Minimizing the Number of Floating Bias Voltage Sources with Integer Linear Programming

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Abstract

Applying the non-heuristic biasing theory as described in [1] results in circuits which are optimally biased. However the resulting circuits will contain many floating voltage sources. This one page paper describes the use of Integer Linear Programming to minimize the number of these sources.

1. The Integer Linear Programming Model

The construction of the ILP model involves taking the following steps:

- First all the original bias voltage sources are removed from the circuit by replacing them with wires.
- Then in series with each edge a voltage source is placed which has a yet unknown value. To each of these voltage sources an on/off switch is assigned.
- Now an ILP model can be constructed based on the obtained circuit. This model contains directives to find the values for the voltage sources for which both the KVL's of the original circuit hold *and* the number of the voltage sources is at a minimum.
- After solving the obtained model with an algorithm like *Branche and Bound* the optimal circuit is obtained.

In order to write down a model formally some definitions have to be made first. Let m be the number of meshes in the circuit, n be the number of edges and the $m \times n$ matrix C be the reduced mesh-edge incidence matrix. Further, let the $n \times 1$ vector $\vec{v}$ be the vector whose elements v_i represent the sources in series with edge i. Finally, let the $m \times 1$ vector $\vec{b}$ be the vector whose elements b_j represent the sum of the sources in mesh j of the original circuit. The switches will be modeled with the binary variables D_i with $i \in \{1..n\}$, one for every edge.

Now we can write down the general form of the ILP model for the minimization:

$$minimize \quad \sum_{i=1}^{n} D_i$$

$$such \ \ that \quad C \cdot \vec{v} = \vec{b}$$

$$-D_i \cdot \infty \leq v_i \leq D_i \cdot \infty \quad , 1 \leq i \leq n$$

$$D_i \in \{0, 1\} \quad , 1 \leq i \leq n$$

When a binary variable D_i belonging to a source v_i is zero, so will be that source because the source will have its upperbound and lowerbound equal to zero. When the binary variable is equal to one then the source can have any value because it has infinite boundaries.

In practice the use of ∞ isn't possible. Therefore, instead of ∞ a sufficiently large constant should be used. The exact value of this constant is not important, only that it should be higher than the highest possible value for a source. For instance the sum of the absolute values of the sources in the original circuit could be used for this.

Solving the model with an algorithm like *Branch and Bound* yields the values for the sources v_i for which the goal-function $\sum_{i=1}^{n} D_i$ is minimal. This also corresponds to a solution with a minimal number of voltage sources.

The model can be extended such that it gives priority to the minimization of floating sources. Also transistor-type switching [1] can be incorporated in the model. Another extension which is possible is modeling sources which don't have a single specified value but a value in a range.

References

[1] C.J.M. Verhoeven and A. van Staveren *Systematic Biasing of Negative Feedback Amplifiers* Design Automation and Test in Europe Conference, 1999, pp 318-322.