Application Note
SAW-Components

Equivalent circuit of 1-port- and 2-port SAW Resonators was evaluated.
A description in Touchstone and in PSPICE syntax is given.

Abstract:

Equivalent circuit for 1-port- and of 2-port SAW is described. For simulation the syntax of these SAWR models for Touchstone and for PSPICE was evaluated.

Author: Alexander Glas
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Department: SAW CE AE PD

EPCOS AG
SAW Components
D-81617 Munich
P.O. Box 801709
http://www.epcos.com

<u>Equivalent circuit of a 1-port SAWR e.g. EPCOS R727</u>

A 1-port SAWR can be described with the following equivalent electrical circuitry.
This equivalent circuit (EQC) can be used to describe the SAWR in the range of the
SAWR´s resonance frequency and in a wide frequency range. The main serial and
parallel resonance is described very well.
Additional parasitic-resonances with much higher IL and different phase relation are
not included, because of much less effect to the main resonance.
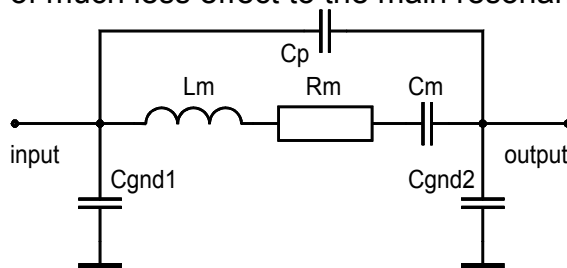
Fig.1: Simplified, general equivalent circuitry of a one –port SAWR

Moving from the general structure to the structure, used in a Colpitz oscillator, the
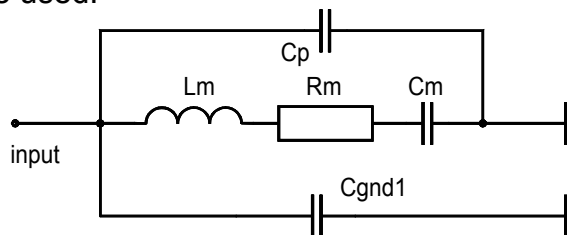following circuit can be used.

Fig.2: Equivalent circuitry of a one –port SAWR, used in a one-port Colpitz oscillator

For this one-port structure the equivalent circuit componet values are placed in
SAWR data sheet. Here C(gnd2) is shorted, Cp // Cgnd1 is Co.
Lm, Rm, Cm = L1, R1, C1 in data sheet.
<u>The exact values for the EQC components are viewed in data sheet.</u>

Describing the the 1-port SAWR EQC in Touchstone based simulators

```
!SAW resonator R727 EQC; Caps in pF, Inds in nH, Res in Ohm
SRLC  1    2     R=12 L=69000 C=0.00195          !internal res. circuit
CAP   1    2     C=2.7                            !C0
DEF2P 1    2     RESO
```

On the other hand a 1-port SAWR can be described in Spice syntax based on equivalent circuit from figure 1 or 2. For Colpitz oscillator design, a Spice model structure is given for fig.2.

```
* SAWR EQC R727: Rm=12, Lm=69.0UH, 1.95fF, Co=2.7pF.
* For simulation Q/1000 should be used to reduce the simulation time
*
L51 50  51  69000N       * Lm
R51 51  52  12           * Rm
C51 52  0   1.95F        * Cm
C52 50  0   2.7P         * C0
```

For reducing the start up time in simulation (transient time analyse), a reducing of Q-factor is recommended to Q(SAWR)/100, or Q(SAWR)/1000 in the first step. To check the natural frequency of the oscillator, reduce the Q-factor strongly to a value of may be 10. Tune the natural freq. of the oscillator, close to the SAWR´s freq.

```
* For simulation Q/100 scenario
L51 50  51  690N         * Lm
R51 51  52  12           * Rm, remains constant to generate the same loading
C51 52  0   195F         * Cm
```

Starting up pule is necessary for activating the oscillation in the simulation. The pulse source (0.01, 0.1V) can be placed between the SAWR grounding point and GND node.

```
C51 52  53  195F         * Cm
V2  53  0   PULSE(0.01 0)
```

Equivalent circuit of a 2-port SAWR e.g. S+M R2701

A 2-port SAWR can be described with the following equivalent electrical circuitry. This equivalent circuit (EQC) can be used to describe the SAWR in the range of the SAWR´s resonance frequency and in a wide frequency range.
Additional parasitic-resonances (with much higher IL and different phase relation, (opposite phase relation)) are not included, because of much less effect to the main resonance. This EQC can be used in Spice simulation for time domain and frequency domain. Furthermore this circuitry can be used in Touchstone too, using an ideal transformer (XFER) with changed output node orientation to create the 180° degree phase shift.
The component values of the EQC can be picked up from data sheet.
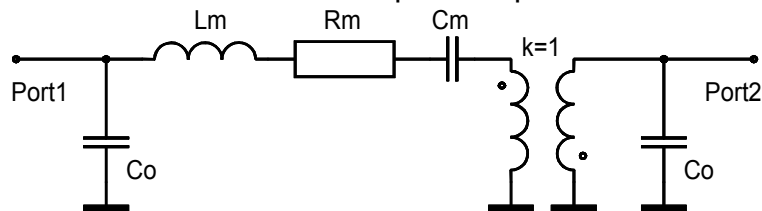

Fig.3: Equivalent circuit of a 2-port SAWR with 180° degree phase shift

To simulate a 2-port SAWR with 180° a internal ideal balloon is necessary to create the 180° phase shift. This balloon is modelled in Spice with LK1 and LK2. The inductivity should be high enough to avoid interactive reactions with the other components (e.g. capacities to GND). Keep an eye on the orientation of the balloon. Starting Spice simulation, it is important to provide a kind of "DC pass", to avoid the error message "node is floating". Therefor a very high resistor is connected at SAWR´s input side and output side to GND.

```
* SAWR EQC R2701: Rm=230, Lm=954UH, 0.141fF, Co=2*2.3pF, 180 degree phase.
* For simulation Q/100 should be used to reduce the simulation time
* RX1 and RX2 are required only by Spice for providing a DC path.
*
* C51, L51, R51 are recalculated to Q/100 !!!!
RX1 50   0    10MEG
C50 50   0    2.3P
L51 50   51   9540N
R51 51   52   230
C51 52   53   14.1F
* 180 degree transformer. L min 10uH at 434MHz
LK1  53   0    10000N
LK2  0    54   10000N
K    LK1 LK2 1
*
C52 54   0    2.3P
RX2 54   0    10MEG
```

For reducing the start up time in simulation, a reducing of Q-factor is recommended to Q(SAWR)/100, or Q(SAWR)/1000 in the first step. To check the natural frequency of the oscillator, reduce the Q-factor strongly to a value of may be 10. Tune the natural freq. of the oscillator, close to the SAWR´s freq.

Starting up oscillation in Spice time domain based simulators:
Starting up pule is necessary for activating the oscillation in the simulation. The pulse source can be placed between the emitter-capacity and GND.

```
V2   33   0 PULSE(0.1 0)
```

Describing the 2-port SAWR EQC in Touchstone based simulators.

```
!SAW resonator R2701 EQC; Caps in pF, Inds in nH, Res in Ohm
CAP   1    0    C=2.3                          !C0
SRLC  1    2    R=230 L=954000 C=0.000141      !internal res. circuit
XFER  2 0 0 3   N=1                            !180°ideal Transformer
CAP   3    0    C=2.3                          !C0
DEF2P 1    3    RESO
```

Starting the simulation, often Q factor is reduced by 10, or 100 to have a look at a wider frequency range.
A Example for Q/100 is given.
```
SRLC  1    2    R=230 L=9540 C=0.0141   !internal res. circuit
```

For more application notes, data sheets and SAWF S-parameter, we refer to our internet site http://www.epcos.com/rke

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