Experiment 2=3

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1 Aim

Study and plot Bode plot of magnitude and phase response for 1-stage, 2-stage, 3-stage RC Low pass filter.

2 Materials and Apparatus Required

1) 3 Reistors (1kΩ used)
2) 3 Capasitors (0.1μF used)
3) Bread Board
4) Function Generator
5) Oscilloscope

3 Theory

The transfter function of a 1-stage RC circuit would be the following,

$$\mathbf{H}(\mathbf{s}) = \frac{1}{1 + sRC}$$

where,

$$s = j\omega$$

expanding, we get,

$$\mathbf{H}(\mathbf{s}) = \frac{1}{\sqrt{1 + (\omega RC)^2}} e^{j\theta}$$

where,

$$\theta = \tan^{-1}(-\omega RC)$$

Applying logarithm on both sides, we get,

$$\begin{aligned}\log \mathbf{H}(\mathbf{s}) &= \log\left(\frac{1}{\sqrt{1 + (\omega RC)^2}} e^{j\tan^{-1}(-\omega RC)}\right) \\ &= -\frac{1}{2}\log\left(1 + (\omega RC)^2\right) + j\tan^{-1}(-\omega RC)\end{aligned}$$

Calculating Amplitude gain,

$$A = 20\log\left(|\mathbf{H}(\mathbf{s})|\right)$$
$$A = -10\log\left(1 + (\omega RC)^2\right)$$

This gives the exact equation for Bode plot of the amplitude gain.
For phase difference,

$$\theta = 20\tan^{-1}\left(-\omega RC\right)$$

Similarly,
The transfer function of 2-stage RC circuit would be,

$$\mathbf{H}(\mathbf{s}) = \left(\frac{1}{1 - (\omega RC)^2 + 3sRC}\right)$$

And following this, we get,

$$\log \mathbf{H}(\mathbf{s}) = -\frac{1}{2}\log\left((1 - (\omega RC)^2)^2 + (3\omega RC)^2\right) + j\tan^{-1}\left(\frac{-3\omega RC}{1 - (\omega RC)^2}\right)$$

And,
The transfer function for 3-state RC circuit is given as,

$$\mathbf{H}(\mathbf{s}) = \left(\frac{1}{(sRC)^3 + 5\,(sRC)^2 + 6sRC + 1}\right)$$

And following that we get,

$$\log \mathbf{H}(\mathbf{s}) = -\frac{1}{2}\log\left(\left(1 - 5\,(\omega RC)^2\right)^2 + \left(6\omega RC - (\omega RC)^3\right)\right) + j\tan^{-1}\left(-\omega RC\,\frac{6 - (\omega RC)^2}{1 - 5\,(\omega RC)^2}\right)$$

4 Procedure

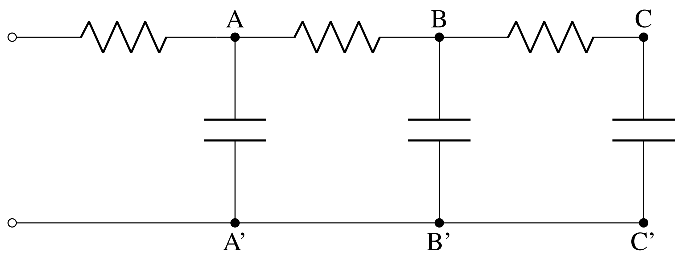

Fig. 1: Circuit Diagram

1) Make connections as given in fig. 1

2) Give input **Vin** in the open end.
3) Measure Voltage across $A-A'$ and Phase difference between input voltage and output voltage for 1 cascade circuit analysis.
4) Record observations for multiple input frequencies.
5) Repeat the experiment for $B - B'$ and $C - C'$ for 2 cascade and 3 cascade circuit analysis respectively.
6) Compare the theoreical caltuations and observed values.

5 Observations

f	V_{out}	Δt
$10Hz$	$5.001V$	$5.6ms$
$100Hz$	$5.001V$	$560\mu s$
$500Hz$	$5.001V$	$300\mu s$
$1000Hz$	$3.201V$	$96\mu s$
$5000Hz$	$1.441V$	$31.2\mu s$
$10kHz$	$880mV$	$18.4\mu s$
$50kHz$	$200mV$	$4.48\mu s$
$100kHz$	$104mV$	$2.2\mu s$
$500kHz$	$30mV$	–
$1MHz$	$16mV$	–

TABLE I: Obsereved 1 Cascade Circuit Response

f	V_{out}	Δt
$10Hz$	$5.001V$	$5.2ms$
$50Hz$	$5.001V$	$520\mu s$
$100Hz$	$5.001V$	$320\mu s$
$500Hz$	$4.401V$	$216\mu s$
$1kHz$	$3.001V$	$184\mu s$
$5kHz$	$580mV$	$68\mu s$
$10kHz$	$184mV$	$40\mu s$
$50kHz$	$16mV$	$10.8\mu s$

TABLE II: Obsereved 2 Cascade Circuit Response

f	V_{out}	Δt
$10Hz$	$4.601V$	$1.6ms$
$50Hz$	$5.001V$	$200\mu s$
$100Hs$	$5.001V$	$220\mu s$
$1kHz$	$3.001V$	$176\mu s$
$5kHz$	$120mV$	–
$10kHz$	$30mV$	–

TABLE III: Observed 3 Cascade Circuit Response

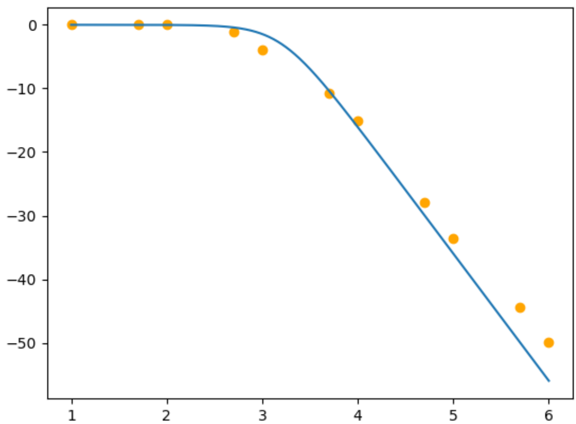

Fig. 2: Amplitude graph for 1 cascase response

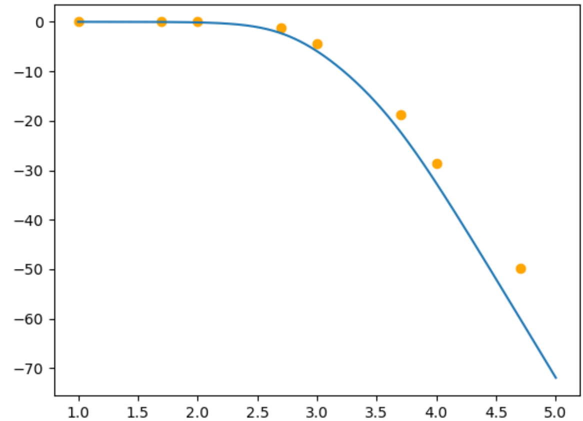

Fig. 3: Amplitude graph for 2 cascase response

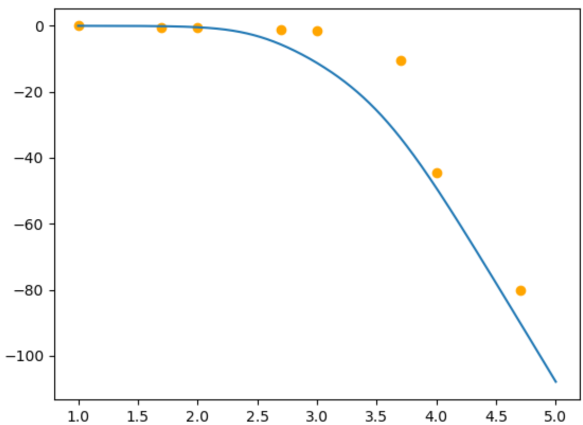

Fig. 4: Amplitude graph for 3 cascase response

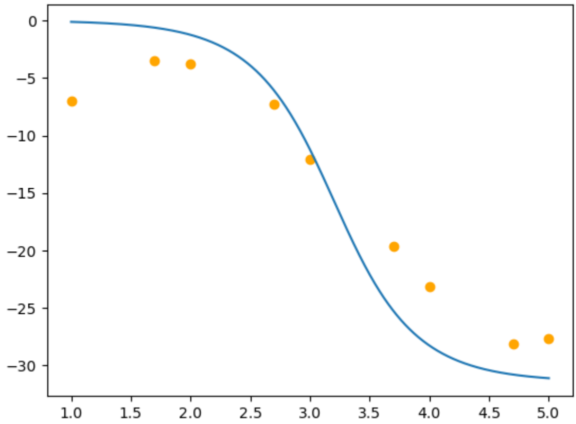

Fig. 5: Phase graph for 1 cascase response

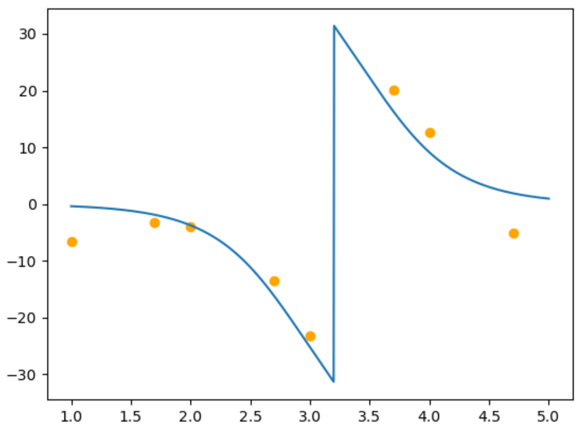

Fig. 6: Phase graph for 2 cascase response

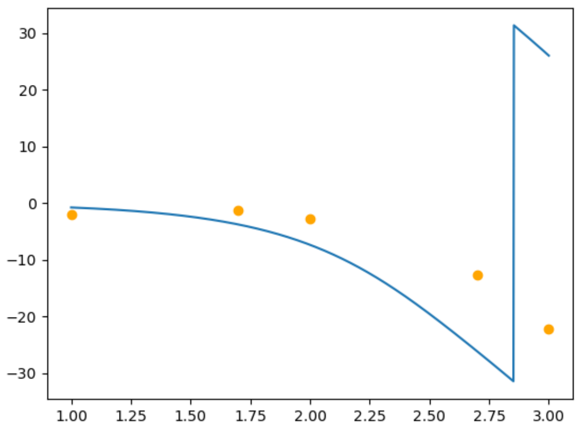

Fig. 7: Phase graph for 2 cascase response