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CONTINUOUS INTRAOCULAR PRESSURE MONITORING BY NONINVASIVE WIRELESS PRESSURE SENSOR

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Abstract:

This project presents that the glaucoma is the second leading cause of blindness and is most accurately defined as a collection of diseases that have in common, damage to the optic nerve and loss of visual field with increased intraocular pressure (IOP) being the primary risk factor. Though there are treatments available, there is a requirement to develop improved diagnostic and therapeutic techniques to overcome this disease. A continuous intraocular pressure measurement during the patients' routine daily activity can provide a valuable insight. Here microcontroller is used to convert the analog signal to digital and which the sensor output through which the pressure of the eye is measured continuously and the monitored data can be send via wireless technology through ZigBee. The transmitted data can be viewed by the doctors through PC were it is received by the ZigBee transceiver.

Key Words: IOP Sensor & Pressure Detection Zigbee

Introduction:

Glaucoma is a condition that causes damage to the eye's optic nerve and gets worse over time. Statistics show that glaucoma is the second leading cause of blindness in the world according to World Health Organization. It's often associated with a build-up of pressure inside the eye. Glaucoma tends to be inherited and may not show up until later in life. The increased pressure, called intraocular pressure, can damage the optic nerve, which transmits images to the brain. If damage to the optic nerve from high eye pressure continues, glaucoma will cause permanent loss of vision. Without treatment, glaucoma can cause total permanent blindness within a few years. Because most people with glaucoma have no early symptoms or pain from this increased pressure, it is important to get diagnosed regularly and treated before long-term visual loss occurs. Glaucoma usually occurs when pressure in your eye increases. This can happen when eye fluid isn't circulating normally in the front part of the eye. Normally, this fluid, called aqueous humor, flows out of the eye through a mesh-like channel. If this channel becomes blocked, fluid builds up, causing glaucoma. Methods like tonometry, ophthalmoscopy, and pachymetry are available for continuous monitoring. Variations of IOP in humans have been known for at least a century, with fluctuations occurring in a regular pattern as a circadian rhythm, or randomly over short and long periods. Statistics show that glaucoma is the second leading cause of blindness in the world according to World Health Organization [4]. Devices capable of monitoring IOP around the clock would improve our ability to understand the dynamic processes at work in glaucoma.

Eye Structure:

The eye is a slightly asymmetrical globe, about an inch in diameter. The front part of the eye (the part you see in the mirror) includes: The iris (the pigmented part), the cornea (a clear dome over the iris), the pupil (the black circular opening in the iris that lets light in), the sclera (the white part), the conjunctiva (a thin layer of tissue covering the front of the eye, except the cornea).Just behind the iris and pupil lies the lens, which helps to focus light on the back of the eye. Most of the eye is filled with a clear gel called the vitreous. Light projects through the pupil and the lens to the back of the eye. The inside lining of the eye is covered by special light-sensing cells that are collectively called the retina. The retina converts light into electrical impulses. Behind the eye, the optic nerve carries these impulses to the brain. The macula is a small extra-sensitive area within the retina that gives central vision. It is located in the centre of the retina and contains the fovea, a small depression or pit at the centre of the macula that gives the clearest vision.

Vitreous humour is a transparent jelly-like mass located behind the lens. It acts as a 'suspension' for the lens so that the delicate lens is not damaged. It helps to maintain the shape of the posterior chamber of the eyeball. Likewise aqueous humour helps to maintain the anterior chamber of the eyeball. The front part of the eye includes:

- The iris (the pigmented part)
- The cornea (a clear dome over the iris)
- The pupil (the black circular opening in the iris that lets the light in)
- The sclera (the white part)
- The conjunctiva (a thin layer of tissue covering the front of the eye, except the cornea)

Just behind the iris and the pupil lies the lens, which helps to focus the light on the back of the eye. Most of the eye is filled with clear gel called vitreous. Light projects through the pupil and the lens to the back of the eye. The inside lining of the eye is covered by special light sensing cells that are collectively called as retina. The retina converts the light into electrical impulse.

Glaucoma:

Glaucoma is an ocular disorder with increased intraocular pressure-associated optic neuropathy. The increased intraocular pressure can permanently damage vision in the affected eye(s) and lead to blindness if left untreated. It is normally associated with increased fluid pressure in the eye (aqueous humour). The term "ocular hypertension" is used for people with raised intraocular pressure (IOP) without any associated optic nerve damage.

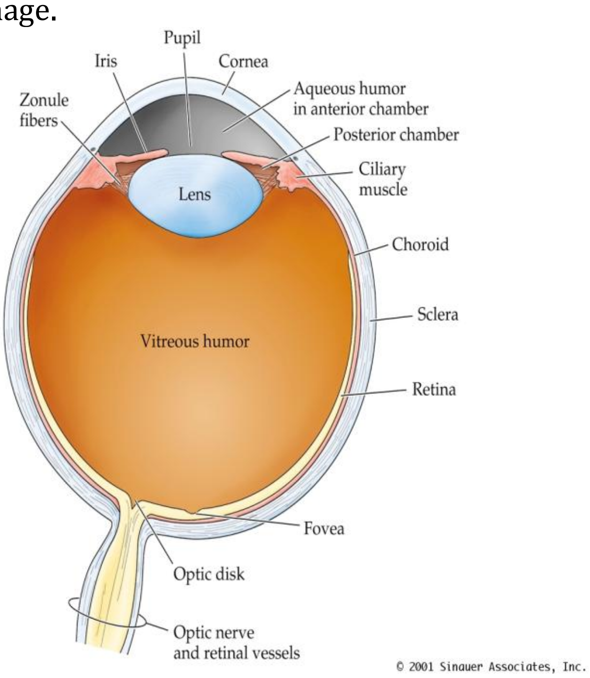

Figure 1: Structure of Eye

The nerve damage involves loss of retinal ganglion cells in a characteristic pattern. The many different subtypes of glaucoma can all be considered to be a type of optic neuropathy. Raised intraocular pressure (above 21 mmHg or 2.8 kPa) is the most important and only modifiable risk factor for glaucoma. However, some may have high eye pressure for years and never develop damage, while others can develop nerve damage at a relatively low pressure. Untreated glaucoma can lead to permanent damage of the optic nerve and resultant visual field loss, which over time can progress to blindness.

In glaucoma, the neuroretinal rim of the optic nerve becomes progressively thinner, thereby enlarging the optic-nerve cup. This phenomenon is referred to as optic-nerve cupping. Its cause is the loss of retinal ganglion cell axons, along with supporting glia and vasculature. Without proper treatment, the elevated IOP would damage patients' optic nerves in the backside of the eye, and causes the blindness in the end.

In this project, propose a non-invasive device that monitors daily and nocturnal IOP changes could assist in establishing the effect of IOP fluctuation in glaucoma, which is important to determine when considering implantable devices

System Architecture Design:

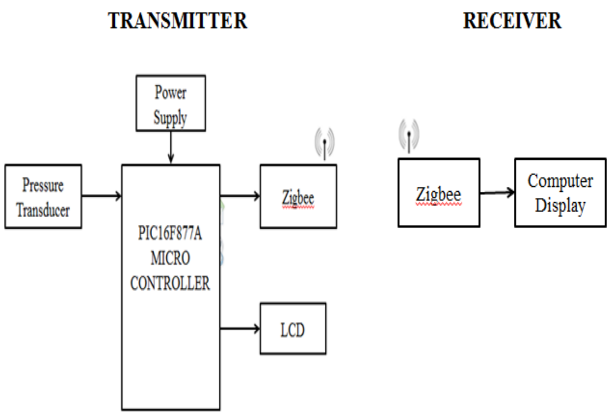

Figure 2: Block Diagram

Glaucoma is a disease that is often associated with elevated intraocular pressure, in which damage to the eye (optic) nerve can lead to loss of vision and even blindness. It is the leading cause of irreversible blindness in the world. It usually causes no symptoms early in its course, at which time it can only be diagnosed by regular eye examinations (screenings with the frequency of examination based on age and the presence of other risk factors). Intraocular pressure increases when either too much fluid is produced in the eye or the drainage or outflow channels (trabecular meshwork) of the eye become blocked.

Infrared transmitter is one type of LED which emits infrared rays generally called as IR Transmitter. Similarly IR Receiver is used to receive the IR rays transmitted by the IR transmitter. One important point is both IR transmitter and receiver should be placed straight line to each other. The transmitted signal is given to IR transmitter whenever the signal is high, the IR transmitter LED is conducting it passes the IR rays to the receiver. The IR receiver is connected with comparator. The comparator is constructed with LM 358 operational amplifier. In the comparator circuit the reference voltage is given to inverting input terminal. The non inverting input terminal is connected IR receiver. When interrupt the IR rays between the IR transmitter and receiver, the IR receiver is not conducting. So the comparator non inverting input terminal voltage is higher than inverting input. Now the comparator output is in the range of +5V. This voltage is given to microcontroller or PC and led so led will glow.

When IR transmitter passes the rays to receiver, the IR receiver is conducting due to that non inverting input voltage is lower than inverting input. Now the comparator output is GND so the output is given to microcontroller or PC. This circuit is mainly used to for counting application, intruder detector etc.

This project involves the measure of the eye blink using IR sensor. The IR transmitted is used to transmit the infrared rays in our eye. The IR receiver is used to receive the reflected infrared rays of the eye. If the eye is closed means the output means the output of IR receiver is high otherwise the IR receiver output is low. This is to know the eye is closing or opening position. This output is given to logic circuit to indicate the pressure produced during eye blinking. This project helps in diagnosing the intraocular pressure created in eye due to age related problems and other disease like diabetes mellitus which is the reason for increased eye pressure through eye blink. Here one eye blink sensor is fixed in the spectacles which the patient wears.

The 16F877A is a capable microcontroller that can do many tasks because it has a large enough programming memory (large in terms of sensor) 8k words and 368 Bytes of RAM. The 40 pins make it easier to use the peripherals as the functions are spread out over the pins. One of the main advantages is that each pin is only shared between two or three functions so it's easier to decide what the pin function (other devices have up to 5 functions for a pin). The input from the eye blink sensor is given to the 15^{th} pin of the microcontroller (i.e) RC0/T10S0/T1CKI.

- RA3 Port A third digital input/output
- AN3 Third analog input
- V ref+ Positive voltage reference
- C1IN+ Comparator C1positive input

The CPU can recognizes only 35 simple instructions (In order to program some other microcontrollers it is necessary to know more than 200 instructions by heart).The execution time is the same for all instructions except two and lasts 4 clock cycles (oscillator frequency is stabilized by a quartz crystal). The Jump and Branch instructions execution time is 2 clock cycles. It means that if the microcontroller's operating speed is 20MHz, execution time of each instruction will be 200nS, i.e. the program will be executed at the speed of 5 million instructions per second. This microcontroller has three types of memory- ROM, RAM and EEPROM. All of them will be separately discussed since each has specific functions, features and organization.ROM memory is used to permanently save the program being executed. This is why it is often called "program memory". The PIC16F887 has 8Kb of ROM (in total of 8192 locations). Since this ROM is made with FLASH technology, its contents can be changed by providing a special programming voltage. Similar to program memory, the contents of EEPROM is permanently saved, even the power goes off. However, unlike ROM, the contents of the EEPROM can be changed during operation of the microcontroller. That is why this memory (256 locations) is a perfect one for permanently saving results created and used during the operation. This is the third and the most complex part of microcontroller memory. In this case, it consists of two parts: general-purpose registers and special-function registers (SFR). Even though both groups of registers are cleared when power goes off and even though they are manufactured in the same way and act in the similar way, their functions do not have many things in common. A part of the RAM used for the stack consists of eight 13-bit registers. Before the microcontroller starts to execute a subroutine (CALL instruction) or when an interrupt occurs, the address of first next instruction being currently executed is pushed onto the stack, i.e. onto one of its registers. In that way, upon subroutine or interrupt execution, the microcontroller knows from where to continue regular program execution. This address is cleared upon return to the main program because there is no need to save it any longer, and one location of the stack is automatically available for further use. It is important to understand that data is always circularly pushed onto the stack. It means that after the stack has been pushed eight times, the ninth push overwrites the value that was stored with the first push. The tenth push overwrites the second push and so on. Data overwritten in this way is not recoverable. In addition, the programmer cannot access these registers for write or read and there is no Status bit to indicate stack overflow or stack underflow conditions. For that reason, one should take special care of it during program writing.

The first thing that the microcontroller does when an interrupt request arrives is to execute the current instruction and then stop regular program execution. Immediately after that, the current program memory address is automatically pushed onto the stack and the default address (predefined by the manufacturer) is written to the program counter. That location from where the program continues execution is called the interrupt vector. Part of the program being activated when an interrupt request arrives is called the interrupt routine. Its first instruction is located at the interrupt vector. How long this subroutine will be and what it will be like depends on the skills of the programmer as well as the interrupt source itself. Some microcontrollers have more interrupt vectors (every interrupt request has its vector), but in this case there is only one. Consequently, the first part of the interrupt routine consists in interrupt source recognition.

An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle. One each polarisers are pasted outside the two glass panels. These polarisers would rotate the light rays passing through them to a definite angle, in a particular direction. When the LCD is in the off state, light rays are rotated by the two polarisers and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent. When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction. The light rays passing through the LCD would be rotated by the polarisers, which would result in activating / highlighting the desired characters. The LCD's are lightweight with only a few millimetres thickness. Since the LCD's consume less power, they are compatible with low power electronic circuits, and can be powered for long durations. The LCD does don't generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD's have long life and a wide operating temperature range. Changing the display size or the layout size is relatively simple which makes the LCD's more customer friendly.

The LCD display consists of two lines, 20 characters per line that is interfaced with the PIC16F877A.The input and output pins from microcontroller to LCD is given to the pins RD0/RD1/RD/2/RD3. The display contains two internal byte-wide registers, one for commands (RS=0) and the second for characters to be displayed (RS=1). It also contains a user-programmed RAM area (the character RAM) that can be programmed to generate any desired character that can be formed using a dot matrix. To distinguish between these two data areas, the hex command byte 80 will be used to signify that the display RAM address 00h will be chosen Port1 is used to furnish the command or data type, and ports 3.2 to 3.4 furnish register select and read/write levels.

ZigBee has a defined rate of 250 Kbit/s, best suited for intermittent data transmissions from a sensor or input device. ZigBee has been developed looking into the needs of communication of data with simple structure like the data from the sensors. ZigBee is typically used in low data rate applications that require long battery life and secure networking. Data's from the LCD are transmitted to doctor's pc through ZigBee network.

Working Principle:

In this project, the Transmitter section, a microcontroller is used to convert the analog sensor output to digital, through which the pressure in the eye is measured continuously. The monitored data can be send via wireless technology through ZigBee .In the Receiver Section, the transmitted data can be viewed by the doctors through PC were it is received by the ZigBee transceiver. In glaucoma diagnosing process, after the input signal is received, the signals are amplified and then send to the microcontroller. Microcontroller converts the analog signal to digital signal and also helps in serial communication. MP lab is used to compile the acquired signal from one language to the other to obtain the required output. Here, ZigBee network is used to transfer data from the system to the doctor's laptop. Since there is no data loss and no interruption occurs in ZigBee, here this network is been used. The required IOP values are displayed in the PC through MATLAB.

Hardware Description:

Circuit Diagram:

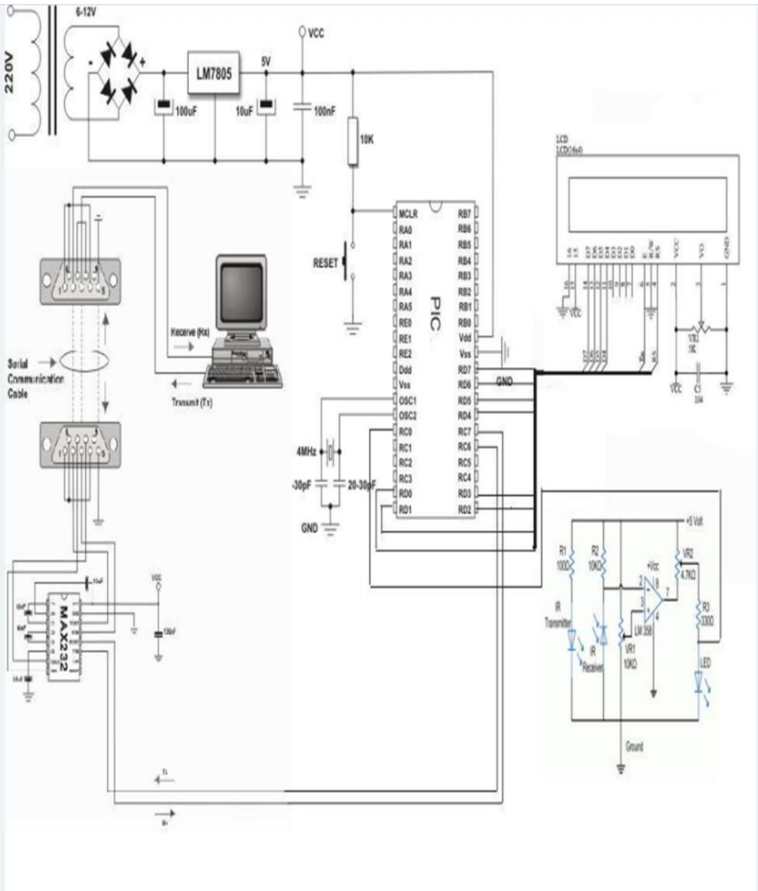

Figure 3: Circuit Diagram

Power Supply:

7805 is a 5V fixed three terminal positive voltage regulator IC. The IC has features such as safe operating area protection, thermal shut down, internal current limiting which makes the IC very rugged. Output currents up to 1A can be drawn from the IC provided that there is a proper heat sink. A 9V transformer steps down the main voltage, 1A bridge rectifies it and capacitor C1 filters it and 7805 regulates it to produce a steady 5Volt DC. The circuit schematic is given below

DC power supplies use AC main electricity as an energy source. Such power supplies will sometimes employ a transformer to convert the input voltage to a higher or lower AC voltage. A rectifier is used to convert the transformer output voltage to a varying DC voltage, which in turn is passed through an electronic filter to convert it to an unregulated DC voltage. The filter removes most, but not all of the AC voltage variations; the remaining voltage variations are known as ripple.

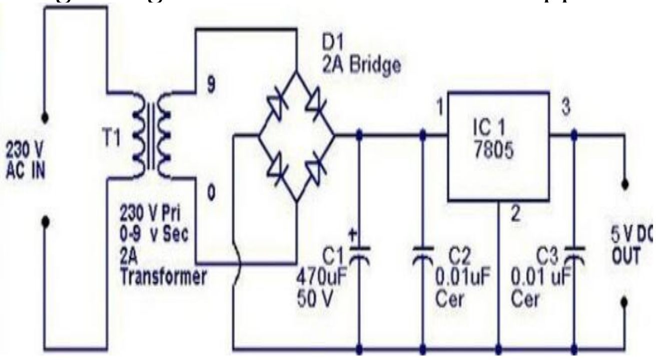

Figure 4: Power Supply

Eye Blink Sensor (QRD1114):

This Eye Blink sensor is IR based. The Variation Across the eye will vary as per eye blink. If the eye is closed means the output is high otherwise output is low. This to know the eye is closing or opening position. This output is give to logic circuit to indicate the alarm

Results and Discussion:

Eye pressure is measured in millimetres of mercury (mm Hg). Normal eye pressure ranges from 12-22 mm Hg, and eye pressure of greater than 22 mm Hg is considered higher than normal. When the IOP is higher than normal but the person does not show signs of glaucoma, this is referred to as ocular hypertension. In time, if the glaucoma is not treated, central vision will also be decreased and then lost; this is how blindness from glaucoma is most often noticed. When eye pressure exceeds more than 22 mmHg and if not diagnosed or noticed for a long period of time it may lead to permanent vision loss.

When the IR sensor is placed on the eye, depending on the blinking of the eye it detects the amount of eye pressure. Not every single blink in the eye is the same, but it varies depending on blinking frequency.

The number of blinking depends on the amount of pressure present in the eye. The IR transmitter is used to transmit the infrared rays in our eye. The IR receiver is used to receive the reflected infrared rays of eye.

The input signal given via the sensor is send to an amplifier which is been and send to the microcontroller where the signal is converted from analog to digital form. The digital signal is now send to the MAX 232 which is a level converter and the signal is transmitted to the receiver section through the ZigBee protocol. The transmitted signal will be given to the PC via RS 232, which is a port. Now the pressure signal can be viewed in the PC from which the glaucoma can be diagnosed.

Outpatient values are taken from an esteemed hospital to compare the readings with the project output reading. The normal eye pressure ranges between 12-22 mmHg, where the patients reading exhibited an increased IOP due to inflammation in the blood vessels.

The increased IOP is 29 mmHg when diagnosed with a Tonometer. The measurement of reading with the for IOP patient with microcontroller based non-invasive device slightly varies from that of the Tonometer reading and the reading is 27 mmHg, which shows an increased intraocular pressure because of inflammation in the blood vess

Conclusion:

This project is simple and is highly efficient for continuous monitoring of IOP with less cost. The work described in this project is concerned the better and accurate output of intraocular pressure. An interesting development has been the shift in emphasis towards high level vision tasks that aim to understand the interpret of the signal and the pressure signal. The project helps to identify the pressure fluctuations with respect to the time. Nocturnal and diurnal pressure varies from one individual to the other. In order to maintain a positive criterion it is important to measure the intraocular output. The simulation output is successfully executed using proteus software in the previous phase and the hardware system is also successfully implemented for hardware phase. The use of microcontroller converts the signal from analog to digital that can be displayed as a pressure output.

Future Work:

The displayed intraocular pressure values can be send to an android phone as an alarm indicating the high pressure and also to diagnose frequently in order to avoid vision loss.

Disadvantages:

- More Time Consumption

Advantage:

- Accurate
- Less discomfort
- Simple circuit design

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