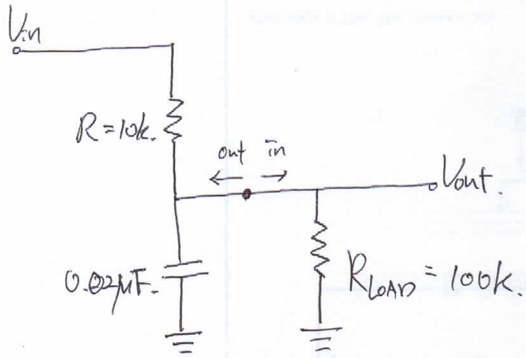
① .

17/09/18.

LPF.



but unclear.

$Z_c = \infty$ (Assumption). → really true?

Impedence : Generalized Resistance.

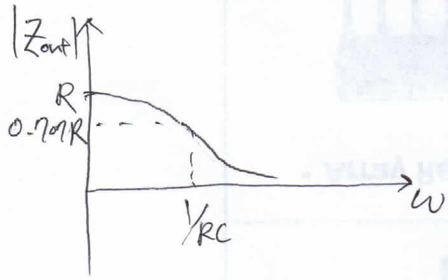
: Resistance + Reactance/Inductance.

$$Z_{out} = Z_R // Z_c = \frac{Z_R \cdot Z_c}{Z_R + Z_c}.$$

$$Z_R = R, \quad Z_c = \frac{1}{j\omega c}$$

$$Z_{out} = \frac{R \cdot \frac{1}{j\omega c}}{R + \frac{1}{j\omega c}} = \frac{R}{1 + j\omega RC}.$$

$$|Z_{out}| = \frac{R}{\sqrt{1+(\omega RC)^2}} \qquad \angle = -\tan^{-1}(\omega RC)$$



$Z_{in} = R_{LOAD} = 100k.$

$\therefore Z_{out} \leq \frac{1}{10} Z_{in}.$ Satisfied.

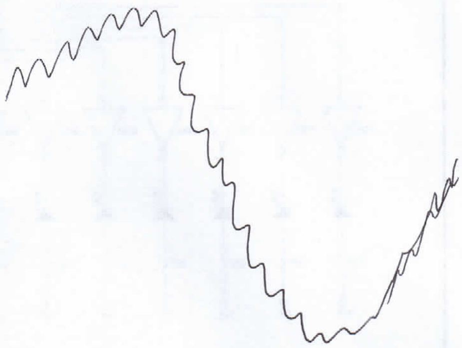
10k 10k.

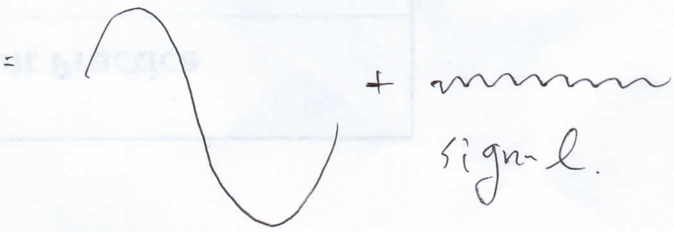
→ Design rule of 10X.

: "Z_{in} is 10 times or more stiff than Z_{out}"

(= bigger).

"HPF".

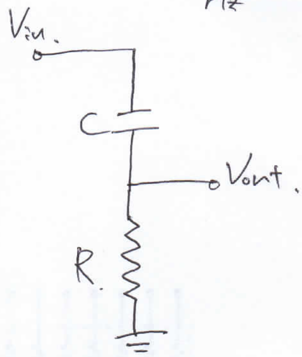




signal.

NOISE.

~~60kHz~~ 60 Hz. 1kHz.



$$\frac{V_{out}}{V_{in}} = \frac{Z_2}{Z_1 + Z_2} = \frac{R}{\frac{1}{j\omega c} + R} = \frac{j\omega RC}{1 + j\omega RC}.$$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{\omega RC}{\sqrt{1+(\omega RC)^2}}$$

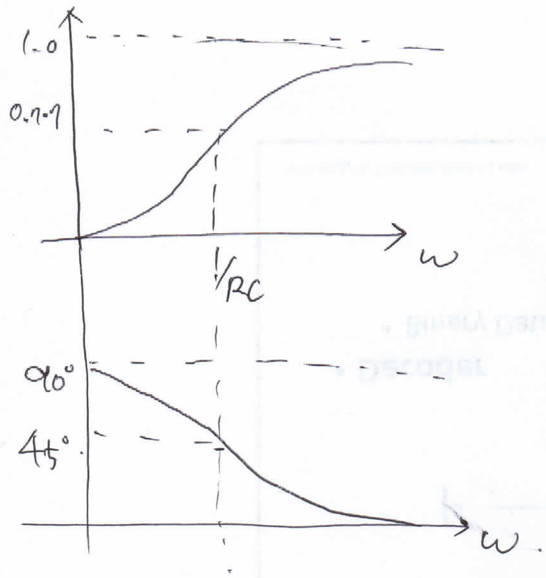
$$\angle = 90^\circ - \tan^{-1}(\omega RC)$$

$\omega \to 0, \quad \left|\frac{V_{out}}{V_{in}}\right| \to 0. \quad \angle \to 90^\circ$

$\omega = \frac{1}{RC}, \quad \left|\frac{V_{out}}{V_{in}}\right| \to \frac{1}{\sqrt{2}} = 0.707 \quad \angle = 45^\circ$

②

$\omega \to \infty, \left|\frac{V_{out}}{V_{in}}\right| \to 1, \angle = 0^\circ$



$\omega \geq \frac{1}{RC} = \omega_{3dB}$ ~~=0.707~~

∴ High Pass Filter.

⑤ $\omega_{3dB} = 1/RC$

Design a HPF, ~~fd~~ f_{3dB} =

NOISE = 1kHz,

Signal = 16kHz...

① freq. Identification.

$f_{signal} = 16kHz$,

$f_{noise} = 1kHz$.

② Choose R.C s.t $\omega_{3dB} = 2\pi f_{signal}$

③ 10X rule.

④ performance verification

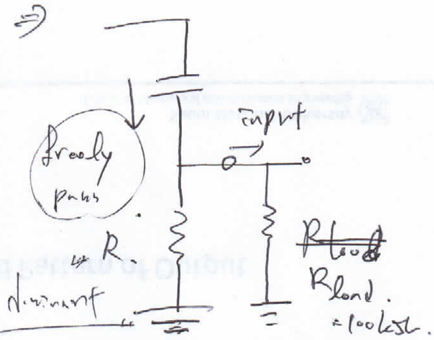
$\omega_{3dB} = 2\pi(16{,}000)$

$= \frac{1}{RC}$ ... ①

To drive A/D converter. = Voltage input

whose input impedance is 100kΩ

⇒



$R = \frac{1}{10} R_{load} = 10k\Omega$ ... ②

∴ $C \simeq 10^{-10}$ F = 0.0001μF.

→ Commercially available

= 100pF.

At. f = 16,000Hz.

$\left|\frac{V_{out}}{V_{in}}\right| = 0.707$.

$f_{noise} = 1kHz, \left|\frac{V_{out}}{V_{in}}\right| = 0.0628$.

S/N Ratio = 11.25.

$Z_c \to 0$ at high freq

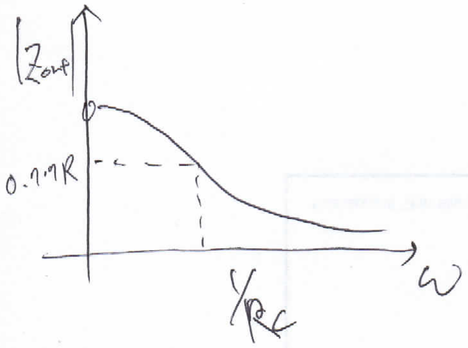
(Assumption)

$Z_{out} = Z_c // Z_R = \frac{Z_c Z_R}{Z_c + Z_R}$

$= \frac{\frac{1}{j\omega C} \cdot R}{\frac{1}{j\omega C} + R} = \frac{R}{1 + j\omega CR}$

$|Z_{out}| = \frac{R}{\sqrt{1 + (\omega RC)^2}}$

③



$$\omega_1 = \frac{1}{R_1C_1}, \quad \omega_2 = \frac{1}{R_2C_2}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1+j\omega R_1C_1} \cdot \frac{j\omega R_2C_2}{1+j\omega R_2C_2}$$

$\omega = \omega_2$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{\omega R_2C_2}{\sqrt{1+(\omega R_1C_1)^2}} \cdot \frac{1}{\sqrt{1+(\omega R_2C_2)^2}}$$

$$\angle = 90^\circ - \tan^{-1}(\omega R_1C_1) - \tan^{-1}(\omega R_2C_2)$$

$|Z_{out}| \leq R.$

$Z_{in} = R_{load}$

$= 100k\Omega.$

$Z_{out} \leq \frac{1}{10} Z_{in}.$

"Satisfy."

BPF amplitude equation 1.6kHz 8kHz

← S. at LPF.

Band Pass Filter (BPF)

Design a BPF. to pass signals between 1.6kHz and 8kHz.

$1.6kHz \leq f \leq 8kHz$

"Band width can be passed"

BPF = LPF + HPF

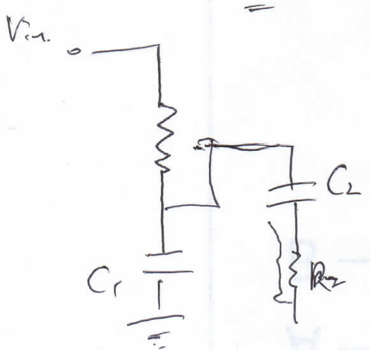
$\omega_{3dB} = (8000)(2\pi) =$

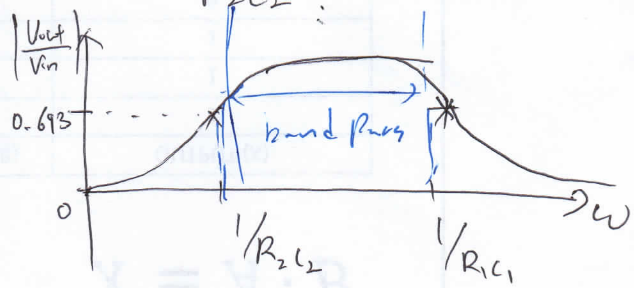
HPF

$\omega_{3dB} = (1600)(2\pi)$

$LPF = \frac{1}{R_1C_1}$ $\quad \frac{1}{R_1C_1} = 8000 \cdot 2\pi$

$HPF = \frac{1}{R_2C_2}$;



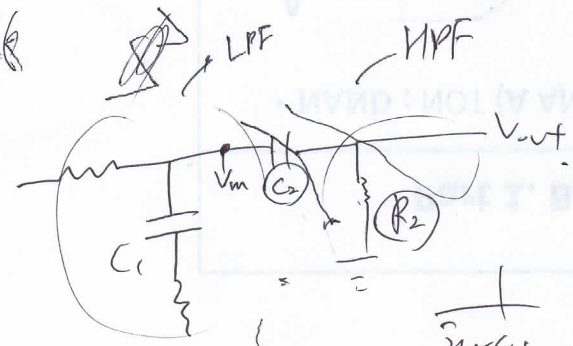


At $\omega = \frac{1}{R_2C_2} = (1600)\cdot(2\pi)$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\sqrt{1+\left(\frac{R_1C_1}{R_2C_2}\right)^2}} \cdot \frac{1}{\sqrt{1+1}}$$

$\frac{R_1C_1}{R_2C_2} = \frac{1}{5}$

$= 0.693$



$$\frac{V_m}{V_{out}} = \frac{Z_{C1}}{Z_{R1}+Z_{C1}} = \frac{\frac{1}{j\omega C_1}}{R_1+\frac{1}{j\omega C_1}} = \frac{1}{1+j\omega R_1C_1}$$

$$\frac{V_{in}}{V_m} = \frac{Z_{R2}}{Z_{C}+Z_{R2}} = \frac{R_2}{\frac{1}{j\omega C_2}+R} = \frac{j\omega R_2C_2}{1+j\omega R_2C_2}$$

$\angle = 90^\circ - \tan^{-1}(1/5) - \tan^{-1}(1)$

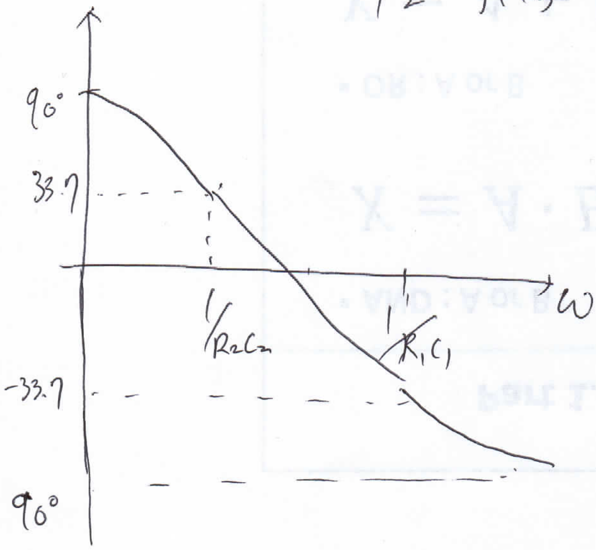
$= 33.7^\circ.$

④

At $\omega = \frac{1}{R_1C_1} = (800)(2\pi)$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{(R_2C_2/R_1C_1)}{\sqrt{1+1^2}\cdot\sqrt{1+\left(\frac{R_2C_2}{R_1C_1}\right)^2}}$$

$$= \frac{5}{\sqrt{2}\cdot\sqrt{1+5^2}} = 0.693.$$



For HPF

$\therefore R_2 = \frac{1}{10} R_{LOAD} = 100\,k\Omega.$

$\therefore C_2 = 9.95\times10^{-4}\,\mu F.$

$10\times10^{-4}\,\mu F$ → commercially available.

LPF.

$R_1 = 10\,k\Omega$ by 10X Rule.

$C_1 = 1.99\times10^{-3}\,\mu F.$

$\simeq 0.002\,\mu F.$

Hw 3

LPF − HPF ⇒ HPF − LPF.

→ not working.

→ why?

For LPF

$$\omega_{3dB} = \frac{1}{R_1C_1} = (800)(2\pi)\cdots ①$$

For HPF

$$\omega_{3dB} = \frac{1}{R_2C_2} = (1600)(2\pi)\cdots ②$$

To drive oscilloscope.

whose $Z_{in} = 1\,M\Omega$.

Design ^ 1.6 kHz ~ 8 kHz BPF

R_{load} 동일

4 ① Design.

3 ② plot

3 ③ Verification

~~1.6kHz − 8kHz.~~

if input 5kHz?

Mag? Phase? S/N?

→ 5kHz → signal

→ 20kHz → Noise