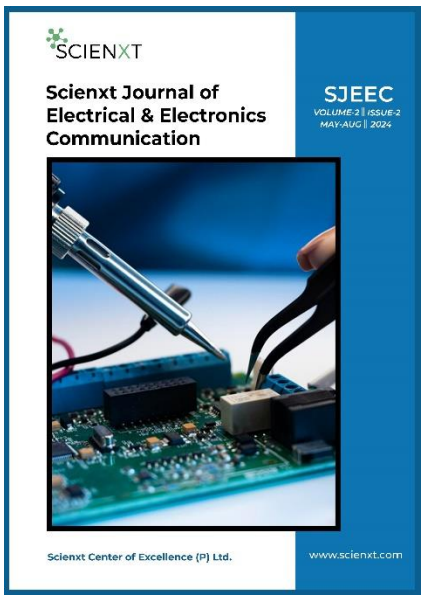

Scienxt Journal of Electrical & Electronics Communication
Volume-2 || Issue-2 || May-Aug || Year-2024 || pp. 1-10

Digitally programmable floating impedance multiplier using DVCC

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Abstract:

A novel digitally programmable floating impedance multiplier is presented. It is realized using differential voltage current conveyor and a digital control module. Digitally programmable floating impedance multipliers can provide digital control to floating impedance functions such as, resistor, capacitor, and inductor without quantizing the signal. The technique used is simple, versatile as well as compatible for microminiaturization in contemporary IC technologies. The simulation results on digitally programmable floating impedance multiplier verify the theory.

Keywords:

Differential voltage; current conveyors; multiplier.

1. Introduction:

In recent years the second generation current conveyors (CCIIs) have proved to be functionally flexible and versatile building block. Considering the advantages of current conveyor circuits such as inherent wider bandwidth and wider dynamic range, there are several applications based on current conveyors. Conventional CCII cannot be used in applications demanding differential inputs. Since, Differential Voltage Current Conveyor (DVCC) is versatile and its implementation is very easy, it can be used to implement different kinds of signal processing circuits.

In this paper a novel digitally programmable floating impedance multiplier (DPFIM) using differential voltage current conveyor is presented. To demonstrate the versatility of the DPFIM, digitally controlled floating resistor(R), capacitor(C) and inductor are realized. The circuit consists of a DVCC, CCII, a digital control module (DCM), which is realized using R-2R ladder and an n-bit switching array, along with impedance under control. The realized DPFIM is simulated for positive and negative resistors using PSPICE.

2. Digital control module:

Digital module is a reliable and efficient scheme that facilitates programmability. A digitally controlled parameters can easily be reconfigured by merely changing the control word. Finer resolution capability can also be extended by increasing the number of bits of the control word in digital module. The basic digital control modules are considered in the following sections.

2.1. Single stage digital control module:

The realization of the single stage digital control module is shown in Fig. 1(a), which uses R-2R ladder and analog switching array.[10]

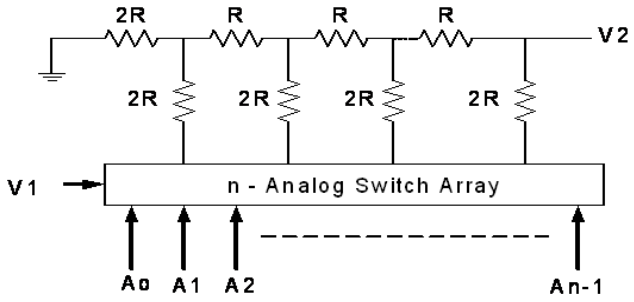

Figure. 1(a): Single stage digital control module

The output voltage V_2 can be expressed as

$$V_2 = \frac{V_{REF}}{2^n}\left(A_0 2^0 + A_1 2^1 + \cdots + A_{n-1} 2^{n-1}\right) \quad (1)$$

Where, A0, $A_{1...}$ A_{n-1} are the bit values of the n-bit digital control word (N). Equation (1) can also be expressed a

$$V_2 = K_1 V_{REF} \frac{N}{2^n} V_1 \quad (2)$$

where , $K = N/2^n$.

The CMOS implementation of Figure 1(a) along with the control switches is given in Figure 1(b). The W/L ratios of the MOSFETs are adjusted to meet the required resistance ratios. Fig. 1(b) now onwards shall be expressed as the as single stage digital control module-K as shown in Fig. 1(c). The channel resistance of the MOSFETs M_{13} and M_{14} can be included with the resistance M_{12} of the R-2R ladder to reduce the parasitic effects.

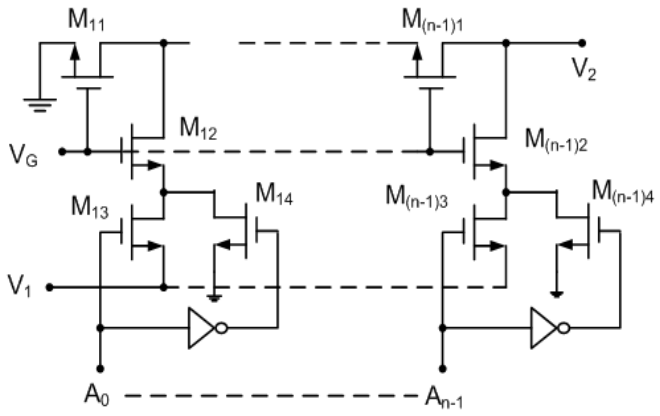

Figure. 1(b): CMOS implementation of Single stage digital control module

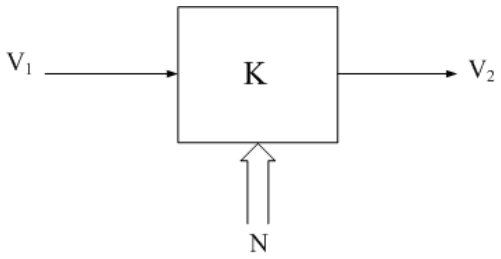

Figure. 1(c): Single stage digital control module symbol

2.2. Double stage digital control module:

If two stages of the single stage digital control module with same control word are cascaded through a voltage buffer as shown in Figure 1(d). The transfer gain of the double stage module can be expressed as

$$\frac{V_2}{V_1} = K^2 = \left(\frac{N}{2^n}\right)^2 \qquad (3)$$

where, $K^2 = K\,K = (N/2^n)^2$.

This module hence-forth shall be referred as the double stage digital control module-K^2. It is obvious from equation (2) and (3) that the transfer gain of the single stage and double stage control modules are programmable through digital control word (N).

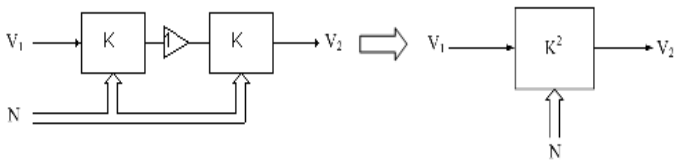

Figure. 1(d): Double stage digital control module symbol

3. Circuit realization:

The proposed DPFIM is realized using a DVCC, CCII and a DCM is given in Fig. 2(a).

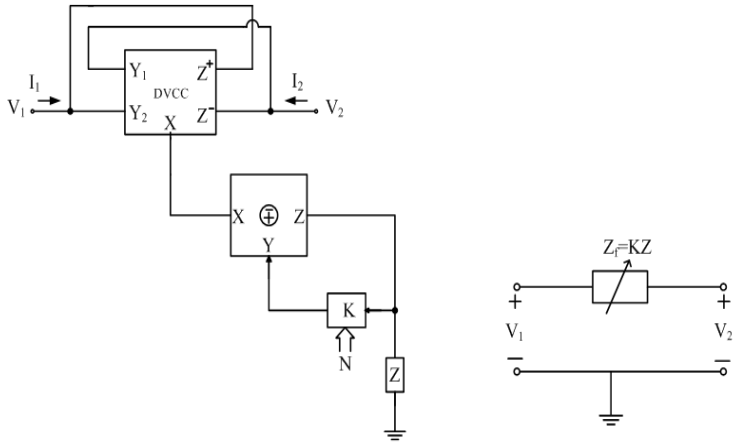

Figure. 2(a): DPFIM and Figure 2(b): Realized DPFIM between $V_1$and V_2

The routine analysis of Figure 2(a) yields its floating impedance function with single stage digital control module-K as

$$Z_f = \pm\frac{N}{2^n}Z \qquad (4)$$

And with double stage digital control module-K^2 as

$$Z_f = \pm\left(\frac{N}{2^n}\right)^2 Z \qquad (5)$$

It is to be noted that for negative CCII the realized impedance Z_f is positive while for positive CCII, a negative Z_f is realized. Thus, from equation (4) it is clear that the floating impedance function Z_f is directly controllable through the control word N. Equation (5) shows that the floating impedance function Z_f is directly controllable through the control word N^2.

3.1. Case 1: Digitally programmable floating resistor:

If Z in Fig. 2(a) is assumed as resistor i.e. Z=R equation (4)

Reduces

$$Z_f = R_f \qquad 6(a)$$

With module-K

$$R_f = \pm\frac{N}{2^n}R \qquad 6(b)$$

With module-K^2

$$R_f = \pm\left(\frac{N}{2^n}\right)^2 R \qquad 6(c)$$

It is can be seen from equation (6) that the realized floating resistance R_f is programmable through digital control word N.

3.2. Case 2: Digitally programmable floating capacitor:

If Z in Fig. 2(a) is assumed as capacitor i.e. Z = 1/sC, equation (4) reduces to

$$Z_f = \frac{1}{sC_f} \qquad 7(a)$$

With module-K

$$C_f = \pm\frac{2^n}{N}C \qquad 7(b)$$

With module-K^2

$$C_f = \pm\left(\frac{2^n}{N}\right)^2 C \qquad 7(c)$$

Thus it is obvious from equation (7) that through digital control word (N), the realized effective floating capacitance (C_e) can be controlled inversely through N or N^2.

3.3. Case 3: Digitally programmable floating inductor:

In Fig. 2(a), if Z is considered as an inductor i.e. Z = sL, equation 4 reduces to

$Z_f = s\,L_e$ 8(a)

With module-K

$$L_f = \pm\left(\frac{N}{2^n}\right)L \qquad 8(b)$$

With module-K^2

$$L_f = \pm\left(\frac{N}{2^r}\right)^2 L \qquad 8(c)$$

Thus by controlling the digital control word N the realized effective floating inductance L_f is programmable either through N or N^2.

4. Simulation results:

The practical validity of the proposed digitally programmable Floating impedance multiplier of Fig. 2(a) was designed and verified using PSPICE for $\pm R_f$. The SPICE model of CCII and DVCC available in the technical literature and respectively, were used. The digital control module of Fig. 1 was implemented for 8-bit. The voltage-current plot obtained from PSPICE simulation for the digitally programmable floating $\pm R_f$ of Fig. 2(a) with the terminating grounded resistor R=100KΩ for various N is shown in Fig. 3(a). Also, by varying the digital control word (N) the floating resistance ($\pm R_f$) is controlled and the results obtained are shown in Fig. 3(b). The Fig. 3 clearly exhibits the responses in close conformity with the design.

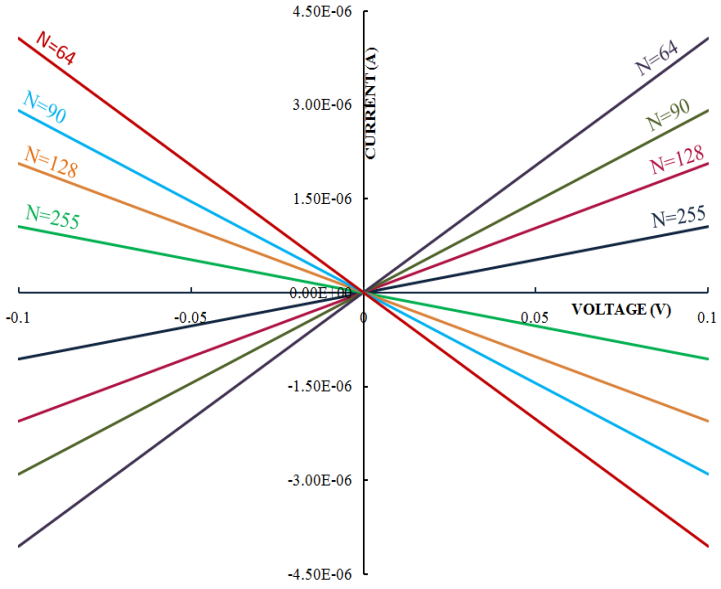

Figure. 3(a): V-I plot for a digitally programmable floating resistors (±R_f) for different digital control word N, of Figure 2(a)

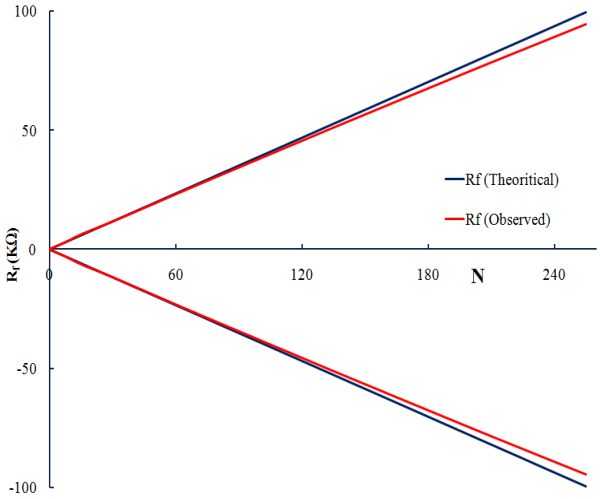

Figure. 3(b): Variation of ±R_f with control word N for digitally programmable floating impedance multiplier of Figure 2(a)

5. Conclusion:

A digitally programmable floating impedance multiplier using DVCC is presented. This impedance multiplier realizes digitally controlled positive as well as negative floating impedance with grounded elements. The technique used is simple versatile as well as compatible in contemporary IC technologies. It is to be noted that the digitally programmable

Circuit parameters in all the realizations are reconfigurable. The resolution of the digital control can be improved by using larger number of bits in the digital control module. The realized circuit was designed and simulated for $\pm R_f$ using PSPICE. The results thus obtained verify the theory.

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