

Measurement of quartz crystal unit parameters by zero phase technique in a pi-network —

Part 1: Basic method for the measurement of resonance frequency and resonance resistance of quartz crystal units by zero phase technique in a pi-network

The European Standard EN 60444-1:1997, with the incorporation of amendment A1:1999 has the status of a British Standard

ICS 31.140

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Electronic Components Standards Policy Committee (ECL/-) to Technical Committee ECL/11, upon which the following bodies were represented:

- EEA (the Association of Electronics, Telecommunications and Business Equipment Industries)
- Electronic Components Industry Federation
- Institute of Physics
- Institution of Electrical Engineers
- Ministry of Defence
- National Supervising Inspectorate

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The following BSI references relate to the work on this standard:
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National foreword

This part of BS EN 60444 has been prepared by Technical Committee EPL/49 (formerly ECL/11), and is the English language version of EN 60444-1:1997 including amendment A1:1999, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 60444-1:1986, *Measurement of quartz crystal unit parameters by zero phase technique in a pi-network — Part 1: Basic method for the measurement of resonance frequency and resonance resistance of quartz crystal units by zero phase technique in a pi-network*, including amendment 1:1999 published by the International Electrotechnical Commission (IEC).

Cross references

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Summary of pages

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English version

Measurement of quartz crystal unit parameters by zero
phase technique in a pi-network —
Part 1: Basic method for the measurement of resonance
frequency and resonance resistance of quartz crystal units
by zero phase technique in a pi-network

(includes amendment A1:1999)

(IEC 60444-1:1986 + A1:1999)

Mesure des paramètres des quartz
piézoélectriques par la technique de phase nulle
dans le circuit en pi —

Partie 1: Méthode fondamentale pour la mesure
de la fréquence de résonance et de la résistance
de résonance des quartz piézoélectriques par la
technique de phase nulle dans le circuit en pi
(inclut l'amendement A1:1999)
(CEI 60444-1:1986 + A1:1999)

Messung von Schwingquarz-Parametern nach
dem Null-Phasenverfahren in einem
Pi-Netzwerk —

Teil 1: Verfahren zur Messung der
Resonanzfrequenz und des
Resonanzwiderstandes von Schwingquarzen
nach dem Null-Phasenverfahren in einem
Pi-Netzwerk
(enthält Änderung A1:1999)
(IEC 60444-1:1986 + A1:1999)

This European Standard was approved by CENELEC on 1997-03-11; amendment A1 was approved by CENELEC on 1999-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Foreword

The text of the International Standard IEC 444-1:1986, prepared by IEC TC 49, Piezoelectric and dielectric devices for frequency control and selection, was submitted to the formal vote and was approved by CENELEC as EN 60444-1 on 1997-03-11 without any modification.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1997-12-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1997-12-01

Foreword to amendment A1

The text of document 49/442/FDIS, future amendment 1 to IEC 60444-1, prepared by IEC TC 49, Piezoelectric and dielectric devices for frequency control and selection, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A1 to EN 60444-1:1997 on 1999-10-01.

The following dates were fixed:

- latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2000-07-01
- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 2002-10-01

1 Scope

This standard specifies a simple method of measurement of resonance frequency and resonance resistance of quartz crystal units and describes a suitable measuring network.

The measuring method and the network are suitable for use over the frequency range 1 MHz to 200 MHz with a fractional frequency accuracy of the order of 10^{-6} with a reproducibility of 10^{-6} to 10^{-8} depending on the type of crystal unit being measured, and an accuracy of the measurement of resonance resistance of $\pm 2\%$ to $\pm 5\%$ depending on the accuracy of the voltage measurement.

However, above approximately 100 MHz the use of this measuring method is limited by the effects of the shunt capacitance C_0 of the crystal unit under test. To enable the measuring method to be used under these conditions, the use of some method of C_0 compensation is advisable.

A method of C_0 compensation will be issued in IEC Publication 444-3 as an IEC report.

NOTE The modifications to the measuring system and network contained in this standard have been introduced to ensure that the claims contained within it are achievable. They do not, however, invalidate the network produced according to the first edition. These networks are still acceptable as an international standard method of measurement of resonance frequency f_r and resonance resistance R_r .

If the reference resistors described in the standard are slightly modified to allow insertion into networks manufactured according to the first edition of Publication 444 then the problem of obtaining satisfactory reference resistors is solved.

2 Definition of resonance frequency

The crystal unit is a 3-terminal network with a complex transfer admittance $Y_{12} = G_{12} + jB_{12}$, as defined in sub-clause A.1.1 of Appendix A.

The enclosure is considered as the common terminal.

For glass enclosures, the third terminal is defined in clause 3.

The resonance frequency is defined as the lower of the two frequencies of the crystal unit alone under specified conditions at which B_{12} is zero.

At this frequency, the resonance resistance is $1/G_{12} = R_r$.

3 Reference plane and shielding box

Because of lead inductance of the crystal unit it is necessary to specify a reference plane at which the measurements are to be made. This plane is located at a distance of 2 mm from the place where the pins or leads emerge from the crystal unit, unless otherwise specified. The third terminal for glass enclosures is a metal shielding box with internal dimensions 27 mm in height and the base plane of 40 mm $\times$ 40 mm (base plane = reference plane) and closed at the top. The crystal unit is to be located at the centre of the base plane of the shielding box.

4 Principle of measurement

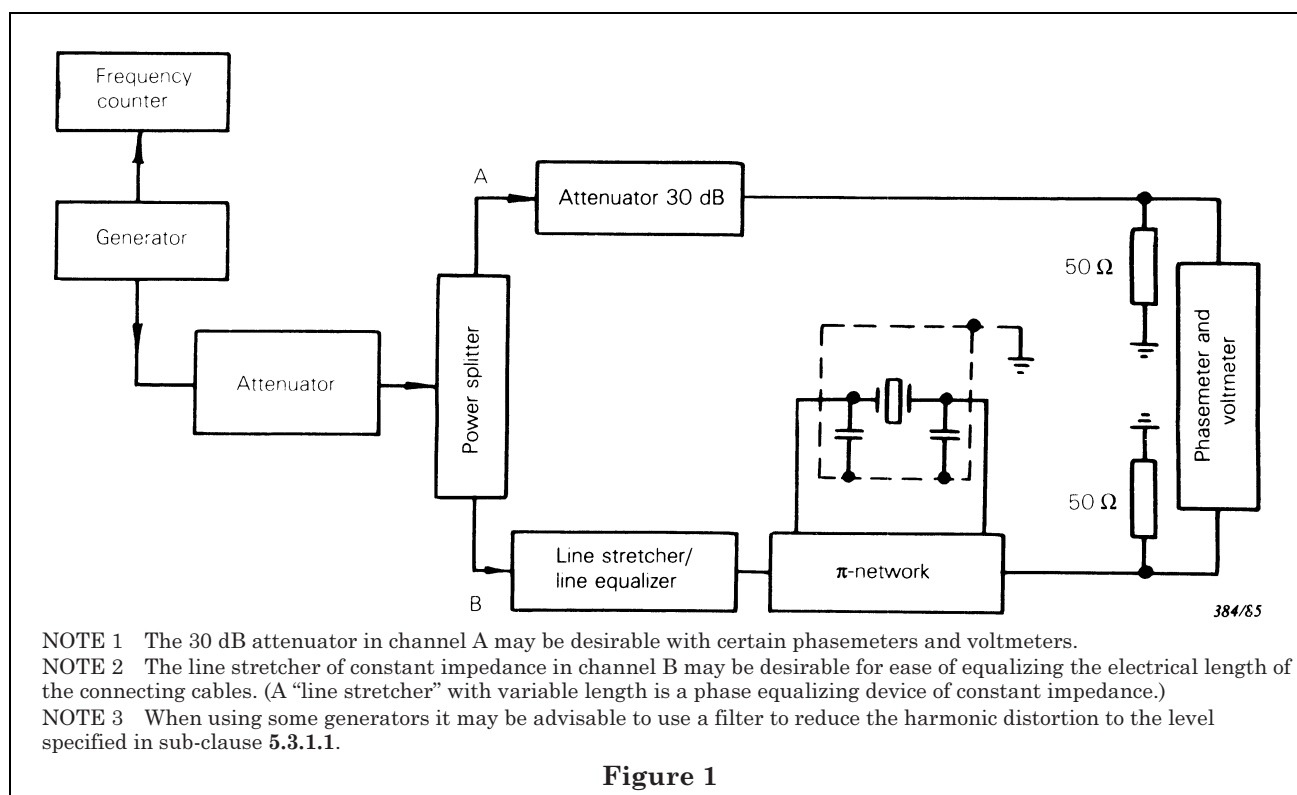
The measurement is reduced to a 2-terminal impedance measurement by inserting the crystal unit in a π -network (see Figure 1).

The phase of the crystal transfer admittance is indicated on a phasemeter connected across the π -network. The frequency giving zero phase reading is measured.

Zero phase is calibrated by inserting a reference resistor in the π -network. The value of the resonance resistance can be calculated from the voltage readings on channels A and B.

5 Measuring circuit

The measuring circuit consists basically of a π -network connected with coaxial cables to the associated equipment (see Figure 1).

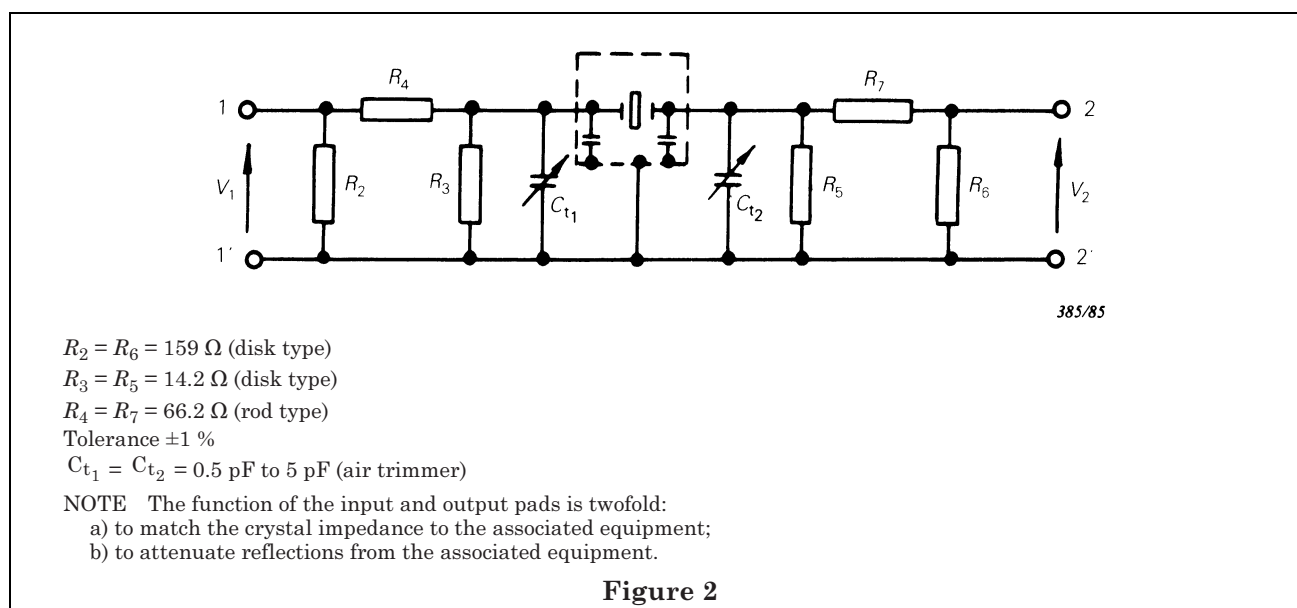


The fact is emphasized that the construction of the π -network determines the accuracy of the set-up, whereas the associated equipment can be extended, if necessary, to produce a very sophisticated set-up. For this reason, only the essential elements of the associated equipment are specified (see sub-clause 5.3).

5.1 The π -network

5.1.1 Electrical specification

5.1.1.1 Circuit diagram



5.1.1.2 The frequency range shall be 1 MHz to 200 MHz.

5.1.1.3 The logarithmic ratio of the respective voltages at the B-channel with and without the shorting blank inserted in the π -network is termed the “cross-talk attenuation” of the π -network test set-up.

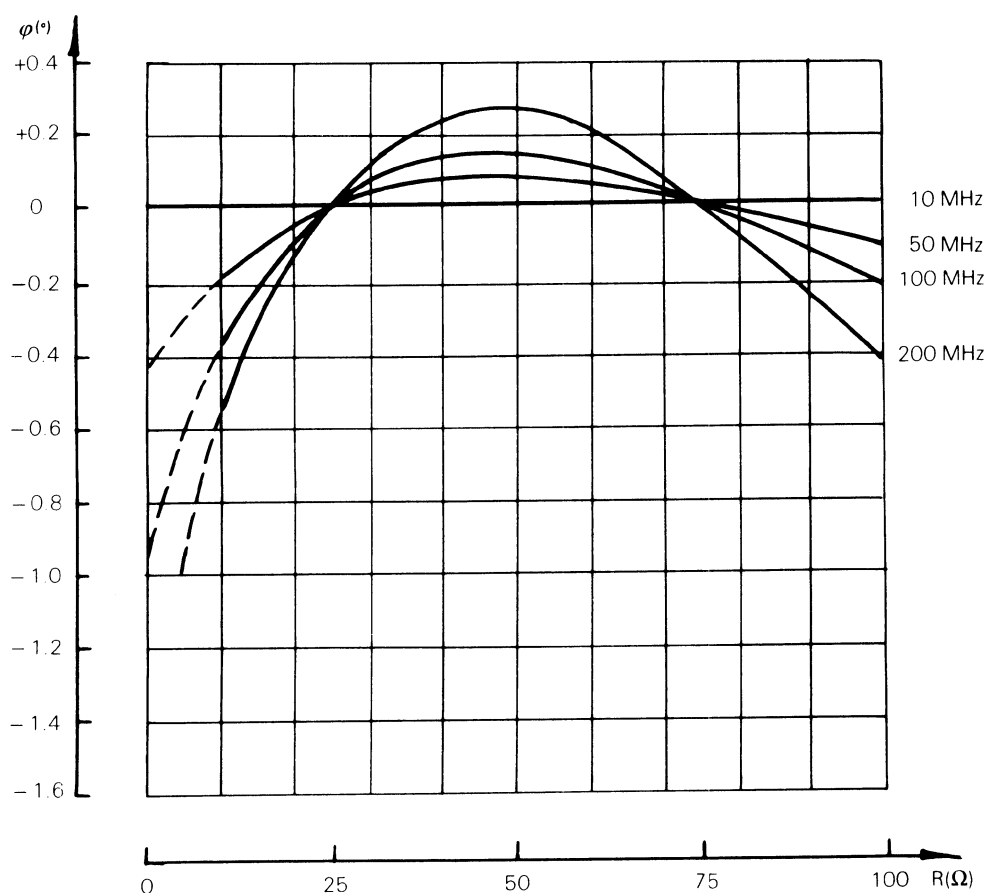
The cross-talk attenuation α_c (in decibels) is given by the expression:

$$\alpha_c = 20 \log \frac{V_{Bs}}{V_{Bo}}$$

where V_{Bs} is the voltage at the B-channel with the shorting blank inserted into the π -network and V_{Bo} is the voltage at the B-channel with the shorting blank removed from the π -network. Measured at a frequency of 100 MHz in the measuring circuit according to Figure 1, page 4, the cross-talk attenuation shall be ≥ 60 dB.

5.1.1.4 At all frequencies between 1 MHz and 200 MHz the phase measured at 75 Ω shall not deviate by more than $\pm 0.2^\circ$ from the phase measured at 25 Ω in the measuring circuit according to Figure 1 (see Sub-clause 6.1).

At a frequency of 200 MHz, the phase over the resistance range 15 Ω to 100 Ω shall not deviate by more than $\pm 0.5^\circ$ from the phase measured at 25 Ω in the measuring circuit according to Figure 1 (see Figure 3, page 5, and sub-clause 6.1).



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Figure 3 — Plot showing the phase change from the value at 25 Ω versus reference resistor values from 0 to 100 Ω at 10 MHz, 50 MHz, 100 MHz and 200 MHz — Measuring circuit according to Figure 1, page 4

5.1.1.5 At all levels of drive between 5 μ W and 5 mW the phase measured at 25 Ω shall not deviate by more than $\pm 0.5^\circ$ over the frequency range 1 MHz to 200 MHz from the phase measured at 0.5 mW in the measuring circuit according to Figure 1.

5.1.1.6 At all frequencies between 1 MHz and 200 MHz the resistance of the 25 Ω reference resistor shall not deviate by more than 2 % from the value measured at 1 MHz in the measuring circuit according to Figure 1.

5.1.1.7 At a frequency of 200 MHz, the reflection coefficient measured with the shorting blank having the dimensions of sub-clause 5.2.2 shall be less than 5 % within the reference temperature range -55°C to $+105^\circ\text{C}$. The output and input shall be terminated within 50 Ω .

5.1.1.8 Measured with the shorting metal blank of sub-clause 5.2.2 in the π -network, the insertion attenuation over the specified frequency range shall be 29.6 ± 0.3 dB.

5.1.1.9 The stray capacitance between contact plates shall be smaller than 0.05 pF.

5.1.1.10 With the 25 Ω reference resistor of sub-clause 5.2.1 in the π -network set-up as Figure 1, page 4, the phase is measured over the temperature range -55°C to $+105^\circ\text{C}$ at a frequency of 200 MHz. The permissible difference is $\pm 0.2^\circ$ with reference to the value at $+25^\circ\text{C}$.

5.1.1.11 The resistance between the contact plates and the body of the terminated π -network shall be 12.5 Ω . The tolerance is defined by the tolerances of R_2 to R_7 (Figure 2, page 4).

5.1.2 Mechanical specification

Typical π -networks which meet the requirements of sub-clause 5.1.1 consist of the following parts (see Figure A.9 to Figure A.13, pages 17 to 20).

- Two resistive attenuators (14.8 dB each) in a metal body, consisting of resistors R_2 to R_7 (see Figure 2).
- Two coaxial connectors (50 Ω) with sufficiently low contact resistance.
- Two contact plates against which the crystal terminals are pressed. The contacts with the crystal terminals shall be made at the top edges of contact plates, which serve to define the reference plane.
- Two spring-loaded plastic blocks.
- Plastic spacer to determine the location of the reference plane.
- Dielectric.
- Two high-frequency precision air trimmers 0.5 pF to 5 pF C_{t1} and C_{t2} (see Figure 2).

5.2 Accessories of the π -network

5.2.1 Reference resistors

The resistors used for calibration are as shown in Figure 4, page 7.

Resistance values for initial calibration are 15 Ω , 25 Ω , 50 Ω , 75 Ω and 100 Ω . D.C. resistance tolerance: ± 1 %.

5.2.2 Shorting blank

The shorting blank is a metal plate with dimensions 12 mm $\times$ 10 mm $\times$ 1 mm (see Figure 4).

5.3 Associated equipment

5.3.1 Generator

5.3.1.1 At both sides of the frequency for which the generator is adjusted and within 10 % of that frequency, the total output power, apart from that at the adjusted frequency, shall be at least 60 dB below the main output.

The level of spurious oscillations and harmonics from the generator shall be sufficiently low for the accuracy of the phasemeter not to be affected (typical value: -40 dB). The frequency resolution and stability of the generator shall be adequate to enable measurements to be carried out on the highest Q crystal under consideration (typical value better than $1 \cdot 10^{-7}$).

5.3.1.2 The phase noise is measured at resonance frequency in the set-up of Figure 1 with a high Q crystal ($Q > 500\,000$) in the π -network. The indicated phase jitter shall be less than 0.2° .