

**Switched Capacitor Based Low Pass Filter**Jinal A. Prajapati¹, Prof. Mehul L. Patel²¹PG Student Electronic & Communication, LCIT-Bhandu
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Abstract — Demand for Low Power, low voltage integrated circuits has rapidly grown due to the increasing importance of portable equipment in all market including telecommunication, computers and consumer electronics with smaller size. The low voltage need for ICs is also motivated by the new dip submicron CMOS technology scaling that required all transistors of smaller size. In recent years, a lot of researches were done on designing switched capacitor filters for low supply voltage. The primary reason is that SC filters achieve high filter accuracy with low distortion. SC filters that can operate with a single 1-V supply in standard CMOS Process have been designed using the switched Op- Amp technique without any clock voltage multiplier or low threshold voltage. Further, the implementation of passive elements like resistors, inductors, etc. on layout by implementing switch capacitor network. Recent advances in monolithic switched capacitor filters have significant impact on voice band communication systems where they found wide acceptance because of their low cost and high precision.

Keywords- SC (Switched Capacitor) , CMOS , Operational amplifier , Dummy Switch, Low pass filter.

I. INTRODUCTION

Until the early 1970s, analog signal-processing circuits used continuous time circuits consisting of resistors, capacitors, and op amps. Unfortunately, the absolute tolerances of resistors and capacitors available in standard CMOS technologies are not good enough to perform most analog signal-processing functions. In the early 1970s, analog sampled-data techniques were used to replace the resistors, resulting in circuits consisting of only MOSFET switches, capacitors, and op amps. These circuits are called switched capacitor circuits and have become a popular method of implementing analog signal-processing circuits in standard CMOS technologies. One of the important reasons for the success of switched capacitor circuits is that the accuracy of the signal-processing function is proportional to the accuracy of capacitor ratios. Switched Capacitor (SC) circuits have been widely used in the design of integrated circuits. They have become popular in integrated filters because they can be used to design filters with very high precision compared to normal RC-filters which often requires a tuning circuit to ensure proper operation. The frequency response of SC filters is ideally a function of capacitor ratios, whereas the frequency response of RC-filters is highly dependable on the operating temperature and the fabrication process. Capacitor ratios can be made very precise and almost independent of fabrication errors. In the VLSI system design, implementation of passive components such as resistors, inductors, etc on layout platform creates significant problem for the designer. Further it requires detail knowledge of the process with large layout area. To overcome these problems by using the switched capacitor techniques.

II. SWITCHED CAPACITOR CIRCUITS**2.1 Switched capacitor**

A switched capacitor is an electronic circuit element used for discrete time signal processing. It works by moving charges into and out of capacitors when switches are opened and closed. Usually, non-overlapping signals are used to control the switches, so that not all switches are closed simultaneously.

Filters implemented with these elements are termed "switched-capacitor filters," and depend only on the ratios between capacitances. This makes them much more suitable for use within integrated circuits, where accurately specified resistors and capacitors are not economical to construct.

2.2 Switched capacitor resistor

The simplest switched capacitor (SC) circuit is the switched capacitor resistor, made of one capacitor C and two switches S_1 and S_2 which connect the capacitor with a given frequency alternately to the input and output of the SC. Each switching cycle transfers a charge q from the input to the output at the switching frequency f . Recall that the charge q on a capacitor C with a voltage V between the plates is given by:

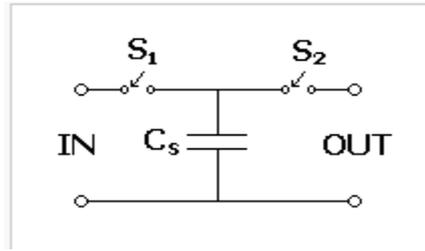


Fig.1 Switched Capacitor Resistor

$$q = C V \tag{2.1}$$

where V is the voltage across the capacitor. Therefore, when S_1 is closed while S_2 is open, the charge stored in the capacitor C_s is:

$$q_{IN} = C_s V_{IN}. \tag{2.2}$$

When S_2 is closed, some of that charge is transferred out of the capacitor, after which the charge that remains in capacitor C_s is:

$$q_{OUT} = C_s V_{OUT}. \tag{2.3}$$

Thus, the charge moved out of the capacitor to the output is:

$$q = q_{IN} - q_{OUT} = C_s (V_{IN} - V_{OUT}) \tag{2.4}$$

Because this charge q is transferred at a rate f , the rate of transfer of charge per unit time is:

$$I = qf. \tag{2.5}$$

Note that we use I , the symbol for electric current, for this quantity. This is to demonstrate that a continuous transfer of charge from one node to another is equivalent to a current. Substituting for q in the above, we have:

$$I = C_s (V_{IN} - V_{OUT}) f \tag{2.6}$$

Let V be the voltage across the SC from input to output. So:

$$V = V_{IN} - V_{OUT}. \tag{2.7}$$

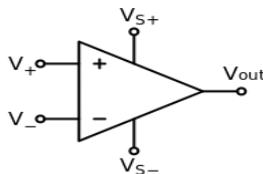
So the equivalent resistance R (i.e., the voltage–current relationship) is:

$$R = \frac{V}{I} = \frac{1}{C_s f}. \tag{2.8}$$

Thus, the SC behaves like a resistor whose value depends on capacitance C_s and switching frequency f .

2.3 Operational-Amplifier(Op-Amp)

The Op-Amp is a DC coupled high gain electronic voltage amplifier with differential input and usually single ended output. The Op-Amp is efficient and versatile device. The Op-Amp is used to designed for performing mathematical operations.



- V_+ : non-inverting input, V_- : inverting input, V_{out} : output
- V_{S+} : positive power supply, V_{S-} : negative power supply

The amplifier's differential inputs consist of a non-inverting input (+) with voltage V_+ and an inverting input (-) with voltage V_- ; ideally the op-amp amplifies only the difference in voltage between the two, which is called the *differential input voltage*. The output voltage of the op-amp V_{out} is given by the equation:

$$V_{out} = A_{OL} (V_+ - V_-)$$

Where, A_{OL} is the open-loop gain of the amplifier (the term "open-loop" refers to the absence of a feedback loop from the output to the input).

• **Characteristics of Op-Amp**

Infinite Open-Loop Voltage Gain, Infinite Slew rate , Input Offset Voltage , Bandwidth , Infinite Common Mode Rejection Ratio , Infinite Input Impedance.

• **Types of Op-Amps:**

- (1) Two Stage Operational Amplifier
- (2) Folded Cascode Amplifier
- (3) Telescopic Cascode Amplifier (4)
- (4) Gain-Boosted Amplifier

2.4 Two Stage Operational Amplifier

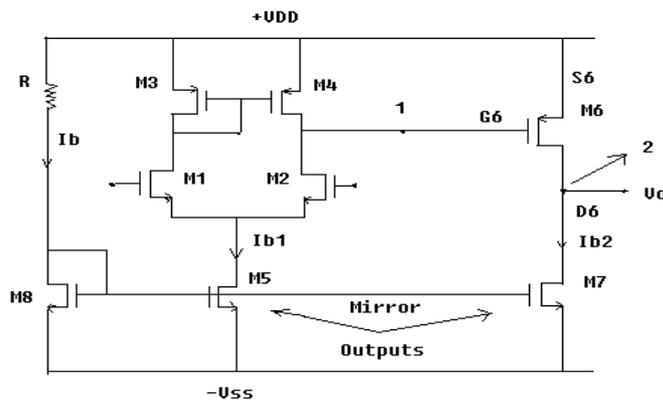


Fig.2 Two Stage Operational Amplifier

Note that the two inputs $V(+)$ and $V(-)$ of the op-amp are the gates of the transistors M2 and M1, respectively.

- 1) We first note that the resistor R is the only passive element in this two-stage Op-amp circuit: the function of R is biasing, i.e. setting up a constant dc bias current I_b . This current is then replicated at various other locations for biasing other amplifier stages through current mirrors. In the op-amp circuit of Fig.3, the bias current I_b is the input current for the current mirror with two outputs: M5 and M7.
- 2) M8, M5, M7 combined together form current mirrors, distributing I_b to the rest circuit. Here, the input side of the mirror is M8. M5 and M7 are the two outputs of the mirror. Since M8, M5, M7 are sharing the same gate-source voltage, the driver source M8 can replicate the bias current I_b as needed for biasing throughout the rest of the circuit. Different aspect ratios W/L of the mirror output transistors with respect to the input transistor can be used to scale the bias currents as needed (more about this in the quantitative analysis later).
- 3) M1 and M2 form the input differential pair, which is also the input of the first gain stage. I_{b1} is the biasing current for the differential pair M1 and M2. This bias current is provided by M5, which acts as a DC current source.
- 4) M3 and M4 form a current mirror that acts as the active load for M1 and M2.
- 5) M6 is the common source gain stage and it is also the second gain stage, note that the input of this gain stage is at node 1 which is the gate of M6, the output of this stage is at node 2 which is the drain of M6 and M6 is biased from node 1. The source of M6 is directly connected to the DC supply voltage VDD and hence no signal component.
- 6) M7 is the active load for M6.

2.5 Switched Capacitor Filter

The SC Filter is technique based on the realization that a capacitor switched between two circuit nodes equivalent to a resistor connecting the two nodes.

Low Pass Filter : A low-pass filter is a filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency.

Two Types Of Low Pass Filter: Active Low Pass Filter, Passive Low Pass Filter

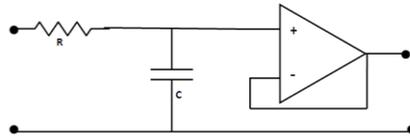


Fig.3 Low Pass Filter

- **Advantages of Switched Capacitor circuits**
 - Compatibility with CMOS technology
 - Good accuracy of time constants
 - Good voltage linearity
 - Good temperature characteristics
- **Disadvantages of Switched Capacitor circuits**
 - Non linear Ron
 - Charge Sharing Effect
 - Clock Feed Through Effect.

III. SIMULATION RESULTS

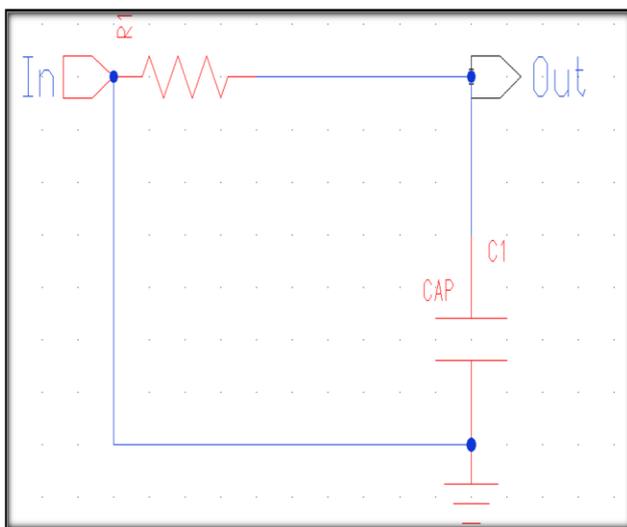


Fig.4 Schematic of simple RC circuit

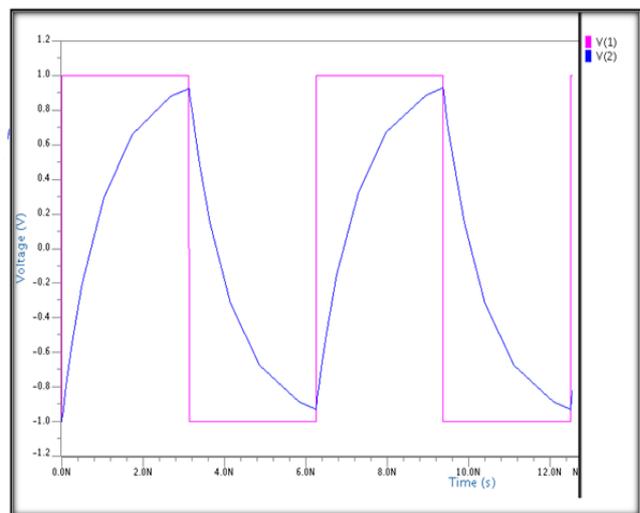


Fig.5 Simulation result of RC circuit

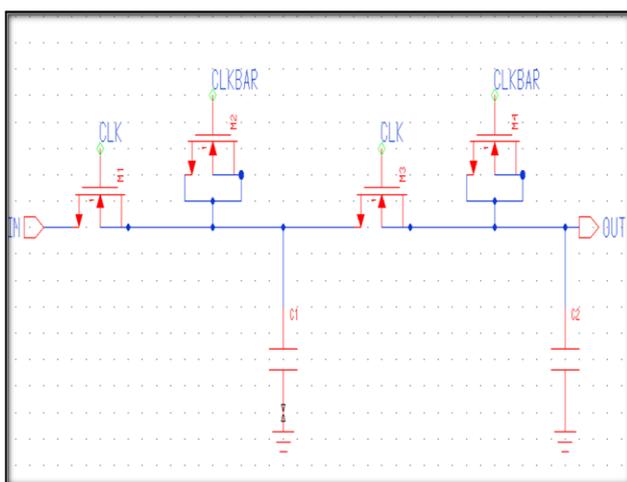


Fig.6 Schematic of RC circuit by using Dummy S witch

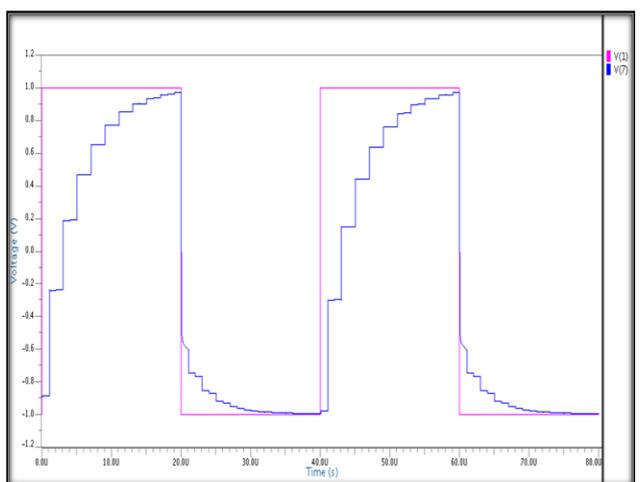


Fig.7 Simulation Result of RC circuit by using Dummy Switch

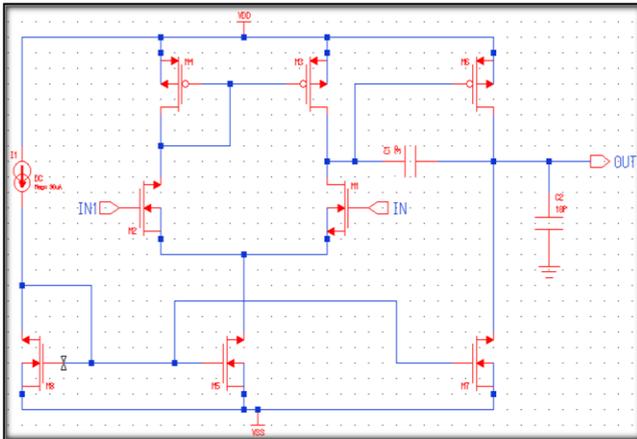


Fig.8 Schematic of Two stage Op-Amp

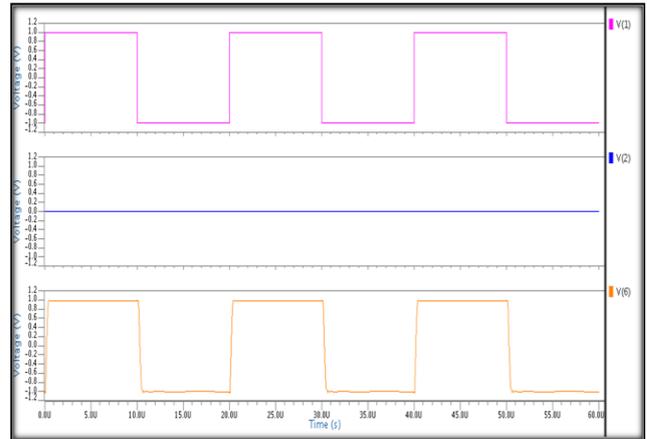


Fig.9 Simulation result of Two Stage Op-Amp

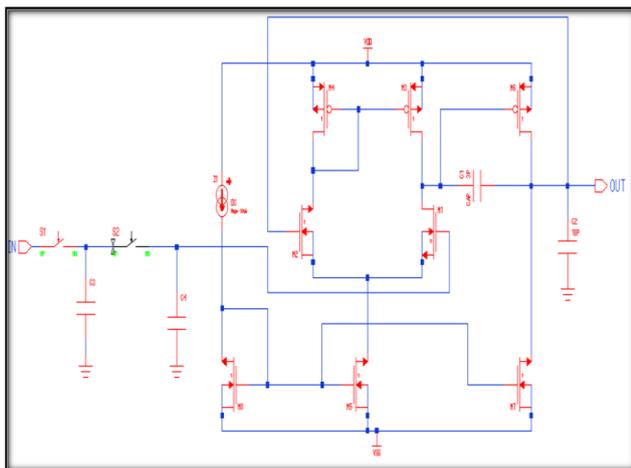


Fig.10 Schematic of Switched Capacitor –RC Filter

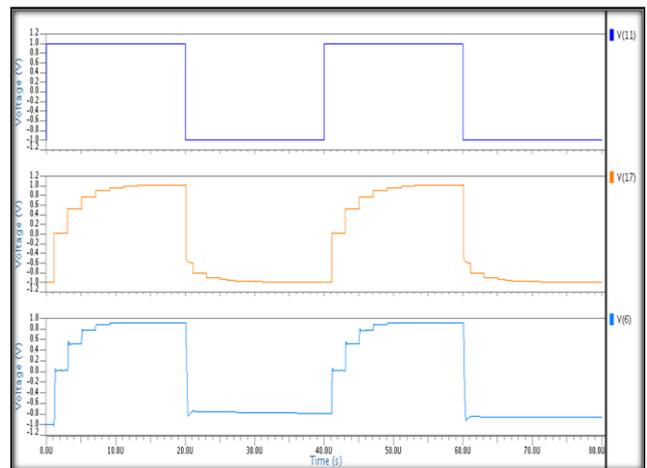


Fig.11 Simulation Result of Switched Capacitor-RC filter

Comparison Table:

References/ Parameters	[15]	This work
Year	2013	2015
Technology	180nm	180nm
Order	1 st RC	1 st RC
Supply Voltage(V)	1.8v	1.8v
Cut Off Frequency	1KHZ	1.5KHZ
Power Dissipation(mw)	0.39	0.26

References/ Parameters	[7]	This work
Year	2013	2015
Technology	180nm	180nm
Order	1 st RC	1 st RC
Supply Voltage(V)	1.8v	1.8v
Cut Off Frequency	1KHZ	1.5KHZ
Power Dissipation(mw)	0.01	0.0048

IV. CONCLUSION

The present work is carried out in 0.18 μm CMOS process at 1 V supply. The result shows improvement of switched capacitor filter. The designed Op-Amp achieved better result as compared to the reference paper carried at 0.18 μm technology in mentor graphic tool. Non-overlapping clock signals and different kinds of switches were adopted to decrease the effect of charge injection and clock feed through. The switched capacitor filter used for audio application, radio application, biomedical application etc.

V. REFERENCES

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