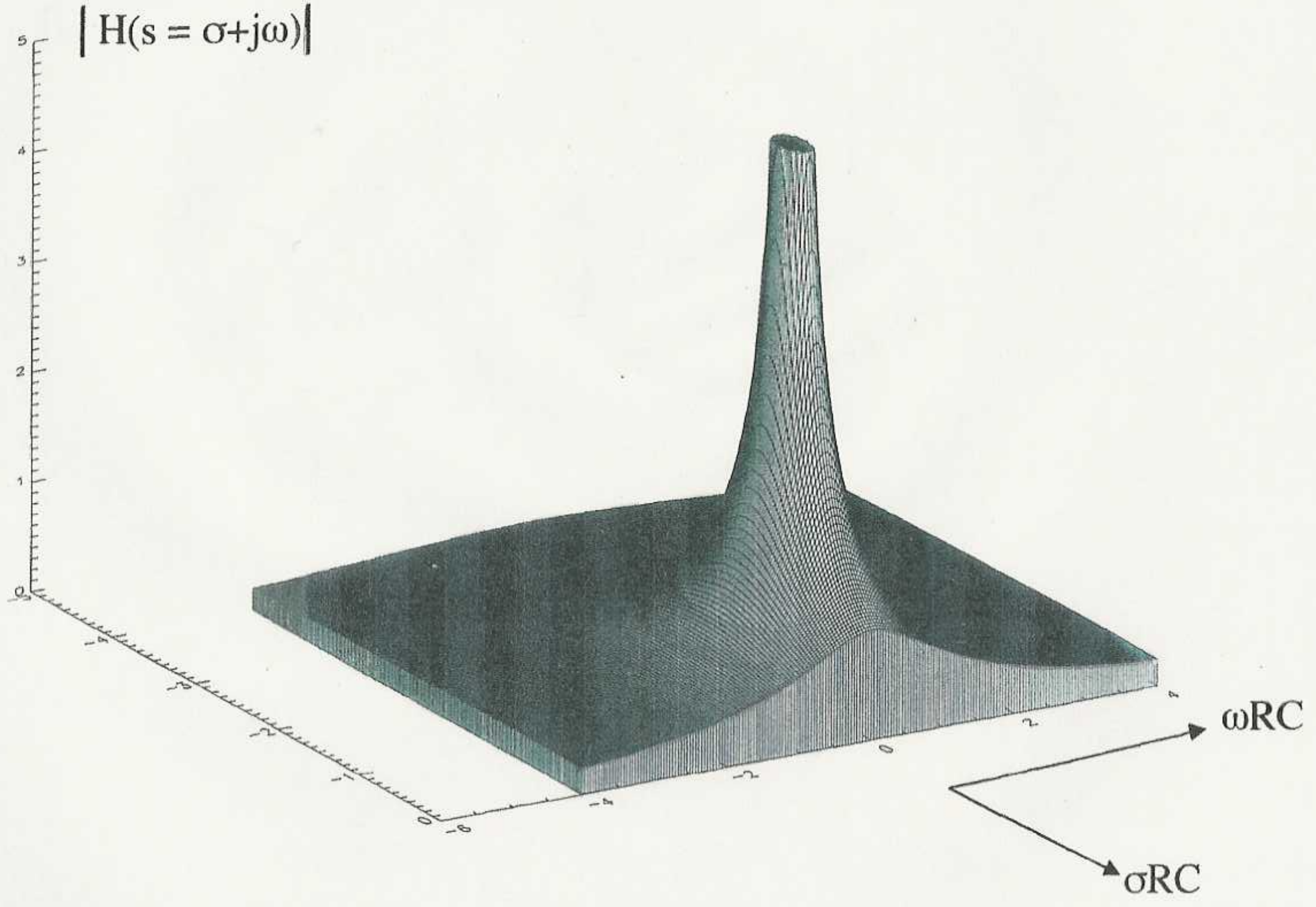
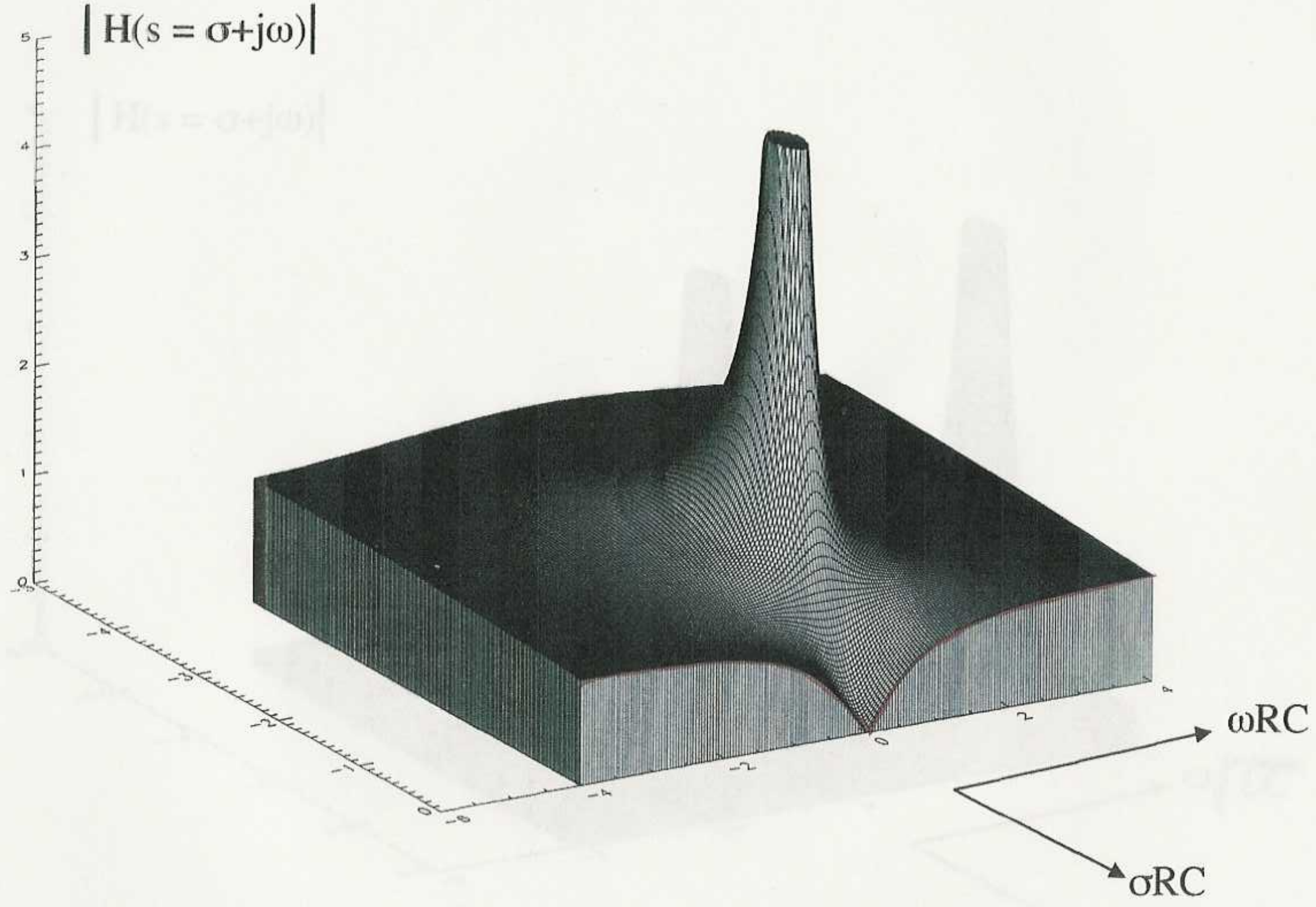
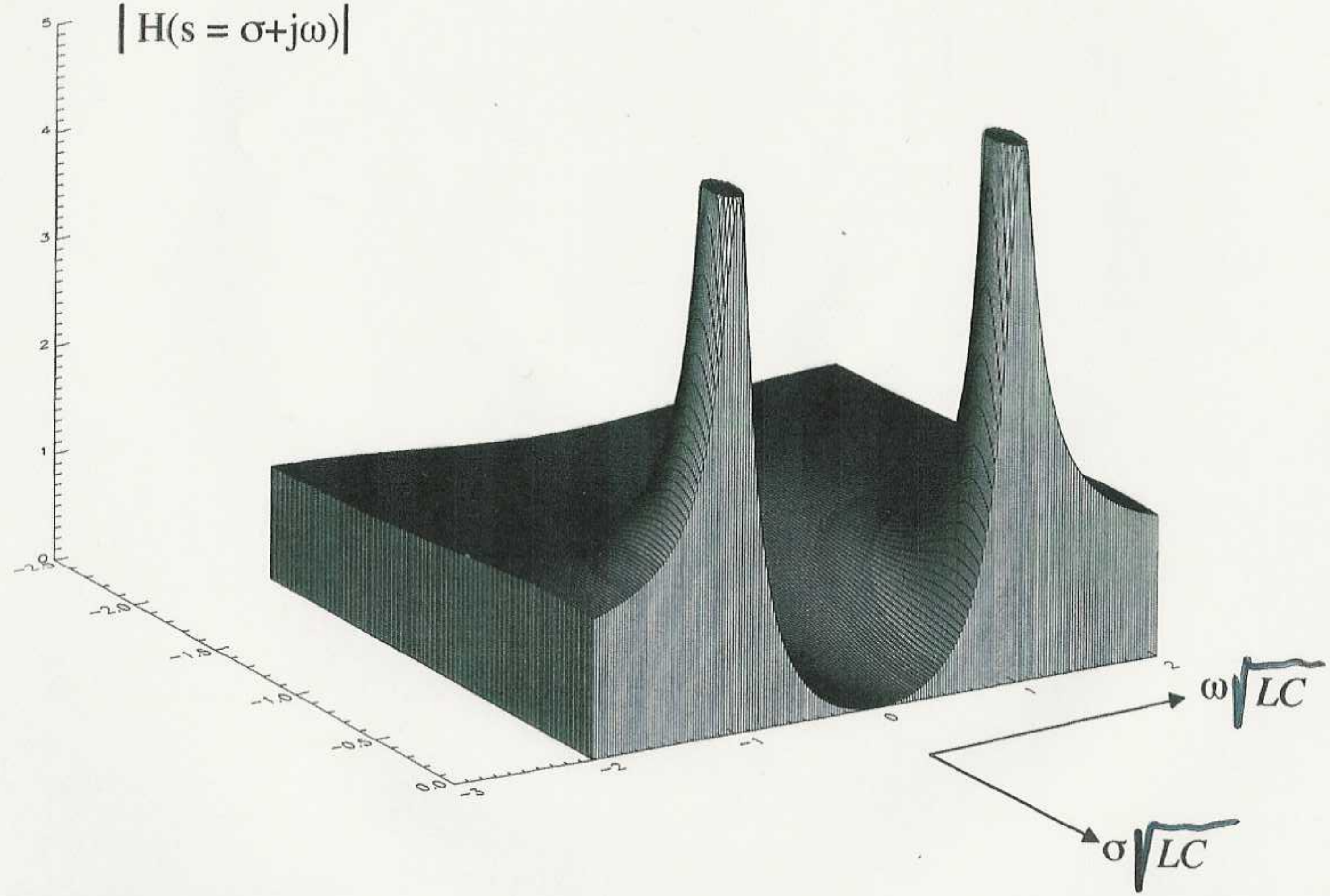


|H(s = σ+jω)|
ωRC
σRC



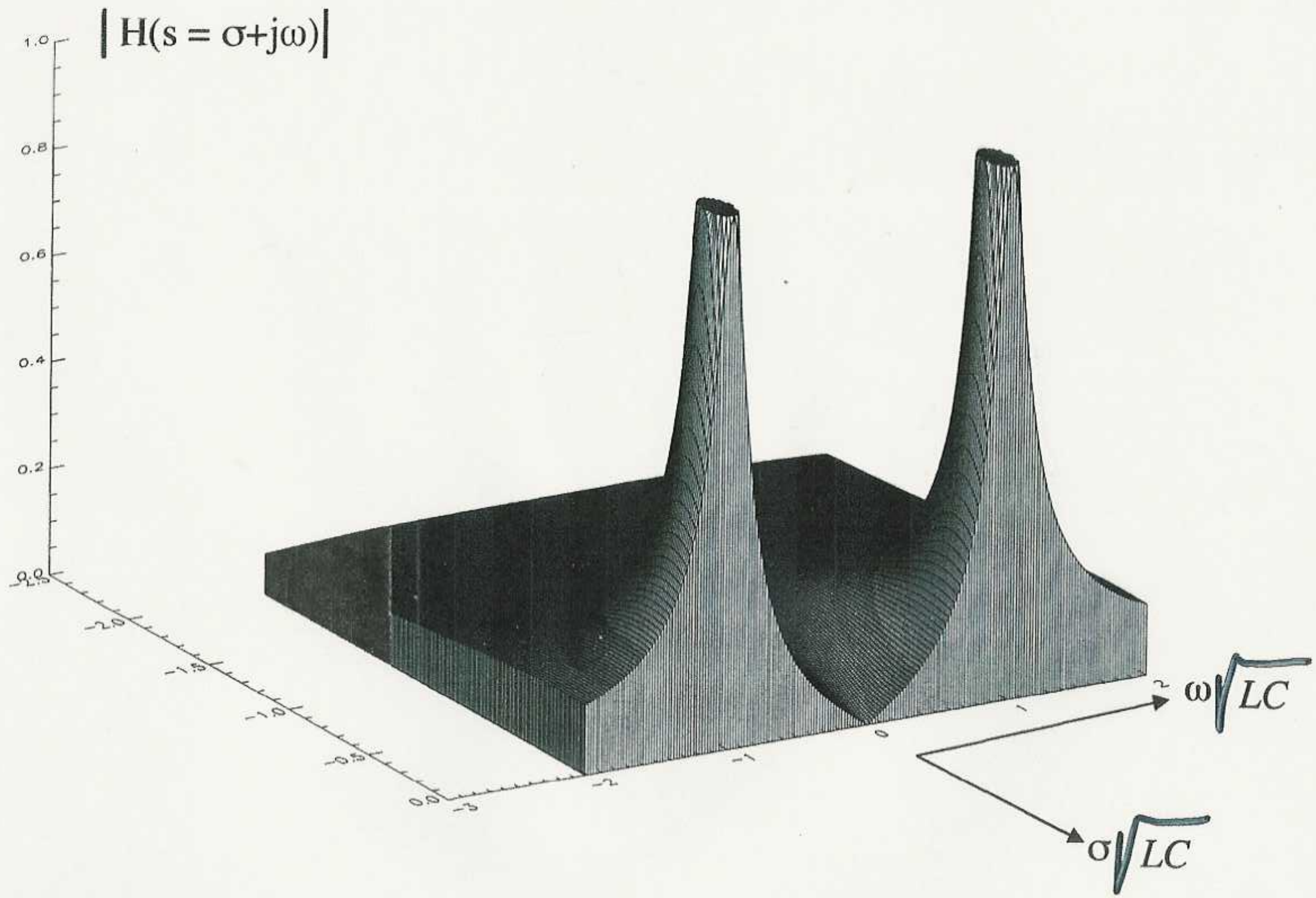
4A

$\frac{V_e}{V_i}$

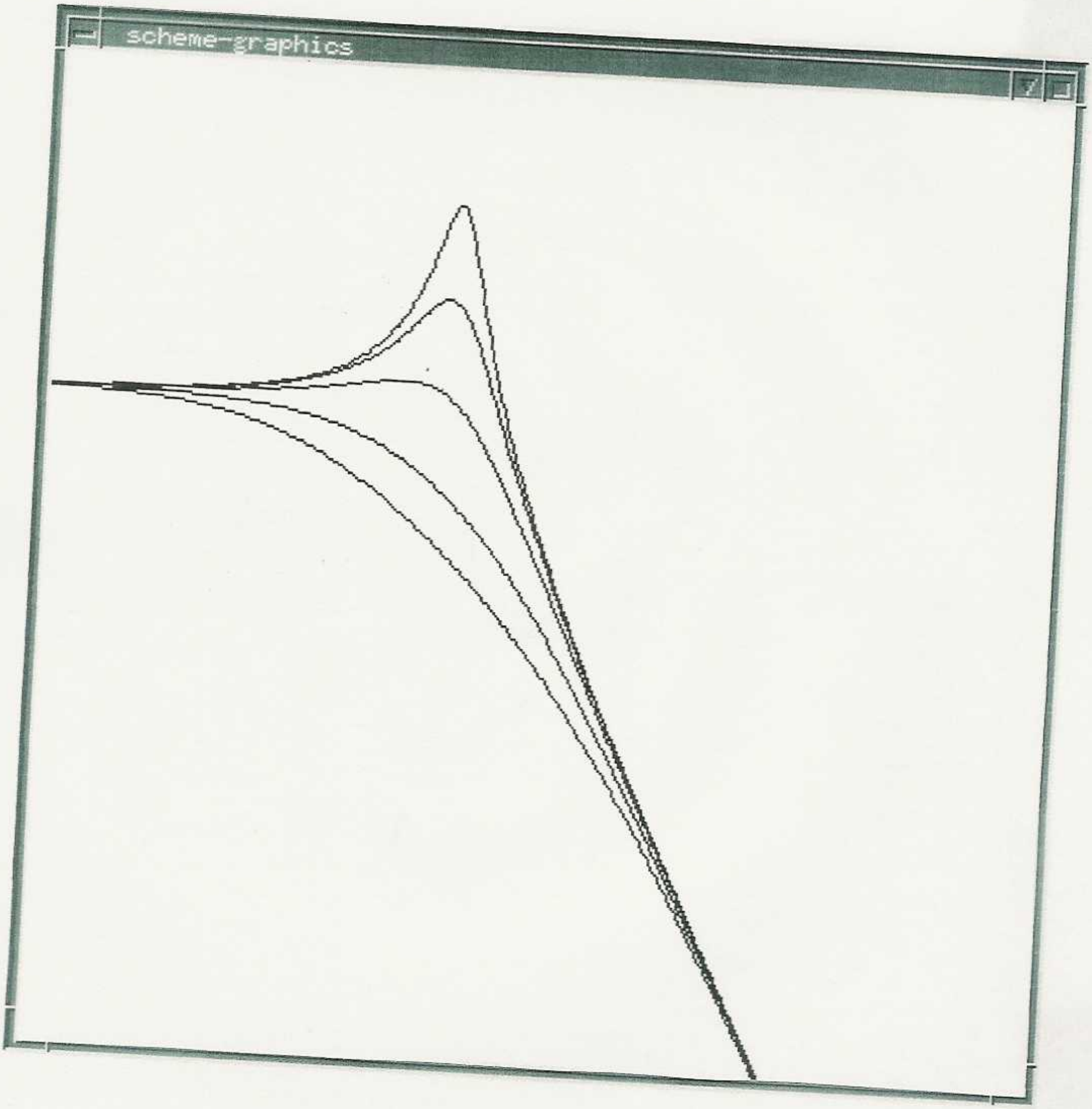

|H(s = σ+jω)|
0
1
2
3
4
5
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
-3
-2
-1
0
1
2
$\omega\sqrt{LC}$
$\sigma\sqrt{LC}$

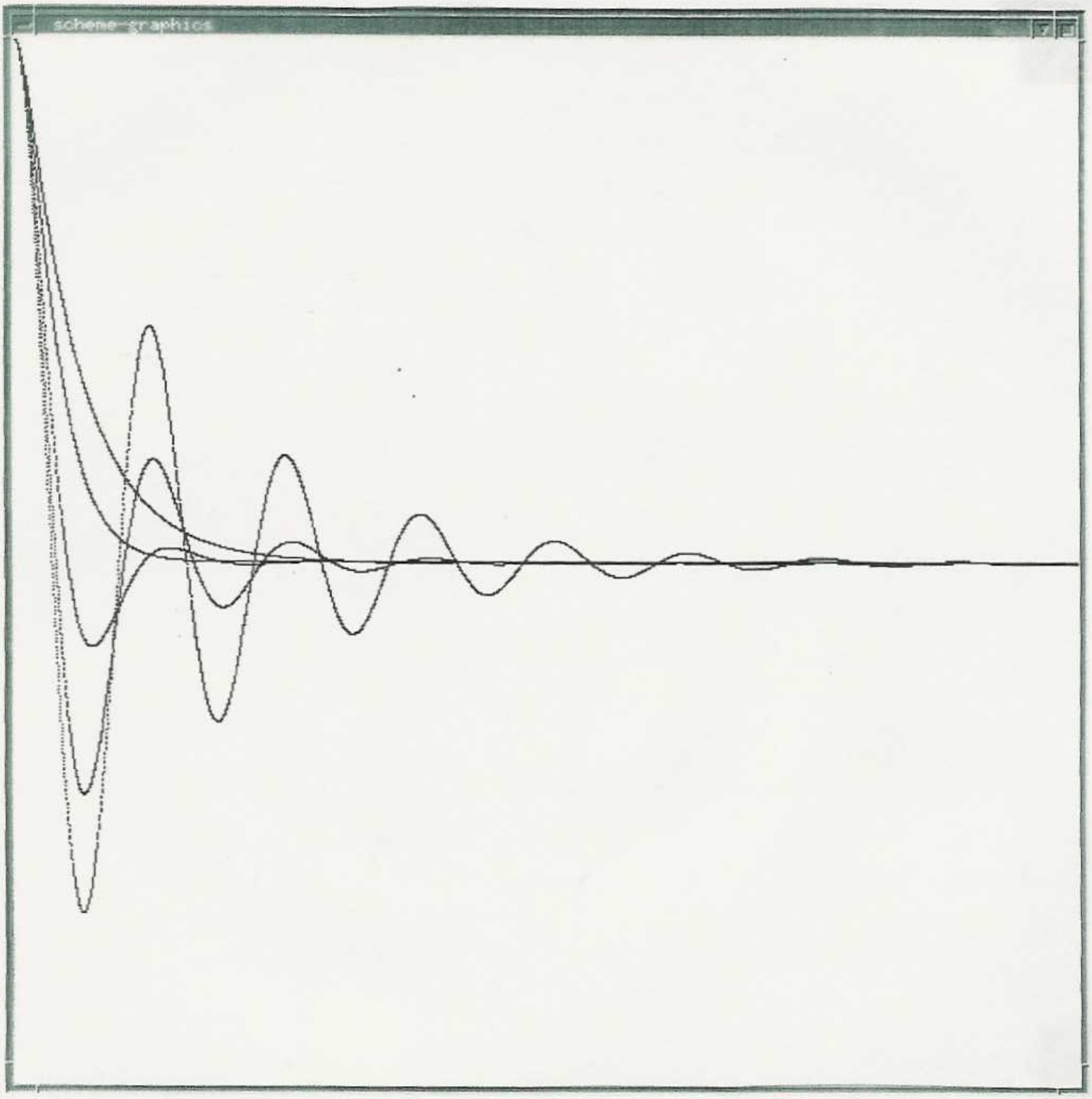
5c

$\frac{V_r}{V_i}$

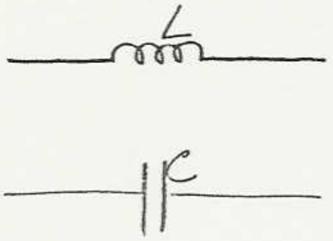


5B


scheme-graphics

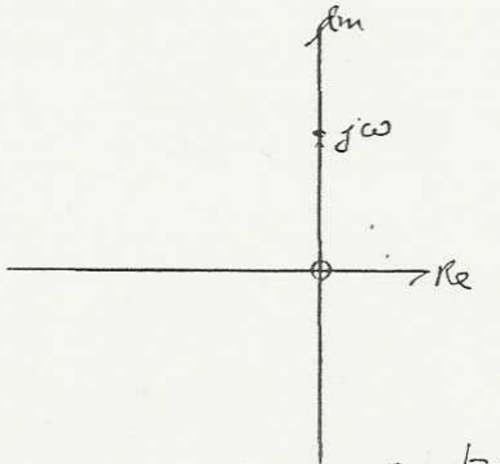

scheme-graphics

Zero at the origin



$$Z = \frac{V}{I} = Ls$$

$$Y = \frac{I}{V} = Cs$$

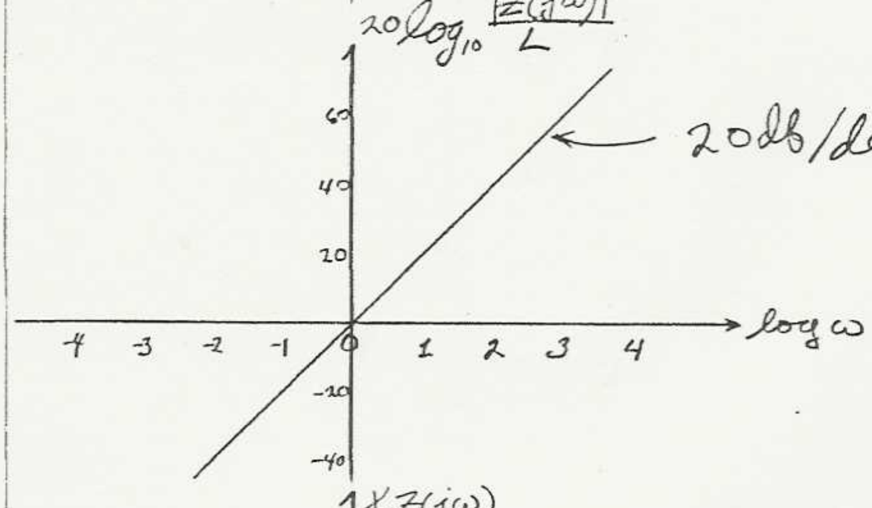


If $Z(s) = Ls$

$$|Z(j\omega)| = L\,|\omega|$$

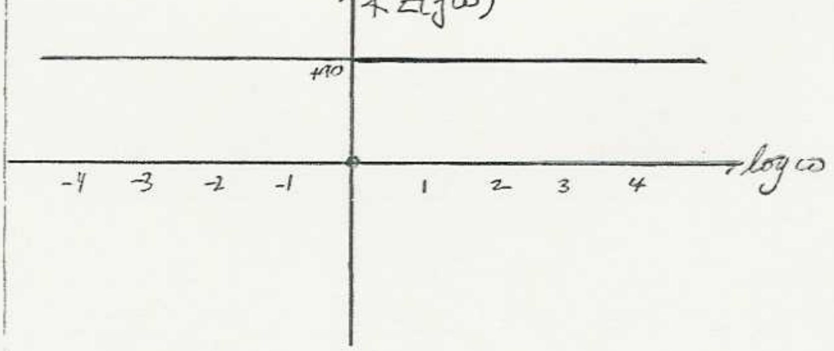
$$\log_{10}|Z(j\omega)| = \log_{10}|\omega| + \log_{10} L$$

$$\measuredangle Z(j\omega) = \begin{cases} -90^\circ \text{ for } \omega<0 \\ +90^\circ \text{ for } \omega>0 \end{cases}$$



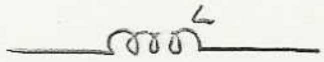
20db/decade slope

log-log scale

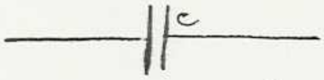


semilog scale

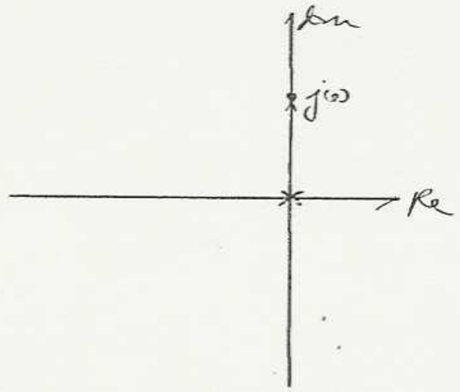
Pole at origin



$$Y = \frac{I}{V} = \frac{1}{Ls}$$



$$Z = \frac{V}{I} = \frac{1}{Cs}$$

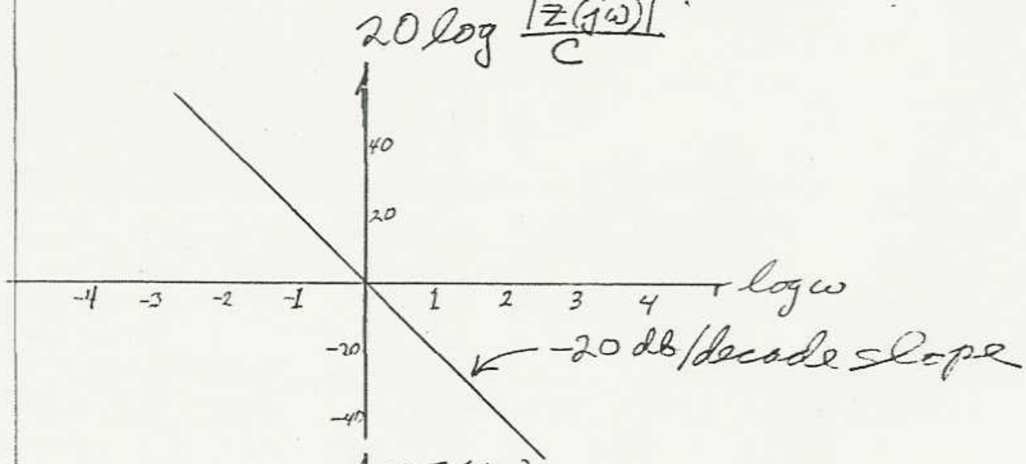


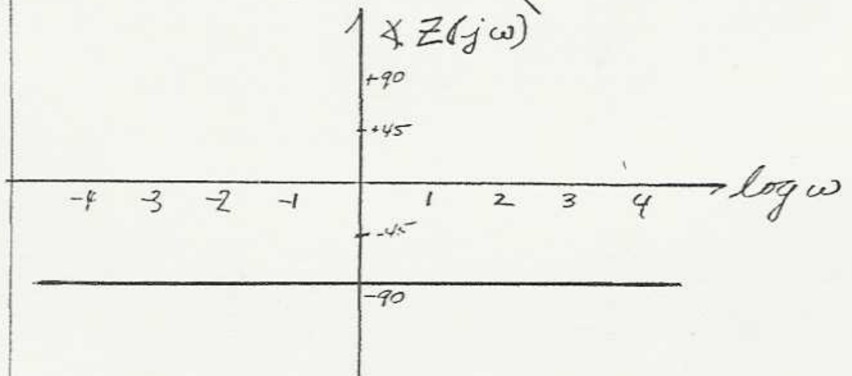
If $Z(s) = \frac{1}{Cs}$

$$|Z(j\omega)| = \frac{1}{C|\omega|}$$

$$\log_{10}|Z(j\omega)| = -\log_{10}|\omega| - \log_{10} C$$

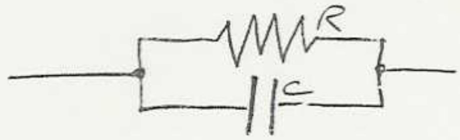
$$\measuredangle Z(j\omega) = \begin{cases} +90^\circ \text{ for } \omega < 0 \\ -90^\circ \text{ for } \omega > 0 \end{cases}$$



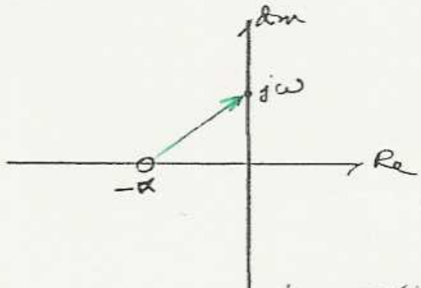


Displaced zero

$$Z = \frac{V}{I} = L\left(s + \frac{R}{L}\right)$$

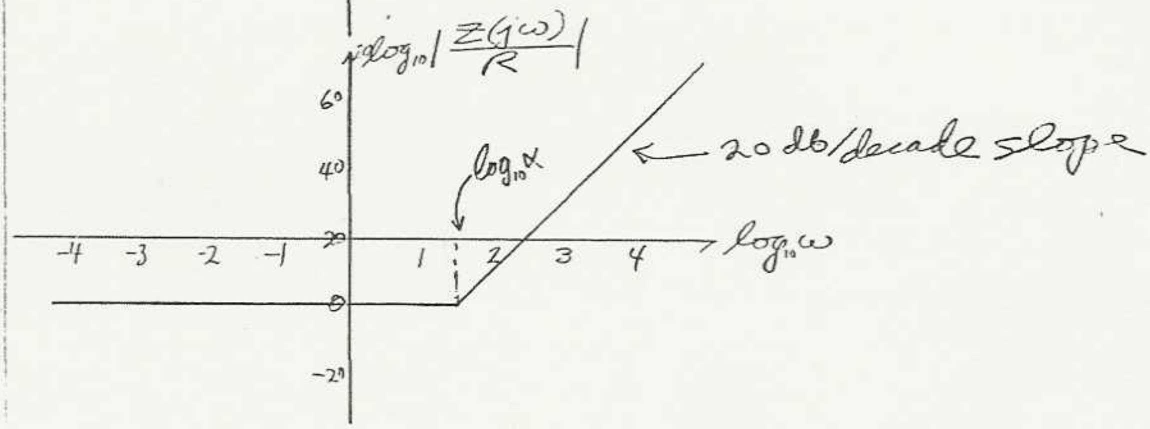


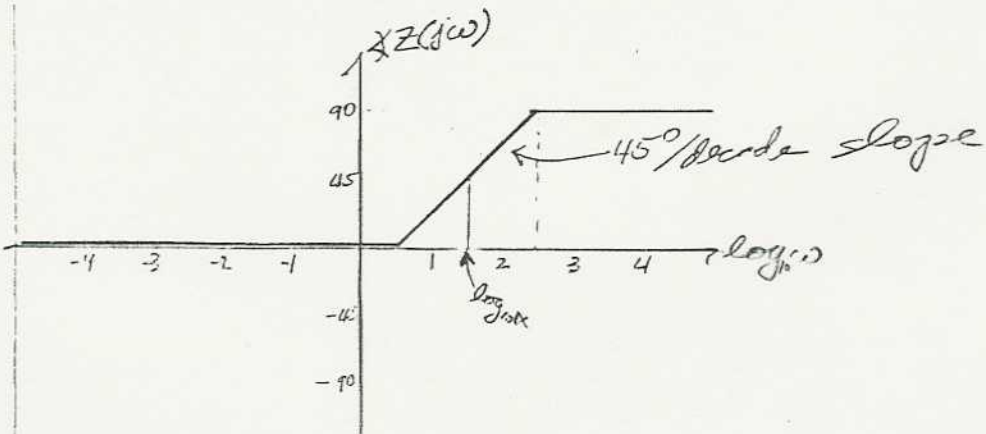
$$Y = \frac{I}{V} = C\left(s + \frac{1}{RC}\right)$$



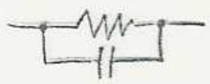
$$Z(j\omega) = L\left(\frac{R}{L} + j\omega\right)$$

$$\alpha = \frac{R}{L}$$

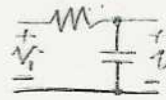




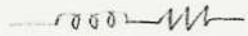
Displaced Pole



$$Z = \frac{1}{C}\left(\frac{1}{s+\frac{1}{RC}}\right)$$

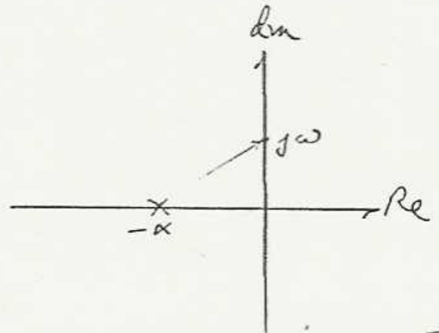


$$\frac{V_2}{V_1} = \frac{1}{RC}\left(\frac{1}{s+\frac{1}{RC}}\right)$$



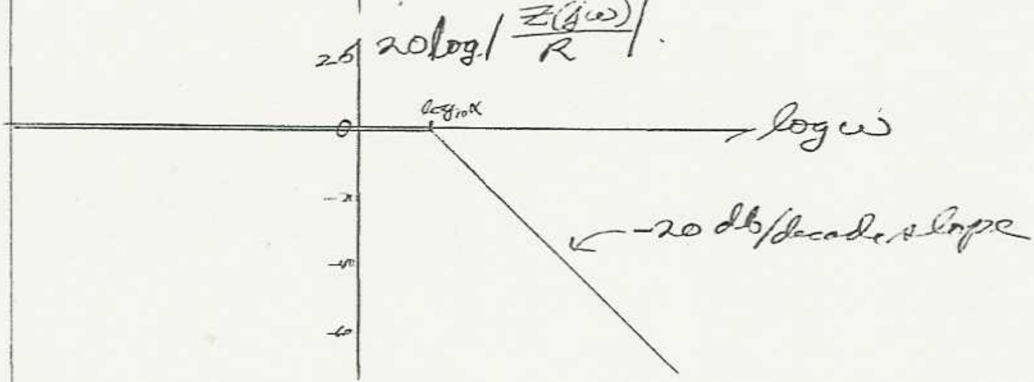
$$Y = \frac{1}{L}\left(\frac{1}{s+\frac{R}{L}}\right)$$

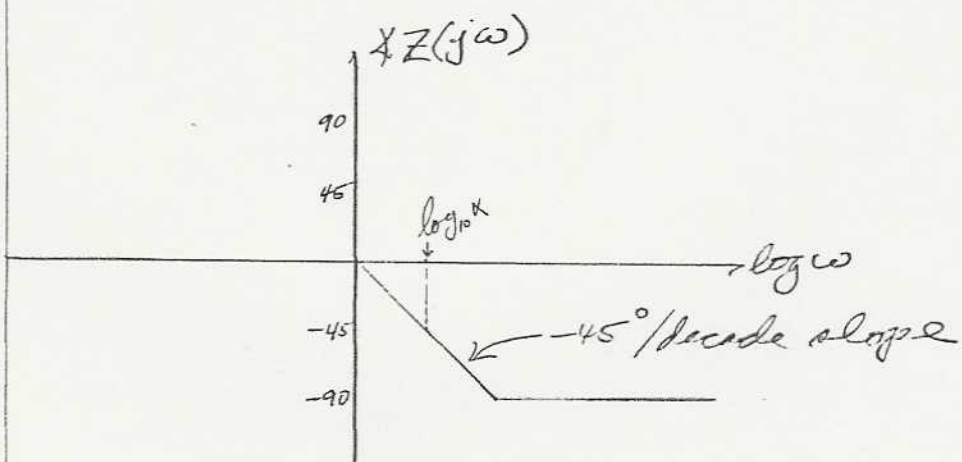
$$\frac{V_2}{V_1} = \frac{R}{L}\left(\frac{1}{s+\frac{R}{L}}\right)$$



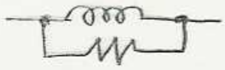
$$Z(j\omega) = \frac{1}{C}\,\frac{1}{j\omega+\frac{1}{RC}}$$

$$\alpha = \frac{1}{RC}$$

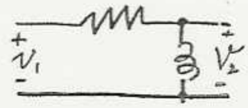




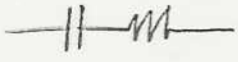
Displaced pole & zero at 0



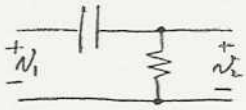
$Z = R\frac{s}{s+R/L}$



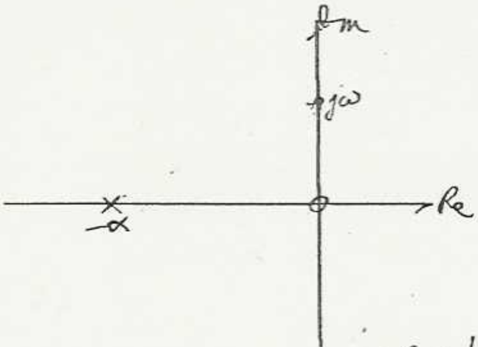
$\frac{V_2}{V_1} = \frac{s}{s+R/L}$



$Y = \frac{1}{R}\frac{s}{s+\frac{1}{RC}}$

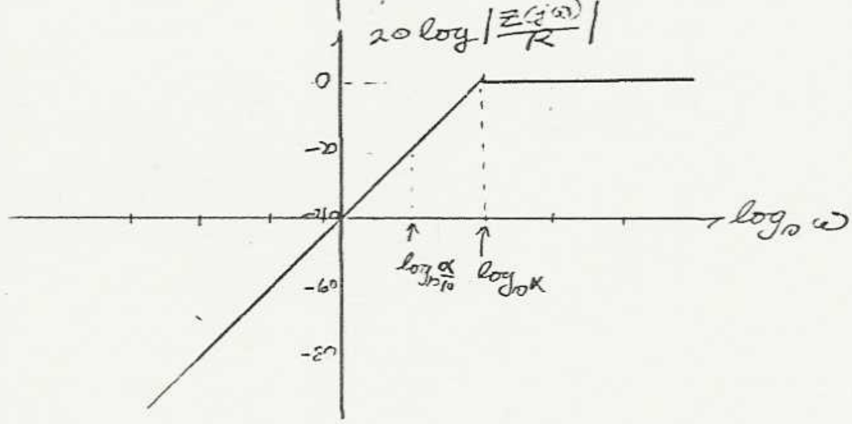


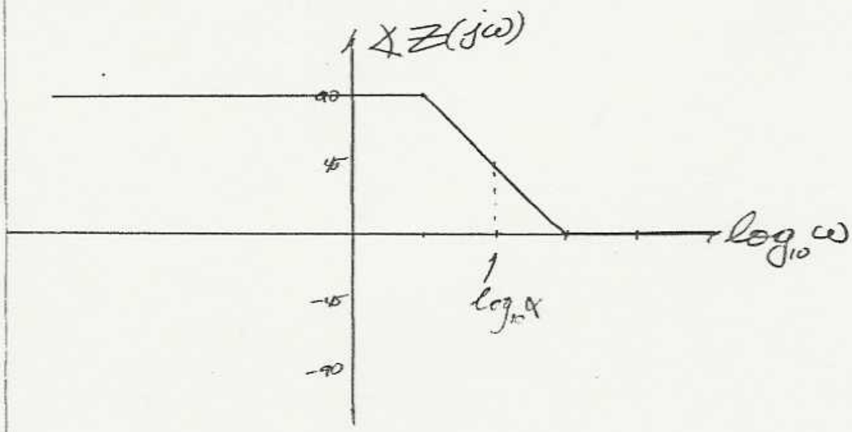
$\frac{V_2}{V_1} = \frac{s}{s+\frac{1}{RC}}$



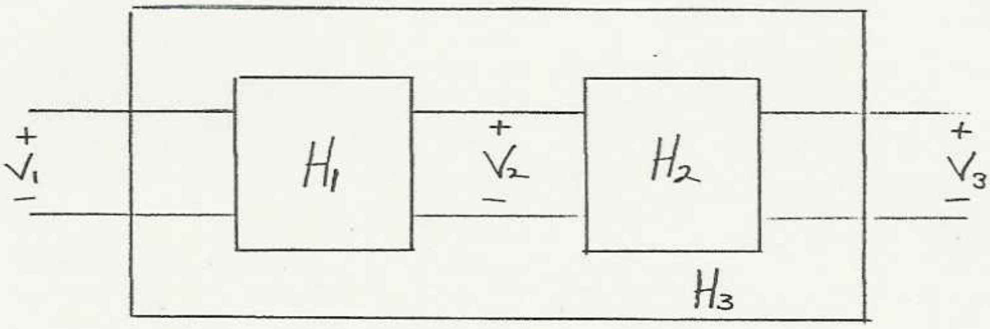
$$Z(j\omega) = R\frac{j\omega}{j\omega + R/L}$$

$$\alpha = \frac{R}{L}$$





CASCADE PLAN



$$H_1 = \frac{V_2}{V_1} \qquad H_2 = \frac{V_3}{V_2}$$

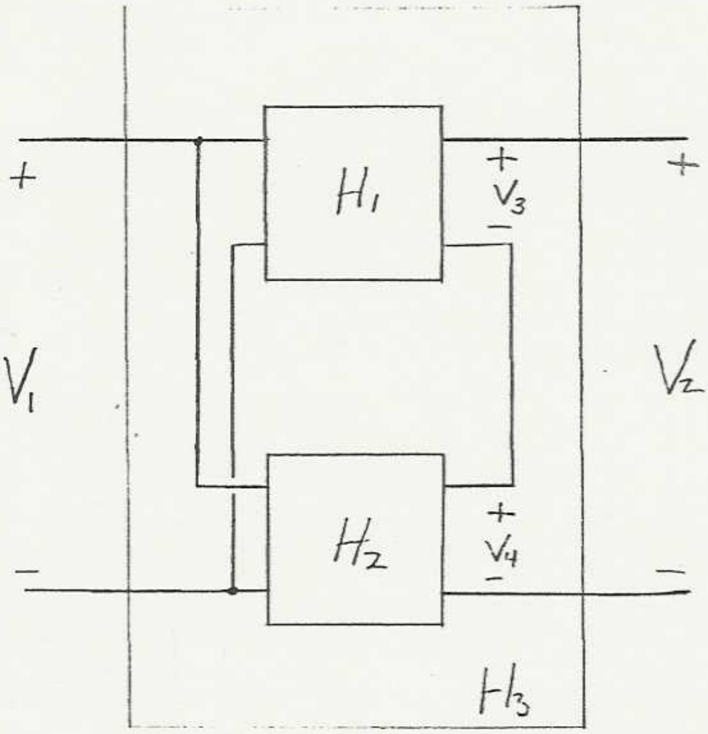
$$H_3 = \frac{V_3}{V_1} = H_1 \cdot H_2$$

When multiplying complex numbers
multiply magnitudes (add logarithms)
add angles

So slopes add in Bode plots!

Note Loading Bug

Parallel-In -- Series-Out Plan



$$H_1 = \frac{V_3}{V_1} \qquad H_2 = \frac{V_4}{V_1}$$

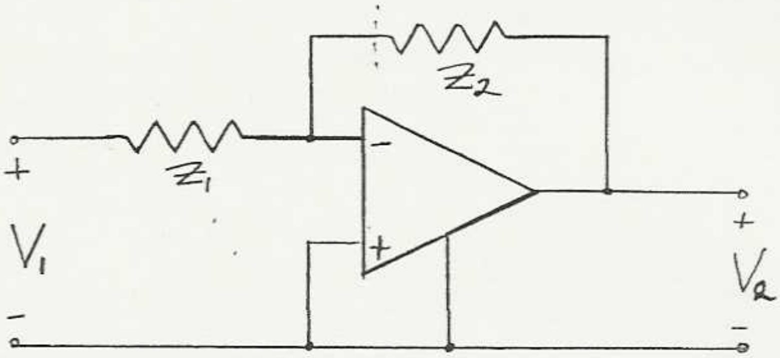
$$V_2 = V_3 + V_4$$

$$\text{so } \frac{V_3 + V_4}{V_1} = H_1 + H_2$$

$$\text{So } H_3 = \frac{V_2}{V_1} = H_1 + H_2$$

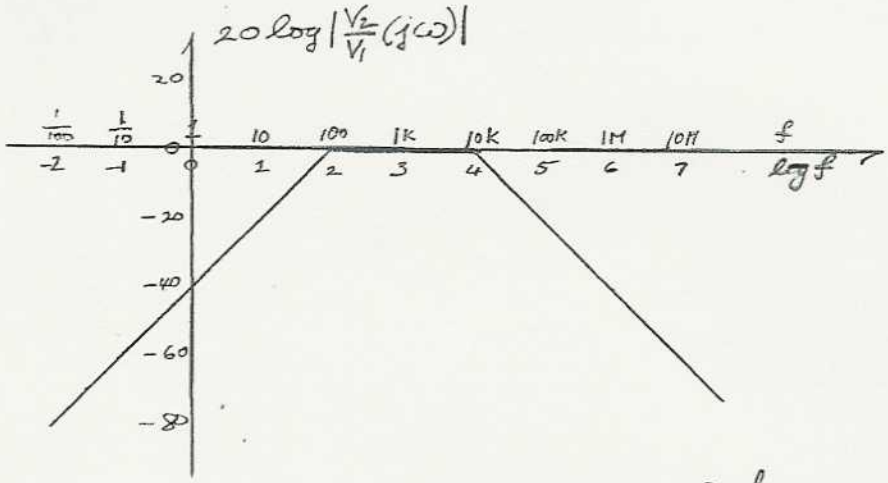
Note Common ground Bug

In general, an impedance or an admittance can be transformed into a voltage-transfer ratio with an op-amp. Even better -- we can form ratios of impedances!

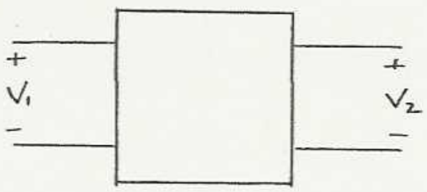


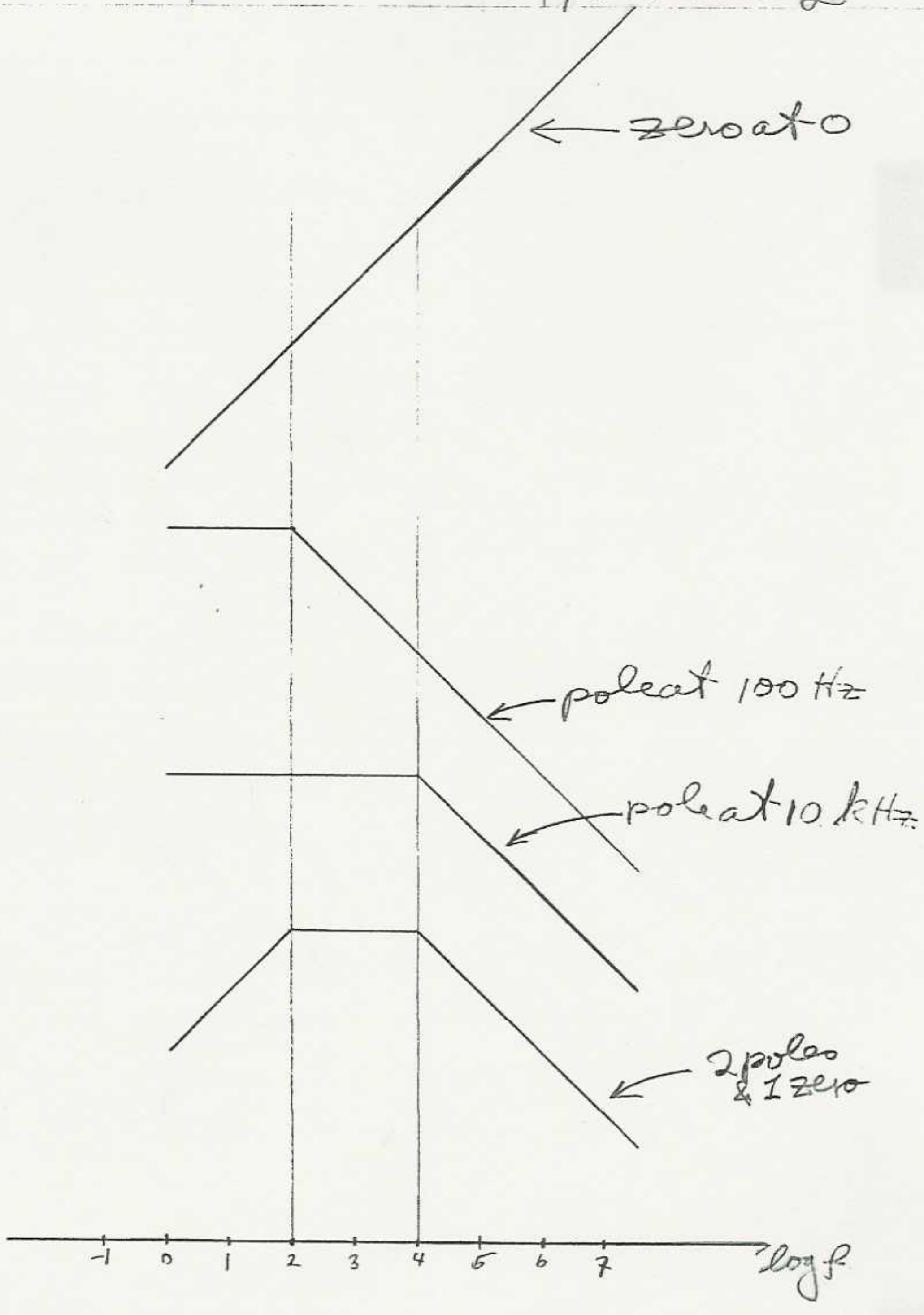
$$\frac{V_2}{V_1} = -\frac{Z_2}{Z_1}$$

Problem: To make a filter with the following characteristic:



Note:
$\omega = 2\pi f$




zero at 0
pole at 100 Hz
pole at 10 kHz
2 poles & 1 zero
-1 0 1 2 3 4 5 6 7
log f

Problem Solving By Debugging Almost-Right Plans

iven a problem to solve

lan:

```
Do I know the answer?

   if so, done.

Can I split the problem into subproblems
 by a known decomposition?

   if so

      Solve each subproblem.

      Construct a putative solution to the
       whole from the solutions of the parts.

      test the composite result:
       does it actually solve the problem?

          if so, done.

          if not

             Describe the difference
              between the behavior obtained
              and the behavior desired.

             Solve a new subproblem:
              Make a modification to our
               putative solution that
               eliminates the difference.

Can I change the representation of the problem?

   if so

      Solve the problem in the new representation.
```

Ideas from programming

Recursion

Subproblems are problems to be solved.
Solutions to subproblems are combined to construct solution to the whole.

Search process

Alternative paths must be considered.
Organization required to prevent considering the same alternative multiple times.

Analysis and Debugging

Must be able to evaluate the consequences of a choice.

Dependencies must be maintained to help with diagnosis of failed paths.

Rule system

Pattern match of rule antecedent to the specification of the problem:

- To determine rule applicability.
- To determine relevant problem-specific values.

Substitution of problem-specific values for variables in rule consequent.

From: Edgar Allen Poe,
The Philosophy of Composition,
1846

. . .

I select ''The Raven'' as most generally known. It is my design to render it manifest that no one point in its composition is referable either to accident or intuition--that the work proceeded step by step, to its completion, with the precision and rigid consequence of a mathematical problem.

. . .