High-Precision Multi-Wave Rectifier Circuit Operating in Low Voltage ±1.5 Volt Current Mode

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Abstract—This article is present high-precision multi-wave rectifier circuit operating in low voltage ±1.5 Volt current modes by CMOS technology 0.5 µm, receive input and give output in current mode, respond at high frequency period. The structure compound with high-speed current comparator circuit, current mirror circuit, and CMOS inverter circuit. PSpice program used for confirmation the performance of testing. The PSpice program shows operating of circuit is able to working at maximum input current 400 µA p-p, maximum frequency responding 200 MHz, high precision and low power losses, and non-precision zero crossing output signal.

Keywords-component; rectifier circuit, high-precision, low voltage, current mode.

I. INTRODUCTION

The rectifier circuit is very significance in analog signal processing for example, AC voltmeter, detector signal circuit, demodulate circuit etc. [1,2] then, always development all the time for example, full wave rectifier circuit operating in voltage mode [3], full wave rectifier circuit operating in diode and bipolar transistor [4], there are used voltage operating around 0.3 volt for Ge, and 0.6 volt for Si, then it has signal error in crossing zero, and in low input signal case the circuit doesn’t work, because of the characteristic of diode and transistor has limited. From the limitation has development to use another active device. In the past of century has a lot of the presentation in rectifier circuit in current mode [5], but the circuit still have complicated, dissipation of current source, it has little precision, responding in low frequency and operating in narrow range current, So, In this article would like to show a new choice of easier rectifier circuit, non-complicate in active devices connected, but still have the high performance of working by 0.5 µm CMOS technology, and the compound with high-speed current comparator circuit, current mirror circuit, and CMOS inverter circuit. Thus, it able to responding at high operating precision, working at high frequency, responding at high input current, high precision signal, high speed, low disputation power, and non-precision zero-crossing output signal.

II. BASIC PRINCIPLE AND DESIGNATION

A. Current Mirror Circuit

The current mirror circuit is compound input and output current circuit, it is the current source to amplifier circuit, because of low input resistance but high output resistance that is the characteristic of current source.

Figure 1. Basic current mirror circuit

From figure 1 M1 pin drain connected to M1 pin gate, which is the same of diode. When current source is stable I1 pass to M1 then voltage drop between pin gate and pin source of M1, thus voltage drop at M2 too, when M1 and M2 has same characteristic then I1=Iin as equation (1) and (2)

\[ I_D = \frac{1}{2} k_I \frac{W}{L} (V_g - V_i)^2 \]  

\[ I_O = I_1 \frac{(W/L)_1}{(W/L)_2} \]

B. Completely High-Precision Multi-Wave Rectifier Circuit Operating in Low Voltage ±1.5 Volt Current Mode

From the principle of current mirror circuit, when designing to rectifier circuit it able to show the structure of completely high-precision multi-wave rectifier circuit operating in low voltage ±1.5 Volt current mode as figure 2. The structure compound with high-speed current comparator circuit.
circuit, current mirror circuit, and CMOS inverter circuit. The functional working is when high-speed current comparator circuit received positive and negative input signal, then it is comparisons the current by sender negative signal to CM1, and sender positive signal to CM2, from the CM characteristics as equation (1) and (2), then will be has half-wave positive and negative phase output signal from CM1 and CM2.

From circuit in figure 3 when sender input current signal as equation (3) after that M3 currenting M4 non currently, output voltage sending back to common source circuit, then M1 currenting and Iin ≤ 0 is equation to M2 pin drain current, and it will mirrored current passing to M6. So, the new signal is half-wave negative phase output signal at M6 pin drain as equation (5).

In the opposite things, when input current signal as equation (4) will make M4 currenting and M3 non currenting, Vss voltage sender to input common source circuit, then M4 currenting Iin ≥ 0 it equation to M2 pin drain current and it passed to M6 pin drain, reflected current to M6, after that output signal will be positive phase at M5 pin drain as equation (6).

$$I_{DM5} = I_{DM6} = -I_{OF}$$  \tag{5}  

$$I_{DM8} = I_{DM9} = +I_{OF}$$  \tag{6}  

From the characteristic and principle of current mirror circuit, if send M2 pin drain signal (it has equation to M4 pin drain signal) pass to M11 pin drain, then reflected to M12 for combine with full-wave positive phase current signal at M10 pin drain and sent it to M13 pin drain then reflected current past to M14 after that output signal is full-wave negative phase at M14 pin drain as equation (7).

$$-I_{OF} = I_{DM14} = I_{DM10} + I_{DM12}$$  \tag{7}  

$$+I_{OF} = I_{DM15} = I_{DM17}$$  \tag{8}  

In the similarly thing, if sending signal at M15 pin drain to M16 pin drain, then reflected current to M17 that output signal is full-wave positive phase at M17 pin drain as equation (8), after that output signal is full-wave positive and negative phase input signal send to M1, M2, M3 and M4 then some part of signal at M3 and M4 pin drain has passed to M18 and M19 for establish square wave signal at pin drain as equation (9).

$$V_{out\text{square}} = V_{ss} \text{ then } I_{in} > 0 \text{ and } V_{out\text{square}} = V_{DD} \text{ then } I_{in} < 0$$  \tag{9}  

Figure 2. Diagram is show high-precision multi-wave rectifier circuit operating in low voltage ± 1.5 volt current mode.

While, if send CM1 output signal to CM1 and add it to CM2 output signal, then sending to CM4 input after that it will be full wave negative phase signal. In the similarly things, when CM4 output signal send to CM2 input by the characteristic and the principle of CM as equation (1) and (2), then it will be full-wave negative phase output signal at the same time positive and negative input signal passing to high-speed current comparator circuit, then some part of signal passing to input CMOS inverter circuit for establish square wave signal operation in voltage mode.

C. Circuit Description

From figure 2 rectifier circuit, if high-speed current comparator circuit, current mirror circuit, and CMOS inverter circuit put together and sitting MOS transistor operation at saturation region after that it will be completely high-precision multi-wave rectifier circuit operating in low voltage ± 1.5 volt current mode as figure 3.

$$I_{DM2} = 0 \text{ and } I_{DM1} = I_{in} \text{ When } I_{in} > 0$$  \tag{3}  

$$I_{DM1} = 0 \text{ and } I_{DM2} = I_{in} \text{ When } I_{in} < 0$$  \tag{4}
III. SIMULATION AND MEASUREMENT RESULT

The PSpice programs used for confirmation the performance of testing, so setting parameter 0.5 µm of MIETEC for PMOS transistor and NMOS V_{DD}=1.5 V V_{SS}=-1.5 V input current operating at range 0-400 µA_{pp}. Figure 4 shows half-wave output signal is sending input signal 400 µA_{pp} at frequency 10, 100, 200 MHz. Figure 5 shows full-wave negative phase output signal is sending input signal 400 µA_{pp} at frequency 10, 100, 200 MHz. Figure 6 shows full-wave positive phase output signal is sending input signal 400 µA_{pp} at frequency 10, 100, 200 MHz. Figure 7 shows square-wave output signal is sending input signal 400 µA_{pp} at frequency 10, 100, 200 MHz. Figure 8 shows the characteristic DC current at input signal 400 µA_{pp} and temperature 25°C, 50°C, 75°C and 100°C.

Figure 4. Half-wave output signal at input current 400 µA_{pp} at (a) frequency = 10 MHz, (b) frequency = 100 MHz and (c) frequency = 200 MHz

Figure 5. Full-wave negative phase output signal at input current 400 µA_{pp} at (a) frequency = 10 MHz, (b) frequency = 100 MHz and (c) frequency = 200 MHz
Figure 6. Full-wave positive phase output signal at input current 400 $\mu A_{p-p}$ at (a) frequency = 10 MHz, (b) frequency = 100 MHz and (c) frequency = 200 MHz.

Figure 7. Square-wave output signal at input current 400 $\mu A_{p-p}$ at (a) frequency = 10 MHz, (b) frequency = 100 MHz and (c) frequency = 200 MHz.
IV. CONCLUSION
The circuit has designed by high-speed current comparator circuit, current mirror circuit and CMOS Inverter circuit. Setting transistor operating at saturation region, so the circuit is able to high precision, but low voltage at +1.5 Volt. The simulation result is able to confirm the performance of working at maximum frequency 200 MHz, maximum output 400 µA_p-p, high precision, dissipation loss power and non-precision zero-crossing output signal, so it suitable to apply in analog signal processing.

APPENDIX
The parameters used in simulation are 0.5 µm CMOS Model obtained through MIETEC [10] as listed in Table I. For aspect ratio (W/L) of MOS transistors used are as follows: 1.5 µm/0.15 µm for all NMOS transistors; 1.5 µm/0.15 µm for all PMOS transistors.

| TABLE I. CMOS MODEL USED IN THE SIMULATION |
|--------------------------------------------|
| .MODEL CMOSN NMOS LEVEL = 3 TOX = 1.4E-8 NSUB = 1E17 |
| GAMMA = 0.5483559 PHI = 0.7 VTO = 0.7640855 DELTA = 3.0541177 |
| UO = 662.6984452 ETA = 3.162045E-6 THETA = 0.1013999 |
| KP = 1.259355E-4 VMAX = 1.42222E5 KAPPA = 0.3 RSH = 7.513418E-3 |
| NFS = 1E12 TPG = 1 XI = 3E-7 LD = 1E-13 WD = 2.334779E-7 |
| CGDO = 2.15E-10 CGSO = 2.15E-10 CGBO = 1E-10 CJ = 4.258447E-4 |
| PB = 0.9140376 MJ = 0.435903 CJSW = 3.147465E-10 MJSW = 0.1977689 |

| .MODEL CMOSP PMOS LEVEL = 3 TOX = 1.4E-8 NSUB = 1E17 |
| GAMMA = 0.6243261 PHI = 0.7 VTO = 0.9444011 DELTA = 0.1118368 |
| UO = 250 ETA = 0 THETA = 0.1633973 KP = 3.924644E-5 VMAX = 1E6 |
| KAPPA = 30.1015109 RSH = 33.9672594 NFS = 1E12 TPG = 1 XI = 2E-7 |
| LD = 5E-13 WD = 4.11531E-7 CGDO = 2.34E-10 CGSO = 2.34E-10 |
| CGBO = 1E-10 CJ = 7.285722E-4 PB = 0.96443 MJ = 0.5 |
| CJSW = 2.955161E-10 MJSW = 0.3184873 |

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