Technical University of Cluj-Napoca

Faculty of Electronics, Telecommunications and Information Technology

AMPLIFIERS WITH OP-AMP

DOCUMENTATION

COMPUTER AIDED GRAPHICS

SEMESTRIAL PROJECT

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1.Introduction

Short description of MATLAB

MATLAB is a software package for high-performance mathematical computation, visualization, and programming environment. It provides an interactive environment with hundreds of built-in functions for technical computing, graphics, and animations.

MATLAB stands for **Matrix Laboratory**. MATLAB was written initially to implement a simple approach to matrix software developed by the **LINPACK** (Linear system package) and **EISPACK** (Eigen system package) projects. It is **Multi-paradigm**, so it can work with multiple types of programming approaches, such as Functional, ObjectOriented, and Visual.

As its name contains the word Matrix, MATLAB does its' all computing based on mathematical matrices and arrays. MATLAB's all types of variables hold data in the form of the array only, let it be an integer type, character type or String type variable.

The development of the MATLAB started in the late 1970s by Cleve Moler, the chairman of the Computer Science department at the University of New Mexico. Cleve wanted to make his students able to use LINPACK & EISPACK (software libraries for numerical computing, written in FORTRAN), and without learning FORTRAN. In 1984, Cleve Moler with Jack Little & Steve Bangert rewrote MATLAB in C and founded MathWorks. These libraries were known as JACKPAC at that time, later these were revised in 2000 for matrix manipulation and named as LAPACK.

Short description of Amplifiers with Op-Amp and its components

The two major classifications of amplifiers with op-amp are the inverting and noninverting amplifiers. The crucial difference them is that an inverting amplifier is the one that produces an amplified output signal which is out of phase to the applied input. As against, a non-inverting amplifier amplifies the input signal level without changing the phase of the signal at the output.

What is an Op-Amp?

Operational amplifiers are considered as the fundamental component of analog electronic circuits. They are linear devices, used for the amplification of the DC signal. Thus, they're used in signal conditioning, filtering, and performing operations like addition, subtraction, integration, etc. The various components like resistor, capacitor, etc. present between the input and output terminals of the amplifier are used for amplifying the voltage level of the applied signal.

They are **three-terminal devices** that have two inputs and one output terminal. Out of the two input terminals, one is an inverting terminal while the other is noninverting.

2.Theoretical presentation

Non-inverting and inverting amplifiers are circuits built using operational amplifiers. The circuit has to be connected to a dual voltage source, $+V_{PS}$ and $-V_{PS}$, that limits the amplification to the corresponding values, V_{OH} and V_{OL}. They both have negative feedback, due to a negative feedback loop (NF), that keeps the differential voltage, $v_D = v_+ - v_-$, equal to 0.

NON-INVERTING AMPLIFIERS

Non-inverting amplifiers are called "non-inverting", as v_i is connected to the v_+ terminal of the op-amp.

They amplify the input signal, v_i with a certain gain, A_V, that depends on the values of the resistances and v_i. The output signal, consequently, will be either equal to, or A_V times bigger or smaller than v_i, but it cannot pass $+/-V_{PS}$. When v_o is smaller, the amplifier is used as an attenuator, and $A_V < 1$.

Due to the fact that it is non-inverting, the two signals v_i and v_o will be in phase.

INVERTING AMPLIFIERS

Inverting amplifiers are called “inverting", as v_i is connected to the $v-$ terminal of the op-amp.

They work just like non-inverting amplifiers, but the 2 signals, v_i and v_o, will be in anti-phase.

The formula for computing the gain:

$$A_V = v_o / v_i$$

The formula for computing the period:

$$T = \frac{1}{f}$$

$$x_o = X_o * \sin(2 * \pi * f * t)$$

The formula for composing the signals:

3.Experimental part

The algorithm for computing the gain works successfully. The two functions created for computing the gain of the non-inverting and inverting amplifiers are able to:

- Compute the period of the circuit (T) using a given frequency (f)
- Compose a signal with a given amplitude (X_o), a given frequency (f) and t, which grows from 0 to N*T, in steps of T/100, N being the displayed number of cycles
- Verify using a function ○ for NON-INVERTING: if one of the signals is >0 and one is <0, which is required for the computation of the gain to be correct
    - ○ for INVERTING: if both signals are >0 or <0, which is required for the computation of the gain to be correct
- Have modifiable values, using edit boxes
- Change the plots on "Enter" when the values are modified, using a button and a function

An example I used to verify the algorithm :

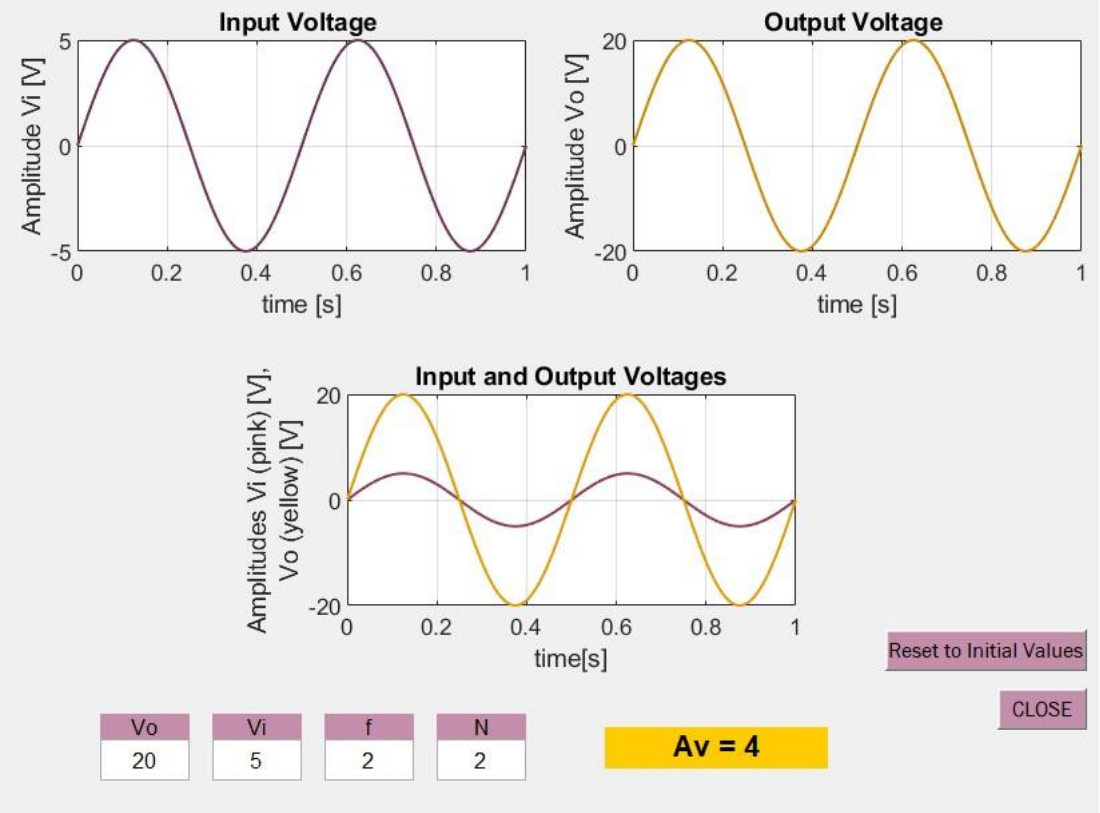
v_i=5V

v_o=20V

F=2KHz

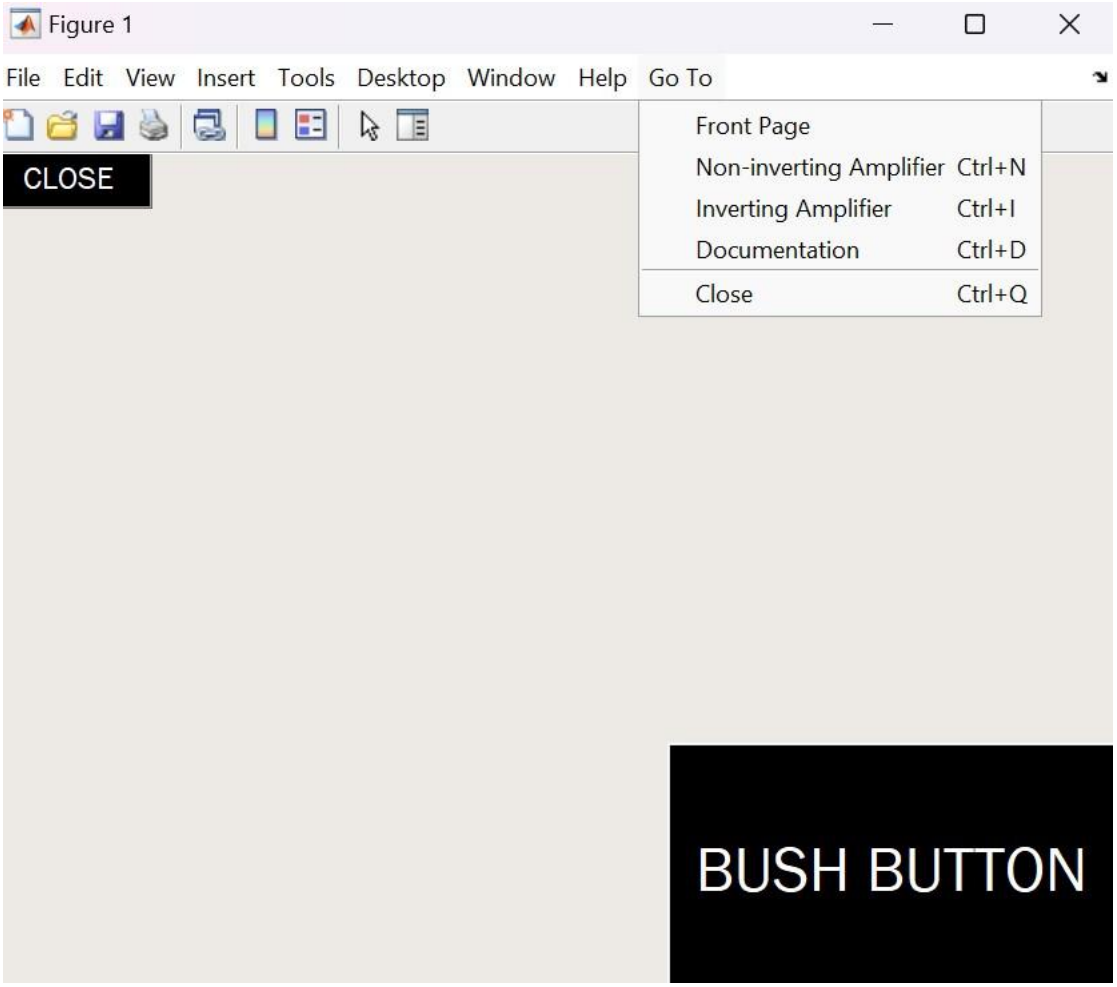
N=2

- The result is correct: A_V=4 (20/4=5)
- The number of cycles displayed is correct: 2 (N=2)
  - The reset button works as intended.
- The values are modifiable and, in turn, they also modify the plots.



4.GUI elements

The main page, “GoToMenu”, includes some parts of the project. The added menu “Go To” has 3 submenus. All the “CLOSE” buttons work, as well as the “Close” submenu as expected (they close the windows).



The “Front Page” submenu takes you to the webpage created by me using html and CSS.

Semester Project

Computer Aided Graphics
Theme: Amplifiers with Op-Amps

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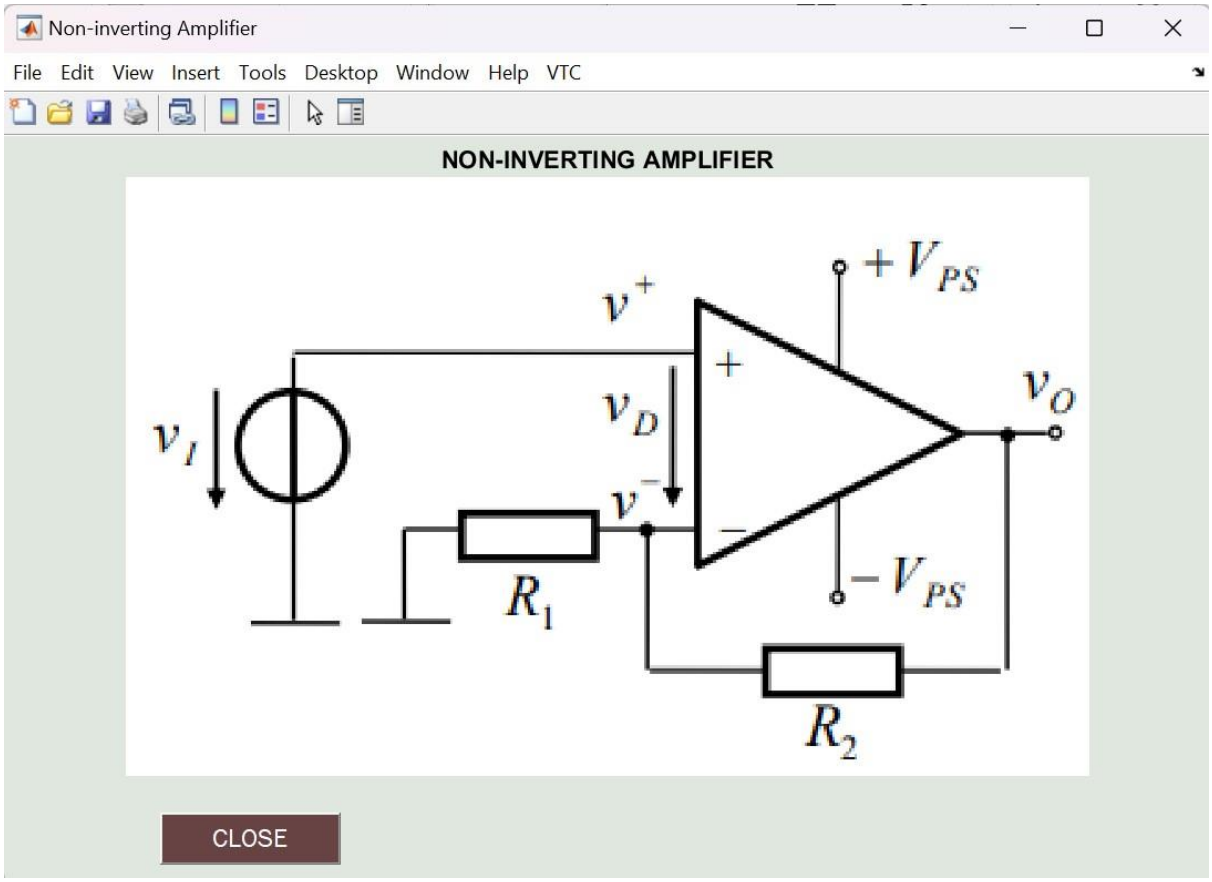
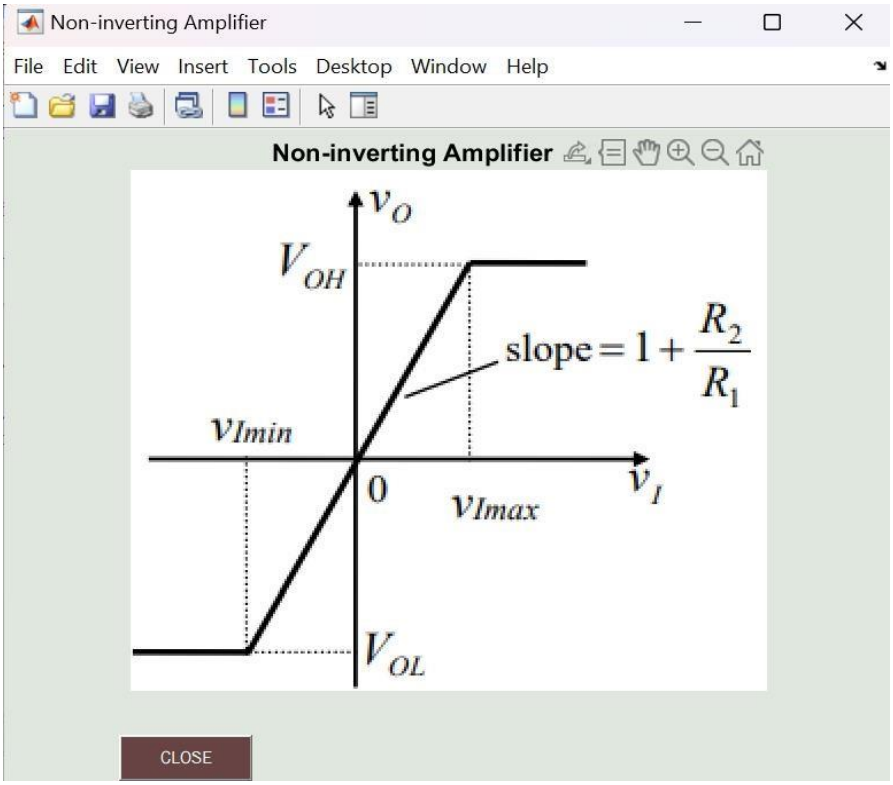
Cluj-Napoca, 2024

Student
Anca-Valentina RADU

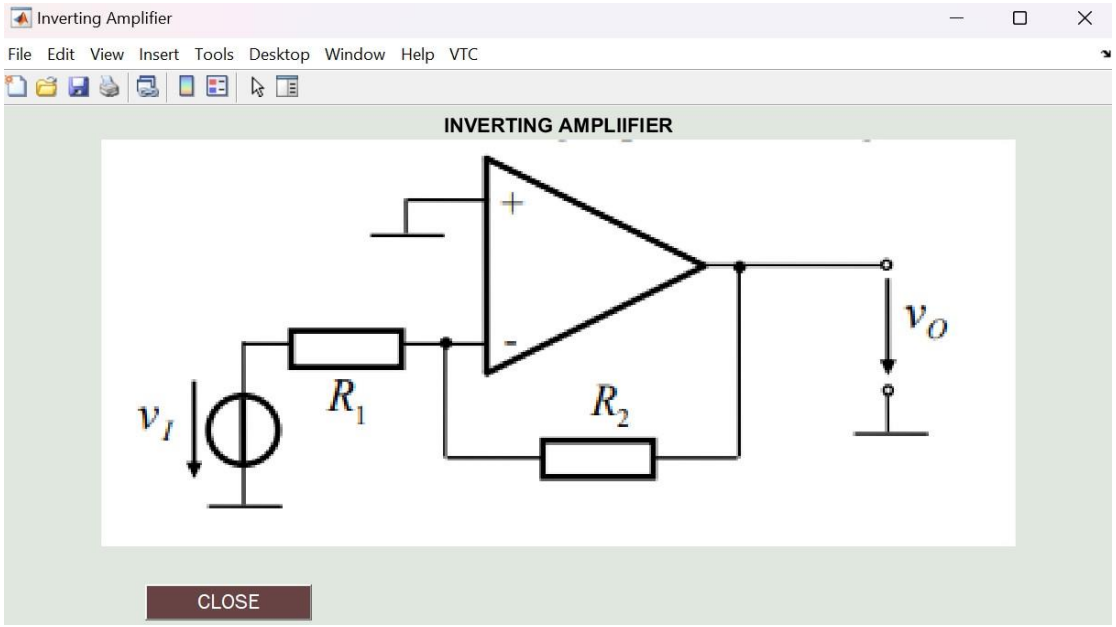
The “Non-inverting Amplifier” submenu takes you to a figure showing a picture of the corresponding circuit.



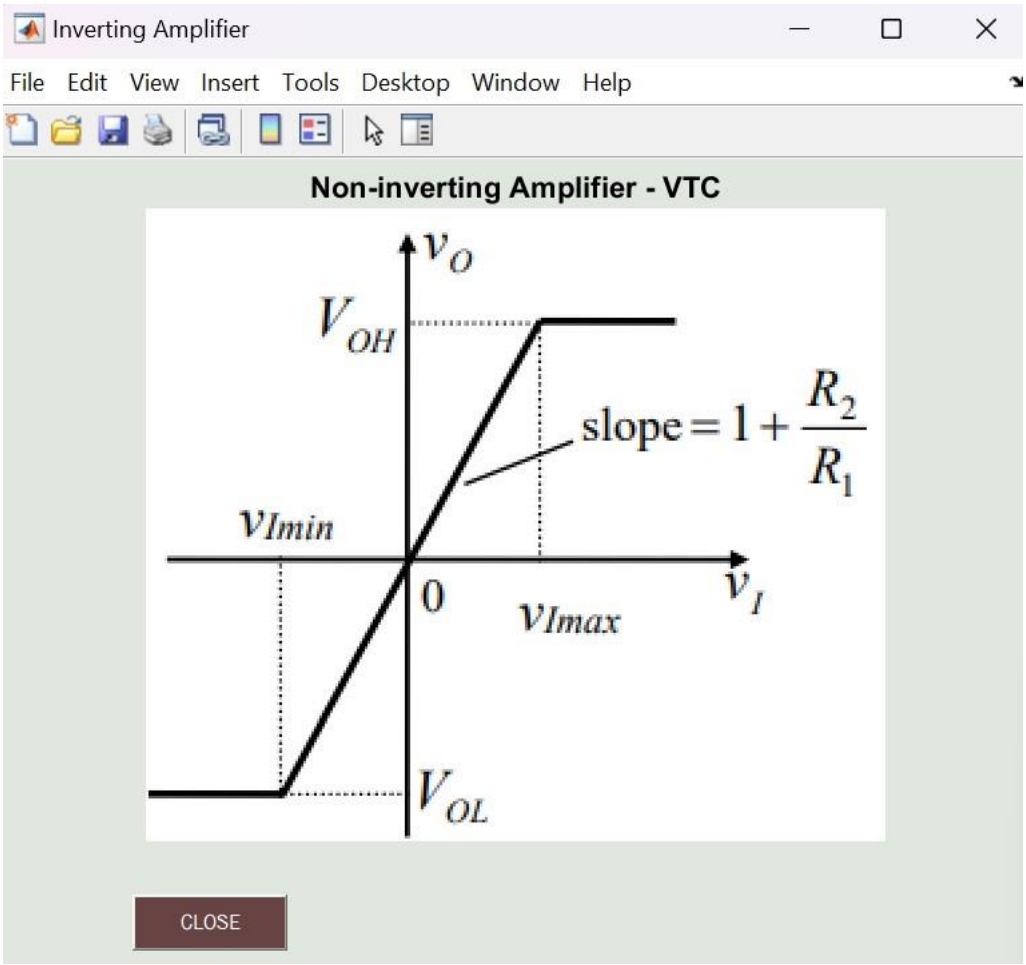
The “VTC” menu takes you to a figure showing a picture of the corresponding circuit' VTC.



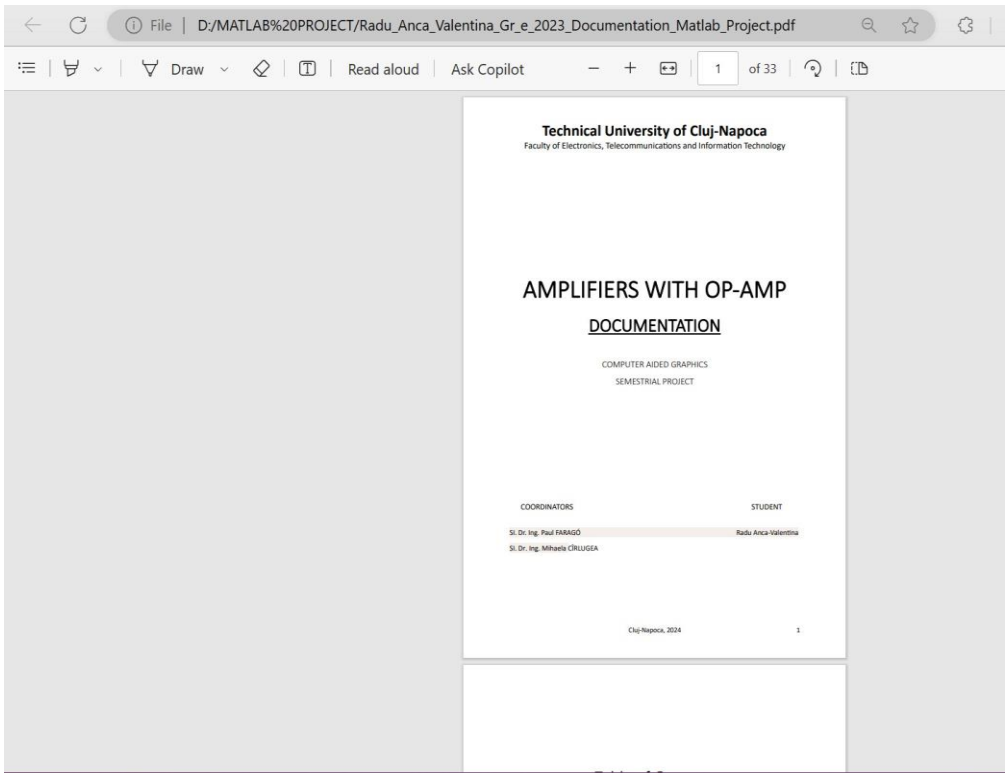
Just like the previous submenu, the “Inverting Amplifier” submenu takes you to a figure showing a picture of the corresponding circuit.



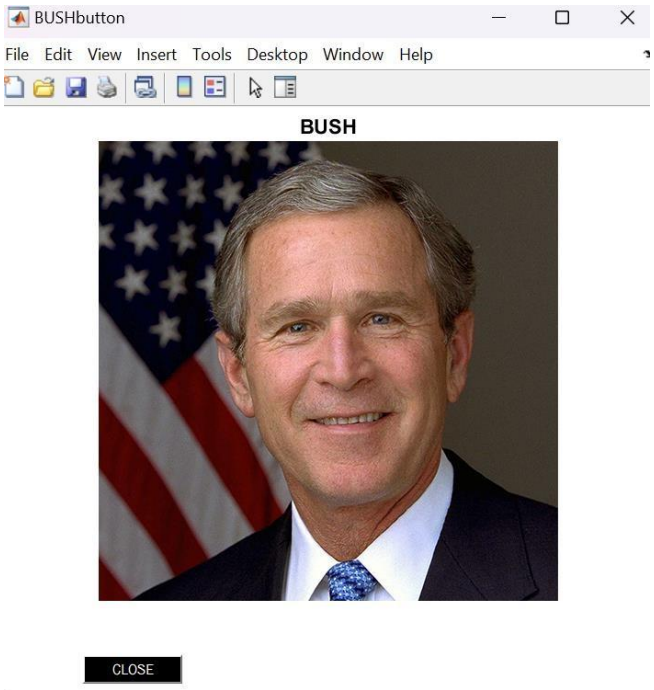
The Inverting Amplifier also has a VTC menu that opens up a figure of the VTC.



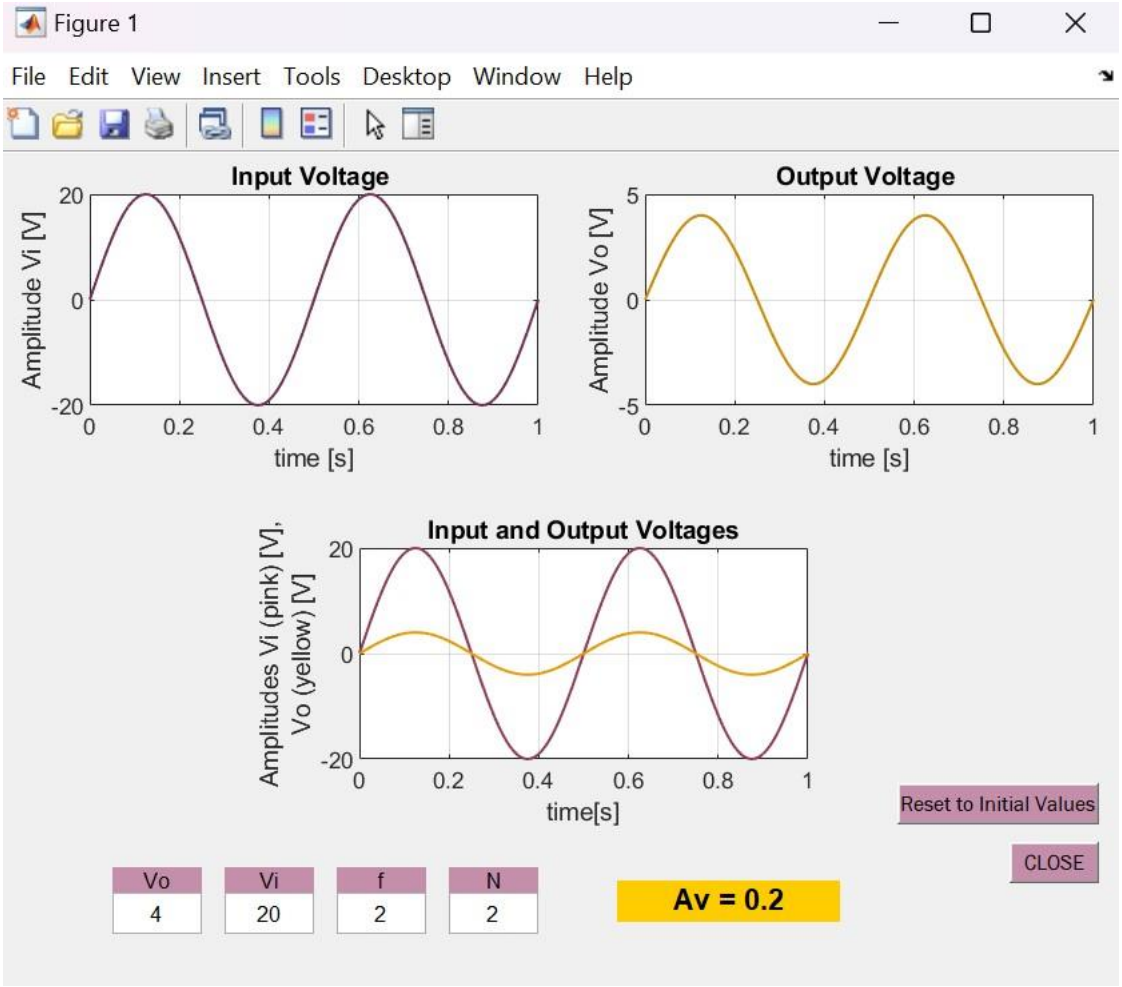
The “Documentation” submenu opens up the pdf of the project’s documentation.

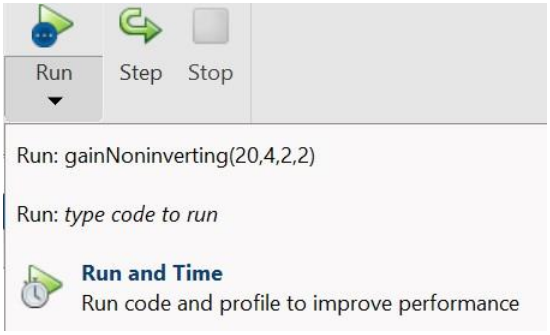


The “BUSH button” brings to life a candid shot of George Bush.

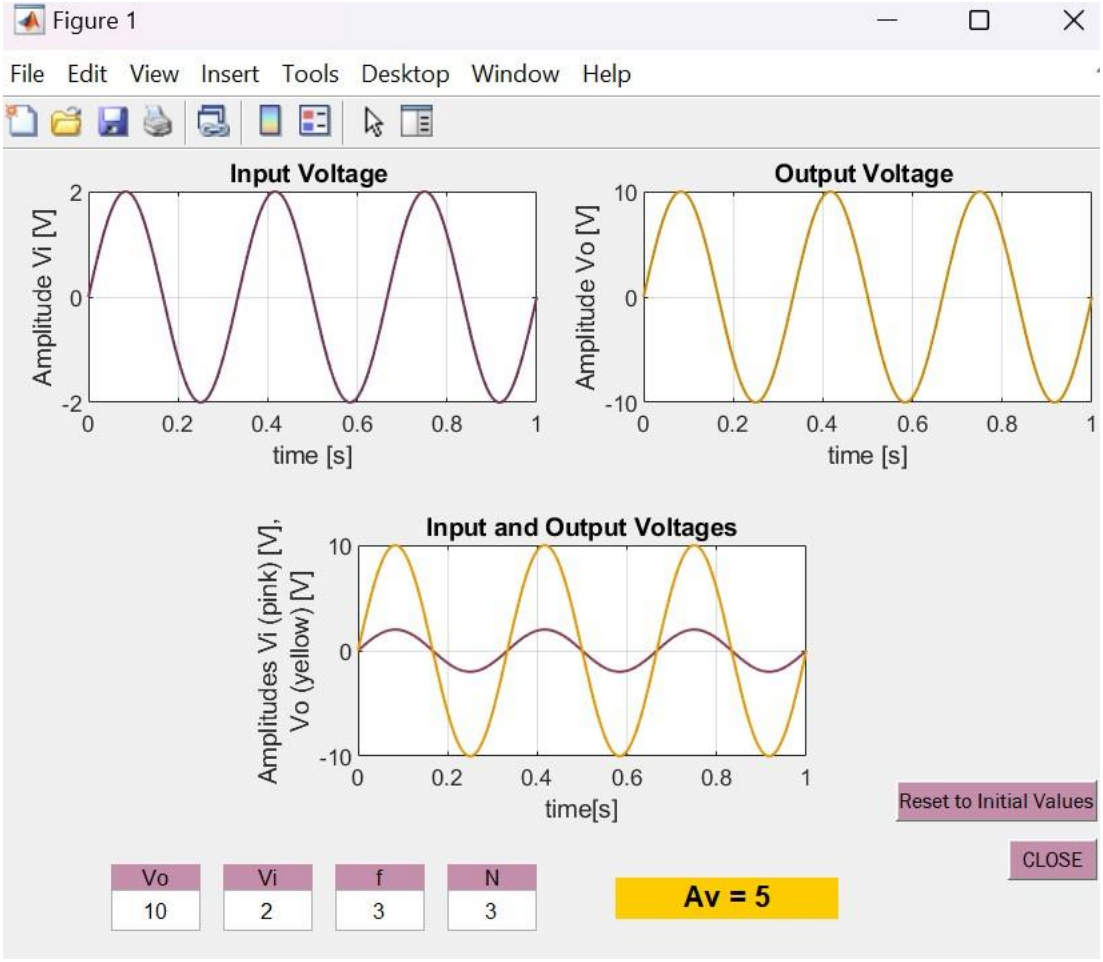


As a consequence to an error caused by the computation of T in the "gainNoninverting" and "gainInverting" functions, they have to be run from the MATLAB code, as the callback does not work. Prior to running them, the values can be changed. These 2 functions compute the gain A_V, and they display it on the figure.

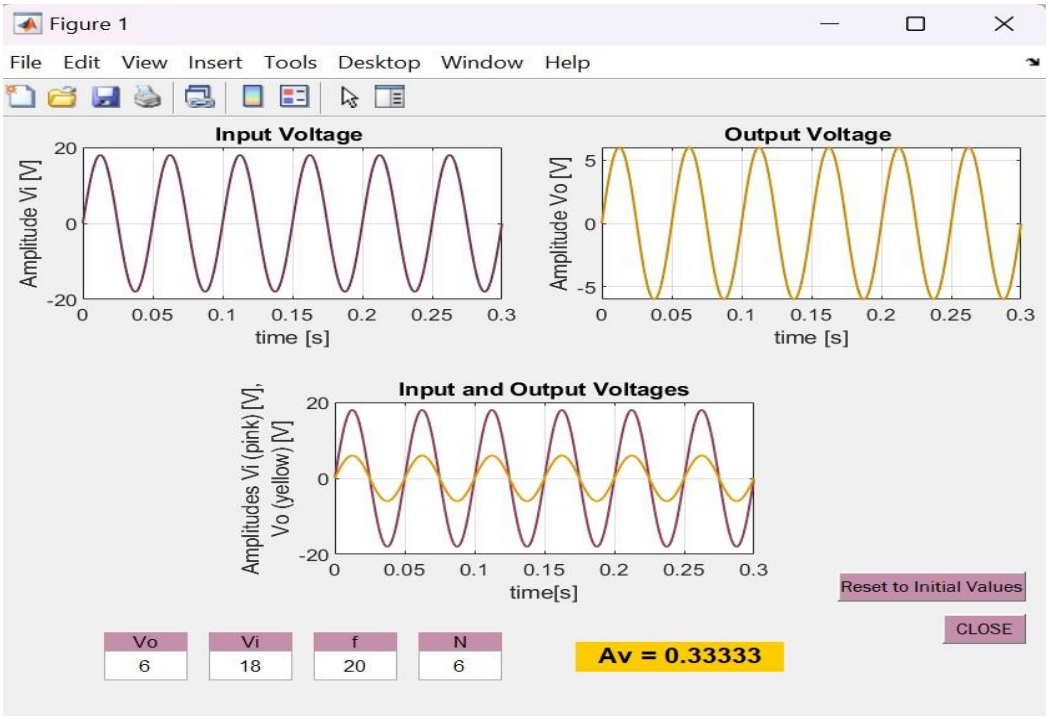




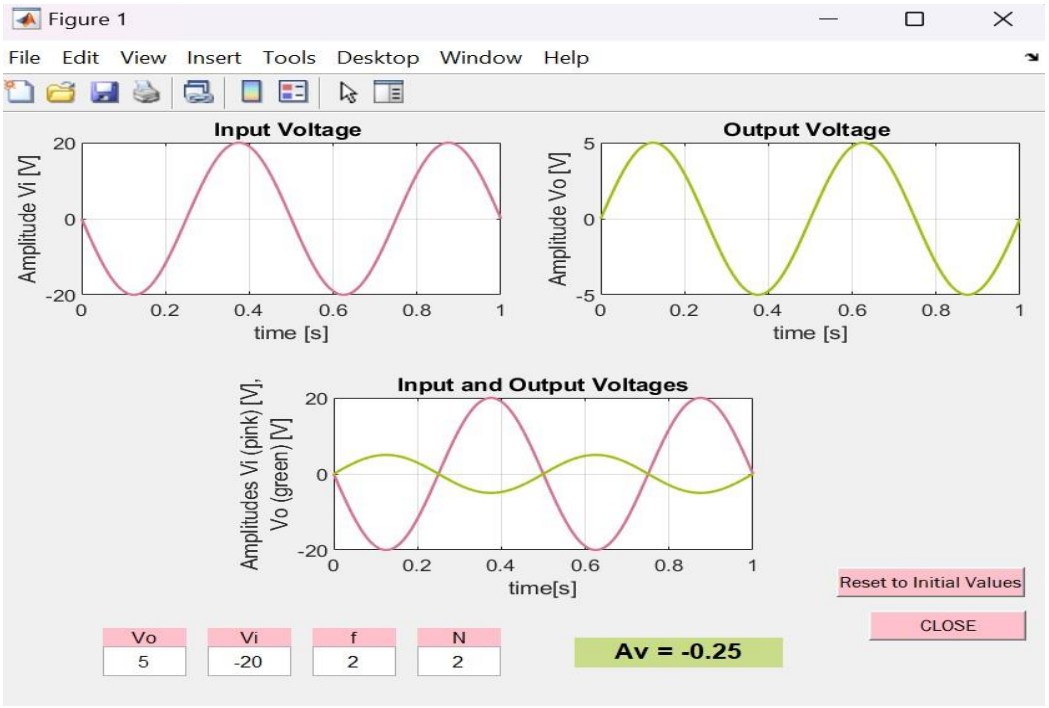
The "Reset to Initial Values" button resets the values and plots to the ones set in the code: 2,10,3,3 (Vo and Vi are reversed).

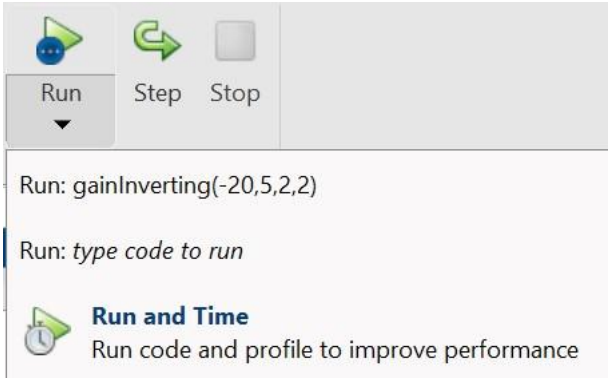


The values are modifiable from the edit boxes.

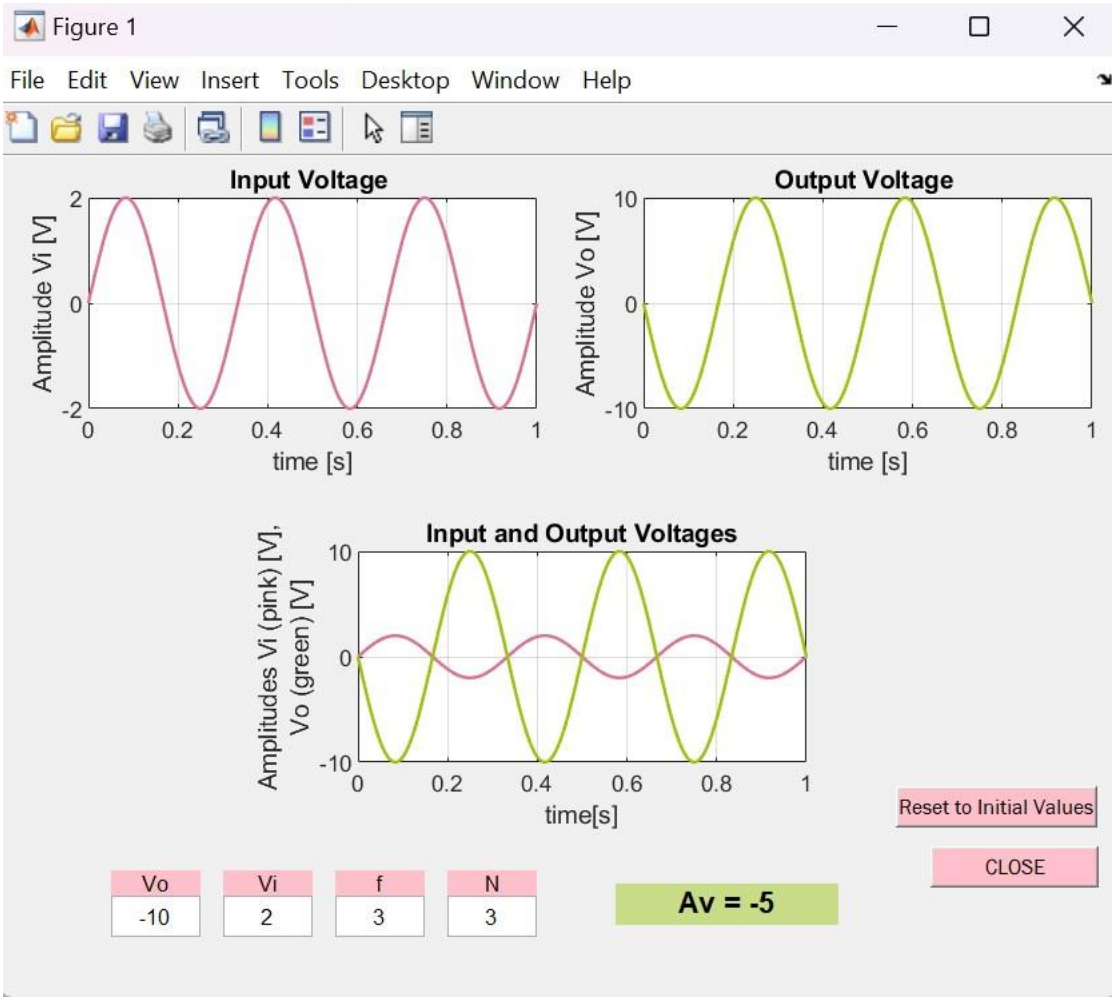


The "gainNoninverting" function works exactly the same. It computes the gain, the values can be changed prior to running the code,

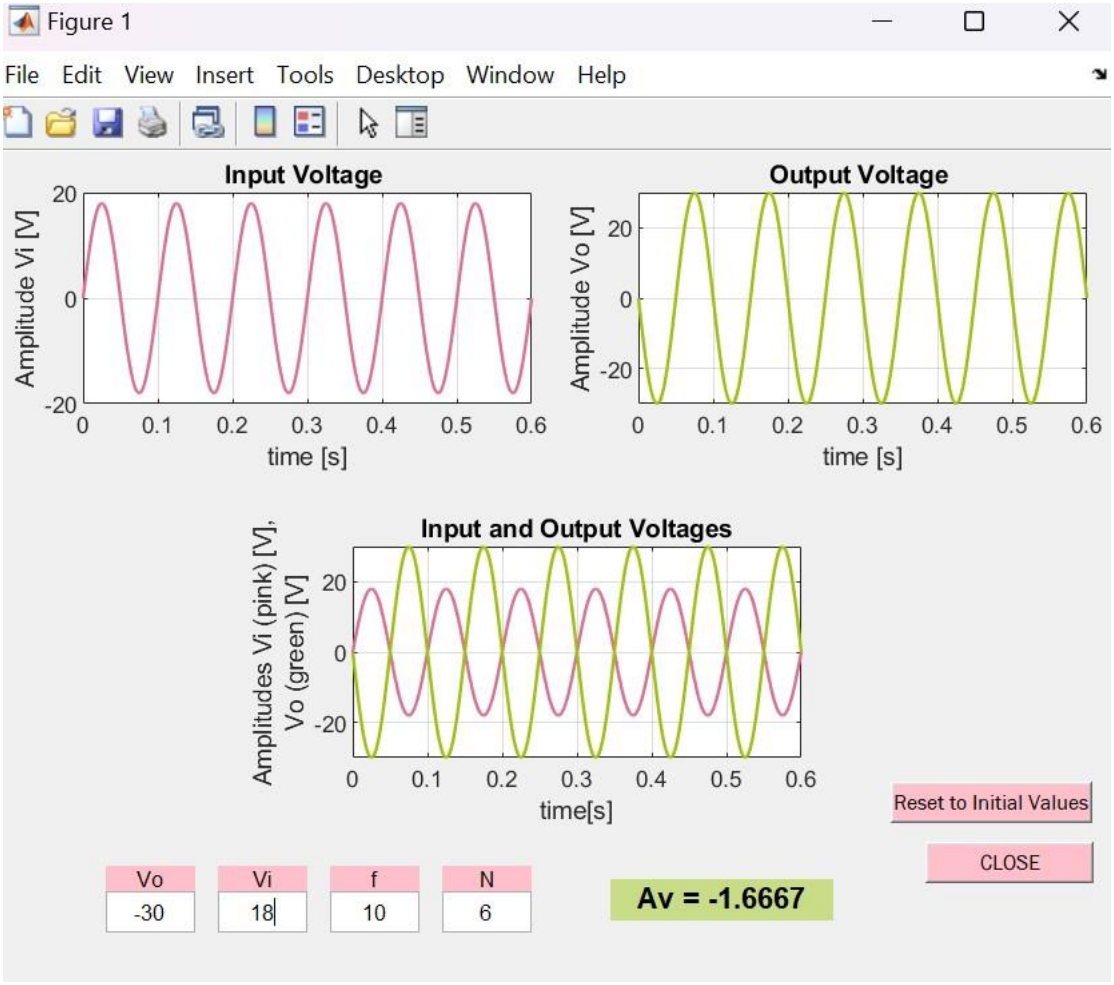




the “Reset to Initial Values” button resets the values to the ones set in the code, 2, -10, 3, 3



and the values are modifiable from the text boxes.



5.Conclusion

The project works the way I wanted it to, computing and displaying both the gain of inverting and non-inverting amplifiers, as well as the plots of the input and output signals and a plot with both of them, with no error.

The issues I encountered were with the callback to the gain computing functions, as stated above, and with setting limits to the output signal, V_{OH} and V_{OL}.

I tried using this function,

```
% ensure that Vo stays within the specified limits (Voh and Vol)
function limitedVo=limitAmplification(Vo, Voh, Vol)
    % Ensure Vo does not exceed positive voltage supply
    limitedVo = min(Vo, Voh);

    % Ensure Vo does not go below negative voltage supply
    limitedVo = max(limitedVo, Vol);
end
```

and calling it here

```
if isValid

    % Limit amplification to specified Voh and Vol values
    Vo = limitAmplification(Vo, Voh, Vol);
```

but the limits only worked when running the code for the first time. After editing it from the button, V_O is not limited anymore.

6.References

- https://circuitglobe.com/difference-between-inverting-and-non-invertingamplifier.htmln chart) - Circuit Globe
- https://www.javatpoint.com/matlab-introduction
- https://biblioteca.utcluj.ro/files/carti-online-cu-coperta/639-5.pdf
- https://html-color.codes/
- https://www.mathworks.com/

7.Appendix

Editor - D:\MATLAB PROJECT\GoToMenu.m

+2 GoToMenu.m | front_page.m | NoninvertingAmpli

```
figure("Color",'#edeae5');

h = uimenu('Label','Go To');

%uimenu(h,'Label','Front Page','Callback','index.html'); not working
uimenu(h, 'Label', 'Front Page', 'Callback', @(src, event) web('index.html', '-browser'))
uimenu(h,'Label','Non-inverting Amplifier','Callback','NoninvertingAmplifier' ,...
 'Accelerator','N');
uimenu(h,'Label','Inverting Amplifier','Callback','InvertingAmplifier' ,...
 'Accelerator','I');
uimenu(h,'Label','Documentation','Callback','documentation' ,...
 'Accelerator','D');
uimenu(h,'Label','Close','Callback','close',...
 'Separator','on','Accelerator','Q');

%uimenu(h,'Label','Gain Inverting Amplifier','Callback','gainInverting' ,...
% 'Accelerator','G');
%uimenu(h,'Label','Gain Noninverting Amplifier','Callback','gainNoninverting' ,...
% 'Accelerator','P'); not working

uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.6 0.00 0.4 0.3],...
'FontSize',24,...
'String','BUSH BUTTON',...
'BackgroundColor','#000',...
'ForegroundColor','#fff',...
'FontName','Franklin Gothic Book',...
'Callback','Bush');


uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[-0.01 0.935 0.15 0.07],...
'String','CLOSE',...
'BackgroundColor','#000',...
'ForegroundColor','#fff',...
'FontName','Franklin Gothic Book',...
'FontSize',12,...
'Callback','close');
```

+4 GoToMenu.m | front_page.m | InvertingAmplifier.m | Noninverti

```
% 'Accelerator','P'); not working

uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.6 0.00 0.4 0.3],...
'FontSize',24,...
'String','BUSH BUTTON',...
'BackgroundColor','#000',...
'ForegroundColor','#fff',...
'FontName','Franklin Gothic Book',...
'Callback','Bush');


uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[-0.01 0.935 0.15 0.07],...
'String','CLOSE',...
'BackgroundColor','#000',...
'ForegroundColor','#fff',...
'FontName','Franklin Gothic Book',...
'FontSize',12,...
'Callback','close');
```

GoToMenu.m | front_page.m

```
function front_page
open('index.html');

end
```

GoToMenu.m | front_page.m | NoninvertingAmplifier.m | Noninv

```
function NoninvertingAmplifier

img=imread('NoninvAmplifier.png');

figure('Name','Non-inverting Amplifier','Numbertitle', 'off',...
 'Color','#dfe7df');


imshow(img,'InitialMagnification',250)

title('NON-INVERTING AMPLIFIER');

uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.13 0.025 0.15 0.07],...
'String','CLOSE',...
'BackgroundColor','#674443',...
'FontName','Franklin Gothic Book',...
'ForegroundColor','#fff',...
'FontSize',12,...
'Callback','close');


uimenu('Label','VTC','Callback','NoninvertingAmplifierVTC' ,...
 'Accelerator','T');

end
```

GoToMenu.m | front_page.m | NoninvertingAmplifier.m | NoninvertingAmplifierVTC.m

```
function NoninvertingAmplifierVTC

img=imread('NoninvAmplifierVTC.png');


imshow(img,'InitialMagnification',200)

title('Non-inverting Amplifier - VTC');

uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.13 0.025 0.15 0.07],...
'String','CLOSE',...
'BackgroundColor','#674443',...
'FontName','Franklin Gothic Book',...
'ForegroundColor','#fff',...
'Callback','close');

```

+4 GoToMenu.m | front_page.m | NoninvertingAmplifier.m | NoninvertingAmplifierVTC.m | gainNoninverting.m

```
function gainNoninverting(Vi,Vo,f,N)

T=1/f ;% period
t=0:T/100:N*T; % representation range in time

% the amplifier is noninverting, so both vvoltages must be positive,
% hence we only go through to code if the function is true
isValid = verifyPositivePositive(Vo, Vi);

if isValid

xo=Vo*sin(2*pi*f*t); % first function
xi=Vi*sin(2*pi*f*t); % second function

% Create or update the figure - to update plot when pressing the reset
% button
createOrUpdateFigure(t, xo, xi);


% pushbuton CLOSE
uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.9 0.13 0.08 .05],...
'String','CLOSE',...
'BackgroundColor','#c58fac',...
'FontName','Franklin Gothic Book',...
'Callback','close');

% reset to initial parameters button
```

+4 GoToMenu.m | front_page.m | NoninvertingAmplifier.m | NoninvertingAmplifierVTC.m | gainNoninverting.m | Inverti

```
% reset to initial parameters button
uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.8 0.2 0.18 .05],...
'String','Reset to Initial Values',...
'BackgroundColor',' #c58fac',...
'FontName','Franklin Gothic Book',...
'Callback','gainNoninverting(2,10,3,3);'); %call with initial values
%'FontWeight','bold',...


% text button for variable Vi = cosine Amplitude
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.2 0.10 0.08 .05],...
'backgroundcolor','#c58fac',...
'string','Vi');

% edit button for Vi = the input voltage
uicontrol('Style','edit',...
'Units','normalized',...
'Position',[0.2 0.07 0.08 .05],...
'String',Vi,...
'Callback',['Vi=str2num(get(gco,''String''));gainNoninverting(Vi,Vo,f,N);']);


% text button for Vo = the output voltage
uicontrol('Style','text',...
```

+4 GoToMenu.m | front_page.m | NoninvertingAmplifier.m | NoninvertingAmplifierVTC.m | gainNoninverting.m

```
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.1 0.10 0.08 .05],...
'Backgroundcolor',' #c58fac',...
'String','Vo');

% edit button for Vo
uicontrol('Style','edit',...
'Units','normalized',...
'Position',[0.1 0.07 0.08 .05],...
'String',Vo,...
'Callback',['Vo=str2num(get(gco,''String''));gainNoninverting(Vi,Vo,f,N);']);


%text button for f = frequency
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.3 0.1 0.08 .05],...
'Backgroundcolor',' #c58fac',...
'String','f');

% edit button for f
uicontrol('Style','edit',...
'Units','normalized',...
'Position',[0.3 0.07 0.08 .05],...
'String',f,...
'Callback',['f=str2num(get(gco,''String''));gainNoninverting(Vi,Vo,f,N);']);
```

```
'Callback',['f=str2num(get(gco,''String''));gainNoninverting(Vi,Vo,f,N);']);


% text Button for n = the no. of cycles to be displayed
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.4 0.10 0.08 .05],...
'Backgroundcolor','#c58fac',...
'String','N');

% edit button for N
uicontrol('Style','edit',...
'Units','normalized',...
'Position',[0.4 0.07 0.08 .05],...
'String',N,...
'Callback',['N=str2num(get(gco,''String''));gainNoninverting(Vi,Vo,f,N);']);



Av=Vo/Vi;

%display Av
Av

uicontrol('Style','text',...
 'Units','normalized',...
 'Position',[0.55 0.0835 0.2 .05],...
 'BackgroundColor','#ffcc00',...
 'FontSize',11,...
```

```
 'FontSize',11,...
 'FontWeight','bold',...
 'String',['Av = ', num2str(Av)]);


%plot windows

%plot Vo
subplot('position',[0.575, 0.7, 0.4, 0.25]);
p=plot(t,xo);
p.Color="#cc8800";
p.LineWidth=1;
grid on;
title('Output Voltage ');
xlabel('time [s]');
ylabel('Amplitude Vo [V]');

%plot Vi
subplot('position',[0.08, 0.7, 0.4, 0.25]);
q=plot(t,xi);
q.Color="#6f3052";
q.LineWidth=1;
grid on;
title('Input Voltage ');
xlabel('time [s]');
ylabel('Amplitude Vi [V]');


%plot both
```

```
%plot both

%custom colors
c1=[142,58,89]/255;
c2=[230, 153, 0]/255;
%MATLAB uses normalized RGB values in the range [0, 1], so you need to divide GB values by 255 to convert them

subplot('position',[0.32,0.28,0.4,0.25]);

plot(t, xi, 'Color', c1,LineWidth=1);
hold on;  % allows multiple plots on the same axes
plot(t, xo, 'Color', c2,LineWidth=1);
hold off; % release the hold

grid on;
title('Input and Output Voltages');
xlabel('time[s]');
ylabel({'Amplitudes Vi (pink) [V],','Vo (yellow) [V]'});
%end plot both

%if the condition is not met
else
    disp('No positive-positive/negative-negative pair found.')

end


function isValid = verifyPositivePositive(Vo, Vi)
    isValid = false;  % initialize the result
```

```
+4  GoToMenu.m | front_page.m | NoninvertingAmplifier.m | NoninvertingAmplifierVTC.m | gainNoninverting.m

function isValid = verifyPositivePositive(Vo, Vi)
    isValid = false;  % initialize the result

    % check if one of Vo and Vi is negative and the other is positive
    if (Vo > 0 && Vi > 0) || (Vo < 0 && Vi < 0)
            isValid = true;

    end

end


function createOrUpdateFigure(t, xo, xi)
        % Plot windows
        subplot('position', [0.58, 0.5, 0.4, 0.25]);
        plot(t, xo);
        grid on;
        title('Output Voltage ');
        xlabel('time [s]');
        ylabel('Amplitude Vo [V]');

        subplot('position', [0.08, 0.5, 0.4, 0.25]);
        plot(t, xi);
        grid on;
        title('Input Voltage ');
        xlabel('time [s]');
        ylabel('Amplitude Vi [V]');
    end
end
```

```
+4  GoToMenu.m | front_page.m | NoninvertingAmplifier.m | NoninvertingAmplifierVTC.m | gainNoninverting.m | InvertingAmplifier.m

function InvertingAmplifier

img=imread('InvAmplifier.png');

figure('Name','Inverting Amplifier','Numbertitle', 'off',...
 'Color','#dfe7df');

imshow(img,'InitialMagnification',250)

title('INVERTING AMPLIIFIER');

uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.13 0.025 0.15 0.07],...
'String','CLOSE',...
'BackgroundColor','#674443',...
'FontName','Franklin Gothic Book',...
'FontSize',12,...
'ForegroundColor','#fff',...
'Callback','close');

uimenu('Label','VTC','Callback','NoninvertingAmplifierVTC' ,...
 'Accelerator','T');

end
```

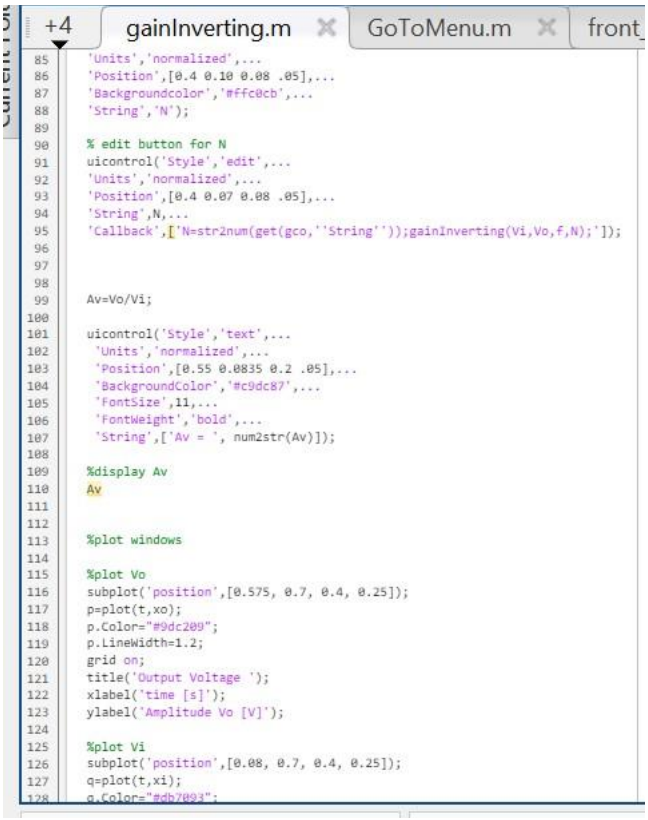
+4 GoToMenu.m | front_page.m | NoninvertingAmplifier.m | NoninvertingAmplifierVTC.m | gainNoninverting.m | InvertingAmplifier.m | InvertingAmplifierVTC.m

```m
function InvertingAmplifierVTC

img=imread('NoninvAmplifierVTC.png');


imshow(img,'InitialMagnification',200)

title('Inverting Amplifier - VTC');

uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.13 0.01 0.15 0.05],...
'String','CLOSE',...
'BackgroundColor','#674443'...
'FontName','Franklin Gothic Book',...
'Callback','close');

```

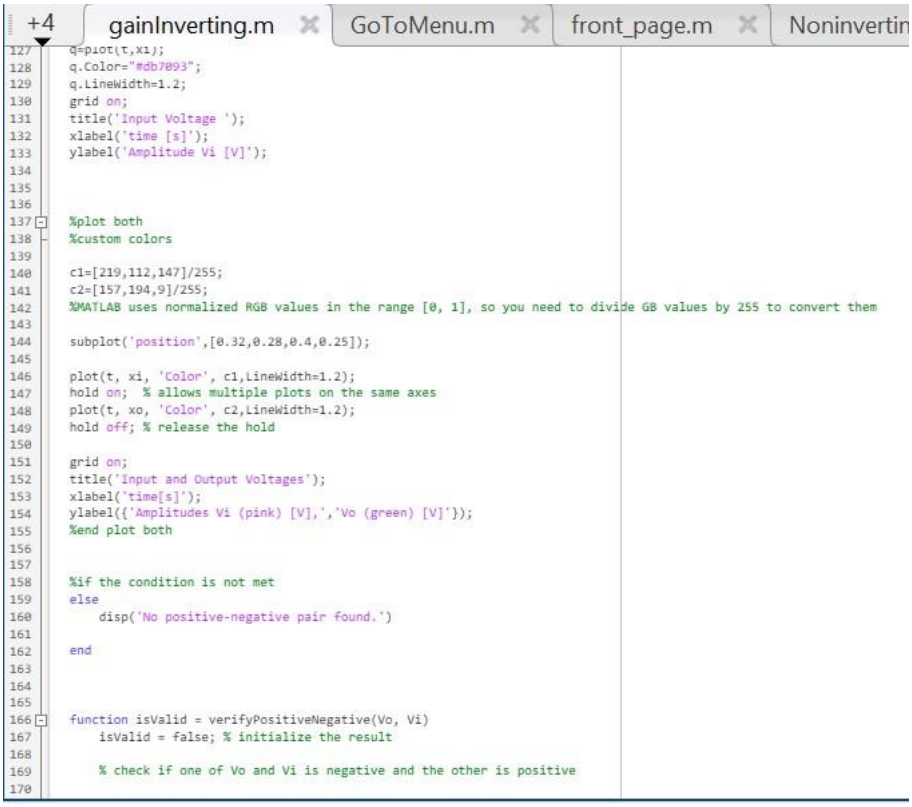
+4 gainInverting.m | GoToMenu.m | front_page.

```m
function gainInverting(Vi,Vo,f,N)

T=1/f;
t=0:T/100:N*T; % representation range in time

% the amplifier is inverting, so one of the voltages has to be negative, one
% positive, so we only go through to code if the function is true
isValid = verifyPositiveNegative(Vo, Vi);

if isValid

xo=Vo*sin(2*pi*f*t); % first function
xi=Vi*sin(2*pi*f*t); % second function

% Create or update the figure - to update plot when pressing the reset
% button
createOrUpdateFigure(t, xo, xi);


% pushbuton CLOSE
uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.831 0.128 0.15 0.05],...
'String','CLOSE',...
'BackgroundColor','#ffc0cb',...
'FontName','Franklin Gothic Book',...
'Callback','close');

% reset to initial parameters button
uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.8 0.2 0.18 .05],...
'String','Reset to Initial Values',...
'BackgroundColor','#ffc0cb',...
'FontName','Franklin Gothic Book',...
'Callback','gainInverting(2,-10,3,3);'); %call with initial values

% text button for Vo = the output voltage
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.1 0.10 0.08 .05],...
'Backgroundcolor','#ffc0cb',...
'String','Vo');

```

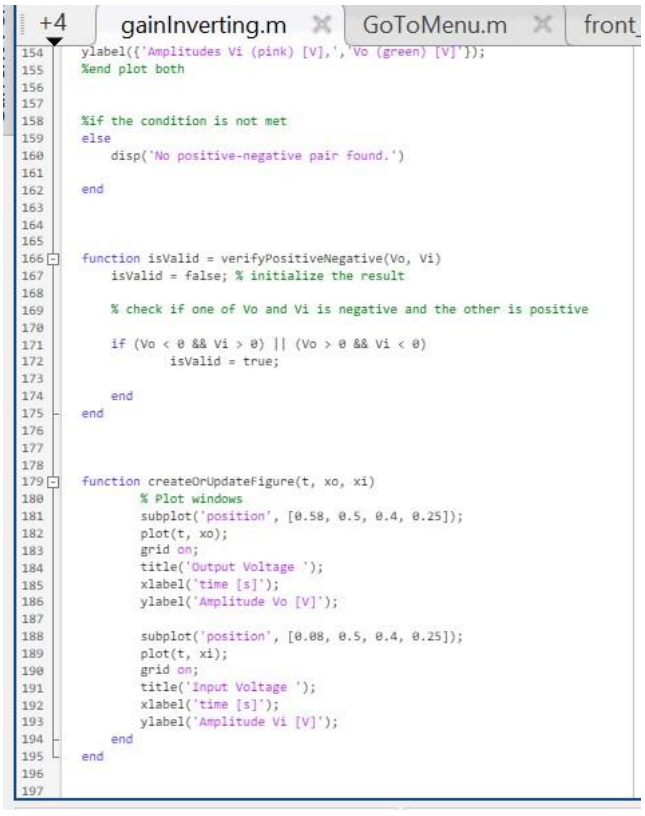

```
'Backgroundcolor','#ffc0cb',...
'String','Vo');

% edit button for Vo
uicontrol('Style','edit',...
'Units','normalized',...
'Position',[0.1 0.07 0.08 .05],...
'String',Vo,...
'Callback',['Vo=str2num(get(gco,''String''));gainInverting(Vi,Vo,f,N);']);


% text button for variable Vi = cosine Amplitude
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.2 0.10 0.08 .05],...
'backgroundcolor','#ffc0cb',...
'string','Vi');

% edit button for Vi = the input voltage
uicontrol('Style','edit',...
'Units','normalized',...
'Position',[0.2 0.07 0.08 .05],...
'String',Vi,...
'Callback',['Vi=str2num(get(gco,''String''));gainInverting(Vi,Vo,f,N);']);


%text button for f = frequency
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.3 0.1 0.08 .05],...
'Backgroundcolor','#ffc0cb',...
'String','f');

% edit button for f
uicontrol('Style','edit',...
'Units','normalized',...
'Position',[0.3 0.07 0.08 .05],...
'String',f,...
'Callback',['f=str2num(get(gco,''String''));gainInverting(Vi,Vo,f,N);']);


% text Button for N = the no. of cycles to be displayed
uicontrol('Style','text',...
'Units','normalized',...
```




```
'Units','normalized',...
'Position',[0.4 0.10 0.08 .05],...
'Backgroundcolor','#ffc0cb',...
'String','N');

% edit button for N
uicontrol('Style','edit',...
'Units','normalized',...
'Position',[0.4 0.07 0.08 .05],...
'String',N,...
'Callback',['N=str2num(get(gco,''String''));gainInverting(Vi,Vo,f,N);']);



Av=Vo/Vi;

uicontrol('Style','text',...
 'Units','normalized',...
 'Position',[0.55 0.0835 0.2 .05],...
 'BackgroundColor','#c9dc87',...
 'FontSize',11,...
 'FontWeight','bold',...
 'String',['Av = ', num2str(Av)]);

%display Av
Av


%plot windows

%plot Vo
subplot('position',[0.575, 0.7, 0.4, 0.25]);
p=plot(t,xo);
p.Color="#9dc209";
p.LineWidth=1.2;
grid on;
title('Output Voltage ');
xlabel('time [s]');
ylabel('Amplitude Vo [V]');

%plot Vi
subplot('position',[0.08, 0.7, 0.4, 0.25]);
q=plot(t,xi);
q.Color="#db7093";
```

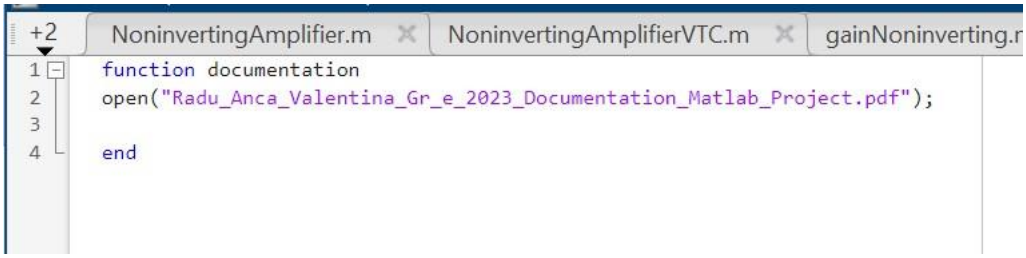



```
q=plot(t,x1);
q.Color="#db7093";
q.LineWidth=1.2;
grid on;
title('Input Voltage ');
xlabel('time [s]');
ylabel('Amplitude Vi [V]');



%plot both
%custom colors

c1=[219,112,147]/255;
c2=[157,194,9]/255;
%MATLAB uses normalized RGB values in the range [0, 1], so you need to divide GB values by 255 to convert them

subplot('position',[0.32,0.28,0.4,0.25]);

plot(t, xi, 'Color', c1,LineWidth=1.2);
hold on;  % allows multiple plots on the same axes
plot(t, xo, 'Color', c2,LineWidth=1.2);
hold off; % release the hold

grid on;
title('Input and Output Voltages');
xlabel('time[s]');
ylabel({'Amplitudes Vi (pink) [V],','Vo (green) [V]'});
%end plot both


%if the condition is not met
else
    disp('No positive-negative pair found.')

end



function isValid = verifyPositiveNegative(Vo, Vi)
    isValid = false; % initialize the result

    % check if one of Vo and Vi is negative and the other is positive

```




```
ylabel({'Amplitudes Vi (pink) [V],','Vo (green) [V]'});
%end plot both


%if the condition is not met
else
    disp('No positive-negative pair found.')

end



function isValid = verifyPositiveNegative(Vo, Vi)
    isValid = false; % initialize the result

    % check if one of Vo and Vi is negative and the other is positive

    if (Vo < 0 && Vi > 0) || (Vo > 0 && Vi < 0)
            isValid = true;

    end
end



function createOrUpdateFigure(t, xo, xi)
        % Plot windows
        subplot('position', [0.58, 0.5, 0.4, 0.25]);
        plot(t, xo);
        grid on;
        title('Output Voltage ');
        xlabel('time [s]');
        ylabel('Amplitude Vo [V]');

        subplot('position', [0.08, 0.5, 0.4, 0.25]);
        plot(t, xi);
        grid on;
        title('Input Voltage ');
        xlabel('time [s]');
        ylabel('Amplitude Vi [V]');
    end
end

```


```
function Bush

img=imread('bush.jpg');

figure('Name','BUSHbutton','Numbertitle', 'off',...
  'Color','#fff');

imshow(img,'InitialMagnification',200)

title('BUSH');

uicontrol('Style','pushbutton',...
'Units','normalized',...
'Position',[0.13 0.01 0.15 0.05],...
'String','CLOSE',...
'BackgroundColor','#000',...
'ForegroundColor','#fff',...
'FontName','Franklin Gothic Book',...
'Callback','close');

```


+2
NoninvertingAmplifier.m
NoninvertingAmplifierVTC.m
gainNoninverting.m
function documentation
open("Radu_Anca_Valentina_Gr_e_2023_Documentation_Matlab_Project.pdf");
end

THANK YOU!