Enhanced Power Efficiency in Piezoelectric Energy Harvesting System Using CMOS Technology

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Abstract:

Energyharvestingistheemergingtechnology,suchdevicesconvertingambientenergyintoelectricalenergy.Varioustypesofambientenergysourcessuchassolar,thermoelectric,bloodpressure,vibrationmicrogenerator,piezoelectricpushbuttonsandambientradiofrequency.Energyharvestingthoroughpiezoelectricisgeneratingverysmallamountofpower.Thislimitsisusetolowenergyelectronicssuchaswearableelectronics,wirelesssensornetworkandlongtermlowpowersensorsetc.Herepiezoelectrictransducerissourceforenergyharvesting.Piezoelectriciscapableofgeneratingelectricalenergywhenavibrationisappliedonthem. Therestrictedlimitoflimitedpowersourceandtherequirementforsupplyvitalityforanexistencetimeofaframework.Thereisanecessityforselfpowergadget.Vitalitygatheringfocusedfrompiezoelectrictransducer.Utilizingpiezoelectrictransducerchangeoverelectricalvitalitybyutilizingrectifier.Theoutputvoltagesofpiezoelectrictransducerare1vonly.Thisvoltageisnotenoughtodrivecircuits.Henceboostconvertersalsoincludedinthiscircuit.Toreducetheoverallpowerdissipationtherectifierandboostcircuitareimplementedusing CMOStechnology.

Keywords:

ACDCpowerconversion,energyharvesting,piezoelectrictransducer,activerectifier,Boostconverter.

1.INTRODUCTION

Energyharvestinghasbeenlargelyresearchedandappliedintoquitealotofpurposesakintowirelesssensornodes(WSNs),implantable,wearablemicroelectronicinstrumentsandmanyothers.Takingcompetenciesofspeedytechnologicaldevelopmentsinlow-energyCMOSdesign.Thesefunctionspermitfortheusageofelectronicsintotoughtoreachlocationsreminiscentofinsidethehumanbody.However,theseimplantedorintegratedelectronicsusebatteriesrequiringperiodicsubstitute.Therefore,theseapplicationsnormallyhaveverystrictrequisitesforbatteryexistence.Tosolvetheproblemsrelatedtopoweringoftheelectronics,powerharvestingfromanambientpowersourcecorrespondingtoelectromagneticsignal, wind,mechanicalvibration,RF,andthermalvigorareconsideredtobeoneofthemostpromisingsolutions.Amongsttheseambientenergysources,piezoelectricvibrationbasedvigorharvestingprocedurehasobtainedaexcellentdealofconcentrationonthegroundsthatofitseaseofintegrationandreasonablepowerdensity.

Technologicaladvancementsinlow-powerCMOStechniqueshavepushedfastprogressofsensorelectronicscorrespondingtoimplantableandwearablesensormethods.Thepoweringofsuchsensortechniqueshasremainedamostimportanttroubleconsideringthattheordinarybatteriescanleakleadingtocriticalwellnessissuesinsufferers.Inaddition,innaturalsensorprograms,thetobehadareaforbatteriesisverylimitedtherebyrestrictingthebatterycapability.Powerharvestinghasemergedasoneofthemostabilitiesoptionsforpoweringthesensorelectronicsandhasbeenextensivelystudiedinrecentyears.Powermaylikewisebegatheredfromdifferentencompassingforcesourcespracticallyidenticaltoelectromagnetic,wind,mechanicalvibration,RF,andwarmpowerandsoforth.Therearethreegeneralpowersourcesthatusevibration,especiallyelectrostatic,electromagnetic,andpiezoelectricamongthesesources,thepiezoelectricvibrationfoundedvigorharvestingmethodhasgotaexcellentdealofconcentrationduetothefactofitseaseofintegrationwithelectronicprogramsandmoderatevigordensity.Afewrectifiercircuitsheadquarteredonpiezoelectrictransducershavebeenstated.Thecircuitsintentiontocurbthevoltagedropthroughoutrectifierdiodeswhilstreferencesgoaltoslashthewastedcostsassociatedwiththechargingoftheplatecapacitanceofthepiezoelectrictransducertoadditionallyexpandthegeneraleffectivityofthetechniques.Thespecialistshaveutilizedtechniquescalledpredispositionflipandsynchronizedswitchreapingoninductor(SSHI)tohelptheextractionofvitality.Nevertheless,thepredominantproblemsassociatedwiththeschemesinvolvetherequirementofrelativelybiginductorstoenhancetheoverallefficiencywhilstnonethelessrequiringverydifficultcontrolcircuits.

Piezoelectric Energy Harvester:

Figure1.showsatypicalbuildingblockofapiezoelectricenergyharvestingsystem.Apiezoelectrictransducerisadevicethattranformsvibrationalenergyintoelectricalenergy. PiezoelectrictransducerproducesanACoutputvoltagecorrespondingtothepressureapplieddataparticularprefuency.Accordingly,anAC-to-DCconverterorarectifierisrequiredtoobtainavaluableDCformoutputvoltage.Byandlarge,thepowerproducedbytherectifieroutputissavedinabattery,agreatcapacitororisregulatedbywayofaDC-DCconverter,LDOandmanyothers.Topowerupthemasses.Therearetwoformsoftraditionalrectifiers:voltage-doublersandfull-bridgerectifier.Themostimportantdrawbacksofatraditionalstructuresarenormallylowextractionandconversionefficiencies.Lowextractionefficiencyiscausedbyusingcharginganddischargingoftheinnercapacitancesofapiezoelectrictransduceritself.

Toovercomethisdrawback,anumberofexclusiveschemeshadbeenstudied,correspondingtosynchronizedchangeharvestingoninductor,switch-onlyharvester,etc.Toimprovetheconversioneffectivityofarectifier,adiodemayalsobereplacedbyusingaCMOScircuit.Forillustration,aCMOScross-coupledrectifierhasdecreasevoltagedropcomparedtoatraditionaloff-chipdioderectifier.Toobtainaregulatedoutputvoltage,itisfascinatingtohavearegulatorequivalenttoDC-DCconverter,LDOandmanyothers.However,theseregulatorswithtobehadpowerbelowa100µWhaveissueswiththeenergyefficiencybecauseoftherelatedenergyconsumptionofthecircuits.

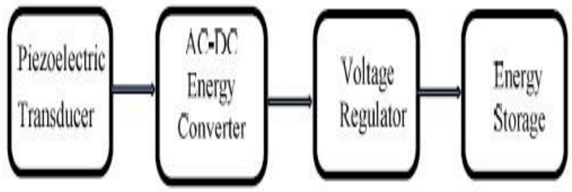


Figure1:Atypicalbuildingblockofapiezoelectricenerg yharvester

I. PREVIOUS WORKA) Transducer Modeling

Apiezoelectricdevicemayalsobemodeledineach mechanicalandelectricaldomainswhichmightbecoupled bymeansofamagneticcoil,asillustratedinfigure2a.Withi nthemechanicaldomainmodelofapiezoelectrictransduce r,RMrepresentsthemechanicaldamping,CMisthereciprocalmechanicalstiffness,andLMistheeffectivemass.Inthe electricalarea,thevibrationalexcitationmayalsobemodel edasacurrentsupplywithaparasiticcapacitance,CPandap arasiticresistance,RP.WithintheproposedCMOSactiver ectifierwithaswitch,ausualmodelofapiezoelectricdevice hasbeenused.Theparametervaluesforthepiezoelectrictra nsducerarechosensuchthatCPis25nF,RPis1 MΩ,andIPis45uA.

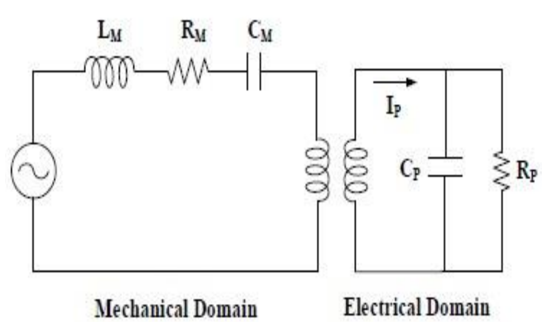


Figure2(a)Schematicofapiezoelectrictransducershowin gmechnicaltoelectricaldomain

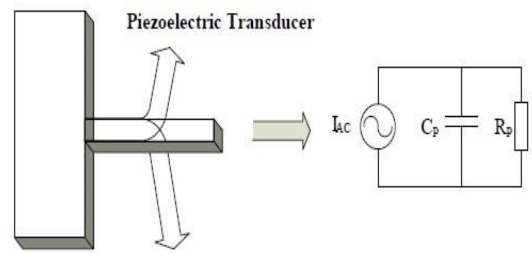


Figure2(b)Simplifiedmodelofapiezoelectrictransducer

B) Full Wave Rectifier

AsshowninFig.2,apiezoelectrictransducermaybemodel edasasinusoidalcontemporarysupplyiP(t) =IPsin2πfPt,inparallelwithaparasiticcapacitorCP,andap arasiticresistor,RP.Theamplitudeofapiezoelectrictransd ucerpresent,IPvarieswiththemechanicalexcitationdiplo maonthepiezoelectrictransducerandfPistheexcitationfre quencyofapiezoelectrictransducer.Aordinarycomplete-wavebridgerectifierconsistsof4diodes.Thedisadvantage ofutilisingadiodeinarectifiercircuitisthatitfinalresultsin aterrificvoltagedropbecauseofthefactthattheflip-onvoltage,Vonofadiodeisextraoftenthannot0.Five~0.7 V.Fig.3depictsconventionalpassivediodeconfiguredfull -waverectifier.

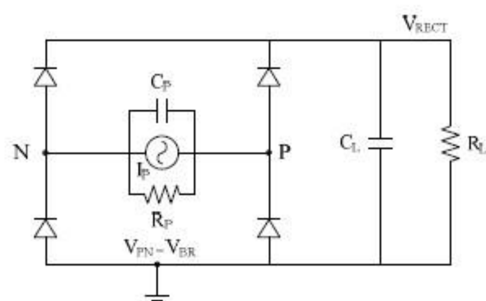


Figure3:Conventionalpassivediodefullwaverecti fier

C) CMOS Full Wave Rectifier

Toreducethevoltagedropacrossadiodewhichimpactsthe conversionefficiency,aCMOSbasedfullwavebridgerectifierisofferedonthispaper.ByusingutilizingaCMOSscienceasasubstitute.Inaddition,aswapmayalsobedeliveredinapiezoelectrictransducercircuittolessenthewastecostwhichfeesordischargestheparasiticcapacitanceofapiezoelectricdevice.Fig.4showsthecircuitdiagramoftheproposedcircuit.Unlikeconventionalrectifiers,theproposedrectifieriscomposedofentirelydigitallycontrolledsystemtominimizedcurrentconsumptionbyacontrolcircuitexceptthe low-energyanalogCMOScomparatorwhichconsumesastaticcurrentof60nA.Powerisminimizedutilizingananalogcircuitwhenyouconsiderthattheessentialpowerconsumptionofthelotsofthecontrolcircuitsisattributedtothestaticcurrentconsumedbywayoftheanalogcircuits.

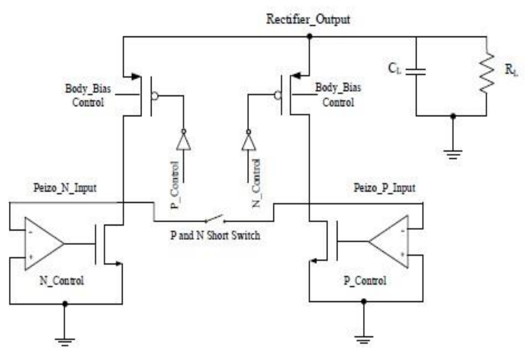


Figure4:Circuitschematicoftheproposedfull-waverectifier

Wheneverapiezoelectrictransduceriscrossingthezeroissue,theonly-shotcontrolcircuitisdesignedtoprovideaquickpulsewhichshortstheinputportsofapiezoelectrictransducer.Thisshortingmovementwillhelpenhancetheefficiencyofthepiezoelectricenergyharvestingwiththeusefulresourceofreducingawasteprice.ThebacksidetwoNMOSgadgetsaremanagedwiththeaidoftheusageofalow-strengthcomparatoratthesametimeasthe pinnaclePMOSgadgetsarecontrolledthrough P_ControlandN_Controlbarindicators.

II. PROPOSED METHODA) Boost Converter

Aboostconverter(step-upconverter)isaDC-to-DC energyconverterwhichconvertsinputvoltagetosomehigherlevelvoltage(ontheidenticaltimeassteppingdowncontemporary)thatisitstepsthesupplyinputstoitsloadoutput.Itisatypeofswitchedmodepowersupply(SMPS)containingatleasttwosemiconductors(adiodeandatransistor)andasabaseonepowersourcedetail:acapacitor,inductor,orthetwointotal.Thefundamentalworkingguidelineofboostconverteristoreducethevoltageripple,filtersproducedfrom capacitors(onceinawhileinmixturewithinductors)aredeliveredtothekindofconverter'soutput(load-facetclearout)andinput(supply-facetclearout).DC-DCconverterswithbetterperformancecanbeachievedthroughtransformerandcoupledinductorbasedtopologies,althoughtherearemanydifficultiesinvolvedindesigningatransformerforhighvoltageswitchingapplications.Parasiticcapacitancecanbealargesourceoflossinatransformer,andagooddielectricmaterialmustbechosentominimizelossesintheparasiticcapacitance.

Intermsoftechnicalpackages,itisrequiredtochangeahardandfastvoltageDCtoconveythecorrectdirectlyintoavariable-voltageDCoutput.ADC-DCexchangingconverterchangesovervoltagespecificallyfromDCtoDCandiseffectivelyknownasaDCConverter.ADCconverterisidenticaltoanACtransformerandiswith analwaysfactorturnsproportion.ADCconvertercouldbe usedtostepdownorstepupaDCvoltagedeliver,likeatransformer.DCconvertersaresignificantlyusedin tractionmotorwhichmanipulateinelectricalvehicles,trolleyvehicles,marinehoists,forkliftscars,andminehaulers. Theyoffersunnecessarystandardgeneralexecution,exactspeedingupcontrolandrapiddynamicresponse.Theywillbeequippedforperforminginregenerativebrakingof DCautostobackwardqualityyetagainintothegive.Thischoice ultimateresultsinenergyeconomicsavingsfortransformationtechniqueswithregularsteps.DCconvertersarecarriedoutinDCvoltageregulators;andarefurtherused,withaninductorinconjunction,togenerateaDCsupply,especiallyfortheprevailingsupplyinverter. Overallperformance,length,andratearethemostextremefundamentaladvantagesofvoltageconvertersevenwhencontrastedwithlinearconverters.Theswitchingpowerconverterefficienciescankeeprunningamong70-80%,onthesimilartimeaslinearconvertersarewiththehelpfulresourceandhuge30%green.TheDC-DCSwitchingupConverterisintendedtogiveanin-experiencedapproachoftakingagivenDCvoltageconvertersandboostingittoausefulvoltage.Inaboostconverter,theoutputvoltageishigherthantheinputvoltage–thereforetheresultwillbe“boosted”.ABoostconverterutilizingapowerMOSFETisestablishedbelow.

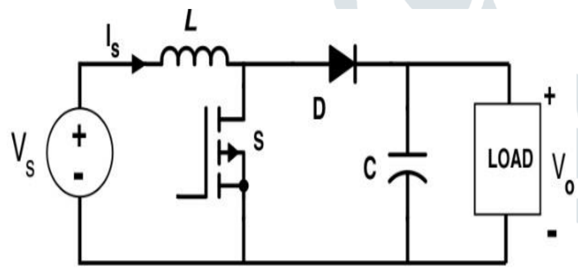


Figure5:CircuitDiagramOfBoostConverter

B) Diode Full Wave Rectifier With Boost Converter

Thediodefullwaverectifierwithboostconverterlayoutisdefinedinfig6.Inthiscircuitdiagramoutputvoltagemaybeextended.Electricitydissipationofthecircuitfurthermoreextendedinevaluationto CMOSfullwaverectifierwithenhancementinvoltageaslikeboostconverter.

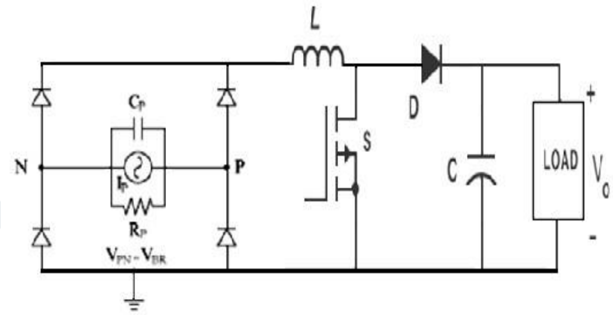


Figure6:CircuitdiagramofDioderectifierwith BoostConverter.

C) CMOS Full Wave Rectifier With Boost Converter

ACMOSFullwaverectifierwithenhancedboostconverterisshowninfig7.Thiscircuitoperationislikeadioderectifier.Inthiscircuit,shortingmovementwillhelpsinbeautifyingorboostingtheoverallperformanceofthepiezoelectricsupplyharvestingthroughreducedwastecharge.Andtheboostconverterwillincreasethevoltageoutputattheload.

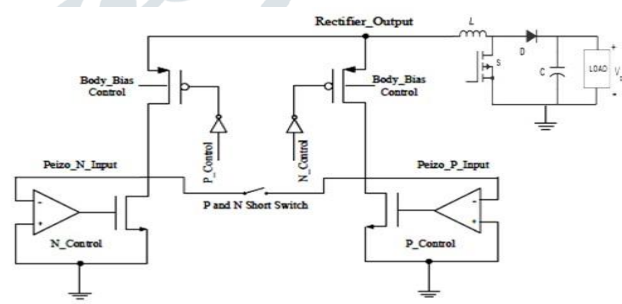
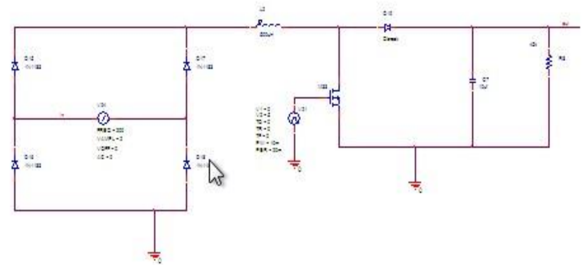


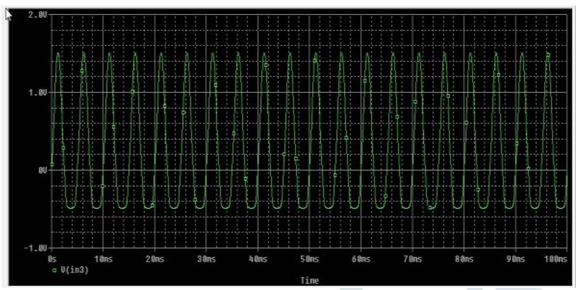
Figure7:circuitdiagramoftheCMOSrectifierwithboost converter

III. RESULTS

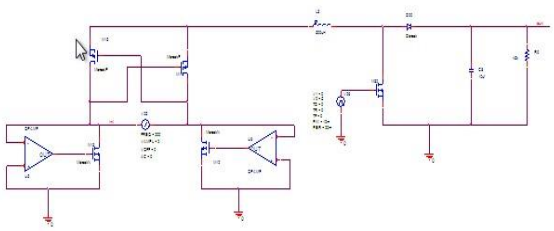
Diode full wave rectifier with boosting:



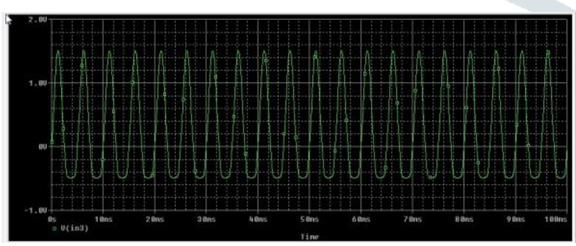
Diode full wave rectifier input:



CMOS Full wave Rectifier with boosting:

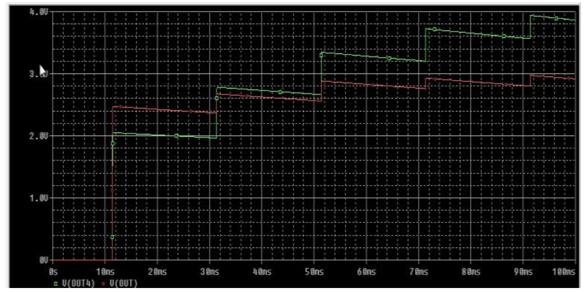


CMOS full wave rectifier input:



ComparisonresultsofdioderectifierandCMOS rectifier.

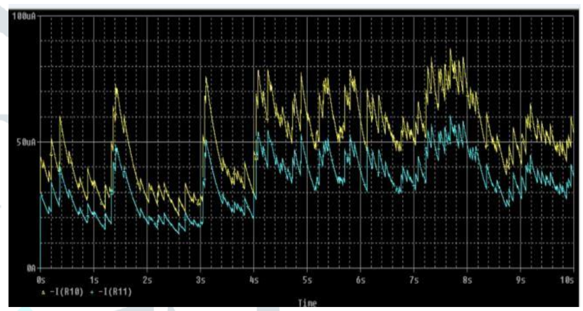
Voltage comparison :



DiodeVoltage

CMOSVoltage

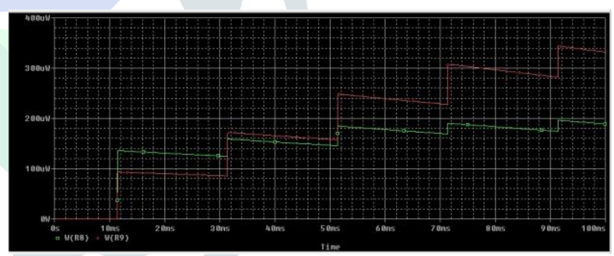
Current comparison :



Diodecurrent

CMOScurrent

Power consumption comparison:



Diodepower

CMOSpower

Diode&CMOS rectifier Comparison

Table:parameterDiodeCMOS Voltage(V)3.04.0		
Power(uW)195340		
Current(uA)6388		
Amplitude(v)22		
Frequency(Hz)200200		

IV. CONCLUSION

Thispapertheimplementationsandsimulationaredoneandwillalsobeaccomplishedin P-spicecapturetool.Inthispaper,Theproposedprocessistoscaledownthepowerdissipationandexaminewiththepreviousdiodefullwaverectifierwithboostconverter.Theamplitudeoftheoutputvoltageis36 V.ThesimulatedconversionratioofVOUTversusVINis80.2%whereascalculatedworthisfiftyeight%.POUTofthe proposedfull-waverectifierwithraiseconverteris5.1µW,andtheaffectivityofthemethodis45%.Thesimulatedandthemeasuredvalueswerenotintentlymatchedseeingthatoftheobstacleofthedimensiontools.Theinputoftheproposedprocessusedtobefurnishedwiththeaidofaperformgeneratorasanalternativeofanactuatortoshakeapiezoelectrictransducer.Theproposedfullwaverectifierwithboostconvertercanretailsawastechargeofnaturallyaspiredpiezoelectricdevice.

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