

# THERMAL ENERGY HARVESTING POWER SUPPLY DESIGN

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**Abstract**— A thermal energy harvesting power supply is presented in this paper. The designed power supply does not need any battery for startup and is used to power up any device with load of 50kiloohm. The power supply circuit includes an oscillator, charge pump, boost converter and a comparator. The circuit is designed to handle the maximum load of 50 kilo ohm. A minimum voltage of 40mV is needed for the circuit to startup. A maximum power of 135uW can be obtained from the output of the boost converter circuit. The circuit is simulated using LTspice and simulation results are verified.

**Keywords**— Thermal Energy Harvesting, Hysteresis Comparator, Low Voltage Oscillator, Dickson Charge Pump, Pacing Signal.

## I. INTRODUCTION

As the ultra large scale integration is attained now, one of the major problem faced by any electronic devices are their batteries. The size of the battery does not become small in size in comparison with the transistor sizing. Even when the transistor size is reduced to great extend, the device does not get small because of large area occupied by the battery. One of the alternatives to replace the battery in any electronic device is by using energy harvesting technique. In this paper, thermal energy harvesting power supply is designed. This could eventually replace battery in any electronic device.

Thermoelectric generators are devices that convert the heat energy into electrical energy. Seebeck effect is the basic phenomenon that causes the heat energy to be converted to electrical energy. The voltage generated by using our body heat is approximately 40mV. In this paper, a circuit is designed which could convert this 40mV to 2.5V output voltage. The power supply circuit is designed to provide 135uW power at maximum pacing so that device could operate without any failure.

## II. THERMAL ENERGY HARVESTING SYSTEM ARCHITECTURE

Fig. 1 shows the architecture of the thermal energy harvesting system. An input voltage of 40mV is applied to the system. Thevenin equivalent of the 40mV source is shown in Fig 2. The working of system as follows. The ultra low voltage oscillator is used to generate the required clock phase for the proper operation of the charge pump system.

Charge pump circuit is used to increase the input voltage for the other circuit to operate successfully. The output voltage of charge pump is used as input to the boost converter circuit. When the specific output voltage is not obtained on the boost converter, the hysteresis comparator output is set high. This drives the clock generator to increase the output voltage of boost converter. This makes the circuit to drive the load continuously.

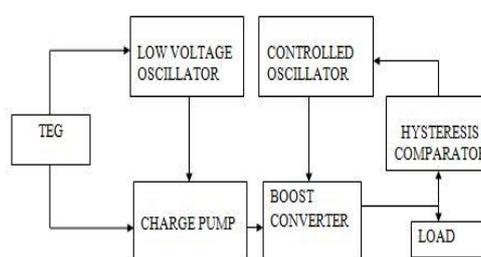


Fig. 1 System Architecture

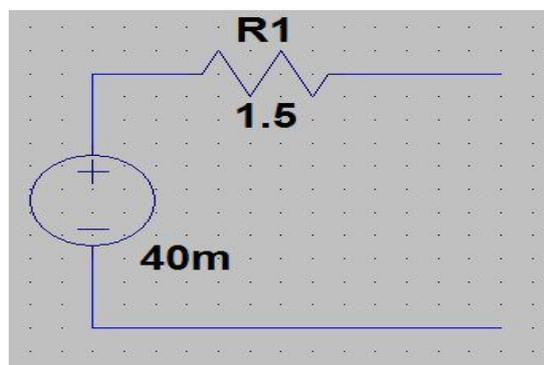


Fig. 2 Thevenin Equivalent of Source Voltage

## III. START UP CIRCUIT

The startup circuit comprises of low voltage oscillator and charge pump circuit. These two stages are used to increase the input voltage as much as required for the other circuit to operate properly.

### 3.1. Low voltage oscillator

The charge pump circuit needs proper clocking circuit to boost up the voltage. The clocking circuit is the heart of the charge pump circuit. Thus choosing proper clocking circuit is of prime importance in the design.

Among various types of oscillator, ring oscillator consumes very less power. The designed ring oscillator is used to generate the clock of frequency 3kHz. The circuit diagram of ring oscillator is shown in Fig 3.

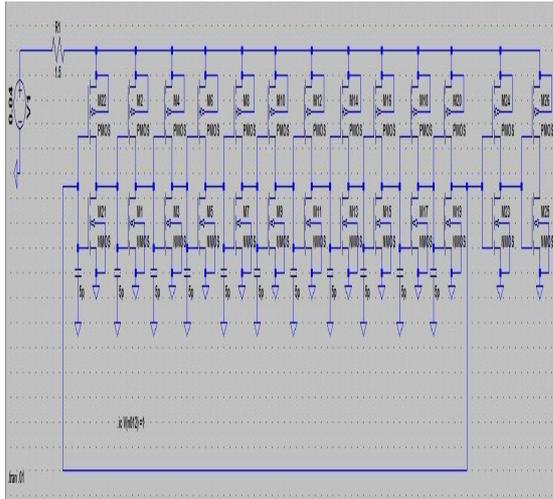


Fig. 3 Low Voltage Oscillator

**3.2. Charge pump circuit**

The charge pump circuit is used to increase the input voltage of 40mV to higher voltage. The output voltage of the charge pump is given by  $V_{OUT} = V_{IN} - V_{TH} + N(V_{CLK} - V_{TH})$  Where  $V_{IN}$  is the input voltage,  $V_{CLK}$  is the clock amplitude and  $V_{TH}$  is the threshold voltage of the MOS switches. Fig. 4 shows the circuit of charge pump.

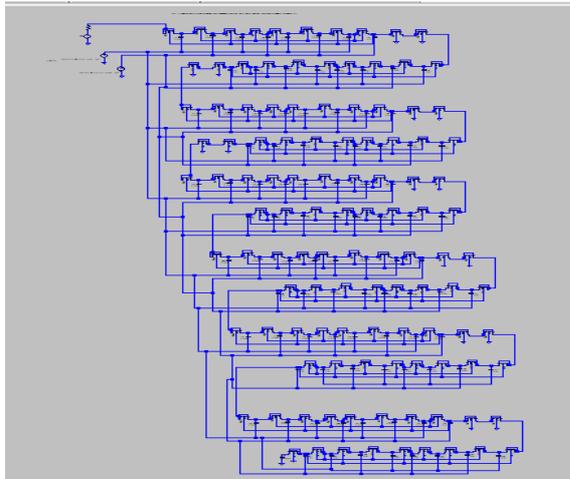


Fig. 4 Charge Pump Circuit.

**IV. BOOST CONVERTER CIRCUIT**

**4.1. Boost Converter Circuit.**

Fig. 5 shows the diagram of ideal boost converter. The fundamental logic behind the working of boost converter is their energy storing and discharging. When switch S1 is closed, the energy is stored in the inductor. When the switch S2 is closed, the stored energy gets transferred to the capacitor. Maximum efficiency completely depends upon the inductor current. When the inductor current falls, efficiency is greatly reduced. Fig.6 shows the diagram of designed boost converter which could convert 1.7 voltage to 2.5 voltage.

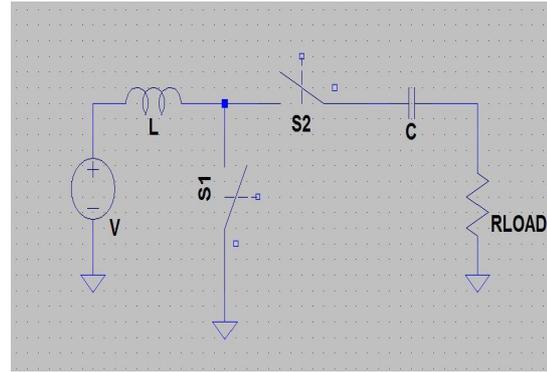


Fig. 5 Ideal Boost Converter

**4.2. Hysteresis Comparator**

The generated output voltage are used to run a hysteresis comparator. The reference voltage is given by the voltage divider circuit for SR flipflop. The SR flipflop set or reset based upon the voltage build upon the resistive divider network. Fig. 7 shows the circuit of hysteresis comparator.

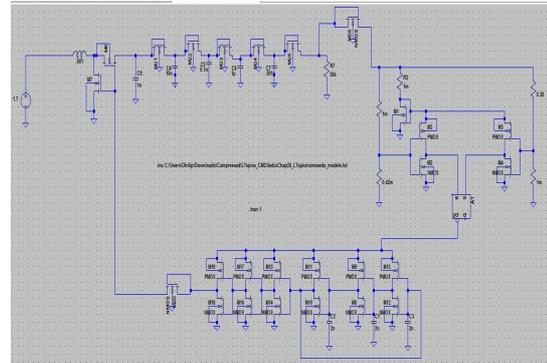


Fig 6. Complete boost converter

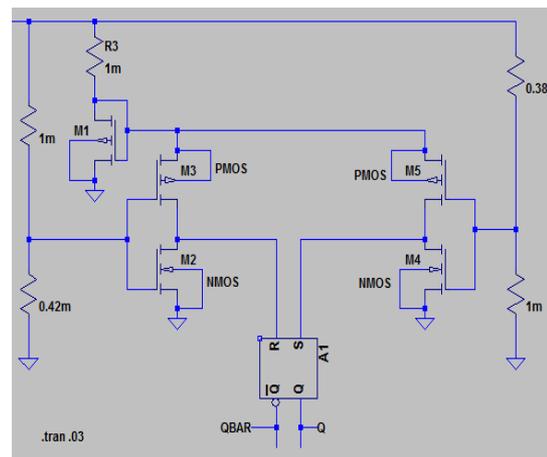


Fig. 7 Hysteresis Comparator

**4.3 Controlled Oscillator**

The output of the hysteresis comparator is used as the power supply for the oscillator. The main purpose of this oscillator is to provide clocking to the boost converter circuit. The storage and discharge of the charge depends upon the clocking frequency. The oscillator is designed to generate 6 KHz frequency. Fig. 8 shows the circuit diagram of the oscillator.

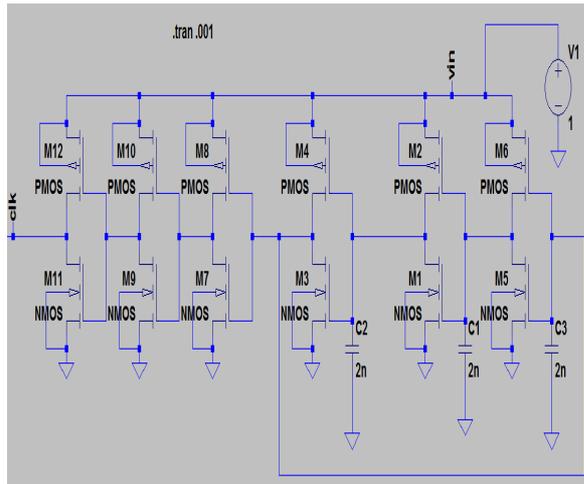


Fig. 8 Controlled Oscillator

V. SIMULATION RESULTS

The thermal energy harvesting power supply is designed and simulated using LTspice. The designed power supply can be used as supply to any circuits with maximum load of 50kiloohm. Electronic Pacemaker consumes maximum of 50uW power which can be continuously delivered by this circuit. A 40mV input voltage with source of 1.5 ohm internal resistance is applied to the input of the circuit and the output voltage is measured by connecting a resistive load of 50kiloohm.

The output voltage of the oscillator is shown in Fig. 9. The input to the oscillator is 40mV with source resistance of 1.5ohm. Eleven inverters are used to generate the required clock signal. Two buffers are needed to drive the charge pump.

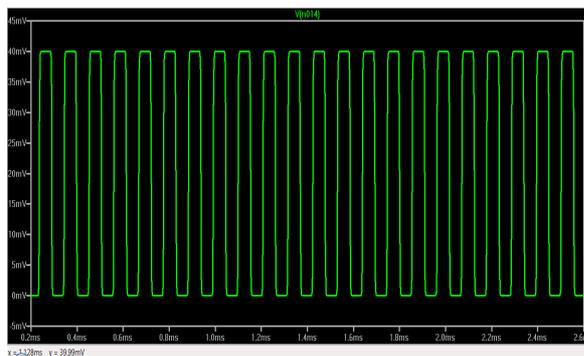


Fig. 9 Output Voltage of Oscillator

The output voltage of the charge pump circuit is shown in Fig. 10. The charge pumping of other stages involved in the circuit are also shown. The final output voltage of 1.7V is obtained from the charge pump circuit.

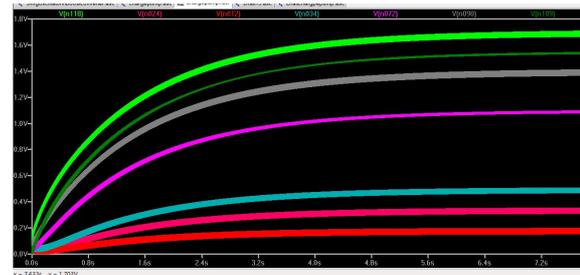


Fig. 10 Output Waveform of Chargepump.

The output voltage of the boost converter is shown in Fig. 11. This boost converter circuit includes hysteresis comparator and controlled ring oscillator which together generates the output voltage of 2.5V to the load continuously.

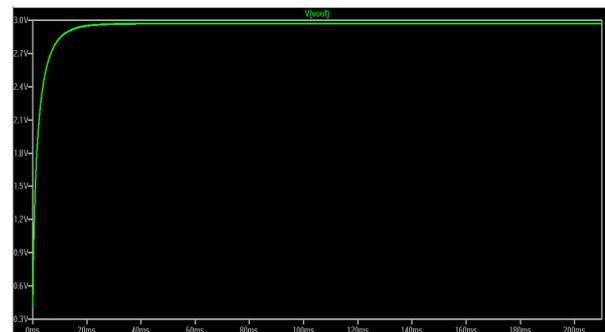


Fig. 11 Output Waveform of Boost Converter

CONCLUSION

Thermal energy harvesting power supply is designed which could convert 20mV provided by TEG to 2.5V. Simulation results shows that the circuit provides 2.5V output and 135uW power for load of 50Kiloohm continuously.

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