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Flicker Noise Optimization with Genetic Algorithm in a MOS Transistor using MATLAB

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Abstract-This paper presents optimization of flicker noise of MOS transistor using genetic algorithm(GA), which is the most important evolutionary algorithm. GA is mainly used for optimization of non linear function. It finds the best solution for an objective function . GA starts with the population of a set of chromosomes choosing randomly. One then evaluates this structure and allocates reproductive opportunities in such a way that those chromosomes which have a better solution for the particular problem are given more chances than those chromosomes which have poor chances. In this paper the flicker noise of MOS transistor has been optimized using GA considering variable frequency (f) and channel length (L) of MOS transistor. MATLAB software has been used to run the GA. Optimization results are satisfactory and have been presented in this paper.

Keywords—Flicker Noise,Optimization,GA

I. Introduction

Noise in electronic circuits is generally associated to the random fluctuations affecting currents and voltages. Noise cannot be completely eliminated and it sets the lower limit of the signal being processed by a circuit without significant deterioration in the signal quality. Noise behavior in MOS Devices are mainly characterized by two types of noises: Thermal Noise and Flicker noise. Flicker noise are mainly due low frequency components of signal , for that flicker noise is called 1/f noise .In MOS devices flicker noise also depends on channel length by means of area . Other sources of noises that are sometimes present in the device are Shot Noise, Burst Noise, and Avalanche Noise. Flicker Noise is the dominant noise source in MOS Devices. Low frequency noise in silicon MOSFET is dominated by Flicker Noise. Spectral density of flicker noise is inversely proportional to the frequency. For efficient design of devices and circuits deals with MOS with other design parameters it is also necessary to optimize flicker noise. In this paper the optimization of flicker noise is performed using genetic algorithm considering frequency and channel length as variable .

II. Flicker Noise(1/F) Noise

1/f noise or flicker noise is the dominant noise source at the low frequencies in the MOS devices. Flicker noise is an important parameter for analog and RF applications. Three different theories are there to explain the origin of flicker noise in the MOS devices.

1.Carrier Number Fluctuation Theory: This theory, originally due to McWorther, the flicker noise exists due to trapping and detrapping of charge carriers in the gate dielectric. Each single trap contribute to a Lorentzian noise power spectrum. For that 1/f noise spectrum is created .

2. Mobility Fluctuation Theory: Mobility Fluctuation Theory from The Hooge model, states that the noise to bulk mobility fluctuations caused by phonon scattering.

3. Unified Flicker Noise Model: Unified Flicker Noise model has been designed to describe the noise characteristics of both p and n channel MOS devices. This model extends the carrier number fluctuation theory to incorporate the Coulomb scattering of free charge carriers. Both charge carriers fluctuation in the channel and mobility fluctuation theory are inter correlated. This unified noise model is very useful in describing the noise performance in both n-channel and p-channel devices of MOS.

Recently, flicker noise in MOS devices is becoming very important as the feature size of the devices is scaling down aggressively. With the decreasing feature size, 1/f noise increases . Generally this flicker noise is generated due to surface imperfections resulting from the emission. The mean square value of this noise current is given as

$$I_f^2 = K_f \frac{I_D^a}{f} \Delta f \quad Amp^2 \text{...............} (1)$$

Where

Δf : noise bandwidth in Hz. , I_D : direct current , K_f : flicker noise constant for specific device a : flicker exponent ranges between 0.5 to 2.

III. Optimization

The main title (on the first page) should begin 1-3/8 inches (3.49 cm) from the top edge of the page, centered, and in Times 14-point, boldface type. Capitalize the first letter of nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, or prepositions (unless the title begins with such a word). Leave two 12-point blank lines after the title.

IV. Genetic Algorithm

Genetic algorithm is used for parameter optimization problem. GA includes mainly four processes selection, crossover, mutation and accepting.

4.1 Necessary steps for GA Execution

a. Start: Initial population of 'n' number of chromosomes are randomly generated
b. Fitness : Fitness value of each chromosome is calculated
c. New Population: New population is created considering the following steps.

Selection: Parent chromosomes from new population are selected considering to their fitness value. Some selection operators – like Roulette wheel selection are being used for this step.
Crossover: In this step crossover is performed among parent chromosomes by pair to form new off springs with the suitable cross over probability.
Mutation :For fine tuning of generation mutation is done on new off spring with a proper mutation probability.
Accepting: New off springs are placed in the new population.
Replace: Now newly generated population are being used for further improvement using step 2 and step 3.
Test: If the desired condition is satisfied, then program is stopped and the best solution is obtained .

V. Optimization Results and Discussions

The expression of flicker noise voltage for MOS transistor is given as

$$V_n^2 = \frac{K\, t_{ox}}{\epsilon_{ox} W L} \frac{1}{f} \quad \text{Volt}^2/\text{Hz} \;\ldots\ldots\ldots\; (2)$$

Where K= Process dependent constant of the order of $10^{-25}\, V^2$ F ; t_{ox} is the oxide thickness ; ϵ_{ox} is the permittivity of oxide layer ;W is the channel width and L is the channel length of MOS and f is the signal frequency .

Equation (2) is considered as fitness function to optimize flicker noise using genetic algorithm. To run GA program frequency and channel length are considered as variable and K, ϵ_{ox} ,W , t_{ox} are considered to be fixed .Value of frequency is varied from 1Hz to 100Hz and L is varied from 45nm to 100nm . Fixed parameter values are taken as K=$10^{-25} V^2$ F, t_{ox} =2nm, W=100nm, ϵ_{ox}=9.1×8.85×10^{-12} F/m.

Followings are the example sample output from MATLAB coding for optimization of flicker noise.

String of chromosome in the population :

v = 1111110011001001110101001000101010100100
0010011001101100001000001100010101011010
....
....
0110101110101001101111001110100110000111

Population size has taken as 20 . So v is the randomly generated in 20 sequences each of 40 bit .
Evaluation from the population:

eval = 1.0e+20 *
2.411457542431343
0.304424958578462
....
....
3.110036089506799
1.535283164386217

Fitness value after the evaluation:
F=2.702962071562166e+21

This fitness value is shown in the first generation

Cummulative probabilities:

q= 0.089215367385368
0.100478010016625
....
....
0.943199973816173
1.000000000000000

Generation of random no.s between 0 & 1:
r= 0.632952443655251
0.710427307863708
....
....
0.962958775368380
0.534013751451731

The identification of the chromosomes which take part in crossover:

Chromosomes: 3, 5,15,17,20

Here the chromosome number selected for crossover is five ,that is odd number . So for mating in pair that is for crossover either one chromosome is rejected or one chromosome has to be added .For this example one is deleted . So number of chromosome take part in crossover is now four .
Chromosomes which take part in crossover:
First pair:
0111101111010101000011100010001010010000
1100110110011101011010100111000001111001
Second Pair:
1010001111100100110100111111101110110000
1111010101011110110100111000000110110100
Positions of cross over site selected randomly for first pair is 32 and for second pair is 16

Chromosomes after crossover:

0111101111010101000011100010001001111001
1100110110011101011010100111000010010000

1010001111100100110100111000000110110100
1111010101011110110100111111101110110000

Generation of 800 random number s between 0 & 1 for mutation :

0.898299948178677
…...............................
…...............................
0.554425288853058
0.229585395135581

The positions of the bits in the overall string of chromosomes which take part in mutation:
18 217 336 447 480 490 549 551 644 770

Chromosomes which are to be mutated:
1 6 9 12 12 13 14 14 17 20

Positions of the bit in the selected chromosome for mutation
18 17 16 7 40 10 29 31 4 10

Ready population for next generation that is for iteration

0100001101011101101110001001000110101100
0111101111010101000011100010001010010000
....
....
0110101110101001101111001110100110000111
1100110110011101011010100111000001111001

Optimum frequency and channel length after some generation are presented in Table:1

NOG No. Of Generation	Optimum frequency (Hz)	Optimum channel length(nm)	Optimum flicker noise of MOS ($Volt^2/Hz$)
1	93.94	86.32	3.08×10^{-12}
5	99.62	55.37	4.5×10^{-12}
10	95.89	80.88	3.22×10^{-12}
15	93.94	97.06	2.74×10^{-12}
20	95.88	89.52	2.91×10^{-12}
25	93.94	96.63	2.75×10^{-12}
30	88.82	89.51	3.14×10^{-12}
35	100	45	5.56×10^{-12}
40	99.99	45	5.56×10^{-12}
45	99.99	45	5.56×10^{-12}
50	100	45	5.56×10^{-12}

It seen from the analysis that there are sets of optimum frequency and channel length. Among these 100Hz and 45 nm is the best choice because here feature size is least and aspect ratio of MOS (W/L) is also satisfactory. Corresponding value of optimum flicker noise is 5.56×10^{-12} $Volt^2/Hz$.

VI. Conclusion

Genetic Algorithm (GA) is very useful search technique to design the device and circuit at nano level. In this paper it has been focused on the optimization of flicker noise of MOS transistor in nano level . Frequency and channel length of MOS are considered as variable to optimize the flicker noise. From result analysis it has been accepted that 45nm channel length and 100Hz signal frequency is the best optimum value and corresponding optimum flicker noise is 5.56×10^{-12} $Volt^2/Hz$.

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