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A Modern Precise Full-Wave Rectifier in CMOS Technology for Various Applications

Aref Vakili, Mohsen Sadeghi, and Abbas Golmakani
Sadjad Institute for Higher Education, Mashhad, Iran
Email:Aref_vakili@yahoo.com

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Abstract: In this article, a modern precise full-wave Rectifier by using non-linear applications of op-amp circuit is presented. By using an appropriate design for proposed op-amp circuit, this circuit is designed as the output is not saturated. A precise full-wave rectifier can be designed for high frequencies. The objective of the proposed circuit is more focused on minimum and maximum input voltage. In the structure of this rectifier Fully-Differential circuit for op-amp circuit is used, and for ideal diode, contact diode is used. Output voltage simulation has been done by using Hspice software in 0.18 um technology.

Keywords: Full-wave rectifier; power consumption; Minimum voltage input; Styling; op-amp circuit

1 Introduction

Rectifiers are used in the entrance of chips, and their responsibility is rectifying AC input signal from external transmitter for providing a stable DC power supply. They are used for all internal blocks of chips with a maximum efficiency of power transmission. By the continuous progress in the field of micro-technology, using implantable chips in body tissues for curing or diagnosing diseases like neurotic impulses, damaged muscles, or paralyzed muscles have been increased. So in these micro-systems it has been tried to decrease their size and improve their methods of power transmission in order to create as much harmony as possible between the space and body temperature, and the most important challenge in their design is achieving outstanding methods in Ease of Use transmission of impulse data in these micro-systems.

These chips are considered as a useful block in implantable integrated rectifier chips. These chips need a stable power supply. Using rechargeable batteries in these chips for an appropriate function is not easy. Recent trends have been more focused on using infusion link for an appropriate function. The next block is a rectifier of ample bandwidth for transforming Ac signal to a reregulated DC power supply. These rectifiers or Hybrid bridges or half-wave rectifier with low efficiency are implemented in substrates by using off-chip diodes. What is used by chips is a fully integrated wave rectifier by the following specifications:

1) Fast function in Megahertz range.

2) Not having losses due to leakage current in substrates along input-output path.

3) Minimum voltage drop possible along input-output path. 4) As latch up risk free as possible. 5) High Current rate.

Full-wave integrated rectifiers of low current rating often are used in wireless sensors and RFID, and Full-wave integrated rectifiers of high current rate, often are used in implantable micro impulses with high Number of actuated impulse.

This article consists of following sections:

Section 1) introduction

Section 2) proposed rectifier plane

Section 3) results of simulation

Section 4) conclusion

1.1 Active and passive rectifiers (active and inactive):

The active rectifier is always along with active diode, this circuit is based on behavior of an ideal diode. The most outstanding difference between active and passive rectifiers is a continues consumption power on controlling the circuit. The active rectifiers are powered by storage capacitor, which have high power efficiency, due to having low consumption power. Usually the active rectifiers have a MOS switch and they are controlled by logic control. Active cross couple rectifier is designed by a comparator and by replacing the MOS diode with a MOS switch. The rectifier is based on simple connections of diode, according to following three reasons, usually it is not used:

1) High probabilities of latch up risk, such as bipolar systems with PN open circuit connections.

2) Low speed switching

3) Poor specialize traits description in documentations of the process especially in the forward direction.

So, MOS transistor usually is used as diode (Gate connected to the drain). Voltage drop is proportional with threshold voltage of transistor. Voltage drop can be reduced by using coupled cross gate. There are other common techniques for designing of passive rectifiers, such as using bootstrap techniques and common body biasing or under the effect of Gate-Drain potential. High voltage drop of a MOS diode can be resulted from the difference between PMOS and NMOS threshold voltage. This voltage drop can be reduced by using bootstrap techniques, and it is the advantage of passive rectifiers.

1.2 Important parameters of rectifier:

Usually, there are five standard criteria for optimizing and comparing different rectifiers. These five criteria are used for clarifying the dynamic range of rectifiers performance. They are as follows:

1.2.1 Power transfer efficiency

This ratio is defined by, ratio of Average power dissipated in load to total average power dissipated in

$$PTE = \frac{P_{out}}{P_{in}} \qquad (1-1)$$

whole circuit.

1.2.2 voltage transfer efficiency

This ratio is defined by, ratio of output average voltage

$$VTE = \frac{V_{out-avg}}{|V_{in}|} \qquad (2-1)$$

to AC Sinusoidal input voltage.

1.2.3 Minimum input voltage

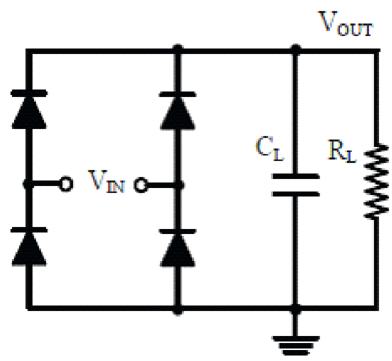
This criterion presents minimum input voltage which can be detected in output with maximum power transfer efficiency and voltage conversion ratio.

1.2.4 Maximum output load current

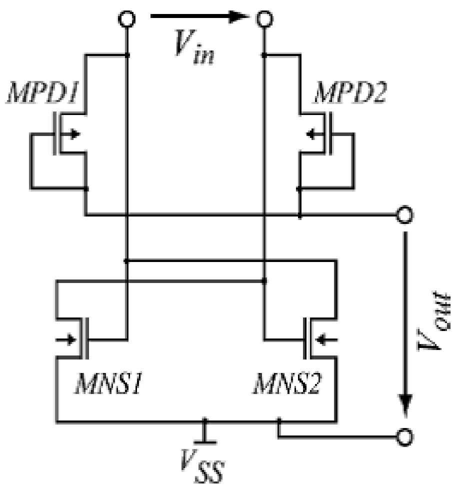
This parameter is maximum input current curve which passes RC load that is connected to output node. This parameter is of high importance in applying stimulation to tissue, because the chip needs high currents for charging the connected capacitor to output.

1.2.5 Output voltage maximum

This parameter is very important for power transmission application in remote controllers, and it is very important for implantable chips. By using a Schmitt Trigger circuit and an appropriate voltage regulator, maximum output voltage as DC output voltage can be created to supply power for all blocks. A sample full-wave bridge rectifier and classic rectifier with coupled gate are respectively shown in figure (1) part (a) and figure (1) part (b). In the figure (1) part (b), two MOS diodes are replaced by MOS switches. (MNS1, 2) can be run by alternate input voltage (VIN). The residual voltage drop of MOS diode can be reduced by using extra biasing circuits.



(a)



(b)

Figure 1: part (a): Full-wave bridge rectifier. Part (b): The schema of full-wave rectifier with coupled gate

2. The proposed rectifier

In fact the general idea of full-wave rectifier is shown in figure (2), in which by using two diodes, positive half cycle and negative half cycle are created.

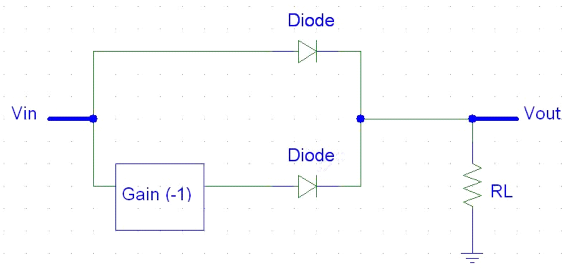


Figure 2: The overall schema of full-wave rectifier

A sample active precise full-wave rectifier is presented by using nonlinear applications of op-amp. In this rectifier, the contact diode (drain connected to the gate) is used into op-amp loop. One of the nonlinear applications of op-amp is constructing precise and fast rectifier. By placing a diode into op-amp loop an ideal diode is created. In order to reduce voltage drop due to transistor threshold voltage (Vth), contact diode is used into op-amp loop. So the rectifier can be used for input voltage lower than 1V. According to the following reasons, this rectifier is limited in high frequencies:

1) Output goes to the saturation.

2) Low speed switching

In order to eliminate frequency limitation, the circshould designed in a way that output does not go to the saturation. Figure (3) and figure (4) respectively are the schema of proposed full-wave rectifier and the schematic circuit in CMOS technology.

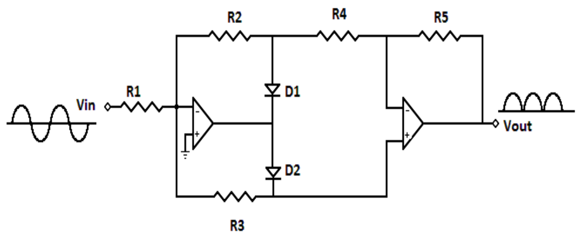
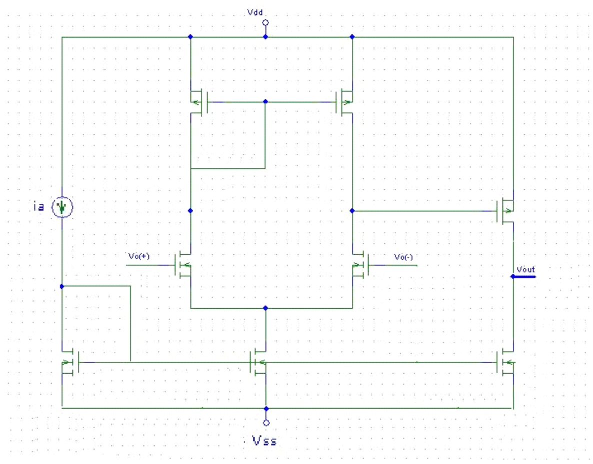
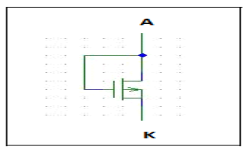


Figure 3: the schematic circuit of precise full-wave rectifier by using op-amp circuit



(a)



(b)

Figure 4: part (a): The used contact diode part (b): The circuit used for op-amp

3. Results of simulation:

3.1 Consumption power

The proposed rectifier circuit simulated with minimum input voltage and RL=1K Ω. The consumption power is consist of sum of proposed Fully Differential for op-amp circuit and some resistors and contact diodes. There are different techniques to reduce consumption power in order to increase power efficiency. (One of these methods is body biasing)

3.2 Transient behavioral of the circuit

In this rectifier by applying input voltage equal to zero, op-amp output and the main output of circuit equals to zero. In positive cycle of input voltage, D1 is on and D2 is off, so output equals to input. In negative cycle of input voltage, D1 is off and D2 is on, so output equals to inverse input. By applying calculations on circuit, it is determined that output never goes to the saturation region, so this circuit is a fast and precise full-wave rectifier. Input waveform and output waveform of proposed rectifier are shown in figure (5).

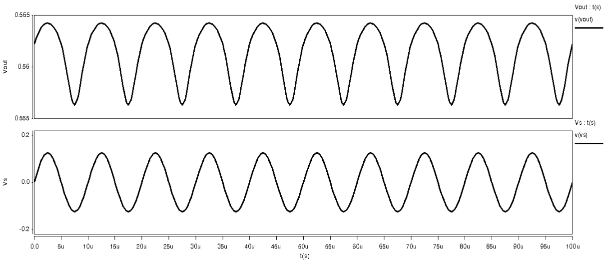


Figure 5: The input waveform and output waveform of proposed rectifier circuit

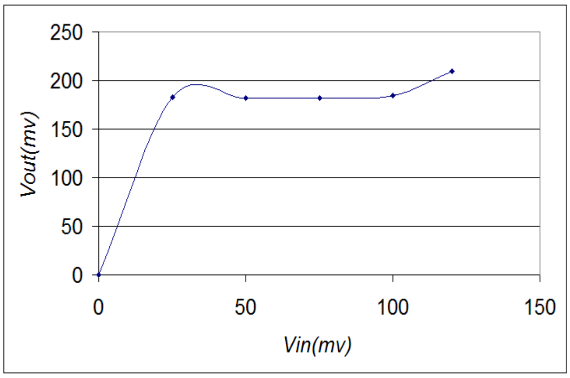


Figure 6: The input - output chart of proposed full-wave rectifier

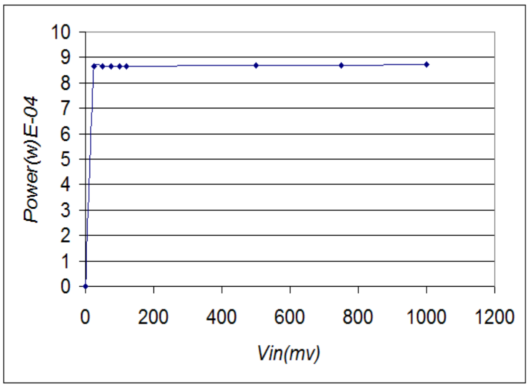


Figure7: The consumption power - input circuit chart of proposed full-wave rectifier

The simulation results of proposed full-wave rectifier are shown in table (1).

Table 1: The simulation results of proposed full-wave rectifier

Design	power	$Vin_{,min}$	I_L(max)
Proposed Full-wave precise rectifier	649uW	100mV	50uA

4. Conclusion

This article presents a sample of fast and precise full-wave rectifier by using nonlinear applications of a proposed op-amp circuit along with the structure of contact diode (drain connected to the gate). As noted in order to have a high frequency rectifier and fast rectifier, output of this circuit should not go to the saturation region. The purpose of this article is designing a circuit to minimize the input voltage as much as possible.

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