# **Experiment BI-4: Filter Frequency Response**

## **Equipment Required**

PC or Mac Computer IX-TA data acquisition unit and power supply USB cable C-DIN-BB: Din to Breadboard cable C-BNC-BB: BNC to Breadboard cable A-BREADBOARD: Breadboard. Electronic components to build a filter on the breadboard.

#### **Breadboard Setup**

- 1. Insert the BNC connector on the end of the C-BNC-BB cable into the S1 stimulator port of the TA.
- 2. Connect the other end of the C-BNC-BB cable to the breadboard.
- 3. Insert the DIN8 connector of the C-DIN-BB cable into the A5 port of the TA.
- 4. Connect the other end of the C-DIN-BB cable to the breadboard.



## **Design the Filter Circuit**

Here is an example of a filter circuit for a 2 pole low pass filter.



60Hz electrical noise picked up from fluorescent lights, computers and AC power lines.

It is implemented here on the breadboard.





### Setting up LabScribe

The provided Filter Frequency-Response LabScribe setting file has been preset with the following settings. The instructions here are for your information and to help you modify other iWorx lab experiments to add the option for additional signal conditioning.

Open the Preferences dialog, by choosing Edit $\rightarrow$ Preferences (LabScribe  $\rightarrow$  Preferences on a Mac) from the Main Menu.

- Channels Tab.
  - Enable the Channels to be recorded and Label them. These channels will be used:
    - A5 (Filter Output): This is the output of the Filter
    - S1 (Stimulator): This is what the Stimulator is outputing, This is the input to the filter circuit.
    - C1 (Frequency): This measures the frequency of the sine wave
    - C2 (Filter-order 51): This is a digital FIR filter using a Hamming Window set for a 50Hz low pass and order 51.
    - C3 (Filter-order 201): This is a digital FIR filter using a Hamming Window set for a 50Hz low pass and order 201.

Channel	Stimulator Vie	ews Macros (	Options Events										
Acquisi	tion Mode	Start	Stop	Speed 2000	~	Sample	ec/Sec v	1					
Chart	~	User ~	User ~			Sample	23/300 -						
				Display Time	55.29	2500 s	sec						
		8	Title				Mo	de/Functio	n YMa	x Y Min	Add Function	n Units	Colo
EM2	EM2							Off	5.0000	-5.0000	Add Function	Units	
i1 1	i1 1							Off	5.0000	-5.0000	Add Function	Units	
<b>-</b> :1 2	:1 0	Filter Setup	Dialog						×	5 0000	Add Eurotion	Unita	
_112	11.2		Filter Type :	Hamming V	Vindov	v(defau	ult) v	ow Cutoff	0	-5.0000	Add Function	Units	
i1 3	i1 3	Filter Orde	r ( odd number)	51				liah Cutoff	50	-5.0000	Add Function	Units	
i1 4	i1 4									-5.0000	Add Function	Units	
✓ S1	S1									-11.457	Add Function	Units	-
	<b>C</b> 2				100	-				5 0000			
52	52				250	1 1 1	2 & A			-5.0000	Add Function	Units	
HVS	HVS	0		Er	250	-			50	-5.0000	Add Function	Units	
🗌 Dout	Dout	Frequences	in Color are pas	sed while tho	se in w	-y hite are	e blocked			-5.0000	Add Function	Units	
Din	Dig. Input 1						0	<b>K</b>	Cancel	-5.0000	Add Function	Units	
✓C1	Frequency						P.I	req.(S1)	122.21	2 -11.004	Add Function	Units	
✓ C2	Filter-order51						FIR	Filter(S1)	5.8764	4 -5.8592	Add Function	Units	
<b>⊡</b> C3	Filter-order201						FIR	Filter(S1)	6.3723	1 -6.0535	Add Function	Units	

## • Stimulator Tab

- Choose S1 stimulator
- Set the mode to Sinewave
- $\circ~$  Set the Amplitude to 5V and the Frequency to 10 Hz.

Channel Stimulator Views Macros O	options Events	
S1 ~ Import Export	Delay 0 sec	
SineWave ~	Delay Amplitude 0 Volts	
Start Stimulator with Recording	Ampirtude 5 voits	
Time Resolution 0.05 msec $$		
Toolbar Steps		
Frequency 1		
Amplitude (V) 0.1		
Time 0.1		
Status		
Preview Stimulator Protocol		
15.000		
544 cm 80		
0.000		
-15.000		

## **Experiment BI-4: Filter Frequency Response**

### **Exercise 1: Filter Frequency Response**

Aim: To record frequency response of a low pass filter.

### Procedure

1. Click on the Freq Response Macro button, located on the upper right side of the LabScribe Main window. The signal should begin scrolling across the screen. The Macro will automatically start recording the data and changing the stimulator output.

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*Note:* If there is no communication between the iWorx unit and computer, an error window will appear in the center of the Main window. Make sure the iWorx unit is turned on and connected to the USB port of the computer. Click OK and select the Find Hardware function from the LabScribe Tools menu.

- 2. The recording will stop after about 1 minute.
- 3. Click on the AutoScale All button on the LabScribe toolbar, to Autoscale all the channels.



### Analysis

Click on the



Analysis button on the toolbar, to switch to the Analysis window.

The Analysis window has been setup to calculate the Max-Min and the Mean value between cursors:

>	Max-N	Min	Mea	n	Add Function				
0.050		10	.010						

When you move the 2 cursors on the screen the Max-Min and the Mean value will be calculated and displayed on the channel bar.

Click on the journal **button** on the toolbar to show the built-in journal.

<	> Max-Min Mean Add	Journal 🗆 🗙									
-C1:Frequency	0.050 10.010				Send data to Journal V						
100- ⊻ 50-					Table Ed	ditor					
0-					*	Α	В	C	D	E	
- S1:S1	9.999 0.088		1								
<u>بم</u>											
10 < <	-										
-10-											
- A5:Filter	8.802 0.049										
≧ 0-1				1							
- C2:Filter-order	9.773 0.087	- M									
-5- -0			-	1							
-C3:Filter-order	9.950 0.088										
5- 10- 5-				1							
-C4:Filter-order	9.986 0.088										
2- -2- -6-				ł							
₩,•	13.8230 sec	27.6460 sec	41.4690 sec	55.2920 sec							

As you can see in the image above, the first graph show the input frequency. Place the 2 cursors on the flat portion so that you can see that the Mean frequency in the first graph is 10 Hz. The Max-Min of the rest of the channels shows the amplitude of the filter, which is about 10V.

Right-Click on the channel and select "Add Title to Journal".

This will add the current measurement titles to the journal. "Title, Max-Min, Mean".

Then Right Click on the channel and select "Add All Data to Journal".

This will add the measurement from all the channels to the journal.

Move the 2 cursors so that they are in the flat region corresponding to 20Hz frequency.

Right-click on the channel and select "Add All Data to Journal".

Repeat this	for all the	other free	quencies	S.								$\square$	
Speed: 2000 s/sec	Display Time:	55.292 sec	Mark	ALL	T2-T1	(26.4625	sec - 23.4185	Journal			*		٥
<ul> <li>C1:Frequency P.Frequency P.Fr</li></ul>	ea.(S1) 🕀 🕲 🖯	fy				Me	an= 50.000 Hz	Send da	ta to Journal	~			
100-					-			Table	Editor				
Ť 50-					-			*	Α	В	с	D	^
- S1:S1 Record ⊕	© ⊖ fv		100			V2-V1	= -2 942 Volts	35	Filter-order51	2.619	0.275		
10-							- LISTE TOTS	36	S1	9.972	0.275		
-0 jets								37	Filter-order201	0.026	0.275		
-10-								38	Filter-order1001	0.007	0.275		
- A5:Filter Output D		x				V2-	V1= 2.158 mV	39	Frequency	0.000	80.000		
> .								40	Filter-order51	1.584	0.314		
E 0-1					_	al.		41	S1	9.952	0.314		
C2:Filter-order51	FIR Filter(S1) 🕀	© ⊖ fv				Max-Mi	n= 5354 Volts	42	Filter-order201	0.003	0.314		
5-								43	Filter-order1001	0.004	0.314		
Olts							_	44	Frequency	3.953	90.087		
_ <u>_</u>								45	Filter-order51	0.817	0.354		
<ul> <li>C3:Filter-order201</li> </ul>	FIR Filter(S1) 🕀	$\mathbb{Q} \ \mathbb{Q} \ f_X$				Max-Mi	n= 4.965 Volts	46	S1	9.959	0.354	-	
र् 2-	4			10		a	3	47	Filter-order201	0.009	0.354		
° .				.0	14			48	Filter-order1001	0.005	0.354		
-5- C4:Filter-order100	1 FIR Filter(S1)					Max-Mi	n= 4 980 Volts	49	Frequency	0.000	100.000		
5-						indix ini	- 1500 1016	50	Filter-order51	0.338	0.395	-	
-0 ^ofts				-	+	+		51	S1	9.843	0.400		
_5-								52	Filter-order201	0.007	0.395		
0	13 8230 6	ec.	27.6460 sec		11 169	0.590	55 2020 sec	53	Filter-order1001	0.002	0.395		~
TimeOfFile <	15.8250 5		27.0400 Sec		-1.409	0 300	>	<					>

The journal now has the measurements from all the channels.

Select all the values in the journal, Right-Click and choose Copy Selection.

These values can now be pasted into a spreadsheet program, where we can plot the bode plot for the different filters.



	A	В	С	D	E	F	G	Н	I	J	К
1	Title	Max-Min	Mean		Frequency	Filter Output	Filter-order51	Filter-order201	Filter-order1001		
2	Frequency	0.05	10.01		10	8.802	9.773	9.95	9.986		
3	S1	9.999	0.088		20	8.126	9.113	9.991	9.998		
4	Filter Output	8.802	0.049		30	6.257	8.085	9.979	9.977		
5	Filter-order51	9.773	0.087		40	4.842	6.792	9.195	9.994		
6	Filter-order201	9.95	0.088		50	3.757	5.354	4.965	4.98		
7	Filter-order1001	9.986	0.088		60	2.955	3.923	0.768	0.011		
8	Frequency	0.202	20.018		70	2.351	2.619	0.026	0.007		
9	S1	9.998	0.076		80	1.908	1.584	0.003	0.004		
10	Filter Output	8.126	-0.034		90	1.573	0.817	0.009	0.005		
11	Filter-order51	9.113	0.076		100	1.311	0.338	0.007	0.002		
12	Filter-order201	9.991	0.076		12			-			
13	Filter-order1001	9.998	0.076		12						L
14	Frequency	0.452	30.032								L
15	S1	9.995	0.11		10	$\sim$					L
16	Filter Output	6.257	-0.015								
17	Filter-order51	8.085	0.111				λ				
18	Filter-order201	9.979	0.11		8						
19	Filter-order1001	9.977	0.11		U						
20	Frequency	0	40								put
21	S1	9.99	0.154		6						er51
22	Filter Output	4.842	-0.001							Eilter-ord	er201
23	Filter-order51	6.792	0.154							Eilter-ord	er1001
24	Filter-order201	9.195	0.154		4						
25	Filter-order1001	9.994	0.154								
26	Frequency	0	50								
27	S1	9.969	0.195		2						
28	Filter Output	3.757	-0.004				N N				
29	Filter-order51	5.354	0.195				X				
30	Filter-order201	4.965	0.195		0	1					
31	Filter-order1001	4.98	0.195		0	20 40	60	80 10	00 120		
32	Frequency	1.783	60.059		-			-			
33	S1	9.984	0.235								
34	Filter Output	2.955	-0.006								
35	Filter-order51	3.923	0.235								
36	Filter-order201	0.768	0.234								
77	Filter order1001	0.011	0.004								

### **Optional Exercises: Frequency response of a high pass filter.**

Extend the first exercise to test the frequency response of a high pass filter. Create an analog high pass filter and set up the digital filters to perform a high pass filter.

For example:

- 1) What happens if you use a 4 pole filter instead of a 2 pole filter?
- 2) What happens if you use a different topology for the filter?
- 3) What happens if you use a high pass filter?
- 4) What happens if you use a band pass filter?
- 5) What happens when you change the windowing function in the digital FIR filter?



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