Full-Wave Rectifier Circuit Responding in Linear Wide Range by Two Stage CMOS

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***Abstract*—This article is present full-wave rectifier circuit responding in linear wide range by two stage CMOS by 0.5 μm CMOS technology, ± 1.5 V low voltage, operation input receiver and output current mode, it responded operational at high frequency. The components of structure circuit are two stage CMOS circuit and current mirror circuit. The performances of the proposed circuit are investigated through PSpice. They show that the proposed circuit can function as maximum input current ranges 300 $\mu A_{p\text{-}p}$, responding at maximum frequency ranges 10 MHz, high precision, low power, non precision zero-crossing output signal, and uses a little of transistors. Furthermore, the circuit is able to generate square signal, it is operating at voltage mode but without modification or elaboration to structure of circuit.**

I. Introduction

Full-wave rectifier circuit is very importance in analog signal processing, such as AC voltmeter, detector signal circuit, demodulate circuit, etc. [1]-[2]. So it always has development in full-wave rectifier circuit. For example full-wave rectifier circuit in voltage mode [3], full-wave rectifier circuit in diode and bipolar transistor [4]. It has to use the threshold voltage 0.3 volt for germanium (Ge) and 0.6 volt for silicon (Si). Therefore, it has unstable signal in crossing zero and in this low input signal case. The circuit, it unable to working, because of diode and transistor characteristics are limit. This limitation is improved by designing, they unused diode and bipolar transistor, but they use other active device. In the past century they have a lot of presentation, who has presented full-wave rectifier circuit in current mode, but the circuit still have complicated of device, thus it have complicated in working and dissipation of current source too. So, in this article we would like to show a new choice of full-wave rectifier circuit, it easier to understand and uncomplicated in compound with active device, but still have high quality of working function with CMOS technology. The CMOS technology has compound with two stage CMOS, it still has translinear and current mirror circuit put together, and then it able to responding in wide linear, working at high frequency, responding at high input precision signal, low losing power and uses a little of transistor.

II. Functional

A. Translinear circuit

From the presented show translinear is the main device, thus should to know about the functional of translinear circuit, and then can be written the relation of voltage and within resistance as fig. 1

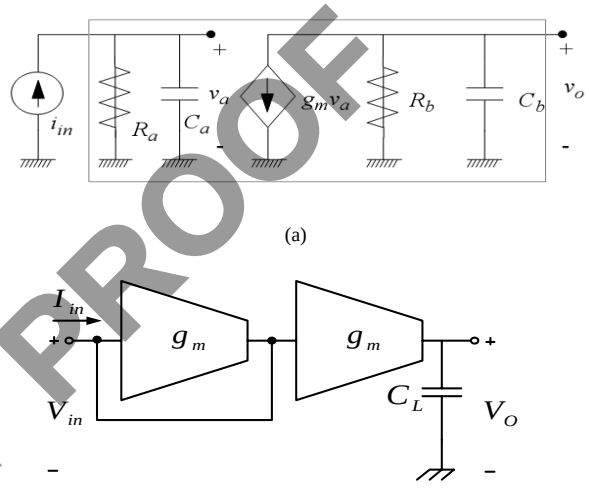

Fig. 1. (a) Equivalent circuit and (b) Basic translinear circuit

Designing of circuit is necessary to know about the inductive resistance within alternating current. For still have translinear characteristics, and use to apply working in current comparator circuit as fig. 2 [5].

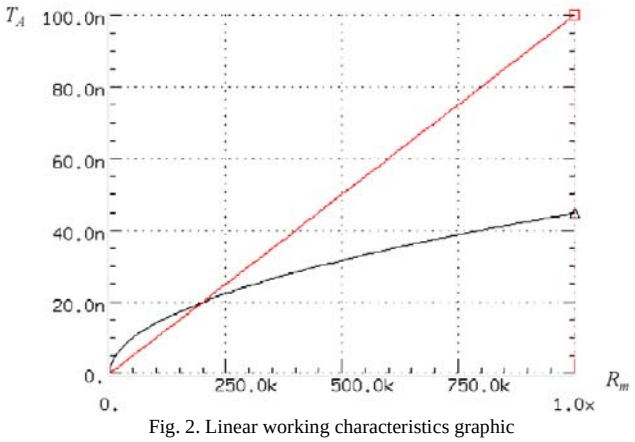

Fig. 2. Linear working characteristics graphic

Generally, in considering we are interested in impedance it able to see from fig. 1 (a). When R_a and C_a parallel compound at input with basic translinear equivalent circuit, after that the working stage is chance and the best working stage able to find out from R_a and R_b as equation (1) should to setting C_a equal to C_b.

$$v_o(t) = g_m R_a R_b J\left(1 - \frac{\tau_a}{\tau_a - \tau_b} e^{-\frac{t}{\tau_a}} - \frac{\tau_a}{\tau_b - \tau_a} e^{-\frac{t}{\tau_b}}\right), t > 0 \quad (1)$$

B. Completely full-wave rectifier circuit responding in linear wide range by two stage CMOS.

From the principle of translinear circuit, when it used to designing in two stage CMOS circuit and current mirror circuit combined with together after that it able to see the structure of completely full-wave rectifier circuit responding in linear wide range by two stage CMOS as diagram block fig. 3

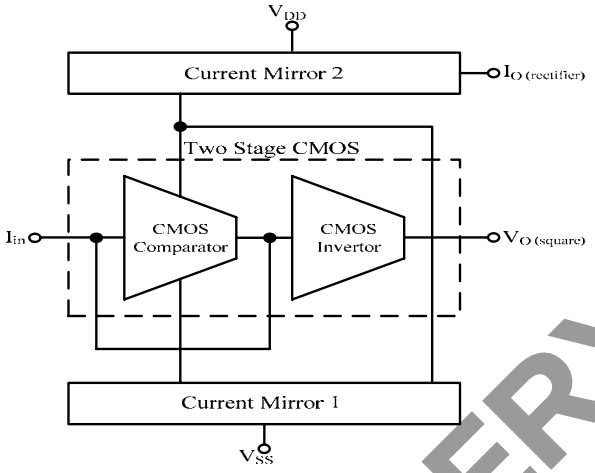

Fig. 3. Diagram full-wave rectifier circuit responding in linear wide range by two stage CMOS

So, the structure it will combine with three part of circuit, first the CMOS current comparator circuit, second the CMOS inverter circuit, and third the current mirror circuit. For the functional, when the CMOS current comparator circuit received input positive and negative, it will starting to compare the circuit by bring negative signal passing to the current mirror circuit 2, and positive signal passing to the current mirror circuit 1. The both of signal, they will be combined with together at input current mirror circuit 2, after that the new signal is full-wave output signal. At the same time positive and negative signal from the CMOS current comparator circuit it has passed to CMOS inverter, after that new signal is output square working in voltage.

$$I_{DM2} = 0 \text{ and } I_{DM1} = -I_{in} \text{ then } I_{in} > 0 \quad (2)$$

$$I_{DM1} = 0 \text{ and } I_{DM2} = I_{in} \text{ then } I_{in} < 0 \quad (3)$$

From the fig. 4 completely full-wave rectifier circuit responding in linear wide range by two stage CMOS, when sending input signal as equation (2) after that M_1, M_4 transistor able to flowing, but M_2, M_3 transistor unable to flowing. Thus, I_{dm1} equivalent to $-I_{in}$ and inversion input signal is less than zero it will make M_2, M_3 transistor able to flowing and M_1, M_4 transistor unable to flowing, thus I_{dm2} equivalent to I_{in} as equation (3)

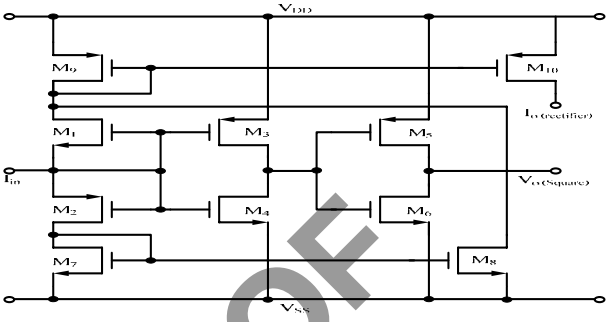

Fig. 4. Completely full-wave rectifier circuit responding in linear wide range by two stage CMOS

While, M_1 and M_2 transistor are flowing, V_{SS} and V_{DD} voltage are sending to M_7, M_8, M_9 and M_{10} transistor. After that M_7 transistor is flowing and it have reflected to M_8 transistor drain pin. For combine with M_9 transistor drain pin, and then it will mirror current passing to M_{10} transistor drain pin, after that appear full-wave signal in current mode at output as equation (4).

$$I_{out(rectifier)} = I_{DM8} + I_{DM9} = I_{DM10} \quad (4)$$

$$V_{out(square)} = V_{ss} \text{ then } I_{in} > 0 \text{ and } V_{out(square)} = V_{DD} \text{ then } I_{in} < 0 \quad (5)$$

At the same time, I_{in} current signal from equation (2) and (3) it will sending back to input CMOS inverter. Thus, M_5 and M_6 switching to flow after that square signal circuit source working in voltage mode at M_5 and M_6 transistor drain pin as equation (5)

III. THE SIMULATION RESULT QUALITY OF WORKING

For confirmation about the performance of circuit, therefore uses PSpice program in the simulation. Setting parameter 0.5 μm of MOSIS for transistor PMOS and NMOS V_{DD} = 1.5 V V_{SS} = -1.5V. Input current working at range 0-300 $\mu A_{p\text{-}p}$. Fig. 5 output signal is sending input size 300 $\mu A_{p\text{-}p}$ and frequency 1 kHz. Fig. 6 output signal is sending input size 300 $\mu A_{p\text{-}p}$ and frequency 10 kHz. Fig. 7 output signal is sending input size 300 $\mu A_{p\text{-}p}$ and frequency 100 kHz. Fig. 8 output signal is sending input size 300 $\mu A_{p\text{-}p}$ and frequency 1 MHz. Fig. 9 output signal is sending input size 300 $\mu A_{p\text{-}p}$ and frequency 10 MHz. Fig. 10 output signal is sending input size 300 $\mu A_{p\text{-}p}$, frequency 1 kHz and temperature 25^O ,50^O,75^O and 100^O. Fig. 11 output square signal is sending input size 100 $\mu A_{p\text{-}p}$ and frequency 1 kHz. Fig. 12 output square signal is sending input size 300 $\mu A_{p\text{-}p}$ and frequency 1 kHz.

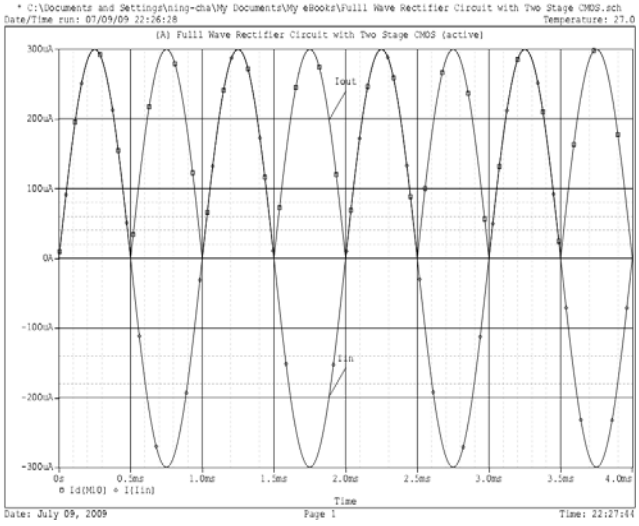

Fig. 5 Output signal is sending input size 300 μA_{p-p} and frequency 1 kHz

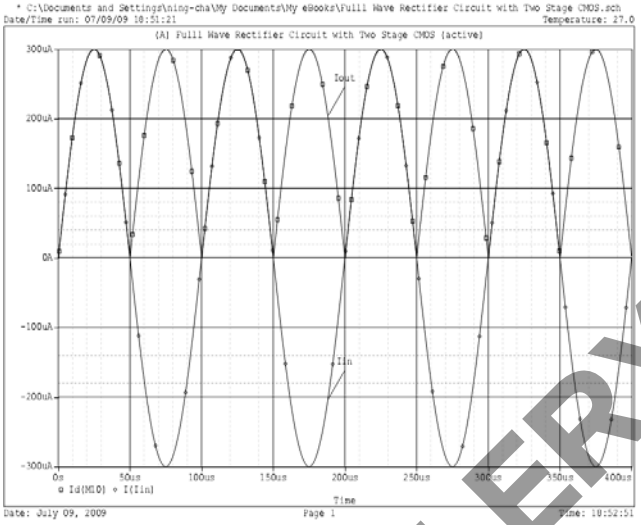

Fig. 6 Output signal is sending input size 300 μA_{p-p} and frequency 10 kHz

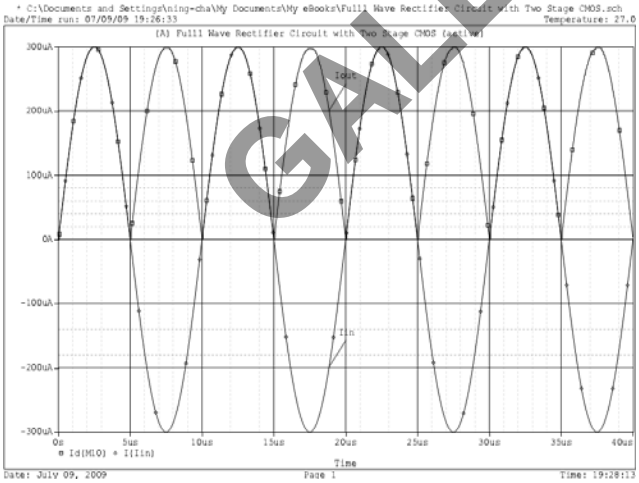

Fig. 7 Output signal is sending input size 300 μA_{p-p} and frequency 100 kHz

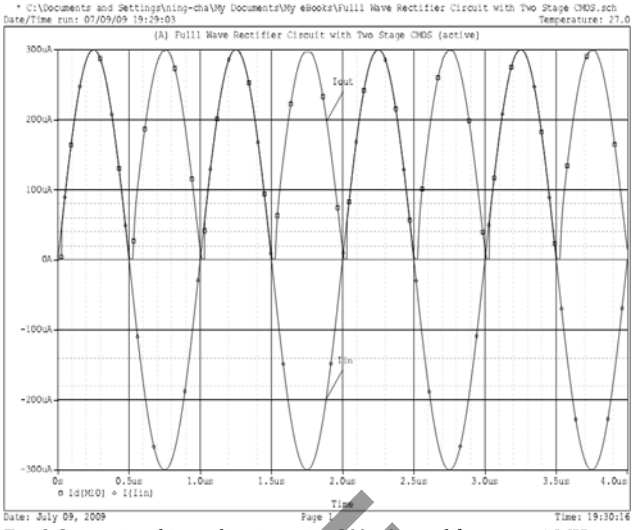

Fig. 8 Output signal is sending input size 300 μA_{p-p} and frequency 1 MHz

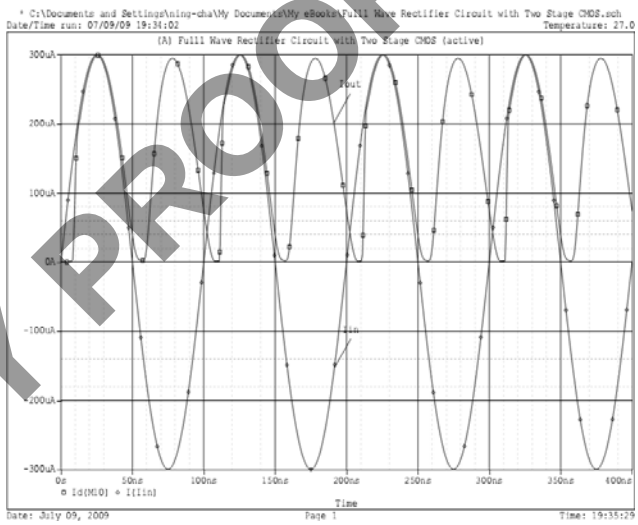

Fig. 9 Output signal is sending input size 300 μA_{p-p} and frequency 10 MHz

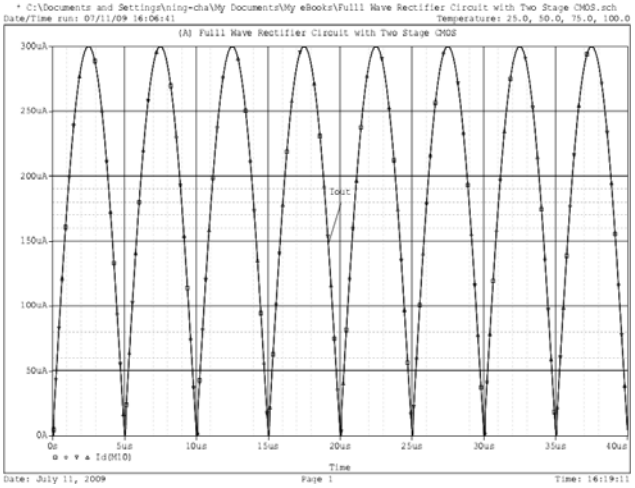

Fig. 10 Output signal is sending input size 300 μA_{p-p}, frequency 1 kHz and temperature 25^O, 50^O, 75^O and 100^O

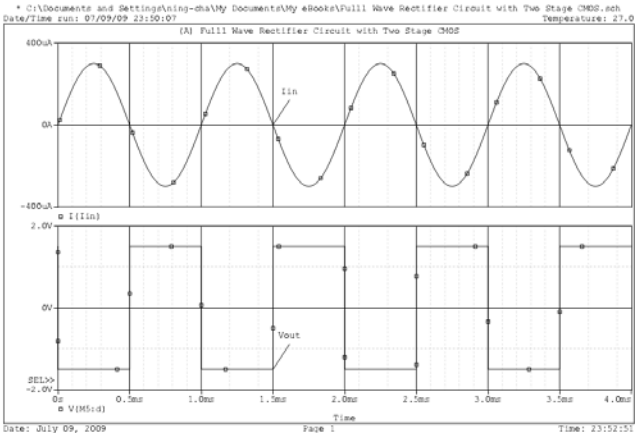

Fig. 11 Output square signal is sending input size 100 μA_{p-p} and frequency 1 kHz

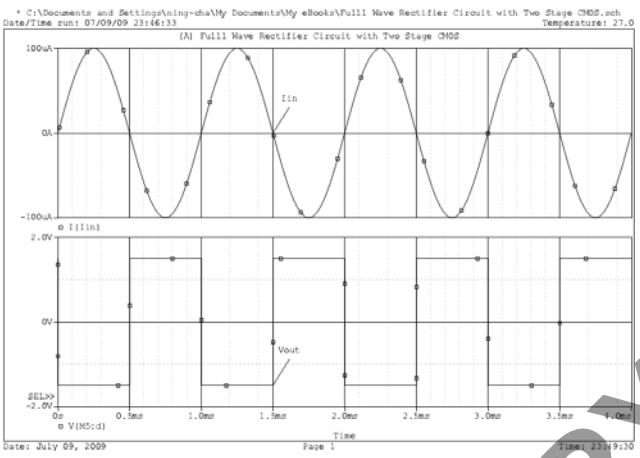

Fig. 12 Output square signal is sending input size 300 μA_{p-p} and frequency 1 kHz

IV. Conclusion

The presented circuit is compound a little of transistor, noncomplex working function, reduce wastage of current source, working at input current mode, output is full-wave signal current mode and square signal voltage responding in linear wide range by low voltage at ± 1.5 V. From the simulation is able to confirm the quality of working at maximum frequency 10 MHz, maximum output 300 μA_{p-p}, losses power 198 pW and insensitive from temperature, thus it suitable to development in integrated circuit and application in analog signal processing field.

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