World Applied Sciences Journal 34 (9): 1261-1268, 2016
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2016.1261.1268

Importance of High Order High Pass and Low Pass Filters

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Abstract: Filters of some sort are highly essential for operating of most electronic based circuits. However, it shows its necessity in computer, mechanical and so on fields too. After days going on, active and passive filters are using gradually escalate. Basically, active means make a filter by using amplifier, transistor and so on which is used for improving the predictability as well as performance of a filter. On the other hand, passive filter actually makes by four basic linear elements such as resistor, capacitor, transformers and inductor. However, non linear passive filters are more complex such as transmission lines. Higher order filters provided greater roll off rates between pass band and stop band. They are also necessary to achieve required levels of attenuation or sharpness of cutoff. In this paper will be discussed High Pass Filter (HPF) and Low Pass Filter (LPF) in both active and passive cases with simulated wave shapes. Furthermore, Here will be simulated the high order low pass and high order high pass filters as well for showing the importance of high order.

Key words: High Order Low pass filter (HOLPF) · High Order High pass filter (HOHPF) · Operational Amplifier · AC signal · Frequency

INTRODUCTION

Filter analysis are core tools in signal processing research which is highly important in today's situation [1]. It actually used in different sectors such as control system [2, 3], circuit analysis field [4], micro processor sector [5] and so on. Based on circuit theory, a filter is nothing but an electrical network. It recasts the phase characteristics and/or amplitude of a signal which changes of frequency [6]. Filters can be categories and sub-categories from several points of views. Most common divisions and sub-divisions are- active or passive; high-pass, low-pass, band-pass, band-reject/notch or all-pass; digital or analog; discrete–time or continues time; linear or non-linear; infinite impulse response (IIR) or finite impulse response (FIR) and so on. However, the most informational filters are Butterworth, Bessel and Chebyshev filters that many books already discussed [7]. Maximum commercial filters used analog technology. These instruments process signals in a continuous (analog) pattern as they exist in the surroundings. Low Pass Filter (LPF) is helped to pass the low frequencies; hence, it helps to get the accurate sine wave for grid connection [8, 9].

Still now, many researchers are doing work for achieving the loss less wave shapes especially in PV-Transformer (TRX)-less inverter system through filters [10-12]. The behaviour of a filter with frequency-domain is described by mathematical term which is transfer function or network function. This is the ratio of the Laplace transforms of its output and input signals. The voltage transfer function H(s) of a filter can therefore be written as, $H(s) = V_{OUT}(s) / V_{IN}(s)$ [6, 8, 13]. Furthermore, Medical/biomedical imaging is a most important segment of medical devices. In diagnostic imaging an MRI scans of a human head is an example of a biomedical engineering application of electrical engineering [14]. For biomedical image processing filter circuits are frequently used. Each bio-signal acquisition system should start with well-designed analog signal processing, because bio-signals are frequently mixed with noise, during acquisition [15]. To reducing noise and other sources of interference digital filters have special utilizations. Where noise is almost common challenge in biomedical applications [16].

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In above, I show some applications of filters which have been started from many years ago and still now it's used and have been developing dramatically. Filter actually nowadays uses in many purposes of electronic circuit and its applications are immense. Moreover, it's possible to improve the circuit gain by using different filters in different ways either active or passive filters especially in active filters because active filters use amplifiers and we know that it helps to increase gain. Here, will be discussed about two filters such as Low pass filter, High pass filter with appropriate diagrams and simulated wave shapes for both active and passive condition. Moreover, here will show the importance of using higher order in the HPF and LPF.

CIRCUIT DIAGRAM OF FILTERS

Filters are often applied in electronic devices to accentuate signals in certain frequency ranges and reject signals in other frequency ranges. Such a filter has a gain which depends on the frequency of the signal. In additionally, filter circuit is a part and parcel in different sectors. In this section will be discussed about ALPF, AHPF, PLPF and PHPF with the appropriate diagram.

Active Low and High Pass Filter: Here used operational amplifier (LF411) where has six legs and to run this amplifier used 15V DC and leg 3 is used as an input with 100k Hz and leg 2 is directly shorted with leg 6 that actually the output of the amplifier. In the Fig. 2.1 shows the active low pass filter where used capacitor C1 and C2 1n farad and Resistance R1 and R2 with 1k?. In the case of AHPF, circuit construction is different, but the using parameter and values are same that has been shown in Fig. 2.2.

Passive Low and High Pass Filter: Passive filters are basically based on few parameters such as resistance, capacitance and inductance where in Figs. 2.3&2.4 shows PLPF and PHPF respectively by using these parameters. In additionally, here used 50Hz frequency in AC mode.

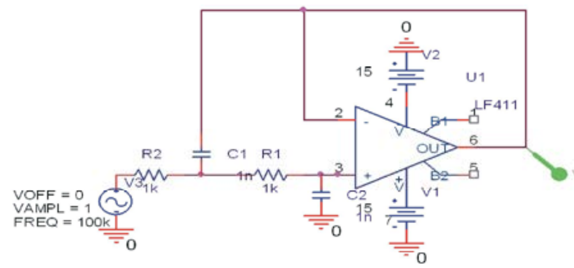

Fig. 2.1: Active Low Pass Filter (ALPF).

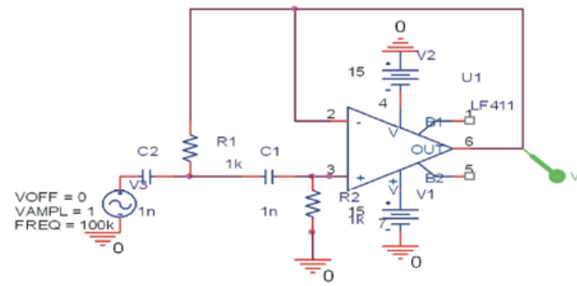

Fig. 2.2: Active High Pass Filter (AHPF)

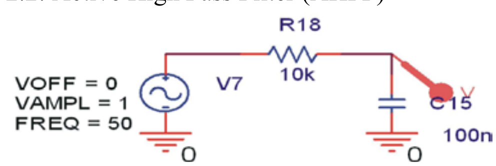

Fig. 2.3: Passive Low Pass Filter (PLPF).

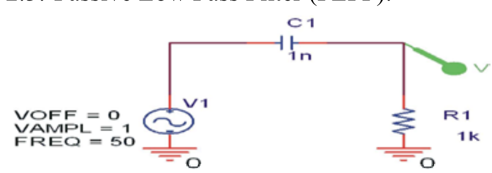

Fig. 2.4: Passive High pass filter (PHPF).3.

WAVE SHAPES OF HPL AND LPF

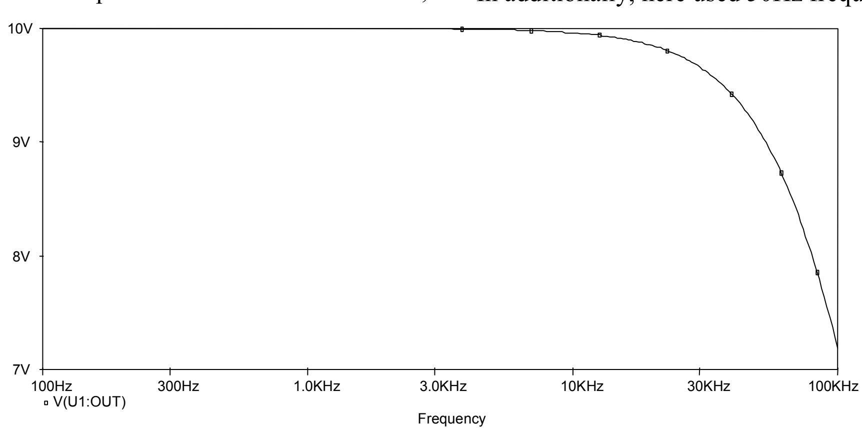

Fig. 3.1: Active Low Pass Filter.

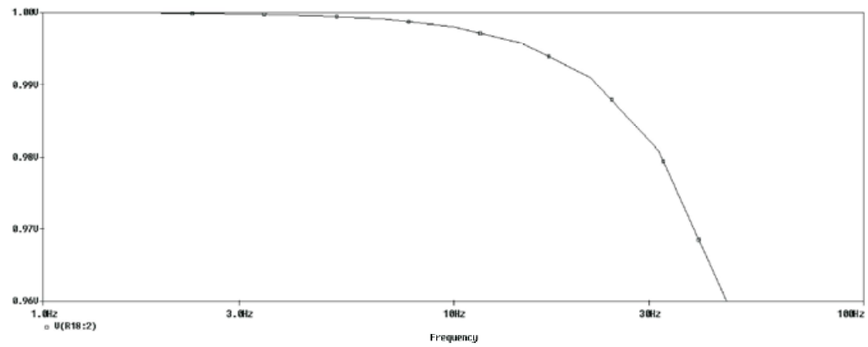

Fig. 3.2: Passive Low Pass Filter.

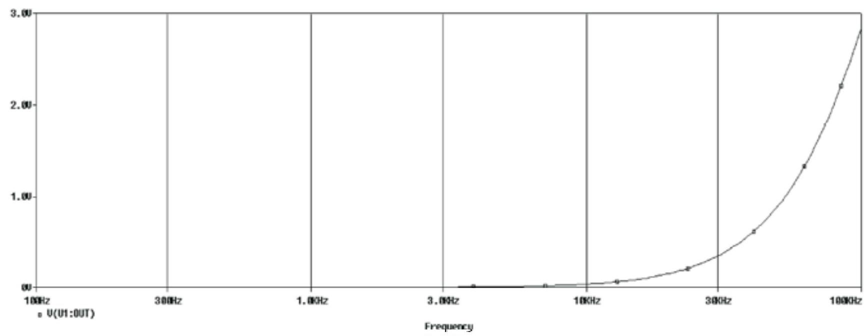

Fig. 3.3: Active High Pass Filter (AHPF).

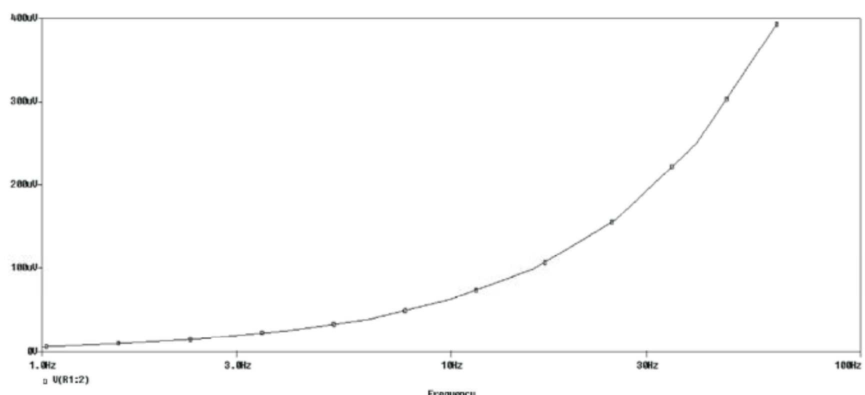

Fig. 3.4: Passive High Pass Filter (PHPF).

In this section has been shown the simulated results of above circuits through Pspice software. In the Figure 3.1 is the figure of ALPF where the applied voltage is 10V with 100k Hz frequency. After simulating the circuit in Figure 2.3 where the frequency is 50Hz, the achieving simulated result is in Fig. 3.2 with the f_c cut-off frequency ($f_c = \frac{1}{2\pi fc} = \frac{1}{2*3.1416*100*10^3*10^{-9}} =$ 1.59 kHz). On the other hand, Fig. 3.3 is the simulation output of Figure 2.2 where the using amplifier is same as ALPF. Last Fig. 3.4 is the wave shape of PHPF with same cut-off frequency.

EQUATION DERIVATION FOR ACTIVE AND PASSIVE FILTERS

This section has been shown the transfer function of HPL and LPF in both active and passive condition.

Transfer Function for ALPF: In the Fig. 4.1 is drawn a figure for transfer function of ALPF.

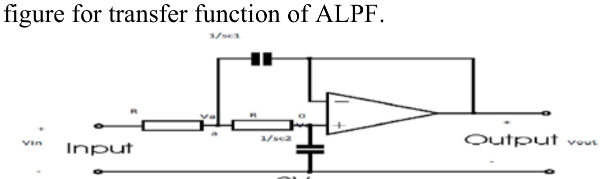

Fig. 4.1: Active Low pass filter.

According to the Fig. 4.1 after using KCL at the point of V_a and V_o,

$$V_a = V_o = SC_2V_o$$
$$V_i = V_a\{2 + SC_1R\} - V_0\{1 + SC_1R\}$$
$$V_a = (1 + SC_2R)$$
$$V_i = V_o\{1 + 2SRC_2 + S^2R^2C_1C_2\}$$
$$\frac{V_o}{V_i} = H\ (S) = \frac{1}{(1 + 2SRC_2 + S^2R^2C_1C_2)}$$

Where H(S) is the transfer function.

Transfer Function for PLPF: Figure 4.2 is the figure of PLPF which is depends on capacitance.

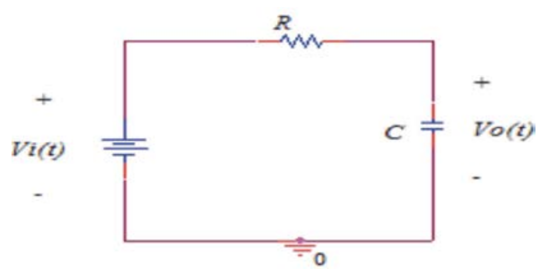

Fig. 4.2: Passive Low pass filter.

$$H(S) = \frac{V_o(S)}{V_i(S)} = \frac{\frac{1}{SC}}{R + \frac{1}{SC}}$$
$$|H\ (j\omega)| = \frac{\frac{1}{RC}}{\sqrt{\omega^2 + \left\{\frac{1}{RC}\right\}^2}}\ (s = j\omega)$$
$$H\ (j\omega) = \frac{1}{1 + j\omega RC}$$
$$H(j * 0) = \frac{1}{1+0} = 1\ (\omega = 0)$$
$$H(j * \infty) = \frac{1}{1+\infty} = 0\ (\omega = \infty)$$

Figure 4.3 is the PLPF with inductance that has been shown in below.

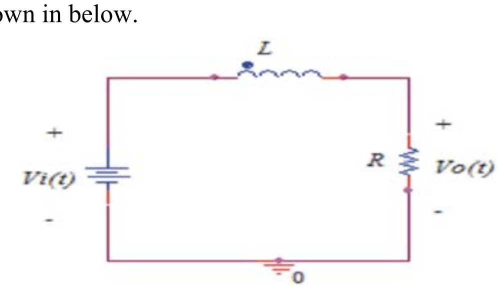

Fig. 4.3: Passive Low pass filter with inductance.

$$\frac{V_o}{V_i} = H\ (S) = \frac{R}{R + SL}V_i(S)$$
$$H\ (S) = \frac{1}{(1 + j\omega L)}$$
$$|H\ (S)| = \frac{1}{\sqrt{1 + (\omega L)^2}}$$
$$H(j * 0) = \frac{1}{1+0} = 1\ (\omega = 0)$$
$$H(j * \infty) = \frac{1}{1+\infty} = 0\ (\omega = \infty)$$

Transfer Function for AHPF: In the Fig. 4.4 is drown a figure for transfer function of AHPF.

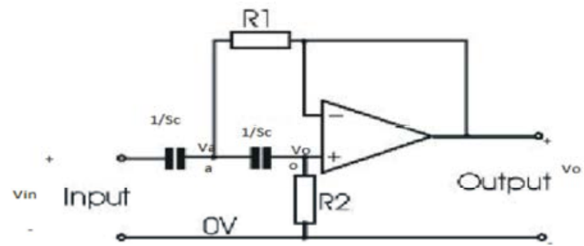

Fig. 4.4: High pass filter Circuit diagram.

According to the figure 4.4 after using KCL at the point of V_a and V_o.

$$V_i = V_a\left\{\frac{1}{SCR_1}\right\} - \left\{\frac{V_o}{R_1SC}\right\} - V_o$$
$$V_a = V_o\left\{1 + \frac{1}{SCR_2}\right\}$$
$$V_i = V_o\left\{1 + \frac{2}{SCR_2} + S^2R_1R_2C^2\right\}$$
$$\frac{V_o}{V_i} = H\ (S) = \frac{S^2R_1R_2C^2}{1 + 2SR_1C + S^2R_1R_2C^2}$$

Transfer Function for PHPF: Figure 4.5 is the PHPF with capacitance that has been shown in below.

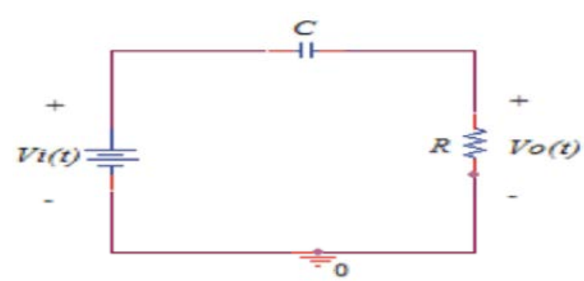

Fig. 4.5: Passive High pass filter.

$$vV_o(S) = \left\{\frac{R}{\left(\left(\frac{1}{SC}+R\right)\right)}\right\}Vi(s)$$

$$H\,(S) = \frac{V_o(S)}{V_i(S)} = \frac{R}{R+\frac{1}{SC}}$$

$$H\,(j\omega) = \frac{j\omega RC}{1+j\omega RC}$$

$$H(j*0) = 0\;(\omega = 0)$$

$$H(j*\infty) = 1\;(\omega = \infty)$$

Figure 4.6 is the PHPF with inductance that has been shown in below.

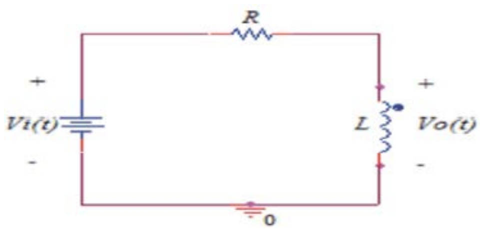

Fig. 4.6: Passive High pass filter with inductance.

$$V_o(S) = \frac{SL}{R+SL}V_i(S)$$

$$H\,(S) = \frac{V_o(S)}{V_i(S)} = \frac{S}{S+\frac{R}{L}}$$

$$|H\,(j\omega)| = \frac{1}{\sqrt{1+\left\{\frac{R}{\omega L}\right\}^2}}$$

$$H(j*\omega_C) = \frac{\omega_C}{\sqrt{\omega_C{}^2+\left\{\frac{R}{L}\right\}^2}} = \frac{1}{\sqrt{2}}$$

$$\omega_C = \frac{R}{L}$$

A high pass filter is design to pass all frequencies above its cut-off frequency is ω_c.

RESULTS AND DISCUSSIONS

The order of a filter is too much important for various reasons. It is directly associated with the number of components in the filter and therefore to its expense, its physical size and the complexity of the design task. Although, higher-order filters are overpriced, take up more space and are more challenging and time-consuming to design, they have a lot of merits. The preliminary advantage of a higher order filter is that it will have a steeper roll off slope than a similar lower-order filter. Active and passive filters are used in different purposes and each of all filters has their own characteristics. Above has been shown the active and passive HPF and LPF with the appropriate diagram and simulated result where the simulated input was in AC mode and frequency domain.

Moreover, I can use mat lab software where I can get all filter in built-in way. Here the using software was Pspice. As all of these filters are built-in, so no need to draw any circuit just inset and sees the output. Hence, the using software was pspice. Active mode, here used operation amplifier to get better output and passive mode, here used capacitor rather than inductor for both low pass and high pass filter. Some problems are actually being faced but, tried to overcome all problem for getting actual and perfect output.

Moreover, in this result and discussion section has been shown the effect of order. Hence, Fig. 5.1 is a 3rd order LPF. Green probe is the output of first order, red one is for 2nd order and blue one is for 3rd order. Moreover, here simulated this circuit and got a nice simulation curve according to the different order where indicated that which curve is for which one.

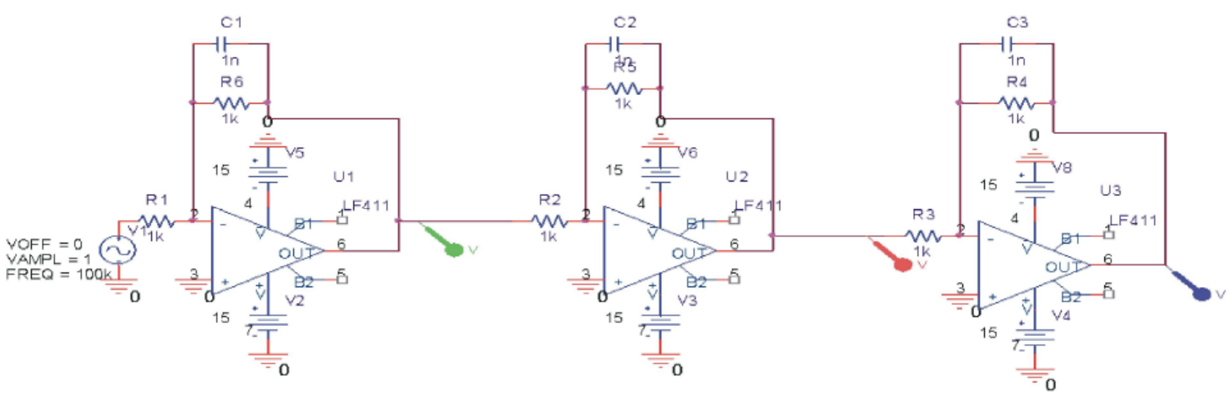

Fig. 5.1: Comparison Circuit of LPF according to the orders.

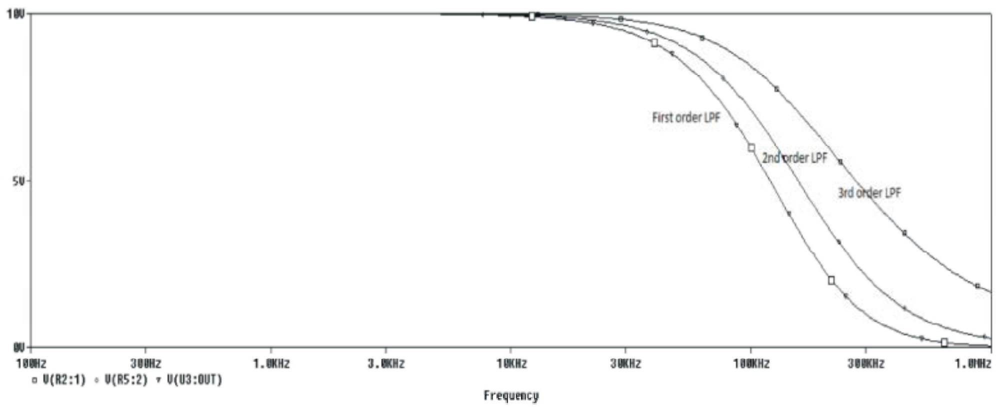

Fig. 5.2: Comparison of LPF according to the orders.

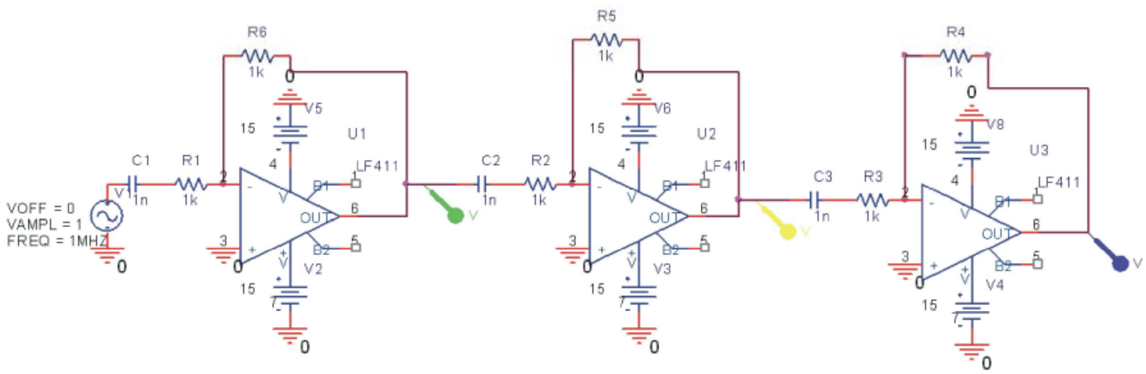

Fig. 5.3: Comparison Circuit of HPF according to the orders.

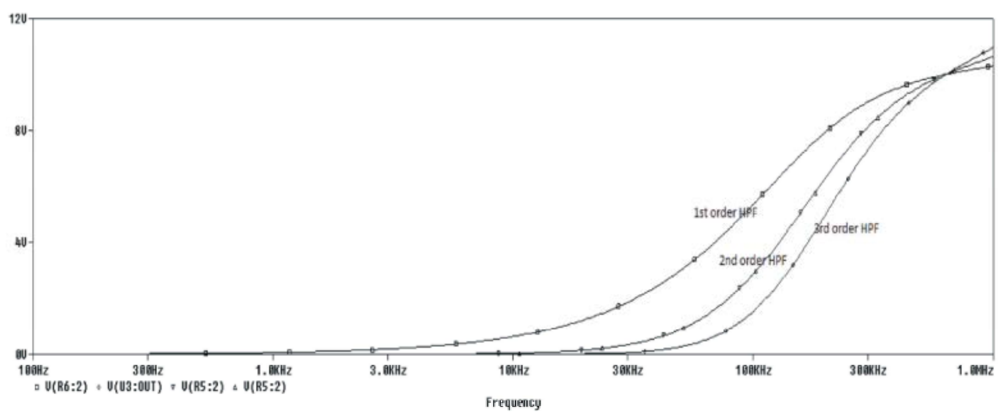

Fig. 5.4. Comparison of HPF according to the orders.

It is clearly shown that the achieving result in Fig. 5.2 for 3rd order LPF is far better compared to others. Here achieved better and perfect LPF.

Figure 5.3 is a 3rd order HPF circuit diagram. Green probe is the output of first order, red one is for 2nd order and blue one is for 3rd order. Moreover, the simulation of Fig.5.3, the achieving output is in Fig. 5.4 where has been gotten a nice simulation curve according to the different order where indicated that which curve is for which one. It is clearly shown that we can get better output for 3rd order HPF compared to others. Hence, more number of order in series will be given more accurate result.

CONCLUSION

Wave shapes of active and passive LP and HP filters have been shown with appropriate circuit diagrams where PSpice software is used for simulation purposes with 100k frequency. On the other hand, the transfer equation derivation also showed for active and passive LP and HP filters. Here showed the importance of using high order filters with accurate circuit diagrams and wave shapes. A higher-order filter does a better job of attenuating higher frequencies. In general, the final rate of roll-off for an n-order filter is 6n dB per octave. In the same diagram has been showed the different order of ALPF and AHPF where can easily cleared the High Order (HO) filters performed better.

Nomenclatures

C	Capacitance
L	Inductance
R	Resistance
V_a	Voltage at a point
V_i	Input Voltage
V_o	Output Voltage

Greek Symbols

π	The numerical value of the ratio of the circumference of a circle to its diameter.

Abbreviations

AHPF	Active High Pass Filter
ALPF	Active Low Pass Filter
FIR	Finite Impulse Response
HOHPF	High Order High Pass Filter
HOLPF	High Order Low Pass Filter
H(s)	Transfer Function
IIR	Infinite Impulse Response
KCL	Kirchhoff's Current Law
KVL	Kirchhoff's Voltage Law
MRI	Magnetic Resonance Imaging
PHPF	Passive High Pass Filter
PLPF	Passive LowPass Filter
PV	Photovoltaic
TRX	Transformer

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