Analog Circuit-Blocks for designing an Artificial Neural Network

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Abstract

I was able to successfully implement a Gilbert Cell-based multiplier, which is one of the analog circuit blocks required for designing an artificial neural network in the form of an analog computer. The designed multiplier cell is capable of four-quadrant multiplication which is necessary for calculating the product of neuron inputs and the corresponding layer weights. The cell makes use of two levels of differential pairs to divide the tail current, so understanding of differential pairs is key to designing a Gilbert cell multiplier. Apart from its apparent use as a four-quadrant multiplier, it can also be used as a variable gain amplifier, balanced modulator and frequency mixer.

1 Circuit Details

In course of the event, I successfully designed and simulated the working of a Gilbert cell-based multiplier that can be used as a circuit block when designing an analog equivalent of an artificial neural network. In order to work as a four-quadrant multiplier, the multiplier output, Vout has to follow the equation Vout = K*V1*V2, the constant K depends on the configuration of the circuit. It is to be noted that in order to be able to achieve outputs close to the theoretical value, the PMOS devices used should be near identical.

The multiplier works by using two levels of cascaded differential pairs, the tail current I1 at the bottom (which maybe replaced by a PMOS) is divided by a differential pair formed by M2 and M5. V1 is fed into the gate of these two devices. The divided tail currents then reach one of the two differential pairs (M1-M3 or M4-M6), one difference at this level is that the input V2 at the gates of these PMOS devices are cross-connected as shown in the circuit schematic. Finally, the divided tail currents reach the resistors where we obtain the output voltage Vout by calculating the difference between the voltage drops across resistors R1 and R2.

The plotted waveform on the left shows the sinusoidal inputs V1 and V2, while that on the right is the plot for Vout. We can notice that the value of Vout reaches zero when one (or both) of the inputs are zero. It is evident that the output waveform follow the rules of multiplication in all quadrants. The waveform described in the literature survey could not be replicated due to the limitations of ngspice.

2 Implemented Circuit

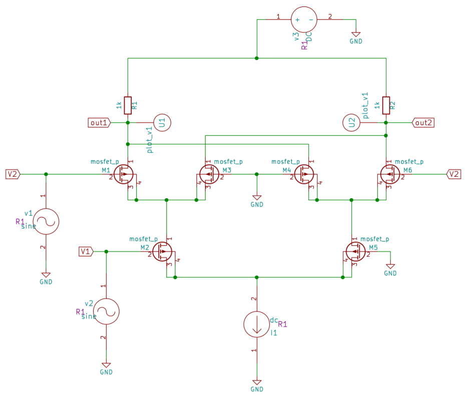

Figure 1: Implemented circuit diagram.

3 Implemented Waveforms

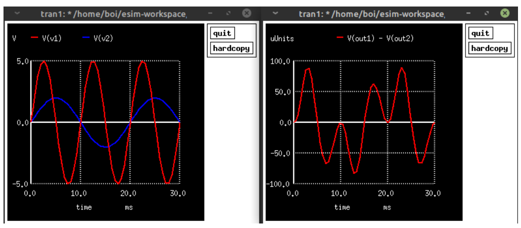

Figure 2: Implemented waveform.

References

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