Short Papers

Microwave Oscillator Analysis

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Abstract—In this paper a generalized oscillation condition for an n-port active device has been presented in terms of its S-parameter matrix and that of the embedding network of the oscillator circuit. The corresponding condition using Z or Y matrices has also been shown.

Verification of the proposed theory for a typical two-port and a three-port oscillator network is presented.

In a recent publication [1] Basawapatna presented a unified approach for oscillation conditions in a two-port which in fact is nothing but a particular case of the generalized oscillation condition presented here.

The oscillator circuits have generally been analyzed treating them as two-port networks represented by their 2×2 impedance or scattering matrix [2], [1]. Certain usual 3-port oscillator circuits have also been analyzed using their 3×3 impedance or admittance matrix [3]. Here a general analysis of the oscillator circuit having n-ports is presented which uses the directly measurable scattering matrix. The results obtained can be converted in terms of Z or Y matrices. This analysis is particulary useful for the oscillators using single gate ($n=3$) or dual gate ($n=4$) FET's.

Generalized Oscillation Condition

An oscillator can be considered as a combination of an active multiport and a passive multiport (the embedding network), as shown in Fig. 1. For the active device:

$$[b_i]=[S][a_i] \tag{1}$$

and for the embedding network:

$$[b_i']=[S'][a_i']. \tag{2}$$

When the active device and the embedding network are connected such that port i is connected to i', we have

$$[b_i']=[a_i] \tag{3}$$

and

$$[b_i]=[a_i']. \tag{4}$$

From (1) to (4) we have

$$[a_i']=[S][S'][a_i'] \tag{5}$$

or

$$\{[S][S']-[1]\}[a_i']=0 \tag{6}$$

where [1] is a unit matrix.

Now since $[a_i']\neq 0$

$$[M]=[S][S']-[1]$$

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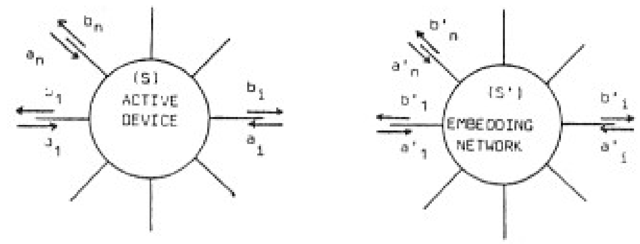

Fig. 1. S-parameter defined active and passive multiports of an oscillator.

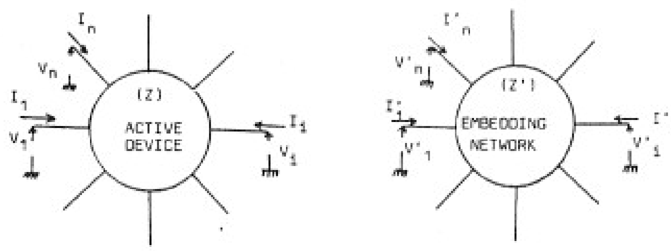

Fig. 2. Z-parameter defined active and passive multiports of an oscillator.

is a singular matrix, or

$$|M|=0 \tag{7}$$

represents the generalized oscillation condition.

It may be noted that in the case of a multiport defined by its impedance or admittance matrix (Fig. 2), we have

For the active device:

$$[V]=[Z][I] \tag{8}$$

and for the embedding network:

$$[V']=[Z'][I'] \tag{9}$$

and by connecting the port i to port i' we have

$$[I]=-[I'] \tag{10}$$

and

$$[V]=[V']. \tag{11}$$

From (8) to (11), we have

$$\{[Z]+[Z']\}[I]=0.$$

Now since $[I]\neq 0$, the matrix

$$[Z]+[Z']$$

is singular, or

$$|[Z]+[Z']|=0 \tag{12}$$

and similarly

$$|[Y]+[Y']|=0 \tag{13}$$

represent the generalized oscillation condition.

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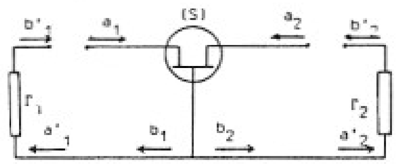

Fig. 3. Two-port FET oscillator circuit.

Verification for a Two-Port Loaded by Two Impedances

In Fig. 3, for the active device:

$$[S]=\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{21} \end{bmatrix} \tag{14}$$

and for the embedding circuit:

$$[S']=\begin{bmatrix} \Gamma_1 & 0 \\ 0 & \Gamma_2 \end{bmatrix}. \tag{15}$$

The oscillation condition from (7) is

$$|M|=|[S][S']-[1]|$$

$$=\begin{vmatrix} S_{11}\Gamma_1-1 & S_{12}\Gamma_2 \\ S_{21}\Gamma_1 & S_{22}\Gamma_2-1 \end{vmatrix}=0 \tag{16}$$

which gives

$$(S_{11}\Gamma_1-1)(S_{22}\Gamma_2-1)-S_{12}S_{21}\Gamma_1\Gamma_2=0. \tag{17}$$

This equation results in the following two well-known conditions [1]:

$$S_{11}+\frac{S_{12}S_{21}\Gamma_2}{1-S_{22}\Gamma_2}=\frac{1}{\Gamma_1} \tag{18}$$

$$S_{22}+\frac{S_{12}S_{21}\Gamma_1}{1-S_{11}\Gamma_1}=\frac{1}{\Gamma_2}. \tag{19}$$

Three-Port Loaded by Three Impedances

In Fig. 4 for $[M]=[S][S']-[1]$ to be singular, we have

$$\begin{vmatrix} S_{11}\Gamma_1-1 & S_{12}\Gamma_2 & S_{13}\Gamma_3 \\ S_{21}\Gamma_1 & S_{22}\Gamma_2-1 & S_{23}\Gamma_3 \\ S_{31}\Gamma_1 & S_{32}\Gamma_2 & S_{33}\Gamma_3-1 \end{vmatrix}=0 \tag{20}$$

or

$$\frac{S_{12}S_{21}\Gamma_1\Gamma_2}{(1-S_{11}\Gamma_1)(1-S_{22}\Gamma_2)}+\frac{S_{13}S_{31}\Gamma_1\Gamma_3}{(1-S_{11}\Gamma_1)(1-S_{33}\Gamma_3)}$$
$$+\frac{S_{23}S_{32}\Gamma_2\Gamma_3}{(1-S_{22}\Gamma_2)(1-S_{33}\Gamma_3)}+\frac{\Gamma_1\Gamma_2\Gamma_3(S_{12}S_{23}S_{31}+S_{21}S_{32}S_{13})}{(1-S_{11}\Gamma_1)(1-S_{22}\Gamma_2)(1-S_{33}\Gamma_3)}$$
$$=1. \tag{21}$$

This is the same relation as is obtained by calculating in the classical way at each of the three-ports the following relation:

$$S''_{11}\Gamma_1=S''_{22}\Gamma_2=S''_{33}\Gamma_3=1$$

where S''_{11} is the modified reflection coefficient at port 1 with ports 2 and 3 loaded by impedances corresponding to refl. coeff. Γ_2 and Γ_3.

It may be noted that though in both the above examples the transfer scattering parameters of the embedding network have been taken as zero, the approach presented is equally applicable to analyse complex embedding networks with nonzero transfer scattering parameters, for example a YIG sphere coupled to both gate and source of an FET [4].

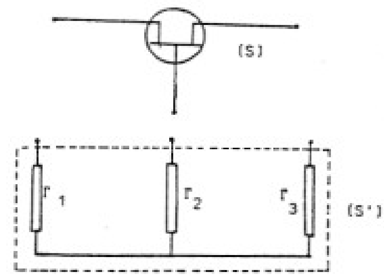

Fig. 4. Three-port FET oscillator circuit.

References

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