USB Impedance Meter

Design, construction and measurements with Visual Analyser

An English technical adaptation of the historical Nuova Elettronica article (LX.1746 / KM1667).

Historical edition — important notice. *This article describes a USB impedance meter and the Visual Analyser software as they existed at the time of the original *Nuova Elettronica* publication. Screenshots, menu labels, installation procedures, operating-system requirements (Windows XP/Vista), component availability and prices are historical and* ***must not be interpreted as current instructions or as a description of Visual Analyser 26****. The measurement principles remain useful. For present-day functions and compatibility, consult the current Visual Analyser documentation. This edition is a* ***restructured technical adaptation****, not a page-by-page literal translation; circuit component designations and the original measurement data are retained. Original drawings are reproduced for documentary reference.*

Overview



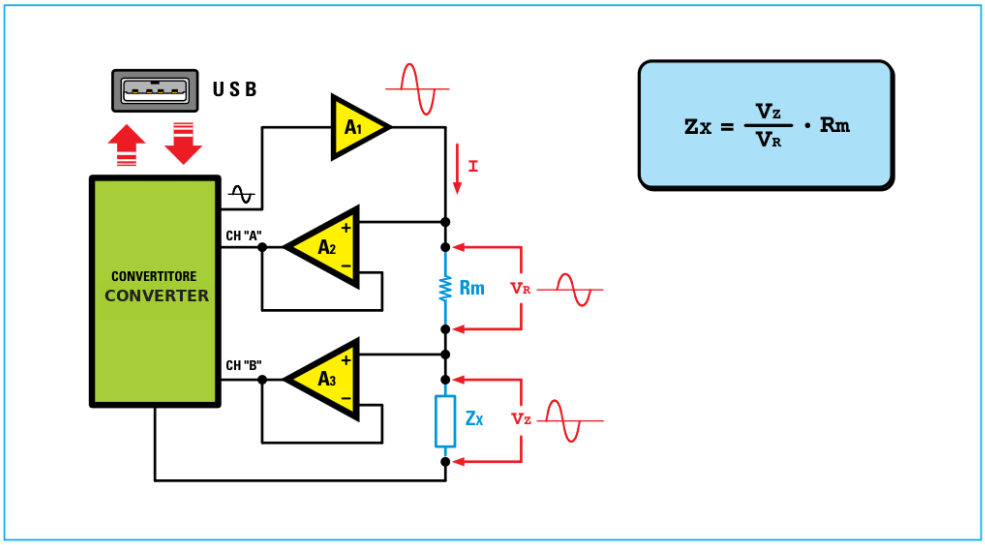
Original USB impedance meter and test components.

This instrument extends well beyond an ordinary capacitance or inductance meter. Controlled from a personal computer over USB, it can measure the impedance of capacitors, inductors, audio transformers, loudspeakers and many other electronic components. Besides impedance magnitude, it determines resistive and reactive components and the phase angle. It can display equivalent series and parallel circuits and a vector representation of the measured impedance.

The concept separates a compact hardware front end from the computation performed by the PC. In the original design, a PCM2902 USB audio codec handles digital-to-analogue conversion of the

excitation signal and simultaneous acquisition of two measurement channels. Visual Analyser provides waveform generation, signal processing and the measurement interface. The software and processing algorithms were developed with the contribution of engineer Alfredo Accattatis, then a researcher at the University of Rome Tor Vergata.

1. Measurement principle



Measurement principle: USB converter, reference resistance, and unknown impedance.

The unknown impedance **Zx** is connected in series with a known precision resistor **Rm**. A sinusoidal excitation drives both components, so the same current **I** passes through them. Measuring the voltages across the resistor (**Vr**) and the unknown component (**Vz**) gives:

Vr = **I Rm**; **Vz** = **I Zx**; therefore **Zx** = **Rm (Vz / Vr)**.

These equations are phasor relationships: in AC operation the voltage amplitudes alone yield the magnitude, while the relative phase provides the complex impedance. If the phase difference is **φ**, then **Z** = **R** + **jX** = **|Z|(cos φ** + **j sin φ)**, with **R** = **|Z| cos φ** and **X** = **|Z| sin φ**. A positive reactance indicates an inductive response; a negative reactance indicates a capacitive response.

The two acquired channels must remain synchronized. Accurate phase estimation is particularly important when a component is predominantly reactive and its small loss resistance must be resolved. The original article discusses synchronized acquisition, zero-crossing information and digital signal processing as essential aspects of instrument accuracy.

For a series equivalent circuit, an inductor is characterized by **Ls** = **X/(2πf)** when X is positive; a capacitor by **Cs** = **−1/(2πfX)** when X is negative. These formulas describe equivalent parameters at the selected measurement frequency, not necessarily frequency-independent physical constants.

2. Hardware architecture

The original hardware uses the **KM1667** module containing the **PCM2902** USB codec, fitted to the **LX.1746** main circuit board. A computer-generated digital sine wave is converted to analogue, amplified by **TDA7052** (IC3) and applied to the series circuit formed by the reference resistor and the device under test (DUT).

Two unity-gain analogue buffer stages, built around the **NE5532** (IC1/A and IC1/B), feed the measurement signals back to the codec's two inputs. The **MC34063A** switching regulator (IC4) generates a negative supply rail from the +5 V USB supply. The LED **DL1** indicates the presence of USB power.

A two-pole six-position switch **S1** selects the appropriate precision reference resistor. Five positions provide the measurement ranges; the sixth was reserved for future applications. The resistor values are:

Switch position	Reference resistor
1	10 Ω
2	100 Ω
3	1 kΩ
4	10 kΩ
5	100 kΩ
6	Reserved / external connector

Critical rule: the physical switch position and the software range setting must match. A mismatch directly corrupts the calculated impedance.

At 1 kHz, the original publication quotes indicative measurement spans of **1 µH to 100 H** for inductance, **10 pF to 1,000 µF** for capacitance and **0.1 Ω to 10 MΩ** for resistance. These are historical figures from the article; practical accuracy depends on frequency, range, parasitic impedances, calibration and signal-to-noise ratio.

3. Circuit implementation and components

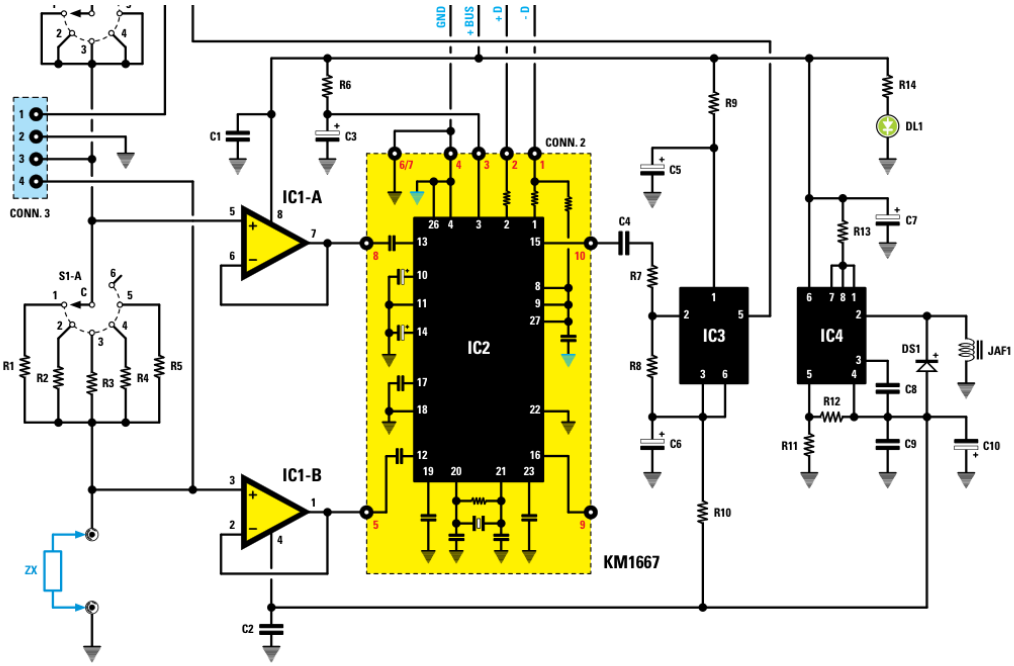


Fig.3 Schema elettrico dell'impedenzimetro. A sinistra è visibile il commutatore S1

Original LX.1746 circuit diagram, reproduced for historical reference.

The original schematic uses a detachable PCM2902-based KM1667 board and a separate LX.1746 PCB. The five precision resistors **R1**–**R5** have a nominal tolerance of 1%; their values are respectively 10 Ω, 100 Ω, 1 kΩ, 10 kΩ and 100 kΩ. The switching, supply and signal paths are shown in the original schematic retained in this edition.

Other original component values are: R6 10 Ω; R7 33 kΩ; R8 680 Ω; R9 and R10 1 Ω each; R11 8.2 kΩ; R12 2.7 kΩ; R13 0.22 Ω; R14 680 Ω. C1 and C2 100 nF polyester; C3 100 µF electrolytic; C4 1 µF polyester; C5–C7 100 µF electrolytic; C8 1.5 nF polyester; C9 100 nF polyester; C10 470 µF electrolytic. JAF1 is a 100 µH choke; DS1 is a BYW100 diode. The original active devices are IC1 NE5532, IC2 KM1667/PCM2902 module, IC3 TDA7052, IC4 MC34063A.

The references and values above reproduce the historical bill of materials. They are not a new validation of substitute parts or of the suitability of the circuit for contemporary USB ports.

4. Assembly notes

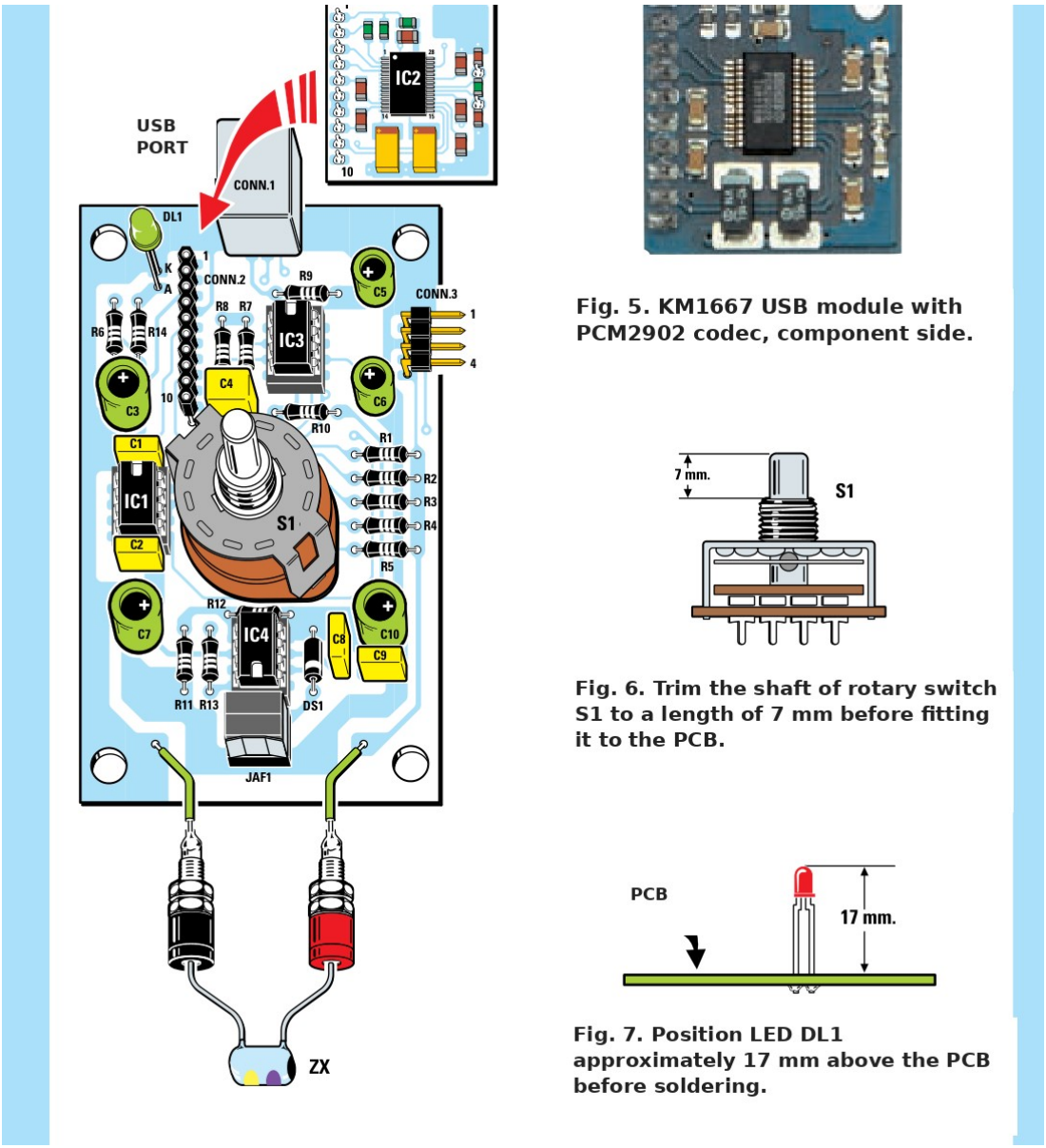


Fig. 5. KM1667 USB module with PCM2902 codec, component side.

Fig. 6. Trim the shaft of rotary switch S1 to a length of 7 mm before fitting it to the PCB.

Fig. 7. Position LED DL1 approximately 17 mm above the PCB before soldering.

Assembly diagram with English explanatory notes (Figs. 5–7).

The original article describes installing the IC sockets, then the five 1% reference resistors and remaining resistors, followed by switch S1, film capacitors, electrolytics, diode, indicator LED, choke and connectors. Correct component orientation matters: check the diode band, electrolytic polarity, LED anode/cathode and IC pin-1 markers before soldering.

For the published enclosure, the shaft of S1 was shortened to approximately **7 mm**, and the indicator LED positioned approximately **17 mm** above the PCB. The KM1667 daughterboard plugs into the ten-pin connector **CONN.2**, above the main board; proper alignment prevents bent contacts and accidental shorts. The output terminals connect to the DUT through short leads.

The original enclosure illustrations document the assembly geometry. Component dimensions and mounting details apply only to that historical kit.

5. Historical software environment

This section documents the original release, not the installation procedure for modern Visual Analyser. The publication lists Windows XP Home/Professional and 32-bit Windows Vista, a Pentium-class PC, 32 MB RAM, 20 MB of free disk space, a CD/DVD drive, 800 × 600 video and a USB port. These specifications are reproduced for archival accuracy only.

The original procedure required the operator to select **USB Audio CODEC** as both input and output device. It specified a **4096-point FFT**, a sampling frequency of **40,960 Hz**, smoothing set to **None**, and **Delay A ch (samples)** = **1**. In the ZRLC options, the relevant settings included **CC level**, the **Fourier** measurement method and **AutoBias** for automatic calibration. The Windows mixer output volume also had to be appropriately enabled.

The names and locations of these controls belong to the historical user interface. They should not be used as a setup checklist for the current VA version without separate verification.

6. Instrument controls and displays

In the original ZRLC interface, **frq. (Hz)** selects the test frequency. **Filter on** enables a software filter intended to reduce excitation distortion. **Loop** repeats measurements and refreshes the displayed result; **On top** retains the measurement window above others. **Reference (Ohm)** identifies the selected reference resistance and its associated range.

Auto selects the guided measurement sequence. In **Manual** mode, the user can select resistance, inductance or capacitance and the preferred units. **Circuit** and **Ser./par** control display of the equivalent circuit; **Vect.** opens a vector representation with real and imaginary components. **Measure** starts the sequence and **Stop** ends it. The results include capacitance, inductance, $|Z|$, real part, imaginary part and phase, together with a quality-related indicator when provided by the historical implementation.

7. Calibration, zeroing and measurement

The article separates a measurement into three operations: **calibration**, **zeroing** and **measurement**.

Open-circuit calibration: leave the DUT terminals disconnected. The system compares the two acquisition paths and compensates small channel differences. Perform it when operating conditions change, including test frequency or relevant measurement settings. Performing this step with a component connected can introduce a large error.

Short-circuit zeroing: short the DUT terminals when the procedure requires it. This compensates residual offsets and is especially relevant for small impedances. Use a secure, low-resistance connection for the short.

Measurement: connect the DUT only when the instrument requests it, select a suitable reference resistor and observe the numerical result together with the acquired waveforms. In the guided

automatic sequence, calibration is carried out with open terminals before attaching the component. In the historical interface, messages such as “REMOVE DUT, check range, press MEASURE” and “Calibration, do NOT connect DUT yet” guided the user through these stages.

Keep excitation amplitude below the point at which the signal clips or otherwise becomes distorted. The original automatic mode adjusted this parameter; the manual mode included an amplitude control.

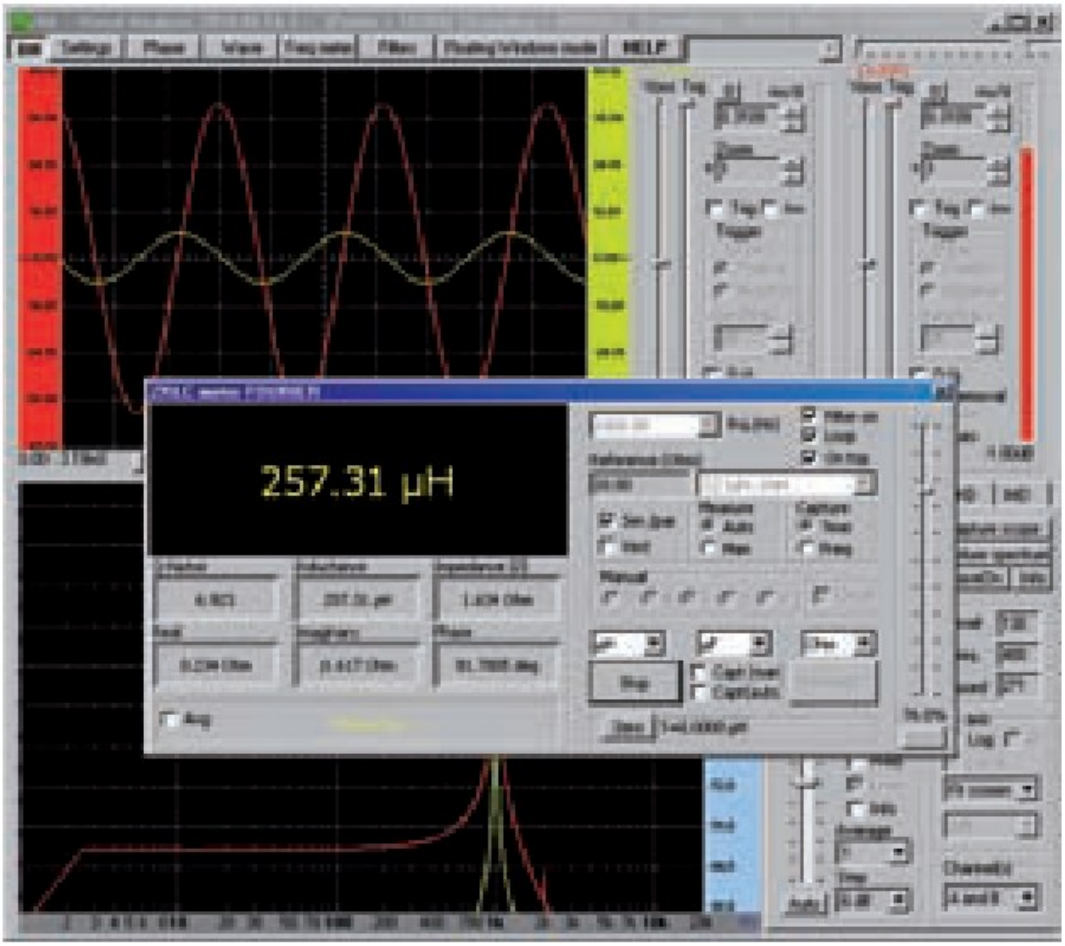
8. Choosing the correct range

A useful reference resistance is usually close to the magnitude of the unknown impedance at the selected test frequency. If **Rm** is far larger than |Zx|, nearly all the excitation appears across the reference resistor and the voltage across the DUT becomes too small to measure accurately. If **Rm** is far smaller, the reference-resistor voltage becomes too small and current estimation deteriorates.

The original article illustrates these effects at approximately **35 Ω** using reference resistors of 10 Ω, 100 Ω and 1 kΩ. The first two ranges can be usable, whereas the 1 kΩ range leaves a weak DUT signal. It also describes very low-impedance measurements where 10 Ω is the most appropriate available reference.

The historical software used **d** (“down”) to suggest selecting a smaller reference resistor, **u** (“up”) for a larger one, and **?** to flag an anomalous or invalid result. In practice, start with an approximate range, inspect the two waveform amplitudes, and refine the selection. Changing the range requires matching the physical S1 switch to the software entry.

9. Example: measuring an inductor



Historical inductor measurement screen; original software interface retained.

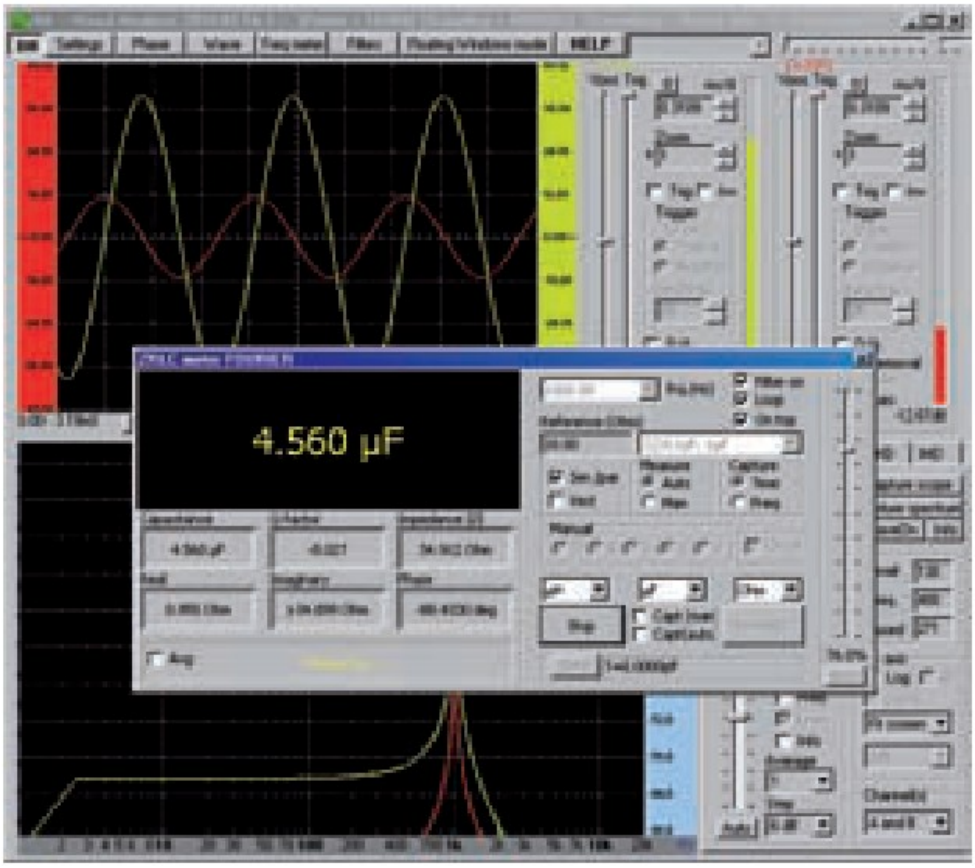
For an inductor nominally **250 µH**, measured at **1 kHz** on range 1, the original article reports:

Quantity	Reported value
Inductance	257.31 µH
Impedance magnitude	1.634 Ω
Real component	0.234 Ω
Imaginary component	+j1.617 Ω
Phase	+81.78°
Q indicator	6.923

The positive imaginary component identifies an inductive load; the angle is less than +90° because the component also has a resistive loss term. In a vector diagram, resistance lies on the positive horizontal axis and inductive reactance on the positive vertical axis. Here **Q ≈ X/R**, the conventional series-model quality factor for an inductor.

The original article also shows a vector-display reading with slightly different values (approximately R = 0.235 Ω, X = 1.619 Ω, |Z| = 1.636 Ω), consistent with separately displayed measurements or rounding.

10. Example: measuring a capacitor



Historical capacitor measurement screen; original software interface retained.

For a nominal **4.7 µF** electrolytic capacitor at **1 kHz**, the reported measurements are:

Quantity	Reported value
Capacitance	4.56 µF
Impedance magnitude	34.912 Ω
Real component	0.955 Ω
Imaginary component	−j34.899 Ω
Phase	−88.43°
Historical “Q factor” field	−0.027

A negative imaginary component indicates capacitive reactance. The angle is not exactly −90° because the capacitor exhibits a resistive contribution, often expressed as equivalent series resistance (ESR). The vector points into the fourth quadrant.

Terminology clarification: the original article labels the last field “Q factor” and explains it as a resistance-to-reactance ratio. In contemporary terminology, $|\mathbf{R/X}| \approx \mathbf{0.027}$ is more naturally described as a **dissipation factor D** or approximately tan δ for the series model; the conventional capacitor quality factor is its reciprocal ($\mathbf{Q \approx |X|/R \approx 36.5}$). The negative sign in the original field reflects the capacitive reactance convention. The historic screen value is preserved above, but should not be confused with the conventional quality factor.

11. Interpreting equivalent circuits

An impedance measurement at a specified frequency provides complex $\mathbf{Z} = \mathbf{R} + \mathbf{jX}$. Series and parallel equivalent circuits are alternate representations of that same two-terminal behavior at that frequency; they are not proof of the component's internal physical construction. For the series-to-parallel conversion, $\mathbf{Rp} = \mathbf{(R^2 + X^2)/R}$ and $\mathbf{Xp} = \mathbf{(R^2 + X^2)/X}$ when R and X are nonzero. Frequency dependence, dielectric losses, winding resistance and parasitics can alter these parameters.

The article's vector display offers an especially useful teaching aid: the horizontal component represents R, the vertical component represents X, and the resultant gives |Z|. Phase and the sign of X help distinguish inductive and capacitive behavior.

12. Practical limitations and present-day relevance

Measurement reliability is affected by the reference resistor, finite channel matching, lead resistance and capacitance, codec resolution, signal amplitude, frequency, and the DUT's non-ideal behavior. Low impedances benefit from careful zeroing; high impedances are particularly sensitive to leakage and stray capacitance. The reported frequency-dependent range capabilities should be understood in that context.

Historically, this project demonstrated how a compact USB hardware interface and desktop software could replace much of the processing circuitry traditionally built into a measurement instrument. That architectural idea remains relevant: waveform generation, synchronous acquisition, phase-sensitive analysis, equivalent-circuit modeling and informative visualization are central to modern impedance measurement systems.

Editorial and historical notes

- Original source: *Nuova Elettronica*, Italian article “Impedenziometro USB per Personal Computer”, reproduced in the supplied 37-page PDF.
- Historical hardware identifiers: **LX.1746** and **KM1667**, with a **PCM2902** USB audio codec.

- Software discussed in the source: a historical release of **Visual Analyser**. It is **not** a guide to current **Visual Analyser 26**.
- This English edition reorganizes and condenses the historical material for technical readability, while preserving the essential design, measurement method, examples, component values and caveats. It is **not an exhaustive literal translation of every sentence**, screenshot or assembly instruction.
- Circuit drawings and photographs remain attributed to their original publication; the relevant reproduction and translation rights should be verified before public redistribution.