An Analysis Method for Negative Feedback Amplifier Network Based on Dual-port Network Model

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Abstract—Block diagram and dual-port network are common methods to solve negative feedback amplifier but with unsatisfied limitations and disadvantages. This paper addresses a new method based on dual-port network to solve the negative feedback amplifier, which shows much clear electrotechnical meaning. The effectiveness of the model is verified by two classical circuit problem and the parameter of the network are accurately given. The method can integrate the theory of dual-port modes into block diagram, which may deepen the insight for further research.

Keywords—block diagram, Dual-port network, Negative feedback

I. INTRODUCTION

Negative feedback network is widely used in amplifier circuit, which can ameliorate the network's stability, spread its band pass, restrain a variety of factors caused by the linear and nonlinear distortion and improve its input and output performance. Negative feedback amplifier network can be divided into four configuration according to their different ways of sampling and summation. Block diagram is the usual way to study them.

Block diagram shows that feedback signal superimposes the input signal at the input. When the feedback signal is inverse with the input signal, the net input signal will decrease, resulting in a corresponding decrease of the output signal. The feedback network $F$ of this kind is called negative feedback network and the amplifier network $A_F$, negative feedback amplifier network.

According to block diagram we can derive the overall gain:

$$A_F = \frac{A}{1+AF}$$

, the factor $A$ is called the open-loop amplification; especially when the conditions meets the deep negative feedback

$$\left|\frac{A}{F}\right| >> 1$$

, which usually satisfies the conditions automatically in negative feedback amplifier networks.

$$A_F = \frac{A}{1+AF} \pm \frac{1}{F}$$

, which shows that the amplification is independent of the amplifier network $A$, but only dependent with the feedback factor $F$. Because the feedback network is usually constituted by resistance network, the electrical characteristics of feedback network is stable and the amplification of negative feedback amplifier network is more stable than usual amplifier network. In addition, negative feedback network $F$ can effectively spread the band pass, reduce the distortion and change the input and output impedance values by $(1 + AF)$ times of negative feedback amplifier network $A_F$ to amplifier $A$.

The block diagram is a simplified model of ideal. From the model we may know

$$X_F = F \cdot X_o$$

. The effect from feedback network to the input and output performance is ignored, as a result, that makes it difficult to analyze and solve the negative feedback amplifier network: fuzzy concept of open loop and closed loop, solving of input and output impedance value and so on. Dual-port network theory is usually based on block diagram, as the reasons given above, it can not solve negative feedback amplifier well.

In this paper, we will study negative networks with method based on dual-port network model theory, give a clear depiction and explanation of its electrotecnical meaning and verify the validity of our method by solving the factors of negative feedback amplifier networks.

II. DUAL-PORT NETWORK MODEL

As the amplifier network and the negative feedback network are all dual-port network, we may study them with dual-port network model. For example, we'll study negative feedback voltage in series amplifying network (Figure 1).

For simplicity, it is assumed that the feedback network is constituted by the resistance network and the signal frequency is in the intermediate frequency (i-f) of the amplifier network. Figure 1 shows the equivalent circuit of the amplifier network $R_e, A_{input}$ means the input and output impedance, voltage amplification coefficient $(R_e = \infty$, open load) of the amplifier network $A$. According to the configuration of feedback network, we may get the equations of the feedback network.
transmission, the transfer coefficient may be ignored the load of port2. Because of one-way nature of the signal resistance. Generally the overall gain the model in Figure. 4 matches the block diagram well. In other words, the concept "open loop" does not mean a simple removal of the feedback network but the removal of the controlled source (The feedback coefficient should be regarded as zero, \( F_w = 0 \)).

### III. ANALYSIS AND SOLUTION

From the above we can get the model of the negative feedback voltage in series amplifying network (Figure 3).

We may further improve the model shown in Figure 1 and get the model shown in Figure 4 so that the model is more in line with its electrotechnical meaning:

In Figure 4, the load effect of feedback network to the input/output port is considered as part of the amplifier network and reflected in the amplifier network. We can see the model in Figure 4 matches the block diagram well.

According to Figure 4, We can solve the voltage gain, input and output impedance respectively:

\[
\begin{align*}
r'_i &= r_i + r_w' = \frac{1}{r_i' + \frac{1}{r_f}}; \\
A_w &= A_w' = \frac{r_i}{r_w'}; \\
A_o &= \frac{R_f}{r_w' + R_f} = \frac{1}{F_w} = \frac{1}{1 + A_w} = \frac{A_w}{A_o} = \frac{r_w'}{r_i'}; \\
F_o &= (1 + A_w) F_w = \frac{R_f}{r_w' + R_f} r_f' \\
E_o &= \frac{r_w'}{1 + A_w} F_w
\end{align*}
\]

\(A_w\) is the open circuit voltage gain of open loop, \(A_{out}\) is the open loop voltage gain considering the load resistance. Generally the overall gain \(A_{out}\) is approximately equal to the factor \(\sqrt{F}\) in the conditions of deep negative feedback, the input and output impedance changes \((1 + AF)\) times than that of closed loop. For the other three configurations, we can also get the same conclusion, which readers can derive them with the method.

When there are several feedback networks (\(F_1, F_2, \ldots\)), we may analyze the networks layer by layer. For example we can combine the feedback network \((F_1)\) and amplifier network \((A)\) to a whole amplifier network \((AF)\) while the other feedback network works independently.

### IV. EXAMPLES AND VERIFICATION

After method obtained from above, we will study some negative feedback amplifier of two feedback configuration.

#### A. 4.1 noninverting scaling operation circuit

See the circuit given below, we’ll find the feedback network in the pane marked with dotted lines. It is easy to judge its configuration which is negative feedback voltage in series. From the above we will easy solve the network:

\[
F_w = K_{11} = \frac{R + R_f}{R} \quad r_f = \frac{1}{V_o} \quad r_f = R_e, r_f' = \infty \Rightarrow r_f'' = 0
\]

We can see the solution is identical with the theoretical value.

#### B. 4.2 single stage quasi-common emitter amplifier

See the circuit given below, we’ll find the feedback configuration is current negative feedback in series: As the figure shown above, we can get the model, \(R_g, R_c\) is outside of negative feedback amplifier network so that its effect may be considered at last.

According to the method given above, we firstly study the feedback network and get the factor of its open loop condition. We’ll get the solution:

\[
r_f = r_w = R_e, F_w = R_e; \\
r_f' = r_w' + r_f = r_w + R_e, r_f' = \infty \Rightarrow r_f'' = \infty, A_{out} = \frac{\beta}{r_w + \beta R_e}
\]

\(A_{out}\) is the factor of open loop (\(F_w = 0\)). Then we will obtain the factor of closed loop:

\[
A_{out} = \frac{1}{1 + \frac{R_w + \beta R_e}{R_w}}
\]

\(R_c\) is the factor of \((F_w = 0)\).
At last, we'll get the final solution by taking into account the impact of resistance outside the loop:

\[ r'_c = \frac{1}{\sqrt{R_0 + \beta R_e + \frac{1}{\beta R_c}}} \]

The values shown above show the effectiveness of our method.

V. CONCLUSION

In this paper, we analyze the structure and function of negative feedback network in negative feedback amplifier, define the concept of open loop and closed loop, make the analysis and interpretation on the various parameters with the method based on dual-port network, and get the solution of the mathematical expression. It shows that the method addressed in this paper has a very clear electrotechnical meaning and reflects the function and role of feedback networks.

By example of solving the negative feedback amplifier, the method has been proved valid and effective, and can be well unified with the block diagram of the negative feedback network.

REFERENCES


Figure 3. Model of negative feedback voltage in series amplifying network-I

Figure 4. Model of negative feedback voltage in series amplifying network-II

Figure 5. Noninverting scaling operation circuit

Figure 6. Single stage quasi-common emitter amplifier