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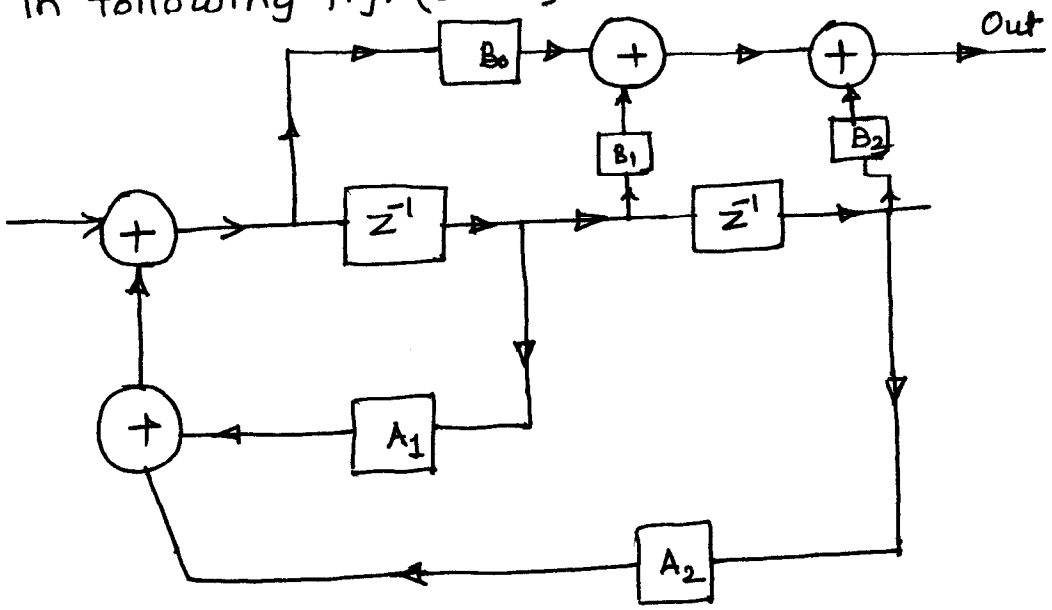
Solution for 35.29 by Pandurang Irkar

Prob. 35.29

Repeat Ex. 35.14 using a digital filter.

Soln : Referring to Ex. 35.14 (35.111 ~~35.13~~). We have to design a digital band pass filter with center frequency $f_0 = 1.59$ MHz and $Q = 20$. It can be done with digital Biquad form shown in following frg. (35.64)



Writing the transfer function

$$H(f) = \frac{a_1 s}{s^2 + \left(\frac{2\pi f_0}{Q}\right)s + (2\pi f_0)^2} \qquad (*)$$

The equation from 35.110 to 35.116 gives that

$$a_2 = B_0$$
$$a_1 = f_s(2B_0 + B_1)$$
$$a_0 = f_s^2(B_0 + B_1 + B_2)$$
$$\frac{2\pi f_0}{Q} = f_s(2 - A_1)$$

$$f_0 = \frac{f_s}{2\pi}\sqrt{(1 - A_1 - A_2)}$$

From ⊛

$$\boxed{a_2 = B_0 = 0}$$

$$a_0 = 0 \Rightarrow B_0 + B_1 + B_2 = 0$$

$$\boxed{B_1 = -B_2}$$

$$\boxed{a_1 = f_s \cdot B_1} \longrightarrow \text{Pass Band gain.}$$

For the center frequency ⇒ 1.59MHz, We can take sampling frequency 100MHz which can satisfy the Nyquist criteria completely.

We need to calculate the coefficients A_1, A_2 and B_1 with the specifications $f_0 = 1.59$MHz and $Q = 20$

From equation 35.115

~~35.115~~

$$\frac{2\pi f_0}{Q} = f_s(2 - A_1)$$

$$\frac{2\pi \times 1.59}{20 \times 10} = 2 - A_1$$

$$\boxed{A_1 = 1.9950}$$

From equation 35.116

$$f_0 = \frac{f_s}{2\pi} \cdot \sqrt{(1 - A_1 - A_2)}$$

putting the above value of A in 35.116

We get

$$\boxed{A_2 = 1.0049}$$

To find B_1 ; We know $q_1 = f_s \cdot B_1$ → decides the pass band gain

Now putting $s = j\omega$ in eqn (*) and taking the magnitude

$\because \omega_0 = 2\pi f_0$.

$$|H(j\omega)| = \frac{\omega_0 q_1}{\sqrt{(\omega_0^2 - \omega_0^2) + \frac{\omega^2 \omega_0^2}{Q^2}}} = \frac{q_1 Q}{\omega_0} \Rightarrow \text{(**)}$$

put $q_1 = f_s B_1$ in eqn (**) and equating to a pass band gain ≈ 20 (Assumed)

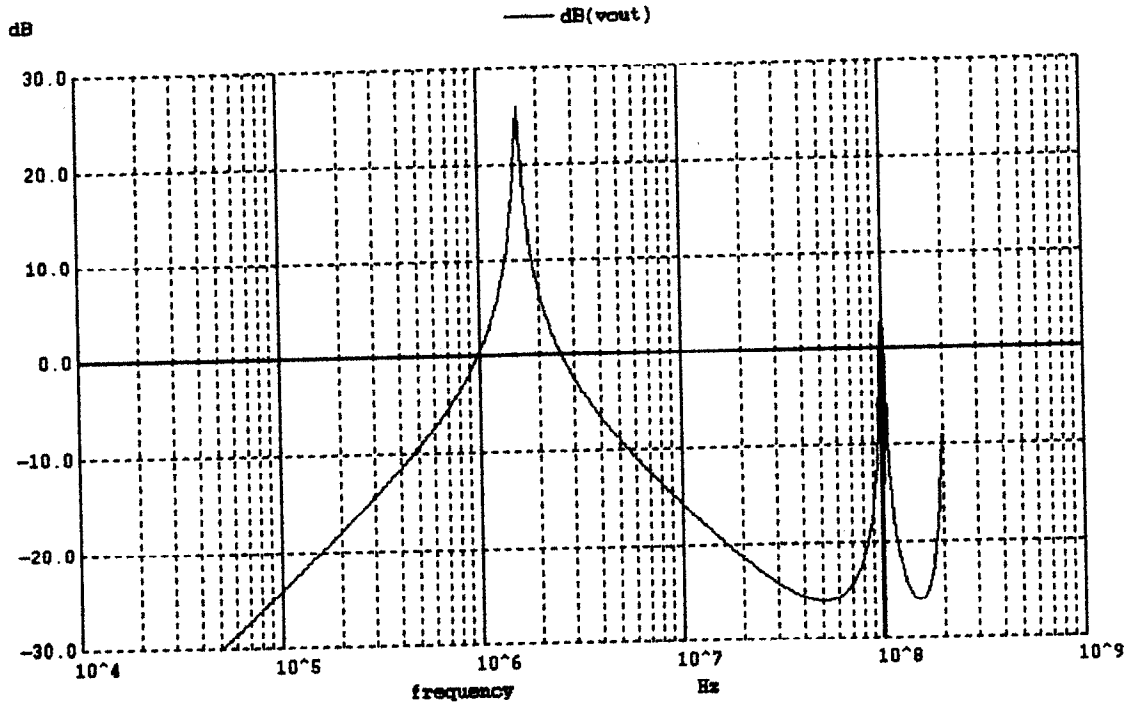
$$20 = \frac{1.59 \times B_1}{2\pi \cdot 159} \times 20$$

$$\boxed{B_1 = 0.099}$$

Thus we found the coefficients. The netlist and simulated results are shown on the following pages. The simulated results shows the effect of high Q i.e. sharp select selectivity of frequency.

Biquad Bandpass Digital filter

```
.control
destroy all
run
set units=degrees
plot dB(vout) ylimit 25 -25
.endc

.AC DEC 100 10k 200MEG

*Input Signal
Vin Vin 0 DC 0 AC 1

*Adders
Eadd1 Voadd1 0 Vin Voadd2 1
Eadd2 0  Voadd2  Voa1 Voa2 1
Eadd3 Vout 0 Vob1 Vob2 1

*Delays Using transmission line and termination
TZ1 Vod1 0 Voadd1 0 TD=10n ZO=50
RZ1 Vod1 0 50

*Add buffer to avoid loading
Ebuf1 Vod11 0 Vod1 0 1
TZ2 Vod2 0 Vod11 0 TD=10n ZO=50
RZ2 Vod2 0 50

*multipliers
EA1 Voa1 0 Vod1 0 1.9950
EA2 Voa2 0 Vod2 0 1.0049
EB1 Vob1 0 Vod1 0 0.099
EB2 Vob2 0 Vod2 0 0.099

* Load resistors
RL Vout 0 1G
Radd1 Voadd1 0 1G
Radd2 Voadd2 0 1G
Roa1 Voa1 0 1G
Roa2 Voa2 0 1G
.end
```



With Q=20 and Gain of Passband=20, we have here Gain =26dB at center frequency