Research Migration Project

https://esim.fossee.in/research-migration-project

The Research Migration Project is an initiative of FOSSEE, IIT Bombay that promotes the use of eSim for reproducing published research circuits originally implemented using proprietary simulation tools. The objective is to migrate these validated designs to eSim to build an open source resource database.

Name of the participant : Mohit Kumar
Affiliation / Institution : Faculty of Technology, University of Delhi

Title of the circuit : CMOS Translinear Loop Based Current Squarer Circuit

Theory/Description :

The translinear circuit is based on the Generalized Translinear Principle, which states that in a closed loop of transistors biased in the active region, the product of currents flowing in the clockwise direction equals the product of currents in the counterclockwise direction. This principle allows implementation of precise nonlinear mathematical functions using only transistors and current sources. In this circuit, a loop of six NPN BJT transistors is arranged to implement the squaring function, where the output current is proportional to the square of the input current ($I_{out} \propto I_{in}^2$). Current mirrors are used to bias the loop and copy the output current accurately. The circuit operates entirely in the current domain, requiring no resistors or capacitors in the core, making it extremely compact and suitable for low supply voltage VLSI applications.

Reason to reproduce with eSim :

This circuit is highly suitable for simulation and reproduction using eSim because it uses standard NPN BJT transistors which are readily available in the eSim/Ngspice component library. Being an open-source tool, eSim makes this circuit accessible to students and researchers without requiring expensive commercial licenses. The circuit has significant educational value as it demonstrates the translinear principle, which is a fundamental concept in analog IC design. Currently no translinear loop based circuit exists in the eSim Research Migration repository, making this a meaningful and original contribution. Reproducing it in eSim also allows easy verification of the squaring characteristic through DC sweep and transient analysis.

Expected Outcome/outputs :

When simulated, the circuit should produce an output current that is proportional to the square of the input current. For a DC sweep of input current from -200µA to +200µA, the output should follow a parabolic curve, always remaining positive regardless of input polarity, which confirms the squaring behavior. For a sinusoidal input of amplitude 200µA at 200Hz, the transient output should appear as a rectified waveform oscillating at twice the input

frequency, always positive. The minimum output should occur near zero input and maximum output near peak input, consistent with Iout ∝ Iin².

Circuit Diagram(s) :

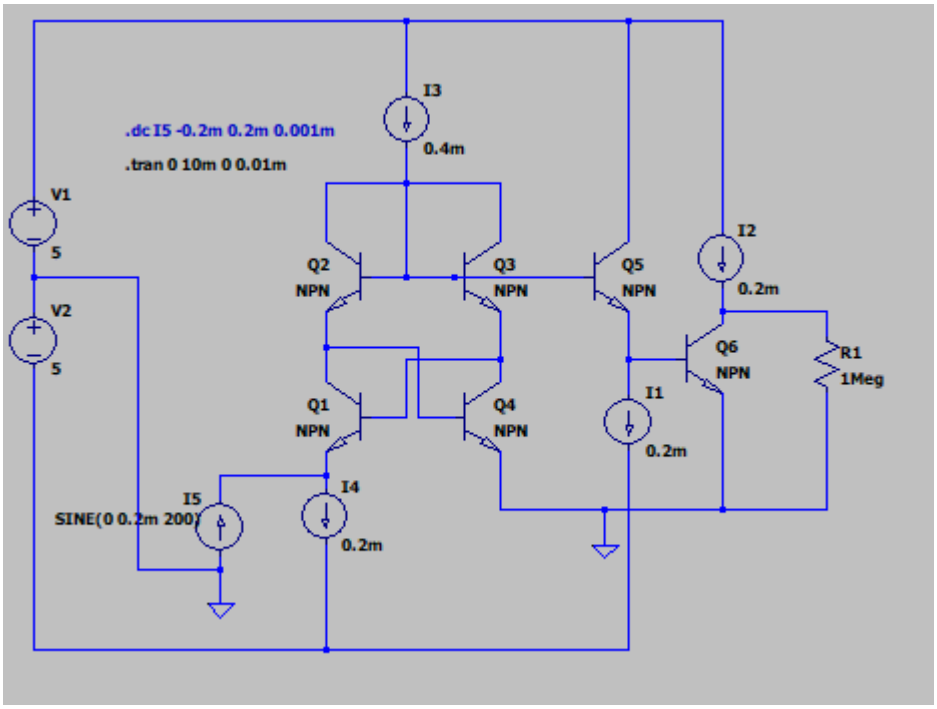

Figure 1: Translinear Current Squarer

Block Diagram (s) :

Input Current Source → Translinear BJT Loop (6 NPN transistors) → Current Mirror → Output Load (R1)

Expected Results (Input, Output waveforms and/or Multimeter readings) :

DC Sweep: Parabolic output curve, Iout ranging from ~0µA at Iin=0 to ~200µA at Iin=±200µA

Transient: Sinusoidal input ±200µA at 200Hz, output always positive, frequency doubled

FFT: Second harmonic dominant, confirming squaring behavior

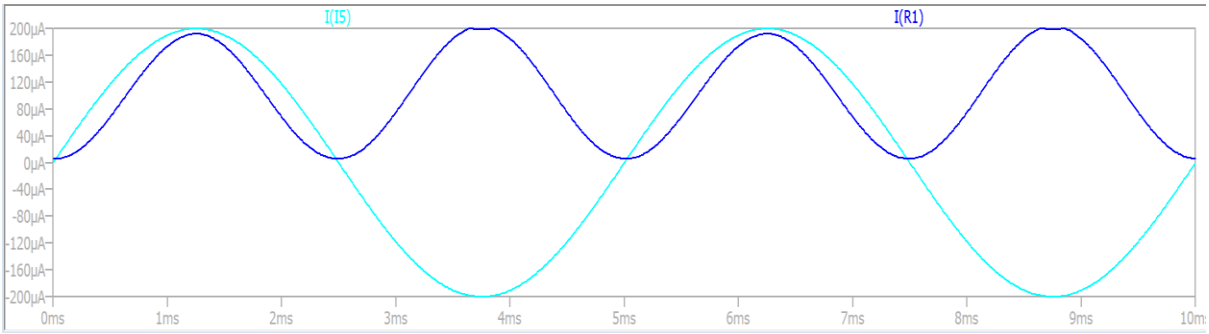

Figure 2 : Transient Analysis

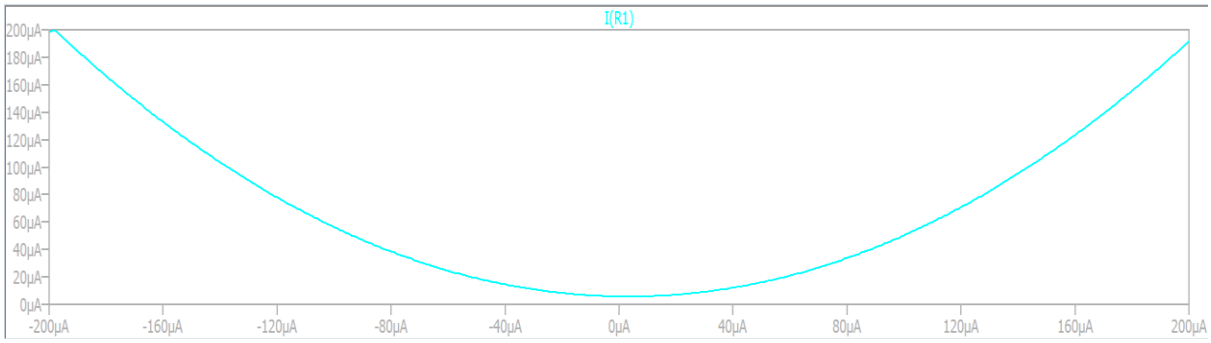

Figure 3: DC Sweep

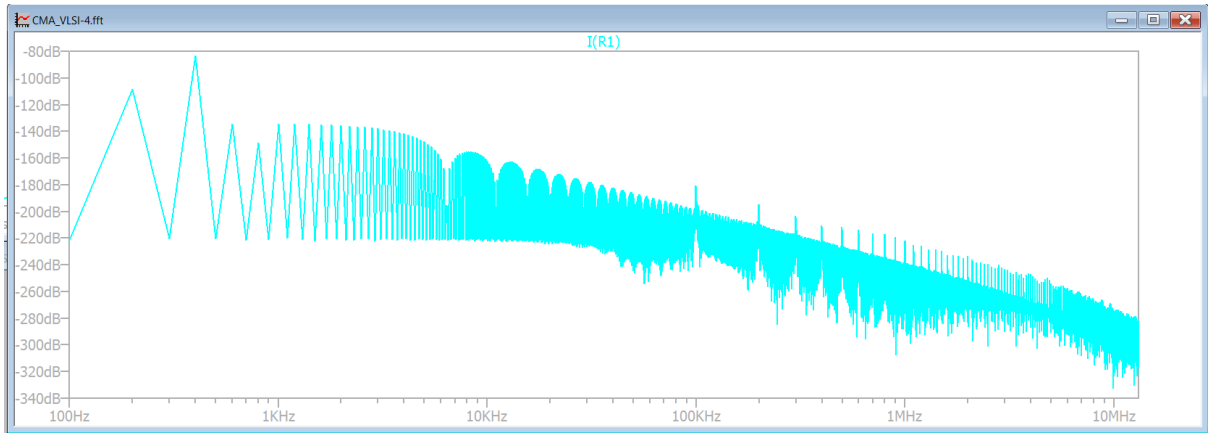

Figure 4: FFT

Research Paper/Journal/etc. :

Title : A low-voltage MOS translinear loop, biased using FVF and its applications in realizing square-rooter and squarer circuits
Author : Aakriti Chhabra, Bhawna Aggarwal, Raj Senani

Journal: INTEGRATION (Elsevier), Vol. 94, 2024, Article 102092

Page Number : Article 102092

Link: https://www.sciencedirect.com/science/article/pii/S0167926023001268

Source/Reference(s) :

1. Class notes and lectures by Dr. Raj Senani, Faculty of Technology, University of Delhi
2. Seevinck, E. and Wiegerink, R.J., "Generalized Translinear Circuit Principle", IEEE Journal of Solid-State Circuits, Vol. 26, No. 8, pp. 1098–1102, August 1991
3. eSim official documentation: https://esim.fossee.in