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An Internal Startup Circuit for Pacemakers Using Body Temperature

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Abstract— **Pacemaker is known as an artificial heart. Pacemaker is a small device that is placed in the chest or abdomen to help control abnormal heart rhythms by generating electrical pulses. The main motive of this paper is to provide the power supply to the pacemakers by sensing our body temperature. Usually, the pacemakers operate using batteries which should be replaced 5 years once by undergoing surgical process. So, we are proposing to operate the pacemakers by sensing our body temperature which avoids surgical and replacement process. The peltier tile is used here to sense our body temperature both in hot and cold conditions. A Digital control oscillator is used in order to get high tuning stability which will be very useful in getting high reliability. The boost converter is used to amplify the input signal where the PWM signal acts as reference signal. There is no need of external voltage. Using this method, the performance of the pacemakers is highly reliable**.

***Key words -- CPLD*, Low power, Pacemakers, thermoelectricity**

I. INTRODUCTION

A Pacemaker is a device, which is small in the size of a half dollar piece, usually implanted just below the collar bone. A pacemaker contains a powerful battery, electronic circuits and computer memory that together generate electronic signal, though it weighs just an ounce. The pacing pulses or the signals are carried along the leads or thin insulated wires to the heart muscle. The heart muscle tends to begin the contractions that cause a heartbeat because of these signals.

On a wide basis, a pacemaker is implanted to compensate slow heart beating, which is called bradycardia. The brain and the body do not get enough flow of blood and may result in a variety of symptoms if the heart beats too slowly.

There are ~3 million people across the world with pacemakers and over 600000 pacemakers are implanted yearly. Mostly people require pacemakers at the age of 60 years or older but people of any age, even children may need pacemakers in certain demanding situations.

One of the major problems with pacemakers is the batteries. They limit the lifetime of pacemakers as the capacity of battery is limited. One should undergo a surgical process to replace the battery after the period of 5 years.

Replacing these batteries through surgical procedures is expensive and difficult to be performed. Apart from this around 60% of the volume of a pacemaker is occupied by its batteries. Eliminating these batteries reduce the dimensions of the pacemaker effectively. Harvesting thermal energy to power up an implantable pacemaker is one of the alternative methods. The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. The term "thermoelectric effect" encompasses three separately identified effects: the Seeback effect, Peltier effect, and Thomson effect. The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors. When a current is made to flow through a junction between two conductors, heat may be generated or removed at the junction.

The Peltier effect can be considered as the back-action counterpart to the Seeback effect if a simple thermoelectric circuit is closed then the Seeback effect will drive a current, which in turn (via the Peltier effect) will always transfer heat from the hot to the cold junction. The close relationship between Peltier and Seeback effects can be seen in the direct connection between their coefficients.

A typical Peltier heat pump device involves multiple junctions in series, through which a current is driven. Some of the junctions lose heat due to the Peltier effect, while others gain heat.

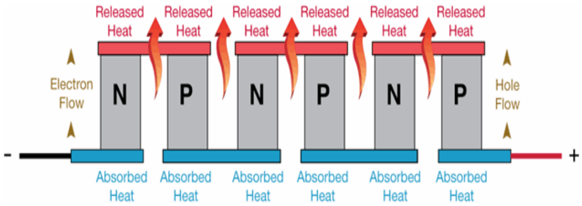

Fig 1. Typical Peltier diagram

II. EXISTING SYSTEM

The existing method [1] consists of thermoelectric generator, voltage control oscillator (VCO) and boost converter. The thermo electric generator is the one which observes the solar energy and converts it into electrical energy. The VCO has poor tuning stability. This system suffers when the solar energy is inconsistent. The system for harvesting the power supply to the pacemakers is created using TEG(thermoelectric generator) and the VCO is used in the system for simulating the process this system replaces the presence of battery with the help of TEG, but this turned out to be inefficient in few cases. Disadvantages:

1.This system demands continue solar energy to work effectively.

2. Tuning stability is comparatively less.

3. Cold climatic conditions are not supported by the system.

4. Highly unstable during the changes of the temperature.

III. PROPOSED SYSTEM

The proposed method consists of peltier tile and digital control oscillator (DCO). The peltier tile senses our body temperature in both hot and cold conditions and the DCO has high tuning stability.

This is highly reliable because it senses our body temperature till we live and doesn't require any external voltage source.

1. PELTIER TILE

Typical Peltier device sandwiches a thin array of p-type and n-type semiconductors between two metal plates along with conductors for direct current. The peltier tile senses our body temperature up to 0.5 mV.

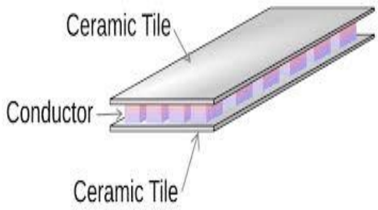

Fig 2. Peltier tile

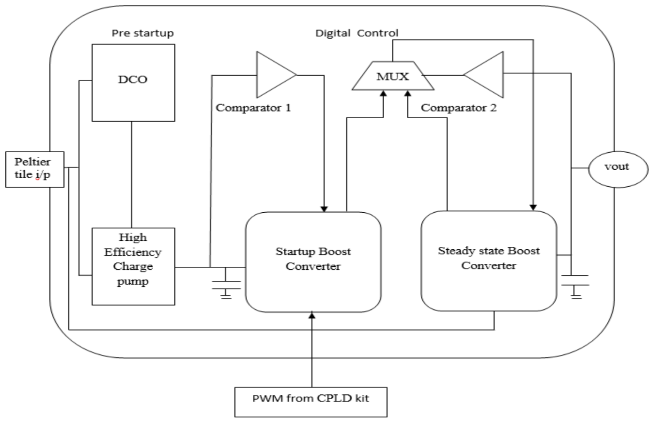

Fig 3. System Architecture of Proposed system

2. Digital Controlled Oscillator

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

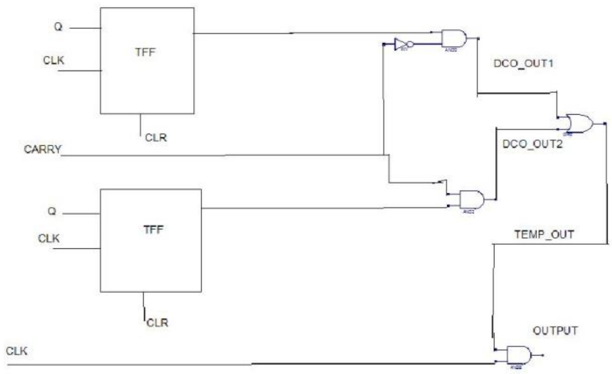

Fig 4. Digital Controlled Oscillator

3. Prestart up Charge Pump Structure

The output voltage of a TEG is very low. It is not sufficient for conventional oscillators to work properly. Among different types of oscillators, ring oscillators consume less power. A ring oscillator comprises an odd number inverters placed in a loop. The most limiting factor for minimum required supplying voltage of an oscillator, *V*dd, is its MOS transistor threshold voltage. One way to reduce the MOS threshold voltage is forward body biasing (FBB). The threshold voltage (*V*TH*)* of an nMOS transistor relates to its body voltage as follows:

$$V_{TH} = V_{TH0} + \gamma \left(\sqrt{(|V_{SB} + 2F|)} - 2\phi F \right) \quad \text{--(1)}$$

where V_{SB} is the source–body voltage, V_{TH0} is the threshold voltage when $V_{SB} = 0$, γ is the body effect parameter, and ϕ_F is the Fermi potential. It is observed from (1) that if V_{SB} in nMOS transistors becomes negative, the threshold voltage decreases. Conversely, in pMOS transistors, if V_{SB} has a positive value, the threshold voltage reduces. This technique is called FBB and is frequently used in digital design.

One of the drawbacks of FBB is that it increases the static power consumption of the transistor when it is OFF. This is not disturbing in oscillators since dynamic power consumption dominates static power dissipation.

Another problem that arises from FBB is that it turns ON the parasitic bipolar junction transistor (BJT) of MOS. In our design, this is not an issue since the supply voltage of the oscillator is so low that it cannot turn ON the parasitic BJT transistor.

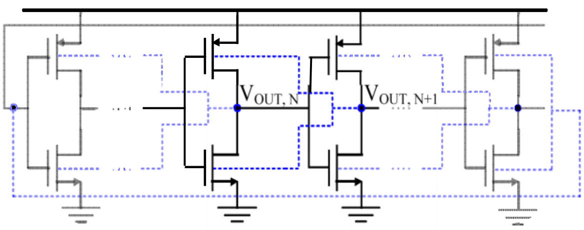

Fig 5. Proposed low-voltage low-power oscillator

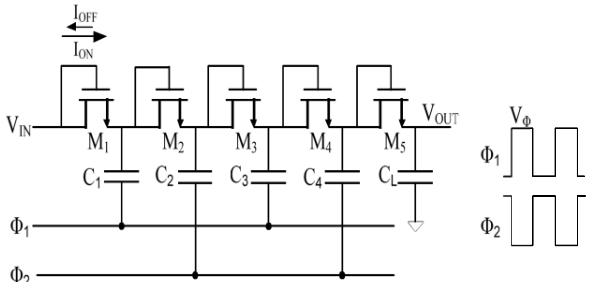

Fig 6. Conventional cp

4. 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 its 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.

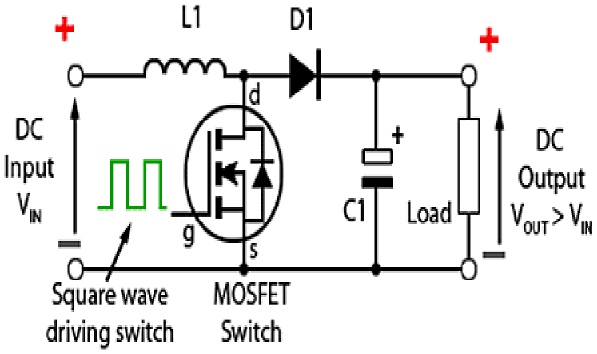

Fig 7. Basic Boost Converter Circuit

Fig 7 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 are used in power switching, the choice being determined by the current, voltage, switching speed and cost considerations. The rest of the components are the same as those used in the buck converter illustrated in Fig.7, except that their positions have been rearranged. In power switching ,both MOSFET and bipolar power transistors are being used.

Boost converter Operation

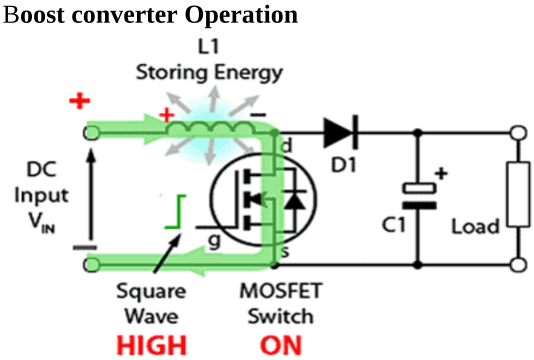

Fig 8. Boost Converter Operation at Switch On

Fig.8 illustrates the circuit action during the initial high period of the high frequency square wave applied to the MOSFET gate at start up. During this time MOSFET conducts, placing a short circuit from the right-hand side of L1 to the negative input supply terminal. Therefore a current flows between the positive and negative supply terminals through L1, which stores energy in its magnetic field. There is virtually no current flowing in the remainder of the circuit as the combination of D1, C1 and the load represent a much higher impedance than the path directly through the heavily conducting MOSFET.

Table 1: Boost Converter Specifications

Parameters	**Value**
Capacitor	100 µf
Diode	IN5819
MOSFET	IRFb46
Inductor	41µh

IV. SYSTEM ARCHITECTURE:

Pacemaker’s power consumption is 50 microwatts and supply voltage is 1.5-120 volts. Therefore the boost converter should convert the input voltage from peltier tile into 5(min)-8(max) with load resistance 50 micro watts. An 500 millivolts of input voltage source with 1.5Ω input resistance applied to the input of the circuit. The output from the peltier tile is the input to the DCO in form of binary digits ,if 1 is given to the DCO it starts working and if it is 0 then DCO is in inactive state.

The output waveform from the DCO is given to the precharge pump where all ON times are equal and all OFF times are equal. The precharge pump amplifies the input where it amplifies regarding NUMBER OF N- MOS-Inverters.

After amplification by the charge pump it further sends it output to the comparator and startup boost converter(SUBC) .then the charge pump gets disconnected from the whole circuit. This unit remains in the circuit just to improve the system reliability. Then the control circuit of the SUBC becomes active and control circuit of the SUBC provides the clock phases for itself and to the SSBC. The comparator VCMP1 and the comparator VCMP2 has the reference voltage of 5 volts .

The output voltage from the charge pump is given as input voltage to the comparator VCMP1.Now the comparator compares the two voltages i.e. The input voltage which comes from the charge pump and reference voltage 5 volts,and if both the voltages are equal it won't enable the SUBC. When the input voltage is greater or lesser to the reference voltage given then it enables the SUBC. If the SUBC is not enabled then the voltage from charge pump flows through the SUBC to the comparator.

Now the Pulse Width Modulation (PWM) signal is used to trigger both the SUBC and the SSBC . The PWM signal is used instead of many digital signals because of varying ON times and OFF times. i.e. varying duty cycles. The PWM signal is used as reference signal because it has varying pulse width(frequency) signal similar to the heart rhythms. The PWM signal is generated using DCO, counter, comparison logic, flipflop. The DCO is used to give the oscillating pulses with all ON Times and OFF Times equal. The counter is used to count the number of oscillating pulses. The comparison logic is used to compare the reference heart beats with the counter output which is given to the comparison logic as the input. The output from the comparison logic is stored in the flipflop.

The PWM signal acts as reference input signal to the SUBC where the output of the SUBC varies according to the PWM signals. The SUBC amplifies the input signal according to the MPP signal. If the input signal to the SUBC is lesser to the reference voltage in the comparator VCMP1 then, SUBC amplifies it . If the input signal to the SUBC is greater than the reference voltage in the comparator then the SUBC decreases the voltage.

The output voltage from the SUBC is given as the one of the inputs to the multiplexer and another input comes from the steady state boost converter(SSBC). The PWM signal is also present in the SSBC which is used to trigger the circuit. The reference voltage to the SSBC is also 5 volts. By default, first the multiplexer selects the SUBC output and sends it as the output VOUT. Now, this output is sent to the comparator VCMP2 as the input. Now the comparator compares the voltages and sends the signal to the multiplexer which voltage to be selected. If the input voltage is less than the reference voltage the comparator sends 0 as the output where the voltage from SSBC is selected and if it sends 1 as output the mux selects the output from SUBC. The respected voltage is given as output VOUT

V. SIMULATION RESULTS

To evaluate the proposed structure, the power supply is designed and simulated using Model Sim. The language used for coding is VHDL which is in industries for their easy implementation. The coding is written in behavioral model. It has advantages as follows.

1. VHDL is not case sensitive.
2. It is easy to learn.

Table 2: Values of the components used

Parameters	Values
Input voltage(From Peltier tile)	50mV
Resistance (Boost Converter)	25 Ω
Inductance(Boost Converter)	$41\mu W$
Output Capacitor	$100\mu F$
Diode	IN5819
MOSFET Diode	MBR8
Output Voltage	5-8V
Load	60K Ω
Prestart up Capacitance	5nF

The input parameters used here are clock, clear, enter1, enter, buffer enable, flow, etc., are forced to 0 and 1 which result in rising and falling edges relatively. When input to clear is given as 0, output obtained is the unknown impedance. Hence to remove that unknown impedance, the input to clear is changed to 1. When buffer input is forced to 0, high impedance is obtained. Clear and clock are used as triggering inputs. In order to generate clock pulses, clear is forced to 0 and hence the final oscillating pulses indicating the voltage are obtained.

Table 3: Comparison of proposed system with existing system

Parameters	Existing System	Proposed System
Power Consumed	14%	5%
Time Delay	6.6ns	6.3ns
Area	24%	13%
Output Voltage	Up to 2.5 volts	Up to 12 volts

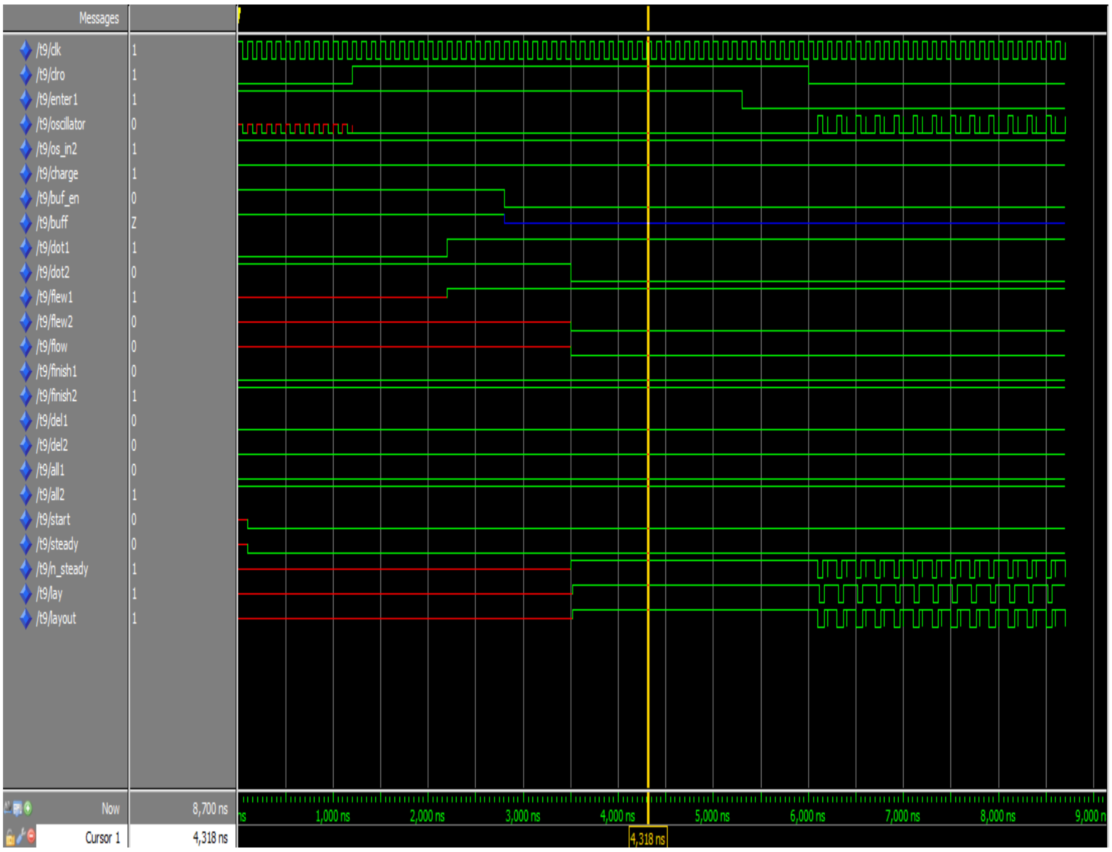

Fig 9: Simulation results

The photo snapshot of our project demo module is shown in fig.10 & fig.11.

Fig 10: Hardware set up

The components used here are CPLD, boost converter and Peltier tile. When the heat is applied on the Peltier tile using soldering rod, the Peltier tile produces the voltage of around 0.5v and the reference signal is taken from CPLD which is around 1.3v.

These two voltages are given to boost converter which gives the output around 1.5v to 3.0v in the multimeter connected. Thus the voltage required for the working of the pacemakers is generated.

The output voltage obtained while using CPLD kit is presented here.

Fig 11: Hardware setup with result

VI. CONCLUSION

An internal startup circuit for implantable pacemakers using body temperature is proposed in this paper. We use the peltier tile to sense our body temperature which would be about 500 mV. An digital control oscillator (DCO) is used instead of VCO as DCO has high tuning stability. The main parameter considered here is frequency. The power consumed and area when we use VCO is 64% and 13%. When DCO is used the power consumed and area is 13% and 13%. The time delay for the existing method is 6.6ns. The time delay for the proposed system is 6.3ns.

The power consumption, area, time delay is reduced when DCO is used. Hence, the proposed system is highly reliable.

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