

# **Powerline noise elimination**

## **MATLAB tutorial series (Part 2.2)**

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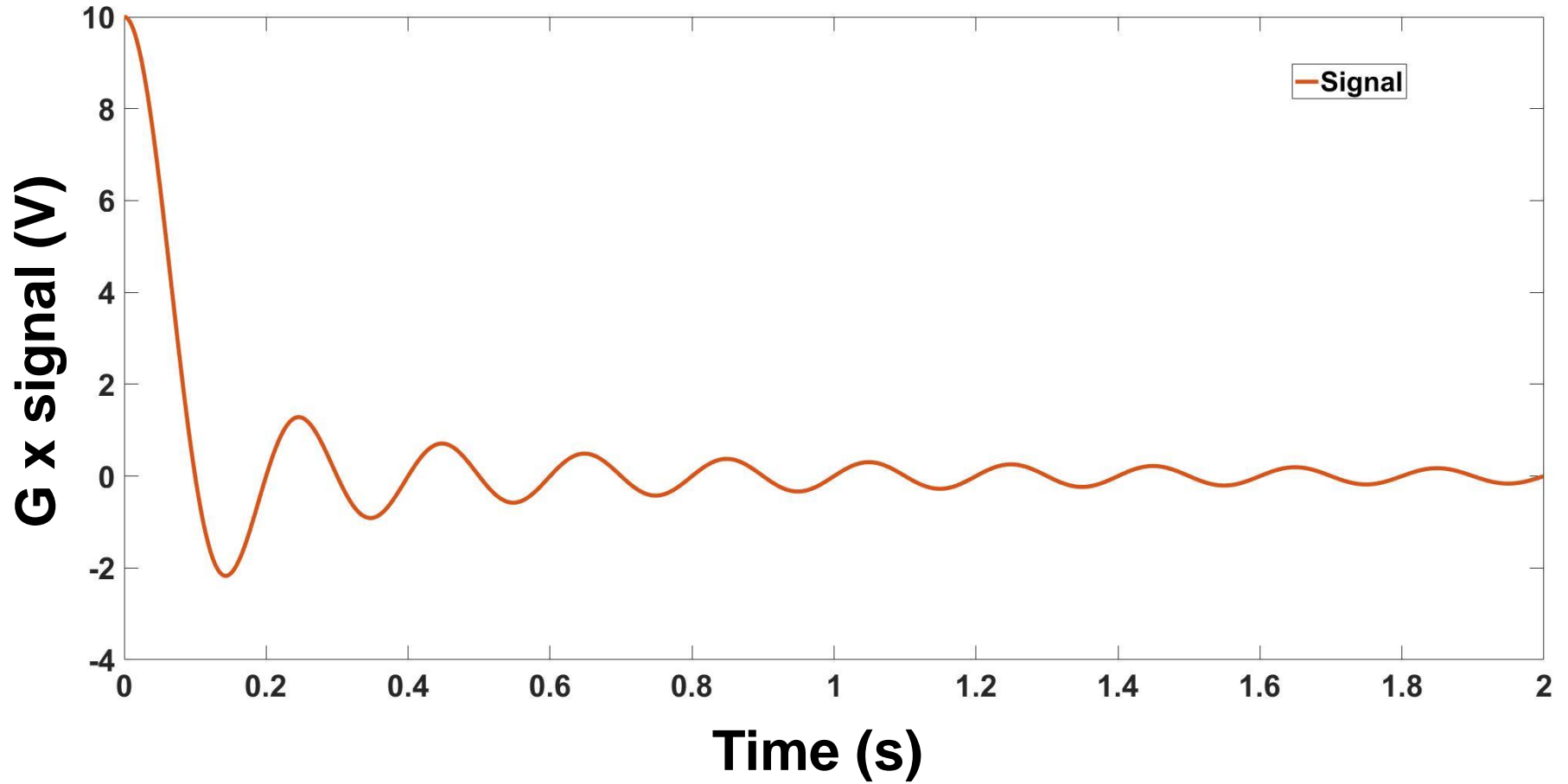
**Laboratory for Signal and Image Exploitation (INTELSIG)  
Dept. of Electrical Engineering and Computer Science  
University of Liège  
Liège, Belgium**

**Applied digital signal processing (ELEN0071-1)**

**31 March 2021**

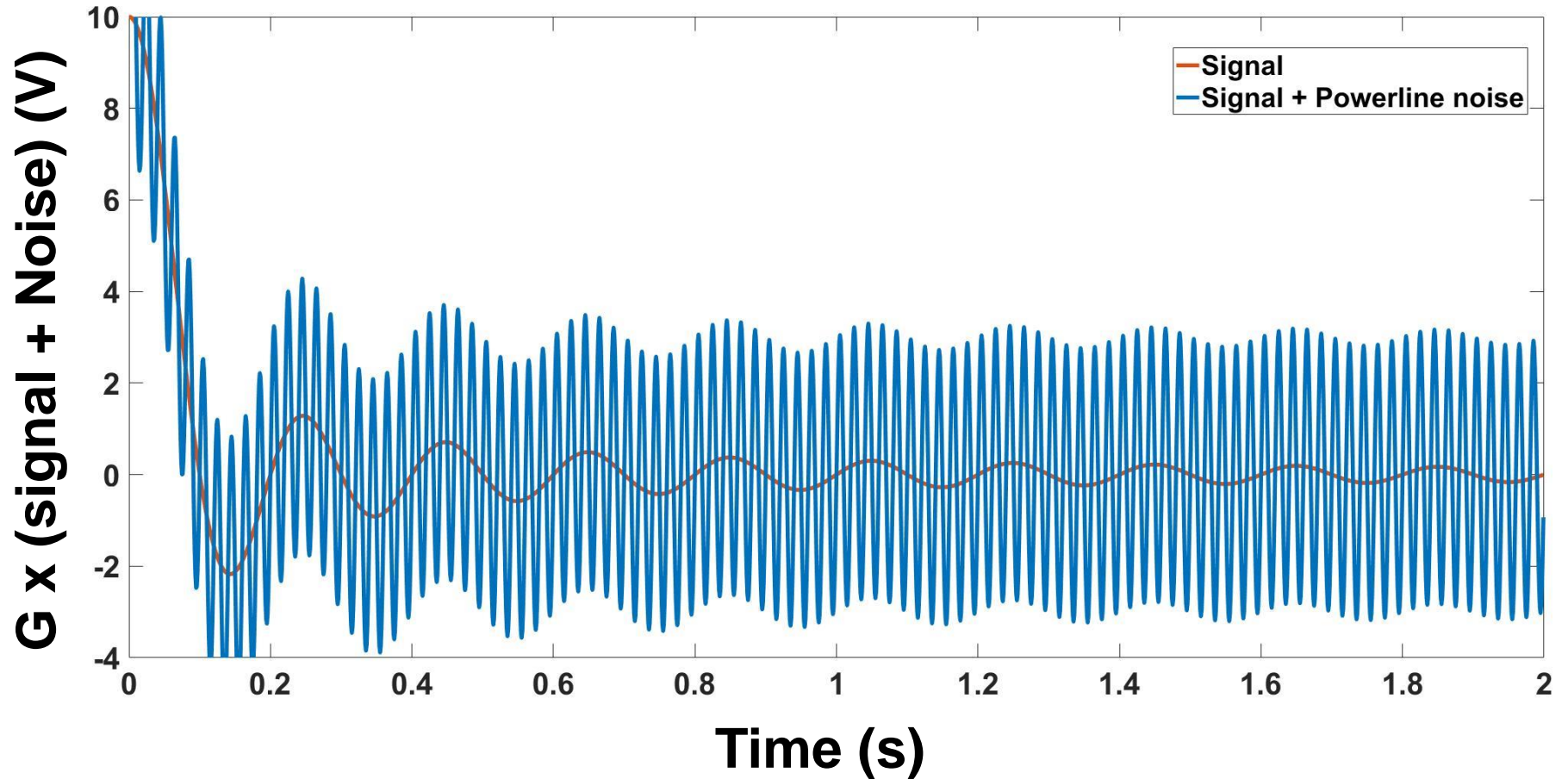
# Motivation

## Signal measured in an ideal environment



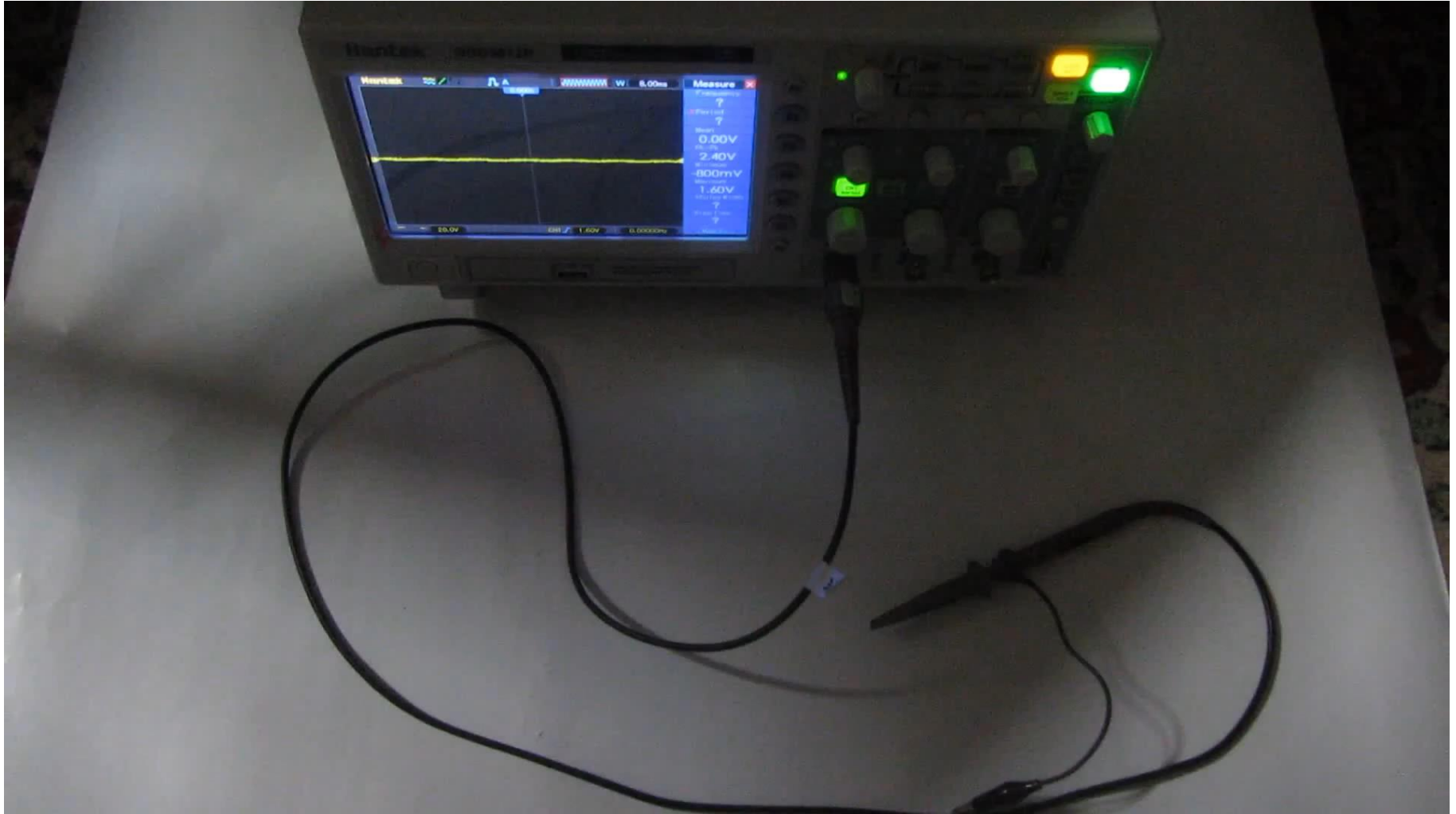
# Motivation

## Signal measured in a real environment



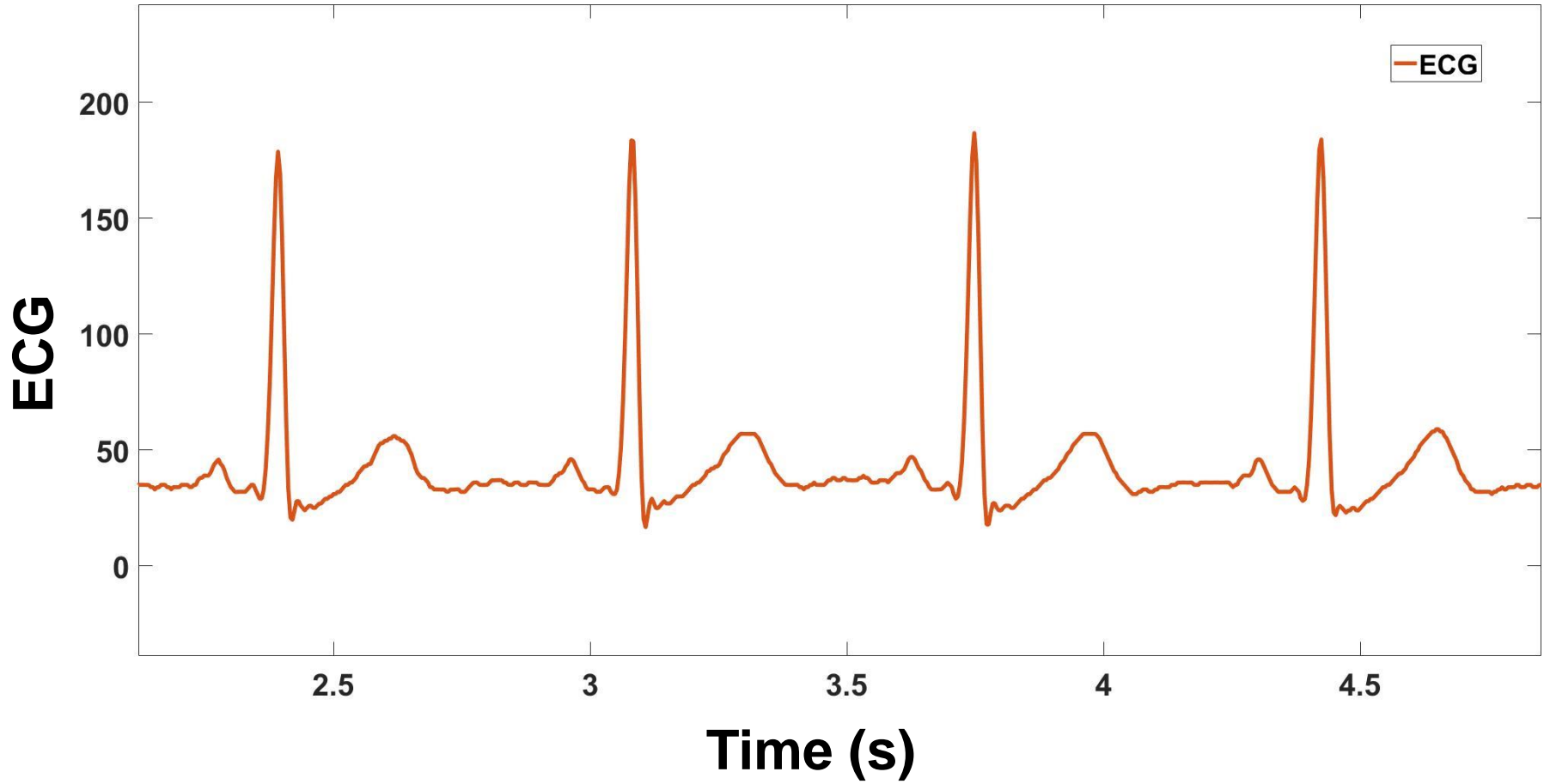
# Human body as an antenna

**50Hz noise exists !**



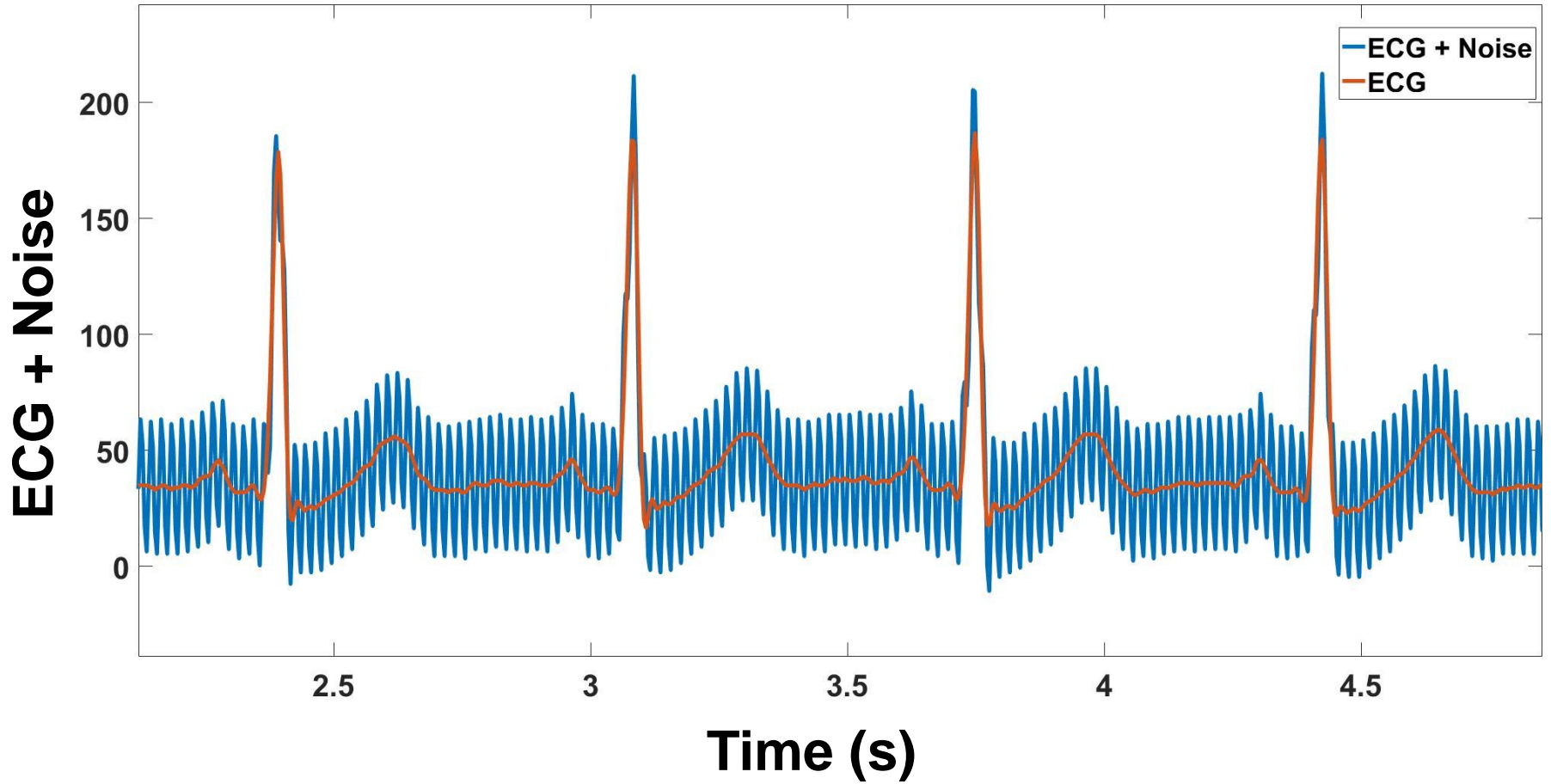
# Electrocardiogram (ECG)

## Clean ECG



# Electrocardiogram (ECG)

## ECG measured in a noisy environment



# Powerline noise elimination

- **Step 1: plot the signal**
  - find the sampling period ( $T_s$ )
  - find the ending time ( $T_{max}$ )
  - find the length of the signal ( $N$ )

# Powerline noise elimination

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- **Step 2: plot one-sided magnitude spectrum**
  - use fft to plot magnitude spectrum



# Powerline noise elimination

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- **Step 3: identify the noise frequencies**

# Powerline noise elimination

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  - use fft to plot magnitude spectrum
- **Step 3: identify the noise frequencies**
- **Step 4: filter out undesired frequency components**
  - here we used **Notch filter** (i.e. Notching)

# Powerline noise elimination

- **Step 1: plot the signal**
  - find the sampling period ( $T_s$ )
  - find the ending time ( $T_{max}$ )
  - find the length of the signal ( $N$ )
- **Step 2: plot one-sided magnitude spectrum**
  - use fft to plot magnitude spectrum
- **Step 3: identify the noise frequencies**
- **Step 4: filter out undesired frequency components**
  - here we used **Notch filter** (i.e. Notching)
- **Step 5: plot the results**
  - Plot the original and filtered signals together

# Step 1: plot the signal

```
% Load ecg signal from .mat file
```

```
load('TNS_2_1_2018_example1.mat','ecg')
```

# Step 1: plot the signal

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% Load ecg signal from .mat file
```

```
load('TNS_2_1_2018_example1.mat','ecg')
```

```
% Fs is given
```

```
Fs=250;
```

# Step 1: plot the signal

% Load ecg signal from .mat file

```
load('TNS_2_1_2018_example1.mat','ecg')
```

% Fs is given

```
Fs=250;
```

% Ts sampling period

```
Ts=1/Fs;
```

% Length of the signal

```
N=length(ecg);
```

# Step 1: plot the signal

```
% Load ecg signal from .mat file
load('TNS_2_1_2018_example1.mat','ecg')
% Fs is given
Fs=250;
% Ts sampling period
Ts=1/Fs;
% Length of the signal
N=length(ecg);
% Ending time
Tmax=(N-1)*Ts;
% Time vector
t=0:Ts:Tmax;
```

# Step 1: plot the signal

```
% Plot the original signal
```

```
figure(1)
```

```
plot(t,ecg)
```

```
xlabel('Time (s)')
```

```
title('ECG + noise')
```



## Step 2: plot one-sided magnitude spectrum

```
% Compute fft  
ECG=fft(ecg);
```

## Step 2: plot one-sided magnitude spectrum

% Compute fft

```
ECG=fft(ecg);
```

% Take abs and scale it

```
ECG2=abs(ECG/N);
```

## Step 2: plot one-sided magnitude spectrum

```
% Compute fft
ECG=fft(ecg);
% Take abs and scale it
ECG2=abs(ECG/N);
% Pick the first half
ECG1=ECG2(1:N/2+1);
```

## Step 2: plot one-sided magnitude spectrum

```
% Compute fft
ECG=fft(ecg);
% Take abs and scale it
ECG2=abs(ECG/N);
% Pick the first half
ECG1=ECG2(1:N/2+1);
% Multiply by 2 (except the DC part), to compensate
% the removed side from the spectrum.
ECG1(2:end-1) = 2*ECG1(2:end-1);
```

## Step 2: plot one-sided magnitude spectrum

% Compute fft

```
ECG=fft(ecg);
```

% Take abs and scale it

```
ECG2=abs(ECG/N);
```

% Pick the first half

```
ECG1=ECG2(1:N/2+1);
```

% Multiply by 2 (except the DC part), to compensate  
% the removed side from the spectrum.

```
ECG1(2:end-1) = 2*ECG1(2:end-1);
```

% Frequency range

```
F = Fs*(0:(N/2))/N;
```

## Step 2: plot one-sided magnitude spectrum

```
% Plot single-sided spectrum
```

```
figure(2)
```

```
plot(F,ECG1,'LineWidth',2.5)
```

```
title('Single-Sided Amplitude Spectrum')
```

```
xlabel('f (Hz)');
```

## **Step 3: identify the noise frequencies**

**Just take a look to the  
single-sided magnitude spectrum  
and you will see**

**...**

# Notch filter for dummies

## Apps

The screenshot shows the MATLAB R2016b interface with the 'APPS' tab selected. The 'APPS' tab is circled in orange. The interface displays a list of applications categorized into several groups:

- FAVORITES:** Curve Fitting, Optimization, PID Tuner, System Identification, Signal Analyzer, Image Acquisition, Instrument Control, SimBiology, MATLAB Coder, Application Compiler.
- MATH, STATISTICS AND OPTIMIZATION:** Classification Learner, Curve Fitting, Distribution Fitting, MBC Model Fitting, MBC Optimization, Neural Net Clustering, Neural Net Fitting, Neural Net Pattern Reco..., Neural Net Time Series, Optimization, PDE.
- CONTROL SYSTEM DESIGN AND ANALYSIS:** Control System Designer, Control System Tuner, Fuzzy Logic Designer, Linear System Analyzer, Model Reducer, MPC Designer, Neuro-Fuzzy Designer, PID Tuner, System Identification.
- SIGNAL PROCESSING AND COMMUNICATIONS:** Bit Error Rate Analysis, Eye Diagram Scope, Filter Builder, Filter Designer, Radar Equation Calculator, Radar Waveform A..., RF Budget Analyzer, Sensor Array Analyzer.
- IMAGE PROCESSING AND COMPUTER VISION:** Camera Calibrator, Color Thresholder, Image Browser, Image Acquisition, Image Batch Processor, Image Region Analyzer, Image Segmenter, Image Viewer, Map Viewer, OCR Trainer, Stereo Camera Calibrator, Training Image Labeler.
- TEST AND MEASUREMENT:** Video Viewer.

The 'Filter Designer' application is highlighted with a tooltip that reads: "Filter Designer Design filters starting with algorithm selection (filterDesigner) Signal Processing Toolbox 7.3".

The left sidebar shows a file explorer with various files, including MATLAB scripts (.m), Excel files (.xlsx), and image files (.png). The right sidebar shows a list of files with their corresponding sizes.



# Notch filter for dummies

The image shows the MATLAB R2016b APPS window. The left sidebar contains a file explorer with various MATLAB files, including 'test\_performance.m', 'test\_ts2.m', 'testdata.xlsx', and several 'testic' and 'teston' files. The main area displays a grid of application icons categorized into sections: FAVORITES, MATH, STATISTICS AND OPTIMIZATION, CONTROL SYSTEM DESIGN AND ANALYSIS, SIGNAL PROCESSING AND COMMUNICATIONS, IMAGE PROCESSING AND COMPUTER VISION, and TEST AND MEASUREMENT. The 'Filter Designer' icon in the 'SIGNAL PROCESSING AND COMMUNICATIONS' section is circled in orange. A tooltip for this icon reads: 'Filter Designer Design filters starting with algorithm selection (filterDesigner) Signal Processing Toolbox 7.3'. A large orange text overlay 'Filter designer' is positioned at the bottom center of the image.

MATLAB R2016b

HOME PLOTS APPS

Get More Apps Install App Package App

FILE

Current Folder

Name

- test\_performance.m
- test\_ts2.m
- testdata.xlsx
- testic2.m
- testic3.m
- testic4.m
- testic5.m
- testic6.m
- testic.m
- teston2.m
- teston.m
- testor2.m
- testor3.m
- testor.m
- testtest.m
- tictoc.m
- TNS2.m
- TNS\_2\_1\_2018\_examp
- TNS\_ECG.asv
- TNS\_ECG.m
- TNS\_fig.asv
- TNS\_fig.m
- TNS\_homework\_1\_201
- TNS\_homework\_3\_201
- TNS\_lowpas.mat
- TNS\_notch\_sound.asv
- TNS\_notch\_sound.m
- TNS\_TP1\_1\_2018.m
- TNS\_TP1\_2\_2018.asv
- TNS\_TP1\_2\_2018.m
- TNS\_TP1\_3\_2018.m
- TNS\_TP2\_1\_2018.m
- TNS\_TP2\_2\_2018.asv
- TNS\_TP2\_2\_2018.m
- toghi.m
- Topo.png
- testh.m

FAVORITES

- Curve Fitting
- Optimization
- PID Tuner
- System Identification
- Signal Analyzer
- Image Acquisition
- Instrument Control
- SimBiology
- MATLAB Coder
- Application Compiler

MATH, STATISTICS AND OPTIMIZATION

- Classification Learner
- Curve Fitting
- Distribution Fitting
- MBC Model Fitting
- MBC Optimization
- Neural Net Clustering
- Neural Net Fitting
- Neural Net Pattern Reco...
- Neural Net Time Series
- Optimization
- PDE

CONTROL SYSTEM DESIGN AND ANALYSIS

- Control System Designer
- Control System Tuner
- Fuzzy Logic Designer
- Linear System Analyzer
- Model Reducer
- MPC Designer
- Neuro-Fuzzy Designer
- PID Tuner
- System Identification

SIGNAL PROCESSING AND COMMUNICATIONS

- Bit Error Rate Analysis
- Eye Diagram Scope
- Filter Builder
- Filter Designer
- Signal Analyzer
- Wavelet Analyzer
- Window Designer
- Radar Equation Calculator
- Radar Waveform A...
- RF Budget Analyzer
- Sensor Array Analyzer

IMAGE PROCESSING AND COMPUTER VISION

- Camera Calibrator
- Color Thresholder
- Image Browser
- Image Acquisition
- Image Batch Processor
- Image Region Analyzer
- Image Segmenter
- Image Viewer
- Map Viewer
- OCR Trainer
- Stereo Camera Calibrator
- Training Image Labeler
- Video Viewer

TEST AND MEASUREMENT

Filter Designer  
Design filters starting with algorithm selection (filterDesigner)  
Signal Processing Toolbox 7.3

Filter designer

# Notch filter for dummies

The screenshot shows the 'Filter Designer' application window. The title bar reads 'Filter Designer - [untitled.fda]'. The menu bar includes 'File', 'Edit', 'Analysis', 'Targets', 'View', 'Window', and 'Help'. The toolbar contains various icons for file operations and analysis. The main workspace is divided into several panels:

- Current Filter Information:** Structure: Direct-Form FIR, Order: 50, Stable: Yes, Source: Designed. Buttons for 'Store Filter ...' and 'Filter Manager ...' are visible.
- Filter Specifications:** A plot of Magnitude (dB) vs. frequency f (Hz). The plot shows a flat line at 0 dB in the passband, a sharp notch at  $F_s/2$ , and a steep roll-off in the stopband. Labels include  $A_{pass}$  and  $A_{stop}$ .
- Response Type:** Radio buttons for Lowpass (selected), Highpass, Bandpass, and Bandstop. A dropdown menu is set to 'Differentiator'.
- Design Method:** Radio buttons for IIR (Butterworth) and FIR (Equiripple, selected).
- Magnitude Specifications:** Units: dB,  $A_{pass}$ : 1,  $A_{stop}$ : 80.
- Options:** Density Factor: 20,  $F_{stop}$ : 12000.

A 'Tip of the Day' dialog box is overlaid on the plot area. It features a lightbulb icon and the text: 'Did you know ... You can add data markers to your analyses by single-clicking on the analysis plot.' The dialog has a 'Close' button circled in orange, with the word 'Close' written in large orange text below it. A 'Next' button and a 'Don't show me this again' checkbox are also visible.

Ready

# Notch filter for dummies

Filter Designer - [untitled.fda \*]

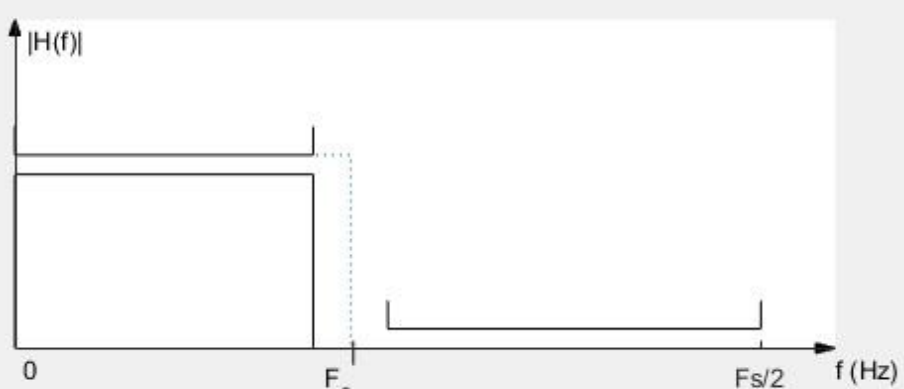
File Edit Analysis Targets View Window Help

Current Filter Information

Structure: Direct-Form FIR  
Order: 50  
Stable: Yes  
Source: Designed

Store Filter ...  
Filter Manager ...

Filter Specifications



Response Type

Lowpass  
 Highpass  
 Bandpass  
 Bandstop  
 Notching

Design Method

IIR Butterworth  
 FIR Equiripple

Filter Order

Specify order: 10  
 Minimum order

Options

There are no optional parameters for this design method.

Frequency Specifications

Units: Hz  
Fs: 48000  
Fc: 10800

Magnitude Specifications

The attenuation at cutoff frequencies is fixed at 3 dB (half the passband power)

Design Filter

Ready

# Notch filter for dummies

Filter Designer - [untitled.fda \*]

File Edit Analysis Targets View Window Help

Current Filter Information

Structure: Direct-Form FIR  
Order: 50  
Stable: Yes  
Source: Designed

Store Filter ...  
Filter Manager ...

Filter Specifications

Response Type

- Lowpass
- Highpass
- Bandpass
- Bandstop
- Notching

Des

- Differentiator
- Multiband
- Hilbert Transformer
- Arbitrary Magnitude
- Arbitrary Group Delay
- Peaking
- Notching

Filter Order

Specify order: 10  
 Minimum order

Options

There are no optional parameters for this design method.

Frequency Specifications

Units: Hz  
Fs: 48000

Bandwidth: 1200  
 Q: 45

Magnitude Specifications

Units: dB  
Apass: 1

Design Filter

Ready

## Notching

# Notch filter for dummies

Filter Designer - [untitled.fda \*]

File Edit Analysis Targets View Window Help

Current Filter Information

Structure: Direct-Form FIR  
Order: 50  
Stable: Yes  
Source: Designed

Store Filter ...  
Filter Manager ...

Filter Specifications

Response Type

Lowpass  
 Highpass  
 Bandpass  
 Bandstop  
 Notching

Design Method

IIR  
Comb  
Comb  
 FIR  
Single Notch

Filter Order

Specify order: 10  
 Minimum order

Options

There are no optional parameters for this design method.

Frequency Specifications

Units: Hz  
Fs: 48000

Bandwidth 1200  
 Q 45

Magnitude Specifications

Units: dB  
Apass: 1

Design Filter

Ready

**Single notch**

# Notch filter for dummies

Filter Designer - [untitled.fda \*]

File Edit Analysis Targets View Window Help

Current Filter Information

Structure: Direct-Form FIR  
Order: 50  
Stable: Yes  
Source: Designed

Store Filter ...  
Filter Manager ...

Filter Specifications

Response Type

Lowpass  
 Highpass  
 Bandpass  
 Bandstop  
 Notching

Design Method

IIR Single Notch  
 FIR Equiripple

Filter Order

Specify order: 10  
 Minimum order

Options

There are no optional parameters for this design method.

Frequency Specifications

Units: Hz  
Fs: 250  
Fnotch: 5

Magnitude Specifications

Units: dB  
Apass: 1

Bandwidth 1  
 Q 45

Design Filter

Ready

# Notch filter for dummies

Filter Designer - [untitled.fda \*]

File Edit Analysis Targets View Window Help

Current Filter Information

Structure: Direct-Form FIR  
Order: 50  
Stable: Yes  
Source: Designed

Store Filter ...  
Filter Manager ...

Filter Specifications

Response Type

Lowpass  
 Highpass  
 Bandpass  
 Bandstop  
 Notching

Design Method

IIR Single Notch  
 FIR Equiripple

Filter Order

Specify order: 10  
 Minimum order

Options

There are no optional parameters for this design method.

Frequency Specifications

Units: Hz  
Fst: 250  
Fnotch: 50

Magnitude Specifications

Units: dB  
Apass: 1

Bandwidth 1  
 Q 45

Design Filter

Ready

**Sampling frequency**

# Notch filter for dummies

Filter Designer - [untitled.fda \*]

File Edit Analysis Targets View Window Help

Current Filter Information

Structure: Direct-Form FIR  
Order: 50  
Stable: Yes  
Source: Designed

Store Filter ...  
Filter Manager ...

Filter Specifications

Mag. (dB)

0

0

$F_{\text{notch}}$

$F_s/2$

f (Hz)

$A_{\text{pass}}$

BW

Response Type

Lowpass  
 Highpass  
 Bandpass  
 Bandstop  
 Notching

Design Method

IIR Single Notch  
 FIR Equiripple

Filter Order

Specify order: 10  
 Minimum order

Options

There are no optional parameters for this design method.

Frequency Specifications

Units: Hz  
Fs: 250  
Fnotch: 50  
Bandwidth: 1  
Q: 45

Magnitude Specifications

Units: dB  
Apass: 1

Design Filter

Ready

**Notch frequency**



# Notch filter for dummies

The screenshot shows the 'Filter Designer' software interface. The title bar reads 'Filter Designer - [untitled.fda \*]'. The menu bar includes 'File', 'Edit', 'Analysis', 'Targets', 'View', 'Window', and 'Help'. The toolbar contains various icons for file operations and analysis.

**Current Filter Information:**

- Structure: Direct-Form FIR
- Order: 50
- Stable: Yes
- Source: Designed

**Filter Specifications:**

A graph shows the magnitude response (Mag. (dB)) versus frequency (f (Hz)). The magnitude is 0 dB in the passbands and drops to a notch at  $F_{\text{notch}}$ . The notch width is labeled 'BW'. The sampling rate is  $F_s/2$ . The passband attenuation is  $A_{\text{pass}}$ .

**Response Type:**

- Lowpass
- Highpass
- Bandpass
- Bandstop
- Notching

**Filter Order:**

- Specify order: 10
- Minimum order

**Options:**

There are no optional parameters for this design method.

**Frequency Specifications:**

- Units: Hz
- $F_s$ : 250
- $F_{\text{notch}}$ : 50
- Bandwidth: 1
- Q: 45

**Magnitude Specifications:**

- Units: dB
- $A_{\text{pass}}$ : 1

The 'Bandwidth' field in the Frequency Specifications section is circled in orange, with the word 'sharpness' written in orange below it.

Buttons: 'Store Filter ...', 'Filter Manager ...', 'Design Filter'.

Status: Ready

# Notch filter for dummies

The screenshot shows the 'Filter Designer' software interface. The title bar reads 'Filter Designer - [untitled.fda \*]'. The menu bar includes 'File', 'Edit', 'Analysis', 'Targets', 'View', 'Window', and 'Help'. The toolbar contains various icons for file operations and analysis.

**Current Filter Information:**

- Structure: Direct-Form FIR
- Order: 50
- Stable: Yes
- Source: Designed

**Filter Specifications:**

The graph shows Magnitude (Mag. (dB)) on the y-axis and frequency (f (Hz)) on the x-axis. The magnitude is 0 dB in the passbands and drops to a notch at  $F_{\text{notch}}$  with a bandwidth (BW). The sampling rate is  $F_s/2$ . The passband attenuation is  $A_{\text{pass}}$ .

**Response Type:**

- Lowpass
- Highpass
- Bandpass
- Bandstop
- Notching

**Design Method:**

- IIR Single Notch
- FIR Equiripple

**Filter Order:**

- Specify order: 10
- Minimum order

**Options:**

There are no optional parameters for this design method.

**Frequency Specifications:**

- Units: Hz
- $F_s$ : 250
- $F_{\text{notch}}$ : 50
- Bandwidth: 1
- Q: 45

**Magnitude Specifications:**

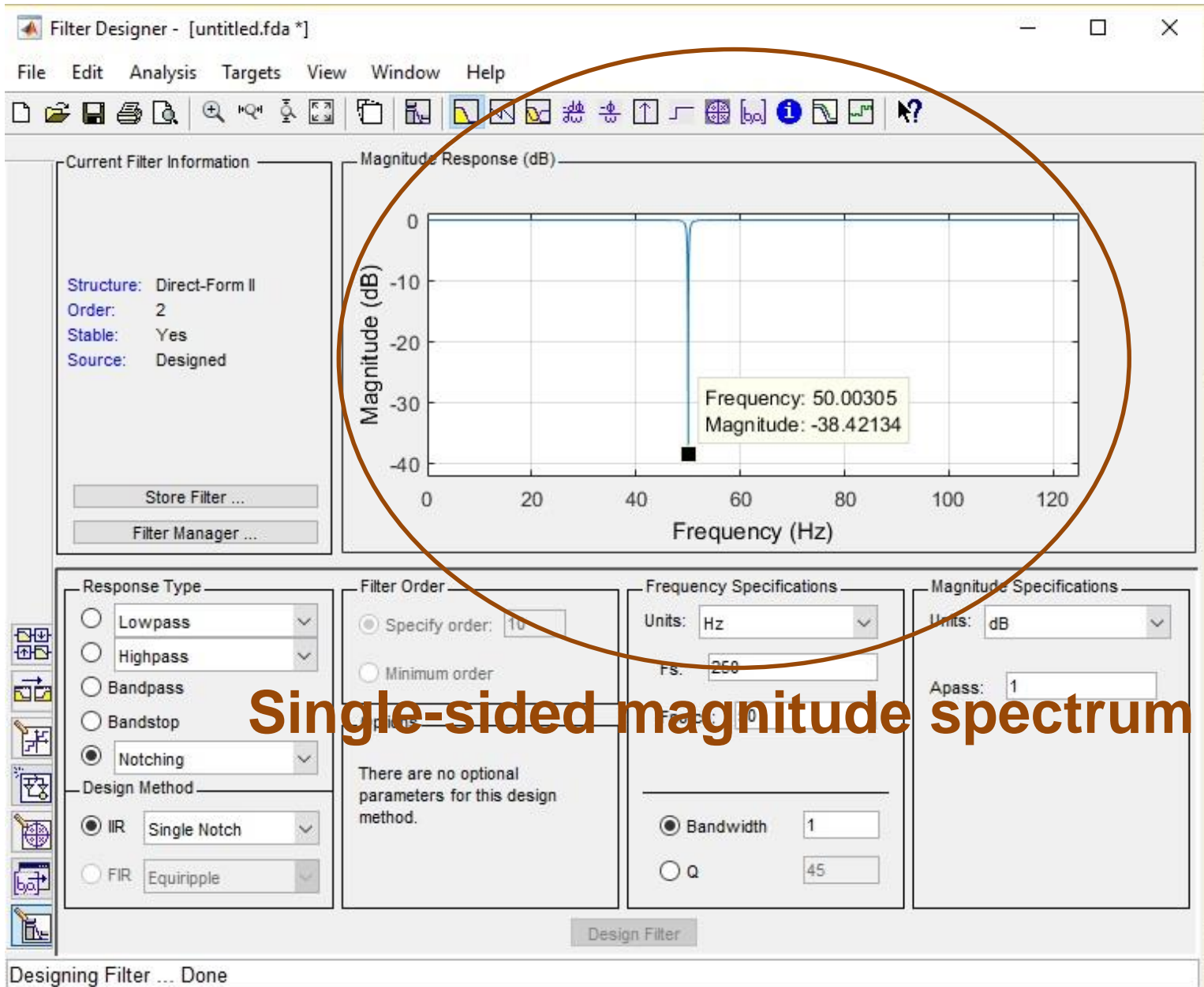
- Units: dB
- $A_{\text{pass}}$ : 1

**Design Filter** (button circled in orange)

**Lets go !** (text overlay)

Ready

# Notch filter for dummies



# Notch filter for dummies

The screenshot displays the Filter Designer software interface. The title bar reads "Filter Designer - [untitled.fda \*]". The menu bar includes "File", "Edit", "Analysis", "Targets", "View", "Window", and "Help". The toolbar contains various icons for file operations and analysis.

**Current Filter Information:**

- Structure: Direct-Form II
- Order: 2
- Stable: Yes
- Source: Designed

**Pole/Zero Plot:**

The plot shows the complex plane with the Real Part on the x-axis (ranging from -2 to 2) and the Imaginary Part on the y-axis (ranging from -1 to 1). A dashed unit circle is centered at the origin. Two poles, marked with blue 'x' symbols, are located on the unit circle at approximately  $z = 0.5 + j0.866$  and  $z = 0.5 - j0.866$ .

**Response Type:**

- Lowpass
- Highpass
- Bandpass
- Bandstop
- Notching

**Design Method:**

- IIR: Single Notch
- FIR: Equiripple

**Filter Order:**

- Specify order: 10
- Minimum order

**Options:**

There are no optional parameters for this design method.

**Frequency Specifications:**

- Units: Hz
- Fs: 250
- Filter order: 50

**Magnitude Specifications:**

- Units: dB
- Apass: 1

**Design Filter**

**Pole and zeros**

Designing Filter ... Done

# Notch filter for dummies

The screenshot shows the Filter Designer application window with the 'File' menu open. The 'Export...' option is highlighted with a blue background and circled in orange. The text 'Export ...' is overlaid in large brown font. The main workspace displays a complex plane plot with a dashed unit circle and two poles marked with 'x' on the imaginary axis. The bottom panel shows filter specifications: Notching, IIR Single Notch, 10th order, 250 Hz sampling rate, 50 Hz notch frequency, and 1 dB passband ripple.

Filter Designer - [untitled.fda \*]

File Edit Analysis Targets View Window Help

- New Session Ctrl+N
- Open Session... Ctrl+O
- Save Session Ctrl+S
- Save Session As...
- Store Filter...
- Import Filter from Workspace Ctrl+I
- Import Filter from XILINX Coefficient (.COE) File
- Export to Simulink Model
- Export... Ctrl+E**
- Generate MATLAB Code >
- Print Preview
- Print... Ctrl+P
- Print to Figure
- Close

Real Part

Frequency Specifications

- Units: Hz
- Fs: 250
- Fnotch: 50
- Bandwidth: 1
- Q: 45

Magnitude Specifications

- Units: dB
- Apass: 1

Design Filter

Designing Filter ... Done

# Notch filter for dummies

The screenshot displays the 'Filter Designer' application window. The main interface is divided into several sections:

- Current Filter Information:** Structure: Direct-Form II, Order: 2, Stable: Yes, Source: Designed.
- Pole/Zero Plot:** A graph showing the imaginary part of the poles and zeros. A pole is visible at approximately  $s = 1 + j$ .
- Response Type:** Notching (selected).
- Design Method:** IIR Single Notch (selected).
- Magnitude Specifications:** Units: dB, Apass: 1.

An 'Export' dialog box is open in the center, with the following options:

- Export To: **Workspace** (circled in red)
- Export As: Objects (selected in the dropdown menu)
- Overwrite Variables:

The text 'Export to workspace' is overlaid in large orange font across the dialog box. The status bar at the bottom indicates 'Designing Filter ... Done'.

# Notch filter for dummies

The screenshot displays the Filter Designer application window. The main interface is divided into several sections:

- Current Filter Information:** Structure: Direct-Form II, Order: 2, Stable: Yes, Source: Designed. Buttons for "Store Filter ..." and "Filter Manager ..." are visible.
- Pole/Zero Plot:** A graph showing the imaginary part of the filter's poles and zeros. A notch is visible at the top of the plot.
- Response Type:** Radio buttons for Lowpass, Highpass, Bandpass, Bandstop, and Notching (selected).
- Design Method:** Radio buttons for IIR (selected) and FIR. Under IIR, "Single Notch" is selected.
- Magnitude Specifications:** Units: dB, Apass: 1.
- Options:** "Bandwidth" is set to 1, and "Q" is set to 45.

An "Export" dialog box is open in the center, with the "Export As" dropdown menu expanded. The "Objects" option is circled in red, and the text "Export as objects" is overlaid in large brown font. The dialog also shows "Export To" set to "Workspace" and an "Overwrite Variables" checkbox.

Designing Filter ... Done

# Notch filter for dummies

The screenshot shows the 'Filter Designer' application window. The main interface is divided into several sections:

- Current Filter Information:** Structure: Direct-Form II, Order: 2, Stable: Yes, Source: Designed. Buttons: Store Filter..., Filter Manager...
- Pole/Zero Plot:** A plot showing the imaginary part of the poles and zeros. A pole is located at approximately (1, 1) and a zero at (1, -1) on the complex plane.
- Response Type:** Radio buttons for Lowpass, Highpass, Bandpass, Bandstop, and Notching (selected).
- Design Method:** Radio buttons for IIR (selected) and FIR. Under IIR, 'Single Notch' is selected.
- Filter Order:** 'Special' is selected.
- Options:** 'There are no optional parameters for this design method.'
- Magnitude Specifications:** Units: dB, Attenuation: 1.

An 'Export' dialog box is open in the center, with the following fields:

- Export To: Workspace
- Export As: Objects
- Variable Names: Discrete Filter: Notch50 (circled in orange)

Buttons: Export, Close, Help.

At the bottom of the window, a status bar reads: 'Variables have been exported to the workspace.'

Choose a name for your filter



# Notch filter for dummies

The screenshot displays the 'Filter Designer' application window. The main interface is divided into several sections:

- Current Filter Information:** Structure: Direct-Form II, Order: 2, Stable: Yes, Source: Designed. Buttons for 'Store Filter ...' and 'Filter Manager ...' are visible.
- Pole/Zero Plot:** A plot showing the imaginary part of the poles and zeros. A notch is visible at the top of the plot.
- Response Type:** Radio buttons for Lowpass, Highpass, Bandpass, Bandstop, and Notching (selected).
- Design Method:** Radio buttons for IIR (selected) and FIR. Under IIR, 'Single Notch' is selected.
- Filter Order:** Radio buttons for Special and Minimum.
- Options:** A message states 'There are no optional parameters for this design method.'
- Magnitude Specifications:** Units: dB, Apass: 1. Radio buttons for Bandwidth (selected) and Q are also present.

An 'Export' dialog box is overlaid on the center of the screen. It contains the following fields and controls:

- Export To:** A dropdown menu set to 'Workspace'.
- Export As:** A dropdown menu set to 'Objects'.
- Variable Names:** A text field containing 'Discrete Filter: Notch50'.
- Overwrite Variables
- Buttons: 'Export' (circled in orange), 'Close', and 'Help'.

A large orange 'Export' text is overlaid on the bottom center of the dialog box.

At the bottom of the application window, a status bar reads: 'Variables have been exported to the workspace.'

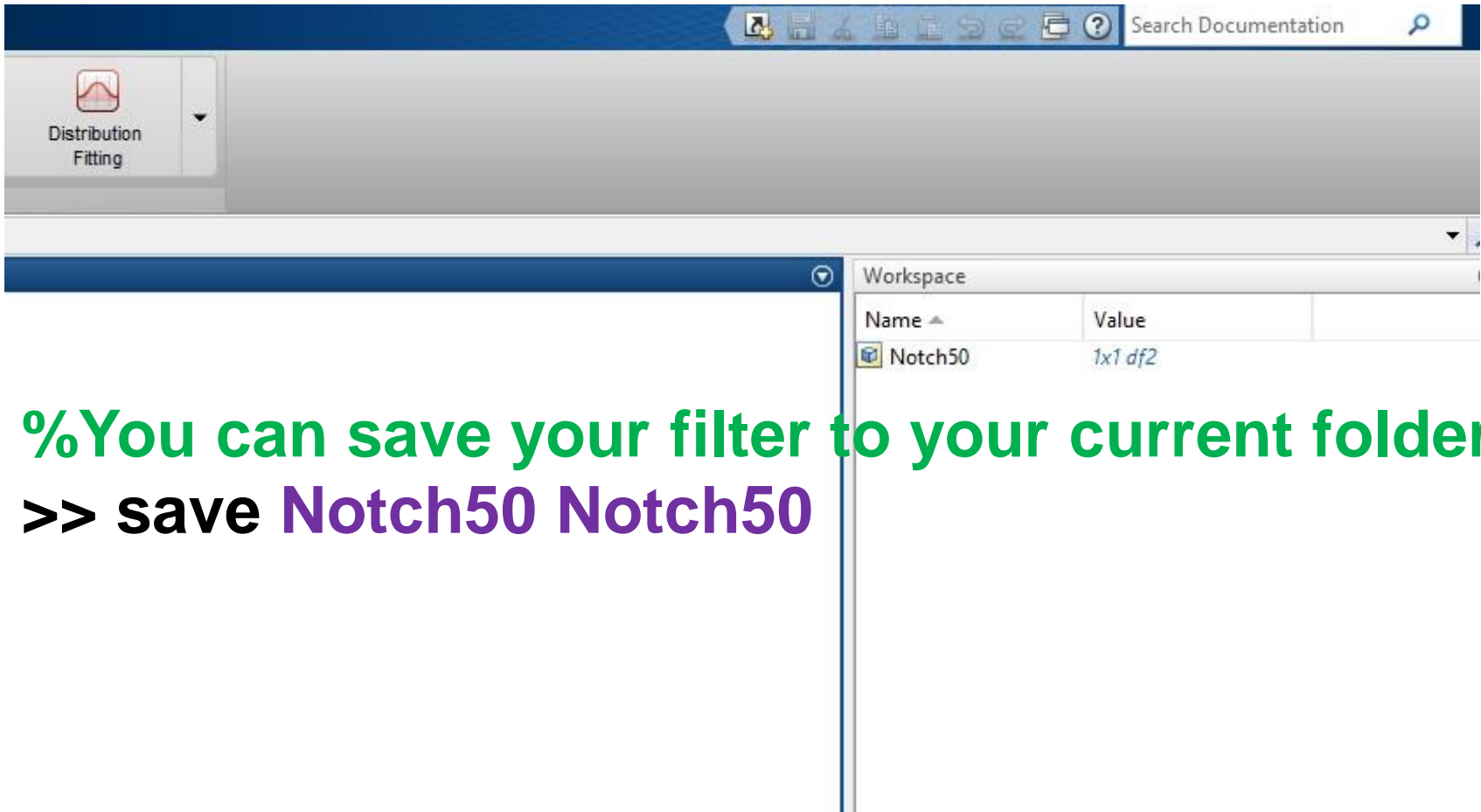
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The screenshot shows a software interface with a 'Distribution Fitting' panel on the left and a 'Workspace' table on the right. The 'Workspace' table has two columns: 'Name' and 'Value'. A single row is visible with the name 'Notch50' and the value '1x1 df2'. The 'Notch50' text is circled in orange. Below the table, the text 'Filter object' is written in a large, bold, brown font.

Name	Value
Notch50	1x1 df2

**Filter object**

# Notch filter for dummies

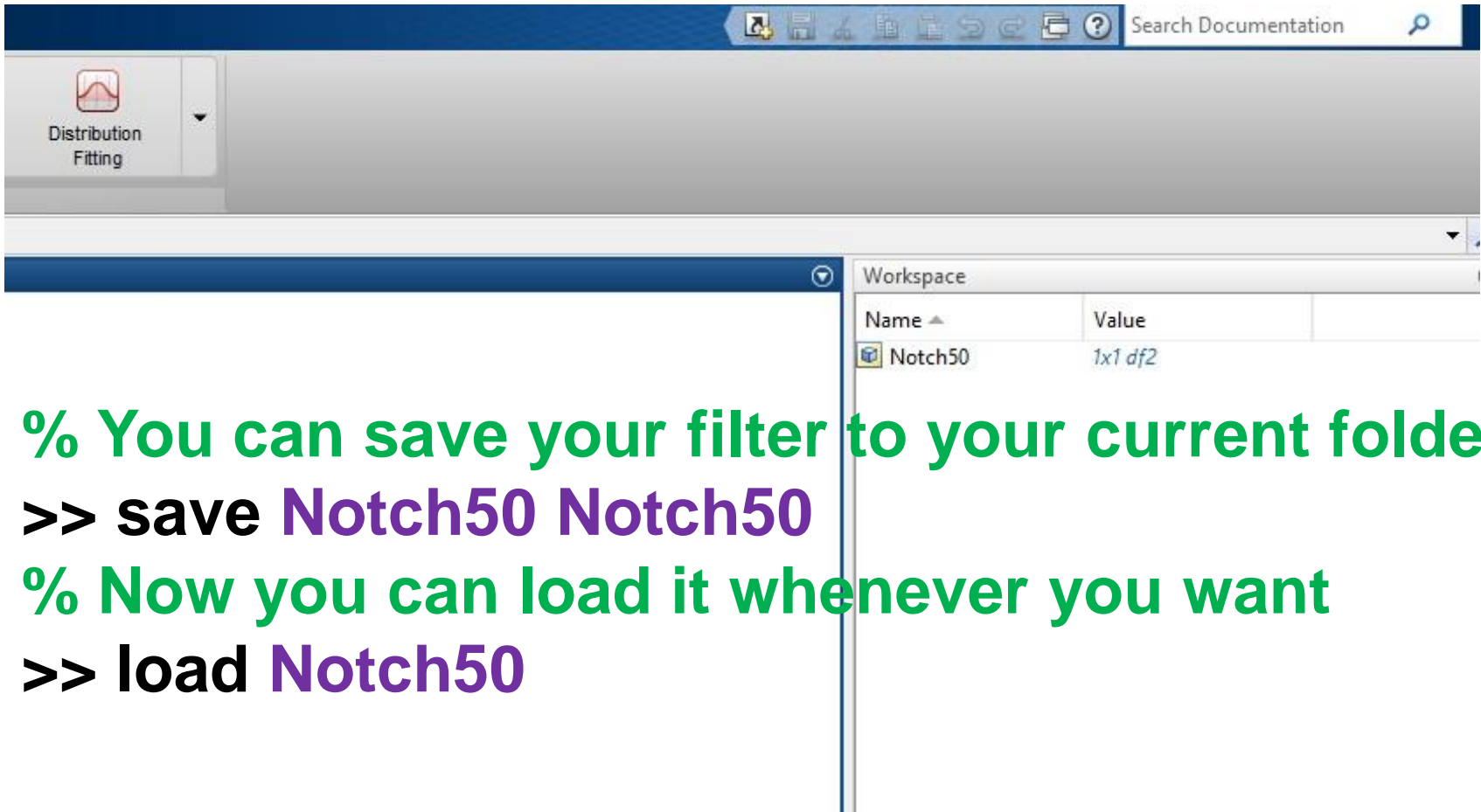


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Name	Value
Notch50	1x1 df2

**%You can save your filter to your current folder**  
**>> save Notch50 Notch50**

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Name	Value
Notch50	1x1 df2

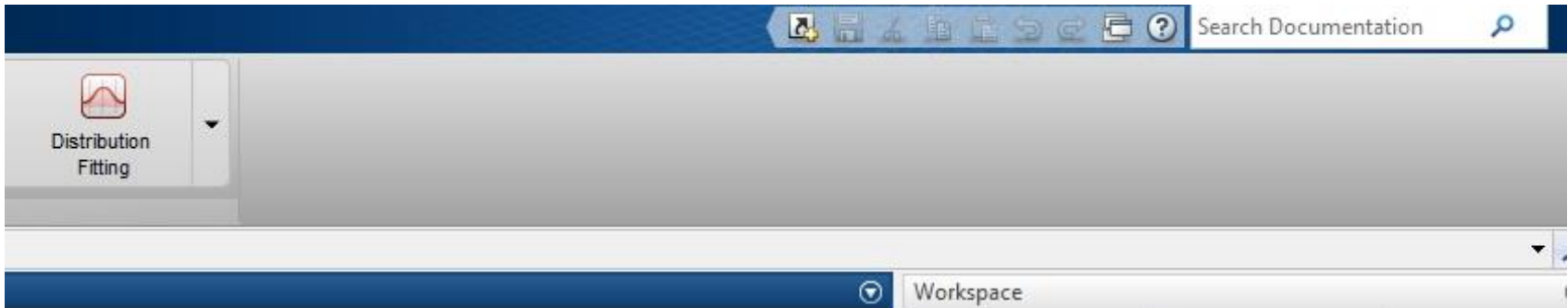
% You can save your filter to your current folder

>> save Notch50 Notch50

% Now you can load it whenever you want

>> load Notch50

# Notch filter for dummies



% You can save your filter to your current folder

>> **save Notch50 Notch50**

% Now you can load it whenever you want

>> **load Notch50**

% You can use filter object directly

>> **y=filter(Notch50,x)**

## Step 4: filter out undesired frequency components

```
% load the filter object
```

```
load Notch50;
```

```
% removing the noise
```

```
pure_ecg=filter(Notch50,ecg);
```

## Step 5: plot the results

```
figure(3)
plot(t,pure_ecg,'LineWidth',2); title('without noise')
xlabel('time (s)')
ylabel('amplitude')
% Zoom in
figure(4)
plot(t(500:length(t)/6),ecg(500:length(t)/6),...
'LineWidth',2.5); title('Noisy and without noise')
xlabel('time')
ylabel('amplitude')
hold on
plot(t(500:length(t)/6),pure_ecg(500:length(t)/6),...
'LineWidth',2.5)
```

# Open filter visualization tool

**MATLAB:**

**fvtool(b,a)**

**or**

**fvtool(object)**

**or**

**...**



# Useful links

- <https://www.youtube.com/watch?v=utrb6DN-Pqc>
- <https://www.youtube.com/watch?v=aZ9fnLzPIWo>
- <https://nl.mathworks.com/help/signal/ug/getting-started-with-filter-designer.html>