Simulating the Loop Transfer Function of Feedback Systems: Breaking the Loop

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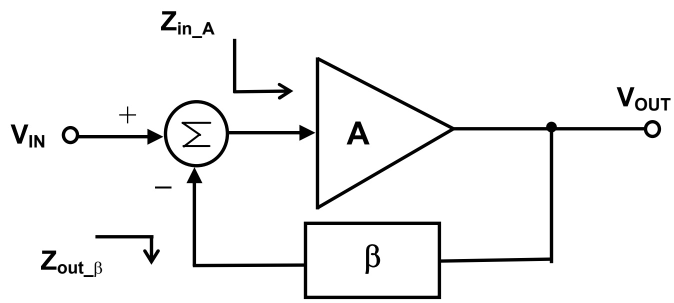
Abstract: Stability of feedback systems is generally accessed from their gain and phase margin information, which can be obtained from the open-loop transfer function bode (gain and phase) plots. This paper presents an approximate model and an exact model for simulation of feedback loops under various DC bias conditions using SPICE like simulator.

Loop schematic



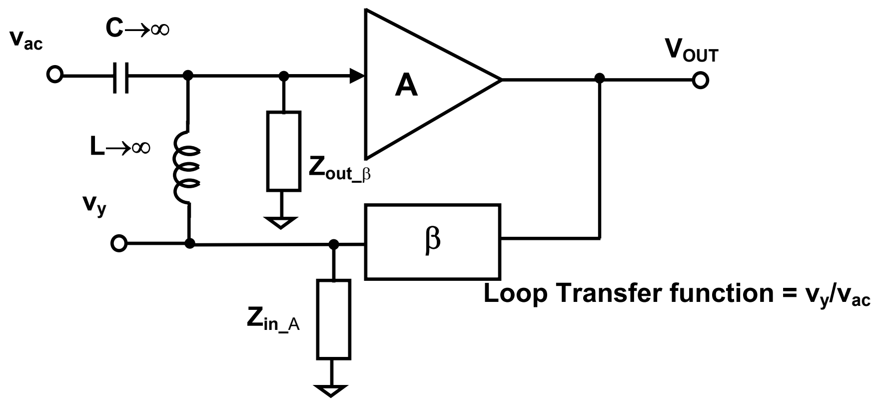
Technique 1: Approximate Model

Try to break the loop at a high impedance node. For example, the gate of a MOSFET is an ideal place to break the loop.

Ideal place to break the loop

Not recommended

Otherwise, model the impedances seen by the sub-circuits in the open-loop schematic, as shown below:



Comments:

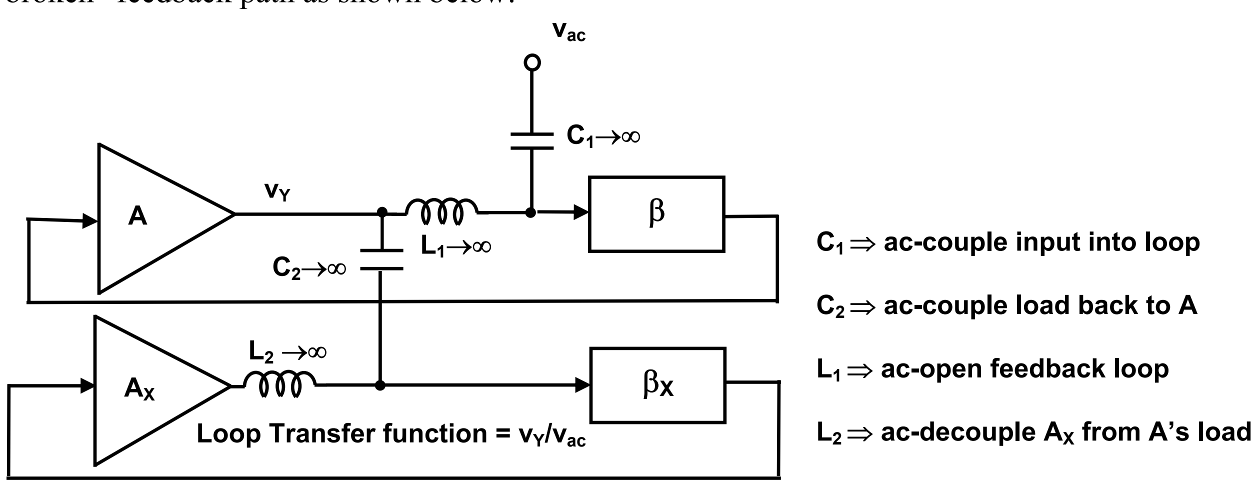
1. Each time the elements/architecture of subcircuits is modified, loading impedances (Z_{in_A} and Z_{out_β}) change. In the open-loop schematic, these changes must be reflected (by changing Z_{in_A} and Z_{out_β}) to obtain correct results.

2. If the loop is opened at a high impedance node with respect to the frequency spectrum of interest, there is no need to change/update the loading impedances.

3. .CAPMAX should be set to a very high value (e.g., 1000 MF).

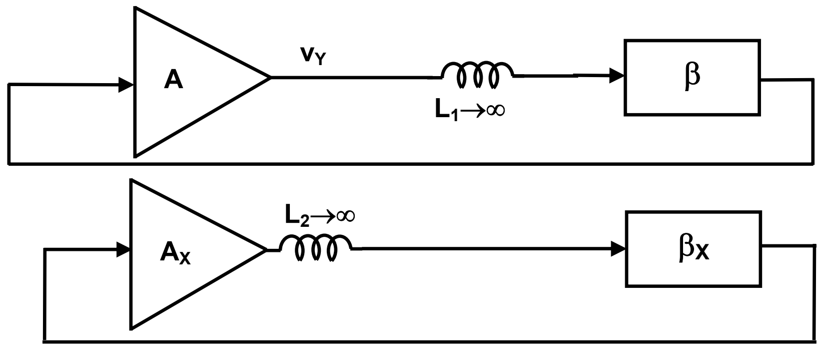
Technique 2: Accurate Model

Create a schematic by replicating the loading effects and biasing conditions of the forward path (A and A_X) and feedback factor (β and β_X) in appropriate places of the "broken" feedback path as shown below:

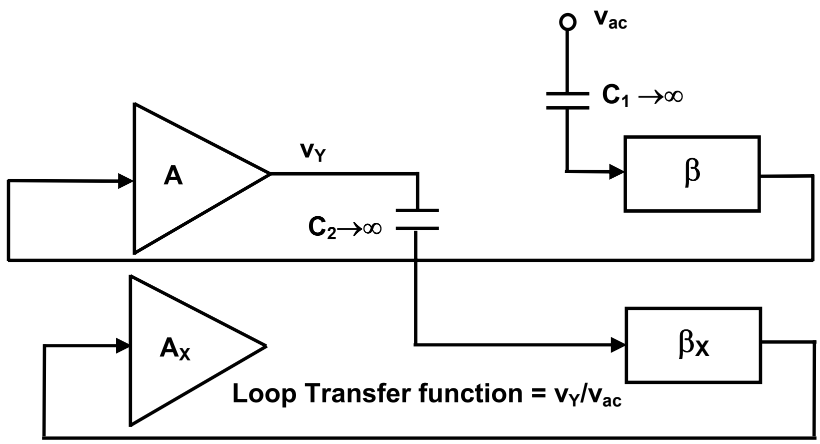


Operation:

(a) Under DC conditions (for biasing the gain and feedback blocks), the schematic can be represented as shown below:



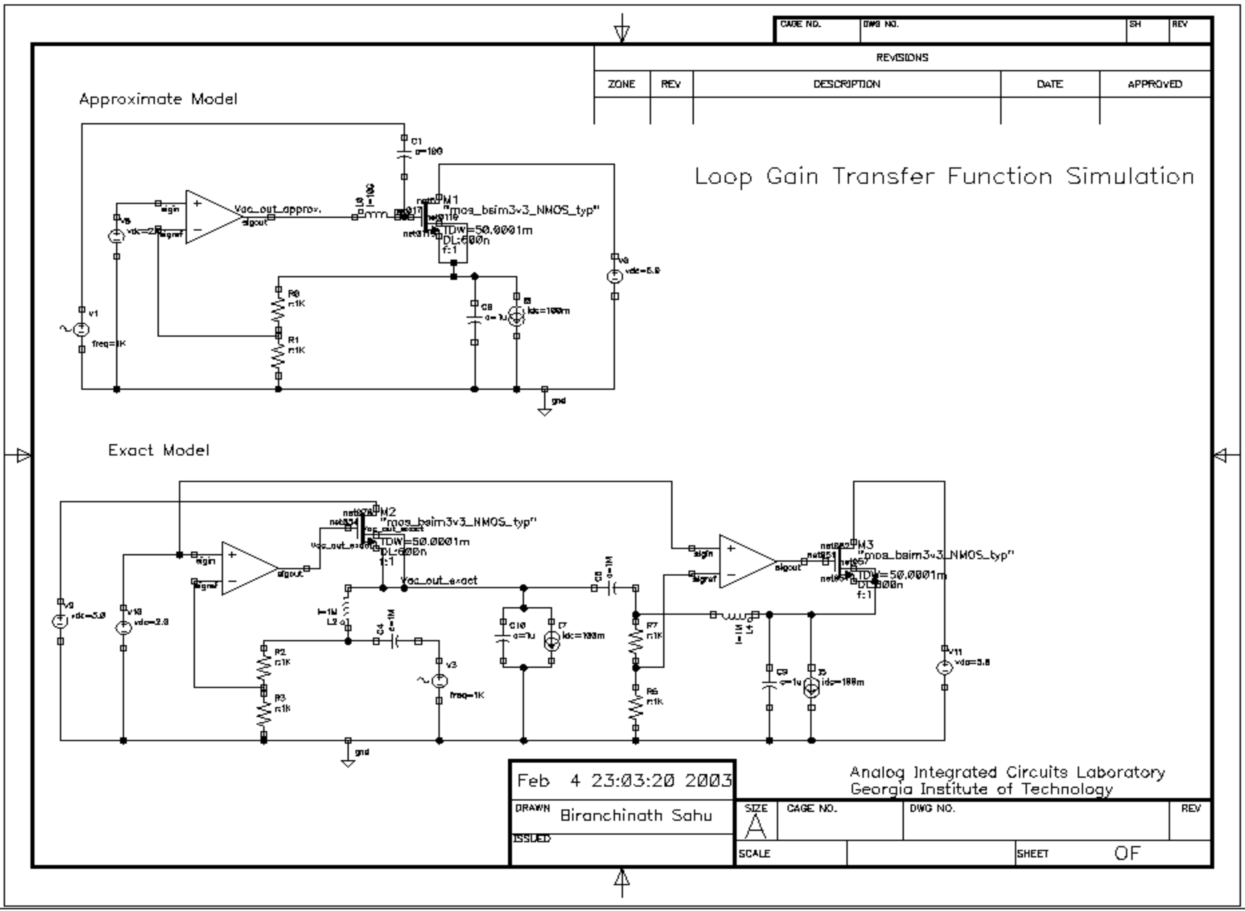
(b) For small-signal AC analysis, the schematic is represented as follows:



Comments:

1. Any change in the original circuit-block must be updated in the "replica circuit" to obtain correct results. These changes can be achieved by instancing the same subcircuit for the original and the replica. In that case, the changes/modifications are updated in both blocks automatically.
2. Similar to the approximate model, .CAPMAX must be set to a very high value.
3. The accurate model should only be used when there is no other choice because of its complexity (it is not difficult to make mistakes).
4. In this example, the loading on the output of the gain block (Z_{in_β}) is acccounted for but not the loading on the input of the feedback block (Z_{out_A}). The results are unaffected because an ideal voltage source is being applied to the input of the feedback block, and therefore, no impedance included there would make a difference.

EXAMPLE



RESULTS