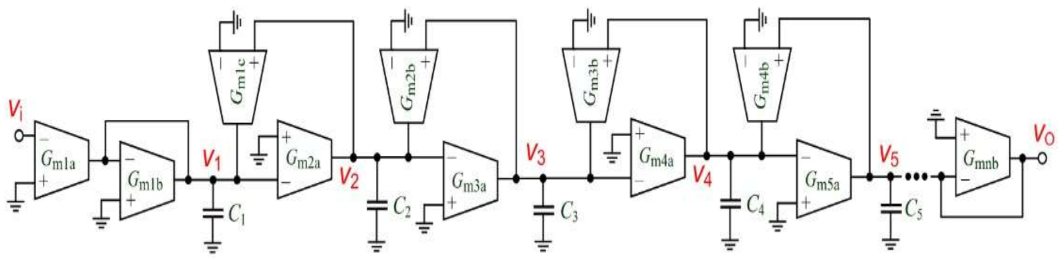
HIGHER ORDER GMC FILTERS(LADDER TOPOLOGY)

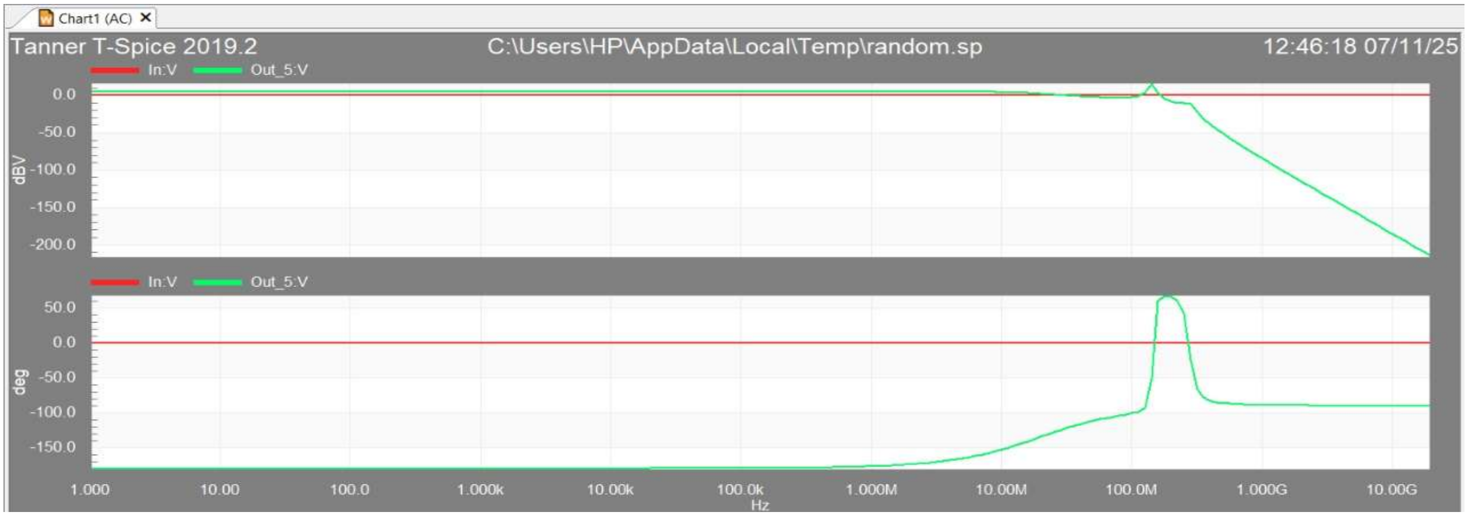
1. LADDER TYPE GMC CONFIGURATION:

The ladder-type Gm-C filter is a structured approach to designing higher-order filters by mimicking passive LC ladder networks using OTAs and capacitors. In this topology, transconductors emulate the behavior of resistors or inductors, enabling the synthesis of complex filtering functions without using actual inductive components. This results in improved linearity, tunability, and integration capability. Ladder structures offer excellent stability, predictable frequency response, and sharp roll-off characteristics. They are especially useful for precision analog applications where gain control, low power, and high performance are essential. By carefully selecting the transconductance values of OTAs and capacitor sizes, the desired cutoff frequency and filter order can be achieved with high accuracy.



SIMULATION RESULTS:

The simulation of the ladder-type Gm-C filter shows a 0 dB gain in the passband, maintaining a flat response up to the cutoff frequency. After this point, the gain drops sharply, exhibiting a roll-off of approximately 105 dB/decade. The result confirms the filter’s high selectivity and effective attenuation of out-of-band signals. The ladder structure ensures stable and accurate performance, validating the design for high-order precision filtering applications.



- Gain at **400 MHz** = **−40 dB**
- Gain at **4 GHz** = **−145 dB**
- Frequency ratio:

$$\frac{4\text{ GHz}}{400\text{ MHz}} = \frac{4\times10^9}{4\times10^8} = 10$$

✅ Roll-off formula:

$$\text{Roll-off (dB/decade)} = \frac{G_2 - G_1}{\log_{10}(f_2/f_1)}$$

$$= \frac{-145-(-40)}{\log_{10}(10)} = \frac{-105}{1} = \boxed{-105\text{ dB/decade}}$$

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2. CIRCUIT OVERVIEW:

The illustrated circuit is a ladder-type higher-order Gm-C filter designed to replicate the characteristics of a passive LC ladder network. It consists of five main sections, each involving operational transconductance amplifiers (OTAs) and capacitors configured to achieve precise pole placement and desired frequency response.

Key features of the circuit:

Series Gm Blocks (Gm1a to Gm5a): These OTAs form the main "series" path of the ladder, analogous to inductors in passive ladder filters. They convert voltage differences into proportional currents and define the energy flow between stages.

Shunt Capacitors (C1 to C5): Connected from each intermediate node to ground, these capacitors serve as the energy storage elements, similar to capacitors in passive designs. They set the filter's pole frequencies in conjunction with the Gm values.

Shunt Gm Paths (Gm1c, Gm2b, Gm3b, Gm4b, Gm5b): These OTAs simulate the shunt admittances (grounded branches) in the ladder network. Each contributes to setting the impedance and gain of the corresponding stage. They are essential in determining the damping, peaking, and bandwidth control.

Voltage Nodes (V1 to V5): These represent intermediate stage voltages. The values at these nodes evolve as the input signal propagates through the filter, with each stage contributing to frequency selection.

Output Buffer (Gmmb): The final OTA acts as a voltage buffer to isolate the load from the filter stages, ensuring that the output does not affect the filter's internal performance.

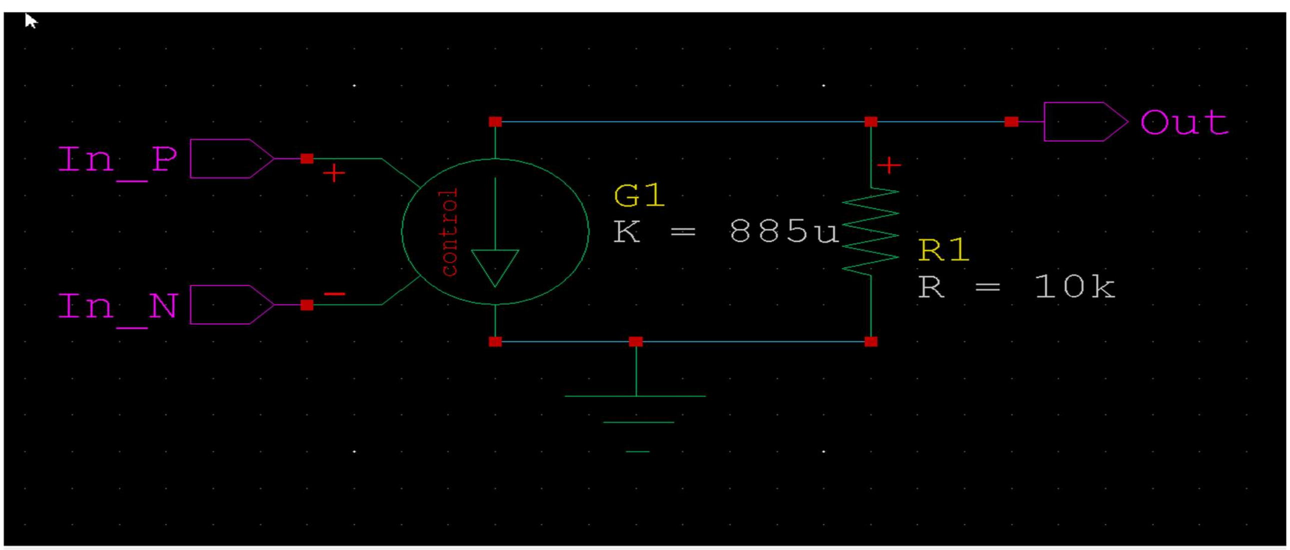
Fully Differential Structure: Many of the OTA pairs are implemented in a differential configuration, which enhances common-mode noise rejection, improves linearity, and allows for balanced signal processing.

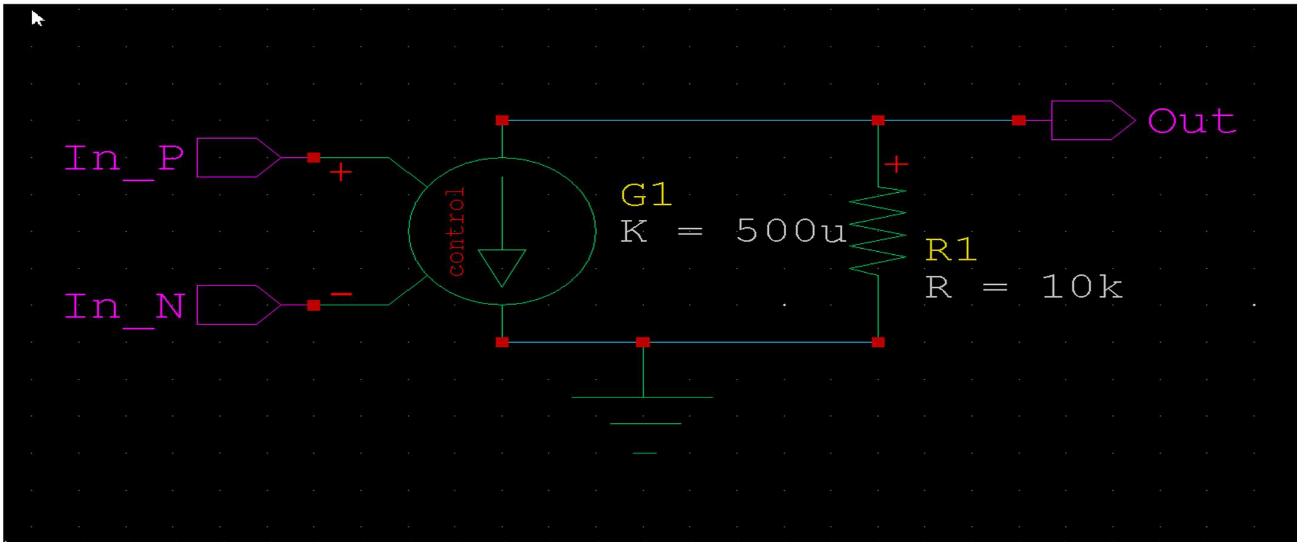
Feedback Paths: Some of the OTAs (like Gm1c, Gm3b, Gm4b) are connected in such a way as to provide local or global feedback, mimicking inductive behavior or improving stability.

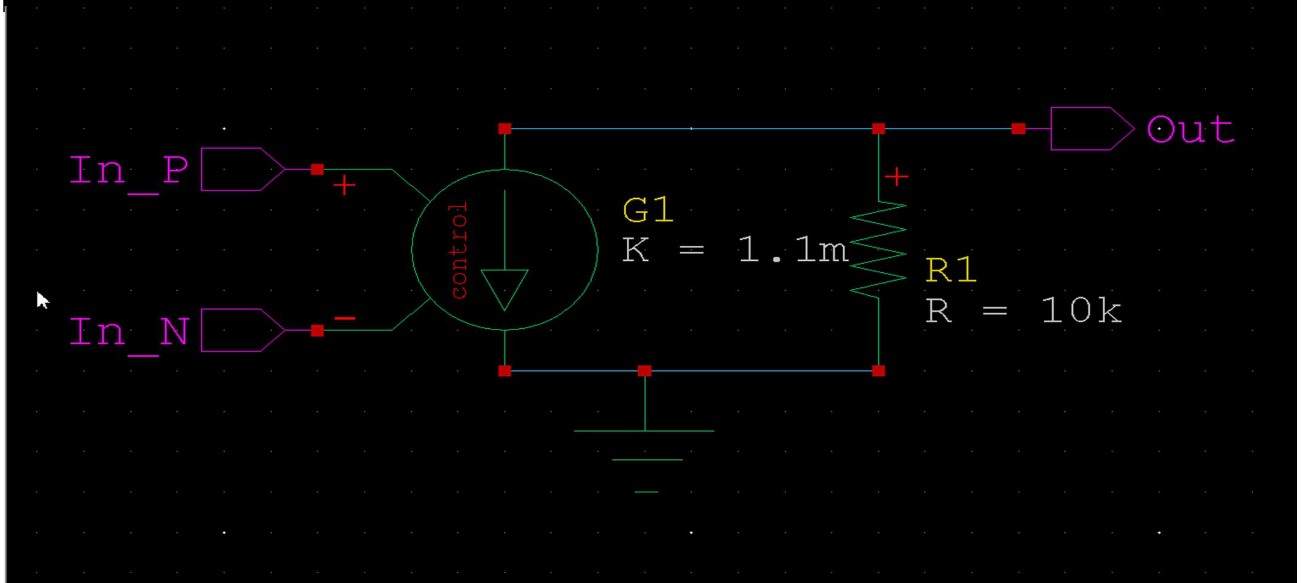
Precision Emulation of Passive Filters: The OTA and capacitor arrangement closely replicates a low-pass passive ladder filter, making it suitable for high-precision applications such as baseband filtering, antialiasing, or channel selection.

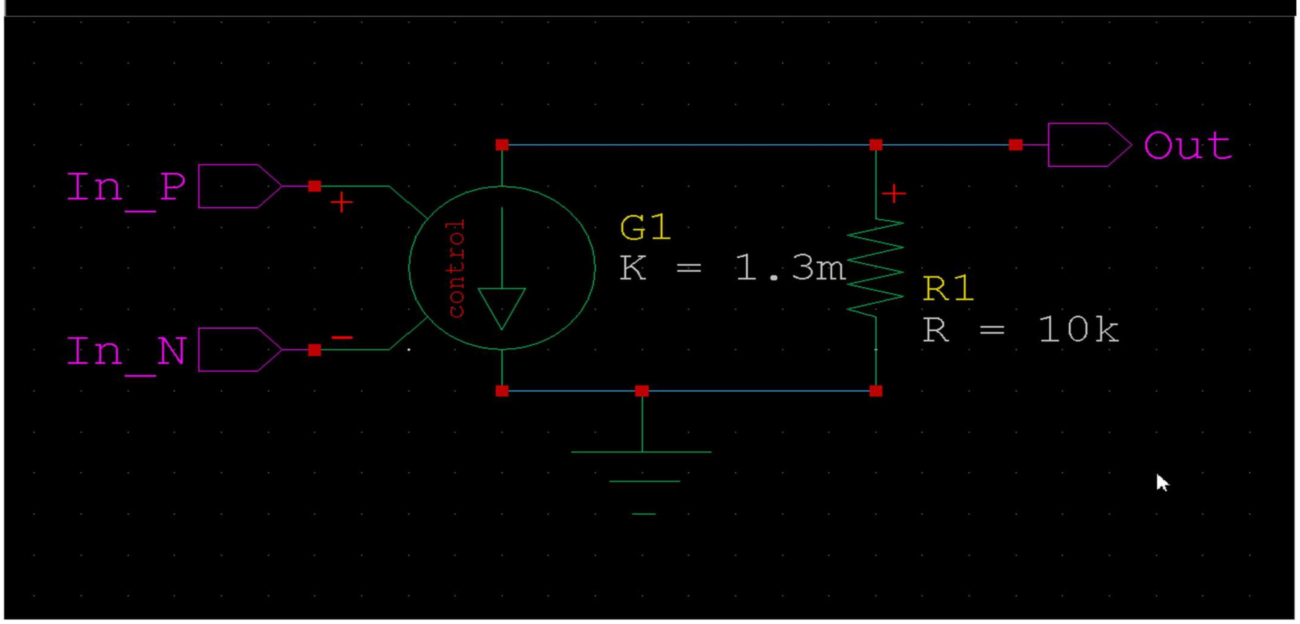
This Gm-C ladder architecture leverages OTA tunability, layout symmetry, and noise optimization, making it highly flexible and robust for integrated analog filtering applications.

OTA	Previous gm (µS)	Sugg
gm1c	885	885 (
gm1a–gm5a	885	885 (
gm1b	547.3	500
gm2b	1250	**1100**
gm3b	1500	**1300**
gm4b	1250	**1100**
gm5b	547.3	500




In_P
In_N
control
G1
K = 500u
R1
R = 10k
Out


In_P
In_N
control
G1
K = 1.1m
R1
R = 10k
Out


In_P
In_N
control
G1
K = 1.3m
R1
R = 10k
Out

Reason for Using Different Gm Values:

Different Gm values are proposed to precisely shape the frequency response of the filter and to control parameters like gain, bandwidth, and damping at each stage. Higher Gm values (e.g., Gm3b = 1300 µS) are used in stages requiring stronger gain or sharper transition, while lower values (e.g., Gm5b = 500 µS) are used to introduce damping or output stability. This selective tuning ensures that each section of the ladder filter contributes optimally to the overall performance, mimicking the impedance scaling of a passive ladder network.

3. RESULTS AND SUMMARY:

Tanner Spice Software Tool

GMC-Filter(ladder topology)

- **The filter has a gain of 0 dB in the passband.**
- **The cutoff frequency is around 61 MHz.**
- **The roll-off rate is approximately 105 dB/decade, indicating very sharp attenuation.**
- **Ideal OTAs with different transconductance (gm) values are used in the design.**