

The Ohm's Law

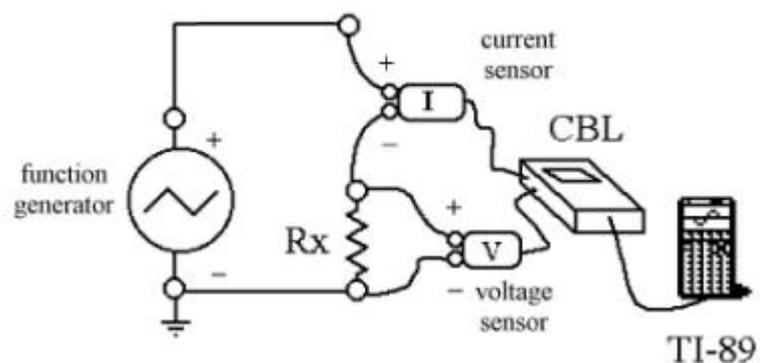
Goal of the experiment is to find the relation between the voltage across a ceramic resistor and the current flowing through a circuit including the resistor.

We chose to use a low frequency function generator with bipolar outputs signals.

Current and voltage measurements, using 3 different resistors and both triangular and sinusoidal waveform, are performed .

Content:

- Theoretical model
- Apparatus setup (TI89)
- Data acquisition (TI89)
- Data samples
- Data analysis (TI89)
- Data analysis (MSExcel)



Theoretical model

The Ohm's Law, is normally written

$$V = RI$$

where the constant R relating the voltage V to the current I , is the *resistance* that depends on the conductor characteristics.

This law defines the resistance unit of measurement:

$$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

that has the symbol Ω .

This definition holds only when the ratio between voltage and current does not depend on the current direction nor on the frequency in the case of alternating current.

The resistance depends on the kind of material and on the conductor geometry.

In particular, when the conductor has constant cross section (e.g. a wire), R is directly proportional to its length l and inversely proportional to its cross section S .

$$R = \rho \cdot \frac{l}{S}$$

The resistivity in the International System is measured in Ωm ; sometimes the non-standard unit $\Omega \times cm$ is used. The conversion factor is: $1 \Omega \times cm = 100 \Omega \times m$.

An alternative non standard unit is $\frac{\Omega \cdot mm^2}{m}$.

Apparatus setup (TI89)

Materials:

- 1 CBL2 or LabPro interface
- 1 TI-89 or TI-92 graphing calculator
- 2 current/voltage sensors
- 1 function generator
- 1 resistor holder
- 3 resistors (nominal values : 100Ω , 220Ω , 470Ω)
- 5 wires

The circuit scheme is reported in the previous page.

Probe Setup

The graphing calculator must have loaded the software science() for data acquisition and handling.

The system should be set as suggested in the following procedure:

- Connect the function generator to the power supply, set knob A to the second frequency range , knob B to zero and knob C to triangular waveform.
- Connect probes to CBL: e.g. connect the voltage probe (sensing the voltage across the resistor) to channel 1 and the current probe to channel 2; check the probe polarity.
- Start the software science() on the graphing calculator and reach the Main Menu.
- In Main Menu select 1:SETUP PROBES ; probe number 2:TWO . Select $\pm 10V$ volotage probe and current probe.
- Zero probes according to zeroing procedure (see the help box in CD or web site)
- In order to test the result of zeroing, in Main Menu select 2:ACQUISITION , and 1:MONITOR . If successful, press + to exit and you go back to Main Menu to proceed with data acquisition.

Data Acquisition (TI89)

- In Main Menu select 2:ACQUISITION , and 2: TIME GRAPH
- Set as sampling interval 0.01 s, and as sample number
- Confirm by pressing ENTER three times until "system ready" appears.
- Switch on the function generator by turning knob D approximately up to half turn (Green LED on)
- Press ENTER to start acquisition
-

During the acquisition a green LED keeps blinking on CBL. At the end a message appears showing the variables used to store thye recorded data.

Data Sample

If the experimental apparatus is not available you may download from CD or on web site data set formatted for TI-89 or in Excel format:

- 100Ω resistor with sinusoidal signal: sin100
- 100Ω resistor with triangular signal: tri100
- 220Ω resistor with sinusoidal signal: sin220
- 480Ω resistor with sinusoidal signal: sin480

Data Analysis (TI89)

The present analysis is made for data taken with a ceramic resistor, with nominal value $R=100\ \Omega$ (5% tolerance).

The sample data for the graphing calculator are in the files:

- [sin100.89c](#) for sinusoidal waveform;
- [tri100.89c](#) for triangular waveform;
- The sample data taken with $220\ \Omega$ resistor are in the file: [sin220.89c](#)
- The sample data taken with $480\ \Omega$ resistor are in the file: [sin480.89c](#)

The first column (labeled C1) stores time values; the second column (labeled C2) stores voltage values and the third column (labeled C3) stores current values.

Graphs display

Using sinusoidal waveform, and choosing 1:CHANNEL 1 we plot $V(t)$ (Fig. 1), choosing 2: CHANNEL 2 we plot $I(t)$ (Fig. 2).

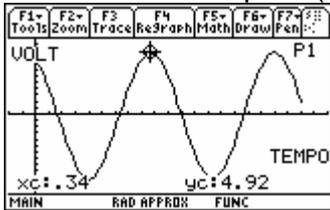


Fig. 1 - $V(t)$

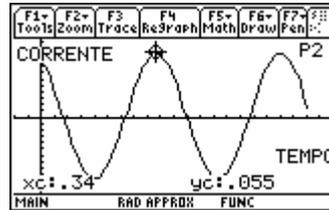


Fig. 2 - $I(t)$

Using triangular waveform, the graphs $V(t)$ (Fig. 1) and $I(t)$ are shown in figures 3 and 4.

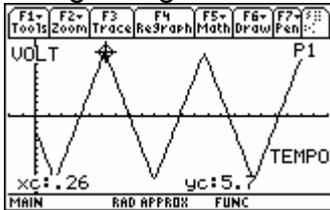


Fig. 3 - $V(t)$

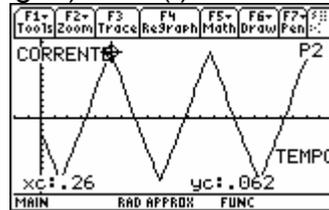


Fig. 4 - $I(t)$

We may note that current and voltage signals are in fase.

Looking for a relation between voltage and current

In Main Menu select 3:ANALYSIS, then 1:PLOT/FIT, then 2:FIT . On the horizontal axis we place current , thus we select 3:channel 2 . On the vertical axis we place voltage 2: channel 1 .

As PLOT OPTIONS we choose 1:POINTS , as type of fit we choose 1:LINEAR . The resulting best fit parameters are shown in figure 5, and the fitting line, together with the values of measured voltage vs current are shown in figure 6.

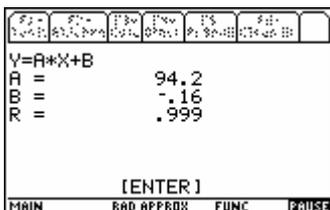


Fig. 5 - best fit parameters

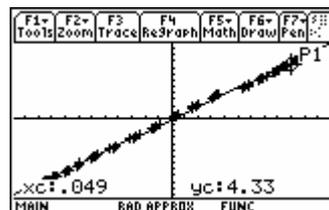


Fig. 6 - fitting line $V(I)$

The chosen linear model is in good agreement with the experimental behaviour. The value of the intercept is negligible, so that proportionality is well obeyed, and the constant ratio V/I (that equals the slope DV/DI) gives the value of the resistance $R = V/I$

The resulting value $R=94 \Omega$ is, within 6%, in agreement with the nominal value $R=100 \Omega$. Similar result is obtained working with the second sample data taken with triangular waveform.

Working with the 220Ω resistor (file [sin220.89c](#)) we obtain for the slope: $R=224 \Omega$, and with the 480Ω resistor (file [sin480.89c](#)) we get: $R=475 \Omega$.

We may conclude that all the used components obey the Ohm's law: plotting the three data sets in a single graph we see the different slopes corresponding to the different resistance values (figure 7).

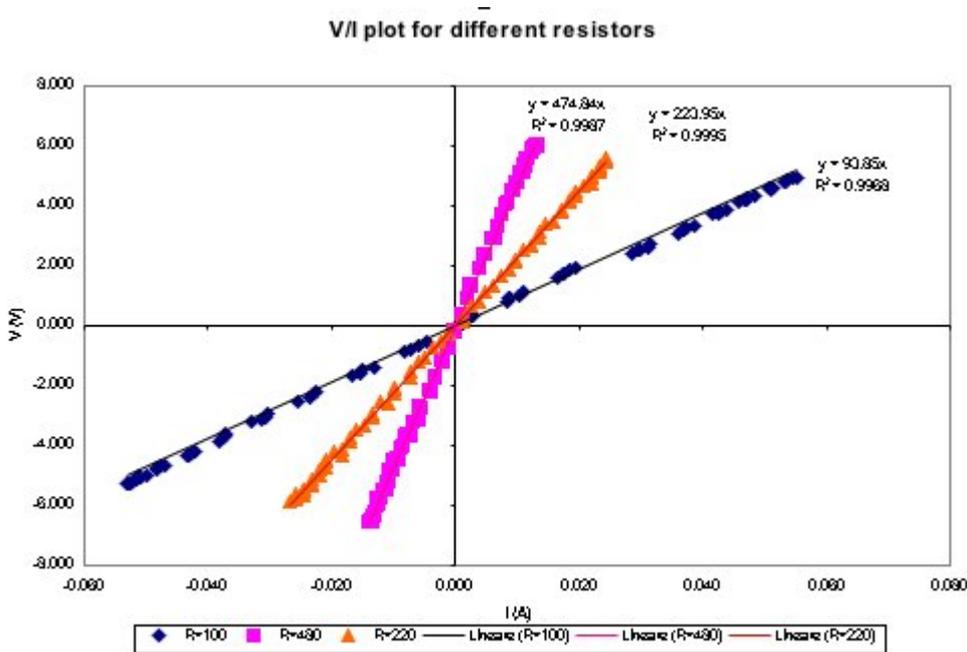


Fig. 7 - Graph V(I)

Data Analysis (MS-Excel)

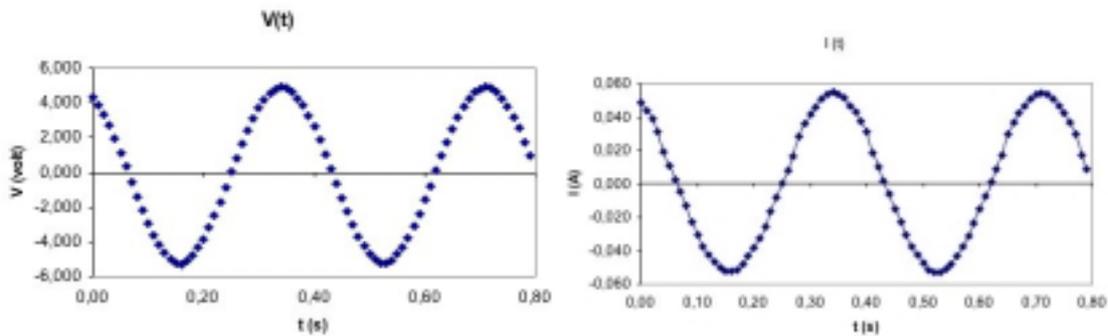
The present analysis is made for data taken with a ceramic resistor, with nominal value $R=100 \Omega$ (5% tolerance). The raw data imported from graphing calculator are contained in file [sin100.89c](#).

To export data in an Excel see the help box on CD or web site.

The first column (labeled A) stores time values; the second column (labeled B) stores voltage values and the third column (labeled C) stores current values.

Time graphs

First you may build the plot of voltage vs. time, figure 1 and the plot of current vs. time, figure 2. You can find an help box on CD or web site.



Looking for the relation between current and voltage

To look for a mathematical model of the relation between voltage and current we must first build a graph with the current (column C) as abscissa and voltage (column B) as ordinate.

If you need you can find an help box on CD or web site ("[How to graph data when columns are not adjacent](#)").

The resulting graph is shown in figure 3, where points follow a straight line. We may therefore try a best fit with a linear function.

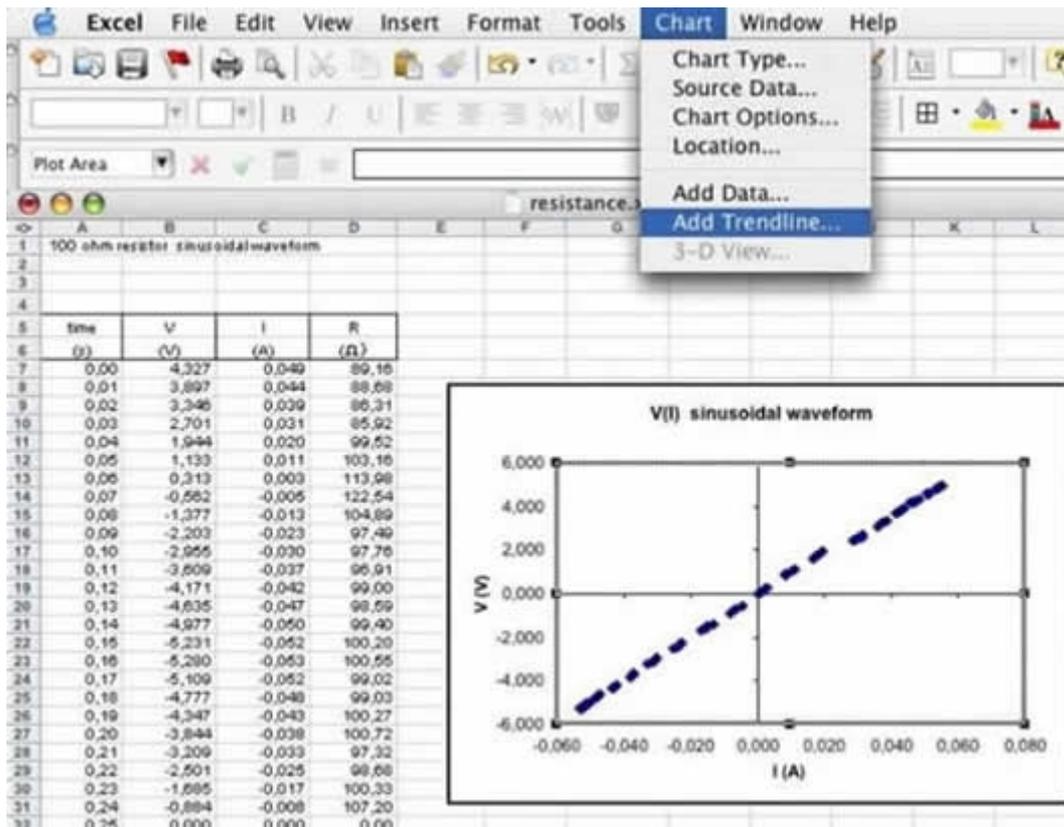


Fig. 3 - Building the graph V(I) and adding a trendline

By first selecting the columns and then by right-clicking the mouse button, appears a menu (figure 3) where you may select "Add trend line". On the next window, figure 4, in menu Type select L linear; choose Options and check the buttons "Set intercept = 0"; and "Display equation on chart"

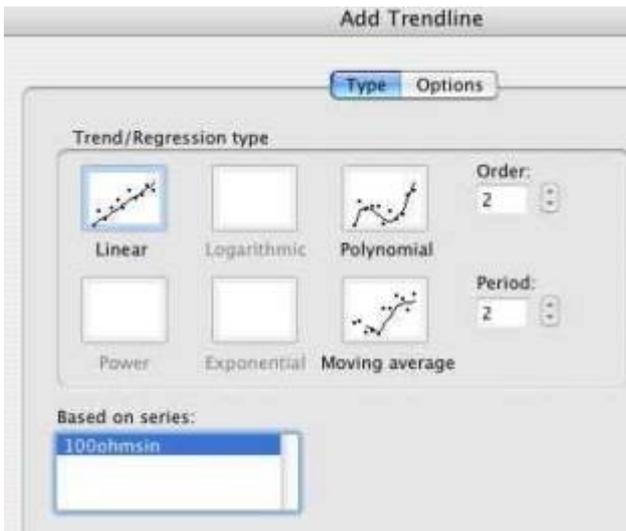


Fig 4



Fig 5

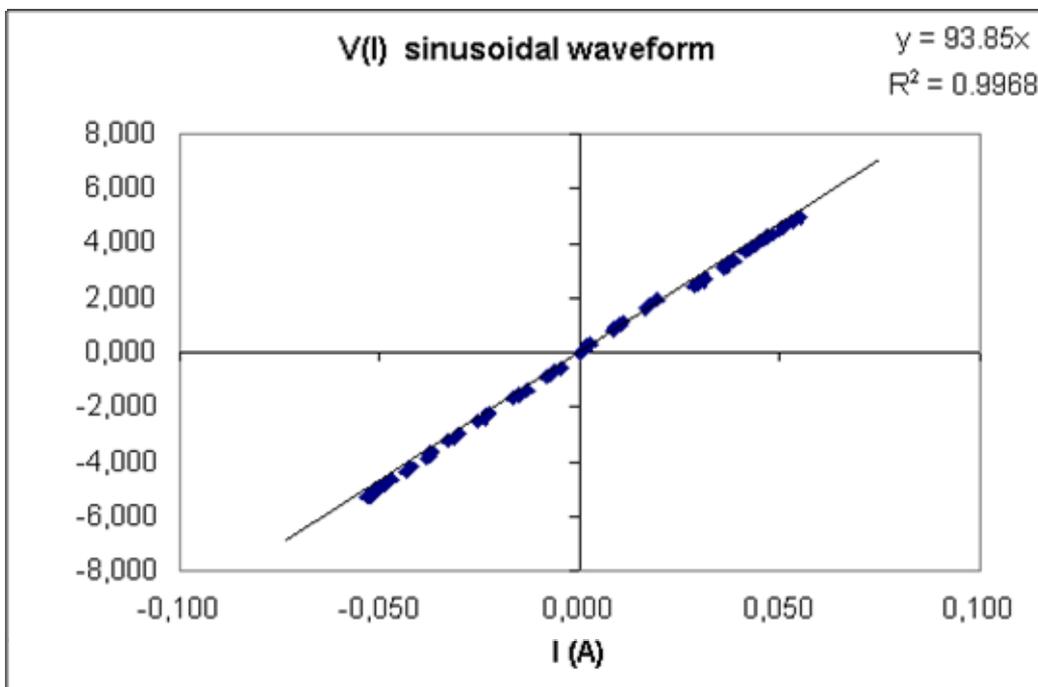


Fig. 6 - Graph $V(I)$ with fitting line and equation

The R^2 value, close to unity, suggests that the linear model is appropriate, i.e. $V/I=R$. The resulting value $R=93.85 \Omega$ is, within 6%, in agreement with the nominal value $R=100\Omega$.

Similar result is obtained working with the second sample data taken with triangular waveform $R=94.\Omega$.

Working with the 220Ω resistor (file sin220.89c) we obtain for the slope: $R=224\Omega.$, and with the 480Ω resistor (file sin480.89c) we get: $R=475 \Omega$.

We may conclude that all the used components obey the Ohm's law: plotting the three data sets in a single graph we see the different slopes corresponding to the different resistance values.

Comparison of data taken with different resistors

For all resistors the measured values are compatible with the nominal ones within the uncertainties.

We may plot in a single graph the voltages vs. currents for the different resistors (figure 7): the fitting lines with different slopes correspond to different resistances

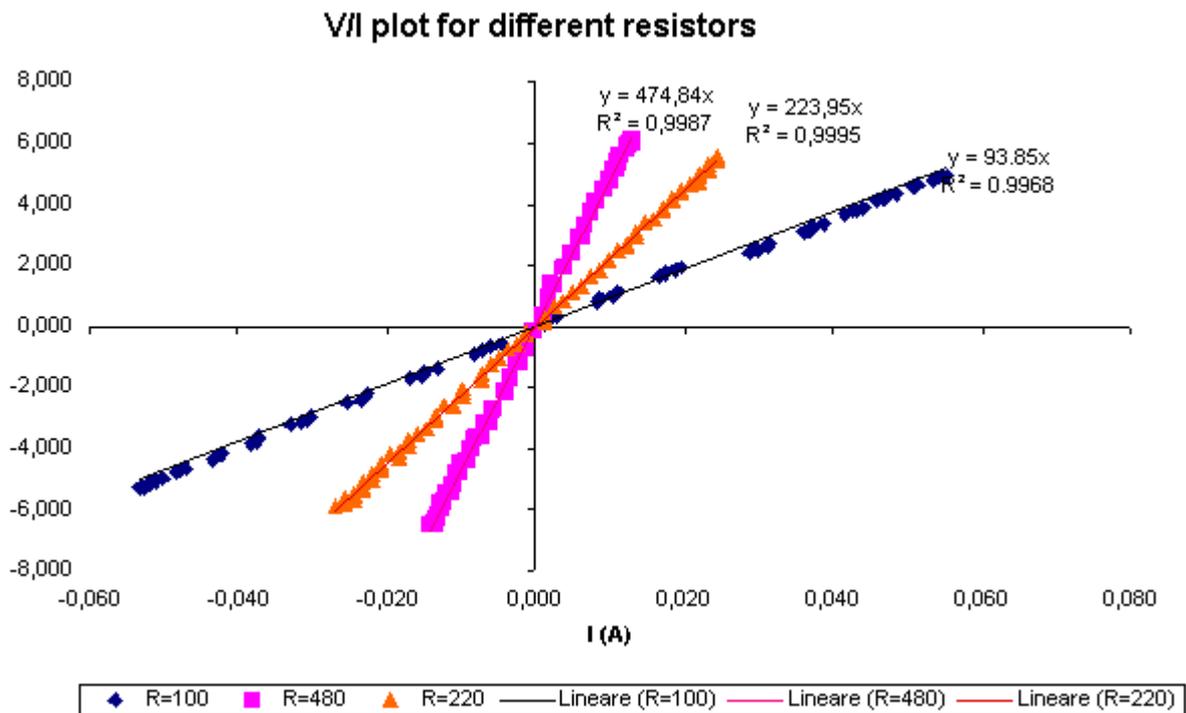


Fig. 7 - Graph V(I)