**Impedance Analyzer**.

An impedance analyzer can be used to measure the impedance, admittance, resistance, capacitance, reactance, or inductance of a passive electronic device. It can also be used to determine the input or output impedance of a circuit, or to measure the amplification (attenuation) and the phase shift of four terminal devices, such as filters and amplifiers.

Impedance measurements on two terminal devices.

To use the 4192A for impedance measurements place the Direct Couples HP16047A test fixture on the inputs named UNKONWN. These are LCUR, LPOT, HPOT, and HCUR. Switch the cable length switch (positioned next to the BNC connectors) to zero meters. Two terminal devices can be inserted in the test structure. Several types of measurements can be performed with the instrument. The type of measurement can be selected by the arrow buttons in the "display A and display B" part of the keyboard. The following choices are available:

1.Measurement of Impedance (or Admittance) in terms of modulus (|Z|/|Y|) and argument (Θ): Display A shows the modulus of the impedance or the admittance and display B shows the argument of the impedance or the admittance.

2.Measurement of the impedance in terms of resistance (R) and Reactance (X): Display A shows the resistance and display B shows the reactance.

3.Measurement of the inductance (L):  display A shows the inductance and display B shows the reactance.

4.Measurement of the capacitance (C): display A shows the capacitance and display B shows the reactance.

For mode 3 and 4 it is also possible to select the quality factor (=Q) or the dissipation factor to be shown on display B.

An impedance element can be represented by a simple series or parallel equivalent circuit comprised of resistive and reactive elements. This representation is possible by either of the (series or parallel) equivalents as both have identical impedances at the selected measurement frequency. The 4192A uses the selected circuit mode model to calculate the displayed values. In equivalent series circuit mode the system will display the impedance, i.e. R+jX. In the equivalent parallel circuit mode the system will display the admittance, i.e. G+jB. Only if no resistance and or conductance are present, and the measured impedance is purely imaginary, both measurement modes will give the same answer. In all other cases the results obtained in both measurement modes can be converted to each other by the equations given in the table below. Resistance and reactance are normally expressed in Ohms. The conductance (G) and the susceptance (B) are expressed in Siemens. One Siemens is similar to a reciprocal Ohm. The relation between all those quantities is given by:

$$Z = R + jX = \frac{1}{Y} = \frac{1}{G+jB} = \frac{G-jB}{G^2+B^2} = \frac{G}{G^2+B^2} - \frac{B}{G^2+B^2}j$$

The dissipation fact D is defined as:

$$D = \frac{G}{B} = \frac{R}{X}$$

**Table 1: Relations between different measurement modes.**

| Circuit Mode | | Dissipation Factor | Conversion to other mode | Conversion to other mode. |
|---|---|---|---|---|
| C | Parallel | $D = \dfrac{G}{\omega C_p} = \dfrac{1}{Q}$ | $C_s = \left(1 + D^2\right)C_p$ | $R = \dfrac{D^2}{1 + D^2}C_p$ |
| C | Series | $D = \omega C_s R = \dfrac{1}{Q}$ | $C_p = \dfrac{1}{1 + D^2}C_s$ | $G = \dfrac{D^2}{1 + D^2}\dfrac{1}{R}$ |
| L | Parallel | $D = \omega L_p G = \dfrac{1}{Q}$ | $L_s = \dfrac{1}{1 + D^2}L_p$ | $R = \dfrac{D^2}{1 + D^2}\dfrac{1}{G}$ |
| L | Series | $D = \dfrac{R}{\omega L_s} = \dfrac{1}{Q}$ | $L_p = \left(1 + D^2\right)L_s$ | $G = \dfrac{D^2}{1 + D^2}\dfrac{1}{R}$ |

The measurement principle is shown in Fig. 1. The 4192A uses a four terminal measurement technique. The oscillator (HCUR site) creates an oscillating current that is lead through the DUT. The current is measured at the LCUR site. Since the current is returned through the shielding of the BNC cable there is no magnetic field generated outside the BNC cables. Since the measurement signal current does not develop an inductive magnetic field, the test leads do not contribute additional measurement errors due to self-or mutual-inductance between the individual leads. Fig.1 also shows that a vector voltmeter is used to measure the voltage over the DUT (complex voltage).
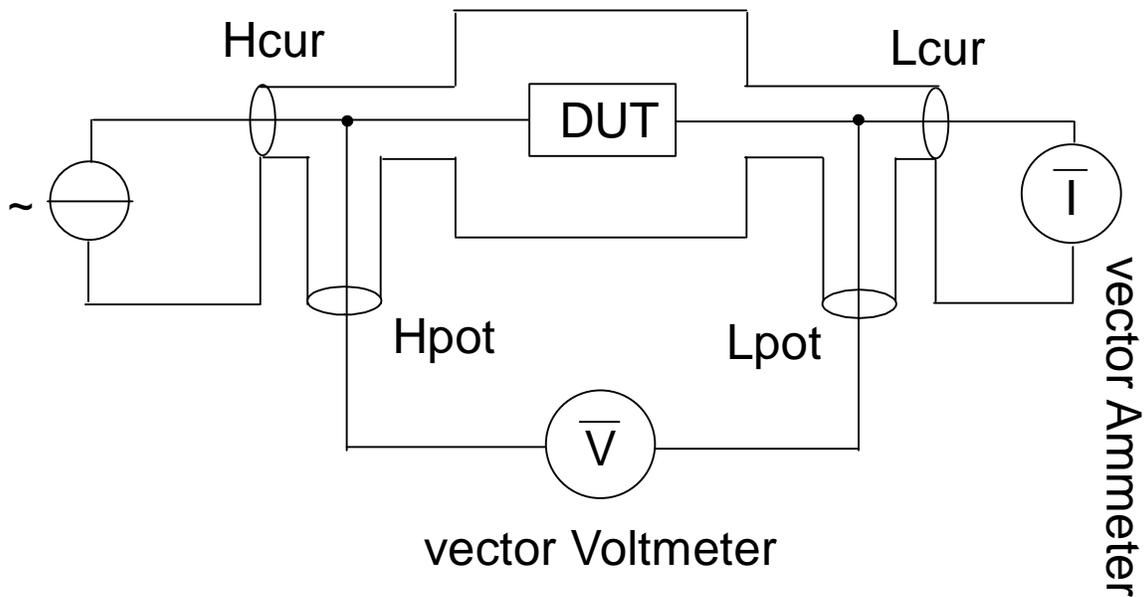


**Fig. 1: Four terminal measurement technique.**

Operating instructions for measurement at one frequency:
1. Switch on the system.
2. Connect the 16047A test fixture to the unknown terminals.
3. Select the desired Display A parameter by pressing the up or down keys in the "display A and B" part of the keyboard.
4. Select the desired equivalent circuit mode, i.e. series or parallel.
5. Select the desired ZY range by pressing the up or down keys. It might be best to select the AUTO option.
6. Press the SPOT FRQ key. Set the desired spot frequency with the data input keys.
7. Press the OSC LEVEL key. Set the desired measuring signal level with the data input keys.
8. Insert a low impedance shorting-bar to the test fixture to simulate a zero ohm resistor.
9. Press the BLUE key and then the ZERO SHORT key. Indicator lamp will come on and R and X reactance offset adjustments are automatically performed at the spot frequency displayed on Display C.
10. Remove the shortening-bar.
11. Set the circuit mode to parallel.
12. Press the BLUE key and the ZERO OPEN key. Indicator lamp will come on and G (conductance) and B (susceptance) offset adjustments are automatically performed at the spot measuring frequency displayed on Display C.
13. Connect your DUT to the test fixture. Make sure that the trigger mode is INTERNAL.

Operating instructions for swept frequency measurements:
1. Follow the instructions as given above. Do the zero offset adjustment procedure for the highest frequency at which you would like to do your measurement. The 4192A will derive the zero-offset adjustments at lower frequencies from the high frequency adjustment values.
2. Press the START FREQ key. Set the start (lower limit) frequency with the DATA input keys and press the appropriate unit key.
3. Press the STOP FREQ key. Set the stop (upper limit) frequency with the DATA input keys and press the appropriate unit key.
4. Press the STEP FREQ key. Set the desired step frequency with the DATA input keys and press the appropriate unit key.
5. For a manual sweep use the STEP-UP and STEP-DOWN keys to change the frequency.
6. For an auto sweep use the SCI program on computer KIRK. For more information on how to communicate with measurement equipment via the SCI program, please check the Manual of the Metrics Software.

Measurements of the transfer function of a four terminal device (Bode plotter):

The 4192A LF impedance analyzer can accurately measure the gain/loss, phase, group delay and level of many types of circuits. In amplitude/phase measurements, the output signal from the OSC OUTPUT terminal is applied to a power splitter to produce two output signals that are in phase and of equal amplitude. One of these signals is applied to CHANNEL A and is used as a reference input; the other signal is applied to input port of the network under test. The output port of the network is than connected to CHANNEL

B. For this type of measurements it is not possible to use the test fixture. A block diagram of the experimental setup is given in Fig. 2.

The type of measurement can be selected by the arrow buttons in the "display A and display B" part of the keyboard. The following choices are available:
1. B-A (dB): In this mode display A will show the ratio between signal B (output) and signal A (input) in dB. On display B you can show the phase shift in degrees or radian ($\Theta$ option).
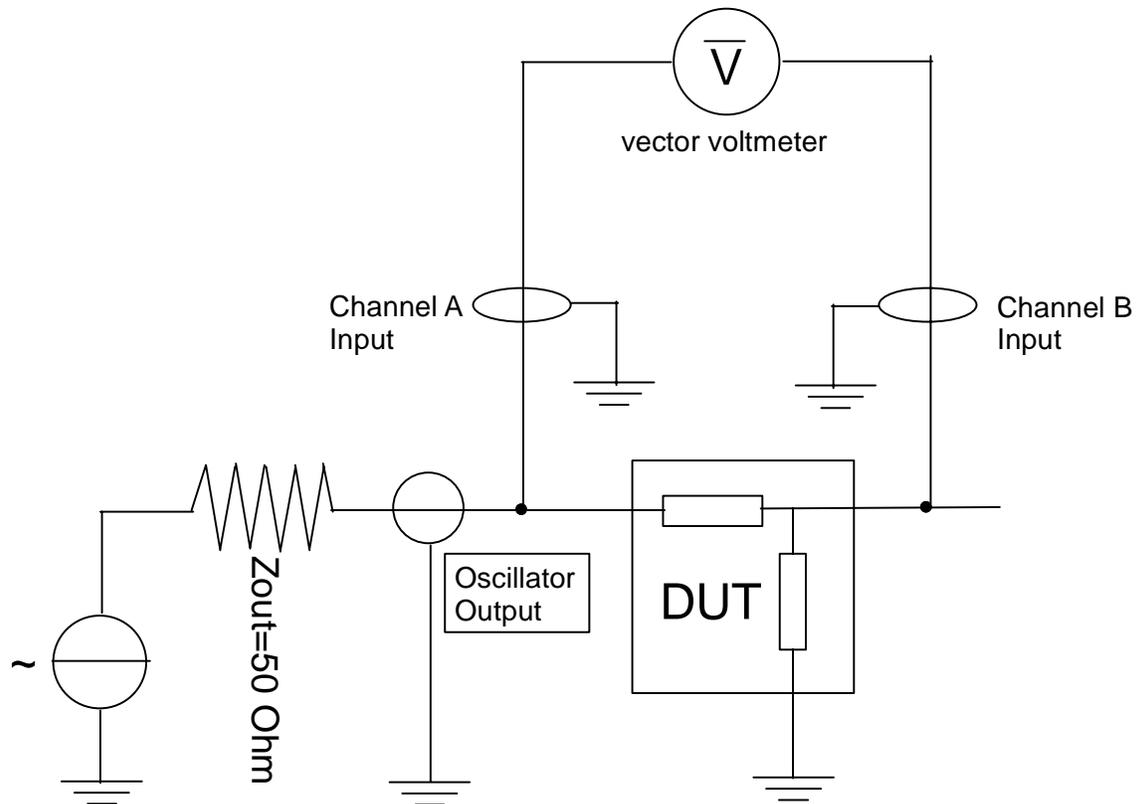2. etc.



**Fig. 2: Block Diagram attenuation/phase measurements.**