A Simple Circuit for Digital Impedance Measurement

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Abstract

A simple circuit for measuring both polar and Cartesian coordinates of an impedance is proposed.

Keywords: impedance measurement, impedance magnitude, complex impedance measurement, digital impedance measurement

Introduction

One very common method for impedance measurement is to connect a resistance *R* in series with the unknown impedance $Z_x = |Z_x| \angle \pm \phi = |Z_x| [\cos\phi \pm j \sin\phi]$ across a sinusoidal source as shown in block (a) in Fig. 1. Then, the voltages across *R* and Z_X are $v_R(t) = \sqrt{2} V_R \sin \omega t$ and $v_Z(t) = \sqrt{2} V_Z \sin(\omega t \pm \phi)$, respectively. These voltages are suitably processed to extract polar coordinates $|Z_x|$ and ϕ, or Cartesian coordinates Re Z_x and Im Z_x. Methods [1]-[3] differ mainly in the processing of the signals.

Circuit

Magnitude of impedance Z_X is given by

$$|Z_x| = |V_{Zx} / I| = R |V_{Zx}| / |V_R| \tag{1}$$

Real and imaginary parts of Z_X are given by

$$\operatorname{Re} Z_x = \operatorname{Re} \; R V_{Zx} / V_R = R V_{Zx} \cos\phi / V_R = R V_C / V_R, \tag{2}$$

$$\operatorname{Im} Z_x = \operatorname{Im} \; R V_{Zx} / V_R = R V_{Zx} \sin\phi / V_R = R V_S / V_R, \tag{3}$$

where $V_C = V_{Zx} \cos\phi$ and $V_S = V_{Zx} \sin\phi$.

Thus, it is obvious that $|Z|$, Re Z and Im Z can be measured digitally by measuring the voltage ratios: V_{Zx} / V_R, V_C / V_R and V_S / V_R, respectively. Instead of measuring the ratios of RMS values of the voltages, one can measure the ratios of the corresponding average voltages or peak voltages. In the proposed circuit, we measure the ratios of peak values of the voltages.

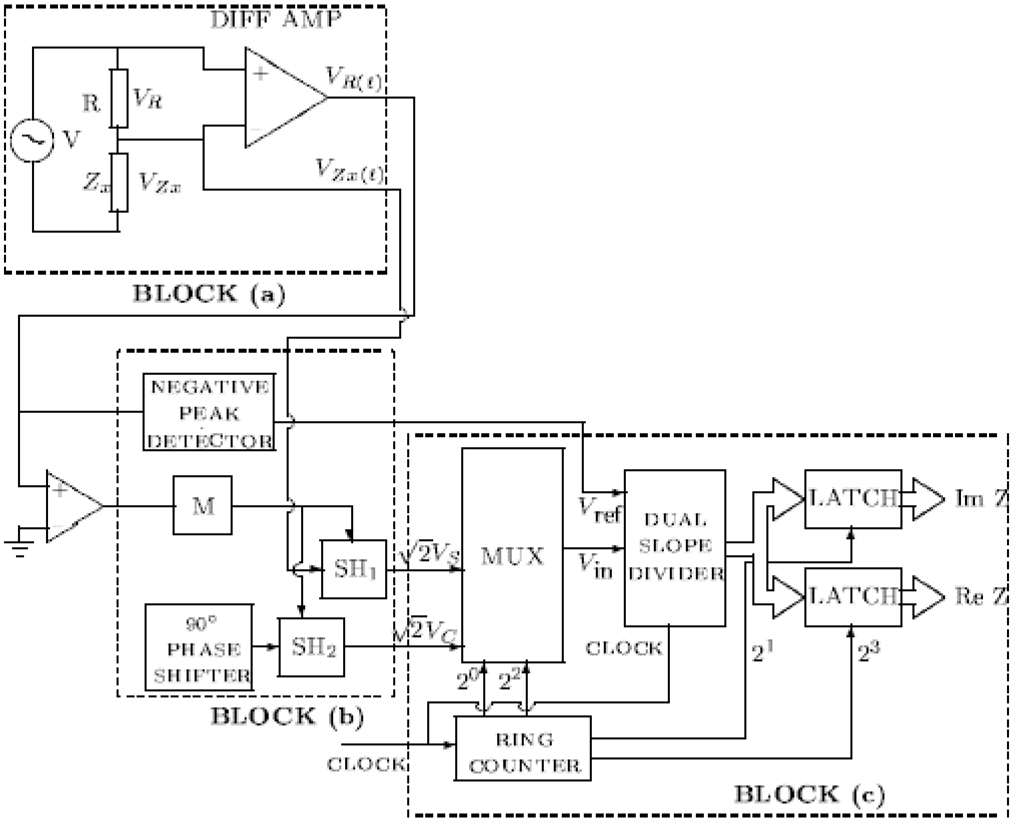

Fig. 1: Simple circuit for measuring $|Z_x|$, ϕ , Re Z_x , Im Z_x

The complete circuit based on the above approach is shown in Fig. 1. It consists of three main blocks. Block (a) for generating $V_R(t)$ and $V_Z(t)$, block (b) for generating the Peak values of voltages V_C, V_S, V_{Zx} and V_R, and block (c) for digital division and display.

Comparison

Essentially the proposed circuit is the simplified version of [1]. The main similarities and the differences between the two circuits are the following.

1. ϕ is measured using a digital phase meter [4] which displays phase angle anywhere between 0^o and 360^o. If the angle displayed is in the range 0^o and 90^o, the impedance is capacitive and if it is in the range 270^o to 360^o, it is inductive. Thus, there is no need for an additional circuit for displaying the sign of ϕ as in [1].
2. $|Z|$ is obtained using the ratios of peak values of voltages while in [1], this is obtained as the ratio of average values of the voltages. Since peak value of a sine wave can be captured in at the most in one cycle, whereas average value requires at least a few cycles, the proposed circuit is faster. In [1], a very elaborate circuit (consisting of two digital vector generators, a binary subtractor, a phase shifter, a rectifier and an averager) is used to generate the average voltage proportional to V_Z.
3. In [1] (also in [3]), the rectifier shown in the circuit is half-wave and not the full-wave as described in the text. Moreover, it should have been configured as a precision type rectifier; otherwise it loses its importance as an active rectifier and produces considerable error for low impedance measurement when diode drop becomes comparable.
4. Cartesian coordinates of Z are measured in the same way as in [1] by evaluating V_S/V_R and V_C/V_R.

5. For economy point of view, the numerator signals input to the digital divider are applied in time-multiplexed manner as in [1].

Ibrahim and Abdul Karim [2] measure the polar coordinates of *Z*. They use a successive approximation type ADC for the division. However, their circuit is also very complicated as they use two digital inverse sine function generators and one full adder. The digital inverse sine function generator itself is very complex and requires a signal frequency dependent clock.

In another paper, Ibrahim and Karim [3] determine the Cartesian coordinates of *Z*. Their circuit is also complicated as they need to generate analog voltage signals for ϕ, $\pi/2 - \phi$ using analog inverse sine generator.

Conclusion

A simple circuit for measuring the polar and Cartesian coordinates of a complex impedance digitally has been proposed. It is less complicated than some of the circuits proposed in the past, and therefore, it is more reliable and accurate.

References

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Author's profile

T S Rathore was born in Jhabhua (M P, India) on Oct. 29, 1943. He received the B Sc (Electrical Engineering), M E (Applied Electronics & Servomechanisms), and Ph D (by research on Passive and Active Circuits) degrees in Electrical Engineering from Indore University, Indore, India in 1965, 1970 and 1975, respectively.

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