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ECG Patient Monitoring System Using SMTP Technology

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This paper leads to developing a Labview based ECG patient monitoring system for cardiovascular patient using Simple MailTransferProtocoltechnology.Thedesigneddevicehasbeendividedintothreeparts.FirstpartisECGamplifiercircuit,builtusinginstrumentation amplifier (AD620) followed by signal conditioning circuit with the operation amplifier (lm741). Secondly, theDAQcardisusedtoconverttheanalogsignalintodigitalformforthefurtherprocess.Furthermore,thedatahasbeenprocessedinLabviewwherethedigitalfiltertechniqueshavebeenimplementedtoremovethenoisefromtheacquiredsignal.Afterprocessing,thealgorithmwasdevelopedtocalculatetheheartrateandtoanalyzethearrhythmiacondition.Finally,SMTPtechnologyhasbeenaddedinourworktomakedevicemorecommunicativeandmuchmorecost-effectivesolutionintelemedicinetechnologywhichhasbeenkey-problemtorealizetheteledianosisandmonitoringofECGsignals.Thetechnologyalsocanbeeasilyimplementedoveralreadyexistinginternet

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I. INTRODUCTION

ECGisusedtomeasuretherateandregularityofheartbeats,thepresenceofanydamagetotheheart,andtheeffectsof drugs or devices used to regulate the heart (such as apacemaker).Normally,thefrequencyrangeofECGsignalis0.05–100Hzanditsdynamicrangeis1–10mV.TheECGsignalas depicted in Figure 1 is characterized by five peaks andvalleyslabeledbythelettersP,Q,R,S,andT.Theperformanceof ECG analyzing system depends mainly on the accurateandreliabledetectionoftheQRScomplex,aswellasT-andP-waves. The P-wave represents the activation of the upperchambersoftheheart,theatria,whiletheQRScomplexandT-waverepresenttheexcitationoftheventriclesorthelowerchamber of the heart. The detection of the QRS complex isthe most important task in automatic ECG signal analysis.Once the QRS complex has been identified a more detailedexamination of ECG signal including the heart rate and theSTsegmentcanbeperformed[1,2].

Mostofthemodern12-leadECGmonitoringsystemsarebased on Einthoven’s triangle, Wilson central terminal, andGoldbergeraugmentedleads[3].

ThedevelopedECGdeviceisimplementedontheprinci-pleofEinthoven’striangleandusedlead-IIconfiguration,asitisknownasamonitoringlead,giveninFigure2.

Basedonabovefacts,therehavebeennumerousattemptstodevelopmedicalsystemssimilartothework.Sucheffortsare primarily led by the academia but extending deeply intothe industries. However, most research efforts have beenfocusing on either the vital sign monitoring aspect or theECGfeatureextractionusingstandarddatabasesbothfallingshortofexpectation.Havinganalyzedtheexistingsolutions,this work vows to bridge the two major research efforts andbring out a more realizable product to directly benefit theconsumersinthemedicalfield.

Thisresearchworkoffersthefollowingcontributionstotheproducedsystem;foremostistheportableECGmonitoringplatformbasedona3-leadsystemandadesign

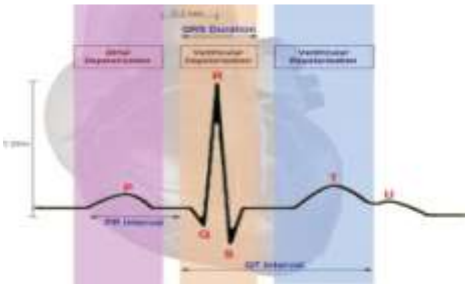
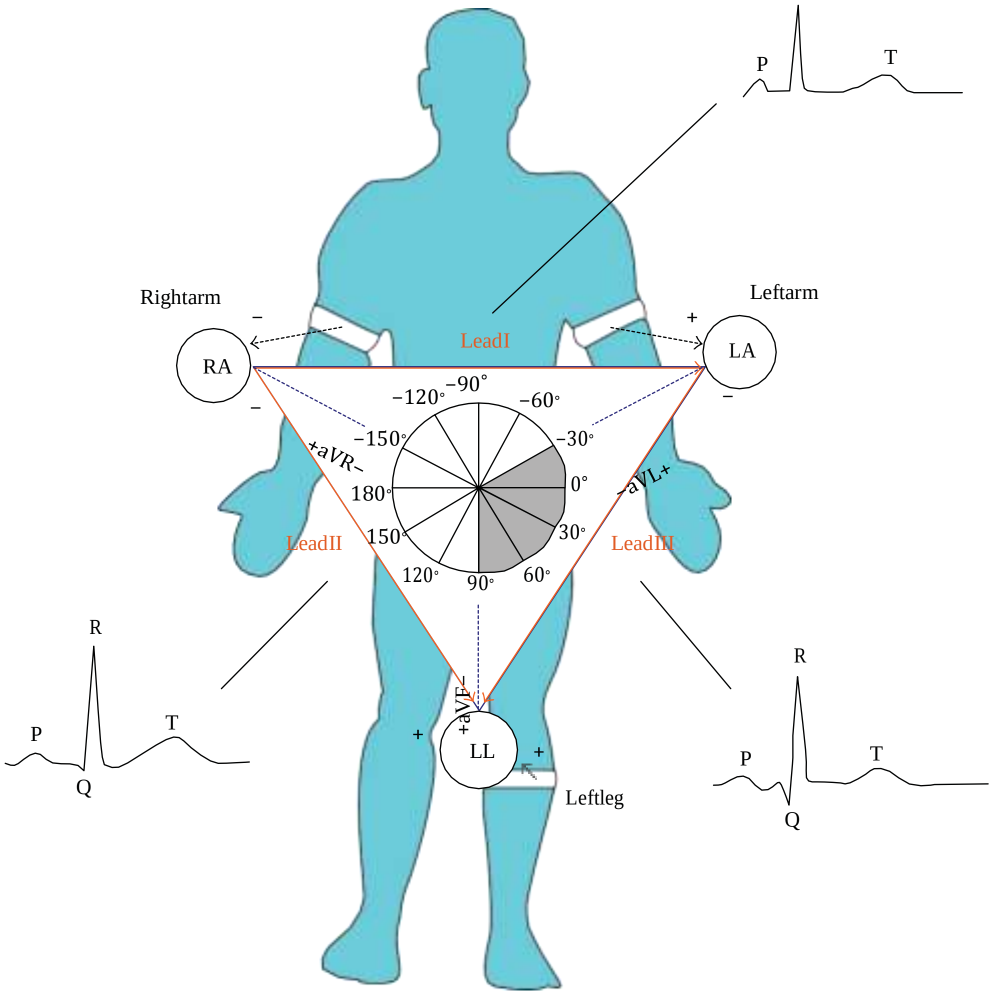
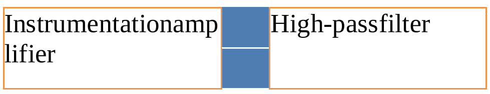


FIGURE1:PeaksofECG.

R



Bipolarlimbleads
Augmentedunipolarlimbleads
FIGURE2:Electrodeplacementusinga3-wirecable.



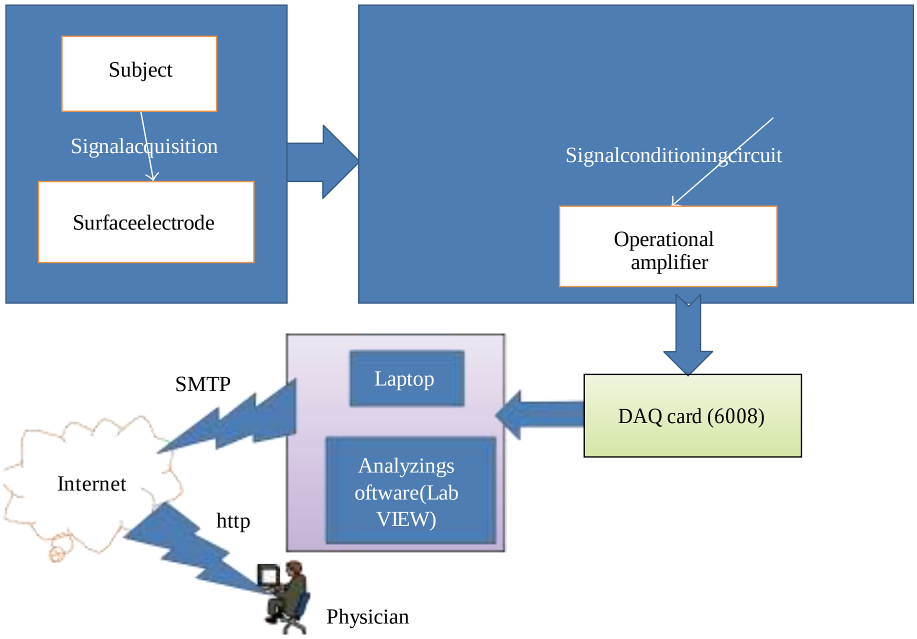


FIGURE3:BlockdiagramofproposedECGdevice.

undertheNIDAQcard(6008).TheECGdatawascollectedthroughtheDAQcardtothePC/laptopandthentransmittedto the end user (physician) through SMTP to analyze thepatientcondition.

Material and Method

Theblockdiagramofthecompletesystemisgiveninfigure3.The complete design was divided into two parts: hardwareandsoftware.

The hardware part comprises instrumentation amplifier(AD620), some passive components, operational amplifier(LM741),DAQcard,andlaptopwhereasLabviewisusedassoftware. The software is used to exchange the data fromanalog to digital form, to perform the calculations, and toproducetheECGwaveformontothemonitor.Eachof the

processed in order to bring the signal in visible form and tolimit the bandwidth of the signal. To do so, the instrumen-tation amplifier was used to amplify the tiny signal whereaspassiveandactivecomponentsareusedtodesignfilterandtoamplifyit.

Figure 4 illustrates the constructive circuit diagram ofsignalconditioning.Thecircuithasbeendesignedandtestedinmultisimstogettheappropriateoutputofsignal.

Instrumentation Amplifier. The voltage gain of theinstrumentation amplifier is calculated using the followingequation:

$$\square = 1 + \frac{49.4k\Omega}{\ },$$

componentsinthisblockdiagramisexplainedindetailinthefollowingsubsections[4].

SurfaceElectrode.Theprincipleoftheelectrodesistoconvertaphysicalparameterintoanelectricaloutput.The

□□

$$\square = 1 + \frac{49.4k\Omega}{1k\Omega} = 1 + 49.4 = 50.4. \quad (1)$$

function of the transducer is to convert biological infor-mation into a quantifiable electrical signal. The transducerinterfaceisprovidedusinganelectrode-electrolyteinterface.The most preferable electrode is Ag/AgCl, as it reduces theimpedance while using it and the gel is used for the propercontactinbetweenthesurfaceoftheskinandelectrode.

OperationalAmplifier.Thevoltagegainoftheopera-tionalamplifierisestimatedusinggivenformulaastheusedoneisnoninvertingamplifier:

□=1+□3,

□2

□=1+

200kΩ=1+200=201.

1kΩ

(2)

SignalConditioningCircuit.Afterreceivingrawecgsignalfromthesubjectthroughelectrode,ithastobe

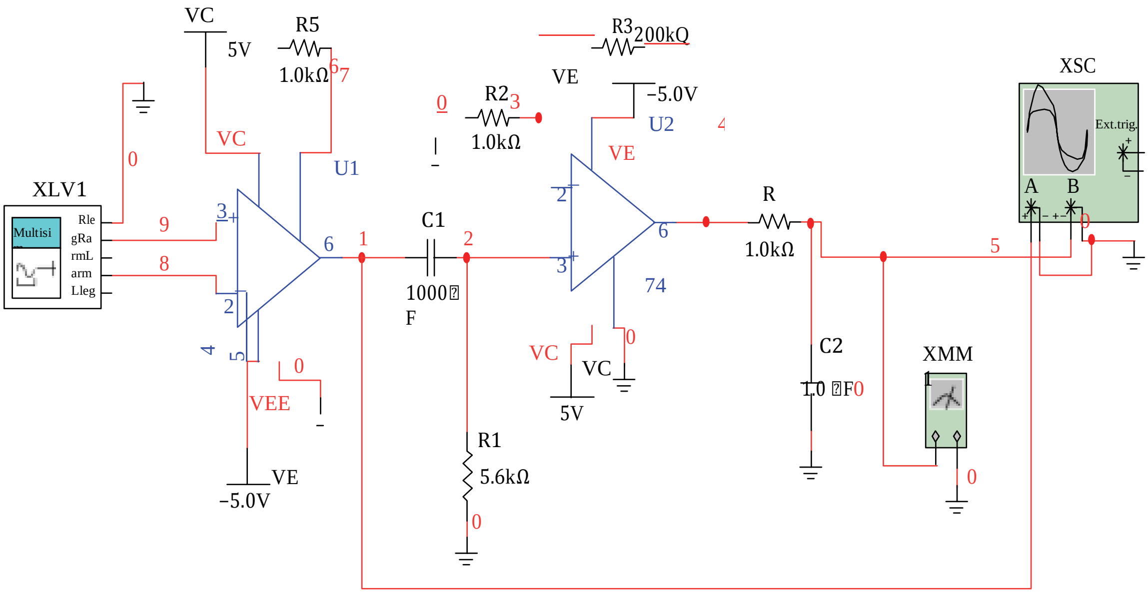


FIgURe4:ECGsignalacquisitionandconditioncircuit.

High-Pass Filter. The output of the instrumentationamplifier is fed into the passive AC coupling with a cutofffrequency,asin(3),of0.02Hzsuchthathigh-passfilters

1

□high-pass=2□□1□1

1

and 12-bit analog-to-digital converter running at a samplingfrequency up to 300 Hz, which can be increased up to 200KHz. This satisfies the sampling requirements of the ECGsignal.

LaboratoryVirtualInstrumentEngineeringWorkbench(Labview).Itisagraphicallyprogrammedcomputerlan-

= 2 ∗3.14 ∗ 5.6∗ 10^3∗ 1000∗ 10^{-6}’

(3)

guageforreal-timeinstrumentation.Itisasoftwarepackagedevelopedtobuildprogramswithsymbols(icons)rather

5

□high-pass=3.14∗56’

□high-pass=0.02Hz.

than writing out lines and lines of programming text. It usessymbols, terminology, and formats that are familiar to tech-nicians,scientists,andengineers.Labviewisprogrammedtoactasaninterface,helpingpiecesofhardware“communicate”

Low-Pass Filter. The second-stage amplified signal isfedintoalow-passfilterwithacutofffrequency,asin(4),of 160 Hz for removing high frequency noise or movement artifacts:

1

□low-pass= 2∗□∗□4∗□2
1

with each other. Moreover, Labview offers built-in librariesthatallowtheusertoworkovertheInternetandusedifferentprogrammingformatsandsystems.

Simple Mail Transfer Protocol (SMTP).Figure 6 showsthe step of SMTP of how the data is processed throughoutthedifferentstagesandtransferredtoclient. ItisapartoftheapplicationlayeroftheTCP/IPprotocol. Usinga

= 2∗3.14∗10∗10³∗ 1 ∗ 10⁻⁶'
1000
(4)

processcalled“storeandforward,”SMTPmovesyoure-mailonandacrossnetworks.Itworkscloselywithsome-thingcalledtheMailTransferAgent(MTA)tosendyour

□low-pass=
=159.2Hz.
6.28

communicationtotherightcomputerande-mailinbox[http://support.aycontrol.com/].

2.3.DAQCard(6008).Theoutputofthesignalconditioningcircuitshouldbesenttothe NIDAQcardfortheconversionofsignalfromanalogtodigitalasithastheinbuiltanalog-to-digitalconverter. Thegivenfigure(Figure5)givestheideaabouttheblock diagram of NI USB-6008 which is a simple and low-costmultifunctionI/OdevicefromNationalInstruments[5].Itisusedtodigitizetheamplified,filteredECGsignal.TheNIUSB-6008cardhas8differentialanaloginputchannels

Designing Strategies

The approach that has been followed in the designing ofdevice is included in Figure 7. There were several stages likefinding the appropriate electrodes to acquire the signal frombody of the subject and analog signal conditioning circuitincludesfilteringandamplifyingstage,DAQcard,anddigitalsignalprocessinganddisplaysystem.

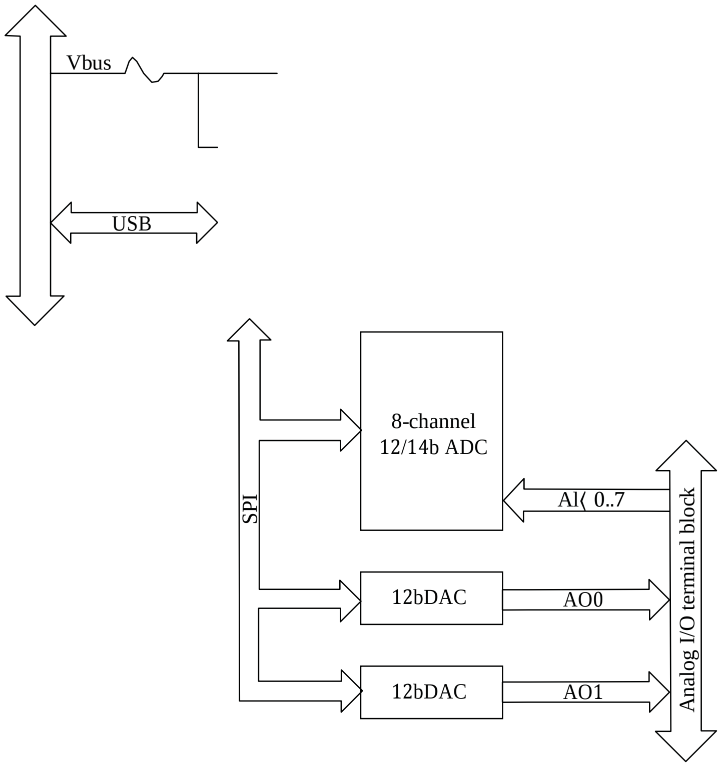
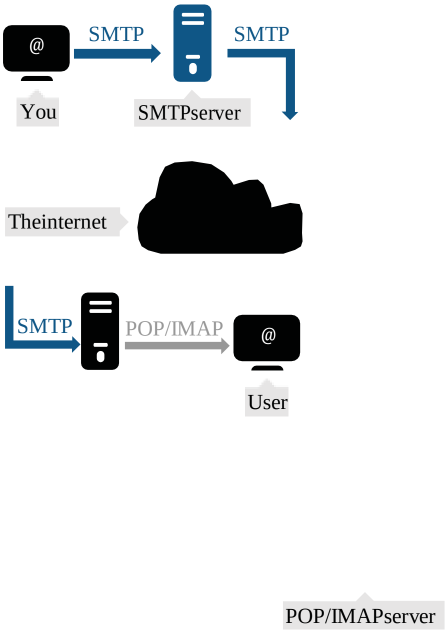


Figure5:NIUSB-6008blockdiagram.



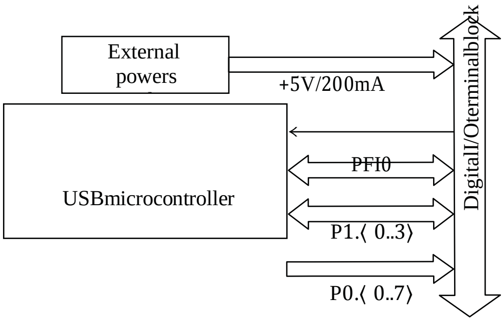


FIGURE6:SimpleMailTransferProtocol(refertohttp://www.serversmtp.com/en/free-smtp-server).

Designed Lab view Interface

The ECG system that has been developed is used for thecontinuous acquisition and chart recording of single inputchannels.Itallowedusertorecordandsavebuffere danalogECGdatafromoneormoreindividuals,whichi scontin-

Retrieving Input Signal. The analog signal is acquiredfromthebreadboardandconvertedtothedigita lonethroughDAQ.Digitalsignalprocessingisdoneacc uratelyasneeded in order to produce high signal-to-noise ratio so thattheheartdiagnosticsystemisprecise.

DigitalSignalProcessing.Here,thedigitalfilt erisdoneto remove the power line interferences and other artifactsavailable in the signal. The necessary data processing todisplayreal-timeECGhadbeenperformed.

Threshold and Peak Detector. The threshold and peakindicatorsareimplementedafterprocessing.Thep urposeoftheseindicatorsistoprovidesomefeedbackto theuser(i.e.,physician)regardingthepatient'saverage heartrate.

Figure 8 gives the idea about the complete ECG systemdeveloped in Labview. The first part shows how the data havebeenacquiredusingdataacquisitioncard(6008);i mmediatein next step, the retrieved data has been processed by BandPassFilteraswellasnotchfiltertoremovetheartifa ctsfromthesignal[9,10].Furthermore,thealgorithmis developedtodetectthepeakofthesignal.

The following given equation is used to calculate the heartrateandtoidentifythearrhythmiacondition[11,12]:

60

uouslyacquiredintoacircularbufferatthesametimeint hatdatapreviouslyretrievedfromthebufferisplotted[6–

HeartRate= ______

t_2

_, (5)

8].Acommonreasontoreaddatawhiletheacquisitionis inprogressistoprocessanddisplaythedatainvirtual-realtime.

with$t_1$beingoccurrence offirstRwaveand$t_2$being occurrenceofsecondRwave.

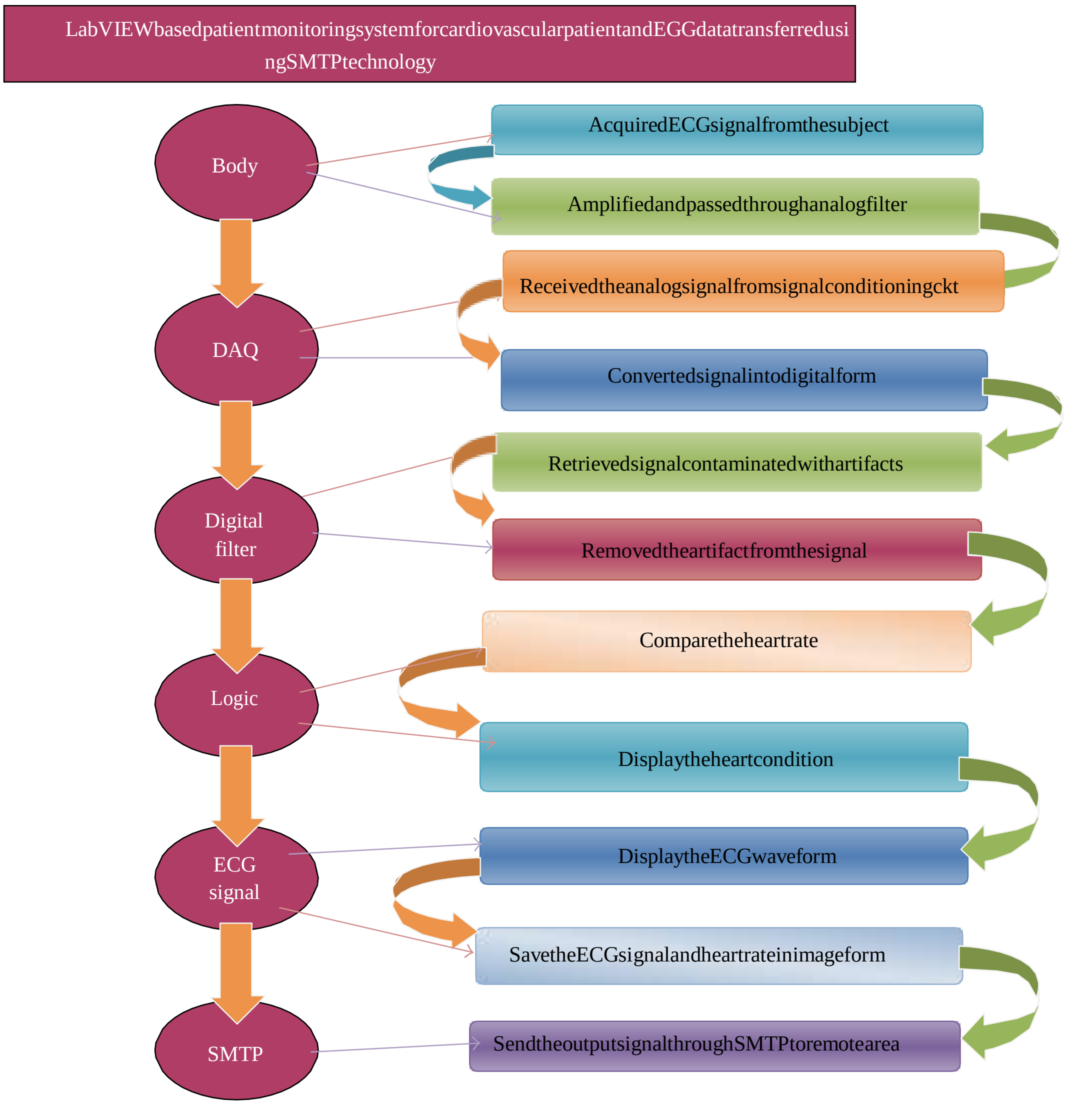


FIGURE7:Designingstrategy.

Dataacquisition Dataprocessing Datapresentation

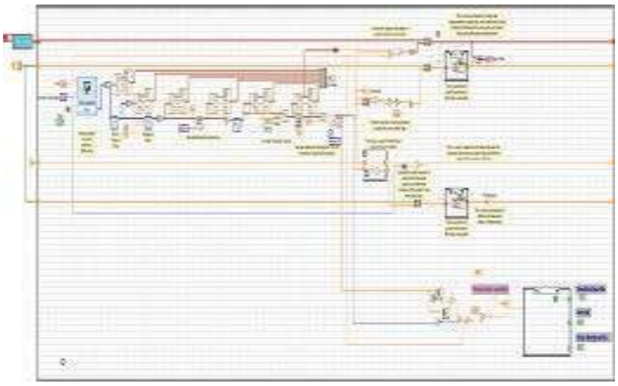


FIgURe8:Acquired,processed,andcalculatedheartrate.

DisplaySystemTool(Toshiba).Afterprocessin grawECGsignal, the signal has been displayed onto the laptop asshown in Figure 9. The display too is compatible with theprerequisiteoftheLabviewsoftware.

SMTP(SimpleMailTransferProtocol).Finally ,thedevel-oped SMTP tool is used to send image file of acquired ECGsignal through Email Express VI, shown in Figure 10 thatrepresents the front panel and Figure 11 that represents theblockpaneldevelopedusingLabviewwhichallows sendingthe data quickly through e-mails from Labview to a healthcarecentreoraphysician.

II. RESULT

Thegivensystemisbasedontheprincipleofheartratem onitoring;itisabletoproducetheresultsshownin

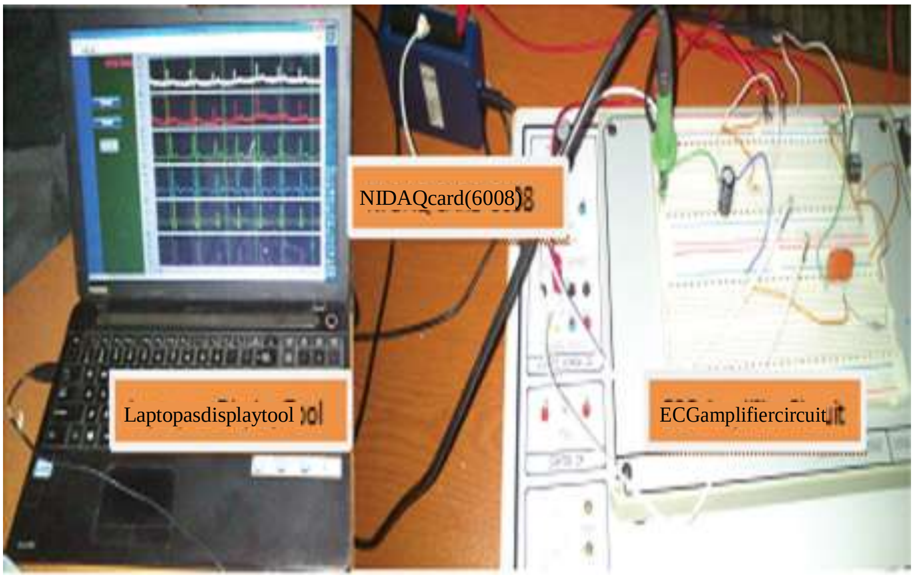


FIgURe9:ProposedECGdevice.

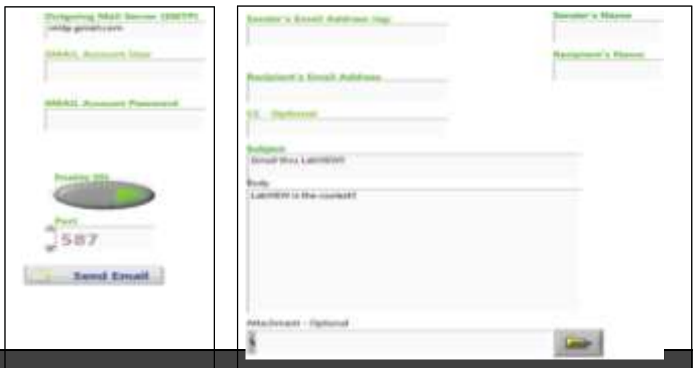


FIgURe10:FrontpanelofSMTP.

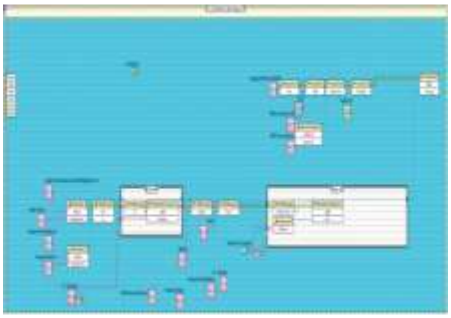


FIgURe11:BlockpanelofSMTP.

Figure12,whichshowaccurateECGsignalsandthecorrectcalculation of both a resting and an elevated heart rate.Initially,therewasanissuewiththesystemregardingdoctornotificationsubsystemwhichhasbeenshortbyvalidatingtheproposed concept by running the VI at home, which sentbothtextande-mailtoour"doctor"notifyingthemthattherewasadetectedproblemwiththepatient'sheart.Itbringsthefreedom for the physician as well as for the doctor to checkup on patients hearts from time to time by seeing real-timewaveformsasshowninFigure12.
The proposed device is functioning well once all thehardware connected properly to meet the criteria for theproposedidea.Asawhole,itisveryreliableandportableaswellascosteffective.

III. DISCUSSION

Mostoftheworkhasbeendonebasedeitheron hardwareoronsoftware.Inthecaseofhardware,totransmittheECG data, transmitter and receiver had been used, whichincreases the cost of the device, whereas the developed oneintegratedwithhardwarealongwithsoftwaretotransmitthe

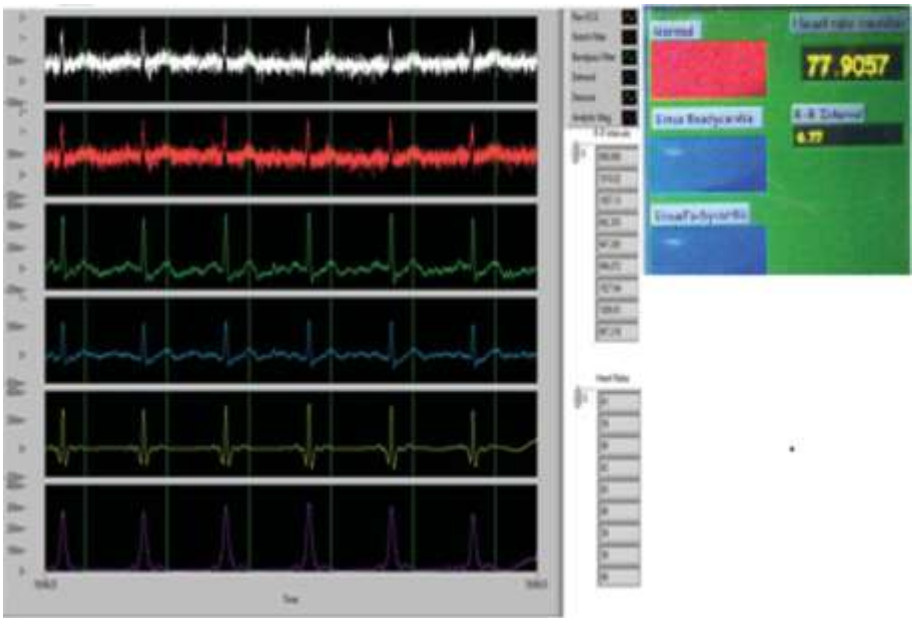


FIgURe12:Acquired,processedECGsignal.

data anywhere using SMTP technology. Thus, the completedevicebecomesmoreuserfriendlyaswellascosteffective.

IV. CONCLUSION AND FUTUREWORK

In this paper, the low-cost biomedical measurement systemwiththeabilityofstorageindigitalformataswell assendingthedatatotheremoteareahasbeenpresented. Thehardwareimplementations using commercially available devices andthe software written in Labview program for continuouslymonitoring ECG data have been described. The proposedmeasurement system is also capable of sending the datathroughSMTPtothephysicianorhealthcarecentre withnotime. The proposed system could be modified by increasingthenumberofchannels.

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