GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 13 NO. 2 2007: 249 - 256
 ISSN 1118 - 0579

# CONSTRUCTION AND OPERATION OF AN ACTIVE BAND REJECT FILTER

**M. O. ITAM and A. C. AGWU**

**(Received 31 March, 2006; Revision Accepted 15 February, 2007)**

**ABSTRACT**

The constructed active band reject (notch) filter is presented with specified notch frequency omega ($\omega$) and 3dB rejection bandwidth using an operational amplifier ($\mu$A 741 op-amp)of unity gain configuration to control the notch frequency. From the filter response the stability of the second-order notch filter is improved along with the noise gain. The Q of the notch filter was determined to be 0.5 obtained by the centre frequency divided by the bandwidth. The device is used for low frequency applications in the reduction of power line noise and it automatically synchronizes to any frequency between 47Hz to 70Hz. In addition to the fundamental frequency of 60Hz, all the upper harmonics including the troublesome 120Hz second harmonics are filtered out.

**KEYWORDS:** Band reject (notch) filter, notch frequency, integrated circuit, bandwidth.

## INTRODUCTION

Filters are essential to the operation of electronic circuits. According to Lacanette (1995), a filter is an electrical circuit that alters the amplitude and or phase characteristics of a signal with respect to frequency. A notch filter rejects a narrow frequency and leaves the rest of the spectrum slightly changed. Agwu (2002) defined a band reject filter as one that attenuates all frequencies within a particular frequency range and passes others that are outside this range. Filters are used in electronic circuits to suppress noise in audio applications. A power interference or band stop filter is an important sub-component in the construction of medical recording systems where minute bioelectrical signals of the milli-volts to microvolts order are measured. In the operation room, or in research facilities there exist a substantial level of electrical interference produced by local power lines. The band reject (notch) filter is used in these systems to improve the signal filtering in biomedical equipments. They are also used in transmitters to verify compliance of network with stipulated limit values for spurious emissions within the transmission band and outside the reception band. Active filters use op-amps with resistors and capacitors in their feedback loops as amplifying elements to synthesize the desired filter characteristics.

### Theory

The frequency-domain behaviour of a filter is expressed in terms of its transfer 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 expressed as

$$H(s) = \frac{Vout\ (s)}{Vin\ (s)} \qquad (1)$$

where Vin(s) and Vout(s) are the input and output signal voltages and s is the complex frequency variable. The transfer function magnitude versus frequency is called the amplitude response or the frequency response in audio applications.

Similarly, the phase response of the filter gives the amount of phase shift in the sinusoid as a function of frequency. Since a change in phase of a signal also represents a change in time, the phase characteristics of a filter become important when dealing with signals where the time relationships between signal components at different frequencies are critical.

Replacing the variable s in (1) with jw, where $j = \sqrt{-1}$, and w is the radian frequency ($2\pi f$), we rewrite equation (1) as

$$|H(jw)| = \left|\frac{Vout\ (jw)}{Vin\ (jw)}\right| \qquad (2)$$

and the phase is:

$$\arg H(jw) = \arg \frac{Vout\ (jw)}{Vin\ (jw)} \qquad (3)$$

**M. O. Itam**, Department of Physics, University of Calabar, Calabar, Nigeria.
**A. C. Agwu**, Department of Physics, Federal University of Agriculture, Abeokuta, Nigeria.

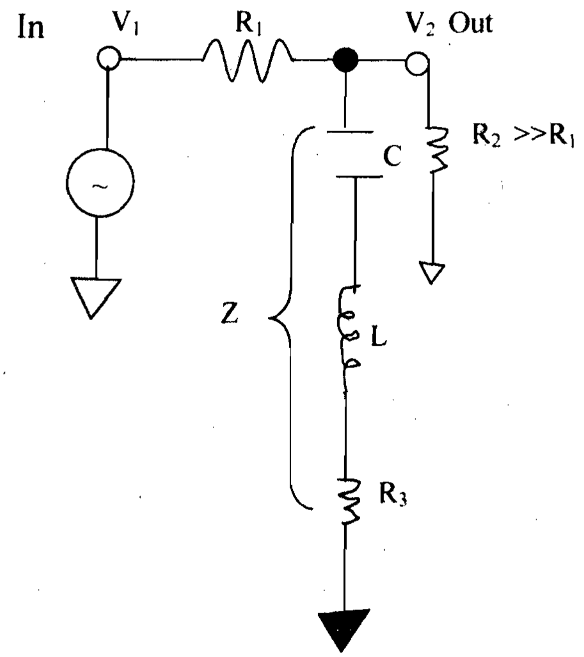


Fig. 1 shows a simple Notch filter

The transfer function is given as

$$\frac{V_2}{V_1} = \frac{Z}{Z + R_1} \tag{4}$$

where Z is the impedance of the series resonant circuit (www.linkwitzlab.com)

$$Z = R_3 + jwL - j\frac{1}{WC} = R_3 + j\frac{W}{W_o}W_oL - j\frac{W_o}{W}\frac{1}{W_oC}$$

$$Z = R_3 + jW_oL\left(\frac{W}{W_o} - \frac{W_o}{W}\right), \text{ where } W_o^2 = \frac{1}{LC} = (2\pi f_o)^2$$

$$|Z| = R_3\sqrt{1 + Q^2\left(\frac{f}{f_o} - \frac{f_o}{f}\right)^2} \tag{5}$$

where $Q = \frac{2\pi f_o L}{R_3} = \frac{1}{2\pi f_o R_3 C} = \frac{f_o}{\Delta f}$ , is the quality factor.

The notch depth $d = 20 \log_{10}\left(1 + \frac{R_1}{R_3}\right) |dB|$ (6)

This signifies that the notch depth is determined by the voltage at the non-inverting input of the op-amp, in the proportion of the resistors $R_1$ and $R_3$.

<u>Synthesis</u>:

Given : $R_1$ is proportional to Q

(1) $$R_3 = \frac{R_1}{10^{\frac{d}{20}} - 1}$$

$$(2) \quad L = R_3 \frac{Q}{2\pi f}$$

$$(3) \quad C = \frac{1}{L(2\pi f_o)^2}$$

Fig. 2 shows the amplitude response curve.

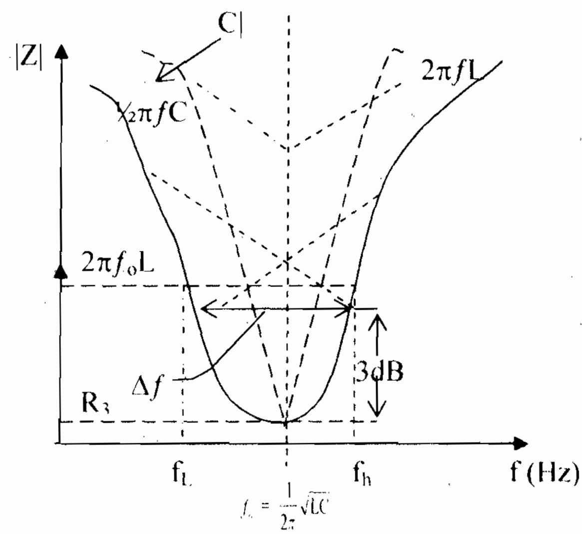


Fig. 2 Amplitude response curve of the notch filter

Notch filters are used to remove unwanted frequency from a signal, while all other frequencies are slightly affected. An example of the use of a notch filter is with an audio program that has been contaminated by a 60Hz power line hum. A notch filter with a centre frequency of 60Hz is used to remove the hum while having little effect on the audio signals.

Besides, the cut of frequency referred to as the centre frequency, the range of frequencies passed is usually assumed to be the frequencies where the gain has dropped by 3 decibels (to 0.707 of its maximum voltage gain). The frequencies are called the –3dB frequencies or the cut off frequencies.

The quality factor Q is another quantity used to describe the performance of the filter. It is a measure of the "sharpness" of the amplitude response. The Q of the notch filter is also given as the ratio of the centre frequency to the difference between the –3dB frequencies (also known as the –3dB bandwidth).

$$\therefore \quad Q = \frac{f_c}{f_h - f_l} \qquad (7)$$

where $f_c$ is the centre frequency, $f_l$ is the lower –3dB frequency and $f_h$ is the higher –3dB frequency.

**MATERIALS AND METHODS**

The components used in the construction are resistors, capacitors, regulators, rectifiers, diodes, 12volts centre tap transformer (full wave), Vero board, and an operational amplifier ( A741) integrated circuit. Horowitz and Winfield (1995); Grob (1983), Sparkes (1978) as well as Jung (1977) and Jung (1978) provided the specifications for the components used.

**MATERIALS**

**THE OP-AMP μA741IC**

Fig. 3 shows the μA741 IC with the pin connections. The dot in the end of the package identifies the location pin 1.

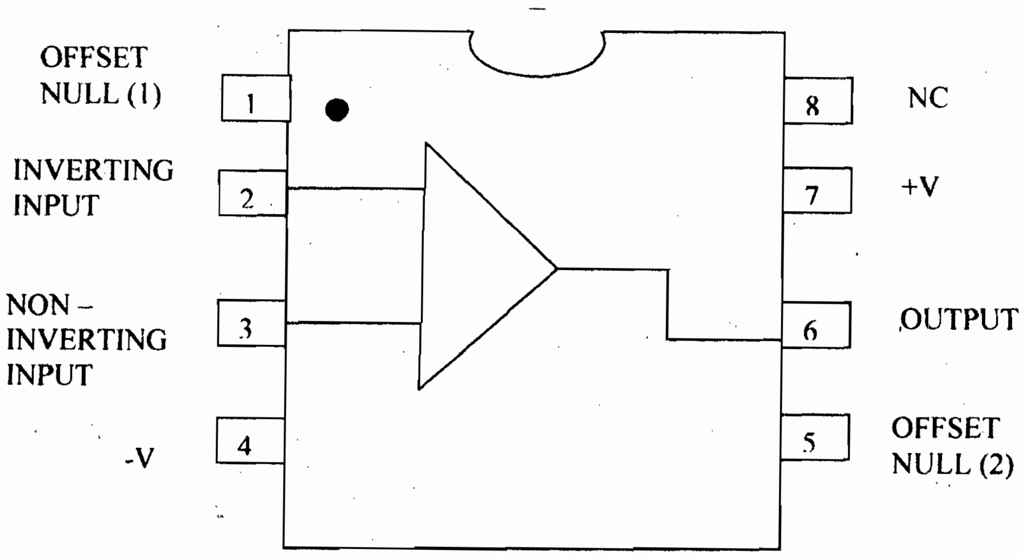


Fig. 3: μA741 IC 8 - pin dual-in-line package

**THE POWER SUPPLY UNIT**

The op-amp μA741 is powered by means of a power supply unit constructed for this purpose Fig. 4 shows the dual rail power supply of 12v using two 470 μF (35v) capacitors, one 7812 regulator, one 7912 regulator, one 2.2 kilohms resistor, one light emitting diode, one rectifier and a 12v centre tapped transformer (full wave).

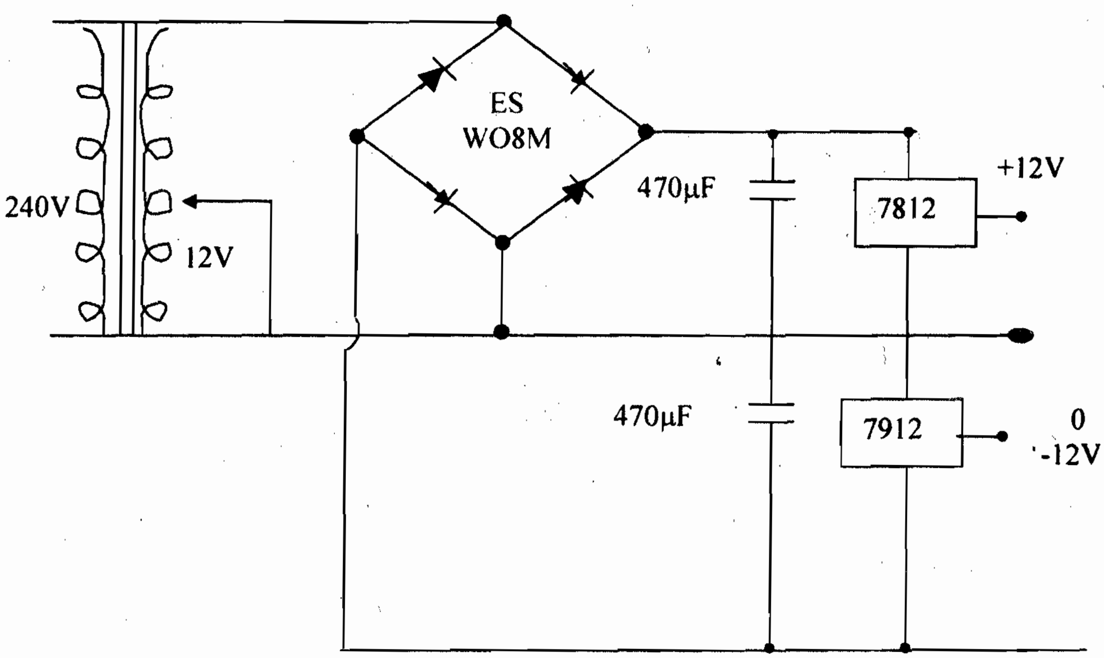


Fig. 4 Dual rail power supply circuit with component values

**METHODS**

The Vero board forms the chassis on which all other components such as resistors R = 27kilohms, capacitor C = 0.1microfarad and μA741 op-amp were mounted and soldered as shown in the circuit layout diagram in Fig. 5. The μA741 IC was fixed in the 8-pin socket before being mounted and soldered on the Vero board to prevent the IC from possible damage due to excessive heat from the soldering iron.

Pins 4 and 7 of the µA741 op-amp were used to power the band reject (notch) filter circuit with a 12v dc delivered from the constructed dual rail regulated power supply, pin 4 was fed with the −12v d.c where pin 7 was used for the +12 vd.c. Pin 6 was used for the output. A d.c dual rail power supply of +12v was constructed to enhance the powering of the µA741 IC op-amp using a 12v transformer, two 470 microfarad (35v) filtering capacitors as well as two power regulators µA7812 and µA7912 for the stabilization.

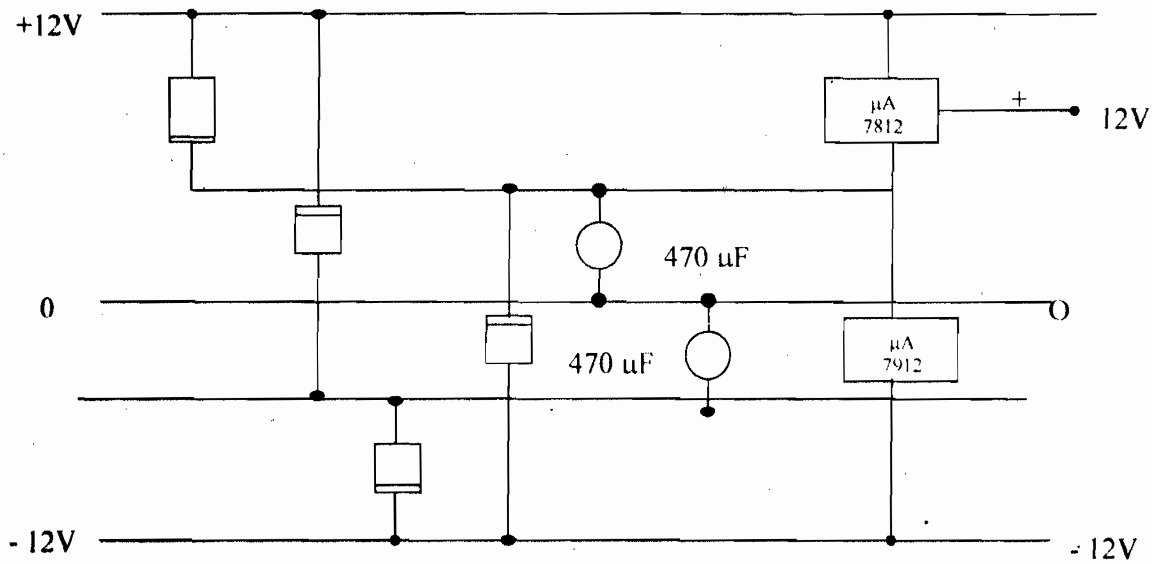


Fig. 5 shows the circuit layout diagram of the constructed power supply

The circuit layout diagram of the active band reject (notch) filter shown in Fig. 6, helps in providing the knowledge of the position of a particular component and how it is linked up with other components in the circuit.

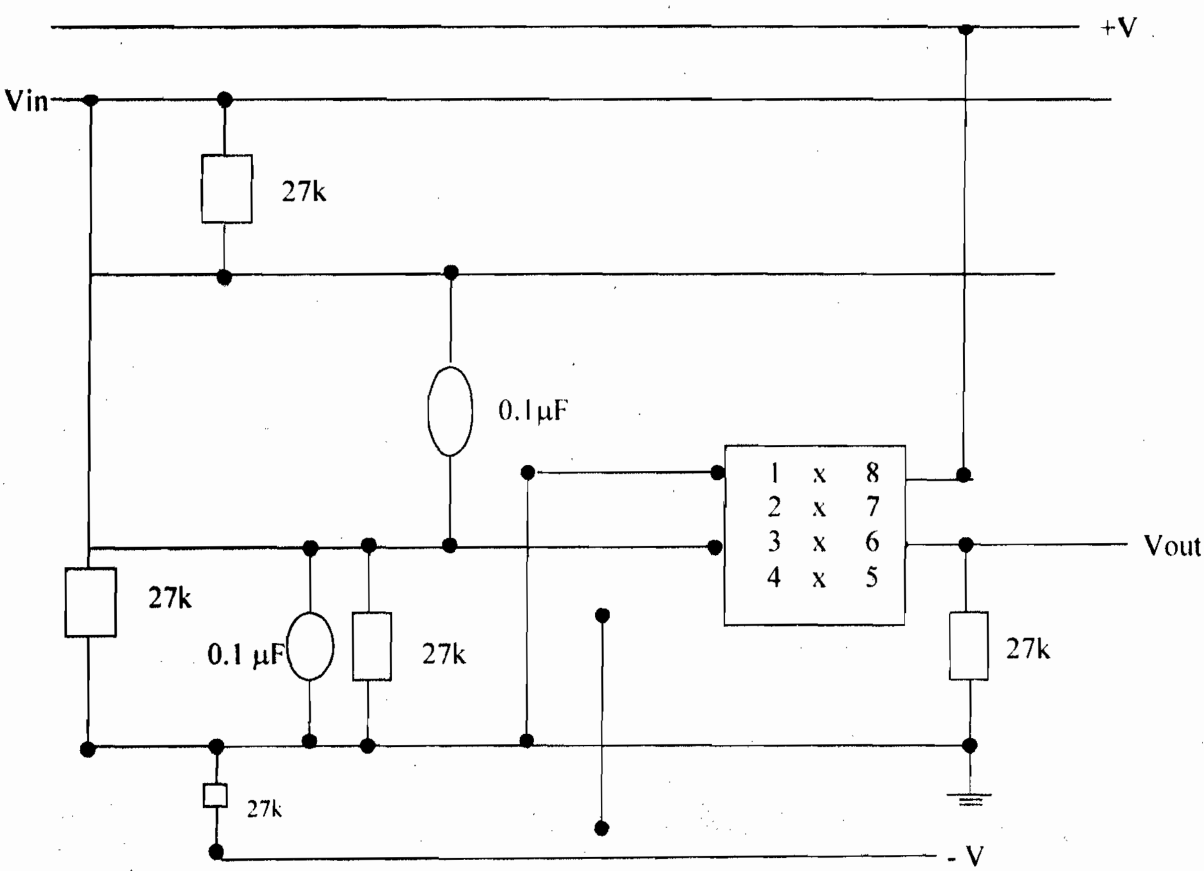


Fig. 6 Circuit layout diagram of the active band reject (notch) filter

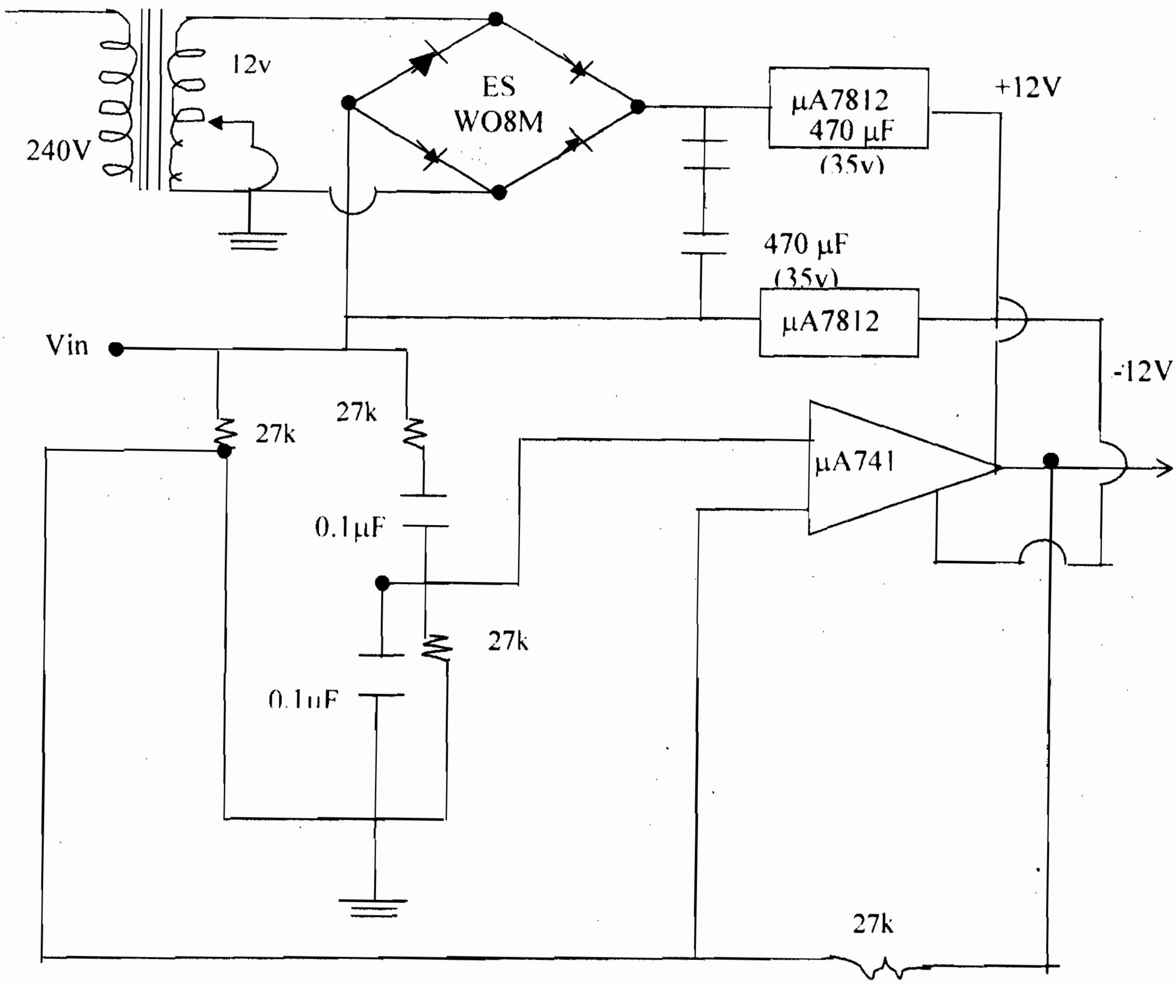


Fig. 7: The circuit diagram of the constructed active band reject (notch) filter

**OPERATION AND CALIBRATION**

Different frequencies for different output voltages and a fixed input voltage were observed. There were monitored by the band reject (notch) filter network connected outside the loop using a signal generator and a cathode ray oscilloscope, connected as shown in the block diagram of Fig. 8.

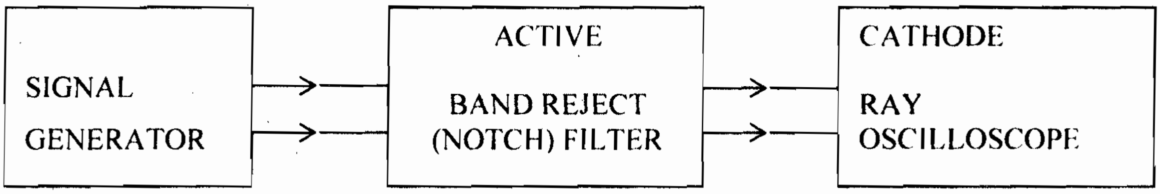


Fig. 8 Block diagram showing active band reject (notch) filter under test.

The signal generator was used to generate signals that were fed into the band reject (notch) filter while the oscilloscope was used to monitor the output signal. The input voltage of 1.0v peak to peak sine wave was fed into the filter and the following output results were obtained and tabulated in Table 1.

Table 1:

| Frequency F(Hz) | Input voltage (v) | Output voltage (v) | Voltage gain ($A_v$) | Gain (dB) |
|---|---|---|---|---|
| 10 | 1 0 | 0 80 | 0 80 | -1 94 |
| 25 | 1.0 | 0.05 | 0.50 | -6.02 |
| 50 | 1.0 | 0.15 | 0.15 | -16.48 |
| 60 | 1.0 | 0.10 | 0.10 | -20.00 |
| 70 | 1.0 | 0.15 | 0.15 | -16.48 |
| 75 | 1.0 | 0.31 | 0.31 | -10.17 |
| 100 | 1 0 | 0.40 | 0.40 | -7.96 |
| 125 | 1 0 | 0 60 | 0.60 | -4.44 |
| 150 | 1.0 | 0.70 | 0.70 | -3.09 |
| 175 | 1.0 | 0.80 | 0.80 | -1 94 |
| 200 | 1.0 | 0.85 | 0 85 | -1.41 |
| 225 | 1.0 | 0.90 | 0.90 | -092 |
| 250 | 1 0 | 0 95 | 0.95 | -0.45 |
| 300 | 1.0 | 1.00 | 1.00 | 0.00 |
| 325 | 1.0 | 1.00 | 1.00 | 0.00 |

**RESULTS AND DISCUSSION**

The results obtained from the experiment using the active band reject (notch) filter are shown in table 1 Fig.9 shows the response of the active band reject (notch) filter. The –3dB bandwidth as shown in Fig. 9 occurs at a frequency of 60Hz. This means that the bandwidth is measured at –3dB point (from 0dB) that is $BW_{-3dB} = F_{notch}/Q$.

$$BW_{-3dB} = f_H - f_L,$$

where, $f_H$ is the upper cut off frequency and $f_L$ is the lower cut off frequency The bandwidth of a filter is stated as Q or in octaves. This is computed by dividing the centre frequency by the bandwidth of the filter as stated above

$$Q = \frac{f_{notch}}{F_H - f_L} = \frac{60}{137.5-8.0} = \frac{60}{129.5} = 0.46 \approx 0.5$$

The notch frequency of 60Hz obtained from the result agrees with that obtained by Molina (1994).

**CONCLUSION**

The process of constructing, an active band reject (notch) filter just like that of any other electronic device is interesting but not quite easy. The difficulty is due to variations in theoretically calculated component values and those actually used. The variations pose problems in a situation where the, researcher is a neophyte in the field of electronics. The constructed active band reject (notch) filter was tested with a 1.0v peak to peak sine wave and the output was observed to have a notch frequency at 60Hz and the resulting Q = 0.5.

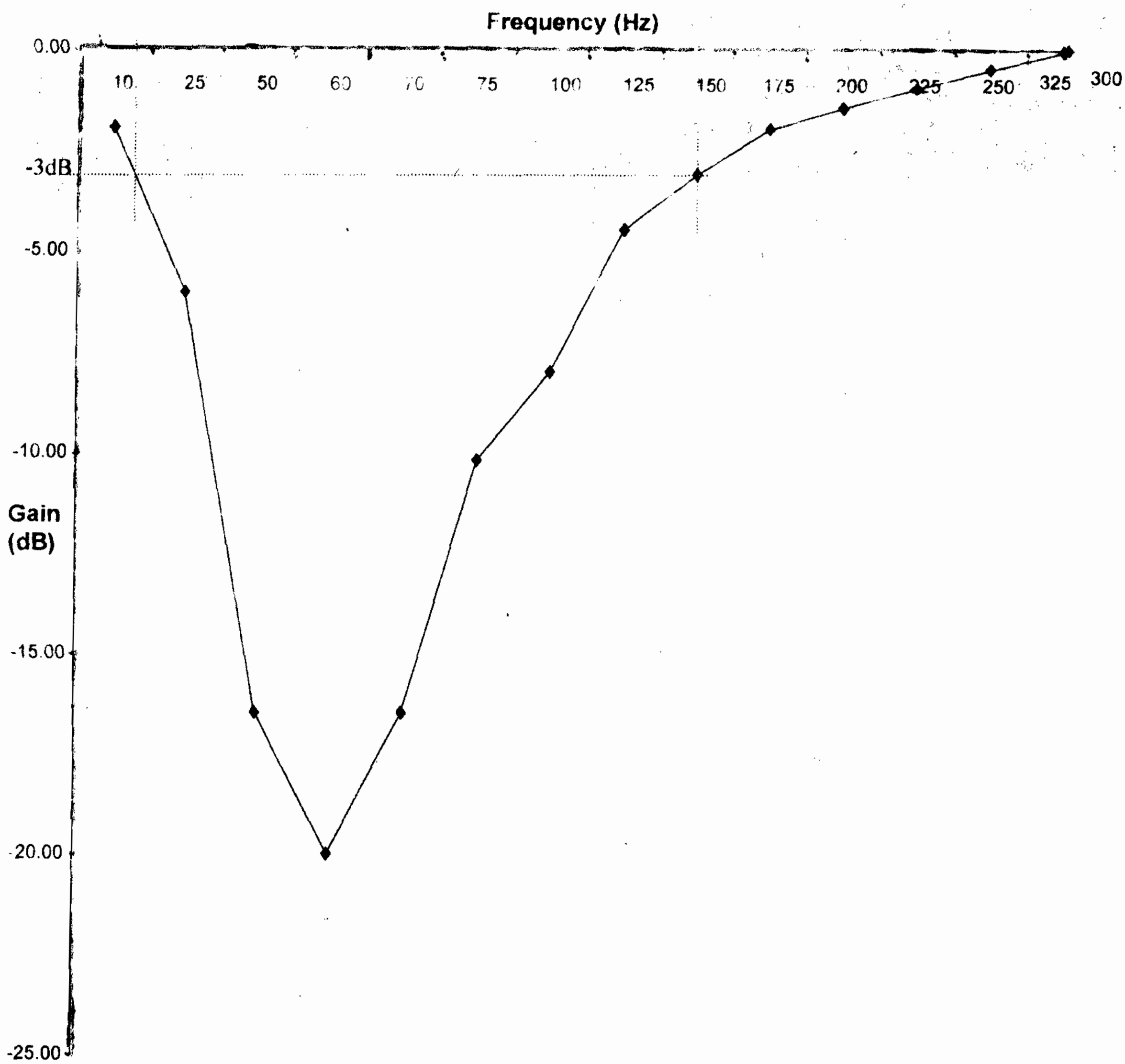


Fig. 9: Graph of gain (dB) against frequency (Hz)

**REFERENCES**

Agwu, A. C; 2002. Construction of an Active Band Reject Filter. Unpublished B.Sc Thesis, University of Calabar, Calabar. pp 37.

Grob, Bernard. 1983. "Basic Electronics". (4th Edition), McGraw Hill International, Book Company, England.

Horowitz, P. and Winfield, Hill. 1995. The Art of Electronics, (Low Price Edition). Cambridge University Press, Great Britain.

http://www.linkwitzlab.com/filters.htm (12/22/2005).

Jung, W, G., 1978. Audio IC Op-Amp Applications; Howard W. Sams & Co., U.S.A.

Jung, W, G., 1977. "IC Op-Amp Cookbook"; Howard W. Sams & Co., U.S.A.

Lacanette, K., 1995. "National Semiconductor Application Note 779". National Semiconductor Corporation, USA.

Molina, Johnnie. 1994. "Design a 60Hz Notch Filter with the AF42 Burr-Brown Corporation, Tucson.

Sparkes, R. A. 1978. Electronics, Hutch Inson Publishers Ltd. London.