RADIO FREQUENCY ENERGY HARVESTING

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Abstract

In many sensor and consumer electronic applications, power supply is embedded into the structure, and operation battery replacement becomes difficult. An attractive solution to overcome this issue and allow perpetual operation of devices is ambient radio frequency (RF) energy harvesting technology. It allows the energy to be harvested from the surrounding environment and stored for use in low power electronic devices.

Objective

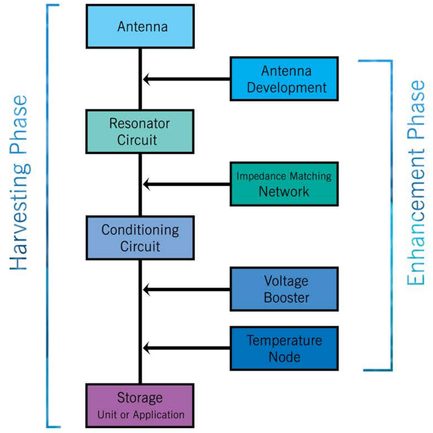
- Create a working device to harvest the free ambient RF energy in the surround to power up a small device
- Analyzing the possibility of employing RF power harvesting solution as unique independent energy source to replace ordinary limited lifetime, small power source & batteries
- Investigating on how the RF energy harvesting can reduce the cost (& other) involves in engineering operations & maintenance

Methodology

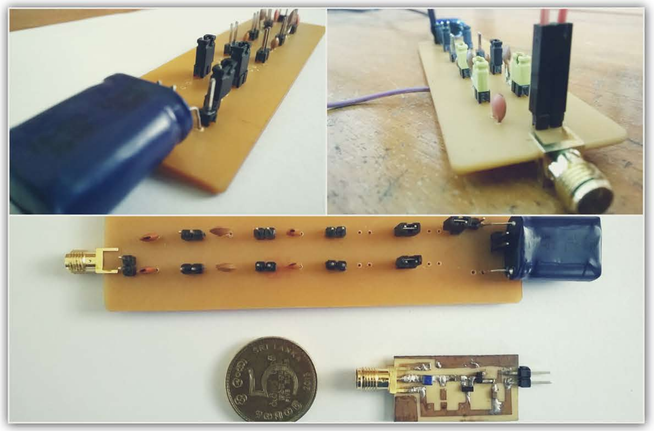
Our approach to the project involves,

- Antenna development
  - Analyzing the frequency variation
  - Design specific antennas
  - Analyze the system for multiple antennas
- Voltage booster
- Impedance matching
  - Analyze impedance variation for multiple frequencies
  - Design a specific design for the matching
- Assemble the module with a real-time temperature node

Product Development & Results

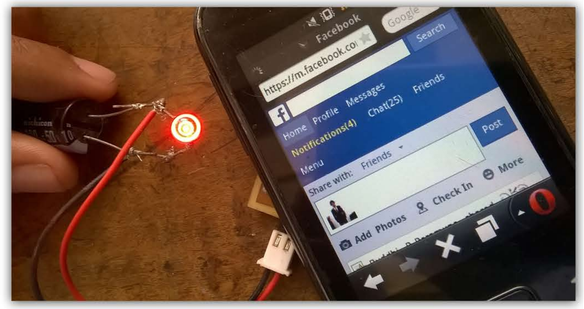


Flow diagram of the proposed method



Implemented Circuit Module

- Harvesting was enough to power up a LED or a small clock
- According to the ambient RF usage the scavenged power varied, more the usage more the harvest



Components & Analysis

Requires the use of antenna as an efficient RF signal power receiving circuit. Main function is to grab RF energy and convert that into electrical form. Designing an efficient antenna which is capable of capturing RF signals is major challenge

Frequency Ranges

30 -300MHz	FM, Television broadcast, Aircraft Communication
300 - 3000MHz	GSM 900 | GSM1800 | 3G-3.5G | 4G LTE
2-10GHz	Wi-Fi, WiMAX

Monopole Antenna

- Quarter wave monopole resonant antenna length *(L)* & the ground plane length *(l)* is based on the dedicated frequency*(f)*

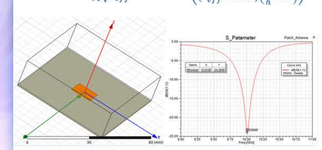
$$L = \frac{c}{2f} \qquad l = \frac{c}{4f}$$

Patch Antenna

- Microstrip antennas are low profile, small in volume, and have low production cost. The feed can be connected directly to the conductor on the same substrate

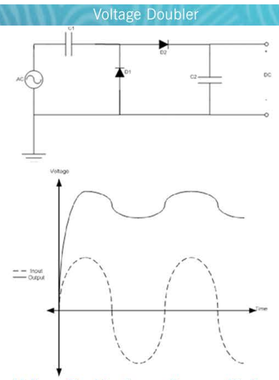
$$Width = \frac{c}{2f_0\sqrt{\frac{\varepsilon_R+1}{2}}}; \quad \varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right]$$

$$Length = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right)$$

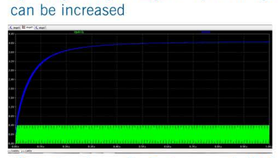


- Higher the frequency, more the energy we can harvest.
- Impedance matching was the crucial part

Voltage Doubler



- Voltage Doubler is a voltage multiplier circuit which has a voltage multiplication factor of two
- By using multiple stages output voltage can be increased

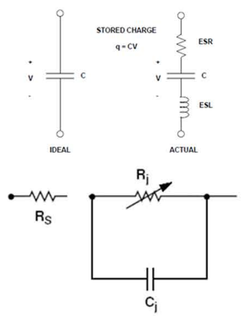


Output variance for 5 stages and 47pf

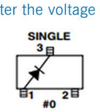
Single stage Voltage Doubler Circuit

- More concern about the power dissipation, if it dissipate more power from the harvested power it is not useful.
- Select suitable components that not only perform their intended task but also will survive under different operating conditions

Equivalent circuits for power dissipation

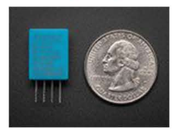


- Losses may be due to equivalent series resistance, dielectric effects and shunt leakage currents between the plates
- Lower the series resistance, the lower the voltage needed to turn on the diode and the lower the junction capacitance the faster the voltage will rise.

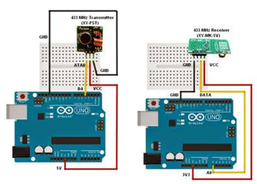


Temperature Node

- The DHT11 is a ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal



- 433 MHz RF module to communicate between Arduinos, to communicate the temperature for about 5 - 6 meters



- The measurement module is powered up by the RF Energy Harvester continuously and that power is stored to a CMOS battery
- ≤ 5mA max current during conversation & standby for sustainability in quite hours
- An optional antenna is used to increase the effectiveness of the wireless communication

Conclusion

- We have successfully designed a RF energy harvester which can power up a clock
- This method is much efficient in urban areas
- The achievable energy gains highly depend on the impedance matching of the network
- Use of multiple harvesters will increase the final output

Acknowledgments

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