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A VCO –Based Energy Harvesting System Using Verilog-AMS

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ABSTRACT: Harvesting is a common and efficient practice to produce usable energy as a loads of sources are available(Eg- Wind Energy Harvesting, Solar Energy Harvesting, Tidal Energy Harvesting etc). Energy harvesting is collecting ambient energy in different forms (i.e. thermal, piezo, and solar).Then, the harvested energy is transformed into an electrical signal using a certain transducer. The transducer output voltage is generally low and has to be stepped up to maintain the required supply voltage.

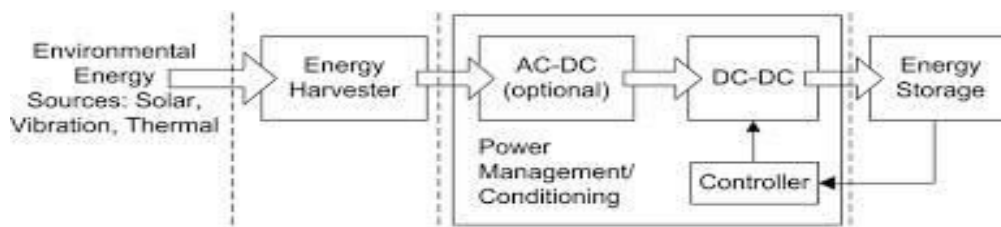
Energy harvesting has many key challenges such as getting a sufficient output power while achieving maximum power efficiency. In this study, a new VCO- based Energy Harvesting System is introduced to cope up this problem. A MPPT system is applied which increases the efficiency of the system . Maximum Power Point Tracking(MPPT) is a technique to maximize power extraction under all conditions. A large number of maximum power point tracking (MPPT) techniques such as : 1) Perturb and Observe denoted by P&O (an MPPT algorithm which is considered as one of the most commonly used algorithms in energy harvesting), 2) Three Point Weight Comparison , 3)Open Circuit Voltage,4) Closed loop MPP can be used.

KEYWORDS: VHDL , VCO , Verilog-AMS, MPPT ,Tidal Energy

I. INTRODUCTION

Harvesting means to acquire from external source, so Energy Harvesting (Power harvesting or Energy Scavenging or Ambient power) is the process of acquiring or deriving energy from an external source. The energy once acquired is converted in electrical form using a transducer. Harvested energy can be stored and used later. Because of the many sources available for energy harvesting, this practice is becoming more popular day by day harvesting, this practice is becoming more popular day by day.

Block diagram of energy harvesting system



Based on the various sources available , Energy harvesting can be of many types-

- Piezoelectric energy harvesting(convert mechanical stress into electrical signal) (
- Electromagnetic energy harvesting(convert energy available in Electromagnetic waves from various radiating sources into equivalent electric current)
- Solar energy harvesting (convert light and heat energy into electrical energy by suitable methods)



- Tidal energy harvesting(energy captured by moving water mass)

With the advancement of technology, continuous developments have been made in Electronics modeling world. Earlier the Analog and Digital systems were modeled individually on different platforms. This lack of a common language for modeling both the systems results in low output performance and efficiency.

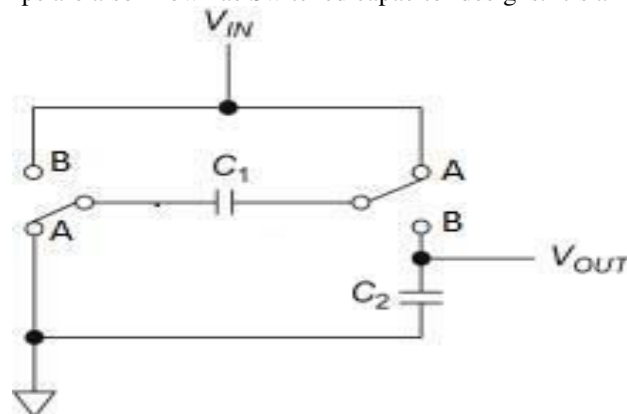
Suppose a system having analog as well as digital components. Now the digital components are modeled using VHDL while the analog parts are modeled using Verilog-A language. So because of using two different modeling language for a single system, simulation time is increased which eventually results in bad performance characteristics of the system. Hence to solve this problem, a new language is developed viz Verilog-AMS. The key advantage of modeling circuits using Verilog-AMS is that it provides a single language and simulator ecosystem which can be shared between analog system-level as well as device-level designers

II. SYSTEM DESIGN AND WORKING PRINCIPLE

Charge pumps are used whenever we want to increase the output voltage of a system. Charge pumps are generally DC-DC convertor with exceptional high efficiencies (sometimes upto 95%). Charge pumps uses capacitors for storing charge for increasing/decreasing voltages. Charge pump uses a switching device to control the supply voltage through a capacitor across a load.

In the two stage operation, in the first stage a capacitor is connected across the supply voltage and thus gets charged upto the supply voltage. In the second stage, circuit is reconfigured so that the capacitor is in series with the load as well as in series with supply, hence the voltage across the loads gets double the supply voltage.

Nowadays most of the appliances require a steady high voltage supply which can be fulfilled by using charge pumps. With owing to its simple circuit charge pumps are the most general choice. As we use a switching technique and capacitors, Charge pumps are also known as Switched capacitor designs. It's a kind of SMPS(switch mode



A basic charge pump (voltage doubler A DickWorking based on above figure

- e pump with MOSFETs
- a PLL charge pump

In our study we are going to use Dickson Charge pumps as it is most efficient as compared to others Let the supply voltage be V volts viz.

$V_{in} = V$, When the switches are in position A, applying KCL
 $V_{in} - V_{c1} = 0$

- $V_{c1} = V_{in} = V$

Now the switches are moved to position B, applying KCL

$$V_{in} + V_{c1} - V_{c2} = 0$$

- $V + V = V_{c2}$
- $V_{c2} = 2V$



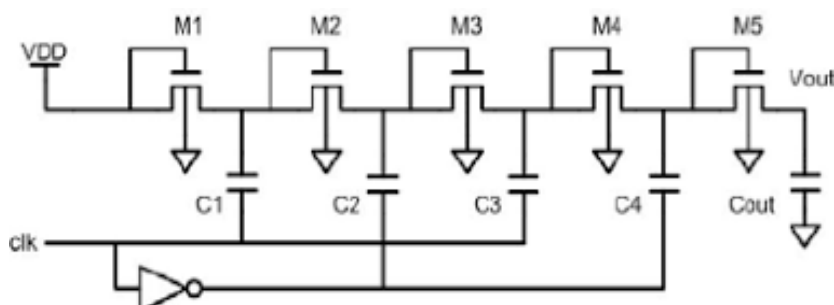
Hence, the output voltage across the capacitor C2 is two times the voltage.

Some charge pumps uses diodes whereas some uses MOSFETs. The output voltage can be increased many folds as per our requirements viz double, triple, quadruple and so on.

There are a variety of charge pumps available such as

- Two stage charge pump with DC voltage supply
- Dickson charge pump with diodes

Dickson charge pump uses a DC supply as its input so it is a DC-to-DC converter.

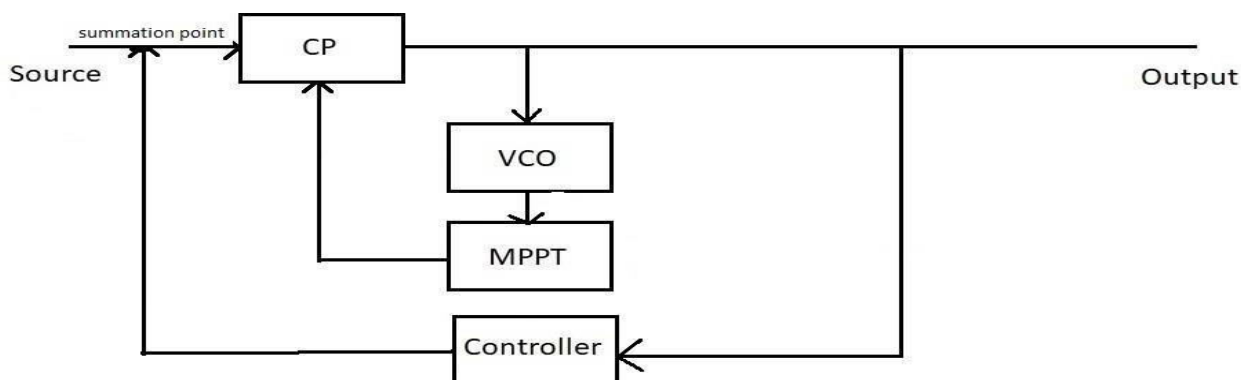


Dickson charge pump(with MOSFETs)

Note in above figure, supply VDD is DC voltage from the source and the clock with NOT gate constitutes the switching mechanism. In the switching mechanism, instead of NOT gate we can also use switches. But using logic gate is more convenient as it increases the switching speed.

It is clear that if we've to further increase the load voltage, all we need is to add a capacitor and a MOSFET. But with increasing components there is a drop in output voltage (because of the threshold drop across the diode). Although we expect the output voltage to be a multiple of the supply voltage, in reality it will be always slightly lesser. But because of the high efficiency it is still the best choice. This particular Dickson charge pump configuration offers an efficiency of 90%.

III. DESIGN OF FBAR FOR PCS APPLICATION



Block diagram of proposed system

According to above fig 8, VCO gets the input from the charge pump and its own output is fed to the digital buffer of the MPPT. VCO is the main component in our proposed model. It forms the core of the MPPT circuit. VCO generates the clock frequency corresponding to the input voltage which is supplied by the charge pump(output of the charge pump is input to the VCO). The frequency generated by the VCO is then fed to a buffer, whose output is given to a non-overlapping clock generator. This constitutes the whole MPPT system.



VCO is responsible for generating the clock frequency which decides the frequency at which the system will run. Initially when energy harvester is not connected, the VCO doesn't give any output. Output of energy harvester is given to the charge pump which is responsible for boosting the voltage level which is one of our primary objective. The charge pump's working is based on the clock generated by the VCO.

So, the working of the system depends mainly on the charge pump which in turn depends on the VCO. If the VCO isn't working well, then the whole system will be affected. VCOs are simple in construction, so they are easy to handle and if any faults are encountered it can be taken care easily. They are cheaper owing to its simple construction. Moreover they are available in both domain digital as well as analog, so they can be fitted in any system.

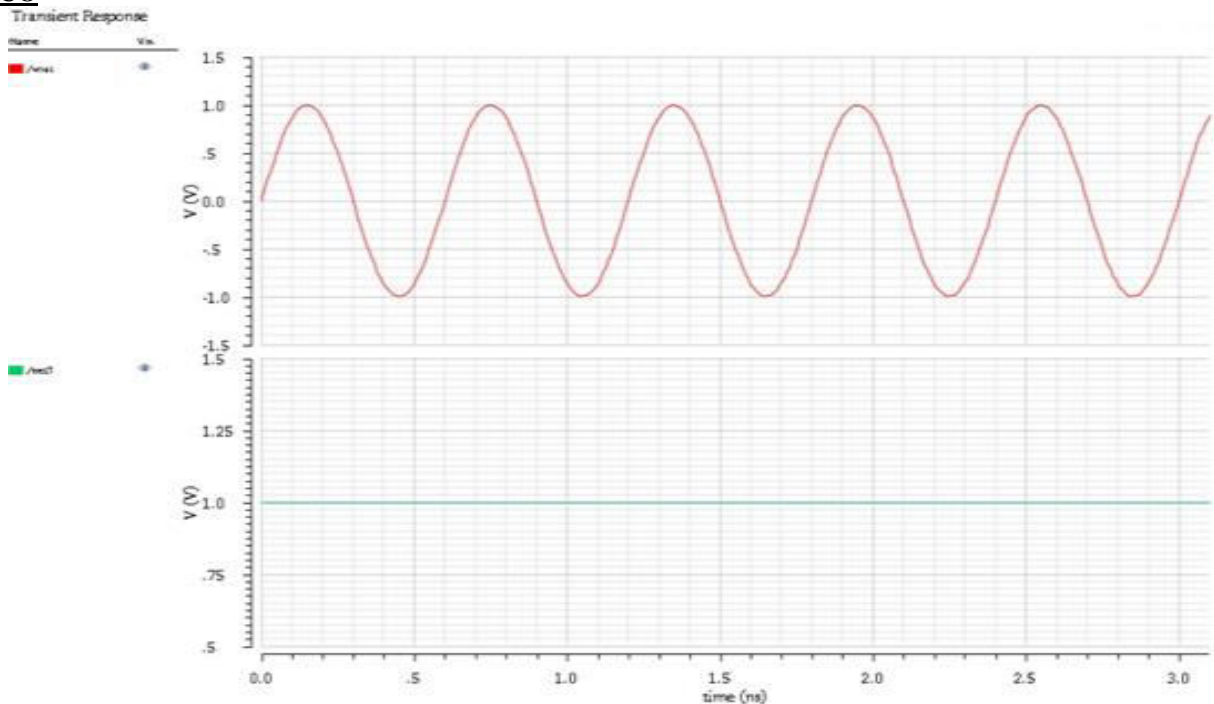
So the main functions of VCO in our system includes-

- generating clock frequency which after passing through buffers and other components is fed to charge pump that boosts the output voltage of energy harvester.
- VCO decides the frequency at which system will run.

Once the working is clear to us, next step is to write the code. Codes are written and simulated in using Verilog-AMS in cadence virtuoso and the simulation results are analysed.

IV. RESULT AND DISCUSSION

For VCO

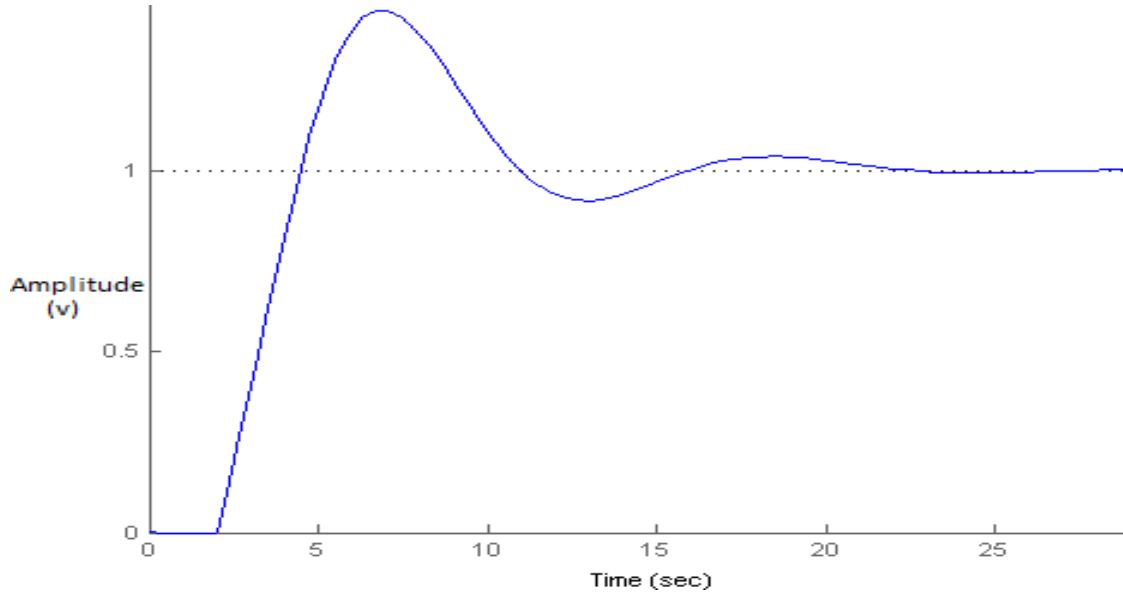


Amplitude vs time(vco)

- When 1 V input is given to the VCO, an output frequency of 1MHz is obtained.
- Frequency will increase as the input voltage to the VCO will increase.



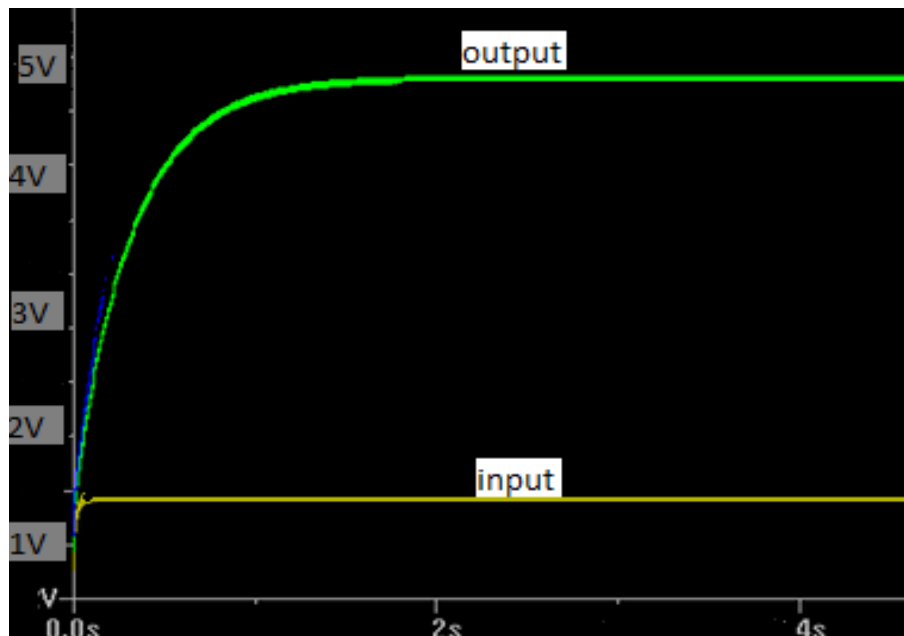
For Controller



Amplitude vs time(controller)

- Rise time = 6 sec. , Settling time = 22 sec.

For Charge Pump-



Output and input curves (CP)

- Input taken around 500-600 mV, then the output we get is around 5V.
- Output is not precisely 5 V, but slightly less than 5V



From the simulation results it can be stated that the modeling done is correct. The controller and VCO response is per the standard response. Charge pump response shows that it successfully boosts the voltage fed to from energy harvester as input. Modeling is correct for the individual components and if it has to be combined and modeled together then also the simulation results will be correct. Based on the simulation results, if input to the VCO is 1V then the system will operate at 1MHz clock frequency. The charge pump capacitors works well with 25pF value and the output is stable giving around 5V supply voltages.

V. CONCLUSION

This paper presents a technique of energy harvesting using Verilog-AMS. Here we have used a VCO based MPPT circuit which efficiently functions with a charge pump to step up the output voltage from an energy harvester. Simulation results from various components shows that the modeling is done correctly. We can conclude that using Verilog-AMS not only gives correct results but is also best option for modeling as any future modifications in the system is easily achievable

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The proposed system can also be modified based on newer MPPT techniques. We just need to change the codes according to the required technique. Using Verilog-AMS greatly reduces simulation time as both analog as well as digital components can be modeled using the same, this reduction in simulation time decreases the time-to-market which is beneficial to us.

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