Introduction to AC Measurements

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In Laboratory 2, we expand our understanding of electronic circuits from Laboratory 1. Instead of DC measurements, we are now working with AC measurements. From there, we will cover concepts of frequency, frequency dependence, and the concepts behind filters, specifically high pass and low pass filters. We will also get an introduction to Bode plots.

I. BACKGROUND

There isn't much background needed for this lab. One of the main factors is making sure that we have a solid understanding of how BNC connectors should be used, and the ins-and-outs of how to work an oscilloscope.

II. PROCEDURE

The procedures for Laboratory 2 is very straight forward, so the Laboratory 2 sheet will be attached at the end of this write up.

III. PRESENTATION OF DATA

A. 2-2: AC Voltage Measurements

Sine Wave (DC Values) 5Vpp, 0 Offset			
Freq (Hz)	DC Min	DC Max	DC Avg
10	-0.68	0.697	0
20	-0.109	0.121	0.007
50	0.006	0.006	0.006
1k	0.006	0.006	0.006
2k	0.007	0.006	0.007
5k	0.007	0.007	0.007
10k	0.007	0.007	0.007
20k	0.007	0.007	0.007
50k	0.007	0.007	0.007

Sine Wave (AC Values) 5Vpp, 0 Offset			
Freq (Hz)	DC Min	DC Max	DC Avg
10	1.702	1.736	1.719
20	1.752	1.752	1.752
50	1.763	1.763	1.763
1k	1.763	1.763	1.766
2k	1.756	1.756	1.756
5k	1.555	1.555	1.555
10k	1.104	1.113	1.108
20k	0.657	0.682	0.672
50k	0.353	0.420	0.392

Square Wave (DC Values) 5Vpp, 0 Offset			
Freq (Hz)	DC Min	DC Max	DC Avg
10	-0.869	0.898	-0.031
20	-0.131	0.161	0.015
50	0.015	0.015	0.015
1k	0.015	0.015	0.015
2k	0.015	0.015	0.015
5k	0.015	0.015	0.015
10k	0.015	0.015	0.015
20k	0.015	0.015	0.015
50k	0.015	0.015	0.015

Square Wave (AC Values) 5Vpp, 0 Offset			
Freq (Hz)	DC Min	DC Max	DC Avg
10	2.455	2.469	2.463
20	2.480	2.480	2.480
50	2.482	2.482	2.482
1k	2.411	2.418	2.415
2k	2.334	2.348	2.341
5k	2.005	2.027	2.016
10k	1.418	1.456	1.436
20k	0.869	0.913	0.889
50k	0.515	0.592	0.566

Triangle Wave (DC Values) 5Vpp, 0 Offset			
Freq (Hz)	DC Min	DC Max	DC Avg
10	-0.555	0.567	0.041
20	-0.087	0.100	0.004
50	0.007	0.007	0.007
1k	0.007	0.007	0.007
2k	0.007	0.007	0.007
5k	0.007	0.007	0.007
10k	0.007	0.007	0.007
20k	0.007	0.007	0.007
50k	0.007	0.007	0.007

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Triangle Wave (AC Values) 5Vpp, 0 Offset			
Freq (Hz)	DC Min	DC Max	DC Avg
10	1.380	1.413	1.396
20	1.430	1.430	1.430
50	1.442	1.442	1.442
1k	1.444	1.444	1.444
2k	1.433	1.433	1.433
5k	1.264	1.267	1.265
10k	0.894	0.902	0.900
20k	0.532	0.556	0.545
50k	0.282	0.342	0.312

B. 2-3: Time/Frequency Measurements

No tabular data.

C. 2-4: Low-Pass and High-Pass Filters

Low-Pass Filter		
Freq (Hz)	V_{in}	V_{out}
10	8.160	8.680
20	9.520	8.600
50	10.08	8.560
100	10.08	7.440
200	10.08	5.320
500	10.08	2.640
1k	10.08	1.360
2k	10.08	0
5k	10.08	0
10k	10.08	0
20k	10.08	0
50k	10.08	0
100k	10.08	0

High-Pass Filter		
Freq (Hz)	V_{in}	V_{out}
10	8.160	0
20	9.520	1.280
50	10.08	3.200
100	10.08	5.520
200	10.08	7.840
500	10.08	9.400
1k	10.08	9.840
2k	10.08	10.00
5k	10.08	10.00
10k	10.08	10.00
20k	10.08	10.00
50k	10.08	10.00
100k	10.08	10.00

IV. DISCUSSION

A. 2-2: AC Voltage Measurements

The AC and DC voltage measurements with the DMM accomplished a couple of things. For an AC input, the DMM will read the average value for DC. It has to sample in order to get these readings, and it averages over the samples. When you have a voltage that is a function of frequency, your "‘average"’ value will always be what your offset is. This is why the DC readings on our tables, regardless of the wave, came out to nearly zero.

For the AC readings, we found out the limitations of the DMM versus the multimeter. This makes sense when you consider what a DMM is likely to be used for, which is mostly consumer electronics. This means you'll have the highest efficiencies at 50-60Hz. Anything below, and you'll get weird readings. Anything higher and you'll get eventually get readings of zero. How quickly you go to zero, and what your readings are for the AC mode on the DMM will depend on your wave.

This goes to show that for basic uses, like consumer electronics, a DMM will most likely suit all your needs. For anything more complex, it may require an oscilloscope.

B. 2-3: Time/Frequency Measurements

Though the DMM did a great job of giving roughly the same measurements as the oscilloscope for the frequency/time measurements, what it lacks is granularity. Once again, looking back to our last experiment, this is due to the uses of the DMM versus the uses of an oscilloscope. Where the oscilloscope gave us a reading of 20.04ms, the DMM gave us a reading of 0.02 seconds. Though they're roughly the same value, the oscilloscope gives us access to more granular data, which can come in handy for sensitive experiments.

C. 2-4: Low-Pass and High-Pass Filters

The High-Pass and Low-Pass filter experiments show us how we can block certain frequencies depending on the output voltage. After looking it up online, we can find that the industry standard for the cutoff point for these filters is in the form of $20 * log(\frac{V_{out}}{V_{in}}) \geq -3dB$. Anything below -3dB is filtered out.

For the Low-Pass filter, the formula for V_{out} is

$$V_{out} = V_{in} * \frac{X_c}{\sqrt{R^2 + X_c^2}}$$

Where R is resistance of the circuit, and X_c is the capacitive reactance, given by $X_c = -\frac{1}{\omega C} = -\frac{1}{2\pi f C}$

For the High-Pass filter, the formula for V_{out} is

$$V_{out} = V_{in} * \frac{R}{\sqrt{R^2 + X_c^2}}$$

You can see that for the Low-Pass filter, as the frequency goes to infinity, X_c goes to zero, making V_{out} go to zero, and the opposite is true for the High-Pass filter.

For filtering out specific frequencies, or having specific cut offs, you choose your frequency first, and set choose your resistor and capacitor that will get you that -3dB cutoff point.

V. CONCLUSION

Though it took a little digging ti figure out why the DMM would be less sensitive (other than the obvious answer that it's cheaper), we learned that oscilloscopes are meant for use in all situations, where most DMMs are built for consumer electronics. This means they are usually less sensitive, which is why we normally opt for the oscilloscope for our experiments.

Beyond that, we learned the formulas for V_{out} for both High-Pass and Low-Pass filters, and how to mathematically formulate our own filters for our own needs. We can also expand this knowledge, and take the output of our High-Pass or Low-Pass filter, and feed it into the other filter so we can filter down to a small window, or band, so we only allow a limited number of frequencies in.