IEC 60862-2

Edition 3.0 2012-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Surface acoustic wave (SAW) filters of assessed quality –
Part 2: Guidelines for the use

Filtres à ondes acoustiques de surface (OAS) sous assurance de la qualité –
Partie 2: Lignes directrices d'utilisation

IEC 60862-2:2012

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SURFACE ACOUSTIC WAVE (SAW) FILTERS OF ASSESSED QUALITY –

Part 2: Guidelines for the use

FOREWORD

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International Standard IEC 60862-2 has been prepared by IEC technical committee 49: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection.

This third edition cancels and replaces the second edition published in 2002 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- Clause 3-"Terms and definitions" has been deleted to be included in the next edition of IEC 60862-1;
- the tapered IDT filter and the RSPUDT filter have been added to the clause of SAW transversal filters. Also DART, DWSF and EWC have been added as variations of SPUDT;
- the balanced connection has been added to the subclause of coupled resonator filters;

- recent substrate materials have been described;
- a subclause about packaging of SAW filters has been added.

The text of this standard is based on the following documents:

CDV	Report on voting
49/933/CDV	49/970A/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60862 series, published under the general title *Surface acoustic wave (SAW) filters of assessed quality*, can be found on the IEC web site.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

This standard has been compiled in response to a generally expressed desire on the part of both users and manufacturers for guidance on the use of SAW filters, so that the filters may be used to their best advantage. To this end, general and fundamental characteristics have been explained here.

The features of these SAW filters are their small size, light weight, adjustment-free, high stability and high reliability. SAW filters add new features and applications to the field of crystal filters and ceramic filters. At the beginning, SAW filters meant transversal filters which have two interdigital transducers (IDT). Although SAW transversal filters have a relatively higher minimum insertion attenuation, they have excellent amplitude and phase characteristics. Extensive studies have been made to reduce minimum insertion attenuation, such as resonator filter configurations, unidirectional interdigital transducers (UDT), interdigitated interdigital transducers (IIDT). Nowadays, various kinds of SAW filters with low insertion attenuation are widely used in various applications and SAW filters are available in the gigahertz range.

SURFACE ACOUSTIC WAVE (SAW) FILTERS OF ASSESSED QUALITY –

Part 2: Guidelines for the use

1 Scope

This part of IEC 60862 gives practical guidance on the use of SAW filters which are used in telecommunications, measuring equipment, radar systems and consumer products. IEC 60862-1 should be referred to for general information, standard values and test conditions.

SAW filters are now widely used in a variety of applications such as TV, satellite communications, optical fibre communications, mobile communications and so on. While these SAW filters have various specifications, many of them can be classified within a few fundamental categories.

This part of IEC 60862 includes various kinds of filter configuration, of which the operating frequency range is from approximately 10 MHz to 3 GHz and the relative bandwidth is about 0,02 % to 50 % of the centre frequency.

It is not the aim of this standard to explain theory, nor to attempt to cover all the eventualities which may arise in practical circumstances. This standard draws attention to some of the more fundamental questions, which should be considered by the user before he places an order for a SAW filter for a new application. Such a procedure will be the user's insurance against unsatisfactory performance.

Standard specifications, given in IEC 60862 series, and national specifications or detail specifications issued by manufacturers, define the available combinations of nominal frequency, pass bandwidth, ripple, shape factor, terminating impedance, etc. These specifications are compiled to include a wide range of SAW filters with standardized performances. It cannot be over-emphasized that the user should, wherever possible, select his SAW filters from these specifications, when available, even if it may lead to making small modifications to his circuit to enable standard filters to be used. This applies particularly to the selection of the nominal frequency.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

None.

3 Technical considerations

It is of prime interest to a user that the filter characteristics should satisfy a particular specification. The selection of tuning networks and SAW filters to meet that specification should be a matter of agreement between the user and the manufacturer.

Filter characteristics are usually expressed in terms of insertion attenuation and group delay as a function of frequency, as shown in Figure 1. A standard method for measuring insertion attenuation and group delay is described in 4.5.2 of IEC 60862-1:2003. In some applications, such characteristics as phase distortion are also important.

Insertion attenuation characteristics are further specified by nominal frequency, minimum insertion attenuation or maximum insertion attenuation, pass-band ripple and shape factor. The specification is to be satisfied between the lowest and highest temperatures of the specified operating temperature range and before and after environmental tests.

SAW filters are classified roughly into two types: transversal filters and resonator filters. Transversal filters are further classified into five types: bidirectional IDT filter, unidirectional IDT filter, tapered IDT filter, reflector filter and RSPUDT (resonant single-phase unidirectional transducer) filter. Also resonator filters are further classified into three types i.e. ladder and lattice filters, coupled resonator filter and IIDT resonator filter. Fundamentals of SAW transversal filters and SAW resonator filters are described in Clauses 4 and 5 of this standard, respectively. In Figure 2, the applicable frequency range and relative bandwidth of the SAW filters are shown in comparison with those of ceramic, crystal, dielectric, helical and stripline filters.

4 Fundamentals of SAW transversal filters

4.1 Frequency response characteristics

A brief description of SAW filters is given here to help users unfamiliar with these filters to understand their operating principles and characteristics. The SAW filter uses a surface acoustic wave, usually the Rayleigh wave. The mechanical energy transported by the wave is concentrated in a surface region of the order of a wavelength in depth. The wave travels on a solid surface at a velocity, 10^3 m/s to 10^4 m/s, which offers the possibility of filtering operations in the VHF and UHF regions in practical SAW filters. The SAW filter has a planar structure, in which electrodes are formed on one surface of a piezoelectric substrate, incorporating a suitable configuration of electrodes as a means of conversion between surface acoustic waves and electrical signals.

Figure 3 is a diagram showing the signal flow through a transversal filter. The filter consists of N taps separated by delays D_n. Each tap is weighted by a coefficient A_n. Filtering is achieved by passing the signal through a number of delay paths and adding these delayed signals. The delays correspond to the positions of IDT fingers on a substrate. The coefficients correspond to weighting coefficients given to the IDT fingers. The frequency response of the filter $H(f)$ is given by a discrete Fourier transformation, expressed as the following Equation (1) at a frequency f:

$$H(f) = \sum_{n=1}^{N} A_n \exp(-\mathrm{j}2\pi f T_n) \qquad T_n = \sum_{i=1}^{n} D_i \tag{1}$$

where T_n is the accumulated delay at the nth tap.

Both amplitude and phase characteristics of the transversal filter are given by two sets of variables: weighting coefficients A_n and delays D_n of the sampling taps.

The SAW transversal filter is essentially constructed with a pair of transducers on a piezoelectric substrate as shown in Figure 4. When an electrical signal is applied to the input IDT, the surface wave is generated by means of the piezoelectric effect and propagates in both directions along the substrate surface. The surface wave is converted again into an electrical signal at the output IDT. If the IDT spatial period $2d$ is uniform, maximum conversion efficiency can be achieved at the frequency for which the surface wave propagates one transducer period synchronously in one RF signal period. The centre frequency f_0 of the IDT is given by this synchronization condition:

$$2df_0 = v_s \tag{2}$$

where v_s is the SAW velocity.

When the SAW transversal filter has two uniform identical transducers, its frequency response is as shown in Figure 5. The transfer function $T(f)$ is approximately expressed as:

$$T(f) = \left(\frac{\sin x}{x}\right)^2 \tag{3}$$

where

$x = \dfrac{N\pi(f - f_0)}{f_0}$ and

N is the number of finger pairs.

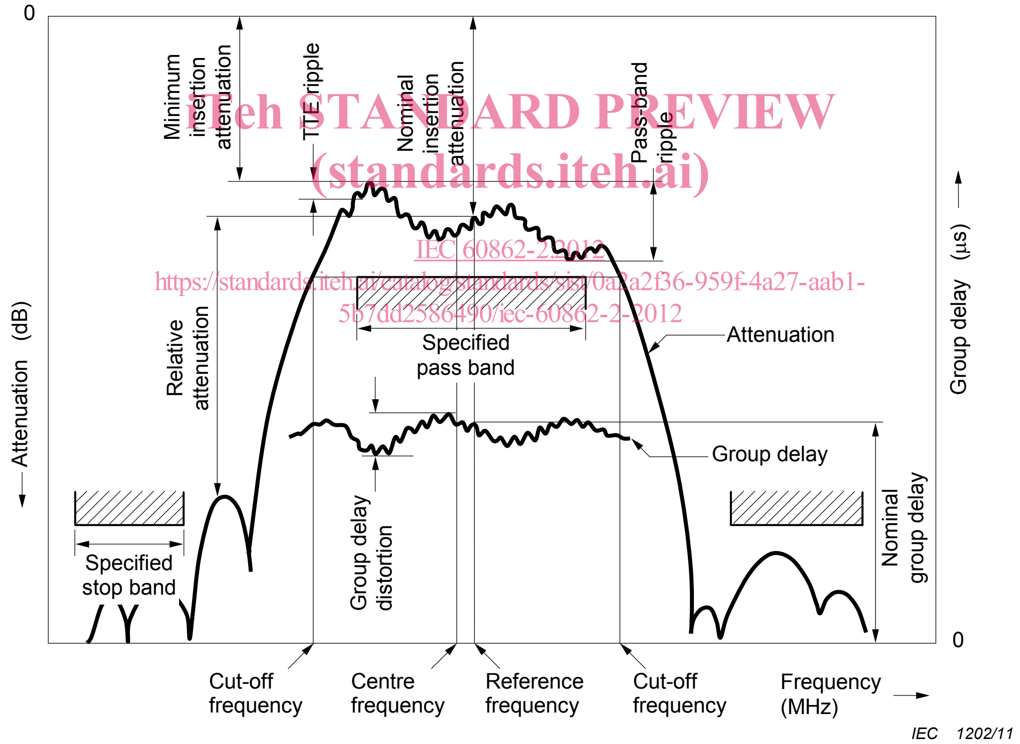


Figure 1 – Frequency response of a SAW filter

4.2 Weighting methods

The IDT operates as a kind of transversal filter with N taps for the weighting. A number of weighting methods are applicable, for example apodization, withdrawal and series (dog-leg) weighting.

a) Apodization weighting
An apodized transducer, as shown in Figure 6, is most commonly used to achieve weighting. An acoustic wave is generated or detected only in regions where adjacent electrodes of opposite polarity overlap.

b) Withdrawal weighting
Weighting is achieved by selectively withdrawing electrodes, as illustrated in Figure 7, to equate with the desired weighting function.

c) Series (dog-leg) weighting
Weighting is achieved by dividing the voltage by segmenting each electrode pair, as shown in Figure 8.

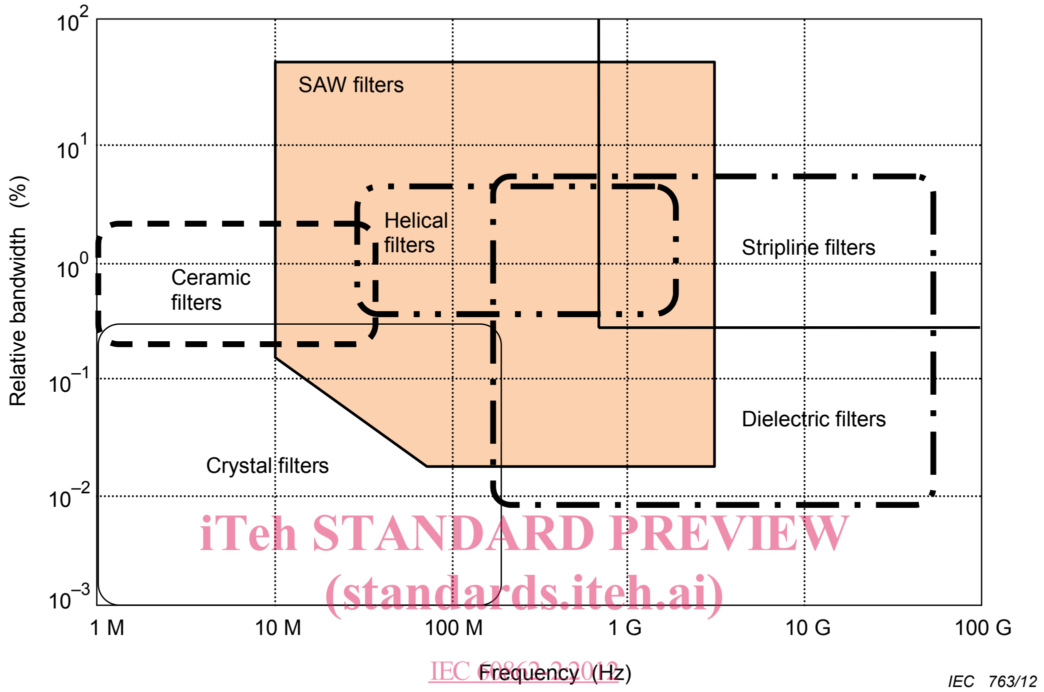


Figure 2 – Applicable range of frequency and relative bandwidth of the SAW filter and the other filters

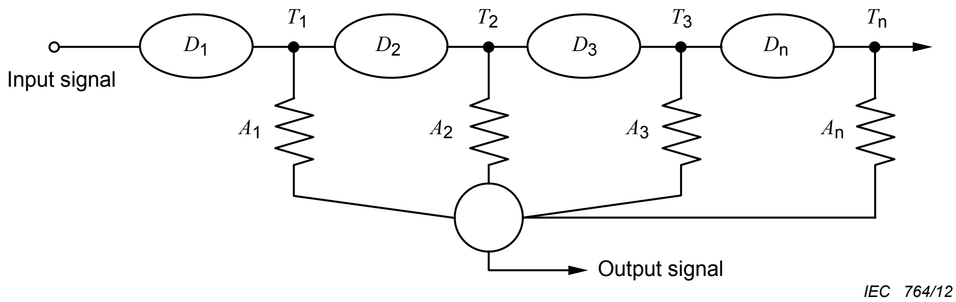


Figure 3 – Schematic diagram showing signal flow through a transversal filter

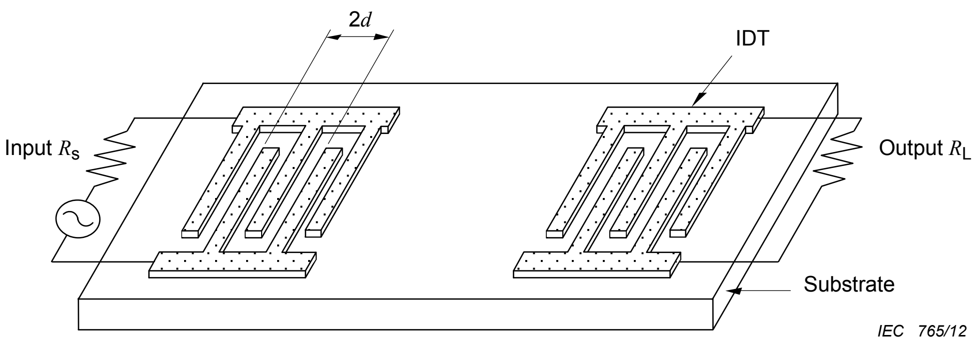


Figure 4 – Basic configuration of a SAW transversal filter

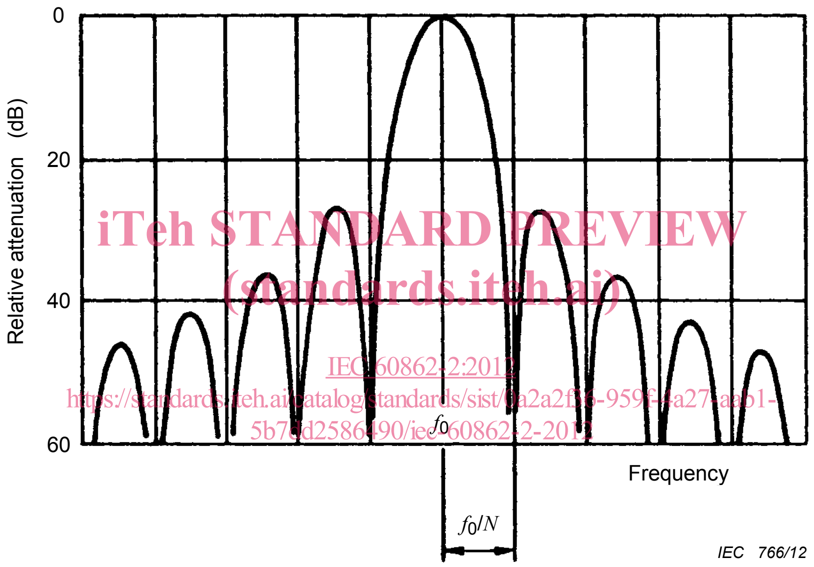
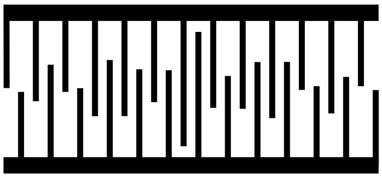
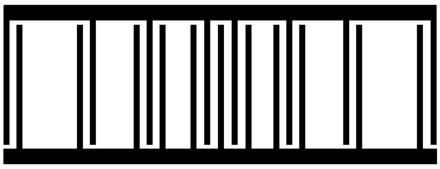


Figure 5 – Frequency response of the SAW transversal filter shown in Figure 4, where f_0 is the centre frequency and N is the number of finger pairs of the IDT



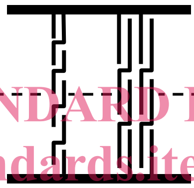
IEC 767/12

Figure 6 – Apodization weighting obtained by apodizing fingers



IEC 768/12

Figure 7 – Withdrawal weighting obtained by selective withdrawal of the fingers



IEC 769/12

Figure 8 – Series weighting obtained by the dog-leg structure

4.3 Filter configurations and their general characteristics

4.3.1 General

In some cases, the split-finger configuration, as shown in Figure 9, is used as the replacement of the solid-finger configuration shown in Figure 4 to reduce SAW reflections at the metal electrodes. With this geometry, the individual reflections, caused by the discontinuity in acoustic impedances on the surface, are cancelled in each finger pair. This finger configuration is now popular in SAW TV-IF filters, etc.

Ordinary IDTs show bidirectional property. These bidirectional IDTs transmit and receive SAWs to and from two directions respectively. For instance, a transmitting IDT converts an electric signal into SAWs. The SAW propagates both forwards and backwards with the same intensities. A receiving IDT will receive either of them with the same efficiency. This means that bidirectional loss values can be estimated at 3 dB each at the transmitting and receiving IDT. Therefore, the bidirectional loss of 6 dB is inherent and is the minimum insertion attenuation in a bidirectional two-transducer SAW filter. Moreover, in these ordinary SAW filters accompanying the bidirectionality, strong pass-band ripple is induced by the triple transit echo (TTE) when the impedances of transmitting IDT and the receiving IDT are matched to the outer loads.

In order to reduce the bidirectional loss and the triple transit echo (TTE) in SAW transversal filters, multi-IDT (IIDT) filters (including three-IDT SAW filters) and unidirectional IDT filters (including tapered IDT filters) are utilized.

Additionally, reflector filters (see Figures 21 and 22) can be included as one type of the transversal filters. Grating technology is widely used as a reflector which changes SAW's propagation direction with some reflection frequency response. The reflector filters utilize not