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An Approach To Develop AModified Resonant Single Ended Primary InductorConverter With High Efficiency And Wide VoltageRanges

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ABSTRACT

Thisworkreports a modifiedresonantSEPICconverter.Itprovidesbetterefficiencyoverawideinputand output voltage range, simple circuit and smallsize. Its controlmethodgivesafasttransientresponseandefficientlight load operation. Theconverter achieves higher than 87% efficiencyacrosstheentireinputvoltagerangeatnominaloutputvoltageandmaintainsgoodefficiency across the wholeoperating range.Here we set up a modified SEPIC converter with switching frequency20MHz.Itsinputvoltagerangesfrom3.6Vto7.2Vanditsoutputvoltagerangesfrom3Vto9V.Itsratedpower is 3W. HereweareusingaPIDcontrollerwhichdoesn'thave sustainedoscillations. ThisdesignissuitableforadaptivebiascontrolofanRFpower amplifierfromabatteryinput,digital cameras, cellular phones,laptops, servers etc…

Keywords:*Single ended primaryinductor converter(SEPIC)converter,soft switching,PIDcontroller,andON-OFFcontrol.*

1. INTRODUCTION

Powerelectronicstechnologyhasgonethroughdynamic evolutioninthelastfourdecades.Recently,itsapplications arefastexpandingininindustrial,commercial, residential, transportation,utility,aerospace,and military environments primarily duetoreductionofcost,size,andimprovementof performance.Inthe globalindustrialautomation,energy conservation, andenvironmentalpollution controltrendsof the21st century,thewidespread impactof powerelectronicsis inevitable.Itappearsthatthe roleofpowerelectronicsonour societyinthefuturewilltendtobeasimportantandversatile asthat ofinformationtechnologytoday.

Power electronicconvertersareafamilyofelectrical circuitswhichconvertelectricalenergy fromonelevelof voltage/current/frequency tootherusingsemiconductor-based electronicswitches.Theinputandoutputmay bealternating currentordirectcurrent.As the power electronics industry has developed, variousfamiliesof powerelectronicconvertershaveevolved, often linked by power level, switching devices, and topologicalorigins.Theprocessof switchingtheelectronic devicesinapowerelectronicconverterfromone state to anotheriscalled modulation,andthedevelopmentofoptimum strategiesto implementthisprocesshasbeenthesubjectof intensiveinternationalresearcheffortsforatleast30years. Each familyof power converters haspreferred modulation strategiesassociatedwithitthat aimtooptimize thecircuit operation for the target criteria most appropriate for that family. Parameters suchasswitching frequency, distortion, losses,harmonicgeneration,andspeedofresponse aretypical ofthe issueswhichmustbeconsideredwhendeveloping modulationstrategiesforaparticularfamilyofconverters.The endgoals ofapowerelectronicconverterare toachievehigh efficiency of conversion, minimize size and weight, and achievedesiredregulationoftheoutput.

The DC-DC converter is an electrical circuit that transfersenergy fromaDCvoltagesource toa load.Inadc-dc converter,boththeinputandtheoutputaredc,and inthe simplestcasetheoutputvoltage needstobe regulatedin presenceofvariationinloadcurrentandchangesinthe input voltage.The switchesaretransistorsanddiodes;thestorage devicesareinductorsandcapacitors.Thisprocessof energy transferresultsinanoutputvoltagethatis relatedtotheinput voltageby thedutyratiosoftheswitches.Inadditiontothe constraintsof size,weight,andcost,DC-DC converter technology alsoaddressesthe issuesofefficiencyand regulation.DC/DCconverters areusedinmost mobiledevices to maintainthevoltageatafixedvaluewhateverthevoltage level of thebatteryis. These converters are also used for electronicisolationandpowerfactorcorrection.

SEPICis a typeofDC-DCconverterallowing theelectricalvoltageatits outputtobegreaterthan,lessthan,orequaltothatat itsinput; theoutputoftheSEPICiscontrolledby theduty cycleofthe controltransistor.ASEPIC issimilartoatraditionalbuck-boostconverter; buthasadvantagesofhaving non-inverted output.Aswithotherswitched modepowersuppliestheSEPICexchanges energy between the capacitors and inductors in order to convertfromonevoltagetoanother.The amountofenergy exchangediscontrolledbyswitch S1,whichistypicallya

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transistorsuch as aMOSFET;MOSFETsoffermuchhigher input impedanceandlowervoltage dropthanbipolarjunction, anddonot requirebiasingresistors.

2. RELATED WORK

SwetaSrivastav,SanjayKumar Singh propose apower convertiblepowerelectronic applicationwe wouldbe ableto achievehighefficiencywithvariableinputandoutput ranging ataverysmallsize. Inaneffforttoreducethecomponent countand alsoimprovetheperformanceanoofsinglestage power factor correction techniqueshavebeen implemented. The concept of variable input and output voltages with reducingthecomponentsizeto smallwithouthampering the efficiency,arealsopresented[2].

JamesR.Warren,III,KathrynAnneRosowski,andDavid J.Perreaultproposedthisdocumentwhichexploresthe design of dc-dc converters operatingin theVHFfrequencyrange (30–300MHz).Itpresentsa methodforevaluatingtransistors andselectingoperatingfrequencies forclass-E-basedpower convertersemployingsinusoidalresonantgating[4].

R.C.Pilawa-Podgurski,A. D. Sagneri,J. M. Rivas,D. I. Anderson,and D.J.Perreaultproposed aresonantboost convertertopology andcontrolmethodsuitablefordesignsat very high frequency. This provides lowtransistor voltage stress,andrequiressmallpassivecomponents,allowingfor veryfasttransientresponse[5].

J.Rivas,R.Wahby,J.Shafran,andD.Perreaultproposed anew architecturefordc–dcpowerconversionthatenable dramaticincreasesinswitchingfrequencies,potentiallyinto themicrowave/ultra-highfrequency (UHF)range.The architectureofmostconventionalsystemsis straightforward: a singlepowerstageofaparticulartopologyregulatedusing a switchingcontroltechnique suchaspulse-widthmodulation (PWM) or frequency modulation. The passive componentsprovideintermediateenergy storageintheconversionprocess andprovidefilteringtoattenuatetheswitching rippleto acceptablelevels[6].

3. ABOUT THE NEW TECHNOLOGY

Thispaperintroducesamodifiedhigh-frequency resonant SEPIC converter and its control methods. In previous converter designs they face many problems like hard switching, less efficiency, complex circuitry and slow transient response.Butinthisproposedapproachitprovides highefficiency overawide input andoutputvoltageranges.In thisit requireslessenergy storage,andthereby wecanachieve fasttransientresponse.Incaseof conventionalresonant convertersitneedsbulkinductorsbutherewecaneliminate the use of bulk inductors and we can achieve portable electronicconverters with small size.The proposed design operatesoverawideinputrangeof3.6V to7.2V,outputrange of3Vto9Vandpowerrangeof0.3W to3W.Thisdesignis suitableforadaptivebiascontrolofanRFpoweramplifier fromabattery input,digitalcameras,cellularphones,laptops, serversetc…

Fig.1.showsthecircuitdiagramoftheproposed SEPIC convertertopology.Therearesomanysimilaritiesbetween theproposedconverterand otherconventionalconverters.The main difference is in its control strategy, component placementandsizing.

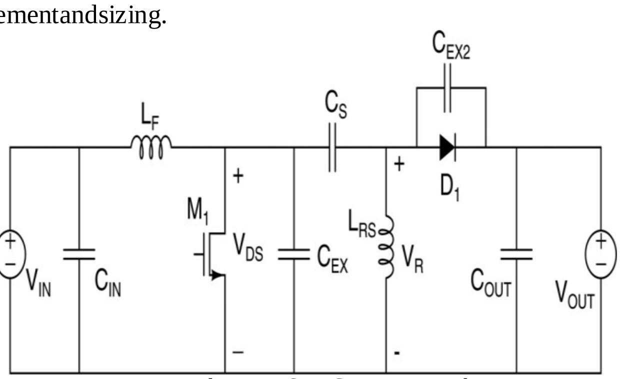

Fig.1.ProposedresonantSEPICconvertertopology

IncaseofaconventionalSEPICconvertertherearetwo bulkinductorsarepresent.Thiswillleadstohardswitchingof theswitchanddiode.Incase ofquasiresonantSEPIC convertersL_F isreplacedwithresonantinductors.Incaseof multiresonantSEPICconvertersitalsousesbulkinductors, but in order to achieve soft switching capacitances are connected in parallel with the switch and diode. In this proposedmodifiedresonantSEPICconvertersthereis nobulk inductors arepresent.Itusestworesonantinductorsone inductorL_F resonateswiththe netswitchcapacitance, $C_{OSS}+C_{EX}$,forresonantinversion,whiletheotherinductorL_{RS} resonates with the rectifier capacitance C_{EX2} for resonantrectification.Thiswillhelpstoimprovetheresponsespee dandreducesthecomponentnumber.

Theother majordifferencebetweenconventionaland modifiedSEPICconverterisinits controlstrategy.Incase of conventionalSEPICconverteritregulatestheoutputvoltage bymakingtheONtimefixedandvariestheOFFtime.This willleadstovariablefrequencyvariableduty ratiooperation. Buthereinthis modifiedresonantSEPICconverteritusesa fixedfrequencyfixedduty ratio.Thishelpsineliminationof bulk components, device stress and enables soft switching overawideinputandoutputvoltageranges.Inthistopology weareusingPIDcontrollertechnique.

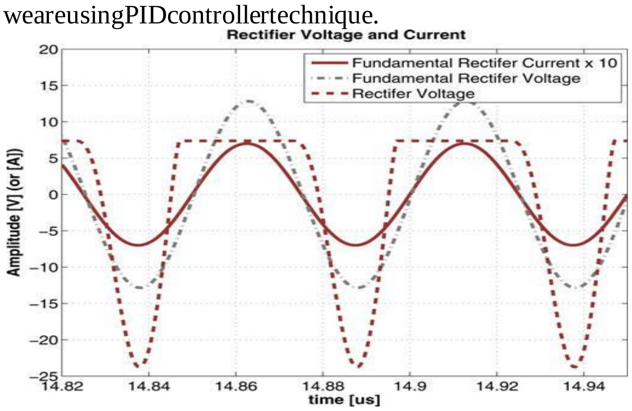

Fig.2.Resonantrectifiervoltageandcurrent

TheoperationofthismodifiedresonantSEPICconverter canbeunderstoodbyconnecting twosubsystems.That isone resonantrectifierandoneresonantinverter.Hereinthiswe aredesigningtherectifierandtheinverterindividually,and thencouplingthem togetherthenretuningasnecessaryto accountfornonlinearinteractionsbetweentheinverterand rectifier.Inthe abovefig.2itshowsthefundamentalsofrectifier voltageV$_R$andcurrentI$_{IN}$oftheresonantrectifieroftunedto lookresistiveatanoperatingfrequencyof20MHz.Herethefundamentalcomponentoftheinputvoltageandthecurrentareinphase.AsthevalueofLRandCEX2arechanged,output powerlevel andthephaserelationship between VR andIIN change.AsthephasedifferencebetweenVRandIINincreases, thelossesduetoreactivecurrentsrise, reducingtheoutput powerandtheoverall efficiencyoftherectifier.

4. CONTROLSTRATEGY

Here we use an ON-OFF control scheme;in which switchingoftheSEPICconverterisgatedONandOFF to controltheaveragepowerdeliveredto theoutput.The frequency atwhichtheconverterismodulatedONandOFFis muchlowerthanthe converterswitchingfrequency.Inthis proposedscheme,thecomponentsaresizedforhighswitchingfrequencywhilethepowerconvertersinputandoutputfilters aresizedforlowermodulationfrequency.

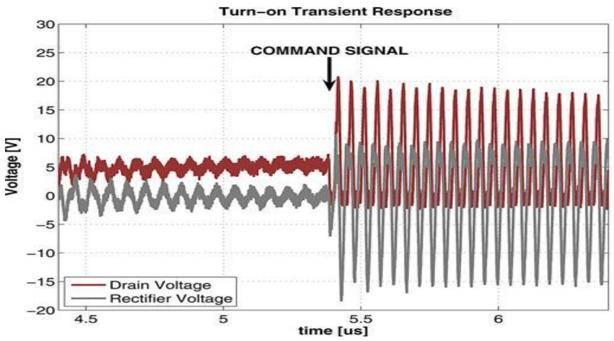

Fig.3.Turn-ONtransientresponse

In previous converter designs they used the ON -OFF controlwithvoltage hystereticcontrolmethod.ThisON-OFF voltagehysteretic method has certain advantages likehigh efficiency atlightload,controlledvoltagebandandgood stability.Buttheinputandoutputvoltagewaveforms have variablefrequency.Thereforethiscontrolbecameundesirable inmany applicationsanditincreasesthedifficultyoffilter design.

Tofacethedifferentproblemsin controlweuseanew approach, in which the on time of the converter is PWM withinafixedmodulationperiod,isutilizedto implementthe ON– OFF control method. In caseof hysteretic ON-OFF controlithasavariablefrequencyoperation.Butin PWM ON–OFFcontrol operatesafixedmodulation frequency. It leadswell-defined frequencycontentattheconverter input andoutput.Ontheotherside,efficiencytendsto reduceat extremelightloads,whentheconvertermayoperateforonlya few switching cycles each modulation period.Characteristicsofthis control methodaresimilarinmany regardstoconventionalfixed-frequency PWM.However, instead of modulating the voltage applied to a filter, thecurrentdelivered totheoutputcapacitorandloadismodulated inthistechnique.

The controllerinthisproposedmodifiedSEPICis implementedwithaconventional PWMchip.Inwhichthe PWMoutputis theenablesignalofthepowerstagegatedrive. The converter power stage can be modeled as a one-pole systemwiththeconverterapproximated asacontrolledcurrent sourcefeedingtheoutputcapacitorandloadC$_{OUT}$andR$_{LOAD}$,whereR$_{LOAD}$istheeffectiveloadresistanceoftheconverter.

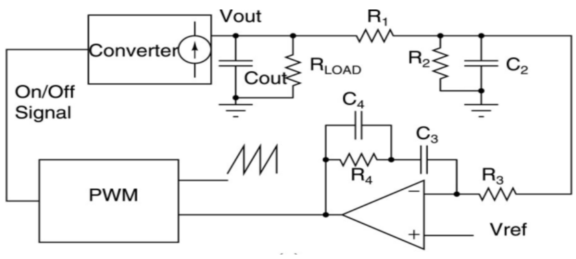

Fig.4.ON/OFF PWMcontrolofaresonant dc-dcconverter

In this proposed topology we are using PIDcontroller. UsingaPIDcontrollercangiveyouperformancethatis better thanusingproportionalorintegral alone,orevenaPIorPD. The controller attempts to correct the error between a measuredprocessvariableanddesiredsetpointby calculating the difference and then performing a corrective action to adjusttheprocessaccordingly.APIDcontroller controlsa processthroughthreeparameters: Proportional(P),Integral (I),andDerivative(D). Theseparameterscanbeweighted,or tuned,toadjusttheireffectontheprocess.PIDcontrollersare atypeofcontinuouscontrollerbecausetheycontinually adjust the output vs.anon/off controller, when looking at feed forwardorfeedbackwardconditions.

5. SIMULATION AND HARDWARE RESULTS

This sectiongivesthe simulationresultsofthe proposed modifiedresonantsingleendedprimary inductorconverter (SEPIC)converter.Theconverteroperatesat 20 MHz.

TABLEI
EXPERIMENTALSPECIFICATIONS

Input Voltage Range	3.6 V - 7.2 V
Output Voltage Range	3 V - 9 V
Switching Frequency	20 MHz
Output Power	0.3 W - 3 W

Thesimulationcircuitand resultsaregivenbelow.

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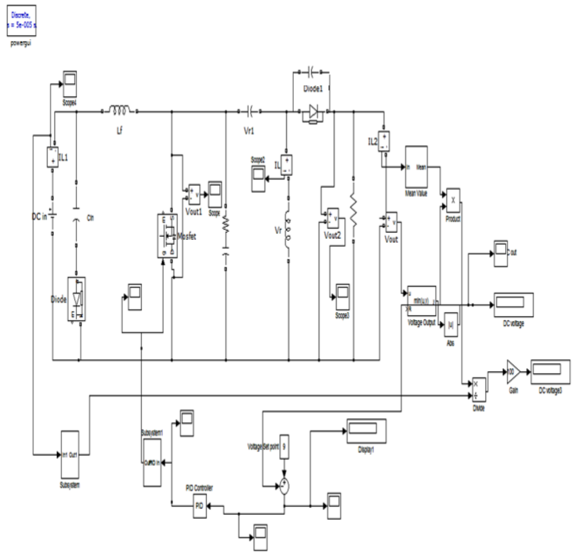

Fig.5.Power circuitofthesystem

Thefig.5showsthepowercircuitforthe modifiedsepic converter.HereweareusingMATLAB softwaretorepresent thesimulation.

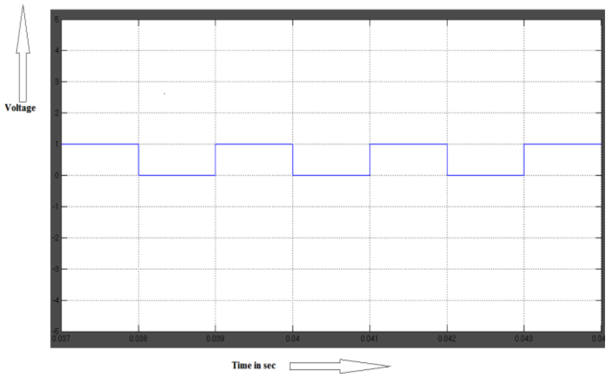

Fig.6.Triggeringpulses

Fig.6.showstheoutputsof thesimulation.Thesearethe triggeringpulseswhicharegiventotheMOSFET.Herewe aregeneratingPWMsignalstotriggertheMOSFET.

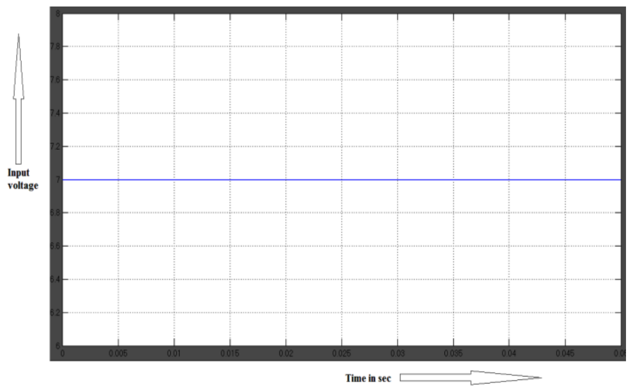

Fig.7.Inputvoltagewaveform

Fig.7. shows theinput voltage waveform. Here we are givinganinputvoltageof7V.

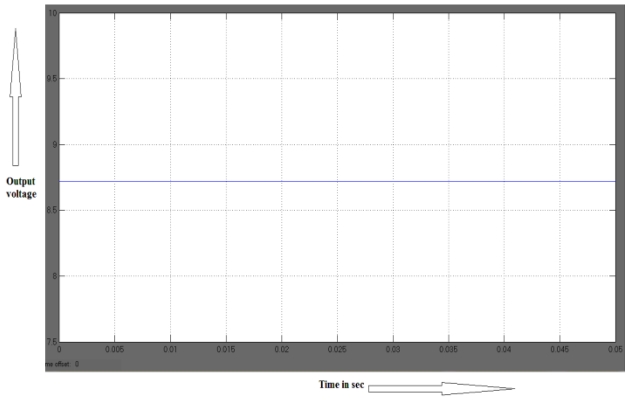

Fig.8.Outputvoltagewaveform

Fig.8.showstheoutputvoltage waveform.Hereweget an outputof8.7V.

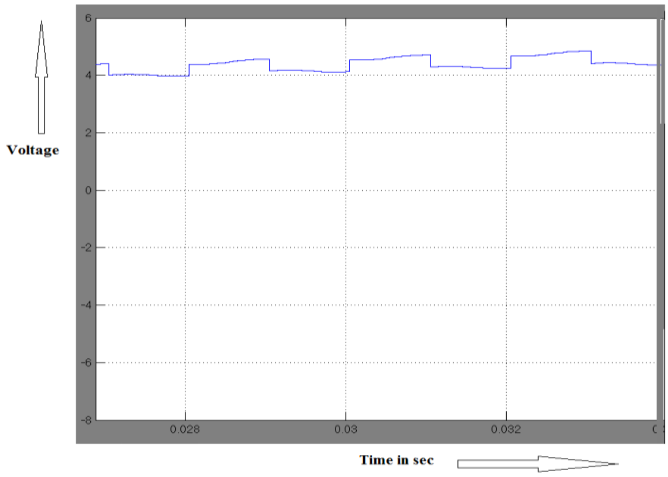

Fig.9.VoltageacrossMOSFET

Fig.9.shows thevoltageacrosstheMOSFET.

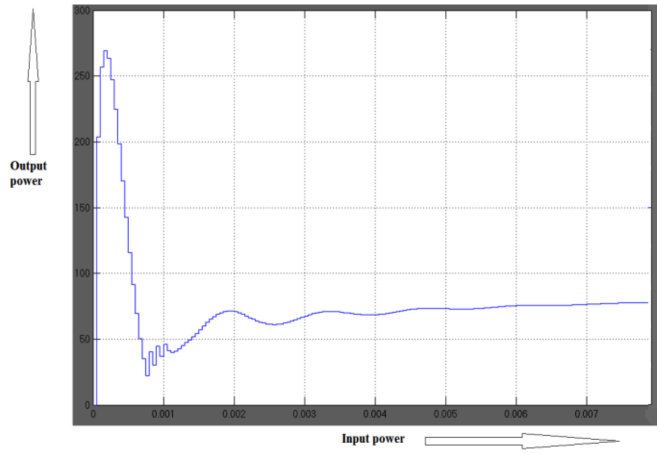

Fig.10.Efficiency waveformofPI controller

Fig.10.showstheefficiencywaveformofPIcontroller.It has moreoscillationscomparedtoPIDcontroller.Alsothe efficiencyisless.

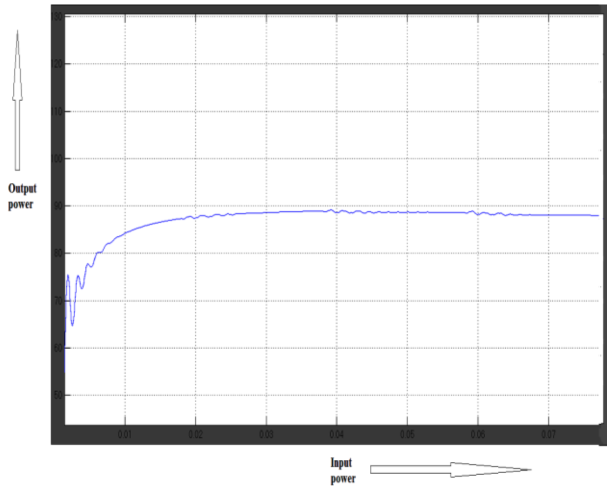

Fig.11.Efficiency waveformofPIDcontroller

Fig.11. shows theefficiencywaveformof PIDcontroller.It hasfeweroscillationscomparedto PIcontroller.Alsothe efficiencyismorethanthatofPI.Itsefficiencyisgreaterthan 87%.

The hardware block diagram is given below.

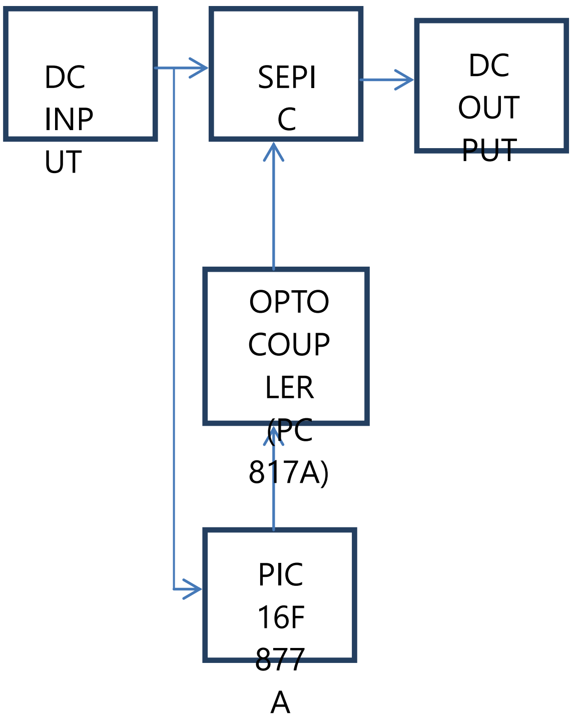

Fig.12. Hardware block diagram

Here the main components used are

- Power supply unit
- PIC Microcontroller (PIC 16F877A)
- SEPIC converter
- Opto coupler (PC817A)

The hardware module is given below. The main requirements of the proposed system are power supply, power circuit and control circuit.

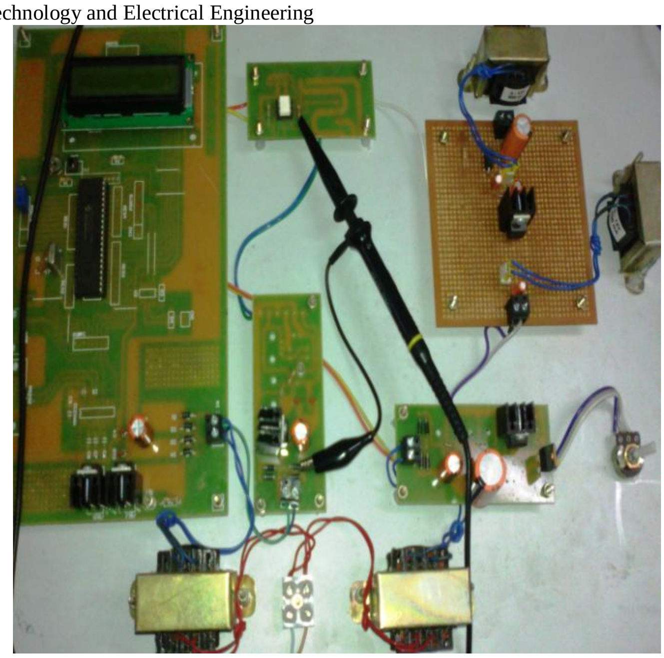
Fig.13. Hardware module

Some of the hardware output results are given below. They are the triggering pulses, input and output waveforms.

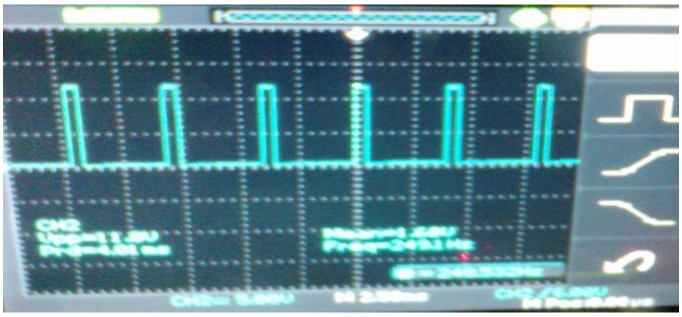
Fig.14. Triggering pulses

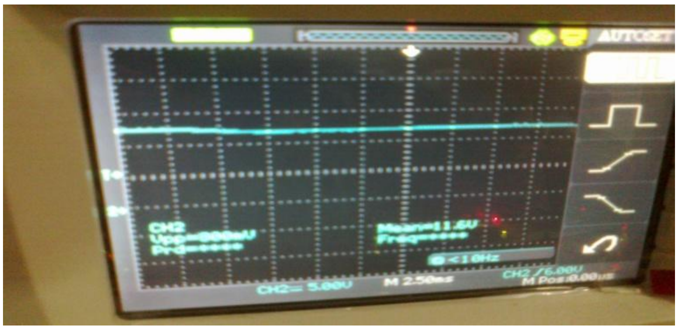
Fig.15. Input voltage

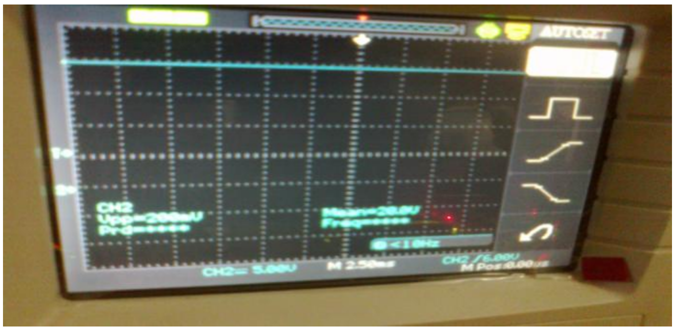
Fig.16. Output voltage

6. CONCLUSION

Thiswork presentsamodifiedresonantSEPIC converter suitableforextremelyhigh-frequency operationandfor operatingacrossawideinputandoutputvoltagerange.Here we set up a modified SEPIC converter with switching frequency20MHz.Itsinputvoltagerangesfrom3.6Vto7.2Vandit soutputvoltagerangesfrom3Vto9V.Itsratedpower is 3W. This work uses an ON-OFF control with fixed frequency. The achievable voltage slew rate is entirely appropriate for applications such as adaptive bias power supplies. It is possible for resonant SEPIC converters to achieve a wide operating range, a small size, and excellent transient response while maintaining good efficiency.Itprovidesfasttransient response andgoodcontrol overwide input andoutputranges. Inthiswecaneliminatethe bulkmagnitudecomponentsandfacilitates highefficient resonantgating.Softswitchingcanbeachievedforawide inputandoutputvoltage ranges.Unlikeconventionalquasi-resonantandmultiresonant convertersnobulk inductoris usedandtheconverteroperatesatfixedfrequency andduty ratio. Theseattributesreducepassivecomponentsize,improveresponse speed,andenablethe useoflow-losssinusoidal resonantgating.

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