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Diketahui : $V_{in} = 5V$

V_{out} :

(a) Gain = -3dB ?

(b) Gain = -90dB ?

(c) Gain = -60 dB

(*) $Gain_{(dB)} = 20 \log_{10}(Gain)$

$\log_{10}(Gain) = \frac{Gain\ (dB)}{20}$

$$Gain = (10)^{\frac{Gain(dB)}{20}}$$

(a) -3 dB → $Gain = (10)^{-3/20} = 0,707$

$V_{out} = (5V) \cdot (0,707) = 3,5397\ V$

(b) -90dB → $Gain = (10)^{-90/20} = 0,01$

$V_{out} = (5V)(0,01) = 0,05\ V$

(c) -60 dB → $Gain = (10)^{-60/20} = 0,001$

$V_{out} = (5V)(0,001) = 0,005\ V$

LPF Orde II

⑨ **Butterworth** ($a_1 = \sqrt{2}$, $b_1 = 1$, $C_1 = 0{,}01\,\mu F$)

⑧ $C_2 > C_1 \frac{4b_1}{a_1^2} \rightarrow C_2 > (0{,}01)\frac{(4)(1)}{(\sqrt{2})^2} \cdot 10^{-6}$

$C_2 > 0{,}02\,\mu F$

$\boxed{C_2 = 0{,}05\,\mu F}$ ✓

⑧ $R_{1,2} = \dfrac{a_1 C_2 \pm \sqrt{(a_1 C_2)^2 - 4b_1 C_1 C_2}}{4\pi f C_1 C_2}$

④ $(a_1 C_2) = 7{,}07 \cdot 10^{-8}$ ✓

⑤ $(a_1 C_2)^2 = 5 \cdot 10^{-15}$ ✓

⑥ $(C_1 C_2) = 5 \cdot 10^{-16}$ ✓

⑧ $R_{1,2} = \dfrac{7{,}07 \cdot 10^{-8} \pm \sqrt{5 \cdot 10^{-15} - 4(1)(5 \cdot 10^{-16})}}{4\pi (1000)(5 \cdot 10^{-16})}$ ✓

$= 10^{12}\,\dfrac{7{,}07 \cdot 10^{-8} \pm \sqrt{5 \cdot 10^{-15} - 2 \cdot 10^{-15}}}{2\pi}$ ✓

$= 10^{12}\,\dfrac{7{,}07 \cdot 10^{-8} \pm 5{,}477 \cdot 10^{-8}}{2\pi} = \dfrac{7{,}07 \pm 5{,}477}{2\pi} \cdot 10^{9}$ ✓

$R_1 = \dfrac{7{,}07 + 5{,}477}{2\pi} \cdot 10^{9} = 1996\,\Omega$

$R_2 = \dfrac{7{,}07 - 5{,}477}{2\pi} \cdot 10^{9} = 253\,\Omega$

(b) **Bessel** $(a_1 = 1{,}3617,\ b_1 = 0{,}618,\ C_1 = 0{,}01\,\mu F)$

(a) $C_2 > C_1 \dfrac{4b_1}{a_1^2} \rightarrow C_2 > 0{,}01 \dfrac{4(0{,}618)}{(1{,}3617)^2} \cdot 10^{-6}$

$C_2 > 0{,}01\,\mu F$

$\boxed{C_2 = 0{,}05\,\mu F}$ ✓

(b) $R_{1,2} = \dfrac{a_1 C_2 \pm \sqrt{(a_1 C_2)^2 - 4b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$

(c) $(a_1 C_2) = 6{,}808 \cdot 10^{-8}$ ✓

(d) $(a_1 C_2)^2 = 4{,}635 \cdot 10^{-15}$ ✓

(e) $(C_1 C_2) = 5 \cdot 10^{-16}$ ✓

(a) $R_{1,2} = \dfrac{6{,}808 \cdot 10^{-8} \pm \sqrt{4{,}635 \cdot 10^{-15} - 4(0{,}618)(5 \cdot 10^{-16})}}{4\pi (1000)(5 \cdot 10^{-16})}$

$= 10^{12}\ \dfrac{6{,}808 \cdot 10^{-8} \pm \sqrt{4{,}635 \cdot 10^{-15} - 1{,}236 \cdot 10^{-15}}}{2\pi \cdot}$ ✓

$= 10^{12}\ \dfrac{6{,}808 \cdot 10^{-8} \pm 5{,}83 \cdot 10^{-8}}{2\pi} = \dfrac{6{,}808 + 5{,}83}{2\pi} \cdot 10^{9}$ ✓

$R_1 = \dfrac{6{,}808 + 5{,}83}{2\pi} \cdot 10^{9} = 20119\ \Omega$ ✓

$R_2 = \dfrac{6{,}808 - 5{,}83}{2\pi} \cdot 10^{9} = 1556\ \Omega$ ✓

√ ⓒ Chebychev ($a_1 = 1{,}065$, $b_1 = 1{,}9305$, $C_1 = 0{,}01\,\mu F$)

⊛ $C_2 > C_1 \frac{4b_1}{a_1^2} \rightarrow C_2 > (0{,}01)\frac{(4)(1{,}9305)}{(1{,}065)^2} \cdot 10^{-6}$

$$C_2 > 0{,}06 \cdot 10^{-6}$$

$$C_2 = 0{,}1\,\mu F$$

⊛ $R_{1,2} = \dfrac{a_1 C_2 \pm \sqrt{(a_1 C_2)^2 - 4b_1 C_1 C_2}}{4\pi f C_1 C_2}$

⊛ $(a_1 C_2) = 1{,}065 \cdot 10^{-7}$

⊛ $(a_1 C_2)^2 = 1{,}134 \cdot 10^{-14}$

⊛ $(C_1 C_2) = 10^{-15}$

$$R_{1,2} = \frac{1{,}065 \cdot 10^{-7} \pm \sqrt{1{,}134 \cdot 10^{-14} - 4(1{,}9305)(10^{-15})}}{4\pi(1000)(10^{-15})}$$

$$= 10^{12}\,\frac{1{,}065 \cdot 10^{-7} \pm \sqrt{1{,}134 \cdot 10^{-14} - 0{,}7722 \cdot 10^{-14}}}{4\pi}$$

$$= 10^{12}\,\frac{1{,}065\,10^{-7} \pm 0{,}6014 \cdot 10^{-7}}{4\pi} = \frac{1{,}065 \pm 0{,}6014}{4\pi} \cdot 10^{5}$$

$$R_1 = \frac{1{,}065 + 0{,}6014}{4\pi} \cdot 10^5 = 13260\,\Omega$$

$$R_2 = \frac{1{,}065 - 0{,}6014}{4\pi} \cdot 10^5 = 3689\,\Omega$$

⊛ LPF Orde III → $C_0 = C_1 = 0{,}01\,\mu F$

(a) Butterworth

Stage 1 :

$$R = \frac{a_1}{2\pi f_c C_0} = \frac{(1)}{2\pi(1000)(0{,}01.10^{-6})} = 15915\,\Omega$$

Stage 2 : $(a_2 = 1,\ b_2 = 1)$

$$C_2 > C_1 \frac{4b_2}{a_2^2} \rightarrow C_2 > (0{,}01)\frac{4.(1)}{(1)^2}.10^{-6}$$

$$C_2 > 0{,}04.10^{-6}\,\mu F$$

$$C_2 = 0{,}05\,\mu F$$

$$R_{1,2} = \frac{a_2C_2 \pm \sqrt{(a_2C_2)^2 - 4b_2C_1C_2}}{4\pi f_c C_1 C_2}$$

⊛ $(a_2C_2) = 5.10^{-8}$

⊛ $(C_1C_2) = 5.10^{-16}$

⊛ $(a_2C_2)^2 = 2{,}5.10^{-15}$

$$R_{1,2} = \frac{5.10^{-8} \pm \sqrt{2{,}5.10^{-15} - 4(1)(5.10^{-16})}}{4\pi(1000)(5.10^{-16})}$$

$$= 10^{12}\,\frac{5.10^{-8} \pm \sqrt{2{,}5.10^{-15} - 2.10^{-15}}}{2\pi}$$

$$= 10^{12}\,\frac{5.10^{-8} \pm 2{,}23.10^{-8}}{2\pi} = \frac{5 \pm 2{,}23}{2\pi}.10^{4}$$

$$R_1 = \frac{5 + 2{,}23}{2\pi} \cdot 10^9 = 11506\ \Omega$$

$$R_2 = \frac{5 - 2{,}23}{2\pi} \cdot 10^9 = 9908\ \Omega$$

⑥ Bessel

Stage 1 : $(a_1 = 0{,}756)$

$$R = \frac{a_1}{2\pi f_c C_0} = \frac{0{,}756}{2\pi (1000)(0{,}01 \cdot 10^{-6})} = 12032\ \Omega$$

Stage 2 ; $(a_2 = 0{,}9996\ ,\ b_2 = 0{,}4772)$

$$R_{1,2} = \frac{a_2 C_2 \pm \sqrt{(a_2 C_2)^2 - 4 b_2 (C_1 C_2)}}{4\pi f_c C_1 C_2}$$

(*) $C_2 > C_1 \frac{4 b_2}{a_2^2} \rightarrow C_2 > (0{,}01) \frac{4(0{,}4772)}{(0{,}9996)^2} \cdot 10^{-6}$

$C_2 > 0{,}02\ \mu F$

$C_2 = 0{,}05\ \mu F$

(*) $(a_2 C_2) = 4{,}998 \cdot 10^{-8}$

(*) $(C_1 C_2) = 5 \cdot 10^{-16}$

(*) $(a_2 C_2)^2 = 2{,}49 \cdot 10^{-15}$

$$R_{1,2} = \frac{9{,}998 \cdot 10^{-8} \pm \sqrt{2{,}49 \cdot 10^{-15} - 9(0{,}4772)(5 \cdot 10^{-16})}}{9\pi(1000)(5 \cdot 10^{-16})}$$

$$= 10^{12}\,\frac{4{,}998 \cdot 10^{-8} \pm \sqrt{2{,}49 \cdot 10^{-15} - 0{,}9549 \cdot 10^{-15}}}{2\pi}$$

$$= 10^{12}\,\frac{9{,}998 \cdot 10^{-8} \pm 3{,}918 \cdot 10^{-8}}{2\pi} = \frac{4{,}998 \pm 3{,}918}{2\pi} \cdot 10^{9}$$

$$R_1 = \frac{4{,}998 + 3{,}918}{2\pi} \cdot 10^{9} = 14190\ \Omega$$

$$R_2 = \frac{4{,}998 - 3{,}918}{2\pi} \cdot 10^{9} = 1718\ \Omega$$

(c) Chebychev 3-dB

Stage 1 ($a_1 = 3{,}3996$)

$$R = \frac{a_1}{2\pi f_c C_0} = \frac{3{,}3996}{2\pi(1000)(0{,}01 \cdot 10^{-6})} = 53310\ \Omega \quad \checkmark$$

Stage 2 ; ($a_2 = 0{,}3559$, $b_2 = 1{,}1923$)

$$R_{1,2} = \frac{a_2 C_2 \pm \sqrt{(a_2 C_2)^2 - 4 b_2 C_1 C_2}}{4\pi f_c C_1 C_2}$$

$$C_2 > C_1 \frac{4 b_2}{a_2^2} \rightarrow C_2 > 0{,}01 \frac{4(1{,}1923)}{(0{,}3559)^2} \cdot 10^{-6}$$

(*) $(a_2 C_2) = 1,7795.10^{-7}$ ✓

(*) $(a_2 C_2)^2 = 3,16 . 10^{-19}$ ✓

(*) $(C_1 C_2) = 5.10^{-15}$ ✓

$$R_{1,2} = \frac{1,7795.10^{-7} \pm \sqrt{3,16.10^{-19} - 9(1,1923)(5.10^{-15})}}{9\pi(1000)(5.10^{-15})}$$

$$= 10^{11} \frac{1,7795.10^{-7} \pm \sqrt{3,16.10^{-19} - 2,3896.10^{-19}}}{2\pi}$$

$$= 10^{11} \frac{1,7795.10^{-7} \pm 0,8805.10^{-7}}{2\pi}$$ ✓

$$= \frac{1,7795 \pm 0,8805}{2\pi} . 10^9$$ ✓

$$R_1 = \frac{1,7795 + 0,8805}{2\pi} . 10^9 = 4233\,\Omega$$

$$R_2 = \frac{1,7795 - 0,8805}{2\pi} . 10^9 = 1430\,\Omega$$