The Hong Kong University of Science & Technology

Design Of High-Gain CMOS Operational Amplifier

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Operational amplifier is one of the most important components in many analog and mixed-signal IC designs. Cascoding and cascading are the most two popular methods to enhance the gain of amplifier. The first approach achieves gain enhancement by increasing the output impedance of a basic gain stage. Double or triple cascoded amplifier can achieve high gain (>90dB), but correspondingly limits the output swing, and are not applicable to low voltage circuit. The second approach achieves gain enhancement by cascading two or more gain stage, however, it seriously limits the high frequency performance.

A new circuit technique called negative impedance for gain enhancement is presented in this report. A negative impedance is used to cancel the positive output conductance of an amplifier, therefore reducing the total output conductance and increasing the gain of the amplifier without scarifying high frequency performance. Single stage CMOS operational amplifiers were designed using this technique. However, resistor, threshold voltage and temperature variation can affect the performance of amplifier using this technique. For resistor variation, the DC-gain of amplifier can drop by 30%-50% within ±3% resistor derivation. But it is known that the derivation of resistor can be as large as ±20% due to process limitation. For threshold voltage and temperature variation, the DC-gain of amplifier also can not be maintained as current level and hence the negative impedance is changed. The main purpose of this project is to solve the above problems.

Block diagram of the fully differential amplifier using negative impedance technique
The success of gain enhancement by negative impedance depends on prefect matching between the positive output conductance and the negative impedance. This requires a constant current to achieve that. Three current sources that can generate current independent of resistor variation are introduced below:

1. $V-I$ converter

2. Current subtraction method

3. Modified Widlar current source
Schematic of the folded-cascoded amplifier using Negative Impedance

With the proposed current generator, the performance of amplifiers with $R$ and $V_{th}$ variation are shown below:

1. Folded-cascoded amplifier using $V-I$ converter

![Graph showing amplifier performance comparison]

2. Folded-cascoded amplifier using current subtraction method

![Graph showing amplifier performance comparison]

3. Folded-cascoded amplifier using modified Widlar current source

![Graph showing amplifier performance comparison]

The above results show that only 5% change in DC-gain with $\pm 20\%$ $R$ variation.