

# NOVEL OTRA-BASED GROUNDED PARALLEL IMMITANCE SIMULATOR TOPOLOGIES

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*Key words: Imittance simulators, OTRA, filters*

## ABSTRACT

**In this study, five novel grounded parallel imittance simulator topologies employing single OTRA are proposed. The presented topologies require fewer passive components than the counterparts in the literature. The performance of the proposed imittance simulators is demonstrated on a current-mode multifunction filter. PSPICE simulation results are included to verify theory.**

## I. INTRODUCTION

Analog designer has focused on operational transresistance amplifier (OTRA) due to recent developments in current-mode analog integrated circuits. Although the operational transresistance amplifier is commercially available from several manufacturers under the name of current differencing amplifier or Norton amplifier, it has not gained attention until recently. These commercial realisations do not provide internal ground at the input port and they allow the input current to flow in one direction only. The former disadvantage limited the functionality of the OTRA whereas the latter forced to use

external DC bias current leading complex and unattractive designs [1-2].

On the other hand, imittance simulators play an important role in areas such as oscillator design, filter design and cancellation of parasitic elements. A large number of simulated grounded imittance simulators that use current conveyor, current feedback op-amp and four terminal floating nullor are available in the literature [3-9]. Some of them are related with simulation of series imittance function [6-7]. Several specific circuits for the simulation of R-L and C-D imittances have been reported in the literature [3-5]. Universal series and parallel imittance simulator topologies employing two FTFNs are presented in a recent work [8]. A general imittance simulator circuit that enable simulation of all possible form of inductors is proposed in reference [9]. However, they use three CCII+. The main purpose of this study is to present new grounded parallel imittance simulator topologies employing single operational transresistance amplifier (OTRA) that provide therefore further possibilities for the designers in the realisation of analog circuits signal processing circuits.

## II. THE PROPOSED CIRCUITS

The circuit symbol of the OTRA is illustrated in Fig.1. The port relations of an OTRA can be characterised by the following matrix form,

$$\begin{bmatrix} V_p \\ V_n \\ V_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ R_m & -R_m & 0 \end{bmatrix} \begin{bmatrix} I_p \\ I_n \\ I_z \end{bmatrix} \quad (1)$$

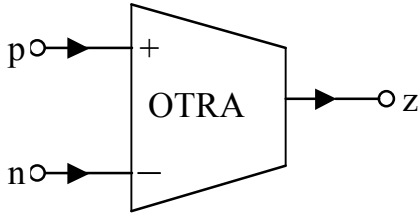
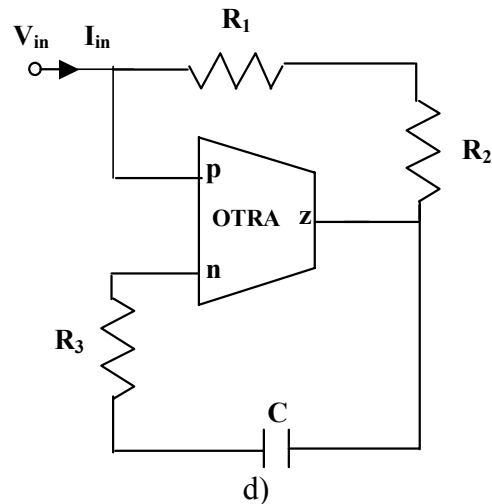
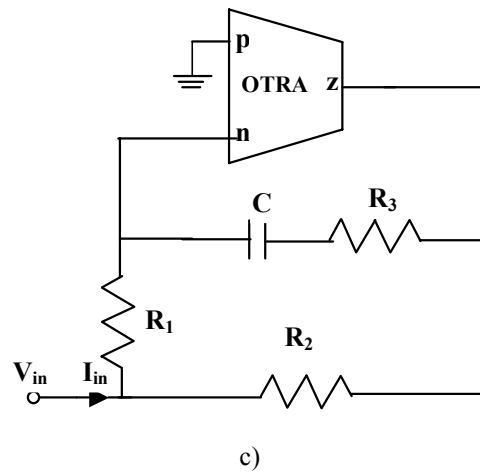
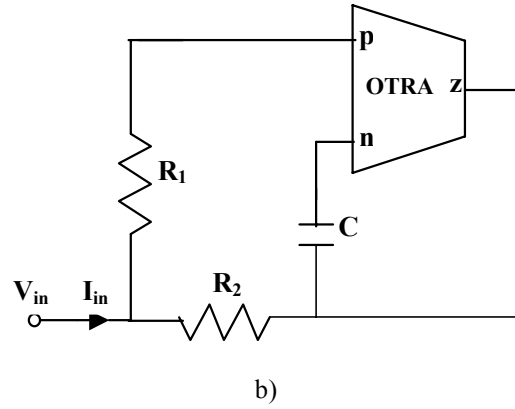
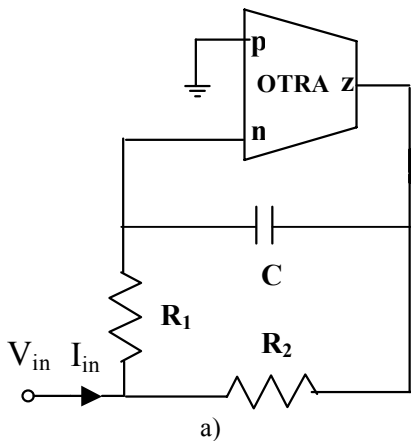


Figure 1: Circuit symbol of the OTRA

Both input and output terminals are characterized by low impedance, thereby eliminating response limitations incurred by capacitive time constants. The input terminals are internally grounded leading to circuits that are insensitive to the stray capacitances. For ideal operation, the transresistance  $R_m$  approaches infinity forcing the input currents to be equal. Thus the OTRA must be used in a feedback configuration in a way that is similar to the op-amp [1-2].

The proposed grounded parallel imittance simulator topologies are shown in Figure 2. Routine analysis yields the input impedance, equivalent inductance and resistors as given in Table 1. It can be clearly seen from Table 1 that the proposed circuits can simulate various combination of parallel lossy inductance. Note that RC:CR transformation makes active simulation of parallel C-D imittance possible which is an important research topic in active network synthesis.



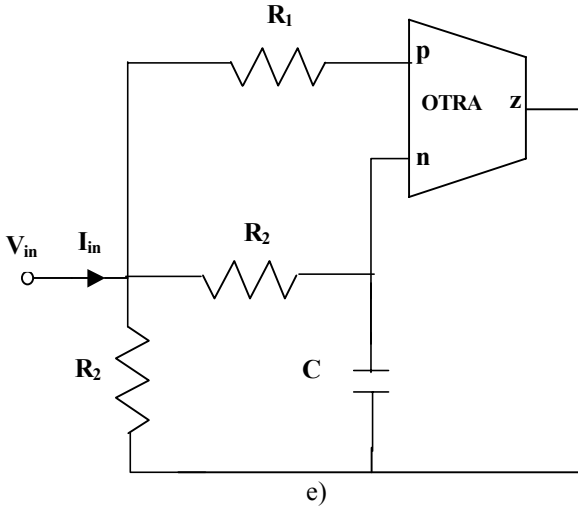


Figure 2: The proposed immittance simulator topologies

### III. APPLICATION EXAMPLE AND SIMULATION RESULTS

To illustrate an application of the proposed topologies a current-mode multifunction filter was designed and simulated. The basic cell is parallel R-L simulator with a parallel capacitor  $C_L$  and  $R_L$  to form resonant circuit shown in Figure 3. In this figure actively simulated R-L circuit in Figure 2.a replaces the parallel R-L circuit. The transfer functions are given by

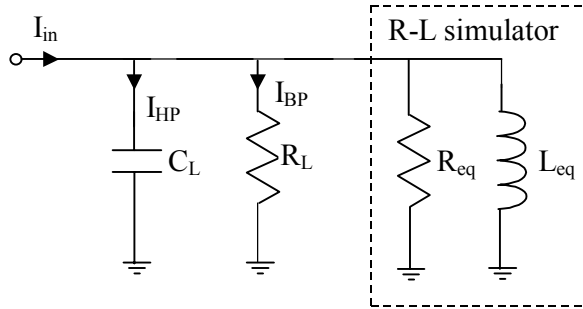


Figure 3: A current-mode multi-output filter as an application of the proposed immittance simulator

$$\frac{I_{HP}}{I_{in}} = \frac{s^2}{s^2 + \frac{(G_{eq} + G_L)}{C_L} s + \frac{1}{L_{eq} C_L}} \quad (2)$$

$$\frac{I_{BP}}{I_{in}} = \frac{\frac{(G_{eq} + G_L)}{C_L} s}{s^2 + \frac{(G_{eq} + G_L)}{C_L} s + \frac{1}{L_{eq} C_L}} \quad (3)$$

To pick up the capacitor or the resistor current two additional current buffers are required which provide the possibility of obtaining high impedance outputs for highpass and bandpass response. The element values of the realised filter are chosen as follows:  $C_L=10\text{nF}$ ,  $R_L=1\text{k}$ ,  $R_1=2\text{k}\Omega$ ,  $R_2=2\text{k}\Omega$  and  $C=1\text{nF}$ , thus an inductor with  $L_{eq}=4\text{mH}$  with a parallel resistance  $R_{eq}=1\text{k}\Omega$  is obtained which result in a pole frequency  $f_p=25,177\text{ KHz}$  and a quality factor  $Q_p=0.78$ .

The designed filter circuit is simulated with PSPICE program using a CMOS realisation of OTRA shown in Figure 4. This circuit was proposed for the realisation of current differencing buffered amplifier in reference [10]. It can also be used as the OTRA with open circuit z terminal. PSPICE simulations were performed by MIETEC  $1.2\mu$  MOS transistor parameters with the same aspect ratio as in reference [10]. Supply voltages are taken as  $V_{DD}=5\text{V}$  and  $V_{SS}=-5\text{V}$ . Simulation result of the filter response is given in Figure 5, which is very in good agreement with the predicted theory. The deviations in the frequency response of the filter from theoretical values are caused by the non-idealities of the OTRA.

Table1: The actively realizable inductance forms

Figure	$L_{eq}$	$G_{eq}$	Type
1.a	$\frac{C}{G_1 G_2}$	$G_1 + G_2$	L parallel with R
1.b	$-\frac{C}{G_1 G_2}$	$G_1 + G_2$	-L parallel with R
1.c	$\frac{C}{G_1 G_2}$	$G_1 + G_2 + \frac{G_1 G_2}{G_3}$	L parallel with R
1.d	$-\frac{C}{G_1 G_3}$	$G_1 + G_2 - \frac{G_1 G_2}{G_3}$	-L parallel with $\pm R$
1.e	$\frac{C}{G_2 G_3} - \frac{C}{G_1 G_3}$	$G_1 + G_2 + G_3$	$\pm L$ parallel with R

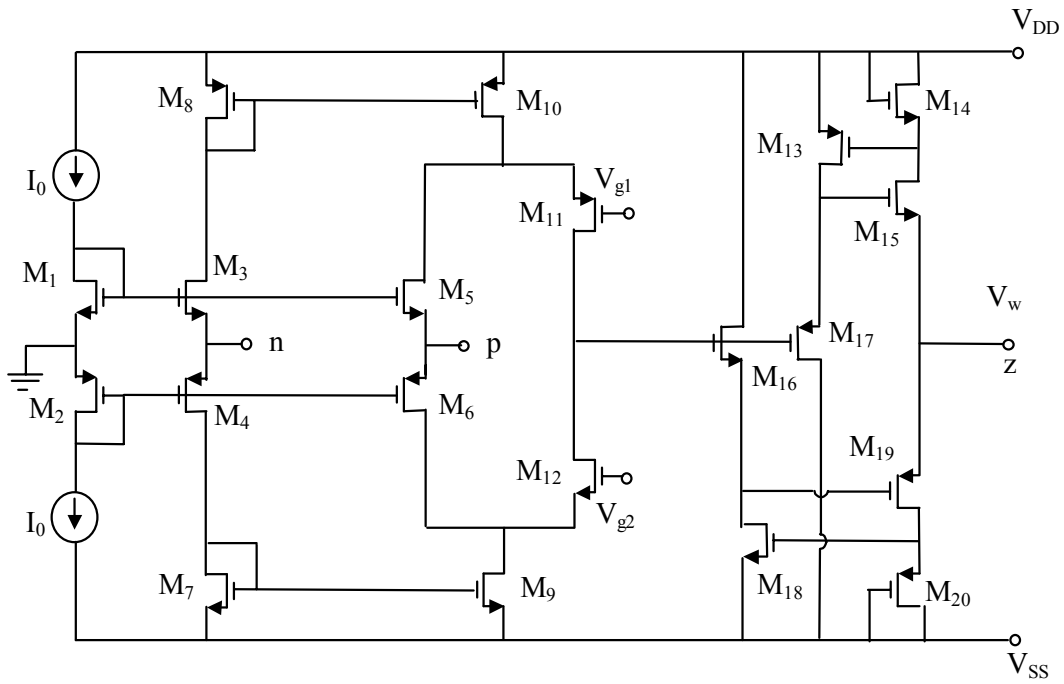


Figure 4: A CMOS implementation of the OTRA

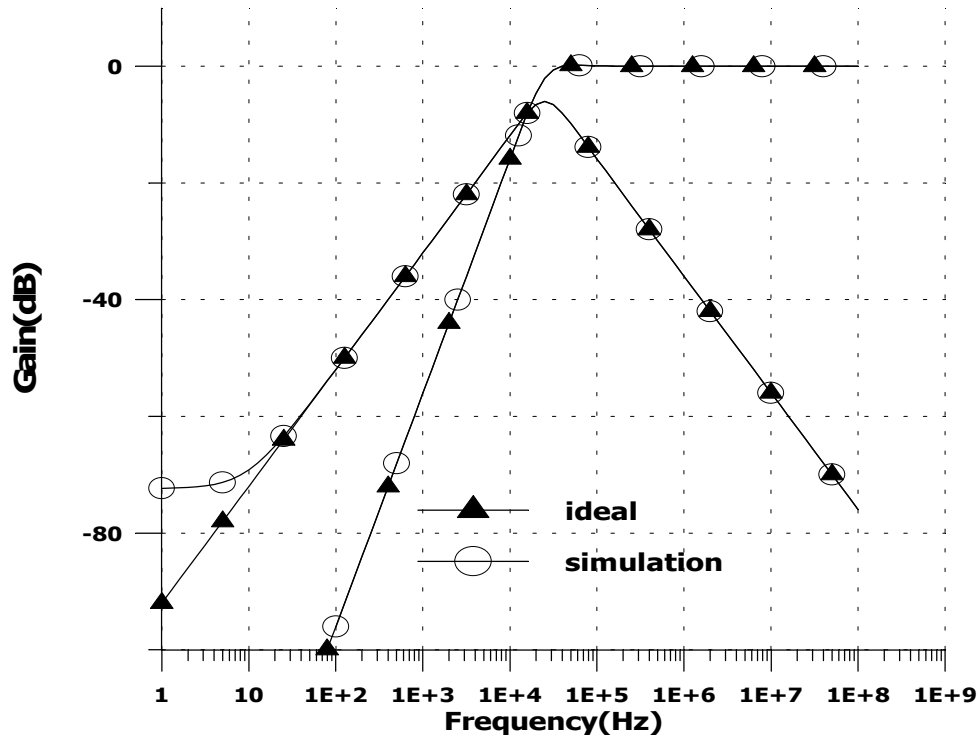


Figure 5: The frequency response of the current-mode filter

#### IV. RESULTS AND DISCUSSION

In this paper, five different actively simulated parallel imittance simulator topologies are proposed. The presented topologies employ only single OTRA. They don't require passive component matching to obtain the desired type of inductance. An application example is given to illustrate the practical use of the proposed topologies. PSPICE simulation results are given to verify the theory. It is expected that the proposed OTRA-based imittance simulator will be useful in design of analog signal processing applications such as filter and oscillators. They provide therefore further possibilities to the designer in the realisation of analog circuits.

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