

# **Application Note** **SAW-Components**

## **ESD protection for SAW filters** **Appnote #17**

### **Abstract:**

In this report some general countermeasures are described how to protect SAW filters against **E**lectro **S**tatic **D**ischarge.

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## ESD Protection for SAW filters

SAW Filters (SAWF) and SAW resonators (SAWR), are using very thin and precise aluminium structures realised on a piezoelectric substrate.

The dimension of each transducer and of each gap between the transducers is in the micrometer range. The basic aluminium structure is similar for SAWR and SAWF.

A basic interdigital structure is shown in Fig.1.

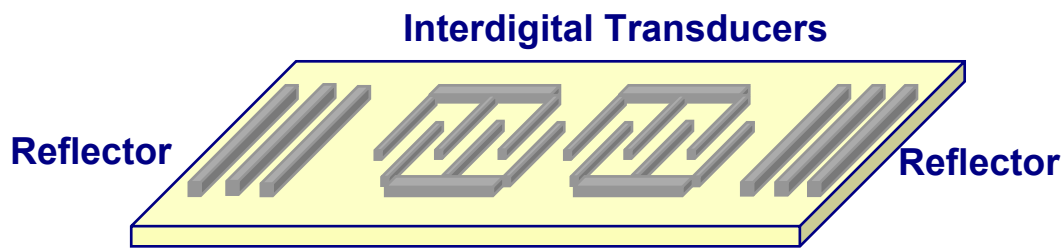


Fig.1: Simplified internal structure of a two-port SAWR

Because of the dense structures, it is important to avoid high DC voltage between the transducers. High DC voltage would create a strong steady state electrical field between the fingers which can cause a disruptive discharge. In this case the filter will be damaged.

Biasing DC voltage from a mixer or an amplifier, applied to the SAWF, is not critical because the value will not exceed several Volt. For maximum ratings we refer to the specific product datasheet.

A much more critical issue is **Electro Static Discharge** in a SAWF / SAWR.

Interdigital transducers are acting like a capacitor with no DC path between the electrodes. Applying electrostatic energy to the SAWF input (e.g. via antenna) the voltage between the interdigital transducers (IDT) rises and creates a disruptive discharge. The whole energy is focused on a very small area in a very short time. Due to the high current flow during the discharge, aluminum fingers are melting. Depending on this current a short circuit between the fingers may occur, or the interdigital structure may be destroyed entirely.

SAW filters are usually used in the front-end of RF receivers like RKE (remote keyless entry) receivers, or TPMS (tire pressure monitoring) receivers, right after the antenna. ESD can be injected through the antenna during several production steps, or when mounting the receiver in the final application surrounding (e.g. into the car).

When connecting a SAW filter to an antenna usually a matching network is needed because of the different impedance levels of SAWF input and antenna.

The standard matching network structure which mostly provides best RF performance for narrowband filters, is a shunt capacitor at antenna side, followed by a series inductor connected to the SAWF input.

Figure 1 shows the standard matching network.

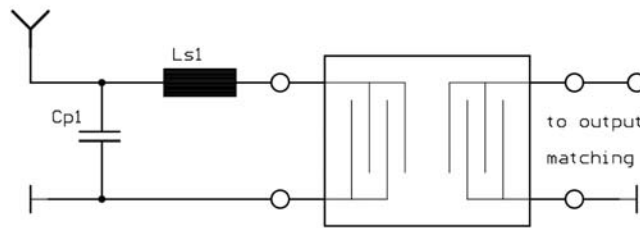


Fig. 1: standard matching network to antenna (antenna impedance: 50 Ohm), No ESD protection!

However this matching structure provides no protection against ESD. Since there is no DC path between antenna and ground, the whole energy is present at the SAWF input. When using this matching topology it should be ensured, that there is an ESD compliant production. Otherwise an additional protection element between antenna and matching network should be used.

### Basic ESD protection

The following two matching structures provide protection against **low electrostatic discharges**. The ESD level, the SAW filter can withstand with this kind of “ESD matching”, depends on the SAW filter (e.g. center frequency, distance between IDT fingers) itself and the energy of the ESD pulse.

Figure two shows a series capacitor, shunt inductor matching.

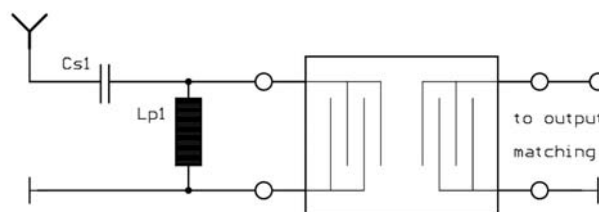


Fig. 2: “ESD matching” series C, shunt L, (antenna impedance: 50 Ohm)

In case of an ESD the capacitor Cs1 will be charged by the current through Cs1 and Lp1. Since the capacitor values are usually small (some pF), Cs1 will be charged very fast. Once the capacitor is charged the whole Voltage lies across Cs1. Here the ESD will be blocked.

Depending on the capacitor and on the energy of the ESD pulse, Cs1 may be damaged once the voltage level across the capacitor exceeds a certain value. Then the ESD protection for the SAW filter is no longer ensured.

This kind of breakdown voltage should be known when using this topology.

The information about this voltage level can be obtained from the manufacturer of the used capacitors.

Using this topology, RF performance is worse than with standard matching.

A shunt L, series L matching is shown in Fig. 3.

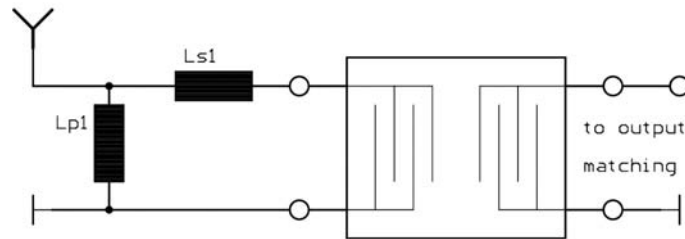


Fig. 3: “ESD matching” shunt L, series L, (antenna impedance: 50 Ohm)

When electrostatic discharge occurs at antenna input, the ESD pulse will be short circuited by  $L_{p1}$ . The whole current will flow through this shunt inductance. The voltage drop across  $L_{p1}$  is directly proportional to the value of the inductance. The higher the inductance, the higher the voltage drop. If this topology is applicable depends on the input impedance of the SAWF. On the one hand it is important, that the value of  $L_{p1}$  is as low as possible to ensure a low voltage drop across  $L_{p1}$ , on the other hand  $L_{p1}$  should be high enough not to influence the RF performance of the SAWF. RF performance of this topology is in between standard matching and the matching shown in Fig. 2.

### Enhanced ESD protection

A common kind of ESD protection is to use two anti-parallel diodes (in one housing) between antenna node and GND. The additional capacitance to GND provided by the diodes is very small and does not disturb the SAWF matching significantly. The value of the shunt capacitor ( $C_{p1}$ ) can be reduced by the capacitance value of the diode. A suitable diode would be BAV99. This protection is able to handle very fast and high ESD transients.

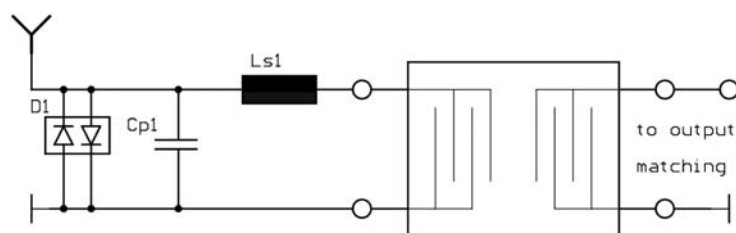
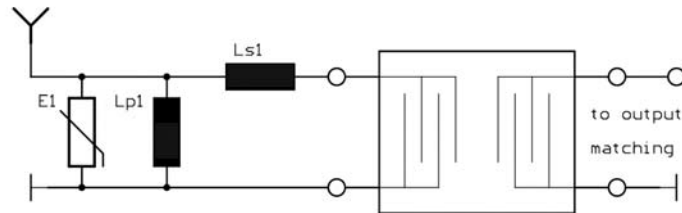


Fig. 4: ESD protection with suppressor diode (antenna impedance: 50 Ohm)

Using this network it has to be checked, if intermodulation is an issue in the respective application. Strong signals at antenna input could cause intermodulation in the diode and may reduce sensitivity of the RF receiver.

Fig. 5 shows an ESD protection with surge varistors.



**Fig. 5: ESD protection with shunt varistor and shunt L-series L matching (antenna impedance: 50 Ohm)**

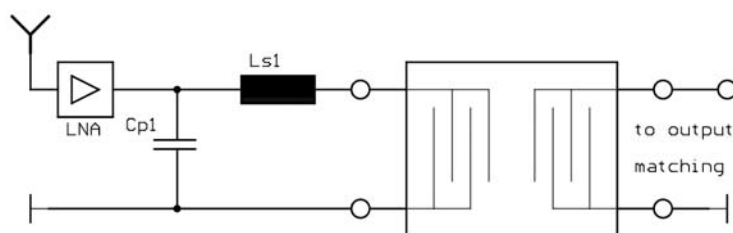
Here a shunt varistor in substitution with the shunt inductor is used. The main energy is absorbed by the varistor, the shunt inductance helps to clamp the voltage to a minimum level.

The trigger voltage as well as the clamping voltage of the varistor should be quite low. For trigger voltage a rough estimation is a value below 200V. Clamping voltage should be below 100V. Please note, clamping voltage rises with increasing current flow caused by ESD.

The capacitance of the varistor should be very low, because it influences the RF performance of the SAW filter. Therefore varistor capacitance has to be taken into account when calculating the matching network.

The combination in Fig. 5 is probably one of the most effective ESD protections.

If a LNA is put in front of the SAWF the ESD protection is provided by the LNA itself. Nevertheless the ability of the LNA to protect the SAWF against ESD is limited. Also here sufficient countermeasures in front of the LNA have to be applied to ensure proper protection.



**Fig. 6: Receiver front-end with LNA in front of SAWF, protection done by LNA (antenna impedance: 50 Ohm)**

**!Please note, before introducing any matching structure shown above, it is recommended to test the effectiveness of the applied ESD protection topology according to relevant industry standards or customer specific requirements!**

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