, the voltage can be maintained within a close tolerant region of the desired output. The regulators IC7812 and 7805 are used to provide the +12v and +5v to the circuit. PIC16F877A

9. CONCLUSION

In this paper, the design of flexible, low- power and wireless sensor nodes has been presented. The sensor nodes are equipped with a 3D accelerometer, an ultralow-power microcontroller and an RF transceiver, allowing for full 3D orientation tracking. Careful implementation of the functionality and maximal use of the low-power modes, has resulted in an average current consumption of less than 3 mA for each node. A TDMA-like protocol allows 10 nodes to transmit data wirelessly at a rate of 100 Hz to a single receiver.The communication protocol still exhibits a weak spot which can mainly be attributed to the synchronization with the master. If the master would malfunction, all slaves would be numbed and the system would no longer work. A more improved version of the protocol in which this problem is avoided, is currently the subject of further work.In an inpatient study, data logged to an online database automatically by an accelerometer provided more detailed and accurate data than did caregiver self-reports or a paper diary. The automated diaries generated by accelerometers are subject to occasional technical and user-induced failures, and do not currently detect seizures lacking rhythmical shaking.

10. REFERENCES

[1] Fisher RS, Blum DE, DiVentura B, Vannest J, Hixon JD, Moss R, et al. Seizure diaries for clinical research and practice: Limitations and future prospects. 2012;24:304–10.
[2] Le S, Shafer PO, Bartfeld E, Fisher R. An online diary for tracking epilepsy. 2011;22(4):705–9.
[3] Kramer U, Kipervasser S, Shlitner A, Kuzniecky R. A novel portable seizure detection alarmsystem: preliminaryresults. J.ClinNeurophysiol 2011;28(1):36–8.
[4] Lockman J, Fisher RS, Olson DM. Detection of seizure-like movements using wrist accelerometer. 2011;20(4):638–41.
[5] Cook MJ, O'Brien TJ, Berkovic SF, MurphyM,MorokoffA, Prediction of seizure likelihood with a long-term, implanted seizureadvisorysystem in patients with drug- resistant epilepsy: a first-in-man study. LancetNeurol 2013;12(6):563–71.
[6] Blum DE, Eskola J, Bortz JJ, Fisher RS. Patient awareness of seizures. Neurology 1996;47(1):260–4.
[7] Tatum 4th WO, Winters L, Gieron M, Passaro EA, Benbadis S, Ferreira J Outpatient seizure identification: results of 502 patients using ambulatory EEG. J Clin Neurophysiol 2001;18(1):14–9.
[8] Heo K, Han SD, Lim SR, Kim MA, Lee BI. Patient awareness of complex partial seizures.Epilepsia 2006;47(11):1931–40.
[9] Kerling F, Mueller S, Pauli E, StefanH. An electro clinical study. 2006;9(2):281–5.
[10] Hoppe C, Poepel A, Elger CE. Epilepsy: accuracy of patient seizure counts.ArchNeurol2007;64(11):1595–600.
[11] Poochikian-Sarkissian S, Tai P, del Campo M, Andrade DM, Carlen PL, Valiante T, et al. Patient awareness of seizures asdocumented in the epilepsy monitoring unit. Can J NeurosciNurs 2009;31(4):22–3.
[12] DuBois JM, Boylan LS, Shiyko M, Barr WB, Devinsky O. Seizure prediction and recall. Epilepsy Behav 2010;18(1–2):106–9.
[13] Elzawahry H, Do CS, Lin K, Benbadis SR. The diagnostic utility of the ictal cry.Epilepsy Behav 2010;18(3):306–7.
[14] Nijsen TM, Arends JB, Griep PA, Cluitmans PJ. The potential value of threedimensionalaccelerometry for detection of motor seizures in severe epilepsy. Epilepsy Behav 2005;7(1):74–84.
[15] Nijsen TM, Cluitmans PJ, Arends JB, Griep PA. Detection of subtle nocturnal motor activity from 3-D accelerometry recordings in epilepsy patients. IEEE Trans Biomed Eng 2007;54(11):2073–80.
[16] Karayiannis NB, Xiong Y, Frost Jr JD, Wise MS, Hrachovy RA, Mizrahi EM. Automated detection of videotaped neonatal seizures based on motion tracking methods. J ClinNeurophysiol 2006;23(6):521–31.
[17] Cuppens K, Lagae L, Ceulemans B, Van Huffel S, Vanrumste B. Detection of nocturnal frontal lobe seizures in pediatric patients by means of accelerometers: a first study. In: Conference Proceedings IEEE Engineering in Medicine and Biology Society; 2009. p. 6608–11.
[18] Poh MZ, Loddenkemper T, Swenson NC, Goyal S, Madsen JR, Picard RW. Continuous monitoring of electrodermal activity during epileptic seizures using a wearable sensor. In: Conference Proceedings IEEE Engineering in Medicine and Biology Society; 2010. p. 4415–8.
[19] Gotman J. Automatic recognition of epileptic seizures in the EEG. ElectroencephalogrClinNeurophysiol 1982;54(5):530–40.
[20] Beniczky S, Polster T, Kjaer TW, Hjalgrim H. Detection of tonic-clonic seizures by a wireless wrist accelerometer: Epilepsia2013;54(4):58–61.