ROHINI
COLLEGE OF ENGINEERING AND TECHNOLOGY
Approved by AICTE and affiliated to Anna University,(An ISO Certified Institution)
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DEPARTMENT OF BIOMEDICAL ENGINEERING

III Semester

BM3301 SENSORS AND MEASUREMENTS

UNIT – 4

4.4 Impedance matching circuits

4.4.1 What is Impedance Matching?

Impedance matching is designing source and load impedances to minimize signal reflection or maximize power transfer. In DC circuits, the source and load should be equal. In AC circuits, the source should either equal the load or the complex conjugate of the load, depending on the goal.

Impedance (Z) is a measure of the opposition to electrical flow, which is a complex value with the real part being defined as the resistance (R), and the imaginary part is called the reactance (X). The equation for impedance is then by definition Z=R+jX, where j is the imaginary unit. In DC systems, the reactance is zero, so the impedance is the same as the resistance.

4.4.2 Why is impedance matching needed?

Impedance matching is crucial in electronic circuits and systems for several reasons, particularly in the context of signal transmission and power transfer. Here are some key reasons why impedance matching is needed:

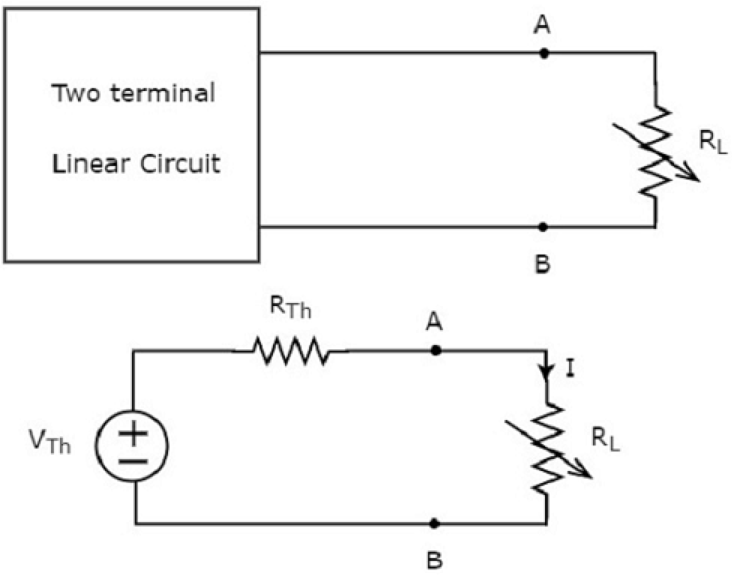
1. Maximum power transfer
2. Reduced signal reflection
3. Prevent of signal distortion
4. RF and microwave applications

5. Electrical safety
6. Maximum efficiency in power transfer
7. Compatibility with Electrode Systems
8. Wearable and Implantable Devices

4.4.3 Maximum Power Transfer Theorem:

Maximum power transfer theorem states that the ***DC voltage source*** will deliver maximum power to the variable load resistor only when the load resistance is equal to the source resistance.

Similarly, Maximum power transfer theorem states that the ***AC voltage source*** will deliver maximum power to the variable complex load only when the load impedance is equal to the complex conjugate of source impedance.



The **maximum amount of power** transferred to the load is,

$$P_{L,Max} = \frac{{V_{Th}}^2}{4R_L} = \frac{{V_{Th}}^2}{4R_{Th}}$$

Where,

V_{Th} - Thevenin's voltage

R_{Th} - Thevenin's resistance

Maximum Power Transfer Theorem is applied for active networks & passive networks.

4.4.3 Impedance Matching Circuits:

For many practical circuits, matching networks are designed not only to meet the requirement of minimum power loss, but are also based on additional constraints, such as minimizing the noise influence, maximizing power handling capabilities, and linearizing the frequency response. In a more general context, the purpose of a matching network can be defined as a transformation that converts a given impedance value to another over a frequency range. We start with a study of networks based on lumped (or discrete) components.

4.4.4 Matching with Lumped Elements:

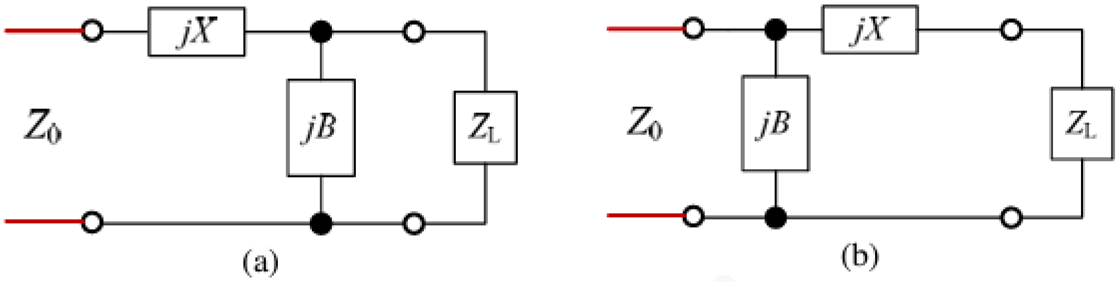
For frequencies up to approximately 1 GHz, matching networks containing lumped elements (L-networks) may be used. The circuit elements (capacitors and inductors) must be small enough relative to wavelength so that the normal circuit equations for voltage and current are valid. L-networks are easily analyzed using either circuit equations

4.4.5 Two Element Impedance Matching Circuits (L Networks):

The simplest type of matching network is the: two-component networks, also known as L-sections or L-type networks due to their element arrangement, which uses two reactive elements to transform the load impedance Z_L to the desired input impedance. Broadly, there are two possible configurations for this network.

The L-section is considered the simplest type of matching network. There are two possible configurations, as depicted in Fig. 2. (a) is the network for $Re[Z_L] > Z0$, while (b) is the network for $Re[Z_L] < Z0$. Note that in both configurations, two components (jX, jB) are required in order to have degree of freedom 2, since the load impedance is generally complex. Consider Fig. 2(a). Let $Z_L = R_L+jX_L$, then the impedance seen looking into the matching network followed by the load impedance must be equal to Z0, i.e.,

$$Z_0 = jX + \frac{1}{jB + 1/(R_L + jX_L)}.$$

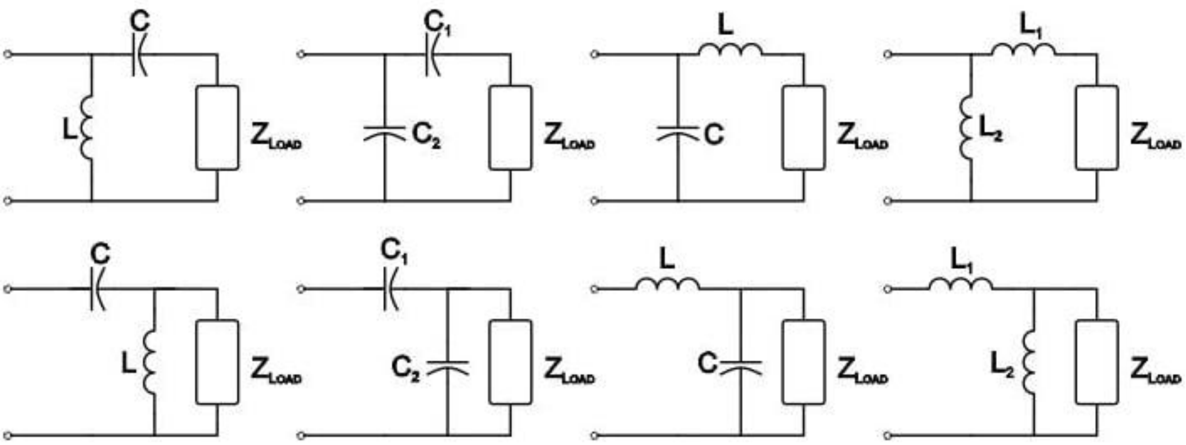


Solving for X and B gives

$$X = \pm\sqrt{R_L(Z_0 - R_L)} - X_L\,;\, B = \frac{\pm\sqrt{(Z_0 - R_L)/R_L}}{Z_0}$$

Considering the circuit diagram as shown in figure, a two-element lumped network is to be used to match the load impedance to the source impedance. For this configuration of L network, must be greater than R_S.

The most straightforward matching-network topology is called the L network. This refers to eight different L-shaped circuits composed of two capacitors, two inductors, or one capacitor and one inductor. The following diagram shows the eight L-network configurations:



It is certainly valuable to understand the concepts involved in manually calculating matching-network values based on the source and load impedances, Here are some common types of impedance matching circuits:

1. Transformers
2. L-matching network
3. T-matching network
4. π matching network
5. Smith Chart

4.4.6. Applications of Impedance matching circuits

i. ***In ultrasound imaging***, impedance matching circuits are used to enhance the transmission of ultrasound waves between the transducer and the tissue.
ii. Impedance matching is important in ***ECG and EEG applications*** to ensure efficient signal transmission between electrodes and the measurement equipment
iii. Impedance matching is crucial in ***implantable medical devices*** such as pacemakers and defibrillators. Matching the impedance between the implanted device and surrounding tissues
iv. Biotelemetry Systems
v. Photoplethysmography
vi. Biomedical Sensors

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