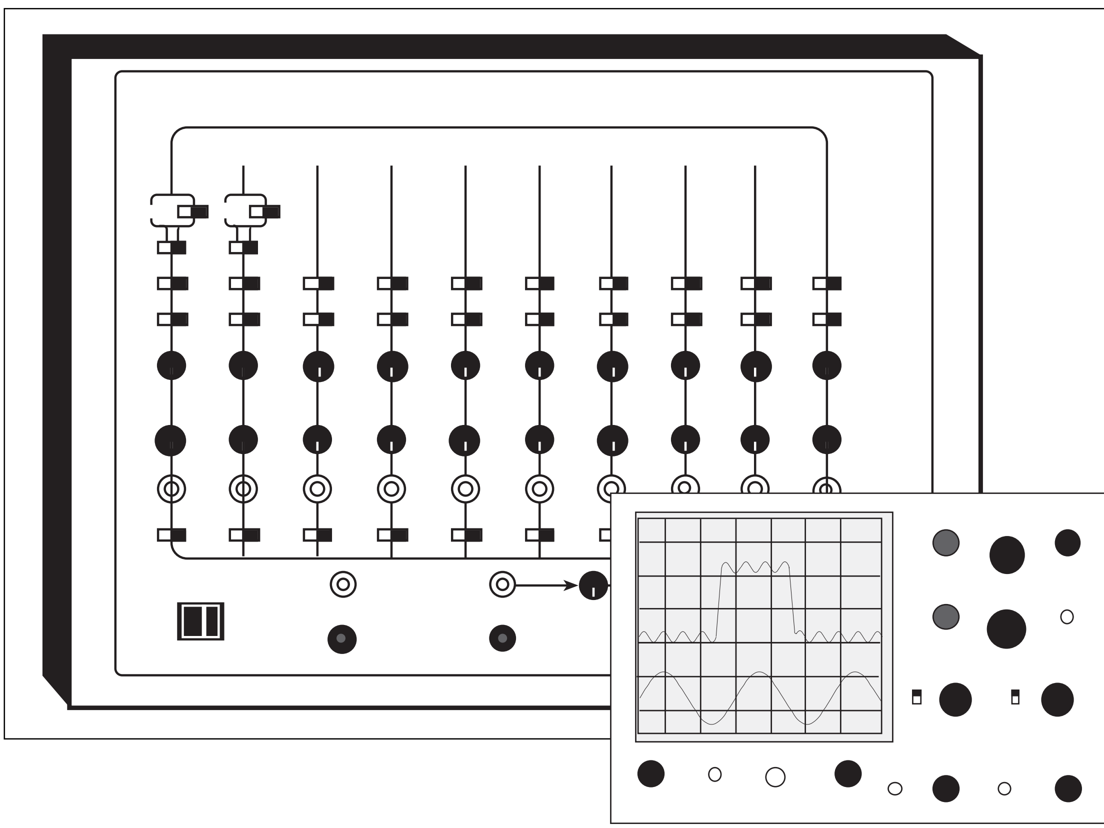
## Instruction Manual and Experiment Guide for the PASCO scientific Model WA-9307A

012-01531D
6/94

# FOURIER SYNTHESIZER





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The exclamation point within an equilateral triangle is intended to alert the user of the presence of important operating and maintenance (servicing) instructions in the literature accompanying the appliance.

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# Copyright, Warranty and Equipment Return

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# Introduction

It's a powerful mathematical fact that any periodic waveform can be expressed as an infinite sum of trigonometric functions,consisting of a sine or cosine function and its successive harmonics.*With the PASCO Model WA-9307A Fourier Synthesizer, you can demonstrate and investigate this mathematical idea, adding a succession of sine wave harmonics and viewing the results waveform on an oscilloscope.

The oscilloscope and speaker are not included with the WA-9307A Fourier Synthesizer. The oscilloscope (SB-9699A) and, speaker (WA-9303), can be ordered seperately.

The Fourier Synthesizer can be used with any standard oscilloscope. However, a dual trace oscilloscope with an external trigger is best.

With a dual trace scope you can view the full output wave (the sum of all the harmonics you have added together), and at the same time you can view the individual harmonic you are about to add or have just added. An external trigger provides a fixed phase reference for all the individual waveforms, so you can easily compare the phase of the final, summed waveform with the individual harmonic you are about to add.

*Mathematically, the waveform must be piecewise continuous, a restriction that is of more significance to the mathematician than to the physicist, since virtually any function encountered in nature will meet the requirements.

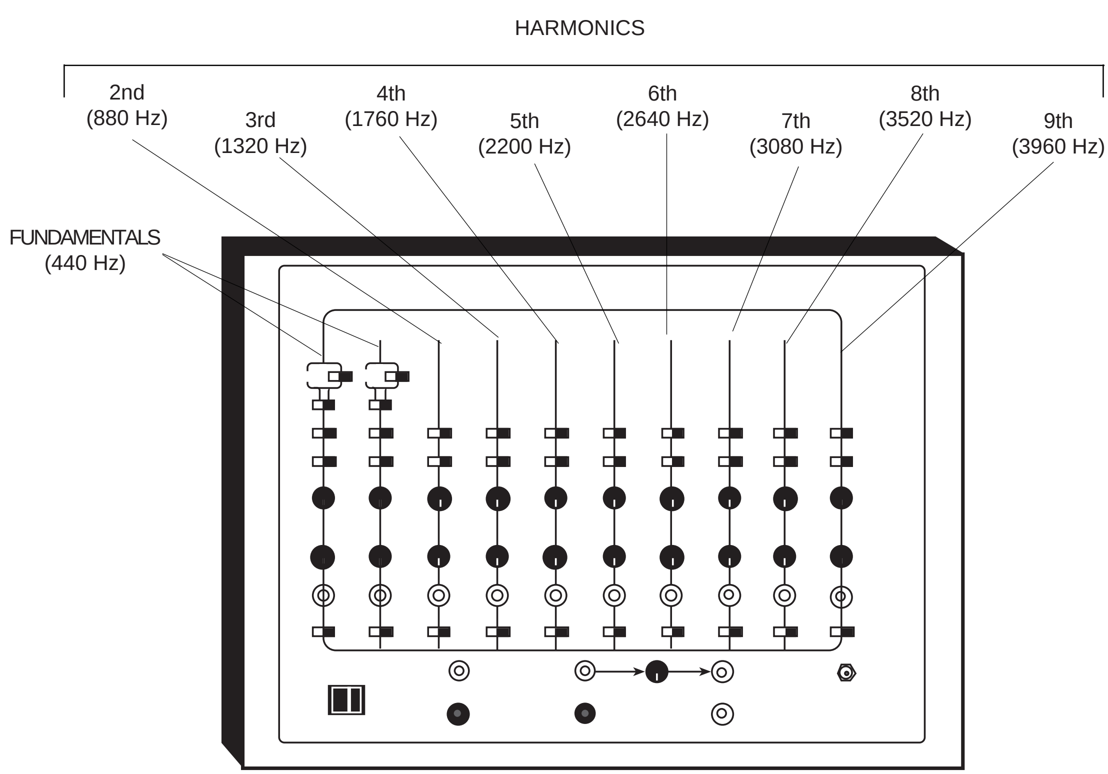


**Figure 1 The Fourier Synthesizer**

# Equipment Setup

Connect the Fourier Synthesizer to your oscilloscope as shown in Figure 2.

① Connect the ground of the oscilloscope to one of the ground jacks on the Synthesizer.

② Connect the Synthesizer TRIGGER OUTPUT to the external trigger jack on the scope. (If you are using an oscilloscope with a recurrent sweep, connect the TRIGGER OUTPUT in the Synthesizer to the external sync jack on the scope.)

③ Connect the scope input to one of the 10kΩ OUTPUT jacks on the Synthesizer. The 10kΩ output jacks include one jack for each of the 10 channels and one jack at the bottom center of the Synthesizer that outputs the sum of all the harmonics that have been added together.
If you are using a dual trace scope, connect Channel 1 to the summed output and use Channel 2 to view the individual harmonics as you add them into the waveform.

**➤NOTE:**

① If you are using PASCO'S WA-9305 Oscilloscope Connecting Cables, connect the BNC connectors to your oscilloscope inputs, connect the black banana plugs to the ground jacks on the Synthesizer, and connect the red banana plugs to the 10kΩ outputs.

② If you are using an unshielded input cable, it should be separated as far as possible from the trigger cable to reduce AC interference from the trigger signal.

③ If you want to hear the output, as well as see it, connect a speaker with an input impedance of 8Ω, between the two 8Ω OUTPUT jacks on the bottom right of the Synthesizer.

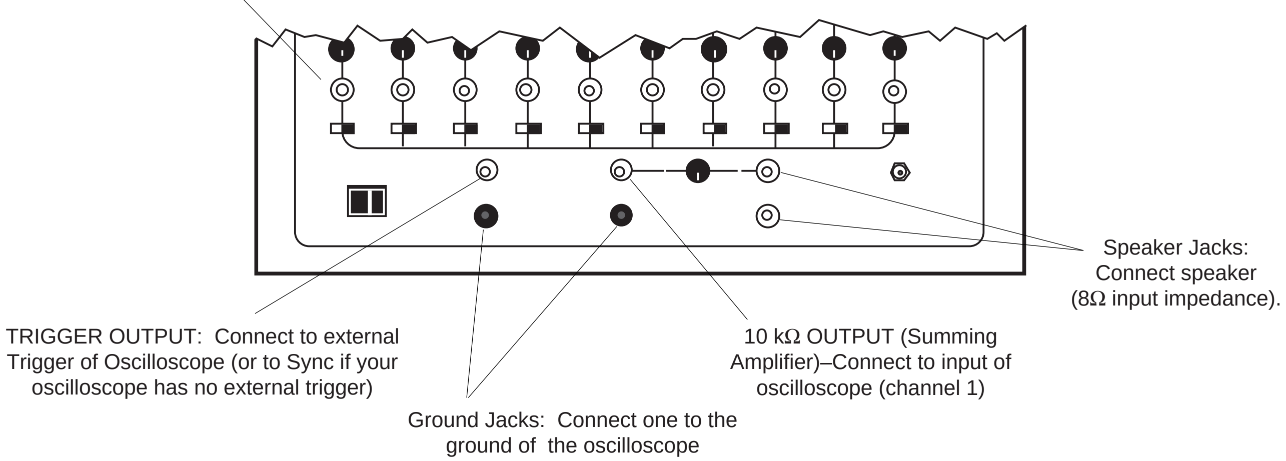


**Figure 1 The Fourier Synthesizer**

# Operation

① Connect the Fourier Synthesizer to an oscilloscope and/or a speaker as explained in the previous section.

② Turn on the oscilloscope , and set the oscilloscope sensitivity to about 0.5 volts/cm.

③ Plug the power cord or the Synthesizer into a standard 120 VAC, 60 Hz (or 220 VAC, 50 Hz) outlet and switch the power switch (bottom left hand corner of the Synthesizer) to ON.

④ The controls of the Synthesizer are arranged in ten columns. Each column of control knobs controls one of the ten individual waveform. The purpose of the knobs are described in Figure 3, below. The controls for each waveform are identical, except that the first two columns, the fundamental waveforms have two additional switches. Unlike the higher harmonics, the fundamentals can be switched to obtain triangular or square waves at the fundamental frequency (440 Hz).

**To become familiar with the controls:**

① Connect the input of the oscilloscope to the 10kΩ output jack if the first fundamental, near the bottom of the leftmost column. If you are using a dual trace scope, connedt the second input to the 10kΩ output summing fack at the bottom center of the Synthesizer.

② Adjust the Amplitude control knob of the first fundamental until a trace appears on the oscilloscope.

③ Adjust the phase of the signal by turning the Variable Phase knob. (If you are triggering the oscilloscope with the TRIGGER OUTPUT from the Synthesizer, you will see the trace on the oscilloscope shift to the right or left.) This knob gives you continuous control of the phase over a range of at least 90°.

④ Try sliding the 0⇔90° switch and then the 0⇔180° switch and observe the signal on your oscilloscope. Using these switches, along with the variable control knob, lets you vary the phase of any individual waveform by a full 360° .

⑤ Try sliding the two slide switches at the top of the column. These switches allow you to change the waveform from a sine wave to a square or triangular wave.

⑥ Now slide the SUMMING AMPLIFIER slide switch to IN. The waveform is now passed through to the summing amplifier, and appears on the second trace of your dual trace scope. (If you are using a single trace scope, plug the oscilloscope input into the 10kΩ OUTPUT jack of the summing amplifier to see the output if the summing amplifier,)

⑦ Now try examining the signals from the remaining columns of the Synthesizer. Vary the amplitude and phase of these signals then slide the SUMMING AMPLIFIER switch for that column to IN to see what happens when you add that waveform to the summed output.

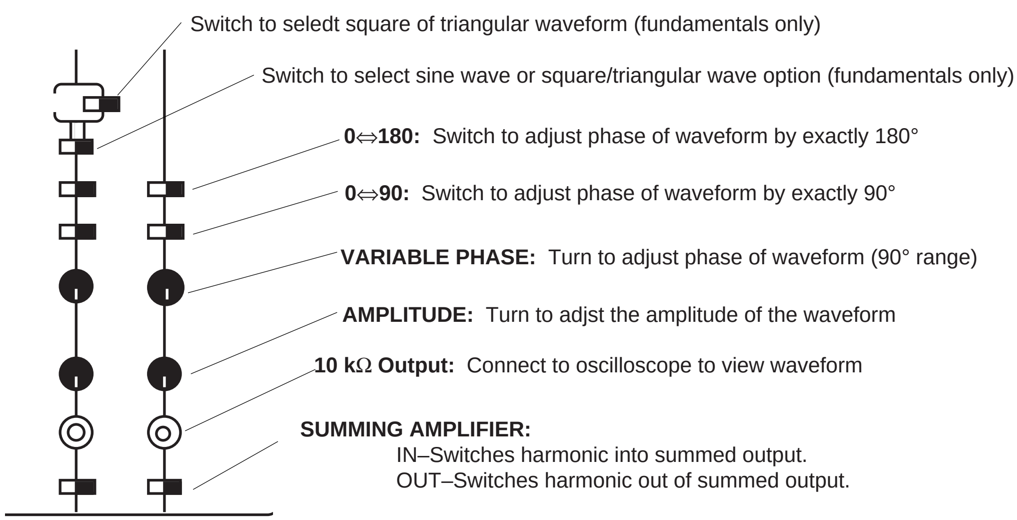


**Figure 3 Synthesizer Controls**

➤**IMPORTANT:**

① The summing amplifier produces a 180° phase shift in each individual waveform. Therefore, when you switch an individual waveform into the summing amplifier, flip the 0⇔180 ° switch for that waveform in order to maintain the same phase relationship you have set between it and the summed output.

② When experimenting, periodically hit the Synthesizer RESET button (lower right corner). Transients in the power line will occasionally affect the digital circuitry of the Synthesizer, and can alter the phase relationship of the waveforms. Pushing the RESET will reset the digital circuitry.

③ The amplitude of the fundamentals ( the two columns labeled 1) and the Second and Third harmonics (the columns labeled 2 and 3) can be varied up to 2 volts peak-to-peak. The amplitudes of the higher harmonics have a maximum of 1 volt peak-to-peak. This makes it easier to make the fine amplitude adjustments that are often necessary for the higher harmonics.

# About Experiments

**Helpful Tips**

① Before beginning an experiment, "zero" the Fourier Synthesizer:

a. Set all the phase switches to zero (the Variable Phase knob, and the 0 ⇔90 and the 0⇔180 switches.

b. Set all the summing amplifier switches to OUT.

c. Press the RESET button.

② Set the summing amplifier switch for the first fundamental waveform to IN. Using your scope, examine the summed output of the Synthesizer. Determine an origin (0° point) on your scope, and adjust the horizontal position of the trace so the Synthesizer waveforms are either sines or cosines (whichever you prefer).

**Remember:**

① The summing amplifier produces a 180° phase shift in each individual waveform when it is added to the summed output.

② When experimenting, periodically press the RESET button to be sure all the waveforms stay in phase.

# Experiment 1: Adding Sine Waves of the Same Frequency

## Introduction

There are standard trigonometric identities that can be used to mathematically add sine waves and cosine waves. You can then graph the resulting waveform to determine exactly what the sum of the two waves would look like. Although a physicist needs to be able to use such mathematical tools, it's important to have an intuitive grasp of what is happening when trigonometric functions are added.

## Procedure

➤**NOTE:** This procedure assumes you are using an oscilloscope with an external trigger.

① Hook up the Fourier Synthesizer to your oscilloscope as described in the SETUP section. Connect the oscilloscope input to the 10kΩ output connector if the summing amplifier. Trigger the oscilloscope from the TRIGGER output.

② Switch the first fundamental signal SUMMING AMPLIFIER switch to the IN position. Make sure the second fundamental and all harmonics are switched OUT. Select the SINE wave output signal option. Adjust the AMPLITUDE control to a convenient value near maximum amplitude, (1V peak is usually convenient). Adjust the vertical scaling in the oscilloscope so that the peak of the sine wave is less than or equal to half of the maximum display on the scope, (0.5V/div is usually convenient). Adjust the 0⇔90° and 0⇔180° switches and the VARIABLE PHASE control to display either a sine or cosine waveform. Switch the first fundamental signal OUT and the second fundamental signal IN. Adjust the controls for the second fundamental to produce a sine wave signal identical in amplitude and phase to the first fundamental signal.

③ Now switch the first fundamental signal IN to the summing Amplifier. Is the combined waveform a sine wave? How does its amplitude and phase compare with the amplitudes and phases of the two original sine waves?

④ Vary the amplitude of one of the fundamentals and examine the amplitude and phase of the combined wave.

⑤ Vary the phase of one of the fundamentals, first with the variable phase control, then with the 0⇔90° and 0⇔180° switches. Examine the amplitude and phase of the combined wave.

⑥ What conditions produce a combined waveform with a maximum amplitude? A minimum amplitude?

⑦ Repeat the above procedure with two triangular waves and then two square waves.

➤**NOTE:** The VARIABLE PHASE control has no effect on the triangle and square wave outputs. The phase of these wave forms can only be shifted 90° or 180° using the 0⇔90° and 0⇔180° switches.

Then try adding a square wave to a sine wave, a square wave to a triangular wave, and a sine wave to a triangular wave. In each case, first examine the constituent waves, then try to sketch what you believe the combined waveform will look like. Then add the two waves together to see how accurate your sketch was.

# Experiment 2: Adding Sine Waves of Different Frequency

## Introduction

Two sine wave of the same amplitude and phase can be added mathematically using the formula:

$$\sin(2\pi v_1 t)+\sin(2\pi v_2 t) = 2\cos\pi(v_1 - v_2)t\sin\pi(v_1+v_2)t$$

If $\nu_1$ and $\nu_2$ are greatly different, then the wave described by the right side of this equation is even more difficult to visualize than the wave described by the left side.

However of $\nu_1$ and $\nu_2$ are nearly the same, the cosine term will have a much lower frequency than the sine term. Then the wave can be visualized as a sine wave of frequency $(\nu_1+\nu_2)/2$, with the amplitude of this sine wave varying slowly with a frequency of $(\nu_1-\nu_2)/2$. If this were a sound wave, you would hear what is called beats, the relatively slow pulsing of the tone as the amplitude rises and falls.

## Procedure

➤**NOTE:**
a. This procedure assumes you are using a dual trace scope with an external trigger.
b. A speaker output, in addition to the oscilloscope, is a valuable addition to this lab.

① Hook up the Fourier Synthesizer to your oscilloscope as described in the SETUP section. Connect one of the oscilloscope inputs to the 10kΩ Output connector of the 9th harmonic. Connect the other oscilloscope input to the 10kΩ Output connector of the summed waveform.

② Switch the 8th harmonic into the summing amplifier. Make sure all the other waveforms are switched out. Examine the 8th and 9th harmonics at the same time. Adjust their amplitudes and phases to the same values.

③ Now add the two waves by switching the 9th harmonic into the summing amplifier (be sure to flip the 0⇔180 switch at the same time to offset the 180° phase shift caused by the summing amplifier). Describe the resulting waveform. Do you see beats? If so, what is the frequency of the beats? What is the frequency of the modulated wave?

④ Describe what happens as you vary the amplitude or phase of either harmonic.

⑤ Repeat the above steps using different combinations of harmonics, such as the 7th and the 8th, the 7th and the 9th, the, 1st and the 2nd , the 2nd and the 9th. Try any combinations that you think might be interesting. In each case, describe your results. Is the resulting waveform periodic? If so, what is the period? Do beats occur?

⑥ From your observations, what generalizations can you make about adding sine waves of different frequencies? Under what conditions do you expect beats?

# Experiment 3: Fourier Synthesis

## Introduction

Joseph Fourier discovered that any periodic function can be expressed as an infinite sum, or series, of sine and cosine functions. In such an infinite series, each term is a harmonic of some fundamental frequency. That is to say, the frequency of each term is an integer times some constant frequency.

The Fourier Series is one of many reasons why harmonic motion is so important in physics and technology. Using Fourier analysis, any periodic motion can be understood as a superposition of harmonic motions. Since harmonic motion is well understood, this offers a powerful approach to studying a large variety of phenomena.

In this experiment, you will have a chance to see how several different waveforms can be built up ("synthesized") by adding sine or cosine waveforms.

## Procedure

① Hook up the Fourier Synthesizer to your oscilloscope as described in the SETUP section.

② Connect the oscilloscope input to the 10kΩ Output connector of the summing amplifier. If you are using a dual trace scope, you can use the other trace to examine the harmonic waveforms, before you add them in to the combined waveform.

③ Zero the Synthesizer. That is, set the phase of all the harmonics to zero.

④ Create a square wave as follows:

a. Switch the fundamental into the summing amplifier (flip the SUMMING AMPLIFIER switch to IN). Adjust the amplifier as high as it will go and adjust the horizontal position of the trace so the wave looks like a cosine function

b. Switch out the fundamental and switch in the 3rd harmonic. Adjust its amplitude to 1/3 the amplitude of the fundamental. Shift its phase by 180° so that it looks like a minus cosine function.

c. Switch out the 3rd harmonic and switch in the 5th harmonic. Adjust its amplitude to 1/5 that of the fundamental. The phase should be the same as the fundamental.

d. Switch out the 5th harmonic and switch in the 7th harmonic. Adjust its amplitude to 1/7 the amplitude of the fundamental. Shift its phase by 180° so that it looks like a minus cosine function.

e. Switch out the 7th harmonic and switch in the 9th harmonic. Adjust its amplitude to 1/9 that of the fundamental. The phase should be the same as the fundamental.

f. Now switch all the harmonics you have just adjusted into the summing amplifier. Observe how each harmonic adds to the square waveform. Of course, to get a perfect square wave, you would have to add an infinite number of harmonics, following this same pattern.

➤**NOTE:** You can often improve your final waveform by making small adjustments to the phase angles (the Variable Phase controls are very sensitive and may not perfectly zeroed when you start). Start over building the wave. Begin with the fundamental. Then add the 3rd harmonic and adjust its phase until the combined waveform is perfectly symmetrical. Add each successive harmonic, each time adjusting the phase until the waveform is perfectly symmetrical. The accuracy of the waveform also depends on how closely the amplitude of each harmonic fits the specification given above.

⑤ You can build other waveforms using the table on the next page. The table lists the relative amplitude of each harmonic needed. The number in parentheses below the relative amplitude gives the phases shift of the harmonic relative to the phase of the TRIGGER output. (e.g., For the square wave, the amplitude of the third harmonic should be 33% of the amplitude of the fundamental and it should be shifted forward by 180° with respect to fundamental.)

**Harmonic Composition of Some Common Waveforms**

| | Harmonics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Waveform | 1* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Square | 100 (0°) | 0 | 33 (180°) | 0 | 20 (0°) | 0 | 14 (180°) | 0 | 11 (0°) |
| Triangular | 100 (0°) | 0 | 11 (0°) | 0 | 4 (0°) | 0 | 2 (0°) | 0 | 1.2 (0°) |
| Sawtooth (see note below) | 100 (90°) | 50 (270°) | 33 (90°) | 25 (270°) | 20 (90°) | 17 (270°) | 14 (90°) | 12.5 (270°) | 11 (90°) |
| Rectified cosine | 100 (0°) | 20 (180°) | 8.3 (0°) | 4.8 (180°) | 3.3 (0°) | 2.1 (180°) | 1.3 (0°) | 1.2 (180°) | 0.9 (0°) |
| Parabola | 100 (0°) | 25 (0°) | 11 (0°) | 6.7 (0°) | 4 (0°) | 3 (0°) | 2 (0°) | 1.5 (0°) | 1.2 (0°) |

*Fundamental Waveform (440 Hz)

➤**NOTE**: The sawtooth waveform must be constructed using sine (not cosine) waves. The 90° phase shift shown for the fundamental is intended to show this, since the 0⇔90° switch must be in the 90° position to produce a sine wave when the TRIGGER output is used as the time references. The 270° phase shift for even-numbered harmonic implies 180° phase shift relative to the fundamental, and is obtained by switching the 0⇔90° switch to the 90° position and the 0⇔180° switch to the 180° position.

# *Experiment 4: Gibbs Phenomenon*

## Introduction

In Fourier Synthesis, adding successive harmonics brings the waveform, closer and closer to the desired shape. However, you'll find that the synthesizer has most difficulty in producing sharp discontinuities in a waveform, such as the instantaneous drop or rise at the corners of a square wave. This is true in Fourier Synthesis in general, and is known as Gibbs Phenomenon. At these discontinuities in the waveform there is generally an overshoot as harmonics are added, as of the harmonics are trying to make the corner, but always go a bit too far before they can get turned around. Gibbs demonstrated that the amount of overshoot does not depend on the number of harmonics used, but the width of each overshoot peak becomes narrower as the number increases. With an infinite number of harmonics, of course, the sum of the harmonics exactly reproduces the waveform. Unfortunately, that's a little tough to demonstrate.

## Procedure

Repeat the procedure of Experiment 3 for building a square wave or other waveform. As each harmonic is added, measure the amount of overshoot and the width of the overshoot peaks.

# Experiment 5: Music

## Introduction

The tones produced by periodic waveforms are example of complex periodic waves. Musicians generally use three terms to describe a musical tone–pitch, loudness, and quality. Pitch refers to the frequency of vibration of the tone. A higher frequency produces a higher pitch. Loudness refers to the amplitude of the sound wave, or to be more precise, to our subjective sense of that amplitude.

Quality is a more complicated phenomena. Two instruments, such as a clarinet and a piano, can produce tones of the same pitch and loudness, yet the two tones will be quite distinct. The reason for this is that virtually all musical tones are made up of a relatively high amplitude fundamental frequency, which determines the pitch, and a variety of higher harmonics at lower amplitudes, which determine the quality of the tone. It is these higher frequencies and their relative amplitudes that let us distinguish the same tone as it is played by different instruments.

In this experiment, you will examine the relationships between wave shape, as seen on the oscilloscope, and the sound produced when the wave drives a speaker.

## Procedure

① Hook up the Fourier Synthesizer to your oscilloscope as described in the SETUP section.

② Connect a speaker (8Ω input impedance) between the 8Ω OUTPUT connectors of the Synthesizer.

③ Turn on the Synthesizer and switch the first fundamental into the summing amplifier. Adjust the amplitude of the wave until it is a convenient size on the oscilloscope. You can adjust the volume of the sound with the GAIN knob on the Synthesizer.

④ Switch the waveform to a square wave and readjust the amplitude to equal that of the sine wave. Now switch to a triangular wave. Switch back and forth between these three waveforms. Describe any differences you notice in the pitch, loudness, and quality of the three tones. Try to relate the differences you hear to differences in the waveforms you see on the oscilloscope.

⑤ Switch the waveform of the fundamental back to a sine wave. Switch in the 2nd harmonic. Vary its amplitude and note the effects on the scope and on the sound. Set the amplitude of the fundamental and the 2nd harmonic to the same level. Does one tone or the other seen to dominate? (i.e. do you hear a single tone that varies in quality as you adjust the amplitude of either harmonic, or do you hear two tones of different pitch?) Change the phase of the 2nd harmonic. Does changing the phase affect the sound?

⑥ Switch in higher harmonics. Vary the amplitude and again, try to relate the pitch, loudness, and quality of the sound to the waveform you see on the oscilloscope.

⑦ The table below show a the harmonic makeup of the tones from a violin, a clarinet, and a piano. Try each tone. Adjust each individual harmonic to the proper amplitude, then switch them all into the summing amplifier to produce the tone.

➤**NOTE:** The tones produced by the Fourier Synthesizer will not sound exactly like the chosen musical instrument. Several other factors play a role. One factor is that higher harmonic may be needed to more closely produce the tone. Another is that most musical instruments do not produce a continuous tone such as those of the synthesizer. The shape of the waveform produced by an instrument varies with time for each note. These variations are not reproduced by the Synthesizer.

| | Harmonics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Waveform | 1* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Violin | 100 | 0 | 33 | 0 | 20 | 0 | 14 | 0 | 11 |
| Clarinet | 100 | 0 | 11 | 0 | 4 | 0 | 2 | 0 | 1.2 |
| Piano | 100 | 50 | 33 | 25 | 20 | 17 | 14 | 12.5 | 11 |

*Fundamental Waveform (440 Hz)

# Experiment 6: Lissajous Figures

## Introduction

Suppose a particle is traveling in harmonic motion in two dimensions, such that its equation of motion is:

$$x=A_x\cos(\omega t+\varphi_x);y=A_y\cos(\omega t+\varphi_y).$$

Since the motion of the particle in the x and y directions have the same frequency, ω they also have the same period, T. So, no matter where the particle is at time t, it will be back at the same point at time t+T. The path of the particle therefore, forms a closed loop.

You can produce a similar sort of motion on an oscilloscope by using one waveform from the Fourier Synthesizer to control the horizontal motion of the electron beam and other waveform to control the vertical motion. Since all the waveforms of the Synthesizer are harmonics of the fundamental, the trace on the oscilloscope will always be a closed loop. These closed loops ate known as Lissajous figures, after Jules Antoine Lissajous.

## Procedure

① Connect the ground jack of an oscilloscope to one of the ground jacks on the Fourier Synthesizer.

② Connect the vertical input of the scope to one of the 10kΩ OUTPUT jack of the first fundamental.

③ Connect the horizontal input of the scope to the 10kΩ OUTPUT jack of the second fundamental.

④ Adjust the amplitude and phase of the second fundamental. Then do the same with the first fundamental. Discuss how amplitude and phase variations affect the shape of the Lissajous figure. What amplitude and phase relationships are necessary to create a circular pattern?

⑤ Try switching one or both of the fundamentals to a square or triangular wave? Again, vary the phase and amplitude and notice the changes in the curve. Try to relate the shape of the curve with the shape of the individual waveforms.

⑥ Try using higher harmonics for one or both of the oscilloscope inputs. Can you make any generalizations about the shape of the curve and the harmonic used?

⑦ To make more complicated curves, try using the 10kΩ output of the summing amplifier as one of the inputs.

# Experiment 7: Interesting Traces

The following are a few suggestions for generating unusual traces on your oscilloscope using the Fourier Synthesizer. They can be fun, and they can also provide an interesting challenge to your students to see if they can determine how the traces are formed.

① **Braces–** Add the first fundamental in the sine waveform with the second fundamental in the triangular waveform. Adjust their amplitudes to the same value and make them 180° out of phase.

② **V's**– Construct the braces, as above, then switch the first fundamental to the square waveform 90° out of phase.

③ **Disjointed sine wave**– Add the first fundamental in the square waveform to the second fundamental in the sine waveform. Set the phases to the same value and adjust the amplitude of the square wave so it is considerably less than that of the sine wave.

④ **Figure Eight**– Connect the oscilloscope to the Synthesizer as for displaying Lissajous figures. Connect the first fundamental (in the sine waveform) to the horizontal input. Connect the second harmonic to the vertical input. With the amplitudes of both waveforms approximately equal, adjust the phase of the second harmonic until the figure eight is centered.

# Technical Information

## Circuit Description

The MODEL WA-9307A Fourier Synthesizer generates two 440 Hz signals and eight exact harmonics (880Hz - 3.96 kHz). Square waves of the desired frequencies are generated first, using digital circuitry to divide a master frequency into waves of lower frequencies.

The master waveform is a crystal-controlled square wave of 4.4352 MHz. It is divided using D-type TTL flip-flops. For example, to halve the frequency of the master wave, creating a square wave with a frequency of 2.2176 MHz, the master wave is used to clock a flip-flop that is wired as a toggle switch. The output of the flip-flop changes states once every time the clocking signal goes through a complete cycle.

Division of the frequency by higher integers is performed by using the input signal to clock a series of flip-flops that are wired as a counter. If the counter resets at the count of three, for example, the output wave will have a frequency one third that of the input wave. All harmonics are created by a series of such divisions. In the case of the eighth harmonic (3.52 kHz), the master wave is divided first by five, then by seven, then twice by three, then twice by two.

Each sequence of divisions ends with two divisions by two. The first division by two ensures that resulting waveform is symmetrical. The second division is used as a 90 ° and 180 ° phase divider (the phase depends on which output of the flip-flop the final waveform is taken from).

Once a square wave of the proper frequency is produced via the digital circuitry, the signal is integrated by an RC circuit to produce a triangular waveform. This triangular wave is then fed into an active filter turned to the desired frequency, which shapes the triangular wave into a sine wave.

A second RC circuit is used to provide the continuous control of the phase, after which the signals fed through a buffer amplifier. Finally there is a summing and an audio amplifier. The audio amplifier uses two LM-380 integrated circuits in a push-pull configuration.

The power supply for the Synthesizer uses two 3-terminal voltage regulators and a full-wave rectifier.

## Maintenance

The Fourier Synthesizer is a complicated electronic instrument, and we don’t recommend that you attempt any repairs yourself. Instead, call PASCO scientific and arrange to return it to us for repair. However if you do wish to repair it yourself, please call us first, and we will send you the necessary documentation.

## Other Wave and Sound Instruments

### Dual Function Generator

The Model WA-9301A Dual Function Generator is built for the physics lab. It includes two independent function generators that produce sine, triangular, pulse, and sawtooth waves, with variable frequency, amplitude, and duty cycle. So experiments requiring two wave or sound sources-beats, acoustic radar, interference, etc.-are easily performed.

Even better, the output from the second generator can be amplitude modulated, frequency modulated, double side-band modulated, or gated by the output of the first generator. The first generator channel can be similarly modulated from an external source such as a radio or tape recorder. The outputs van also be summed with each other, or with an external source.

### Waveform Analyzer

The WA-9302A Waveform Analyzer is the perfect companion to the Fourier Synthesizer. With this instrument, you can analyze the harmonic composition of any wave in the audio range (20 Hz to 20 kHz), determining both the frequency and the amplitude if each component. You can also examine how the signal would look (or sound) when one or more harmonic component is removed.

# Notes:

# Technical Support

## Feedback

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

## To Reach PASCO

For technical support, call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

fax: (916) 786-3292

e-mail: techsupp@PASCO.com

web: www.pasco.com

## Contacting Technical Support

Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

➤ If your problem is with the PASCO apparatus, note:

- Title and model number (usually listed on the label);
- Approximate age of apparatus;
- A detailed description of the problem/sequence of events. (In case you can't call PASCO right away, you won't lose valuable data.);
- If possible, have the apparatus within reach when calling to facilitate description of individual parts.

➤ If your problem relates to the instruction manual, note:

- Part number and revision (listed by month and year on the front cover);
- Have the manual at hand to discuss your questions.