THE SWITCHED CAPACITOR FILTER IS REVOLUTIONIZING LOW FREQUENCY FILTERING

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ABSTRACT

Technology has at last overcome many obstacles which previously prevented the realization of a totally integrated filter. The concept of replacing each resistor in a conventional active filter by a capacitor and a pair of MOS switches is revolutionizing the field of low frequency filters. This paper describes two different families of integrated switched capacitor filters. These filter building blocks offer improved flexibility due to their modular nature and ease of tuning.

INTRODUCTION

The revolutionary shot "heard 'round the world" can be best illustrated by the simple circuit of Figure 1 (a). Hosticka, et al [1], have pointed out the equivalence of this circuit to the resistor of Figure 1 (b) --- provided that V_1 and V_2 are voltage sources or ground connections. They further point out the feasibility of implementing the switched capacitor by the circuit of Figure 1 (c), where ϕ and $\bar{\phi}$ represent nonoverlapping clocks.

The fundamental switched capacitor circuit described above forms the basic component in the differential switched integrator depicted in Figure 2. The advantages of this configuration (and of a number of related topologies) were pointed out by Broderson, et al [2], and by Allstot, et al [3]. The principle strength of the circuit is its freedom from parasitic capacitance effects in an MOS implementation. In addition, it shares the advantage of all switched capacitor circuits: Its gain is precisely given by $f_s(Cu/C)$, where f_s is the switching rate.

The building block filters to be subsequently described rely on the switched integrator to achieve precision performance.

SWITCHED CAPACITOR LEAPFROG FILTERS

The classical LC ladder filter has extremely low sensitivities to component variations. This fact has prompted the development of active ladder topologies, which have recently been implemented with switched capacitor integrators [4]. A new line of filters using this technique has been recently announced. (See Figures 3a through 3c, which indicate the general filter format and a typical frequency response.) This product line consists of the single chip realizations of an ANSI Class III full octave bandpass filter (R5606), two ANSI Class III half octave bandpass filters (R5605), and three ANSI Class III one-third octave bandpass filters (R5604). All filters are synthesized as six pole Chebyshevs. The center frequency of each is tunable by varying the clock rate, the dynamic range is 80 dB, and the distortion is less than 0.1 percent.

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Insertion loss is less than ±0.2dB.

Forthcoming additions to this product line will consist of a seven pole elliptic low-pass, a five pole high-pass, and a four pole notch. Custom designs are also available.

PROGRAMMABLE QUAD ARRAY

The latest addition to previous switched capacitor filter products is a programmable array of four state variable filters on a single chip, as illustrated in Figure 4. Each filter section has provisions for a bandpass input, as well as for a low-pass input. The low-pass and bandpass outputs of each filter are derivable from a single pin. On-chip logic accepts nine bits of data and dynamically programs each filter independently to one of thirty two preselected frequencies in an octave and to one of thirty two Q values between 0.577 and 50. In addition, the logic allows selection of any one of the contiguous seven octaves of frequency extending below half the clock rate.

This filter block is unique in its capability to dynamically alter its characteristics under the nearly real time control of its programming data bus. This permits the economic fabrication of time varying systems such as formant speech synthesizers and vocoders. An added dimension of flexibility is offered by its capacity to have its programmed parameters "burned in" by means of fusible links. Custom devices are available, too, with values of Q and tuning frequency prescribed by the customer.

The basic filter unit shown in Figure 5 is similar to the configuration proposed by Allstot, Brodersen, and Gray [5]. It consists of two switched capacitor integrators and an analog summer in a state variable structure. The two integrator feedback capacitors are programmed to the tuning frequency, and the summer feedback capacitor is adjusted to the desired Q. The C_G/C_S ratio is set to yield a peak gain of unity.

SUMMARY

The switched capacitor concept has indeed revolutionized the field of low frequency filtering. Deemed impossible only a short while ago, the filter blocks described above offer the modular flexibility of the long awaited "filter on a chip."

REFERENCES

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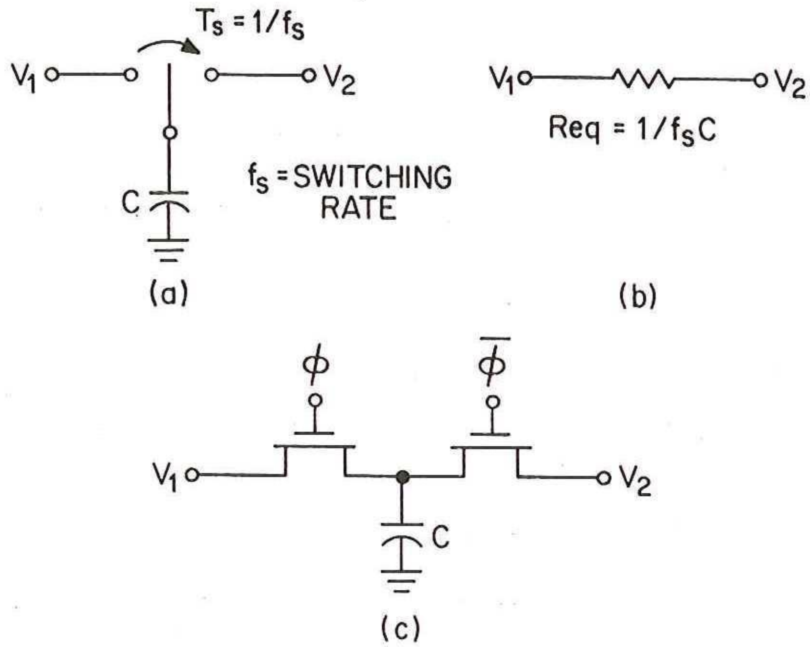


Figure 1.

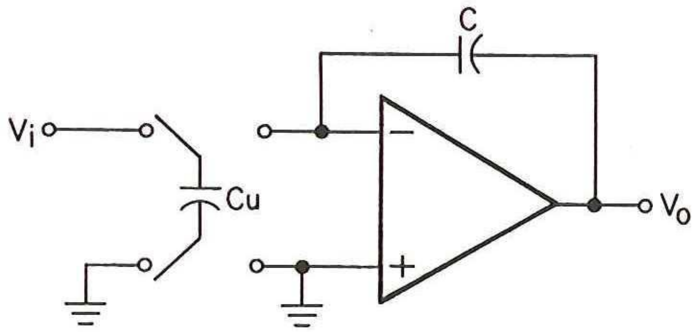
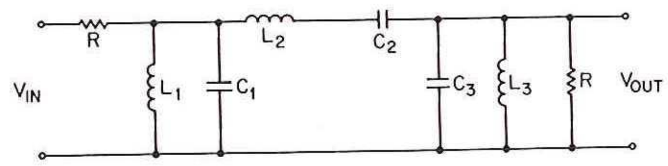


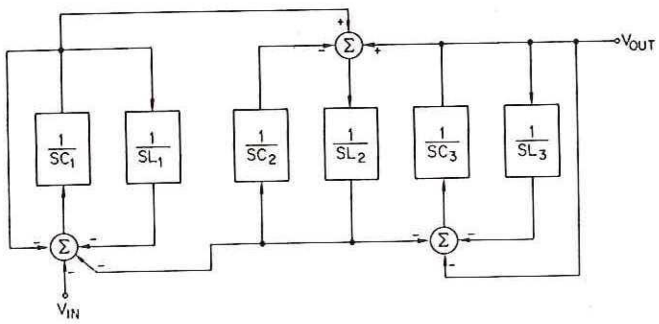
Figure 2.

(a)



L-C circuit equivalent to the switched capacitor filters.

(b)



Filter realization - Active leap-frog technique.

(c)

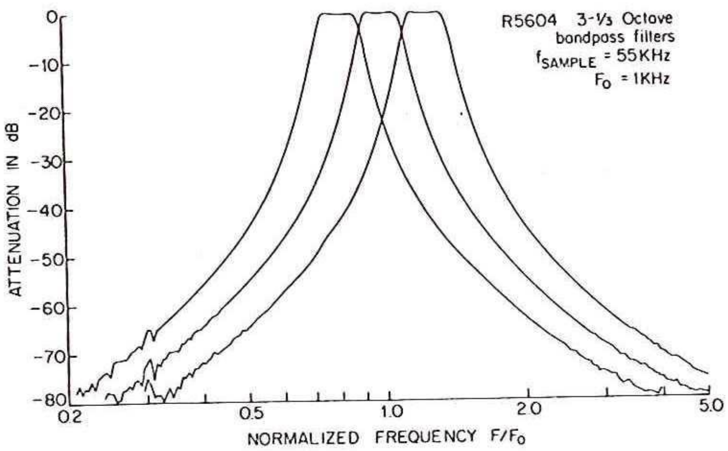


Figure 3.

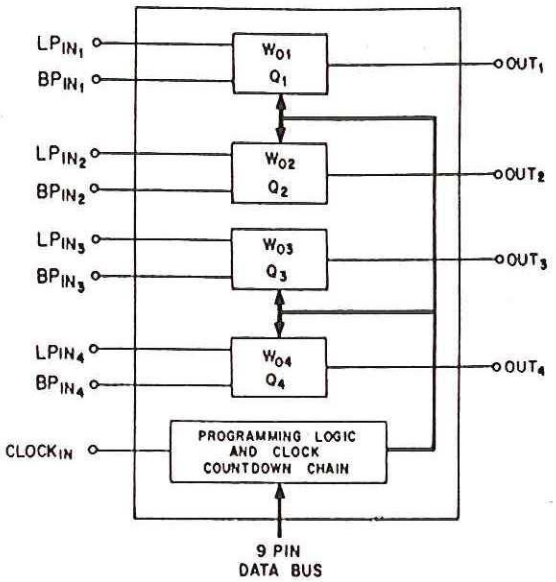


Figure 4.

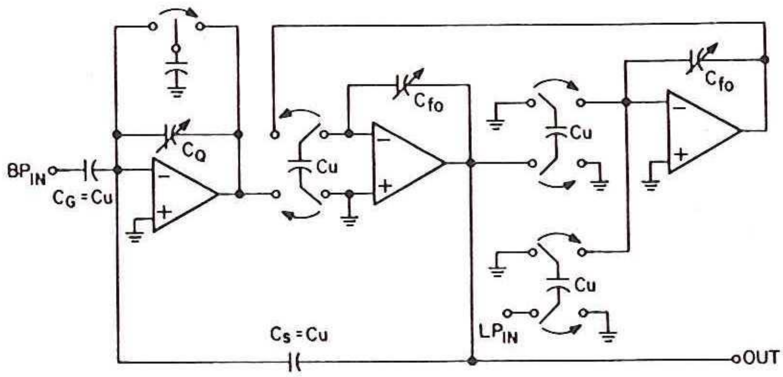


Figure 5.