**Effect of Frequency and Phase on Electronic Circuits (Rev 7/30/12)**

Use the Teach Spin Signal Processor & Lock-In Amplifier apparatus to study the effect of frequency and phase on the outputs of various circuits. Use a band pass filter as an electronic spectrum analyzer. Use a lock-in detector to detect a dim light source and measure low value resistance. An oscilloscope (Model 2121 if available) and function generator (signal generator) will be needed. Several longer 50 Ohm cables with BNC connectors are needed. Use short cables with BNC connectors to wire up the circuits on the Teach Spin apparatus. Vary oscilloscope time/div knob as needed. If an oscilloscope that has a frequency counter is not available you will need one of the DMMs that measure frequency.

Background: Before doing Part VI read about lock-in detectors in Appendix D at <http://www.advancedlab.org/mediawiki/index.php/Appendix_D:_the_Phase_Sensitive_(Lock-In)_Detector>.

Part I Effect Of Frequency On Gain Of An Amplifier

1. Wire up the circuit show in Fig 1 on separate page. Use 2 to 1 adapter to connect function generator to noise input and Ch.2.
2. Turn on oscilloscope and function generator. Set function generator to 100 Hz scale and sine wave.
3. On Teach Spin Apparatus: Set preamp gain to 20. Select ground for minus input. Set + input to AC. In noise section set noise to off and attenuator to 1.
4. Turn on Teach Spin apparatus. Look at the signal on Ch. 2. Adjust function generator for frequency of ~100 Hz as measured by scope readout. Set Ch. 2 on 1v/div and adjust amplitude control on function generator so peak to peak amplitude is ~ 1v.
5. Look at the signal on Ch. 1. If the top is flat rather than rounded reduce amplitude.
6. Vary frequency and record peak to peak amplitude as a function of frequency. Measure at 100Hz, 500Hz, 1000Hz, 5,000 Hz, 10,000 Hz and every 10,000 Hz up to 200,000 Hz.
7. Turn off function generator and Teach Spin apparatus while changing circuits.
8. After all data taking is complete plot amplitude vs. frequency. Estimate the frequency at which amplitude has dropped to ½ its low frequency value.

Part 2 Low Pass Filter

1. Wire up the low pass filter circuit shown in Fig. 2 on separate page. Use 2 to1 adaptors to connect output to filter input and Ch. 2. Set filter switch (Q) to Butterworth. Turn filter fine frequency knob all the way up. Set filter range knob to 100-300. Turn on Teach Spin apparatus.
2. Look at the signal on Ch. 2. Adjust reference oscillator controls for frequency of 100 Hz as measured by scope readout. Set Ch. 2 on 1v/div and adjust amplitude control on reference oscillator so peak to peak amplitude is ~ 2v.
3. Start at 100 Hz and look at signal on Ch. 1. Adjust volt/div and amplitude for larger initial amplitude. Record amplitude versus frequency at 50 Hz increments from 100 to 1000 Hz.
4. Later plot amplitude versus frequency. Estimate frequency at which amplitude has dropped to ½ of the 100 Hz value.

Part III High Pass Filter

1. Switch cable going to Ch. 1 from LP output to HP output. Turn filter range scale to highest setting. Start with 2000 Hz. Adjust volt/div or amplitude as needed to set initial amplitude on Ch. 1.
2. Measure peak to peak amplitude as function of frequency from 2000 down to 500 HZ in 50 Hz increments.
3. Turn off the Teach Spin apparatus.
4. Later plot amplitude versus frequency. Estimate the frequency at which output is ½ maximum value.

Part IV Use Of The Band Pass Filter As A Spectrum Analyzer

1. Move cable connected to Ch. 1 from High Pass output to Band Pass output. Set Q knob to 20. Turn on Teach Spin Apparatus.
2. Set reference oscillator to ~300 Hz according to the scope readout. Treat this as the signal whose spectrum you want to determine. Set reference oscillator gain to 2.
3. Set the filter frequency knob to lowest value. Measure Ch. 1 amplitude as you vary the fine adjust knob. Record fine adjust reading and scale for each measurement Repeat using the higher settings on filter frequency knob.
4. If you have a problem with the peaks repeatedly getting clipped off redo the spectrum with a lower gain.
5. Later plot amplitude vs frequency. Does the spectrum match what you expect for your “unknown signal”?

Now let’s try a more complicated signal

1. Turn off the Teach Spin apparatus and wire up Fig. 3. Add a 2 to 1 adapter to send noise signal to Ch. 2 and pre-amp input. Use a 2 to 1 adapter to connect amp output to low pass filter/amplifier input and Ch.1.
2. Set minus input switch to ground. Set + input to AC. Set filter Q knob to 10. Set Amp detector to AC, Gain =20, select lock in detector. Set noise knob to 1/10. Set attenuation to off. Since this is a noise signal it will be jittery. It would be difficult to measure amplitude on Ch.1. Instead use the meter in the low pass/amplifier section. A time constant will smooth out the variation. Set time constant to 3, Db to 6, & DC Offset to 0. Set gain to20.
3. Turn on Teach Spin apparatus. Look at signal on Ch. 2
4. Vary the filter range switch and make sure reading on meter does not go off scale. When changing range scale allow needle to settle down before reading. If it goes off scale adjust gain controls.
5. Vary the filter frequency range and collect data as above.
6. Later plot amplitude versus frequency. Is the signal concentrated around one frequency, appear at several frequencies like a line spectrum of light, or is it spread out over a range of frequencies? Give value(s) of frequency or range of frequencies where the noise is strongest.

Part V Phase Detection

1. In this part you will use a circuit that is sensitive to the phase of a signal not just the frequency.
2. Turn off Teach Spin Apparatus. Wire up Fig. 4. Use 2 to 1 adapter to connect reference oscillator output to detector input and Ch.2.
3. Adjust reference oscillator to ~1000 Hz. Set amplitude knob to 2.
4. Set Phase Shifter to 0 degrees. Set Lock In /Amplitude Detector to AC & Gain=20. Select Lock In Detector.
5. Turn on Teach Spin apparatus. Draw the signal on Ch. 1 for different phases (0, 45, 90, 180, and 270). Adjust Lock In section gain or oscilloscope volt/div knob to keep amplitude low enough to fit signal on the screen.

Part VI Light Detection Using Lock In Detector

1. In this part you will use the Lock-In Detector to increase how far away from the solar cell a dim light source can be before you lose it against the bright background of the room lights.
2. Connect the solar cell to Preamp input using alligator clips and banana plug to BNC adapter. Connect Preamp output to Filter Input. Connect Bandpass output to Ch. 1. See note below.
3. Observe the pattern produced by the overhead light shining on the solar cell. Adjust the preamp gain and volt/div as needed. Draw the pattern. Since the lights are powered by AC the brightness will vary but at 120 Hz the variation is too small and too quick to see.
4. Wire up a 1000 Ohm resistor and LED on the protoboard. Use clips & adapter to connect resistor/LED combination to the reference oscillator output. Set frequency to a few Hz. Set sine/square switch to square. This is a TTL output that is on 50% of the time. Raise the amplitude until you see the LED flash. The LED will serve as the weak signal.
5. Place solar cell on its edge and place next to LED. Turn out room lights or cover the LED and solar cell. Raise the frequency to ~ 400 Hz. Put filter frequency knob on 300-1K scale. Adjust amplitude or volt/div as needed to see LED pattern on scope. Draw pattern.
6. Turn lights back on and look at combined pattern. Turn the reference oscillator amplitude up and down to make sure LED signal is affecting scope pattern.
7. Turn off the Teach Spin Apparatus and wire up Fig, 5. Signal is from solar cell. Reference oscillator output is to resistor/LED combination. Set Q in Filter section to 10.
8. Temporarily disconnect preamp output from filter and connect to Ch.2. Turn on the Teach Spin apparatus. Hold the solar cell on edge and facing you. Place next to LED and observe pattern on scope. See how far you can move the solar cell away from LED before you lose the effect on the pattern. Disconnect Ch2. from preamp and connect Ch. 2 to output of Low Pass Amplifier. Reconnect preamp output to filter input. Place solar cell next to LED. In phase shifter section switch phase to 90 deg. Adjust phase fine adjust and low pass filter amplifier gain for highest reading on meter without going off scale. Switch Ch. 2 to DC and adjust volt/div and position so line is near top of screen. If Ch. 1 display is distracting move it off screen. Move the solar cell away from the LED. See how far you can move it before meter reading goes to zero. You can also see the DC voltage drop on the Ch. 2 display. If this is working correctly the distance will be further than first measurement of distance. Advantage: You can detect signal further away. Disadvantage: You only get DC output. You lose details of how signal varies.
9. Questions to consider. The bandpass filter reduces the effect of the background light if set correctly but how large an effect does it have as used in Part VI? You are told to set sine/square switch to square. Does the signal from LED look like a square wave? You were told to set the reference oscillator to 400HZ. Does the scope display show ~400 or ~800? Redo steps 2-8 but this time connect the output of Preamp directly to the input of Lock-In Detector thus bypassing the Filter (Bandpass) section. Compare your results. Besides supplying a DC meter, why is the Lock-In detector output fed into the Low Pass Filter Amplifier?
10. Turn off equipment and disconnect circuit.

Note (step 2): You may pick up some type of interference at ~5,000 Hz. See if you can block the interference by covering the solar cell partly. The scope frequency should drop from ~5,000 to ~120 if looking at signal from lights.

PART VII Use OF The Lock- In Detector To Measure Resistance

1. Wire up Fig. 6 using a 1,000 Ohm resistor for R (series) and a 10 Ohm resistor for R (wire). Measure these resistances before installing in circuit. Don’t trust color code. Use the built in Reference Oscillator for your signal. Use a 2 to 1 adapter so you can connect the Reference Oscillator output to the scope. You will need a DMM to measure total voltage across both resistors (V (in)). Instead of sync output from a function generator connect the Phase Shifter output from the Reference Oscillator to the Phase Shifter. Connect Phase Shifter output to Reference input of Lock- In Detector.
2. Connect Lock-In Detector output to Low-Pass Filter Amplifier input. Set gain on Lock-In Detector to 10. Connect the Low-Pass Filter Amplifier output to a DMM that can measure DC millivolts. Set gain on Low-Pass Filter Amplifier to 1. Set time constant knob to 1 sec.
3. Turn on the Teach Spin Apparatus and scope. Set sine/square switch on Oscillator to sine. Adjust reference oscillator for ~75 Hz and a peak voltage of ~1v.
4. Use a DMM to measure V (in). Adjust the Phase Shifter for highest reading on the DMM attached to Low Pass Filter Amplifier. Divide voltage by 10 ( = gain) and record as V (wire).
5. Turn off equipment and take apart circuit.
6. Use your data and formula provided to calculate R (wire) using formula below. Compare with value measured with DMM. To make it easier to measure voltages a 10 Ohm resistor was used. This setup could be used as indicated in figure to measure resistance of a wire whose resistance was too low to measure using DMM.

FORMULA: R(wire) = R(series) X V(wire) / (V(in) – V(wire))