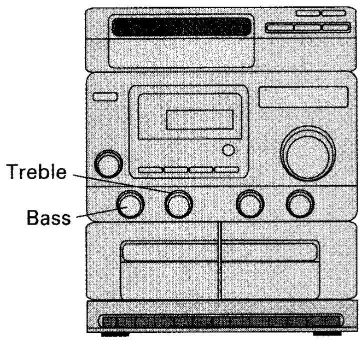
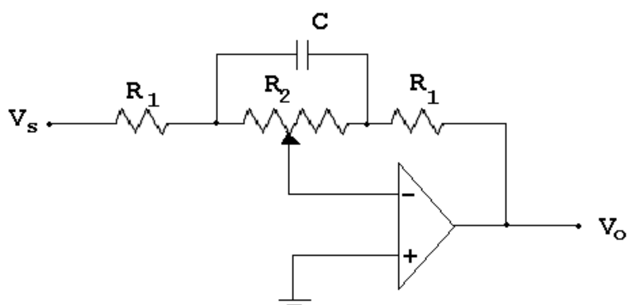
Note09: Active Filters ---Part 3: Practical Perspectives

Note; This discussion is essential to your success in the project

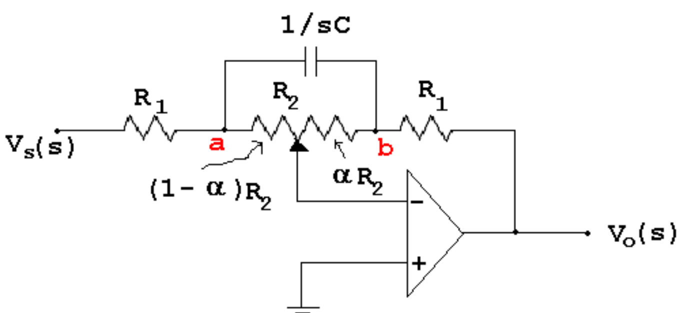
6. Practical Perspective (Bass Volume Control)



1. Objective
   - (i) OP Amp Circuit
   - (ii) Amplification of an audio signal in the bass range
   - (iii) audio signal range: 20 - 20000 Hz
   - (iv) bass range: 20 - 300 Hz
   - (v) Bass Volume Control Circuit Analysis
2. Bass Volume Control Circuit Analysis
   - (i) Let's start from a circuit shown below.



   - (ii) s-domain circuit becomes:



(iii) Node voltage equations:

@node a: $\frac{V_a - V_s}{R_1} + \frac{V_a}{(1-\alpha)R_2} + \frac{V_a - V_b}{1/sC} = 0$

@node b: $\frac{V_b}{\alpha R_2} + \frac{V_b - V_a}{1/sC} + \frac{V_b - V_o}{R_1} = 0$

@center of the variable resistor: $\frac{-V_a}{(1-\alpha)R_2} + \frac{-V_b}{\alpha R_2} = 0$

(iv) Then, the transfer function becomes: $H(s) = \frac{V_o}{V_s} = \frac{-(R_1 + \alpha R_2 + R_1 R_2 Cs)}{R_1 + (1-\alpha)R_2 + R_1 R_2 Cs}$

(v) The magnitude of steady-state transfer function is:

$$|H(jw)| = \frac{|(R_1 + \alpha R_2) + jwR_1R_2C|}{|(R_1 + (1-\alpha)R_2) + jwR_1R_2C|} \quad ....(1)$$

3. Analysis of the Bass Volume Control Transfer Function

(i) Let's consider the equation (1) with different values of α.

(ii) If α=0.5, $|H(jw)| = \frac{|(R_1 + 0.5R_2) + jwR_1R_2C|}{|(R_1 + 0.5R_2) + jwR_1R_2C|} = 1$. Therefore there is no amplification or attenuation

(iii)Volume control (Amplification or Attenuation) is controlled by the values of α.

(iv) Numerical values of R_1, R_2,and C are determined by the following 2 design decisions

(a) Passband amplification in the Bass range (w --> 0)

(b) The frequency at which the amplification is changed by 3dB (cutoff)

4. Procedures for finding the numerical values based on the design decisions

(i)The maximum magnitude relationship (remember it is a LPF)

$$|H(jw)|_{\max} = |H(j0)|_{\alpha=1} = \frac{R_1 + R_2}{R_1}$$

(ii)Minimum magnitude relationship

$$|H(jw)|_{\min} = |H(j0)|_{\alpha=0} = \frac{R_1}{R_1 + R_2}$$

(iii)Cutoff frequency relationship (*Derivation of this follow*s)

$$|H(jw)|_{cutoff} = \frac{1}{\sqrt{2}} |H(jw)|_{\max} = \frac{1}{\sqrt{2}} \frac{R_1 + R_2}{R_1}$$

or $|H(jw_c)| = \frac{1}{\sqrt{2}} |H(j0)|_{\alpha=1} = \frac{1}{\sqrt{2}} \frac{R_1 + R_2}{R_1}$

(iv) The magnitude at the cutoff frequency using equation (1):

$$|H(jw_c)|_{\alpha=1} = \frac{|(R_1 + R_2) + jw_cR_1R_2C|}{|(R_1 + jw_cR_1R_2C|} = \sqrt{\frac{(R_1 + R_2)^2 + (w_cR_1R_2C)^2}{R_1{}^2 + (w_cR_1R_2C)^2}}$$

and it becomes: $|H(jw_c)|_{\alpha=1} = \sqrt{\frac{(R_1 + R_2)^2 / R_1{}^2 + (w_cR_2C)^2}{1 + (w_cR_2C)^2}}$

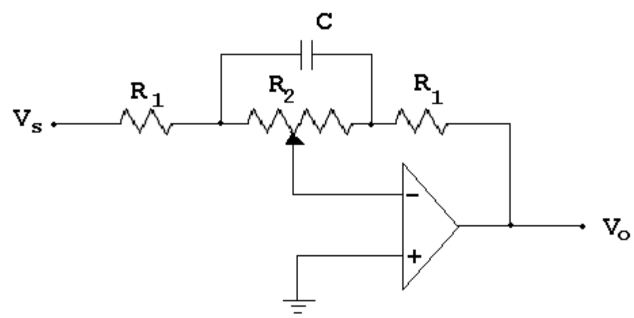
(v) Let's replace w_c by $1/R_2C$, then the equation becomes:

$$|H(jw_c)|_{\alpha=1} = \sqrt{\frac{(R_1+R_2)^2/R_1^{\ 2}+1}{2}}$$

(vi) To simplify the above equation, let's assume that $\frac{R_1+R_2}{R_1} >> 1$. Then the equation reduces to: $|H(jw_c)|_{\alpha=1} = \sqrt{\frac{(R_1+R_2)^2/R_1^{\ 2}}{2}} = \frac{1}{\sqrt{2}}\frac{R_1+R_2}{R_1}$

5. EXAMPLE PROBLEM:

Using the circuit below, design a volume control circuit to give a maximum gain of 20dB and a gain of 17dB at a frequency of 40 Hz.



(SOLUTION)