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Year: 2

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“High Pass Filter”

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CONTENT

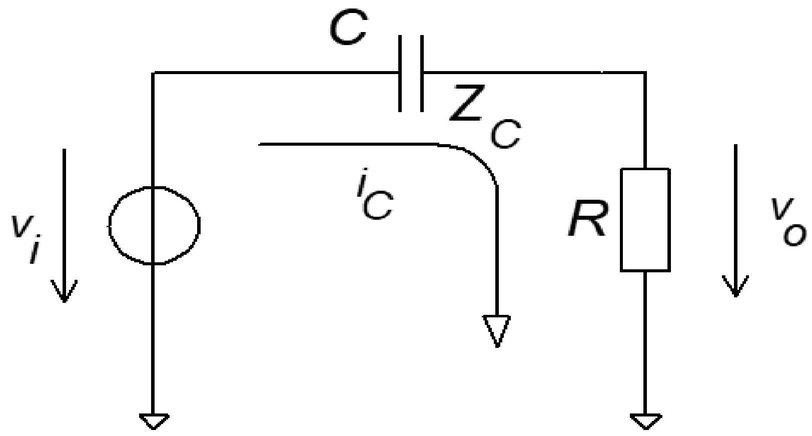
MATLAB

MATLAB is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.

MATLAB was invented by mathematician and computer programmer Cleve Moler.The idea for MATLAB was based on his 1960s PhD thesis. Moler became a math professor at the University of New Mexico and started developing MATLAB for his students as a hobby. He developed MATLAB's initial linear algebra programming in 1967 with his one-time thesis advisor, George Forsythe. This was followed by Fortran code for linear equations in 1971.

High Pass Filter

A high-pass filter (HPF) is an electronic filter that passes signals with a frequency higher than a certain cutoff frequency and attenuates signals with frequencies lower than the cutoff frequency. The amount of attenuation for each frequency depends on the filter design.



Formulas used for the project

- **The cutoff frequency**

fo=1/2πRC

❖ “Vi” is a sinusoidal voltage with “ω” pulsation (or a frequency: f=ω/2π).

$$v_o = \frac{R}{R + z_C} v_i = \frac{R}{R + \dfrac{1}{j\omega C}} v_i$$

❖ The transfer function

$$H(j\omega) = \frac{v_o(j\omega)}{v_i(j\omega)} = \frac{j\omega RC}{1 + j\omega RC}$$

-The pulsation-

$$\omega_0 = \frac{1}{RC}$$

$$H(j\omega) = \frac{v_o(j\omega)}{v_i(j\omega)} = \frac{j\dfrac{\omega}{\omega_0}}{1 + j\dfrac{\omega}{\omega_0}}$$

$$\Downarrow$$

$$H(j\omega) = \frac{\left(1 - j\dfrac{\omega}{\omega_0}\right) j\dfrac{\omega}{\omega_0}}{1 + \dfrac{\omega^2}{\omega_0^2}}$$

$$H(j\omega)=\frac{\dfrac{\omega^2}{\omega_0^2}}{1+\dfrac{\omega^2}{\omega_0^2}}+j\frac{\dfrac{\omega}{\omega_0}}{1+\dfrac{\omega^2}{\omega_0^2}}$$

The transfer function of a HPF

❖ **The transfer function’s modulus (magnitude):**

$$|H(j\omega)|=\sqrt{\mathrm{Re}^2_{H(j\omega)}+\mathrm{Im}^2_{H(j\omega)}}$$

$$\boxed{|H(j\omega)|=\frac{\dfrac{\omega}{\omega_0}}{\sqrt{1+\dfrac{\omega^2}{\omega_0^2}}}}$$

❖ **The transfer function’s phase:**

$$\varphi_{H(j\omega)}=arctg\left(\frac{\mathrm{Im}_{H(j\omega)}}{\mathrm{Re}_{H(j\omega)}}\right)$$

$$\varphi_{H(j\omega)}=arctg\left(\frac{\omega_0}{\omega}\right)$$

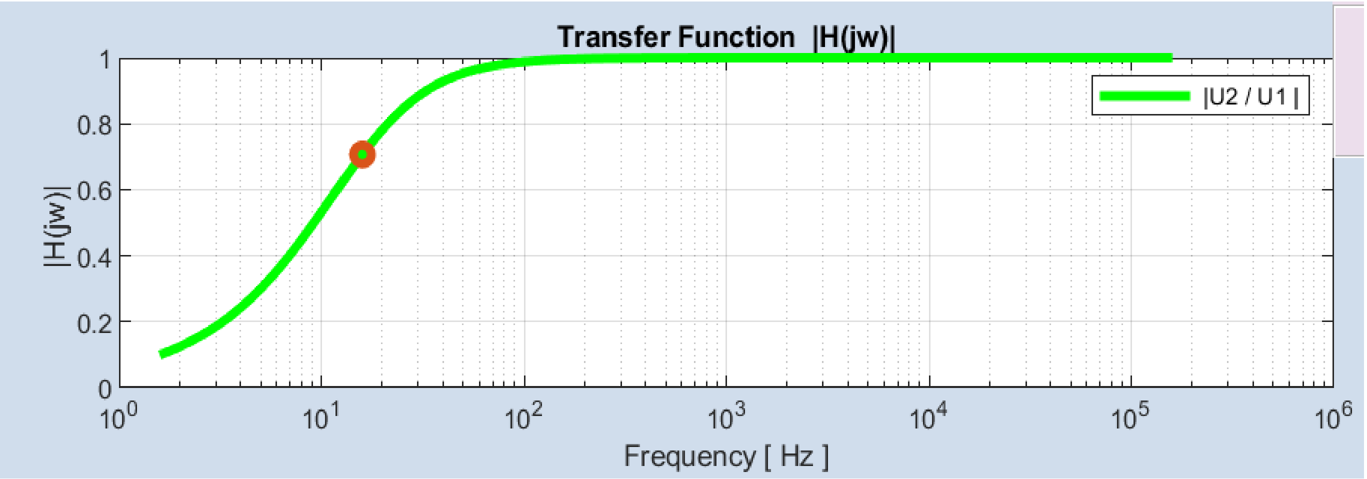
LOG

$$|H(j\omega)|_{dB} = 20\lg \frac{\frac{\omega}{\omega_0}}{\sqrt{1+\frac{\omega^2}{\omega_0^2}}}$$

The interface (pictural photos of the graphics and plots)

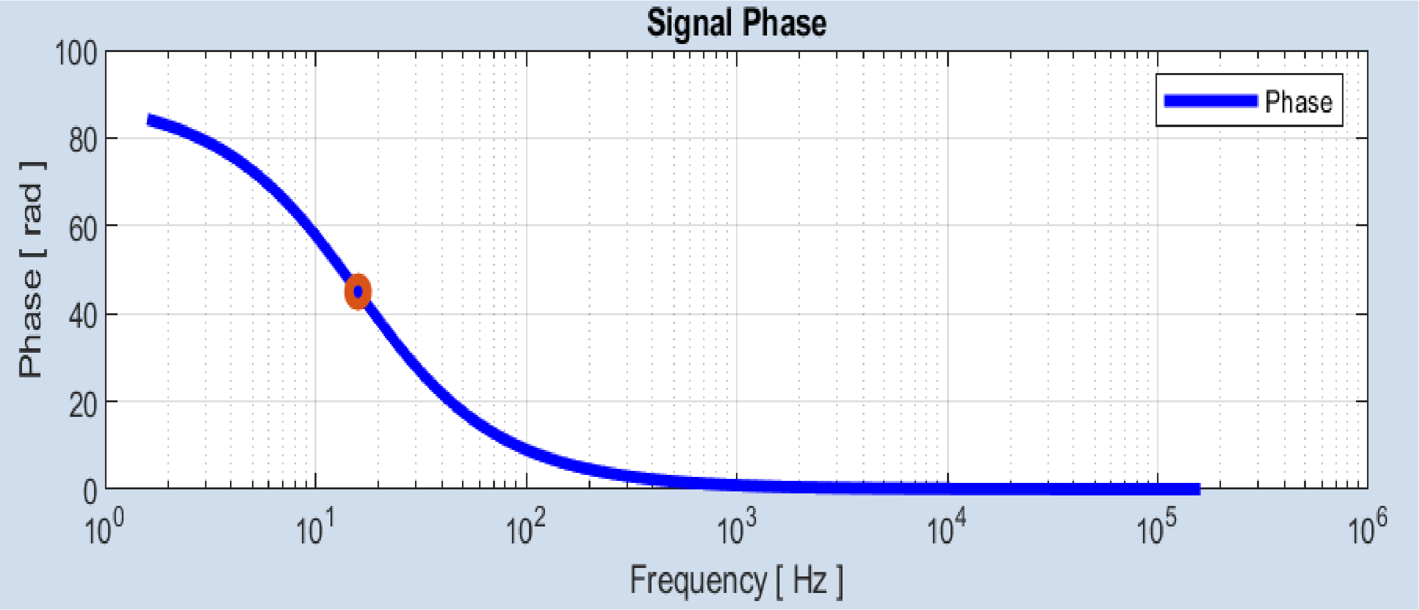
- Graphical representations of the High Pass RC Filter
- Customizing features for R=10000 [ohms] and C=1e-06 [F]

The transfer function representation |H(jw)|

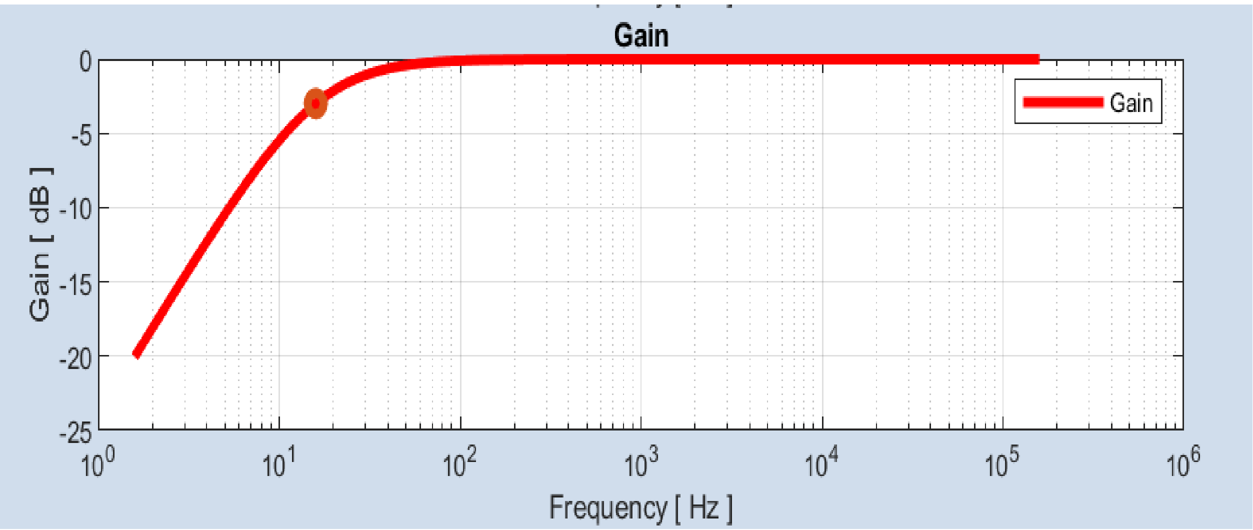


The Signal Phase representation of the High Pass RC Filter

$$\varphi_{H(j\omega)} = arctg\left(\frac{\omega_0}{\omega}\right)$$



The Gain representation in dB of the High Pass RC Filter



Formulas and calculations used in the code + explanations

```
f0 = 1./(2.*pi.*C.*R);
w0 = 2.*pi.*f0;
```

- **f0**: Calculates the cutoff frequency using the formula **f0 = 1 / (2 * pi * C * R)**.
- **w0**: Converts the cutoff frequency to angular frequency using the formula **w0 = 2 * pi * f0**.

```
w = logspace(1,6,f);
f2 = w/(2*pi);
```

- **w**: Generates a logarithmically spaced vector of angular frequencies (pulsation) using the **logspace** function.
- **f2**: Converts angular frequency back to frequency.

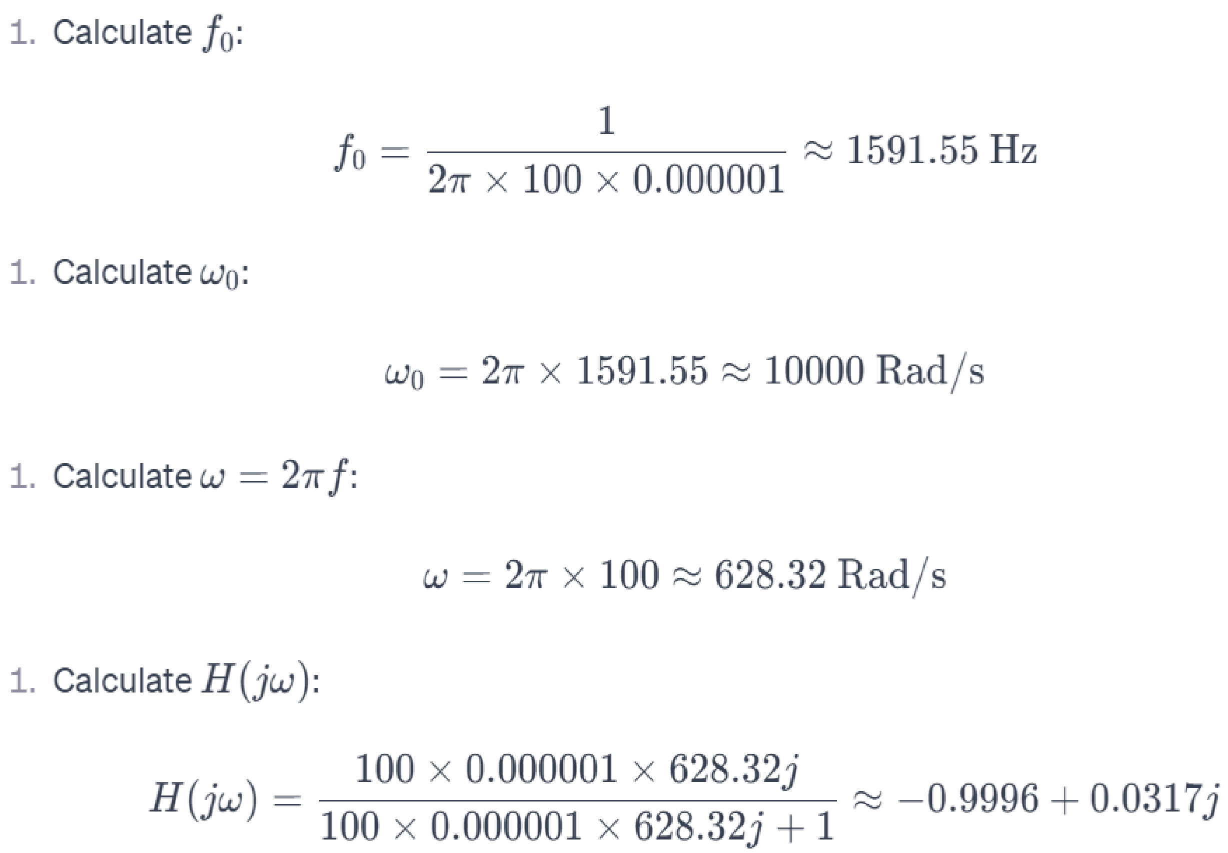
```
num = R*C*w*j;
 den = R*C*w*j + 1;
```

- **num**: Numerator of the transfer function
- **den**: Denominator of the transfer function

```
h = abs(num./den);
gain = 20*log10(h);
faza = angle(num./den)*180/pi;
```

- **h**: Calculates the magnitude of the transfer function.
- **gain**: Calculates the gain in decibels using the magnitude.
- **faza**: Calculates the phase in degrees using the angle of the transfer function.

We calculate the values of the gain plot where R=100, C=0,000001, f=100



1. Calculate f_0:

$$f_0 = \frac{1}{2\pi \times 100 \times 0.000001} \approx 1591.55 \text{ Hz}$$

1. Calculate ω_0:

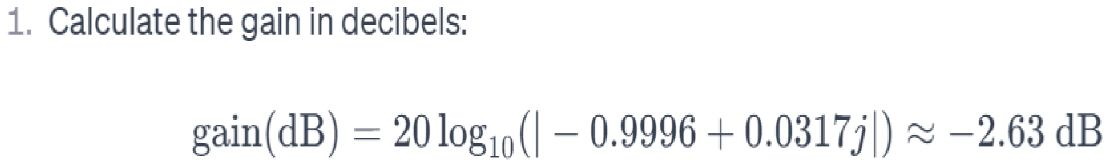
$$\omega_0 = 2\pi \times 1591.55 \approx 10000 \text{ Rad/s}$$

1. Calculate $\omega = 2\pi f$:

$$\omega = 2\pi \times 100 \approx 628.32 \text{ Rad/s}$$

1. Calculate $H(j\omega)$:

$$H(j\omega) = \frac{100 \times 0.000001 \times 628.32j}{100 \times 0.000001 \times 628.32j + 1} \approx -0.9996 + 0.0317j$$



1. Calculate the gain in decibels:

$$\text{gain(dB)} = 20 \log_{10}(| - 0.9996 + 0.0317j|) \approx -2.63 \text{ dB}$$

Therefore, the calculated gain at the given frequency is approximately -2.63 dB, which is close to the expected value of -3 dB. There might be slight variations due to rounding and numerical precision.

CONCLUSION

The theme of designing high pass filters for an RC circuit involved creating graphical representations of the filter's behavior, including phase, gain, and transfer function plots. The implemented MATLAB code successfully generated these plots based on user-defined circuit parameters.

The results aligned with expectations, accurately depicting the filter's characteristics at different frequencies. The gain plot correctly displayed the cutoff frequency, and the phase plot illustrated the expected phase shift.

Potential improvements could include enhancing the user interface for better usability and incorporating additional features or analysis options. Future research and development may explore optimizations for computational efficiency and the inclusion of more advanced filter designs.

Bibliography

https://en.wikipedia.org/wiki/MATLAB

https://en.wikipedia.org/wiki/High-pass_filter

https://chat.openai.com/c/9a49dc13-0217-4b1a-ad7a-b03ecc2e6777

https://drive.google.com/file/d/1_XcEQFM_OVrasOlCixHjMmEgQYoeQPCQ/view

--The_Code---

%Start% - (This code creates a GUI with a background image, a title, menus, and buttons for different functionalities related to the RC high-pass filter project. The buttons trigger specific callback functions, HPF_RC_circuit, HPF_RC_values, front_page, and close when clicked)

```
close all;
% Interface Creation
Fig=figure('Name','CAG Project-HPF',...
'Units','normalized',...%-Unitatile de masura – 0->1-%
'Position',[0.1 0.1 0.8 0.7],...%Pozitia ferestrei pe ecran
'NumberTitle','off');%Numarul ferestrei - nu se atribuie%
set(gcf, 'Color',[0.768 0.811 0.737]);
ah = axes('unit', 'normalized', 'position', [0 0 1 1]);
bg = imread('picture.jpg');
imagesc(bg);
set(ah,'handlevisibility','off','visible','off')
%Title
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.3 0.70 0.4 0.15],...
'foregroundcolor','k',...
'backgroundcolor',[0.815 0.866 0.925],...
'Fontname','Times New Roman',...
'FontWeight','Bold',...
'FontSize',32,...
'String','RC High Pass Filter');
% Menus
m=uimenu('Label','Documentation Project');
uimenu(m,'Label','Documentation','Callback','open(''Documentation.pdf'')');
uimenu(m,'Label','Close','Callback','close','Separator','on','Accelerator','Q');
% Buttons Creation
uicontrol('style','pushbutton',...
'Units','normalized',...
'Position',[0.28 0.5 0.2 0.11],...
'string','The HPF Circuit ',...
'FontName','Times New Roman',...
'FontSize',15,...
'Foregroundcolor','k',...
'Backgroundcolor',[0.815 0.866 0.925],...
'FontWeight','Bold',...
'Callback','HPF_RC_circuit');
uicontrol('style','pushbutton',...
'Units','normalized',...
'Position',[0.52 0.5 0.2 0.11],...
'string','Graphics',...
'FontName','Times New Roman',...
'FontSize',17,...
'foregroundcolor','k',...
'FontWeight','Bold',...
'backgroundcolor',[0.815 0.866 0.925],...
'Callback','HPF_RC_values');
uicontrol('style','pushbutton',...
'Units','normalized',...
'Position',[0.04 0.2 0.2 0.11],...
'string','Front Page',...
'FontName','Times New Roman',...
'FontSize',17,...
'foregroundcolor','k',...
'FontWeight','Bold',...
'backgroundcolor',[0.815 0.866 0.925],...',..
'Callback','front_page');
uicontrol('style','pushbutton',...
'Units','normalized',...
'Position',[0.76 0.2 0.2 0.11],...
'string','Close',...
'FontName','Times New Roman',...
'FontSize',15,...
'foregroundcolor','k',...
'backgroundcolor',[0.815 0.866 0.925],...'
'FontWeight','Bold',...
'Callback','close;');
```

%Front_page% (The purpose of this function is to open an HTML file named "front-page.html."

```matlab
function front_page
open ('front-page.html');
end
```

```matlab
%HPF_RC_graphics% (The GUI provides an interactive way to explore the behavior of an RC High
Pass Filter by adjusting parameters and observing changes in the transfer function, gain, and
phase plots. The code structure allows the user to interact with the filter characteristics.)
function HPF_RC_graphics(R,C,f,val)
% Interface
figure('Name','RC High Pass Filter',...
'Units','normalized',...
'Position',[0.05 0.05 0.7 0.85],...
'NumberTitle','off');
set(gcf,'Color',[0.815 0.866 0.925]);
% Frames
Group1=uibuttongroup('BackgroundColor', [0.925 0.870 0.925],...
'Title','Circuits Parameters',...
'FontWeight','b',...
'FontSize',13,...
'Position',[0.75 0.5 0.2 0.38],...
'TitlePosition','centertop',...
'Tag','radiobutton');
%Resistance
uicontrol('Style','Text',...
'Units','Normalized',...
'Position',[0.25,0.80,0.5,0.08],...
'BackgroundColor',[1 1 1],...
'FontSize',10,...
'FontWeight','b',...
'String','Resistance',...
'Parent',Group1);
uicontrol('Style','Edit',...
'Units','Normalized',...
'Position',[0.25,0.70,0.5,0.08],...
'FontSize',10,...
'String',R,...
'Callback',['R=','str2num(get(gco,''String'')),close,HPF_RC_graphics(R,C,f,val)'],...
```

```
'Parent',Group1);
uicontrol('Style','Text',...
'Units','Normalized',...
'Position',[0.75,0.70,0.2,0.08],...
'BackgroundColor',[1 0.6 1],...
'FontSize',8,...
'FontWeight','b',...
'String','[ohm]',...
'Parent',Group1);
%Capacitance
uicontrol('Style','Text',...
'Units','Normalized',...
'Position',[0.25,0.50,0.5,0.08],...
'BackgroundColor',[1 1 1],...
'FontSize',10,...
'FontWeight','b',...
'String','Capacitance',...
'Parent',Group1);
uicontrol('Style','Edit',...
'Units','Normalized',...
'Position',[0.25,0.40,0.5,0.08],...
'FontSize',10,...
'String',C,...
'Callback',['C=','str2num(get(gco,''String'')),close,HPF_RC_graphics(R,C,f,val)'],...
'Parent',Group1);
uicontrol('Style','Text',...
'Units','Normalized',...
'Position',[0.75,0.40,0.2,0.08],...
'BackgroundColor',[1 0.6 1],...
'FontSize',10,...
'FontWeight','b',...
'String','[F]',...
'Parent',Group1);
%Frequency
uicontrol('Style','Text',...
'Units','Normalized',...
'Position',[0.25,0.20,0.5,0.08],...
```

```
'BackgroundColor',[1 1 1],...
'FontSize',10,...
'FontWeight','b',...
'String','Precision',...
'Parent',Group1);
uicontrol('Style','Edit',...
'Units','Normalized',...
'Position',[0.25,0.10,0.5,0.08],...
'FontSize',12,...
'String',f,...
'Callback',['f=','str2num(get(gco,''String'')),close,HPF_RC_graphics(R,C,f,val)'],...
'Parent',Group1);
uicontrol('Style','Text',...
'Units','Normalized',...
'Position',[0.75,0.10,0.2,0.08],...
'BackgroundColor',[1 0.6 1],...
'FontSize',10,...
'FontWeight','b',...
'String','[Hz]',...
'Parent',Group1);
Group2=uibuttongroup('Visible','on',...
'BackgroundColor','[0.925 0.870 0.925]',...
'ForegroundColor','black',...
'Title','Calculations',...
'FontSize',13,...
'FontWeight','b',...
'Position',[0.75 0.30 0.2 0.18],...
'TitlePosition','centertop',...
'Tag','radiobutton');
%Formulas/Calculations
f0=1./(2.*pi.*C.*R);
w0=2.*pi.*f0;
w=logspace(1,6,f);
f2=w/(2*pi);
num=R*C*w*j;
den=R*C*w*j + 1;
h=abs(num./den);
```

```
gain=20*log10(h);

faza=angle(num./den)*180/pi;

uicontrol('Style','Text',...

'Units','Normalized',...

'Position',[0.10,0.7,0.8,0.2],...

'BackgroundColor','[1 1 1]',...

'FontSize',13,...

'FontWeight','b',...

'String',['f0 = ',num2str(f0),' Hz '],...

'Parent',Group2);

uicontrol('Style','Text',...

'Units','Normalized',...

'Position',[0.10,0.3,0.8,0.2],...

'BackgroundColor','[1 1 1]',...

'FontSize',13,...

'FontWeight','b',...

'String',['w0 = ',num2str(w0),' Rad/s '],...

'Parent',Group2);

% Display group

GroupAfis=uibuttongroup('Visible','on',...

'FontWeight', 'bold',...

'Title','Signal:',...

'FontSize',10,...

'BackgroundColor','[0.925 0.870 0.925]',...

'TitlePosition','centertop',...

'Position',[0.70 0.88 0.30 0.12]);

% GRID

uicontrol('style','text',...

'Units','normalized',...

'String','Grid:',...

'FontWeight', 'bold',...

'Position',[0.05 0.05 0.5 0.4],...

'BackgroundColor','[1 1 1]',...

'Parent',GroupAfis);

RadioB1=uicontrol('style','radiobutton',...

'Units','normalized',...

'String','ON',...
'FontWeight', 'bold',...
'Position',[0.55 0.25 0.2 0.2],...
'Parent',GroupAfis,...
'BackgroundColor','[1 0.6 1]',...
'Callback','val=1,close;HPF_RC_graphics(R,C,f,val);');
RadioB2=uicontrol('style','radiobutton',...
'Units','normalized',...
'String','OFF',...
'FontWeight', 'bold',...
'Position',[0.75 0.25 0.2 0.2],...
'BackgroundColor','[1 0.6 1]',...
'Parent',GroupAfis,...
'Callback','val=2,close;HPF_RC_graphics(R,C,f,val);');
%Graphics
subplot('Position', [0.1 0.72 0.6 0.23]);
semilogx(f2,h,'g-',f0,1./sqrt(2),'o', 'LineWidth',3);
grid on;
xlabel('Frequency [ Hz ]');
ylabel('|H(jw)| ');
title('Transfer Function |H(jw)|','Fontweight','b');
legend(' |U2 / U1 |');
if val == 1
set(RadioB1,'value',1)
set(RadioB2,'value',0)
grid on;
else
set(RadioB1,'value',0)
set(RadioB2,'value',1)
grid off;
end
subplot('Position', [0.1 0.40 0.6 0.23]);
semilogx(f2,gain,'r-',f0,-3,'o','LineWidth',3);
grid on;
xlabel('Frequency [ Hz ]');
ylabel('Gain [ dB ]');
title('Gain','fontweight','b');
legend('Gain')
```

```
if val == 1
set(RadioB1,'value',1)
set(RadioB2,'value',0)
grid on;
else
set(RadioB1,'value',0)
set(RadioB2,'value',1)
grid off;
end
subplot('Position', [0.1 0.08 0.6 0.23]);
semilogx(f2,faza,'b-',f0,+45,'o','LineWidth',3);
grid on;
xlabel('Frequency [ Hz ]');
ylabel('Phase [ rad ]');
title('Signal Phase','Fontweight','b');
legend('Phase');
if val == 1
set(RadioB1,'value',1)
set(RadioB2,'value',0)
grid on;
else
set(RadioB1,'value',0)
set(RadioB2,'value',1)
grid off;
end
%Close
uicontrol('Style','pushbutton', ...
'Units','normalized', ...
'Position',[0.80 0.1 0.10 0.06], ...
'BackgroundColor','[1 0.6 1]',...
'String','Close', ...
'FontName','Times New Roman',...
'FontSize',19,...
'FontWeight','Bold',...
'Callback','close;');
uicontrol('style','pushbutton',...
'Units','normalized',...
'Position',[0.8 0.02 0.10 0.06],...
'string','Back',...
'FontName','Times New Roman',...
'backgroundcolor',[1 0.6 1],...
'FontSize',19,...
'FontWeight','Bold',...
'Callback','start');
end
```

```
%HPF_RC_circuit% (The GUI provides a visual representation of the RC High Pass Filter circuit, showing the circuit's physical layout.)
function HPF_RC_circuit
figure('Name','RC High Pass Filter Project',...
'Units','normalized',...
'Position',[0.1 0.07 0.7 0.83],...
'NumberTitle','off');
set(gcf, 'Color',[0.815 0.866 0.925]);
% Title
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.25 0.82 0.5 0.08],...
'backgroundcolor',[0.925 0.870 0.925],...',...
'foregroundcolor','black',...
'Fontname','Times New Roman',...
'FontWeight','Bold',...
'FontSize',26,...
'String','RC High Pass Filter');
% Read HPF Image
uicontrol('Style','text',...
'Units','normalized',...
'Position',[0.35 0.73 0.3 0.05],...
'backgroundcolor',[0.925 0.870 0.925],...
'foregroundcolor','black',...
'FontWeight','Bold',...
'Fontname','Times New Roman',...
'FontSize',18,...
'String','The HPF Cricuit');
subplot('position',[0.15 0.20 0.7 0.5])
z = imread('fts.png');
image(z);
axis off;
uicontrol('style','pushbutton',...
'Units','normalized',...
'Position',[0.7 0.05 0.205 0.1],...
'string','Back',...
'FontName','Times New Roman',...
'backgroundcolor',[0.925 0.870 0.925],...
'FontSize',19,...
'FontWeight','Bold',...
'Callback','start');
end
```

%HPF_RC_values% (The primary purpose is to initialize parameters and then visualize the graphical user interface (GUI) created by the HPF_RC_graphics function for an RC High Pass Filter with the specified parameters. The GUI displays the plots of the gain, phase, and transfer function, based on the given parameters.)

```
close all;
clear;
R = 10000;
C = 0.000001;
f = 100;
val=1;
HPF_RC_graphics(R,C,f,val);
```