Experiment 3

The Four Op-Amp Biquad Circuit

(Experimental)

OBJECTIVE

To build different second order (biquad) filter circuits employing four operational amplifiers (OP-AMPs).

INTRODUCTION

A common practice in IC fabrication is to manufacture chips with multiple devices. A four op-amp biquad takes advantage of the availability of four op-amps on a single chip enabling generation of several different second order filter responses. The four op-amp biquad realizes the general biquadratic function and exhibits low-pass, band–pass, high-pass, band-stop and all-pass characteristics simultaneously.

The Four Op-Amp Biquad Circuit

Fig. 1

The four opamp biquad shown in Fig. 1 has the general transfer function:



The constants,  and  in the general transfer function determine the type of filter. For example if the constant and  the general transfer function reduces to:



which is the standard low-pass transfer function with .

Similarly, for  and  we obtain a high-pass transfer function:



For and  we obtain a band-pass transfer function:



For  and we have a band elimination (BE), also called a band-stop or notch, transfer function.



with  and  the transfer function represent an all-pass filter.



Pre-Lab

1. Derive the transfer function  in Fig.1, and compare it with the general transfer function when  and. What is the cut-off frequency, and, in terms of? What value of  yields unity gain at the center frequency?
2. Derive the transfer functions  and . Comment on the differences/similarities. Compare the transfer function  with the general transfer function, when  and . What is the cut-off frequency, and , in terms of ? What values of  will make the gain, at the cut-off frequency, equal to *Q* for ?
3. Derive the transfer function  with the **switch opened**, and compare it with the general transfer function when  and, , and when  and .What values of  yield band-stop and all-pass responses? (Hint: For All Pass R1 = 2R3. For Band Stop R1 = R3).
4. Derive the transfer function  with the **switch closed**, and compare it with the general transfer function when, , and . What values of  and  yield a high pass response?

Procedure

1. Calculate the value of that yields a cut-off frequency,  , and a Q value of 1.5. Use resistance values between 1 kΩ and 1 MΩ. One possible solution is the following: C1 = C2 = 1nF; R1 = R2 = R3 = 51 KΩ, R4 = 20 KΩ. Note that the resistor values have been adjusted a bit on the basis of what is available in the lab.
2. Build the biquad circuit shown in Fig. 1 using the closest values of C available. If the value of C is not the same as obtained in part 1, recalculate the cut-off frequency.
3. Apply 1V, peak-to-peak sinusoidal signal to the circuit, and sweep the frequency from 100 Hz to 15 KHz in step 500 Hz. Keep the switch *closed*. Measure the three points, . Take more readings at smaller intervals, around the cut-off frequency.
4. With the switch *opened*, apply a 1V, peak-to-peak sinusoidal signal to the circuit. Monitor the output at . Sweep the frequency from 500 Hz to 15 KHz.