TRANSAT
Sansei-Showa Co.,Ltd.

PI Networks and the IEC-444 Specification

Traditionally, PI Networks have been specified in terms of the IEC-444 standards. However, over time, there have been changes and additions to these standards. Further, parts of the standards are no longer sufficient to cover customer requirements for crystal testing. This raises the question whether PI Network specification in terms of IEC-444 is still meaningful. In an attempt to answer this, the following section gives a brief, subjective summary of the IEC-444 evolution. This is followed by a description of Transat PI Network specifications and their relation to IEC-444.

IEC-444-1 Specifications

The first edition of IEC-444 was published in 1973. It includes physical and electrical specifications for a PI that approximates the purely resistive equivalent circuit of Figure 1 (the capacitance Cp is ignored). The construction technique described uses disk and rod type resistors. Two trimmers per Figure 2 are recommended for adjusting the phase response that is introduced by the network (which is largest when the network is short circuited) to be flat within +/-0.5 degrees over a frequency range of 1 to 125MHz. The PI is used to measure Zero-Phase frequency and resistance of crystals.

The second edition of IEC-444 was split into several parts, each referring to different aspects of crystal measurement. Only Part 1 addresses the electrical specifications of the PI, while the remaining parts cover application and adaptation of the PI to various crystal measurements (see Reference 1).

Part 1 of the second edition was published in 1980. One major difference compared to the original specifications is an extended frequency range to 200 MHz. The rod and disk construction and the use of trimmer capacitors per figure 2 are maintained. The performance specifications are again aimed at keeping the phase response flat within narrow limits, so that the PI Network is assumed to be approximately resistive as shown in Figure 1. As in the original specifications, the PI is used to measure the crystal’s zero-phase frequency and resistance.

In summary, the IEC-444-1 specifications cover the physical construction, electrical performance, and measurement purpose of PI Networks:

- The construction is based in the use of rod-and-disk type resistors and trimmer capacitors, which makes it unsuitable for miniaturization.
- The performance specifications are designed to reduce stray capacitance effects, such that for calculation purposes, the PI can be considered to be purely resistive.
- The measurement purpose is to determine a crystal’s zero-phase frequency and resistance from 1 to 200 MHz.

The advantage of the IEC-444 specification is that a calibration at only one frequency suffices for measuring over the whole frequency range, and that a relatively accurate evaluation of the crystal parameters can be based on a simple equivalent circuit.

This advantage was all-important before the advent of affordable process computers, but it is no longer sufficient for modern applications with requirements such as small size, extended frequency range, and increased accuracy.

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Transat PI Networks

In 1976, Transat introduced a miniaturized thick film PI substrate, which is still the basis for all Transat PI Networks. When packaged in Transat's original Model TFP-1 PI Network frame, it has an equivalent circuit per Figure 3, including Lp = 3 nH and Cp = 0.1 pF. Lp introduces a linear phase slope versus frequency, but the circuits other stray reactance's are low enough such that the short circuit phase response is flat within +/- 0.5 degrees of the inductive phase slope for frequencies up to 250 MHz. Hence, the phase flatness per IEC-444 is maintained for a frequency range up to 250 MHz. The network has the IEC-444 advantages of single frequency calibration and a simple equivalent circuit. In addition it offers miniature size, no need for adjustment, and extended frequency range.

The Model TFP-1 has found wide customer application. It was used in the IEC's "Round Robin" correlation measurements (Reference 1) and is pictured in the IEC-444-5 specifications. Other Transat PI Networks, including those for twopole measurements, use the same substrate. They are described in separate data sheets.

Transat PI Network Specifications

Figure 3 shows the equivalent circuit for the Transat PI substrate. When it is packaged in a PI Network frame it includes coaxial connectors and cables which can be represented by a coaxial cable length connected in series with the circuit. For example, for the TFP-1, the added length corresponds to about 55mm of RG188/U coaxial cable. Generally, this value does not need to be known, since it is absorbed in the cable length adjustment for the overall system. The value for Rp is nominally 25 Ohms, but its exact DC value is inscribed on the frame of each Transat PI Network.

In reality, the resistors in the equivalent circuit of Figure 1 are not resistors but complex impedances as shown in the equivalent circuit of Figure 4. Today with the omnipresence of computers, there is no longer a need for approximating a simple resistive circuit. On the contrary, it is desirable to know the circuit in as much detail as possible.

The impedances of Figure 4 can be evaluated by calibration at many points over the operational frequency range using known insert impedances. The values can be stored in memory and used for the parameter evaluation. This method is described in IEC-444-5 and is used in all Transat system applications.

For PI Networks that have provisions for load frequency measurements, it is important to know the stray capacitance's inside the network (shown in Figure 5). Especially critical is the capacitance Cs1, which shunts the interconnection between two high impedances to ground. The capacitance values are inscribed on the frames of Transat PI Networks.

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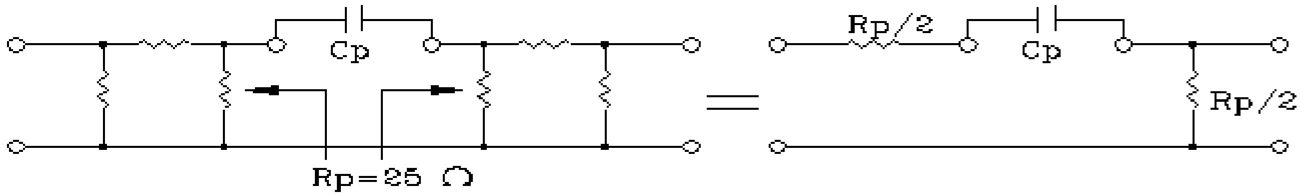

Figure 1

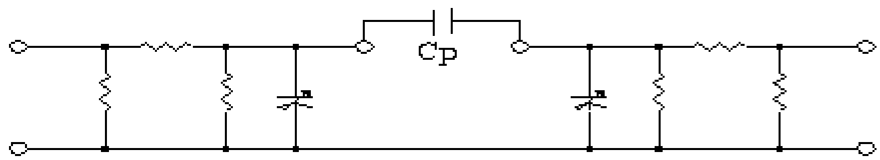

Figure 2

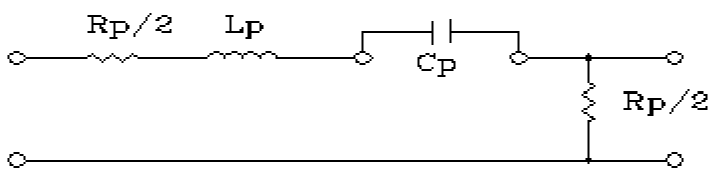

Figure 3

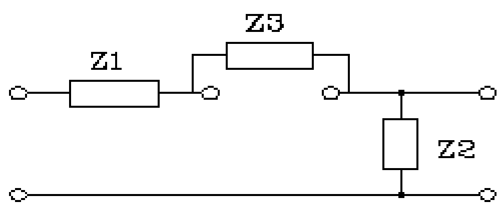

Figure 4

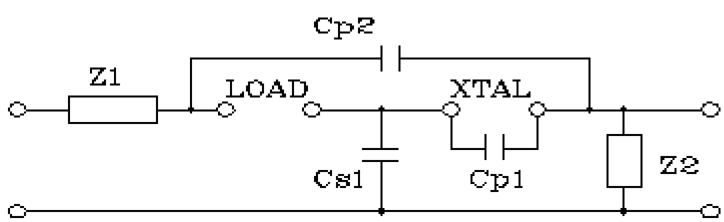

Figure 5

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References

Reference 1. Summary of IEC-444 parts 2,3,4,5,6

- · Part 2. Phase offset method for motional parameter measurement
- · Part 3. Measurement of Fs and R1 by Co cancellation
- · Part 4. Precision load capacitance inserts
- · Part 5. S-Parameter and transmission measurements
- · Part 6. Measurement of Drive Level dependence

Reference 2. Report on IEC TC49 workshop, Yugoslavia 1988