Novel Electronically Tunable FDNR Simulator Employing Single FDCCII

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Outline

- Introduction
- FDCCII
- Proposed Circuit
- Application Example and Simulation Results
- Conclusion

Introduction

- There is a big demand for hand-phones easier and more battery life; low-voltage low-loss IC Design solutions must be developed. Since the degree of integration in the RF transceiver increases, CMOS is the technology with the greatest potential for cost-benefit ratio.

- Current-mode circuits are used instead of voltage mode circuits for a wide variety of applications. The reason is that in voltage mode circuit parasitic capacitances create dominant poles at relative low frequencies, which limits the bandwidth.

- Furthermore current-mode circuits are also suitable for integration with CMOS technology and thus become more and more attractive in electronic circuit design.

Introduction (cont’d)

- High-order low-pass inductorless ladder structures are difficult to realize because of the requirement for simulated ungrounded inductances.
- The frequency dependent negative-resistance (FDNR) technique, employing an l/s transformation of all LCR prototype impedances, is a particularly useful method because it can exhibit zero pass-band insertion-loss sensitivity and uses fewer amplifiers than previously suggested methods.
- By contrast, the frequency-dependent negative resistances (FNDRs) are useful elements for the synthesis and design of active filters.
- In this paper, an electronically tunable FDNR is presented. The proposed circuit can be tuned electronically, employing single FDCCII and three passive components

Introduction (cont'd)

- The performance of the FDNR is demonstrated on an example of seventh order elliptic filter design.
- The theoretical results are verified on the seventh order elliptic filter with PSPICE simulations.

Fully Differential Second Generation Current Conveyor (FDCCII)

- The FDCCII is basically a fully differential device as shown in Fig. 1.

- Using standard notation, the symbol of FDCCII shown in Fig. 1 and its i-v relationship is given by matrix equation in Eq. (1)Using standard notation, the port relations of an ideal FDCCII shown in Fig.1 can be characterized by

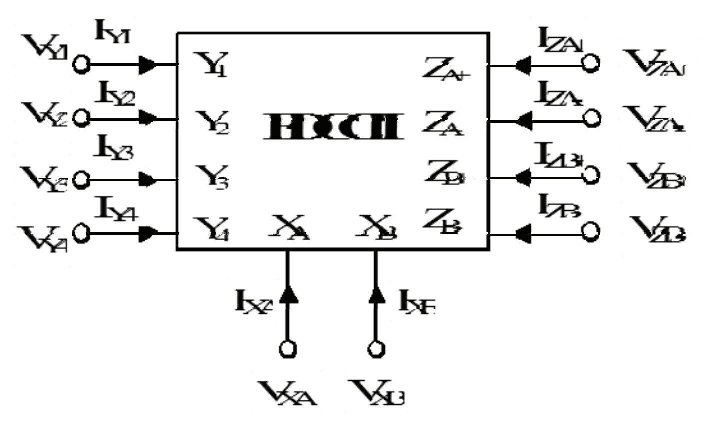

Figure.1. The Symbol of the FDCCII

$$\begin{bmatrix} I_{Y1} \\ I_{Y2} \\ I_{Y3} \\ I_{Y4} \\ V_{XA} \\ V_{XB} \\ I_{ZA\pm} \\ I_{ZB\pm} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \pm 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \pm 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} V_{Y1} \\ V_{Y2} \\ V_{Y3} \\ V_{Y4} \\ I_{XA} \\ I_{XB} \\ V_{ZA\pm} \\ V_{ZB\pm} \end{bmatrix}$$

CMOS Realization of FDCCII

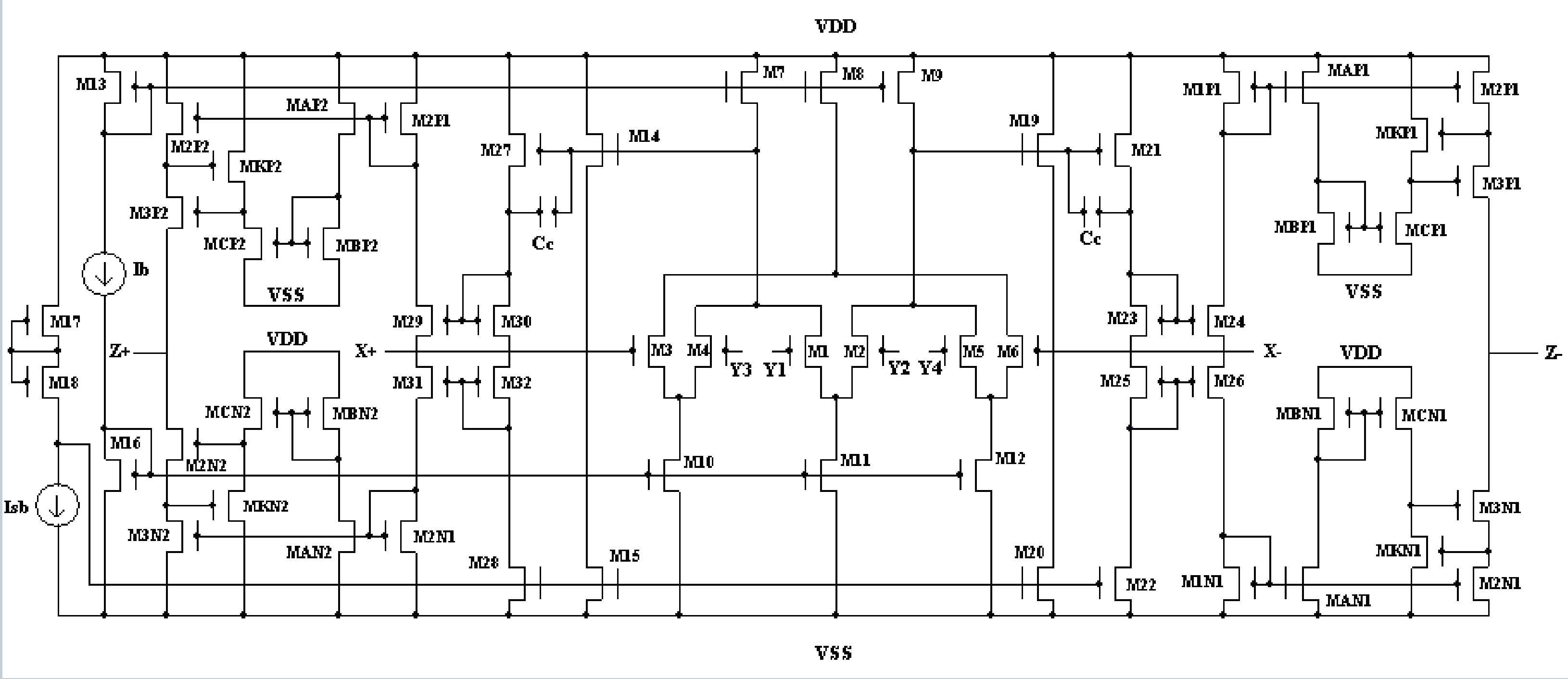

Fig.2. CMOS FDCCII implementation [13]

Proposed FDNR

- The proposed frequency dependent negative resistor simulator is shown in Fig. 3. Taking into account the basic terminal properties of the FDCCII and by performing a routine algebraic analysis the input impedance derived as

$$Z = \frac{1}{s^2 C_1 C_2 R}$$

- Eq. (4) represents a type-D FDNR with the general form $1/Ds^2$, where $D=RC_1C_2$.

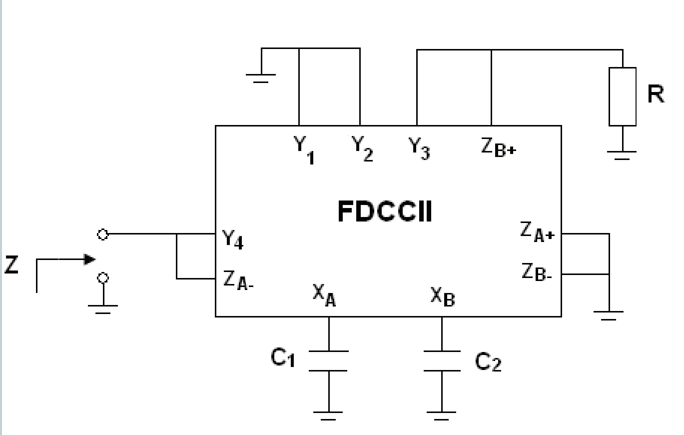

Fig.3 Frequency Dependent Negative Resistor (FDNR) realized using single FDCCII

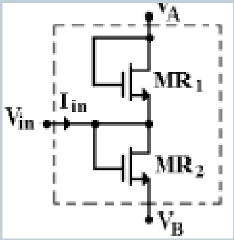

Fig.4. Electronic resistor

Proposed FDNR

- Advantages of the proposed FDNR are the following:
- Only grounded capacitors are used, and this gives potential for high frequency operation
- Tunability is possible through the grounded resistor R.
- There is no restriction regarding the matching between passive components.

Proposed FDNR

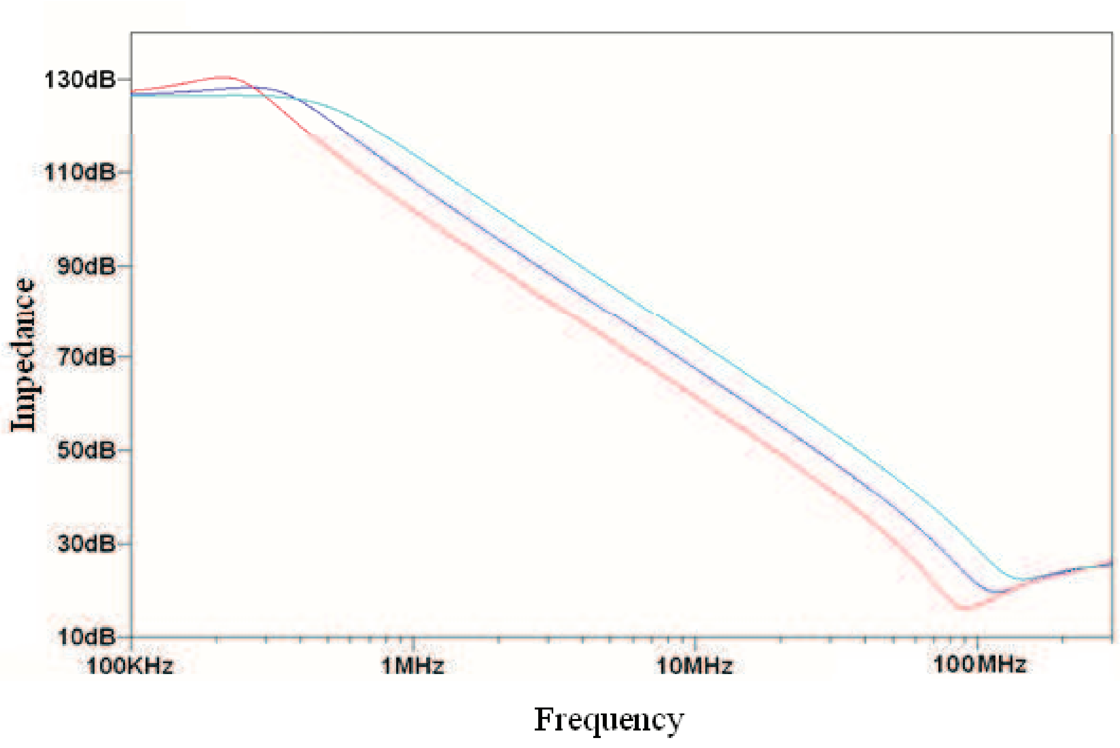

Fig.5: Frequency responses of impedance of electronically tunable FDNR

Application Example and Simulation Results

- Low-pass filters are essential components in the communication. The rapid growth of wireless and mobile communication has an increasing demand for new technologies to meet the challenges in terms of size, performance, cost and requirements.
- The functionality of the proposed circuit is demonstrated on the seventh order elliptic filter design example shown in Fig. 6 [16].
- In this Fig the presented circuit replaces the FDNR. The seventh-order elliptic low-pass filter is modified as explained above and is simulated using SPICE TSMC CMOS 0.35µm process model parameters.
- In the simulations, we have used the FDNRs in Fig. 6, which are supplied under $V_{DD}= -V_{SS}=1.5V$ DC.

Application Example and Simulation Results

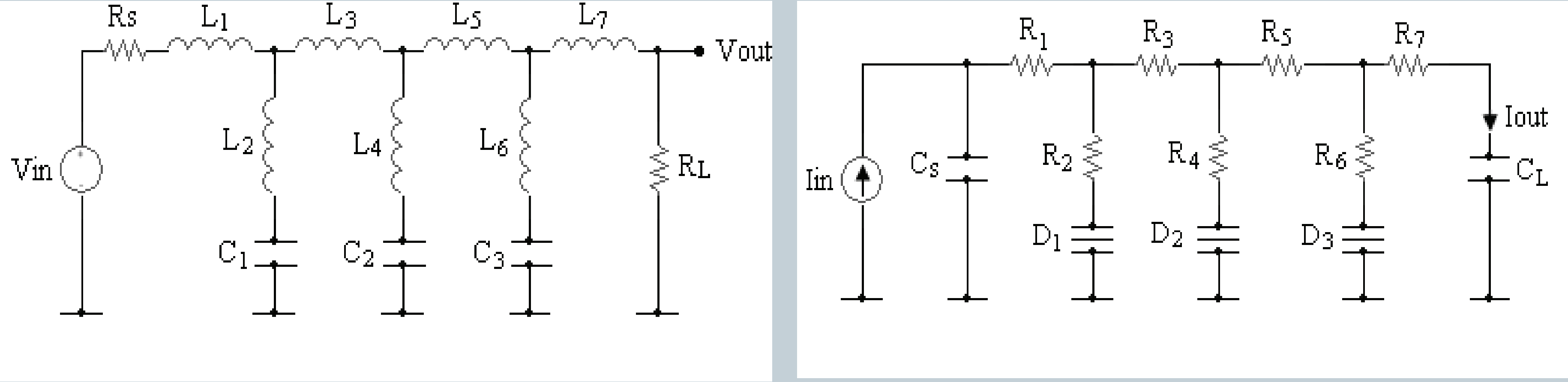

Fig.6 Transformation of Low-Pass Filter for FDNR Realization a) The LC elliptic ladder filter. b) The Prototype circuit

Simulation Results (cont'd)

- The seventh-order elliptic filter function designed as explained above has a cut-off frequency of 85MHz .
- PSPICE simulation result of the filter is given in Fig. 7. The deviations in the cut-off frequency from theoretical values are caused by the non-idealities of the FDCCII such as current and voltage tracking errors, finite output and input impedances.
- To test the input dynamic rang of the proposed filters, the simulation of the band-pass filter asan example has been repeated for a sinusoidal input signal at *fo* ≈ 85 MHz. Fig.8 shows that the input dynamic range of the filter response extends up to amplitude of 200μA (peak to peak) without significant distortion.
- The dependence of the total harmonic distortion at the output on input signal level is illustrated in Fig.9.

Simulation Results (cont’d)

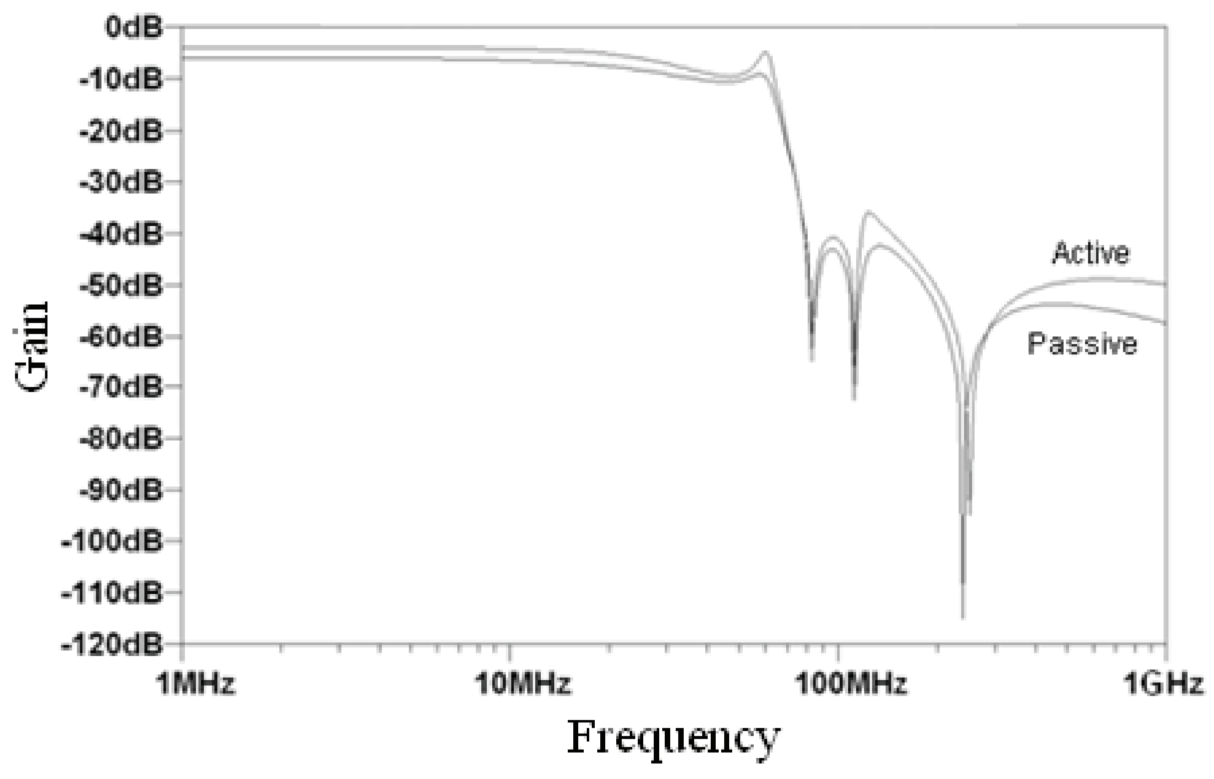

Fig.7. Simulation results of the seventh order elliptic filter in Fig.6

Simulation Results (cont’d)

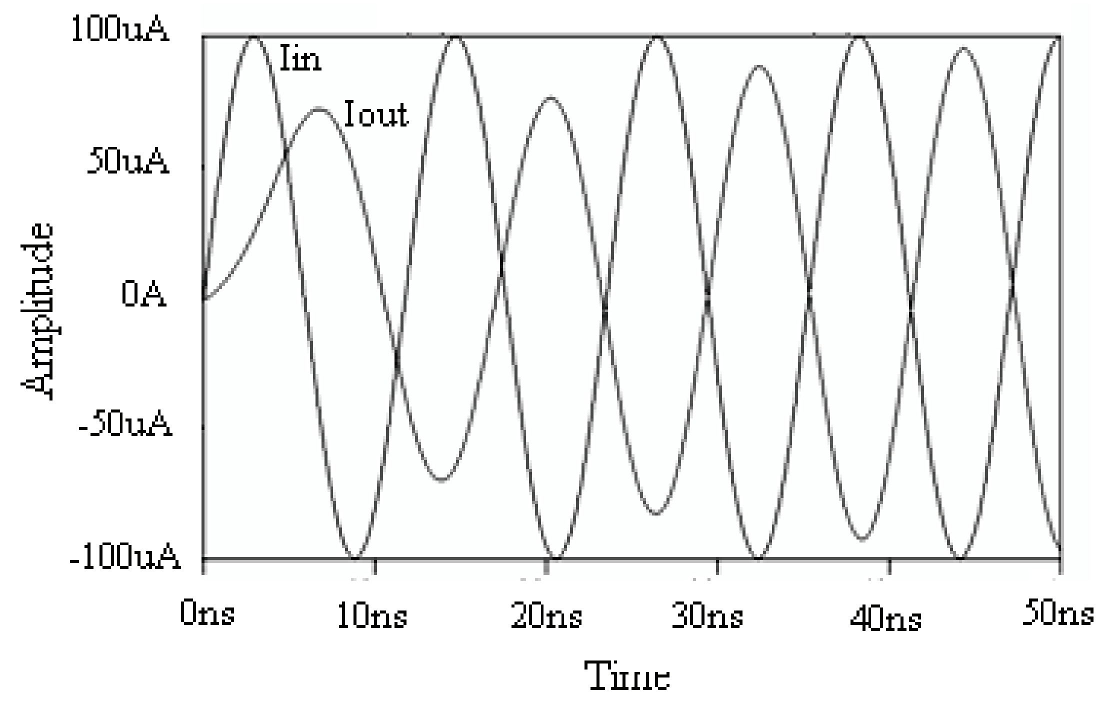

Fig.8. The input and output waveforms of the filter of for 85MHz sinusoidal input current of 200µA(peak to peak)

Simulation Results (cont'd)

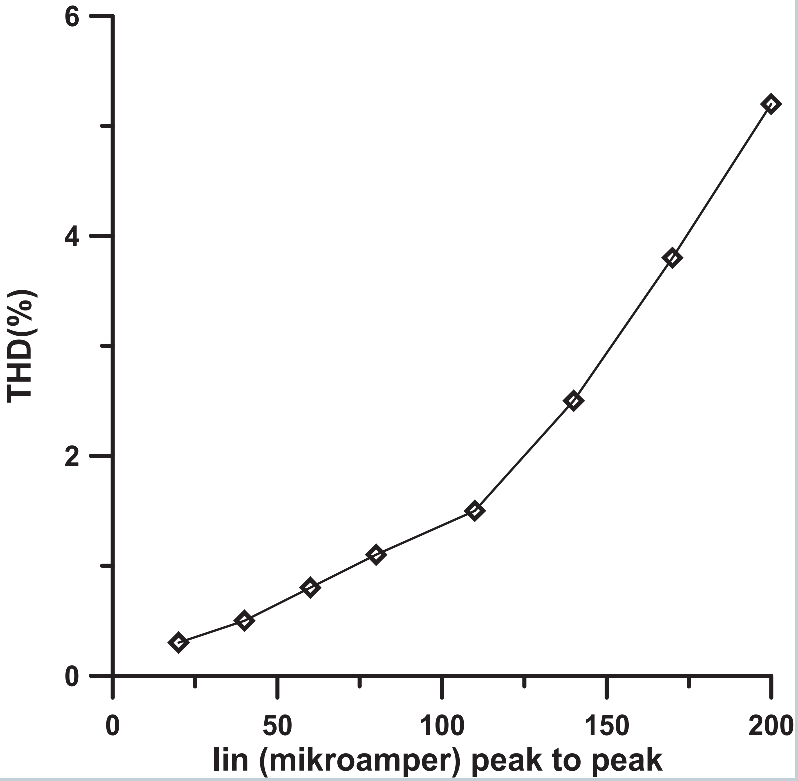

Fig.9. Total harmonic distortion (THD) at the filter output against input signal level for 85MHz

Conclusion

- In this paper, new electronically tunable FDNR simulator has been presented.
- A novel FDNR simulator circuit employing only FDCCII and two grounded capacitors and one grounded resistor is proposed.
- The proposed circuit requires no component matching.
- The performance of the FDNR simulator circuit is demonstrated on seventh order elliptic filter circuit.
- The simulation results verify the theoretical analysis.
- It is expected that the presented FDNR will be helpful in analog communication systems and in analog signal processing.