A THERMAL ENERGY HARVESTING POWER SUPPLY WITH AN INTERNAL STARTUP POWER SUPPLY FOR PACEMALERS.

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ABSTRACT:

A pacemaker is a small device mostly driven by battery. This pacemaker senses when your heart is beating irregularly ie slowly or fastly. It sends a signal to your heart so that it makes your heart beat at the correct pace.

Pacemaker batteries can last between 5 and 15 years (average 6 to 7 years), depending on how active your pacemaker is. The wires of your pacemaker also may need to be replaced eventually. Your doctor can tell you whether your pacemaker or its wires need to be replaced.

A complete thermal energy harvesting power supply for implantable pacemakers is presented in this paper. The designed power supply includes an internal start-up and does not need any external reference voltage. The start-up circuit includes a pre start-up charge pump and a start-up boost converter. The Pre start-up charge pump consists of an ultra low-voltage oscillator followed by a high-efficiency modified Dickson multiplier. The system is designed so that no failure occurs under overload conditions. Using this approach, a thermal energy harvesting power supply has been designed using 180-nm CMOS technology. According to HSPICE simulation results, the circuit operates from input voltages as low as **40 mV** provided from a thermoelectric generator and generates output voltages up to **3 V.**

A maximum power of **130 μW** can be obtained from the output of the boost converter, which means that its efficiency is **60%**. A minimum voltage of **60 mV** and a maximum time of 400 ms are needed for the circuit to start up.

Keywords:

DCO, boost converter

1.1 Introduction

Every year over 6,00,000 pacemakers are implanted. Although most people who receive pacemakers are aged 60 years or older, people of any age, even children, may need pacemakers. Most often, a pacemaker is implanted to treat slow heart beating, which is called bradycardia. If the heart beats too slowly, the brain and the body do not get enough blood flow and a variety of symptoms may result. Pacemaker is a small battery-operated device that helps the heart to beat in a regular rhythm. Pacemaker has two parts of generator and leads (wires).

The generator is a small battery-powered unit.It produces the electrical impulses that stimulate your heart to beat.

The generator may be implanted under your skin through a small incision.

The generator is connected to your heart through tiny wires that are implanted at the same time.

The impulses flow through these leads to your heart and are timed to flow at regular intervals just as impulses from your heart's natural pacemaker would.

One of the main problems about pacemakers is their batteries. As the capacity of the batteries is limited, they limit the lifetime of pacemakers. After a period of five years, one should undergo a surgical procedure to replace the battery of the pacemaker. Replacing these batteries is cumbersome since it requires surgical procedures. In addition, 60% of the volume of a pacemaker is taken up by its batteries. Eliminating these batteries effectively reduces the dimensions of the pacemaker. One of the alternative methods to power up an implantable pacemaker is harvesting thermal energy. Harvesting ambient thermal energy using thermoelectric generators (TEGs) is a convenient means of supplying power to implantable sensors, especially pacemakers. Micro-TEG is scalable and reliable and does not require any moving parts like vibration energy transducers.

1.2 Existing System

Voltage controlled oscillators (VCOs) are widely used to generate a switching signal where certain characteristics of this signal can be controlled a digitally controlled pulse width Modulator (PWM) comprised of a header circuit, ring oscillator, and duty cycle to voltage (DC2V) converter.

1.3 Proposed System

It uses a Digital to Analog converter using DPWM and Boost converter. The Proposed system consists of Digital controlled oscillators, a synchronous counter, a combinational reset and a combinational comparison logic. We are replacing VCO through DCO to design Digital pulse width modulator. DCO is designed using flip flops. DCO acts as the register and it's tunable strength is high comparing VCO. Digital to analog converter designed by the digital pulse width modulator and low pass filter.

1.4 Block Diagram of CPLD

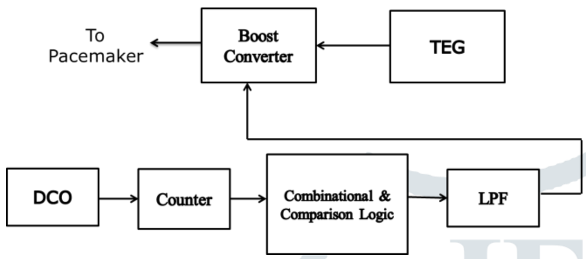

Fig1.4. CPLD block diagram

The block diagram contains Boost Converter, TEG and CPLD training kit in which DCO, Counter, Combinational & Comparison Logic and Filters are designed using VHDL software.

Methodology:

Thermoelectric generator (TEG) placed in superficial layer of skin produces a very small amount of voltage due to temperature difference in the skin.

The output voltage is given as one input to Boost converter and it's another input is a pulse generated from CPLD kit. CPLD kit is programmed using VHDL programming language.

Both inputs from CPLD kit and Peltier sensor is given as input to boost converter which boosts lower voltage to higher voltage.

Then finally boosted voltage is stored in pacemaker battery.

1.5 Thermo electric generators

A thermoelectric generator (TEG), also called a See beck generator, is a solid state device that converts heat (temperature differences) directly into electrical energy through a phenomenon called the See beck effect (a form of thermoelectric effect). Thermoelectric generators function like heat engines, but are less bulky and have no moving parts. However, TEGs are typically more expensive and less efficient. One of their main benefits when used as high power generators is that they make use of wasted heat and convert it into useful high electrical power that help to reduce power usage and at the same time help in reducing pollution.

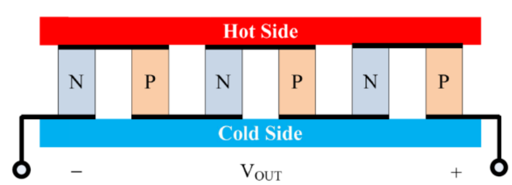

Fig 1.5. Typical TEG

When a p-type element electrically connected to the n-type element, the mobile holes in the p-type element and the mobile electrons in the n-type element, move just to the other side of the junction. For every hole that migrates into the n-type element, an electron from the n-type element migrates into the p-type element. Soon, each hole and electron that "switch sides" will be in equilibrium and act like a barrier, preventing more electrons or holes from migrating. This zone is called the depletion zone.

1.6 Boost Converter

Switched mode supplies can be used for many purposes including DC to DC converters. Often, although a DC supply, such as a battery may be available, its available voltage is not suitable for the system being supplied. For example, the motors used in driving electric automobiles require much higher voltages, in the region of 500V, than could be supplied by a battery alone. Even if banks of batteries were used, the extra weight and space taken up would be too great to be practical. The answer to this problem is to use fewer batteries and to boost the available DC voltage to the required level by using a boost converter. Another problem with batteries, large or small, is that their output voltage varies as the available charge is used up, and at some point the battery voltage becomes too low to power the circuit being supplied. However, if this low output level can be boosted back up to a useful level again, by using a boost converter, the life of the battery can be extended.

The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply or DC from solar panels, fuel cells, dynamos and DC generators. The boost converter is different to the Buck Converter in that it's output voltage is equal to, or greater than its input voltage. However it is important to remember that, as power (P) = voltage (V) x current (I), if the output voltage is increased, the available output current must decrease.

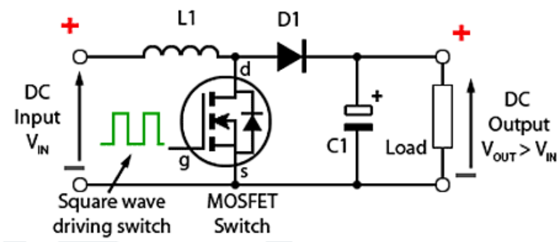

Fig. 1.6 Basic Boost Converter Circuit

Fig1.6 illustrates the basic circuit of a Boost converter. However, in this example the switching transistor is a power MOSFET, both Bipolar power transistors and MOSFETs can be used in power switching, based on the choice of the current, voltage, it also depends on switching speed and cost considerations.

1.7 Pulse Width Modulation

Pulse Width Modulation (PWM) uses digital signals to control power applications, as well as being fairly easy to convert back to analog with a minimum of hardware.

Analog systems, such as linear power supplies, tend to generate a lot of heat since they are basically variable resistors carrying a lot of current. Digital systems don't generally generate as much heat. Almost all the heat generated by a switching device is during the transition (which is done quickly), while the device is neither on nor off, but in between. This is because power follows the following formula:

P = E I, or Watts = Voltage X Current

If either voltage or current is near zero then power will be near zero. PWM takes full advantage of this fact. PWM can have many of the characteristics of an analog control system, in that the digital signal can be free wheeling. PWM does not have to capture data, although there are exceptions to this with higher end controllers.

The reason PWM is popular is simple. Many loads, such as resistors, integrate the power into a number matching the percentage. Conversion into its analog equivalent value is straightforward. LEDs are very nonlinear in their response to current, give an LED half its rated current you you still get more than half the light the LED can produce. With PWM the light level produced by the LED is very linear.

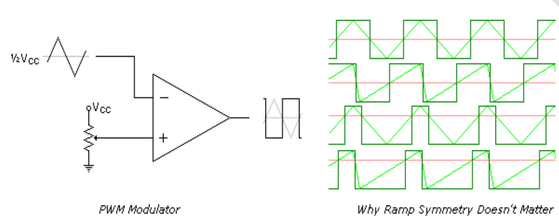

Fig.1.7 PWM

If there isn't any computation involved PWM can be fast. The limiting factor is the comparators frequency response. This may not be an issue since quite a few of the uses are fairly low speed. Some microcontrollers have PWM built in, and can record or create signals on demand.

Uses for PWM vary widely. It is the heart of Class D audio amplifiers, by increasing the voltages you increase the maximum output, and by selecting a frequency beyond human hearing (typically 44Khz) PWM can be used. The speakers do not respond to the high frequency, but duplicates the low frequency, which is the audio signal. Higher sampling rates can be used for even better fidelity, and 100Khz or much higher is not known.

1.8 Digitally Controlled Oscillator

A digitally controlled oscillator or DCO is a hybrid digital/analogue electronic oscillator used in synthesizers. The name is an analogy with "voltage-controlled oscillator". DCOs were designed to overcome the tuning stability limitations of early VCO designs.

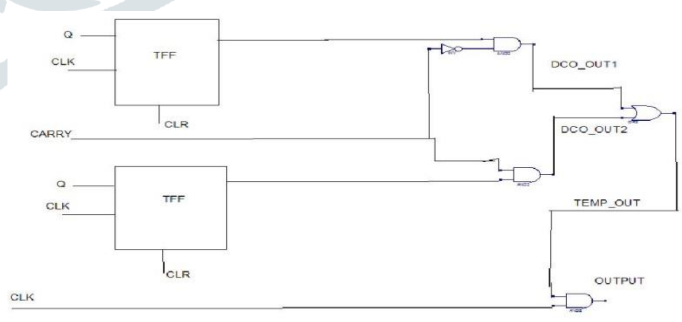

Fig 1.8 DCO using Flip Flops and gates

1.9 Counter

A counter circuit is usually constructed of a number of flip-flops connected in cascade. Counters are a very widely used component in digital circuits, and are manufactured as separate IC and also be incorporated as parts of larger integrated circuits. Here 8bit Synchronous counter is used to count the pulses getting from DCO .Using Boost converter reference output from DCO and TEG output are compared and difference voltage is boosted up and it drives pacemaker battery.

1.10 Simulation Result and Discussion

The design implementation for the existing and proposed system is simulated using Xilinx ISE software. The below Fig 5.1 and Fig 5.2 indicates the timing delays that happens in the existing system and proposed system respectively. It clearly shows that delay for existing system is about 12.300ns and time delay for proposed system is about 3.500ns.

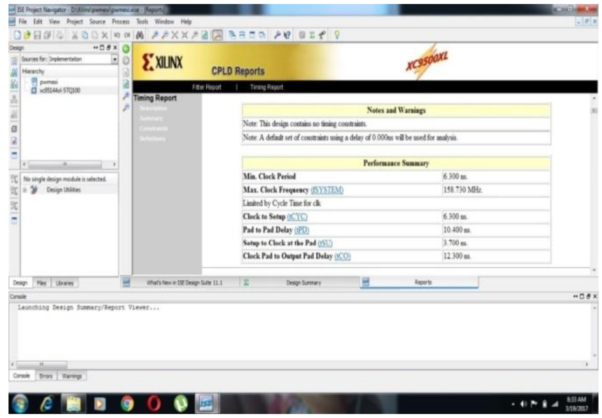

Fig 1 .9 Timing delay of the existing system

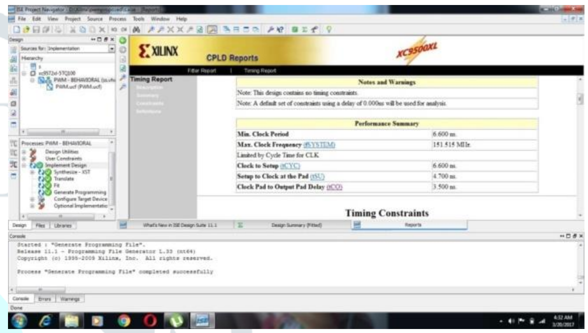

Fig 1.10 Timing delay of the proposed system

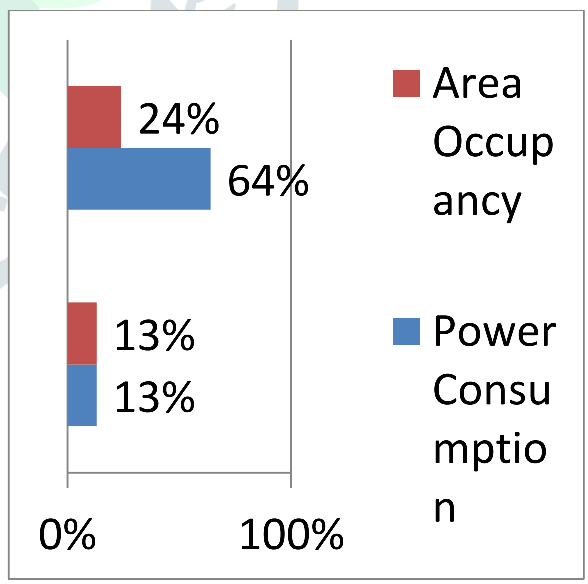

Fig 1.11 Simulation graph

1.10 Conclusion

In this paper, thermal energy harvesting using TEG is explained. Boost Converter helps to increase the lower level voltage into higher level voltage. The digital pulse to boost converter is given from CPLD kit. Digital Controlled oscillator is used in place of Voltage controlled oscillator which provides more tuning stability. The noise produced during these process is removed using low pass filter. Simulated results indicated that even the methods have their own disadvantages and merits, both of them can solve the problems in quite complicated cases, such as the temperature difference is low. Applying a **40-mV** input voltage, the output voltage of the proposed power supply is **2.5 V** under any load conditions. The circuit includes an internal reference voltage. No extra reference voltage source is needed.

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