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Wearable Wireless Sensor Network for human limbs motion

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Abstract—***Most of the existing systems require wiring that restrains the natural movement. To overcome this limitation, a wearable wireless sensor network using accelerometers have been developed in this project. In this project, a wearable wireless sensor system is proposed to overcome this limitation. The wireless feature enables the unrestrained motion of the human body as opposed to a wired monitoring device and makes the system truly portable. This will also allow the system to be deployed in a cluttered home environment. The small form factor and lightweight feature of the sensor nodes also allow easy attachment to the limbs. This technology also used in sports technology, in this field we know about the players' behaviour. In our project we will introduce the MEM sensors and FLEX sensors in to medical and sports applications.***

Keywords— ***MEMs, FLEX, Wireless Sensor.***

I. INTRODUCTION

Tracking of human motion has attracted significant interest in recent years due to its wide-ranging applications such as rehabilitation, virtual reality, sports science, medical science and surveillance. In recent years, inertial and magnetic tracking have attracted much interest as they are source-free approaches unlike the audio and radar that require an emission source. The development of micro electromechanical system technology and flex sensor technology had also made such sensors lighter, smaller, and cheaper. Consequently, they are good candidates conducted in patient's home or office. This will also reduce the frequency to visit the hospital for patients undergoing physiotherapy. This technology also used in sports technology, in this field we know about the player's behaviour. In this project the MEMS sensors and FLEX sensors will be introduced in to medical and sports applications. The wireless feature enables the unrestrained motion of the human body as opposed to a wired monitoring device and makes the system truly portable. This will also allow the system to be deployed in a cluttered home environment. The small form factor and lightweight feature of the sensor nodes also allow easy attachment to the limbs.

II. BLOCK DIAGRAM

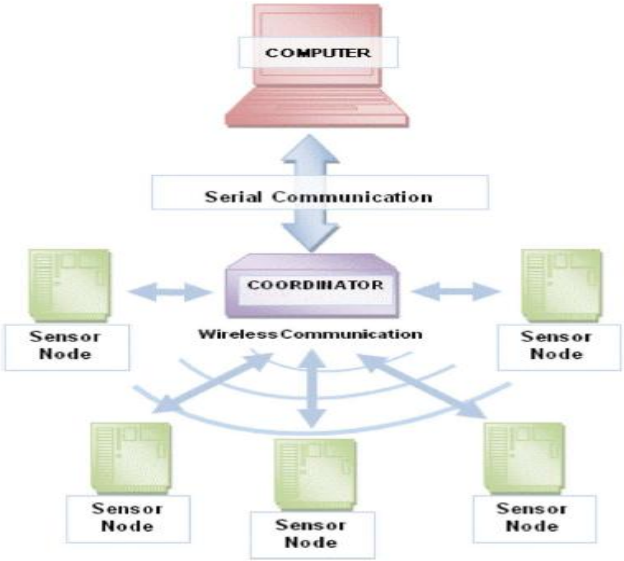


Figure 1.*General configuration of the system*

III. SERIAL COMMUNICATION

Serial communication is basically the transmission or reception of data one bit at a time. Today's computers generally address data in bytes or some multiple thereof. A byte contains 8 bits. A bit is basically either a logical 1 or zero. Every character on this page is actually expressed internally as one byte.

The serial port is used to convert each byte to a stream of ones and zeroes as well as to convert a stream of ones and zeroes to bytes. The serial port contains an electronic chip called a Universal Asynchronous Receiver/Transmitter (UART) that actually does the conversion. The serial port has many pins. We will discuss the transmit and receive pins first. Electrically speaking, whenever the serial port sends a logical one (1) a negative voltage is effected on the transmit pin. Whenever the serial port sends a logical zero (0) a positive voltage is affected. When no data is being sent, the serial port's transmit pin's voltage is negative (1) and is said to be in a MARK state. Note that the serial port can also be forced to keep the transmit pin at a positive voltage (0) and is said to be the SPACE or BREAK state. (The terms MARK and SPACE are also used to simply denote a negative voltage (1) or a positive voltage (0) at the transmit pin respectively).When transmitting a byte, the UART (serial port) first sends a START BIT which is a positive voltage (0), followed by the data (general 8 bits, but could be 5, 6, 7, or 8 bits) followed by one or two STOP Bits which is a negative(1) voltage. The sequence is repeated for each byte sent. When transmitting a character there are other characteristics other than the baud rate that must be known or that must be setup. These characteristics define the entire interpretation of the data stream. The first characteristic is the length of the byte that will be transmitted. This length in general can be anywhere from 5 to 8 bits.

The second characteristic is parity. The parity characteristic can be even, odd, mark, space, or none. If even parity, then the last data bit transmitted will be a logical 1 if the data transmitted had an even amount of 0 bits. If odd parity, then the last data bit transmitted will be a logical 1 if the data transmitted had an odd amount of 0 bits. If MARK parity, then the last transmitted data bit will always be a logical 1. If SPACE parity, then the last transmitted data bit will always be a logical 0. If no parity then there is no parity bit transmitted.

The third characteristic is the amount of stop bits. This value in general is 1 or 2. Assume we want to send the letter 'A' over the serial port. The binary representation of the letter 'A' is 01000001. Remembering that bits are transmitted from least significant bit (LSB) to most significant bit (MSB), the bit stream transmitted would be as follows for the line characteristics 8 bits, no parity, 1 stop bit and 9600 baud. LSB (0 1 0 0 0 0 0 1 0 1) MSB. The above represents (Start Bit) (Data Bits) (Stop Bit). To calculate the actual byte transfer rate simply divide the baud rate by the number of bits that must be transferred for each byte of data.

In the case of the above example, each character requires 10 bits to be transmitted for each character. As such, at 9600 baud, up to 960 bytes can be transferred in one second. The above discussion was concerned with the "electrical/logical" characteristics of the data stream. We will expand the discussion to line protocol. Serial communication can be half duplex or full duplex. Full duplex communication means that a device can receive and transmit data at the same time. Half duplex means that the device cannot send and receive at the same time. It can do them both, but not at the same time. Half duplex communication is all but out-dated except for a very small focused set of applications. Half duplex serial communication needs at a minimum two wires, signal ground and the data line. Full duplex serial communication needs at a minimum three wires, signal ground, transmit data line, and receive data line.

These signals are the Carrier Detect Signal (CD), asserted by modems to signal a successful connection to another modem, Ring Indicator (RI), asserted by modems to signal the phone ringing, Data Set Ready (DSR), asserted by modems to show their presence, Clear To Send (CTS), asserted by modems if they can receive data, Data Terminal Ready (DTR), asserted by terminals to show their presence, Request To Send (RTS), asserted by terminals if they can receive data. The section RS232 Cabling describes these signals and how they are connected. The above paragraph alluded to hardware flow control. Hardware flow control is a method that two connected devices use to tell each other electronically when to send or when not to send data. A modem in general drops (logical 0) its CTS line when it can no longer receive characters. Note that hardware flow control requires the use of additional wires. The benefit to this however is crisp and reliable flow control. Another method of flow control used is known as software flow control. This method requires a simple 3 wire serial communication link, transmit data, receive data, and signal ground. If using this method, when a device can no longer receive, it will transmit a character that the two devices agreed on. This character is known as the XOFF character. This character is generally a hexadecimal 13. When a device can receive again it transmits an XON character that both devices agreed to. This character is generally a hexadecimal 11.

IV. FLEX SENSOR

The Flex Sensor patented technology is based on resistive carbon elements. As a variable printed resistor, the Flex Sensor achieves great form-factor on a thin flexible substrate. When the substrate is bent, the sensor produces a resistance output correlated to the bend radius—the smaller the radius, the higher the resistance value. Flex sensors are sensors that change in resistance depending on the amount of bend on the sensor. They convert the change in bend to electrical resistance - the more the bend, the more the resistance value. They are usually in the form of a thin strip from 1"-5" long that vary in resistance from approximately 10 to 50 kilo ohms. They are often used in gloves to sense finger movement.

2.1. Attributes of FLEX Sensors

- Custom designed to match customer specs
- High level of reliability, consistency, repeatability
- Harsh temperature resistance
- Variety of flexible or stationary surfaces for mounting
- Infinite number of resistance possibilities and bend ratios

2.2. TILT ANGLE MEASUREMENT

The movement of the human arm along sagittal plane, i.e., the plane that bisects the human body into left and right is investigated. This corresponds to the flexion and extension movements of the forearm and the upper arm. Flexion is a bending movement in which the relative angle of the joint between the adjacent segments decreases. Extension is a straightening movement in which the relative angle of the joint between two adjacent segment increases as the joint returns to the reference anatomical position. For the physical therapist, the range of the elbow motion and shoulder joint of the patient is of particular interest for monitoring the rehabilitation progress. To capture the arm's rotational motion, an accelerometer is integrated to the sensor node as an inclinometer.

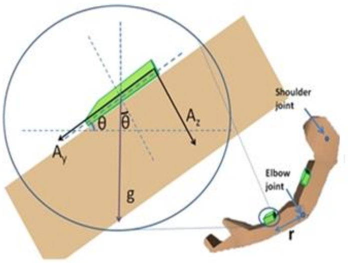


Fig: 3. *Tilt Angle Measurement in Y-Z Plane*

V. TILT/STATIC MEASUREMENT

Figure 2 shows an accelerometer mounted on the forearm. In the static conditions, i.e., the arm is not moving; the tilt angle θ of the accelerometer can be determined by measuring the acceleration due to gravity g. The accelerations A_Y in the Y -axis and A_Z in the Z-axis that are due to gravity can be determined as

$$A_Y = g \sin \theta \text{ --------------(1)}$$

$$A_Z = g \cos \theta.\text{------------- (2)}$$

From (1) and (2), the tilt angle θ can be determined as

$$\theta = \tan{-1}\ A_Y/A_Z \text{ ------------ . (3)}$$

The quadrant of θ can be determined by the sign of AY .The output voltage Vout of the accelerometer is related to the acceleration Ai of a particular axis (i = Y or Z) by the following relationship:

$$\text{Vout} = \text{Voffset} + S \times \text{Ai} \text{ ------------------(4)}$$

Where S = ΔV/Δg is the sensitivity of the accelerometer (in volts per meter per second squared), and Voffset is the offset of the accelerometer at 0g.

The corresponding ADC value can be expressed as

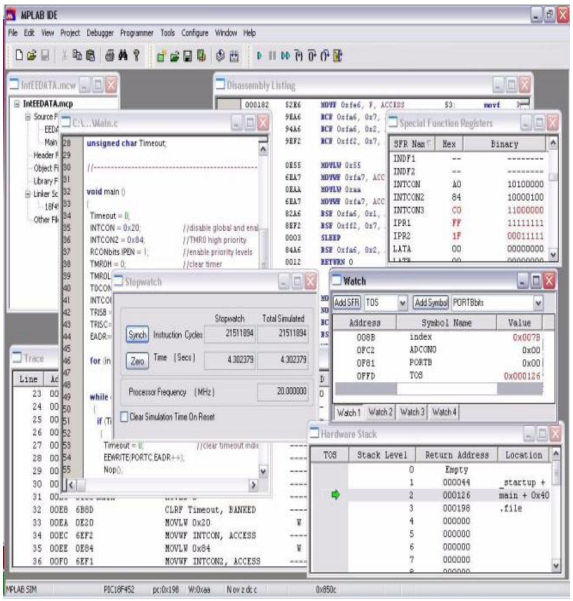
$$\lambda_i = Q\left[\frac{2^n}{V_{\mathrm{REF}}^{+} - V_{\mathrm{REF}}^{-}} V_{\mathrm{out}}\right] \text{ ---- (5)}$$

Where n is the resolution bits of the ADC (n = 8 in this case), V + REF and V−REF are the reference voltage levels, and Q[ ] is the quantized function. The accelerometer is ratio metric, i.e., the output voltage and sensitivity linearly scale with the reference voltage. From (4) and (5), it is observed that the supply induced errors are cancelled in the analog-to-digital conversion process.

Substituting Vout from (4) into (5), the acceleration Ai is approximately proportional to λi after subtracting an equivalent ADC offset. As such, (3) can be rewritten as follows:

$$\theta = \tan{-1}[\ \lambda_Y - \lambda_{Y\,o} / \lambda_Z - \lambda_{Zo}] \text{ --------------(6)}$$

Where λ_Y and λ_Z are the ADC output values of the accelerometer in the Y - and Z-axes, respectively, and λ_Y o and λ_{Zo} are the offsets of the accelerometer at 0g.



```
unsigned char Timeout;

//--------------------------------------------

void main ()
{
 Timeout = 0;
 INTCON = 0x20;              //disable global and enal
 INTCON2 = 0x84;             //TMR0 high priority
 RCONbits.IPEN = 1;          //enable priority levels
 TMR0H = 0;                  //clear timer
 TMR0L
 T0CON
 INTCO
 TRISB =
 TRISC=
 EADR=

 for (in


 while
 {
  if (Ti
  {
   Timeout = 0;               //clear timeout indi
   EEWRITE(PORTC,EADR++);
   Nop();
```

```
000182   52E6   MOVF  0xfe6, F, ACCESS      53:   movf
         9EA6   BCF   0xfa6, 0x7,
         94A6   BCF   0xfa6, 0x2,
         9EF2   BCF   0xff2, 0x7,

         0E55   MOVLW 0x55
         6EA7   MOVWF 0xfa7, ACC
         0EAA   MOVLW 0xaa
         6EA7   MOVWF 0xfa7, ACC
         82A6   BSF   0xfa6, 0x1,
         8EF2   BSF   0xff2, 0x7,
         0003   SLEEP
         84A6   BSF   0xfa6, 0x2,
         0012   RETURN 0
```

SFR Name	Hex	Binary
INDF1	--	--------
INDF2	--	--------
INTCON	A0	10100000
INTCON2	84	10000100
INTCON3	C0	11000000
IPR1	FF	11111111
IPR2	1F	00011111
LATA	00	00000000

	Stopwatch	Total Simulated
Instruction Cycles	21511894	21511894
Time (Secs)	4.302379	4.302379
Processor Frequency (MHz)		20.000000

□ Clear Simulation Time On Reset

Address	Symbol Name	Value
008B	index	0x007B
0FC2	ADCON0	0x00
0F81	PORTB	0x00
0FFD	TOS	0x000126

```
Line  Ad
 23   00
 24   00
 25   00
 26   00
 27   00
 28   00
 29   00
 30   00
 31   00
 32   00E8  6B8D     CLRF Timeout, BANKED       ----
 33   00EA  0E20     MOVLW 0x20                    W
 34   00EC  6EF2     MOVWF INTCON, ACCESS       ----
 35   00EE  0E84     MOVLW 0x84                    W
 36   00F0  6EF1     MOVWF INTCON2, ACCESS      ----
```

TOS	Stack Level	Return Address	Location
	0	Empty	
	1	000044	_startup +
➡	2	000126	main + 0x40
	3	000198	.file
	4	000000	
	5	000000	
	6	000000	
	7	000000	

VI. MICROCHIP MPLAB IDE

MPLAB Integrated Development Environment (IDE) is a free, integrated toolset for the development of embedded applications employing Microchip's PIC® and dsPIC® microcontrollers. MPLAB IDE runs as a 32-bit application on MS Windows®, is easy to use and includes a host of free software components for fast application development and super-charged debugging. MPLAB IDE also serves as a single, unified graphical user interface for additional Microchip and third party software and hardware development tools. Moving between tools is a snap, and upgrading from the free software simulator to hardware debug and programming tools is done in a flash because MPLAB IDE has the same user interface for all tools.

The MPLAB IDE software brings an ease of software development previously unseen in the 8/16-bit microcontroller market.

The MPLAB IDE is a Windows® based application that contains:

- An interface to debugging tools
    - simulator
    - programmer (sold separately)
    - emulator (sold separately)
    - in-circuit debugger (sold separately)
- A full-featured editor with colour coded context
- A multiple project manager
- Customizable data windows with direct edit of contents
- High level source code debugging

The MPLAB IDE allows you to:

- Edit your source files (either assembly or C)
- One touch assemble (or compile) and download to PIC micro emulator and simulator tools
- Debug using:
    - source files (assembly or C)
    - absolute listing file (mixed assembly and C)
    - machine code

MPLAB IDE supports multiple debugging tools in a single development paradigm, from the cost effective simulators, through low cost in-circuit debuggers, to full-featured emulators. This eliminates the learning curve when upgrading to tools with increasing flexibility and power.

VII. EXPERIMENTAL RESULTS

Figure 4 shows the experimental set up of the project. The transmitter and the receiver sections are connected to PC. The MEMS sensor and the FLEX sensor are connected to the transmitter, transmits the sensed data. Receiver is connected to the COM port of the computer. It receives the data and sends to the PC via RS232 cable.

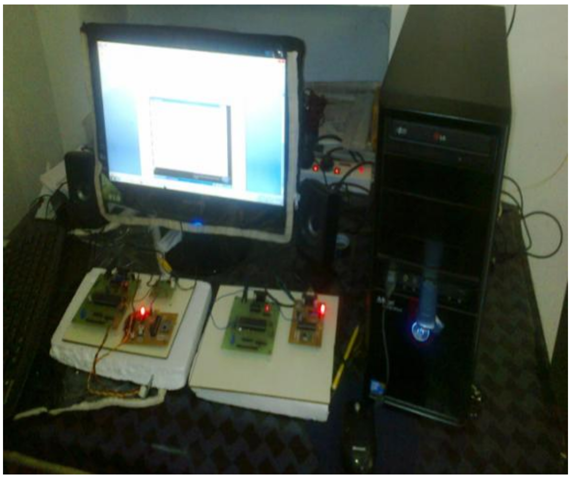


Figure 4: *Experimental Set up*

The MEMS sensor shown in figure 6.2 is attached to the forearm of the human as shown in figure 6.3. The FLEX sensor is attached to the fingers of the human as shown in figure 6.4. These sensors senses the movements of forearm and the fingers of the human and corresponding analog values are send to the microcontroller.

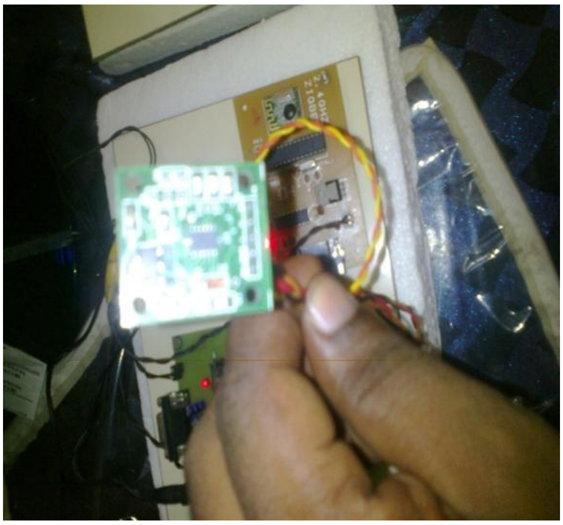


Figure 4.1: *MEMS Sensor*

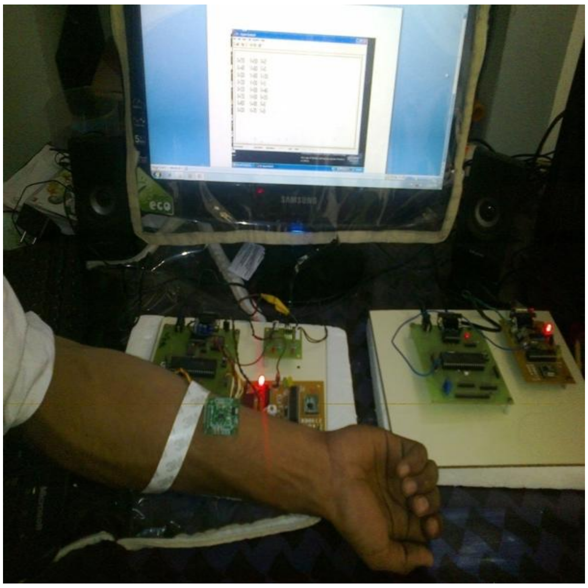


Figure 4.3: *MEMS Sensor attached to the human*

The on chip ADC of the PIC microcontroller converts the analog value to Digital and sends to the RF transceiver which is then transmitted to the receiver. The receiver receives the data and sends it to the microcontroller which is then serially transmitted to the PC. The data is displayed on the PC with the help of hyper terminal.

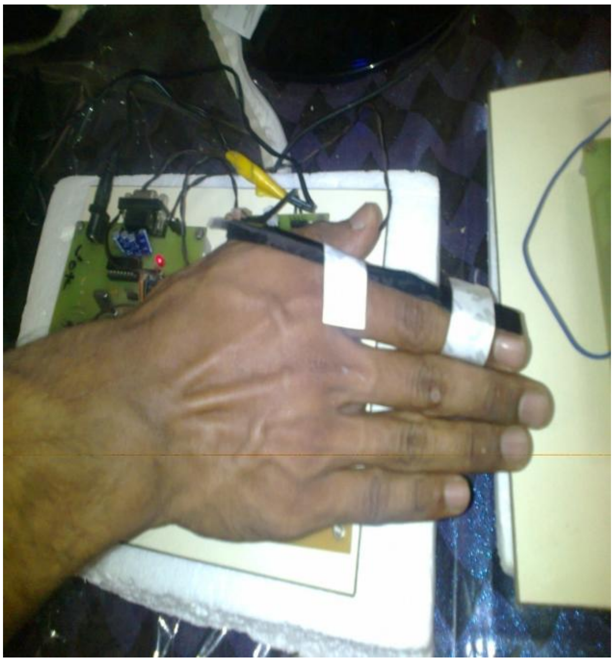
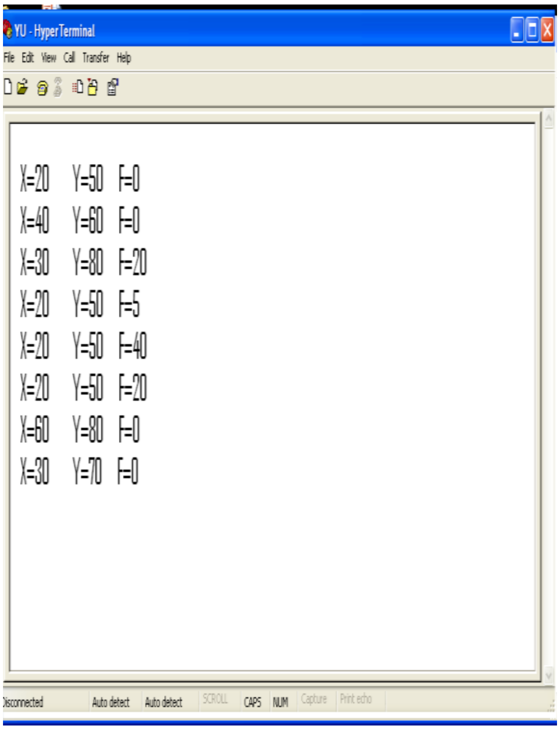


Figure 4.2 : *FLEX sensor attached to the finger of human*

As the movements of forearm and fingers of human changes, the corresponding values are displayed on the PC as shown in the figure 6.5.



```
X=20   Y=50  F=0
X=40   Y=60  F=0
X=30   Y=80  F=20
X=20   Y=50  F=5
X=20   Y=50  F=40
X=20   Y=50  F=20
X=60   Y=80  F=0
X=30   Y=70  F=0
```

Figure 4.4: *Results displayed on PC*

VIII. FUTURE SCOPE

An ambulatory and unrestrained measurement system based on a wearable wireless sensor network for tracking the human arm motion in the sagittal plane has been proposed. The wireless feature enables the unrestrained motion of the human body as opposed to a wired monitoring device and makes the system truly portable. This allows the system to be deployed in a cluttered home environment. The small form factor and lightweight feature of the sensor nodes also allow easy attachment to the limbs.

As compared with other existing approaches, the new system is portable and easy to use. It allows the patients to be monitored without restraint, and rehabilitation can be carried out in a home environment instead of a specialized laboratory in the hospital. For future work, experiments conducted with stroke patients in collaboration with a hospital are being planned using the developed system. More tests can also be conducted to investigate the effect of RF interference from other patient monitoring devices and wireless systems.

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