Circuit Simulation Project

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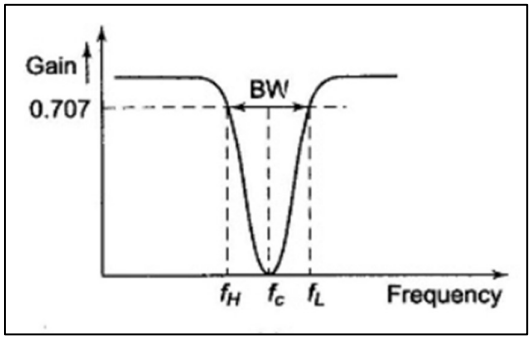
Title of the circuit: Narrow band reject filter

Theory:

A narrow band reject filter(BRF) is a type of frequency selective circuit that is, in fact, the opposite of a band pass filter. The narrow band reject filter attenuates a very narrow band of frequencies while allowing frequencies outside this band. The Q factor of this circuit must be designed to be greater than 10 to ensure better selectivity and narrower rejected band. A narrow BRF is also called as a notch filter due to the sharp attenuation of certain frequencies. A very narrow and steep stop band exists at the centre frequency and the width of the stop band is decided by the quality factor.

The most common type is the twin-T notch filter(also called parallel-tee).



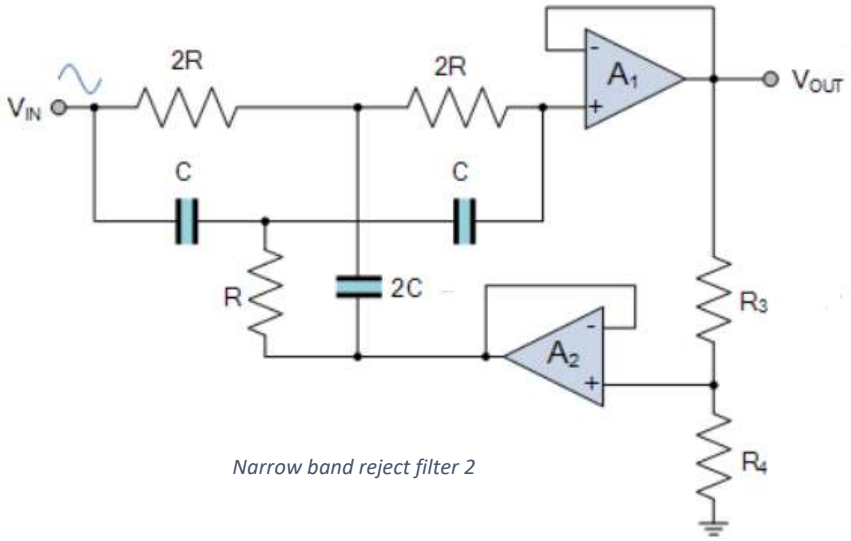
Narrow band reject filter 1

Bandpass filters are widely used in wireless transmitters and receivers. The main function of such a filter in a transmitter is to limit the bandwidth of the output signal to the band allocated for the transmission. In a receiver, a bandpass filter allows signals within a selected range of frequencies to be heard or decoded. This prevents the transmitter from interfering with other stations while preventing signals at unwanted frequencies from getting through the receiver.

In case of countries with 50 Hz power lines, harmonics present in the lines tends to create a magnetic hum. A well-designed notch filter with attenuation range of 49-51 Hz can be used to attenuate this band and greatly reduce magnetic hum.

In case of communication systems, it so happens that a certain frequency might interfere with the received frequencies, especially in cases when the transmitter is close to the receiver. A specially designed LC circuit is used to remove the specific interfering frequencies.

Design:



Narrow band reject filter 2

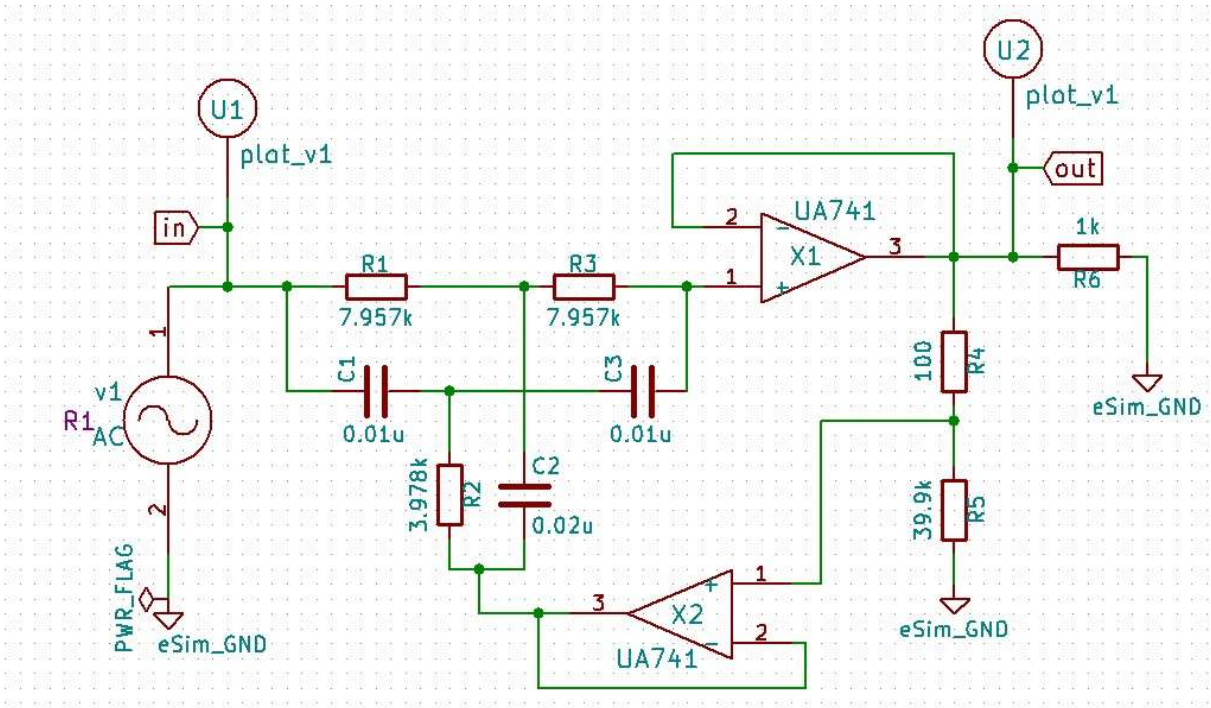
In the design of a narrow band reject filter, passive components 2R and C form a Twin T network commonly used for attenuation of a single frequency. In order to make the notch filter more selective, connect the junction of R and 2C to the central pin of a voltage divider network powered by the output signal, the amount of signal feedback, set by the voltage divider ratio, determines the value of Q which in turn, determines to some extent, the depth of the notch. The feedback network is formed by resistors R_3 and R_4. The main parameter that is used in design is the notch-out frequency of the filter represented by f_N.

- Choose filter capacitor $C \leq 1$ µF for better performance
- Calculate $(2R) = 1 / 4\pi f_N C$
- R and 2C can be implemented using two resistors and two capacitors in parallel.
- Feedback factor $k = R_4/(R_3 + R_4) = 1 - (1/4Q)$. Appropriate choice of either R_3 or R_4 gives the other resistor.

Notch filter of centre frequency = 1kHz (assuming a small bandwidth of 10Hz)

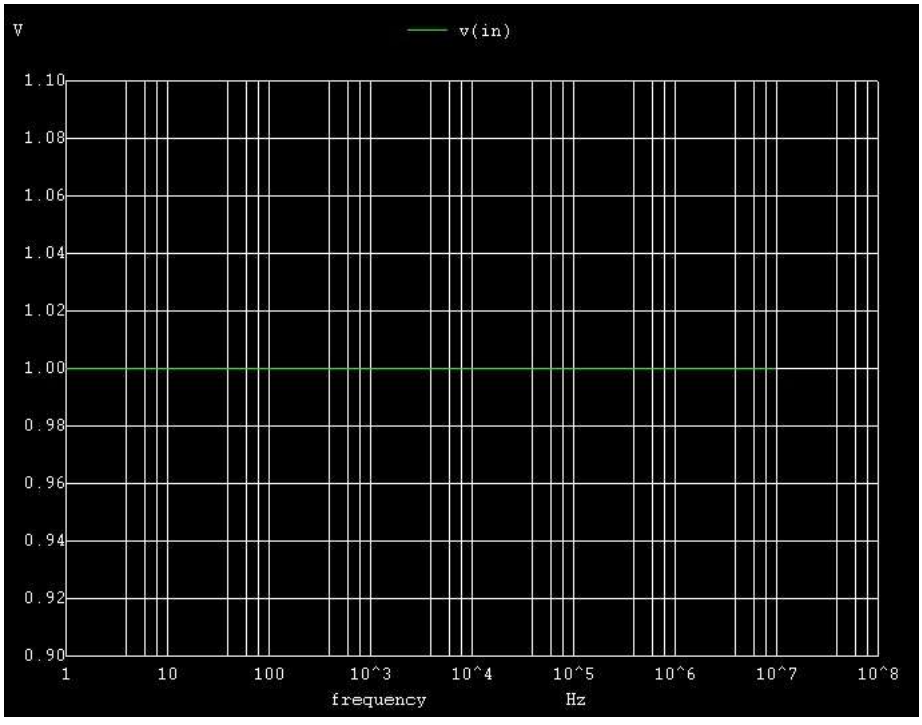
- $C \leq 1$ µF = 0.01 µF
- $2R = 1 / 4\pi f_N C = 7.957k\Omega$
- $R = 3.978\ k\Omega$
- $2C = 0.02$ µF
- $Q = f_N/BW = 1kHz/10Hz = 100$
- Feedback factor $k = 1-(1/4Q) = 0.9975$
- Assuming $R_3 = 100\Omega$, $R_4 = kR_3(1-k) = 399R_3 = 39.9k$

Schematic:

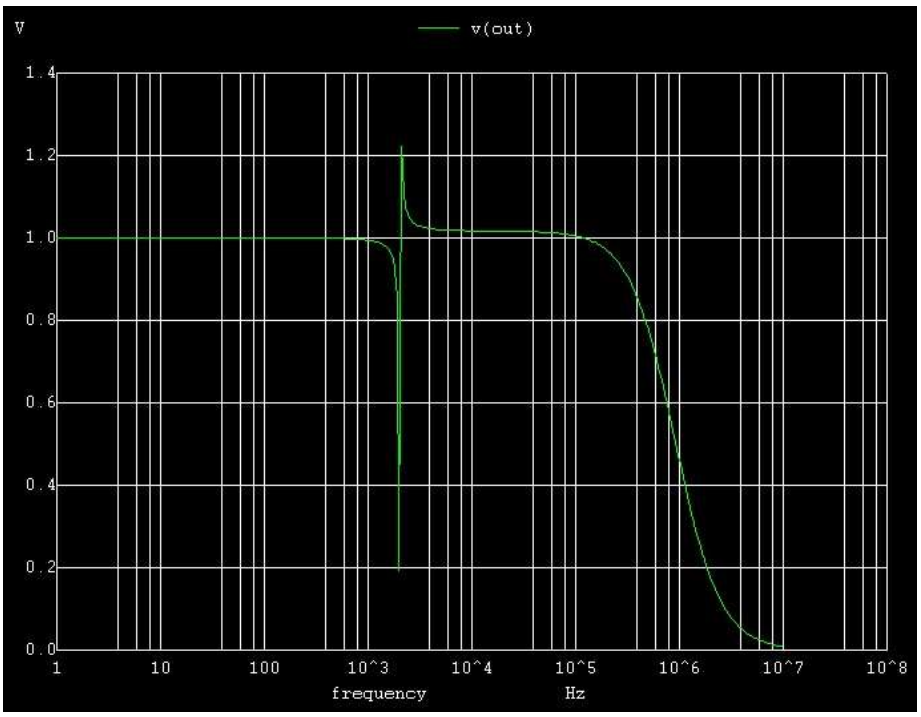


Waveforms(Frequency response):

Ngspice Plots:

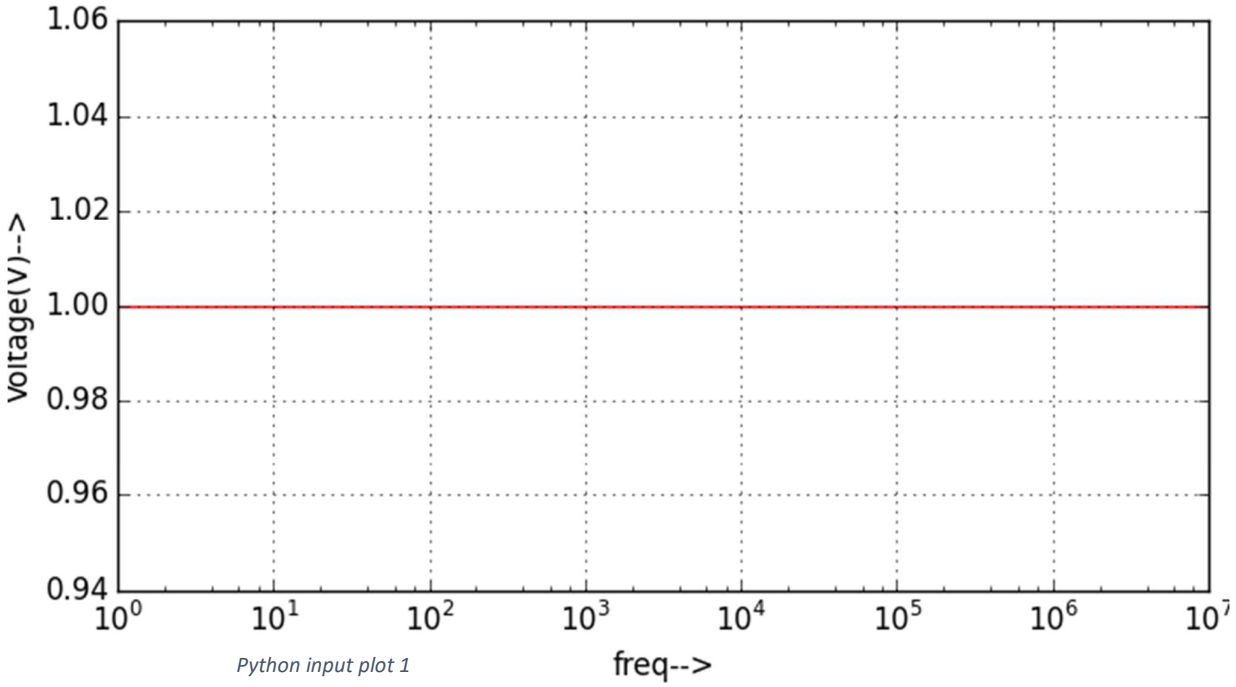


ngspice input plot 1

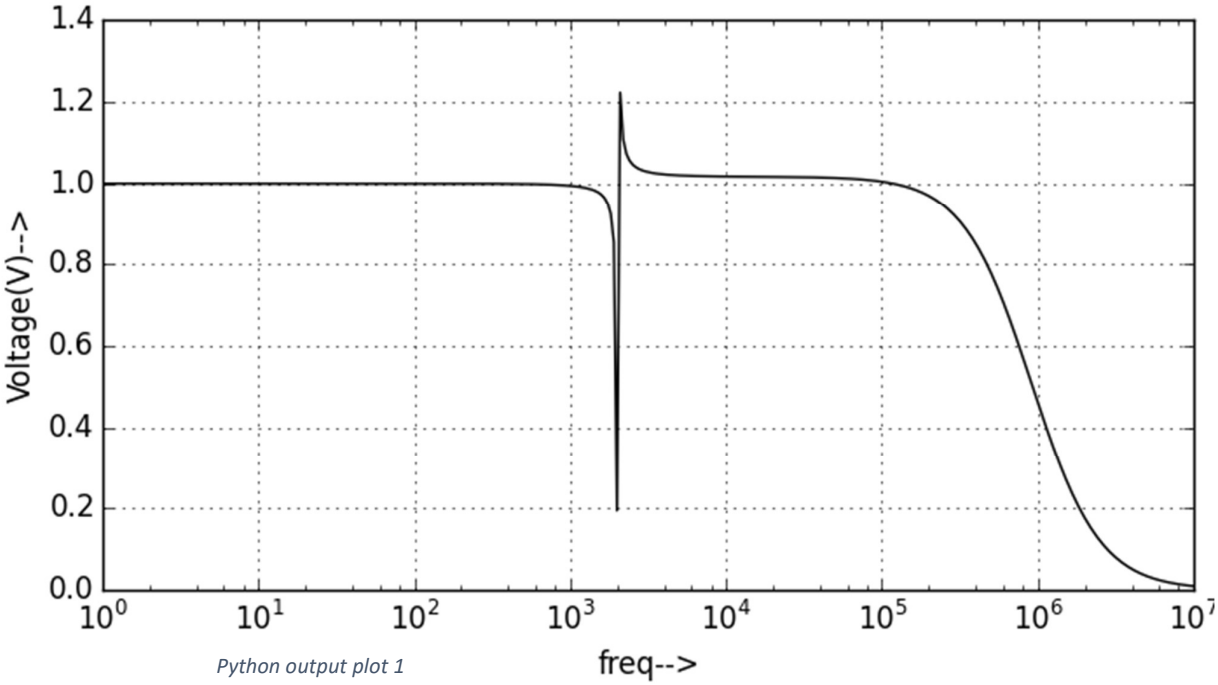


ngspice output plot 1

Python Plots:



Python input plot 1



Python output plot 1

Observations:

An attenuation was observed at nearly 1kHz frequency, followed by a sudden spike in the voltage. This seems unusual, but is a common behaviour in practical circuits.

Conclusion:

The notch filter for 1kHz was designed and realized successfully using the eSim software and the result was verified.

Sources/References:

https://www.electronics-tutorials.ws/filter/band-stop-filter.html

https://en.wikipedia.org/wiki/Band-stop_filter

Op-amps and Linear Integrated Circuits by Ramakant Gayakwad