FINAL YEAR PROJECT

Wireless ECG

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بسم الله الرحمن الرحيم

In the name of Allah, the Beneficent, the Merciful

DEDICATION

We dedicate this project to our parents, teachers and friends who were by our side to encourage us in struggle for our dreams and success and taught us to never lose hope for anything we desire.

CERTIFICATE OF APPROVAL

It is certified that the project work presented in this project report, entitled "**Wirless ECG Monitoring"** *was conducted by students of Bahria University under the supervision of Mr. Ahsan Sohail* by *Saad Amjad, Ahmed Mukhtar & Saqib Rasheed Alvi*

.

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Advisor	H.O.D
Faculty of Electronic Engg.	Department of Graduate Studies & Applied Scienes.
Dated:__________________	Dated:__________________

Acknowledgement

First of all we would like to thank the Almighty One who gave us strength and the sufficient knowledge to take this project to fulfillment.

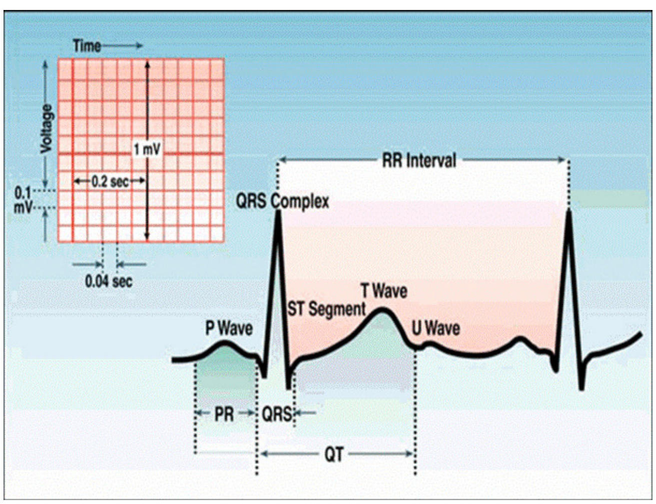
On the other hand we like to thank our advisor Mr Ahsan Sohail for his guidance and because of his help we were able to work in a very friendly environment. Alongside the skillful guidance of our advisor we would like to express our gratitude for his moral support which gave us encouragement to complete this task with utmost dedication.

Thanks to Bahria University of Engineering & Management Sciences for providing us the facilities of lab equipment & research lab which was a great deal of help in our project.

We are also very thankful to our parents for being there for us both morally & financially throughout our academic carrier.

ABSTRACT

As we all know heart is the most important part of a human body it pumps blood 24/7 all around the body to keep the oxygen flowing in our entire body. To carry out this process the heart emits small electric charges to make the heart muscle contract which causes the pumping of blood in the body. The individual may be suspected of serious health issues including cardiac arrest if there is any problem with the process. To predict complication before serious harm the care givers must monitor these charges. To measure these charges a device called ECG Electrocardiograph is used. It consists of electrodes which are placed on desired location of human body to measure the electrical signals. These electrodes are connected to the monitoring system which then measures the voltage difference across the location where the electrodes were placed. Fig 2 shows one of the placement positions of electrodes & Fig 1 shows the waveform of a healthy heart.



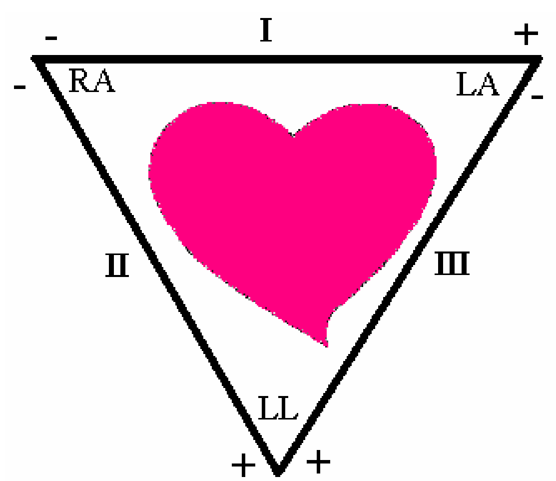


Figure 1 **Figure 2**

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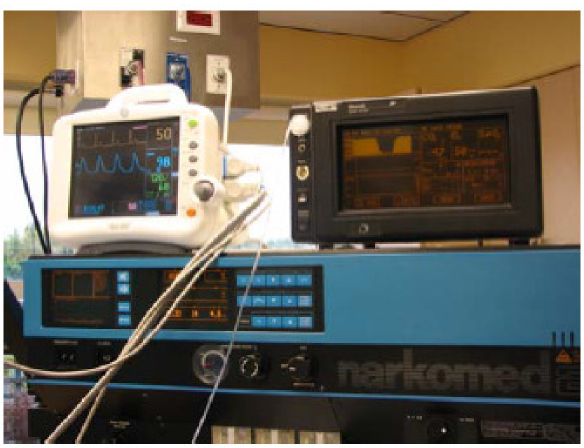
CHAPTER-1 Introduction

Objective

The main problem with the current method of monitoring a patient's heart is very awkward and restricting. The leads are constantly being dislodged from the patient by the nurses, doctors, and even the patient themselves. This causes complications because it appears to the monitoring station that the patient is going into cardiac arrest. (Figures 3 & 4 show a typical operating room with an excess of wires) Another problem with the current system is that the mobility of the care givers is limited due to the number of wires connecting the patient to various monitoring equipment. It is not possible for a nurse or doctor to completely walk around the patient without having to navigate the wires. A solution to this would be to make the hospital utilize wireless data transmission as much as possible to eliminate the need for wires. This process is currently being experimented with. Currently there are various wireless applications in use in the hospital industry. The objective of this project is to design a Wireless System that will reliably measure the electrical activity around the heart and transmit this data to a receiver connected to a PC. The data will then be displayed on the PC in the same manner that the current method already does.



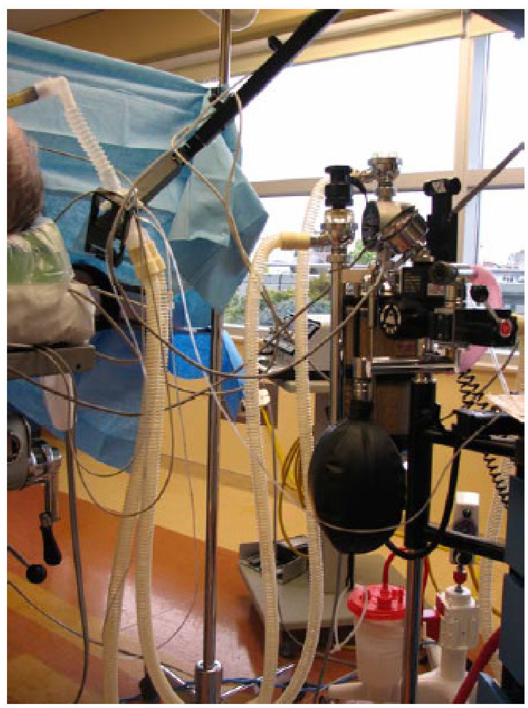


Figure 3-Present Day ECG **Figure 4-Excess of Wires**

CHAPTER-02

Hardware Detail

2.1 ADC/DAC

In electronic equipments current and voltage may be vary continuously over some range of different values. But when we take about digital circuits, the signals are represent levels of values 0 and 1. An analog to digital converter (ADC) works on the principals that it can obtain analogy value and convert in to digital. Digital to analog converter is basically perform reverse operation of ADC it convert digital code (usually binary) into analog (current and voltage).

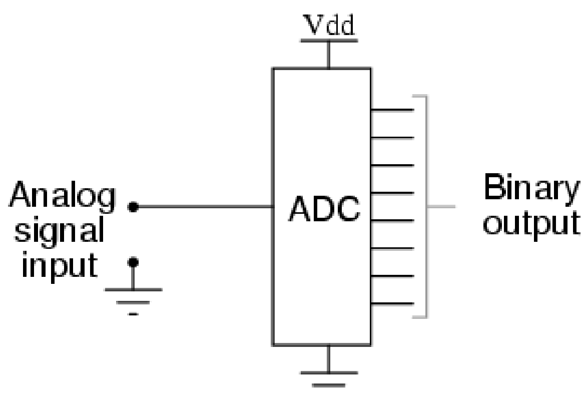


Fig-5

Fig-6

2.2 RAM

Random access Memory is mostly commonly known as RAM. It is a most common type of memory found in computers and other electronic devices. Ram is a temporary storage device. It is also a dynamic device which can lose data if the power will cut off suddenly.

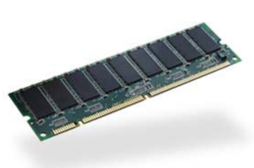


Fig 7

2.3 Electronic Switch

A electronic switch is a component that is used to break up the interrupt the circuit, flow of current and ability to divert from current one electronic component to another. It can operate both manually and automatic according to our needs.

Fig-8

2.4 Resister

A resister is an electrical component with a known specified value of resistance. It is probably found in all types electrical and electronic components. Resister basically opposes or creates resist in the flow of current. Resistance is necessary for any circuit to do useful work. In fact without resistance every circuit is short circuit. Most of the resistance identify through colour coding. Basically there are two types of resistance found:

1- Fixed Resistance
2- Variable Resistance

Fig-9

2.5 Capacitor

Capacitor is another basic electronic component. It has ability to store charge. The amount of charge which it store is depend upon its size, shape and dielectric which we use during manufacturing. Capacitor has ability to oppose any change of voltage in the circuit and it also blocks the passage of direct current through it. Like resisters it also divided in to two general classes.

1- Fixed Capacitors

2- Variable Capacitors.

Fig-10

2.6 Diode

A diode is basically two terminal devices consisting of PN junction. P junction is made up of Anode and N junction is made up of cathode. A diode is one way device, offers low resistance when forward biased and almost act as an insulator in reverse biased. Mostly diode is used as rectifier for converting alternate current into direct current.


Fig-11

2.7 LED

LED is forward biased P-N junction which emits visible light when it energized. A charge carrier recombination takes place when electrons from N-side cross the junction and recombine with the hole on the P-side. As electrons are on higher conduction band and holes are in the lower valance bad so due to be energy difference is given up in the form of heat and light.

Fig-12

2.8 RE-Chargeable Battery

A battery is consists of two or more than two cells connected in series are parallel or both. These are also known as secondary cells because there electro-chemical reaction is electrically reversible. Rechargeable batteries are available in different shape and sizes.

Fig-13

2.9 Stick Antenna

Stick Antenna is basically a transmitting device which transmits signals from transmitting end. Stick antenna are use both transmitting and receiving, it is doubly valuable.

Fig-14

2.10 Transformer

Transformer is basically a stationary piece of device that transfers electric power from one circuit to another having mutual inductance with it. The whole process is done through electromagnetic induction without changing any frequency. Transformer may be either isolation transformer (with electrically insulated primary and secondary winding) or autotransformers (with electrically-connected primary and secondary winding).

Fig-15

2.11 Max 232

Max 232 is a 16 pin (IC). The function Max 232 is to convert Rs 232 serial port signals into appropriate use in TTL compatible digital logic circuit. Max232 is act both as driver/receiver and it usually converts Rx, Tx, Cts and Rts signals.

Fig-16

2.12 LM 741

LM 741 is a general purpose operational amplifier with continuous improvement in manufacturing which makes their application almost perfect like overload protection at input and output, freedom from oscillation and no latch up.

Fig-17

2.13 AD 620

AD 620 is also one of the most important operational amplifier which low price and high accurate instrumentation amplifier that required with one external resister 1 to 1000. The AD 620 feature 8 lead SOIC and DIP packaging that is much smaller than distinct designs and offer lower power (1.3 mA) which makes it high-quality battery powered and transportable application.

Fig-18

2.14 LM 386

LM 386 is a low voltage consumer power amplifier. Internal gain is set to 20 to keep external part count low, but its gain value is increase from 20 to 200 due to the addition of external capacitors and resister from pin 1 to 8. The input is ground and the output biases to one-half supply voltage automatically. It drains only 24 milliwatts when we operate from a 6 volt supply. So that's why is ideal for battery opertion

Fig-19

2.15 LM 3914N

LM 3914N is a massive IC that sense analog voltage level. Circuit contains its own variable reference and perfect 10-step voltage divider. Low bias current input receives signals down to ground. Flexibility is design in LM 3914 so that visual alarm, controller and expanded scale function are easily added on system. The internal voltage 1.2V to 12V and operate supply of less than 3V.

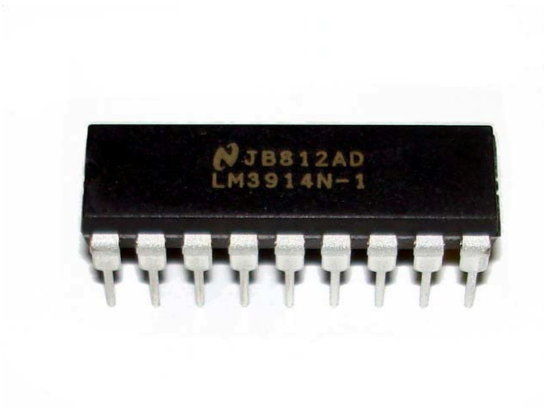


Fig-20

2.16 HEF 4011BP

The HEF4011 is a quad –input NAND gate. The output of HEF4011B is fully buffer for the highest noise protection and pattern insensitivity to the output impedance. The recommended V is 3v to 15v. Its input and output is protected against electrostatic effects.

Fig-21

2.17 MC14017BCF

A five-stage decode counter with built-in code converter. It is a spike free and high speed free output. The outputs are normally low, and go high only at their suitable decimal time period. Output occurs on the positive going edge of the clock pulse. Also this part is use d in decade counter and Frequency division application. Its dc supply range is -0.5 to +18.0 and power dissipation per package 500mW

Fig-22

2.18 ECG Probes

ECG probes are the sensitive leads that are used to monitor the heart's electrical signals. These are very sensitive wires as they are of very low resistance so that it can measure and monitor the heart's movement effectively and efficiently. As the heart has pulses of a few mili volts so sensitive wires are required for the flow of current. So ECG probes are manufactured with the least resistance as possible for effective transmission of heart pulses. ECG probes have 12 standard leads and at the end of the leads all leads are connected to a DB 12/15 male end so that they can be connected to the ECG machine with ease.

Fig-23

2.19 Electrodes

ECG electrodes are used to retrieve the heart signals from the heart.ECG probes are used to carry the heart's signal with the least resistance.We should not confuse ECG electrodes with ECG probes, ECG electrodes are shown in figure given below.

ECG electrodes are not used alone. We have to use a Conducting Gel on the skin of the person so that maximum conduction can be achieved and the heart signal retrieved.

There are two kinds of electrodes, one kind is for the wrist and the other for the chest.We need to place the electrodes in specific order to get the desired results.

Fig-24

2.20 DB 15(FEMALE)

DB 15 which is called ‘D-subminiature’, its a very useful component in electronics which is commonly used for interfacing with generally PC’s. ECG probes have commonly DB 9 or DB 15 male connectors depending upon the number of ECG probes. So for ECG probes the DB 15(FEMALE) is used for interfacing the ECG probes with the ECG machine. Whereas computers have DB 9 ports for interfacing with electronic equipments such as burning a code on the microcontroller through a buring software requires serial port interfacing, so in such cases DB 9 is used, But DB 15 is mainly used for interfacing the ECG probes.

DB has a ‘D’ shaped front and hence the name DB. It has 2 rows of pins and is a very useful electronic component as it can be easily fitted in the PC board

Fig-25

2.21 8052 Microcontroller

See Appendix D

Fig 26

CHAPTER 03 PROJECT APPROACH

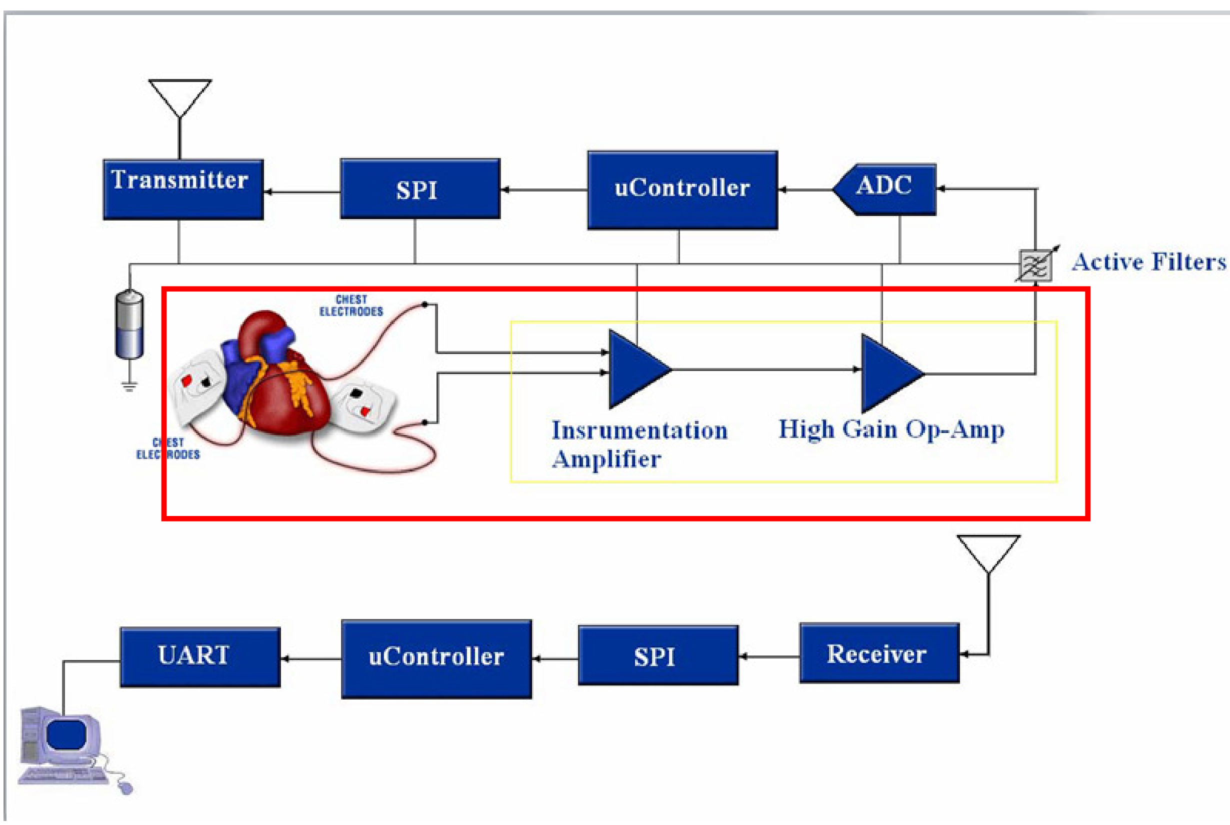
3.1 The Early Approach

The early design was a basic approach to a more complex design. The project was started & divided into three basic tasks

- Data Collection
- Data Filtering and Compression
- Data Transmission/Reception

These steps were implemented both on hardware & software to understand the working & helped us to proceed in more advance hardware design. This approach helped in troubleshooting & identification of more suitable equipment.

Block Diagram



3.2 Software Simulation:

We started the approach via software simulation. The highlighted portion in fig 5 was first tested using the software Multisim to understand the data collection & filtering phase as they are the most sensitive area of our project. In this phase the components were basic:

- AD602
- LM740
- Capacitors
- Resistors
- Voltage Generator
- Oscilloscope

Note: Instead of original heart signal the millivolt values were generated using a voltage generator.

The main purpose of this simulation was to check either our circuit which were about to implement is it applicable to amplify the heart signal & performing the filtering to remove the noise. The software simulation was a success. It showed the positive result of amplification & filtering. The values of the resistor & capacitor were determined via hit and trial method to design the bandpass filter of 60Hz because the heart signal is of about the same value. The values were determined using the following formula.

$$f_{cutoff} = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

3.3 Hardware Implementation:

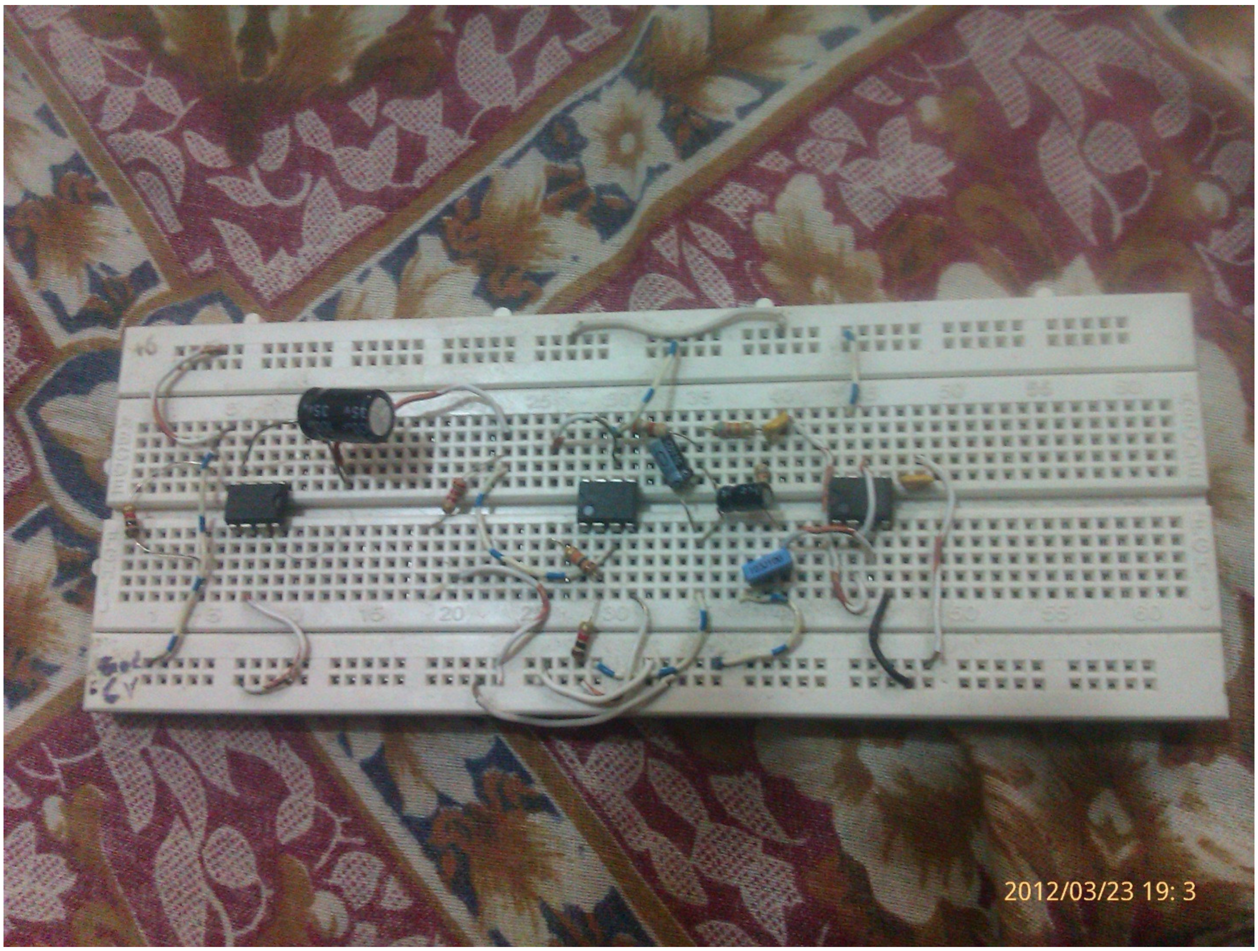
After successful software simulation of this phase the simulated circuit was implemented on actual hardware but during the implementation the we encountered various problems such as

- Burning of IC's
- Irregular flow of current
- Extreme Noise

- Improper Wiring

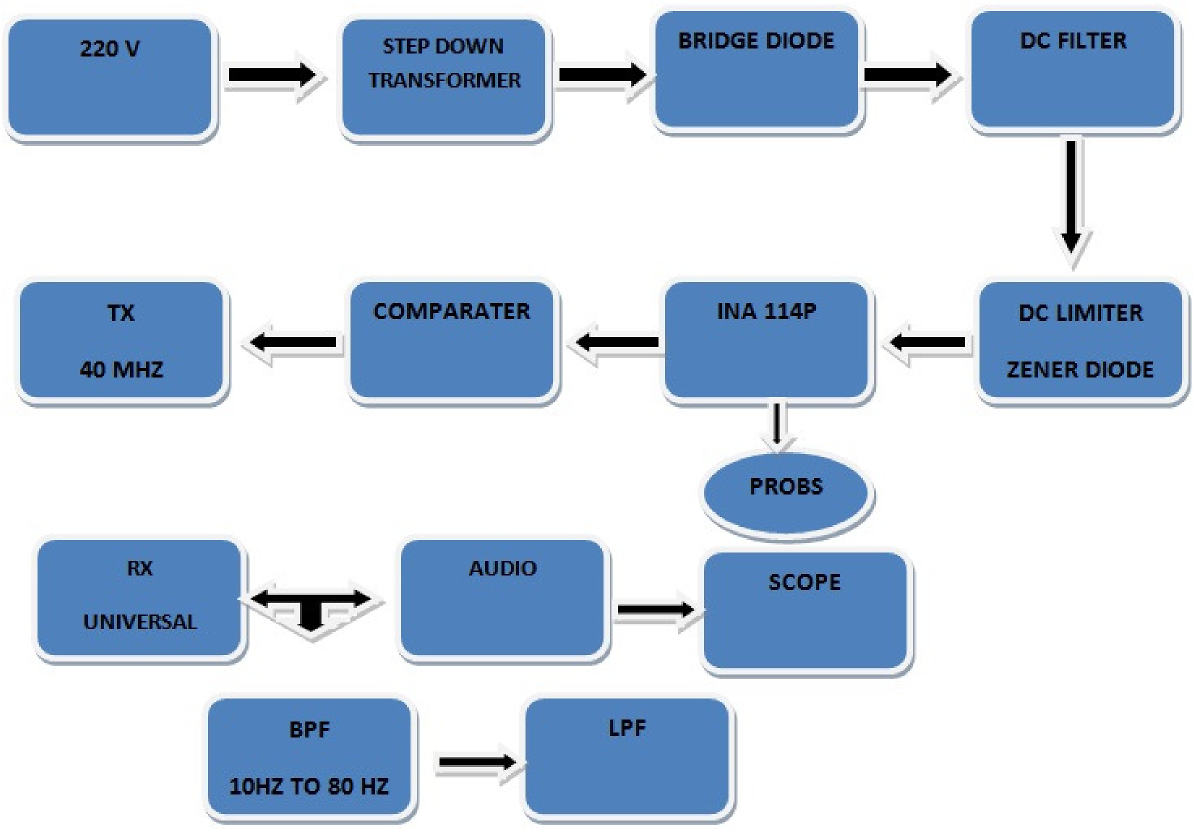
3.4 Hardware Troubleshoot:

The hardware implementation helped us understand that AD602 used must of good quality as it is widely used in medical applications. The wire required to retrieve heart readings must be very sensitive as heart signal generates voltage in millivolts & good quality IC's are must to reduce noise factor.



3.5 The Advanced Approach:

After performing initial testing the project was taken to more advanced approach where all the occurring problems were reduced to aid in good hardware design.

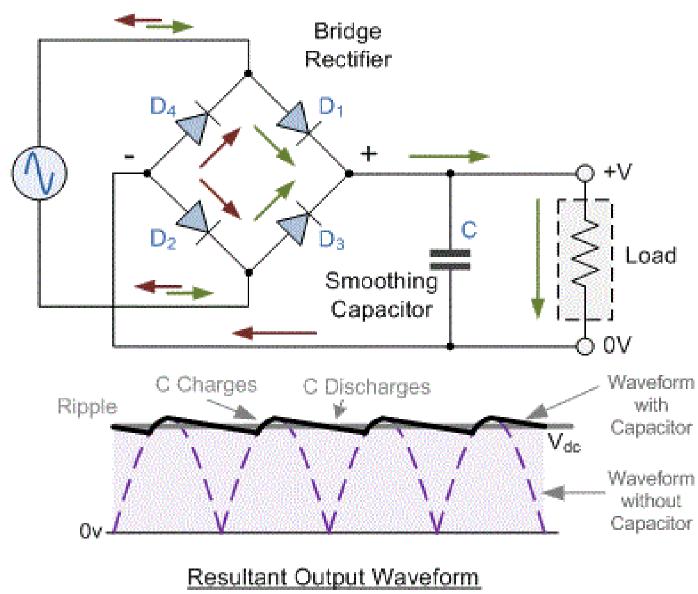


CHAPTER 04 Working and Implementation

4.1 Supply circuit

Our amplification circuit required a constant DC supply, using a battery we were able to do so but the battery drained out after some time, so we needed a constant battery supply source so we had to use a step down transformer to supply the required voltage which was 6 Volts for the ECG amplifier circuit.

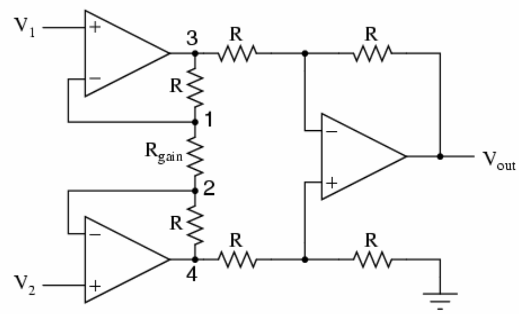
But the problem was that the transformer supplied constant AC voltage's and we needed DC volts so we had to use a Bridge circuit to avoid variation of voltage, and to get a constant DC supply. The problem now was that the wheat stone bridge produced ripples when we used it so we had to use capacitors with it to avoid the ripples produced by the bridge.



We also worked on the batteries, we used rechargeable batteries so that we can charge the batteries and so that the transmitter and receiver can be operated on battery. In that way in the absence of a power source of 220 volts the transmitter and receiver can be operated conditioned that the battries are charged enough.

4.2 ECG amplification circuit

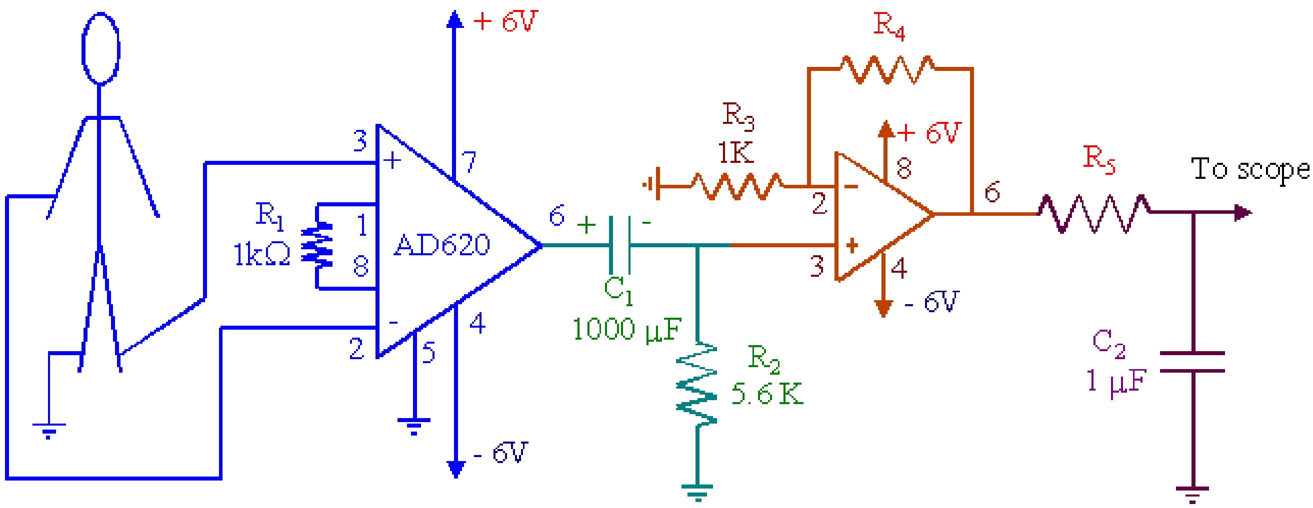
Once the probes are connected to the human body with a specific combination e.g LA (Left Arm) and RA (Right Arm) or LA (left Arm) and RL (right leg) with a ground through the ear or through one of the legs, then we had to use an AD620 IC to get the difference and a single output.

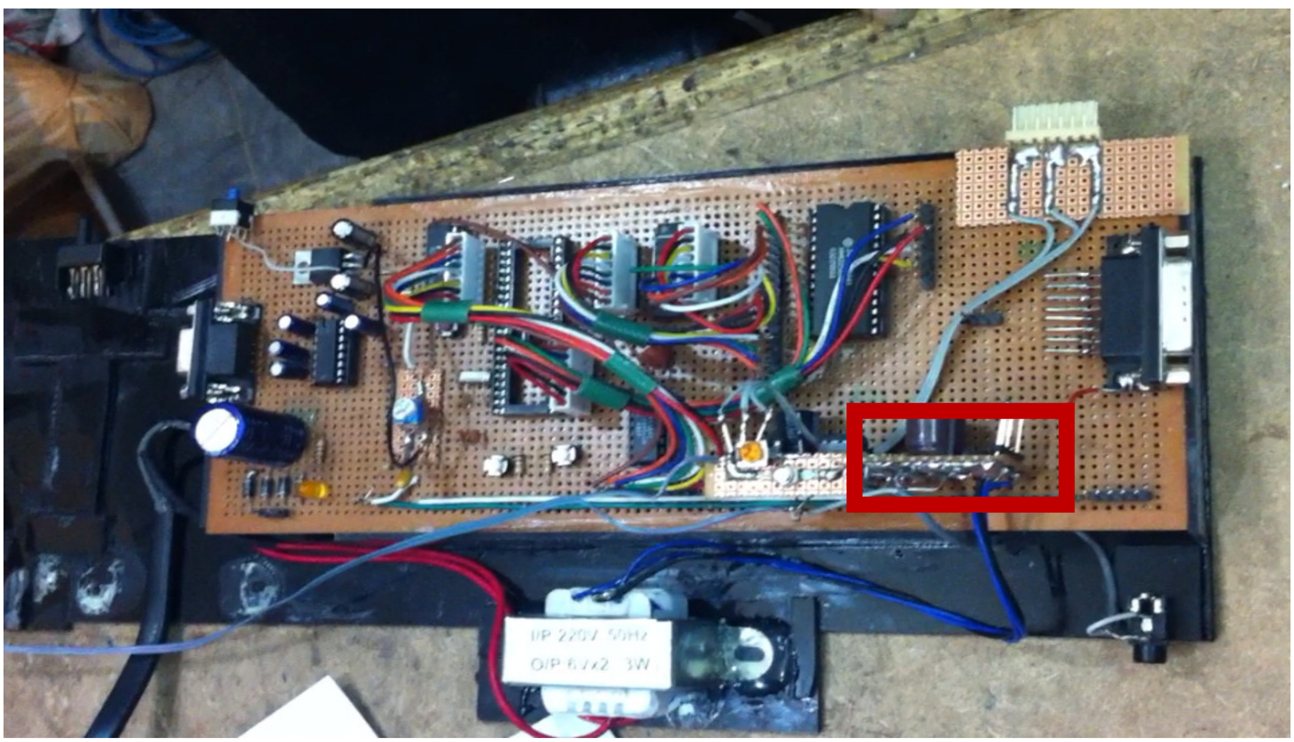


The above figure is the internal circuitry of AD620 which is an instrumental amplifier of special type. This instrumental amplifier will amplify the difference between the voltages of its two points. Its gain can be set by changing its resistance at pins 1 and 8 as we can see in the Data sheet in the appendix

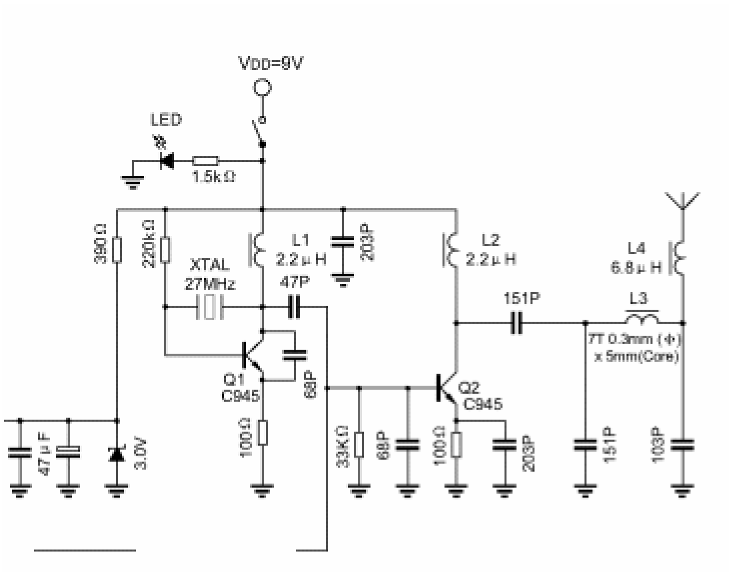
The problem then occurred was that the output of the AD620 had a great deal of noise in it and we had to some how apply filters to reduce the noise as much as we could and the other problem was that we had to amplify the output to at least 200 times more.

LM741 was the perfect IC to amplify the ECG signal 200 times, but the problem with that the noise was also being amplified 200 times so we had to somehow also filter that output so we applied a third order filter to minimize the noise.


+ 6V
R4
R3
1K
+ 6V
AD620
R1
1kΩ
C1
1000 µF
R2
5.6 K
R5
To scope
C2
1 µF
- 6V
- 6V

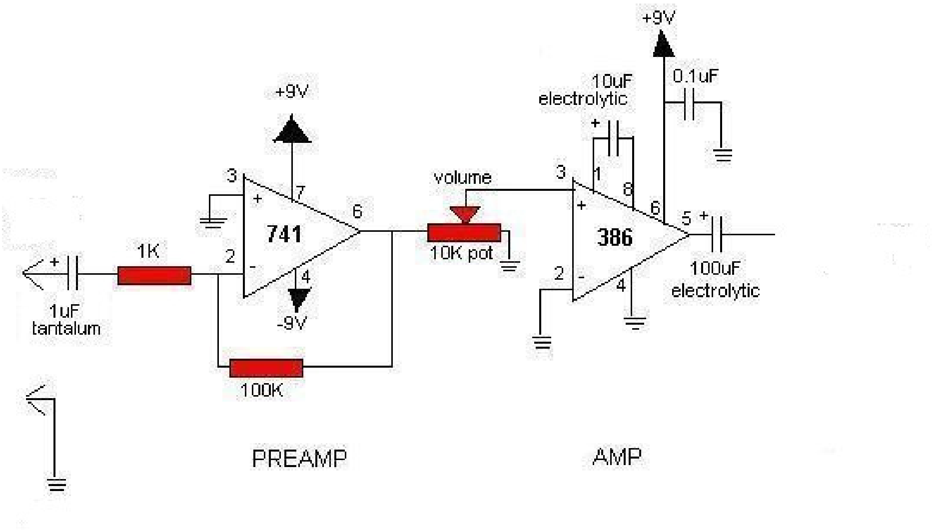


4.4 Transmitter



The following is the transmitter circuit, the circuit operates in the 40MHz range , even though it has a small size and has less component's it has a good range for data transmission. So we have used the above circuit for data transmission for both digital and analogue transmission .

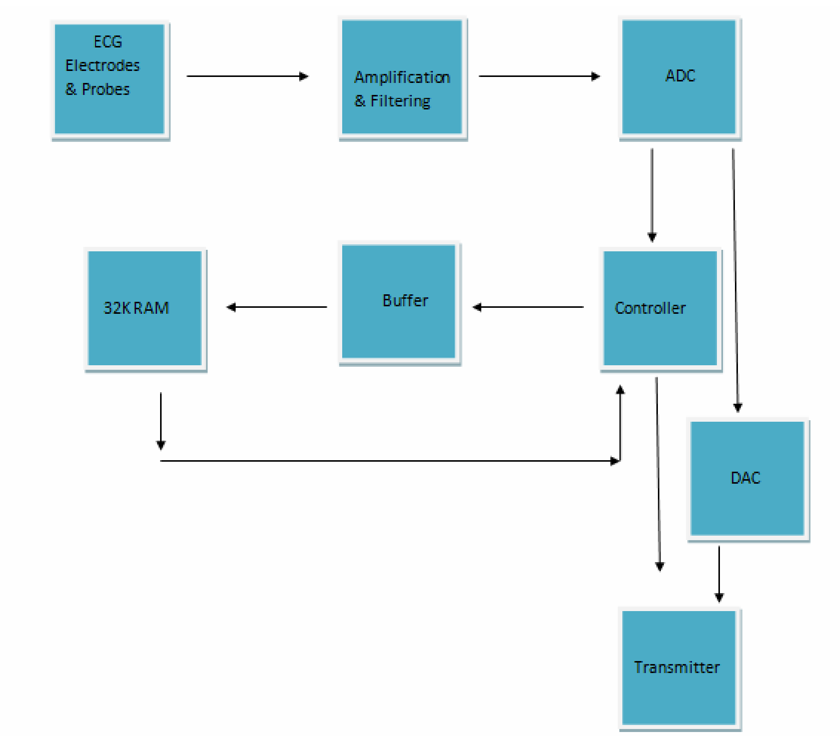
4.5-Receiver

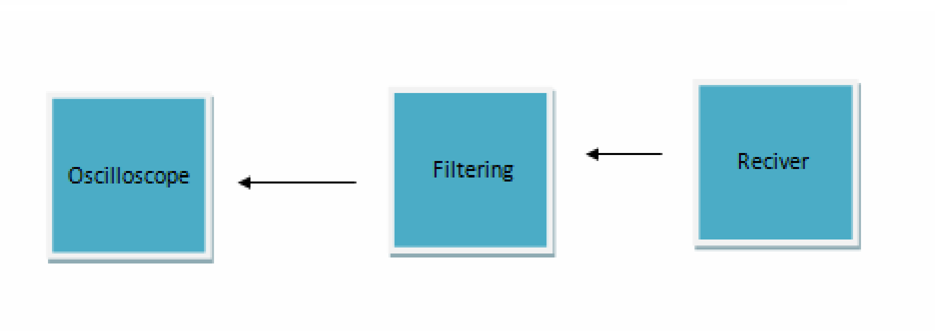


The receiver circuit receives the data and the data is amplified by LM741 so that the attenuated signal is then amplified, but the problem again is that the noise is then amplified.

So to overcome that problem filtering is done using LM386, then the signal is fed to the oscilloscope for the readings to be measured.

CHAPTER 05 FUTURE WORK

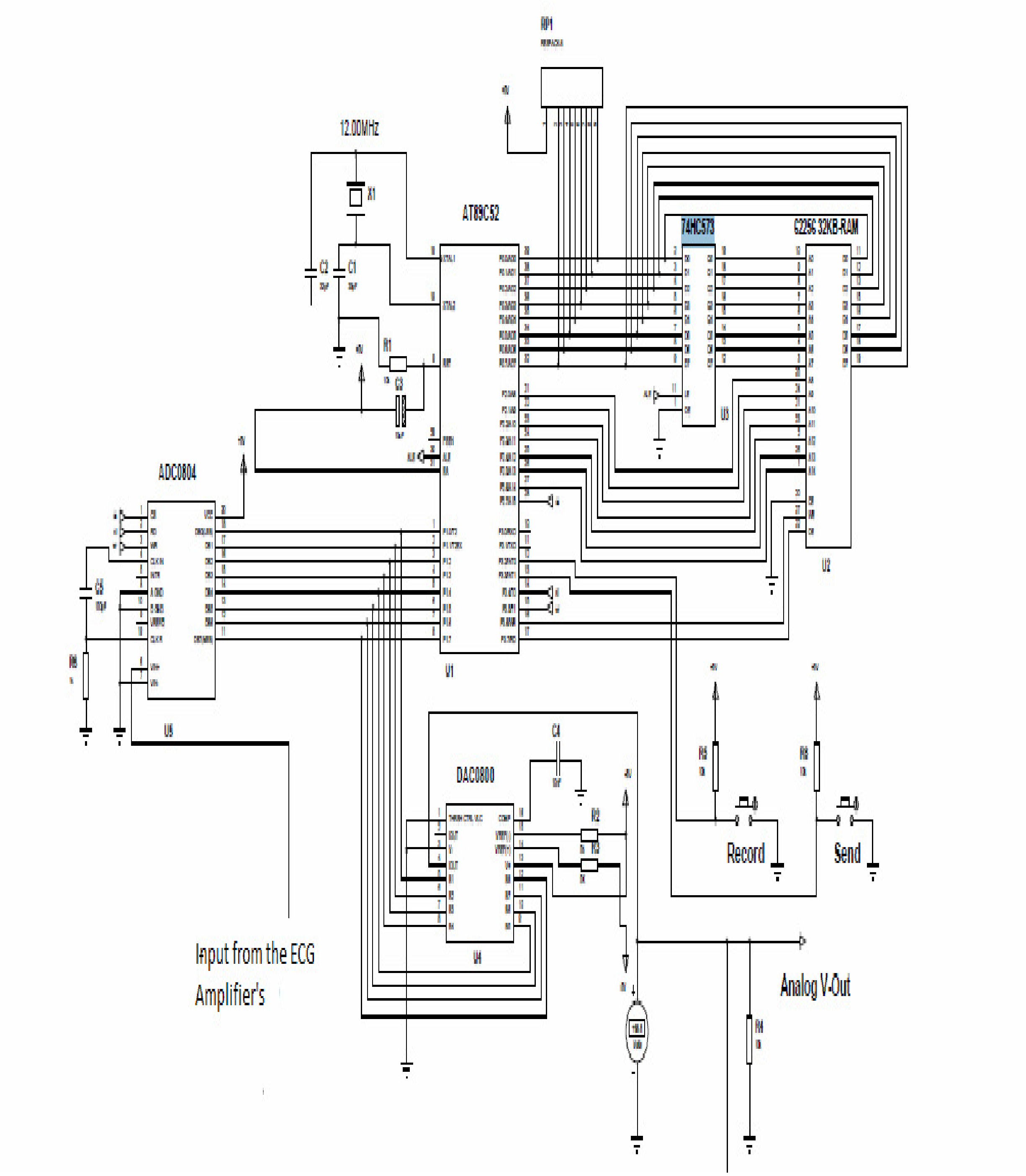




5.1 Future Recommendation:

Once the ECG signal has been amplified then after that it can be converted into the digital format to be fed into the microcontroller. An 8 bit ADC will fullfill that purpose. A PIC microcontroller can also be used as it has many features which are built in it. The most common is that it has a built in ADC which is 10 bit. The ECG recording circuit can use a 62256 32KB-RAM to store the ECG signals, using a buffer the ECG signals can be saved in the RAM and thus can be recorded and then can be played at some later stage.

Not only this circuit stores the data but also real time data can be seen, because the ADC outputs are also connected to the DAC inputs, so we can also observe and transmit the analog signal's.



ECG Recording Circuit For Future

Chapter-05

CONCLUSION

Speedy growth of wireless groundwork in succeeding years will allow a range of new medical tenders that will expressively improve the quality of health care.

There is considerable interest in using wireless and mobile equipment in patient monitoring in assorted surroundings comprising hospitals and nursing homes. However, there has not been much work in determining the necessities of patient observing and nourish`ing these requirements using wireless networks. In this project, we derive several necessities of patient monitoring and show how wireless technology could be used for patient observing.

REFRENCE:

- www.engr.uvic.ca
- www.caritasuni.edu.ng
- www.howstuffworks.com
- LM7401 Datasheet
- Dallas Semiconductors
- Phillip Datasheets for 8051 family

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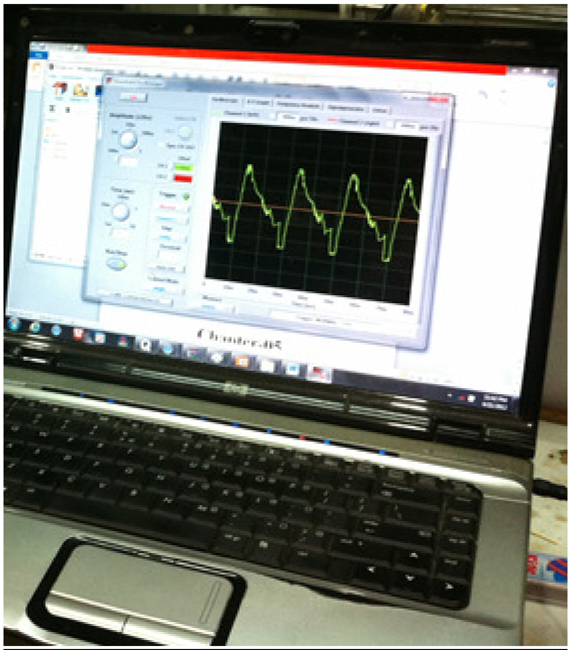
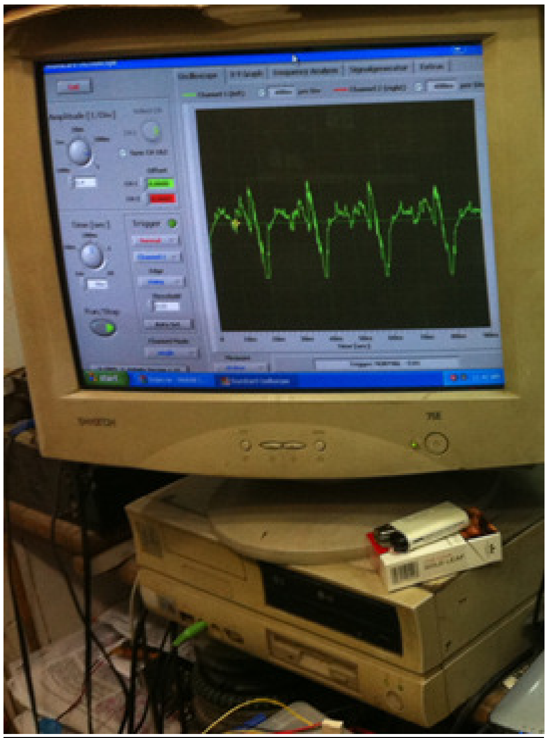
APPENDIX

APPENDIX-A

The Results

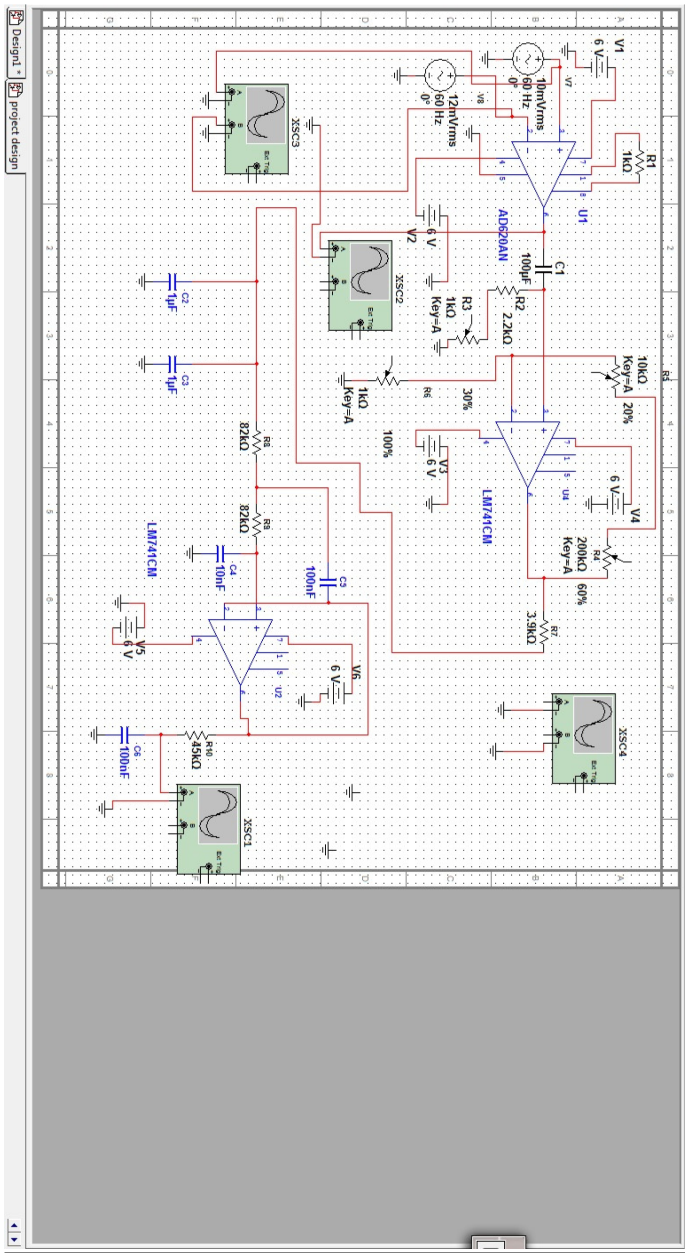


Transmitter Connected to Laptop



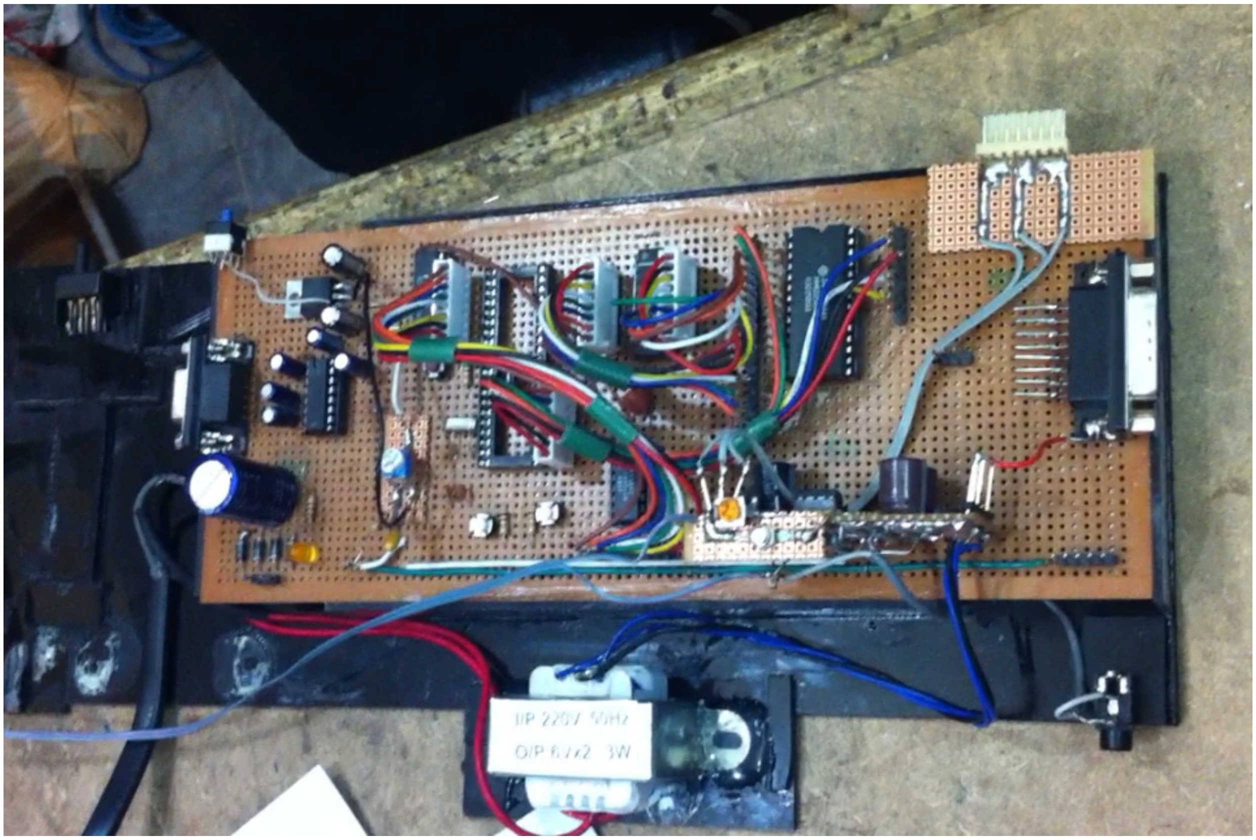
Receiver connected to PC

APPENDIX B



INITIAL APPROCH SIMULATIN

APPENDIX C



The Actual Hardware

APPENDIX D

80C51 8-bit microcontroller family
4 K/8 K OTP/ROM low voltage (2.7 V–5.5 V), low power, high speed (33 MHz), 128/256 B RAM

80C51/87C51/80C52/87C52

DESCRIPTION

The Philips 80C51/87C51/80C52/87C52 is a high-performance static 80C51 design fabricated with Philips high-density CMOS technology with operation from 2.7 V to 5.5 V.

The 8xC51 and 8xC52 contain a 128 × 8 RAM and 256 × 8 RAM respectively, 32 I/O lines, three 16-bit counter/timers, a six-source, four-priority level nested interrupt structure, a serial I/O port for either multi-processor communications, I/O expansion or full duplex UART, and on-chip oscillator and clock circuits.

In addition, the device is a low power static design which offers a wide range of operating frequencies down to zero. Two software selectable modes of power reduction—idle mode and power-down mode are available. The idle mode freezes the CPU while allowing the RAM, timers, serial port, and interrupt system to continue functioning. The power-down mode saves the RAM contents but freezes the oscillator, causing all other chip functions to be inoperative. Since the design is static, the clock can be stopped without loss of user data and then the execution resumed from the point the clock was stopped.

SELECTION TABLE

For applications requiring more ROM and RAM, see the 8XC54/58 and 8XC51RA+/RB+/RC+/80C51RA+ data sheet.

Note: 80C31/80C32 is specified in separate data sheet.

ROM/EPROM Memory Size (X by 8)	RAM Size (X by 8)	Programmable Timer Counter (PCA)	Hardware Watch Dog Timer
80C31*/80C51/87C51			
0K/4K	128	No	No
80C32*/80C52/87C52			
0K/8K/16K/32K	256	No	No
80C51RA+/8XC51RA+/RB+/RC+			
0K/8K/16K/32K	512	Yes	Yes
8XC51RD+			
64K	1024	Yes	Yes

FEATURES

- 8051 Central Processing Unit
  - 4k × 8 ROM (80C51)
  - 8k × 8 ROM (80C52)
  - 128 × 8 RAM (80C51)
  - 256 × 8 RAM (80C52)
  - Three 16-bit counter/timers
  - Boolean processor
  - Full static operation
  - Low voltage (2.7 V to 5.5 V@ 16 MHz) operation
- Memory addressing capability
  - 64k ROM and 64k RAM
- Power control modes:
  - Clock can be stopped and resumed
  - Idle mode
  - Power-down mode
- CMOS and TTL compatible
- TWO speed ranges at V_{CC} = 5 V
  - 0 to 16 MHz
  - 0 to 33 MHz
- Three package styles
- Extended temperature ranges
- Dual Data Pointers
- Security bits:
  - ROM (2 bits)
  - OTP/EPROM (3 bits)
- Encryption array – 64 bytes
- 4 level priority interrupt
- 6 interrupt sources
- Four 8-bit I/O ports
- Full–duplex enhanced UART
  - Framing error detection
  - Automatic address recognition
- Programmable clock out
- Asynchronous port reset
- Low EMI (inhibit ALE and slew rate controlled outputs)
- Wake-up from Power Down by an external interrupt

Appendix E

LM741

Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 7)

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 3)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 4)	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Junction Temperature	150°C	150°C	100°C
Soldering Information			
N-Package (10 seconds)	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C
M-Package			
Vapor Phase (60 seconds)	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

ESD Tolerance (Note 8)	400V	400V	400V

Electrical Characteristics (Note 5)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V

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APPENDIX F

SPECIFICATIONS

Typical @ 25°C, V_S = ±15 V, and R_L = 2 kΩ, unless otherwise noted.

Table 2.

Parameter	Conditions	AD620A Min	AD620A Typ	AD620A Max	AD620B Min	AD620B Typ	AD620B Max	AD620S[1] Min	AD620S[1] Typ	AD620S[1] Max	Unit
GAIN	G = 1 + (49.4 kΩ/R_G)										
Gain Range		1		10,000	1		10,000	1		10,000	
Gain Error[2]	V_{OUT} = ±10 V										
G = 1			0.03	0.10		0.01	0.02		0.03	0.10	%
G = 10			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 100			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 1000			0.40	0.70		0.35	0.50		0.40	0.70	%
Nonlinearity	V_{OUT} = −10 V to +10 V										
G = 1–1000	R_L = 10 kΩ		10	40		10	40		10	40	ppm
G = 1–100	R_L = 2 kΩ		10	95		10	95		10	95	ppm
Gain vs. Temperature											
	G = 1			10			10			10	ppm/°C
	Gain >1[2]			–50			–50			–50	ppm/°C
VOLTAGE OFFSET	(Total RTI Error = V_{OSI} + V_{OSO}/G)										
Input Offset, V_{OSI}	V_S = ±5 V to ± 15 V		30	125		15	50		30	125	µV
Overtemperature	V_S = ±5 V to ± 15 V			185			85			225	µV
Average TC	V_S = ±5 V to ± 15 V		0.3	1.0		0.1	0.6		0.3	1.0	µV/°C
Output Offset, V_{OSO}	V_S = ±15 V		400	1000		200	500		400	1000	µV
	V_S = ± 5 V			1500			750			1500	µV
Overtemperature	V_S = ±5 V to ± 15 V			2000			1000			2000	µV
Average TC	V_S = ±5 V to ± 15 V		5.0	15		2.5	7.0		5.0	15	µV/°C
Offset Referred to the Input vs. Supply (PSR)	V_S = ±2.3 V to ±18 V										
G = 1		80	100		80	100		80	100		dB
G = 10		95	120		100	120		95	120		dB
G = 100		110	140		120	140		110	140		dB
G = 1000		110	140		120	140		110	140		dB
INPUT CURRENT											
Input Bias Current			0.5	2.0		0.5	1.0		0.5	2	nA
Overtemperature				2.5			1.5			4	nA
Average TC			3.0			3.0			8.0		pA/°C
Input Offset Current			0.3	1.0		0.3	0.5		0.3	1.0	nA
Overtemperature				1.5			0.75			2.0	nA
Average TC			1.5			1.5			8.0		pA/°C
INPUT											
Input Impedance											
Differential			10‖2			10‖2			10‖2		GΩ_pF
Common-Mode			10‖2			10‖2			10‖2		GΩ_pF
Input Voltage Range[3]	V_S = ±2.3 V to ±5 V	$-V_S + 1.9$		$+V_S - 1.2$	$-V_S + 1.9$		$+V_S - 1.2$	$-V_S + 1.9$		$+V_S - 1.2$	V
Overtemperature		$-V_S + 2.1$		$+V_S - 1.3$	$-V_S + 2.1$		$+V_S - 1.3$	$-V_S + 2.1$		$+V_S - 1.3$	V
	V_S = ± 5 V to ±18 V	$-V_S + 1.9$		$+V_S - 1.4$	$-V_S + 1.9$		$+V_S - 1.4$	$-V_S + 1.9$		$+V_S - 1.4$	V
Overtemperature		$-V_S + 2.1$		$+V_S - 1.4$	$-V_S + 2.1$		$+V_S + 2.1$	$-V_S + 2.3$		$+V_S - 1.4$	V