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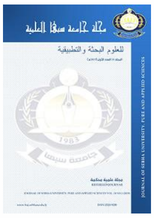

Automatic Balance for The Digital AC Bridge

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ABSTRACT

Impedance is an important parameter used to characterize electronic circuits, components, and the materials used to make components. Impedance (Z) is generally defined as the total opposition a device or circuit offers to the flow of an alternating current (AC) at a given frequency. A fast and wide - range balanced theory of the method is designed. In a implementation , an impedance component is based on a GIC (General immittance converter) system. Which provides a variable impedance. The principle of this method is comprehensive and its implementation is simple. As a digital measurement technique, the method takes full advantage of the powerful arithmetic and processing ability of a microprocessor.

الاتزان الالي لقنطرة تيار متردد رقمية

محمد المهدي علي

قسم الهندسة الكهربية ، جامعة سرت ، سرت ، ليبيا

الملخص

المعاوقة هي سمة مهمة تستخدم لوصف الدوائر الإلكترونية والمواد المستخدمة في صنع مكوناتها. تُعرَّف المعاوقة (Z) عمومًا على أنها المقاومة الكلية التي يقدمها النظام أو الدائرة لتدفق التيار المتردد (AC) عند تردد معين. تم تصميم نظرية متوازنة سريعة ذات نطاق عريض . حيث يعتمد مكون المعاوقة على نظام GIC (محول الممانعة العام). الذي يوفر مقاومة متغيرة. مبدأ هذه الطريقة شامل وتنفيذها بسيط. كأسلوب قياس رقمي ، هذه الطريقة تستفيد بشكل كامل من القدرة الحسابية والمعالجة القوية للمعالج الدقيق.

الكلمات المفتاحية:
قنطرة تيار متردد
طريقة الموازنة
قياس المعاوقة
محول ممانعة عام
قنطرة رقمية

Introduction

impedance is shared by scientists and engineers from different backgrounds. Various circuits, techniques, and instruments have been developed over past years to satisfy differing requirements. They are characterized by different operational methods, operational ranges, accuracies, measurement rates, fields of application, and cost. In precision measurements, the impedance is, however, usually measured by an AC bridge, which is balanced either manually or iteratively and is thus slow in operation[1]. Impedance is an important parameter used to characterize electronic circuits, components, and the materials used to make components. Impedance (Z) is generally defined as the total opposition a device or circuit offers to the flow of an alternating current (AC) at a given frequency and is represented as a complex quantity that is graphically shown on a vector plane[2].

There are many impedance measurement methods to choose from when measuring impedance, each of which has advantages and disadvantages. You must consider your measurement requirements and conditions, and then choose the most appropriate method while considering such factors as frequency coverage, measurement range, measurement accuracy, and ease of operation. the impedance measurement is of great importance in the electrical test. Measuring the impedance of the key components in a system precisely helps predict the state of the system. A popular method to measure the unknown impedance is based on the AC bridge method. Most conventional impedance measurement techniques typically rely on manually – adjusted bridge networks[3].

AC bridges can easily be combined with automatic test systems. They also provide the following advantages in comparison to conventional AC bridges: high accuracy, reproducibility, reliability, and flexibility [4].

The paper proposes a General immittance converter GIC - based technique for impedance measurement, which can give the balance parameters of a digital AC

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bridge in a wide range by adjusting the bridge twice only. The applicability of the proposed theory is discussed, and simulation examples are given and analyzed. Matlab was used to do some assistant in the simulation of the system and plot the Imbalance output voltage.

2. Analysis of the AC Bridge

The AC bridge is a natural outgrowth of the Wheatstone bridge. An AC bridge, in its basic form, consists of four arms, a source of excitation, and a balance detector. In an AC bridge each of four arm is an impedance, and the battery and galvanometer are replaced by an AC source and a detector sensitive to small alternating potential difference[5]. The usefulness of AC bridge circuits is not restricted to the measurement of unknown impedances and associated parameters like inductance, capacitance, storage factor, dissipation factor etc. this circuits find other application in communication systems and complex electronic circuit. Alternating current bridge circuit are commonly used for phase shifting, providing feedback paths for oscillator and amplifier, filtering out undesirable signals and measuring the frequency of audio signals[6].

electrical impedance consists of three factors that affect the ability of current to flow in a circuit. The first is resistance, If there is a varying AC component to the voltage then the other factors, inductance and capacitance [7].For a given circuit the capacitance and inductance are constant, but the extent to which they affect the current is related to the frequency of the variation in voltage. This property is called capacitive reactance and inductive reactance. For a given inductance, the reactance rises with frequency while capacitance behaves in the inverse matter. The effect of the resistance of the circuit stays the same regardless of the frequency.

In figure 1, **$U = A\sin(\omega_o t)$** is a sinusoidal voltage source. **$e(t)$** is the imbalance voltage. **R_1** and **R_2** are two nice resistors. **Z_1** is an impedance based on the GIC, which can be denoted as **$Z_1 = r\angle\varphi$** (both **r** and **φ** are adjustable) and **Z_x** is the unknown impedance.

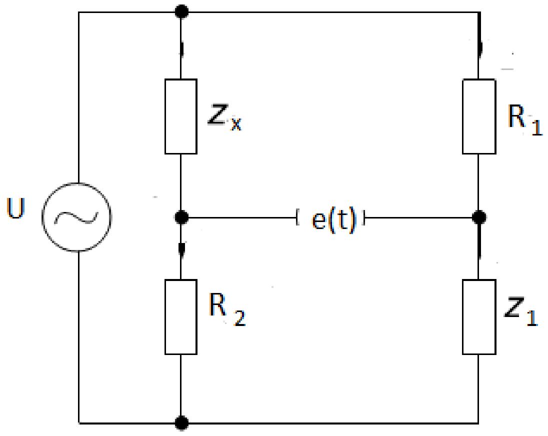

Fig.1.AC Bridge

Now, the balance of the AC bridge is controlled by the resistor **R_2** and the impedance **Z_1**.

We can analyze the balance condition with the voltage drop of the two bridge arm. That is the imbalance output **$e(t) = 0$** when the bridge is balance. So the voltage drop of the bridge arm **Z_x** is equal to the voltage drop of the bridge arm **R_2**.

Therefore, we could conclude the expressions because of the principle above.

$$\frac{Z_x}{Z_x + R_1} = \frac{R_2}{R_2 + Z_1}$$

and

$$\frac{R_1}{Z_x + R_1} = \frac{Z_1}{R_2 + Z_1} \tag{1}$$

Then we can conclude that ,

$$Z_x \times Z_1 = R_1 \times R_2 \tag{2}$$

So we can deduce the unknown parameters when the bridge is balanced.

3. Condition of the Balance Bridge

Based on the circuit theory, the imbalance output voltage **$e(t)$** of the bridge can be expressed as

$$e(t) = B\sin(\omega_0 t + \theta_2) - A\,sin(\omega_0 t + \theta_1) \tag{3}$$

Where,

$$A = \frac{|Z_x|}{|Z_x + R_1|}$$

and

$$B = \frac{|R_2|}{|R_2 + Z_1|}$$

$$\frac{Z_x}{Z_x + R_1} = A\angle\theta_1$$

and

$$\frac{R_2}{Z_1 + R_2} = B\angle\theta_2$$

There into the angle **φ** is produced by the GIC **Z_1** ., we can deduce Eq.(10) as follow, so we can conclude the balance parameter when **$e(t)=0$**

$$\begin{cases} \theta_1 = \theta_2 \\ A = B \end{cases}$$

or

$$\begin{cases} \theta_1 - \theta_2 = 2\pi \\ A = -B \end{cases} \quad \textbf{(4)}$$

4. Measures to Balance the Bridge

In order to obtain the balance parameters, adjust the impedance of General immittance converters (GIC) twice. The Fourier coefficients of the imbalance output voltage can be obtained.

$$a = \frac{1}{\pi} \int_0^{2\pi} e(t) \cos(\omega_0 t) d(\omega_0 t)$$

$$b = \frac{1}{\pi} \int_0^{2\pi} e(t) \sin(\omega_0 t) d(\omega_0 t)$$

In simplified representation is

$$a = B \sin\theta_2 - A \sin\theta_1$$

$$b = B \cos\theta_2 - A \cos\theta_1 \quad \textbf{(5)}$$

where

$$B = \frac{1}{\sqrt{1 + (\frac{R_2}{|Z_1|})^2 + 2\,\frac{R_2}{|Z_1|} cos\varphi}} \quad (6)$$

$$\theta_2 = \arctan \frac{\sin\varphi \frac{R_2}{|Z_1|}}{1 + \cos\varphi \frac{R_2}{|Z_1|}} \quad (7)$$

We can see from Eq. (6) and Eq. (7) that the angle **θ_2** will turn from **θ'_2** to **θ_2''** when the model of **Z_1** is fixed and the angle of **Z_1** from **$\varphi = \pi/2$** to **$\varphi = -\pi/2$**.

The change of the flourier coefficient is express as

$$a' = B_1 \sin\theta'_2 - A \sin\theta_1$$

$$b' = B_1 \cos\theta'_2 - A \cos\theta_1$$

$$b'' = B_1 \cos\theta''_2 - A \cos\theta_1 \quad (8)$$

$$a'' = B_1 \sin\theta''_2 - A \sin\theta_1 \quad (9)$$

$$e(t) = B \sin(\omega_0 t + \theta_2) - A\, sin(\omega_0 t + \theta_1)$$

$$\begin{aligned} e(t) = B \sin(\omega_0 t + \theta_2) \\ - A[\cos(\theta_1 - \theta_2) \, sin(\omega_0 t + \theta_2) \\ - \sin\,(\theta_1 - \theta_{2)}\, cos(\omega_0 t + \theta_2)] \end{aligned} \quad (10)$$

$$B = \frac{L}{P} \times K \quad (11)$$

Where

$$L = \sqrt{\left\{ (b'' - b'\ )ctg\left[\frac{(\theta'_2 - \theta''_2)}{2}\right] - a' - a''\right\}^2 + \left\{(a'' - a'\ )ctg\left[\frac{(\theta'_2 - \theta''_2)}{2}\right] - b' - b''\right\}^2}$$

,

and

$$K = B_1 \sin[(\theta'_2 - \theta''_2)\,/2\,]$$

$$P = \sqrt{(a' - a'')^2 + (b' - b'')^2}$$

$$\theta_2 = tg^{-1} \frac{(b'' - b')ctg\left[\frac{\theta'_2 - \theta''_2}{2}\right] - a' - a^n}{(a' - a'')ctg\left[\frac{\theta'_2 - \theta''_2}{2}\right] - b^n - b'}$$

$$- tg^{-1} \frac{b'' - b'}{a' - a^n} - \frac{\theta'_2 - \theta''_2}{2} \quad \textbf{(12)}$$

So when **B** and **θ_2** Can be calculated with Eq. (11) and Eq. (12), The bridge is balanced **(e (t)= 0)**. It can be figure out the relevant parameter **Z_1** and **R_2** based on the result **B** and **θ_2**.

5. The generalized immittance converter (GIC)

General immittance converter (GIC) are electronic circuits which have been widely used as controllable impedance in AC regime, especially in active filter synthesis.

The circuit diagram of the General immittance converters (GIC) system is shown in figure .2.

Its equivalent impedance is

$$Z_{in}=(\ Z_1\ Z_3\ (\ Z_5+Z'_5\ )/\ Z_2\ Z_4\ )$$

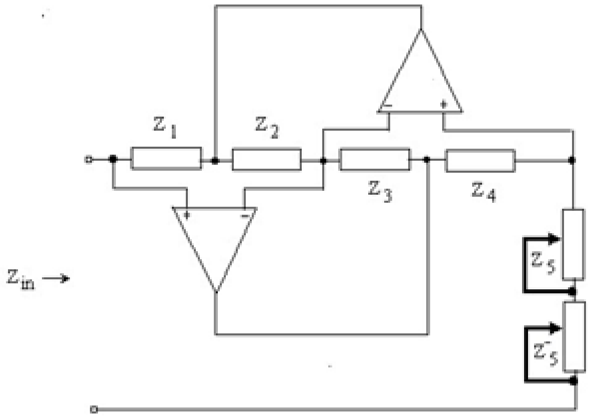

Fig.2. General immittance converter system .

When **Z_3** is replaced with capacitance and inductance, while the other ones are replaced with high precision resistance, **Z_{in}** is a high linear reference impedance.

When **Z_3** turns from capacitance to inductance, the angle of **Z_{in}** correspondingly turns from **$\pi/2$** to

$-\pi/2$.

6. Simulation and Hardware Implementation

In order to verify the performance of the measurement system fully and simply, simulation experiments are studied . In the simulation, the primary error of the system , that is the quantization error of the analog to digital converter (A/D) conversion, is considered.

Assume that **$A=1V$**. **$f=1000Hz$**, **$R_1=10\Omega$**, **$R_2=10\Omega$** , **$Z_1=20\angle\varphi$** and 140 data are sampled during a cycle, **$e(t)$** with computed balance parameters is computed and then plotted in figure-3.

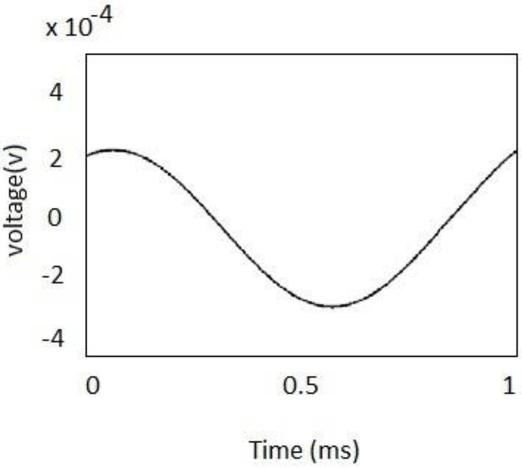

Fig.3. Imbalance output voltage with 12-bit ADC.

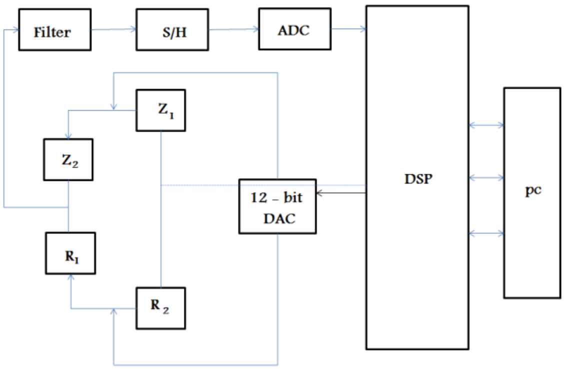

Fig.4. hardware are implementation of the system.

Figure. 4 presents the block diagram of a hardware implementation of the measurement principle above. The AC bridge shown in figure . 1 is controlled by a microprocessor. The 12-bit DAC provides a sinusoidal voltage source, and S/H is a sample-and-hold circuit. The outputs of the A/D conversion are processed by a DSP to obtain the modulus and angle of **Z_1**.

7. Conclusion

Motivation The interest in the accurate measurement of electrical impedance is shared by scientists and engineers from different backgrounds. Bridges are often used for the precision measurement of component values, like resistance, inductance, capacitance. Experiments show that the measurement method leads to precise, fast, and automatic impedance measurement. It improves the conventional AC bridge and makes the measurement digital. In addition, it is wieldy, cost-efficient, and portative.

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