Comparison Between Experimental and Analytical Operational Amplifier in a Closed Loop Configuration Models

by

Kevin Moran

Lab Partner : Jorge
Date of Experiment : Thursday, October 14th, 2020

University of Southern California
Aerospace and Mechanical Engineering Department
AME 341A : Mechoptronics

1 Introduction

Operational Amplifiers, often referred to as *op-amps*, are a vital part of data acquisition circuits and circuits that rely on threshold voltage inputs to activate additional components. As the name suggest, om-amps serve as voltage amplifiers and can be setup in various configurations using passive circuit elements such as resistors and capacitors. Figure 1 illustrates a LM741 op-amp in a negative feedback loop configuration.

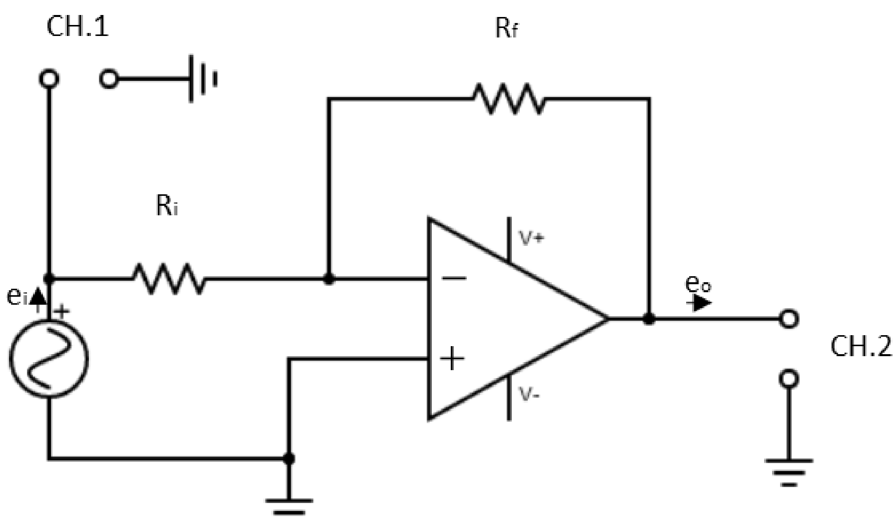

Figure 1: LM741 operation amplifier negative feedback loop schematic. All components of the circuit are grounded using a common ground. CH1 and CH2 represent probe connection on Vbench Interface.

In an open loop configuration, the output voltage often reaches saturation and may not provide useful results in many data acquisitions applications. A negative feedback loop, however, allows for greater control over amplification characteristics. Alternatively referred to as *gain*, the relationship between input and output voltages can be expressed as :

$$e_o = -Ge_i = -\frac{R_f}{R_i}e_i \qquad \text{(Eq. 1)}$$

G refers to the a property known as gain and R_f and R_i correspond to resistors shown in Figure 1. The negative sign is a consequence of the input voltage, e_i, feeding input the inverting channel on the op-amp.

2 Methods and Materials

This is where you write the methods and materials section

3 Results

This is where you show your results and key values

A MATLAB Script

```
clear;clc;close all
format short
%% Import and Label Data for each setup
Ri1 =  19649;
Rf1 = 196960;
G1 = Rf1/Ri1;
dG1 = G1 * sqrt( (Rf1*.01/Rf1)^2 + (Ri1*.01/Ri1)^2 );
dataSetup1 = xlsread('RawData.xlsx','Setup1');
f1 = dataSetup1(:,1);
ch1vdiv1 = dataSetup1(:,2);
dei1 = dataSetup1(:,3);
ei1 = dataSetup1(:,4);
ch2vdiv1 = dataSetup1(:,5);
deo1 = dataSetup1(:,6);
eo1 = dataSetup1(:,7);
H1 = dataSetup1(:,8);
dH1 = H1 .* sqrt( (deo1./eo1).^2 + (dei1./ei1).^2 );

Ri2 =  1958;
Rf2 = 196960;
G2 = Rf2/Ri2;
dG2 = G2 * sqrt( (Rf2*.01/Rf2)^2 + (Ri2*.01/Ri2)^2 );
dataSetup2 = xlsread('RawData.xlsx','Setup2');
f2 = dataSetup2(:,1);
ch1vdiv2 = dataSetup2(:,2);
dei2 = dataSetup2(:,3);
ei2 = dataSetup2(:,4);
ch2vdiv2 = dataSetup2(:,5);
deo2 = dataSetup2(:,6);
eo2 = dataSetup2(:,7);
H2 = dataSetup2(:,8);
dH2 = H2 .* sqrt( (deo2./eo2).^2 + (dei2./ei2).^2 );

%% Determine Cutoff Frequency and Uncertainty
i = 1;
while H1(i) >= G1*.707
    i=i+1;
end
f01  = .5 * ( f1(i) + f1(i+1) );
df01 = .5 * abs( f1(i) - f1(i+1) );

i = 1;
```

```
while H2(i) >= G2*.707
    i=i+1;
end
f02  = .5 * ( f2(i) + f2(i+1) );
df02 = .5 * abs( f2(i) - f2(i+1) );
%% Build Analytical Model.
% k represents the constant associated with the Op-Amp A/(2*pi*mu)
k1 = f01*G1;
k2 = f02*G2;
dk1 = k1 * sqrt( (df01/f01)^2 + (dG1/G1)^2 );
dk2 = k2 * sqrt( (df02/f02)^2 + (dG2/G2)^2 );
f_theo = [100:100:1000000]';
H_theo1 = G1 ./ sqrt( 1 + (f_theo/k1*G1).^2 );
H_theo2 = G2 ./ sqrt( 1 + (f_theo/k2*G2).^2 );
%% Plot
figure(1)
set(gca,'xscale','log','yscale','log','defaulttextinterpreter','Latex')
ylim([0 110])
hold on
scatter(f1,H1,'o','MarkerFaceColor','b')
errorbar(f1,H1,dH1,'vertical','LineStyle','none')
plot(f_theo,H_theo1,'k','LineWidth',1.5)
xlabel('$f [Hz]$','FontSize',12)
ylabel('$|H|$','FontSize',12)

figure(2)
set(gca,'xscale','log','yscale','log','defaulttextinterpreter','Latex')
ylim([0 110])
hold on
scatter(f2,H2,'o','MarkerFaceColor','b')
errorbar(f2,H2,dH2,'vertical','LineStyle','none')
plot(f_theo,H_theo2,'k','LineWidth',1.5)
xlabel('$f [Hz]$','FontSize',12)
ylabel('$|H|$','FontSize',12)
```