**Laboratory 3  
Negative Feedback in Opamp applications**

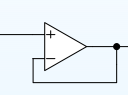
**A**: /3 **B** : /6 **C**: /6 **Tot:** /15

**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: *Vo* switches alternately between positive and negative saturation. Now we would like to use it as a linear amplifying device with output *vo= G∙vin* 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~106 is a characteristic of the devicethat 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.



*vo*

*vin*

Fig 1: Basic negative feedback

/2 mks

/1 mk

Using Kirchoff’s laws, obtain the relation between *vo* and *vin* and hence the gain *G* of this circuit.

G = 1

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

1. Demonstrate *vout* and *vin* on the DSO as two time traces.
2. Measure the phase difference (if any) between *vo* & *vin*. 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 *Δφ.* Measured *Δφ* = (in degrees)

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

Use X-Y mode : lissajous figure angle(vo/vin) gives *Δφ* (1 mk)

**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 R2/R1 : G= (1+R2/R1) : choose reasonable values of R1 R2 ­ 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

/0.5 mk

/0.5 mk

/0.5 mk

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

A: Demonstrate the time traces of *vin* and *vout* .Note that *G=10* and the maximum allowed *v*o=±*Vmax* places restrictions on the amplitude of *vin*

Basic demo of working circuit – cut marks for wrong ckt connections  
B: Running the circuit with *Vcc=±12V* and *G=10,* what is the maximum *vin* the circuit can *theoretically linearly* amplify without hitting the saturation limits *v*o=±*Vmax*?  
*vin*|*max =*\_\_\_\_\_\_\_\_\_   
Set your *vin at 0.1* × *vin*|*max*

*vin*|*max =* 1V – work with 100 mV

C: Measure the phase difference *Δφ*=\_\_\_\_\_\_\_\_\_ degrees for *vin* amplitude at 0.1×*vin*|*max*

*Δφ*= 0

**Q3:** Measure how the gain and phase differencechange as you increase the frequency of *vin* 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 *Δφ* plot as per your measurements.  
  
A): Measure gain and *Δφ* at frequencies 100 Hz, 1kHz, 10 kHz, 100 kHz and 1 MHz. Keep *vin* amplitude set at one tenth of *vin*|*max*

102

103

104

105

106

*frequency (Hz)→*

*(Hz)→*

*Phase difference Δφ (degrees) →*

0.01

0.1

1

10

102

103

104

105

106

*frequency (Hz)→*

*Gain G →*

/2 mks

/2 mks

G=10 till 104 then drops at ~ 20 dB/decade; unity gain G=1 at ~ 105  
  
*Δφ*=0 till pole at 103. Reaches ~ -45 deg by unity gain ~ 105 and ~ -90 deg by 106 Hz

B) For one low frequency *vin* where G=10 (eg. 1 kHz) increase *vin*  to *vin*|*max* .   
 You would expect to see linear amplification with G=10 since *vo* would be within the limits of ±*Vmax* 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 vin ~ 1V, slew rate of opamp causes distortion = 2 mks*

*Note: this has nothing to do with saturation because output is still within ±Vmax*

**Part C: Load Test** to be performed at reduced *vin = 0.1× vin*|*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 *RL* between *vo* and 0V. Make a sketch of *vo(t)* for each, noting the amplitudes:

1. *RL = 1000 Ω*
2. *RL = 100 Ω*
3. *RL = 50 Ω*

/3.5 mks

/2.5 mks

1. *RL = 25 Ω (eg. 50 Ω* || *50 Ω)*at *RL ~ 30Ωvo 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 *RL = 0 Ω*With this information explain your observations 1,2,3,4 above.   
*vo = G × vin* and our *vin is set at less than vin*|*max*  so in principle we expect *vo* to swing linearly in the full range up to ±*Vmax*. If this is not the case, provide a quantitative explanation for any deviation observed from the expectation. *vo = imax \* RL 1.5 mkimax ~ 25 mA so RL ~ 10Ω →vo*|*max ~ 250mV or 0.25 V 1 mk (datasheet lookup)  
for DSO probe RL ~ infinite so vo*|*max ~ infinity (limited by ±Vmax) 1 mk*