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POWER SUPPLY FOR PACEMAKERS WITH PRESTARTUP CHARGE PUMP CIRCUIT

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Abstract - *Harvesting energy from the environment by using thermoelectric generators (TEG) provides solutions for battery-free pacemakers. One of the main challenges is the extremely low output voltage that the energy harvesters can provide. The TEG generates output voltages in the range of 10 mV/K to 50 mV/K, depending on its process and size. The power supply includes an internal startup and does need any external reference voltage. The startup circuit includes a prestartup charge pump(CP) and a startup boost converter. The prestartup charge pump consists of ultralow-voltage oscillator. Forward body biasing is used to reduce the MOS threshold voltages as well as the supply voltage in oscillator and CP. These voltages are lower than the threshold voltages of most standard CMOS technologies. Using this approach, a charge pump circuit for thermal energy harvesting power supply has been designed using 180—nm CMOS technology.*

Key Words: Charge pump, energy harvesting, MOS threshold voltage, pacemakers, power supplies.

1. INTRODUCTION

A pacemaker is implanted to treat slow heart beating. It is a small device that 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. The signals cause the heart muscle to begin the contractions that cause a heartbeat. 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.

Harvesting energy from the environment by using thermoelectric generators (TEG) provides solutions for battery-free pacemakers. One of the main challenges is the extremely low output voltage that the energy harvesters can provide. The TEG generates output voltages in the range of 10 mV/K to 50 mV/K, depending on its process and size [11], [12]. For body-wearable applications, the output voltage is less than 100 mV for a temperature difference of 2K. These voltages are lower than the threshold voltages of most standard CMOS technologies. Therefore, a low-startup voltage step-up DC-DC converter is required to kick-start the system. It also needs to convert the harvested energy to usable output voltages because the harvested voltages are too low for pacemakers

1.1 EXISTING SYSTEM

A cardiac pacemaker uses half of its battery power for cardiac stimulation and the other half for housekeeping tasks such as monitoring and data logging. The first implanted cardiac pacemaker used nickel-cadmium rechargeable battery, later on zinc-mercury battery was developed and used which lasted for over 2 years. Lithium iodine battery invented and used by Wilson Greatbatch and his team in 1972 made the real impact to implantable cardiac pacemakers. This battery lasts for about 10 years and even today is the power source for many manufacturers of cardiac pacemakers.

The major problems were two fold; the first being very short life time and the second was to place the responsibility for recharging in the hands of patients, which is not a good medical practice. It was well known that primary or non-rechargeable batteries would give longer lifetime compared to secondary batteries. There are still some rechargeable pacemakers in use though not sold any more.

Biological batteries (which use power from within the human body) were experimented unsuccessfully for practical use in pacemakers. *Nuclear batteries* were tried successfully for some period. Practical nuclear batteries use plutonium (^{238}Pu). However it is highly toxic and 1µg in the blood stream could be fatal. Nuclear powered pacemakers are no longer sold but still a small number of implanted nuclear devices that remain in use. Nuclear power sources became obsolete with the development of lithium batteries.

With several features being added to the implantable cardiac pacemakers and other implanted medical devices, manufacturers are going to need to pull more energy out of the battery more quickly. Today's pacemakers typically use lithium iodine batteries. 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.

2. THERMOELECTRIC ENERGY HARVESTING SYSTEM

As shown in Fig. 1 TEGs (also called Seebeck generators) are devices that convert heat (temperature differences) directly into electrical energy, using a phenomenon called the Seebeck effect (a form of TE effect). A voltage source in series with an internal resistance is a representative of TEGs [8], [9]. The open-circuit output voltage of the TEG is proportional to the temperature gradient. When implanting a TEG, the best place should be as close as possible to the superficial skin, where a maximum temperature difference between the two junctions of the TEG could be established. This would guarantee a good output of the TEG [10].

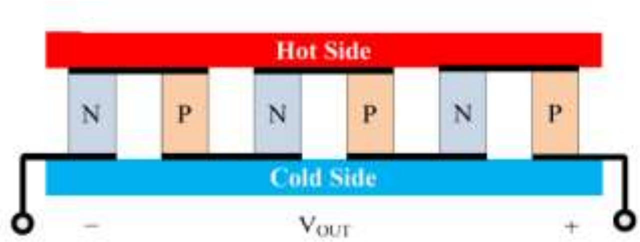

Fig.1 (a) Typical TEG

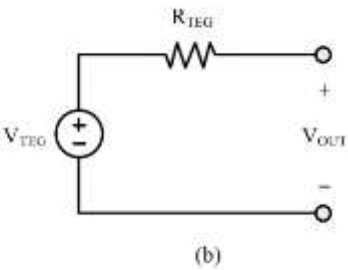

Fig 1. (b)Electrical equivalent circuit

3. PRESTARTUP CHARGE PUMP STRUCTURE

Fig. 2 shows a conventional CP circuit [3]. The circuit comprises two phases. The output voltage of a conventional

CP circuit after *N* stages is

$$V_{OUT} = V_{IN} - V_{TH} + N(V\phi - V_{TH}) \qquad (1)$$

where V_{in} is the input voltage, $V\phi$ is the clock amplitude, and

V_{TH} is the threshold voltage of MOS switches. From Equation (1), to have a high-efficiency CP, V_{TH} must be minimized. When ϕ1 is low (ϕ2 is high), M1 (and the following switches of odd stages)is ON. In addition, the output voltages of the even stages are in a high state. Conversely, when ϕ1 is high (ϕ2 is low), *M*2 (and the following switches of even stages) is ON. In addition, the output voltages of the odd stages are in a high state. As a result, to have the largest V_{BS} voltage (least V_{TH}) 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. 3. 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.

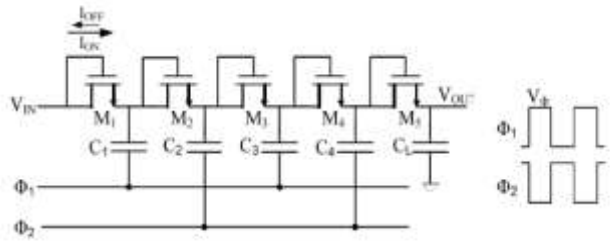

Fig.2 Conventional Charge pump circuit

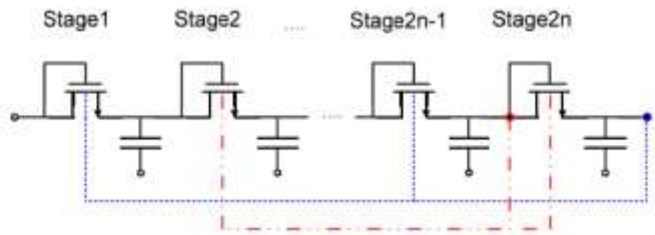

Fig. 3 Modified Charge pump circuit

The threshold voltage has been reduced with this technique [1], the clock amplitude is still smaller than V_{TH}. However, there still exists the current difference between I_{ON} and I_{OFF} [4], as shown in Fig.2. This current difference charges the pumping capacitor and pumps up the output voltage. Since the amplitude of the clock provided for the CP is small, the available output current of the CP is limited. Therefore, the output capacitor of the system (C_{OUT}) cannot be placed at the output of the CP since it has a large value. Instead, a small startup capacitor is placed at the output of the CP.

The optimum number of pumping stages is 20 [2]. Lower or higher number of pumping stages may result in a reduction in output voltages or waste energy. As the output voltage provided by this 20-stage CP is not sufficient for the rest of the circuit to operate, as shown in Fig. 4, five 20-stages CPs are cascaded to produce the required output voltage.

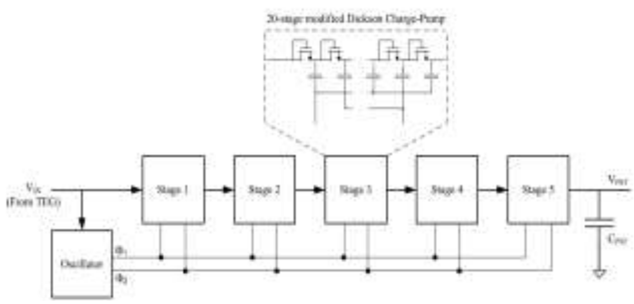

Fig. 4. Structure of the prestartup circuit

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4. SIMULATION RESULTS

A basic switched capacitor was simulated using cadence, as it is the basic building block of charge pump. Fig 5 shows the schematic of the switched capacitor circuit used for simulation.

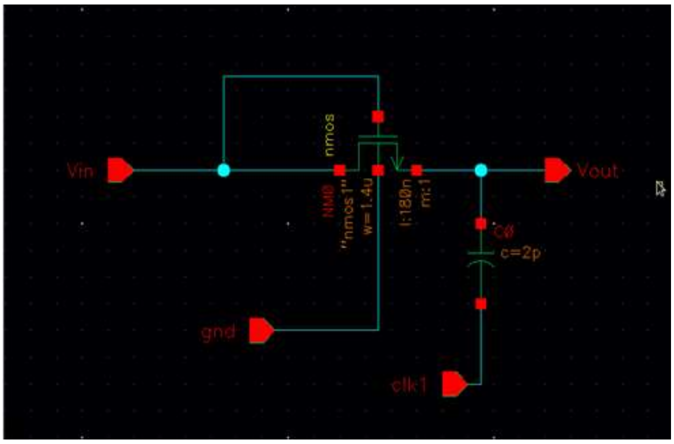

Fig 5. Schematic of switched capacitor circuit

The switched capacitor consists of an NMOS connected in series with a capacitor. A symbol view(Fig. 6) of the circuit is needed for the subsequent simulation steps; thus, the schematic capture of the circuit topology is followed by the creation of a symbol to represent the entire circuit. The default symbol icon is a simple rectangular box with input and output pins. This icon can now be used as the building block of another module, and so on.

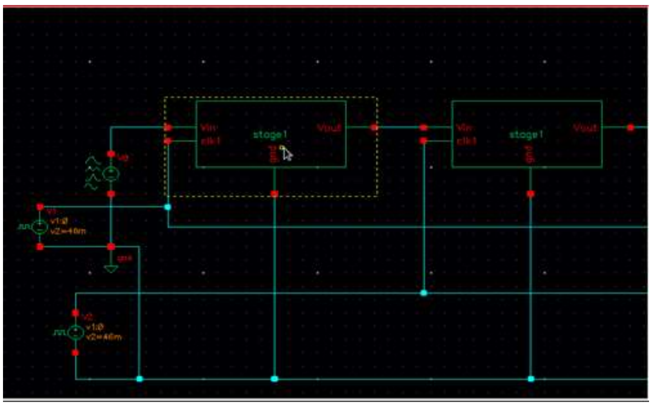

Fig 6. Symbol of switched capacitor circuit

A 40-mV input voltage source is applied to the input of the circuit. In addition to the DC input, the circuit requires a feed of two clock pulse trains with amplitude swinging between the DC supply rails. These pulse trains are in anti-phase as shown in fig.7.

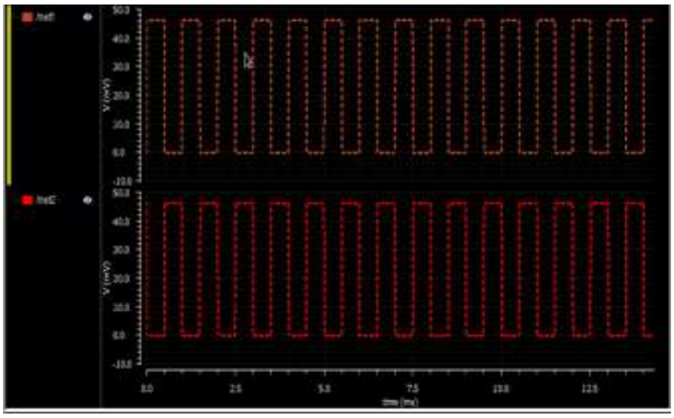

Fig 7. Clock pulses

Since more pumping stages are needed, the symbol is connected repeatedly as required. We have connected 20 pumping stages together since lower or higher number of pumping stages may result in a reduction in output voltages. Fig 8. shows the 20 stages of charge pump. The circuit parameter values are as follows:

Input voltage-40mV, Clock amplitude-46mV, NMOS W/L-1.4 U/180N, Capacitor value-2pF

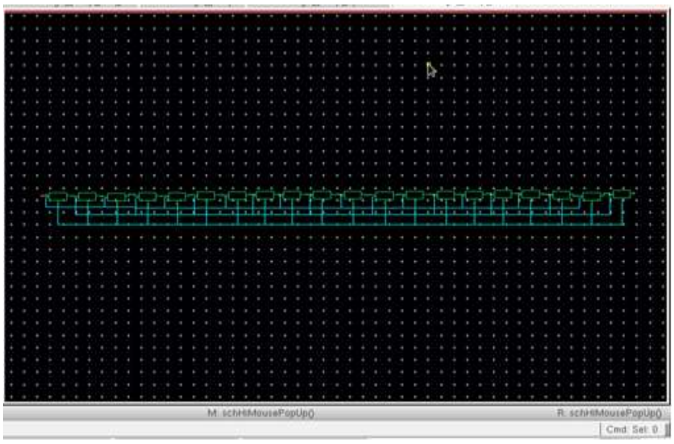

Fig 8. Schematic of 20 stage charge pump

As the output voltage provided by this 20-stage charge pump is not sufficient for the rest of the circuit to operate, five 20-stage CPs are cascaded to produce the required output voltage. When C=1Pf, W/L=1.4u/180n, the output voltage reaches 450 m V. By changing the W/L ratio, capacitance, input voltages, maximum output voltage obtained was approximately 1V. Comparison was listed in Table 1.

Table 1:Comparison of output voltages with some circuit parameters

Vin (mV)	W	L	Vout (mV)	Clk Amp (mV)	Clk Frequency (K Hz)
40	1.1 u	180 n	433.74	46	1
40	1.4 u	180 n	507.42	46	10
60	1.4 u	180 n	537.24	66	1
60	440 n	200 n	628.27	66	1
60	400 n	200n	660.9	66	1
60	400 n	180 n	710.26	66	10
60	400 n	180 n	905.5	66	1

Fig.9 shows the output of the charge pump. As seen from figure, after a specified duration, the prestartup circuit reaches 710mV from 60mV input voltage.

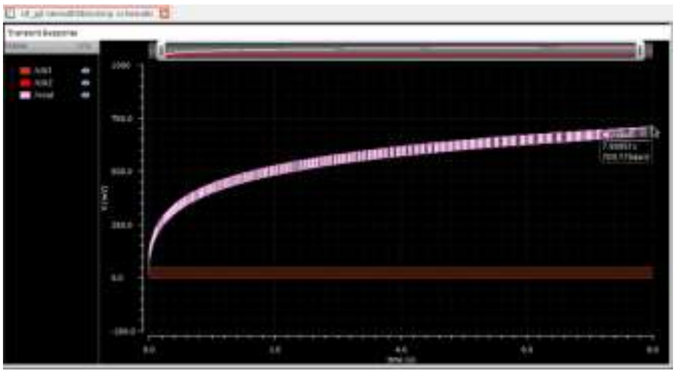

Fig 9. Output voltages of the prestartup CP stages

5. CONCLUSIONS

A high-efficiency modified Dickson CP was used to increase the input voltage to the extent that is needed for the whole circuit to operate successfully. The output voltage of the TEG is applied to the input of CP. Comparison of charge pump output voltage with some circuit parameters has been done.

REFERENCES

[1] Mohammadreza Ashraf and Nasser Masoumi," A Thermal Energy Harvesting Power Supply With an Internal Startup Circuit for Pacemakers",*IEEE Trans.Ind.Appl* Volume: 24, Issue: 1, Jan. 2016

[2] C. Lu, S. P. Park, V. Raghunathan, and K. Roy, "Stage number optimization for switched capacitor power converters in micro-scale energy harvesting," in *Proc. DATE*, 2011, pp. 16.

[3] J. F. Dickson, "On-chip high-voltage generation in MNOS integrated circuits using an improved voltage multiplier technique," *IEEE J. Solid-State Circuits*, vol. 11, no. 3, pp. 374–378, Jun. 1976.

[4] P.-H. Chen *et al.*, "Startup techniques for 95 mV step-up converter by capacitor pass-on scheme and VTH-tuned oscillator with fixed charge programming," *IEEE J. Solid-State Circuits*, vol. 47, no. 5, pp. 1252–1260, May 2012.

[5] M K Mandal and B C Sarkar, "Ring oscillators – Characteristics and applications", *Indian journal of pure and applied physics*, vol 48, Feb 2010

[6] M. M. Mano and M. D. Ciletti, Digital Design. Englewood Cliffs, NJ, USA: Prentice-Hall, 2013, p. 216.

[7] R. J. Baker, CMOS Circuit Design, Layout and Simulation. Hoboken, NJ, USA: Wiley, 2010, p. 351

[8] R. P. Rocha, J. P. Carmo, L. M. Goncalves, and J. H. Correia, "An energy scavenging microsystem based on thermoelectricity for battery life extension in laptops," in *Proc. 35th Annu Conf. IEEE Ind. Electron.*, Nov. 2009, pp. 1813–1816.

[9] L. Chen, D. Cao, Y. Huang, and F. Z. Peng, "Modeling and power conditioning for thermoelectric generation," in *Proc. IEEE Power Electron. Specialists Conf.*, Jun. 2008, pp. 1098–1103.

[10] Y. Yang, X.-J. Wei, and J. Liu, "Suitability of a thermoelectric power generator for implantable medical electronic devices," *J. Phys. D, Appl.Phys.*, vol. 40, no. 18, pp. 5790–5800, 2007.

[11] M. Kishi *et al.*, "Micro thermoelectric modules and their application to wristwatches as an energy source," in *Proc. 18th Int. Conf.Thermoelectr.*, 1999, pp. 301–307.

[12] S. Lineykin and S. Ben-Yaakov, "Modeling and analysis of thermoelectric modules," *IEEE Trans. Ind. Appl.*, vol. 43, no. 2, pp. 505–512,Mar./Apr. 2007.