Name: *Roll Number:*

A: /3	**B** : /6	**C**: /6	**Tot:** /15

Laboratory 3
Negative Feedback in Opamp applications

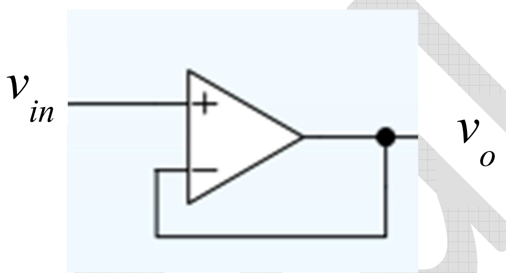
Introduction

We will see today how to employ negative feedback to control the gain of an opamp working in amplification mode. In the Lab 2 exercise of building a Schmitt trigger, the opamp was working in switching mode: V_o switches alternately between positive and negative saturation. Now we would like to use it as a linear amplifying device with output $v_o = G \cdot v_{in}$ where G is a value set by the designer. Note that G is different from the *intrinsic open-loop gain A* of the amplifier. $A \sim 10^6$ is a characteristic of the device that you cannot change. We will build circuit connections around the opamp to make it a linear amplifier with gain G.

Part A: Simple Negative Feedback

Consider the circuit shown in Fig 1. It implements a simple negative feedback loop. Feedback is negative when some fraction of the output is *subtracted* from the input.

Fig 1: Basic negative feedback



Using Kirchoff's laws, obtain the relation between v_o and v_{in} and hence the gain G of this circuit.

G = 1

/1 mk

Warmup: Setup the circuit of Fig 1 your breadboard to make sure that your basic circuit is working. Use v_{in} as a sine wave of frequency 1 kHz and suitable amplitude. Note carefully where you connect $+V_{cc}$, $-V_{cc}$,0V and v_{in} ,v_o connections. Earth ground is typically *not* used in opamp circuits.

1. Demonstrate v_{out} and v_{in} on the DSO as two time traces.
2. Measure the phase difference (if any) between v_o & v_{in}. Figure out a simple method of measuring the phase difference since you will be making many phase measurements in the next part of the lab.
   Let's call the phase difference $\Delta\varphi$. Measured $\Delta\varphi$ = (in degrees)

Basic demo of working circuit – cut marks for wrong ckt connections (1 mk)

Use X-Y mode : lissajous figure angle(v_o/v_{in}) gives $\Delta\varphi$ (1 mk)

/2 mks

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Part B: Negative Feedback with gain G

We would like to modify the circuit of Fig 1 to have a gain *G=10*. Draw here the circuit diagram of a negative feedback circuit you would design to set *G=10*.

Standard R_2/R_1 : $G= (1+R_2/R_1)$: choose reasonable values of R_1 R_2 in kΩ range

Hint:As discussed in lecture, this is a linear circuit and requires adding just two passive components to the circuit of Fig 1

Q1: What is the input impedance of your *G=10* circuit? (calculated)

You can try measuring the DC value of the input impedance (i.e. resistance) using the DMM

infinity (or very large)

/0.5 mk

Q2: As in Part A, setup your circuit on the breadboard. Use v_{in} as a sine wave of frequency 1kHz.

A: Demonstrate the time traces of v_{in} and v_{out} .Note that *G=10* and the maximum allowed $v_o=\pm V_{max}$ places restrictions on the amplitude of v_{in}

/0.5 mk

Basic demo of working circuit – cut marks for wrong ckt connections

B: Running the circuit with $V_{cc}=\pm 12V$ and *G=10,* what is the maximum v_{in} the circuit can *theoretically linearly* amplify without hitting the saturation limits $v_o=\pm V_{max}$?

$v_{in|max}$ = __________

Set your v_{in} *at 0.1* × $v_{in|max}$

/0.5 mk

$v_{in|max}$ = 1V – work with 100 mV

C: Measure the phase difference $\Delta\varphi$=_________ degrees for v_{in} amplitude at $0.1 \times v_{in|max}$

$\Delta\varphi$= 0

/0.5 mk

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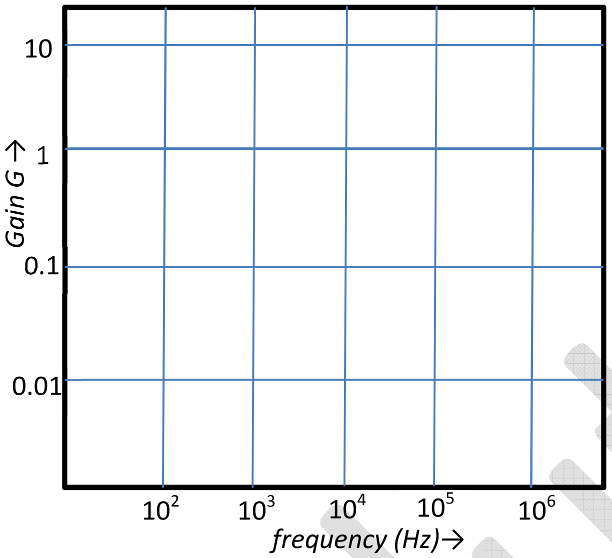
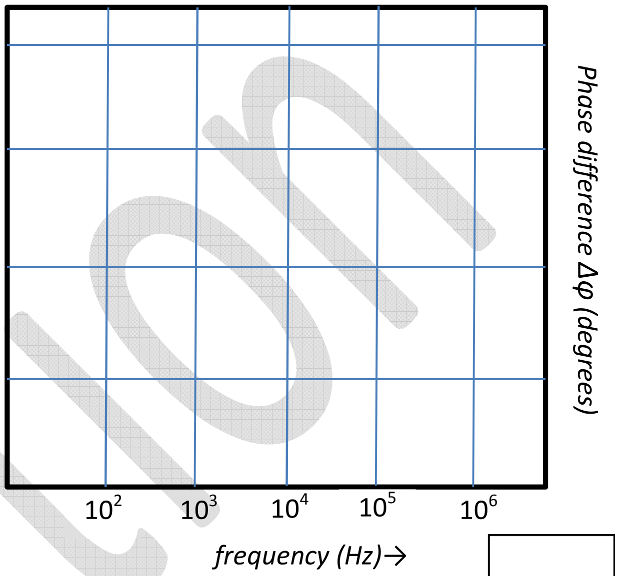
Q3: Measure how the gain and phase difference change as you increase the frequency of v_{in} You may mark your observations on the following plot. Note that the x axis on both plots is logarithmic. The values for y axis on the gain plot are already marked. Label the y axis values on the phase difference $\Delta\varphi$ plot as per your measurements.

A): Measure gain and $\Delta\varphi$ at frequencies 100 Hz, 1kHz, 10 kHz, 100 kHz and 1 MHz. Keep v_{in} amplitude set at one tenth of $v_{in|max}$





/2 mks

G=10 till 10^4 then drops at ~ 20 dB/decade; unity gain G=1 at ~ 10^5

$\Delta\varphi$=0 till pole at 10^3. Reaches ~ -45 deg by unity gain ~ 10^5 and ~ -90 deg by 10^6 Hz

B) For one low frequency v_{in} where G=10 (eg. 1 kHz) increase v_{in} to $v_{in|max}$.

You would expect to see linear amplification with G=10 since v_o would be within the limits of $\pm V_{max}$

Draw a sketch of your observations here indicating the amplitudes and signal shapes.

Provide an explanation of your observation here: sine wave is 'stretched out'

For v_{in} ~ 1V, slew rate of opamp causes distortion = 2 mks

Note: this has nothing to do with saturation because output is still within $\pm V_{max}$

/2 mks

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Part C: Load Test to be performed at reduced $v_{in} = 0.1\times v_{in|max}$

As discussed in the lecture, we have built a *Voltage Controlled Voltage Source (VCVS)*. An ideal voltage source provides voltage to the load irrespective of the value of load resistance. We will test the limits of 'ideal' behavior of our negative feedback circuit.

So far you have been using the DSO probe directly at the output of the LM741. The DSO probe has very large impedance .

Connect the following values of R_L between v_o and 0V. Make a sketch of $v_o(t)$ for each, noting the amplitudes:

1. $R_L = 1000\ \Omega$

2. $R_L = 100\ \Omega$

3. $R_L = 50\ \Omega$

/2.5 mks

4. $R_L = 25\ \Omega$ *(eg.* $50\ \Omega \,||\, 50\ \Omega$*)*

   at $R_L \sim 30\Omega$ v_o *refuses to go above ~ 0.2V*

Look up the LM741 datasheet on your desktop PC – it specifies the short circuit output current for the opamp. This is the maximum current the opamp can supply when $R_L = 0\ \Omega$
With this information explain your observations 1,2,3,4 above.
$v_o = G \times v_{in}$ and our v_{in} *is set at less than* $v_{in|max}$ so in principle we expect v_o to swing linearly in the full range up to $\pm V_{max}$. If this is not the case, provide a quantitative explanation for any deviation observed from the expectation.

/3.5 mks

$v_o = i_{max} * R_L$ — *1.5 mk*
$i_{max} \sim 25$ mA so $R_L \sim 10\Omega \rightarrow v_o|_{max} \sim 250$mV or 0.25 V — *1 mk (datasheet lookup)*
for DSO probe $R_L \sim$ infinite so $v_o|_{max} \sim$ infinity (limited by $\pm V_{max}$) — *1 mk*