Thermal Energy Yielding Technique for Health Applications Using Startup Boost Converter

1J. Stella Mary, 2Dr.D.Sasikala

1PG student, Department of ECE, Vivekanandha College of engineering for women, Tiruchengode, Namakkal (Dt)
2HEAD/ECE, Department of ECE Vivekanandha College of engineering for women, Tiruchengode, Namakkal (Dt)

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ABSTRACT
In this proposed work a thermal energy yielding technique for health applications using startup boost converter is presented. The power supply element contains a multi feedback ring oscillator, charge pump circuit, comparator and boost converter circuit. These circuits are used to power awake the implantable medical device (IMD) to carry the obtainable power to the load circuit depends on the maximum pow

INTRODUCTION
The advance healthcare, aiding or delivering the functions of malfunctioning organs in Implantable Medical Devices (IMDs) to have been around for years. They have been developed for diagnosis, prognosis and treatment. Implantable medical devices can be categorized as active and passive devices depending on whether it need a power source or not, respectively. At the present time, a host of chronic diseases have been addressed using Implantable medical devices all over the body, from the brain, cochlea as well as retina to the heart, lungs, knee joints and yet vessels, the esophagus and the bladder. These specifics indicate that implantable medical devices have become more popular in humans’ life. At present, all handy electronic devices are power up by only a different type of batteries. Still, the energy harvesting from like, human or environmental sources has proved to be a useful alternative or set off. In this sense, it is should expect that batteries were also created in smaller size providing more energy storage accessibility. On the other hand, due to practical and scientific issues, the batteries have not been following by the same evolution development, warning the operational time and performance of portable devices as it necessitate be replacing or recharging periodically, adding also useless weight and amount. To solve these problems, there are a number of energy yielding sources are used. In worldwide nearly 3 million people having pacemakers, and annually over 6, 00,000 pacemakers are fixed. Generally, a pacemaker is fixed to treat slow heart beating, which is called bradycardia. When the heart beat is too slow, the human brain and the body do not get adequate blood flow and a kind of symptoms may occur [4].
After five years, a surgical process is wanted to replace the battery of the pacemakers. The major drawback regarding the pacemakers is its batteries. As the potential of the battery is limited, it limits the lifetime of pacemakers. In addition, nearly 60% of pacemakers are associated with its batteries as show in Fig. 1 A pacemaker is a small device, about the size of a half Dollar piece, implanted just below the collarbone. Although it weighs just about an ounce, a pacemaker contains a powerful battery, electronic circuits, and computer memory that together generate electronic signals. The signals, or pacing pulses, are carried along thin insulated wires, or leads, to the heart muscle.

That is kinetic energy (wind, waves, gravity, vibration), electromagnetic energy (photovoltaic, radio-frequency), thermal energy (solar-thermal, geothermal gradients of temperature, combustion), atomic energy (nuclear, radioactive decay) or biological energy (bio-fuels, biomass) [12]. In this context, appears the energy harvesting concept. The Energy harvesting market from 2011 to 2017 map can see as Fig.2.

![Energy harvesting market from 2011 to 2017](image.png)

**Fig. 2:** Energy harvesting market from 2011 to 2017.

![TEG circuit](image.png)

**Fig. 4:** TEG circuit.
One of the different methods used to replace the battery in pacemaker by using energy harvesting technique. Harvesting ambient heat energy using thermoelectric generators (TEGs) [11] is a convenient means to supply power to body-worn and industrial sensors, especially pacemakers. In this paper, a power supply with an internal startup is introduced that successfully converts a minimum of 40-60mV input voltage provided from a TEG into a 1 to 3 V output voltage needed for a pacemaker to operate usually as shown in Fig.3. Typically, pacemakers consume an average of 50 μW at 100% of efficiency. As a result, the circuit should be able to provide available power to the pacemakers.

The existing system ultra low voltage low power oscillator was used. It increases the noise characteristics and power consumption. To overcome this method using the multi feedback ring oscillator.

**Proposed system:**

**A. TEG Architecture:**

Fig.4 shows the architecture of the proposed thermoelectric energy yielding system. A 40 mV input voltage is given to the multi feedback ring oscillator, which is generated by the TEG. The multi feedback ring oscillator is generate available clock phase for the charge pump circuit. The charge pump circuit is used to speed up the startup voltage for the boost converter circuit. If the boost converter does not reach the predefined value at the time the comparator can be set high, which is used to compare the threshold values and reduce the leakage current and MOS threshold voltage. When we set the comparator is high, the boost converter deliver the available power to the load circuit.

**B. Multi feedback ring oscillator:**

Disclosed is a multiple feedback ring oscillator and delay cell with high oscillation voltage. It is an object of the present invention to implement a new ring oscillator for the VCO of a high speed PLL and a proper delay cell with a high speed and low noise. The apparatus is composed of multiple feedback loop ring oscillator that 4 delay cells which have the first main input stage, the second main input stage, the first subsidiary input stage, the second subsidiary input stage, the third subsidiary input stage, the forth subsidiary input stage, the first output stage and the second output stage is connected to the main loop and subsidiary loop.

The present invention has advantages that it can be operated in high speed, it has low power sensitivity, there is no power noise because there is no variation of a supply current and it can improve noise characteristics.
As show in Fig.5, the present development has advantages that it can be operated in high speed, it can improve noise characteristics. It has low power sensitivity; there is no power noise because there is no variation of a supply voltage. In addition, to minimize power consumption, minimum-size inverters are used. The output buffer consists of a chain of inverters. The chain includes eight inverter-based buffers.

C. Charges pump circuit:

Fig.6 shows that the charge pumps circuit. This multi feedback ring oscillator can correctly control output swing, although it has a disadvantage that the power noise characteristic is bad because an output is linked to a power line directly through a small impedance triode transistor. To reduce an output swing is a clamping of output voltage of diode is other method. If we connect a gate and a drain of transistor, transistor is in a saturation region the diode can be used. If a diode turns on, the voltage of both terminals of a diode is proportional to the square root of a current (I), and a voltage dropping of diode is very small, so it can be used as a voltage clamping which fixes an output voltage to a exact voltage.

\[ V_{\text{DD}} \]

\[ D_1 \]
\[ D_2 \]
\[ D_3 \]
\[ D_4 \]
\[ V_{\text{ref}} \]
\[ C_1 \]
\[ C_2 \]
\[ C_3 \]
\[ C_4 \]
\[ C_L \]

CLK

CLKB

Fig. 6: Dickson charge pump.

As a result, to have the largest VBS voltage (least VTH) for each transistor (at the time the switch turns ON), the body voltages of the MOS switches of the odd (even) stages should be connected to the output voltage of the last even (odd) stage. This is shown in Fig. 5.Therefore, when M1 turns ON, its body voltage is in a high state and so its body–source voltage is large. This results in a reduction in threshold voltage.

D. Comparator:

Fig. 7 shows a comparator circuit introduced in [12]. A pMOS transistor with its gate and source terminals connected to each other is used. This transistor operates in the subthreshold region and has a constant current. This constant current flows through a resistor and builds a reference voltage. The generated reference voltage is used as the supply of an inverter. A percentage of output voltage (k · VOUT) is applied to the input of the inverter. Using this method, if the output voltage is larger than a desired value, then the output of the comparator (VCMP) becomes low. The relative values of R1 and R2 set the threshold level of the comparator. Process variations of the pMOS threshold voltage can be compensated for by the resistive dividers which are discrete components. In addition, the proposed reference generator does not suffer much from temperature variations in this application since the pacemaker needs to be implanted in the body. The temperature variations inside the body are about ±1 °C. These variations do not impact on the generated reference voltage since the temperature coefficient of the proposed circuit is about −2 mV/°K.

\[ \text{CLK} \]
\[ \text{Out} \]
\[ \text{M2} \]
\[ \text{M3} \]
\[ \text{M4} \]
\[ \text{M5} \]
\[ \text{M6} \]
\[ \text{M7} \]
\[ \text{M8} \]

Fig. 7: comparator design circuit.
E. startup Boost Converter Structure:

The startup boost converter is used to step up technique an input voltage to some upper phase, required by a load. This restricted capability is achieved by storing energy in an inductor and releasing it to the load at a higher voltage phase. When using boost regulators this main highlights some of the more common pitfalls. These contain maximum possible output current and voltage, short circuit behavior and basic end of this document provide exceptional overviews of the action of a boost regulator; and should be consulted if the reader is not familiar with the basic action of this type of Converter. Fig. 8 shows a diagram of an ideal boost converter and its equivalent circuit in each phase [11].

![Ideal Boost Converter Circuit](image)

**Fig. 8:** ideal boost converter circuit.

A new Maximum power point tracking (MPPT) method is introduced as show in Fig.8. The Maximum power point (MPP) is an operating point in boost converters. MPP based on maximizing the stored power in the inductor. Depending on maximum power point, at which maximum power is delivered to the load. Then again, it does not consider the ON resistances of the switches as well as the series resistance of the inductor.

The parasitic effects are considered, MPP will be changed. The maximum available power can be delivered to the boost converter is,

\[ P_{\text{AVA, MAX}} = \frac{V_{\text{TEG}}^2}{4} \times R_{\text{TEG}} \]  

The output voltage of a boost converter is,

\[ V_{\text{OUT}} = \frac{V_{\text{IN}} (T_{\text{rise}} + T_{\text{fall}})}{(T_{\text{fall}})} \]

The output of the comparator 1 controls the activity of the oscillator. When \( V_{\text{CMP1}} \) is low, the oscillator is inactive. When it becomes high, the oscillator starts its operation. As the SUBC and the SSBC both need a similar oscillator, one oscillator is shared between them to reduce power consumption.

![Startup Boost Converter Waveform](image)

**Fig. 9:** startup boost converter waveform.

**Simulation results:**

To assess the proposed structure, the power supply with internal startup circuit includes a multi feedback ring oscillator, charge pump; comparator and boost converter is designed and simulated in LT spice. The designed power supply unit with startup circuit is used to supply the power to the Implantable medical device. The IMD does not need external battery. A 50mV input voltage is applied to the input of the multi feedback ring oscillator (MFRO), which is used to generate a necessary clock phase for the charge pump circuit and reduce a
MOS threshold voltage. A 40mV input voltage is applied to the The charge pump (CP) circuit it generate from the multi feedback oscillator. The charge pump has a 5 stage of inverter, each stage inverter having the energy stored capacitor. This circuit is used to boost up the startup voltage and reach the defined value is shown in Fig 8.the output voltage of charge pump is 270mV.

When the charge pump reach the defined value at the time the compactor can be set high otherwise it will be set low. This is used to compare a low or high voltage phase for the circuit and leads the boost converter circuit to work correctly. If comparator compares to set a high value the startup boost converter can generate a appropriate voltage and deliver an available power to the load. This input is depends on output of charge pump (CP) circuit. This generates an output voltage up to 1.15V and the consume power is up to 100 to 1250uW as shown in Fig. 9.

From above result the startup circuit power consumption is low compare to existing system and also reduces a voltage drop as well as increase a circuit performance.

**Conclusion:**

A thermal energy yielding technique for health applications using startup boost converter presented in this paper. The startup circuits are designed and simulated in LTSpice. From the thermoelectric generator (TEG) is used to generate a 40mV input voltage is given to the starting voltage of startup circuits. Applying a 320mV voltage from charge pump, which enable to generate an output voltage of the boost converter is 1.15V and consume power is 125uW under 50kilo ohm load conditions. In future work, the steady state circuits with multiplexer circuit are added to the startup boost converter to analysis the overall circuit performance and reducing the power consumption.

**REFERENCES**