DIGITALLY CONTROLLED LINEAR FOUR-PORT NETWORK

Zdeněk Kolka, Václav Michálek
Institute of Radioelectronics
Technical University Brno
Czech Republic

Abstract

The paper deals with the design of a universal linear multiport. The circuit is based on digitally controlled multiple voltage-controlled voltage sources (MVCVSs). The main advantages of this control are accuracy, invariability, and very small area requirements. The whole system is simply connected to a PC via its parallel port. This multiport can generally be used as a building block for any model of a nonlinear dynamic system, namely for the piecewise-linear (PWL) model in both explicit and implicit forms.

Keywords:

circuit modelling, linear transformation blocks, digital control

1. Introduction

The modern approach to nonlinear dynamic system consists in decomposing of the whole system into several parts, so called functional blocks. In the most frequent case they are the linear transformation block and the loading blocks which can be either nonlinear (resistive) or linear (capacitive and inductive, i.e. innertial). The advantage of such an arrangement is its universality in the realization of a given system. Unlike the classical synthesis this approach is entirely based on mathematical procedures.

The linear block is assumed to be resistive and defined by a certain matrix description. This presumption, however, cannot generally be fulfilled because the real circuit can contain even active devices whose parameters are practically frequency dependent. As the synthesis has not a unique solution certain additional criteria can be chosen for the circuit optimization. A universal linear two-port utilizing digitally controlled summing voltage amplifiers has been designed for the verification of the new synthesis procedures.

2. Basic Configuration

Let us assume the linear n-port to be described by the implicit matrix form

$$Mv + Ni + Q = 0 \qquad (1)$$

where v and i represent the port variables

$$v = [v_1, ..., v_n] \quad \text{and} \quad i = [i_1, ..., i_n]^T,$$

respectively. Matrix Q represents that the circuit contains even independent sources.

As the basic active blocks ideal summing voltage amplifiers (multiple voltage-controlled voltage sources - MVCVSs) are used [1]. They can simply be realized by voltage-mode operational amplifiers and a resistive network. In the symbolic circuit diagram (Fig.1) the double-line symbols represent sets of network elements (linear resistors and MVCVSs). The double and full lines represent the zero-current and nonzero-current connections, respectively.
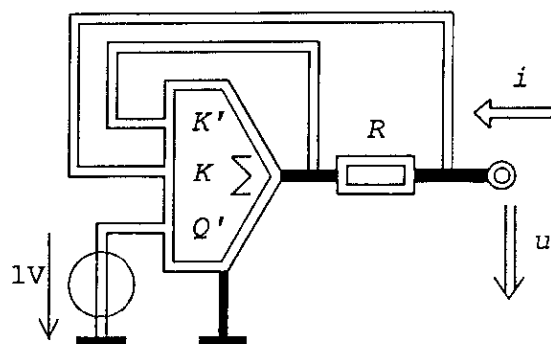

Fig. 1
Symbolic circuit diagram.

The gains of the MVCVSs are

$$K = T(M + NR^{-1}) \qquad (2)$$

$$K' = 1 - TNR^{-1} \qquad (3)$$

$$Q' = TQ \qquad (4)$$

where $K, K' \in R^{n \times n}$, $Q \in R^n$, and 1 is the unity matrix.

Matrix R is the resistance diagonal matrix of the sensing resistors in the individual ports

$$R = diag\{R_1, ..., R_n\} \, .$$

Usually these resistors are identical. Each row of matrices K and K' represents a set of the corresponding partial MVCVS gains. The individual elements of matrix Q' represent the corresponding dc input voltage. Auxiliary transformation matrix $T \in R^{n \times n}$ is an arbitrary regular square matrix by which eqn (1) is multiplied from the left. This invariant operation represents infinite number of possible solutions in synthesis, i.e. by a suitable choice of matrix T the dynamic behaviour of the block can be optimized without changing its dc parameters [2].

3. Practical realization

3.1 Basic considerations

For a start a four-port network ($n=4$) is chosen to realize the majority of basic important cases. Regarding the universality required all the gains (K, K', Q') must be adjustable independently. Each element of these matrices is realized by one D/A converter so that their total number is ($2n^2 + n$), i.e. 36. The block diagram of the whole circuit is in Fig.2.
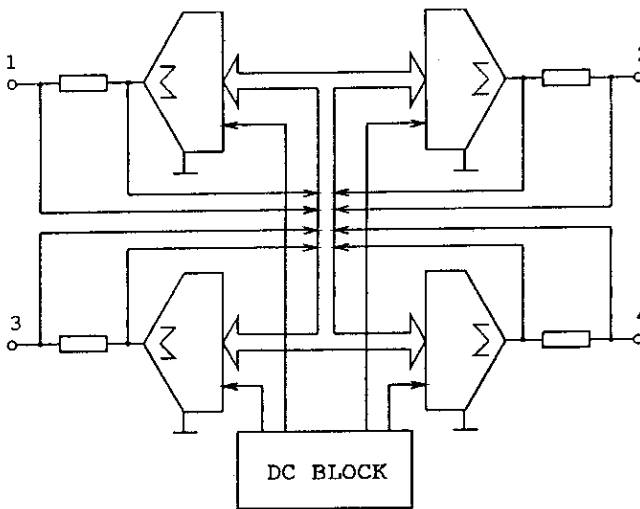

Fig. 2
Block diagram of the circuit realized.

Unlike the general configuration in Fig.1 each MVCVS has fixed gain for each dc input while the values of dc sources are adjusted. Such a modification is given by the components available.

3.2 Digitally controlled MVCVS

The practically realized circuit contains four identical MVCVSs each of them having ($2n+1$), i.e. 9 inputs. For the gain control multiplying 8-bit 8-channel D/A converter DAC-8840 is used. It can operate in all four quadrants. The gain of each channel can be independently adjusted in interval $+1,-1$. After the converter a normal configuration of MVCVS having fixed gains (k) and separate dc port is

connected. The principal diagram of a single MVCVS is shown in Fig.3 and its complete practical configuration in Fig.5.
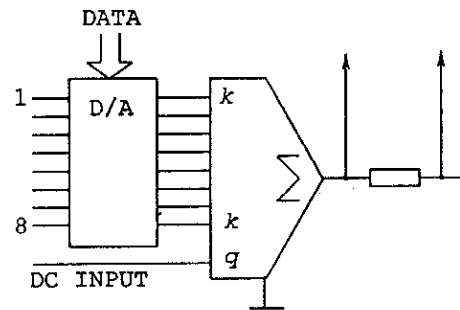

Fig. 3
Principal diagram of single MVCVS.

OA1 operates as a summing inverter. The input voltage range of converter DAC-8840 is +3,-3 volts, supply voltage is 12 volts, so that it is necessary to match the voltage levels. For this purpose OA2 and OA3 are used. They also act as separating amplifiers as the converter has a relatively low input resistance (>3 kiloohms). The voltage reference diodes serve as a protection of the converter inputs in case of a breakdown of an operational amplifier. The choice of the resistances depends on the required range of gains K and K'. In our case the range +4,-4 is chosen with respect to the number of levels for 8-bit conversion.

3.3 Block of DC Sources

The dc voltages needed for summing amplifiers are generated by four independent digitally-controlled voltage sources. Used converter MAX 528 has 8 bits and 8 channels. Two channels are used for each source, one for the positive and the other for the negative range. In such a way the width of conversion can reach 9 bits. This block also serves for the equalisation of the parasitic voltage offsets in the inputs of summing amplifiers. All the corrections can be controlled by a programme without using control elements. In Fig.4 only one section is shown.
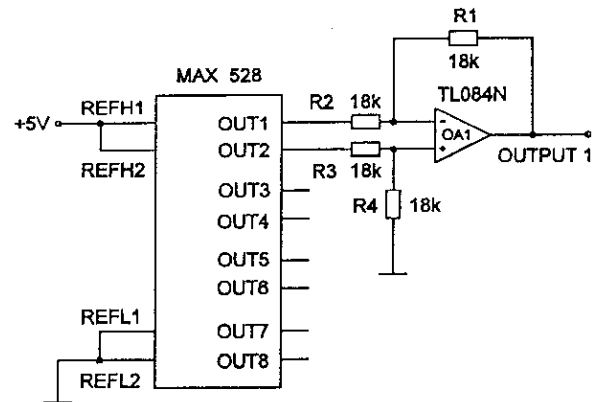

Fig. 4
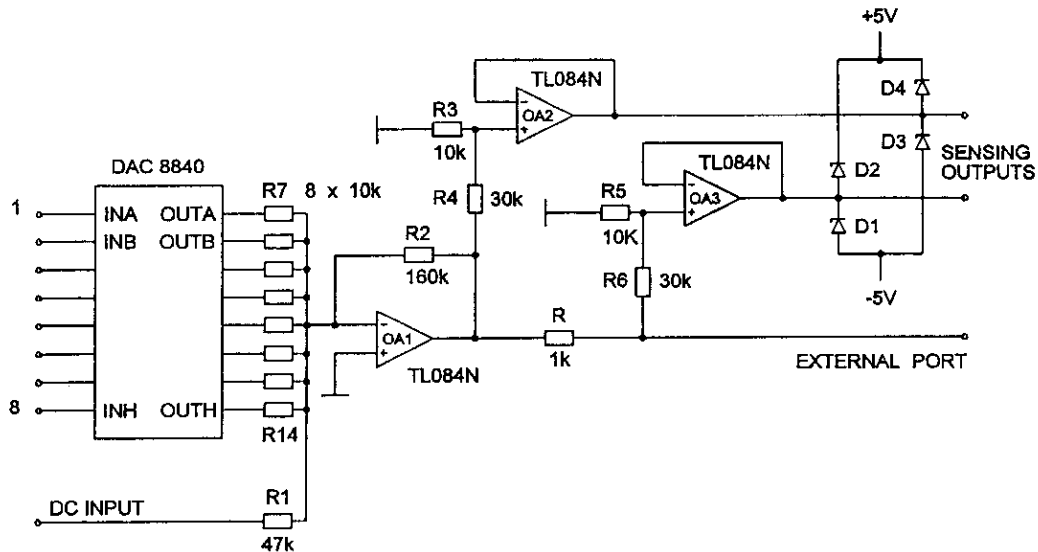Digitally controlled dc source.

Fig. 5
Complete practical configuration of single MVCVS.

3.4 Digital Part

Both DAC-8840 and MAX 528 are controlled by a serial bus. In this case the transfer speed is not important because the programming is executed before the circuit operation starts. The converters used can be also connected in a chain, which minimizes the number of connections in the system. The function is evident from Fig.6. The partial circuits form a shift register tacted by the CLK signal. The LOAD signal writes the content of this register into the internal memories of the converters. The serial bus is connected to the PC parallel port. The advantage of this arrangement is its simplicity and a very easy operation.
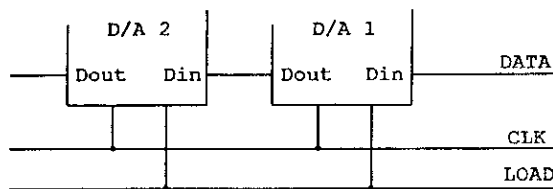

Fig. 6
Principle of digital control.

4. Conclusion

A new configuration of the linear four-port network as a universal building block for circuit synthesis has been developed and practically realized. A digital control is utilized for setting up its individual parameters by PC to obtain higher accuracy and invariability. The circuit is assumed namely for the modelling of nonconventional behaviour of nonlinear dynamic system.

5. References

[1] POSPÍŠIL,J.: Rozklady matic a některé jejich aplikace v teorii obvodů (Matrix decompositions and some their applications in circuit theory). Knižnice oborových a vědeckých spisů VUT v Brně, vol. A-31, 1986.

[2] KOLKA,Z.: Syntéza realizovatelných PWL obvodů metodou transformace jejich statických modelů (Synthesis of realizable PWL circuits using their static models transformation). In: Radioelektronika'93, Brno, 1993, pp.33-35.

About authors,...

Zdeněk Kolka was born in Brno, Czechoslovakia, in 1969. He received the M.S. degree in electrical engineering from the Faculty of Electrical Engineering, Technical University of Brno, in 1992. At present he is a PhD student supervised by Prof. Jiří Pospíšil at the Institute of Radioelectronics, Technical University of Brno. He is interested in PWL circuit modelling and design.

Václav Michálek was born in Boskovice, Czechoslovakia, in 1949. He received M.S. and Ph.D. (equivalent degrees) in 1972 and 1989, respectively, both from the Technical University of Brno, Czechoslovakia. From 1974 he is Assistant Professor in Dept. of Radioelectronics Technical University of Brno. His current interests are digital systems, microprocessor technique and computer architecture.