An Efficient Design and Implementation of Ambient Power Harvesting Method Using Radio Waves for IoT System Monitoring Module

Karthika Ramachandran [1], M. Arun kumar [2]

[1]PG Scholar, Dhanalakshmi Srinivasan College of Engineering, Coimbatore, Tamilnadu, India
[2]Assistant Professor, Dhanalakshmi Srinivasan College of Engineering, Coimbatore, Tamilnadu, India

---

Abstract - *Radio frequency [3MHz-300GHz] are the next generations energy sources. Utilizing and harvesting the radio frequency for electronics requirements will be advantageous and are supporting for many applications with the best quality requirements. Also, we are presenting the key to overcome the current issues on Radio Frequency based wireless charging methodology.*

Key Words: RF energy harvesting, Quality of service, Wireless charging, Pulse Width Modulation.

1. INTRODUCTION

Energy harvesting from the ambient energy source are of the future scope for energy. RF energy is converted in to electricity this gives an efficient solution in powering the energy constraint the wireless devices. The radio waves are in range of the 3 kHz to 300GHz are often used to carry energy in of the form of EM radiation in an RF energy harvesting module. Harvest of energy from radio waves that are comes under the wireless energy transferring technique. There has been no such limitation for RF energy transfer. The far field energy transferring technique is considered as the RF energy transfer. So, Radio energy transfer is more suitable in the powering of larger number of the devices distributed in the wide area. The reciprocal of distance in between the transmitters and that the receiver is attenuated in according to the strength of far fields RF transmission. RF to the DC energy conversional efficiency is much lower especially when harvested RF power is small. As the increase in need of power sources in the future generation the new harvesting technical skills must be introduced for the better management of the power harvestment. Thus, this issues are making us to improve a new idea of creating power from the RF waves that are spreading in the air. RF waves are emerging from the antennas these waves are the EM spectrum and from this range of RF spectrum we can create RF power. RF energy haves waves of frequencies range about 3000 waves / second (3 kHz) - 300 billion waves /second . Microwaves are one of the kind of radio waves and having the frequencies range from 300 million waves around / second i.e.,300 MHz to 3 billion waves/ second (3 GHz). The harvesting ability of RF energy from the ambient sources establishes the wireless low-power devices charging and has results in benefits of product design, usability, and reliability. Battery based systems are being charged to eliminate the need replacement of the battery or using disposable batteries for extending the operating life of systems. Battery-free devices can be designed to operate upon demand or when sufficient charge is accumulated. In both of the cases, devices is not having any connectors, cables, and battery access panels, and have freedom of placement and mobility during charging and usage. The RF energy is a "free" energy source.

Estimation of the ABI Research and Supply sum ups the number of subscriptions in mobile phone that has recently surpassed 5 billion and the ITU estimates there uses over 1 billion subscriptions for mobile broadband. Many numbers of transmitters are needed in mobile phones to the need of harvest radio energy, and enable the users potentially to give power on the demand for the wide application range. In some urban environments, it Detection of hundreds of WiFi access points is possible from one location. In a short range, as inside the same room from a router of Wi-Fi with 50mW- 100 mW transmitter power level of a little energy is harvested . Longer range operation is carried out through the higher gain greater antennas with the harvesting energy from RF in mobile base stations.

RF energy harvesting at 2.4 km from a small, 5kW AM radio station is demonstrated in 2005 by the Power cast. The bands without license such as 868MHz, 915MHz, 2.4GHz, and 5.8GHz can be broadcasted by the RF energy more power then is needed than that occupied from ambient sources. Frequency bands without licensed range of 4W, at 915MHz are limited by the government regulations also the power radio output using as in the effective isotropic radiated power (EIRP).

1.1 An Efficient RF Energy Harvest System

Radio wave creates the radio frequency (RF) which is one of the sources of energy. The combination of electric and magnetic fields moving together in space forms the electromagnetic energy. The region in which these waves are found is called an electromagnetic field. In this modern electronic era radio waves can be used for many applications in according to the user's requirements. There are many other forms of electromagnetic energy sources. Electromagnetic energy can travel through wireless medium so it can be used in a wide range of wireless applications.

Thus, this kind of energy is the most ecofriendly and long life time means of energy for the next generation. By utilizing these energy sources we can charge many types of equipment. It supports charging of low power required devices from little high power required devices thus these energy sources are having more adventurous applications in the electronics. Thus, this ensures support for the many quality service requirements. Mostly, the RF charge acquired devices are used in sensor application in the remote areas. In the remote areas the powering of the low power needed remote sensors are powering by the RF charged devices. Many other available forms of energy also available those are from the mechanical vibration, thermal gradients, convection flows, energy from sunlight etc.

The general architecture of an RF energy harvesting network is shown in the figure 1. Producing energy from the radio waves are the most modern and most efficient energy harvesting method.

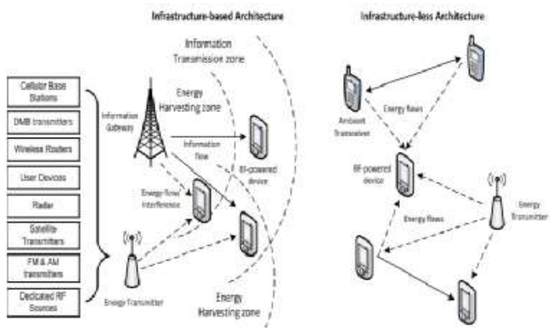

Fig -1: A general architecture of an RF energy harvesting network.

When the RF powered devices are embedded into a device that it makes possible for the making replacement of battery without degrading the system. Firstly, in ambient power harvesting circuit there will be a DC power conversion circuit which converts the DC power obtained from EM waves and the gets converted to power the passive device to operate. Previously reported that the RF power generated from the device will get only the signal when it is near to the source at least 10m distance. At the distances greater than 10m the power will loss occur in high range thus in those times the system is inadequate for the high power applications.

In the new energy harvesting systems the RF signal can be captured from the far located RF source antennas and thus charge can be stored in a battery by the means of DC power conversion circuit in the system. This makes the system more efficient in high power device s and the high quality service requirement needs.

2. AMBIENT POWER HARVESTING MODULE

Our new design harvests the radio waves that is spreading in the air and stores the power generated by converting it in to a DC signal and then that is stored in to a battery. Also, we are utilizing the RF signal that is produced during the call (mobile communication) and power generated is stored in the battery. This will reduce the radiation effect in human body by utilizing the unwanted signal produced in to power. The major issue in the android devices is their power consumption.

Android device consumes most power in running apps, data usage by using Google maps especially, the more power is consumed during the calling process the existing system will not provide the solution for this issue. The block diagram of design is shown the figure 2.

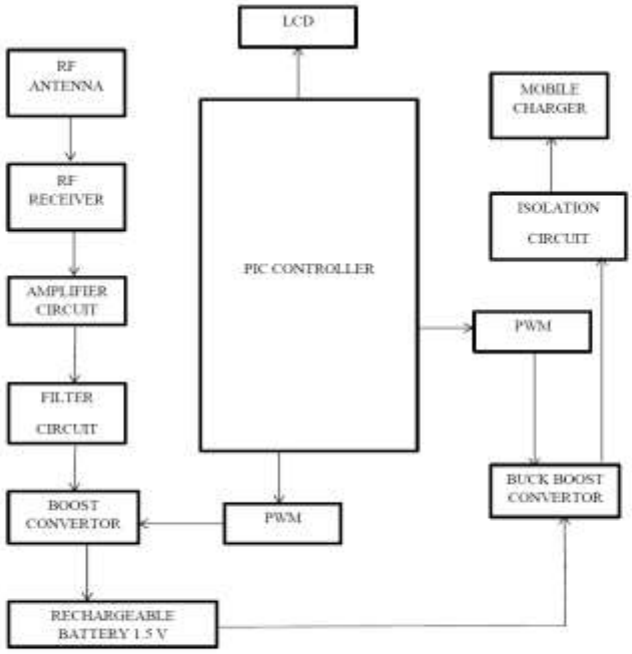

Fig -2: Block representation of RF power generation system

Thus, in this new design we are utilizing the RF signal generated during the call and storing that power in to a battery. This will extend the battery backup. Thus we need not to put our mobile phones on charge while on call. The system is designed mainly for need of a charger in wireless that the Radio waves converted at the at any frequency in to DC signal. The power generated is stored in the battery and it can recharge itself.

Thus, in this new design we are utilizing the RF signal generated during the call and storing that power in to a battery. This will extend the battery backup.

2.1 RF Receiver

The radio waves received by the receiver travels in the light speed. When the wave received by the receiver the electrons inside the receiver gets vibrate and this effect produces electric current. The receiver uses the filters that filters out the desired frequency and eliminates the unwanted frequencies that obtained.

Electronic amplifier is also there is the circuit that amplifier amplifies the signal and increases the strength of the signal on the processing time. Radio receiver is in the electronic circuit that itself on the device. Also, they can be the components of the broadcasting, communications remote control, and network systems.

Antenna is attached to the receiver that converts the incoming radio frequency in to AC voltage. The typical metal arrangement inside the antenna gets effected by the time varying EM field produced from the radio waves. They push back and forth the electrons and produce an oscillating voltage. This generated voltage is used in the next stage of operation.

2.2 PIC Controller

PIC microcontroller is fabricated in CMOS technology. It is 1st RISC logic controller.PIC is having a separate bus for data and instruction which is operated by data memory and the programs. .PIC is more feasible because of the low power consumption. Since it is fabricated by CMOS technology it has high immunity from noise.

In this module we are using PIC 16F877 microcontroller. It is having flash technology and easy programming. The 8bit PIC controller is having 40 pins and 5 ports. The port C, the RB7 is connected with the Wi-Fi device for the IoT monitoring of the received voltage in the system.

2.3 Isolation Transformer

An isolation transformer isolates the power source and the powered device. It is used in circuit for the safety needs. These give galvanic isolation in the circuits for the protection from the shock. Also, used for suppress the electrical noise. The isolation transformers are having high voltage at their wings.

Also, it blocks the DC signals to pass from the one circuit to other and pass the AC signal. Also these transformers eliminate the interference issues generated from the ground loops.

2.4 Buck Boost Converter

Buck boost converter is used for the converting of the input DC voltage in to the amplified DC voltage. Thus, the value of the DC voltage gets increased. Both the increase and to decreasing the DC voltage can be done according to the circuit requirement. It is designed by a single inductor and not a transformer. The o/p voltage is just opposite to that as compared to the input.

Buck Boost converter circuit operates by the duty cycle variations. The duty cycles are provided by the transistor. The two transistors are connected that is, the NPN and the PNP. When first transistor is off then the other transistor is on. Thus, the duty cycle is created.

The MOSFET is in connection to the Buck Boost converter operated at a medium voltage of 12 to 15 volts. The MOSFET is ON based on the transistor output. When the second transistor is off then the MOSFET will be ON. Thus, the boosted of voltage is obtained.

2.4 PULSE WIDTH MODULATION (PWM)

The encoding of message to the pulse signal is done by the Pulse Width Modulation Scheme. The controlling of the power supply devices can be done by the PWM technique. PWM is also called as Pulse Duration Modulation. PWM's switching frequency will depend on load and application. The PWM depends on the particular duty cycle. Duty cycle means the ON time in particular intervals of the time.

When at the low duty cycle that means the power is low. PWM scheme's main advantage is its less loss of power during switching frequencies. No current is there when switch being OFF state when switch is ON then the power is transferred in load. The pulse width of the PWM's rectangular pulse wave is modulated resulting by the variation occurs in the average range of waveform.

Also, if we are getting an input of 2 volts that gets boosted in to 12 volts and if we are getting a 16 volt then that voltage gets decreased in to 12 volts. This conversion is done by the PWM scheme. By this voltage variation the pulse width gets changes.

3. RESULTS AND DISCUSSION

The strength of RF signal received gets boosted by buck converter and the appropriate pulse is generated by the PWM. Simulation results using Proteus Tool is shown in the figure 3 below:

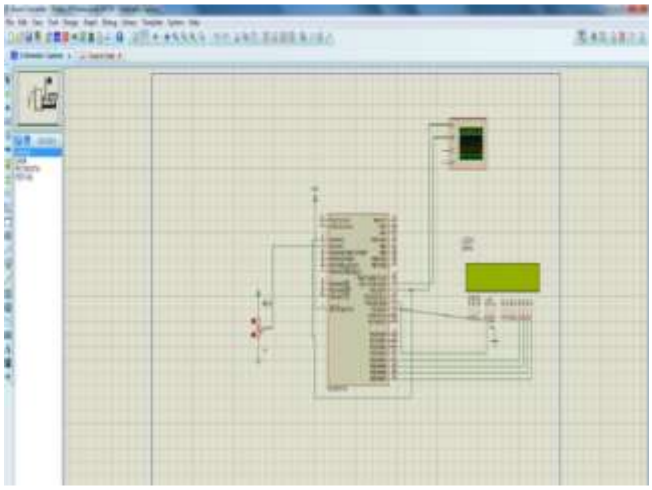

Fig -3: Simulation Results using Proteus Tool

The PWM Pulse width decreases with increase in the voltage.

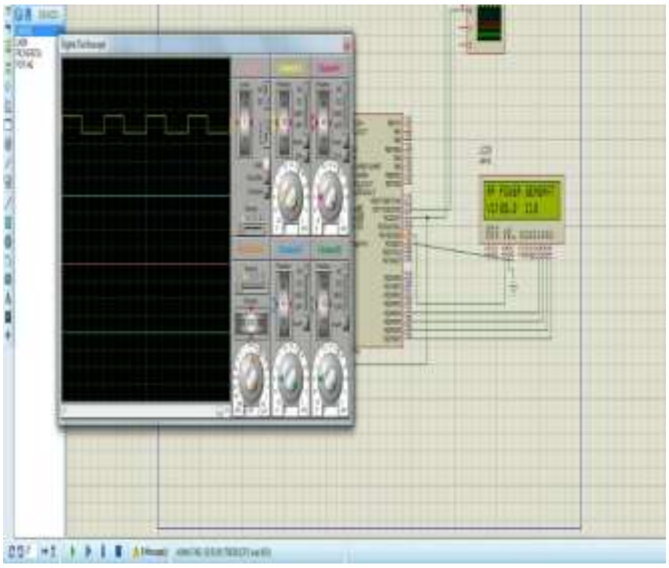

Fig -4: Variation in Pulse Width Increasing Voltage

The PWM Pulse width increases with decrease in the voltage.

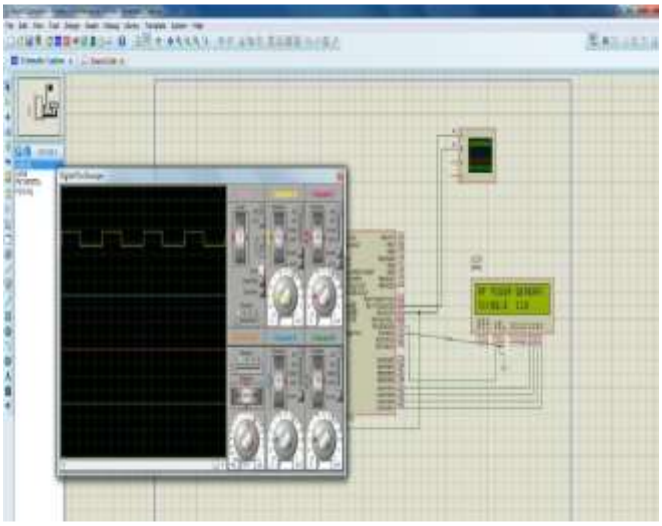

Fig -5: Variation in Pulse Width Decreasing Voltage

3.1 RF Power Harvesting Module

The system module is shown in the figure 6 whenever the radiation is detected then the LED glows. Thus, in the figure 6, we can notice that the LED is glowing and the input voltage gets boosted in to 12 volts from 2.7 volts. Also, when a mobile is kept near the capacitor diode parallel network during the calling time the radiation gets generated and the system acquires the RF signal and voltage gets boosted. The RF radiation in any place mainly near to tower (almost at a 1km distance) the battery can be charged by the RF power harvesting module.

Fig -6: RF Power Harvesting Module

Fig -7: Input voltage and boosted output voltage

In the above LCD of RF power harvesting module input voltage gets boosted in to 12 volts from 2.7 volts. The boosted voltage can be noticed in the waveform.

3.2 IoT Monitoring of Voltage in RF Power Harvesting Module

The Wi-Fi module connected with the system provides the IoT monitoring of RF power generated.

Fig -8: Output waveform of boosted voltage

In the above figure 8, the output voltage is 12.4.This 12.4 volts is obtained from the radio frequency signal received by the system.

Fig -9: Input voltage and output voltage waveforms

In the above figure 9, the first waveform shows input voltage. Here the input voltage is 2.7 volts. This voltage will be boosted to 12 volts, which is depicted in figure 8. Thus the efficient RF energy harvesting system captures the radio frequencies from the atmosphere and charges the battery. Also, during the calling process the radio frequency signal is captured by the system and the output power is boosted. The voltage generated is monitored by the IoT module which is shown in the figure 8 and 9.

Thus, the new design provides an intelligent solution for the harvesting of radio waves in the form of power. The radio waves are harmful for Human beings so, our design will reduce the harmful effects of radio waves to an extent by absorbing it and direct power consumption.

4. CONCLUSIONS

The major issue in the android devices is their power consumption. Especially, most of the power is consumed during the calling process the previous systems will not provide the solution for this issue. Thus, in the new design we are utilizing the RF signal generated during the call and storing that power in to a battery. This will extend the battery backup. The main concept is to boost the input voltage obtained in to 12 volts. This 12volts is stored back to battery.

The output voltage obtained is monitored in the IoT module. The Wi-Fi module connected to the design enables the system to link with the IoT. Thus the input voltage and the output voltage obtained can be monitored in waveforms. Also, RF radiations are harmful to human body thus utilizing the RF radiations can reduce the harmful effect to an extent. Thus, this design reduces such problems that are facing now in daily life.

In future we can implement the RF power harvester module to provide free charging in IOT equipment's such as in home applications, industrial applications, to charge the sensors in remote areas for the analysis of power consumption in those areas, also we can charge bulbs, and other low voltage required components to save electricity.

ACKNOWLEDGEMENT

The authors thank the Management and Principal of Dhanalakshmi Srinivasan College of Engineering, Coimbatore for providing an excellent computing facility and encouragement.

REFERENCES

[1] H. Liu, "Maximizing efficiency of wireless power transfer with resonant Inductive Coupling," 2011.

[2] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P.Fisher, and M. Soljacic, "Wireless power transfer via strongly coupled magnetic resonances," Science, vol. 317, no. 5834, pp. 83-86, June 2007.

[3] J. O. Mur-Miranda, W. Franklin, G. Fanti, Y. Feng, K. Omanakuttan, R. Ongie, A. Setjoadi, and N. Sharpe, "Wireless power transfer using weakly coupled magnetostatic resonators," in Proc. of IEEE Energy Conversion Congress and Exposition (ECCE), Atlanta, GA, Sept. 2010.

[4] Tutorial Overview of Inductively Coupled RFID Systems, UPM Rafsec, 2003.

[5] K. Huang and V. K. N. Lau, "Enabling wireless power transfer in cellular networks: architecture, modeling and deployment," IEEE Transactions on Wireless Communications, vol 13, no. 2, pp. 902-912, Feb. 2014.

[6] L. Liu, R. Zhang, and K. C. Chua, "Multi-antenna wireless powered communication with energy beamforming." (available on-line at arXiv:1312.1450).

[7] G. Yang, C. K. Ho, and Y. L. Guan, "Dynamic resource allocation for multiple-antenna wireless power transfer," IEEE Transactions on Signal Processing, vol. 62, no. 14, pp. 3565-3577, July 2014.

[8] X. Chen, X. Wang, and X. Chen, "Energy-efficient optimization for wireless information and power transfer in large-scale MIMO systems employing energy neamforming," IEEE Wireless Communications Letters, vol. 2, no. 6, pp. 667-670, Dec. 2013.

[9] T. Le, K. Mayaram, and T. Fiez, "Efficient far-field radio frequency energy harvesting for passively powered sensor networks," IEEE Journal of Solid-State Circuits, vol. 43, no. 5, pp. 1287-1302, May 2008.

[10] M.Erol-Kantarci and H.T. Mouftah, "Suresense: sustainable wireless rechargeable sensor networks for the smart grid," IEEE Wireless Communications, vol. 19, no. 3, pp. 30-36, June 2012.

[11] M. Erol-Kantarci and H.T. Mouftah, "DRIFT: differentiated RF power transmission for wireless sensor network deployment in the smart grid," in Proc. of IEEE Globecom Workshops, pp. 1491-1495, Anaheim, CA, Dec. 2012.

[12] J. A. Hagerty, F. B. Helmbrecht, W. H. Mccalpin, R.Zane, and Z. B. Popovic, "Recycling ambient microwave energy with broad-band rectenna arrays," IEEE Trans. on Microwave Theory and Techniques, vol. 52, no. 3, pp. 1014-1024, March 2004.

[13] M.Ghovanloo, and K. Najafi, "Fully integrated wideband high-current rectifiers for inductively powered devices," IEEE Journal of Solid-State Circuits, vol. 39, no. 11, pp. 1976-1984, Nov. 2004.

[14] J.P. Curty, M. Declercq, C. Dehollain, and N. Joehl, Design and optimization of passive UHF RFID systems, 1st edn., Springer Science Business Media, New York, 2007.

[15] J. A. G. Akkermans, M. C. Van Beurden, G. J. N. Doodeman, and H. J. Visser, "Analytical models for low-power rectenna design," IEEE Antennas and Wireless Propagation Letters, vol. 4, pp. 187-190, June 2005.

[16] R. Zhang and C. K. Ho, "MIMO broadcasting for simultaneous wireless information and power transfer," IEEE Transactions on Wireless Communications, vol. 12 , no. 5, pp. 1989-2001, May 2013.

[17] X. Zhou, R. Zhang, and C. K. Ho, "Wireless information and power transfer: architecture design and rate-energy tradeoff," IEEE Transactions on Communications, vol. 61, no. 11, pp. 4757-4767, November,2013.

[18] M. Arun Kumar and N Kirthika, "Efficient implementation of ROM-less FFT/IFFT processor using fused multiply and added unit," International Journal of Electrical and Electronic Engineering & Telecommunications, vol. 2,No. 2,April 2013.

[19] Dinesh Kumar, Asit xaxa and Dushyant Kumar Sahu", Electromagnetic wave theory based on wireless charger", SSRG International Journal of Electronics and Communication Engineering (SSRG-IJECE), volume 2 Issue 3 March 2015.

[20] M. Arun Kumar and Dr.Arvind Chakrapani,"An survey of low power FFT processor for signal processing applications,"Jour of Adv Research in Dynamical & Control Systems, 15-Special Issue, October 2017.

[21] Balanis C.A., Antenna Theory, 3rd edition. Jhon Wiley & Sons, New York, 2005.

[22] M. Arun Kumar, "Efficient implementation of MIMO using OFDM applications," International Journal of Science and Research(IJSR), volume 3 Issue 6, June 2014.

[23] Eric Y. Chow, Chin-Lung Yang, Yuehui Ouyang, Arthur L. Chlebowski, Pedro P. Irazoqui, and William J. Chappell, "Wireless Powering and the Study of RF Propagation Through Ocular Tissue for Development of Implantable Sensors," IEEE Transactions on Antennas And Propagation, vol. 59, No. 6, June 2011.

[24] M. Arun Kumar , C.P Jena Samuel, L.Saranya and T.Karthik,"Efficient time sharing of traffic signal using wireless sensor networks,"International Journal of Applied Engineering Research, ISSN 0973-4562 vol.10 No.20 (2015).

[25] Zhen Ning Low Raul Andres Chinga , Ryan Tseng, and Jenshan Lin, "Design and Test of a High-Power High-Efficiency loosely coupled planar wireless power transfer system," IEEE Transactions On Industrial Electronics, Vol. 56, No. 5, May 2009.

[26] Malik Sikandar Hayat Khiyal, Aihab Khan, and Erum Shehzadi Software Engineering Dept., Fatima Jinnah Women University,Rawalpindi, Pakistan ,"SMS Based Wireless Home Appliance Control System (HACS) for Automating Appliances and Security," Issues in Informing Science and Information Technology, Volume 6, 2009.

BIOGRAPHIES

Karthika Ramachandran

Received her bachelor of Electronics and Communication Engineering degree from Anna University, Chennai in 2016 and doing Master of Engineering in Applied Electronics from Anna University, Chennai. Her research interest includes RF Power Harvesting and VLSI design.

M. Arun Kumar

Received the Bachelor of Engineering degree in Electronics and Communication Engineering from Maharaja Institute of Technology Arasur Coimbatore, India, in 2010 and received Master of Engineering degree from the Department of VLSI Design, from Sri Ramakrishna Engineering College, Coimbatore, India, in 2013. He is currently working as Assistant Professor at Karpagam College of Engineering, Coimbatore. His area of interest includes Digital Signal Processing, Low power VLSI Design.