On the matter of building high-frequency amplifiers minimally influenced by interstage stray reactances

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Abstract. The expedience of building wideband multistage amplifiers, the stages of which are connected with each other so, that the “modes of impedance mismatch” are realized, is justified. Those modes allow us to reduce considerably the sensitivity of amplifier transfer factors to the stray (constructional) capacitances and inductances of interstage circuits. The procedure of synthesizing the schematics of such amplifiers is proposed, the efficiency and clarity of which are provided by using the method of signal graphs.

The quality of front-end electronics (especially the one implemented by microelectronic technology) is largely determined by amplifier parameters and first of all by their stability.

It is well known, that the most drastic means of raising the stability of amplifier characteristics (reducing their sensitivity to destabilizing factors) is the use of common feedback (FB) with its amount as high as possible. At FBs of high amount the requirements to the stability of separate stage parameters may be reduced. But, at an increase of the amplifier’s upper cut-off frequency, the application of common FBs can become unacceptable due to the impossibility of providing amplifier stability. In such cases the influence of stray reactances (capacitances and inductances) in interstage circuits can be considerably reduced by using the mode of “impedance mismatch” between the stages [1].

That mode takes place, when the output resistance of the previous stage is much less, than the input resistance of the following one (“voltage matching”) or, on the contrary, when the output resistance of the previous stage is much greater, than the input resistance of the following one (“current matching”). Namely in such a mode the time constants of the transients, both caused by stray capacitance and stray inductance will become minimal.

With the number of stages rising there grows naturally the number of possible structures, providing the specified transfer factor at the condition of all interstage circuits implementing the mode of impedance mismatch. For instance, in a 3-stage amplifier (see figure 1) any transfer factor can be obtained by four different ways. For simplicity and visuality let us consider the case, corresponding to ideal stages, characterized by an ultimate transfer factor and ultimate values of input and output resistances. In this figure and further on the symbols 0 and ∞ denote low-ohmic and high-ohmic input and output impedances of stages. In that same figure 1 K u ∞ 0 – the ultimate voltage gain factor, K i 0 ∞ – the ultimate current gain factor, S u ∞ ∞ -- the ultimate transresistance, S i 0 0 -- the ultimate transconductance [2].

Thus, in the considered cases the transresistance S u = u i /i g can be realized by 4 ways:

S u = K i1 0 ∞ K i2 0 S i3 ∞ = K i1 0 ∞ S i2 ∞ K i3 0 = S i1 ∞ S i2 0 S i3 ∞ = S i1 ∞ K i2 0 K i3 0.

Naturally, the expounded matters are valid also for non-ideal stages. In such a case, however, the transfer factor will be less (comparing to the ultimate values) due to the actual values of input and output resistances of stages and also the finite values of biasing resistors in interstage circuits.
The implementation of the necessary transfer factor may be reached by following a procedure of synthesizing wide-band amplifiers, based on a consequential consideration of possible two-, three- and so on-stage amplifiers. Thereat the simplest and most visual way of drawing and analyzing those structures will be the one of signal graphs [3]. In figure 2 there are presented some examples of such structures, providing the acquisition of the transimpedance $S_\nu$ with 3 stages (sections), where $i_1, u_1$ and $i_2, u_2$ indicate the type of output signal of the first and second stages correspondingly.

The choice of any structure is expedient to be governed by practical considerations, for instance, by the available selection of transistors, regularity of the multistage amplifier’s structure, simplicity of arranging the FB loop of the necessary type. A significant part is played also by the reactance type, the influence of which on IC characteristics predominates. For instance, in the course of designing ICs, wherein the stray capacitances limit the speed in a greater degree, than the stray inductances do, the designer should avoid voltage signals in interstage circuits, preferring current signals for them.

The presentation of amplifier structures in the form of signal graphs allows us to determine at once the necessary FB types, applied to stages and sections. Figure 3 shows the above stated with the example of a structure, where the indexes “dt” and “rt” denote the transfer factors of the direct and reverse channels (of the FB loop).
Figure 3. Presentation of amplifier structures in the form of signal graphs.

Figure 4 shows the actual structures with bipolar transistors, corresponding to the graphs of figure 3.

Figure 4. Actual amplifier structures with bipolar transistors.

Conclusion
In the course of designing and implementing pulse amplifiers, which are the basic parts of contemporary systems of radiation detector signal acquisition and processing, it is necessary to pay attention to the influence of stray (structural) elements, which are always present in interstage circuits of amplifiers and worsen their stability and speed. The given work gives recommendations on building pulse amplifiers, the stages of which are coupled with each other in the modes of either current or voltage matching. Namely those modes reduce to a minimum the influence of stray elements. The synthesis of such structures, considered in the work, is described most visually by the use of signal graphs for their analysis.

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