4^{th} Order Switched Capacitor Band Pass Filter

Kamal K Chapagai, Hemanth Sabbella, Saurav Kumar
Mentor: Dr. Pydi Ganga

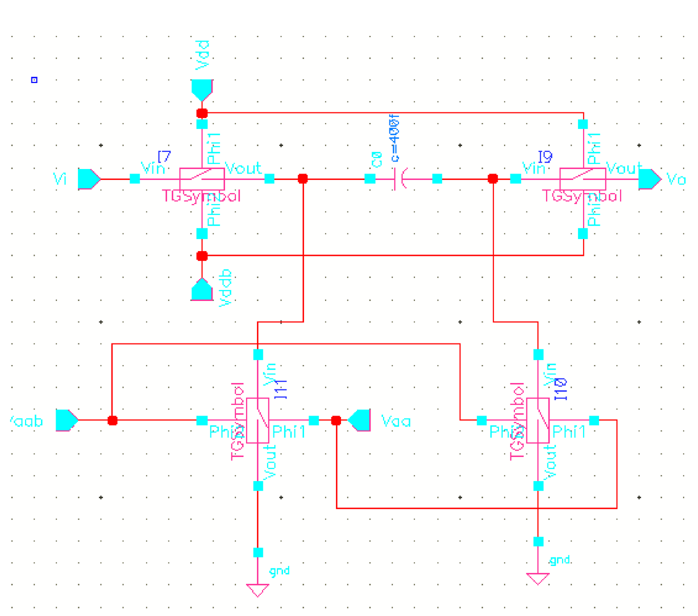
Introduction

The aim of the project is to implement a narrow band pass switched capacitors filter.

- Applications: Gamma wave filtering (25Hz-100Hz). Typically around 30-50 Hz, peaking at 40Hz.
- Filter Specifications:
  - 4^{th} order
  - Narrow band
  - Pass band gain> 40 dB
  - -3dB bandwidth: 25 Hz -100 Hz.
  - Center frequency: 40Hz.
  - Response: Butterworth.

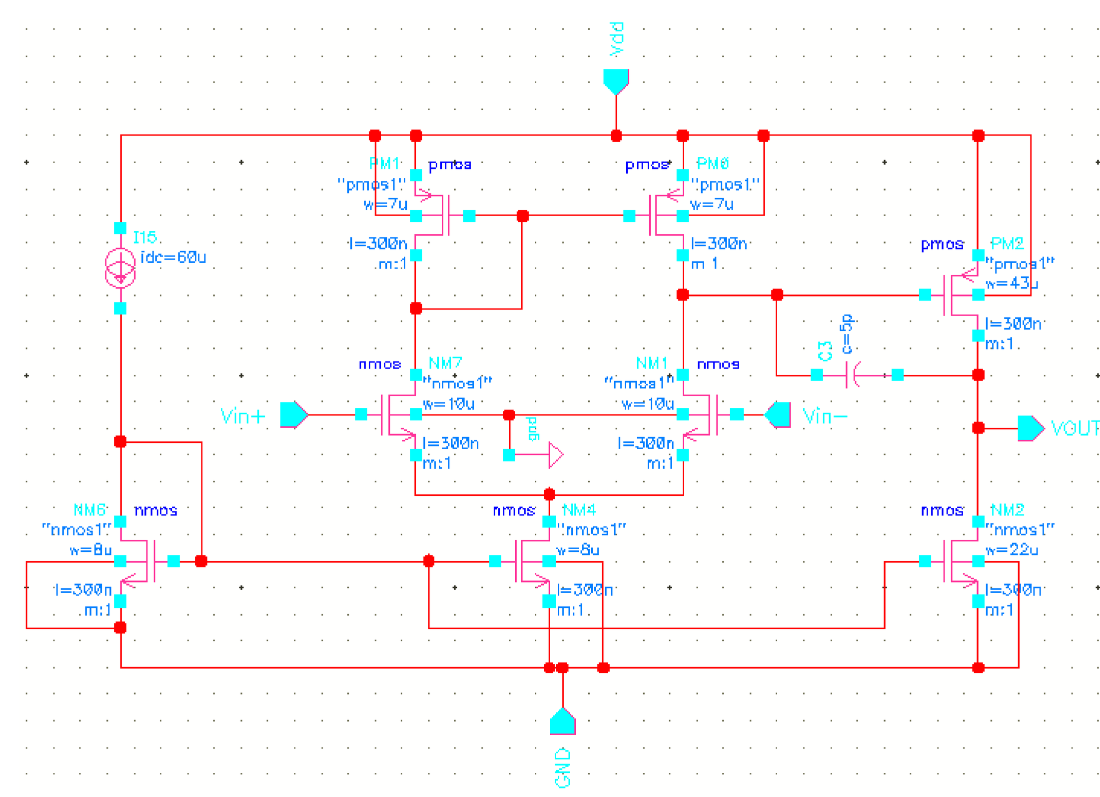
Approach

- 4^{th} order filter – Cascading of two 2^{nd} order band pass filters.
- Topology of 2^{nd} order filter: Multiple feedback.
- Design of Op-amp:
  - Specifications Op-amp:
    - A_v > 40dB
    - GBW = 10Mhz
    - PM > 60
    - V_{dd} = 1.8V, V_{ss} = 0
    - O/P swing = 0.2 – 1.6V
    - ICMR = 0.8 -1.6
    - P_{diss} = 0.5 mW
    - C_L = 10pF.
- Design of 4^{th} order RC filter.
- Converting the RC filter into switch capacitor(SC) filter using resistor equivalent switch capacitor.

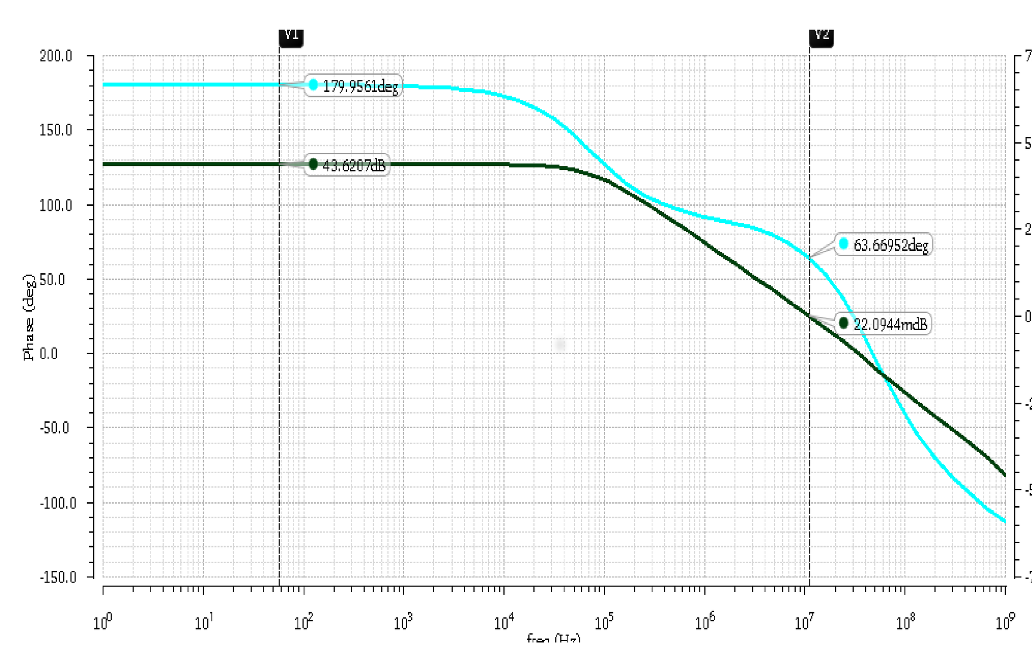


R = T/C

Op- amp Implementation



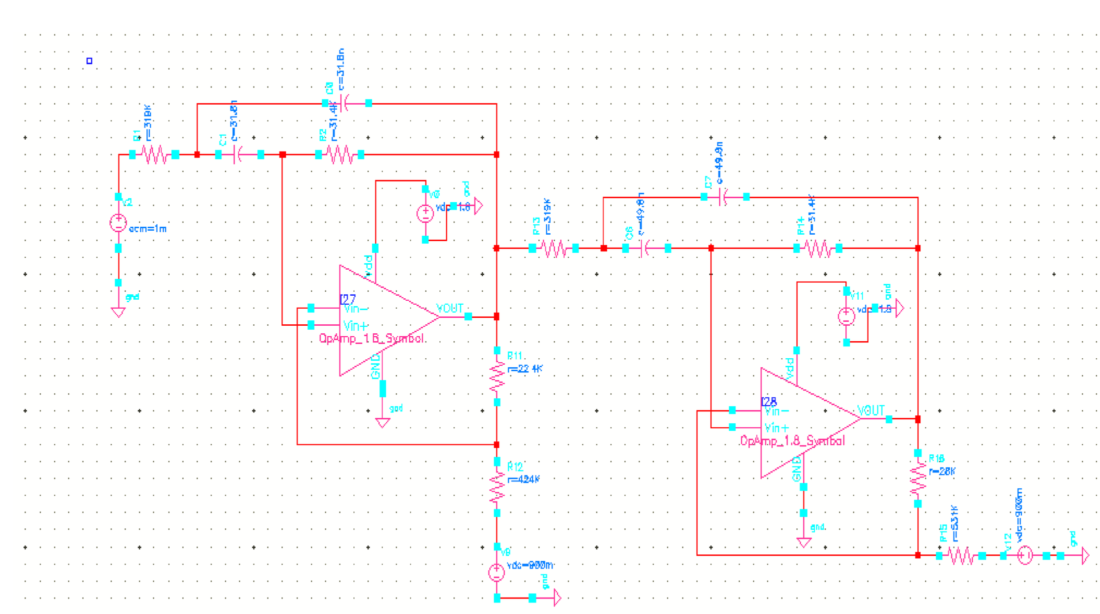
Op-amp design



Op-amp response

- The op-amp outcomes: A_v = 43 dB, GBW = 10MHz, PM = 63 deg, P_{diss} = 500uW, Offset = 135nV, CMRR = 60dB, PSRR = 151dB.

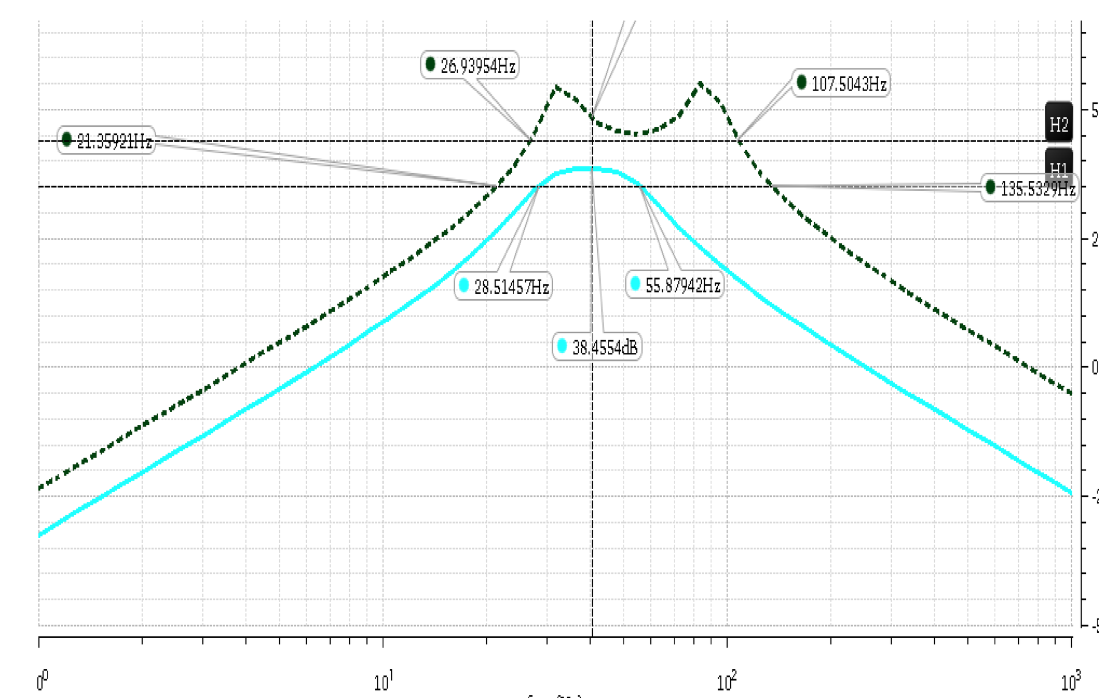
4^{th} Order RC filter Implementation



$$A(s) = \frac{\frac{A_{mi}}{Q_i}\cdot\alpha s}{\left[1+\frac{\alpha s}{Q_i}+(\alpha s)^2\right]}\cdot\frac{\frac{A_{mi}}{Q_i}\cdot\frac{s}{\alpha}}{\left[1+\frac{1}{Q_i}\left(\frac{s}{\alpha}\right)+\left(\frac{s}{\alpha}\right)^2\right]}$$

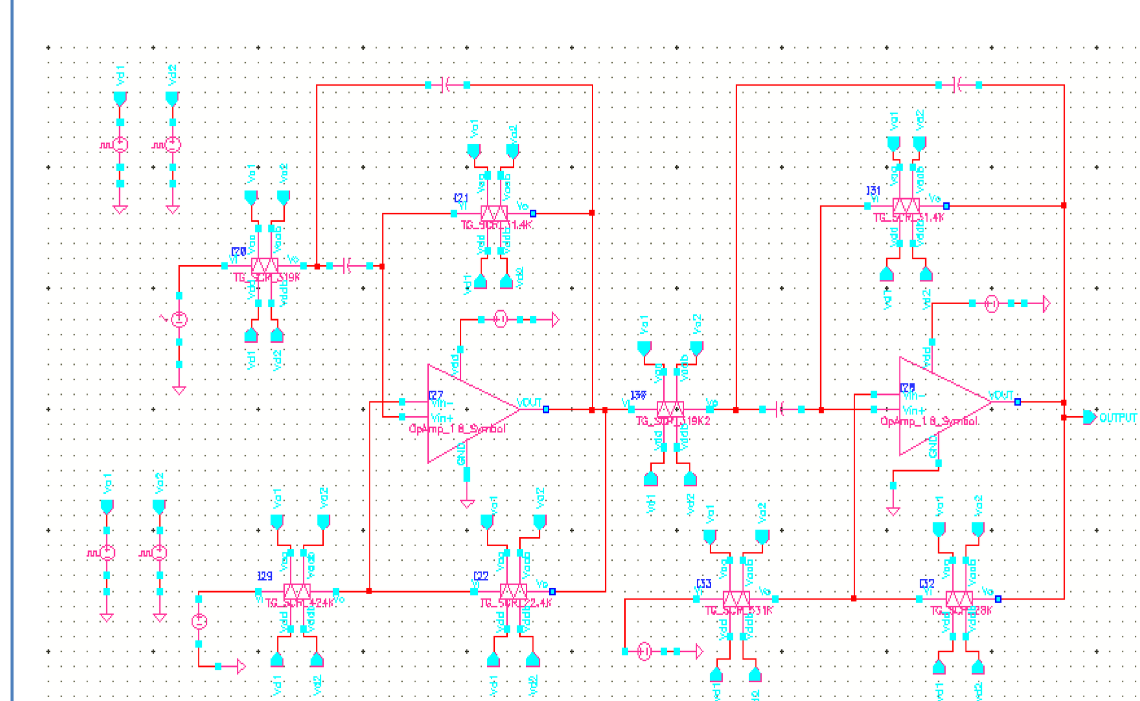
$$\alpha^2+\left[\frac{\alpha\cdot\Delta\Omega\cdot a_1}{b_1(1+\alpha^2)}\right]^2+\frac{1}{\alpha^2}-2-\frac{(\Delta\Omega)^2}{b^1}=0$$

Butterworth			
a_1	1.4142		
b_1	1.0000		
Q	100	10	1
ΔΩ	0.01	0.1	1
α	1.0035	1.036	1.4426

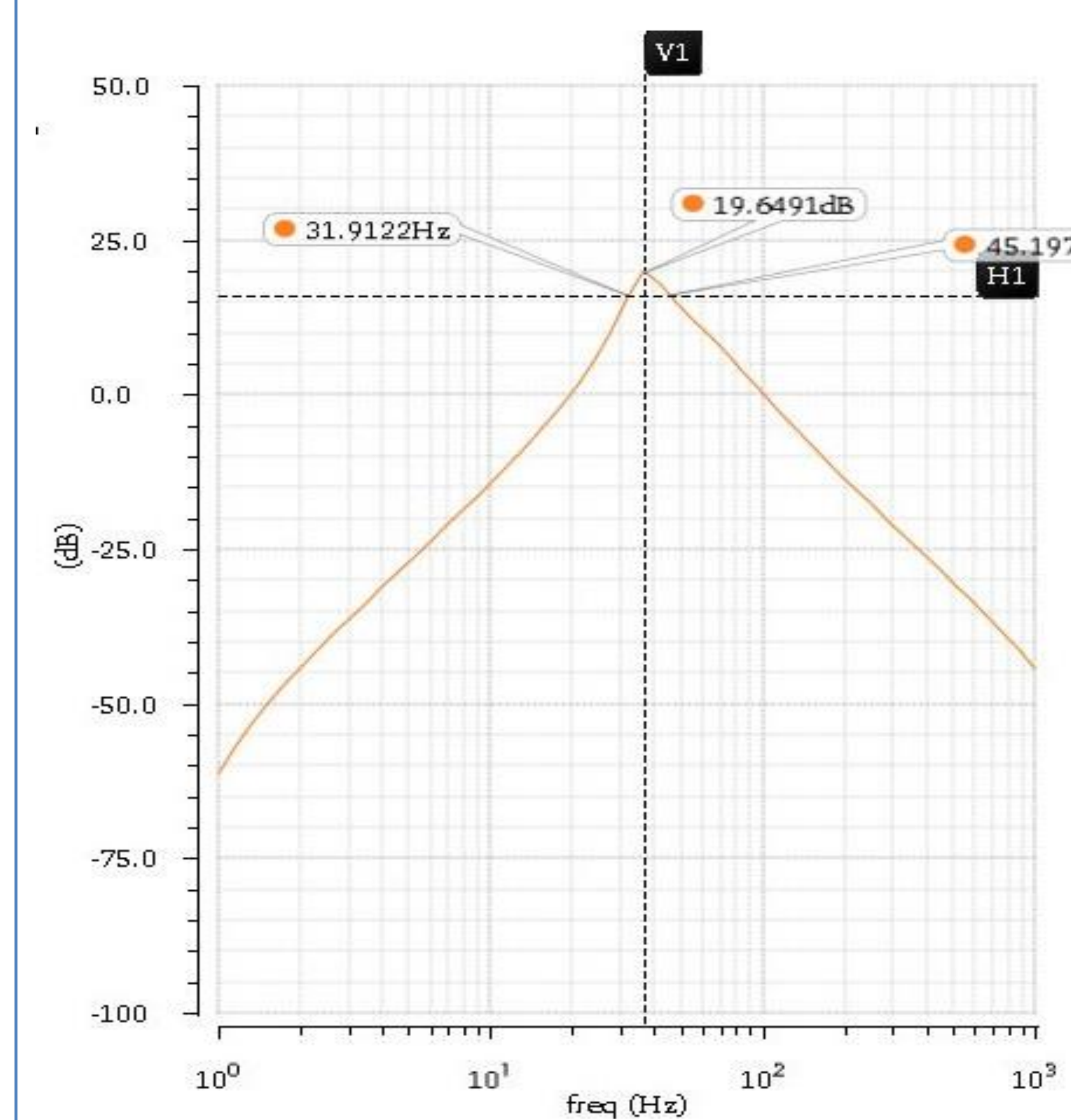


- The gain of the filter is 40 dB with 25 Hz bandwidth and a smooth response.

4^{th} Order SC filter Implementation



- The resistors in the RC filter is replaced by the resistor equivalent switched capacitor circuit.



- The gain of the SC filter is 20 dB with 15 Hz bandwidth and a smooth response. The maximum output noise of the filter is 334uV/√Hz

Conclusion & Future work

- Although, the response of SC filter is bit degraded from RC filter, which is normally expected in the SC circuits, SC filter still serves as a good solution for filtering the typical gamma waves in the range of 30-50Hz.
- Optimize the Switched capacitor circuit for better outcome.
- Reduce the capacitors to fF range to make it more feasible for fabrication.

References

[1] Jim . Karki Active Low-Pass Filter Design Application Report SLOA049B , September 2002.

[2] Phillip E. Allen
CMOS Analog Circuit Design
Oxford University Press, International Second Edition, 2009.