Technical Introduction

Filters/ Discriminators

Applications for Filters/ Discriminators

KVG provides a wide spectrum of standard and custom specific filters for telecommunication, navigation, avionics and precise measurement for filters in the frequency range of 1 MHz to 200 MHz. In house filter design and crystal manufacturing combined with new technologies like HFF-crystals gives a maximum of flexibility to the customer.

Filter performance

Most of the applications imply an exact specification of the filter. They can be summarized as follows:

-Size, case
-Filter frequency
-Bandwidth, stopband attenuation, ripple, group delay, intermodulation etc.
-Temperature-range
-Termination
-Stability

Depending on the applied technology it is common to divide filters into five main types:

-Monolithic crystal filters
-Discrete crystal filters
-Linear phase filters
-Front end filterss
-LC-filter

A very similar product is a **crystal disriminator**, which can be used for FM-demodulation and for measurement applications.

Monolithic crystal filters

Monolithic crystal filters are mostly used in IF-stages of fixed and mobile radios.

Discrete crystal filters

The crystal filters supplied by KVG are mainly band-pass filters with Chebyshev-characteristic (theoretical ripple 0.1 dB). Depending on the selection in the stop-band range and the ripple in the pass-band range the filter design can be chosen between Chebyshev-design and Butterworth design (theoretical ripple 0 dB). Some of the filters give the option of internal matching networks.

Linear phase filters

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In order to get a low distortion transmission of signals and pulses (digital signals), crystal filters with a linear phase response or low group delay distortion are necessary. However, these linear phase filters (Gaussian or Bessel characteristic) have low selection characteristics. By several transfer functions (Gauss 6 dB, Gauss 12 dB, EQR) between linear phase and selection filters, better selectivity can be achieved without essentially changing the group delay in the pass band range.

Antenna filters

Antenna filters, used as preselection or as front-end filters in the VHF-range, suppress unwanted signals. The most important characteristics of these filters are low insertion loss and good intermodulation characteristics.

Crystal discriminators

Currently KVG produces crystal discriminators in the frequency range of 1 MHz to 35 MHz (priority from 9 MHz to 25 MHz) for linear FM-demodulation and for measurement applications. Within a certain frequency range, crystal discriminators produce a DC-voltage proportional to the input frequency. The linearity and the temperature characteristic of the slope is determined by the electrical parameters as well as by the temperature characteristics of the crystal.

LC-filters

LC-filters are a combination of coils and capacitors instead of using a crystal. These filters provide a much wider passband with nearly the same shape-factor as crystal filters. Another advantage is the lower spurious response of a LC-filter. A drawback is the higher temperature response of LC-filters because of the temperature dependent elements coils and capacitors.

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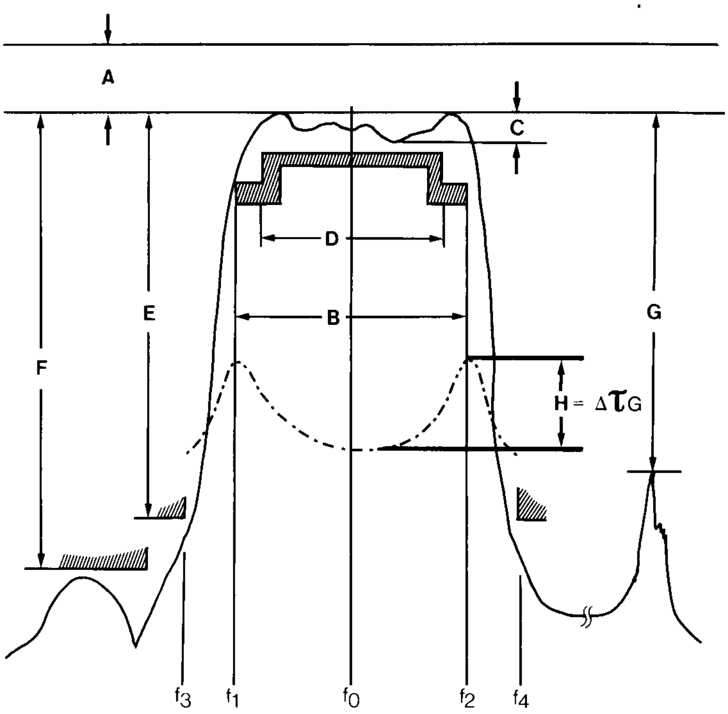
Definition of electrical parameters



A) Insertion loss
In order to measure the insertion loss, the test adapter is short circuited and the imaginary impedances are compensated at the corresponding centre frequency. The resulting attenuation value is the corresponding reference point 0. When the filters are inserted at the test adapter, the insertion loss is the difference between the minimum attenuation value of the filter and the reference point.

B) The passband range between two frequencies (f1, f2), where the attenuation should be equal to or higher than a specific value. The passband range is mostly related to the 3 dB or 6 dB points.

C) The passband ripple is the difference between the maximum and the minimum attenuation in the passband range, or in a specific range of the passband.

D) Range in which the ripple is specified. KVG specifies this range with 80% of the 3 dB-bandwidth.

E) The stopband is a band of frequencies in which the relative attenuation is equal to, or greater than the specified value. In the diagram the specified stopband attenuation values are f_3 and f_4. In many cases the shape factor (SF) is also specified.

$$SF = \frac{f_4 - f_3}{f_2 - f_1}$$

F) The ultimate attenuation is the difference between the attenuation in a given frequency range and the minimum attenuation in the passband.

G) Spurious responses are various resonances caused by crystals which do not correspond to the normal crystal frequencies of the filter design.

H) The group delay distortion is the difference between the minimum and the maximum value of the group delay in a specific frequency range. $\Delta t_G = |t_G \max. - t_G \min.|$

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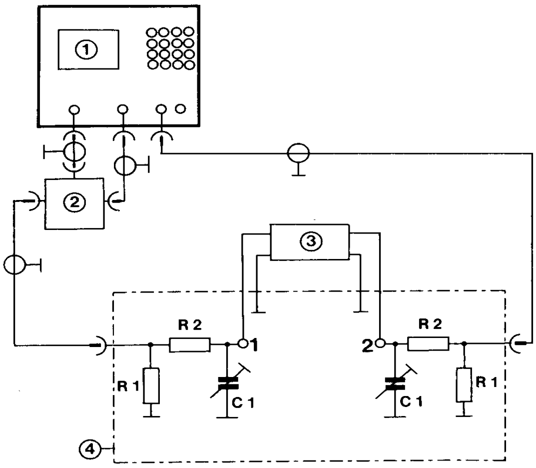
Measurement technique of crystal filters

Calibration and final control of the filters are carried out by means of a selective level measurement or with a network analyzer, depending on the requirements. The different filter impedances are adapted to the measurement system impedances by transformer circuits which are integrated in test adapters.



1. Network analyzer
2. Power splitter
3. Test sample
4. Test jig

Attenuation, phase and group delay distortion measurement for filter terminating impedances R_F // C_F with $R_F \leq 1$ kOhm and $C_F \geq 5$ pF.

The matching pads can be calculated as follows:

$$R_1 = \frac{R_G}{\sqrt{1 - \frac{R_G}{R_F}}} ; \quad R_2 = R_F - \frac{R_G}{1 + \sqrt{1 - \frac{R_G}{R_F}}}$$

In the following table the resistances of some typical filter impedances are listed:

R_F (W)	> 1000	910	820	700	620	500	400	350	200	150	75	60	50
R_1 (W)	50	51.5	51.5	52	52	53	54	56	58	61	87	120	¥
R_2 (W)	R_F - 25	885	795	675	595	475	374	324	172	123	43	25	0

For terminating impedances above 1 kOhm, additional attenuation due to the matching network is extremely high. This result in problems with the ultimate measurement. In this case the filters are adapted with LC-transformers in accordance to the next figure:

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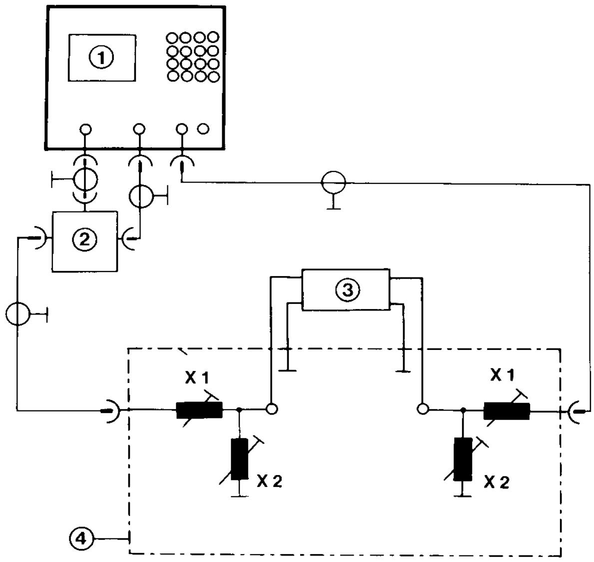

1. Network analyzer
2. Power splitter
3. Test sample
4. Test jig

The following relations are valid for the reactances X_1 and X_2 depending on the circuit

$$X_1 = \sqrt{R_G\left(R_F - R_G\right)}\ ;\ X_2 \frac{R_F}{\sqrt{\frac{R_F}{R_G} - 1}}$$

with:

$$L_1 = \frac{X_1}{w_0}\ ;\ C_1 = \frac{1}{w_0 X_2}$$ for $X_1=L_1$; $X_2=C_1$

or:

$$L_1 = \frac{X_2}{w_0}\ ;\ C_1 = \frac{1}{w_0 X_1}$$ for $X_1=C_1$; $X_2=L_1$

The impedances of the test adapters are adjusted at the centre frequency of the crystal filters using a vector impedance meter. In order to avoid a cross-talk between input and output, the input and output have to be carefully shielded and the filter case has to be taken to ground. For measuring the ultimate attenuation, the attenuation of the test adapter has to be better by 10 dB than the specified ultimate attenuation of the test unit. KVG offers corresponding test adapters for every filter.

The centre frequency f_0 of symmetrical bandpass filters is calculated as follows:

$f_0 = \sqrt{f_1 \cdot f_2}$ for standard filters and $f_0 \approx \frac{f_1 + f_2}{2}$ for linear phase filters.

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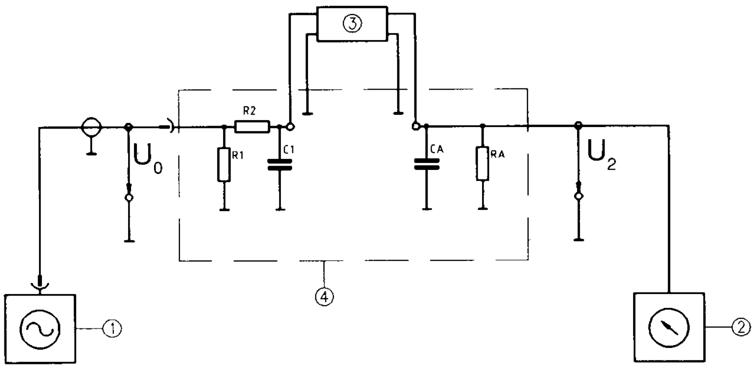
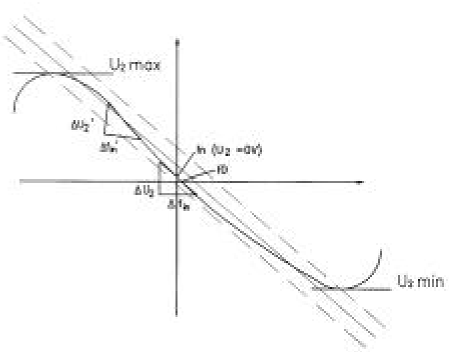
Measurement technique of crystal discriminators



1. Generator
2. Voltmeter
3. Test sample
4. Test jig

Test circuit for crystal discriminators

The specified data of the crystal discriminators are valid for a constant input voltage U_0=1V or P_0=+13dBm(50 Ohm) at the input of the test jig.



The non-linearity (λ) of the voltage-frequency-characteristic is the percentage deviation of the output voltage U2 from a linear shape. Monolithic crystal discriminators are available for narrow-band FM combined with FM-demodulators.

The slope is defined as:

$$S = \frac{\Delta U_2}{\Delta f_{in}}; \qquad l = \left(\frac{\frac{\Delta U_2'}{\Delta f_{in}'}}{S} - 1 \right) \cdot 100\%$$

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